

SSEC NO.78.04.11

FINAL REPORT

INNOVATIVE VIDEO APPLICATIONS IN METEOROLOGY

(IVAM)

A REPORT

from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin

Scanner's note:

This page is blank.

INNOVATIVE VIDEO APPLICATIONS IN METEOROLOGY

August 1974 - March 1978

Final Report, NOAA Contract 5-35156

The Research reported in this document
has been supported by the National
Oceanographic and Atmospheric Administration

April 1978

Published for the

Space Science and Engineering Center
University of Wisconsin
1225 West Dayton Street
Madison, WI 53706

PREFACE

IVAM, The Innovative Video Applications in Meteorology program, is completed. Submission of this Final Report, and delivery of the software package and video cassettes completes all program requirements. The program has been highly successful to the extent that success is achieved by fulfilling all contractual requirements and a little besides. For this success we are deeply grateful to Robert Wollersheim, William Krueger, Robert Linn, Steven Roush, Jerry Sitzman, Terry Kelly, and many others who contributed ideas and energy to the program.

The program has also been a disappointment, especially to us who worked on it, because we did not have the opportunity to put the IVAM system into operation. Now we know how the team feels when they are a yard from the goal and the gun goes off. We will debate what might have been for a long time in the locker room.

This Final Report is intended to stand alone, and to give the reader a good picture of IVAM and its accomplishments. Much more highly detailed information was presented in the Annual Reports and the delivered software package. Still greater detail is retained in the IVAM program files at SSEC. We would be happy to provide access to these data upon request.

Verner E. Suomi
Principal Investigator

Thomas O. Haig
Program Manager

CONTENTS

		<u>Page</u>
1.0	PROGRAM OVERVIEW	1
1.1	BACKGROUND	1
1.1.1	Roots of IVAM	1
1.1.2	Early Proposals to NASA	4
1.1.3	Proposals to NOAA	6
1.2	THE IVAM CONTRACT	8
1.2.1	Statement of the Problem	8
1.2.2	Contract Work Statement	9
1.3	CONDUCT OF THE STUDY	12
1.3.1	General Overview	17
1.3.2	Program Management and Direction	22
1.4	SUMMARY OF RESULTS	22
1.4.1	Accomplishments and Goals	22
1.4.2	Last Words	27
	REFERENCES	29
2.0	PRESENTATION CONTENTS STUDIES	2- 1
2.1	APPROACH	2- 1
2.2	USER GROUP STUDIES	2- 1
2.3	MEDIA CONSTRAINTS	2-27

	<u>Page</u>
2.4 PRESENTATION FORMAT STUDY	2-36
2.5 COMPILATION AND DEFINEMENT OF SEGMENTS	2-66
2.5.1 Determination of Segment Format and Storyboarding	2-68
2.5.2 Impact of System Design Parameters on Presentation Format	2-78
2.6 EMERGENCY NEEDS	2-79
2.7 AUTOMATIC SYSTEM SELECTION OF SEGMENTS	2-86
REFERENCES	2-88
 3.0 SOFTWARE	 3- 1
3.1 SOFTWARE OVERVIEW	3- 1
3.2 REQUIREMENTS	3- 2
3.3 IMPLEMENTATION APPROACH	3- 8
3.3.1 Image Elements	3- 8
3.3.2 Parallel Processing	3- 9
3.3.3 Module Design	3-10
3.3.4 Video Chain	3-15
3.3.5 Processes	3-15
3.3.6 Assembler Influence on Software	3-21
3.3.7 McIDAS Dependence	3-25
3.3.8 RSX 11/M	3-26
3.4 DEVELOPMENT	3-27
3.4.1 TABSYS	3-27
3.4.2 Video Chain	3-49
3.4.2.1 Definition	3-49
3.4.2.2 Specific Requirements	3-54
3.4.2.3 Alternative Methods	3-57
3.4.2.4 Method Chosen	3-63

	<u>Page</u>
3.4.2.4.1 Case Analysis	3-64
3.4.2.4.2 Processing Steps	3-71
3.4.3 RSX11/M	3-83
3.4.4 Device Software	3-86
3.4.4.1 The Talos Data Tablet	3-87
3.4.4.2 The Applied Digital Data System Terminal	3-89
3.4.4.3 The Digital Terminal	3-91
3.4.4.4 The Video Tape Recorder (VTR)	3-92
3.4.5 Graphics	3-93
3.5 PRODUCTION SYSTEM	3-96
3.5.1 System	3-96
3.5.2 Directory	3-97
3.5.3 Controller and Directory	3-99
3.5.4 Assembly Process Control	3-138
3.5.5 Assembler Display Control	3-140
3.5.6 AFOS Interface	3-142
4.0 HARDWARE CONCEPT STUDY	4- 1
4.1 THE IVAM SYSTEM	4- 1
4.1.1 Overview of System Requirements	4- 1
4.1.2 Basic System Configuration	4- 1
4.2 SYSTEM REQUIREMENTS	4- 3
4.2.1 Data Input Interfaces	4- 3
4.2.2 SCEG Processing Requirements	4- 5
4.2.3 Video Assembler Requirements	4- 6
4.2.4 System Throughput Requirements	4- 8

	<u>Page</u>
4.3 DEVELOPMENT SYSTEM	4-11
4.3.1 Design Objectives	4-11
4.3.2 SCEG Development Hardware Study	4-11
4.3.2.1 Data Communication Bus	4-12
4.3.2.2 Crosspoint Memory Approach	4-22
4.3.2.3 Comparison of Two Approaches: Communication Bus vs. Crosspoint	4-22
4.3.2.4 Arguments by Configuration	4-26
4.3.2.5 Summary	4-27
4.3.3 Hardware Procurement	4-27
4.3.4 Development System Description	4-34
4.3.4.1 Control and Element Generatory Subsystem	4-35
4.3.4.2 Center Equipment	4-38
4.3.4.3 Development Tools	4-38
4.3.4.4 Performance	4-39
4.4 VIDEO ASSEMBLER STUDY	4-41
4.4.1 Real-time Assembler with Staging Disk	4-41
4.4.1.1 Real-time Assembler Design Concepts	4-41
4.4.1.2 Real-time Assembler Problems	4-49
4.4.2 RAM/Dual Disk Video Assembler	4-49
4.4.2.1 System Description	4-50
4.4.2.1.1 Assembly Operation	4-50
4.4.2.1.2 Display Operation	4-53

	<u>Page</u>
4.4.2.2 Implementation and Cost	4-54
5.0 OUTPUT DISTRIBUTION STUDY	5- 1
5.1 ALTERNATIVE DISTRIBUTION SCHEMES	5- 1
5.2 BROADCAST TELEVISION	5-11
5.3 CABLE TELEVISION	5-13
5.4 DISTRIBUTION TO CABLE TV AND INDEPENDENT BROADCAST STATIONS	5-17
5.5 OTHER DISTRIBUTION SCHEMES	5-21
5.6 LOW BANDWIDTH DISTRIBUTION	5-22
REFERENCES	5-29
6.0 PRESENTATION TEST AND EVALUATION	6- 1
6.1 APPROACH	6- 1
6.2 IVAM WEATHERCASTER ADVISORY COMMITTEE	6- 1
6.3 PICTURE QUALITY STUDIES	6- 8
6.4 DEMONSTRATION VIDEO TAPES	6-14

APPENDICES

Appendix A	SYSTEM SPECIFICATIONS
Appendix B	INITIAL SEGMENT LISTING
Appendix C	OUTPUT SPECIFICATIONS
Appendix D	INPUT SPECIFICATIONS
Appendix E	CLOUD GRAPHICS STUDY REPORT
Appendix F	GUIDELINES FOR IVAM TRANSITIONS

1.0 PROGRAM OVERVIEW

1.1 BACKGROUND

1.1.1 The Roots of IVAM

In 1971 the National Academy of Sciences report, "The Atmospheric Sciences and Man's Needs -- Priorities for the Future," included the following discussions:

"Despite the fact that little predictive capability can be claimed for time scales less than 12 h ..., a significant fraction of atmospheric variability occurs on these smaller time and space scales. Tornadoes, thunderstorms, and other destructive storms are included here, but predictions are rarely sufficiently specific in terms of intensity, location, and time of occurrence. Terminal forecasts are made for aircraft, and probability forecasts are issued for severe storms expected to occur in large regions ... There are theoretical bases for understanding at least some of the important phenomena. Why then has short-range prediction not advanced as rapidly as has prediction on the synoptic and planetary scales? Two factors explain the situation.

The first concerns the basic physics of mesoscale and microscale phenomena. There are severe mathematical and theoretical difficulties in developing general prediction models for these smaller scales. The time scales are, of course, so short that the quasi-geostrophic relation between wind velocity and pressure is not valid. Furthermore, many of the weather systems are fully three-dimensional so that the hydrostatic approximation which is essential to general circulation theory cannot be applied to the smaller scales. Gravity waves are ubiquitous, and their effects must be accurately represented. Change of phase in clouds must be included. Also, the boundary layer plays a crucial role in many weather phenomena, so that the effects of turbulence must be incorporated in successful models.

The second difficulty concerns the observations required to describe mesoscale and microscale phenomena. In many cases, differences are small, and the required accuracy of the observations is correspondingly high. Also, the data required to describe the small-scale features are numerous, and the time available for processing, interpretation, and dissemination of results is short.

In the face of all these difficulties, can one realistically hope to improve short-range prediction? Indeed there are several avenues that should lead to major improvements. For periods extending from a few minutes to perhaps 2 h some meso-scale features can be successfully predicted by simple extrapolation of present conditions and rates of change. In order for extrapolation to be useful, the characteristic time scale for significant changes of the phenomenon must be larger than the time period of extrapolation. Thus, an individual wind gust whose time scale is a few minutes could not be reliably predicted for longer periods by simple extrapolation.

The crucial need is to apply modern technology to describe the local weather as it occurs, and to communicate the desired information immediately to users. At the present time, critical minutes or even hours often elapse between the time of observation and dissemination to the user ... "

IVAM was the development program designed to meet "the crucial need... to apply modern technology to describe the local weather as it occurs, and to communicate the desired information immediately to users."

Ten years ago, the Space Science and Engineering Center undertook a series of related studies directed initially toward measuring the impact of meteorological satellite programs on the social, economic, and political activities of the U.S. However, it was soon apparent that the impact had not yet been felt outside the meteorological services because the new data were being used almost entirely to support the existing synoptic scale weather advisory service. Possibly the public benefitted from satellite data, but if so, there was no public awareness of the fact. It was also apparent to the study investigators that the public was greatly interested in the new data, and that individuals with no meteorological training quickly learned to interpret the images and to derive new knowledge about the weather [1, 2].

The studies shifted emphasis at this point to explore two questions, "What meteorological information do people really need?" and "What is the best way to present this information to them?" The results of this series of studies

clearly indicated that the greatest needs and desires were for more information about local weather, NOW and in the near future [3, 4]. People used the synoptic services with the 24 hour forecast emphasis as a planning tool, but they decided how to react to weather based on current weather and short-term expectations -- with that kind of weather information being very hard to find.

The third phase of the study, conducted in 1973-1974, attempted to assess quantitatively user needs for current and short-term prediction information, and to pursue concepts for generating such a service at reasonable costs [5,6]. The concept which developed is called NOWCASTING, a name not original with the University, but one which served to differentiate a new service emphasizing current descriptions and short term predictions of local weather. The NOWCASTING concept was new because it concentrated on using the full information content of radar and satellite observations to describe mesoscale phenomena. NOWCASTING was new because it projected use of the latest data processing and information dissemination technology to deliver a detailed weather service to the public while it is still current. NOWCASTING is still "new" because it has not been provided to the public by the National Weather Service.

IVAM was the development program intended to implement NOWCASTING.

In 1976 a paper was written following a conference of the NWS Southern Region Weather Service Forecast Offices (WSFO's). The paper included an exceptionally clear presentation of what NOWCASTING is and why it is important to the National Weather Service. It said:

"What is it? -- Nowcasting is a combination of real time weather reporting with short term forecasting -- from time now out to about six hours in advance -- with emphasis on weather that is likely to affect the public both in terms of unusual and critical conditions and in terms of immediate occurrence.

"Should it be done? -- WSFO analyses submitted late this spring provided an interesting case of Management by Objective. The consensus of these reports clearly identified 'the communication of useful weather information on a current and immediate basis' as a primary objective of our organization. This is nowcasting. Yes, we should go ahead with this concept.

"How can it be done? -- Although most WSFOs are now using some nowcasting features and the consensus of WSFOs was to move on, there was a diversity of problems outlined and a limited experiment is proposed rather than proceeding at all offices at this time. Effectiveness of a nowcasting program hangs on all the links of a chain of facilities -- a means of gathering pertinent information quickly, techniques for translating this into a release, and a means for disseminating the release to the public quickly..."

The paper continued to outline an experimental implementation of NOWCASTING via the National Weather Radio facilities - an excellent plan in our judgement. We would like to repeat one sentence from the paper:

"Effectiveness of a Nowcasting program hangs on all the links of a chain of facilities -- a means of gathering pertinent information quickly, techniques for translating this into a release, and a means for disseminating the release to the public quickly."

And that is what IVAM was all about.

1.1.2 Early Proposals to NASA

In the fall of 1972 SSEC proposed to NASA a multi-year study program to investigate, develop, and test techniques for producing accurate and useful short-range forecasts, using satellites as a primary data source. This proposal was a direct consequence of the experience which SSEC had gained in performing the multi-disciplinary studies for NASA and the development of techniques to utilize the Synchronous Orbit satellite images from the ATS satellites which, by

this time, had produced the first version of the Man-computer Interactive Data Access System (McIDAS). The multidisciplinary studies had clearly established the value and need for a mesoscale meteorological service in the United States, and the development of techniques to obtain useful information from the ATS data indicated that the data sources and the technology to exploit them existed upon which a mesoscale service could be based. The SSEC proposal described the elements needed for such service, and pointed out that major development efforts were required to produce mesoscale prediction models, and to produce the high speed, high efficiency information dissemination capability required to move mesoscale information from the Federal operating agencies to the public.

The proposal projected a five-year program, consisting of the following major elements:

1. Developing and testing methods of extracting quantitative information for numerical models from SMS/GOES, Nimbus, and other satellite type data.
2. Establishing jointly with NASA/GISS a nested set of numerical models (synoptic scale, mesoscale, and cloud scale).
3. Developing SMS/GOES satellite system sensor design improvements and improvements to data handling, data quality control, and data analysis.
4. Developing sensor design criteria, data flow patterns and system function plans for a large optics geosynchronous meteorological satellite (SEOS type) system.
5. Developing and demonstrating (to the extent available capabilities permit) short range prediction and information dissemination processes.

The proposed program was discussed at some length with officials at the Goddard Institute of Space Studies, the Goddard Space Flight Center, and Headquarters NASA. The predominant opinion was that while Wisconsin was judged competent to conduct the proposed program and the need for such a program was generally accepted, the major thrust of the program was to develop an operational capability appropriate to NOAA, and therefore inappropriate for NASA to support. It is also true that during late 1972, the Meteorology Program Office at GSFC

was preoccupied with planning for STORMSAT and a Severe Storms research program to be conducted with in-house resources at GSFC.

1.1.3 Proposals to NOAA

Informal discussions with individuals in the National Weather Service and the National Environmental Satellite Service of NOAA during late summer and early fall of 1973 indicated considerable interest existed in developing a NOAA program for NOWCASTING. SSEC was encouraged to document a possible program which might bring together the appropriate elements in NESS, NWS, and the University of Wisconsin. In November of 1973 SSEC sent copies of a concept paper for a joint NOAA-University of Wisconsin program which would involve major portions of SSEC and the Department of Meteorology, as well as portions of NESS and NWS in a multi-year mesoscale research and development program, leading to a prototype operational test of the full-blown mesoscale service to the public. As a result of the concept paper, the University of Wisconsin was encouraged to submit a formal proposal which was sent in draft to NESS and NWS officials in December 1973. This proposal was prepared jointly by Space Science and Engineering Center, the Department of Meteorology, the Mass Communications Research Center, and the Extension Telecommunications Center of the University of Wisconsin, Madison. Included were all of the elements necessary to develop, test, and evaluate a pilot NOWCASTING service. Six sub-programs were defined, as follows:

1. Definition of user requirements for mesoscale weather information
2. The development and testing of local short-range forecasting techniques
3. The development of a computer-based, semi-automated information processing system to support a NOWCASTING service
4. A thorough investigation of video media weather information dissemination techniques

5. The development and optimization of audio media weather information dissemination techniques

6. Conduct of the prototype NOWCASTING service, and evaluation of public reaction to this service

Reaction by NOAA officials was generally favorable to the proposed program, and an active discussion was continued with modifications to the draft proposal being submitted to NOAA on 30 March 1974, and on 9 April 1974. One important change was made in the program during this time with the deletion of the conduct of a prototype NOWCASTING service, which limited the program to development of techniques to be conducted over a three-year period.

In April 1974 in a meeting of NESS, NWS, Headquarters NOAA, and the University of Wisconsin representatives, the scope of the program was further reduced to delete the development of objective mesoscale prediction techniques and development of audio media dissemination capabilities. These deletions were made because National Weather Service representatives indicated the very strong desire to conduct these portions of the program within their own laboratories. What remained was the development of techniques and capabilities for the dissemination of mesoscale weather information via the video media.

Thus, of the original proposal, the only part remaining was that which was to be performed by SSEC. Consequently, SSEC drafted a new proposal for the development of a system to produce video weather presentations automatically from satellite and conventional weather data. This proposal included the early feasibility and systems engineering studies, as well as the development, fabrication, and activation of a prototype system, and a period of test operation of the system to confirm design validity. The proposed effort was to be funded equally by NWS and NESS, with NOAA management being exercised by representatives from NWS, NESS, and Headquarters NOAA. The proposed effort was further reduced, at the insistence of NWS representatives, to delete fabrication, test, operation,

and evaluation of a complete prototype capability. The result was a feasibility study which included the provision for preliminary design of hardware, partial development of software, and laboratory testing only of important components of a full capability. The program was given the title, "Innovative Video Applications in Meteorology" (IVAM), and the program was started in August 1974.

1.2 THE IVAM CONTRACT

1.2.1 Statement of the Problem

The purpose of the IVAM program was stated in the contract work statement prepared by NOAA, as follows:

The Problem

The National Oceanic and Atmospheric Administration would achieve a significant gain in keeping the public advised of changing weather conditions if effective, automated methods of delivering video segments of weather information to TV outlets could be devised. Although this is known to be a technologically possible accomplishment, the methods needed to make it economically feasible have not been developed.

Solution

The National Weather Service and National Environmental Satellite Service jointly undertake the funding of a study to develop a state-of-the-art capability to efficiently deliver quality video presentations of weather information to the public at acceptable cost.

Study Objective

This study will be directed toward the development of formats and techniques designed to maximize the effectiveness of the TV presentation of weather information to the public. Program content and organization will be addressed, as well as the conceptual design of the communications methods and systems that would allow the presentations to be economically delivered from NOAA sources to various redistribution terminals. The objectives of the study are to develop techniques and formats that are characterized by:

- High information content in an interesting and understandable presentation
- A maximum employment of automated presentation formatting, in

order to keep staffing levels reasonable

- The maximum utilization of existing or planned NOAA facilities, methodologies, and communications systems
- Modest NOAA implementation costs and modest-to-low cost for media, public, or private acquisition
- Quality and utility coefficients that generate media and public enthusiasm and demand

1.2.2 Contract Work Statement

The contract spelled out the approach and tasks as quoted below.

As the program progressed, a new set of objectives were discussed with NESS and NWS representatives to produce and demonstrate a completed prototype IVAM system. For a period of nearly a year the program was redirected informally to press toward the new objectives; however, proposals to amend the contract made in 1975 and 1976 were not accepted by NOAA. Therefore the performance by SSEC on the IVAM program must be judged against the requirements as stated here:

Approach

NWS and NESS will share the funding of this study.

NOAA Principals will be designated to monitor study activities. They will reserve to their mutual decision the major authority for study direction.

Each of NWS and NESS will appoint a Contract Officer's Technical Representative (COTR) to act as coordinators on behalf of the NOAA Principals.

The contractor will designate a study manager to act as coordinator for the contractor's Principal Investigator.

It is anticipated that the study will take three years to complete. Contracting will be on a year-to-year basis, renewable at option for the second and third year.

Tasks

The video media offers a direct, versatile means for presenting weather information to the public. Both broadcast and cable TV now

provide some form of public weather service. If high-quality video segments of weather information could be made available to TV outlets by NOAA, redistribution to the public would be assured. If the cost of acquiring these segments was low, and if the service was sufficiently advantageous and convenient to obtain, industrial, recreational, and other single-interest users could be expected to appear. The tasks outlined here are intended to result in the definition of the techniques and system designs that will allow these video weather segments to be made available to the public. These tasks are presented in the context of the Objectives mentioned above and also in the sense of the NOWCASTING concept: that is, to provide the public with a complete video weather service that emphasizes the current description and short term prediction of local weather conditions.

- Task A. Determine presentation contents: Determine the range of video weather segment presentations that are possible in terms of content, format, length, and technical feasibility. Select candidate presentations for development and evaluation.
- Task B. Develop presentation formats: Assemble and format segment contents to fit the requirements of various presentation situations. Some variables to be considered are: the programming difference among cable, commercial broadcast, and public service TV; the possible requirements of single-interest users; the regional and/or seasonal needs of public users requiring emphasis on certain weather parameters; the threat-level and severity of existing or forecast weather conditions.
- Task C. Evaluation of presentations: Devise and conduct tests to determine which of the various presentation techniques and features are most acceptable to user-viewers and determine if user needs are being met by presentation content.
- Task D. Evolve improved presentations: Using development and evaluation feed-backs, evolve and test more effective and interesting presentations.
- Task E. Automation of presentations: Maximum automation of the assembly and formatting of presentation segments will be attempted and evaluated. The major constraints to be considered under this task are the capabilities and loadings of available NOAA on-line computers and the work-load and professional prerogatives of the responsible NWS duty forecaster.
- Task F. Conceptual design of distribution system: The conceptual design of a national distribution system for these video weather segments will be addressed. The system

will be tailored to the origin and flow of data along NOAA paths, to junctures with redistribution points or single-interest users. Cost options, reliability considerations, and implementation feasibility will be considered. Although the final design and hardware specification will depend on technological developments in industry, optimal system design with existing technology will be an influence factor with respect to the other tasks under this contract.

Task G. Reports: A progress report will be prepared by the contractor each month of the contract. It will be delivered to NOAA in 25 copies. The progress report will be in letter form and will include information on technical events, major personnel changes, problems, and the like. It will also include a report of expenditures during the month (manhour costs, materials, overhead, etc.), expenditures to date, and expenditures expected during the coming month. A briefing will be given NOAA at the completion of each major milestone or each six months. One of the briefings shall be the Annual Briefing, described below.

Task H. Annual Report: An annual report and an annual briefing will be presented by the contractor between February 20 and March 10 each year of the contract. The briefing will take place in the Washington, D.C. area. The report, in 25 copies, will be a comprehensive review of the year's activities and a projection of the work to be undertaken in the following year, if appropriate. A video tape (2 copies) showing representative weather programming segments will accompany the annual report. At or prior to the annual meeting, and at NOAA/NWS option, the contractor will furnish both completed software used to generate weather segments presented at the briefing and software writeups for the previous year's portion of the contract.

The annual briefing will be presented by contractor personnel. NOAA Principals and other interested NOAA personnel will attend. The briefing will review past and projected activities and will serve as one of the decision elements in NOAA's determination of contract renewal for the following year.

Each of the annual reports and annual briefings will include a description of the "current best distribution system design" as addressed in Task F.

Task I. Documentation: The contractor will provide NOAA with comprehensive documentation relating to all significant aspects of the studies and completed computer software under-

taken. The intent of the documentation is to allow NOAA to translate study successes into operational programs without prolonged consultation with contractor personnel. Weather display choices, format selections, operating techniques, hardware designs, system specifications, and suggested implementation methods will be documented.

Task J. Software: Computer program software that is to be delivered to NOAA will be accompanied by at least the following:

- Software be directly compatible with NOAA/NWS Automation of Field Operations and Services (AFOS) software.
- Narrative description of the program, showing purposes of the routines, computational and/or logical methods used, formats of data input, formats of data output, and possible error conditions.
- Functional Flowchart, showing major processing blocks and logical decisions.
- Source listing of the program as written, with comments delineating the processing and logical sections. In the source listing, element and array names should be identified as to data content or logical function.
- Test data or testing methods.

1.3 CONDUCT OF THE STUDY

1.3.1 General Review

The IVAM program was organized in five major tasks, based on an anticipated three year development period. The correspondence of the five major tasks to the ten tasks specified in the contract work statement is indicated by the lettered task designation in parentheses which refer to the work statement. The overall program plan and progress by major task was as follows:

Task 1 - Software Development (Tasks E,J)

This was the major development effort in the IVAM program. If the objectives as described by NOAA above were to be achieved, the software system

had to be as efficient and as flexible as the state-of-the-art allowed. Early in the program SSEC conducted a series of very thorough, and very critical reviews of several possible routes which could have been pursued. The decision was to start at the very beginning, and to defer any actual software development until a sound software system concept had been developed which we were confident could support a development program capable of meeting the NOAA objectives. The software system concept document was attached to the first annual report as an Appendix, and the concept was a major part of the required briefing in Washington in May 1975.

The software design philosophy which was adopted was based on the following considerations and decisions:

- 1) The system to be developed is a production system. The output is a large number of graphic images, properly sequenced, meeting high aesthetic standards, complying with NTSC standards, and coming off the line at 30 frames per second. This is the first time such a system has been attempted.
- 2) The system must be automatic. To meet output requirements it must work at high speed and must not depend upon human interaction. At the same time, full system control must be available to the WSFO forecaster.
- 3) Software will be organized to operate in a basic net structure to provide an efficient, fast response operating system.
- 4) Software will be completely modular with standard module to module and module to net interfaces to decrease development time and to permit modification at low cost. This approach will trade memory size for software and maintenance economy.
- 5) A multi-processor, multi-memory hardware design will be used to

implement the system to obtain least cost in hardware, low maintenance costs, and high processing rates.

6) Maximum integration with AFOS will be a principal objective to eliminate function redundancy and hold implementation and operation costs to the minimum.

Task 2 - Presentation Content Studies (Tasks A,B)

Starting with an extensive review of previous work at SSEC and in the literature, users' needs for weather information were assembled and tabulated. This voluminous data set was consolidated through a series of carefully defined steps to a tabulation of users' needs listed by parameters which could be used as decision bases by the IVAM control processor. These parameters are season, time of day, weather situation, TV medium, emergency status, past and present or predicted, and spatial scale. The minimum set (about 150) of presentation segments were determined which were uniquely identified by the seven parameters and which met all important users' needs. A representative portion of these segment specifications were translated into video storyboards to define system performance requirements.

The task was approximately 80% completed during the first year and the study methodology was reported in detail in the May 1975 annual report. The complete set of segment specifications and storyboards was attached to the May 1977 annual report as an appendix.

A new task was added to the IVAM program in 1977 to demonstrate techniques to reduce satellite images to graphic format automatically and produce a videotape of examples to be used by NWS to evaluate the information content and viewer acceptability of these images. This task was completed in February 1978.

Task 3 - Hardware Concept Studies (Tasks E,F)

Hardware definition was purposely deferred until the system and software

concepts were well developed. We viewed hardware as just the means of implementing IVAM and tried to avoid having hardware decisions determine system performance. As we proceeded to purchase the equipment for the prototype of the first half of the system the validity of this approach was fully confirmed. The problem we faced was not to find a set of equipment capable of the IVAM task but to select from among many alternatives. Thus we were able to optimize the equipment selection for low costs, maintainability, flexibility, suitability of software ,etc.

Only the hardware for the front end of the IVAM prototype was procured. Specification of the remainder of the system was completed during 1977 and the IVAM design is complete at the system level. In May 1977 NOAA decided not to fund the completion of the IVAM prototype, but to end the program with software defined and partially completed; hardware defined on paper only, and system flexibility demonstrated on the development facility consisting of the McIDAS with a part of the IVAM prototype hardware.

Concepts for distribution of the IVAM products to broadcast and cable TV stations were developed during the first year of the program and were reported in May 1975. Briefly, it is feasible to distribute presentation segments via network facilities during the half-hourly station break periods when the network is normally "black". Further inquiries during the past two years have confirmed the feasibility of this concept. For cable distributors the plan was not as easy to define since each cable company presented a different set of circumstances. Inquiries to cable operators made each year of the program confirmed the unanimous enthusiasm of cable system operators for the IVAM product. Operators of systems located near WSFO's likely to be equipped with IVAM foresaw no significant difficulty in obtaining the output. Those located at greater dis-

tances expressed interest in the possibility of obtaining an automatically updated presentation via telephone lines. Possible designs for such a capability were discussed in the May 1977 report.

Task 4 - Program Test and Evaluation (TaskC)

During the first year two test video tapes were produced, one of a possible IVAM presentation for broadcast stations and one for cable outlets. The tapes were made from films of graphics designed to simulate IVAM images. Technically the tapes differed from and were inferior to the expected IVAM product because of the limitations of filmed graphics. Nevertheless, the tapes proved to be of great value in demonstrating IVAM and in obtaining answers to important system design questions. In 1976 two filmed simulations of IVAM outputs were made to test specific presentation concepts of importance in determining system design. In May 1977 portions of three segments were assembled on video tape using only IVAM software. The quality of this tape was degraded because it had to be produced on an awkward mix of IVAM and McIDAS hardware -- a consequence of a program funding delay discussed more fully later. In December 1977 a final IVAM program video tape was produced which compares the actual IVAM capability with the simulation shown in the 1975 tape. This last tape, produced entirely by the IVAM system, provides a suitable basis for judging whether SSEC has succeeded or failed in meeting the contract objectives.

The IVAM Weathercasters Advisory Panel was organized and met first in February 1976. Five of the nation's top TV weathercasters make up the panel. This group met regularly at six month intervals during 1976 and 1977 to consider a broad range of IVAM design problems. Their advice was of great value to the program and the system design includes numerous improvements which they contributed.

Task 5 - Final Program Development (Tasks D,I)

This task was planned to start only after NOAA was satisfied that the implementation of IVAM was feasible, and that when implemented, IVAM would meet the NOAA objectives. This is the effort required to wrap-up the software development, complete the prototype IVAM hardware design, fabrication and assembly, install and interface IVAM to an AFOS installation, and place the system in full operation for test purposes. At the beginning of the program, as stated in the May 1975 report, SSEC anticipated starting this task in 1977. In the May 1976 report SSEC proposed the contract modifications which would have allowed this task to start in 1977. Prior to the May 1977 report the proposals for this task were reiterated. In May 1977 NOAA decided not to implement this task.

1.3.2 Program Management and Direction

Several management aspects of the program are worth noting:

A. Delay of FY 76 Effect

The initial funding increment for the IVAM program covered the period 1 August 1974 to 31 July 1975. At the end of that period approximately \$30,000 remained unspent and was reserved to cover part of the costs of the first hardware buy. The second increment of funding was to cover the period 1 August 1975 to 31 July 1976, but the contract amendment was not received by the University until 17 November 1975. Also, authority to use the remaining \$30,000 for capital equipment purchases was not received until 17 November 1975. During this period from 1 August 1975 to 17 November 1975, while the contract was actually unfunded, we continued work on IVAM but at a reduced level, and we were unable to proceed with hardware procurement until we received approval to spend the \$30,000 on capital equipment or until additional funds were actually

in hand. During this period we obtained and evaluated bids, but did not release purchase orders until 17 November 1975. This represented an actual delay of about five months compared to the program schedule presented in May 1975, because we had anticipated proceeding in June 1975 to purchase the PDP-11/40 computer with the \$30,000 on hand at that time. The consequences of this delay were:

- 1) We had a much longer time to evaluate alternative hardware configurations. The basic multi-processor approach was reaffirmed and developed in greater detail. Some significant improvements in the hardware design resulted. The adequacy of the 16 bit minicomputer for this application at this time was firmly established.
- 2) We were forced to restructure our software development program to minimize overall program delay. We decided to adopt the RSX-11M system software as the starting point for the prototype IVAM system rather than to proceed with development of the specialized net structure originally planned. This decision allowed us to proceed with development of applications modules on McIDAS in FORTRAN using the specification of the RSX-11M system for interface definition. The downstream consequences were to preclude development of the optimum system software design for IVAM.
- 3) We missed some short delivery schedule opportunities, and had actual hardware deliveries delayed well beyond the 109 days of delay in funding authority. Most of the computer hardware was delivered in March 1976. Consequently, transfer of software modules to the IVAM equipment from McIDAS was seriously delayed.
- 4) We were unable to generate or to display graphics on IVAM equipment to IVAM standards. Testing of graphics modules was on McIDAS equipment in which

aesthetic considerations are secondary. The video tape which accompanied the May 1977 resport was a demonstration of the IVAM graphics generation software modules, but the aesthetic qualities of the images were determined, and severely limited, by the McIDAS equipment.

5) The overall program slipped four to six months, but may have benefitted from the more extensive hardware design review.

B. Interface with AFOS

The NWS program, Automation of Field Observing Service, (AFOS), was well started before the IVAM program was approved. AFOS consisted of sub-programs to collect and distribute information within the NSW structure, and to display information to NWS forecasters. The original concept of IVAM as presented by SSEC was to develop a capability, complementary to AFOS, to convert information to video format for the TV media. IVAM was envisioned as the system which would interface AFOS to the public through broadcast and cable TV outlets. As SSEC understood the AFOS and IVAM concepts there was no conflict or competition between the two development programs, but it was necessary that IVAM be developed to fit comfortably between AFOS and the TV media. Therefore early definition of the AFOS/IVAM interface was an important task.

During 1975 and 1976 several meetings were sought and some were held between AFOS Program Office and SSEC personnel to develop a suitable interface. These efforts were handicapped because the AFOS program experienced a series of problems which lead to a complete change of approach and a new prime contractor in 1976. Internal AFOS program problems continued throughout 1976 and 1977 and preoccupation with these undoubtedly accounted for the apparent lack of interest in IVAM by the individuals from the AFOS Program Office who were assigned the additional duty of IVAM Technical Monitor. (Four persons held this position

during the three and a half years of the IVAM program).

It became clear early in the program that IVAM was not seen in the same light by all members of NWS. Some agreed with SSEC and the NESS Technical Monitor that IVAM was a study and development program complementary to, but external to AFOS. Others saw the program as a software development effort which would be integrated into the AFOS hardware at a later date. Some regarded IVAM as a competing program. These different attitudes were discussed repeatedly with NWS representatives, but were never resolved within NWS and the lack of a clear conceptual relationship between AFOS and IVAM contributed to the difficulty in defining an interface.

Without a clear interface, and because of delays and technical difficulties within the AFOS program, SSEC had no alternative but to develop IVAM as an independent system capable of operating with or without AFOS. In fact, IVAM has developed or adapted from McIDAS, a complete capability to ingest, store, process, and display surface and upper air data, radar data, satellite images, and NMC forecast products. The capabilities sought in the AFOS program for the Forecasters Console were achieved in IVAM incidental to developing the far more difficult objectives of IVAM. This situation, coupled with continuing delays in the AFOS program which made it apparent that an IVAM prototype could be in full operation before an AFOS capability existed, tended to support those who regarded IVAM as competitive to AFOS. There is little doubt that this attitude contributed to the NOAA decision not to continue IVAM to full prototype operation.

C. Program Costs and Schedule

The original program cost was estimated to be \$141,000, \$145,000, and \$150,000 for each of the three years of the program for a total of \$436,000.

Before the contract was activated overhead and fringe benefit rates, which are negotiated separately each year by the University and the resident HEW auditor, had increased the first year cost to \$147,576, making the expected total \$456,000. Two other actions also resulted in increasing program costs. In April 1975 we requested approval to procure the hardware needed to support the second year of the program. A second request was made in the annual presentation and report and was reiterated by letter 22 May 1975 in which the need for approval by mid June 1975 was explained or the program would face a serious delay. Authorization to purchase the equipment (which was already part of the original proposal) was not received until 17 November 1975. As explained above, this delay caused a six month slip in the major parts of the program despite attempts to work around the problem. Costs were necessarily increased accordingly. On a proportional basis the total cost of the program was increased to \$532,000 and the completion date was extended to January 1978 because of this delay alone.

In April 1977 an additional task, the cloud graphics study, was added with an increase of \$19,000. This task was unrelated to the IVAM program, but it increased the total contract amount. Actual program costs have been:

First year	\$147,576
Second year	\$170,000
Third year	\$222,990
Fourth year	\$ 70,000
TOTAL	\$610,566

Actual cost growth of the program, over original estimates, amounts to \$59,566 or 9.75% of program total. Program schedule was extended eight months to 31 March 1978 to accommodate the earlier interruption in program funding and delay of procurement approval and to allow for final report preparation.

1.4 SUMMARY OF RESULTS

1.4.1 Acomplishments versus Goals

The original goals of the University of Wisconsin aimed at the establishment of a long term joint University/NOAA team to develop a prototype mesoscale weather service including rapid data collection and analysis, objective mesoscale prediction techniques, and rapid information dissemination to the public. These objectives were reduced through several steps as discussed above to those which NOAA was willing to support and which made up the IVAM contract work statement quoted earlier. It should be noted that the University's objectives have not changed and that they are being realized through later programs. A six person detachment of NESS scientists is now in residence at the University and is working in close cooperation with SSEC and the Department of Meteorology to develop a substantial mesoscale analysis and prediction capability. SSEC has expanded the capabilities of the McIDAS system and is building the first unit of a new system (McIVAM, Man-Computer Interactive Video Assembly Machine) which will provide the best of McIDAS and IVAM to private weather services and the TV media at easily affordable costs. The NESS/University of Wisconsin team is working closely with other elements of NESS and other universities to bring together several development efforts in the mesoscale weather area to form a prototype NOWCASTING service at an early date.

Naturally, we in SSEC are disappointed that the IVAM program was not continued to full prototype development and operation. We are sure that rapid conversion of weather data to TV format will be done (McIVAM will do it) and that eventually the public will receive effective NOWCASTING service. We are also sure that the accomplishments of the IVAM program as described in this and

earlier reports will contribute significantly to that service.

On a task-by-task basis the IVAM results are as follows:

Task A.* Determine the presentation contents: The content of broadcast and cable presentation was derived by a traceable and fully documented series of steps from a large number of earlier studies of weather service users' needs. The technical feasibility of producing the segments has been demonstrated by both simulation and actual production of selected segments using only IVAM software. While the television medium itself imposes requirements and limitations on the form of the presentation, there is no significant limitation on the meteorological content of the presentation which IVAM can produce. This task has been completed fully.

Task B. Develop presentation formats: The complete family of possible sectors was reduced by a series of careful analyses and evaluations to eliminate redundant and trivial cases. A total of 145 segments were documented and included as part of the 1977 IVAM Annual Report. This set constitutes the complete "menu" of sectors which IVAM must be capable of producing to provide a full weather information service to broadcast and cable TV media. It should be noted that variation of color, line quality, shading, library image element constructs, and several other pictorial factors is permitted to provide a greatly expanded apparent set of segments, but the basic set of 145 segments remains. Thirty-six of the segments were converted to video storyboard format, a process which translates the segment description from meteorological terms to video terms. This task has been completed fully.

Task C. Evaluation of Presentations: During each of the three years

* The complete task statements were quoted from the contract in section 1.2.2

of the program films and video tapes of simulated and actual segments and parts of segments have been produced. A complete listing of these test materials is given later in this report. Evaluations were made by expert weathercasters, qualified meteorologists, and several groups of "the general public". Alternative color sets, fade and dissolve techniques, alphanumerics, animation rates and techniques, information density, scintillation and other special effects, as well as overall segment organization, content, etc were evaluated in detail. The bounds of viewer acceptance were established well enough to provide a sound basis for IVAM development. This task was completed fully within the objectives of the contract. Evaluation of IVAM in full operation should be performed but was not within the scope of this program.

Task D. Evolve improved presentation: This task and Task C were parts of the same process. As test materials were produced and evaluated the results of the evaluations were incorporated in the IVAM design and in producing the next set of test materials. Some alternative techniques which influenced hardware and software design criteria strongly, such as scene to scene transition techniques, were subjected to several test and evaluation iterations before sufficient evidence was collected upon which to base sound decisions. This task was completed fully.

Task E. Automation of presentation: The design objective of fully automatic IVAM operation was retained throughout the program. It was not possible to demonstrate a fully automatic system because the program was not allowed to continue to this point. However, all software and hardware designs and specifications were based on fully automatic operation. With the IVAM system fully defined, and with software about 80% completed no difficulties were identified which would preclude fully automatic operation within reasonable design and cost limits.

No loads were added to NOAA on-line processors except that equivalent to a single forecaster display to the AFOS data base processor. This task was completed fully and successfully.

Task F. Conceptual design of distribution system: A completely compatible existing capability for distribution of IVAM presentations to all network broadcast TV stations was developed and documented during the first year of the program. Repeated contacts with network and station representatives during later parts of the program confirmed the validity and availability of this distribution path. Since the capability already exists, the only costs involved in employing it are the cost of connecting from the IVAM equipment to the nearest network station or communication feed, and a relatively minor increase in labor by station operating engineers. These costs were considered to be trivial or easily affordable by network and station representatives. Distribution to independent broadcast stations and to cable outlets can be handled partially by the network distribution system. However, the local and regional variation in input arrangements is so large that it is not possible to specify a system for all possible TV outlets. Nevertheless, the cable outlet operators which we contacted individually or at conventions all agreed that if the IVAM service were available they could and would find a way to connect to it. This task was completed to the full extent possible short of actually negotiating distribution agreements.

Task G. Reports: Monthly progress reports were submitted most of the time. They were suspended during the six months period when the program was without contractual coverage and they were not submitted from May to December 1977 when the program was in a "close-out" phase. This task was not performed in complete compliance with the contract.

Task H. Annual Report: An annual report and briefing were presented

each year at the time and place specified by the NOAA technical monitors.

Video tapes were delivered at the same times as required. Software has been delivered by pieces when requested by the NOAA technical monitor, and a complete software set is being delivered with this final report. This task has been completed fully.

Task I. Documentation: All parts of the program have been fully documented and delivered to NOAA at the time of, or as part of, the annual reports and this final report. This task has been completed fully.

Task J. Software: The software which has been developed by IVAM is described in considerable detail in this report and is thoroughly documented in the software package delivered with this report. Of the specific requirements stated in the contract under this task the following should be noted:

- The IVAM system is completely compatible with AFOS so far as we have been able to determine the AFOS configuration. No attempt was made to write software for the AFOS computer nor was there any requirement to do so.

- Narrative descriptions of the software, etc., have been completed and delivered.

- Functional Flowcharts have been submitted at the highest level. More detailed flowcharting has not been done because it would be a useless exercise and because the contract does not require it.

- Source listings with comments for all software have been completed and delivered.

- Test data and testing methods are described in the software documentation where appropriate. Since the IVAM software is incomplete there is no way to test the software as a system.

This task has been completed fully.

The Cloud Graphics Study was added to the IVAM contract in 1977. The task, as described in the Work Statement amendment was to: "Perform the necessary work to develop the techniques and software to transform satellite images into video graphics and to participate in the determination of the meteorological significance and value of the graphics in particular applications. The study shall be conducted in accordance with the Scope of Work set forth in Contractor's letter of proposal dated October 19, 1976. The total estimated cost for this additional work is \$20,000.00."

The work performed under this task is described completely in Appendix E. The task was undertaken at the request of representatives of the AFOS Program Office who were interested in techniques which might permit transmission of satellite images over the narrow-band digital AFOS data link (National Data Circuit). Several schemes for reducing bandwidth were investigated and two were developed in generalized software programs. Using these programs, video tapes were made of several weather situations at several geographic scales reduced in bandwidth by several combinations of reductions in resolution in x,y and amplitude dimensions. Both software and video tapes were delivered for evaluation by the AFOS office. This task was completed fully and all objectives were met.

1.4.2 Last Words

The objectives of the IVAM program were ambitious and there was ample reason to consider the program to be one of high risk. The NOAA leaders who supported the program deserve credit for their courage and foresight. We who worked on the program are grateful to them for the chance we were given. We wish we had been allowed to complete the remaining 20% of the job and to put an IVAM system into test operation. We are proud of the work we did, and we consider the program to have been a complete success. All contractual objectives

have been met or exceeded on schedule (to the extent we were able to control the schedule) and nearly within costs. In this period of increasing inflation an overrun of 9% is neither unusual nor unexpected -- although it is regrettable.

The results of IVAM provide an excellent foundation upon which to produce a complete system. We would be happy to assist others in building the system even as we seek ways to do it ourselves. It is less important who produces the mesoscale weather service than it is that it be done well and soon. The needs of the public for a mesoscale weather service have been well established. IVAM has demonstrated the feasibility of meeting those needs economically. We should get on with the job.

1.4.1 Last Words

The objectives of the IVAM program were ambitious and there was again reason to consider the program to be one of high risk. The NOAA leaders who supported the program deserve credit for their courage and foresight. We who worked on the program are grateful to them for the chance we were given. We wish we had been allowed to complete the remaining 10% of the job and to put an IVAM system into test operation. We are proud of the work we did, and we consider the program to have been a complete success. All contractual objectives

REFERENCES

1. SSEC, 1971: Multidisciplinary Studies of the Social, Economic, and Political Impact Resulting from Recent Advances in Satellite Meteorology, Interim Report, Volume 1.
2. *ibid*, 1971: Volume 2.
3. *ibid*, 1972: Volume 3.
4. *ibid*, 1972: Volume 4.
5. *ibid*, 1973: Volume 5.
6. *ibid*, 1974: Final Report, Volume 6.

Scanner's note:

This page is blank.

2.0 PRESENTATION CONTENTS STUDIES

2.1 Approach

The purpose of this study area was to determine the contents of the IVAM TV weather presentations. Several approaches were considered, such as cataloging the present TV weather shows into several categories, based on style, station network, geographic location, etc. or defining a few basic TV presentation formats based solely on weather data available.

Instead, a more general approach was chosen which was to study the needs for weather information by various user groups, identify the parameters of those needs, then determine the constraints on a TV presentation based on limits of data available and limits inherent to the TV media. These requirements, approached separately from the user's standpoint and the producer's standpoint were then combined into a series of matrix charts, further refined by combining various parameters, until a set of units exist, described in terms of all the parameters. These basic units are called segments, and by defining a scenario of segments, one can define a complete TV presentation.

2.2 User Group Studies

A series of intensive library searches were performed to determine the needs of various users. The users were sorted into three major groups, with subgroups, as shown in Table 2-1.

TABLE 2-1 USER GROUPS

General Public

Recreation

Health and Convenience

Pollution

Personal Transportation

Industry

General Construction
 Concrete Laying
 Utilities
 Manufacturing, Retailing and Transportation

Agriculture

Field Preparation
 Planting
 Spraying
 Growing
 Harvesting

The user's needs were defined in terms of weather parameter and season. Some items not strictly weather elements but highly weather dependent (depth of frost, degree days) are included as weather parameters because of their importance. The weather parameters identified in the needs study are:

TABLE 2-2 WEATHER PARAMETERS

Temperature	Dew Point/Fog
Degree Days	Snow Cover
Frost	Sunny/Cloud Drying Conditions
Soil Temperature	Wind
Depth of Frost	Barometric Pressure
Precipitation	Dry/Wet Spells
Relative Humidity	Severe Weather

The studies showed a seasonal dependence on needs relating to the user activity and geographic location. For instance, frost is of concern during the gardening season, but not of strong interest in northern states in winter. However, frost is of concern in southern states even in "winter". Defining "season" was approached from a strictly needs standpoint. Transitions are important to users, so a winter-spring, spring-summer, etc., definition was tried. However, these transitions still vary for different parts of the country. Certainly, calendar dates are not a reliable basis for defining season.

Suomi and others have used climatic seasonal changes as a definition of season. The method applies well here and is used for definition of season throughout the study. The important climatic changes are first frost, last frost, ground freeze, and ground thaw. These transition points are significant for virtually all user groups. While they at first seem to be mostly of agricultural interest, they apply to larger segments of the population in relationship to pollen count (allergies), fishing, hunting, camping, home gardening, etc. They further allow for large differences in climate for various geographical locations; i.e., San Diego never experiences winter as defined here. The seasons are defined as:

Spring - Ground thaw until last spring frost

Summer - Last spring frost until first fall frost

Fall - First fall frost until ground freezes

Winter - Ground freeze until ground thaw.

The user needs study results are consolidated into three study reports General Public, Industry and Agriculture, followed by Table 2-4 which is the composite matrix of needs by user group, season, and weather parameter.

Constraints, involving media, timing, and scale are discussed after Table 2-4.

GENERAL PUBLIC NEEDS - RECREATION

Outdoor recreational activities are heavily reliant on the weather for their success, either because they capitalize on some particular weather event for their performance (how can one ski without snow?) or because the activity can be extremely unpleasant without the right environment (as, for instance, going to the beach in subfreezing temperatures). Despite the paramount importance of weather, there have been few scientifically sound studies done on the subject. This lack may be because everyone has directly experienced out-

door recreation in some aspect and feels that he "knows" what role weather plays in his recreation. This subjective knowledge may not be a good guide to what is actually true. Reactions vary widely as to what weather is pleasant and what is unpleasant. Weather too cold for some is invigorating for others, the latter being more inclined to use the day as an excuse for some form of exercise. Nonetheless, it is possible to treat the matter statistically and to average out individual attitudes. Paul(16) has, for example, looked at the attendance figures for various park facilities under various weather conditions and has been able to conclude that only 10% of the people will use the beach if temperatures fall below 19C. Where available, this sort of data has been used in this report. Hopefully, more such studies will be done in the future.

SUMMER OUTDOOR RECREATION

Summer activities considered here have a fairly wide range: from the more solitary activities of hunting and fishing to the public use of park facilities for sports, swimming, touring, and picnicking. Weather factors which were considered range from the particular needs of the activity concerned (tracking animals is harder or easier depending on wind, precipitation, etc.) to the general conditions under which most people find it feasible to be out-of-doors. Also, the importance of weather severity varies according to the activity. Only the worst conditions will stop many hunters, relatively little discouragement is enough to cancel a picnic or a trip to the beach.

Also considered were dangers of inconveniences to persons who are outside, such as forest fires and insects. If fire dangers are high, people should be aware of this before they enter a wooded area. Similarly, an otherwise ideal outdoor setting can be unpleasant if long term weather conditions have been conducive to mosquito breeding.

Temperature and precipitation are the two most important variables in recreational activities. Mild temperatures are conducive to good fishing(5), while warm temperatures above 22°C encourage swimming and beach activities. Warm temperatures have their disadvantages too: insects such as mosquitoes like warm humid air especially at night (12), and hot daytime maxima dry out wood and increase the danger of forest fires (11). Cool temperatures, on the other hand, tend to preserve animal scents and increase hunting prospects (14). Not surprisingly, below normal temperatures over an extended period in summer have a definite depressing effect on the tourist trade (9).

Perhaps the most unpleasant event that can normally occur to a recreational activity is rain. Sports events may be cancelled (10), race tracks closed (2), picnics and park sports forgotten (16), and general tourist trade and camping discouraged if wet weather continues for an extended period (18,19). Pools and puddles of standing water also increase insect breeding (12).

Relative humidity also plays an important role. While high humidity makes swimming, park and beach use more inviting, active sports are discouraged (16). High moisture also increases hunting prospects by preserving animal scents (14). Low relative humidity can increase forest fire danger (11). One should also mention fog, which is a menace to boating (1) and ruinous to scenic views (18).

WINTER OUTDOOR RECREATION

Winter activities are more limited than in summer and are mainly dependent on conditions of the snow and ice. These include skiing, skating, snow-mobiling, ice fishing, and ice boating. Among the most weather sensitive of these is skiing. Taking place in hilly or mountainous areas, the weather there usually varies appreciably from residential areas, thus increasing the need for pertinent weather data. Although artificial snow-making has decreased the skiers'

dependence on proper snow conditions, such snow-making has weather criteria of its own, including proper conditions of temperature and humidity.

One winter hazard is included here, that being the threat of avalanches. This is a very real threat in the mountainous areas of the West, against which the skier is not always adequately forewarned.

In winter, an optimal range of subfreezing temperatures is necessary, both to preserve the quality of snow for skiing (8) and snowmobiling (17), or to allow freezing of ice (4) and artificial snow-making (6). Temperatures too low can lead to dangerous icing of the ski slopes (8). Alternate freezing and thawing constitutes another danger to ice fishermen and snow-mobilers since such fluctuations weaken ice and create large cracks (4).

Besides the obvious advantage of snow cover to skiing and snowmobiling (8,17), snow aids in tracking animals for hunting (3). Rain in winter is seldom a welcome event; it hurts snow conditions (8) and can increase the danger of avalanches (13). High relative humidities are also undesirable since they prevent artificial snow-making and help make a day raw and damp -- weather particularly uninviting to a skier (7).

High winds are known to cause closing of chair lifts and ski tows (15), to discourage snow-making (7), and to cause drifting and packing of snow, a factor in avalanches (13).

GENERAL PUBLIC - HEALTH AND CONVENIENCE

Certain weather conditions have a definite effect on the comfort or health of the human body. These effects fall into two general categories: those to which a normal, healthy body may be subjected, as in heat stroke or discomfort from humidity, and those which a person suffering from some disability or ailment may find harmful (e.g. the effect of cold air outbreaks on asthma pa-

tients). There is little doubt that adequate warning to persons especially vulnerable to certain kinds of weather would be generally beneficial to public health.

Temperature has been shown to have an effect on human health. Falling temperatures or cold winter outbreaks of arctic air have been associated with a range of public health problems from arthritis and heart ailments to glaucoma and asthma. Warm air, especially with humid air, correlates well with congestive heart disease, heat stroke, glaucoma, and tuberculosis (21,31). A number of interesting studies have found that reaction times are slowed in the warm, humid sector of cyclones with an unmistakable rise in the factory and motor vehicle accident rate.

Of course, temperature is associated with less severe and more mundane matters. No one would dress without some consideration of what clothing would be warm or cool enough, although often such a basic decision is guesswork that is later regretted. There do exist, however, definite quantitative guides to adequate clothing (29). Home heating is another every day factor which could be estimated over the season for the benefit of those who are keeping track of their fuel bills (21).

Periods of warm, humid weather especially in the spring or early summer play a large role in the size of the insect population (27). While not commonly harmful, large numbers of mosquitoes are certainly an example of a nuisance to be avoided.

Health problems due to actual rain or snowfall are not serious; however, high relative humidities can cause scar pains, besides being plainly uncomfortable (21,31). Very low relative humidities in winter have been related to the spread of influenza while fog in combination with cooling has been correlated with bronchitis and arthritis (31). Insects are encouraged by puddles and pools

of stagnant rain water (27).

High winds may cause structural damage (32), or endanger large vehicles on highways (as a crosswind). Crosswinds on highways combined with loose snow can seriously hamper or stop traffic entirely. Wind speed is also an important factor in deciding about appropriate clothes (29). Low wind speeds have been cited as a factor in the spread of influenza (31).

Sun angle, visibility, and cloudiness, while not crucial factors in human health, all enter into the problem of sunburns (21). Bright sunlight can also encourage glaucoma (31).

Radiation, in addition to temperature and wind, is an important factor in determining adequate clothing (29).

POLLUTION

Because of its importance, air pollution is considered as a separate topic in Table 2-1. The concern of the public with pollution falls into two general areas; damage to materials and dangers to health.

Air pollution is estimated to cause 2 to 12 billion dollars damage a year to materials, much of which is private property (23). Such damage can take many forms from deterioration of paint to corrosion of building metallic objects, and damage or death to plants and trees.

Health effects from air pollution are becoming increasingly serious. In addition to episodic stagnation of air masses, trapping industrial pollutants in a small area, there are daily problems associated with traffic which releases carbon monoxide and other gases. Such pollutants are more dangerous to certain groups of individuals such as the very young and old, and those with chronic respiratory problems.

Either of the above problems associated with air pollution could be ameliorated by adequate warning on days when damaging effects were anticipated.

Temperature, by increasing chemical reaction rates, increases damage to materials due to pollution. Temperature inversions, are also a problem because they trap harmful gases and particulates close to the surface (23,24, 25,26).

High soil moisture, dew, and high relative humidities are all conducive to pollution damage and poor air quality (23).

Wind speed, direction, and duration are crucial factors in determining the spread or dispersion of pollution, an especially important factor during periods of peak traffic (8 AM and 5 PM) (23,24,25,26).

GENERAL PUBLIC - PERSONAL TRANSPORTATION

Weather is frequently the sole or contributing cause to many motor vehicle accidents, sometimes due to the fact that the motorist has not been warned of possible dangers such as slippery spots on the road. Either snow, rain or fog may increase the accident rate (22, 30). Subfreezing temperatures at the road surface can form dangerous icy spots. Frost may also be a threat to safety when deposited on infrequently traveled roads (28,30). Timely weather data, tailored to the peculiarities of the local situation, could do much to improve road safety.

INDUSTRY

The desire for improved weather information by business and utilities is evidenced by the increase in hiring of meteorological consultants or even full-time meteorologists by industry. Industrial fuel usage, generally considered in the past as primarily an economic element, has taken on new meaning in terms of energy conservation and is a greater economic consideration.

Survey of the literature suggests dividing industrial meteorological concerns into three broad areas; construction, utilities, and general commercial

needs. Separate categories for construction and utilities are used because these two industries are especially weather sensitive and both are very large operations, involving billions of dollars through the U.S.

INDUSTRY - CONSTRUCTION AND CONCRETE LAYING

The construction industry is a general term which covers operations from the initial surveying and site preparation to the laying of concrete, carpentry, masonry, roofing and painting, ending with fencing and light installation (33). Also included under construction is road building and laying of utility lines. Each of these operators has its own particular weather sensitivity, but for the purpose of this study it seems sufficient to generalize, with the exception of concrete laying which has an especially complicated relation and sensitivity to the elements. Three types of weather information are needed for construction work: forecasts for day-to-day planning of work, forecasting to insure the timely delivery of materials, and warnings of adverse weather that might occur suddenly during the course of a day (58).

It is estimated that the construction industry alone amounts to nearly 10% of the U.S. gross national product and that 45% of the construction expenditures are in weather sensitive areas. In fact, weather is among the three most important causes of delays (34). It is estimated that 500 million to 1 billion dollars or more could be saved annually if efficient use of current weather information could be maintained (68). Columns 1 and 2 of Table 2-4 show where these losses may be incurred with regard to concrete and general construction and general construction operations respectively.

Most forms of precipitation are harmful to construction projects, especially rain, sleet, dense fog, high relative humidities, and heavy snow (33,59,64). Rain, for instance, can wash out or ruin concrete (35,44,45). Even very dry conditions are not ideal since concrete that dries too quickly weakens the material.

Construction firms are generally well aware of these factors and feel the need for special information, if in fact they have not already hired a meteorological consultant (35).

High wind speeds (greater than 20 mph) create numerous problems for both construction and utility work. Wind gusts can make work with structural steel impossible (64,33) and can increase fuel consumption (38,50).

Although there is a general need for timely weather information during all parts of the day, such data is most useful at two particular times: from 6 to 7 AM and from 2 to 3 PM, when construction operations are beginning or ending (33).

Generally both very warm and very cold temperatures are inimical to construction operations (33,64). In particular, concrete laying is a sensitive operation in that both excessive heat or freezing weakens the freshly laid mixture and operations must be cancelled or redone if such temperatures occur (35, 44,45). Bricklaying is also halted in subfreezing temperatures (66). Long periods of mild weather, especially in the spring, however, can be advantageous for the economy by encouraging housing starts early in the year (50). Such an effect could be amplified if such mild spells could be foretold in advance.

INDUSTRY - UTILITIES

Two sorts of utilities were surveyed: fuel and electric companies. Both types are quite vulnerable to slight changes in the weather. Home heating, for instance, begins when outside temperatures fall below 19°C and for each 1°C below 19°C, 3 kilowatt hours per day are needed for each 100 m² of floor area. It is not surprising therefore, that utilities would pay up to \$1500 per day for a perfect forecast (37). Temperature is a prime consideration in such forecasts, which may be either short or long term (one day or several days); however, other factors such as solar radiation, cloudiness, wind (which may account for up to

30% of the meteorological variability of the load) and precipitation may also affect the load. It is economically important that fuel distributors and electric companies have the capacity to handle the day's demand without having a wasteful over-supply. Further, severe weather may impede fuel deliveries or knock down electrical lines (51).

Utility weather information is generally designed not for the astronomical day, but the "gas day", from 7 AM to 7 AM (38). Continuous updating of 24 and 48 hour forecasts are needed every three hours during the day (62).

For utilities, temperature is the primary factor in determining fuel and electrical consumption (43,37,47,50). Because of the problems connected with the storage of energy, the proper forecasting of very cold weather lasting 4 or more days is very important. Utilities are also concerned with the problems of pollution when their smokestack effluents are trapped by inversions (51).

Temperature is a primary factor in river and reservoir management in that snowmelt and runoff is directly dependent on this parameter (60).

For utilities, precipitation and relative humidity are not as important as temperature in determining electrical and fuel consumption, but nonetheless, should be taken into account (47). Precipitation may also be a factor in pollution damage from utility smokestack and cooling tower effluents. Rain falling through smokestack plumes may pick up a high acidity which will damage surrounding vegetation and pollute the groundwater (52). Cooling tower evaporation may lead to condensation and dense fog on days with high relative humidities, thus constituting a danger to nearby highway travel (52). Snow or storms may also damage electrical wires (47) or affect fuel deliveries (37).

Precipitation is the single-most important factor in river and reservoir

management and flood control. Quantitative rainfall estimate, intensities, durations, type, coverage, motion of rain storms, and distribution of rain and snow are vital needs, along with a knowledge of soil moisture and evaporation (50,60).

While clouds and sunshine are not as vital as the preceding factors, they nevertheless figure into a number of operations. Cloud-cover can, for instance, increase fuel consumption, but most importantly, it can affect electrical use since cloud heights, amounts, thicknesses, and visibilities all determine how much more electrical lighting is used (38,43,50,47).

INDUSTRIAL - MANUFACTURING, RETAILING AND TRANSPORTATION

The interests represented in this section are extremely varied; chemical companies, chocolate manufacturers, snow removal contractors, department stores, distributors, merchants, bakeries, water navigation (for large cargo ships), land transportation, etc., all have needs for varied and complex sorts of weather data which have been shown to have direct economic value in these interests (37). For example, retail trade sales and the weather type (good or bad for shopping) fluctuations move in the same direction (better sales with better weather) four times more frequently than in the opposite direction (better sales, worse weather) (53). Furthermore, sales after stormy periods do not seem to make up for the slack sales during bad weather. This finding makes it apparent that weather has great economic value to the retailer. Sales are most vulnerable when mornings are wet, discouraging the potential customer from leaving home at all, and dropping trade by up to 15% off the normal. Duration of the rain is also significant, with sales progressively falling as duration increases. Snow can have a similar effect with the added twist that suburban trade drops more drastically than that within the city or within the residential neighborhood (57). Snow has widespread effects (37)

especially on truckers, food distributors, newspapers, and street clearing crews, who need at least four hours notice for impending storms (43).

Temperature effects on general industrial and commercial needs are varied and numerous. Consumption of beer (55,61), retail sales (54), breadbaking (58) manufacturing of precision machinery parts (66), ship navigation problems with icing (65), pollution control (43), and distribution of all kinds of foods and seasonal clothing (37,57,53,66) depend on optimum temperatures which are neither too warm nor too cold. Many distributors have found it to their economic advantage to stock their products according to the national distribution of the weather (57).

In addition to the obvious problems connected with navigation of merchant ships (correct routing of ships around storms and high waves can save millions of dollars world wide in time and cargo) (65), strong crosswinds can threaten trucks and other large vehicles (69) as well as tall structures with limited tolerance to wind load (63). Wind speeds and directions are also instrumental in spreading or dispersing noxious pollutants from industry and traffic (40, 41, 36,39).

Those interests represented on Table 2-1 can only be said to provide a sampling of possible meteorological needs; many more have only begun to be discovered and met by the existing meteorological know-how.

An additional factor to be considered in this area is the effect of pollution on industry. While actual construction is not affected greatly by pollutants, utilities have to worry about pollution they may generate in the course of their operations (51). The physical plant of many industries, as well as their materials, may also be adversely affected by pollution combined with certain weather conditions. Paint, metals, and masonry have a much shorter life-

time when various gases such as SO_2 and various flourides can combine with available moisture in the air to form corrosive chemicals that destroy the appearance or substance of common building materials. It is estimated that 2 to 12 billion dollars damage per year is made on materials in the U.S. , many of these materials associated with commercial and industrial interests (39).

Of course, the ultimate solution to this problem will depend on air quality control; however, until then industry must be aware of pollutant conditions against which they might guard if given adequate warning. Gaseous pollutants can cause virtually no damage when the moisture in the air is low; on days with higher relative humidities, industries could protect vulnerable equipment from the high moisture content through the use of special storage or dehumidified areas. High relative humidities have a different range of effects on the storage of chemicals (37) and rust or corrosion potential (66). This is particularly important where air pollutants are high (43). Plentiful sunshine can also induce more retail trade (54,64). Finally, movie producers and aerial photographers are examples of trades that are highly dependent on natural lighting conditions (37).

AGRICULTURAL

To farmers and other agriculturists, the close relationship between their enterprise and the weather is a very constant one. By the same token, the influence of weather on crops and other aspects of agribusiness is fairly common knowledge around the world. All meteorological elements are important to agriculture, from simple temperature and rainfall to solar radiation and the complex relations of evapotranspiration (93). Historically, man's concern with weather and crops goes back to Biblical times and before. No doubt the prehistoric change from nomadic to "settled" cultures depended to a large degree on,

among other things, a suitable aggregation of weather factors(112).

Coming up to the present times, a tremendous amount of technical interest has been shown in the field of agrometeorology. For example, Wang and Barger (1962) published a formidable bibliography of this field with 10,762 entries, acknowledging nonetheless that in many areas the titles do not represent an exhaustive list. Furthermore, the entries date back only to the beginning of century. In addition, hand and computer searches of recent literature carried out for this paper indicate that there has been an extremely large contribution to the agrometeorological literature since 1962.

On a national level, the Department of Commerce and the USDA cooperated in the development of a plan for a national agricultural weather service (120). Since many of their arguments, particularly the focus, rationale and objectives are consistent with those of IVAM, a discussion is presented here of various aspects of the federal plan (hereafter cited by page reference).

In the foreword, Coordinator Robert M. White points out that the plan "focuses on the need for providing specialized weather services to farmers and other agribusiness interests." As part of its rationale the report states, "Weather is the most significant variable explaining year-to-year fluctuations in ... yield ...," and "Less-than-optimum growing conditions for 79 of the principal crops ...[are estimated to]...reduce farm income by an average of \$1.6 billion per year". (Page 1).

As an objective, "Weather support to agriculture should be designed to contribute to user decisions which will minimize losses resulting from adverse weather conditions and will improve the yield and quality of agricultural products through effective cultivation, processing and marketing procedures and control of pests and diseases" (Page 2). An additional parameter to the foregoing

area is that , "Producers in particular require more than strictly meteorological information; they require detailed and specialized assistance in the determination of the implications of forecast conditions to their immediate operations" (Page 14). A moderate, well-planned and scientifically-based system of advisories would indeed be a useful and necessary adjunct to an effective agrometeorological program.

For emphasis, at this point it seems appropriate to quote from a report (119) which will be used extensively to document the tabular presentation accompanying this paper. The report, extensive and detailed, is a carefully worked out investigation of the significance of accurate weather predictions to the management of a representative list of specific horticultural crops. The authors state:

Complete and precise weather information is of significance to crop production because the scheduling of most operations is controlled by the weather and because the plant itself grows and responds differently under varied weather conditions. Thus weather information is a necessary factor in the majority of decisions concerning the production and marketing of each crop. Each grower tends to make maximum use of all available weather information to arrive at the best estimate of climatic conditions for the decisions that he has to make. (Page 36)

As a key part of the method of the federal plan, "The total user population ... [was divided] ... into a number of categories and subcategories. For each of these groups, weather-sensitive operational decisions were identified, and for each of these decisions the necessary weather information inputs were determined" (Page 5).

A follow-up report (121) shows that in certain selected areas of the U.S. the existing Agricultural Weather Service "effectively meets the needs of agricultural interests within existing technical capabilities" (Page 27). The balance of the report describes a proposed improvement of the service by implement-

ation of a phased program to provide coverage to all currently unserved areas.

Less-than-optimum growing conditions for 79 crops reduce farm income by well over \$1 billion per year (120). Much, if not all, of this reduction is due to weather factors and some of it could not be prevented even if weather forecasting methods for agrometeorology were, in fact, perfect.

The value in improved forecasts to agriculture lies not so much in warnings of severe weather, but in information that will improve the efficiency of a farming operation. A grower's response to accurate, specific information on expected weather can be in the form of effective decision-making, leading to costs savings or improved return; whereas in the event of impending severe weather the most a grower can do is get livestock, machinery or men in from the field, secure shed doors, or in certain cases, begin a forced harvest or work up soil to reduce loss by wind.

A farmer may vary some of his operations within a given time block to accommodate vagaries of weather, but extreme delay can be costly, and once committed to an operation, such as planting, he must face subsequent weather elements as they appear. For example, in a study using the parameters of soil temperature and autumn sowing of wheat in England, the variety Capelle, it has been found, should not be sown earlier than 10 days after soil temperature at a 4 inch depth first falls below 13C, nor later than 45 days after the same point. Failure to plant in this period will result, on the average, in a yield reduction of 2 cwt. per acre per week (114). Hence, an accurate prediction and reporting of soil temperatures would be of economic benefit to English wheat farmers. At the same time, forecasts of rainfall would be helpful so that the farmers would be able to plan for wheat planting within the optimum soil temperature time period.

This same line of reasoning can be applied to crops grown in the U.S., although the details regarding specific temperature, number of days, and so on, will vary. The farmer will be capable of making the decisions applying to his crops or livestock, assuming he is provided accurate weather information and pertinent advisories.

Crop Values

The federal weather plan (120) defines highly weather-sensitive crops as those "for which growth, disease and pest control, and productivity are closely associated with one or more elements of the weather; and for which the farmer, given an accurate forecast of unfavorable weather, can take protective, preventive or corrective action or given a forecast of favorable weather, can take position action (plant, spray, harvest)" (Page 24).

On the basis of this definition, the following crops were considered the most weather-sensitive: vegetables, fruits and nuts, cotton, tobacco, peanuts Irish potatoes and hay.

Looking at estimates of some crop values that could indeed be affected by accurate, timely weather forecasts, Dancer and Tibbits (76) reproduce a USDA table for crops whose value, at more than \$24 billion, represents over 92 per cent of total U.S. crop value for the 1970-71 season (See Table 3). By a search of the literature and a series of personal interviews with crop and production experts in many sections of the country, they arrived at several sets of figures that approximated the savings in dollars that could be realized by improved forecasts of various weather elements for the crops listed in Table 3.

The operations that were affected included:

- (4) Seedbed preparation, planting
- (1) Spraying (air, ground, insect, weed, disease control)

(2) Protection of certain crops from high or low temperature extremes

(3) Harvesting, combining, processing

(The numbers indicate ranking in estimated dollar value of savings accrued from improved forecasts).

The total crop value of improved forecasting on a nationwide basis was estimated to be over \$74 million. Within the short-forecast-period parameters of their study, Dancer and Tibbits were not able to establish direct savings from improved forecasts for several main crops, including field corn, soybeans, wheat and oats. These crops, of relatively low value on a per-acre basis, are grown on a large scale in this country and around the world, and do not lend themselves to high-cost weather-preventive actions such as intensive irrigation, frost-fighting, etc. However, on a longer-term forecast basis, especially at planting, spraying and harvest periods, the literature does infer benefits to these crops from improved forecasting. Because of the large acreage devoted to these crops, the \$74 million dollar figure cited alone would no doubt begin to approach the \$1 billion figure of the 1967 federal weather report.

According to the federal Plan for a National Agricultural Weather Service first priority should be assigned to the forecasting of precipitation, its occurrence, timing and amount. Next is evaporation, with emphasis on measurement and accuracy of forecasts. Other factors in order of the importance assigned by those writers are temperatures, inversions, wind and dew.

In another paper (89) where the National Weather Service is shown to be moving even more in the direction of providing specific forecasts for agricultural and other particular users, it is suggested that the following weather information, added to the present forecast format and given to television meteorologists, would be useful to farm as well as urban viewers: 1) an extended outlook,

2) wind speed information, 3) the average daily soil temperature at a 4 inch depth under sod, 4) a drying index, 5) a livestock temperature index, and 6) a dew forecast for the next morning.

In their report, Dancer and Tibbits decided that the following weather elements were most pertinent: precipitation (intensity, duration); wind (direction, velocity); cloud cover; critical low temperature (time, duration); critical high temperature (rate and time of change); dew point, and air temperatures.

Temperature, Air

In a complex study by Guise (84) high-predictive-value regressions on wheat yields were found for the influence of the following weather elements: pre-planting temperatures, harvest temperatures, planting rainfall, and growth period rainfall. Wang and Suomi (128) found that warm and cold spells, rather than merely mean temperatures, are important parameters for all crops. Puffer and Turrell (105), in discussing frost protection in citrus, feel that important parameters are freezing, frost, dewpoint, temperature inversion and cold air drift.

The heat-unit system is in use with many crops; Decker (78) gives a useful review of the topic, as do other workers, so this paper will not attempt more than a brief summary: growth generally begins for many plants when several consecutive days with maximum temperatures above 4.4°C occur. For other plants, grown usually under warmer conditions or planted later in the season, the threshold temperature appears to be near 10°C or, for some even 15.6°C . Cereals and forage crops tend to fall in the 4.4°C category; crops such as corn, sorghum and soybeans in the 10°C group.

Temperature, Soil

The effect of soil temperature has already been introduced in regard to

Capelle wheat (114). With peanuts, soil temperature is considered ideal for spring planting after the mean temperature at a depth of 10 cm has exceeded 18°C for at least 10 days (132).

As one of the bases for his system of "crop prediction without weather forecasts", previously mentioned, Wang (125) reports that the effects of soil temperatures on the subterranean ears of sweet corn in the early seedling stage determine the number of days required for maturity.

Precipitation; Drying Index; Evaporation

The influence of rainfall is commonly known to be of great importance on crops and is well documented by a representative study of irrigation practices (122). Rainfall variations account for appreciable portions of the variability in irrigation water demands. Current rainfall is usually relevant, particularly in summer and fall. In summer, rainfall of the previous month has its least influence. Spring temperature variations also contribute to demand at that season. Hence, accurate rainfall predictions will be of decision-making help to the increasing number of irrigators in the country.

In other farm operations, such as haying and combining, rainfall forecasts are essential (119,76,85), and the prediction of dry spells and wet spells is of even greater importance (128,116).

Wind: Speed, Direction, Duration

Because of its influence on many farming operations, wind is another of the main parameters to consider (76,82,87,88,115,119). Apple harvest, grain combining and other harvest operations are more successful if they can be carried out before rather than after windstorms, assuming the crop is otherwise ready to harvest. Sprinkler irrigation is adversely affected by wind velocities over 8.047 Km/h; wind forecasts help irrigators plan their field schedules. Scores

of many disease alerts can be influenced by accurate forecasts. Hot, drying winds are a positive influence on haying, although they have a harmful effect on the growth of hay crops and other farm plants. Wind forecasts enable a grower with sandy soil types to work up the soil prior to the arrival of high wind to prevent soil erosion and the killing off of young seedlings by the blowing soil particles.

Solar Radiation: Cloud Cover

These two parameters, although related to drying and evaporation, have important effects on their own, some of which are sensitive to forecast efforts and other that are not. In the latter category is the fact that the quality and intensity of solar radiation have a direct influence on the dry matter composition of various crops, most notably, the Irish potato (2). This phenomenon is essentially a constant for a given region, and accounts, for example, for the slightly better processing quality of potatoes grown in Idaho compared to those from Wisconsin. On the other hand, net solar radiation which should be susceptible to forecasting, has an influence on air turbulence in the plant microclimate which in turn can adversely affect the spray pattern of small-droplet-size pesticide sprays (89).

Multiple Parameters

Although not all of their factors lend themselves to prediction, or decision making, models are appearing in the literature that depend on complex agrometeorological approaches. As an example, the abstract of a Russian paper (92) reports on the multiple interaction of several weather elements with cereal yields: rainfall of August and September, sum of minus temperatures in the frost period, number of days with thaw, depth in mm to which the land is thoroughly soaked in March, rainfall in the spring - summer period, time for the beginning of vegetation to shooting, number of days from swelling to full

ripening, number of days with dry winds, and rainy days in the harvest period. The authors claim that the rate of yield increase is thus determined on the basis of the appropriate rate of increase of the factors investigated.

IMPROVED TECHNOLOGY

An increasingly larger segment of the literature reflects satellite technology, such as Nagarajan "Satellite television cloud photography as a possible tool to forecast plant disease spread" (100).

Simultaneously, a continuing improvement is being made in the sophistication and efficiency of weather forecasting instruments and procedures (126) so that the weather prediction capability asked for or implied in the foregoing discussion are now, or soon should be, available.

AGROMETEOROLOGISTS - LIAISON SPECIALISTS

Up until the present time, meteorologists with a little training or background in agriculture -- or often with no such training -- have been assigned weather bureau offices where weather forecasts have been prepared for farming communities (120,121). That such a program has been only marginally effective no doubt prompted the article title, "Agriculture - the Forgotten User of the Forecast" (87). These two U.S. Department of Commerce publications discuss in detail the requirement for trained agrometeorologists who will be equally capable and "at home" in interpreting weather data for agriculturalists (and vice versa). Such persons are indeed being trained at Land Grant Colleges and elsewhere to fill the need for agricultural forecasters.

DISCUSSION AND SUMMARY

The problem of improving agricultural operations by expanding and refining meteorological capabilities is of concern in the "established" nations as well as the "upcoming" nations of the world, and a great deal of agrometeorological activity is going on in all those places. The interchange of agrometeorological

technology, in terms of both "software" and "hardware" inputs, is enabling the production of systems that are indeed improving the planning and production efficiency of agriculturalists around the world.

The following weather elements or forecast parameters are of greatest importance for the agricultural phase of IVAM:

Precipitation	Occurrence, timing, amount
Evaporation	Amount, drying index
Temperature	High, low, duration; critical levels
Wind	Velocity, direction, duration
Dew and dewpoint	
Degree days	
Soil temperature	
Soil moisture	
Others (of great importance in certain situations):	solar radiation, cloud cover, storms

The following crops are considered to be most weather sensitive:

vegetables, fruits and nuts, cotton, tobacco, peanuts, Irish potatoes, and hay. All crops, at one phase or another of their growth cycle, can benefit from timely, accurate weather forecasts coupled with agricultural advisories. The twenty most valuable crops or crop categories in the USA are summarized in Table 2-3.

Table 2-3

Production Value and the Principal Growing Areas for the Major Economic Crops Grown in the United States. 1970-1971 Growing Season. (USDA Crop Report).

<u>Crop</u>	<u>Production (millions of tons)</u>	<u>Value (millions of dollars)</u>	<u>Growing Area (Principal States)</u>
Field Corn	155.0	5890	Iowa, Ill., Ind.
Soybeans	35.1	3465	Ill., Iowa, Ind.
Hay	131.0	3333	Cal., Wis., N.Y.
Wheat	49.2	2168	Kan., Daks., Wash.
Cotton	7.0	1679	Cal., Texas, Miss.
Tobacco	0.9	1368	N.Car., Ky., S.Car.
Sorghum Grain	25.1	926	Texas, Kan., Nebr.
Citrus*	11.3	670	Fla., Cal., Texas
Potatoes	15.8	626	Idaho, Cal., Maine
Oats	14.0	638	Minn., Daks., Wis.
Tomatoes	5.8	444	Cal., Ohio, Ind.
Barley	11.1	443	Daks., Minn., Cal.
Rice	4.2	440	Texas, Ark., La.
Sugar Beets	26.9	414	Cal., Idaho, Colo.
Peanuts	1.5	406	Ga., Ala., N.Car.
Grapes	4.0	372	Cal., N.Y., Mich.
Apples	3.1	308	Wash., N.Y. Mich.
Lettuce	2.3	272	Cal., Ariz., N.M.
Peaches	1.4	173	Cal., S.Car., Ga.
Processed Vegetables**	3.2	161	Wis., Ore., Minn., N.Y.
TOTAL	507.8	24,096	

* Includes oranges, grapefruits, and lemons

** Includes green peas, snap beans, and sweet corn

2.3 Media Constraints

IVAM concepts were discussed with different sections of the television industry to identify a basic framework defining programming requirements. The conferences involved people within the main offices of the major networks, government regulating agencies and local stations. A survey from the AMS Weathercaster Convention in Denver in 1975 and current literature on the media were reviewed. Three types of television media require separate consideration:

1. Commercial Broadcast Television
2. Public Broadcast Television
3. Cable Television

Commercial Broadcast Television

Commercial television has been in existence for roughly 25 years. Its remarkable growth and impact on society quickly overshadowed most of radio and the print media. The motivating force in this nearly exponential growth is free enterprise. Advertisements consume about 25% of daytime television and about 13% of prime time. While this compares favorably with other media, program content is determined by the commercial needs of the industry, not the public interest. Entertainment and sports comprise 75-90% of the total commercial television offering, with public service accounting for just 2 1/2%. The remaining percentage is divided among news and wide variety of other programs. (144)

Commercial broadcast-television presents two nearly opposing views on needs for weather information. The general opinion held by the three major networks is negative to changes in weather information presently provided. (141, 143, & 145) IVAM concepts were considered, but suggestions for any changes were met with resistance. In general, the network officials liked the idea of IVAM but felt it must be handled locally. However, each network said they would

distribute IVAM if the other networks were using it. The thrust for getting IVAM implemented into the networks is through a "grass roots" need expressed by the public and local affiliate stations. This need exists now, and was stated definitely by those interviewed; however, we believe that its full impact will not be felt until there is a clear demonstration of how IVAM would improve existing weather information systems. For instance, satellite pictures now distributed by networks are of poor quality, but are delivered because affiliate stations use them. This has set the standard for "improved" weather information, and the networks will not provide more until they see that an improved service is possible and is demanded from the public and affiliate stations (141, 143 & 145).

Local affiliates have a very different attitude. They want weather data better in quality, better in timeliness, and more specific to the locale.

Affiliates display differing weather information requirements. The three Madison network outlets offer the following options:

Station 1 Weather is part of the news program, but receives only summary coverage with emphasis on "newsy" weather. They would prefer a completely prepared 1-2 minute format and would use it on their news without any changes. If the audio is acceptable to them, they would use it as received. (134)

Station 2 They definitely want their own audio and "personality" in the program. They also want a choice of formats so they can be different from other local stations. (136)

Station 3 This station has a professional meteorologist and wants IVAM data in segments so it can be presented with a varied program format leaving maximum options for professional meteorological expression. The IVAM concept is highly desirable to this station since their meteorologist presently spends 3-4 hours per day in graphics preparation. (148)

At the AMS Weathercaster Convention in Denver in 1975 the IVAM program was described and an opinion questionnaire circulated. IVAM concepts were enthusiastically received as great improvements in providing timely data and saving time in the preparation of graphics. Most weathercasters said they would use

short (30-60 second) segments of weather updates during regular daily programming breaks. (137)

Results from a study of stations conducted by SSEC provide some general guidelines:

1. None of the stations present weather information outside their news blocks. The locally generated news blocks were the 6 PM and 10 PM segments and less frequently at noon. Networks supplied news and weather at breakfast time. When asked about plans for increasing program lengths or the number of presentations, an overwhelming majority said they had none.
2. Calculations based on a segment of the total sample indicate the mean program length for selected Midwest stations is 3.3 minutes, the median is 3.5 minutes and the standard deviation is 1.156 minutes. These figures suggest a program of 2.5 to 4.5 minutes, broadcasters may not balk at more frequent and more lengthy weather presentations, but presently available data and manpower cannot support greater weather coverage. Most stations said they would "consider" greater frequency and length if IVAM products were available.

Public Television

This form of broadcasting originated out of a general feeling of inadequacy over commercial television's programming in the public interest. The PBS relies primarily on foundation grants and, more recently, government subsidy and is free of commercial broadcasting pressures for advertising revenue.

Public television stations as a rule do not have daily news teams; however, there are notable exceptions. Most PBS Stations do not compete with the networks or local stations with area news due to the expense. Commercial stations provide this service because of public service requirements and sponsor desire to advertise.

Public broadcasting lacks the stereotyped news telecast format found in most commercial stations. Lacking this tight format, PBS can exercise greater flexibility in the use of IVAM information. (147)

The PBS is most responsive to requests of its affiliate stations. The IVAM

products would be distributed on PBS when it is requested by a number of stations. For example, the Aviation Weather Show, produced weekly on PBS, is very well received. While it is aimed at aviators, its large following by non-aviators is attributed to its clear, thorough presentations of high quality graphics. (138)

The PBS has less rigid programming schedules than the commercial networks, and often has 1-2 minute spots to be filled. These spots are filled now with fillers like musical interludes. On some days public television even has 5-15 minute time spots open. These voids could contain IVAM programming. For longer periods, tutorial weather presentations would be welcomed. (147)

For PBS, with more program time available (on the average) than commercial television, greater coverage of weather information is possible. Studies show the public's television attention span lasts about 20 minutes, so 5-15 minute weather shows may be feasible. (147) Further, public television does not promote the "personality" weatherperson, allowing a longer show with less concern for devices like "chromakey" and cuts.

Cable Television

Cable television began as community antenna television (CATV) and provided service by cable to areas unable to receive conventional broadcast signals. Since then, cable has grown into a very large business, servicing rural communities as well as cities. The ability to receive the broadcast is now assured and the importation of programs from other areas is the real attraction. The Federal Communication Commission, which initially refused to regulate cable, has changed its mind. This decision forced cable television businessmen out of the cable installing business and into the broadcast business. Requirements for local origination of programs, provision for access by the public and limitations on importation has complicated the situation. The impetus for

three tiered regulation (federal, state and local) is the realization of cable television's potential to provide greatly expanded public service communication.

This has created concern among cablecasters. While the cost of production equipment and staff is an important concern, it is really another problem to fill a channel with locally originated programs from the start to the end of the broadcast day. This feat is accomplished by commercial network affiliates only with the help of extensive network programming. This is the reason we see stock market alphanumerics, screens filled with news teletype output, and whole "weather" channels devoted to 20 second scans of weather dials. One solution is "netting" or interconnecting various cable companies for mutually shared programming. This subject will be discussed further in the IVAM distribution section on cable netting.

Our experience in preliminary discussions with local cable operators indicates a genuine willingness to experiment with new presentations of weather data and willingness to commit a full-time channel to weathercasting. This presents perhaps the greatest opportunity for the ultimate weather presentation format; a continuous, dedicated 24-hour service. In fact, many localities require the local cable TV company to provide 24 hr. continuous weather coverage. Utilization of such a channel is the IVAM challenge. Cable TV can reach more varied segments of the population more often than the broadcast media. Given the conservative projections that 60% of the American public will have cable service in the next 15 years, the full service potential of cable TV becomes a major communications opportunity. Warning systems incorporated into some cable companies in severe storm areas of the South has led to increased subscribership.

Specific methods for covering cable needs will be presented in the formation of segments section.

Significant differences in requirements are posed by each of the media alternatives. Three important examples of these are evident when considering presentations of weather information on commercial television:

1. The use of weather "personalities" requires the IVAM product to be prepared so that both voice and image of the weathercaster can be placed in the foreground by relatively simple techniques (chromakey or camera insert) available at most stations. The IVAM graphics must be a significant improvement over the locally generated visual aids now in use, but this objective is easy to achieve.
2. By making the same video package available to all commercial stations in a market area, there would be little to distinguish one weather show from another. Broadcasters will "individualize" the segments through selective videotaping, and by adding some locally generated visual aids, but one can expect that weathercasters will seek a greater element of control over initial segment development.
3. The question of credibility, or accuracy, is also important, for this would be one of the criteria used by the broadcaster to decide in favor of implementation. Believability is dependent upon the original source and timeliness of the data, the speed of the processing, analysis and packaging of the data, and the quality and style of delivery. High standards must be constantly maintained in all these areas. Frequency of presentations also affects this issue because credibility may be seen as a function of frequency.

Public television also challenges our weather presentation program. Some of the major issues are:

1. Public broadcasting stations have not established a weather broadcast schedule to the extent that commercial stations have. One can expect considerable experimentation by the PBS stations in the use of the IVAM product and a serious attempt by these stations to identify and meet the weather needs of their particular audiences. Requests for reporting of weather parameters not normally used by the commercial stations can be expected.
2. The PBS audience is small, select and dedicated; PBS programming does not attract the same audience as does commercial station programming. However, polls have shown that when regular programming of materials of general interest is provided, PBS stations do capture a large segment of the market.

Problems presented by the cable television industry include:

1. Rural areas will be the last to be completely cabled. Exclusion of this service jeopardizes achieving the goal of reaching one of the largest single groups of weather information users. The financial health, and therefore the audience expansion rate, of the cable TV industry has been affected by opposition from broadcasters and by severe government regulation. There is no doubt that cable TV will continue to grow, but the rate of growth is dependent upon factors not under the immediate control of the cable TV industry.
2. Timeliness and quality of the cable TV weather presentations are important to establishing credibility. It is not true that standards for cable TV can be lower than for broadcast TV simply because cable TV stations are willing to use almost any material.

Development of weather presentations for delivery on commercial television requires that considerations be given to the following factors:

1. Segments must be of superior technical quality, to meet network broadcast standards.
2. Segments must be new, innovative and interesting packages.
3. Materials must stress local weather within the station viewer area.
4. Segments must consist of individually useful blocks, which can be assembled to make up presentations ranging from 2.5 to 4.5 minutes in length.
5. A choice of subject matter and formats is desired so that stations can have different weather programs in format, style and emphasis. The choice should allow chromakey, cuts between station weather-caster and weather video and segments at several scales and for various specific audiences served by the stations.
6. Segments must be timely and accurate.
7. Segments must be provided to meet present station schedules of breakfast, lunch and dinner times plus the 10 PM to 11 PM news slot. Shorter update segments at frequent intervals are desired.

For Public/Broadcast TV:

1. Segments must be of superior quality, meeting commercial network broadcast standards.
2. Segments must consist of the latest, most comprehensive data available to ensure maximum accuracy and usefulness.
3. Segment construction must be flexible, allowing feedback and modification according to area user need.
4. Educational and informational programs, devoted to urban, rural and business/industry needs are needed for both regular daily

programming and for seasonal, severe weather, and other occasional use.

Cable television's potential emerges as the most challenging and probably the most effective of the three media discussed. The use of a complete 24-hour channel for weather information allows development of a completely automated computer video presentation. This is the only way to deal effectively with some of the many different special information requirements in real time. Here, too, we do not have to overcome established conventions, but can set out to create a new service. Some of the factors involved in delivery of weather information via cable include the following:

1. Segments must be of superior video quality, meeting commercial network broadcast standards.
2. Segments must consist of the latest, most comprehensive data available to ensure maximum accuracy and usefulness.
3. Segments must consider the total picture, fully utilizing each block according to critical and useful times for specific viewers.
4. Production of regularly scheduled educational blocks must be considered to provide users with the means to apply specialized weather information and to establish credibility of the service.
5. Segments must be provided on an automatically selected basis since cable stations do not have staff available to select and control programming of weather information.

2.4 Presentation Format Study

While time and space scales could be considered separately, the development and motion of weather systems and weather phenomena define a general time-space relationship. The 1972 ICAS report, The National Research Effort on Improved Weather Description and Prediction for Social and Economic Purposes, describes five space scales: 0-2 kilometer, 2-200 Km, 200-2,000 Km, 2,000-6,000 Km, and >6,000 Km, labeled microscale, mesoscale, macroscale, continental and hemispheric - global respectively. Five time scales are defined as 0-1 hr, 1-6 hr, 6-24 hr, 24-72 hr, and 72 hr - 1 month. These scales were slightly modified by our group to provide some overlap and to be aligned with more recent AMS definitions of time and space scales. Further, from the ICAS report, space-time relationships are defined with isopleth's indicating most intense weather information needs in the 1-6 hr and 2-200 Km range. The time-space scales used for this study are defined and labeled as follows:

<u>SPACE</u>	<u>TIME</u>	<u>NAME</u>
<10 Km	0-1 hr	Microscale
2-200 Km	1-6 hr	Mesoscale
150-2000 Km	3-18 hr	Subsynoptic
1500-6000 Km	12-72 hr	Synoptic
>6000 Km	>48 hrs	Hemispheric-global

Program needs vary during a 24 hour day, and depend on data available, audience group and media. Four time groups are defined as:

Midnight - 6 AM	4 PM - Midnight
6 AM - 4 PM	24 hour continuous

The midnight - 6 AM group serves mainly the industrial needs where minimum report-to-work notice times are required; trucks are loaded for

fuel oil, highway maintenance, etc., or for frost and freeze threats to agricultural crops.

The 6 AM - 4 PM time groups covers many general public needs, housewives, transportation, and agricultural planning.

The 4 PM - Midnight time group reaches the largest population group where weekend plans, travel, recreation, etc., are being considered.

The 24 hour continuous is designed for cable television where a dedicated weather channel is used. The audience group there is largely urban; a large variety of weather data can be provided as the audience group is better defined. It is the most rapidly changing audience at this point with the growth of cable television.

Efforts to define TV audiences in terms of weather needs were frustrating. TV audiences are generally categorized by age, sex, religion, income group, mental attitude, etc., but not by any topic relating to weather. Several urban/rural group combinations were considered but simplified to a basic urban/rural consideration.

Time and space scale information were applied to the information of Table 2-4, with the results represented by Table 2-5.

Another matrix is needed, where the needed segments as shown in Table 2-5 are further described in terms of audience group, time-of-day of presentation, and media used. This final step then provides a list of all possible program segments, based on the needs and the constraints. To avoid the confusing format of showing the entire array of segments in a table, the data were punched on cards and a listing is included as Appendix B of this report.

Table 2-4 Time/Space Scales of Interest by User/Weather Parameter

WEATHER	GENERAL PUBLIC										PERSONAL TRANSPORTATION									
	RECREATION					HEALTH & CONVENIENCE					POLLUTION					PERSONAL TRANSPORTATION				
	W	SP	S	F		W	SP	S	F		W	SP	S	F		W	SP	S	F	
TEMPERATURE																				
Current	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4											
Low for	3,4	3,4	3,4	3,4		3,4	3,4													
Day																				
High for	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4						
Day																				
Variation of	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4						
Current Range	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4						
Inversions																				
Degree						4	4	4	4							2,3	2,3			2,3
Days																2,3	2,3			2,3
FROST																				
Time of																				
Arrival																2,3	2,3			2,3
Lowest																				
Temp.																				
Duration																				
SOIL																				
TEMPERATURE																				
Ground Freeze	3,4																			
or Thaw																				
Depth of																				
Frost in																				
Ground	4,5																			
PRECIPITATION																				
Form (Rain,	2,	2,3,4	2,3,4	2,3,4		2,	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4	2,3,4
Drizzle, etc.)	3,4					3,4										3,4				3,4
Quantity	2	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4	2,3,4
Time of	2	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4	2,3,4
Arrival	3,4	2,3,4	2,3,4	2,3,4		3,4	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4	2,3,4
Duration	2	2,3,4	2,3,4	2,3,4		2	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4		2,3,4	2,3,4	2,3,4	2,3,4	2,3,4
Relative	3,4	2,3,4	2,3,4	2,3,4		3,4	2,3,4	2,3,4	2,3,4		3,4	2,3,4	2,3,4	2,3,4		3,4	2,3,4	2,3,4	2,3,4	2,3,4
Humidity																				
Dewpoint																				
(Dew, Fog)	2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3	2,3

1-microscale, 2-mesoscale, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter
GENERAL PUBLIC

WEATHER PARAMETERS	RECREATION					HEALTH & CONVENIENCE					POLLUTION					PERSONAL TRANSPORTATION				
	W	SP	S	F		W	SP	S	F		W	SP	S	F		W	SP	S	F	
DRY SPELLS (WET SPELLS)																				
SNOW																				
COVER	3,4	3,4		3,4		3,4	3,4			3,4						3,4	3,4		3,4	
SOIL																3,4	3,4		3,4	
MOISTURE																				
SOLAR RADIATION																				
WIND CLOUDS	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4	3,4										
DRYING CONDI- TIONS																				
EVAPORATION																				
WIND	3,4	3,4	3,4	3,4							3,4	3,4	3,4	3,4		3,4	3,4		3,4	
SEVERE WEATHER	2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3	

1-microscale, 2-macroscopic, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

WEATHER PARAMETERS	GENERAL CONSTRUCTION					CONCRETE LAYING					UTILITIES					MANUFACTURING					RETAILING				
	W	SP	S	F		W	SP	S	F		W	SP	S	F		W	SP	S	F		W	SP	S	F	
TEMPERATURE																									
Current																									
Low for	3,4	3,4	3,4	3,4																					
Day																									
High for																									
Day			3,4																						
Duration of																									
Current Range		3,4																							
Inversions																									
Degree																									
Days																									
FROST	1,3					1,3	1,3																		
Time of																									
Arrival																									
Lowest																									
Temp.																									
Duration						1,3	1,3	1,3	1,3																
SOIL																									
TEMPERATURE																									
Ground Freeze						3,4	3,4	3,4	3,4																
or Thaw	3,4					3,4	3,4																		
Depth of																									
Frost in																									
Ground	4,5																								
PRECIPITATION																									
Form(Rain,	2,																								
Drizzle, etc.)	3,4, 2,3,4	2,3,4	2,3,4	2,3,4																					
Quantity	2																								
Time of	3,4 2,2,4	2,3,4	2,3,4	2,3,4																					
Arrival	2																								
Duration	3,4 2,3,4	2,3,4	2,3,4	2,3,4																					
RELATIVE	2																								
HUMIDITY	3,4 2,3,4	2,3,4	2,3,4	2,3,4																					
DEWPOINT	2																								
(Dew,Fog)	3,4 2,3,4	2,3,4	2,3,4	2,3,4																					
	2,3	2,3	2,3	2,3																					

1-microscale, 2-macroscale, 3-subsynoptic, 4-synoptic, 5-hemispheric

2-40

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

WEATHER PARAMETERS	INDUSTRY												RETAILING											
	GENERAL CONSTRUCTION				CONCRETE LAYING				UTILITIES				MANUFACTURING				RETAILING							
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F
DRY SPELLS (WET SPELLS)									4,5	4,5	4,5	4,5					4,5	4,5			4,5	4,5		4,5
SNOW									3,4				3,4				3,4							
COVER	3,4	3,4											3,4											
SOIL																								
MOISTURE		2,3	2,3	2,3					2,3	2,3	2,3	2,3	2,3				2,3							
SOLAR RADIATION																								
vs. CLOUDS									3	3	3	3	3				3	3			3	3		3
DRYING CONDI- TIONS																								
EVAPORATION		3	3	3		3	3	3																
WIND	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4	3,4								
SEVERE WEATHER	2,3	2,3	2,3	2,3		2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

WEATHER PARAMETERS	MARITIME				COMM. TRUCK				TRANSPORTATION							
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F
TEMPERATURE																
Current																
Low for																
Day	4	4		4												
High for																
Day																
Duration of																
Current Range																
Inversions																
Degree																
Days																
FROST	3	3		3												
Time of																
Arrival	3	3		3												
Lowest																
Temp.																
Duration	3	3		3												
Soil																
TEMPERATURE																
Ground Freeze																
or Thaw																
Depth of																
Frost in																
Ground																
PRECIPITATION																
Form(Rain,					2,3											
Prizzle, etc.)																
Quantity					2,3											
Time of					2,3											
Arrival					2,3											
Duration					2,3											
RELATIVE																
Humidity																
WIND																
(Dir, For)	3	3	3	3												

1-microscale, 2-macroscopic, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

WEATHER PARAMETERS	MARITIME				COM. TRUCK				TRANSPORTATION							
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F
DRY SPELLS																
(WET SPELLS)																
SNOW								3,4								
COVER																
SOIL																
MOISTURE																
SOLAR RADIATION																
VS. CLOUDS																
WINDING CONDI- TIONS																
EVAPORATION																
WIND		3,4	3,4	3,4	3,4	3,4	3,4	3,4								
SEVERE WEATHER	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3								

1-microscale, 2-macroscopic, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

WEATHER PARAMETERS	AGRICULTURE												HARVESTING		
	FIELD PREPARATION				PLANTING				SPRAYING				GROWING		
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S
TEMPERATURE	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Current	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Low for	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Day	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
High for	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Day	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Duration of	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Current Range	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Inversions															
Degree															
Days															
FROST															
Time of															
Arrival															
Lowest															
Temp.															
Duration															
SOIL															
TEMPERATURE	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4
Ground Freeze	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4
or Thaw	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4
Depth of															
Frost in															
Ground															
PRECIPITATION	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Form(Rain, Drizzle, etc.)	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Quantity	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Time of															
Arrival															
Duration															
RELATIVE															
HUMIDITY															
DEWPOINT															
(Dew,Fog)															

1-microscale, 2-macroscale, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Time/Space Scales of Interest by User/Weather Parameter

AGRICULTURE																															
WEATHER PARAMETERS		FIELD PREPARATION						PLANTING						SPRAYING						GROWING						HARVESTING					
		W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F		
DRY SPELLS (WET SPELLS)							4,5	4,5																							
SMOKE																															
COVER		3,4	3,4																												
SOIL																															
MOISTURE																															
SOLAR RADIATION																															
VS. CLOUDS																															
DYEING CONDI- TIONS																															
EVAPORATION																															
WIND																															
SEVERE		3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	
WEATHER		2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	

1-microscale, 2-macroscale, 3-subsynoptic, 4-synoptic, 5-hemispheric

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	AGRICULTURAL FIELD PREPARATION			AGRICULTURAL PLANTING			AGRICULTURAL SPRAYING			AGRICULTURAL GROWING SEASON			AGRICULTURAL HARVESTING		
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S
TEMPERATURE															
Current	87	119, 84 87	87	119, 87	87	87	119 87	87	86, 88, 94	119, 76 86,88 94	75, 87, 92	X, 75, 86, 87, 122 133	X,71, 86,87, 115, 129	X, 71, 85,86, 87,115 129	X, 71, 84, 86, 87, 95 115, 129
Low for Day	87	119, X, 89 87	87	119, X 87	119, 87	X, 87	119 X, 87	X, 87	X, 86 88, 104	119, 76, X 86, 88 91	75, 87, 92	X, 75, 86, 87, 122 113	X, 71, 86, 87, 115 129	119, 76 X, 71 85, 86 87, 95 129	X, 71 84, 86 87, 95 115, 129
High for Day	87	84, 87	87	87	87	X, 87	X, 87, X, 87	X, 87	X, 86 94, 104	119, 76, X 86, 88 91	75, 87, 92	119, X, 75 86, 87, 122 133	X, 71 86, 87 115, 129	119, X, 71 76, X 85, 86 87, 115 129	X, 71 84, 86 87, 95 115, 129
Duration of Current Ranges	87	84, 87	87	87	119, 87	X, 87	X, 87, X, 87	X, 87	X, 86 88, 94 88, 94	119, 76, X 86, 88 91	75, 87, 92	119, X, 75 86, 87, 122 133	119, 76, X 71, 86, 87, 115, 129	119, X 85, 86 87, 115, 129	X, 71, 84, 86 87, 95 115, 129
Inversions									X	119, 86, X	105				
Degree Days						X	X					119, 86, X 78	X, 78	X, 78	X, 78

X denotes requirements by agricultural consultant

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	AGRICULTURAL FIELD PREPARATION			AGRICULTURAL PLANTING			AGRICULTURAL SPRAYING			AGRICULTURAL GROWING SEASON			AGRICULTURAL HARVESTING		
	W	SP	S	F	W	SP	S	P	W	SP	S	F	W	SP	F
FROST															
Time of Arrival	119	119	119			X, 130				105, 113	76, X	X, 113	119	X	X
Lowest Temp. Duration	119	119	119			X, 130				115, 123	76, X	X 113	119	X, 119, 76	X
Ground Freeze or Thaw		X		X		X				92		X			X
Depth of Frost in Ground		X													2-47
PRECIPITATION															
Form (Rain Drizzle, etc.)	X			X		76, X	X		119, X	76, X	76, X	76, X		X	X
Quantity	87	119, X, 87 90	X, 87 92	87, 90, 92	87	X, 84, 87	X, 87, 122	X, 87, 86, 87, 91	X, 86, 87, 94, 99, 111	76, X, 75, 86, 87, 107, 131	X, 71, 75, 88, 84, 86, 87, 92, 107, 122, 131, 133	X, 71, 86, 87, 101, 129	87	86, 87	X, 71, 86, 87, 101, 129

X denotes requirements by agricultural consultant

Table 2-4 cont'd Weather, Parameter, Season, User

Time of Arrival	AGRICULTURAL FIELD PREPARATION				AGRICULTURAL PLANTING				AGRICULTURAL SPRAYING				AGRICULTURAL GROWING SEASON				AGRICULTURAL HARVESTING			
	W	SP	S	P	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S	F
Duration	119 76									X, 87, 94, 99, 111	X, 87, 84, 89, 111	76, X, 87, 91	X, 87	76, X, 87			87	85, 86, 87	71, 85, 86, 87, 101, 129	X above refs.
RELATIVE HUMIDITY	87	87	87	87	87	X, 87, 87	X, 87, 94, 99, 111	76, X, 87, 91	X87	76, X, 87	X, 87, 87	76, X, 87	87	76, X, 87	X, 87, 87		87	76, X, 87	X, 87	X, 87
DEWPOINT (Dew, Fog)		X				X	X			76, X	X	76, X	87, 105	X, 87	X, 87, 87		87	X, 87		X, 87 2-48
DRY SPELLS (Wet Spells)	87	X, 87 90	87	87, 90		X, 87	X, 87		82	76, X, 87	76, X, 87	76, X, 87	87	76, X, 87, 92	76, X, 80, 87, 92	X, 76, 87	87	76, X, 85, 87, 87 90	X, 85, 87, 92	X, 87, 90,
SNOW, SNOW COVER	X	X			119								X	X						X
SOIL MOISTURE		X	X	X		X	X	X		X	X	X	X	X, 115, 92	X, 115, 129		X	X, 115, 129	X, 115, 129	X, 115, 129

Table cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	AGRICULTURAL FIELD PREPARATION			AGRICULTURAL PLANTING			AGRICULTURAL SPRAYING			AGRICULTURAL GROWING SEASON			AGRICULTURAL HARVESTING		
	W	SP	S	W	SP	S	W	SP	S	W	SP	S	W	SP	S
SOIL TEMPERATURE	87	87	87	87	X, 87, 125, 132	X, 87		X		87	X, 87, 125, 132	X, 87		87	X, 87
Drying															
Conditions		X	X		X	X		X		87	X, 87	X, 87	87	X, 87	X, 87
Evaporation															
WIND															
Speed	87	X, 87	X, 87	87	X, 87	X, 87	87	X, 86, 87, 88	X, 86, 87, 88	87	119, X 86, 87 133	X, 115X, 115 129 129	X, 86 87	X, 71 86, 87, 115, 129	X, 71, 86, 87, 115, 129
Direction	87	X, 87	X, 87	87	X, 87	X, 87	87	X, 86, 87, 88	X, 86, 87, 88	87	X, 86, 87, 64	X, 115X, 115 129 129	X, 86 87	X, 71, 86, 87, 115, 129	X, 71, 86, 87, 115, 129
Duration	87	X, 87X, 87	X, 87	87	X, 87	X, 87	87	X, 86, 87, 88	X, 86, 87, 88	87	X, 86, 87, 64	X, 115 129	X, 86 87	X, 86, 71, 87, 115, 129	X, 71, 86, 87, 115, 129
CLOUD COVER															
Amount		X	X		X	X		X	X	119	119, X	119, X	119	119X	119, X
Duration		X	X		X	X		X	X	119	119, X	119, X	119	119X	119, X

X denotes requirements by agricultural consultant

Table cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	AGRICULTURAL FIELD PREPARATION			AGRICULTURAL PLANTING			AGRICULTURAL SPRAYING			AGRICULTURAL GROWING SEASON			AGRICULTURAL HARVESTING		
	W	SP	S	F	W	SP	S	F	W	SP	S	F	W	SP	S
Barametric Pressure Change		X	X	X		X		X		X	X	X		X	X
SOLAR RADIATION										X		X			X

X denotes requirements by agricultural consultant

Table 2-4 Weather, Parameter, Season, User
Numbers refer to reference entries

WEATHER PARAMETERS	RECREATION FALL, SPRING & SUMMER	RECREATION WINTER		
TEMPERATURE				
Current	Mild T good for fishing Water T too warm or too cold discourages fishing (5) T & RH determine pos- sibility of forest fires(11) Good hunting scents depend on low temperature (14)	Important for skiing condi- tions (8) For making snow T 2.2°C (6)		
Low for Day		T 2.2°C needed for ice skating rink flooding (4) Low temp causing icing bad for skiing (8)		2-51
High for Day	Swimming comfort needs max. T 22°C(16) Beach area needs 19°C. More use of parks & outdoor sports in warm, not hot weather (16, 19)			
Duration of Current Ranges	Periods of warm humid temp with some fluctuations encourage insect formation (12) Low summer temp for extended periods discour- ages use of resorts (9)	Prolonged high temperatures can run skiing (8) (1 day) Prolonged low temp. increase use of snowmobile (17)		
Inversions				
Degree Days				

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	RECREATION		RECREATION WINTER		
	FALL, SPRING & SUMMER				
FROST Time of Arrival					
Lowest Temp. Duration					
Ground Freeze or Thaw			Thawing & freezing danger- ous to ice fisherman (4)		2-52
Depth of Frost in Ground					
PRECIPITATION: form(Rain Drizzle, etc.)	Park use, tennis, sports beach use, swimming dis- couraged by rain (16) Also picnicing.		Rain or freezing rain can ruin snow cover (8) An inch or more of rain can lubricate snow layers in preparation for an avalanche (13)		
	Pools of rainwater en- courage insect forma- tion (12) Baseball games may be cancelled due to wet field (10)		An inch or more of rain can lubricate snow layers in preparation for an avalanche (13)		
Quantity					

Table 2-4 cont'd Weather, Parameter, Season, User

Time of Arrival	RECREATION		Weather, Parameter, Season, User
	FALL, SPRING & SUMMER	WINTER	
Duration	1 hr. precip. probabilities needed by racetrack operators, stadiums(2) Rainy spells discourage	Rain or freezing rain can ruin snow cover (8).	
RELATIVE HUMIDITY	High RH encourages, park beach & swimming use(16) High RH discourages golf & other sports (10) RH Affects forest fires(11) High RH gives good hunting spells(14)	RH \leq 61% for artificial snow making (6) Raw damp weather discourages skiing (15)	
DEWPOINT (Dew, Fog)	Fog dangerous to boating (1) High visibility needed for scenic areas(18)		2-53
DRY SPELLS (Wet Spells)	Wet spells discourage tourists (18)		
SNOW, SNOW COVER	Snow cover useful for tracking in hunting (3)	Important to skiing (8) & snowmobiling (17)	
SOIL MOISTURE			

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	RECREATION FALL, SPRING & WINTER	RECREATION WINTER		
SOIL TEMPERATURE Drying Conditions Evaporation				
WIND				
Speed	Light winds for fishing (5) Low winds encourage outdoor sports(16), used beaches(18) Winds need for boating navigation (1)	Needed for ice boating. Important for artificial snow making (7)		2-54
Direction	Wind speed, direction & duration determine rate of forest fire spread (11)	Wind direction & speed deter- mines snow deposition- a factor in avalanches(13)		
Duration		High winds discourage skiing (15) chairlifts close for high winds).		
CLOUD COVER	Cloudy weather discour- ages tourists (18)			
Amount				
Duration				

Table 2-4cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	RECREATION FALL, SPRING & SUMMER	RECREATION WINTER		
Barometric Pressure Change	Falling p bad for fishing Rising p good (5)			
SOLAR RADIATION	High sunshine encourages swimming, beach use, sports (16)			

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	PUBLIC NEEDS HEALTH & CONVENIENCE SPRING	PUBLIC NEEDS HEALTH & CONVENIENCE SUMMER	PUBLIC NEEDS HEALTH & CONVENIENCE FALL	PUBLIC NEEDS HEALTH & CONVENIENCE WINTER	PUBLIC NEEDS POLLUTIC WINTER, SPRING, SUMMER & FALL
TEMPERATURE					
Current	Warm humid cyclonic air associated with car accidents & suicides 21, 31 Also Summer, Fall, Winter Falling T., moist-- 31 (Also Fall, Summer, Spring)	Air conditioning needed For T - 25°C 21 Also Spring & Fall Tuberculosis encouraged by warm humid weather 31	Home heating needed for mean daily temp - 18°C 21 Also Winter, Spring	Breathing very cold air carries heavy burden on heart-lung system 21 Temp. a factor in type of clothes to be worn 29 (Also Fall, Summer, Spring)	High T encourages pollution damage to plants and materials 23
Low for Day					2-56
High for Day	High T & RH dangerous congestive heart disease 21 Also Summer, Fall	Heat Stress (Function of T, Wind, RH) source of heat stroke, death 20, 21 High T a comfort factor 31			
Duration of Current Ranges	Periods of warm, humid temperatures, with fluctuations encourage insect breeding 27	Very warm days associated with glaucoma 31	Arrival of first cold outbreak causes asthma attack to rise 21, 31	Large T changes can cause blood clotting 21 Very cold days assoc. with glaucoma 31 Strong cooling--heart attacks 31	
Inversions					Inversion causes increase in pollution 23, 24, 25, 26
Degree Days					

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	PUBLIC NEEDS HEALTH & CONVENIENCE SPRING	PUBLIC NEEDS HEALTH & CONVENIENCE SUMMER	PUBLIC NEEDS HEALTH & CONVENIENCE FALL	PUBLIC NEEDS HEALTH & CONVENIENCE WINTER	PUBLIC NEEDS POLLUTION WINTER, SPRING, SUMMER & FALL
FROST					
Time of Arrival	Frost can be a danger to vehicles on sparsely traveled roads 30 Also, Fall, Winter				
Lowest Temp., Duration					
Ground Freeze or Thaw					
Depth of Frost in Ground					
PRECIPITATION					
Form (Rain Drizzle, etc.)	Rain associated with 12.5% of car accidents 22 28		Rain washes out pollens which affect hay fever 21		
Quantity	Pools of water left from rain encourage insect breeding 27				

Table 2-Cont'd Weather, Parameter, Season, User

Time of Arrival	PUBLIC NEEDS HEALTH & CONVENIENCE SPRING	PUBLIC NEEDS HEALTH & CONVENIENCE SUMMER	PUBLIC NEEDS HEALTH & CONVENIENCE FALL	PUBLIC NEEDS HEALTH & CONVENIENCE WINTER	PUBLIC NEEDS POLLUTION WINTER, SPRING, SUMMER & & FALL
Duration	Pools of water left from rain encourage insect breeding 27		Rain washes out pollens which affect hay fever 21		
RELATIVE HUMIDITY	Moist air, falling T. encourages arthritis	High RH causes scar pains 21 See also pressure change Humid wx a factor in tuberculosis 31 High RH a comfort factor 31		RH 50% encourages influenza 31 See T, High for Day above.	High RH encourages pollution damages plants & animals 23
DEWPOINT (Dew, Fog)	Fog hazardous to car trans. Associated with 2.5% of car accidents 22, 28			Fog associated with bronchitis & cooling 31	Dew can encourage pollution damage 23, 258
DRY SPELLS (Wet Spells)					
SNOW, SNOW COVER	Snow associated with 6.1% of car accidents 22 Also Fall, Winter				
SOIL MOISTURE	Variable dryness and Wetness of road surface leads to slippery spots 28				High soil moisture encourages pollution damage 23

Table 2-4cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	PUBLIC NEEDS HEALTH & CONVENIENCE SPRING	PUBLIC NEEDS HEALTH & CONVENIENCE SUMMER	PUBLIC NEEDS HEALTH & CONVENIENCE FALL	PUBLIC NEEDS HEALTH & CONVENIENCE WINTER	PUBLIC NEEDS POLLUTION WINTER, SPRING, SUMMER FALL
SOIL TEMPERATURE Drying Conditions Evaporation	Road stc temperature below freezing danger- ous Also Fall 30 28				
WIND Speed	Strong crosswinds across highways endan- ger large vehicles with high center of gravity 28			Wind speed a factor in what sort of clothes to be worn 29 Also Summer, Fall, Spring	NO, SO, EO & other gases spread by wind. Dangerous to materials & health (esp. at peak traffic hrs 8AM - 5PM 23, 24, 25, 26
Direction					
Duration				Low wind speeds encourage influenza (see R.H.) 31	
CLOUD COVER		Cloudiness a factor in sunburn potential 21			
Amount					
Duration					

Table 2-*cont'd* Weather, Parameter, season, user

WEATHER FACTORS	PUBLIC NEEDS HEALTH & CONVENIENCE SPRING	PUBLIC NEEDS HEALTH & CONVENIENCE SUMMER	PUBLIC NEEDS HEALTH & CONVENIENCE FALL	PUBLIC NEEDS HEALTH & CONVENIENCE WINTER	PUBLIC NEEDS POLLUTION WINTER, SPRING, SUMMER & FALL
Barometric Pressure Change					
SOLAR RADIATION	Sunny days worsens glaucoma 31	Sun angle, visibility & cloudiness determines sunburn potential 2]		Radiation a factor in what kinds of clothes to wear 29 Also Fall, Summer, Spring)	

Table 2-4 Weather Parameter, Season, User

WEATHER PARAMETERS	INDUSTRY-GENERAL CONSTRUC. WINTER, SPRING, SUMMER & FALL	INDUSTRY-CONCRETE LAYING WINTER, SPRING, SUMMER & FALL	INDUSTRY - UTILITIES WINTER, SPRING, SUMMER & FALL	INDUSTRY & COMMERCE-GENERAL WINTER, SPRING, SUMMER & FALL
TEMPERATURE				
Current			Electrical and fuel consumption depends mainly on ave. daily T. 43, 37, 47, 50	For every 1°F change, consumption of beer changes 1.1% 55, 6] High T encourage plant pollution and materials damage 43 Retail sales can be partly estimated from T at noon 54 Optimum T, RH needed for breadbaking & storage of yeast, flour 58 Variations in T affect tolerances & dimensions in precision machinery plant 66
Low for Day	T 0 9 somewhat harmful T -12.2 very harmful 33, 64	Freezing weakens concrete 35, 44		Temperature conducive to icing important to merchant ships 65
High for Day	T 32.2C harmful (1)	Excessive heat weakens concrete 35, 45		Warm, sunny weather affects candy manuf. & distributors Manmade textiles less tolerant of warm T, RH, during weaving 57
Duration of Current Ranges	Mild Spring weather increases housing starts 59		Very cold weather very important to utilities, esp. 4 days 38 Temp. trends needed for river management 60	Heat wave prediction useful to merchants trying to sell summer merchandise 37, 57 Winter coat sales in Sept proportional to Sept. mean temp. 53
Inversions			Inversion may trap pollution from fuel driven electrical generators 5]	Inversions trap pollutants and increase pollution damage 40, 4], 36, 39
Degree Days			Degree days a primary factor in fuel consumption 43 37	Sales of air conditioners related to degree days 57

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	INDUSTRY-GENERAL CON-STRUCT. - WINTER, SPRING, SUMMER & FALL	INDUSTRY - CONCRETE LAYING WINTER, SPRING, SUMMER & FALL	INDUSTRY - UTILITIES WINTER, SPRING, SUMMER & FALL	INDUSTRY & COMMERCE-GENERAL WINTER, SPRING, SUMMER & FALL
FROST				
Time of Arrival	Bricks cannot be laid in freezing temp. 66	Frost harmful to concrete 35, 44		Freezing wx necessitates use of insulation for shipping of some products 66
Lowest Temp. Duration			See temperature duration above	
Ground Freeze or Thaw	Ground freeze harmful 70) Earthmoving difficult below -9.5°C 49			
Depth of Frost in Ground				
PRECIPITATION				
Form (Rain Drizzle, etc.)	Rain, sleet harmful Freezing rain somewhat harmful 33		Precip. affects electrical consumption 47	Retail sales can be partly estimated from forecast precip. 54
Quantity		Rain can wash out, delay or ruin concrete 35, 44, 45	Type, amount, coverage, duration, intensity needed for river management 60, 50 Rain falling through smokestack plumes may damage vegetation & increase activity of ground water 52	Amount of snow forecast needed by clearance crews, newspapers, distributors, truckers, dept. stores, bakery chains 37 →

Table 2-4 cont'd Weather, Parameter, Season, User

Time of Arrival	INDUSTRY-GENERAL CONSTRUC. WINTER, SPRING, SUMMER & FALL	INDUSTRY - CONCRETE LAYING WINTER, SPRING, SUMMER & FALL	INDUSTRY - UTILITIES WINTER, SPRING, SUMMER & FALL	INDUSTRY & COMMERCE-GENERAL WINTER, SPRING, SUMMER & FALL
Duration	Rain, sleet harmful Freezing rain somewhat harmful 33	Rain can wash out. delay or ruin concrete 33, 44, 45	Type, amount, coverage, duration, intensity needed for river management 60, 50	Duration of precip. affects amount of retail sales 57
RELATIVE HUMIDITY	THI 777 harmful 33		RH affects fuel consumption & electrical needs 62, 38 Cooling towers may reduce visibility if RH is high 52	High RH encourages plant & materials damage from pollution 43 High RH causes storage problems of chemicals, metals 37, 66 drying operations.
DEWPOINT (Dew, Fog)	Fog, dense is harmful 33, 64			Dew can encourage pollution damage to materials 39 Fog hampers navigation of ships 65
DRY SPELLS (Wet Spells)			Needed for river management 60	Wet spell-prediction useful to merchants 37
SNOW, SNOW COVER	Snow generally harmful 33 Housing starts cut by snow in Spring 59		Snow can affect fuel deliveries 37	Snow clearance crews need info. 4 hrs before storm 43 Retail sales can be partly estimated from snow depth 54
SOIL MOISTURE	Important to road construction 67		Needed for river management 60	High soil moisture encourages pollution damage 43

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	INDUSTRY-GENERAL CON- STRUC. - WINTER, SPRING SUMMER, FALL	INDUSTRY - CONCRETE LAYING WINTER, SPRING, SUMMER & FALL	INDUSTRY-UTILITIES WINTER, SPRING, SUMMER & FALL	INDUSTRY & COMMERCE-GENERAL WINTER, SPRING, SUMMER & FALL
SOIL TEMPERATURE	See Ground freeze or thaw			
Drying Conditions	Excessive drying harmful 33	Excessive drying can harm concrete 35, 44, 45	Evaporation needed for river management 60	
Evaporation				
WIND Speed	Winds 20mph harmful 35mph very harmful 64	Wind can dry out and weaken concrete 35, 44, 45	High winds increase fuel consumption 38, 50	NO, SO & CO & other gaseous pollutants are spread by wind. Dangerous to materials & health (esp. at near traffic hours-8AM-5PM 40, 41, 36, 39 Navigation of Ships 65
Direction				Strong crosswinds across highways endanger large vehicles with high center of gravity 69 Navigation of Ships 65
Duration				Maximum wind gust for crane operators, off-shore oil rig 11 wind load on structures 61 Navigation of Ships 65
CLOUD COVER			Cover affects fuel & electric consumption 38, 43, 50	Movie producers, aerial photographers need info 37
Amount				
Duration				

Table 2-4 cont'd Weather, Parameter, Season, User

WEATHER PARAMETERS	INDUSTRY-GENERAL CON- STRUC. - WINTER, SPRING SUMMER FALL	INDUSTRY - CONCRETE LAYING WINTER, SPRING, SUMMER & FALL	INDUSTRY - UTILITIES WINTER, SPRING, SUMMER & FALL	INDUSTRY & COMMERCE-GENERAL WINTER, SPRING, SUMMER & FALL
Barometric Pressure Change				
SOLAR RADIATION			Insulation can affect elec- trical consumption 45,50	See Cloud Cover. See High T. Retail sales can be part- ly estimated from % sunshine predicted 54,64

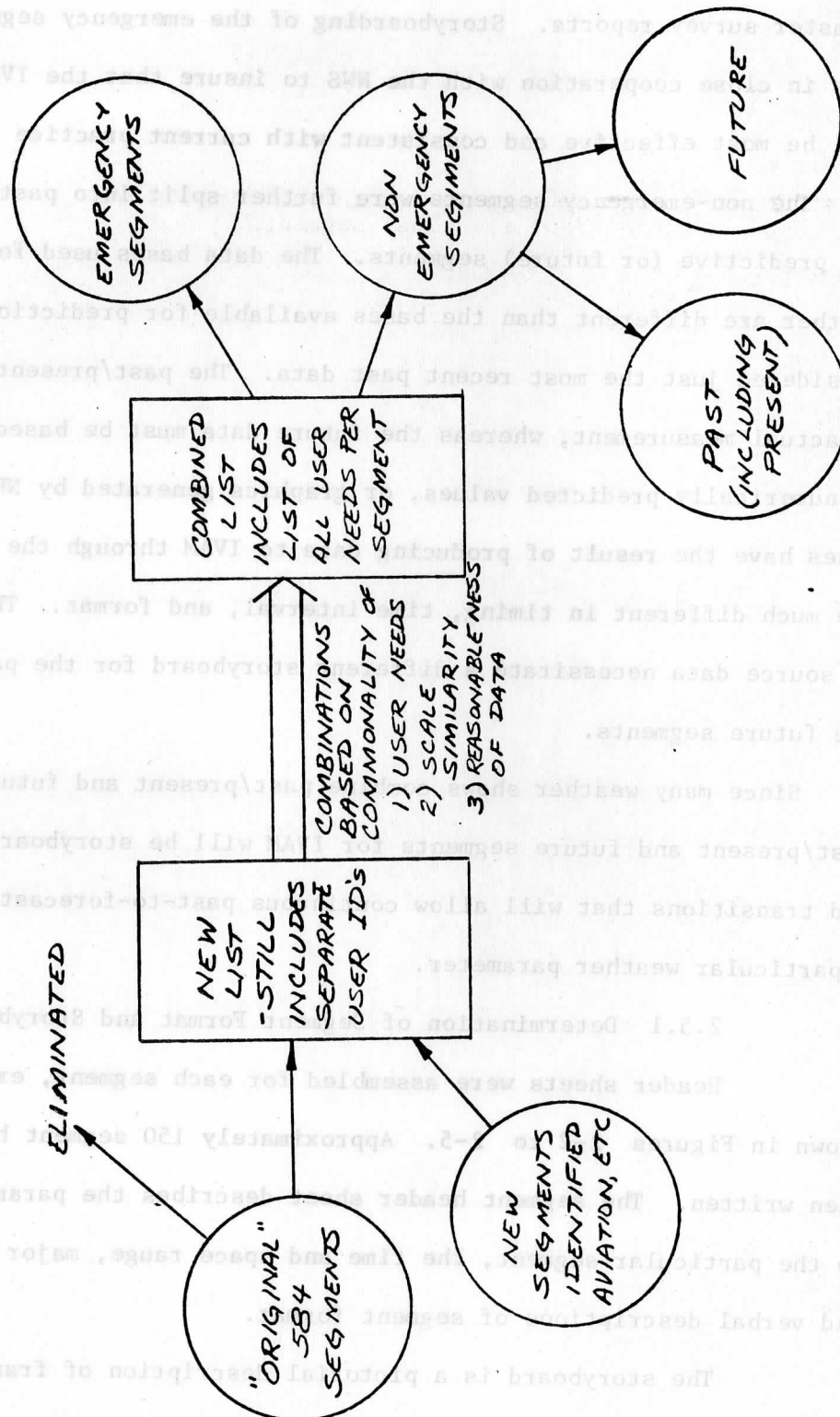
2.5 Compilation and Refinement of Segments

The presentation content study was refined and reduced the segment list from the 584 to 240. The needs of the weather user, identified in the 584 original segments, have been carried forth through the reduction steps to identify the contents of the final segments. The segments are identified by the following parameters which are decision criteria for the IVAM control processor:

- 1) Emergency status
- 2) Season
- 3) Time of day of presentation
- 4) Weather situation
- 5) TV medium (broadcast TV or cable TV)
- 6) Weather parameter
- 7) Time/space scale
- 8) Past/present or predicted information

Reduction of the segments was performed by holding four of five parameters (numbers 2, 3, 5, 6, and 7 above) constant and combining within the fifth. This was done for each parameter in turn, until a minimum set of segments was reached. The practical limit of time allowed on broadcast TV was also considered in limiting the time and range of subjects which can be addressed on that medium. A set of about 100 segments was reached, but did not distinguish between past and future, or emergency and non-emergency. The user needs identified earlier were carried through the segment reductions and assigned to the new combined segments. A diagram of the steps used is shown in Figure 2-1.

The next step was to expand the segment list into two categories, emergency and non-emergency. The assignment of emergency status is based on current practice for watch and warning messages, and storyboarding of those



FLOW DIAGRAM OF SEGMENT COMBINING STEPS

FIGURE 2 - 1

segments would include recommendations from various disaster preparedness and disaster survey reports. Storyboarding of the emergency segments would be done in close cooperation with the NWS to insure that the IVAM warning messages will be most effective and consistent with current practice at the time.

The non-emergency segments were further split into past/present segments and predictive (or future) segments. The data bases used for past and present weather are different than the bases available for prediction. Present is considered just the most recent past data. The past/present data are based on actual measurement, whereas the future data must be based on extrapolated or numerically predicted values, or graphics generated by NPC. These different bases have the result of producing data to IVAM through the AFOS system that are much different in timing, time interval, and format. These basic differences in source data necessitate a different storyboard for the past/present and the future segments.

Since many weather shows combine past/present and future information, the past/present and future segments for IVAM will be storyboarded with start and end transitions that will allow continuous past-to-forecast presentation for a particular weather parameter.

2.5.1 Determination of Segment Format and Storyboarding

Header sheets were assembled for each segment, examples of which are shown in Figures 2-2 to 2-5. Approximately 150 segment header sheets have been written. The segment header sheet describes the parameters that apply to the particular segment, the time and space range, major users of segments, and verbal descriptions of segment format.

The storyboard is a pictorial description of frame-by-frame TV output, indicating size, shape, timing, color, etc. The storyboard is the ultimate description of detailed IVAM output. It is what the programmers use as

SEGMENT HEADER

2-69

SEGMENT NUMBER _____

EMERGENCY _____ NON EMERGENCY X

MEDIUM Cable _____ Broadcast _____ Both X

SEASON Winter X Spring X Summer X Fall X

TIME OF DAY Midnight - 6am _____ 6am - 4pm X 4pm - Midnight X All _____

WEATHER SITUATIONS 1) After widespread storm in U.S. _____

2) After excessive precipitation
or during major flooding episodes _____

WEATHER PARAMETER(S) Precipitation _____

TIME REFERENCE Past (incl. present) X 12-72 Prediction _____

SCALE National X Regional _____ State _____ Local _____

COMMENTS ON DESIGNATORS (i.e., use in _____ area only, etc) _____

MAJOR USER OF SEGMENT: (reference previous IVAM study) General Public (GPA)

WHY CAN'T SEGMENT BE COMBINED WITH ANOTHER These are past weather "results," not combinable with other weather parameters - unique emphasis.

PURPOSE OF SEGMENT (WHAT'S TO BE CONVEYED) Areas where precipitation exceeded a boundary threshold in last 72 hours. (See below.)

FORMAT OF SEGMENT (scale, background, foreground, duration, etc) National map with state outlines. Contours of precipitation (not to exceed 4 contours) beginning at .25", then .50", 1.0", then year contour for maximum received, with annotation of that total within contour. Within contour to be shaded - lightest shading in .25 to .50 contour etc. Probably add areas one at a time at 5 sec. intervals - start with least.

Should be provision to overlay hatching in red to indicate flooding areas or states.

Duration: 20 sec. plus 10 sec. if flooding areas are overlayed.

DATA SOURCE (if non-existent, describe probable source) Fax precip. maps, teletype data; flood forecast and report on rawarc circuit and weather wire.

SEGMENT HEADER

2-70

SEGMENT NUMBER _____

EMERGENCY _____ NON EMERGENCY X

MEDIUM Cable _____ Broadcast _____ Both X

SEASON Winter X Spring X Summer _____ Fall X

TIME OF DAY Midnight - 6am _____ 6am - 4pm X 4pm - Midnight X All _____

WEATHER SITUATIONS Days when mean temperature
falls below 65° - optional use
segment (not used every day)

WEATHER PARAMETER(S) Degree Days (Heating) _____

TIME REFERENCE Past (incl. present) _____ Prediction 12-72 HRS

SCALE National _____ Regional _____ State _____ Local X

COMMENTS ON DESIGNATORS (i.e., use in _____ area only, etc)

Probably not fed in S.E. or S.W. states

MAJOR USER OF SEGMENT: (reference previous IVAM study) General public, and/or dealers.

WHY CAN'T SEGMENT BE COMBINED WITH ANOTHER Unique parameter, and too complex for combination.

PURPOSE OF SEGMENT (WHAT'S TO BE CONVEYED) Expected degree day totals next 1, 2, 3 days.

FORMAT OF SEGMENT (scale, background, foreground, duration, etc) Bar graph - days at bottom, degree days vertical. Space, bars and shade in color. Overlay each bar with large numerals indicating number of D-Days on that day. Perhaps dissolve in each day separately (1 + 2 + 3)

DATA SOURCE (if non-existent, describe probable source) fax forecast of temperatures;

NWS zones forecasts and extended outlooks. Computer to perform calculation required.

SEGMENT HEADER

SEGMENT NUMBER _____

EMERGENCY X NON EMERGENCY _____MEDIUM Cable _____ Broadcast X Both _____SEASON Winter _____ Spring X Summer X Fall XTIME OF DAY Midnight - 6am _____ 6am - 4pm _____ 4pm - Midnight _____ All XWEATHER SITUATIONS Expected or actual temps. below 32° - all such days between
15 days before normal last frost and until hard freeze occurs in
the fall.

WEATHER PARAMETER(S) Frost and Freeze (28° and 32° contours)

TIME REFERENCE Past (incl. present) _____ Prediction 1-6 HRSSCALE National _____ Regional _____ State X Local _____

COMMENTS ON DESIGNATORS (i.e., use in _____ area only, etc) _____

MAJOR USER OF SEGMENT: (reference previous IVAM study) AgricultureWHY CAN'T SEGMENT BE COMBINED WITH ANOTHER Emergency segment - impact required. Large dollar losses possible from frost.PURPOSE OF SEGMENT (WHAT'S TO BE CONVEYED) The areas of state or region which are currently, or will be within time frame, below freezing.FORMAT OF SEGMENT (scale, background, foreground, duration, etc) State map with temperature contours every 4° beginning at 32° and extending lower. Higher temperatures are extraneous and should not be recorded. Area between 32° and 28° contour to be colored yellow; area less than 28° to be colored red. Possibly overlay wind arrow (with speed included) but detailed wind information is not desirable - too complex.

DATA SOURCE (if non-existent, describe probable source) Local and zone forecasts on weather wire; fax computer chart of min. temps. is secondary (not as good) info.

SEGMENT HEADER

2-72

SEGMENT NUMBER _____

EMERGENCY X NON EMERGENCY _____

MEDIUM Cable _____ Broadcast _____ Both X

SEASON Winter X Spring X Summer X Fall X

TIME OF DAY Midnight - 6am _____ 6am - 4pm _____ 4pm - Midnight _____ All X

WEATHER SITUATIONS Pollution concentrations exceed
or are forecast to exceed alert
standards.

WEATHER PARAMETER(S) _____

TIME REFERENCE Past (incl. present) _____ Prediction 1-6 HRS

SCALE National _____ Regional _____ State _____ Local X

COMMENTS ON DESIGNATORS (i.e., use in _____ area only, etc) _____
Primarily major urban use.

MAJOR USER OF SEGMENT: (reference previous IVAM study) GP 3; utilities

WHY CAN'T SEGMENT BE COMBINED WITH ANOTHER Warning segments must stand alone for
impact and for individual use.

PURPOSE OF SEGMENT (WHAT'S TO BE CONVEYED) _____

FORMAT OF SEGMENT (scale, background, foreground, duration, etc) City name predominantly
at bottom. Horizontal cross-section of city skyline with smoke curling in air

- Annotation: time of segment - time alert is valid 'til - phrases "avoid unnecessary
 activity or overexertion, especially elderly and small children"

- Annotate with outlook: "Improving by _____" or "little change"

DATA SOURCE (if non-existent, describe probable source) NOAA wire, ?

requirements for creating graphics output. There are about 30 segments storyboarded. The set of header sheets and storyboards is included in Appendix B of this report.

At this point in the program, the effort to identify more segments, or to storyboard them, has been stopped. The requirements of the contract have been met in terms of determining the range of video weather presentations, formats, and presentation techniques. The ultimate set of segments available at an IVAM installation will be determined by locally established needs. As a study, the last word in segment identification cannot be written because of the necessary differences of local style and values, specific uses of weather information, and local constraints of transmission and timing. The study has approached the description of segments from two standpoints: (1) identifying what is needed, and (2) identifying what is possible with available data. The answers to the two questions are changing rapidly with time and technology. A further complexity is the fact that the answer to the question, "What is needed?" is undesirably, but clearly, affected by knowledge or expectation of what is possible. The parameters of weather are often thought of in terms of their measuring device, rather than the weather effects or the weather element, itself. We look at the radar, not at the rainfall; we look at the satellite picture, not at the clouds or temperatures. The real meaning of weather information (as opposed to weather data) will be an area of great growth as the capability and usefulness of meteorological measurement become known and appreciated by the non-meteorologist.

The output presentations defined at this point provide the basis for handling any new segment or new information identified in the future. The operational structure of handling segments as output product modules allows any TV output which can be defined to be handled by the IVAM system.

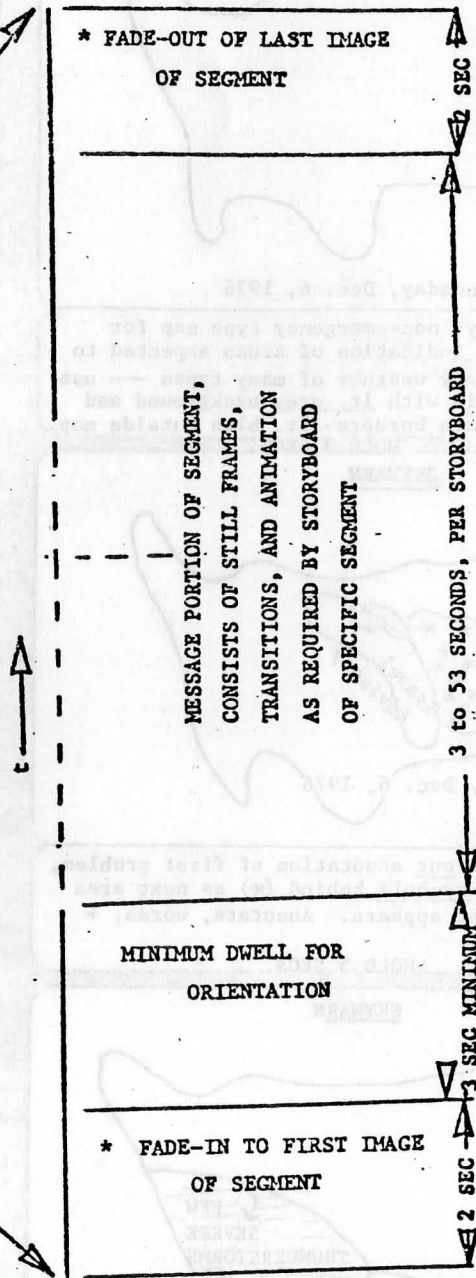
The segments are constructed of a basic sequence of images according to Figure 2-6. A start-up and an ending hold provide orientation for the viewer. Effective communication to the non-meteorologist requires adequate time for the viewer to realize the subject and context of the weather message. In addition, there is the practical consideration of interfacing segments and providing an aesthetically pleasing beginning and end to each segment. Fade-in and Fade-out satisfy the requirements for smooth transitions between segments and also allow a dissolve of information from one segment to the next, if the weathercaster wishes, by simply overlapping the fades at the user TV station. This may be particularly useful when the weather subject has interesting past information covered by one segment and interesting forecast information (on the same subject) on another segment. The past and forecast are produced as separate segments to give the weathercaster sufficient options in choices of segments to use, also to maintain a more consistent time range in the length of segments.

Given a relatively standard start and end format for most segments, the "message" portion of the segment is the most expressive portion. Outside of this portion only two still images are used for each segment. Within the message, output may consist of a mixture of still frames, transitions, and animation. The choice of specifically what images are shown in terms of satellite picture, graphics, annotation, stills or animation, etc., is prescribed by the storyboard of the segment. Only the input data values need to be provided to the system to produce the full video output of the segment.

As an example of how a segment is constructed, the steps of producing Segment #14 will be described. The Storyboard for that segment is shown in Figure 2-7. The data in the system at all times for this segment includes all of the non-changing data:

* The Fade-In/Fade-Out Requirements Are Waived for Emergency Segments

TOTAL SEGMENT DURATION 10-60 SECONDS



BASIC SEQUENCE OF SEGMENT IMAGES

FIGURE 2-6.

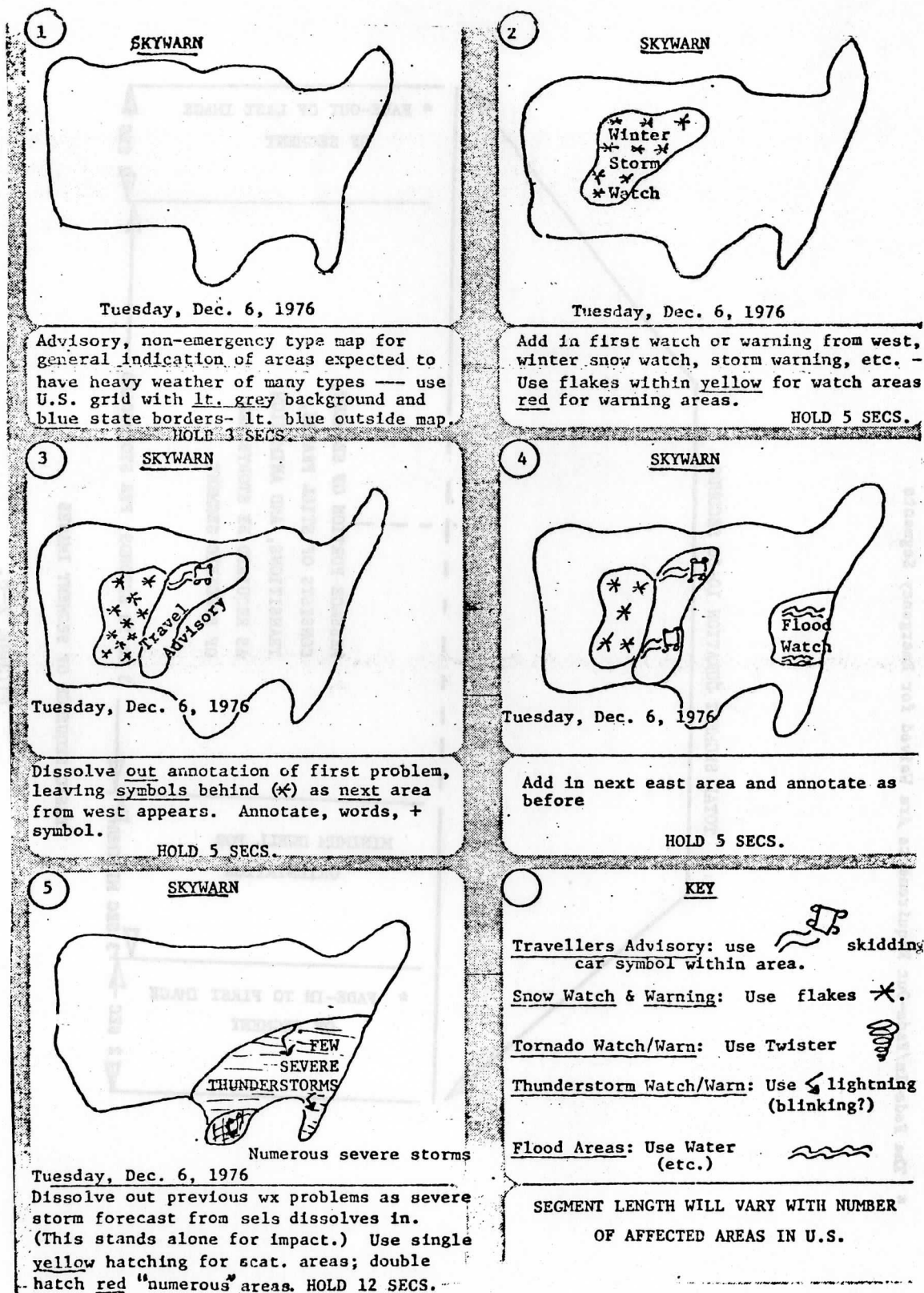


FIGURE 2-7.

U.S. Map

Fixed Annotation

Control information (including knowledge of current season and input data required.)

The input data required include:

Date

Any Storm Watch data (in identified graphical format)

Any Travel Advisory data (in identified graphical format)

Any Flood Watch data (in identified graphical format)

Any Thunderstorm data (in identified graphical format)

When the decision is made by the system that the segment is to be

Produced, the system already knows, without considering input data:

1) The timing of the segment will be 30 seconds total, comprised of:

2 second fade-in of U.S. grid with annotation SKYWARN and location for data annotation

1 second hold of same

5 second hold of annotated storm watch on map, if any; otherwise, annotation stating, "NO CURRENT STORM WATCH REPORTS."

5 second hold of annotated travel advisory on map, if any; otherwise, annotation stating, "NO CURRENT TRAVEL ADVISORY."

5 second hold of annotated flood watch on map, if any; otherwise, annotation stating, "NO THUNDERSTORM REPORTS."

2 second fade of previous picture.

2) Which data is needed (4 graphical image inputs), how to display

them, and in what order.

3) Which symbols to display (snowflakes, lightning, etc., if needed).

The input data, however important, occupies a small portion of the

output "volume." It determines:

1) The graphical area display in the four different parts of the

segment

2) The date information

3) The decision basis to display the "NO CURRENT..." when no graphical input exists for that parameter.

By comprising the segment as a number of elements, each of which has a pictorial meaning, the system can use those elements for many other segments as well. This is true of both input-determined elements, such as the flood watch outline, and preprogrammed elements such as the map grid. The system need not store these for each segment in which they are needed, but may call them from a common element storage as needed.

2.5.2 Impact of System Design Parameters on Presentation Format

Beyond the most general determination of final output, the details of graphics creation and assembly must be carefully co-designed with the actual physical system. While this issue is obvious, and all of the information surrounding it is implied in the Presentation Content, Software, and Hardware Concept Studies sections, this section is included to highlight some of the tradeoffs.

Separation of past/present and future segments is a necessary result of the nature of the input. The two types of inputs are derived from sources of data with different parameters and timing so scheduling and combining of information cannot be addressed jointly.

System storage capacity is largely a function of information format. To minimize storage space requirements, the system has been designed to store data in the most primitive form, but using some pre-processing to make mutual use data sets into a form for serving several segments. Expansion of minimal data information into full color pictorial graphics requires several quantum jumps in data volume. Data at intermediate steps is also designed for common use by several segments.

Designing segment format for use in a system with significant storage limitations requires that the number of variables within a segment be limited, as can be consistent with the "rules" for aesthetic quality. The real "message"

part of the segment is the greatest variable, and many other parts can be routinely controlled, as discussed in Section 2.5.1. In fact the pre-formatted nature of the segments is significant in sizing system requirements, yet the issues determined in that process (timing, order, transitions) are not issues where the fixed nature is significant in public acceptability and aesthetics.

2.6 Emergency Needs

Emergency situations can be defined as those in which danger is threatened to life, health, or property. The thrust of this discussion deals with emergency situations related to weather, although the same considerations may apply to other disaster threats such as chemical leaks, large fires, etc. Our concern is one of preventing or minimizing loss rather than one of survival after occurrence.

Background

A warning system, like any communication system, can be thought of as a general system of information flow as in Figure II-8.

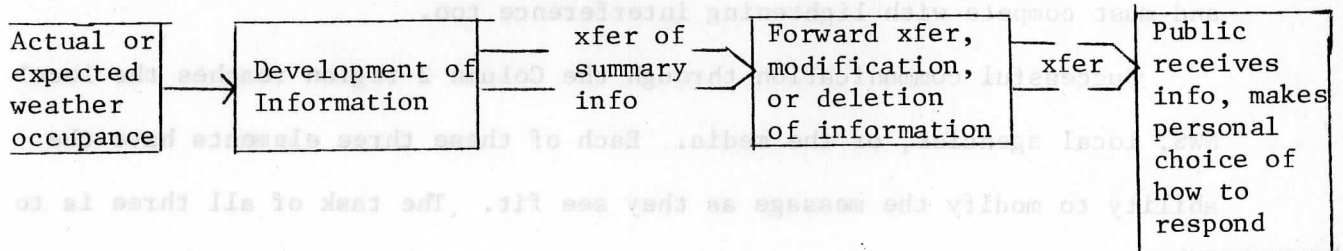


FIGURE 2-8 - GENERAL INFORMATION FLOW DIAGRAM

The seven elements are all necessary for the system to work, but how well it works is not controlled, since the system has no feedback. This diagram fairly well describes the present warning system. It may be well to review the general advantage and disadvantages of the elements.

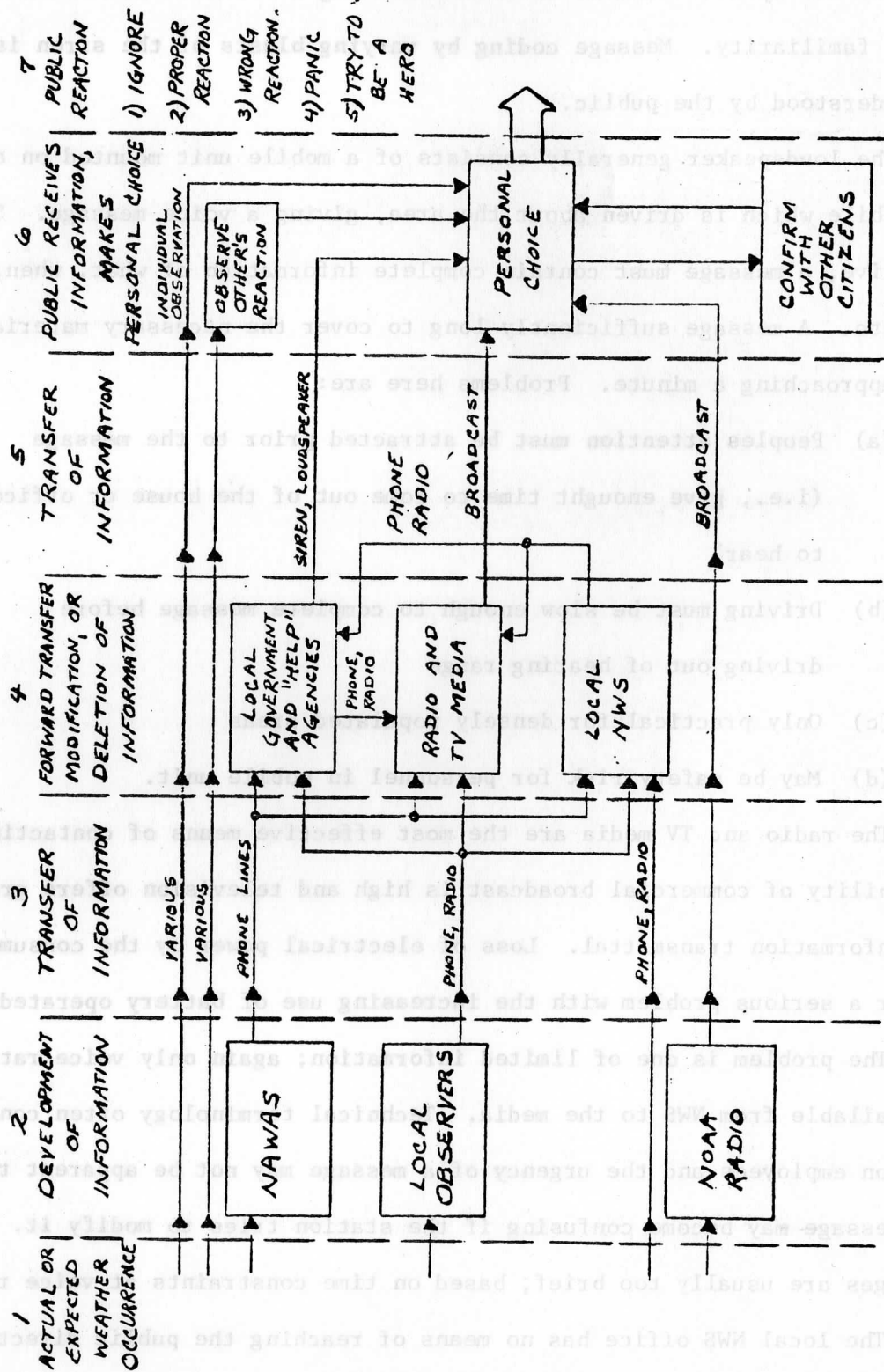
Figure 2-9 shows the same system, but with greater detail. Column 2 is the first point of analysis, i.e., a decision point for determining that an emergency situation exists. Of the five paths of information, two are of high integrity, NAWAS and NOAA radio. A third one, local observers, may or may not be reliable, depending on individual training and the specific situation. Value of the warning of any of the three depends on (1) technical competence of observer, (2) source information available and analytical capability of the organization, (3) timeliness of observation, and (4) local specificity of the observation.

Column 3 of the diagram labeled "Transfer of Info" appears unimportant but is critical for two reasons, reliability and bandwidth. The two media used are limited to voice transmission (or voice rate). Warning information often lacks in completeness because of limits on transmission capacity. Further, reliability of phone communication is low during severe weather situations since phone lines are highly susceptible to storm damage. CB radio communication is more reliable in a storm but the channels are often over used during such times, and must compete with lightening interference too.

Successful communication through the Column 2 region reaches the local NWS, local agencies, or the media. Each of these three elements have the ability to modify the message as they see fit. The task of all three is to reach the public with the warning information as effectively as possible.

The four avenues of communication are SIREN, LOUDSPEAKER, RADIO BROADCAST, and TELEVISION BROADCAST. While telephone is also possible, its inefficiency in reaching a significant part of the public rules out its utility.

The siren signal reaches a relatively large percent of the population, and could be considered reliable in the sense of likelihood to operate. However, the information content of a siren signal is very low. Further, it causes



DETAILED INFORMATION FLOW DIAGRAM

confusion and misunderstanding. (149) Overuse and misuse of the siren causes a "wolf-wolf syndrome" where the sound no longer commands attention because of its familiarity. Message coding by varying blasts of the siren is generally not understood by the public.

The loudspeaker generally consists of a mobile unit mounted on an automobile which is driven about the area, giving a voice message. To be effective, a message must contain complete information of what, when, where, who, etc. A message sufficiently long to cover the necessary materials takes time approaching a minute. Problems here are:

- (a) Peoples attention must be attracted prior to the message
(i.e., give enough time to come out of the house or office to hear)
- (b) Driving must be slow enough to complete message before driving out of hearing range
- (c) Only practical for densely populated areas
- (d) May be safety risk for personnel in mobile unit.

The radio and TV media are the most effective means of contacting the public. Reliability of commercial broadcast is high and television offers great capacity for information transmittal. Loss of electrical power by the consumer is no longer a serious problem with the increasing use of battery operated radio and TV. The problem is one of limited information; again only voice rate information is available from NWS to the media. Technical terminology often confuses the station employees and the urgency of a message may not be apparent to them. (150) The message may become confusing if the station tries to modify it. Instructional messages are usually too brief, based on time constraints at voice rates.

The local NWS office has no means of reaching the public directly, except Through phone answering. Their major function is to provide accurate up date

information to the local government agencies and media. A serious problem is that of workload in the local office. The local NWS office is staffed for a full workload for normal weather; severe weather increases the amount of work dramatically. The further complication is that the work being done and decisions being made during severe weather periods are much more important but must be done with less data, in less time, by an overworked staff. (150)

An effective warning system must not burden a system already working at or near capacity with nominal weather. (150)

The last two columns of Figure II-9 deal with the public response to an emergency. The individual has six bases of information from which to make a choice. In the face of conflicting evidence, his choice is based on the credibility or completeness of the various messages. Individual observations, other's reactions, and confirmation of other citizens is generally a non-reason for taking specific action. Such inputs provide an emotion for action and are not usually a good base of judgment. The sound of a siren generally serves no more than the function of an attention getter. Its real function is to alert people to then tune into the media. The loudspeaker method has already been discussed, leaving radio and TV. The NOAA radio is a great improvement for communication of instruction and information, but only a small percentage of the public has the special receivers, and still lacking is the ability to convey a picture. The public must be able to maintain a choice, but the lines of communication must provide a credibility and confidence so as to create correct priority in the mind of the individual.

Public Needs for Emergency Warning

The public needs warning and instruction that is:

- unmistakably clear in content
- timely
- specific as to locale
- authoritative

The message of emergency warning must have a clearly understandable terminology. There are numerous references to the watch/warning confusion in the literature. The Agnes Floods study (150) states "...It's (NWS) credibility is sure to slip if it speaks to the public in codes or symbols. Time is too short for translations. NACOA strongly recommends that NOAA review its battery of warnings to develop improved ways of communications warning information." Reporting the status or expected condition is not sufficient information upon which to act. The public must have a clearly defined instruction of what to do.

In the Agnes Floods, less than 10% of the news media in the stricken areas had access to the latest forecasts and warnings. (150) The problem was one of the NWS not having time to keep up with the weather events and to communicate them to the media. Automation of relaying the information is certainly to be considered.

The general public's needs are greatest for weather forecasts within a six hour/100 mile scale for normal weather (151). When severe weather occurs, the interest within this scale is intensified. Certainly the mesoscale and even the microscale, is important. In the Agnes Floods "...hurricane and weather systems responsible for extremely heavy precipitation.. were... smaller...than the effective resolution of the models." Radar, aircraft, and satellite observations were not available for analysis. Availability of such "pictorial" information is technically feasible; such capability must be developed.

The Agnes Flood study (150) states "Where public authorities exercised a strong command and control initiative, the response tended to be excellent. Where people had to make their own decisions or improvise, the response was as varied as human nature. When radio or TV announcers conveyed a sense of the seriousness of the risks the public became more responsive. The report further

states "...accountability for warning delivery is fragmented to the point where no agency has the responsibility." It is the opinion of the report that NWS must see that the proper message reaches the public. "Releasing a forecast to the media is only one and sometimes a minor part of the whole system." The potential for IVAM to effectively reach the public is a powerful tool for meeting the needs of emergency warning.

IVAM's Role in Emergency Warnings

The two avenues of NWS reaching the public directly with emergency information are the NOAA weather radio (152) and IVAM. Both systems must be used, for they offer complementary and distinctly different capabilities.

The NOAA weather radio is expected to serve as the primary warning device. It provides an automatic turn-on capability which is implemented in the home on a voluntary basis. The ultimate limit on the NOAA radio, however, is the voice rate of information transfer. It could be likened to listening to an instructor who has no blackboard or visual aids. There is a distinct disadvantage compared to an instructor who uses good topical visual aids.

IVAM would provide the visual aids which can be used with or without the "instructor", or voice channel. The National Cable Television Association (NCTA) has made several studies of ways in which cable TV can provide emergency warning service to subscriber (154). In fact, subscribership of cable service has shown a marked increase where emergency warning service is available (155). Many communities have, or are developing, plans in which the local emergency operating center uses the free access channel. Special IVAM emergency sequences can be used on that channel which complement those in use on the regular weather channel.

On broadcast TV, timely visual information is hardly ever available for emergency coverage. Periodic IVAM updates, along with standard formatted instructional messages can be available as needed.

The generation of specific TV presentation segments for emergencies by warning does not pose a special problem for IVAM. Severe weather segments are just one more type of segment. The problem which needs further study is how to bring local emergency service authorities into the weather telecast. Since this does not involve generation of TV images by IVAM, we have not considered this problem to be of direct concern to the program, but would rather address the issue close to time of implementation.

2.7 Automatic System Selection of Segments

Since IVAM is to be an automatic system, the selection of segments to be used for a particular day must be done on an automatic basis as well. Most of the 145 segments available on IVAM do not apply on any particular day because of time-of-day, season, or weather situation. In other words, only a subset of the 145 segments are topical at a particular time in terms of the eight parameters listed earlier. The principal basis for deciding which segments are to be prepared is a determination of the weather situation. Each header sheet lists the weather situation for which the segment applies. To decide which segments to prepare, the control processor will reduce the total set by comparing the current situation with the segment designators, proceeding through the parameter list in the order shown. Of course, the weather situation will change during the day. The control processor will proceed through the decision tree once each hour to determine which segments to produce during the next hour. In most cases this procedure will work very well. However, the time required to transmit all of the segments needed for the network weathercasters is several hours. Care must be exercised to produce first those segments least affected by local weather change.

The set of weather situations will differ for different WSFO locations, depending upon whether flood conditions, hurricane situations, drought, high

tides, etc., apply. Weather situation selection can be made either by the forecaster keying into the system or by the automatic comparison of specified weather parameters against preset limits.

The result of the automatic select process is a "menu" list of segments which will be output on the distribution system. One segment would be a straight listing of those segments and their schedule for distribution. This would allow interested station operations to plan/schedule recording of particular segments, and also provide update information for updating segment schedules during changing weather conditions. A priority can be assigned to segments by the WSFO forecaster, which will be reflected in the selection and order of segments by the IVAM system. This allows the forecaster an input to the automatic selection of segment outputs without requiring him to interrupt the system and select the segments manually. While he has the option of doing the latter, he may not have the time or need to do so.

Scanner's note:

This page is blank.

REFERENCES

1. Whelpley, Donald A., 1961: Weather, Water, and Boating, Cornell Maritime Press, Cambridge, MD. 160 pages.
2. Myers, Joel N. and Cahir, John, J., 1971: The Weather Business, Weatherwise, 24, 64-67.
3. Sell, Francis, E., 1964: The Deer Hunter's Guide, Telegraph Press, Harrisburg, PA, 192 pages.
4. Peterson, Gunnar A. and H.D. Edgren, 1962: The Book of Outdoor Winter Activities, Association Press, New York, 219 pages.
5. Scharff, Robert, 1963: Esquire's Book of Fishing, Harper and Row, New York, 340 pages.
6. Hovey, William B., 1970: High Pressure Snow-Making, Weatherwise, 23, 244-277.
7. Lawler, Dennis A., 1974: Comparison of the Physical Properties of Natural Versus Artificial Snow Surfaces, M.S. Thesis, University of Wisconsin.
8. Gilligan, J. and Gow, D., 1971: The potential impact of advanced satellite weather forecasting on the skiing industry: a case study. Multidisciplinary Studies of the Social, Economic, and Political Impact Resulting from Recent Advances in Satellite Meteorology, Vol. I, 358-397.
9. Taylor, J. A., ed., 1972: Weather Forecasting for Agriculture and Industry, Fairleigh Dickinson University Press, Rutherford, U.K., i-xv.
10. National Collegiate Athletic Assoc., 1975: NCAA Official Collegiate Baseball Guide, NCAA Publishing Service, Shaunee Mission, KS, 62 pages.
11. Roberts, C.F., 1974: Weather and forest fires, Weatherwise, 27: 100-105.
12. Uvarov, B., 1931: Insects and climate, Trans. Ent. Soc. London, 79:1-247.
13. Williams, K., 1972: Avalanches in our western mountains: what are we doing about them?, Weatherwise, 25: 220-227.
14. Spenk, P., 1973: Hunting scent prospects by degrees, Weather 28:212-213.
15. Perry, A., 1972: The weather forecaster and the tourist - the example of the Scottish ski industry, Weather Forecasting for Agriculture and Industry, Taylor, J., ed., Fairleigh Dickinson University Press, Rutherford, U.K., 126-131.

16. Paul, A., 1972: Weather and the daily use of outdoor recreation areas in Canada, Weather Forecasting for Agriculture and Industry, Taylor, J., ed., 132-146.
17. Wis. Dept. Natural Resources, 1974: A Program for Snowmobiling in Wisconsin, Dept. Nat. Res., Madison, Wisconsin, 40 pages.
18. Holford, I., 1967: Planning your days according to the weather, Weather, 22: 132-33.
19. Clawson, M., 1966: The influence of weather on outdoor recreation, Human Dimensions of Weather Modification, Sewell, W., ed., U. Chic. Dept. Geog., Res. Paper #105, 307-322.
20. Helfand, L. A. and C. Bridger, 1971: Hippocrates, Thermal Stress and Stroke Mortality, Weatherwise, 24: 100-105.
21. Landberg, G.E., 1969: Weather and Health, Doubleday and Company, Garden City, New York, 148 pages.
22. Peterson, James O., 1974: Wisconsin Accident Facts, 1973, Division of Motor Vehicles, Traffic Accident Data Section, 29 pages.
23. Stern, Arthur C., 1968: Air Pollution, Vol. 1, Academic Press, New York, 694 pages.
24. Nicholson, Sharon: A Carbon Monoxide Survey of Madison, Wisconsin, Inst. Environ. Studies Report #3, November 1972, 14 pages.
25. Ragland, K. and Peirce, J.: Air Pollution Due to Highway Traffic, Inst. Environ. Studies Working Paper 13, Sept., 1973, 22 pages.
26. Institute for Environmental Studies, 1973: Monitoring and Control of Regional Air Pollution, IES, Univ. of Wis., Report #4, 86 pages.
27. Uvarov, B., 1931: Insects and Climate, Trans. Ent. Soc. London, 79: 1-247.
28. Taylor, J.A., ed., 1972: Weather Forecasting for Agriculture and Industry, Fairleigh, Dickinson Univ. Press, Rutherford, U.K., i-xv.
29. Auliciems, A. and F. Hare, 1973: Weather forecasting for personal comfort, Weather, 28: 118-121.
30. Hay, J. and C. Young: Weather forecasting for the prevention of icy roads in the United Kingdom, Weather Forecasting for Agriculture and Industry, Taylor, J., ed., Fairleigh Dickinson Univ. Press, Rutherford, U.K., 155-165.
31. Sargent, F. and S. Tromp, 1964: A Survey of Human Biometeorology, World Meteor. Org., Tech. Note #65, #160, TP 78, 113 pages.
32. Collins, G., 1956: A severe weather service for industry, Bull. Amer. Met. Soc., 37: 514-516.

33. Russo, John A., Jr., 1966: The economic impact of weather on the construction industry of the United States, Bull Amer. Met. Soc., 47: 967-973.
34. Baldwin, J., J. Manthei, H. Rothbart, and R. Harris, 1971: Causes of delay in the construction industry, Jour. Construct. Div., Proc. Amer. Soc. Civil Eng., 1977: 187.
35. Kachelhoffer, S. and M. Koziara, 1973: Final Report on the Role of Private Meteorological Consultants for the Greater Madison Area General Contractors, Unpublished manuscript.
36. Landsberg, H.E., 1969: Weather and Health, Doubleday and Company, Garden City, New York, 148 pages.
37. Myers, Joel N. and Cahir, John J., 1971: The weather business, Weatherwise, 24: 64-67.
38. Leavitt, Peter R., 1973: Some aspects of long and short-range temperature forecasting, American Gas. Assoc. Distribution Conference, May 14-17, 1973, Unpublished manuscript.
39. Stern, Arthur C., 1968: Air Pollution: Vol. 1, Academic Press, New York, 694 pages.
40. Nicholson, Sharon, A carbon monoxide survey of Madison, Wisconsin, U. Wis. Inst. Environ. Studies Report #3, November 1972, 14 pages.
41. Ragland, K. and Peirce, J., 1973: Air pollution due to highway traffic, U. Wis. Inst. Environ. Studies Working Paper #13, September, 1973, 22 pages.
42. Branch, Dale, 1973: Snow and Ice Control, Unpublished manuscript.
43. Taylor, James A., 1968: Weather Economics, Pergamon Press, New York, 126 pages.
44. Wilson, J.R., et al., 1969: Winter Concrete Construction - An Operational Manual, Dewey Portland Cement Co., 17 pages.
45. Wilson, J.R., et al., 1971: Summer Concrete Construction - An Operational Manual, Dewey Portland Cement Co., 20 pages.
46. Institute for Environmental Studies, 1973: Monitoring and control of regional air pollution, IES, Univ. Wis., Report #4, 86 pages.
47. Limaye, S., 1973: Meteorology and Electric Power Production, Unpublished manuscript.
48. Stanton, K.N., P.C. Gupta, and A.A. El Abiad, 1969: Long range demand forecasting for the electric utility industry, Proc. 6th Power Industries Computer Applications Conf., 1969, Denver, CO, 656-671.

49. Stone, W., 1971: A case study to determine the nature of the impact on single-family home construction, resulting from recent advances in satellite meteorology. Multidisciplinary Studies of the Social, Economic, and Political Impact Resulting from Recent Advances in Satellite Meteorology, Vol. II, 236-297.
50. Willeke, G., 1971: Impacts of recent advances in satellite meteorology on water resources management, Multidisciplinary Studies of the Social, Economic, and Political Impact Resulting from Recent Advances in Satellite Meteorology, Vol. II, 236-297.
51. Middleton, J., 1967: Air quality as a controlling factor in life process, Biometeorology, W. Lowry, ed., 67-79.
52. Ludwig, J., 1971: Technical needs in meteorology for our affluent future: air quality, Bull. Amer. Met. Soc., 52: 534-537.
53. Maunder, W., 1973: Weekly weather and economic activities on a national scale: an example using United States retail trade data, Weather, 28: 2-18.
54. Steele, A., 1951: Weather's effect on the sales of a department store, J. Marketing, 15: 436-443.
55. Ziesel, H., 1950: How temperature affects sales, Printers Ink, 223: 40-42.
56. Shor, M., 1963: Exploratory work in measurement of the effect of weather factors on retail sales, Proc. Amer. Stat. Assoc. (Section on Business and Economic Stat.), 54-58.
57. Linden, F., 1959: Weather in Business, Conf. Board Business Record, 16: 90-94.
58. Buchanan, R., 1972: Weather forecasting for industry, Weather Forecasting for Agriculture and Industry, J. Taylor, ed., Fairleigh Dickinson Press, Rutherford, U.K., 115-125.
59. Musgrave, J., 1968: Measuring the influence of weather on housing starts, J. Const. Rev., August, 1968, 4-7.
60. Goodhew, R. and E. Jackson, 1972: Weather forecasting and river management, Weather Forecasting for Agriculture and Industry, J. Taylor, ed., Fairleigh Dickinson Press, Rutherford, U.K., 166-183.
61. Gander, R., 1972: The demand for beer as a function of weather in the British Isles, Weather Forecasting for Agriculture and Industry, J. Taylor, ed., Fairleigh Dickinson Press, Rutherford, U.K., 209-223.
62. Barnett, C., 1972: Weather and short term forecasting of electricity demand, Weather Forecasting for Agriculture and Industry, J. Taylor, ed., Fairleigh Dickinson Press, Rutherford, U.K., 209-223.
63. Collins, G., 1956: A severe weather service for industry, Bull. Amer. Met. Soc., 37: 514-516.
64. Roth, R., 1963: Further application of weather information, Bull. Amer. Met. Soc., 44: 72-74.

65. World Meteorological Society, 1956: Meteorology as applied to the navigation of ships, WMO, #76, Technical Paper 30, 25 pages.
66. Bickert, C. and T. Browne, 1966: Perception of the effects of weather on manufacturing: a study of five firms, Human Dimensions of Weather Modification, W. R. Sewell, ed., U. Chicago, Dept. Geog. Paper #105, 307-322.
67. Maunder, W., S. Johnson, and J. McQuigg, 1971: The effect of weather on road construction: a simulation, Mon. Wea. Rev., 99: 939-945.
68. World Meteorological Organization, 1968: Economic benefits of meteorology, WMO Bulletin, 18: 181-186.
69. Taylor, J., ed., 1972: Weather Forecasting for Agriculture and Industry, Fairleigh Dickinson Press, Rutherford, U.K., xi-xix.
70. Aristov, N. and V. Moiseichik, 1972: Weather forecasting and agrometeorological conditions for autumn, Zemledelie 9: 39-40 [in Russian].
71. Bad weather reduces Belgian fruit crops in 1972, Int. Fruit World, 31(3): 196, 199.
72. Barger, G., 1972: Weather and agriculture, California Tomato Grower 15(10): 4-5.
73. Boschi, V., 1971: Agro-meteorological survey of Ponaro River basin for 1970, Ist. Sper. Agron. Ann. 2(1): 77-116 [in Italian], English summary.
74. Byrne, G.F., 1973: An approach to growth curve analysis, Agricultural Meteorology 11(2): 161-8.
75. Coffing, A., 1973: Forecasting wheat production in Turkey, U.S. Dept. of Agriculture, Economic Research Service, Foreign Agricultural Economic Report, GPO, Washington, D.C.
76. Dancer, W.S. and T.W. Tibbits, 1972: Impact of Nowcasting on the production and processing of vegetable crops. Unpublished manuscript.
77. Davis, J.M., 1973: Ohio crop and weather summary for 1971 and 1972. Ohio Agr. Res. Develop. Cent. Agron. Dept. Mimeogr. Ser., 211.
78. Decker, W.L., 1967: Temperatures critical to agriculture. N. Cen. Reg. Pub. no. 174, Univ. MO, AES, Columbia.
79. Ehrler, L.R., 1973: Cotton leaf temperatures as related to soil water depletion and meteorological factors. Agron. J. 65(3): 404-409.
80. Ervio, L.R., 1972: Effect of temperature and dry-weather period on competition between Chenopodium album L. and some spring cereals [oats, wheat], Suomen Maatal. Seura Maatal. Aik. 44(3): 138-148, [in Finnish] English Summary.

81. Ewalt, R.E., 1973: Operational value of weather information in relation to soil management characteristics, Agron. J., 65(3): 404-409.
82. Felch, R.E., 1973: How weather influences crop disease, Crops/Soils, 25(7): 12-16.
83. Geslin, M. H., 1972: Meteorology and agriculture, C.R. Science Acad. Agric. Fr. 15 (Special number): 1169-1171 [in French].
84. Guise, J.W.B., 1969: The effect of weather and technological change on New Zealand crop yields, an econometric analysis, Tech. Pap. Agric. Econ. Res. Unit, Lincoln College, Canterbury, N.Z., No. 5: pp. 42+.
85. Heger, K., 1973: Estimating the storm risk to grain harvested by a combine harvester using an agrometeorological model, Berichte uber Landwirtschaft 51 (1): 176-207 [in German].
86. Hering, M., 1972: Weather, development of grapes, diseases, pests, and injuries in vineyards of German Federal Republic in 1971, Weinberg Keller 19(6): 321-339.
87. Hill, J.D., 1972: Agriculture - the forgotten user of the forecast, Bull. Amer. Meteor. Soc. 53: 1166-9.
88. Hooker, A.L., 1972: Southern leaf blight of corn: present status and future prospects, J. Environ. Qual., 1(3): 244-249.
89. Johnstone, D.R. and others, 1974: Micrometeorological and operational factors affecting ultra-low-volume spray application, Agr. Met., 13: 39-57.
90. Jose, H.D., R.L. Christensen, and E.I. Fuller, 1971: Consideration of weather risk in forage machinery selection, Can. Jour. Agric. Econ.(Ottawa) 19(1): 98-109.
91. Kable, P.F., 1972: Murrumbidgee Irrigation Areas, III. Influence of weather conditions during harvest period on disease incidence in canning peaches, Australian J. Agr. Res., 23(6): 1035-1044.
92. Korobov, V.A. and B.I. Bugera, 1972: Factor analysis of yield and its forecasting by means of a transcendental production function, Ekonomika Matematicheskie Metody (Moscow), 8(2): 232-241 [in Russian].
93. Landsberg, H.E., 1961: Foreword, in Wang and Barger 1962, Bibliography of Agricultural Meteorology, University of Wisconsin Press, Madison, WI.
94. Lapwood, D.H., 1972: Relative importance of weather, soil, and seed-borne inoculum in determining incidence of common scab (Streptomyces scabies) in potato crops, Plant Pathol., 21(3): 105-108.
95. Link, L.A., 1972: Yield and value of Burley tobacco as affected by exposure to weather during harvesting, Tob. Sci., 16: 52-54.

96. Lomas, J., 1972: Activities of division for agricultural meteorology of Israeli Meteorological Service, Isr. Agric., Fall: 19-20.
97. Molga, M., 1962: Agricultural Meteorology, Part II, Transl. from Polish for NSF and USDA, Central Inform. Inst., Warsaw.
98. Moore, I., 1973: Farming to beat weather, Country Life (London), 153 (3950): 623-624.
99. Muthappa, B.N., 1972: Studies on Colletotrichum coffeanum in India. I. Stalk-rot of green berries and leaves of Coffea arabica during wet weather of monsoon, J. Coffee Res. 2 (2): 16-22.
100. Nagarajan, S., 1973: Satellite television cloud photography as a possible tool to forecast plant disease spread, Current Science 42: 273-74.
101. Nambu, S., 1973: Considerations of weather and operation for hay balers, Obihiro Zootech. Univ. Res. Bull. (ser. 1) 7(4): 661-671 [in Japanese], English summary.
102. Newman, J.E., 1974: Applying meteorology to agriculture (editorial), Agri. Met. 13: 1-3.
103. O'svath, J. and V. Rethy, 1972: Separating parameters of growth and weather conditions, Z. Acker. & Pflanz 135(4): 310-325 [in German], English summary.
104. Oyokawa, T., 1972: Meteorological effects on plant growth, Soc. Agr. Meteorol. Jap. J. Agr. Meteorol. 28(1): 45-51.
105. Puffer, R.E. and F.M. Turrell, 1967: Frost protection in citrus, Univ. Cal. Ag. Ext. Bull. AXT-108.
106. Rahn, J.J. and G.L. Barger, 1973: Weather conditions and screwworm activity, Agricultural Meteorology 11: 197-211.
107. Ray, S.K., 1971: Weather and reserve stocks for foodgrains, Economic and Political Weekly (Bombay) 6(39): A-131 - A-142.
108. Reid, G.K.R. and D.A. Thomas, 1973: Pastoral production, stocking rate, and seasonal conditions, Quarterly Review of Agricultural Economics 26(4): 217-227.
109. Rizzo, V., 1971: Agrometeorological survey of Apulia and Basilicata for 1970, Ist. Sper. Agron. Ann. 2(1): 117-194 [Italian], English summary.
110. Robertson, G.W. and G.A. de Weille, 1973: Rice and weather, WMO Bull. 22(1): 16-24.
111. Royle, D.J., 1973: Quantitative relationships between infection by hop downy mildew pathogen, Pseudoperonospora humuli, and weather and inoculum factors, Ann. Appl. Biol 73(1): 19-30.

112. Seddon, B., 1967: Prehistoric climate and agriculture: a review of recent paleoecological investigations, in Taylor, J.A. (ed.), Weather and Agriculture, Pergamon Press, Oxford.
113. Sporleder, T.L., 1972: Temperature probabilities and the Bayesian "no data" problem, Southern Journal of Agricultural Economics 4(1): 113-117.
114. Stansfield, J.M., 1970: The effect of the weather on farm organization and farm management. In Taylor, J.A. (ed.), Weather Economics, Pergamon Press, Oxford.
115. Stock, H.G., 1971: Effect of temperature, soil moisture, and wind velocity on growth of red clover and alfalfa, Arch. Acker. Pflanz Bodenkd. 15(11): 951-962 [German], English summary.
116. Taylor, J.A., ed., 1967: Weather and Agriculture, Pergamon Press, Oxford.
117. Taylor, J.A., ed., 1970: Weather Economics, Pergamon Press, Oxford.
118. Taylor, J.A., ed., 1972: Weather Forecasting for Agriculture and Industry: A symposium, Univer. College of Wales, Aberystwyth.
119. Tibbitts, T.W. and N.A. Meier, 1969: The significance of accurate weather predictions to the management of certain horticultural crops. Unpublished manuscript.
120. U.S. Department of Commerce and U.S. Department of Agriculture, 1967: Federal Plan for a National Agricultural Weather Service, Government Printing Office, Washington, D.C.
121. U.S. Department of Commerce, 1971: Federal Plan for a National Agricultural Weather Service, Government Printing Office, Washington, D.C.
122. Veitch, L.G. and R.I. Forrester, 1973: Monthly weather-irrigation relationships, Agricultural Meteorology 12: 347-60.
123. Walser, K. and others, 1972: Clinical contribution to knowledge of acute mastitis (Mastitis acuta gravis) of cattle. 3. Influence of weather, Berliner Munchener Tierarztl. Wochenschr. 85(17): 330-333 [in German], English summary.
124. Wang, J.Y., 1962: Crop forecasts without weather predictions, Crops and Soils 14(9): 7-9.
125. Wang, J.Y., 1967: Agricultural Meteorology, Omega Enterprises, Agricultural Weather Information Service, Palo Alto, CA.
126. Wang, J.Y., 1972: In Agricultural Meteorology, 1972, Proceedings of the WMO seminar on agricultural meteorology, held at Barbados, November 1970, WMO, Geneva, Switzerland.
127. Wang, J.Y. and G.L. Barger, 1962: Bibliography of Agricultural Meteorology, University of Wisconsin Press, Madison.

128. Wang, J.Y. and V.E. Suomi, 1958: The phyto-climate of Wisconsin. Part 2: Temperature: normal and hazards, University of Wisconsin, Institute for Environmental Studies, Madison, WI.
129. Watson, D.J. and others, 1972: Effects of shading and of seasonal differences in weather on growth, sugar content and sugar yield of sugar beet crops, Ann. Appl. Biol. 71(2): 159-185.
130. Whan, I.F., 1970: Frost and wheatgrower's dilemma: A Bayesian approach, Farm Management (Melbourne) 6(3): 8-10.
131. Yao, A.Y.M., 1969: Climatic hazards to the agricultural potential in North China Plain, Agricultural Meteorology 6(1): 33-48.
132. Yao, A.Y.M., 1973: Evaluating climatic limitations for a specific agricultural enterprise, Agricultural Meteorology 12(1): 65-73.
133. Zub, L., 1971: Influence of weather conditions during hop flowering time on yield losses, Inst. Uprawy Nawozenia Glebozn. Pamiet. Pulawski 43: 169-180 [in Polish], English summary.
134. Bolger, Thomas, Network Affiliate Station, Madison: Personal interview, December 3, 1974.
135. Donner, S.T.: The Meaning of Commercial Television, 1966.
136. Herling, Steven, Network Affiliate Station, Madison: Personal interview, December 3, 1974.
137. IVAM Survey Results, AMS Weathercaster Conference, January 1975.
138. Lacy, Madison Davis, PBS Coordinator of Production Liaison, Washington, D.C., Personal interview, March 4, 1975.
139. Lichty, L.W. and J.M. Ripley: American Broadcasting, Volume I, 1972.
140. Lichty, L.W. and J.M. Ripley: American Broadcasting, Vol. II., 1972.
141. Little, Robert, CBS: Personal Interview, January 10, 1975.
142. Martin, L.A. and W.L. Quaal: Broadcast Management - Radio and Television, 1968.
143. Mullholland, Robert, NBC: Personal interview, January 10, 1975.
144. Schiller, H.I.: Mass Communications and American Empire, 1970.
145. Sheehan, William, ABC: Personal interview, January 10, 1975.
146. Stavins, R.L., editor: Television Today, 1971.
147. Tiano, Anthony, Operations Director, WHA-TV, Madison: Personal Interview, December 6, 1974.

148. Zuelsdorf, Robert, Network Affiliate Station, Madison: Personal interview, December 6, 1974.
149. Mills, Craig J., 1973: Severe Weather Study, Interim Report on NGL 50-002-114, Vol. V, November 1973.
150. NACOA, November 22, 1972: The Agnes Floods - A Post Audit of the Effectiveness ...
151. ICAS, 1971: The National Research Effort on Improved Weather Description and Prediction for Social and Economic Purposes.
152. The Use of Telecommunications to Warn the General Public, January 13, 1975.
153. OTP, January 13, 1975: National Policy for the Use of Telecommunications to Warn the General Public.
154. Dyson, Hazel S., November 6, 1974: Cable TV and Engineering Services, National Cable Television Association.
155. Delmar Ports, Vice-president, NCTA, March 4, 1975: Personal interview.

3.0 SOFTWARE

3.1 Software Overview

The IVAM software is designed to provide the tools necessary to produce the image sequences described in the IVAM storyboards. The ultimate goal of this software is to produce aesthetically pleasing video images from AFOS data on a timely and automated basis. The goal of the current contract was to investigate the feasibility of doing this, to design the hardware and software required, to implement the software required on a prototype basis, and to code the software required to generate "representative" segments. Actually the software effort went considerably beyond these requirements.

The need for a multiple processor and special purpose hardware was identified early in the program. Therefore, all IVAM design considered the ultimate presence of such resources. Also, in addition to a development system for generating sample IVAM images, the IVAM effort has developed a large part of the production software that would be required if the follow-on contract to do a production prototype were funded. The modules developed for the development system are thus designed to be easily moved into the production environment which is currently prepared to run them on multiple processors if they were available to the system.

This software section considers the software requirements of the production system. It then outlines the implementation approach that guided the design of both the development system and the production system. The function and implementation of the development system called TABSYS is then described. Finally, the software associated with the production system is also described. This includes the overall executive system called the Controller, plus the software required to operate the hardware assembler which has not been built.

3.2 Requirements

The requirements on the IVAM software fall into two categories. First, there are the requirements of the original IVAM study, and second, the requirements of a production IVAM system that would generate images at high speed and be interconnected with both AFOS and a source of satellite pictures on an operational basis. Clearly there is no way that the software peculiar to the production environment can be tested without having it available. Similarly, there is no way production speeds can be reached without the special hardware designed to attain it. What can be done is to indicate the specific nature of the missing pieces, the steps necessary to create them, and the effect their addition would have on the system.

There are three types of requirements on the software. First, there are requirements on the kind of output it must be able to produce. Second, there are requirements on the system and its ability to fit into the intended operational environment. Third, there are performance criteria which define the rate at which the software must operate.

The IVAM software must be capable of generating the range of images specified by the IVAM segments definitions and storyboards. The current contract does not require that all of these segments be coded, but rather that representative segments be coded. This has been done, as demonstrated in the final tape. Where the segments have not been coded, they can be, assuming that the product from which they are derived is available. IVAM can produce any of the segments currently, if the elements are available in IVAM formats.

All of the images must be of color broadcast quality. The color requirements are that IVAM images be aesthetically pleasing and their information content preserved on both NTSC color and black and white television sets where the signal has been RF modulated, transmitted, and demodulated. This requirement

limits the colors that can be adjacent to each other. It also limits the colors that can be used on narrow vertical lines, depending on their width.

Another visual requirement is that the features in the image not appear to flicker. This phenomenon occurs with horizontal line segments that are only one pixel high. Therefore, all lines must be at least two pixels high.

Another constraint on the images is that their detail and information content be geared for someone sitting at least six times the width of the screen away. This situation is quite different from the normal computer terminal where the user sits very close to the screen. Therefore, alphanumeric characters will be quite large, and images will be relatively simple so they may be easily viewed by people with less than perfect vision sitting at normal viewing distance.

The content of the images should be designed to communicate meteorological information to the layman in terms that he can understand in the brief time any single image is likely to be held. This contrasts strongly with many of the NWS products which are designed to be scrutinized over a period of time by a professional meteorologist.

The requirements on the production system software include flexibility, the ability to format AFOS and satellite data, and that it not be specific to any particular locale.

The requirement of AFOS compatibility has been a difficult one to deal with in a number of aspects. First, the AFOS data formats have changed a number of times during the IVAM development. Second, as the formats have changed, the sample products that have been requested a number of times have not been provided. Third, the identification of the products relevant to each of the IVAM that was requested has not been done. Therefore, what has been done has been to postpone the implementation of the format translation modules that would

convert AFOS products into IVAM formats, and to design the system so their insertion causes a minimum of disruptions. In fact the division of processes described earlier make the postponement of these modules easy to overcome, and in fact desirable.

However, the requirement that IVAM handle AFOS data raises a deeper, more profound issue. In practice, the requirement becomes a reciprocal one. The AFOS data must be in such form that the information needed by IVAM is easily accessible. In the case of the graphic products this is not true. These products are designed to be transmitted and displayed by computers, but interpreted only by human operators. However, IVAM must be able to interpret the images if it is to know how to convey the information they provide in a filled-in color image, as opposed to a line drawing. The problem is that the curves and the alphanumerics that label them are sent separately. They are associated by the human operator who observes their propinquity on the screen and thereby associates them with each other. For the computer to try to make this association through software is theoretically possible, but practically unreasonable. It is far more direct for the AFOS product to be altered in some minor way, so the meteorological significance of the various curves can be recognized easily by software. This need has been expressed at every opportunity for the entire history of the project.

Another concern about the AFOS data is that it is presented in a limited variety of scales and resolutions which may not be ideal for the IVAM purpose. For instance, if an AFOS product showed temperatures contoured at 10 degree intervals over the entire U.S., IVAM might want to display 5 degree bands for just a five-state area. Or IVAM might want to display only a 0C contour level.

This information is readily available from the uniform grids from which NMC generates the AFOS products, but very difficult to derive from the products themselves.

The point is that the addition of a new product type would permit very flexible image generation from existing NWS data. In general, the IVAM task must include considering the information the public, as opposed to meteorologists, wants, and then recommending that new products be created where none exists at the moment. With a number of the existing segments, there is a question as to what product could be used to generate them.

An additional goal which appeared desirable at the beginning of the contract was to make IVAM code directly compatible with AFOS and capable of running under it. It became clear, early in the program, to both IVAM and AFOS personnel, that this goal was neither desirable nor attainable. At that time AFOS definitely did not have the kind of control structures that IVAM requires. In fact, it still appears that the perceived tasks of the IVAM and AFOS systems are sufficiently different that it is more natural to think of them as two independent systems each specialized to its own function, one of which happens to be an almost standard user of the other. This division of labor is far more natural than trying to force AFOS to accommodate an additional responsibility which is at least as demanding as those it handles already. However, the IVAM module structure is the simplest possible, in that it makes the absolute minimum number of assumptions about the environment in which it operates. Therefore, modules are easily transportable. Machine language modules observe FORTRAN calling conventions, are well specified, and could be easily recoded.

Another requirement is that the IVAM system be easily tailored to fit

different geographic areas, and that it easily accommodate the addition of new segments. None of the IVAM modules are specific to geographic locale, to display device, or to the segments they are being used to generate. Image generation is controlled by an interpreter which sequences the appropriate modules and passes the appropriate parameters. The definition of such a command chain can be done interactively, and in fact may involve no new code, compilation, or task building. The specification of map windows, cities of interest, etc., is done by the same process. If a new segment requires a new computation, a new module will have to be written. However, the insertion of the new process into the system is just a matter of compiling it as part of an isolated virtual process, and then interactively adding to the system directory, and defining command chains which involve it.

IVAM was also to determine what would be required to make its operation automatic. The automatic generation of images from existing data and existing image elements has already been attained. The ability to automatically request the appropriate data from AFOS has not been demonstrated, as the two systems are not connected. Here the issue is not one of feasibility, but rather the definition of a relationship between the two systems that does not place an undue burden of requests on AFOS, and yet provides IVAM the data it needs on a timely basis. Since the volume of data actually used by IVAM does not appear to be large, it appears that it should be possible to make IVAM appear as a civilized user to AFOS. The only step that appears difficult to automate is the selection of the segments that are to be shown at a particular time. This problem is essentially the same as modelling the weathercaster, which is in the province of artificial intelligence. It is aggravated by the fact that the criteria are likely to vary with different locations, and different seasons. It is not that

it is not possible to automatically make a selection; rather it is the unlikelihood of consistently making an intelligent determination. If the task is relaxed considerably it is clearly solvable. If the system sticks to a fairly standard set of base segments and only adds those which are clearly of interest, such as significant precipitation or high winds, it can be automated. Alternatively, if the system is allowed to generate more segments than necessary or interesting, on the assumption that the networks will edit it before showing, the problem again becomes more tractable. Currently, the software assumes that it is given a list of segments to generate and could do so automatically. However, the process of creating that list can be added without any impact to the system as a whole, once the meteorological criteria are specified.

The software performance criteria apply to the production, not the development system. Therefore, what must be judged at this point is whether the software implemented so far would perform as required when combined with the production hardware specified.

The performance standard derived from the content studies is that a production system must be capable of producing one hundred new frames per hour. This amounts to a new frame every thirty-six seconds. This rate cannot be met with current equipment because of the very slow speed at which the image assembly process proceeds, and because only one processor is available for the job.

However, what can be done is to ask whether the image elements can be generated at the rate required, assuming that image assembly hardware of sufficient speed were available. Assuming that each new frame requires ten different image elements, then 1000 image elements per hour must be generated, or one every 3.6 seconds. In fact, the system is able to do considerably better than this, especially if there is the normal redundancy of image elements across frames. For instance, it is quite common for a map to be repeated in every frame of a segment. Because of the parallel processing of the crosspoint system, processes which are larger

than the others do not have to appear as rate limiting steps. For example, the reformatting of AFOS data should not be a large process on a per pixel basis. However, the computation of a U.S. grid or a set of contours in satellite projection is much larger on a sixteen bit processor. The grids should not be a problem for several reasons. First, as the requirements stand now, the satellite images should be pre-gridded. Second, if they are not, only a limited number of projections are required during the day. These are known at the beginning of the day, and the processing can be spread throughout the day. While the positioning of any AFOS or generated data over a satellite image must be computed in the period after the display is requested and before it is displayed, the fact that a processor is dedicated to such processing and the code is permanently resident means that the full time is available for such products. Therefore, the generation of elements requiring arithmetic processing appears to be well within the capability of the system. The only other single large process is the Video Chain, which is currently implemented as a set of software modules but which is intended to be reduced to hardware or firmware with an order of magnitude increase in speed. Given the presence of this hardware, IVAM software should perform at the rate required.

3.3 Implementation Approach

3.3.1 Image Elements

The design of the IVAM system is based on several observations on the nature of the IVAM task. The first observation is that the amount of data input is rather small compared to the number of points in the output image. Therefore, it is desirable to postpone this explosion of data as long as possible so the system has to process and store smaller units of data. Second, it was noted that IVAM images are made of distinct image elements, and that the processing of these elements is completely independent as long as it is done with

respect to the same frame of reference (i.e., the same screen or earth coordinates). It is only in the final image that these elements are combined. As long as the relative priorities of the various image elements are enforced (which elements appear to be in front of the others), there is no interaction between elements. The only exception is the placement of alphanumerics which requires that underlying information not be obscured. The treatment of alphanumerics is somewhat separate from the rest of the system since they will be generated in the output assembler. Examples of image elements would be satellite pictures, maps, graphic clouds, wind arrows, contour lines, etc. Each of these is generated by a separate process, and only combined in the final image. One theme of the IVAM design is to maintain the separation of these image elements and the processes that generate them as much as possible. Thus, the IVAM system becomes concerned with the generation of elements on the one hand and the combination of elements on the other. Maintaining this distinction is important because it simplifies software design and preserves hardware options. It also allows IVAM to take advantage of another significant characteristic of its presentations: the tremendous redundancy of elements among the images of a sequence and the lesser but still significant overlap among different segments.

3.3.2 Parallel Processing

Another aspect of the software design was the early decision to permit parallel processing. The nature of the IVAM task suggested more than one kind of parallel processing. First, the independence of image elements suggested that separate processors could be working on different elements. Second, the steps of the preparation of image elements suggested a pipeline process where each processor was working on different data at consecutive stages in processing.

As each processor was finished with its process, it would pass the results on to the next processor. Finally, the number of points that must be specified in the final image and the number of images to be generated almost dictate that a special hardware or firmware process be created for the job. Software alone on a single processor would clearly be unequal to the task. Another force pressing toward parallel processing is that both processors and memory have become cheap; that is, eight and sixteen bit processors and memories for them have become cheap. Machines with larger address spaces have not yet responded to the declining costs. Therefore, the current critical resource is address space, and the one trick to keep as much memory busy as possible. This allows the system to have the greatest amount of code available at electronic, as opposed to mechanical, speeds. The best way to do this is to have a number of processors and memories tied together in as intimate a fashion as possible. The most effective such architecture is the Crosspoint which interconnects processors and memories in such a way that large blocks of memory can be switched from one processor to another almost instantaneously. Although the Crosspoint System was not integrated with the development system, all of the IVAM software design and implementation is consistent with its inclusion. The IVAM Controller currently can keep track of multiple tasks under RSX 11M, so all the structures exist to handle parallel processing. Only the low level crosspoint primitives remain, and these cannot be approached without a hardware interface.

3.3.3 Module Design

The processing needs of the IVAM system can be characterized as a modest number of processes tied together in a very large number of ways. The traditional means of accomplishing this flexibility would be to unite these functions in a general program. Such a program would consist of the irreducible

part required by the functions themselves, together with the case logic that would decide which of the plethora of options was being involved in any given case. The general part of the code is quite likely to require more space than all the functions combined. All of the general code is always present, even though only a small part of it is actually used in any given run. Such a program rapidly grows large and unwieldy as space limits are exceeded, both for code and for symbol tables. Also, since all of the case logic is interdependent, new functions become more and more difficult to add.

In the IVAM system a quite different approach is taken. All IVAM functions are accomplished by modules which have an absolute minimum dependence on any other parts of the system. In fact, the control relationship between IVAM modules is less than minimal; it is nonexistent. IVAM modules know nothing about each other. They cannot use each other for utility functions, nor can they transfer control to each other in any way. This means that IVAM modules cannot be vested. The only entity a module can communicate with is the system. Even then, a module can have no in-process communication with the system. Its only communication is a return to the system. This inability to transfer control means that an IVAM module has no responsibility for sequencing. That function is solely in the hands of the system (Fig. 3-1).

In general, modules are also incapable of doing their own I/O. The only modules that can perform I/O functions are I/O modules. Each of these has a specific function and is unique to the system. This means that device and system dependencies are localized, and that I/O routines do not require space in every module. For instance, it is not uncommon to find that a large percentage of a system's user disk is actually consumed by multiple copies of FORTRAN routines.

SEQUENTIAL MODULES

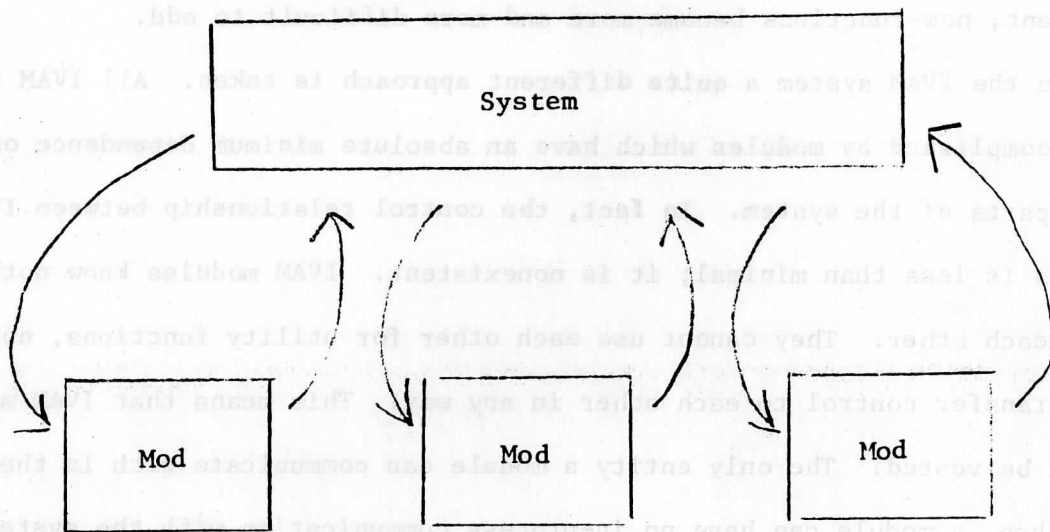


FIGURE 3-1.

Having described the constraints on the IVAM modules it is now necessary to show how they are implemented and the advantages that accrue to the system because of this design. All IVAM modules are called as FORTRAN subroutines. It is not necessary that the modules be written in FORTRAN (many are not), only that they can be invoked by a FORTRAN call. The sole communication with the rest of the system is exactly that of a FORTRAN subroutine; i.e., FORTRAN call, FORTRAN RETURN, parameter list, and the variables and arrays specified by the parameter list. Furthermore, IVAM modules operate on arrays that are external to them. This convention circumvents one of the most annoying features of FORTRAN, the necessity to dimension arrays at the maximum size they will ever attain. Even if the typical space needs are much smaller, the dimensioned space is forever lost to the system. By keeping all data outside the module, its size is kept small and the system can be responsible for allocating only the amount of space that is required for a given execution. This is especially advantageous since, in many cases, the IVAM system can know exactly the output requirements based on the number of input points.

Thus, an IVAM module is conceptually very simple. It is pure algorithm. It inputs data sets and outputs data sets. In fact, in all existing cases, it outputs only one data set. Once a module is invoked, it runs to completion and returns to the system, including information such as the size of the output array as a return parameter. The important programming consideration with an IVAM module is not the control interface, since that is standard; rather, what defines a module is the format of its input and output data sets. Therefore, a number of standard formats have been defined. IVAM modules then manipulate data from one format, and place it in another which may in fact be the same as the first. Therefore, IVAM modules can be concatenated with the same ease as

FORTTRAN operators as long as the module formats are compatible. Also it is easy to stop the flow of IVAM modules, so as to define an alternative path. For instance, if a chain of modules defines a certain process, and one desires to check the correctness of the processing, it is easy to insert a new module

$$(M_1 \longrightarrow M_2 \longrightarrow M_3 \longrightarrow M_4)$$

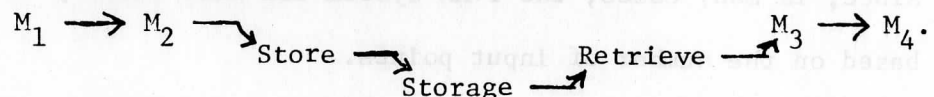
in the sequence which dumps the processed data after any step. This is done

$$(M_1 \longrightarrow M_2 \longrightarrow \text{DUMP} \longrightarrow M_3 \longrightarrow M_4)$$

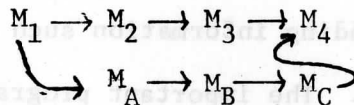
interactively under TABSYS, and by editing a command chain under the Directory.

In neither case must the modules involved be recomputed or re-task-built.

Similarly, if the operation of the system were changed drastically so the command chain was broken, the intermediate results stored on disk, the results later retrieved from disk, and the command chain continued. Again, the change is easily accomplished by the insertion of two new modules, one to store the results, and another to retrieve it. Again, no recompilation is required; all is accomplished by changing the command chain. The system interprets:



Similarly, the system can accommodate alternative ways of accomplishing the same function as long as the formats are preserved:



The result of this module design is that IVAM modules can be assembled in a variety of ways. However, the system does not bear the burden of resolving which of many general functions is requested. Rather IVAM provides a general framework within which to define specific functions without incurring the usual costs of generality. The resulting IVAM modules are small and their single copy

available to the system for any composite function. The sizing is important because of the original goal of running modules on either the 11/40 or one of the subordinate LSI 11's.

3.3.4. Video Chain

Perhaps the most important group of modules are those referred to as the Video Chain. These modules take an element defined in an arbitrary rectangular coordinate space, and prepare it for display. This process is implemented in a series of separate modules, each of which advances the element one step further toward display. These modules are implemented separately for greatest flexibility, so the system can use their functions in a variety of ways. Also, each of these modules is a candidate for implementation on some kind of special purpose processor. Therefore, the steps are separated so that the hardware options are clear. The modules involved in the Video Chain are shown in Fig. 3-2. The details of their function and design will be described under the discussion of the Tablet System in section 3.4.1. They represent a considerable effort, and are easily separable from the rest of the system. They provide the processing required to plot curves or to fill in the area enclosed or excluded by a curve. While these functions have only been used in the ways required by the IVAM task, these modules are of general utility in graphics programming, and could support a number of additional uses.

3.3.5. Processes

The operation of the IVAM System in a production situation is divided into a number of independent processes, each of which produces results which are passed on to the subsequent process. These processes are:

1. Clock Schedule
2. Weather Determination and Segment Selection
3. AFOS Request/Reply
4. Data Formatting and Storage

VIDEO CHAIN

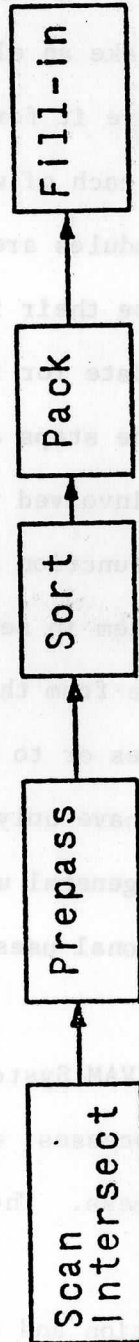


FIGURE 3-2.

5. Element Generation
6. Image Assembly
7. Display Control

These processes operate independently of each other in the sense that each can process the functions in its queue without regard to the execution of any other process. They do depend on each other in the sense that the commands for a higher number process may be queued by a lower number process or may depend on functions performed by the lower number process. However, the reverse is never true. Lower number processes do not depend in any way on the results of higher number processes. Each process is always trying to service the commands entered in its queue. If the queue is empty, then the process, of course, is asleep. Each process consists of a sequence of commands which can effect the execution of modules and the creation of modes in the Directory. Thus, these functions have results on both the control level, as reflected in the Directory and on the data level where disk files and images are created. There will be further discussion of the means by which the IVAM processes have been implemented after the Directory and Controller have been described.

The Clock Schedule invokes those IVAM actions which are dependent upon the time of day. These actions include the initiation of the routine IVAM presentation cycle through which the system cycles every hour or half-hour to generate the appropriate segments. In addition, the clock schedule would reflect a knowledge of the arrival times of AFOS products which are scheduled for particular generation times at NMC and particular transmission times on the NDC. It would also indicate the time of day to the process which selects the segments to be included in a particular presentation. The list of product arrivals would be passed to

the AFOS Request/Reply queue which would assure that these products would be requested from AFOS. Similarly, if there are any segments which are arbitrarily scheduled to be shown at a particular time, or even at every time these are queued for process 2, the actual time of time determination would be handled by an existing RSX 11/M scheduling function. Most of the actual function of the time of day process would actually be accomplished by internal prompt chains within the Controller, as there is very little processing to be done.

The second process, the Weather Determination and Segment Selection Process, decides what segments are appropriate, based on the current weather and the time of day. To solve this problem in the general sense is to faithfully model the behavior of the human weathercaster, a problem in artificial intelligence. As the solution to this problem was not provided in a meteorological sense, the IVAM software does not automatically select segments based on current weather. However, the control structures exist to support this process. It is assumed that the process would investigate a small number of weather products, and based on these, identify the current weather situation as best fitting into one of a not-too-large number of possible weather situations. Associated with each of these situations would be a list of segments to be shown. This process can be trivialized by assuming that IVAM receives a situation identifier as input. It also can be short circuited in the case where the time of day schedule dictates that a particular segment be shown regardless of the weather. In either case, this process arrives at a list of segments that are to be generated. Associated with each segment in that list are four sequences of commands: one to get the data, one to generate the elements, one to assemble the elements, and the last to display the images that result.

Each of these sets of commands are performed by a different process. Each is associated with the segment name through the Directory. Thus, the sequence of segment identifiers is sufficient to specify the processing required of the remaining processes. Since each process makes different use of the list of segments, each gets its own copy of the list.

The AFOS Request/Reply Process accepts a list of segments and a list of scheduled product arrivals as inputs. The list of segments is associated with a list of additional required products through the Directory. The list of required and scheduled products is then passed, one at a time, to the module that accomplishes the communication with AFOS. This convention assures that all AFOS communication is localized in the system and that communication with AFOS is decoupled from the rest of the IVAM processing, both so the AFOS communication channel is kept busy, and so it is not kept busier than is desirable for AFOS. When IVAM requests a data set from AFOS, that data set is stored immediately in the form received in an IVAM data set. Typically this data set is stored immediately on disk. Then the data product involved is deleted from the AFOS Process input queue, and added to that of the Reformatting Process. At this point the AFOS Process is free to request the next input data set. It is oblivious to all subsequent processing of the data sets it inputs. Its sole responsibility is the communication with AFOS.

The Data Reformatting and Storage Process accepts a list of input data sets which have been received from AFOS. In some cases IVAM may be able to use the data directly from its AFOS format, although it is more likely that it will have to be converted to a form that is more suitable for IVAM processing.

AFOS formats are designed to minimize the time required to transmit them, whereas IVAM formats are designed to facilitate processing. Translation from a particular AFOS format and a particular IVAM format will be done by a module which is specific to that translation. In addition to the translation of the data, the Directory will be updated to reflect the presence of the new data. Subsequent processing of the data awaits this change in the Directory.

The Element Generation Process associates with each segment specified a list of the elements required to produce it. For each of these elements there is a prompt chain in the Directory which directs all of the processing required to generate the element and to store it in the element pool on the disk.

Typically the prompt chain will invoke modules to:

1. Select the set of data to be processed
2. Generate the element in an arbitrary coordinate space
3. Manipulate the element within that space
4. Convert the element into a raster space
5. Process the raster element into a form suitable for line-widening or fill-in
6. Store the video ready element in the element pool on the disk
7. Record the fact that the element is ready in the Directory

Since the element is recorded as a particular node in the Directory, it is possible for that same element to be used in several frames without being regenerated. The modules required by this process have been implemented under TABSYS. While the driving software in TABSYS is not the same as that in the Controller, the modules do not depend on the context within which they are executed.

The Image Assembly Process inputs a segment list which is translated into an ordered list of elements for each image whether they are to be filled in or line-widened, and the pixel level that is to be used. The details of this process are dependent upon the design of the production image assembler. One version

of this process ran under TABSYS where previously prepared image elements could be assembled automatically into finished elements. The modules required to perform this function exist in software and, in one case, in hardware. The only exceptions are the modules which will look at the generated images to determine where alphanumerics should be placed. These algorithms are specific to the hardware that will be used and can only be simulated in software at great cost. Thus, some of the software that actually communicates with the assembly hardware will have to be altered, whatever the ultimate division of hardware and software tasks. In any case, the Assembly Process will proceed until all of the images required of all of the segments listed have been assembled. It will pause only if it gets ahead of the Element Generation Process; i.e., if there are no images for which all of the elements are ready.

The Display Process consists of a sequence of commands that are used by the display hardware to control the actual presentation. These commands cause the loading of digital images from disk to bit map refresh buffers, the generation and placement of alphanumerics, and the loading of color assignments in the enhancement tables. Since these commands are to be executed by a microprocessor or in the output Assembler, their details are almost completely a function of that device.

3.3.6. Assembler Influence on Software

The IVAM software effort was tied more closely to the hardware effort than originally expected for two reasons: First, hardware planning required considerable software input and hardware decisions, once made, had considerable impact on software design. Second, hardware implementation required significant software support during the test and debugging stage.

The Output Assembler design considered a range of hardware and software options, which are discussed here only so far as they affect software design

and implementation. One of the major issues was whether to store finished frames or assemble the images in real-time from image elements. Once the decision was made to store finished frames on a disk, the operation of the IVAM system was divided into two disjoint modes. The image preparation and the presentation periods would not overlap because the assembler resources would be totally committed during the display period. This means that either there is no image element preparation during the presentation period, or that image elements once generated must be stored on the disk until the assembler is free to assemble them into completed frames. This means that during the assembly process a large percentage of the data flow is from disk to the assembler, rather than from a processor to the assembler. Several other factors also decrease the importance of this flow. First, the Assembler will provide hardware and firmware to assist in the fill-in process, which means that the path from disk to Assembler can be direct. Second, the IVAM storyboards include a significant percentage of "story frames" where part of the content is stored, rather than generated. Again, these elements can be stored in a form that is ready for assembly without further processing. This flow of data from disk to the assembler during the assembly process suggested that the 11/40 should be interfaced to the Assembler, as well as one of the subordinate processors.

Even more important than the decision to store frames was the realization that the output process virtually dictated the use of several bit-map refresh memories, both for refresh while the disk heads were moving, and for dissolving or wiping from one frame to another. The existence of several such powerful resources in the system suggested that they be applied to software needs as well as the refresh problem. In evaluating the effect of these memories on the software, several opportunities were recognized. First, the merge process could be eliminated. (The merge process is the one which takes a number of

image elements defined in terms of a scan ordered list of the intersect points which define them and combines them into a single ordered list which is the complete skeleton for the final filled-in image.) The Merge Process was considered troublesome for a number of reasons. First, it was the only process that appeared likely to overflow the resources of a single processor. While the overflow is easy to deal with in conceptual terms, there is a significant price in system overhead, and the development price paid is the same whether it happens routinely or infrequently. An additional factor arguing for the elimination of the merge process was the fact that the disk on the Digital Terminal failed catastrophically and was to be out of commission for five months while it was refurbished. Therefore, given the fact that a bit map based assembly system does not require a merge process, and that the disk required would not be available during much of the IVAM development, the decision was made not to develop the Merge Process and to emphasize bit map based methods instead.

The bit map based design presents a number of powerful options. By designing the software to continually overwrite elements into the bit map, the elements can be written into the memory in order of ascending priority. Therefore, the higher priority elements occlude the lower priority ones by the simple expedient of overwriting them.

Another significant feature is that the software need not be as concerned with the constraints of the raster. It is possible to plot lines directly into the bit map according to their coordinates. On a disk based system the same act of plotting a curve would require two disk accesses per point, one to read what was currently on the line, and another to rewrite the line with the new point inserted. Therefore, on disk based systems one must sort points into scan order

and merge them with other elements in order to avoid excessive disk transfers.

IVAM must fill in domains after they are outlined. Since the fill-in process requires tracing the curve along scan lines to assure that every point is filled in, it would appear that scan ordering or a similar process would still be required. However, the bit map memory suggests that a curve can be written into the bit map in the connected order in which it was defined, and then read back in scan order by scanning the memory. If the curve were written out according to the proper discipline, it is possible for an external, very simple processor to scan it and fill in the domain it defines. Multiple curves which do not cross each other, such as contours, can be filled in simultaneously by this method if two bit maps are available -- one for the curves, and one for the filled in image.

Another problem simplified by the bit map is alphanumeric placement. While the computer generates all of the elements of an image, it knows very little about the image. It is difficult for the computer to determine from the one dimensional arrays how the curves interact in two dimensions and where they leave room for the aesthetic placement of alphanumerics in the vicinity of the feature they label. However, by allowing the computer to read back the two dimensional image the problem becomes more tractable and, in fact, can be partly implemented in firmware.

A final feature of the assembler design which has software implications is the ability to store separate elements in the different bit planes of a single frame. Thus, Bit One could be one element and Bit Two another. This would be useful for animation where often only a single element is moving. Five steps in the animation could be stored in a single frame, while the static information would be stored in a separate bit map. This technique is also useful for storing alphanumeric fonts. A number of different fonts and sizes of characters will be stored in a single frame and then written into the bit maps under firmware and software control.

3.3.7. McIDAS Dependence

Another feature of the IVAM development was the project's relationship to the McIDAS system, the Center's interactive research tool. While this system does not provide a suitable environment for either the development or the implementation of the IVAM system, it does possess a number of resources that were necessary for the IVAM effort. The most important dependence that IVAM had on McIDAS was based on the fact that IVAM had no color display device dedicated to its use. Therefore, it was necessary for IVAM to get access to one of the McIDAS terminals. The McIDAS terminal which IVAM used was the digital terminal, which has both a digital refresh disk for satellite pictures and a two-bit image refresh memory for graphics. IVAM's initial access to this terminal was through McIDAS, itself. An RS232 interface was made between the two systems which was used by IVAM to send display packets to McIDAS, which then relayed them to the digital terminal. Later, in June 1977, a direct connection was made between IVAM and the digital terminal. While the graphic images then could be generated by IVAM, the satellite images were still sent from McIDAS. In addition to display hardware and satellite images, McIDAS was IVAM's sole source of meteorological data. However, most of the McIDAS data is in different formats than those that the AFOS data ultimately took. Therefore, it was important not to let the IVAM software become specific to McIDAS. IVAM also made use of McIDAS peripherals, such as the high speed line printer and the tape drive, both of which the IVAM system lacked.

While McIDAS would seem to address a similar set of issues as the IVAM system, any resemblance is only superficial. Therefore, virtually none of the McIDAS code was used in the IVAM system. In fact, IVAM concepts influenced McIDAS development more than the other way around. McIDAS originally had only

a limited number of highly specific programs for producing specific products. Since then, the contouring functions have been generalized as originally suggested by IVAM. However, most of these new products are of interest to meteorologists, not laymen. There is no general graphic capability in the software. IVAM's task was to provide a flexible tool for formatting meteorologic information, and then to consider the problem of automating the generation of the most effective formats.

3.3.8. RSX 11/M

The IVAM system was significantly affected by the decision to purchase DEC's RSX 11/M operating system. This decision was necessitated by the delay in funding and a series of delivery delays with the 11/40.

RSX 11 is a powerful multitasking executive with a variety of file structures and software development tools. The IVAM system uses RSX 11/M for all of its file handling, for some of its device handling, and some of its process staging and intertask communication. However, because of the 32K address limit for a single task on the PDP 11, a significant aspect of RSX 11/M and, therefore, the IVAM task is the need to overcome this space limitation and to create tasks which are significantly larger than 32K. Therefore, most of the capability of RSX 11/M is actually designed to compensate for a weakness in the system. More recent versions of the operating system have provided a richer and more flexible set of such compensatory facilities. The general problem the operating system presents is that it takes charge of all resources in the system and provides mechanisms for user programs to request their use. However, the relationship is very much that of a subordinate asking permission to accomplish desired functions. There is not conception of the user task controlling the system and simply delegating certain utility functions to the operating system.

This presents a problem in that it is the IVAM software which must be in charge because only the IVAM system has any knowledge of the physical resources of the crosspoint system. Also, IVAM seeks to pass data from one process to another without writing it out to a disk file. Unlike many operating systems, RSX 11/M does provide mechanisms for accomplishing this, but only at the expense of permanently partitioning the memory. Similarly, while the system claims to handle real-time events, it is really not suitable for controlling time critical processes. It is very easy to attempt what seem not to be particularly taxing operations, only to find that they cannot be made to work reliably because of the overhead involved in initiating and servicing I/O requests. Overall, RSX 11/M provides some very good features for program development, but does not accede gracefully to the needs of a dedicated system with time constraints.

3.4 Development

3.4.1 TABSYS

TABSYS is the name given to the data tablet based system which was used during the IVAM development as a test bed within which to program the IVAM modules and to test visual formats and techniques.

The Data Tablet is a device which senses the position of a special electrically connected pen on a 22" square tablet. The tablet has a grid of equally spaced wires in both the horizontal and vertical direction. These wires are selectively activated as transmitters of a signal which is picked up by an antenna in the pen. By checking the timing and amplitude of the signals picked up by the pen it is possible for the circuitry to infer the X, Y position of the pen on the tablet to an accuracy of within 1/100 inch. The pen's position is sampled at any rate up to 100 samples per second. In addition to providing

a means of generating test curves for the IVAM software, the tablet was used for pointing within the two dimensional screen space and for selecting and sequencing IVAM modules. These functions were possible because only part of the tablet was used for drawing curves. Much of it was divided into control blocks which when touched, caused a specific function to be executed. While some of these functions required a variety of input parameters, the user did not have to remember them since the system would ask him for each parameter as it was needed. Many of the module parameters did not have to be stated explicitly because they were implied by the operation or embedded into the control structure of the tablet system. In fact, some of the control blocks invoked a lengthy series of modules with a single command. Only those parameters likely to be varied by the user are requested by him.

While IVAM will operate as an automated system, it must also have an interactive capability during development, field installation, and even, to a lesser extent, during production. During development there is a need to interact with the IVAM modules. First, the logic associated with the video chain modules is quite complex, and the number of possible pathological cases very large. While many cases could be analyzed formally, others were only likely to be discovered after extensive experience. Also, when a new error condition is discovered, it often takes a number of examples before the unique features of the new case can be isolated. Therefore, the tablet provided an extremely flexible way of generating and debugging graphic software. Second, the tablet provided a powerful tool for exploring the visual characteristics of NTSC video. As has been reported earlier, NTSC color is quite different from the RGB (Red, Green, Blue) color that the computer necessarily thinks in terms of. NTSC encoding provides bandwidth constraints that make it impossible to make clean transitions from one color to another. The bandwidth constraints also make it impossible to draw a

narrow vertical line of any given color because the signal cannot respond in the time it takes the video scan to traverse the line. Before it can make the transition to the new color, it is asked to return to the background. While earlier color studies had identified a number of rules, additional color issues surfaced in practice. Using the tablet, it was easy to tune the colors suggested by the studies so they would fit the particular kind of use for which the color was being employed in a given image. The rules for domains, lines, and crosshatching turned out to be quite different. Third, the tablet was used to explore the composition of video frames. By making it possible to repeatedly regenerate an image with slight variations, it is possible to refine the understanding of what makes an effective presentation. Alphanumeric placement, line width, crosshatch parameters, contour intervals, and colors can all be varied with ease. Of course, this process need not be repeated with every image, but it is important when developing a new segment.

During field implementation a certain amount of interaction with the system is required to tailor it to the particular location. The character of a particular segment may change, based on the local geography. The rules for alphanumeric placement might have to be adjusted to fit the particular locale. The definition of "local" and "regional" will definitely vary from one locale to another. Also, the identification of cities of interest will have to be made, and the question answered as to whether any specialized segments have to be designed specifically for a particular IVAM site.

During Production, any IVAM site would have only a limited interactive ability. At the minimum, the system must allow the forecaster to take control in severe weather situations. However, in the case of products such as a pollution alert, where all the information is generated locally, it may be desirable for the forecaster to preview the image before it is broadcast. This requires an interactive

capability. Even if standard operation requires no interaction, there is no such thing as a static system. Every major system is subject to continual refinement and software maintenance. Therefore, it is useful to provide a means of interacting with the system, so this update process is easier.

The tablet system was designed to ease the development task. Therefore, it included debugging aids, as well as a number of features that were peculiar to the development circumstances. For instance, since IVAM had no color display device committed to it, it originally used the limited graphic capability of the ADDS Terminal which provides a monochrome raster of 72 lines by 160 elements. During development IVAM was to use the center digital terminal which became operational in February of last year. Since the medium speed interface which was to connect IVAM to the Digital Terminal was not completed until June 1977, it was necessary to make a more circuitous connection with this display. An RS232 interface was effected between IVAM and McIDAS. Then IVAM packets were sent to McIDAS, which then relayed them to the Digital Terminal. The status packets from the terminal were then returned to McIDAS which sent them to IVAM. At 1200 baud this interface was very slow, but it did allow the test and development of color graphic software earlier than would have been possible otherwise. When the medium speed interface was installed it became possible to send packets directly to the display terminal which was at least one hundred times faster than the earlier method. More recently a hardware fill-in box was added which changed the display path yet again. During the development and debugging of each of these steps it was important to have the older means available, both as backup and as a reference in case problems arose. Furthermore, since the digital terminal was also used for other projects it was often helpful to be able to revert to the ADDS when the Digital Terminal was in use. These options were preserved by having the system ask the user which display device he was using before it output. Thus it was very

easy to switch from one display method to another. This capability was extremely easy and frequently used.

From a user point of view, Tabsys provided a number of possible functions which had intuitive meaning to the user. Once he had selected one of these, the system would ask him for any additional information it required to effect the operation. In some cases no additional information was required, and the execution proceeded immediately. The additional information would include the selection of a display device, an input or output array, or specific parameters such as latitude or longitude windows. The functions, the prompts they make to the users, and the modules used to implement them will be described below.

DRAW

Touching the large control block in the lower left corner of the tablet signals the computer that the user wishes to draw a curve with the pen. The system will then ask him which array he wants the data to be stored in, and which device the output should appear on. While this function is typically used for drawing a shape which will either be line-widened or filled in, its output could be used for other purposes. For instance it could be used to define an intensity versus time relationship for a pulsing effect which would highlight a particular symbol. It could also be used to define the path that a moving object would follow in an animation sequence. The size, speed, and intensity of the object as it moved along that path could be similarly handled. The end of the drawing process is signalled by touching the control block a second time. If the user attempts to enter too many points, the drawing function exits and displays an error message on the ADDS. Then it returns to the control level, and displays the message, "AWAITING COMMAND."

ERASE

The Erase block is used to erase either the ADDS or the RAM Refresh on the Digital Terminal. It asks which device is desired, and then effects the operation.

EXIT

The Exit block causes TABSYS to exit unconditionally. All system wrap-up is accomplished. In particular, IVAM returns control of the Digital Terminal to McIDAS.

PLOT

The Plot block causes the system to plot the curve contained in the indicated input array on the indicated device. The result is a continuous single pixel wide curve on the display. Thus each pixel is immediately adjacent to the preceding and following points on the curve. This function requests the display device, the input array, and the output array. The output array is used as a work space. It invokes the execution of the SCAN and CONVERT Module, followed by the transmission and display routines.

CLOSE

The Close function chooses a curve so that it can be filled in. It asks only which array the points are in. The closing is done by copying the first point in the array immediately after the last point, so the first and last point are identical. This is necessary to assure that the scan conversion process interpolates all of the points between the first and last point. Since this is not always desired it is necessary to indicate this function explicitly.

FILL

The Fill function performs a complex function, and contains many alternative execution paths. Its function is to take a curve and fill in either the area enclosed by the curve or the whole screen except for the area enclosed by the curve. It can do either a solid or a crosshatch fill-in. It asks for the input

easy to switch from one display method to another. This capability was extremely easy and frequently used.

From a user point of view, Tabsys provided a number of possible functions which had intuitive meaning to the user. Once he had selected one of these, the system would ask him for any additional information it required to effect the operation. In some cases no additional information was required, and the execution proceeded immediately. The additional information would include the selection of a display device, an input or output array, or specific parameters such as latitude or longitude windows. The functions, the prompts they make to the users, and the modules used to implement them will be described below.

DRAW

Touching the large control block in the lower left corner of the tablet signals the computer that the user wishes to draw a curve with the pen. The system will then ask him which array he wants the data to be stored in, and which device the output should appear on. While this function is typically used for drawing a shape which will either be line-widened or filled in, its output could be used for other purposes. For instance it could be used to define an intensity versus time relationship for a pulsing effect which would highlight a particular symbol. It could also be used to define the path that a moving object would follow in an animation sequence. The size, speed, and intensity of the object as it moved along that path could be similarly handled. The end of the drawing process is signalled by touching the control block a second time. If the user attempts to enter too many points, the drawing function exits and displays an error message on the ADDS. Then it returns to the control level, and displays the message, "AWAITING COMMAND."

ERASE

The Erase block is used to erase either the ADDS or the RAM Refresh on the Digital Terminal. It asks which device is desired, and then effects the operation.

EXIT

The Exit block causes TABSYS to exit unconditionally. All system wrap-up is accomplished. In particular, IVAM returns control of the Digital Terminal to McIDAS.

PLOT

The Plot block causes the system to plot the curve contained in the indicated input array on the indicated device. The result is a continuous single pixel wide curve on the display. Thus each pixel is immediately adjacent to the preceding and following points on the curve. This function requests the display device, the input array, and the output array. The output array is used as a work space. It invokes the execution of the SCAN and CONVERT Module, followed by the transmission and display routines.

CLOSE

The Close function chooses a curve so that it can be filled in. It asks only which array the points are in. The closing is done by copying the first point in the array immediately after the last point, so the first and last point are identical. This is necessary to assure that the scan conversion process interpolates all of the points between the first and last point. Since this is not always desired it is necessary to indicate this function explicitly.

FILL

The Fill function performs a complex function, and contains many alternative execution paths. Its function is to take a curve and fill in either the area enclosed by the curve or the whole screen except for the area enclosed by the curve. It can do either a solid or a crosshatch fill-in. It asks for the input

array, the output array, the output device, whether it is to be an inside or outside fill-in, and whether crosshatching is desired. If the crosshatch feature is requested additional information is required to control its operation. Crosshatch requests the delta-X and the delta-Y for the slope of the crosshatch line, as well as the offset which is analogous to the Y-intercept of the base line. The width of the crosshatch line and the width of the gap separating them is also requested. Most of these parameters may be multidigit integers. These are specified, using a part of the drawing area which has a special function when integer inputs are desired. This area consists of an array of twelve control blocks as shown below:

5	-
4	9
3	8
2	7
1	6
0	CR

When integer parameters are requested, the user touches the digit control blocks, starting with the high order digit. The end of a multidigit integer is indicated by touching the CR (Carriage Return) block. A number is made negative by touching the negation block after the rest of the digits and before the CR.

The modules used by FILL are SCAN, CONVERT, PREPASS, LINK, SORT, PACK, and FILL, as well as the display and transmission routines.

LINE WIDENING

The Line Widening function is similar to PLOT except that the width of the line can be controlled. This is done by drawing a rectangle about each point

along the plotted line. The length and width of that rectangle is requested of the user. The input and output arrays are also requested, as well as the device on which the curve is to be displayed. The system then proceeds to fill in the rectangle about each point on the line. The effect is that the line is widened and its appearance is more pleasing because it is more stable. As in PLOT, only the Scan Conversion Module on the display and transmission routines is used.

SMOOTH

The Smooth block causes the points in the indicated array to be smooth by the indicated smoothing window. The window is the number of neighboring points on the input curve that are used in the weighted average that is computed for each point. Input and output arrays are requested, as well as the smoothing window.

MOVE

The Move function allows the user to place objects on the screen. The operation assumes that the user has previously performed the following actions: First, he has moved the cursor to the current center of the object. Second, he has touched the MARK control block so TABSYS would store the cursor position. Third, he moved the cursor to the new position. Then, when he hit the MOVE control block, the points in the input array are translated by the X and Y differences between the two cursor positions. Notice that movement is completely relative and so the two cursor positions could specify only the direction and magnitude of the movement without requiring any knowledge of past and future position. This function requests only input and output arrays and uses the MOVE module.

SCALE

The Scale function allows the user to scale a curve by an arbitrary scale factor. While what scaling means seems intuitively obvious, the function actually

involves some subtle issues in computer terms. If the coordinates defining the object are scaled, then the object is moved as well as shrunk. However, if an object is scaled with respect to its own center of mass, its scaling will appear proper only if it is defined in isolation from other objects. For instance, if a group of objects are each scaled about their respective centers, their relative positions are changed by the scaling. For a group of objects to be scaled together, they have to be considered with respect to a common center. In fact one method is not right and the other wrong; there are cases where each is appropriate. Tabsys allows the user to choose either of the methods. When a symbol is to remain fixed on the screen as it is scaled, the center is computed from the points themselves. However, if the curve is part of a larger scene, the center of the scaling must be provided externally. This ability to scale about an arbitrary point is also true with alphanumerics, as will be discussed later. The user is asked to specify input and output arrays, the numerator and denominator of the scaling factor, and whether or not scaling is to be done about a specific point. The Scale module is used by this function.

ROTATE

The Rotate module rotates the points in an array about an arbitrarily defined center. The function assumes that the user has moved the cursor to the point about which he wants the object rotated. He is asked for the input and output arrays and the angle of rotation in degrees. The rotated points are left in the output array, not displayed. The Rotate module is the only one used for this function.

PLOT MAP

The Plot Map function is similar to PLOT except that it is prepared to handle maps defined in standard plot format where the sign bit is one as long as the pen

is down, and zero only when the pen is lifted and a discontinuity occurs. This function allows the user to indicate a particular storage file and then a particular latitude-longitude window which will map on to the corners of the screen. If the area in the map file is greater than that included in the window, the points outside the window are clipped properly and not shown. Notice that this function does not, itself, do any transformation of the maps because there is not sufficient space within TABSYS to run the mapping transformation. In fact, there is not sufficient space for the entire U.S. grid to be read in and plotted in a single operation. The U.S. grid is currently broken down into three separate files which are read in separately. If a transformed map is desired, it is assumed that the points in the mapfiles have been transformed external to TABSYS. Points can be plotted in arbitrary rectangular coordinates, stereographic projection, or satellite projection. The only difference is that the corners of the plot window must be entered with their transformed values.

This function also allows the user to control the width of the lines used to plot the maps.

COLOR

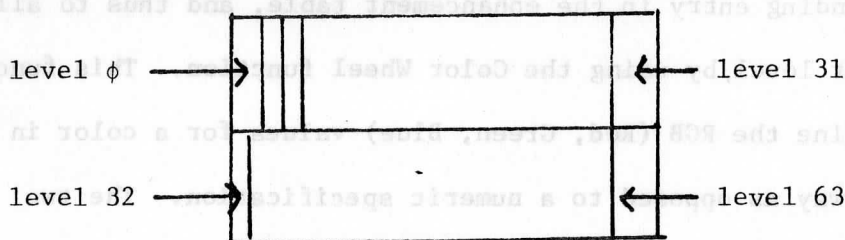
The color functions under TABSYS are very useful, but some explanation of the digital terminal is necessary to understand them. The digital terminal has two independent display devices whose images are shown on a single screen. One of these is a digital disk where satellite images were stored, and the other is the three-bit deep bit map memory. Each of these display sources has its own enhancement table. Therefore, while most IVAM graphics were shown from the bit map memory, it was still necessary for IVAM software to be able to deal with both kinds of display. With the color selection functions, it was necessary to identify first which device color table was to be changed, and then to identify

which entry was to be changed, then finally to select the color value which is to be stored in that entry. The functions that follow perform these operations:

Select Current Index

This function does not effect any color change; it merely identifies which device and which entry within that device's color table is to be changed. The actual assignment of color is accomplished by a later operation. This function asks the user to indicate which channel is desired. Channels A and B are disk channels and C is the bit map memory graphics. The bit map is selected by touching CHANNEL SELECT WRRRM, where WRRRM is the SSEC term for bit map. After the channel has been selected, the user is asked for the index which is to be selected within the device's color table. He can select the index level he is interested in without knowing its numeric value. As the pen is moved around the drawing area its position corresponds to the various enhancement indices. The actual relationship is that the drawing area is divided horizontally into two rectangles. The horizontal positions in the upper rectangle correspond to levels 0-31, and the horizontal positions in the lower rectangle correspond to the levels 32-63.

DRAWING AREA



The two disk channels do in fact allow all 64 levels to be defined; however, the enhancement table associated with the bit map has only seven valid

levels currently (Level 0 is excluded because it is always used to select the disk image; i.e., wherever the bit map contains level 0, the disk image is visible; elsewhere, the bit map graphics cover the disk image). The user receives feedback about the current location of the pen because the corresponding entry in the enhancement table is repeatedly zeroed and then restored to its original value. The visual effect is that all of the points on the screen which are currently assigned that value appear to blink. Thus, to select the enhancement level associated with a particular point on the screen, the user simply moves the pen around until that point blinks. He then fixes the blinking level and exits by touching the same control block again.

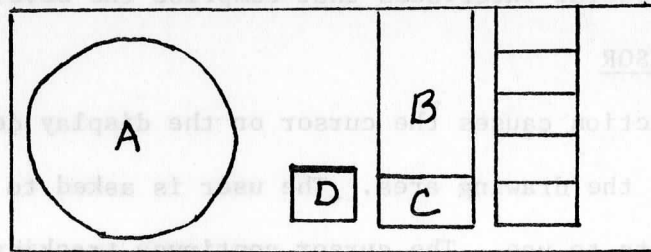
Select WRRRM Level

Since most of the IVAM work is done with the bit map graphics, it is convenient to have a less general, but quicker, way to specify enhancement levels on that device. The Select WRRRM level control block does that by allowing the user to indicate the integer value of the enhancement index required.

Color Wheel

Once an enhancement level has been selected, the user can assign color values to the corresponding entry in the enhancement table, and thus to all points on the screen with that level, by using the Color Wheel function. This function allows the user to define the RGB (Red, Green, Blue) values for a color in an intuitive interactive way as opposed to a numeric specification. The two dimensions of the tablet drawing area do not directly map into the hue, intensity, saturation coordinates of color. Therefore, it was necessary to divide these functions on the tablet. The solution chosen was to allow the user to choose a hue and saturation in one step and then to vary the intensity with another. The hue and saturation are chosen using a traditional color which is defined on the tablet surface. As the pen is moved about this circle, its angle relative

to the center of the circle determines the hue, and the distance from the center controls the saturation. All colors in the center are white, and all those on the circumference are fully saturated. Once a hue and saturation have been chosen, the intensity can be varied by moving the pen in the area marked B in the next figure. The bottom of this rectangle indicates full brightness of the hue intensity selection, whereas the points at the top indicate that the intensity is zero. The intensity variation is accomplished by scaling the RGB values of the color by the factor indicated by position of the pen in rectangle B. Fine tuning of the RGB values can be done by touching any of the six squares arrayed vertically to the right of the intensity control rectangle. These squares allow the user to increment or decrement the red, green, or blue values of a color individually. The original color that was assigned before the COLOR WHEEL function was initiated can be restored by touching square D. During this process the color of the screen points at the



selected level varies with the movements of the pen. This function allows the user to very quickly consider a wide range of color options. When the user is satisfied with the color he has chosen, he touches the COLOR WHEEL block a second time to exit the function. This fixes the assignment of the selected color which had been temporary until this point. The exit procedure displays the RGB values of the color selection on the Adds screen.

INIT WRRRM

This function sets each of the seven levels of the bit map color enhancement table to a standard color. The result is one standard IVAM color set which is NTSC compatible.

ENTER ENHANCEMENTS

This function allows a user to enter the integers associated with the known RGB values of a given color. The user is asked for the channel and then the level. Then he is asked for the red, green, and blue values separately. The range of these values is 0-31. This function is used for setting up the colors required for a particular segment.

DISPLAY CURRENT INDEX

At any point the user may want to know what the currently selected enhancement level is. This function causes the index to be printed on the ADDS.

There are also a number of functions which allow TABSYS to control the devices and special interfaces that comprise the Development System.

MOVE CURSOR

This function causes the cursor on the display device to track the movements of the pen in the drawing area. The user is asked to indicate which display device he wants to use. The cursor continues tracking until the user touches the MOVE CURSOR block again, which releases the pen and leaves the cursor displayed at its current position.

MARK

This function causes the current position of the cursor to be stored in the MARK variable within TABSYS. Its application was described with the MOVE command.

ADVANCE FRAME

This command allows the user to step the image disk that is part of the Digital Terminal from frame to frame. This operation allows only advancing the frame number by one. It is self-exiting.

BACK FRAME

This operation is the complement of ADVANCE FRAME. It allows the user to decrement the current frame number by one.

WRRRM ON/OFF

This function either enables or disables the output of the bit map graphic display, depending on its previous state.

CURSOR ON/OFF

This function either enables or disables the output of the cursor generator, depending on its prior state. This operation is important during taping where the presence of the cursor would be intrusive.

DISK ON/OFF

This operation either enables or disables the display output of the digital disk, depending on its prior state.

SELECT HARDWARE FILL-IN

This function selects either the hardware or software fill-in. It asks the user to enter a one if he wants the hardware fill-in. Any other response selects the software fill-in. The difference between the two processes is the routine which effects the final interval fill-in in the fill-in module. The fill-in module computes endpoints of an interval which is to be filled in along a particular scan line. With the hardware fill-in the X values of these endpoints, the line number, and the pixel value to be filled in are placed in a transmission

packet and sent to the terminal immediately. In software fill-in mode, these same parameters are sent to another routine which computes the points in the interval and formats all of these points in a transmission packet.

SLOW SPEED

This command causes the communication with the Digital Terminal to be sent through McIDAS. It first switches the Medium Speed Interface off, so McIDAS can communicate with the terminal. Then all communication with the terminal is done by sending packets to McIDAS through an RS232 line. McIDAS then sends the packets to the terminal through its medium speed line. The return packets are then received by McIDAS and relayed back to IVAM.

MEDIUM SPEED

This control block breaks the connection between McIDAS and the digital terminal. It then connects IVAM to that terminal through its medium speed interface. The logic of the system operation is not changed at all from the user's point of view. However, the speed of communication with the Digital Terminal is increased by a factor of 500.

SET WRMLT BUFFER SIZE

This is strictly a hardware and software debugging utility which allows the size of the transmission packets to be controlled interactively when there are system problems.

DRAW STAR

This is also a test function. It repeatedly draws a test pattern on the digital terminal, using the hardware fill-in. It quickly demonstrates whether or not the hardware is working. If it is not, the repeated pattern provides a source of test signals for engineers working on its repair.

VTR ON

This function can turn on a solenoid-operated video tape recorder if one is connected to the system.

DELAY

This function causes TABSYS to delay the indicated number of seconds. Its use is almost exclusively through command files. It is used to provide fixed length delays during automatic taping.

VTR OFF

This causes the video tape recorder to stop recording.

READ FILE

This operation allows the user to read in any one of 1000 previously defined data files. The user is asked to indicate the file number, the space of the input points, and the array in which they should be stored. Points can be in tablet space, one of the display spaces, or an arbitrary space.

WRITE FILE

This function takes the contents of one of the TABSYS arrays and writes it out into one of the 1000 IVAM disk data files. The user is asked to indicate which array is to be stored and what file number is to be used. The contents of any previous file with the same name is then inaccessible to TABSYS. However, the previous version of the file still exists, and can be retrieved through RSX 11/M utilities.

PRINT

It is also possible to print out the contents of an array during module testing. At any point the user can request that TABSYS print out the contents of one of its arrays on the LA 36. The printing is done in octal.

COPY

It is also possible to copy the contents of one array into another, using the copy block. The system asks for the input and output arrays, and then effects transfer.

INTERPRET COMMAND FILE

This function allows a powerful expansion of the tablet system. It gives the user the capability of defining command chains with parameters which are stored on disk and then invoked as a single command. The values read into TABSYS look exactly like data tablet points; however, they are defined in terms of powerful macros which are then assembled by the DEC macro assembler. For example, the U.S. grid is too large to be read in and plotted as a single file. Therefore, it was convenient to define a command file which would read in and plot the three files of the grid with a single command. The user simply touches the command file block. The system then asks him which file he wants interpreted, and proceeds with the sequence of executions.

EXIT COMMAND MODE

This block is never invoked by the user interactively. It is simply the last step in any command file. It tells TABSYS to exit the command file processor and return its attention to the tablet.

MACROS

The command file macros allow the user to define complex chains of IVAM tablet commands and to store them in disk files which are read in and executed by the Command File Processor in TABSYS. A number of low level macros are already defined which allow the user to simulate the action of the pen on the tablet through written commands. A macro has been defined for each of the control blocks defined on the tablet. Some of these are expanded directly into a pair of integers corresponding to a point within the block. Others which invoke functions rather than just defining values accept a number of parameters and are expanded into a series of tablet point pairs.

Simple macros include:

MINUS	-	minus sign
ZERO	-	integer zero
ONE	-	1
TWO	-	2

THREE	-	3
FOUR	-	4
FIVE	-	5
SIX	-	6
SEVEN	-	7
EIGHT	-	8
NINE	-	9
CR	-	Carriage Return
ADDS	-	indicates Adds
RT	-	indicates Remote Terminal
ARR1	-	indicates Array 1
ARR2	-	indicates Array 2
TAB	-	indicates tablet space = 1
MSPEED	-	selects medium speed interface
IWITWM	-	initializes the colorizer tables
DISK	-	generates command to turn Digital Terminal disk on and off
CURSOR	-	sets cursor on and off
WRRRM	-	Sets Bit map on or off
VRECD	-	Sets VTR in record mode
VSTOP	-	Stops VTR

The compound macros include:

DEV1 DEV

Specifies device. Accepts either "ADDS" or "RT" as an argument.

TRDIWT INTVAL, MIN, MAX

generates tablet points required to specify integer "INTVAL"

INTGEN IVAL

called by TRDINT. Generates tablet point associated with single digit integer "IVAL."

RDARR IARR

Generates a point corresponding to an array selection. Its one arrangement must be either "ARR1" or "ARR2"

MAP IN, OUT, SCAL, MNLA, MNLO, MXLA, MVLO, DEV, VER, HZ, DEL

Generates the points necessary to plot the map points held in the "in" array. It is given minimum and maximum latitudes and longitudes, as well as the device and line widening parameters.

RGB CHNL, LEVEL, RED, GREEN, BLUE

Generates the commands necessary to change a single entry in the Digital Terminal Enhancement table.

CURROT ARR, ANGLE, DEV, X, Y

Generates commands required by rotation function.

CHATCH DEV, ARR, ORIGIN, NUM, DEN, WIDTH, DIST, OFFSET

Generates commands required to do a crosshatch fill-in of domain. The input array, output device, and inside or outside fill-in are specified. The numerator and denominator of the slope of the crosshatch lines are stated, as well as their width and spacing.

MOVDRV ARR

Moves the points in "ARR".

MCURSOR DEV, MARKX, MARKY, FINALX, FINALY

Generates the cursor points for the MOVDRV function.

CTIDX CHNL, LEVEL, NIDXS

Selects colorizer index.

SCALE ARR, NUM, DEN, ORIGIN

Generates points for SCALE function, including numerator and denominator of scale factor and whether the scaling is done about the origin or about the center of the element.

TDELAY TIME

Delays for number of minutes and seconds specified by "TIME" = MMSS where M = minutes and s = seconds.

SWLEVL LEVEL

Sets the current bit map level.

LABEL TEXT, IX, IY, NUMER, DENOM, LEVEL, R, G, B, DEV

Places the alphanumeric specified by the string TEXT at the position (IX, IY) on the screen. The letters are scaled by NUMER/DENOM and displayed at the level and color indicated.

ALPHA CHAR, X, Y, NUMER, DENOM, LEVEL, DEV

Called by LABEL. Displays one character, CHAR.

ELEM CHAR, X, Y, NUMER, DENOM, LEVEL, DEV, NUM

Called by ALPHA. Determines name of file containing one of the curves defining CHAR and displays it.

PLOT CURVE, X, Y, NUMER, DENOM, LEVEL, DEV.

Called by ELEM. Reads in one of curves defining CHAR. Then MOVES, scales, and fills-in the curve.

The macros defined above can be used to generate complex images. All of the images in the final tape were generated using this method. In fact, these macros are sufficient to generate most of the segments described in the IVAM storyboard once their source data has been stored as IVAM elements. Even the football sequence from the first tape has been completely described in terms of these macros.

The Top Level Structure of TABSYS

The overall control structure of TABSYS is very simple. The main routine of TABSYS repeats the following cycle of activities until told to exit. The tablet is read until a point is read from a two inch square 'control block' of the tablet. Each control block selects a unique function. The routine corresponding to the chosen function is then called via a computed goto. When control is returned to the main routine a branch is taken back to the point of the tablet read and the cycle repeats.

Two data structures are used by almost all of the routines. Two arrays of x and y coordinates are dimensioned in the main routine as follows:

```
DIMENSION IX(MAXPTS,NARRS), IY(MAXPTS,NARRS)
```

Each column of the arrays is treated by TABSYS modules as a separate array of coordinates. Thus MAXPTS defines the size of each array and NARRS defines the number of arrays. The number or size of these arrays can be changed for the entire task by simply redefining the two variables MAXPTS and NARRS in the main routine (DX:[170,10]TABSYS.FTN). The points in a given array are generally in

the raster space of either the tablet, the ADDS, or the digital terminal. The space of the points in a given array is stored in a table known as the Device Space Table. This is realized via array SPACE declared in the main routine. The routine which converts from one raster space to another is the scan conversion routine (see DX:[170,10]SCAN2.FTN). The device space table permits TABSYS to automatically scan convert points from one device space to another when necessary.

Command Files

TABSYS command files permit a sequence of functions to be defined and automatically executed whenever desired. When placed in interpretive mode TABSYS reads a disk file rather than the data tablet. The disk file contains values which look like the coordinates of tablet points. Command files are generated external to TABSYS using the RSX-11M macro assembler. The command files are created via the following sequence: The user creates a file of macro calls. These macros have highly mnemonic names and are very simple to use. A single macro and its arguments generate values which look like the tablet values which would be used to interactively specify the desired function. This file is assembled and task built along with a fixed main routine. This routine is then executed to create the file used by TABSYS. RSX-11M indirect command files are used to make this process simple for the casual user. When TABSYS is placed in interpretive mode it asks the user for the name of the disk file containing the commands. A flag is then set which will direct subsequent tablet reads to this disk file. The final values in the file reset this flag so that the next tablet read is directed to the tablet again. Documentation on how to set up a TABSYS command file is contained in file DX:[170,40]CMDDOC.DAT. The macros used to generate the commands are stored in files DX:[170,40]CFMAC1, CFMAC2, CFMAC3, CFMAC4, CFMAC5, and CFMAC6. Printouts of these files are in the binder of TABSYS listings.

The Overlay Structure of TABSYS

TABSYS is rather heavily overlaid to stay within the 32K task size limit. (In fact task size is limited to 28K because of use of the device common partition. This constraint could be removed through use of the interrupt driven tablet driver. (See the IVAM devices document.) The overlay structure is pictured in Figure 3-3.

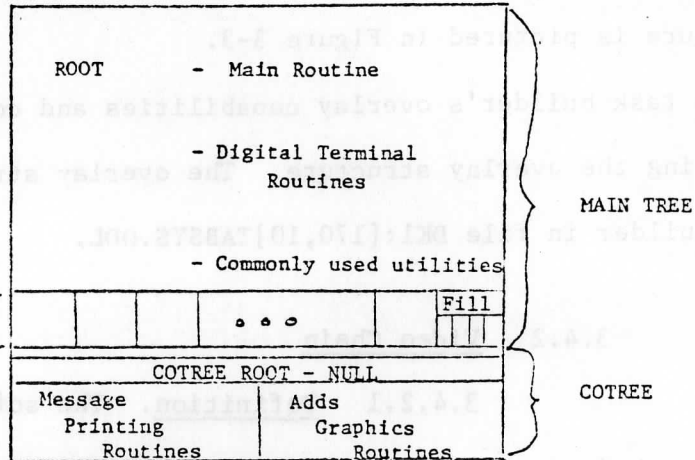
A thorough understanding of the task builder's overlay capabilities and constraints is necessary for modifying the overlay structure. The overlay structure is defined for the task builder in file DK1:[170,10]TABSYS.ODL.

3.4.2 Video Chain

3.4.2.1 Definition. The software video chain is a sequence of processing steps that take image elements stored as sequences of X,Y pairs of points defined in any arbitrary space and converts them into the pixel by pixel values that will be seen in the final image. Conceptually these processes include translating the element curve to the raster space, combining it with other elements in the image, and filling in the individual pixels of the element.

This process is by far the most important one in the IVAM system. First, it is the innermost loop in the system, the one executed the greatest number of times and, therefore, the rate limiting process. There are 250K pixels on the video screen, and some algorithm must determine the value for every one of them. In fact, each point on the screen may have to be considered several times for it is common for several elements to be defined at a given point with only the highest priority actually showing.

OVERLAYED GRAPHICS
ROUTINES, DISK I/O
ROUTINES. ONLY THE
SEGMENT WITH THE
FILL-IN ROUTINES IS
FURTHER OVERLAYED



TABSYS OVERLAY STRUCTURE

See Also DK1:[170,10] TABSYS.ODL

FIGURE 3-3.

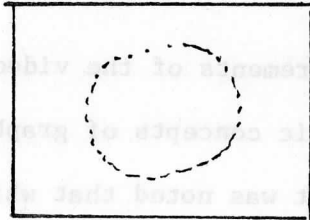
Because it is the largest process in the system (in terms of number of operations), it should be an important influence on system architecture and output hardware design. Similarly, hardware constraints can dictate the type of video chain which must be used. Because many of the processes in the video chain are very simple, trade-offs can be made between software, firmware, and special purpose hardware in its implementation.

Before going into the requirements of the video chain process, it seems appropriate to review some of the basic concepts of graphics processing in general and IVAM in particular. First, it was noted that while there were 250,000 pixels in an output image, the information from which it was generated was considerably more compact, sometimes three orders of magnitude more compact. Therefore, it seemed reasonable to postpone this tremendous expansion of data as long as possible in the processing until right before the image generation step.

It was noted that a typical weathercast image was made up of a number of image elements; e.g., a map, cloud areas, contours, annotation, and special symbols such as wind arrows, snowflakes, and lightning flashes. Also, the generation of each of these elements is independent of the others. For instance, the processing of the underlying map is not affected by the particular symbols or cloud areas that are displayed upon it. Similarly, the shape of a rain area is not computed from the points of the map it overlays. True, both the map and the rain area are computed with respect to a common reference concerning the mapping of points on the screen onto latitude and longitude coordinates on the earth. However, both are computed from information that is available at the beginning of the processing. Beyond that point it is never necessary for the processing of either to refer to the other. Theoretically, each element can be properly placed on the screen independently of any other. However, when

several elements are defined at the same point on the screen it is necessary to resolve their relative priority so that the higher priority element occludes the lower at the points where they overlap.

Typically each element is defined as a sequence of X,Y points in some arbitrary space. The range of values in the space will differ, depending on the



element space 1

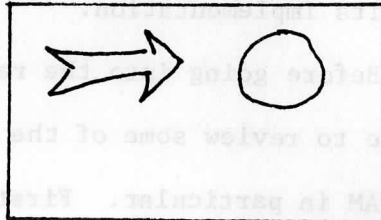
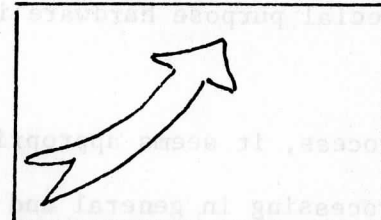


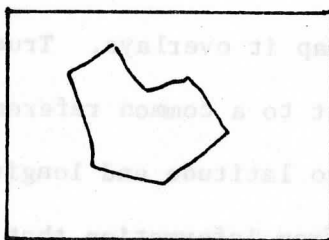
image space



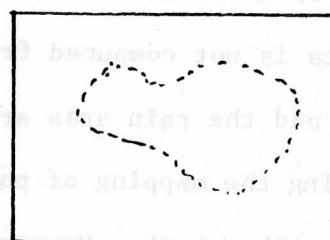
element space 2

processing history of the element. For instance, maps in satellite projection will be in terms of the mapped latitude-longitude values of the area being depicted. Library symbols, on the other hand, will be defined in a totally unrelated space. In each case, a different transformation must be applied to the points of the element, so that it is displayed in the proper orientation in the screen space.

Also, the points of the curve that define the element are spaced at arbitrary intervals along its length. It is thus necessary to resample the line segments that define it, in order to compute their intersections with the scan lines and pixels of the video screen. In fact, for reasons that will become clear later,



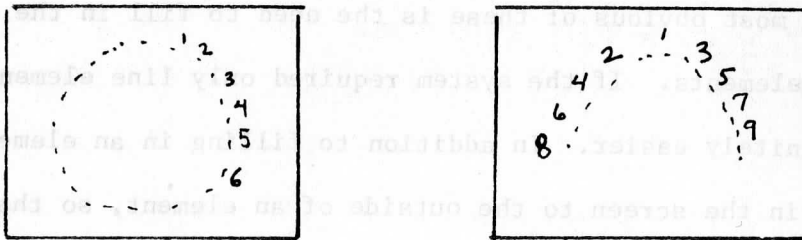
arbitrary
sampling



uniform
raster
sampling

it is not sufficient simply to compute the intersections of the curve within the scan lines, but to assure that there is defined a continuous curve of adjacent (line, pixel) raster pairs whose line and pixel values never differ from each other by more than one.

Once an element has been converted to the raster space its points must be re-ordered, so they occur not in the order in which they are connected, but in the order in which they will be displayed by the video raster scan, which is quite different.



Finally, a means must be found whereby the outline of the element can be used to control the fill-in of the pixels it encloses and/or the widening of the curve itself.

At this point we have the ability to handle a single element separate from all others. It is necessary to have a method for combining image elements so that some are placed on top of others. Finally, it must be possible to place alphanumerics so they are close to the point they label, but also so the image is not cluttered or confused by the coincidence of a number of elements in a single area of the screen. This requires a process which can determine what elements occur in a certain area of the screen, and decide what placement of the label is optimal, close enough to its referent so as to be easily associated, and yet not placed so as to obliterate other important information. These, then, are the very general requirements on any video chain approach. More specific requirements that may be peculiar to the IVAM approach follow.

3.4.2.2. Specific Requirements

There are also requirements which while not universally applicable to all graphic systems, are necessary to IVAM because of the nature of its task and its expected operation.

The most obvious of these is the need to fill in the domains defined by the image elements. If the system required only line elements, the problem would be infinitely easier. In addition to filling in an element, it is necessary to fill in the screen to the outside of an element, so that all the points on the screen are filled in with the exception of those enclosed by the element. This feature is necessary where a graphic frame is defined around a satellite picture, for instance.

It is also necessary to be able to widen the line representing the boundary of the element on the screen. Widening the line in the vertical direction prevents it from scintillating as a single line will, since it is refreshed 30 times a second instead of the apparent 60 times a second for a double line. It would seem possible to handle the line widening of an element boundary differently from the filling in. However, there are several reasons it is desirable to use the same method for both. First, while line-widening does not require a sorting of the points into scan order, this factor does not help when an element must be filled in with one color and line-widened with another. The reason is that while line-widening can be done from a more primitive form of the data, it is in fact not done until after the element is filled in because the widened line is always a higher priority than the domain it delimits. Therefore, to take advantage of the unsorted form for the line widening this data would have to be saved while the processing is done to fill in the domain. Obviously, nothing is saved and something is lost, for by keeping the same element around in two forms, the most precious system resource (on-line, random access memory) is being wasted.

Second, in the case where an element is only to be line-widened and not filled in, another factor comes into play. In the IVAM system the display hardware is the same as that used to do the image assembly. Therefore, the system cannot do assembly during the display period, and the system must either be completely idle during the display time, or it must do as much processing as it can during the display time and store the results in a form that is as close to the displayed form as possible. If the results are stored, then disk space, transfer time, and core space become important constraints. Therefore, it is noteworthy that a single raster ordered format can be a more compact form than a single plot ordered format. The reason is that on a 512 x 512 screen, 9 bits each are required for the X and Y coordinates, implying that two 16-bit words are required to represent the curve in the form in which it is generated. Of course greater compaction is possible by Delta Coding and Exception Vector techniques. However, if an encoding process is required, it seems economical to use one which will serve all uses to which the element might be put, and not just one, particularly since one of the objectives of the encoding here is to keep the stored form of the element as close as possible to the filled in image, so the final hardware, software, or firmware process that accomplishes the final fill-in and line-widening can be as simple as possible.

Another minor argument for storing all curves in raster order has to do with the possibility that CCD memories might be used for image refresh. Since the CCD is a cycling shift register it is completely ill suited for random plotting, and thus it would likely require a raster ordered element even for plotting.

The video chain must also provide flexibility and ease of use. It must be flexible to allow the full promise of the modules implemented. This means not that the system be capable of doing everything, but rather that the means used

to implement what absolutely must be done to assure that any other desirable, if not strictly necessary, functions that are implied by the implementation be available for use. It is, therefore, desirable to be able to enter the video chain at any point so that data can be processed through part of the process, stored, and then re-entered in the chain. This allows the system the greatest flexibility in its strategy for performing the IVAM task. It is, therefore, required that the video chain not be a single unit of processing, but instead a sequence of modules which are, in fact, implemented separately and invoked one-at-a-time by the system. While this requirement might appear to slow down the operation of the video chain, it clarifies the separate phases of the processing and allows one to consider each step as a candidate for special purpose hardware or firmware. It was recognized early in the program that percentage efficiencies in the software operation of the video chain were of no significance compared to order of magnitude gains promised by hardware or firmware implementation. Given the continual flux in the trade-offs available, it seemed prudent to take an approach which would preserve the hardware options and allow the software to be used in radically different display hardware environments.

The video chain should allow for independent processing of image elements to allow for the use of multiprocessing, both in parallel processing and pipeline forms.

A final requirement was imposed during the development process which would not be present in a production crosspoint system. Since the Crosspoint System was never integrated, it meant that the Video Chain modules had to run on the 11/40 where less space was available since it had to be shared with RSX 11/M, Fortran Library routines, control code, etc. This space constraint forced some compromises that could be easily undone in a production system. These compromises affect

not the design of the modules, but the order in which they are executed. The effect of these decisions will be cited where appropriate below.

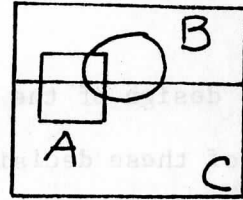
The video chain also had to allow for the effect of the coarse resolution of the raster space. Due to this effect, it is possible for an element which is well-formed in an X-Y space to cross itself in the raster space, particularly where small features are involved, as as the laces of the football shown in the first IVAM tape. Since any fill-in process may be confused by self-crossing curves, the Video Chain must either accept such occurrences or correct for them.

3.4.2.3 Alternative Methods

A number of alternative methods were considered for the video chain. Some of these turned out to have conceptual difficulties that became apparent as their details were considered. Others, while perfectly practicable, were excluded because of the nature of the IVAM task and the kind of hardware trade-offs that appeared propitious. A number of these alternatives will be discussed here, and the reason why they were excluded will be given. Some other options which are specific to the process of contouring will be discussed in a later section.

There are several major categories of possible video chains. The first division is made between approaches that merge elements before the fill-in process and those that do not. Since elements are generated independently and therefore may overlap on the screen, it is necessary to resolve the conflict and determine which element has priority. In the early days of IVAM when memory was far more expensive than it is now, two merged processes were considered. These differed in when the priority determination was done. In each case each element was sorted into a merged construct which contained an ordered list of the pixel locations at which each element intersected each line.

Line 250: 100, A, 200B, 250A, 400B



This construct contains all of the information required to generate the final image and typically requires one tenth the space or less. At one point, storing these outline images was considered in lieu of generating filled-in images. This construct would have saved image storage and allowed the transmission of a more compact form of the image. The ultimate fill-in could be done in real-time by a special hardware processor. The design of this processor could have been simplified by resolving element priorities in the software so the example earlier would be stored as :

Line 250: 0C, 100A, 250B, 400C if A was higher priority than B or

Line 250: 0C, 100A, 200B, 400C if B was a higher priority than A.

In this case the design of the expander is quite easy, and its ability to operate in real-time guaranteed.

The implementation of a merge process was postponed because of space constraints on the 11/40. Inherent in the merge approaches described above is the need for space for the input elements and the outline image construct simultaneously. While the LSI 11's in the crosspoint system could dedicate their entire memory to this process, the 11/40 had to share its memory with a large operating system, device partitions, and other overhead. Therefore, an implementation expedient was considered which had some merit in its own right. This alternative made the merge process the final output from the system. Consequently as each line of the image was merged, it would also be filled in and the result stored on the refresh disk. Since there is no need to store the merged construct, the space requirement is relieved tremendously.

A number of difficulties were noted with all merge approaches. First, the process in all of its forms requires a great deal of space equal to the sum of the elements. In most cases an LSI 11 would be sufficient to perform the operation. In the rare cases where too much space was required, the upper and lower part of the screen could be considered as separate images and merged separately. While the solution would be straightforward, implementing the software to get around the lack of space would be an unwelcome burden and would clutter up the system. Second, the expansion process was made more difficult by the line-widening requirement which either greatly increased the number of entries in the outline construct or the complexity of the expansion process. Third, the merge process is a very time-consuming one, and with the line-widening requirement, competes with the fill-in process as requiring the most cycles. Fourth, any of the merge processes would require several months to implement and debug. For these reasons one of the software inputs to the Assembler design study was that a system that obviated the merge process would have great merit.

The second class of approaches accomplishes the merge process by generating the elements separately and then overlaying them in order of ascending priority. In this way the higher priority elements overwrite the lower. The fill-in process is lengthened somewhat because any given point on the screen may be filled in several times.

In order to do this sort of cumulative merge there must be a screen-size resource somewhere that can be used for the fill-in process. In the old McIDAS software there was a construct called the Plot File which was used for a similar purpose. However, since the construct was too large to reside in core all at once, it was necessary to swap parts of it in and out from disk. As the disk access was very slow compared with the software, the disk swapping became a critical bottleneck in the system, and all of the software had to be designed

around it. Obviously, any process that depends on mechanical movement within one of its inner loops is going to be very slow. Therefore, we were loath to consider such an implementation, particularly since the development system was severely limited in its disk resources.

The second such approach is the much more desirable bit map memory which provides screen size resource to work with, and allows the image generation to proceed undistorted by hardware constraints. With such a resource elements can be filled in one at a time without regard to the other elements.

A third method of avoiding the merge would be to have separate hardware expanders for each element. Then the priority determination would be a matter of simple gating. Since the elements would never be merged, and so need only occur once in the system, it would be possible to take advantage of the tremendous element redundancy from one image to another. It would, therefore, allow easy sequencing between similar images by deleting and adding only the elements that change without either recomputing or restoring the whole image. With such an approach a certain degree of animation could be maintained easily. However, there were two problems with this approach.

First, as mentioned earlier, a line widening expander capable of real-time operation is difficult to design. Second, the multiple expander approach would distribute rather than concentrate the video rate circuitry. This means that the circuitry is inherently unreliable and difficult to design with confidence.

The third class of video chain design assumes the existence of a random access bit map memory that can be read back. This approach observes that all of the information required to fill in an element must be contained in the curve itself. Therefore, it might be possible to write the element into the bit map memory immediately after it is converted into raster order. Then it should be

possible to rescan the element in the raster space in raster order in a way that provides the information needed to fill it. If this were possible, the scan ordering process could be eliminated. Such a process would probably take at least 1/30 second as it would have to scan the frame memory to locate the element and then determine the area it encloses before filling it. This process could be abbreviated if it were initialized to start on the first line on which the element occurs. The process could be improved if the earlier one, the one that computed the intersections of the element with the raster line, kept a list of the element points that occur on its top line. From knowledge of these points it can control the fill-in process by following both sides of the curve down the screen a line at a time. As the element branches a second pair of lines will be formed and both followed down the screen. Similarly, a process could operate from a point within a domain to fill it in, again under the control of a special purpose processor. Such algorithms would not be sufficient where a domain had a hole in it, as a cloud might easily have. In this event the process must be modified considerably, but not so much as to be impractical. The curve defining the hole is handled as a separate element. It has to be because otherwise the scan conversion process would interpolate a line from the outer curve to the inner one. Since the inner curve has been handled separately by the same process that handled the outer one, its starting line has also been determined. Therefore, both elements can be written into the frame memory. The outer element can be filled in until the top of the inner element is encountered. The process then would be restarted and the other points from the inner and outer elements would be handled together as a single element. It appears that this algorithm would work as desired. The only problems would

occur when two elements at the same level are in immediate proximity or actually overlapping. In this case, if the desired result is the union of the two domains, the algorithm may not operate properly. The result is more likely to be the exclusive OR of the two domains, as is desired when one describes a hole in the other. When the elements are contiguous, it is possible that pathological cases will exist. This problem of multiple domains at the same level can be handled more confidently by one of two stratagems. First, the element to be filled can be drawn in at a special reserved level which is not used for any other purpose and will not appear in the final image. As the fill-in process proceeds, it would be writing a different level -- the one that was to be assigned visually to the element. However, the processing of each line would be in terms of the reserved level which would then be overwritten by the Fill level. This procedure is fine as long as the algorithm never has to look back to see what the curve was doing on previous lines. Bench checking analysis suggests that the algorithm would work this way, but until it is checked on real or simulated hardware, there is no way of being 100 percent certain. Alternatively, if two-frame memories are available, a copy of the element can be written into one frame at a unique value used as a reference while the actual fill in and scan is performed in the other frame. In this case the problem of overwriting its own context information does not exist. This approach will handle any case as long as the elements themselves are well formed.

A more conservative and more secure path is to perform a preprocessing step on the raster space points which are still in the order in which they lie along the curve. This process would navigate the curve and determine the local context of each point; i.e., whether the points before and after are on the same line, the one above, or the one below. This context information is sufficient to guide the fill-in process later. It preserves information about the curve

that would be destroyed in the raster sorting process. This information can be encoded with each point in the space of a few bits. Also, the information required for line-widening is also included so the same construct can be used for both fill-in and line-widening.

This construct can be used in two ways. If two read-back frame memories are available, it can be written into one with each of the control bits being given a different level. Then this frame can be scanned and the control values encountered used to guide the fill-in process on the other frame. If there are read-back frame memories the points in the prepass construct can be sorted into raster order and then used to control a software fill-in that writes directly into the frame memory. This method requires extra processing steps, but is unavoidable if it is not possible to read the frame memory. It does also have some advantages in that the fill-in process that results is very simple and can be implemented in hardware or firmware. Also, the construct that is used for the scan sort process can be used for other purposes which will be described later.

3.4.2.4. Method Chosen

The method chosen was the last one described. It was chosen because it met all of the requirements mentioned earlier and because its use obviates the merge process. It assumes the existence of at least a write-one frame memory that allows a selective write (one in which it is possible to only change part of a line without affecting what is already written there). It is consistent with a CCD or RAM based frame store or read-modify-write disk operation, although the latter would be tediously slow. In practical terms the decision was possible because of an accompanying hardware decision. The requirement for a crossfade between satellite images mandated the existence of at least two frame memories in the output assembler. Therefore, it was natural, from

a software point of view, to consider using these frame size resources to do the frame processing. Within the Assembler design decisions that are so far committed, the existence of such frame stores and their use for accumulating image elements is assured. The availability and sufficiency of read back algorithms is not guaranteed, and cannot be until equipment capable of running them is built or a completely divergent simulation of such a device is performed. The path chosen is consistent with such equipment but does not require it, and therefore could be implemented during the development period.

3.4.2.4.1. Case Analysis

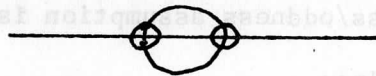
The discussion of the method used in the IVAM Video Chain becomes more detailed and will deal first with the problems that must be solved and only then with the modules that are used to effect the solution. This is done because the algorithms employed would seem very obscure without an overview. Also it is the analysis as much as the code that constitutes the results of the study.

The problems that must be addressed are:

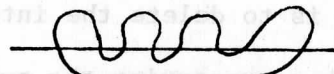
1. The conversion of a curve defined in an arbitrary X-Y space into the uniformly sampled raster space.
2. The determination of whether a curve which crosses the boundaries of the screen includes the origin (line 1, pixel 1) within it.
3. The detection of any anomalous features such as a curve crossing itself which is unlikely with mathematically generated elements such as contours, but can happen when elements are scaled.
4. Points which lie off the screen must be deleted.
5. Points which lie along a horizontal line section of a curve and are not the endpoints of the line are redundant and can be deleted.

6. The local behavior of the curve must be encoded at every point while it is still in curve order.
7. The raster space curve must be sorted into scan order as opposed to curve order.
8. The scan ordered points must be packed into a concise format which will facilitate the fill-in process.
9. The fill-in process assigns the pixel-by-pixel detail to the interior of the element.
10. The fill-in data must be sent to the system display.

The approach that all of these steps assume is that there is a basic order to a closed curve. (A closed curve is one where the last point and first point coincide and, therefore, by the Jordan Curve Theorem, divides the space into two domains, an inside and an outside.) This order is suggested by the observation that each time a scan line encounters the boundary of a curve it is either entering or leaving the domain it encloses.



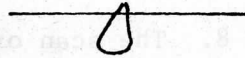
In addition, these occurrences appear at first glance to alternate; i.e., if the first crossing enters the second leaves, and the third re-enters and so on.



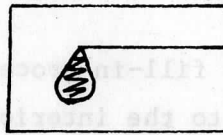
If this is true, the fill-in process becomes very simple indeed. It could be accomplished with a single integrated circuit (a flip flop). In fact we have built hardware that demonstrates that a limited form of graphics is possible with just such an assumption. In fact, if elements were constrained not to

overlap and not to change their direction too abruptly, a real-time fill-in would be sufficient. However, the behavior of the element curves and their relation to scan lines is somewhat more complex than that. For instance, it is possible for only one point on a curve to intersect a particular scan line.

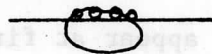
We refer to this as a "cusp."



It would obviously violate our even and odd crossing assumption and produce the following result:



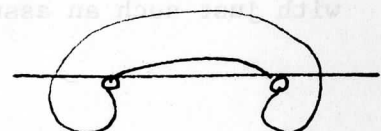
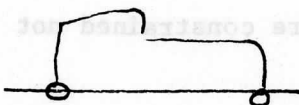
It would be possible to detect and delete such features from a curve. In fact, it can be argued that a single pixel is a meaningless feature in the color video world, since no aspect of the NTSC color encoding system can respond in one pixel time. However, while such a feature has no color of its own, it does have a luminence and its appearance or absence can be detected visually. Also, the color of the area of which it is a part is associated with the isolated pixel by the eye. For these reasons this case is handled within the video chain. Another case which violates the evenness/oddness assumption is that of a curve that is tangent to a particular scan line:



Here the number of points has nothing to do with entering or leaving the domain. What is done is to delete the interior points as redundant, and to keep only the endpoints, thus preserving the evenness/oddness:

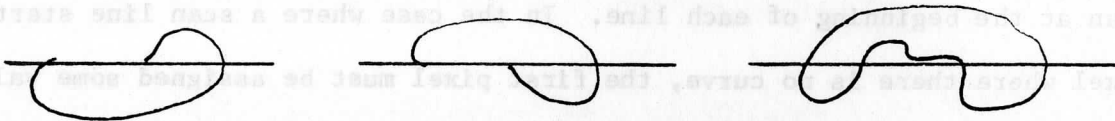


This case can manifest itself anywhere along a curve as shown below:

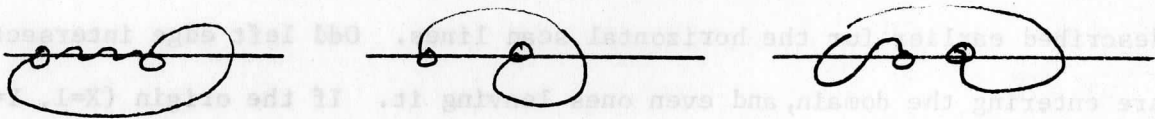


Note that the function of such a pair of tangent points is not identical to a normal boundary case because the section between the two points is always inside the domain regardless of what was happening before the horizontal section and what will happen after it. Therefore, the points between the endpoints of such a section should be filled in, and the fill-in process should revert to whatever domain it was in before it encountered the line section afterwards.

This kind of line section must be distinguished from another kind of horizontal section where a domain change does occur:



In this case again the interior points are deleted and the endpoints saved.



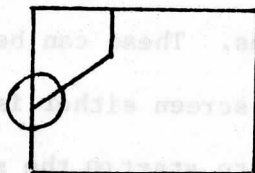
Again the section between the endpoints is always filled in. However, the domain changes after the second point in the pair is encountered. Thus such a pair together have the effect of a normal boundary point.

These cases suffice for closed curves which do not intersect the edge of the screen.

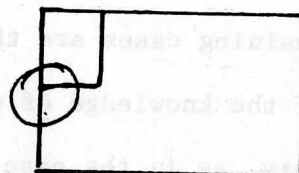
The remaining cases are those that intersect the edges. These can be handled correctly if the knowledge of what the curve does off the screen either is available or unnecessary, as in the case where the curve is assumed to start on the screen as a contour typically does. Thus, closed domains that cross the edge of the screen will be considered separately from open domains whose endpoints are on the edges.

If a curve originates on the top, bottom, or right edge, it will be handled properly if it is a cusp or a normal boundary case. A curve that intersects only the right edge will be handled properly in all cases. A curve that ends with a horizontal line section on either the top or bottom line will be handled properly only if it is treated as a domain change case.

This leaves the left edge cases unaccounted for. There are two kinds of control involved along the left edge. First, there is the normal left to right scan. Second, there is the top to bottom scan which initializes the horizontal scan at the beginning of each line. In the case where a scan line starts at a pixel where there is no curve, the first pixel must be assigned some value. Therefore, there is the additional issue of keeping track of domains vertically. Domains are entered and left only when they intersect the left edge. Therefore, the left edge cases observe an evenness/oddness discipline similar to that described earlier for the horizontal scan lines. Odd left edge intersections are entering the domain, and even ones leaving it. If the origin ($X=1, Y=1$) is included in the domain, this order is reversed. Therefore, the vertical domain state must be updated upon each left edge intersection. The vertical domain state is then used as the initial value for each scan line where the left edge is not intersected. As was the case in the horizontal, not all left edge intersections have the same effect. There are normal and horizontal line intersections.



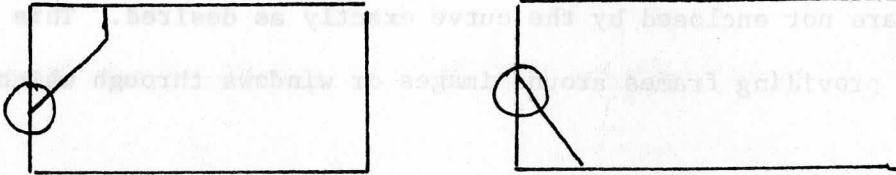
normal
intersection



horizontal line
intersection

In this case cusps are indistinguishable from normal intersections. For the normal intersection there are two subcases, depending on the local slope of the

curve at the intersection. In both cases the action to be taken is similar



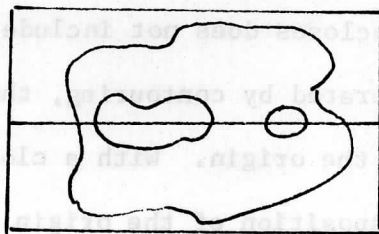
except that when the slope is positive the domain change occurs at the intersect, and when it is negative, it occurs on the line after the intersect.

In the case where the curve intersects the left edge with a horizontal line section, there are in fact four different cases. When the intersect is an odd numbered one along the left edge, the action required is the same as that required for the normal intersection except that the local slope is determined at the right end of the horizontal line section. On even numbered intersections, the actions for positive and negative slopes are reversed.

All of the above analyses assume that the origin ($X=1$, $Y=1$) is known to be either inside or outside the curve. If a curve is closed and does not cross any edges, the domain it encloses does not include the origin. With an open curve such as might be generated by contouring, the generating process determines whether the curve includes the origin. With a closed curve that crosses the edge of the screen, the disposition of the origin is more complicated because it requires analyzing points off the screen as well as those on. Basically what must be done is to determine whether there are an even or odd number of true crossings to the left of the origin. A true crossing is a scan line intersection which is either a normal boundary case, or a horizontal line domain change case. If there are an odd number of crossings, the origin is included. If there are an even number of crossings, the origin is not included. In any of these cases, the areas filled in can be reversed completely by arbitrarily

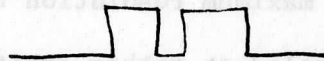
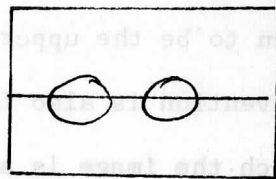
choosing to do an outside fill-in. In this case the origin is initialized to the opposite of its true state. The fill-in algorithms will fill in all the points which are not enclosed by the curve exactly as desired. This feature is useful for providing frames around images or windows through which data can be seen.

Another case which must be considered is that of a donut or any topologically equivalent domain with one or more holes through it. This case occurs commonly where rain clouds contain clear areas (for example). Such cases can be analyzed as follows: First, it must be assumed that none of the curves defining either that of the enclosing domain or those of the contained holes cross or contact one another. Therefore, each of the holes is a proper subset of the enclosing domain. Second, each of the curves is properly defined and amenable to the even/address discipline described earlier. Then the discipline that works for single domains will work for domains with holes if the intersects of all of the curves involved are sorted together in scan order.



Domain state

During the fill-in scan, the hole defining curves are first encountered when inside the enclosing domain, thus switching the domain state to the background. Even encounters with hole defining curves switch the domain state from background back to interior. Notice that if several curves are present at the same level it is not necessary to determine whether any particular curve bounds a hole or domain, for the approach works when disjoint domains are indicated.



Domain state

This completes the case analysis.

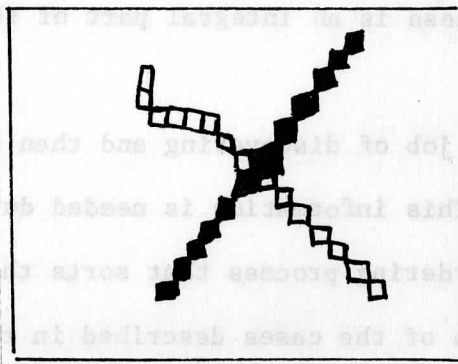
3.4.2.4.2. Processing Steps

The processing steps required to implement the discipline described above actually have some leeway in what order they may be executed. These different orders affect the processing time and, more important to IVAM during its cramped development, the space required. These steps will be described in the order they are currently chained together. Some of the small steps are not treated as separate modules, but are included in with others.

Before the video chain starts, it is assumed that the data is defined in some arbitrary rectangular coordinate space. Examples would be stereographic latitude and longitude, satellite transformed latitude and longitude, or time versus temperature. These are stored in alternating (X,Y) pairs. The Y coordinate is first because on the video screen one thinks intuitively in terms of lines and pixels instead of the more traditional (X,Y). Also, the origin on the video screen is taken to be the upper left, rather than the traditional bottom left. This convention is also for intuitive video reasons. It reflects the order in which the image is actually scanned. In the arbitrary spaces in which the data is defined it can be assumed to have infinite resolution, or at least the maximum resolution that the computer representation allows. It also may be sampled at rather arbitrary intervals in that space. The first step then is to sample curve in the arbitrary space at the uniform intervals of the raster space in such a way as to assure that adjacent pixels are never more than one pixel apart in either the X or the Y direction. In the vertical direction this requirement assures that the curve intersects every scan line it crosses. This is important because the intersect controls the fill-in process later. In the horizontal direction the need is less compelling. Aside from the end points, all of the points along a horizontal line section are redundant. They are preserved here only for two reasons. First, the redundant points are currently used to detect the case where a curve crosses itself. Second, they provide a format which can be plotted directly, which is useful with those curves which are not filled in.

The second step, the self-crossing check, determines if the curve crosses itself, thereby creating two domains and completely violating the assumptions on which the video chain is based. When this occurs the algorithms described can get confused.

These problems can be completely resolved if enough processing is applied, but the price is too high. For instance, to be absolutely sure that a curve does not cross itself it is necessary to treat every adjacent pair of points on the curve as a vector and check to see if it crossed or contacted every other such pair in the curve. The reason each pair must be treated as a vector is that in a discrete space such as a digital raster it is possible for a curve to cross itself without intersecting itself; that is, without containing the same point twice. Clearly such a solution is prohibitively time-consuming. Therefore, it



was necessary to make further assumptions. First, it is assumed that IVAM is never interested in curves that cross themselves. Thus, when one occurs, it is an error. Second, it is assumed that when one occurs it will be as a result of the digitizing of a small feature. Therefore, its effect is local to the crossing. Third, it is assumed that a large percentage of self-crossing curves do in fact intersect themselves, even though it is possible not to. By these assumptions the bulk of these occurrences can be detected by just checking locally for a pair of identical points and deleting the points that lie between them. While it is possible for a small feature to be lost from a domain by this method, the result is preferable to having the fill-in process very obviously blow up. In fact, experience, so far, has found this expedient to be quite satisfactory.

The next step is the horizontal redundancy check which allows deletion of

all but the endpoints of horizontal lines. There are three places where this can be done. It could be done immediately after Scan Conversion and before the self-crossing check, except that process would be complicated somewhat. Second, it could be done as a separate process after the self crossing check. While this would require a separate step, it would most clearly indicate the existence of this step. Third, it can be embedded in the process that follows. Fourth, it could be avoided completely at the expense of about 20% in element storage and some complication in the fill-in process itself. The alternative chosen was the third. This process is an integral part of the Prepass Module which follows.

The Prepass has the job of discovering and then preserving the local context of each point. This information is needed during the fill-in, but destroyed during the reordering process that sorts the points into raster order. This process detects each of the cases described in the case analysis. It does this by looking ahead and behind from each point. It is only necessary to look forward and back one point to detect a cusp or a normal crossing. With a cusp the point before and the point after are both on the same line, although a different one from the point itself. With a normal crossing the point, the point before, and the point after are all on different lines. If when checking for these cases it is discovered that the point and the one following are on the same line, then the next point beyond is also considered. If the point and the two following are on the same line, the middle point is deleted and yet another added. The same check is made and the same action taken until a point is found that is not on the same line as the original point. Here, the point and the one following are known to be the endpoints of a horizontal line section. All redundant interior points have already been deleted. It remains to determine

whether a domain change occurs at either end of the horizontal line. This is done by comparing the point before the horizontal line with the point after it. If they are on the same line, then the horizontal line is a local minimum or local maximum and no domain change has occurred. If, on the other hand, the point before and the one after are on different lines, a domain change has occurred, and the effect of the line as a whole is the same as that of a normal boundary case. Since with both kinds of horizontal lines, the line itself is within the domain, it should always be filled in. Prepass distinguishes between the two horizontal line cases by associating different bit codes with the endpoint of each case.

The left edge cases are recognized first by the presence of an X value of one. Then by checking the point before and the point after, the local context can be determined. One of the adjacent points must be off the screen or it would not be the edge point. The context then is controlled completely by the adjacent points on the screen. If the immediately adjacent point is not on the same line, the edge intersection is a simple boundary case and direction of the curve away from the edge is encoded with the point. If the curve slopes up, the Delta Y bit is set to zero. If it slopes down, it is set to one. If the adjacent point is on the same line as the edge point, the intersection is a horizontal line, and the local context is determined by the first point beyond the end of this horizontal line. Thus, prepass must check adjacent points until the end of the horizontal line section is found and then determine the Delta Y value as before.

LINK

When the Prepass process is complete the local context of each point is preserved with the point. However, the points are still in the order they will appear along the curve, and not the order in which they will be displayed. Also,

they still occupy two words per point, one for X, one for Y. The process called "Link" sorts the intersects into the order in which they are scanned in the raster. This sort is accomplished by a combination of bucket sort and linked list techniques. Before the sort begins, a table is set up with one entry per scan line. Each entry requires two words, one for the X coordinate, and one for the link to the next entry. Initially, each entry has an X value of zero and a link of zero. An X value of zero indicates that the list is empty; i.e., that there are no intersects on this line. The link of zero indicates that there are no more intersects in the list. Each intersect is then entered into the list. Its Y value is used directly to determine which list is appropriate, and then the X value is compared to each element in the list until it finds one that is larger. The new element is then inserted in the list immediately before the larger element. If there are no elements in the list, then the new intersect is entered directly into the list leader and the zero link left unchanged. If the new intersect is larger than any others in the list, it is added at the end of the list and given a zero link. When all of the intersects have been added into this construct the curve has been raster sorted. Since there are no Y values stored in this construct it requires exactly the same amount of storage as it did in unsorted form. In terms of the processing required, it is minimized because each intersect is only compared to those other intersects which occur on the same line and whose X values are smaller.

The information in this form could be used directly for graphic purposes which are not currently in the IVAM requirements, but which could be desirable embellishments which are relevant to the IVAM task, and could be added easily.

With this constant it is very easy and very fast to answer the question:

Is a given point (X,Y) enclosed by the curve? This information could be used to do some additional graphic effects. For instance, it would be possible to fill the area enclosed by the curve with uniformly spaced rain drops or snow flakes. Points within the boundary would be randomly filled and unfilled to simulate poor visibility due to moving fog or gusting winds mixed with snow.

PACK

After the points have been sorted into raster order, using the linked list construct, the curve typically will be stored on disk in the production system. This is necessary because much of the time the output assembler will be busy displaying the early segments. Therefore, if processing is to be done during these times the results must be stored on disk until the Assembler is ready to accept them. Library elements such as weather symbols must be stored permanently on the disk. Also, elements from earlier presentations which are common to current and future segments may also need to be stored. Therefore, the amount of disk space required for element storage is a consideration. In order to conserve disk space a compact storage format was required. While the construct used to sort the curve into raster order was optimum for the sorting process, both in terms of space and speed, once the sorting process is completed, half the space can be eliminated. The scan ordered curve uses two words for each point, one for the X intersect and one for the link to the next intersect on that scan line. The Y coordinate is implied by the relative position of the line list header to the top of the output array from link. Therefore, it is possible to copy the X intersects from the linked array, deleting the links in such a way that no information is lost. The process that performs this operation

is called "Pack" and the output data is said to be in Packed Format.

The Pack process finds the header entry for the first line and copies the X entry into the output file. It indicates that this entry is the first in the given line by setting the sign bit to one. It then follows the linked list of intersects for that line until a zero in the link field indicates the last entry on that line. Each X intersect is copied into the output array as it is encountered. When the list associated with one scan line is exhausted the header entry for the next line is found and copied again with the sign bit set to indicate the first entry of the line. In the event that the curve defining element is discontinuous, a special entry is inserted in the output file which has both the sign bit (bit 15) and bit 14 set. These bits indicate that the low order nine bits of the entry are the number of the scan line on which the next intersect occurs. The result is a compact representation of the curve that includes the local context of each intersect, as well as its X value. The Y values of the intersect points are implied by the input parameter that tells on what line the first intersect occurs, and then the number of sign bits that have been set before the particular X value is encountered. The output in packed format can either be stored on disk or filled in directly.

FILL-IN

The Fill-in process has actually been implemented several times. The first effort was just intended to provide a working version to be used to support other modules. The second was intended to make the algorithm amenable to hardware or firmware implementation. The third was a modification to permit its use with a special purpose piece of electronics that hardwires a small part of the algorithm, and considerably speeds up its operation. While the current implementation is orders of magnitude faster than the first, another factor of

ten improvement would be realized in the Output Assembler.

The Fill-in process takes a curve in Packed Format and fills it in. An input parameter indicates the first scan line on which the curve occurs, and the fill-in proceeds by taking each packed intersect in turn and observing the simple discipline described earlier. The state of origin (i.e., whether it is inside or outside the curve) is an output parameter. If the origin is to be filled, the raster is filled until the first intersect of the curve is reached. If the origin is not included, all of the points and lines before the first intersect are left alone. When an intersect is encountered in the middle of a line, the fill-in changes state, depending on what it had encountered before. If the intersect encountered a normal boundary, the state of the fill-in simply reverses. If the points immediately before the intersect were filled, then those after will not be. Conversely, if those points before the intersect were not filled, those after it will be. In the case of a cusp, only the intersect point is affected. The points after the intersect are filled if, and only if, those before the intersect were also filled. In any of the horizontal line cases, the horizontal section, itself, is filled. However, what happens after the horizontal line depends on whether the two intersects defining the horizontal line are tagged as signalling a domain change or not. If a domain change is indicated, the state of the fill-in after the horizontal line is the reverse of what it was before the line. If no domain change is indicated, the fill-in after the horizontal line reverts to what it was doing before the line was encountered. When an intersect with its sign bit set indicating the first entry on a new line is encountered, it is necessary to handle the remaining part of the current line. Whatever domain state resulted from the last intersect encountered is used to fill or skip the rest of the current

line as appropriate. Then it is necessary to determine the initial state of the new line at the left edge. Note that the state of the left edge need have no relation whatsoever with the final state of the previous line. Therefore, a domain state variable is used to keep track of the curve's intersection with the left edge. This variable is set to the state of the origin at the beginning of the fill-in, and is changed as lines are encountered where the curve intersects the left edge. The changes along the left edge are similar to those along horizontal lines where the domain state below a left edge intersect is the opposite of that above. However, there are differences in that in some cases the vertical domain change occurs after the current line, rather than on it; or it occurs at the end of the horizontal line that intersects the left edge. Whether the vertical change affects the current line is determined by the vertical slope of the curve away from the left edge. This logic will be described in somewhat more detail with the module code, itself.

The fill-in process described here is intersect-oriented. It looks only at the intersects of the curve, and decides whether the horizontal line joining consecutive intersects, or joining an intersect with either edge of the screen, should be filled in. Therefore, its output is in terms of the bounding pairs of X values, the current Y value, and the pixel value to be filled in. Due to the enormous number of pixels likely to be enclosed within any curve, there is no provision for storing them within the computer. Thus, the effects of these four triples must be output as they are generated, or they will swamp the machine. However, there are several ways in which this final output can be accomplished, and some special effects which can be based on it. First, the points lying between the endpoints can be computed and sent to the output device,

one at a time. Second, the endpoints can be sent to a special output processor which will compute the intervening points and perform the fill-in. Finally, the interval can be sent to a crosshatch routine which will fill in the interval with a regular pattern of marks and spaces, based on the intersections of slanted lines with each scan line, the width of these lines, and the distance between them.

Any of these processes can be applied either inside or outside the curve. To do a fill-in of all the points outside a given curve, all that is required is to change the initial state of the origin. Then the rest of the fill-in algorithm will execute exactly as desired. This capability is also available for the crosshatch process.

The crosshatching algorithm is very simple. A slope, a line width, a gap width, and an offset are passed as parameters, along with the endpoints of the horizontal line segment to be crosshatched. The algorithm creates a field of equally spaced equal width lines throughout the area enclosed or excluded by the curve. This is accomplished by using a single line with the given slope as a reference and computing its intersection with the given scan line. Then the offset parameter is added to this reference X coordinate. The purpose of the offset is to allow several crosshatches, of the same slope but of different colors, to be staggered throughout the domain. Then the distance between the left boundary of the interval and the reference X-value plus the offset is computed with the sum of the line width and the gap width. This value determines where, in line width, gap width pattern, the left boundary occurs. Starting at the left boundary of the interval, those pixels corresponding to marks in the pattern are filled in, while those corresponding to gaps are skipped.

In addition to controlling the fill-in process, the packed format can be used to control line-widening. The algorithm has not been coded because it is only necessary in a production system. However, the algorithm is clear. The process would need the X and Y line-widening factors. These would be expressed in terms of the number of X points before and after each point which are to be filled in. The number of Y points above the point and the number of Y points below each point must also be included. Each point then becomes the origin of a rectangle of filled-in points. Its upper left-hand corner is the X coordinate of the point minus the number of X points before and the Y coordinate of the point minus the number of Y points before the point. The width of the rectangle is the number of X points before the point plus the number of X points after the point plus one. Its length is the number of Y points before the point plus the number of Y points after the point plus one. The visible result of the line-widening process is exactly as if such a rectangle were drawn about every point on the curve. At normal boundary crossings and cusps, such a rectangle is in fact drawn. However, along all horizontal line segments, a larger rectangle is drawn. Its upper left-hand corner is the same as that for the left point in the interval. Its width is the difference between the two intersects plus the number of X points before each point, plus the number of X points after each point plus one. Its length is the same as the length of a rectangle about a given point. Using interval fill-in hardware, this algorithm should be very rapid.

3.4.3 RSX11/M

The RSX11/M Operating System was purchased from DEC with the 11/40. The intent of its purchase was to regain some of the time lost in funding and delivery delays. RSX11/M is a powerful multi-tasking operating system. Its linguistic capabilities are somewhat limited as it supports only FORTRAN and a macro-assembler. It has a number of powerful capabilities such as a variety of file structures and access controls. It also supports indirect command files and interprocesses messages. It provides several methods by which different tasks can share data in memory. During the IVAM development, IVAM has used two different versions of RSX11/M, Versions II and III. While these systems provide a number of useful capabilities, they are often awkward to use and not accurately documented. Therefore, the value of much of what is provided is vitiated by the effort expended trying to put it in a form which is more usable.

One of the major features of RSX11/M is the file system. It supports block, record and random access files as well as a variety of types of protection. Unfortunately, the file functions require the user to explicitly do a lot of housekeeping that could more naturally be done by the operating system. Therefore, it was necessary for IVAM to implement an additional file system on top of the one provided by DEC. The purpose of this system was to provide a single interface between RSX11/M and the IVAM system and to make that interface more convenient to use. Thus, a number of file functions which we refer to as the "file primitives" were implemented. These functions provide a number of useful services such as the allocation of logical unit numbers and the allocation of all the scattered fragments of memory that the DEC operations require. These functions are accessed as part of a system of traps which are task built separately from the rest of the IVAM system. This method allows

them to be accessed from a number of independently running tasks. The use and implementation of both the traps and file primitives are described in the Software Documentation.

The IVAM system contained a number of non-standard device interfaces. RSX11/M provides two methods by which devices can be introduced to the system. One method is to create a device partition that includes the upper 4K of the address space. Then the task can access the device registers directly. The problem with this method is that a mapping register is required for this partition and the maximum size of the task is reduced by 4K. Also, the code required to access the device is part of every task that uses it.

The alternative is to create an RSX11/M device driver that formally defines the device to the system. Because no device partition is required and the device driver code is not part of the task, more than 4K is saved from the user task. The implementation of a device driver is not difficult in principle. All that is required is to understand the DEC conventions and to create the tables through which the system accesses the driver. Unfortunately, under Version II, each step in the effort to implement and test a new device driver required a separate SYSGEN. This process is lengthy enough that it was judged prohibitive until the arrival of Version III which introduced the concept of a loadable device driver which can be built and tested independently of the rest of the system. Due to weaknesses in the documentation, even this loadable type of driver is surprisingly difficult to create. The only device for which a loadable driver has been written is the data tablet.

The greatest problem with the PDP11 is the fact that its 16 bit word allows it to address directly only 64K bytes or 32K words. This address space is augmented somewhat by the addition of mapping registers and two extra bits on the address bus so that 128K words can be addressed. However, under Version II

a user task had no means of occupying more than 32K words at one time. Of course, disk overlays are possible but at a tremendous speed penalty. The tablet system is heavily overlaid, so much so that it almost exceeds the symbol table space provided by the task builder. However, for a production system disk, overlays are too slow to be acceptable.

Therefore, a central problem in the implementation of the IVAM system is the creation of a system that occupies more than 32K. RSX11/M does provide features that allow the cooperation of larger amounts of code. In fact, overcoming the 32K limit is one of the central tasks of the RSX11/M system. In Version II there were only two features that permitted the close coupling of separate tasks. One was the ability of separate tasks to be linked to a common code or data partition. The use of these partitions is rather restrictive because they must be defined at SYSGEN time. Also, the linkage to the common partition must be done explicitly by the Task Builder and therefore it subtracts address space from any task that uses it. While this is to be expected for normal code and data sharing, the need for explicit linkage to the trap partition is less clear and is a function of the way RSX11/M handles the trap instruction. An additional feature of RSX11/M Version II is the message capability that allows independently running tasks to communicate with each other through thirteen word messages.

Version III further facilitates the creation of larger tasks by the addition of new capabilities, in-core overlays and the passing of mapping windows. With the latter it is possible for tasks to pass blocks of data and code back and forth with arbitrary flexibility. It is therefore possible to create an aggregate of tasks which can cooperate to form a single system. However, it is important to note that all that has been gained is what would never have been lost if the address space had been larger in the first place.

Also, what might have been a single integrated task whose intermodule communication was handled implicitly by a language processor must now be approached as independent tasks whose communication and control mechanisms must be created by the user. The discussion of the mechanisms created will be treated in more detail with the Controller and the Directory under the section, 3.5, "Production System."

3.4.4 Device Software

This section is a description of the PDP-11/40 peripheral devices used by the IVAM project. A brief description of each device and its uses within the IVAM project is given. The low level software routines written to make effective use of each device are also described. This discussion is not intended to be a substitute for the relevant device manuals provided by the manufacturers.

Information on device register addresses, bit functions and symbolic bit mask definitions is not included here. That information is available in the program listings binder labeled "System's Configuration" and in disk files DX:[107,2]XPOINT, TABLET, VTR and MSPEED.

Several of the devices described below are referenced via a "device common partition". Under RSX11/M a device common partition is a common partition which encompasses some of the device registers. This construct is useful for permitting a nonprivileged task access to device registers. Using this feature a task may include a user written routine which handles I/O operations directly, without operating system intervention. The DR11C device common partition was established to permit user written routines to perform I/O with the data tablet, the digital terminal, the crosspoint switches and a video tape recorder. A task wishing to use the device common partition need only specify the DR11C common partition by using the COMMON command in the 'options' input to the task

builder. The source code file necessary to establish a device common partition may be found in disk file DX:C107,4JDR11C.MAC.

3.4.4.1. The Talos Data Tablet

The Talos data tablet generates x and y coordinates giving the position on the tablet of the associated pen. It has an active area 22 inches by 22 inches and a resolution of 100 points per inch. Points are generated at a maximum rate of 100 per second. The tablet is used by TABSYS, CONTRL and virtual processors as a source of data and control information. These tasks view the tablet as logically subdivided as shown in Figure 3-4.

A 16 by 12 inch area serves as an interactive drawing area. The remainder of the tablet is divided up into two inch square 'control blocks'. These control blocks are used for entering control information to the tasks. Software routines for reading integers and text are also available and often used. Two different software approaches have been used for reading data from the tablet. The first approach involved a routine directly accessing the device registers for the tablet via the DR11C common partition. This approach involved only user written routines and required 'polling' the device registers. Two routines are used in this approach:

1. TABLET - this routine polled the device registers, insured that an x followed by a y was read and separated out the pen up, margin and proximity flags which are sent with the coordinates. This routine is in disk file DX:[160,160]TABLET.MAC, which also includes tablet initialization and wrap up routines.
2. TABPNT - this routine calls TABLET and then examines the flags returned. If any are zero then TABLET is called again. A minimum distance between successive tablet points read can also be specified when TABPNT is called.

The second approach involved writing an interrupt driven device handler which

2200	111	112	113	114	115	116	117	118	119	120	121
2000	FILL HDWR FLAG	101	102	103	104	105	106	107	108	109	110
1800	SET CURRENT LEVEL	90	91	92	93	94	95	96	97	98	99
1600	89	DISP INDEX	MARK	COPY	SCALE	READ	WRITE	MAP	DELAY	SLOW INTER- FACE	DISK ON/OFF
1400	INIT WARRM	78	80	81	82	83	84	85	86	87	88
1200	MOVE	ROTATE	SELECT CT INDX	COLOR SELECT	LINE WIDEN	ARBSCH	STAR	FILL	IX3	IX2	IX1
1000	67	48	69	70	71	72	73	74	75	76	77
800	PRINT	BACK RT	ADVANCE RT	5	-						
600	56	57	58	4	9						
400	CLOSE	SMOOTH	CURSOR	47	3	8					
	45	46	47	3	8						
	LOAD		PLOT	3	8						
	FRAME	34	35	36	7						
	ADDS	RT	CHNL C (WARRM)	2	7						
	23	24	25	1	6						
	12	13	14	STOP	1						
	DRAW										
	1	2	3	0	CR						
	200	400	600	800	1000	1200	1400	1600	1800	2000	2200

TABSYS (22090)

TABSYS TABLET CONTROL BLOCKS

then became an official part of the executive. This driver was then called via an executive request. Using this approach the device common partition is no longer necessary. The driver written returns a single word, either an x or a y coordinate plus flags. The type of driver used is known in RSX-11M terminology as a 'loadable driver.' A loadable driver need not be permanently resident in main memory. Instead it can be loaded only when needed and removed when no longer needed. An 'official' RSX-11M driver has another advantage. It is far less wasteful of CPU time than a driver which spends time in a tight, constantly busy loop while it polls the device registers. The device common partition approach has one other major disadvantage. The use of common partitions requires dedicating enough memory mapping registers to cover the common partition. This is very wasteful if the common partition is not very close to a multiple of 4K words of potential address space from the task image.

The routines relevant to the interrupt driven tablet driver are:

1. RDTBT - this is a modified version of TABLET. The code for actually accessing the device registers has been replaced by system calls. Note that TABPNT would still normally be used at one level higher to call this routine. RDTBT is in disk file DX:[160,160]RDTBT.MAC.
2. TBCRV and TBTAB. These routines are the actual tablet driver and associated data structures. Note that these routines are part of the executive and not part of a user task image. They reside in files DX:[170,10]TBDRV.MAC and TBTAB.MAC.

3.4.4.2. The Applied Digital Data Systems Terminal (ADDS)

The ADDS is a CRT terminal with a limited graphics capability. The ADDS display consists of 24 80-character lines. Each character position is divided into 6 points to give a graphics resolution of 72 lines of 160 points each. The ADDS was used extensively for testing and debugging graphics routines when

the color features of the digital terminal were not necessary.

The ADDS may be operated in one of three modes - message, page or conversational. The conversational mode corresponds to communication with the CPU on a byte-by-byte basis. This mode was used exclusively by IVAM. The ADDS has several other capabilities not used by IVAM. These include defining protected areas on the screen, blinking selected data and use of halftone displays.

The ADDS was interfaced via DEC's DJ-11 16 line multiplexer. The normal DEC terminal driver was used for I/O operations. Thus standard RSX-11M system calls were used for the actual I/O. However a user level routine was written to permit easy use of the graphics capabilities of the ADDS. The two routines used for plotting points on the ADDS were:

1. POSIT - this routine is passed x and y coordinates and a function flag (erase, move cursor or plot). It calculates lower level parameters needed by the following routine and then calls that routine. (See DX:[160,30] POSIT.FIN).

2. PNTPLT - this routine issues the system call to actually plot the point.

The same file also contains INIPLT which erases the ADDS screen and puts the ADDS in graphics mode, and ENDPLT which changes the ADDS to non-graphics mode. The file also contains a 1920 byte data area used as a copy of the screen image. This is necessary because every time a point is plotted all six points of the character position are rewritten. (See DX:[160,30]PNTPLT.MAC.)

The ADDS has a switch selectable baud rate variable from 110 to 9600 baud. We initially operated the ADDS at 9600 baud but soon reduced that to 1200 baud. This was unfortunately necessary because we were losing some information when an array of points was quickly plotted. Apparently the PDP-11/40 was unable to handle the higher baud rate.

3.4.4.3. The Digital Terminal

The digital terminal is a color terminal built by SSEC. The terminal has several devices associated with it. It has twelve disk frames, each capable of holding a single screen image, generally a satellite picture. A random access semiconductor memory known as the WRRRM also is capable of holding an entire screen image. The disk frames and the WRRRM may be enabled or disabled independently. When both are enabled data written into the WRRRM appears over the disk image. Both devices have hardware color tables with each entry containing color values for Red, Green and Blue. Each color value is an integer between 0 and 31. The WRRRM color table has had between 2 and 4 entries at various times. The disk color tables have 64 entries. (The disk actually has two color tables - one for the first six frames and one for the second six frames). The digital terminal also incorporated special fill-in hardware. The fill-in box is sent a line number and starting and stopping pixel numbers. It then writes a specified color into the given interval. A separate CRT and keyboard were also associated with the digital terminal, though these devices were not used by IVAM.

The digital terminal was communicated with by formatting packets of information and sending them to the appropriate device address within the digital terminal. The device address might be the WRRRM, the fill-in hardware, the cursor or any of several other possibilities. After receipt of a packet the digital terminal generated a return packet with the current CRT keyboard character, if any, and a word of status bits. The packets sent the terminal included a checksum byte. The return packet status byte notified the sender of any packets which arrived with invalid checksums. The digital terminal would also spontaneously generate a timeout packet if the terminal did not receive any packet within a certain period of time (approximately one half second).

The digital terminal was connected to the PDP-11/40 via a DMA interface designed by SSEC. This interface was operated at 300K baud and is known as the medium speed interface (MSI). A fairly elaborate communications protocol was used to insure reliable communication. Status bit checking, re-transmission attempts and time-outs were all employed. Details of this protocol may be seen in routines FMCSR, FMSPKT and RTIO (in files DX:[104,14]FMCSR.MAC, FMSPKT and DX:[160,45]RTIO.MAC). FMCSR and FMSPKT are the actual I/O routines. They directly manipulate the device registers via the DR11C device common partition. RTIO handled the higher level protocols - status checking and retry counts. Utility routines, data areas and packet formatting routines may also be found in files DX:[160,40]RTDATA, RTUTIL, RTPKTS and DX:[160,45]SENDCP, WMPACK, SENDWM and SNDWM2. These files also contain some code for a 'slow speed interface' to the terminal via the McIDAS system. This route was used before the medium speed interface was completed.

3.4.4.4. The Video Tape Recorder (VTR)

A computer controlled VTR was used to produce video tapes. The device registers were located in the device common partition. Thus a user level routine was used for I/O operations with the VTR. The routine used is called FVTR. It is simply called with a function code - play, record or stop. This routine may be found in file DX:[150,30]FVTR.MAC.

3.4.5 Graphics

Associated with the capabilities of the IVAM graphics there are a number of aesthetic and procedural issues that will be discussed here. These issues include those of the generation and storage of image element, their detail and color, and the process by which the final tape was created.

The IVAM image element commonly defines the boundaries of a domain. This boundary is used to control an inside fill-in, an outside fill-in, or a line-widening process. The simple fill-in is the most commonly used. The outside fill-in can be used to define and fill-in a border around the screen or to fill-in any open boundary that encloses the origin. The line-widening process is currently done by filling in a rectangle about each point on the curve. This widening process is needed vertically to prevent the flickering that occurs with single horizontal lines. It is needed in the horizontal to give the NTSC system time to slew to the new color. The width of line required is dependent not only on the phase angles of the chrominance signals but also on the amount of I and Q each color requires. The rate of change of the chrominance and the luminance components of the colors are determined separately. The luminance information is given on the order of 5 Mhz bandwidth and weighted 59% green, 30% red, and 11% blue. However, the chrominance information is divided between the I and Q signals which have 1.5 Mhz and 0.5 Mhz bandwidths respectively. Each color differs in the proportion of its information which is sent through the I versus the Q signals. Therefore color transitions are a complex function of the phase angles of adjacent colors and the proportions of I and Q they require. The adjacency of simple domains follows the phase angle rules described elsewhere in this document. However, with the crosshatch fill-in unanticipated results can occur. The cross hatching can switch back and forth at a rate higher than the bandwidth

of the I and Q signals. Therefore the color can become separated from the luminance pixels it should be associated with. The result is that a chrominance haze is created which can be used as a colored transparent overlay with which to identify an area on a satellite picture without obscuring the cloud detail underneath. This procedure works well with blues and greens but it is very difficult to get a good red and impossible to get a yellow. For certain values of the cross hatching parameters in combination with certain colors wild scintillations are created in the crosshatch area. Therefore the use of crosshatching is a touchy issue which must be tested extensively with each image type before it is used in production. It may well be that the transparency effect might be better generated with the help of analogue circuitry which could do it easily.

The line-widening procedure used by IVAM currently fills in a rectangle about each point on a curve. Where the dimensions of the rectangle are no more than two or three pixels, the result is a pleasing curve. However, when the dimensions of the rectangle are increased to seven pixels, the effect is not quite as pleasing. The corners of the widening rectangle are quite apparent at the ends of the curve and whenever it changes direction abruptly. An alternative would be to move a circle along the curve which should soften this effect.

Alphanumerics created within a 512 x 512 raster will be aesthetically wanting. The digitizing effect of the digital raster will be apparent on any character comprised of curved edges. They will be readable but not as good as the lettering used by the networks. The best broadcast alphanumeric generators use a 22 Mhz clock for generating their characters, twice the resolution of the IVAM raster.

Special symbols such as lightning bolts and wind arrows cannot be moved, scaled, and rotated with complete freedom within the arbitrary coordinate space. Small differences in position or scale can result in quite apparent changes

in perceived shape. Therefore symbols should be defined and tested for each size and each angular rotation to see if their appearance is the one desired. Then they should be digitized according to any specific position on the screen. Translations on the screen should be accomplished by moving the object within the raster space after it has been digitized. This would require applying the move module after the scan conversion process rather than before. This capability does not exist in TABSYS currently but could be implemented under the Directory with existing code.

Map grid points can be plotted directly provided they are widened at least in the vertical direction. When a grid is shown over a satellite picture, it is easy for the grid to compete visually with the cloud detail underneath. This was least true with a black grid which was widened to two pixels vertically but not at all horizontally. This problem only exists with a U.S. scale image. On smaller scale images a wider grid line can be used without obscuring the satellite information. With strictly graphic images a wider grid line is desirable because it can be emphasized without distracting from other information.

Long satellite sequences are affected adversely by the rising and setting of the sun. This causes darker images at the beginning and end of the daylight sequence. There are procedures for normalizing all of the images in a sequence according to a uniform distribution of grey levels. However, IVAM has no means of processing satellite images currently nor was such processing a stated requirement on the system. Such functions could be added in the production system although they might not be easily merged with the current assembly design.

The final video tape was generated with IVAM software. It consists

of three sequences: a U.S. satellite sequence with colored air masses, a U.S. graphic sequence, and a satellite sequence of the middle Atlantic states with rain areas crosshatched. The generation of the tape was done using TABSYS. The generation of each image was controlled by a TABSYS command file containing IVAM macros. Although a solenoid operated tape recorder was not available for the final taping, these macros were capable of automatically generating each image and controlling the timing of the tape recorder, all automatically. In fact a command file exists for the football sequence from the original tape, which has to be one of the most taxing segments from a software point of view. It was only because of the ponderous rate of image generation under the development system that this segment was not taped.

3.5 Production System

3.5.1. System

The IVAM Production System requires the addition of several major subsystems to the environment of the Development System. In particular, the Production System requires the Crosspoint System, the IVAM Assembler, the creation of a data store, and the interface to the AFOS System. In addition to the device software required to control each of these subsystems there is a powerful set of control software which defines the IVAM processes described earlier and orchestrates the operation of all systems processors.

The Crosspoint System provides a means of increasing the processing capability of IVAM by two means -- by providing three additional processors, and by allowing IVAM to have much more of its code resident than would normally be possible. The 11/40 currently has 64K words. Each of the LSI/11's has 12K dedicated to its use. In addition there are ten 8K modules which can be swapped from one processor to another almost instantly for a total of 180K.

With this much memory all of the most commonly used IVAM code could be permanently resident. This is possible because the IVAM task is characterized by a modest number of modules which must be tied together in a large variety of ways. Therefore, the IVAM control software provides powerful structures for invoking these modules. New methods can be developed without recoding, recompiling, or retask-building these modules.

The IVAM image assembler provides the means of speeding up the operation of the video chain described earlier, as well as providing for the storage and display of completed sequences of images. It provides the bit map memories required to facilitate the assembly process and the read back capability required for the placement of alphanumeric.

In the Production System all weather data will be gained through the interface to the AFOS system. This interface will require a series of request/reply protocols, as well as the implementation of a series of straightforward modules for storing AFOS data into IVAM formats and then into the IVAM data store which represents data in a form convenient for the IVAM task of generating and filling in image elements.

3.5.2. Directory

The Production System requires a rich set of data structures for organizing all IVAM code, permanent data sets, in-process data sets, segment and process definitions, resource allocation, system context, and process queues. A single structure is used for all of these purposes. It is an arbitrary linked structure which organizes all IVAM information into a single hierarchical tree structure. This structure is called the Directory. Some of the nodes in this tree structure contain control information and are executed by an interpreter in the IVAM executive. The executable nodes

are called "prompt nodes" and the interpreter is called the "Controller". The prompt nodes define sequences of modules which are to be executed. However, requests for input from an operator can be made through the prompts so the sequences defined can be fully automatic, fully interactive, or any combination of the two. The definition of these prompt sequences is an interactive process so the definition of new control has no effect on the modules which are already coded in the system.

An image format is a series of prompt nodes that completely defines the commands required to generate an image. There are essentially three different kinds of information in such a format: the information required to generate the elements that comprise the image, the information required to assemble and fill-in the elements to form a digital image, and the information required to display the image. These three types of information correspond to three of the IVAM processes -- element generation, assembly, and display. The format header is entered into the queue of each of these processes after the processing of the earlier one has been completed.

If an image is to be formed completely from library elements permanently stored in the system the generation phase is small and the Assembly Process consists only of a sequence of fill-in and line-widening commands applied to elements from the library. However, it is more likely that the image format is somewhat general; e.g., it is not specific to time of day, or to location, or to cities labelled. Therefore, part of the element generation is a binding process where the variable information in the image format is bound to the specifics of the particular presentation. Therefore, prompts are provided for computing the time of day and identifying the map windows

to be used in data selection and the set of cities to be used for labelling.

A segment is defined as just a sequence of image formats. It also allows for a certain amount of variable information which it passes to each of the segments. The information in the segment definitions and image formats is now completely sequential. It could instead be arranged in a dependency tree structure so the system would be free to execute any of the modules which are ready for execution in order to make greater use of parallelism.

The IVAM processes are also defined as sequences of prompt nodes which invoke the execution of modules on specified data sets. Each process has a queue of functions it is supposed to accomplish. The results of computations in one process are removed from its queue and added to the queue of the next process. Except for the queues the operation of each process is completely independent of the others. Therefore, it is possible for these processes to operate in parallel on different processors without mutual interference.

3.5.3 Controller and Directory

The following section describes the production software system produced by the IVAM project to be used with the Crosspoint and Assembler subsystems which were not implemented. The software is intended to form the basis of a system capable of automatically staging and sequencing graphics application modules. The system runs on a PDP-11/40 but is designed to permit an easy transition to the crosspoint system. The crosspoint system consists of the 11/40, 3 LSI-11's and 10 8K word blocks of memory connected to the processors via a crossbar switch. The system described consists of three principle elements:

1. A program called CONTRL, also known as the controller, designed to control and stage the execution of modules within independent tasks.
2. The directory - a data structure which the controller uses as permanent data base.
3. Virtual Processors - independent tasks containing one or more applications modules. Virtual processors are automatically initiated by the controller.

The controller's primary function is to automatically stage and initiate the execution of applications modules contained within independent tasks. In support of this function it also contains routines useful in displaying and maintaining its data base, the directory. (The controller's main routine is in disk file DX:[160,105]CONTRL.MAC.)

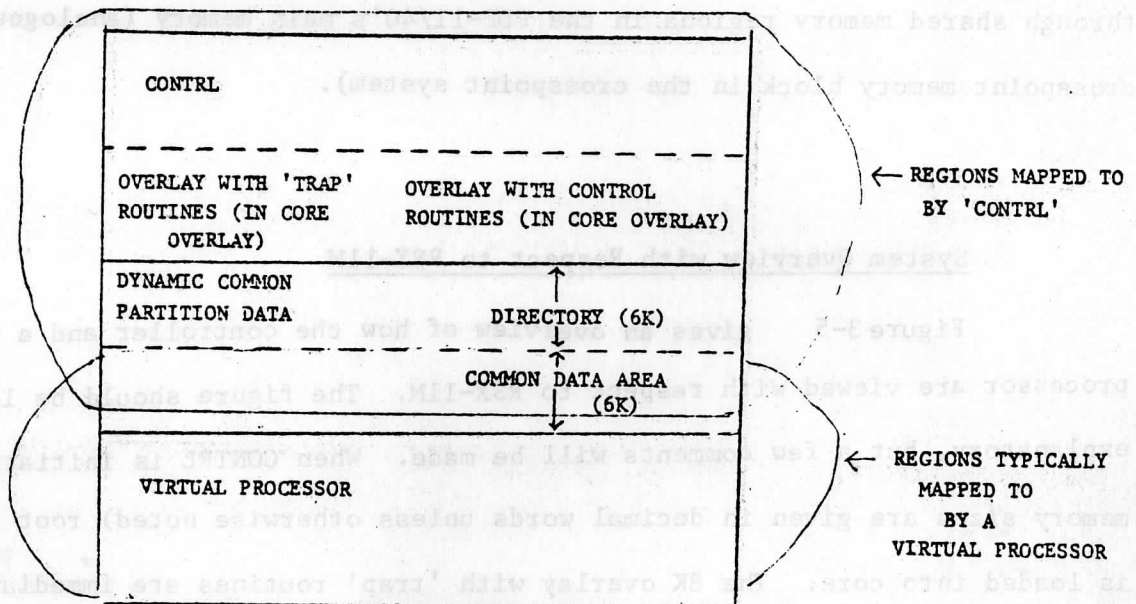
The directory is a disk file which CONTRL reads into main memory when it begins execution. The directory is subdivided into pages. Each page in turn is composed of 128 'nodes'. Each node is composed of 8 sixteen-bit words. Every node in the directory is of one of a small number of types. Many nodes in the directory are of type 'free' and are available for dynamic allocation for any of a variety of purposes. (Node related routines include DX:[160,170] GETND, FREEND, FRCNT, FINDND.) It is nodes within the directory which direct the sequencing and staging of a series of module executions. Nodes known as 'prompt' nodes are linked into chains. Each prompt node contains parameters within it which are passed to a 'prompt routine'. Each prompt node has a subtype code. Each subtype has a unique prompt routine associated with it. Thus CONTRL is basically an interpreter for chains of prompt nodes. (The directory is stored in disk file DK1:[160,100]DIRECT.DAT.)

The modules staged by CONTRL are within independent tasks known as virtual processors (because these tasks are logical equivalents of the physical processors in the crosspoint multiprocessor system). The controller communicates with virtual processors through RSX-11M messages (analogous to the hardware interface between the PDP-11/40 and an LSI11 in the crosspoint system) and through shared memory regions in the PDP-11/40's main memory (analogous to a crosspoint memory block in the crosspoint system).

System Overview with Respect to RSX-11M

Figure 3-5 gives an overview of how the controller and a virtual processor are viewed with respect to RSX-11M. The figure should be largely self-explanatory, but a few comments will be made. When CONTRL is initiated the 8K (all memory sizes are given in decimal words unless otherwise noted) root section is loaded into core. The 8K overlay with 'trap' routines are immediately referenced and also loaded. The trap routines are a collection of utility routines which provide I/O and resource allocation services. They are designed to reside in a common partition and be accessible to multiple tasks simultaneously. At present, however, they are merely part of CONTRL's task image rather than a separate partition. CONTRL begins execution by dynamically creating the common partition DATA. (See DX:[160,220]MMDATA.MAC.) The TRAP routines are then used to read the directory from disk into the lower 6K of the common partition. At present the directory has 6 pages; thus the entire directory is being read in.

SYSTEM OVERVIEW W.R.T. RSX-11M




EACH HORIZONTAL SECTION  REPRESENTS 4K DECIMAL WORDS.

FIGURE 3-5.

The TRAP routines are also used to provide a uniform means of allocating logical unit numbers and event flags. After the directory is read in the traps are not referenced until CEXIT, CONTRL's exit routine (DX:[160,105] CEXIT.MAC) is called to write the directory back to disk (if desired) and to free up resources allocated by the TRAP's. Thus after the directory is loaded the first reference to the other overlay section will cause it to be loaded and it will then remain in core until CONTRL is ready to exit.

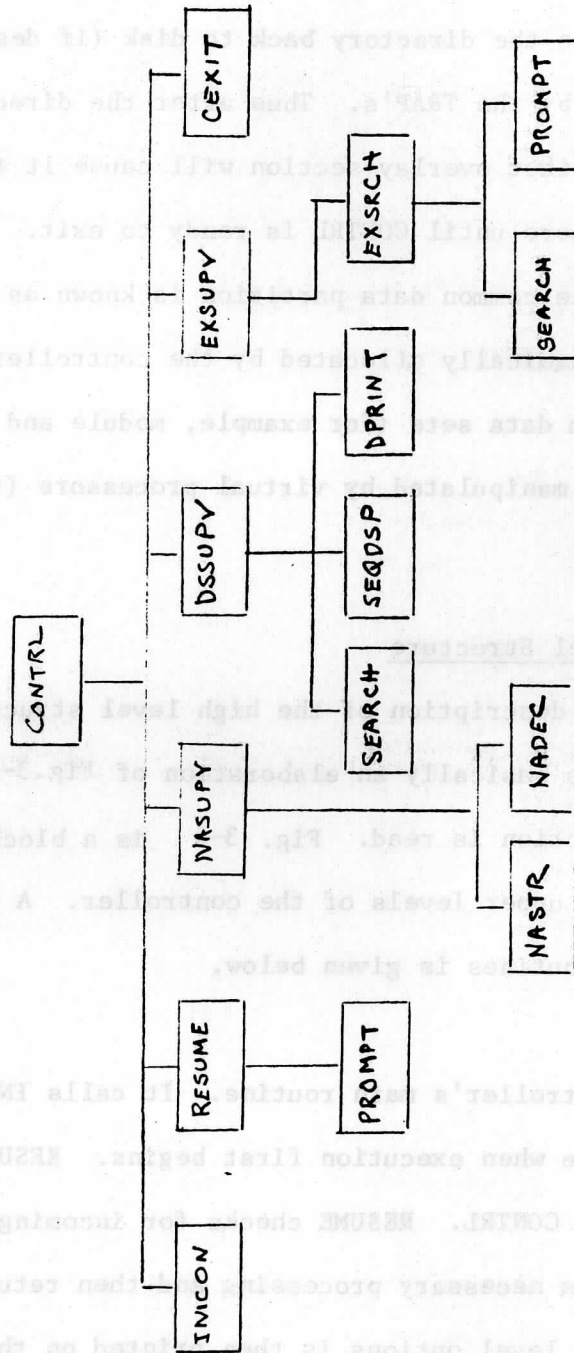
The upper 6K of the common data partition is known as the common data area. This area is dynamically allocated by the controller's routines. It is used to contain system data sets (for example, module and directory parameter blocks) and data sets to be manipulated by virtual processors (typically sets of points).

CONTRL's High Level Structure

This section is a description of the high level structure and routines of CONTRL. The narrative is basically an elaboration of Fig.3-6, which should be close at hand as this section is read. Fig. 3-6 is a block diagram showing the primary routines at the upper levels of the controller. A functional description of each of these routines is given below.

CONTRL

CONTRL is the controller's main routine. It calls INICON to perform various initializations once when execution first begins. RESUME is called whenever control returns to CONTRL. RESUME checks for incoming messages from virtual processors, performs necessary processing and then returns control to CONTRL. The display of top level options is then printed on the ADDS. The user chooses one of these options via the tablet and one of the remaining routines shown directly below CONTRL is called. (CONTRL's source code is in disk file DX:[160,105]CONTRL.MAC.)



HIGH LEVEL ROUTINES OF THE CONTROLLER

FIGURE 3-6.

INICON

INICON is the controller's initialization routine. It initializes data structures used in I/O operations with the data tablet and the ADDS. A common partition is created and attached. The directory is then read into the common partition. (See DX:[160,105]INICON.MAC)

RESUME

RESUME processes any messages sent from virtual processors. A message indicates a module within a virtual processor has completed execution. RESUME then calls PROMPT to resume interpretation of the prompt chain which initiated the module. The Active Task Table is updated to reflect the new status of the module. (See DX:[160,230]RESUME.MAC)

PROMPT

PROMPT is the controller's prompt node interpreter. It traverses a linked list of prompt nodes and at each node calls the associated prompt routine. Prompt interpretation continues until either the end of the prompt chain is reached or until suspended for a module execution. (See DX:[160,230]PROMPT.MAC)

NASUPV

NASUPV is the node addition supervisor. It displays a menu of the available node addition routines on the ADDS. The user then selects the desired routine via the tablet and NASUPV calls the selected routine. (See DX:[160,150]NASUPV.MAC)

NASTR

NASTR enables a user to add string nodes to the directory. The user enters a text string via the tablet. NASTR allocates and links together as many nodes as are necessary to store the entire string. (See DX:[160,150]NASTR.MAC)

NADEC

NADEC is the 'decimal' node addition routine. The user is prompt for a decimal integer, entered via the tablet, for each subfield of a node. Thus

an arbitrary node type may be added with this routine. (See DX:[160,150] NADEC.MAC)

DSSUPV

DSSUPV is the node display supervisor. It prints a menu of display options on the ADDS and permits the user to choose one via the tablet. The routine corresponding to the chosen option is then called. These options include displaying nodes via a list traversal of the directory, sequentially displaying directory nodes or printing all non-free nodes in the directory. (See DX:[160,140]DSSUPV.MAC)

SEARCH

SEARCH is a list traversal node search and display routine. It first displays a starting node passed to it as a parameter. Three options are then available to the user. The 'push' option permits the user to select a subfield of the currently displayed node and have it interpreted as a new node number. This new node is then displayed. The 'pop' option permits the user to 'back up' and have the node previous to the current node displayed. (A stack is used to record the path traversed so far.) The third option permits the user to return to the caller after recording a specified offset within the current node. This routine is used both for simple displays of the directory and for selecting a module to be executed. (See DX:[160,210]SEARCH.MAC)

SEQDSP

SEQDSP permits the user to display a series of sequentially numbered directory nodes. It prompts the user for a starting node number and then displays that node. Each time the user touches the 'carriage return' control block on the tablet the next directory node is displayed. The routine returns to the caller when a positive integer is entered from the tablet. (See DX:[160,140]SEQDSP.MAC)

DPRINT

DPRINT prints out all directory nodes except free nodes on the console listing device. (See DX:[160,140]DPRINT.MAC)

EXSUPV

EXSUPV is the execution supervisor. It permits a user to initiate the execution of a module on a virtual processor. A menu of possible methods of specifying the module to be executed is first printed on the ADDS. Currently only the tree search option is implemented. EXSUPV then calls the routine corresponding to the option selected. (See DX:[160,230]EXSUPV.MAC)

EXSRCH

EXSRCH calls SEARCH to enable the user to select a module node. The module node includes a pointer to the first prompt node in the module's prompt chain. EXSRCH then calls PROMPT, the prompt interpreter, with the starting prompt node as a parameter. (See DX:[160,230]EXSRCH.MAC)

CEXIT

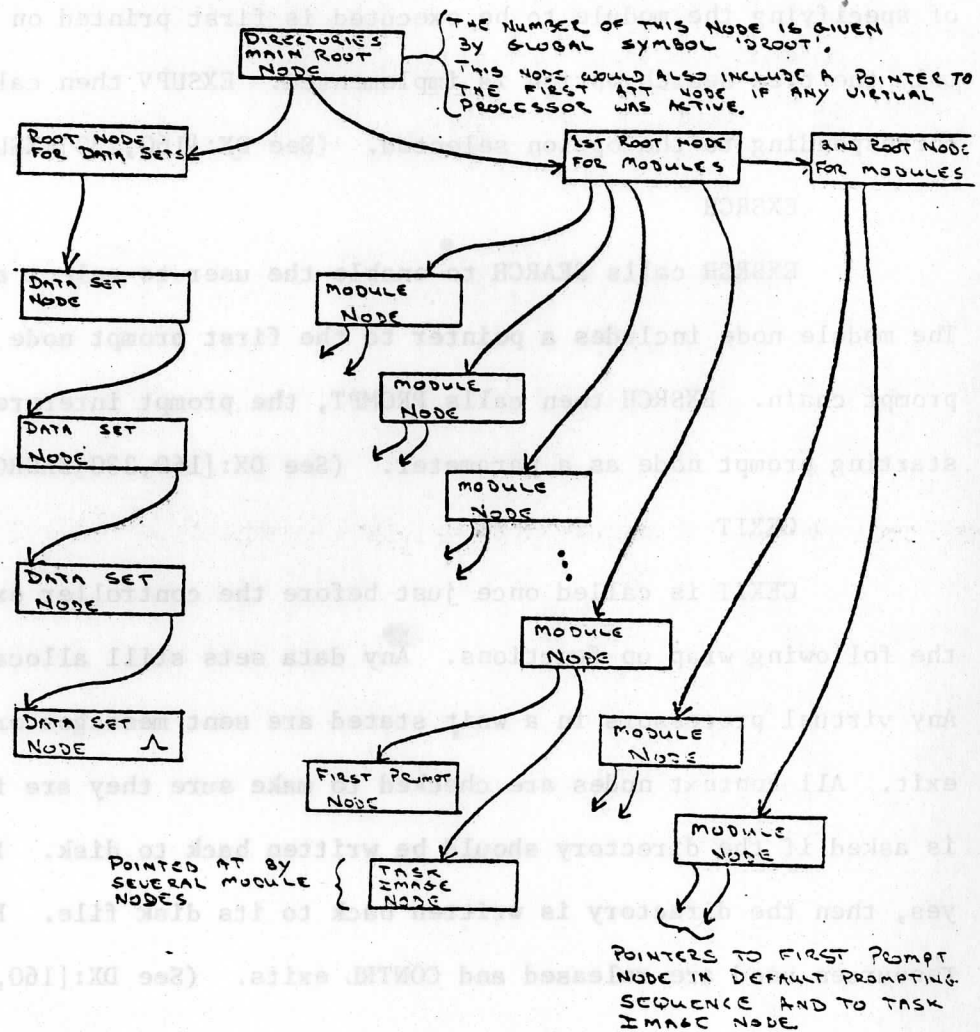
CEXIT is called once just before the controller exits. It performs the following wrap up functions. Any data sets still allocated are freed. Any virtual processors in a wait stated are sent messages ordering them to exit. All context nodes are checked to make sure they are free. The user is asked if the directory should be written back to disk. If the user responds yes, then the directory is written back to its disk file. Finally any TRAP resources used are released and CONTRL exits. (See DX:[160,105]CEXIT.MAC)

Data Structures Used Within CONTRL

The Directory Nodes

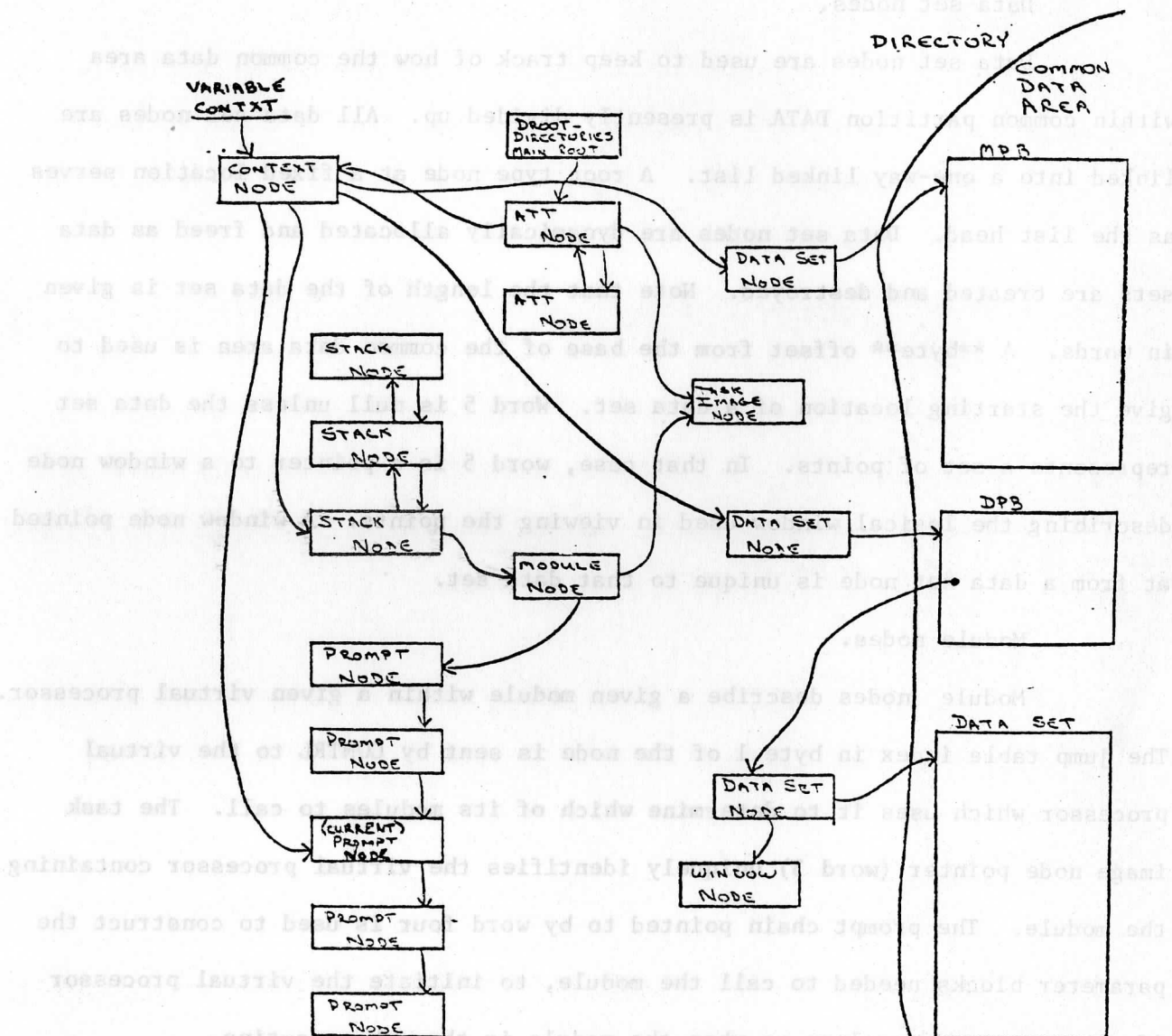
Root nodes.

Root type nodes are used simply as connectors. They are used primarily in that part of the directory which forms a tree. (See Fig. 3-7, The "Rooted"



The "rooted" Directory

FIGURE 3-7.



A snapshot of the Directory and Common Data area after initiation of a module.

FIGURE 3-8.

Directory.) The second word of the node may contain a pointer to a string node describing the root node or word two may be zero. Words three through seven point to the children of the node. Word eight may contain a link field to another root node, thus permitting tree structures with logical nodes with arbitrarily many children pointers.

Data set nodes.

Data set nodes are used to keep track of how the common data area within common partition DATA is presently divided up. All data set nodes are linked into a one-way linked list. A root type node at a fixed location serves as the list head. Data set nodes are dynamically allocated and freed as data sets are created and destroyed. Note that the length of the data set is given in words. A ****byte**** offset from the base of the common data area is used to give the starting location of a data set. Word 5 is null unless the data set represents a set of points. In that case, word 5 is a pointer to a window node describing the logical window used in viewing the points. A window node pointed at from a data set node is unique to that data set.

Module nodes.

Module nodes describe a given module within a given virtual processor. The jump table index in byte 1 of the node is sent by CONTRL to the virtual processor which uses it to determine which of its modules to call. The task image node pointer (word 3) uniquely identifies the virtual processor containing the module. The prompt chain pointed to by word four is used to construct the parameter blocks needed to call the module, to initiate the virtual processor if necessary and to clean up when the module is through executing.

Prompt nodes.

Prompt nodes are linked into one-way linked lists to form chains. These chains, when interpreted by CONTRL's prompt interpreter, control module

staging, execution and clean up. Chains for individual modules may be linked to permit automatic staging and execution of sequences of modules in different virtual processors. The action or prompt routine number in byte 1 is used by the prompt interpreter to determine which prompt routine to call. The parameters in words four through seven are then used as parameters to the prompt routine which is called. These parameters are often offsets within a module or directory parameter block, data structures used both in staging the module and to permit the individual prompt routines to 'communicate' via a common data structure.

String (or text) nodes.

String nodes are linked together to contain strings of ascii text. They are used for a variety of purposes. CONTRL's prompts and error messages are stored in the directory as string nodes. Many string nodes are fixed locations within the directory. The file DX:[160,106]MSGNO.MAC on floppy CONTRL1 defines symbols giving these locations.

Task image nodes.

Task image nodes are used to identify a virtual processor. They are pointed at by the module nodes for those modules contained within the given task image. The only information they contain is the task name in radix 50. This is used to initiate virtual processors and to send messages to them.

Context nodes.

Context nodes are used by CONTRL to provide a centralized location for information about the staging and execution of a module. At any given time there is exactly one 'current' context node. The current context node is defined as that context node pointed at by global variable CONTEXT. (This pointer may be null if no modules are being staged or have been executed.) Thus when a module is initiated the context associated with the execution of the module may be quickly switched and restored by simply changing the contents of global CONTEXT. The context node for a module currently executing is stored

in the Active Task Table.

Stack nodes.

Stack nodes are used to record search paths through the directory. When either displaying nodes or when selecting a module for execution the user may search through the directory by following pointers within nodes to other nodes (DX:[160,210]SEARCH.MAC). As the user selects successive nodes a stack of pointers to the nodes selected is dynamically constructed. The stack is composed of stack nodes dynamically allocated and linked into a doubly linked list. Because this stack records the search path, the user may back up to previously selected nodes. CONTRL will automatically pop the top stack node and free it as necessary. A context node points to the top stack node at all times. In addition to pushing (DX:[160,210]SPUSH.MAC) and popping (DX:[160,210]SPOP.MAC) nodes to or from the stack, the user may exit the search routine after selecting a given offset within the last node chosen. The offset selected is recorded in word four of the top stack node.

Free nodes.

Free nodes are simply any unallocated nodes in the directory. The free nodes on each page are linked into a linked list. The list head is the first node on the page, which is never allocated.

Data nodes.

Data nodes are broken down into subtypes based on the code contained in byte 1 of the node. Presently two subtypes are defined.

ATT nodes.

ATT nodes are used in CONTRL's Active Task Table. The active task table (ATT) is a data structure used to keep track of virtual processors. It is described in detail later.

Window (or space) nodes.

Window nodes are used to describe the viewing window parameters

currently associated with a set of points. A unique window node is associated with each data set which contains points. In addition three window nodes exist describing the standard windows associated with the data tablet, the ADDS terminal and the digital terminal. Generally a copy of one of these permanent window nodes is made when a set of points is established.

Major Data Structures Within CONTRL

The 'rooted' directory.

Many of the nodes within the directory are linked together into a single, large connected data structure. The links consist simply of pointers within nodes to other nodes. The only major group of nodes not linked into this structure are the string nodes. The 'root' of this structure, the point where it is usually entered, is at a root type node at a fixed location. This location is assigned to the global symbol DROOT in DX:[160,106]CONDAT.MAC. The directory search routine automatically starts at DROOT. DROOT contains pointers to three other nodes. In word three there is a pointer to another root type node which serves as the list head for the data set list. Word four contains a pointer to a root node containing pointers to module nodes. Word five contains a pointer to the first node in the active task table (note that since the active task table is allocated dynamically as modules are executed, this pointer is null when CONTRL begins execution.) By following these pointers most non-string nodes in the directory can be accessed.

The data set list.

The controller dynamically allocates and deallocates blocks of the common data area as needed. (See DX:[160,200]ALOCDS,FREEUN,FREEDS,COLAPS.) Data set nodes are used to keep track of how the common data area is currently divided up. The data set list is a linked list of all the data set nodes, both those describing free areas and those for allocated areas. The list is maintained

in order based on the offset of the described data set from the base of the common data area. Initially two data set nodes exist. One serves as the data set list head and describes a null data set, i.e., it contains a length of zero and thus will never be allocated or freed. The second data set node describes a free data set whose length is the length of the common data area and whose offset is zero. It should be noted that as part of its initialization procedure (DX:[160,105]INICON.MAC), CONTRL immediately allocates a two word data set. This data set will always be the first two words of the common data area. These two words are used to hold the module parameter block pointer and a global event flag number used in synchronizing use of the data tablet by CONTRL and a virtual process. The data set node serving as list head is pointed at by a root type node which in turn is pointed at from DROOT. (Word three of the root node pointed at from DROOT contains the pointer to the data set list head.)

Module and directory parameter blocks.

Module parameter blocks (MPB) and directory parameter blocks (DPB) are types of data sets (and thus reside in the common data area) used in staging the execution of a module. Both are allocated dynamically by prompt routines. The module parameter block is used by a virtual process in the call of a module. The structure of a MPB is essentially that of a standard RSX-11M Fortran block of parameter pointers used in a subroutine call, followed immediately by the actual values of the scalar parameters. The major difference between an MPB and a Fortran parameter block is that the parameter addresses used in a MPB are offsets from the base of the common data area rather than direct addresses. (This permits the controller and a virtual processor to map to the common data are using different virtual addresses (mapping registers).) An example of an MPB is given in Figure 3-9. A directory parameter block is used for communication within CONTRL rather than between CONTRL and a virtual processor. Prompt

MPB	
0	NUMBER OF PARAMETERS (5)
2	OFFSET OF ARRAY IXY.
4	OFFSET OF MAXPTS
6	OFFSET OF NPTS
8	OFFSET OF LEVEL
10	OFFSET OF IDEV
12	VALUE OF MAXPTS
14	VALUE OF NPTS
16	VALUE OF LEVEL
18	VALUE OF IDEV
20	OFFSET OF THE NUMBER OF PARAMETERS

DPB	
	NUMBER OF DATA SET NODE FOR ARRAY IXY.

Above are the Module Parameter Block (MPB) and Directory Parameter Block (DPB) for a Virtual Processor Module with the FORTRAN Call:

CALL DRAW(IXY,MAXPTS,NPTS,LEVEL,IDEV)

All offsets are from the base of the common data area.

FIGURE 3-9.

routines may move information to or from the current DPB and thereby communicate dynamically bound information to other prompt routines. A typical example would be the number of a data set node for a data set to be passed to a virtual processor module.

The Active Task Table.

The active task table (ATT) is a dynamically created list of nodes used to keep track of virtual processors which are currently active. Each active virtual processor has one entry (node) in the ATT. Note that an 'active' virtual processor is not necessarily executing a module. After a module is through executing the virtual processor does not automatically exit. Thus an active virtual processor may be either executing a module or in a wait state, waiting on a command message from CONTRL. An ATT node for a virtual processor in a wait state contains two primary pieces of information (in addition to the node identification codes and the linkages to other ATT nodes). First the number of the task image node corresponding to the virtual processor is in word three. The task status, waiting in this case, is recorded in the first byte of word four. A busy virtual processor; i.e., one currently executing a module, will have a status code in the first byte of word four indicating that it is currently busy. In addition a busy virtual processor will have two other fields filled in in its ATT node. Word four, byte one, contains the module number for the module currently executing. (This is the number stored in the second byte of a module node.) Word five contains the number of a context node which preserves additional context about the module execution currently in progress. The active task table is implemented as an unordered doubly linked list. The first entry is pointed at from word five of node DROOT. (See DX:[160,270]FRATT,CLRATT,REQUST,ATTASK for routines which manipulate the ATT.)

The Virtual Processor

Overview

A virtual processor is initiated by CONTRL, which also sends a message with the number of the module to be executed. The virtual processor begins execution by issuing a receive to obtain the module number (the receive is actually done by an asynchronous trap routine which is entered when the message is first queued for the virtual processor by RSX-11M). The virtual processor then locates the module parameter block, which is within the common data area, via the pointer left at the first word of the common data area. The address of the start of the common data area must then be added to each parameter pointer in the MPB. The desired module is then called using the standard Fortran calling sequence. When the module returns the virtual processor sends a message to CONTRL with the module number. It then awaits the next command message from CONTRL. The details of this process are described under the individual routine descriptions below. (These routines are in disk files of the same names under UIC [160,250].)

The Routines Common to All Virtual Processors

VPROC

VPROC is the main routine of each virtual processor. Upon beginning execution it attaches to the dynamic common partition containing the common data area. It then specifies the entry point for a receive asynchronous systems trap (AST) routine. This routine will be entered asynchronously whenever a message is queued by RSX-11M for the virtual processor. VPROC, however, merely specifies the entry point of the AST routine and then waits on an event flag. It hangs at this point until a message is received and the AST routine sets the event flag which it is waiting on. Thus when execution resumes a message has been received with the number of a module to be executed. Using the pointer in the first word of the common data area, VPROC calculates the address of the

module parameter block (MPB) for the module to be called. The pointers to the module parameters are then relocated by adding the starting address of the common data area to each pointer. The module is then called via a standard Fortran call. When the module returns, VPROC clears a flag which indicated the virtual processor was busy, sends a message with the module number back to CONTRL and then branches back to the event flag wait. VPROC's execution is suspended at that point until another message is received and the AST routine sets the event flag VPROC is waiting on.

VAST

VAST is an asynchronous systems trap routine entered whenever a message is queued for the virtual processor by RSX-11M. It first issues a receive for the message queued. The module number contained in the message is compared with the module number of the KILL command. If it is the KILL command, the virtual processor exits after sending a message to CONTRL with the KILL module number. Otherwise VAST checks to see if the busy flag is set. If so another module is currently executing and the command is rejected. If these checks are passed, the busy flag is set and the event flag VPROC is waiting on is set and VAST returns.

VIABLE

VIABLE is the module jump table and is unique to each virtual processor. The first few entries in each jump table are reserved for common test or utility modules. After these entries are the entry point addresses of the application modules.

VDATA

VDATA is the impure data area for the routines common to all virtual processors. It contains the send/receive buffer, the busy flag and several miscellaneous variables.

VPURE

VPURE is the pure data area for the routines common to all virtual processors. Its primary contents are error and tracing messages.

Miscellaneous routines.

In addition to the above there are a few utility routines to handle functions such as I/O and mapping to the common partition.

Operations

The Module Execution Sequence

The module execution sequence begins with the user searching the directory for the module node of the module to be executed (DX:[160,230] EXSRCH.MAC). A context node is allocated and made the 'current' context node by moving the number of the context node allocated to global variable CONTXT. After a module node is selected the context node will contain a pointer to the top stack node in the search stack. This top stack node will in turn contain a pointer to the module node selected. The context node will also contain a pointer to the module node selected.

The prompt interpreter (DX:[160,230]PROMPT.MAC) is then called with the number of the first prompt node associated with the module node. The number of the prompt node is obtained from the module node selected.

(Prompt nodes can specify a wide variety of actions to be performed by their associated prompt routines. What follows is a description of a 'typical' prompt chain when a single module is staged and executed.)

The first prompt node in the chain causes a prompt routine to be called which allocates a module or directory parameter block in the common data area (DX:[160,240]ALOCPB.MAC). The number of the data set node describing the parameter block is moved to the current context node.

A series of prompt nodes follow which fill in MPB and DPB values. For example space for arrays may be allocated in the common data area and the number of the corresponding data set node moved to the DPB (DX:[160,240]GETDS.MAC). Offsets within the MPB and DPB are generally constants contained within the prompt node. Actual values may be constants (DX:[160,240]LDMPBI.MAC), requested from users or obtained from some node in the directory.

Eventually the module execution prompt causes the module execution prompt routine to be called (DX:[160,240]EXMOD.MAC). This prompt routine does the following:

The ATT table is searched (DX:[160,270]ATTASK.MAC) to see if the task containing the given module is currently active (either executing a module or waiting for a command message from CONTRL). The current context node contains a pointer to the module node selected. The module node in turn contains a pointer to the task image node for the module. The task name within the task image node is used as the key in the ATT table lookup.

If the task is not active then the following actions are taken. First all active, non-busy tasks are sent messages telling them to exit (DX:[160,270]CLRATT.MAC). Second, the task containing the desired module is initiated via an RSX-11M executive request and an entry is made in the ATT table (DX:[160,270]REQUEST.MAC).

If the task containing the desired module is already active then the ATT entry for it is examined to see if the task is currently busy; i.e., currently executing a module. Unless the module being requested is the KILL module, it is an error condition if the task is busy, and, the prompt interpretations will be aborted. The KILL module is distinguished in that it must be present in every virtual processor, the module number for it

is always the same and it is the only command which may be sent to a busy virtual processor.

Next the current context node is updated with a pointer to the next prompt node in the prompt chain.

The offset of the module parameter block for the module being called is moved to the first word of the common data area. The virtual processor is also mapped to the common data area and reads this location to find the parameter block for the module it is to call. The current context node contains a pointer to the data set node for the MPB. It is from this data set node that CONTRL obtains the MPB offset.

CONTRL sends a message to the virtual processor containing the number of the module to be executed. The current context node contains a pointer to the module node selected. The module number to send is obtained from the module node.

At this point the desired module is executing and prompt interpretation must be suspended. After the command is sent, CONTRL frees the search stack (DX:[160,210]FRSTK.MAC) used in finding the module node and clears CONTXT, the current context node pointer. It then returns to its top control level, and the user is free to do whatever he likes (other than initiate the identical module again before it completes). The execution content is preserved via the ATT table and the context node pointed to from the ATT entry.

The execution sequence resumes at some later time via the following series of events. The module finishes executing and the virtual processor sends a message with the number of the module to CONTRL. Each time CONTRL returns to its top level display it checks for messages queued for it (DX:[160,230]RESUME.MAC).

When CONTRL finds the message it looks up the task name (provided with the message by RSX-11M) in the ATT. The ATT node contains the number of the associated context node. That context node is made the current context node. The ATT table entry is updated by changing its status entry to 'waiting' and by zeroing the module number and context node fields.

CONTRL checks to see if the module number received is that of the distinguished module KILL. If so the ATT node for the task is removed from the ATT table and freed (DX:[160,270]FRATT.MAC).

The number of the next prompt node is obtained from the current context node and the prompt interpreter is called to resume prompt interpretation. For an execution sequence involving only a single module, the remaining prompts might return to the common data area space which was allocated for an array of points but not entirely used (DX:[160,240]RETUN.MAC) or the prompt might free the space used by the MPB and DPB (DX:[160,240]FREEPB.MAC).

At this point the module execution cycle is complete. CONTRL returns to its top control level and awaits further commands.

Multiple Module Prompt Chain

This section presents a detailed example of a prompt chain which stages and initiates several modules. The emphasis is on how the module parameter block (MPB) and the directory parameter block (DPB) are modified by prompt routines to permit the correct staging of multiple modules. The example

is hypothetical in that only the interactive drawing module is currently incorporated within a virtual processor. However, the prompt chain used and the parameter block manipulations described are typical of a multiple module sequence. Figure 3-10 pictures the module parameter block prior to the execution of each of the modules. Note that both parameter blocks remain fixed in size and location throughout the example, though the MPB's contents vary substantially. Four modules are staged and executed by the prompt chain described in this example. The modules and their parameters are described in the next section. The prompt chain is described below. Only those prompts which manipulate the parameter blocks are described in detail. A few of the prompt routines described are not currently implemented. Such cases are noted in the discussion.

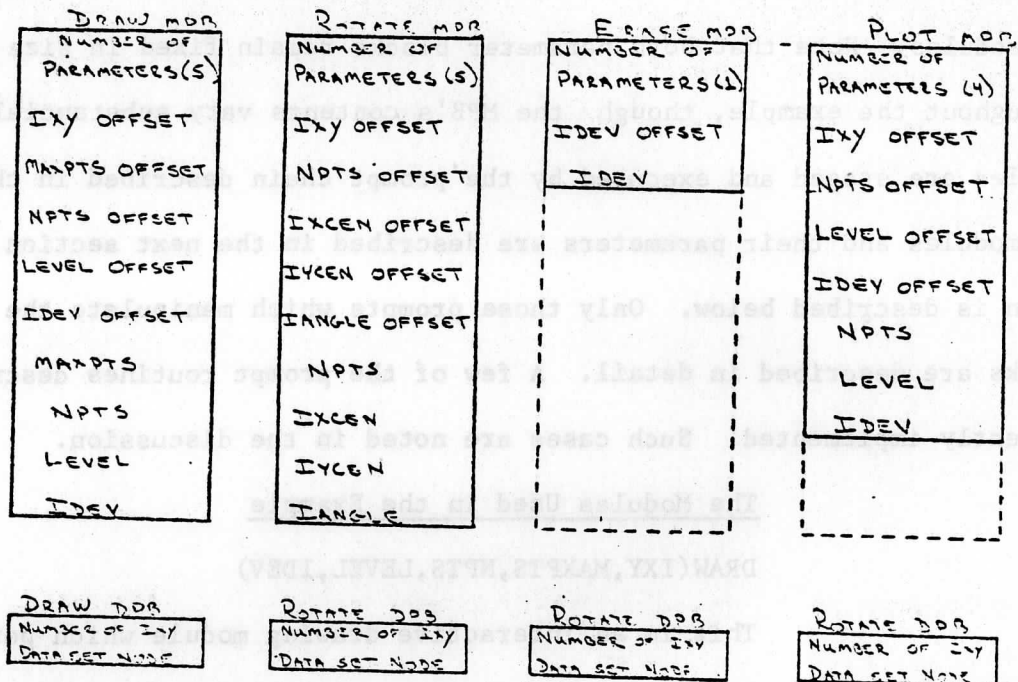
The Modules Used in the Example

`DRAW(IXY,MAXPTS,NPTS,LEVEL,IDEV)`

This is an interactive drawing module which permits a user to draw on the tablet and have the result appear interactively on a display device. The parameters required are: (1) an array to hold the points read, (2) the maximum number of points the array can hold, (3) a variable which DRAW will set to the number of points actually read, (4) the level at which the drawing will occur (for a color terminal this effectively selects the color used), (4) the display device to be used.

`ROTATE(IXY,NPTS,IXCEN,IYCEN,IANGLE)`

This module rotates the points in array IXY by the angle specified in IANGLE and about the point specified by IXCEN and IYCEN.



MODULE AND DIRECTORY PARAMETER BLOCK SEQUENCE FOR
 PROMPT CHAIN DESCRIBED IN SECTION 5 OF THE DOCUMENTATION.

FIGURE 3-10.

ERASE(IDEV)

This module erases the screen of the display device specified by IDEV.

PLOT(IXY,NPTS,LEVEL,IDEV)

This routine plots the NPTS points stored in array IXY on the display device specified by IDEV at the level specified by LEVEL.

The Prompt Chain

ALOCPB. This prompt routine allocates a 10 word MPB in the common data area.

ALOCPB. Allocates a one word DPB.

ALOCDS. Space for the array IXY is allocated within the common data area. The number of the data set node corresponding to the array is moved to the DPB and the offset of the array within the common data area is moved to the MPB.

LDMPBI. The number of parameters for routine DRAW is moved to the MPB. This routine is often used when the value of a parameter is fixed. It requires three parameters: (1) the MPB offset where the common data area offset of the value to be loaded will be stored, (2) the MPB offset of the actual value which is to be loaded, (3) and the actual value to be loaded.

LDMPBI. The maximum number of points permitted in the array is moved to the MPB as is the offset of MAXPTS within the common data area.

LDMPBI. The initial number of points, zero, is moved to the MPB along with the offset of the value.

LDMPBI. The level and its offset are both moved to the MPB.

LDMPBI. The device specification and its offset are moved to the MPB.

EXMOD. The module execution prompt routine is executed. Prompt interpretation is suspended at this point until the user is finished drawing and the virtual processor notifies CONTRL. At that point prompt interpretation is resumed with the next prompt node.

RETUN. The unused space within IXY is returned to the common data area. This prompt node contains the DPB offset of the data set node corresponding to IXY. The MPB offset of the variable NPTS is also in the prompt node. These pieces of information provide all the linkage information necessary to return the unused space to the common area.

LDMPBP. This is the first prompt node used in staging the ROTATE module. This prompt will cause the offset and the value of parameter NPTS to be loaded into the MPB. Note that the pointer to array IXY is already at the correct MPB offset. The value for NPTS is obtained from the data set node for array IXY. This data set node is located via the pointer to it in the DPB. The prompt node contains four parameters: (1) the DPB offset of the pointer to the data set node, (2) the offset within the data set node of the value to be moved, (3) the MPB offset which is to receive the common data area offset of the value and (4) the MPB offset which is to receive the value NPTS. Note that this prompt routine is specific to loading a point count since the value stored in the data set node is a word count and therefore must be divided by two. An alternative approach would be to have the routines assume they were being passed the word count. (This prompt routine has not been implemented at this point.)

LDMPBT. This routine loads the offset and value of the x coordinate of the center of rotation. The integer is assumed in this example to be entered by the user via the data tablet. The prompt node contains three parameters: (1) the number of a string node to be printed as a prompt to the user, (2) the MPB offset to receive the common data area offset of the value and (3) the MPB offset to receive the value entered by the user.

LDMPBT. This prompt loads the offset and value of the y coordinate of the center of rotation (after prompting the user for it and reading it from the data tablet).

LDMPBT. This routine loads the offset and the value of the angle of rotation after prompting the user for it and reading it from the data tablet.

EXMOD. This prompt node causes the rotate module to be executed. Again the interpretation of this prompt chain is suspended pending completion of the module's execution.

LDMPBI. This prompt begins the staging of the erase module. It causes the number of parameters, one in this case, to be loaded into the first word of the MPB.

LDMPBI. The device code and its offset are loaded into the MPB from the prompt node.

EXMOD. The erase module is executed.

LDMPBI. The number of parameters to module PLOT is loaded into the MPB.

LDMPBA. This prompt loads the offset of array IXY into the MPB. The parameter to the ERASE routine has overwritten the reference which previously existed, so the data set node for the array must be accessed. The action of this prompt routine is very similiar to that of LDMPBP except that only an offset is needed, not an actual value. The parameters within the prompt node are: (1) the DPB offset of the data set node pointer, (2) the offset within the data set node of the array's base address (with respect to the start of the common data area) and (3) the offset within the MPB which is to receive the base address. (This prompt routine is not currently implemented.)

LDMPBP. This prompt routine loads the offset and value of NPTS into the MPB.

LDMPBI. This prompt loads the offset and value of parameter LEVEL into the MPB.

LDMPBI. This prompt loads the offset and value of parameter IDEV.

EXMOD. This routine causes the PLOT module to be executed.

FREEPB. This routine causes both the MPB and the DPB to be freed, i.e., returns the space occupied by both to the common data area.

Operator Procedures

Introduction

Using the controller is very simple. All control information is entered via the data tablet. The user is prompted by the controller for information when it is needed. 'Menus' of possible options are used in several places.

The controller is initiated via the following sequence of RSX-11M commands:

1. >set /uic = [160,100]
2. >ins dkl:[160,250]VPtest
3. >run dkl:contrl

The first command sets the UIC to the one which the controller's task image resides under. The second command installs a virtual processor which the user wanted to run. The third command initiates the controller.

There are three primary means of entering control information via the tablet. Each is described below.

Menu selection. At several places the user must select one of several possible functions. The user does this via the following menu selection procedure. The controller lists the possible options on the ADDS screen. Each possible selection is on a different line of the screen.

The user uses the tablet pen to position the ADDS cursor on the line of the desired option. The user then touches the cursor control block of the tablet with the pen. (See Fig. 3-11 for a layout of the data tablet control blocks.) The controller reads the user selection and transfers control to the appropriate routine.

Entering integers. The user is often prompted for an integer value. All integers are entered in decimal via the tablet pen. Two columns just to the left of the center of the tablet are used for entering integers. These blocks are labeled one through nine, 'CR' and '-'. The user enters the desired value by touching the pen to the appropriate digits (high order digits first), then the minus sign if a negative number is desired, then the 'CR' block. The value accumulated so far at each step is displayed on the ADDS. If an error is made the user may 'back up' a digit by touching the 'BS' or backspace block near the lower right hand corner of the tablet.

Entering text. Frequently the user is asked to enter a text string. Often this is just a 'y' or 'n' in response to a yes/no question. Text strings are entered by touching the control block labeled with the appropriate character in the lower four rows of the tablet and then touching the control block in the lower right corner of the tablet. Note that digits entered as part of a text string use different blocks than the same digit entered as part of an integer. As above the 'BS' block may be used to back up a character.

User Options

When the controller begins execution it prints a menu of the major functions it is capable of performing. The user selects one of these via the menu selection procedure described above. The options at this level

[illegible]

TABLET LAYOUT AS VIEWED BY THE CONTROLLER

FIGURE 3-11.

are described in detail below.

Add directory nodes. Also see Figure 3-12.

This option permits the user to add new nodes to the directory (that is to remove nodes from free lists and initialize them for other purposes). When this option is selected the user is asked to enter an integer giving the directory page from which the node will be allocated. Next the screen is cleared and a new menu with the following options is presented.

Add string nodes. The user is prompted for a text string which will be stored in string nodes as part of the directory.

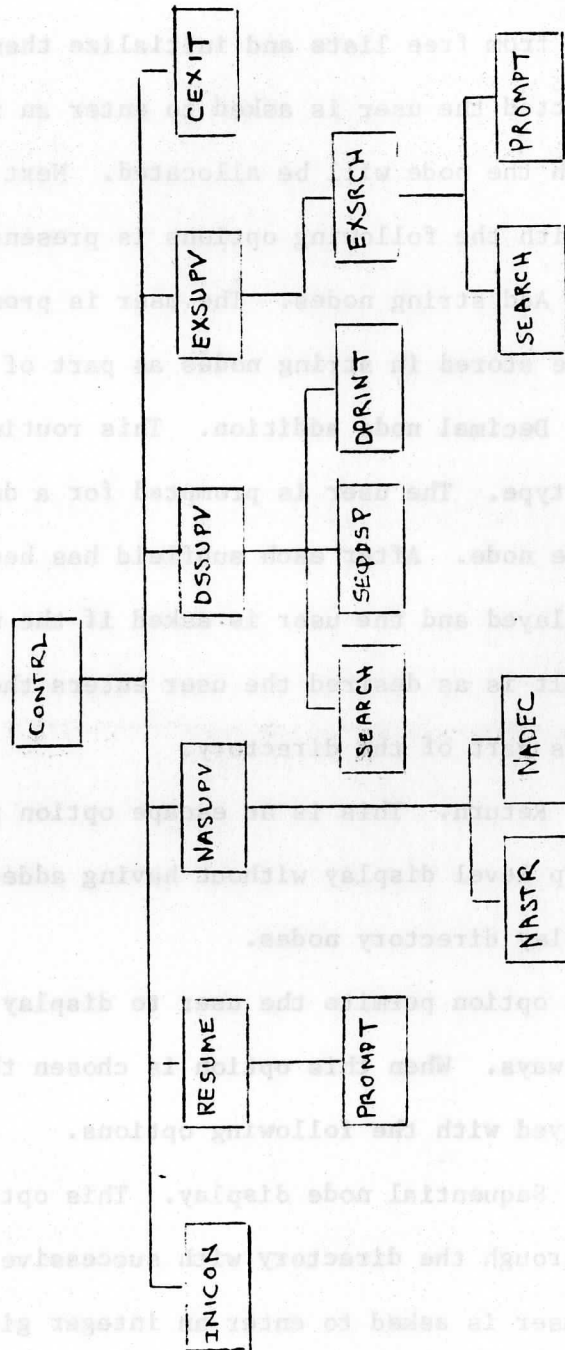
Decimal node addition. This routine permits adding nodes of arbitrary type. The user is prompted for a decimal integer for each subfield of the node. After each subfield has been entered the entire node is displayed and the user is asked if the node should be saved. If the result is as desired the user enters the text string 'y' and the node becomes part of the directory.

Return. This is an escape option permitting the user to return to the top level display without having added a node.

Display directory nodes.

This option permits the user to display the nodes of the directory in one of two ways. When this option is chosen the screen is cleared and a new menu is displayed with the following options.

Sequential node display. This option permits the user to sequence through the directory with successive nodes being displayed on the ADDS. The user is asked to enter an integer giving the number of the first node to be displayed. From then on a new node is displayed each time the user touches the integer 'CR' control block. This sequence is ended when the user enters a positive integer.



HIGH LEVEL ROUTINES OF THE CONTROLLER

FIGURE 3-12

Random node display. This function is not implemented and if selected will cause a return to CONTRL's top level.

Tree search. This routine permits the user to following links through the directory. It begins by displaying node DROOT, the directories main root node. After each node is displayed the user must select a subfield of the node and then select one of three functions. The first function is to interpret the value in the subfield selected as a node number and to display that node. The second option is to display the previous node displayed (a stack of the search path is kept which makes this possible). The third function is to return after recording the node offset chosen in the top stack node. The offset is chosen by positioning the cursor to the line with the desired subfield and then touching the cursor control block. The three functions are chosen by touching one of the three control blocks labeled 'push', 'pop' and 'return' on the left half of the tablet.

Print the directory. This selection will cause all non-free nodes in the directory to be printed on the systems listing device.

Return. This is an escape option permitting the user to immediately return to the top level.

Execute a module.

This option initiates the sequence described earlier under Virtual Processors. In brief the dialogue proceeds as follows. The user is asked to choose a module node via the tree search procedure described above in earlier section. The prompt interpreter then asks the user if tracing is desired. If the user responds with 'y', then after each prompt routine is executed the user may inspect the directory before the next prompt node is interpreted.

Exit the directory.

This option will cause the controller to exit. The user is

first asked if the directory should be written out. The user should respond 'y' if any permanent additions have been made to the directory.

Possible Future Extensions

Paged Directory

The directory was designed from the start to be paged. Here the term paged is used to indicate that most of the directory would remain on disk while CONTRL executed. Pages would be read into core only if a node on the page was actually referenced. A least-recently-used type algorithm would be used to determine which page in core would be replaced when a non-resident page was referenced. This facility can be added easily. It has not been thus far simply because the directory is small enough that all of it can reside in core at once. The changes required to add this facility can be localized to the node address calculation routine (DX:[160,110]NDADDR.MAC). This routine need only keep track of which pages are currently resident, keep page usage counts, read in pages which are non-resident and write out the replaced page if it was modified. Retaining this capability does require carefully disciplined programming of CONTRL's routines, however. A node whose address has been calculated cannot be assumed to be at that same address after any node-referencing routine has been called.

Permanent Data Files

Currently the directory keeps track of data sets only within a single execution of CONTRL. Two extensions of this capability are envisioned. First a facility for reading data sets from disk into the common data be added. This could be done initially via user supplied file names. Routines to do the reading and writing could either be added directly to CONTRL or could be made part of a virtual processor.

The second extension along these lines would be to have CONTRL permanently keep track of data sets on disk via the directory. During the

development stage this would contain potential pitfalls since disk files could be created, deleted and modified independent of the controller through RSX-11M. In a fully automated system this problem would disappear. This capability could be implemented in a manner very similar to the way in-core data sets are handled now.

Looping in Prompt Chains

At present prompt chains are interpreted in a strictly sequential fashion; i.e., no branches are allowed. A looping capability would be valuable for some applications. For example, the contouring module outputs a variable number of contour curves depending on the input data. A short prompt chain which could be repeatedly executed a variable number of times would be ideal for plotting the contours produced. This capability could be added to CONTRL in the following fashion. A 'conditional branch' prompt node would be inserted into the prompt chain at the appropriate place. Within the conditional branch prompt node would be a value representing a module parameter block offset. At the given MPB offset would be stored an integer variable. The prompt interpreter (DX:[160,230]PROMPT.MAC) would examine this variable and if it was greater than zero take the number of the next prompt node from a given location within the conditional branch prompt node. If the variable was less than or equal to zero, then the number of the next prompt node would be taken from the normal location - the last word of the prompt node. Another prompt routine or a virtual processor module would be responsible for decrementing the variable during each iteration. In a sense this is a pseudo-prompt routine because the prompt interpreter itself must do this rather than simply call a prompt routine.

The Crosspoint System

As mentioned earlier this system was designed to be highly compatible with an implementation using the crosspoint multiprocessor system.

Virtual processors correspond to LSI-11's, messages to the hardware interfaces between the PDP-11/40 and the LSI-11s, and the common data area to a crosspoint memory block. Conversion to the crosspoint system would require both a moderate number of changes to existing software and fairly extensive additions.

The virtual processor would require relatively minor changes. The module staging mechanism would be unchanged. The virtual processor task image would be moved as a single unit to the LSI. Thus the task image created by RSX11-M can remain essentially intact. The present virtual processor software would require two changes in order to make this possible. First the code to map to the common data area can be removed. The crosspoint memory blocks, which serve the same function as the common data area, would be switched under the control of CONTRL. An LSI need not be aware that memory blocks are even being switched. Second all RSX-11M system calls must be removed from the LSI controller (as the virtual processor would then be known). Basically this means replacing the I/O routines now used for tracing and error reporting by other mechanisms. Such messages could either be sent to the PDP-11/40 over the interface or the same function could be served via the updating of status codes in module parameter blocks. I/O routines for the PDP-11/40 interface would have to be written as well as routines for any other devices with which the LSI's were expected to communicate directly. However, these could be straight assembly language subroutines assembled on the PDP-11/40 and task built along with the rest of the LSI controller task image. The I/O routines for the PDP-11/40 interface would replace the present message sending and receiving mechanism used by the virtual processors.

The controller would also have to replace its message send and receive system calls by calls to I/O routines. The active task table (ATT) and related routines would probably also change substantially. The exact

nature of the change would depend on whether or not all application routines could be permanently resident on an LSI. If space on the LSI's permitted this, the issues of task initiation and termination would disappear. However, a mechanism for keeping track of the current status of the LSI's, such as currently busy or not, would still be needed. Additional bookkeeping would be necessary if it was necessary to swap code in and out of LSI's. This would also require mechanisms to load a crosspoint memory block with a task image and a utility on each LSI to move the task image to local memory.

The controller would also require a number of additions. First a processor would have to be associated with each task image. Second multiple 'common data areas'; i.e., crosspoint memory blocks, must be allocated, switched from processor to processor and generally kept track of. Related to this would be the need for a more sophisticated resource allocation and job scheduling mechanism. In a fully automated system the controller could be aware of how long different modules take to execute, opportunities for parallel sequencing of jobs and the precedent constraints inherent in jobs. A scheduler sophisticated enough to use these types of information would be highly desirable in an automated system. This area would require further study when a multi-processor system was running and ready for performance tuning.

3.5.4 Assembly Process Control

The Assembly Process takes image elements in priority order, fills them in, line-widens them, and then stores completed images on the assembler disk. The first step in the process is the allocation of disk frames for the presentation. This step is accomplished by separate modules that accept the segment and frame lists as one input and the current disk allocation as another. The allocation module then attempts to assign disk frame numbers to presentation frames. In addition to the constraint that some frames are already allocated, there is the requirement that the disk be able to seek each successive frame during the time the previous one is being shown. For anything but animated sequences this requirement represents no constraint at all since the disk heads can be moved to any track in the time between frames. Therefore every effort will be made to place animation sequences in contiguous frames. If the approach of allocating animation frames first and still frames later does not provide an acceptable allocation, then the process can indicate that certain frames should be moved to make room for the new frames. The output from the allocation consists of two arrays, one with the list of frames to be moved with their new locations and the other with the list of frame addresses that have been assigned to the new frames. If the array of frames to be moved is not empty, it is fed to an assembler move module that seeks each source frame, loads it into a bit map memory, seeks the destination frame, and then writes the image into the new frame. The frame address of each frame that has been moved is then changed in the Directory. Then the list of frame assignments from the allocation process is used to update the assembly process definition of the segments and frames so they now refer to physical frame numbers on the assembler disk.

When the allocation step has been completed, the assembly process

proper can begin. This consists of a sequence of frame numbers each followed by a list of elements arranged in order of increasing priority. Each graphic element entry contains the Directory identifier through which the element can be found, the level at which the element is to be filled in, and the fill-in control information. The fill-in control indicates whether the element is to be filled inside or outside, whether it is to be line-widened and if so by what parameters, and whether it is to be crosshatched and according to what parameters. If an element is to be both line-widened and filled in, it appears twice in the list with the fill-in done first and the line-widening second. Thus the Assembly process passes the Assembler an element and a command about what should be done with it until all of the graphic elements in the frame have been overlaid on each other.

At this point it is time to determine the placement of alphanumerics and special symbols. In some cases alphanumerics are arbitrarily placed at fixed locations on the screen. In these cases there is obviously no problem. However, there are cases where the positioning of alphanumerics must be done carefully so that underlying information is not obscured by the text. In these cases the assembler will be given a special element which indicates the bounds of acceptable placement for the particular element and the point to which the text refers if there is one. Then the assembler reads back the image until it finds a box large enough to hold the text that minimizes the presence of the pixel values that indicate underlying information. The placement of each such label is done in this way except that successive placement boxes are compared with those already chosen so one label does not overwrite another. Only when all alphanumerics have been tentatively placed are any of the locations fixed. The actual method of display for the alphanumerics is not yet clear. Characters may be generated by a separate commercial vidifont or may be written into

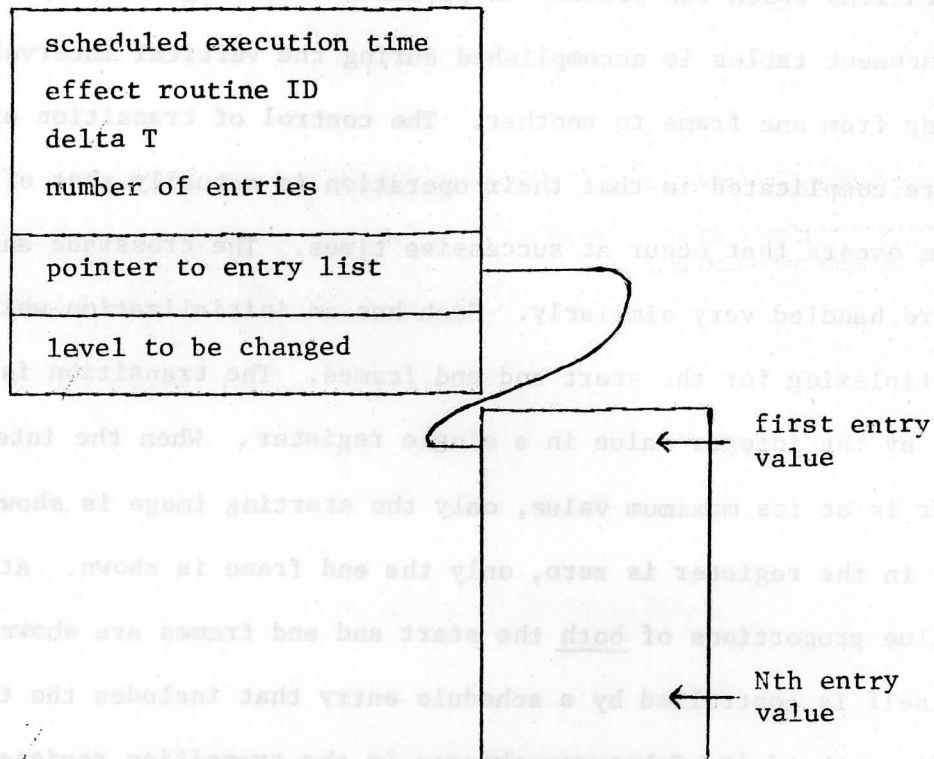
the bit maps that hold the IVAM images. In the later case the fonts for the characters would be stored in special disk frames which could be read into a free bit map memory and copied from these into the image. The copy operation would have to be able to accomplish the translation of each character from its position in the font image to that in the product image. A number of fonts can be stored in different sizes on these font frames. Since each character is really only one bit deep each of the five bit planes that store a five bit image could be used to store a different set of fonts and symbols. Thus only a few such frames would be required. After the alphanumeric characters have been handled, the finished frame is written out to the assembler disk frame allocated earlier.

3.5.5 Assembler Display Control

The display control process is responsible for the actual real-time display of color video images. It must assure that the proper frames have been loaded into the bit map memories, that the enhancement tables have been loaded with the proper color values, that the proper multiplexing control has been established for selecting the output from the desired bit maps, and finally that any special effects are accomplished. The information sent to the Assembler is essentially a schedule expressed in terms of frame times with each presentation starting at frame zero at the command of the 11/40. Then each command is executed at the time indicated. More than one command can be scheduled to occur at a given frame time. Disk seeks are initiated as far in advance as possible to assure that they are accomplished before the frame is needed. The allocation of the bit map memories used for refreshing the display is not done dynamically; it is permanently specified in the definition of the segment. The seeking of disk frames and their loading into unused bit maps

are operations which can proceed in parallel with image display. The loading of enhancement tables is accomplished during the vertical interval as is the switching from one frame to another. The control of transition effects is somewhat more complicated in that their operation is actually that of a series of discrete events that occur at successive times. The crossfade and wipe functions are handled very similarly. Each has an initialization which establishes the multiplexing for the start and end frames. The transition is then controlled by the integer value in a single register. When the integer in the register is at its maximum value, only the starting image is shown. When the integer in the register is zero, only the end frame is shown. At any intermediate value proportions of both the start and end frames are shown. The transition itself is controlled by a schedule entry that includes the transition effect identifier, the delta T between changes in the transition register, and the delta X which is to be subtracted from the current value of the transition register each time the command is issued. After the transition command is originally issued, it subtracts the delta X from the current value of the transition register and if the result is still greater than zero reschedules itself to occur again at the current time plus delta T. If the transition register has a value less than or equal to zero the transition is complete and the command removes itself from the schedules.

While not absolutely required it is desirable to be able to change enhancements dynamically during the display of an image. With such a capability it is possible to produce lightning flashes or to call attention to certain features by pulsing them. This would be done by scheduling a sequential event which would contain:



When scheduled time arrived the register would load the first entry in the entry list in the enhancement table location for the level being changed. It would then decrement the number of entries and increment the entry list pointer to point at the next entry. If the number of entries is now zero the effect is removed from the schedule, if not it is rescheduled to occur at current time plus delta T. Note that a number of such entries can be in the schedule simultaneously so different lightning bolts flash at different times.

The functions described above are sufficient to control the assembler for the display of any IVAM sequence.

3.5.6 AFOS Interface

The AFOS interface has not been completely specified at this time. The feeling of the AFOS contacts through the program has been that a final resolution of this issue is premature. However the nature of the interface re-

quirements are fairly clear even if some of the details are not. The interface takes place in three areas: control, data, and hardware.

Control

There are two essentially different modes of control relationship between the IVAM and AFOS systems. The first is the routine situation where IVAM is requesting products from the AFOS data base. The second is the exceptional situation where the AFOS operator wishes to take control of the IVAM system in order to directly communicate a severe weather situation to the public.

The routine data transfer relationship between IVAM and AFOS becomes very important because on the one hand, IVAM represents a potential load on AFOS and on the other hand, AFOS represents a potential bottleneck to IVAM. It therefore seems prudent to plan for peaks but to operate in such a way as to avoid them. One way of doing this is for IVAM to take relevant AFOS data as it comes in and not to wait until it has a real-time requirement for a given product. On the other hand, it should be recognized that a certain amount of the data will be needed quickly, for it is the nature of both IVAM and AFOS to be interested in the most up-to-date information. Therefore a high bandwidth channel should be provided even if it is not fully utilized.

In software terms there are several possible relationships between IVAM and AFOS. At one extreme IVAM is passive and AFOS notifies IVAM when new data arrives and transmits it as soon as IVAM is ready. At the other extreme AFOS is passive and IVAM continually checks the AFOS data base to see if new products have arrived. A number of such possibilities will be cited below.

1) AFOS could simply let IVAM tap off the NDC or the WSO line directly. This is not desirable because IVAM would have to monitor all transmissions to determine which were of interest. It would also have to deal with the ADCCP

protocols which have already been observed by AFOS. IVAM would rather not duplicate any part of AFOS.

2) AFOS could have a list of products of interest to IVAM and send them automatically in accordance with a fixed input schedule.

3) AFOS could send IVAM the PIL entry for each new product as it arrives and let IVAM then indicate whether it wants the message data.

4) IVAM could continually check the PIL for new products. However, while it is easy to find the latest product from the PIL it is more difficult to determine whether the "latest" entry is also a "new" entry unknown to the IVAM system as yet. To do this IVAM would have to save the last version of the PIL and compare it with the new version. Those entries in the new PIL which were not in the old PIL would, of course, be the new products.

The best IVAM/AFOS relationship probably is a combination of those listed above. Most of the traffic between the systems will be the routine automatic transmission of relevant products originated by AFOS as per option 2. The software constructs necessary to provide this service may not exist nor be natural within AFOS, in which case it may be necessary to use option 3. IVAM will maintain the list of products in which it was interested and check each new PIL entry against that list. As the deadline approached it would check to see which products had arrived and keep requesting those either until they came in or until it was too late. Thus there should be both a notification and a request capability. We prefer option 2 with a request capability to be used only for exceptions.

In addition to the software required for IVAM to make use of the AFOS data base there must be additional software to allow the AFOS operator to control IVAM. While IVAM is honestly presented as an automated system, it is but part of the AFOS system, an AFOS output processor which should be controllable

by the AFOS operator. There are several reasons this feature is desirable:

- 1) In extreme weather situations the AFOS operator may want to take control of IVAM and communicate directly to the public.
- 2) He may want to assemble his own scenario for special situations.
- 3) IVAM will be sized to handle its peak loads which will tend to occur around the times of network broadcasts. At other times IVAM may have extra computing capability which would augment that available to the AFOS system.
- 4) During the field installation process each site will have its own peculiar needs which are best met locally. Therefore, the installation operator will have to interact with the system through the AFOS terminal because IVAM will not have its own terminal. The alternative is that he bring a portable control device to address IVAM.

In all of the cases described above, systems software is required to effect the communication and control, and decisions as to where the software is to reside is not something the IVAM system can decide unilaterally. Therefore the closing of this interface would require a very significant AFOS input. It is likely that the nature of this control relationship and the request/reply protocols will be shaped more by what can be done easily within the AFOS system than by IVAM needs. Therefore it is likely that IVAM would be made to look as much like another AFOS terminal as possible, both to minimize software effort and because AFOS control structures may permit no other approach. IVAM's needs are simple: it must know what products are available and it must be able to request them.

Data

A major issue separating the two systems now is that of data availability and format. The purpose of the IVAM study was partly to determine the

feasibility of doing such a system using AFOS data. That means that part of the IVAM task is to identify information needs which are felt by the public but not met directly by the existing AFOS products. In some cases AFOS products can be processed or combined to provide the desired information; however, there do appear to be cases where the information is simply not available. Similarly there are cases where information is not available with the frequency required or on the scale needed. For instance very frequent, very local up-to-date radar information could be very effectively animated and would be very well received by the public. It was in order to discover this sort of problem that the IVAM storyboards were submitted to the AFOS group. What was requested was the identification of which products were needed to produce which segments. Since there was no response to this request, there was no way the IVAM group could make a definitive judgement about the products needed. The lists of AFOS products IVAM had received were simply not specific enough to work from.

Where the data is available there is an even more immediate problem. Much of the AFOS data is transmitted in formats which are forever beyond the reach of the IVAM software and there are other cases where changes in the AFOS data format would make our task easier.

The most important is graphics. AFOS graphic products are planned to be transmitted in a form that is directly compatible with the AFOS display devices; however, the significance of the parts of the image is lost in the transmission format. The alphanumeric information labeling the contour curves is transmitted separately from the curve itself. This works fine for AFOS because the label is placed near the curve by the display and the operator makes the association. But for IVAM to try to determine which label goes with which curve on the basis of position is a very elaborate process which is not guaranteed to succeed and could be easily avoided. This information is available in

the programs at NMC and is not planned to be transmitted because there is no need in AFOS. It would be easy to include the labels with the curves.

In informal discussions with members of the AFOS Program Office, the advantages and disadvantages of transmitting graphic data in the variable exclusion vector code were discussed. Sending the basic uniform grid point values in an optimized (i.e., redundancy removed) code should be considered as an alternative. Based on the limited information available to us, the advantages of this approach could be:

- 1) Greater efficiency because the message length might be reduced by a factor of two to four.
- 2) Greater commonality because uniform grid values can be used by any graphics generation process while the variable exception vectors and other encoding techniques used by AFOS are peculiar to their system.
- 3) Much more convenient to IVAM which must now add software to convert the vector code whereas we could use grid point values directly.
- 4) Reduced effort at NMC since it would not have to convert grid point values to vector code.
- 5) More useful to the rest of the meteorological community, all of which is interested in computer processing of AFOS data.

The only disadvantage would appear to be the need to augment the AFOS display software to generate displays from grid point data. We are not able to assess the impact on AFIS, but it might even be an advantage since the necessary software is available from several sources.

There is also a class of products which are transmitted as unformatted English text. While these items are conceived as communication between human operators they present a problem to an automated system which must substitute software for intelligence. The more of this information that can be constrained

to fixed formats the more will be usable by the IVAM system.

Once AFOS data has been organized into products that can be interpreted by the IVAM software, then it would be necessary to write additional software to translate them into a form suitable for IVAM. This is necessary because of the difference between the AFOS data base and the IVAM data store. AFOS currently thinks in terms of messages designed to communicate directly with a human operator through a high resolution CRT display. IVAM, on the other hand, must automatically take data designed for professional meteorologists and turn it into displays which communicate to the lay public over standard TV. This means that IVAM must take data out of its message format and disassociate it from its source, such as Service A or Service C, and just present the weather quantities the public understands.

Also, graphics products which are encoded in terms of the raster characteristics must be decoded from their AFOS 1000 pixel resolution vector format, translated into the IVAM standard coordinate space, and rescanned by a 525 x 672 raster. Some sort of smoothing function may be required if the two digitizing steps interact in an unfavourable way.

Thus for each type of product it will be necessary to write an IVAM module which is specialized to the reformatting task converting into the form needed by IVAM. In the cases where the formats of these products have been specified and the specifications not changed over a period of time, it would be possible to write the conversion modules. However, such code would be untestable until IVAM either had test data to work from or was on line with AFOS. While such test data has been requested a number of times, none has been received. Therefore, no progress could be made in the processing of actual AFOS data. However, the process of translating data from one system to the other is completely independent of much of the rest of the IVAM task and the control struc-

tures needed to control the process exist.

Hardware

There are a number of points where IVAM could physically interface to the AFOS system. The trade-offs here are speed versus the existence of software support for certain interfaces. To some extent the hardware options parallel the software options mentioned earlier.

However, it seems most likely that IVAM will interface directly to the AFOS graphics bus and appear to be another operator's display. This seems to be a relatively natural interface because IVAM could simulate an AFOS operator and would get data without maintaining any elaborate communication protocol.

Summary

The AFOS/IVAM interface must meet the following criteria:

- 1) It must provide IVAM complete "read only " access to the AFOS data base.
- 2) The AFOS data must be in a form which is usable or translatable by a computer program.
- 3) Annotation should be available with graphic products so IVAM can determine the significance of each of the graphic elements.
- 4) The control interface between AFOS and IVAM needs to be defined.
- 5) The data interface should be a high bandwidth DMA channel such as the interprocessor or graphics channels.

Scanner's note:

This page is blank.

4.0 Hardware Concept Study

4.1 The IVAM System

4.1.1 Overview of System Requirements

The functional requirement of an operational IVAM system, stated in broadest terms, is to ingest meteorological data from various sources, and process these data to generate TV segments of weather information for distribution to TV outlets. System programs provide the capability of easily selecting program content, format, and production schedule from a wide variety of options.

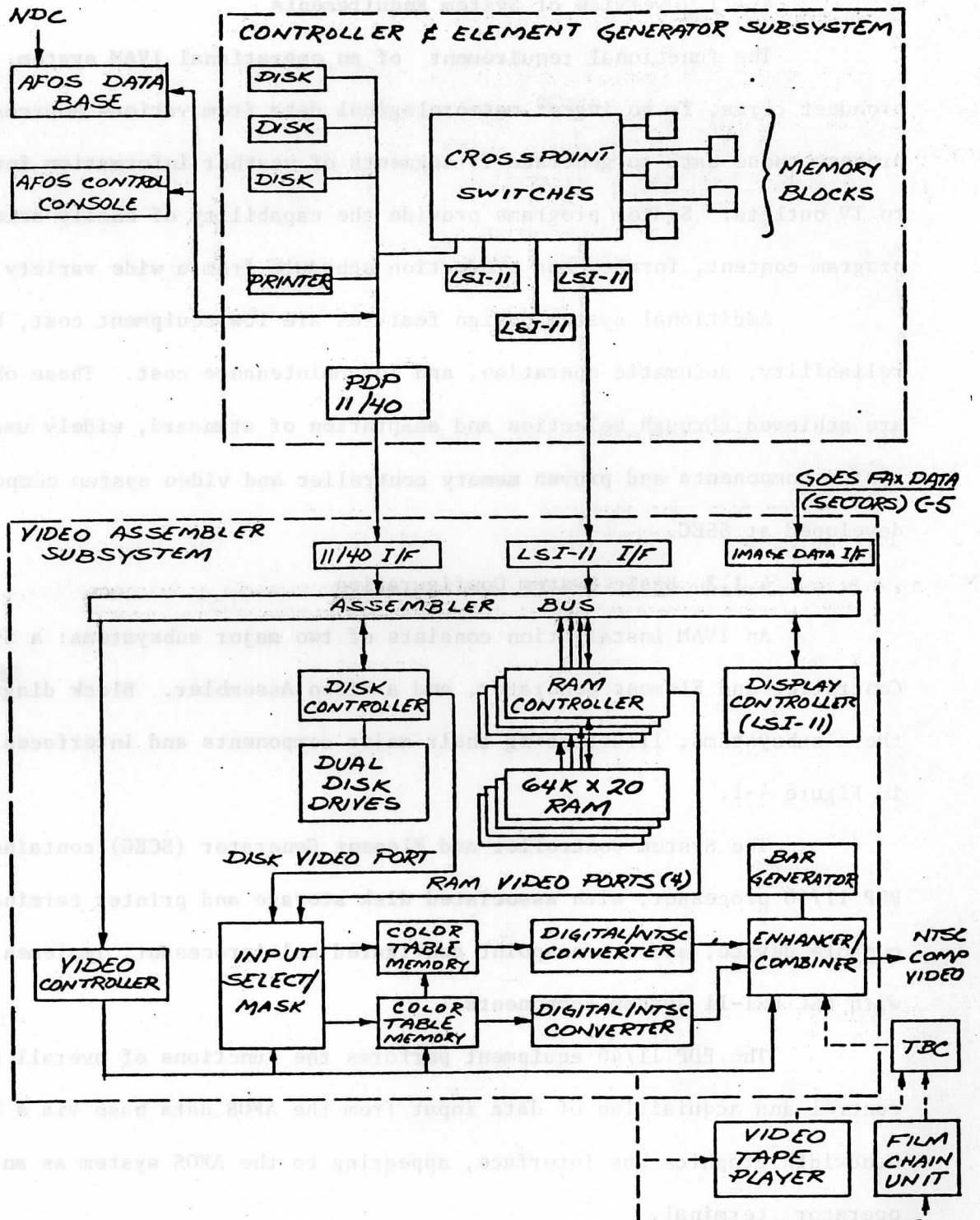
Additional system design features are low equipment cost, high reliability, automatic operation, and low maintenance cost. These objectives are achieved through selection and adaptation of standard, widely used computer system components and proven memory controller and video system component designs developed at SSEC.

4.1.2 Basic System Configuration

An IVAM installation consists of two major subsystems: a System Controller and Element Generator, and a Video Assembler. Block diagrams of these subsystems, illustrating their major components and interfaces, are shown in Figure 4-1.

The System Controller and Element Generator (SCEG) contains a DEC PDP 11/40 processor, with associated disk storage and printer terminal console device, and a crosspoint configured multiprocessor, implemented largely with DEC LSI-11 system components.

The PDP 11/40 equipment performs the functions of overall system control and acquisition of data input from the AFOS data base via a high-bandwidth graphics bus interface, appearing to the AFOS system as an additional operator terminal.



IVAM SYSTEM BLOCK DIAGRAM

FIGURE 4-1.

The crosspoint multiprocessor, which may contain up to eight processor buses and 16 memory blocks, performs the tasks of image element generation, manipulation (scaling, mapping, etc.), scan conversion, prepass, and sorting into raster-scan order.

The Video Assembler provides the resource for final processing and assembly of SCEG-generated image elements into completed TV frames, storage of these elements and frames, and generation of the output TV segments. In addition, the Video Assembler ingests and stores satellite image data received from CDDS facsimile lines.

To accomplish these functions, the Video Assembler utilizes RAM buffers with "smart" controllers, a pair of modified large-capacity computer disk drives, and a video chain and controller. A Display Controller provides overall control of these components in the display mode of operation. The system configuration and capabilities meet all display requirements defined for IVAM segments.

4.2 System Requirements

4.2.1 Data Input Interfaces

The IVAM system is planned to interface with up to four input data sources--AFOS, CDDS Sectorizer lines, a video tape player, and a film chain. AFOS will interface with the System Controller; the other sources will be interfaced to the Video Assembler.

1. AFOS Interface

Of the several hardware interface possibilities considered for AFOS the method of choice is the interface with the AFOS graphics bus. This interface, simulating an AFOS display terminal, provides adequate bandwidth for IVAM needs. If coupled with a "request only" mode of IVAM operation, this interface should introduce a negligible impact on AFOS system operation or software. No development work was undertaken for a PDP-11/40 interface module which meets the AFOS graphics bus specifications.

2. CDDS Interface

The CDDS line, providing sectorized GOES image data in facsimile format, interfaces to an Image Data input module on the Video Assembler bus.

The capability of the Video Assembler disks to store over 800 frames of TV data affords the capacity to store all of the image data required for segment productions. An external system to provide storage and TV output of satellite image data is not needed. Other advantages which result from this approach are:

- a) A simpler interface, consisting of the telephone fax line only. There are no problems of synchronization and control of an external image data TV display terminal.
- b) The image data is always accessible to the IVAM Controller, and, therefore, allows generation of cloud graphics from the data.

The Image Data interface is a low-cost, microprocessor-controlled module which receives, demodulates and digitizes the image data, and resectorizes the data to a 512 x 512, 5-bit pixel format for TV display.* It is functionally similar to the Fax Receiver and Sectorizer subsystems of the Satellite Image Sequencer developed for NESS, but the system design has been improved to: (1) allow multiple TV frames with the same or different resolutions to be extracted from each sector input, (2) provide continuous AGC control, and (3) provide more accurate lock to the fax data line starts to yield improved frame-to-frame data registration.

3. Tape Recorder and Film Chain Interfaces

Film and tape pre-recorded video is fed directly to the Enhancer/Combiner output module of the Video Assembler to be directly outputted without processing by the IVAM system. A single time-base corrector is used to correct the video from either of these sources.

Both the film and tape units must be capable of single-frame edit, so these outputs may be merged precisely with IVAM-generated video. Control signals for these units are supplied from the Video Controller, in the video output section of the Video Assembler.

4.2.2 SCEG Processing Requirements

The major tasks of the System Controller and Element Generator subsystem are to:

- a) Program and control the entire IVAM system
- b) Acquire the meteorological data from the AFOS data base and prepare it for IVAM processing
- c) Generate graphical image elements required to describe meteorological

*Note that sampling and readout timing are selected to yield pixels with a 4/3 aspect ratio. Hence, the 512 x 512 memory space holds an image which, when read out of the IVAM system, meets NTSC picture format.

parameters, maps, contours, etc.

- d) Convert the information from image element format to sets of image element/TV raster line intercept designators
- e) Merge the element/line intercept sets corresponding to final TV frames, including performing the operations of line-widening, alphanumeric placement and fill-in
- f) Store completed TV frames and element sets needed for future use to the Video Assembler disk file
- g) Program the Video Assembler Display Processor with segment presentation instructions

The control task is continuous but it never becomes a large-scale job in comparison to processor load. It is the image element production that determines the size of this part of the system. Weather information enters the AFOS data base continuously with specific message formats being repeated at periods of one, three, six, twelve, and 24 hours. Some information, such as emergency notices, will be received on a non-scheduled basis, but these are exceptions. Since the IVAM controller anticipates these scheduled input times, and because it knows what the system must produce during the next several hours, it schedules the production of image elements at a steady, nearly uniform rate. In this way, the basic image parts are produced most economically and then stored on the SCEG discs in a form which takes minimum space until needed by the Video Assembler.

4.2.3 Video Assembler Requirements

The Video Assembler must perform two primary functions:

- a) The generation of broadcast-quality TV output on a real-time basis from a store of image and graphics, as directed by a display control program, and
- b) Final processing, merging, and storage of raster - coordinate image elements for subsequent display.

In addition, the Video Assembler ingests and stores satellite image data from CDDS facsimile line outputs and provides control of external tape or film-chain TV sources.

The Video Assembler Subsystem contains a digital disc memory, capable of storing 815 TV frames of data, four one-frame random-access memories (RAM), a display controller, and video chain which converts the digital video inputs from the disc and RAM to NTSC video output.

The Video Assembler operates in two modes - assembly and display. In the assembly mode, the disc and memory resources are controlled directly by the System Controller via the 11/40 Interface. Image elements are transferred to RAM from the element generator through the LSI-11 Interface where final processes of line widening, fill-in, and combining are performed with bit-slice processors contained in the RAM controllers. Completed TV frames are then transferred to disk for later display. Instructions for display of a prepared segment are loaded to the Display Controller memory.

In the display mode, the Video Assembler operates essentially "off-line" from the SCEG - the disk and memory resources have priority and are largely utilized in the generation of the segment TV display. The output of the disk, as well as the contents of the RAM, are available in exact TV timing format at their Video Port outputs. Port outputs are selected for the desired display at the Input Select/Mask stage of the video chain. Concurrent with supplying data at a video port, disk data may be simultaneously transferred to RAM via the Assembler Bus. By appropriately utilizing RAM's as frame buffers, any desired sequence of displays may be generated, such as consecutive cross-faded satellite images, each with its own graphics overlays. The video chain provides two processing channels in which the digitized input is remapped to desired color values and converted to NTSC video format. These channel outputs, as well as output supplied

from a tape or film source, are applied to an Enhancer/Combiner which selects the sources, provides transition control (pop, fade-in, fade-out, crossfade), and performs edge enhancement to the final video output. The subset of display instructions which control operation of the video chain are applied to the Video Controller, which generates the required sequences of control signals and codes at the exact times within the TV frame period necessary to maintain a defect-free display.

At all times, during either display or assembly modes of operation, the Video Assembler accepts and stores satellite image data input via the Image Data Interface.

4.2.4 System Throughput Requirements

It is easier to work backward through the IVAM system since the output rate is firmly determined at 30 frames per second and the output volume is relatively well-fixed at 20 minutes of TV segments per hour. The 20 minutes are made up of one full update of cable TV presentation (5 minutes) per half-hour and up to ten minutes of segments to be sent to broadcast stations per hour. The total output of frames is:

$$20 \text{ minutes} \times 60 \text{ seconds/minute} \times 30 \text{ frames/second} = 36,000 \text{ frames}$$

Previous studies of simulated IVAM presentations and similar TV programs showed that each TV frame is repeated from 6 to as many as 120 times. At six repetitions per frame, the Video Assembler subsystem must be capable of generating display at a peak rate of 5 new frames per second, although it is capable of operating at least 15 frames per second. The average new frame rate will be much lower.

If we examine TV graphic images, we find that the most complex average fewer than 20 image element intersections per TV line. Using one word for each element/line intersection, the maximum number of words required to describe

a set of image elements for one TV frame is

$$485 \text{ lines} \times 20 \text{ crossings/line} = 9700 \text{ words/frame}$$

Since frame assembly is performed as an off-line process, the throughput rate to the Video Assembler need not proceed at the peak rate of 9700 words/frame \times 5 frames/second = 48.5K words/second, 2K words/second as shown in the following analysis).

The rate at which new sets of image element/raster line intersects must be generated is the product of the following factors:

- 1) Element generation can be going on continually whereas the Video Assembler will operate only 20 minutes per hour. This fact lowers the data rate of the output of the Element Generator by a factor of 1/3.
- 2) The rate of element generation is determined by the average number of times a frame is repeated, not the minimum number. Experience with the IVAM films has shown that on the average each frame is repeated 25 times, reducing the element generation rate to 1/25 that of full video.
- 3) While the TV images delivered to the broadcast nets will appear to be quite different from those sent to the cable TV outlets, many of the images in both sets will be generated from the same element/line intercept sets. Also, each hour's presentation will include images from data more than one hour old. It is estimated that these two factors reduce the new frame production rate by at least 1/3.

Therefore, the total number of new output frames to be computed each hour is:

$$36000 \text{ frames/hour} \times 1/25 \text{ (average repetitions per frame)} \times 2/3 \text{ (previously generated frames)} = 480 \text{ new frames per hour}$$

or equivalently, an average of one new frame every 7.5 seconds.

Since the Video Assembler is available for assembly processes 40 minutes of each hour, one new frame must be assembled every five seconds, requiring an average data transfer rate of data from the SCEG of:

$$9700 \text{ words/frame} \times 1/5 \text{ frame/sec} = 1.94\text{K words/sec.}$$

The Controller and Element Generator subsystem design allows for operation at this rate.

The Video Assembler must have the capacity to store all of the finished sets of image element/raster line intercepts; i.e., processed to completed TV frames needed for display generation. The total of these sets will be very close to the following:

480 frames one hour old or less

120 frames one to six hours old

60 frames six to 48 hours old

20 frames of "permanent" images

680 total TV frames

Assuming a worst-case 20 minutes of continuous display time, during which SCEG intercept sets cannot be transferred to the Video Assembler, approximately 160 TV frames of generated intercept sets must be stored on the SCEG disks.

The maximum number of words per set is 10,000 and the minimum is about 2,000 with the average being close to 6,000 words. Therefore, the SCEG disc must have capacity for:

$$160 \text{ sets} \times 6,000 \text{ words} \times 2 \text{ bytes/word} = 8.16 \text{ megabytes}$$

for intercept set storage.

4.3 Development System

4.3.1 Design Objectives

Goals defined early in the program for an IVAM development system were:

- 1) Flexibility to allow an optimum interface definition between AFOS and IVAM.
- 2) Flexibility for a good interface of IVAM to the media when the specifics of distribution would be confirmed.
- 3) Desire maximum advantage from latest developments in new hardware technology.

A further consideration stated was that the software developed must not be limited to running on the machine of a single manufacturer, but the hardware choice must also allow development of general software which runs (or can be easily adapted to run) on any machines of appropriate power.

The PDP-11/40 and LSI-11 based multiprocessor were selected as most appropriate for the task as System Controller and Element Generator and were procured to develop and test software. In addition, hardware and software interfaces with SSEC's McIDAS system to utilize that system's capabilities as a data source and video and graphics display device, pending design and procurement of a Video Assembler which meets IVAM display requirements.

4.3.2 SCEG Development Hardware Study

Several hardware configurations were studied for use as the development system. Since the exact size of the system needed could not be determined until the software was developed, the subject of expansion capability was carefully considered to ensure that the final system would have the capability of performing 100% of the required task.

The single processor approach was abandoned early in the study, for

the only guarantee of having adequate system capacity with a single computer was the choice of a computer exceeding the budget. Further arguments against use of a large single computer were: (a) the inability to implement the final hardware in incremental fashion, and (b) far less likelihood of rapid decline of the purchase price in the next several years.

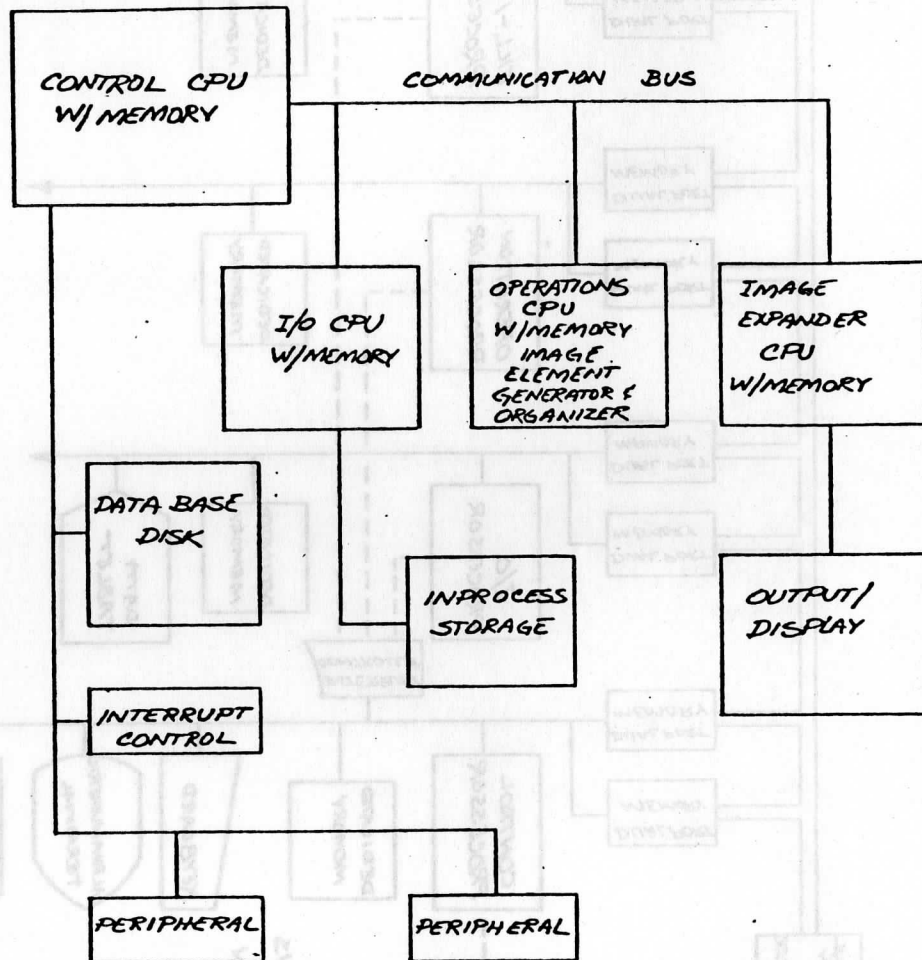
Two basic configurations discussed below, and variations of them, were analyzed in detail.

4.3.2.1 Data Communication Bus

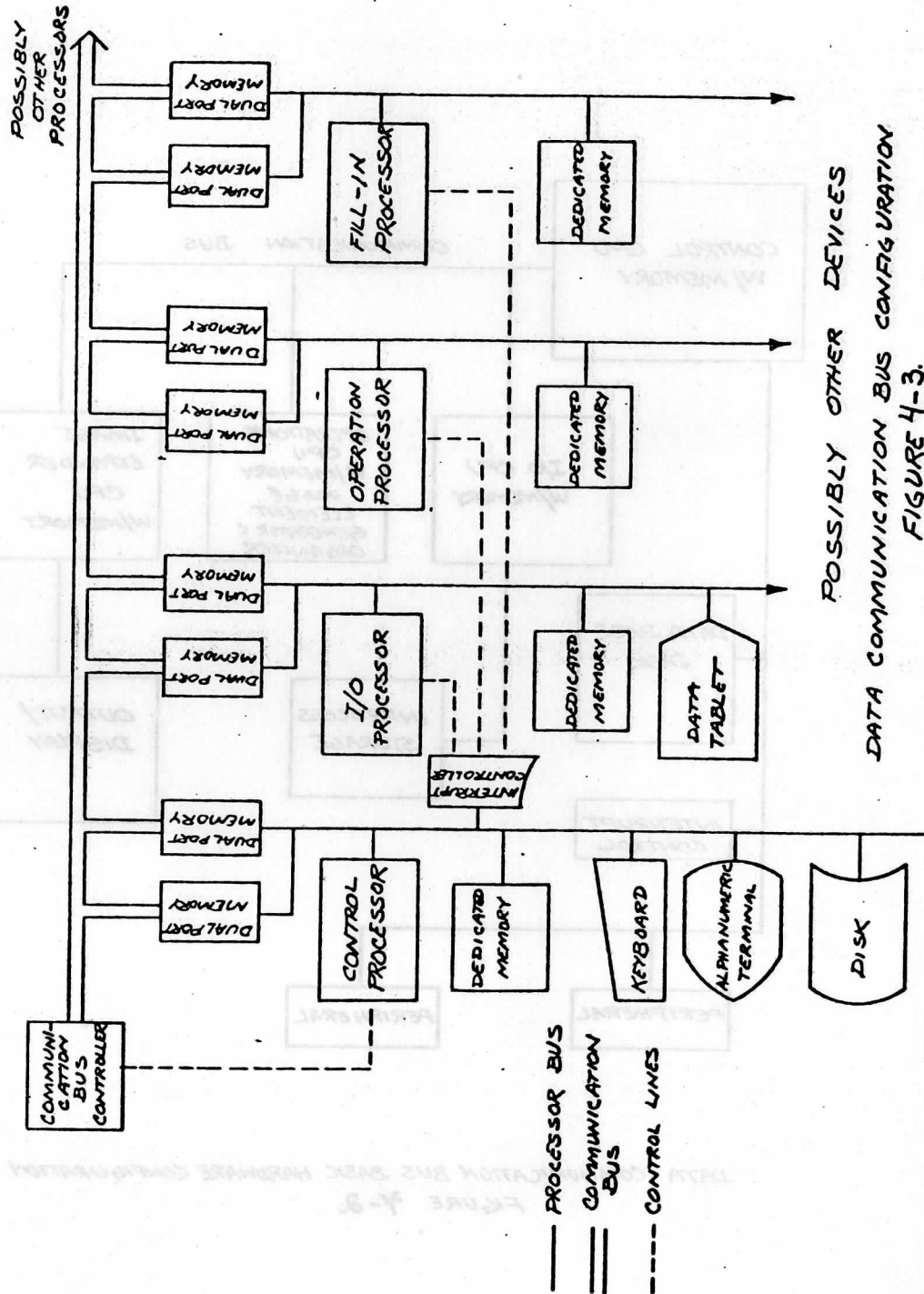
The basic Communication Bus configuration, shown in Figure 4-2, is designed to have at least four processors configured to allow transfer of data between any two of them. The system is expandable to accept additional processors, memory, or hardware devices as needed.

Since the ratio of data transfer to processing is expected to be high, the design of the interprocessor communications is of crucial importance to the performance of the system. Such transfers consist mainly of block data rather than individual words so it is not necessary for all processors to share a common address space. Data transfer is initiated by the control computer but may actually be effected by a microprocessor or a hardwired bus controller. Since this process may involve more than one computer, it is imperative that the transfer process not interrupt or degrade the processing of any machine more than necessary. Several alternative approaches, all based on the Communication Bus concept, were considered:

a. Approach #1: The first approach, shown in Figure 4-3, furnishes each machine with at least two dual port memories as well as a small amount of dedicated storage. Each dual port memory is accessible to both its CPU and to the communications bus. Since the dual port memories on each



DATA COMMUNICATION BUS BASIC HARDWARE CONFIGURATION
FIGURE 7-2



processor are independent, the CPU can work in one memory while the communication bus fills the other. When the CPU has done its task in one memory it signals the controlling processor and starts working in the other memory. Note that the transfer does not impede or degrade the performance of the CPU.

In this configuration it is desirable that the amount of memory accessible by the communication bus not be constrained by an arbitrary limit. It is worth noting that "dual port" here refers only to the ability to reference the memory from two different buses. This can be accomplished by simple electronic switching between the two buses or by true dual porting, where the memory has two independent sets of addressing hardware.

b. Approach #2: The communications computer has the pair of dual port memories associated with each of the subordinate processors within its address space as shown in Figure 4-4. In this case the transfer of data from one machine to another is seen as a block transfer within the communications machine. Note that the transmission of data from machine B to machine C operates at program rates and may "steal" machine A cycles of up to 50%. However, if machines B and C are operating in their other dual port memories they are unaffected. Since a minicomputer having a large address space is likely to be more expensive, this alternative seems less desirable than the first approach.

c. Approach #3: In using a machine with an extended address bus as the communication controller, at least that processor is lost to the system during transfer. Therefore, the question arises whether that machine can still accomplish functions other than data transfers. One way of relieving the communication burden on the computer whose bus has access to every machine's memory is to create an additional interprocessor path that is dedicated to

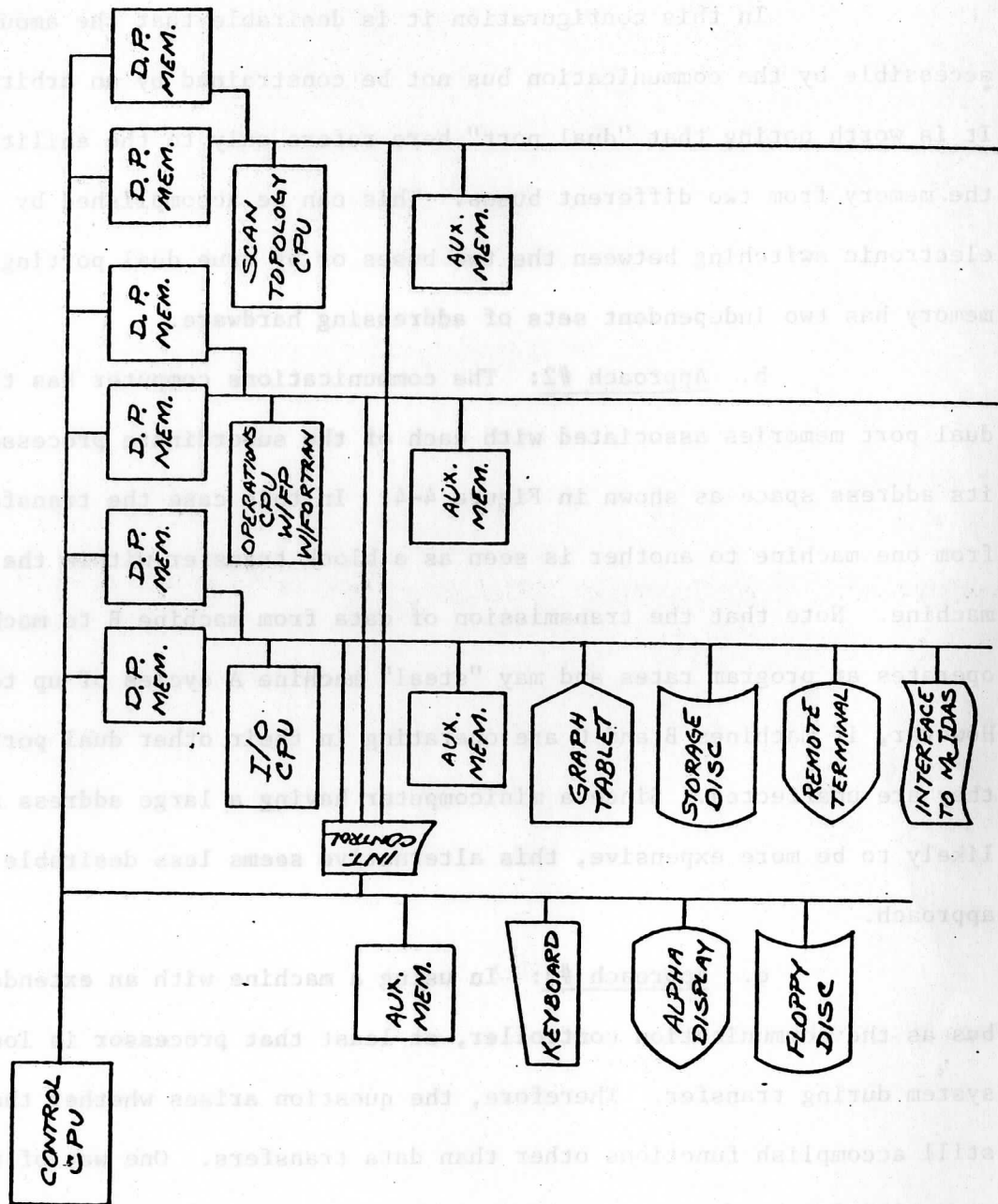


FIGURE 4-4

transfers between two of the machines, as shown in Figure 4-5. This lowers the volume of traffic along the main bus. However, the software in those machines must be more sophisticated.

d. Approach #4: Approach #2 is modified by using only one dual port memory per subordinate processors as in Figure 4-6. In this case the interprocessor transfer further degrades the system in one of two ways. If the subordinate processor is operating within its dual port memory, its processing is degraded and perhaps precluded by the cycle stealing of the transfer. On the other hand, if the subordinate processor is executing within a dedicated memory, some overhead would be incurred when it moved its data to that memory.

e. Approach #5: Each of the computers is fitted with conventional single port memory and a standard DMA channel as in Figure 4-7. The communications processor then has a second back-to-back with each of the other processors. The first step is a DMA transfer from machine B to the communications processor which would degrade that machine's performance.

f. Approach #6: A special DMA processor is used, as shown in Figure 4-8. This option again assumes that each of the subordinate processors has its own DMA. Then a path is established by tying the output of the DMA from one machine into the input to the DMA for another. In this case, a transfer from machine B to machine C is a one-step process which would degrade both machines simultaneously, but would not require the communication processor to have its own storage.

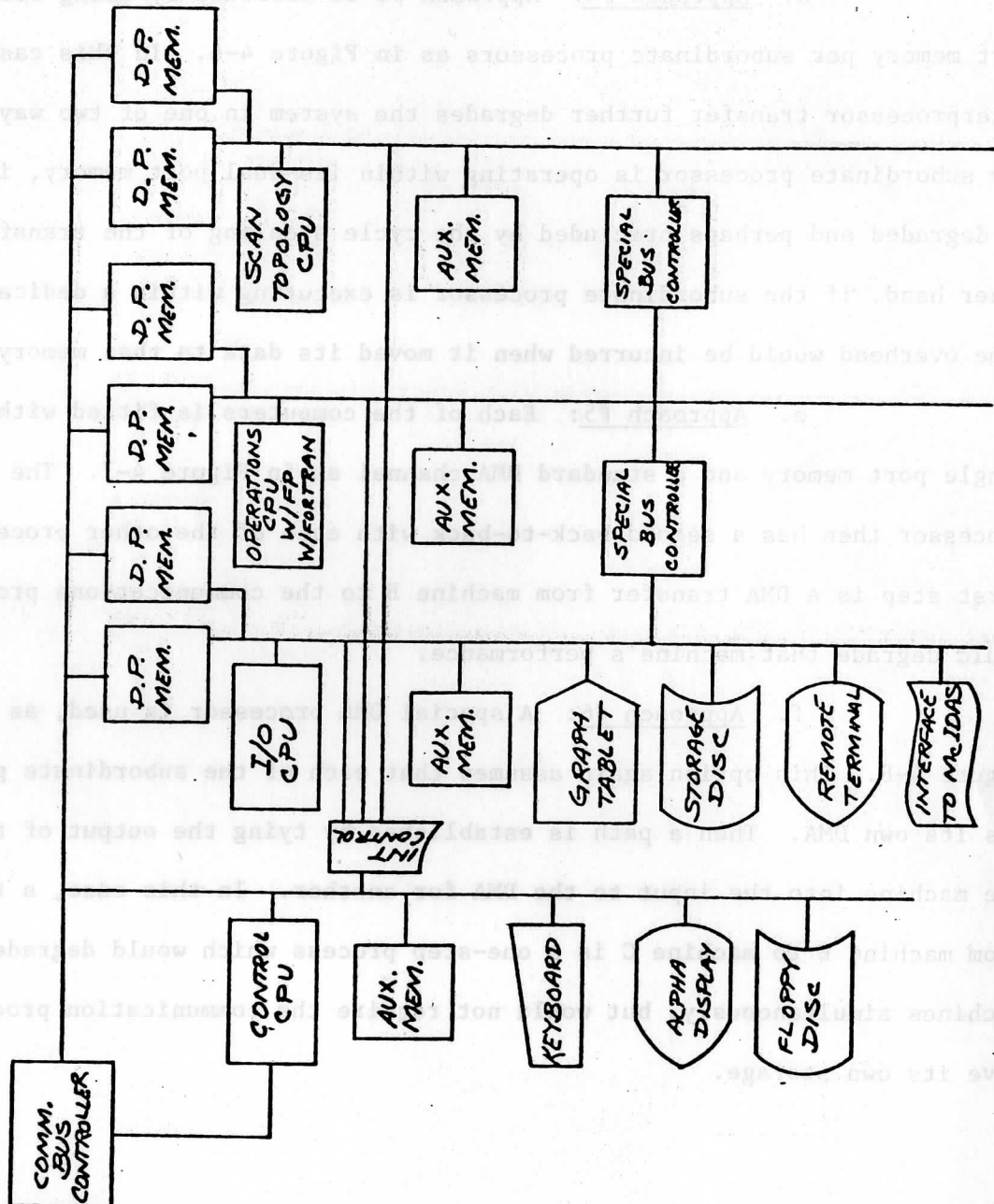


FIGURE 4-5

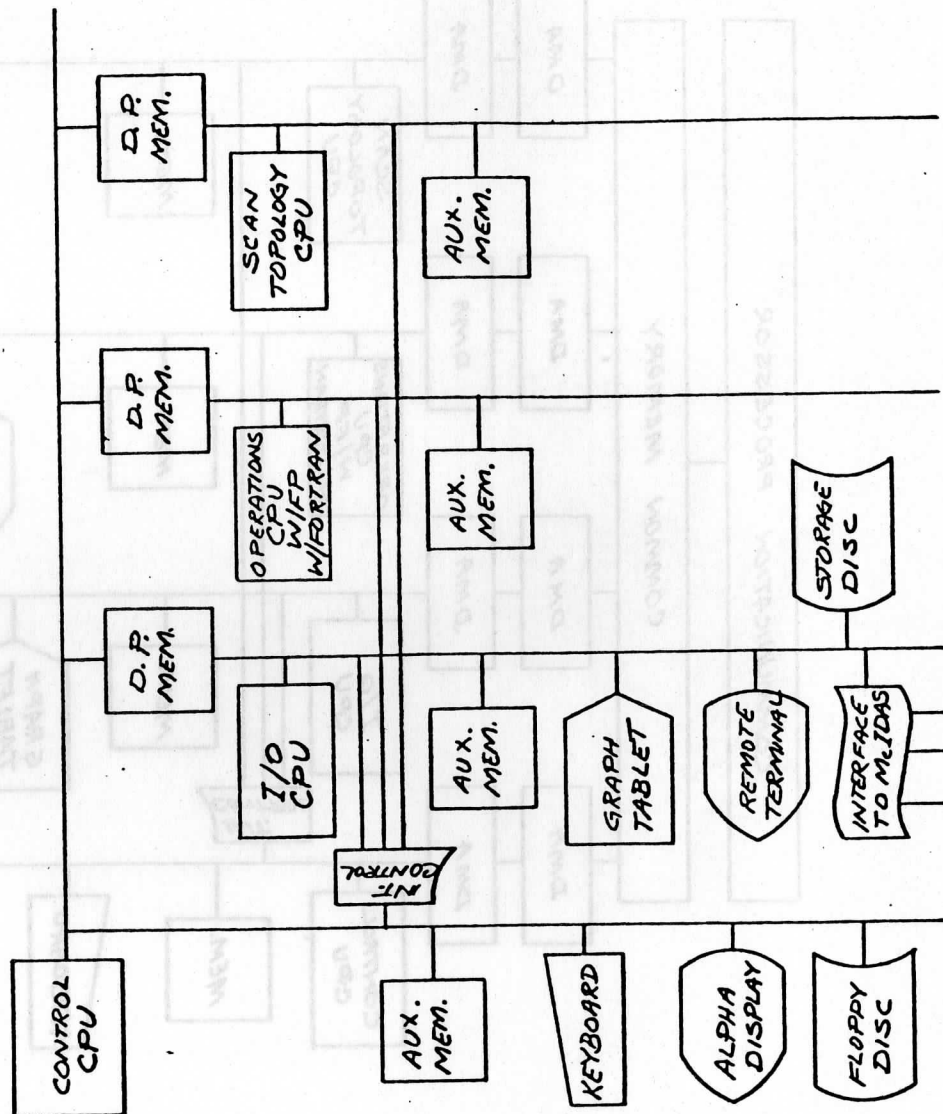
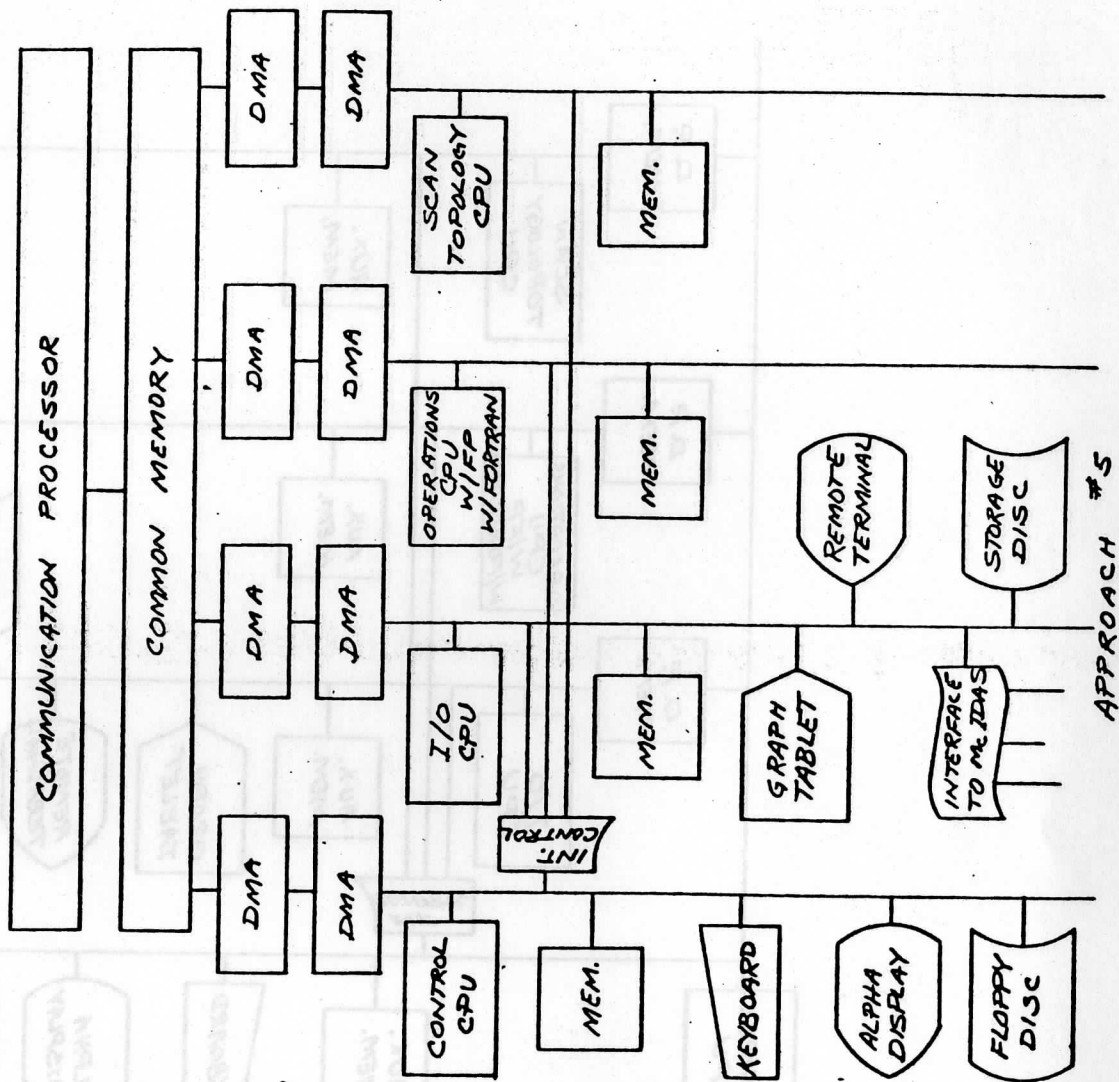
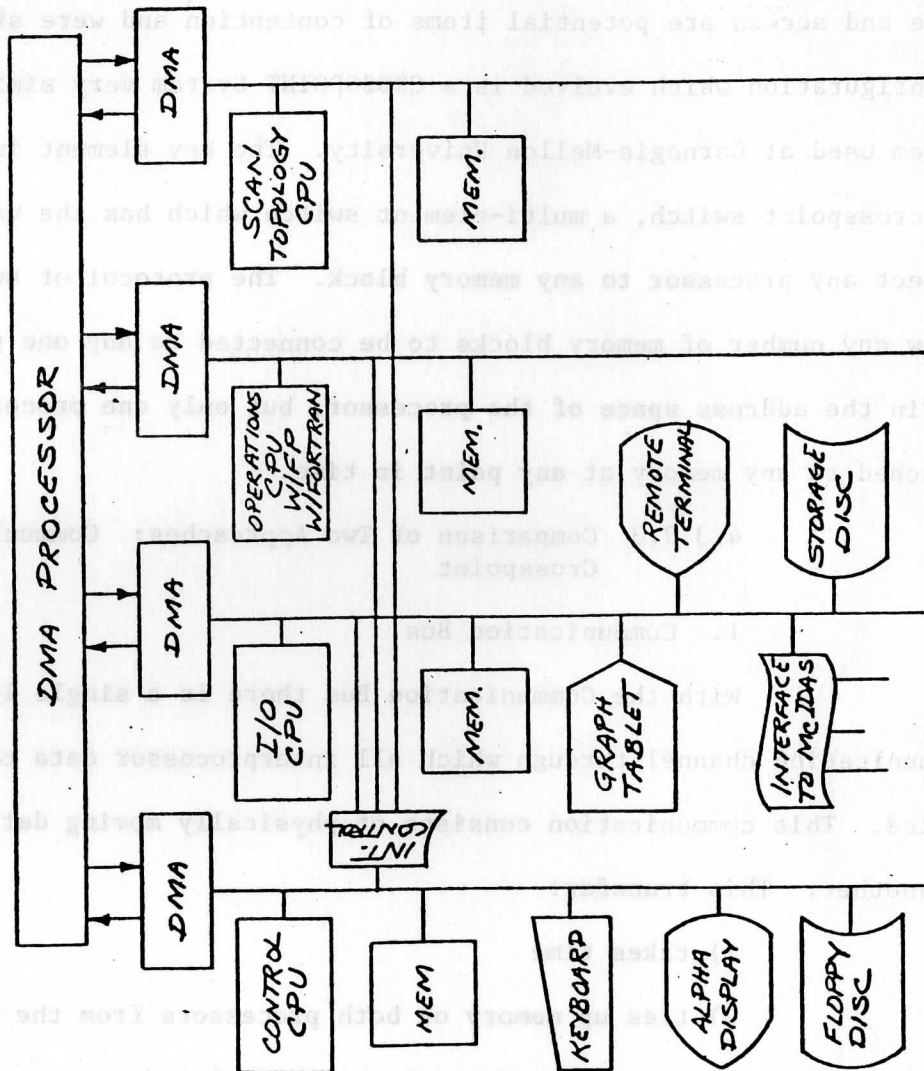


FIGURE 4-6.



APPROACH #5
FIGURE 4-7.



APPROACH #6

FIGURE 4-8.

4.3.2.2 Crosspoint Memory Approach

Since the nature of the data processing is more one of manipulation and formatting rather than actual processing, a method of memory pooling was investigated, as shown in Figure 4-9. Each processor has a dedicated memory in addition to the access to the common memory. Address space and access are potential items of contention and were studied in detail. A configuration which evolved is a CROSSPOINT System very similar to the HYDRA System used at Carnegie-Mellon University. The key element in the system is the crosspoint switch, a multi-element switch which has the capability to connect any processor to any memory block. The protocol of switching allow any number of memory blocks to be connected to any one processor, within the address space of the processor, but only one processor can be attached to any memory at any point in time.

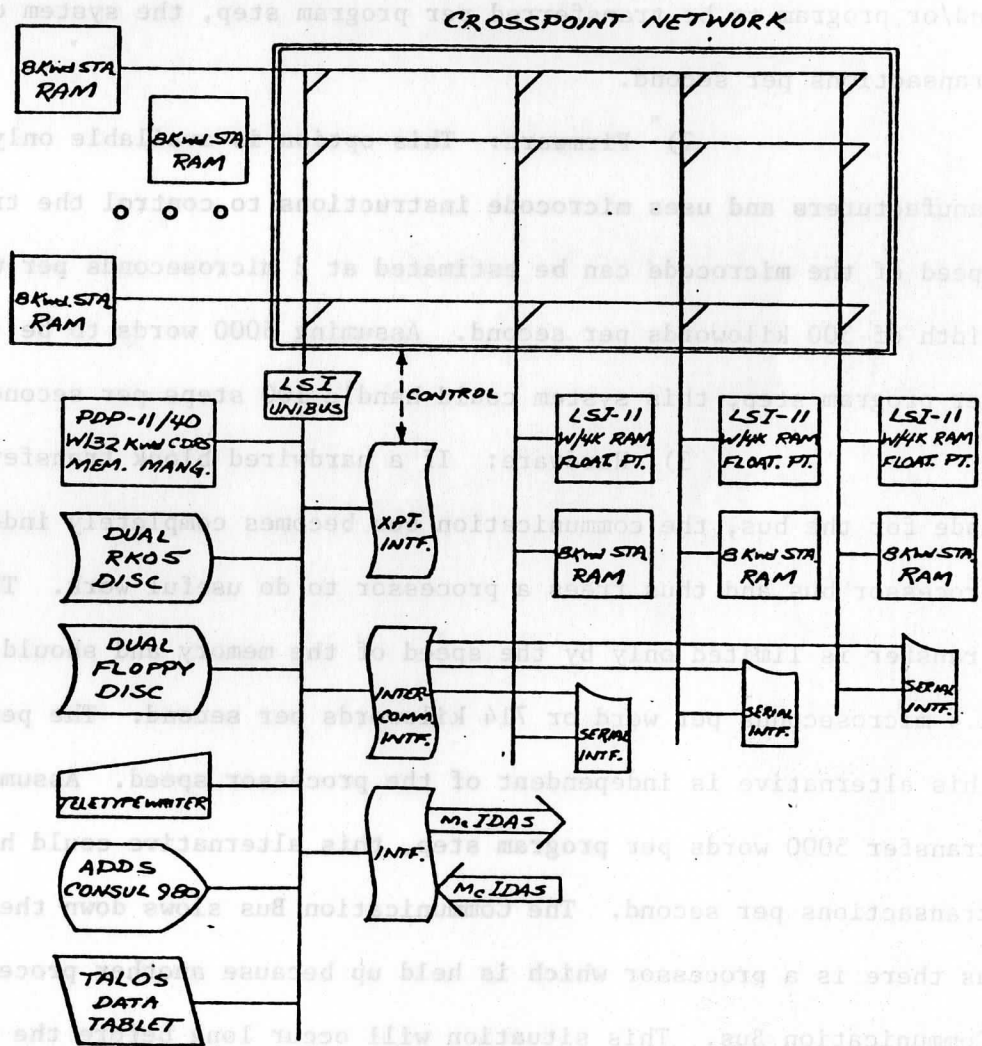
4.3.2.3 Comparison of Two Approaches: Communication Bus vs. Crosspoint

1. Communication Bus

With the Communication Bus there is a single limited bandwidth communication channel through which all interprocessor data communication is routed. This communication consists of physically moving data from one computer to another. This transfer:

- 1) takes time
- 2) ties up memory on both processors from the moment the transfer is requested until it is completed
- 3) may require a dedicated processor
- 4) may become a bottleneck as the communication path saturates and processors have to wait for data.

The Communication Bus can be implemented in several different



IVAM CROSSPOINT SYSTEM

FIGURE 4-9.

ways. The difference is the bandwidth of the Communication Bus and the amount of processor power required to drive it.

a. Options

1) Software Control of Transfer: The data is transferred a word at a time under program control requiring 6.2 microseconds per word, yielding a bandwidth of 161 kilowords/second. Assuming 5000 words of data and/or program to be transferred per program step, the system can handle 32 transactions per second.

2) Firmware: This option is available only with certain manufacturers and uses microcode instructions to control the transfer. The speed of the microcode can be estimated at 2 microseconds per word or a bandwidth of 500 kilowords per second. Assuming 5000 words to be transferred per program step, this system could handle 100 steps per second.

3) Hardware: If a hardwired block transfer controller is made for the bus, the communication bus becomes completely independent of the processor bus and thus frees a processor to do useful work. The speed of the transfer is limited only by the speed of the memory and should be better than 1.4 microseconds per word or 714 kilowords per second. The performance of this alternative is independent of the processor speed. Assuming the need to transfer 5000 words per program step, this alternative could handle 143 transactions per second. The Communication Bus slows down the system as soon as there is a processor which is held up because another processor is using the Communication Bus. This situation will occur long before the Communication Bus itself is in use 100 percent of the time. In fact, as soon as bus utilization reaches 20 percent, some contention is to be expected. The bus can be considered saturated as soon as its utilization climbs above 50 percent.

The problem is alleviated somewhat because only three processors would be doing work and thus generating request for transfers.

No one can say for sure that the Communication Bus will saturate at any particular load level because software could be designed to minimize that danger. The answer hinges on the ratio of transfer and processing. If the amount of time required to input to and output from a module is small relative to the time spent processing within the module, then communication would not be too great a problem. For some modules already coded, the ratio of processing to transfer is about 25 to 1.

2. Crosspoint

With the crosspoint system data is not physically moved from one memory to another; instead the memory containing the data is reassigned to a different processor, an action requiring only a few microseconds. Obviously switching an entire memory is faster than moving its contents a word at a time. With 10 memory modules of 8K each which can be completely reassigned in less than 50 microseconds the theoretical bandwidth of the system is:

$$\frac{1,000,000}{50} \times 10 \times 8000 = 160,000,000 \text{ words/second}$$

or 32,000 transactions/second

While it is unlikely that the processors could make meaningful use of this capability, it is clear that system performance is not limited by the interprocessor communication paths.

4.3.2.4 Arguments by Configuration

1. Communication Bus

a. Advantages

Off-the-shelf components

Likely to be standard product in the future

Likely to decline in costs

Simple and reliable

Easily expandable until the bus saturates

Software, firmware, and hardware are not mutually exclusive

the optimum mix of the three can be changed later if desired.

b. Disadvantages

Transfer data slowly

Limited bandwidth transfer channel may saturate and limit performance.

c. Unknown

Cost: Not currently available as a system; prototype copy must incorporate one-time costs; future copies' cost unknown.

Programming: The protocols for communication bus control must be carefully worked out to allow optimum use of bus transfer.

Avoidance of bus saturation would require careful vigilance on the part of the implementers. It will always be an important constraint which could kill the system. With the crosspoint this issue is avoided completely.

2. Crosspoint System

a. Advantages

Extremely fast, transfer time transparent to the system

Processors not involved in transfer are available for processing while other processors are transferring,

Control of the system will not require a dedicated processor.

A working example (at Carnegie-Mellon) exists.

Development prototype will perform much like a production model.

Software development can progress rapidly because contention for priority on the data channel does not exist.

b. Disadvantages

The multitude of cables needed for switching may cause reliability problems.

Not likely to decline in cost because major cost is mechanical -- cables, connectors, etc.

Expansion difficult because number of switches grows as the product of the processors and memory blocks.

c. Unknown

Large blocks of switch hardware may be expensive, depending on hardware vendor choice.

4.3.2.5 Summary

There is a clear performance advantage to the crosspoint system. Earlier concern that costs might be prohibitively high was dispelled.

4.3.3 Hardware Procurement

A hardware specification was prepared for the multi-processor system, outlining the requirements for system components separately. The Request for Bid asked for bids on any single item or combination of the following:

- 1) Entire system with dual port memory
- 2) Entire system with single port memory

3) Individual processors or peripherals within the system

4) Any other option which the bidder felt might meet the requirements.

Also required in the bids were inclusion of any additional cost associated with use of the equipment, such as documentation, software, software licenses, maintenance, special interfaces and other support.

Requests for bids were sent to over 50 manufacturers of computers, peripherals, and systems.

1. Bid Evaluation Process

Bids were received from 20 companies, covering complete systems, peripherals, and components only. The bid evaluation was done in two steps, technical evaluation with no knowledge of cost, then a second step with cost and performance trade-offs considered.

a. First Step - Technical Evaluation

A technical evaluation committee was named, made up of two system programmers, one applications programmer, one electronic engineer, and one systems expert from the Computer Science Department. Technical evaluation was based on the computer system in the proposed configuration or application of individual computers proposed to specific configurations of crosspoint or communication bus. Seven manufacturers of processors bid and the bids were separated into two groups: bids generally meeting requirements, and bids not technically acceptable. Several of the bidders proposed more than one approach and each of those bids were evaluated separately. An evaluation form was used for numerical scoring of the bids, shown in the following pages, and final rankings of bids are listed in Table 4-1.

b. Second Step - Cost versus Performance Evaluation

Of the top four configurations bid, three were from Digital Equipment Corporation (DEC), using PDP-11 type machines. A Bus Window was a new system development from DEC, not yet released, developed for the telephone

I. PROCESSOR EVALUATION (40)

A. Processor (30)

WEIGHT

		Data 100	Computer Automation	Harris Corporation	Digital Equipment	Bolt, Beranek & Newman	Modular Computer System	Varian Data Machines
Registers	1.5							
Addressing Modes	2.1							
Address Space	1.5							
Hardware Stacks	1.7							
Byte Manipulation	1.8							
Auto Increment/Decrement Registers	1.5							
Memory to Memory Instructions	1.5							
Hardware Multiply/Divide	.5							
Floating Point	.5							
Reentrant Code	1.7							
Relocatable Code	1.7							
Memory Management	1.8							
Microprogramability	1.3							
User/System Mode	1.2							
Stack Overflow/Underflow	1.4							
Illegal Instruction Trap	1.2							
Memory Protection	1.9							
Start-up	.7							
Throughput	1.5							
Consistency	1.8							
Instruction Speed	1.2							

B. Software

General Category - Including

Real-time

Multiprogramming

Multiprocessor Operating System with:

File System

Editor

Assemblers

Compilers

Debugging Package

WEIGHT
10

Data 100	Computer Automation	Harris Corporation	Digital Equipment	Bolt, Beranek & Newman	Modular Computer Systems	Varian Data Machines

II. CONFIGURATION EVALUATION (60)

			Quad Port Memory	Shared Mem. Pair						
			WEIGHT							
A. Ease of Development (20)										
1.	Amount of in-house effort to complete configuration	(Policy)								
2.	Ease of start-up (4)									
	Multiprocessor systems software	2.0								
	Hardware - time availability	2.0								
3.	Complexity	4.0								
	Components in system can be treated in consistent manner									
4.	Protection & Vulnerability (6)									
	Standard Memory Protection	2.3								
	Configuration established protection	3.7								
5.	Support (6)									
	Listings	1.3								
	Hardware guarantees for completeness	2.1								
	Software updates	.9								
	Maintainability	1.7								
		20								
B. Product (Production) (20)										
1.	Reliability (3)									
	Fail soft	1.5								
	MTBF	.9								
	MTTR	.6								
2.	Flexibility (4)									
	Reassign functions	1.8								
	Reassign peripherals	.9								
	Configuration Change	1.3								
3.	Ability to implement production Model in increments	5								
4.	Expansion Capability (3)									
	More Processors	1.2								
	More Memory	0.9								
	More Communications Paths	0.9								
5.	Total Address Space	2								
6.	Adapatability to Expected Hardware cost	3								

(See Below)

C. Efficiency (20)

WEIGHT

1. Throughput (20)

Transparency of Communication

3.5

CPU Degradation

5.0

Processor Bus Degradation

2.5

Communication Path saturation

5.0

Memory space tied up during communication

2.0

Systems setup overhead for a communication

2.0

20

Quad Port Memory

Shared Memory Pairs

TABLE 4-1

PROCESSOR/CONFIGURATION FINAL RANKINGS

	<u>Processor</u>	<u>Configuration</u>	<u>Average</u>
1.	DEC	Crosspoint	85.93
2.	Data-100	Crosspoint	84.08
3.	DEC	Comm. Bus	80.63
4.	DEC	Bus Window	80.02
5.	BBN	Multiple Mem. Bus	78.34
6.	DEC	Multiplexed Mem. Bus	77.85
7.	Data-100	Multiplexed Mem. Bus	76.20
8.	DEC	DMA Approach	73.63
9.	DEC	Shared Mem. Pairs	73.33
10.	Data-100	DMA Approach	71.98
11.	Data-100	Shared Mem. Pairs	71.68
12.	Harris	Single Processor	67.225
13.	Mod Comp	Quad Port Mem.	64.445
14.	Varian	Shared Mem. Pairs	62.885
15.	Varian	Quad Port Mem.	62.175
16.	Computer Automation	Single Processor	58.485

company in Canada. It is a data communication bus similar to our design, but uses "time slices" on the bus for the transfer of data. The bus has a rigid use structure in terms of time multiplexing, and would not allow optimum use of the bus for data transfer as needed for IVAM. In addition, delivery of a Bus Window system from DEC in the near future seemed doubtful and could have delayed the development of IVAM software even further.

The real trade-off was between the Data Communication Bus system using DEC computers and the Crosspoint Switch system using DEC computers. Using the standard PDP-11's, the cost of the crosspoint would have been high because the cost of hardware components compatible with the DEC UNIBUS is high. However, using the new DEC microprocessor board, LSI-11, the cost drops dramatically. The basic processor costs less than \$1,000 each, low cost memories are available, and the mechanical hardware associated with the LSI-11 is low cost. The combination of a PDP-11/40 for system control and main processing with LSI-11's for subordinate processors was by far the most cost effective purchase of processing power. Two very powerful software operating systems, RSX-11M and RSX-11S, were available on the processors so that the crosspoint operating system primitives could be developed and implemented later as the system development progressed.

4.3.4 Development System Description

The prototype system for the development and demonstration of the IVAM capability consisted of equipment in three categories:

1. A Multiprocessor Assembly which is the Control and Image Generator Subsystem of the prototype system and which was purchased under the IVAM contract.

2. McIDAS and other equipment which was used temporarily to support IVAM development (but which were not intended to be part of a deliverable system).

3. Development tools purchased by IVAM which supported the software development but were not to be part of an operational system.

In addition, there were a number of interfaces fabricated in-house which tied the parts of this system together.

The major elements of the system are shown in Figure 4-10 and are described separately below.

4.3.4.1 Control and Element Generator Subsystem

The Control and Element Generator Subsystem consisted of the following components:

PDP-11/40

Three LSI/11 microcomputers

Interprocessor Communication System

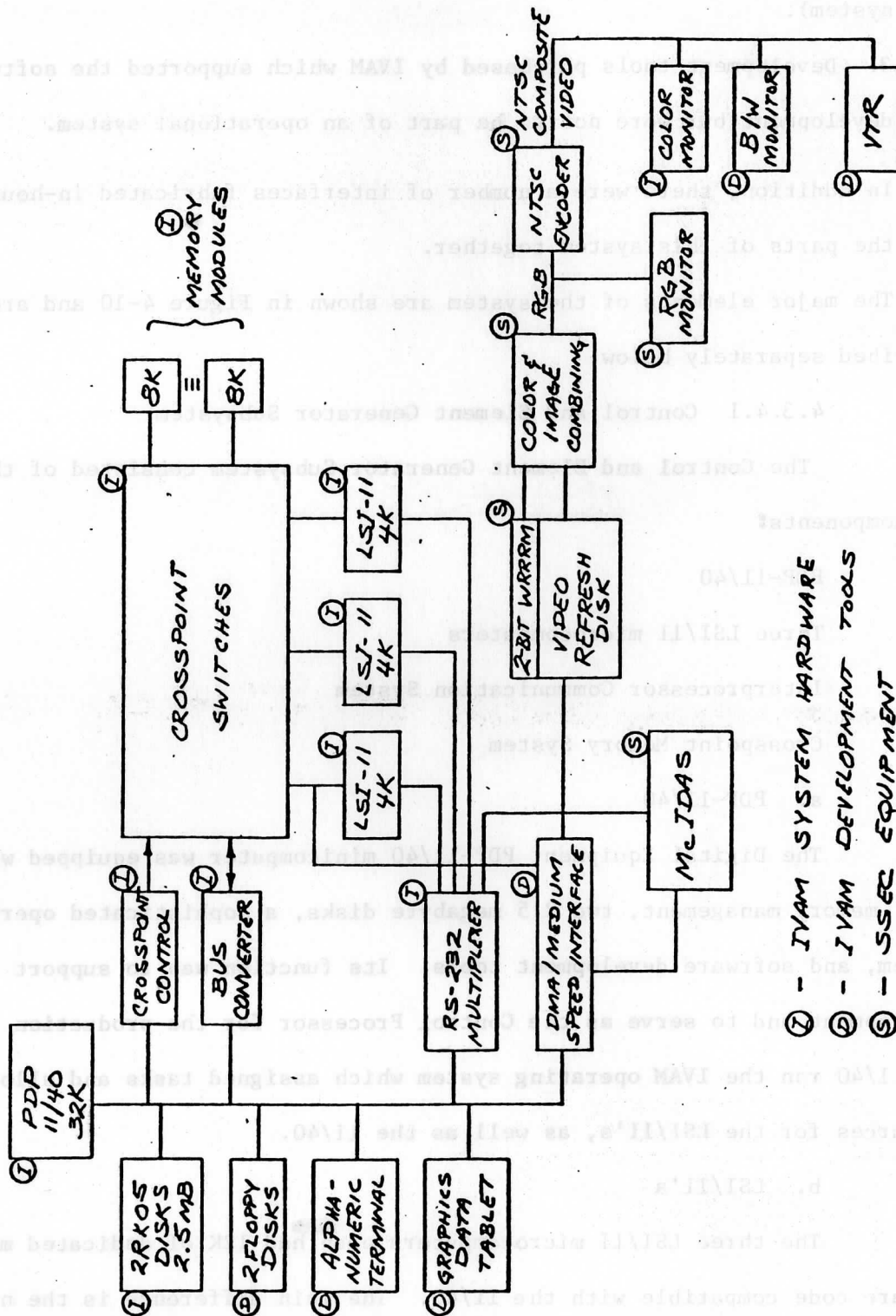
Crosspoint Memory System

a. PDP-11/40

The Digital Equipment PDP-11/40 minicomputer was equipped with 32K core, memory management, two 2.5 megabyte disks, a sophisticated operating system, and software development tools. Its function was to support software development and to serve as the Control Processor for the production system. The 11/40 ran the IVAM operating system which assigned tasks and allocated resources for the LSI/11's, as well as the 11/40.

b. LSI/11's

The three LSI/11 microcomputers each had 12K of dedicated memory and are code compatible with the 11/40. The main difference is the number of interrupt priority levels and the fact that the address and data bits are



- ① - IVAM SYSTEM HARDWARE
- ② - IVAM DEVELOPMENT TOOLS
- ⑤ - SSC EQUIPMENT

IVAM DEVELOPMENT SYSTEM
FIGURE 4-10.

multiplexed on the same bus. Each LSI could access one of several additional 16K words of memory at any point in time through the crosspoint system. The LSI's were used to execute modules under the direction of the Control Processor.

c. Interprocessor Communication System

All interprocessor command and status information was communicated between each LSI and the 11/40 over RS232 lines at 9600 baud on an interrupt basis. Each of the LSI's had a single serial channel while the 11/40 had a 16 channel multiplexer board which it also used to communicate with McIDAS and to control the alphanumeric terminal.

d. Crosspoint System

The passing of data and code between processors was accomplished not by block transfer, but by switching the memory so that the receiving processor could access it. Since the entire contents of the memory were switched simultaneously, the apparent transfer rate was very high.

The IVAM crosspoint system was designed to allow each of up to 8 processors to access any of 16 memory modules. At any one time a given memory module could be accessed by only one processor. However, a processor could simultaneously access as many memory modules as its address space allows, two for each LSI and four for the 11/40. The crosspoint system was under the complete control of the 11/40. It allocated crosspoints to processors and determined when to switch them to other processors. It determined whether a memory is read-only and what addresses it would occupy on the processor it was connected to.

During initial development, the multiprocessing system was to perform every step required to generate full video images, generating complete 485 line x 672 pixel images, a line at a time, in software. Each line would be transmitted to the digital refresh disk as it was generated. In the finished

prototype the fill-in process would be performed in the Video Assembler. The output of the Multiprocessing system was to be graphic image element - TV raster line intercept sets which provide in compacted form all the information required to generate the full image.

4.3.4.2. Center Equipment

Part of the final IVAM system was simulated by the following Center equipment:

- 1) The McIDAS system was simulating both AFOS and CDDS. It acted as a data source for IVAM sending it Service A, Service C, and radar data. It also sent the satellite image to the digital refresh disk.
- 2) The digital refresh disk is capable of storing twelve full raster, 6 bit video images in digital form. It also contains a two bit semiconductor video refresh buffer. This terminal can simultaneously read out, colorize, and to some extent combine the two 6-bit disk images with the 2-bit RAM image.
- 3) TV monitors: During development it was necessary to view the IVAM output on both Black and White and Color commercial TV monitors to insure that the IVAM output is compatible with NTSC system characteristics and both types of displays.

4.3.4.3. Development Tools

The following devices were used during the IVAM development effort and will not be part of the final system except for Item 4:

- 1) Data Tablet: This is a 22" x 22" tablet with 100 points per inch resolution. It was used to generate graphic input data, weather symbols, and complex parameters.
- 2) Dual Floppy Disks: These disks were used for offline storage of programs and test data.
- 3) NTSC Encoder: The output of the refresh disk is converted to RGB video which must be passed through the Center's NTSC encoder which

produces a broadcast compatible color video signal which could be viewed on a standard color monitor. This device was important because its bandwidth characteristics strongly affected IVAM color relationships.

4) Video Tape Recorder: This is a Sony cassette recorder with full edit capability. It has the ability to synchronize its movement with an external video source. A controller was planned to allow the computer to number every frame sequentially on the tape, to allow full computer control of the recorder's tape movement and read/write controls. The recorder and controller would become the video tape library for the prototype system with implementation of the Video Assembler. Time constraints did not permit this controller development, and tape editing for demonstrations was performed manually. A simple VTR control interface was developed, however, to allow computer control of basic transport functions.

5) Medium-speed Interface

A Medium-speed Interface was added to relieve the communications speed bottleneck to McIDAS and the Video Refresh Disk imposed by the 9600 baud rate of the RS-232 interface to McIDAS. The Medium speed interface connected into an existing McIDAS-to-Video Refresh Disk serial line, capable of data rates up to 600 kilobaud. It provided the capability of simultaneous communications between the 11/40 and McIDAS and between an LSI-11 and the Video Refresh Disk, or the reverse connection could be established. The interface also permitted usual McIDAS-to-Video Refresh Disk communication. Data transfer between the interface and the 11/40 and LSI-11 buses was accomplished by DMA controllers.

4.3.4.4. Performance

The McIDAS digital refresh disk represented a major throughput bottleneck during development because it can input only one digital scan line every 1/30 second, requiring 16 seconds to update a frame. A later hardware addition improved this to approximately 3 seconds per frame. Since the disk holds only 12 frames, that is the greatest number of different frames that could be shown in a

single continuous output. Since each of these frames could be repeated as many times as desired, the disk could maintain a continuous sequence of video still frames for a minute or more. However, if the images were changing at the peak rate of 5 new frames per second, one loading of the disk provided only 2.4 seconds of output.

Because of this limitation, the Sony cassette recorder was needed to produce the five minute test tapes that were required for evaluating the IVAM product. The video tape recorder allowed IVAM to generate short sequences at the rate the disk allows, and then to assemble them into longer presentations on the tape.

As a further consequence of using the refresh disk, one of the LSI processors was dedicated to the fill-in process and to transmitting the scan lines to the disk. With the proposed Video Assembler, both the fill-in process and the output staging tasks would be performed, freeing that processor for other work. At that point the multiprocessor system would have been able to generate outline messages at the rate required to sustain 20 minutes of video output of every hour as required.

4.4 Video Assembler Study

4.4.1 Real-time Assembler with Staging Disk

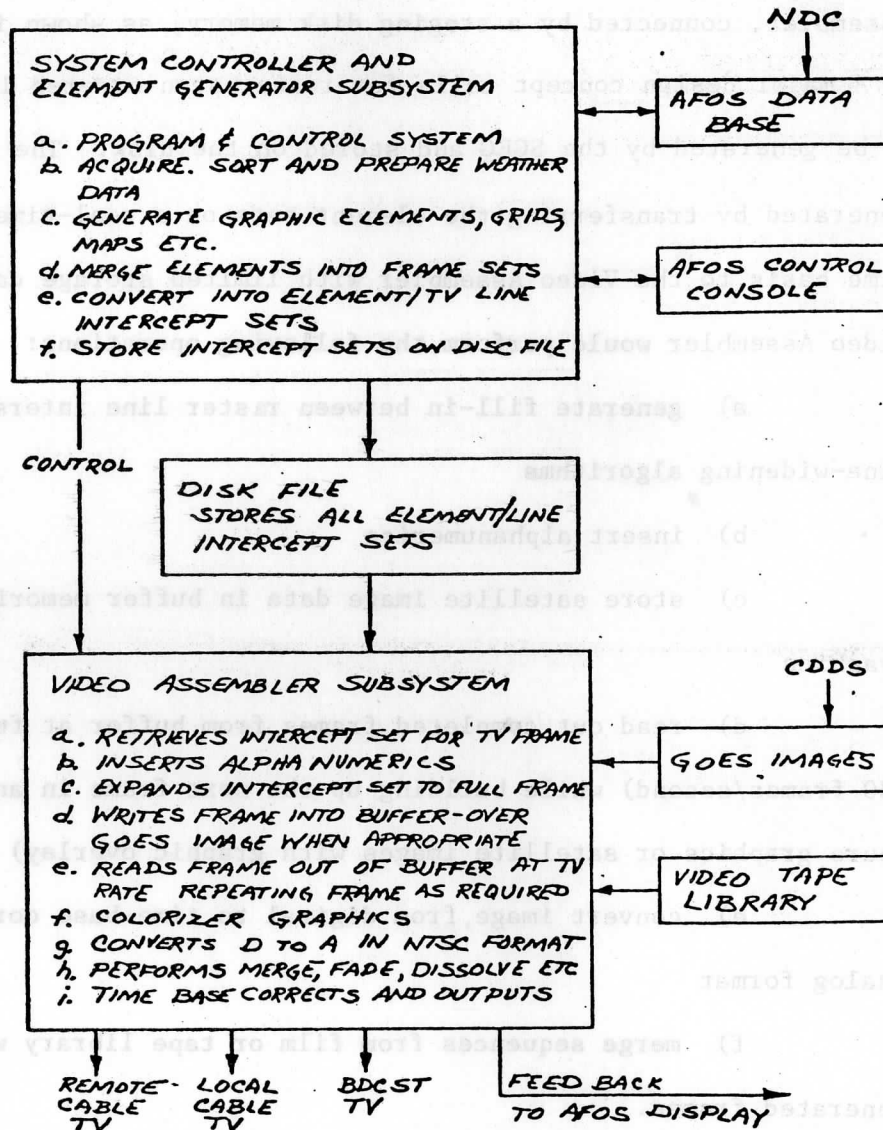
Early in the IVAM study, the hardware system was conceived to consist of a System Controller and Element Generator and a Video Assembler, connected by a staging disk memory, as shown in Figure 4-11.

A major design concept calls for raster-scan ordered image element sets to be generated by the SCEG and stored on the disk. The display would be generated by transferring the element sets on a real-time or near-real time basis to the Video Assembler with limited storage capacity. The Video Assembler would perform the following operations:

- a) generate fill-in between raster line intersects, including line-widening algorithms
- b) insert alphanumerics
- c) store satellite image data in buffer memories and overlay graphics
- d) read out completed frames from buffer at full video rate (30 frames/second) while building up the next frame in another buffer (pure graphics or satellite images with graphic overlay)
- e) convert image from digital to time-base corrected NTSC analog format
- f) merge sequences from film or tape library with IVAM-generated frames.

4.4.1.1 Real-time Assembler Design Concepts

Several alternative designs for this type of Video Assembler were considered. Three design concepts which appeared most promising are described below.



SIMPLIFIED IVAM SYSTEM PLAN

FIGURE 4-11.

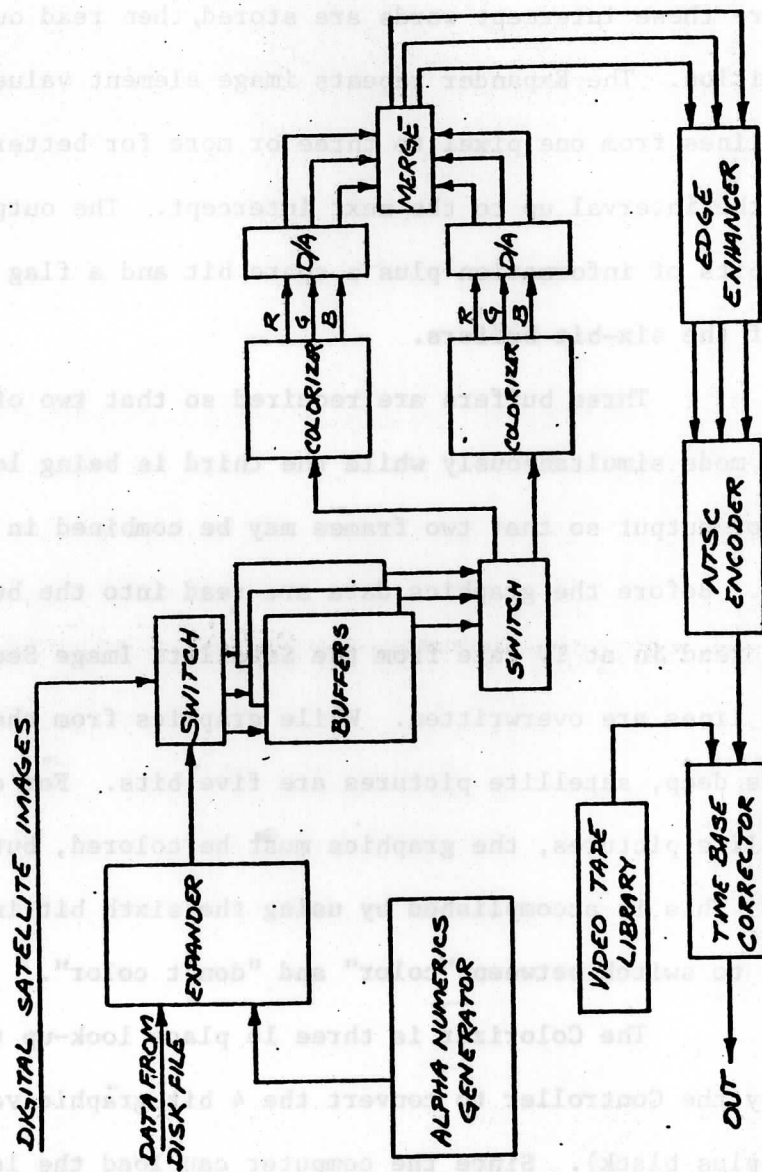
a) Alternative One

This alternative is shown in Figure 4-12.

Data from the disk file and from the Alphanumeric Generator, in 16 bit element/line intercept word format, is read into the Expander at the direction of the Controller. The Expander includes a small buffer pair where these intercept words are stored, then read out in order of line position. The Expander repeats image element values to either widen graphic lines from one pixel to three or more for better appearance, or to fill the interval up to the next intercept. The output of the Expander is four bits of information plus a spare bit and a flag bit to be stored in one of the six-bit buffers.

Three buffers are required so that two of them can be in the read-out mode simultaneously while the third is being loaded. Two buffers are needed for output so that two frames may be combined in a fade-in, fade-out mode. Before the graphics data are read into the buffer the satellite image is read in at TV rate from the Satellite Image Sequencer, then the graphics lines are overwritten. While graphics from the Expander are only four bits deep, satellite pictures are five bits. For overlays of graphics on satellite pictures, the graphics must be colored, but not the satellite picture. This is accomplished by using the sixth bit in the buffers as a flag bit to switch between "color" and "don't color".

The Colorizer is three 16 place look-up tables which are loaded by the Controller to convert the 4 bit graphic value to one of 15 colors (plus black). Since the computer can load the look-up tables at TV frame rate the Colorizers are also used to fade one image and increase the other for fade dissolves. The output of the Colorizer is a three wire R.G.B. digital signal which is converted to analog and then the two images are merged.



ALTERNATIVE ONE
VIDEO ASSEMBLER SUBSYSTEM

FIGURE 4-12.

The output of the Merger is passed through an Edge Enhancer, a standard piece of TV equipment which sharpens the edges of lines and letters to provide crispness to the final image. The final steps are to convert from R.G.B. to NTSC format and to correct the video time base to broadcast stability levels.

b) Alternative Two

The cost of the three full frame buffers in Alternative One might prove to be excessive. This alternative eliminates the full frame buffers and replaces them with two smaller buffers before the Expander. Figure 4-13 shows Alternative Two in block diagram.

The input from the Disk File is switched to the empty buffer which need have a capacity of only 10% of the bits of the full frame buffer of Alternative One. The full buffer is read-out at 30 frames per second as many times as needed into the Expander synchronized with the input of the Alphanumeric Generator. The Expander overwrites one or the other as instructed by the Controller, widens lines, and fills areas as before. The expanded full TV frame is colorized as in Alternative One.

Without the full frame buffers a new technique must be employed to combine the graphics and satellite images. This is done by passing the synchronized digital satellite image and the colorized graphic through a "Decider" which determines which pixel has priority and signals the Merger through a delay line. After the signal is converted from digital to analog the Merger combines them properly.

The fully assembled RGB image is passed through an Edge Enhancer and an NTSC encoder as in Alternative One. But at this point some images will be switched to the recorder of the Video Tape Library where they

are stored temporarily. This is done in advance to every second image in a series which is to have fade-dissolve transitions when shown in sequence.

c) Alternative Three

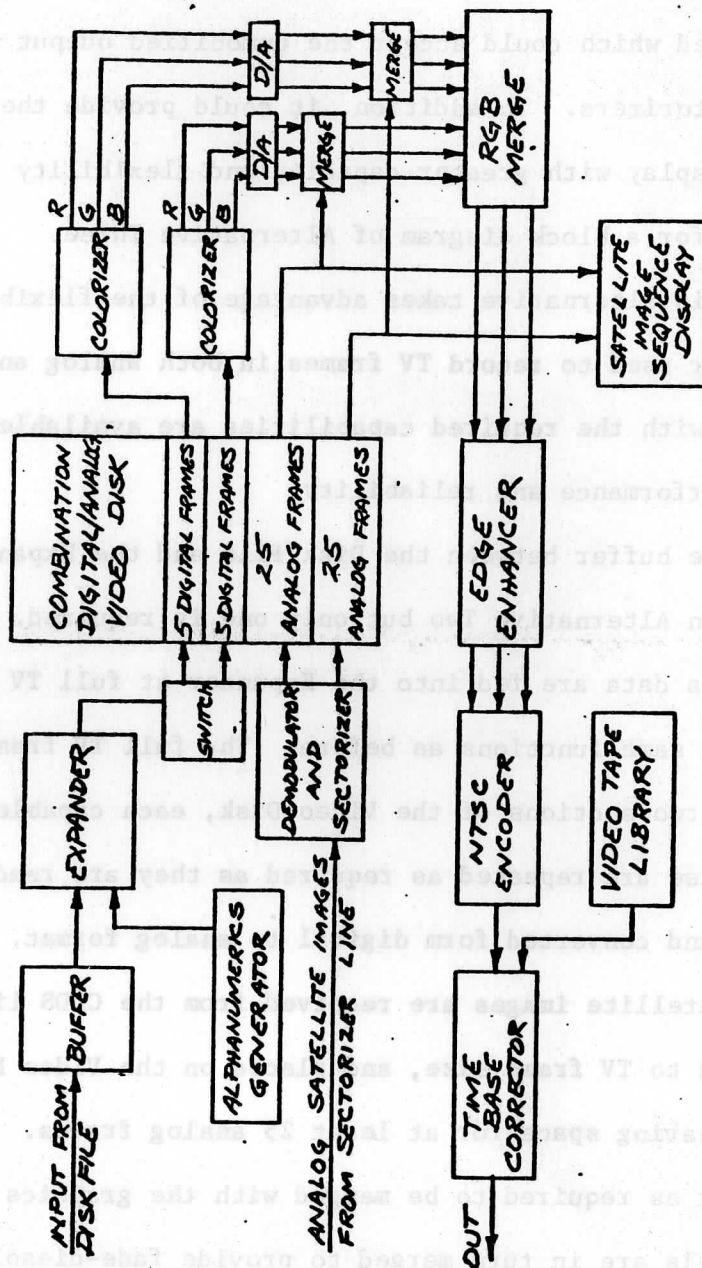
Both Alternative One and Two presupposed the availability of a Satellite Image Sequencer or similar device capable of serving as a source of digitized satellite images. Since this was uncertain, a third alternative was considered which could accept the unmodified output of the CDDS line from the NESS Sectorizers. In addition, it could provide the Satellite Image Sequencer display with greater capacity and flexibility "for free"! See Figure 4-14 for a block diagram of Alternative Three.

This alternative takes advantage of the flexibility provided by a disk recorder used to record TV frames in both analog and digital format. Disk drives with the required capabilities are available and have demonstrated excellent performance and reliability.

The buffer between the Disk File and the Expander is the same size as the two in Alternative Two but only one is required. Disk File input and Alphanumerics data are fed into the Expander at full TV rate and the Expander performs the same functions as before. The full TV frames are switched alternately into two sections of the Video Disk, each capable of holding five full frames. These are repeated as required as they are read out from the disk, colorized, and converted from digital to analog format.

Satellite images are received from the CDDS line, demodulated and resectorized to TV frame size, and placed on the Video Disk in one of two sections each having space for at least 25 analog frames. The satellite images are read out as required to be merged with the graphics and the two completed image channels are in turn merged to provide fade-dissolve or other special effects. The merged signal is passed through an Edge Enhancer, NTSC Encoder, and Time Base Correcter as before.

The block diagram also shows a Satellite Image Sequencer Display



ALTERNATIVE THREE
VIDEO ASSEMBLER SUBSYSTEM
FIGURE 4-14

which could be incorporated with the AFOS display either as an additional CRT or as a call-up display on existing consoles.

4.4.1.2 Real-Time Assembler Problems

Attempts to detail the design concepts described above revealed a variety of problems which led to the conclusion that this basic approach did not represent a good solution to the IVAM display problem.

The need for merging, line-widening, and fill-in of multiple image elements in a single-pass operation introduced the problems of tagging the various element sets to establish line width parameters, priority (for one element overlying another), and fill-in topography (initial scan line values, cusps, etc.). Dealing with these problems required complexity in both hardware and software that exceeded expectations.

Additional problems resulted from lack of access to the completed image frames, thereby restricting possibilities for alphanumeric placement and requiring a separate means of image data ingestion to the SCEG for generation of cloud graphics.

Finally, the need for retrieving all necessary image elements for each new frame, no matter how slight the change, and performing all the processing and control operations necessary to maintain a display sequence indicated a significant real-time system programming effort would be required.

4.4.2 RAM/Dual Disk Video Assembler

Continuation of the effort to design a Video Assembler system concentrated on avoiding the problems of the staging disk-real time assemblers. An acceptable solution was found in the RAM/dual-disk system which:

- a) eliminated the need for the staging disk
- b) eliminated the need for real-time frame generation and display control by SCEG
- c) provides ample storage for all frames required for IVAM segment presentation as well as elements to be re-used in a segment production and alphanumeric fonts
- d) provides access to assembled frames so alphanumeric placement and cloud graphics algorithms may be applied
- e) provides powerful display capabilities, including frame-by-frame animation, crossfades or pops between arbitrarily long sequences of image data frames with graphic overlays as fast as 15 frames per second, and special effects such as texturing, scintillations, and wipes.

4.4.2.1. System Description

The final Video Assembler system block diagram is shown in Figure 4-15, with detail of the Video Chain shown in Figure 4-16.

The basic unit of storage in the system, for both disk and RAM, is the 512 x 512 (256K) by five-bit frame. The disk system provides storage capacity for 815 such frames, estimated to be adequate for IVAM needs. This capacity may, however, be readily expanded if necessary by the addition of dual drives. Each disk cylinder, in addition to storing a frame of data, has the capacity to store 12,800 bytes in the area corresponding to the TV frame vertical interval.

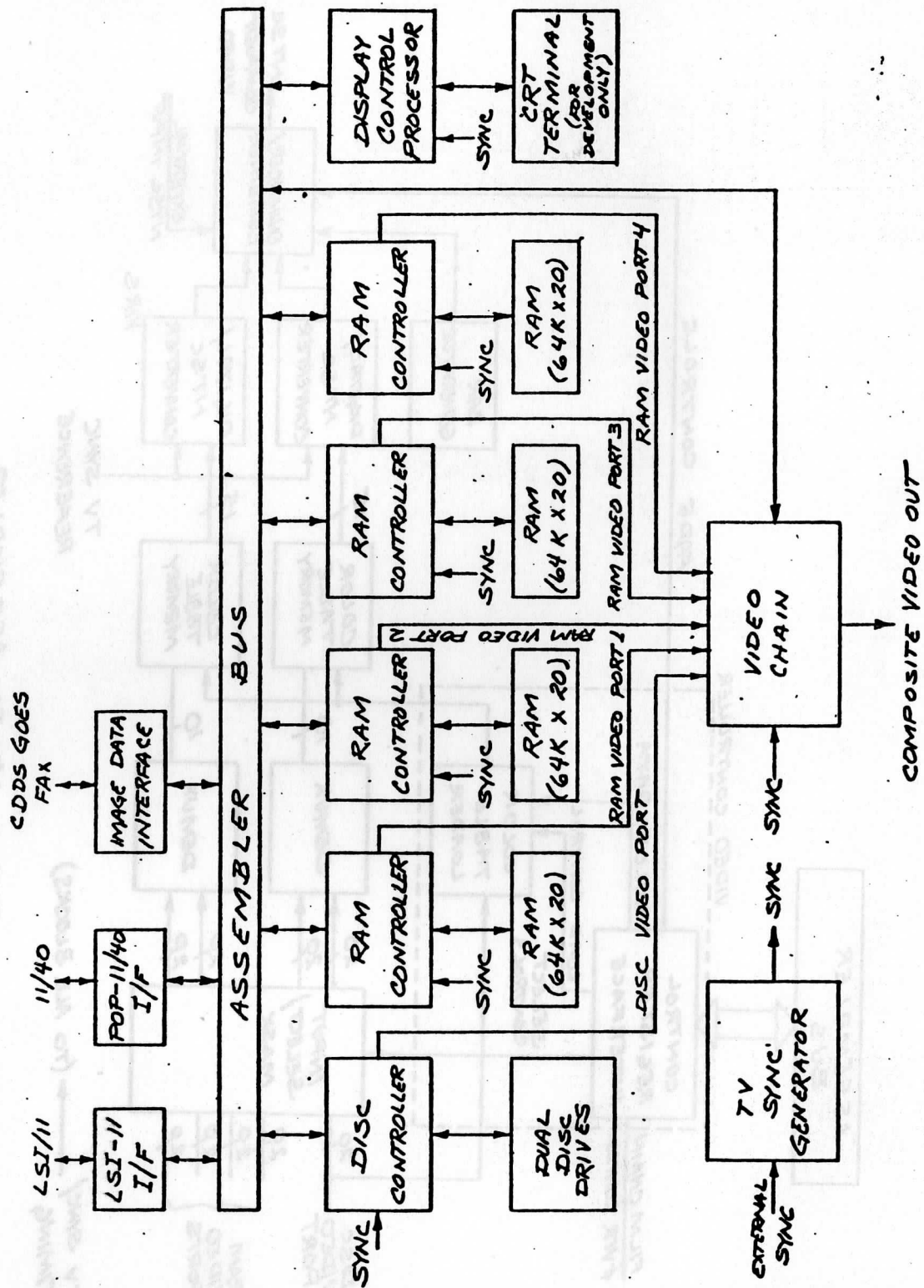
4.4.2.1.1 Assembly Operation

Referring to Figure 4-15, the Video Assembler provides interfaces for the System Controller (PDP-11/40) and a Crosspoint Processor (LSI-11) to the Assembler Bus. Either SCEG processor may input instructions to any of the devices on the Assembler Bus and read or write data to the four one-frame capacity RAMs. The Video Assembler instruction set allows the following operations or functions to be performed:

- a) RAM-to-disk or disk-to-RAM frame transfers
- b) Execution of fill-in, line-widening, and translation algorithms on RAM contents in selected memory space areas and bit planes
- c) Loading of display programs to the Display Controller.

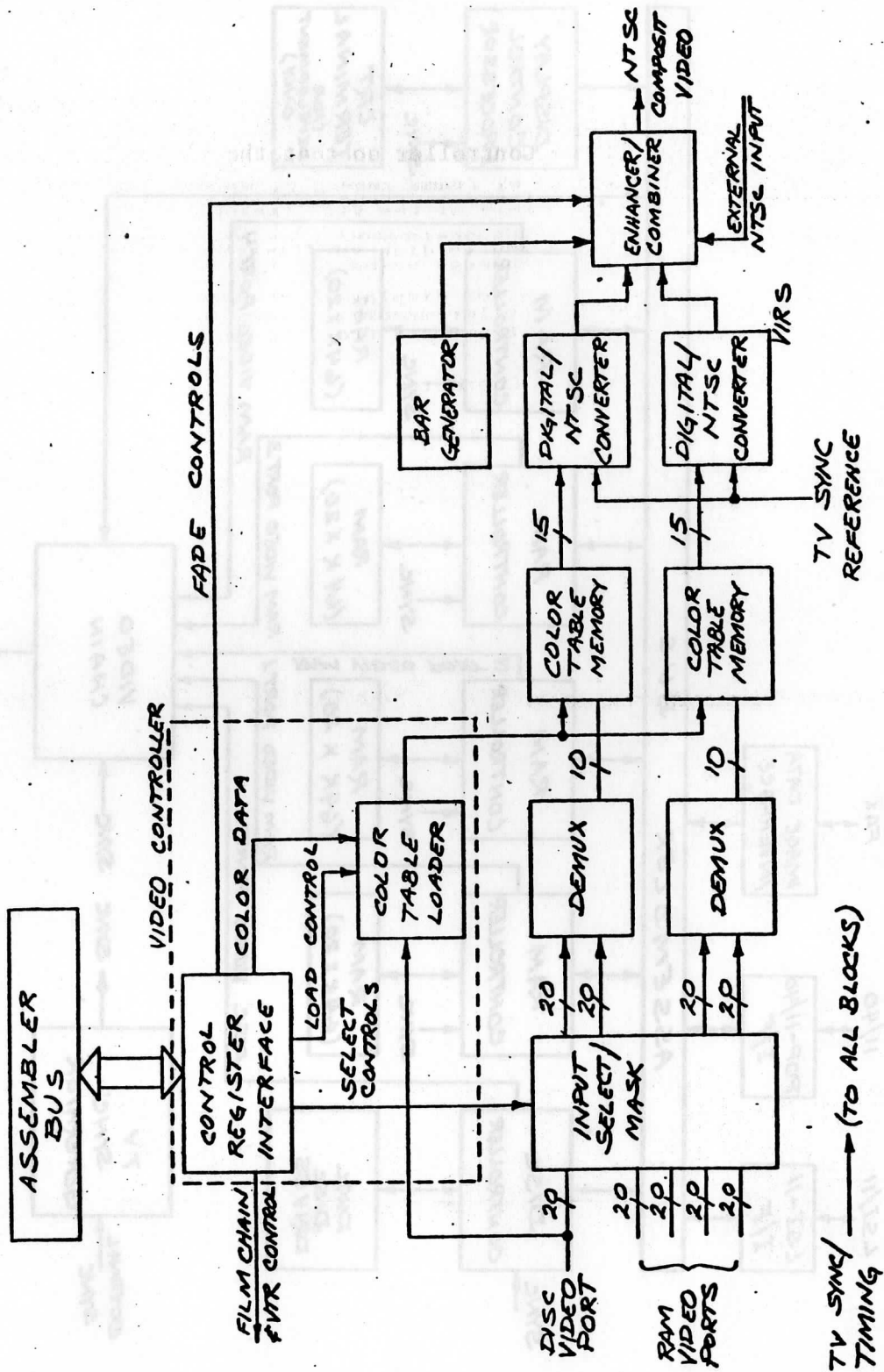
These resources are utilized in the program assembly process in the following manner:

- a) Image elements are loaded to RAM from the Element Generator.
- b) The RAM controllers, containing bit-slice processors, rapidly execute simple algorithms to perform the functions of element translation, line-widening, fill-in, and combining, usually in the course of RAM-to-RAM transfers. For simple graphics, such as would be used for image data overlays, the RAM's may be operated as independent bit-plane memories so that up to five such graphics may be stored in a single RAM or disk frame.



IVAM VIDEO ASSEMBLER
BLOCK DIAGRAM

FIGURE 4-15



IVAM VIDEO ASSEMBLER
VIDEO CHAIN BLOCK DIAGRAM.

FIGURE 4-16.

- c) Alphanumeric fonts, stored on the Video Assembler disks, are transferred to RAM and characters from the font are combined in the same manner as any other image element to a frame being assembled. Alternately, a separate alphanumeric frame may be composed for instances where the same alphanumerics are displayed over several different image data or IVAM-generated graphics frames. For variable location alphanumerics the RAM area of interest is first read to the System Controller so that the placement algorithm may be applied before characters are inserted into a frame.
- d) Upon completion of frame assembly, or the ingestion of a frame of image data, the frame is transferred to disk. The System Controller maintains the directory of the Video Assembler disk contents.
- e) A color table (the assignment of colors to pixel values in the frame data) is written to disk vertical interval sectors of the first frame of a sequence, using the table.
- f) The instructions for display of the prepared segment are loaded to the Display Controller memory. These instructions are executed on receipt of a start command from the System Controller.

4.4.2.1.2 Display Operation

When the Video Assembler is operated in the display mode, the RAM's are addressed in raster-scan sequence, with address timing derived from a TV sync generator source. The rotation of the disk drives is always phase-locked to TV sync timing. The RAM and disk controllers contain line buffers, which provide time-base corrected outputs termed "video ports" to the video chain.

Video chain functions (Fig. 4-16) are controlled by the Video Controller which generates specific control outputs in response to display control instructions. These controls include video port data routing, bit masking, digitally generated special effects, video switching and transitions, and tape and film edit control. In addition, the Video Controller reads color table information supplied from disk or Display Controller program, and loads the Color Table Memories.

The Input Select/Mask logic allows any two video input ports to be routed to either Color Table Memory, and any combination of input bits to be masked (i.e., held in a fixed logic state). The masking feature is useful for

displaying single-bit graphics sequentially without the necessity of reloading the Color Table Memory and for certain flashing special effects generation.

The Color Table Memory provides the translation of input data values to display color values. In a development system, the memory would be fully programmable and any color value may be selected for every possible input data value. For a prototype or operational system, "palettes" of NTSC-compatible color sets in read-only memory would be provided, and the input values would be simply mapped to the few codes available on the selected palette. The Color Table Memory also contains line and pixel clock-driven gate generators to provide inputs used to create horizontal or vertical "wipe" special effects. Scintillation is performed by modifying the color table look-up at frame rates.

The Color Table Memory outputs are converted to analog NTSC video and applied to the Enhancer/Combiner, which performs conventional image edge enhancement, selects input sources, and produces fade-type special effects.

4.4.2.2. Implementation and Cost

A survey of available commercial memories disclosed that the most economical memory system suited for the Video Assembler application was the 94550 Memory System produced by Control Data Corporation. The cost of the memory for four frames of storage is approximately \$18K in single unit quantities. Further, as the 16K RAM chips are introduced, the eventual cost of equivalent memory may be expected to drop significantly.

No digital disk CRT refresh systems are marketed which could provide the several hundred frame capacity at a cost less than astronomical. IBM 3330 drives, available from several sources and reasonably low in cost, provided the required capacity, but are not designed for CRT refresh applications. A design feasibility study in this area demonstrated that a pair of these drives can be made to function as a CRT refresh with relatively minor modification.

5.0 Output Distribution Study

5.1 Four methods have been studied for transfer of IVAM weather data from the NWS to local stations. Both sides of the "interface" were considered: distribution within NWS, and within the media to the consumer. The approaches studied are:

- a) Transmit at low data rate and reconstruct at station
- b) Transmit at TV rates via satellite or auxiliary network
- c) Insert into network feed blanks at New York or Washington
- d) Insert at regional nodes in the networks.

a) Transmission at Low Data Rate

There are a large number of schemes for slow-scan TV, and line-at-a-time transmission which have been investigated and some show real promise for the future. The best of these are:

(1) Slow-scan transmitted via telephone circuit: In principle it is completely feasible to transmit high quality video via narrow band lines and to reconstruct it at the receiving end. Using rather elaborate equipment, high quality slow-scan TV has been demonstrated several times. There are at least four companies now marketing moderate cost equipment for slow-scan transmission. After investigating the best of these we have concluded that to obtain broadcast quality consistently at the receiving end required an investment of at least \$25,000 in 1976. It is reasonable to expect that new technology will reduce costs of digital transmission and receiving equipment which can assure high quality images. We estimate that the receiving terminal costs can be expected to drop significantly in the next few years. At that time the combined cost of equipment and line rental falls into the marginally acceptable range for broadcast stations and probably into the fully acceptable range for regional distribution to local cable TV sets. The data rate is so low for phone lines

that the bandwidth will limit the variety of programming available by this method. Nevertheless, slow-scan digital transmission may be the best answer for some applications, and this option should be developed further when the technology available at implementation time is known.

(2) Transmission during TV frame retrace: In England, the BBC Commercial Service is broadcasting a signal with its normal TV program which is decoded and accumulated by a relatively inexpensive (\$150) add-on to a home TV set, and which can present single frames of alphanumeric information upon request. This program, called "CEEFAX", is the first practical use of the otherwise unused time interval between TV frames called the "retrace period." In the United States TV format the retrace period is equivalent to the time required to transmit 17 TV lines. This period is now used to send gray scale and color calibration information, but it is technically feasible to consider sending at least 10 lines of video during this period and to build up full TV frames at the receiving end. It would take less than two seconds to send one IVAM frame at 10 lines per TV frame. This data rate is much better than the rate offered by the slow-scan option, and there is no additional transmission line cost. The commercial potential for this technique, as demonstrated in England, is so large that it is doubtful that the capability would be available for weather information if it were installed in the U.S. However, it is an attractive concept, and deserved further consideration.

b) Special Weather Net

While studying the existing communications facilities in the U.S., we were impressed by the number of "spare" lines which can be found at any time of normal operations. We attempted to construct a separate video net from these spare lines, with the idea that perhaps a reliable public service capability could be identified which could carry IVAM presentation at no cost to the government, and at no

additional cost to the facilities operators. We are convinced that such an attempt is futile because of deeply entrenched FCC and other government regulations which would forbid it, and because of adamant opposition by the carriers. The cost of the net (\$12,000,000 per year) makes it impractical. However, it may be possible that new facilities, such as satellites, would change this picture.

c) Insertion into Existing Network Blanks at New York or Washington

As seen in Table 5-1, a network may have on the order of twenty blank spots during a typical day, each open from 32 to 72 seconds, providing the potential for ten to twenty minutes of information to be transmitted. Since the IVAM programming is designed in segments from a few seconds to one minute in length, it is feasible to fit such information into the blanks and to record the segments at the using stations to make up complete presentations. In addition, there are several half-hour open periods each day, usually between 3:00 pm and 7:00 pm. Also, the time between 1:00 am and 7:00 am is almost completely open and continuously available, except for infrequent maintenance down time. The programming in all networks provides ample unused available time to distribute IVAM presentations on a timely basis. This is true even for the pre- and post-prime time newscasts.

To use this network free time, there must be a video tape recorder available to store the segments at each station. Local TV stations informed us recorders normally are occupied with local commercial message playbacks. Most stations do have two or three recorders which are played alternately for the convenience of the engineer. Given priority to tape the IVAM presentation feed, the engineer can "stack" the commercials on one or two recorders to free up the other. No additional equipment would be needed at most stations, but a change in procedure

Mon - Fri

Saturday

Sunday

	Mon - Fri			Saturday			Sunday			PBS
	ABC	NBC	CBS	ABC	NBC	CBS	ABC	NBC	CBS	PBS
7AM			32			32				
8AM		72	62		72	62				
9AM	73	72	62	73	72	32	73			62
10AM	73	32	62	73	32	32	73		72	32
11AM	73	72	72	73	72	32	73		32	32
12AM	73	32	72	73	32	32	73		72	32
1PM	73	72		73	72	62	73		32	62
2PM	73	72	72	↑	↑	↑	↑	↑	↑	
3PM	73	72	72	↑	↑	↑	↑	↑	↑	
4PM	73	72	72	↑	↑	↑	↑	↑	↑	
5PM	73			↓	↓	↓	↓	↓	↓	
6PM	73			↓	↓	↓	↓	↓	↓	
7PM	33-73		32			62				
8PM	33-73		62			32			32	
9PM	33-73		33, 62			32			62	
10PM	33-73		72, 42			72			42	
11PM	33-73		32, 62			32			32	
12AM	73		32			32				
1PM	73	72			72			72		
2PM	73	72			72			72		
3PM	73	72			72			72		
4PM	73									
5PM										
6PM										
7PM										
8PM										
9PM										
10PM										
11PM										
12AM										
1AM										

Table 5-1
Open Network Feed Times for Typical Week

would be required. The use of minicomputers simplifies this problem of scheduling by programming control of the recorders for commercials, public service announcements, network program recording, and local station playback on-the-air. The distribution of national scale IVAM data from a central feed in New York or Washington does not appear to pose a serious problem. The necessary facilities, equipment, and techniques already exist, and the service can be provided at no additional equipment cost to the government networks or local stations. The possibility of additional cost to the local stations for engineer's time to man the recorders to intercept the IVAM segments appears to be decreasing.

d) Insertion at Regional/Local Network Nodes

While providing IVAM presentations on the national scale is a worthwhile goal in itself, the major value of IVAM is to provide current information on the local scale. We discussed local distribution at great length with affiliated and independent stations and with the large networks. These discussions have produced a feasible plan to feed network stations (12).

Although most commercials originated by the networks are distributed nationally, there are some which are distributed regionally, such as snowmobile ads, soap commercials narrated in regional accents, certain beer ads, etc. To accommodate these commercials the networks have developed techniques for originating distribution at points along their network paths so the area of interest is the only one served. For example, suppose a Coors beer ad is to be shown during a particular commercial program slot, but only in the Rocky Mountain and Northwest areas. The commercial will probably be made up in New York, and then is sent before program time to those stations which

are located "up-stream" on the network from the area of interest. When the programmed commercial slot time arrives, the pre-recorded commercial is originated by the up-stream station. Stations located downstream on the network from the area of interest, but still up-stream from, say California, are instructed to use local programming during the commercial intended for California viewers. In principle, any network station can break the net and act as an originating point for all stations downstream from that point. Some stations are better equipped for this service than others. All of these network control and switching functions are performed by network and station people; AT&T is not involved in any way. No additional network charges are incurred in this kind of operation.

Commercials, or other program materials which are distributed regionally, may be originated live at the up-stream station, but they usually are sent to the station at the end of the daily news feed and recorded for replay at the designated time.

The potential for feeding IVAM presentations on a local, or at least small-region, basis to network affiliate stations exists, and has been amply demonstrated. The next question was whether the four network distribution lines and the location of National Weather Service Forecast Offices (WSFO's) coincided sufficiently well to make up-stream regional IVAM distribution feasible. We requested net routing maps from the four networks and were told the actual physical location of lines, switching centers, etc., is not made public for fear of destructive acts. However, after requesting more general information, all four networks gave us route billing maps which show the direction of transmission, mode of transmission (AT&T, private net, broadcast intercept, etc.), and general routing. We agreed not to republish these maps since the network

officials consider them proprietary. (At the working level, we found that all networks had copies of all other networks' maps, and used them to help each other out during equipment failures.) The PBS map is shown in Figure 5-1, and a composite network map, altered to conceal any one network's pattern, is shown in Figure 5-2.

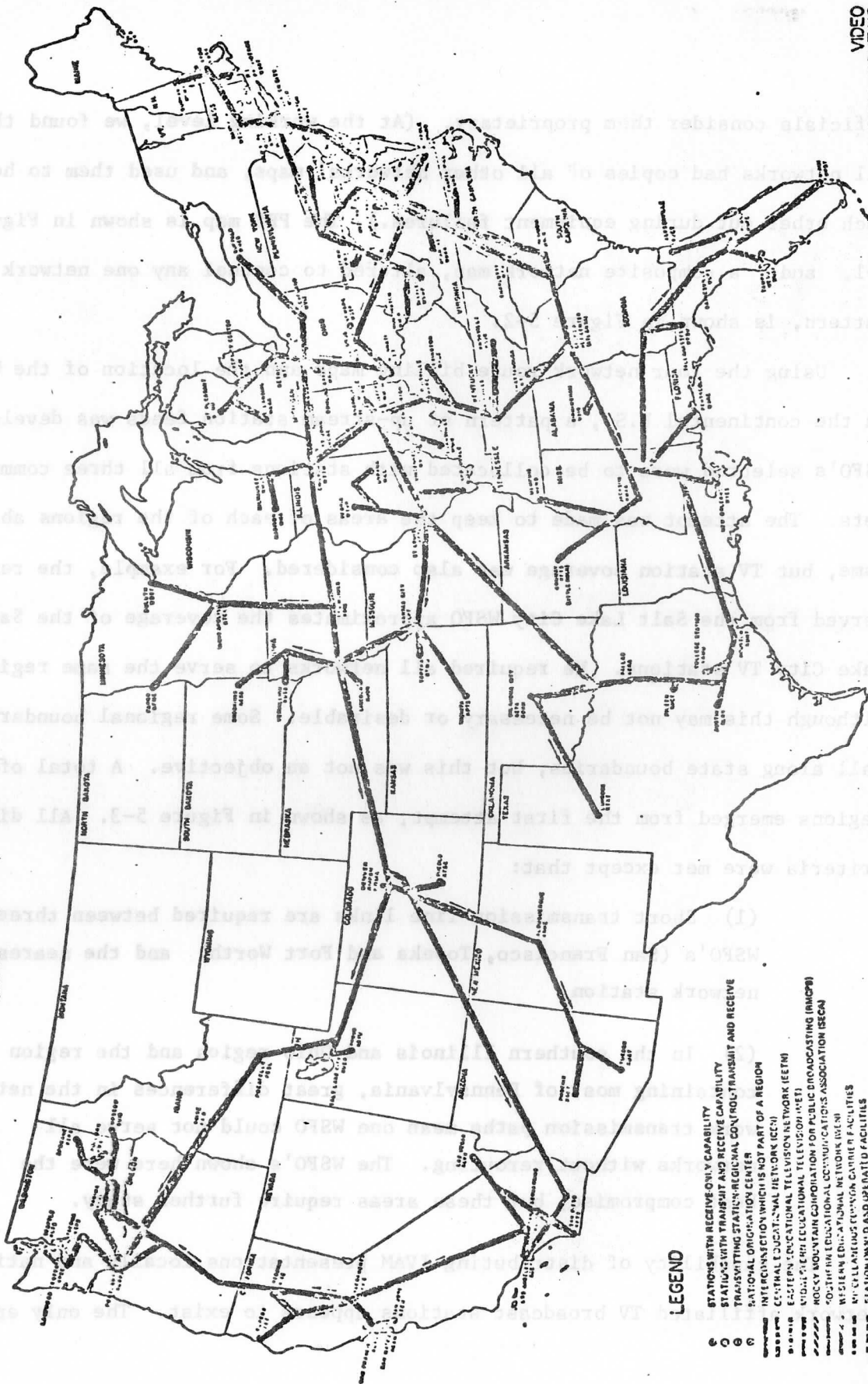
Using the four network route billing maps and the location of the WSFO's in the continental U.S., a pattern of up-stream station feeds was developed. WSFO's selected were to be collocated with stations from all three commercial nets. The attempt was made to keep the areas of each of the regions about the same, but TV station coverage was also considered. For example, the regions served from the Salt Lake City WSFO approximates the coverage of the Salt Lake City TV stations. We required all networks to serve the same regions, although this may not be necessary or desirable. Some regional boundaries fall along state boundaries, but this was not an objective. A total of 24 regions emerged from the first attempt, as shown in Figure 5-3. All distribution criteria were met except that:

- (1) Short transmission line links are required between three WSFO's (San Francisco, Topeka and Fort Worth) and the nearest network station.
- (2) In the southern Illinois and Ohio region and the region containing most of Pennsylvania, great differences in the network transmission paths mean one WSFO could not serve all networks without rerouting. The WSFO's shown here were the best compromise, but these areas require further study.

The capability of distributing IVAM presentations locally and nationally to network affiliated TV broadcast stations appears to exist. The only apparent



INTERCONNECTION SYSTEM



LEGEND

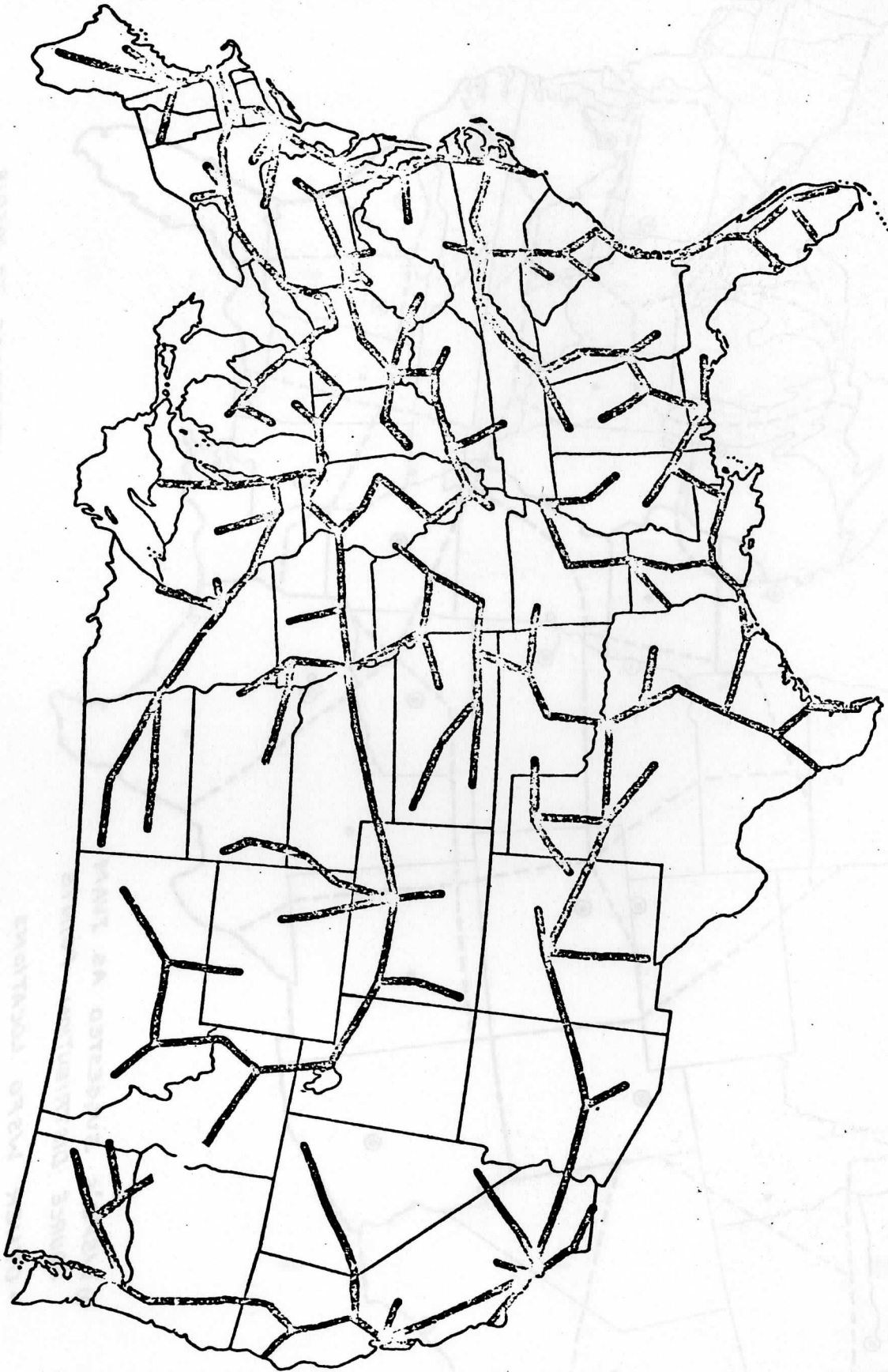
- STATIONS WITH RECEIVE ONLY CAPABILITY
- STATIONS WITH TRANSMIT AND RECEIVE CAPABILITY
- TRANSITING STATION REGIONAL CONTROL TRANSMIT AND RECEIVE
- NATIONAL ORIGIN CENTER
- INTERCONNECTION WHICH IS NOT PART OF A REGION
- CENTRAL EDUCATIONAL TELEVISION NETWORK (CETN)
- EASTERN EDUCATIONAL TELEVISION NETWORK (EETN)
- MIDWESTERN EDUCATIONAL TELEVISION NETWORK (METN)
- ROCKY MOUNTAIN EDUCATIONAL TELEVISION NETWORK (RMETN)
- SOUTHERN EDUCATIONAL TELEVISION NETWORK (SETN)
- WESTERN EDUCATIONAL TELEVISION NETWORK (WETN)
- STATION UNLINKED AND OPERATIONAL FACILITIES

This map is based on data provided by member stations and is subject to change without notice. It is not intended to be a legal document.

**VIDEO
PHYSICAL ROUTING**
REVISED 10/10/77
BY PBS STATION 1, 1977
FOR PBS

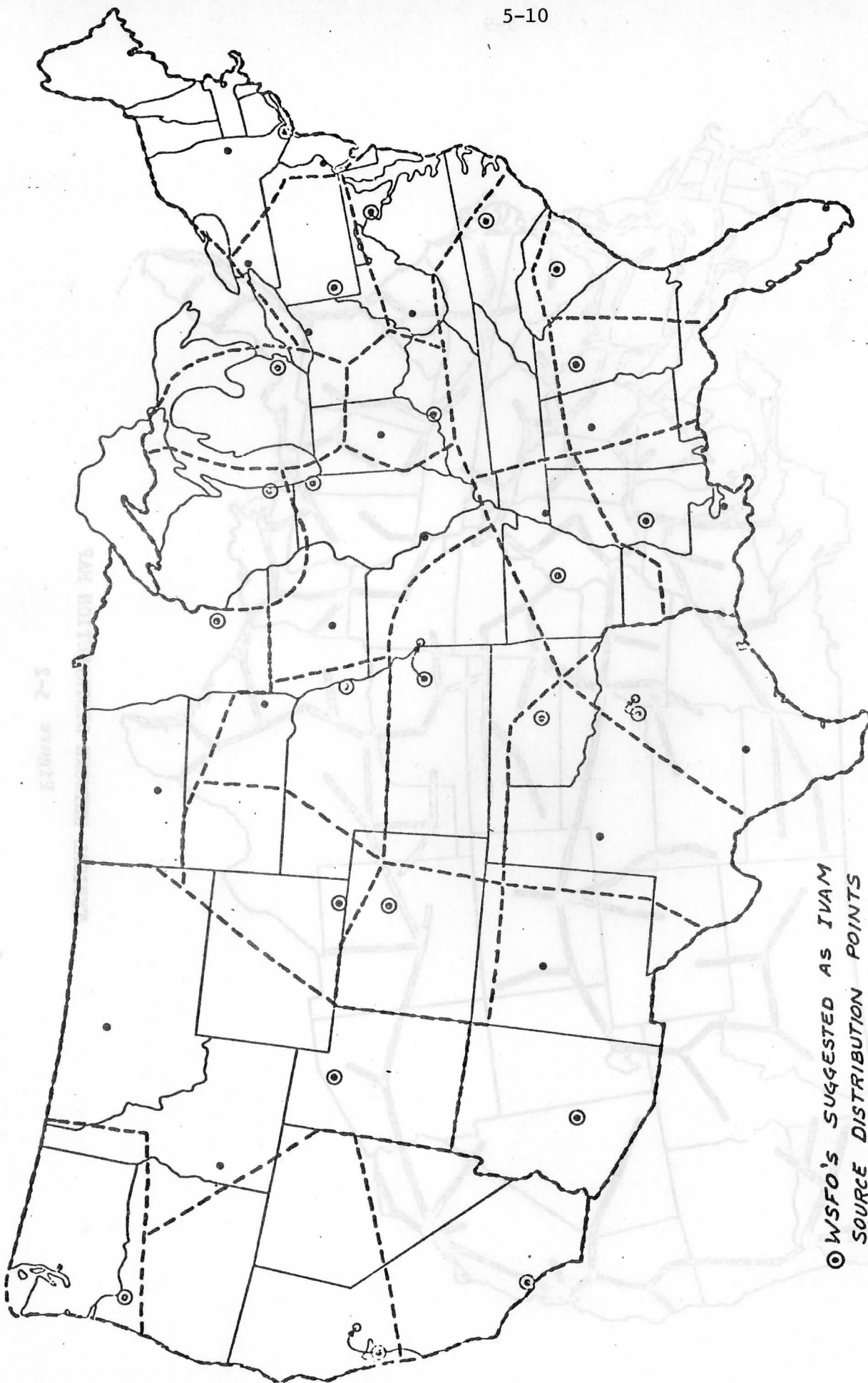
PBS PHYSICAL ROUTING MAP

Figure 5-1



TYPICAL NETWORK DISTRIBUTION MAP

Figure 5-2



○ WSFO'S SUGGESTED AS IVAM
SOURCE DISTRIBUTION POINTS

• OTHER WSFO LOCATIONS

LOCATIONS OF WSFO'S FOR IVAM INTERFACE TO MEDIA
FIGURE 5-3

additional costs are small added personnel costs at the stations, and the cost of installing video lines between the WSFO's and the local network stations. Neither appears to be a large cost, and both are compensated for by the improved service and reduced weathercaster effort. The majority of station managers with whom we spoke considered the cost to be acceptable, and encouraged us to proceed with the program.

At one of the annual briefings in Washington, D.C., it was recommended that this distribution scheme be applied to all WSFO's. The same principle would apply, and the task would be facilitated by the increased ease in linking the WSFO to the area of coverage. However, the actual details of connection and programming at each WSFO need to be addressed when the implementation is imminent.

5.2 Cable TV

All cable TV stations have access to one or more networks. In some cases this access is via broadcast intercept; i.e., the cable station simply intercepts an out-of-town station and distributes it locally. Cable stations having access to network feeds can record and use the IVAM segments as the broadcast stations do. However, this does not seem to be a valid basis for supporting cable TV outlets. The segments distributed by network feed will be intended to support up to five short (2.5-4.5 minute) presentations per day (8:00 am, noon, 5:00 pm, 6:00 pm, 10:00 pm) and perform some very short spot updates.

This quantity of material, most of it probably received in short segments and requiring a weathercaster to present it, is of little value to the cable TV operator. He lacks the manpower to operate the recorders and to assemble the presentation and few, if any, cable TV stations employ weathercasters. The

cable TV station operators need a service which will fill up to a complete channel for as many hours as the station operates; in return, he will provide the channel.

It is reasonable to project a satisfactory cable station operation based on an endless loop tape recorder with five minute capacity operating continuously. Each 30 minutes, a five-minute IVAM presentation is received and simultaneously cablecast and recorded. The recording is repeated each five minutes until the next presentation is received from IVAM. If the IVAM service were available, the cable stations would buy the loop recorder (estimated cost is \$18,000), according to the cable operators we interviewed.

The problem is to get the IVAM presentations to the cable TV stations. We are not able to propose a detailed plan for distribution of IVAM presentations to cable TV stations at this time. We have studied the cable TV industry sufficiently and know it is too immature and chaotic to present a sufficiently unified and defined interface to treat on a system basis.

When considered on a local or regional basis, each case must be treated individually. In the Fort Worth-Dallas area, we have been assured that as soon as IVAM is ready at the Fort Worth WSFO, the cable will be installed to feed the regional net already in existence. We believe other major metropolitan areas (but not all of them) also would be prepared to provide the necessary cable to WSFO's in their vicinity.

The inability to assure service to all cable TV outlets at this time should not retard development of IVAM. Cable TV is in its infancy and growing rapidly. The value of continuous, current, local weather service to the public is very great, and the value of IVAM service to the cable TV stations is recognized by

cable industry representatives to be large. We are confident that as the cable TV industry grows, it will incorporate the capability of distributing the IVAM presentations.

5.3 Broadcast Television

Four major video distribution networks feed affiliate stations on a nationwide scale: CBS, NBC, ABC, and PBS. For the most part, distribution of PBS programming is handled like that for the three commercial networks, and is considered the same in this report, with the exceptions noted (1, 2, 3).

Most programming for the three commercial networks originates in New York City (the PBS programming generally originates in Washington, D.C.) and all networks can originate from Washington. Most network transmission is through facilities owned by AT&T and leased to the networks. Each of the three commercial networks pays AT&T about \$12 million per year for 24-hour-a-day service. This service is a one-way service; it allows a feed of information from New York or Washington to the stations only.

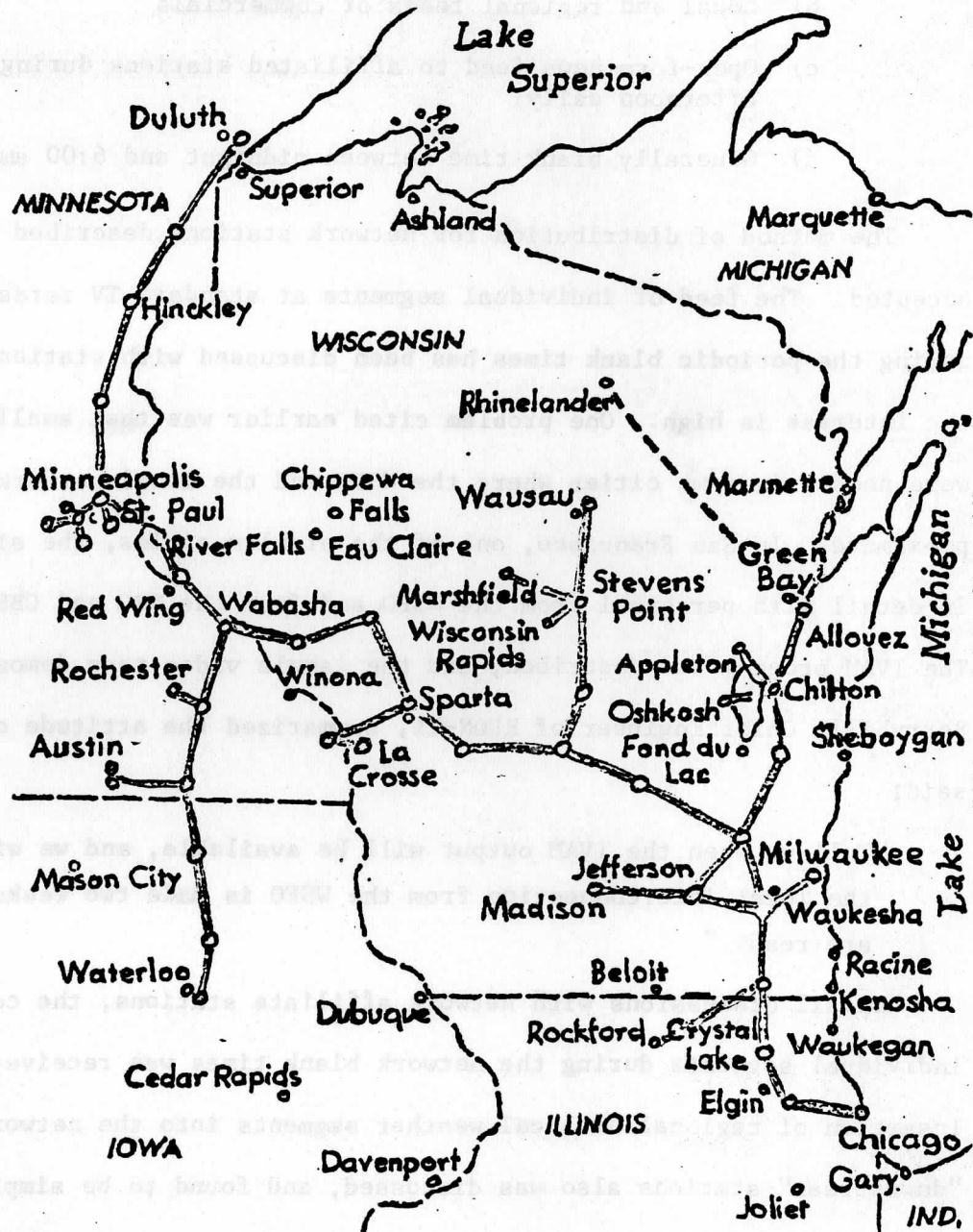
The feeding of information from locations other than New York or Washington requires the use of one of three types of part-time service provided by AT&T. One type builds the channel for a special event and takes it down each time. This service, used on an occasional basis, costs \$.75 per hour per mile, plus set-up costs. Another service, provided to TVN (Television News Service), but available to anyone with the need (and funds), is based on one hour per day and costs \$18 per mile per month. Actually AT&T sets up and takes down the equipment every day, so it can be used for other services. A third service provides ten hours per day at a cost of \$40 per mile per month. This is used by the regular networks and the Hughes Sports Network for special events originating outside New York or Washington, D.C. (1).

AT&T provides about 20,000 miles of "dedicated" interconnection. while this interconnection is leased as unidirectional, much of it can be used for transmission in the opposite direction (under a separate lease agreement, of course). Studying the network's distribution map, it appears the networks are routed so that in a few cases, two networks are feeding over the same path but in opposite directions. In addition to the dedicated interconnection, there is unspecified mileage of part-time lines and back-up links which are used in case of failure of the primary network links.

A small but growing number of independent relay companies are forming in different parts of the country. They have developed as competition with AT&T links to reduce cost to the networks and local stations. For example, a Milwaukee-owned company, Midwestern Relay Company, provides service for all four networks to Wisconsin, Minnesota, western Iowa, and northern Illinois. A physical routing map is shown in Figure 5-4. Typical of most relay companies, Midwestern offers bidirectional service and special channels at rates much lower than AT&T. The networks have encouraged the development of independents, and their continued formation is likely unless AT&T reduces rates by a large factor and for a long period. They are of interest to IVAM because they provide additional flexibility in the future transmission of video data on a local and regional scale.

The general characteristics of network TV distribution are characterized as follows:

- 1) Leased by each network annually for 24 hour-per-day use
- 2) Dedicated lines for national coverage
- 3) Generally fed in a single direction, but many links could be reversed if necessary
- 4) Backup channel is available



MIDWESTERN RELAY SYSTEM

FIGURE 5-4.

- 5) Each of the four networks operates independently, but all follow the general rule of:
 - a) Periodic blank times on the feed of 15, 30, 60, 72, or 96 seconds, at least every half-hour
 - b) Local and regional feeds of commercials
 - c) Open-form news feed to affiliated stations during late afternoon daily
 - d) Generally blank time between midnight and 6:00 am every day.

The method of distribution for network stations described has not been widely accepted. The feed of individual segments at standard TV rates on the network during the periodic blank times has been discussed with station operators and the interest is high. One problem cited earlier was that small local links were needed in some cities where the WSFO and the local network terminal were not proximate. In San Francisco, one of the problem cities, the situation was discussed in detail with personnel from the WSFO and from the NBC and CBS TV stations. The IVAM program was described, and the sample video tape demonstrated. Mr. Berryhill, Chief Engineer of KRON-TV, summarized the attitude of all when he said:

"Tell us when the IVAM output will be available, and we will see that the local interconnection from the WSFO is made two weeks before you are ready."

In all discussions with network affiliate stations, the concept of feeding individual segments during the network blank times was received positively. Insertion of regional or local weather segments into the network for use by "downstream" stations also was discussed, and found to be simply a matter of working out details, similar to regional commercials using the same scheme.

5.4 Distribution to Cable TV and Independent Broadcast TV Stations

While network broadcast TV reaches 95 per cent of the U.S. population, cable TV is a very important medium with its capacity for supplying a much greater volume of information. Even considering the growth that has occurred in the past few years, cable TV is still in its infancy. The major obstacles of licensing and other legally-oriented restrictions have been passed, and cable TV has before it a major growth period. Cable TV now serves almost 11 million homes in the U.S. today, or 15.3 per cent of the total U.S. population, and its cables pass nearly 30 per cent of the homes with TV sets in the country. This means laying cables, one of the major costs for cable companies, is behind them for a large market and increasing subscribership is less costly for the future. As reported in the 15 March 1976 issue of New Yorker, Mr. William Donnelley, a Young and Rubicam executive, recently pointed to what he calls, "a magical and critical number: 30 per cent penetration for cable TV." By 1981, he estimates 33 per cent of all TV sets will be wired for cable. He then pointed out that major advertisers left radio for TV when 30 per cent of the nation's households had TV's, and then switched to color commercials when 30 per cent of the Nation's TV owners bought color sets.

According to Mr. Donnelley, "In 1980 cable TV will have the bone structure for a quantum leap followed by an effectively wired nation a decade later."

Cable TV is an ideal medium for the dissemination of IVAM data, since the number of channels provided by cable TV allows dedication of one channel to full-time weather advisory service. Many municipalities require the local cable TV to provide continuous weather coverage 24 hours a day on a dedicated channel.

Cable television, being a relatively new industry, does not have established methods of distribution as does broadcast television. In fact, the entire

subject of distribution for cable television is in a state of rapid change within the industry at this time (4). Cable television stations across the country share the problem of finding sufficient program material to fill their allotted channels with interesting subject matter. Origination of many hours of programming from the local stations is impossible because of demands on equipment, studio space, talent, and funds. The cable stations have begun to look to each other for the sharing of programs, and interconnection (or "netting") is being established.

Netting takes place at local and regional scales, and national nets are being planned. Local interconnection is relatively inexpensive for companies with adjoining territories and easy if the interconnection is done within one governmental jurisdiction. Interconnection between different communities or regions requires a more organized plan, since it involves the policies of more than one government authority. In spite of difficulties, cable systems have installed a large amount of netting throughout the country connecting both large and small companies.

The netting of cable companies is in response to a need for more and more diverse programming. In some cases cable networks have developed around the independent broadcast television stations because of the broadcast station's greater capability to generate programs (4). If cable companies continue to interconnect with broadcast independents, a very powerful new communication network can grow, one which can easily include a dedicated weather channel.

The number of local cable TV interconnections is nearly as large and varied as are the cable TV stations themselves. For example:

WGN feeds a cable network to the large Chicago and northern Indiana area. A large cable network in Kansas City serves over one million people, reaching into Kansas, Idaho, South Dakota, and Nebraska. Johnson City, Texas,

is served by 12 interconnected cable companies. Sterling Communications of New York City serves 70,000 subscribers for major events in Madison Square Garden. It also has interconnection with independent channels 5, 9, and 11 of NYC. The statewide Pennsylvania Cable Operators is largely state funded, in a combination of cable and educational broadcast TV. They use state-owned fire watch towers for microwave relay antenna mounts.

Obviously, the development of cable TV nets is a new part of a very young industry. As these nets grow and mature they will provide increasing opportunities for distribution of IVAM presentations.

In addition to the various local and regional nets, there are some very positive forces at work for organized, national netting. The CSAE (Cable Satellite Access Entity) is a national organization of 80 major cable systems established to study an organized approach to national cable network interconnection. They have sponsored a four-part study conducted by Booz, Allen, and Hamilton covering (5,6):

- a) Availability of programs, netting, fee policies, etc.
- b) Business format of organization, amortization, cash flow, etc.
- c) Engineering -- applications problems, using equipment within state-of-the-art
- d) Regulations -- national, regional, local.

The outcome of the study provides a practical plan for a nationwide cable interconnection via satellite. Tradeoffs consider low cost receivers vs high cost spacecraft, or higher cost receivers and low cost spacecraft. The detailed report has not yet been released outside the CSAB group, but has received high acceptance within the group.

Another consortium comprised of PBS stations (5) is planning to develop a second network, using some cable to provide:

- a) higher sound fidelity (with stereo)
- b) higher picture fidelity
- c) higher transmission reliability. Presently AT&T can "dump" a PBS broadcast without warning if the channel is needed to support a commercial broadcast.

Inter-city connection of cable companies continues to grow, as well as cable "networks" who are hungry for programming. Microwave and satellite links are continuing to multiply, and interconnection of cable companies is beginning to be more of an industry than isolated instances of local solutions. The specific plan for each locale, and sometimes each station, must still be addressed individually, but patterns are beginning to develop for general classes of interconnection.

Studies about the future of cable TV have reached widely varying conclusions, depending upon the sponsors of the study. Parallels can be recognized in the similar arguments made about broadcast television twenty years ago. The facts are the cable TV industry has met and passed the initial challenges of government regulation, public acceptance, and capital financing. The biggest problems remaining are program generation and distribution. Local distribution from house-to-house is progressing. The 629 cable systems in 1974 already pass 11 million homes (7). (Cables can reach about 1/6 of the U.S. population.) Technology may improve the physical cable laying methods and reduce the cost to rural service. The other problem, distribution between stations, also will be solved by the application of technology and the investment of capital in ground and satellite communication systems.

5.5 Other Distribution Schemes

The use of satellites for relay of video data has been growing steadily, particularly for providing source programming to cable TV stations. There are two satellite systems used: the Western Union, with 12 channels, and the RCA satellite with 24 channels. There are about 200 earth stations receiving satellite relayed video, each station feeding three or four cable TV systems.

There is a tendency for the cable companies to interconnect in areas surrounding the receiving stations, forming an informal sort of networking. The likelihood of transmitting IVAM data via satellite is low, since IVAM's weather for cable is emphasis on the local, and satellite transmission is suited for cross-country communication. However, the netting being developed at satellite terminals provides a strong cable distribution system at the local and regional level. In fact, the local netting of cable coincides with the location of many of the WSFO's identified as IVAM sources.

In addition to the increase in satellite communications, new land-based communication networks are developing which will compete with AT&T. Data Transmission Company has proposed a switched system for digital data transmission at voice rates, but one which may handle video rate data as well. Microwave Communications, Inc., has proposed a point-to-point (closed circuit) interconnection system which could deliver television signals to areas servicing 75 per cent of the nation's population (10). Clearly the possibilities of interconnection are very real and improving.

5.6 Low Bandwidth Distribution

When considering data transmission at less than video rate, there are four standard options available:

- 1) 4.8Kbps switched phone line
- 2) 9.6Kbps dedicated phone line
- 3) 19.2Kbps conditioned phone line
- 4) 56Kbps conditioned phone line.

The standard "dial-up" phone line is sufficient for transmission rates up to 4.8Kbps. The dial-up line has been used up to 7.2Kbps, but the reliability is low for such use on a regular basis. Conditioned lines are available up to the 56Kbps rate, guaranteed bandwidth, with the appropriate conditioners at each end.

A full video image in digital format takes 10 minutes to transmit on a conventional phone line at 4.8Kbps. For a half-hour update period, this allows an update of three pictures. Assuming an update requirement of 20 per cent of information per hour, this would allow change of 6 out of 30 TV frames. While this seems hopelessly slow, compared to the video rates discussed in other parts of IVAM, using good quality graphics to present past and predicted information is a great improvement over the alphanumerics currently in use on cable TV. The display of current data in color on a map makes the "picture's worth 1,000 words" phrase come true.

A 9.6Kbps phone line is available over conventional switched lines at a small increase in cost. The greater bandwidth doubles the possibilities described in the previous paragraph. Up to 12 complete frames can be transmitted every hour.

The larger number of available frames would allow slow step, animated sequences, as well as static graphic presentations.

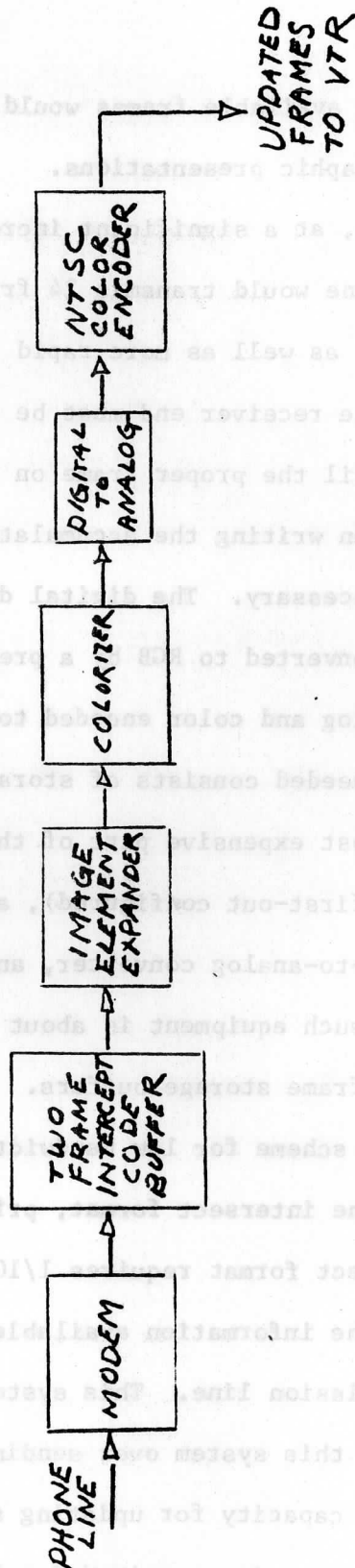
The next option, at a significant increase in cost, is to install a 19.2Kbps phone line. This line would transmit 24 frames per hour with a greater range of animation available, as well as more rapid response to changing weather conditions.

Equipment at the receiver end must be capable of accumulating the digital data, storing it until the proper frame on the looping program tape reaches the record head, and then writing the accumulated data into the proper frame on the tape, repeated as necessary. The digital data would output from the accumulator at video rate, be converted to RGB by a prewired colorizer, and then be converted from digital to analog and color encoded to NTSC standards before being recorded.

The equipment needed consists of storage space for two complete frames of digital data (the most expensive part of the system, but within reason since they are first-in, first-out configured), a simple colorizer with prewired color assignment, digital-to-analog converter, and an NTSC color-phase-modulator. Estimated cost for such equipment is about \$30,000 to \$40,000, the major cost being the two full frame storage buffers.

An alternative scheme for low bandwidth transmission is to send data in the image element-TV line intersect format, prior to being expanded into full TV frames. The intersect format requires 1/10 the data volume of fully expanded scan lines, increasing the information available to a cable station by a factor of ten for the same transmission line. This system is shown in Figure 5-5. The two major advantages of this system over sending fully expanded images are:

- 1) Increased capacity for updating segments
- 2) Decreased capacity required for buffer storage.



ALTERNATE SCHEME FOR RECEPTION OF LOW BANDWIDTH IVAM TRANSMISSION

FIGURE 5-5.

This system does not include a temporary storage buffer which can hold frames until the looping tape player (assuming about a five-minute cycle time) reaches the frame to be replaced. It appears possible to time the transmission of new frames to coincide with the position of the looping tape, but we have not yet analyzed this distribution mode completely. The use of an analog video recording disk instead of a looping tape recorder must be studied carefully.

If we take the 9.6Kbps line as the basis for a low bandwidth distribution system and use the intercept coding scheme, the average frame rate will be about 120 frames per hour. The characteristics of the presentation which this capability can support would have been explored in greater detail next year. The possibilities are very attractive, and receiving end equipment costs could probably be kept quite low.

Equipment needed for this system is basically the same as for the fully expanded frame data, but with the requirement for buffers reduced to 1/10 and the addition of an Expander. Cost of the buffers will drop from \$20,000 for the full frame buffers to about \$5,000 for the 1/10 frame buffers. Additional cost of the Expander amounts to about \$5,000, resulting in a projected cost for this configuration around \$25,000. The control functions necessary for this receiving system are straightforward and may be simply prewired. However, it may be less expensive to use a microprocessor, and our cost estimate is based on that alternative.

The extent to which low bandwidth transmission using intercept coding will be used depends to some extent on the acceptability of presentations which do not include unmodified satellite images. It is possible to process satellite pictures to produce smoothed contours of cloud brightness and to reconstruct them at the

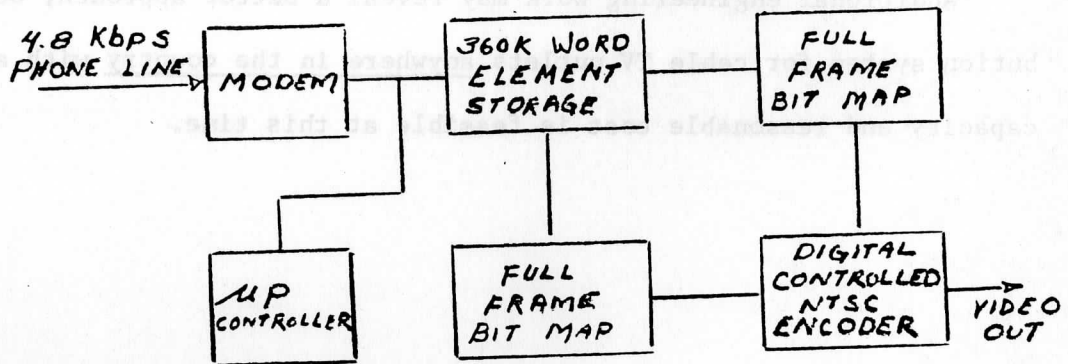
receiving end. The result is a simplified cloud cover graphic which includes most of the large-scale information present in the original image. However, small-scale details are eliminated, and it does not "look like a picture."

The acceptability of these cloud graphics has been evaluated and is discussed in Appendix E of this report.

A more economical approach to low bandwidth transmission for graphics can be used to transmit "image elements" from the video assembler of IVAM at the WSFO, using a common 4.8Kbps phone line. A typical element is 2K words in size. An image may consist of up to about 10 elements, half of which are data dependent. (The other half are "constant" for the picture, and may consist of map data, annotation of titles, and other basic format data.)

Assuming a five element picture x 2K per element = 10K words (or 160K bits), this means that all data required for a picture (or picture update) could be sent in 30 seconds on a 4.8Kbps typical phone line. This scheme, of course, would require a certain amount of "smart" processing at the receiving end. (See Figure 5-6.)

Assuming three minutes of a five minute cyclical program must be updated each hour, and each frame has an average dwell of 10 seconds, 18 frames total would need to be handled. Element storage, at 10 elements per frame, would amount to 180 elements (360K words). Of the 180 elements, only 90 are dependent on changing data, which means a complete update of all segment information can be done in 45 minutes. This scheme is not restricted to updating only new data information, but new segments can be programmed directly. In addition, during emergency conditions, alphanumeric data can be transmitted within seconds of warning.



BLOCK DIAGRAM OF RECEPTION SCHEME FOR
LOW BANDWIDTH TRANSMISSION

FIGURE 5-6

The 360K word storage need not be fast. It could be a floppy disk or other low cost recorder. The two full-frame bit maps would cost about \$5K each, and the NTSC encoder and μ P controller would cost another \$5K.

Total hardware cost for such a system would be \$20-25K. This system would be limited to graphic data, but could provide sufficient programming change capacity each hour and the capability to transmit emergency information nearly immediately, all via conventional 4.8Kbps phone line.

Additional engineering work may reveal a better approach, but a distribution system for cable TV outlets anywhere in the country with adequate capacity and reasonable cost is feasible at this time.



Block Diagram of Reception Scheme for Low Bandwidth Transmission

Figure 2-6

REFERENCES

1. H. Pappert, ATT, Personal Interview, January 10, 1975.
2. M. D. Lacey, PBS, Personal Interview, March 4, 1975.
3. A. Tiano, WHA-TV, Station Manager, Personal Interview, December 6, 1974.
4. P. Fox, Cable Television Information Center, Personal Interview, March 3, 1975.
5. Delmer Portz, Vice-President, NCTA, Personal Interview, March 4, 1975.
6. Probing Prospects for Cable Hook-up via Satellite, Broadcasting, p. 27, December 16, 1974.
7. Nat'l Cable TV Association, Local Organization Directory, 1974.
8. R. Shermaoski, Vice-President, TVN, Personal Interview, January 28, 1975.
9. New York Times, TV News Service to Transmit Materials by Satellite, January 28, 1975.
10. Cable Television Interconnection, CTIC, The Urban Institute, 1974.
11. R. Little, CBS News, Personal Interview, January 10, 1975.
12. A Cusumano, ABC Director of Traffic, Personal Interview, January 10, 1975.

Scanner's note:

This page is blank.

6.0 Presentation Test and Evaluation

6.1 Approach

The separation of Presentation Test and Evaluation from the Presentation Content and Format Studies is a somewhat unnatural division since a great amount of material in the content and format is a result of the test and evaluation efforts. However, the separation is maintained since the contract addresses the topic as two efforts.

The evaluation of program content is a highly subjective activity and, without careful control, could become an indeterminate set of opinions. To avoid such a pitfall we have limited our evaluation efforts to two areas:

- a) Output demonstration tapes
- b) Organization of and feedback from the IVAM Weathercaster Advisory Panel.

6.2 IVAM Weathercaster Advisory Panel

In January 1975, Mr. Tom Haig delivered a paper on IVAM at the AWS Weathercasters' Association Meeting in Denver, Colorado. He suggested to the weathercasters that they form a small group of volunteer members to serve as an advisory panel to the IVAM program. The suggestion was received warmly, and several members of the association expressed interest in a questionnaire that was circulated by Mr. Haig.

The first meeting of the AMS Advisory Panel was held on 15 February 1976. Attending were: Conrad Johnson (Chairman), WMT-TV, Cedar Rapids, Iowa; Mark Eubank, KUTV, Salt Lake City, Utah; Fred Norman, KOCO-TV, Oklahoma City, Oklahoma; Elliot Abrams, WPSX-TV, State College, Pennsylvania; Gerge Winterling, WNIV-TV, DeKalb, Illinois; and University of Wisconsin personnel. IVAM concepts and status were discussed, and the panel made several suggestions for improving the IVAM output.

The panel emphasized:

- 1) Animation is very important for conveying certain weather information, especially precipitation patterns and history.
- 2) All of the panel members urged IVAM to provide, as an additional service, a special series of TV frames with the "raw" weather data in the AFOS manner for weathercasting use only.
- 3) Panel members felt that, if unavoidable, they could afford hardware for recording image segments and perhaps also to provide data to remote locations.
- 4) IVAM must be capable of providing warnings.

Several of the weathercasters use their own animated artwork, using various schemes to produce it. The production is tedious and expensive. IVAM animated segments were discussed with great enthusiasm. Mark Eubank remarked, "One of the most difficult things is to stand in front of a still map and try to describe how the weather is moving." Conrad Johnson uses an elaborate system of mirrors, rotating disks, and a viticon camera with chromakeyed overlays to simulate radar motion.

All of the weathercasters expressed interest in having the raw data available from which the IVAM segments are produced. There were three major reasons:

- a) to be able to adjust, or at least comment on, situations which may be modified by specified local effects;
- b) to check on the accuracy or timeliness of certain data; and
- c) to be able to produce special user programs or forecasts for special audiences or private meteorological service.

A special series of TV frames, not to be broadcast but for weathercaster use only, could transmit Service A, Service C, and forecasts in a single half-minute segment. These could be recorded by the weathercaster and reviewed one frame at a time. The data is readily available in the data base and could be simply defined

as another segment.

Transmission of picture information on phone line was discussed. The cost of \$50,000 to \$100,000 for a piece of equipment was considered a reasonable amount for a TV station to buy. That would make possible the production of data for phone line transmission locally, and the TV station could receive image elements by telephone for updating the data base.

Elliot Abrams said that once the idea of "NOWCASTING" is established, there will be pressure "to be right." The ability to adjust the forecast where one knows of very local effects is important. For instance, if the segment shows a snow cover of 2-4 inches, but locally there is ten inches, you have to be able to show ten inches or you are in trouble.

Fred Norman said, "You have to be able to do warnings! That's what it's all about in Oklahoma. If you are not warning about tornadoes, you might as well not be in business!" Where warnings cannot pre-empt a current TV program, IVAM could transmit a part of a frame, each frame during the retrace period, without disrupting the program. Special equipment would be required at the receiving station to strip out the part images and to reassemble them into complete frames. A new frame could be transmitted every three seconds by this method.

The second meeting of the Panel was held on 29 August 1976. The major item on the agenda was review of the segment header sheets for the 104 broadcast TV segments developed earlier. The meeting included not only the review of segment content, but provided an opportunity to judge the effectiveness of segment descriptive terminology and categories. Review comments could be categorized into the areas of:

- 1) Additional information needed
- 2) legal implications of statements
- 3) presentation style.

Specific additional information was recommended for certain segments. In general, the group felt it to be more important to compare current data with last year, last week, or yesterday, as appropriate, rather than with "normal". The weathercasters found that typical TV viewers do not relate to "normal", but more value is derived by comparing with data from weather the viewer remembers or has experienced. When appropriate, the river stages should be included in segments covering flooding. Precipitation "total for year to date" was identified for some precipitation segments. Wind chill was covered in some segments, but the question was raised as to whether a better indicator could not be developed which included relative humidity, along with temperature and wind.

Needs for segments beyond the first 104 were discussed -- specifically to include boating, hurricanes, upper air/jet stream information, dew point, historical and climate information, and tutorial and informational segments which could be provided for the season or fed on particularly "slow" days for weather information.

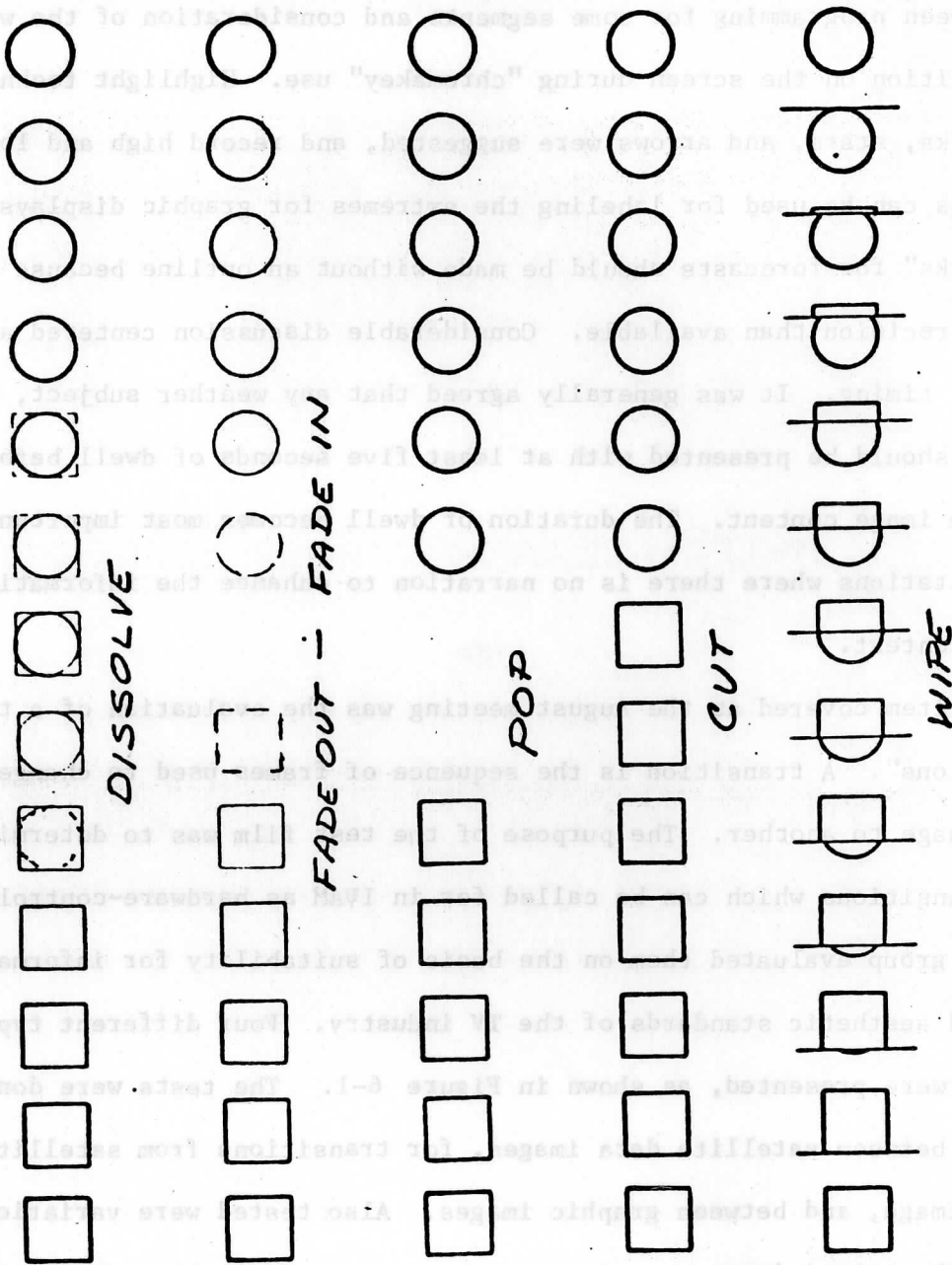
Questions of legal implications of statements about weather identified the need for a category between the EMERGENCY and NON-EMERGENCY segments, such as ALERT or CRITICAL, for instance. It was felt that certain segments, while not deserving the priority received by EMERGENCY, should receive attention above the usual. (The terms WATCH and WARNING have been deliberately avoided to reserve the applications of those values solely to NWS.) The use of language which presents consequences of weather (rather than just weather) brings about questions of legal responsibility and terms such as "Use Extreme Caution" or "Poor Driving" or "Hazardous Conditions" must be reviewed. Indeed, as the information presented becomes more immediately useful to the viewer, the meaning of weather data has greater impact and consequence.

Discussions of the advisory group on presentation style covered such things as split screen programming for some segments and consideration of the weather-caster's position on the screen during "chromakey" use. Highlight techniques such as blinks, stars, and arrows were suggested, and record high and low values of parameters can be used for labeling the extremes for graphic displays. Use of "hash marks" for forecasts should be made without an outline because outlines imply more precision than available. Considerable discussion centered around the issue of timing. It was generally agreed that any weather subject, no matter how simple, should be presented with at least five seconds of dwell before changing the image content. The duration of dwell becomes most important in cable presentations where there is no narration to enhance the information or to provide context.

Another item covered at the August meeting was the evaluation of a test film of "transitions". A transition is the sequence of frames used to change from one video image to another. The purpose of the test film was to determine some standard transitions which can be called for in IVAM as hardware-control subroutines. The group evaluated them on the basis of suitability for information transfer and aesthetic standards of the TV industry. Four different types of transitions were presented, as shown in Figure 6-1. The tests were done for transitions between satellite data images, for transitions from satellite image to graphic image, and between graphic images. Also tested were variations of timing for the transitions.

Results for the transition evaluation were compiled and summarized into a set of guidelines for IVAM use, included as Appendix F of this report.

The third advisory meeting was held February 26-27, 1977, also attended by all committee members. Major items on the agenda were to review storyboarding



IVAM TRANSITION TYPES

FIGURE 6-1.

and general program content, also to evaluate quality of several limited animation techniques presented on test film.

Each member of the review committee was requested to storyboard six segments and present them for discussion at the meeting. A number of guidelines can be established from the discussion and comments of the storyboards:

- 1) Viewers of TV weather programs expect a standard use of colors to be able to understand more quickly (and feel comfortable with) the presentation.
- 2) Use of animated sequences does not pose a problem for the weather-caster in terms of his timing and pace.
- 3) There was interest in the group in presenting more meaningful terms, such as gallons of fuel oil or dollars, rather than degree-days.
- 4) When possible, use shading or crosshatch without outline to avoid implying too much accuracy in location of weather.
- 5) General consensus was not to use counties to define WATCH areas.
- 6) There should be a segment which lists all current WARNINGS and their times of start and end.
- 7) Location of certain information, like WARNING, etc., should be in the standard place on picture.

The storyboard for segment 82 was produced on film for testing the suitability of various types of animation. Two rates of motion were tested, with several frame repeat rates within each. Also tested were several different dissolve-dwell techniques to provide animation. The aesthetic quality drops off very quickly as the animation is changed from single frame to repeat frame mode. The consensus was that single frame animation is clearly most desirable, with double-framing acceptable for slow moving images. All other graphics

animation techniques tested were considered marginal or unacceptable, including dissolve-dwell sequences. The conclusion for animation quality is that little room for compromise exists, and that animation must be very well done, or not done at all.

6.3 Picture Quality Studies

The ultimate test of the IVAM system is the public's reaction to the pictorial output. To establish the levels of excellence which the IVAM system must meet, we conducted a picture quality study. This study was an ongoing effort, and probably will continue long after IVAM is in full operation. Until IVAM can address the public on a regular basis, we must depend upon the advice and criticism of experts. The AMS Advisory Panel, consisting entirely of meteorologists expert in the communication of weather information, proved to be of great value to the program.

IVAM must operate under constraints inherent in the US television systems and those imposed by the necessity to limit cost in the IVAM system itself.

1. Compatibility with Commercial TV

Color information in the IVAM system is created and processed in the RGB convention because it is cheaper and easier to do so. A greater range of color and brightness possibilities exist in the RGB system than are allowed by the NTSC system used by broadcast and cable TV in the United States.

a. Bandwidth Limits of the NTSC

The phase modulation scheme of NTSC encoding exerts two limits on the system capability to produce color:

- 1) Many colors attainable in RGB are not attainable in the NTSC system.
- 2) Adjacency of certain colors causes "color crawl".

The RGB system makes use of a large bandwidth by virtue of its three separate channels, which allows a broad range of combinations of full range red, full range green, and full range blue. With the NTSC encoding system the full information must be "squeezed" through a bandwidth which does not pass the full range of R, G, and B combinations. This slew-limiting generally pre-empts encoding of colors beyond a point determined by the combined values of luminance and saturation. The large choice of colors attainable by combinations of R, G, and B must be limited in the selected color sets to those which can be transmitted on standard TV.

The same bandwidth limit causes "color crawl". When two adjacent colors within a TV scan line require a significant difference in phase angle representation by the color subcarrier, the system does not allow phase shift quickly enough and the first color "smears" into the adjacent color. The two fields of the TV frame are produced at 180° polarity (for electronic convenience) so adjacent scan lines in the picture smear differently and a scintillation effect can occur.

Hence, in addition to concern about the reproduction of a certain color, the issue of adjacent colors must be addressed. Color crawl increases when the colors used are farther apart on the color wheel; i.e., colors with greatly different phase angles.

b. Black and White Compatibility

When a color signal is shown on monochrome TV, the only distinction between colors (which show as gray levels) is the luminance value. Two colors may have sufficient color contrast but still have the same luminance, and when shown on monochrome TV they will be indistinguishable. To be acceptable for monochrome reception, adjacent colors of a colored image must have significantly

different luminance values. The practical limit of number of gray levels discernible on a monochrome TV receiver is ten, but industry guidelines suggest no more than five. These numbers are very restrictive in terms of colors available, unless one adds another level of complexity, the consideration of non-adjacent use of different colors with the same luminance.

c. Line Quality Considerations

The present system on McIDAS draws map and contour lines one pixel (picture element) wide. These lines are acceptable within the wide bandwidth of the RGB system, but the one pixel vertical lines disappear when displayed on the NTSC monitor. Widening the line to 2, 3, or 4 pixels helps, and is designed into the Video Assembler subsystem. Horizontal lines one pixel wide tend to "blink" because they reside in only one field of each frame and are refreshed only 30 times per second. Widening these lines helps, and will be done, but the optimum line width in TV lines and pixels depends upon the context of the complete graphic. The digital "stair-step" appearance of thin lines can be decreased by "shading" the lines on the outside pixels. Tests of shading and smoothing have been performed and software modules exist for smoothing the stair-step effect.

d. Other Limitations Due to Use of Conventional TV

Some TV broadcast stations use a "hard AGC" (Automatic Gain Control) which forces all frames to an average brightness. If color choice (and corresponding gray levels) are not properly chosen, color balances and adjacent gray values are shifted up or down in brightness and the picture quality is lost. This effect can be noticed on some local TV stations when playing old films which use subtle lighting effects.

Picture brightness must follow the rules of:

- 1) Picture is viewable with normal ambient light conditions
- 2) Picture does not make large changes in average brightness from frame to frame, or segment to segment.

Tests were performed on a standard set of color swatches, COLOR-AID PACK, manufactured by Geller Artist Materials, Inc., to evaluate the RGB values and suitability for TV use. The tests were performed using a calibrated TV camera set-up, with color vector scope and oscilloscope for quantitative read-out. AGC variation was balanced out by adjusting each TV picture to normalized gray scale and color balance. Measurements were made of R, G, B values, as well as hue, saturation, and luminance for each color. Many colors were too intense to be used for TV, either in luminance or in the combination of luminance and saturation, especially many yellows and oranges.

While the color swatch tests provide useful information on the suitability of a particular color for TV, some difference in the color reproduced using the RGB values is likely. The printer's ink used for producing such samples generally provides narrow spectra of wavelength, whereas the TV camera has a wider three color responsivity peaking at different frequencies. In addition, some components of ink on a swatch contain components of color outside the wavelength of the camera responsivity.

The establishment of color sets for selection at IVAM output may be generated by generating color combinations of the color bar test pattern which are within known allowable saturation levels. By varying the luminance of the color-bar colors and combining them, a complete palette can be generated, and the resultant combinations will be reproducible within the NTSC system.

The literature generally recommends a minimum number of colors be used in graphics. The number of colors, choice of colors for color compatibility, and black and white compatibility are closely related to the issues of image "clutter" and the length of time required for a segment to convey information. Here engineering begins to get close to subjective evaluation, and timing and image clutter have been the subject for testing with the AMS Advisory Panel.

The purpose of addressing color issues is to define a collection of "color sets" which can be selected automatically by the Controller to provide a pleasing image and satisfy the requirements of NTSC and black and white compatibility. A segment will have a basic requirement for a number of colors -- two, three, four, and up to eight. There will be several sets of three colors which could be used for any segment requiring three colors. However, to be suitable for the content of the segment, some of the sets may be excluded to avoid showing water on the map image as red or green, etc. The color set(s) which apply to certain segments is identified in the segment descriptor. Several different color combinations might be available for the same segment, but fed at different times. This would allow different local TV stations to maintain a certain amount of individuality while still showing the same basic segment.

The amount of time required for effective communication of a particular message must be determined for each segment. Some brief tests of the time required to convey warning messages have been performed, but only tentative conclusions have been reached. The timing consideration is dependent on context, color choice, picture complexity, and special effects, such as scintillation and animation. Storyboarding will determine the explicit "style" of each segment, and the timing should be determined by testing the segments with an Advisory Panel, and finally the audience itself. Since transmission times are limited, optimum use of segment time is paramount.

3. Alphanumerics Placement

When images are produced on an automated basis, the location of labeling in the picture must also be determined automatically. This task is easily done by hand, where one looks at the picture and can subjectively determine the size and location of alphanumerics. However, the algorithms for doing it automatically are not obvious. As the segments are storyboarded, a pattern of space use within

the picture format will allow the algorithms to be developed so that important picture information is not covered with alphanumeric.

e. Summary Color Rules for IVAM

The choice of color sets which the IVAM system uses must be determined at the implementation phase of the program. One or more color sets may apply to a particular segment and will be stored in the Controller to be called up as part of the automatic system operation. Each color set must satisfy the following:

- 1) ADJACENT COLORS should be at least two gray levels apart in the standard 10 level gray scale. This is to insure black and white compatible color.
- 2) ADJACENT COLORS must not be greater than 90° apart on the color wheel, to avoid color "crawl" at the edge between colors.
- 3) THE SUM OF LUMINANCE VALUE AND $1/2$ THE SATURATION VALUE for any single color must be less than 1.1 to be reproducible through the NTSC encoding system.
- 4) COLOR CHOICE should represent mid-range values of average picture luminance for best picture balance and brightness.
- 5) NUMBER OF COLORS should be minimized for best information transfer.

The apparent conflict between "rules" 1 and 4 is resolved by compromise, depending on the information content of the picture. One can make some adjacent colors only one gray level apart if the gray values are near mid-scale and the overall picture is uncluttered and well-balanced.

6.4 Demonstration Video Tapes

Efforts during the first year of the contract included production of a video tape to demonstrate the characteristics of output IVAM was being designed for, and also to provide an example of production issues early in the program. Many of the issues to be dealt with as the system developed would be centered around timing, color choice, art work, etc. Since the software development (and hardware application) would delay the opportunity to view an actual IVAM output, it was decided to simulate the output. Animation techniques were used to prepare a film which was later transferred to video tape. The film included a sequence for both broadcast TV and cable TV.

As the presentation developed from segment specification, to storyboards, to scenarios, and finally to artwork and motion pictures, the differences between the two presentations surprised even the creators. The same basic data set was used, October 30, 1974, and that day was picked because the weather was not spectacular. It was a "typical" Wisconsin fall day (haze, rain the night before, fog forecast for evening). The differences between the presentations developed as the peculiarities of the broadcast and cable TV media were satisfied:

The broadcast presentation was designed in easily separable segments, each carrying a complete message which could be assembled in several different logical orders. The cable presentation was designed to be shown as a complete unit. We found that the broadcast segments had to have more informational redundancy than the cable segments.

The broadcast presentation was designed to serve as supporting visual aids

to a weathercaster while the cable presentation could be shown with background music only. An audio commentary can be used with the cable presentation, but no provision was made for a person to be on the screen. We found that with a weathercaster to guide the viewer, much more information could be placed in any particular image; however, without audio help the information density on the screen had to be reduced. Therefore, it takes longer to present the same amount of information on the screen (not considering additional information in the audio channel too) via cable TV.

We learned that the images for broadcast TV must be planned to provide room for the weathercaster's image to be chromakeyed over the IVAM image without obscuring needed information. In some cases it will probably be necessary to designate certain segments as inappropriate for chromakey and only the weathercaster's voice will be added. The entire screen is available for the cable TV presentation.

The ratios of basic images to different images, and to final frame count were about the same for both presentations. That is, for a five minute presentation 9000 frames are required, of which about 450 are different in some respect, but which were derived by minor changes from 90 basic images. This implies that for the same amount of information fewer basic images were required for the broadcast presentation, and this proved to be true by about 10 per cent.

Some important limitations about use of film animation were learned from the production of this first demonstration tape; for example:

All graphics for the films were produced by photographing opaque art work; therefore, colors were limited to available color papers and paints. When produced by IVAM the range of available colors, tints and shades is unlimited, and more pleasing color relationships can be obtained. Color blends and transitions are not

feasible by photographing opaque materials, while with IVAM color transitions (blending from one color to another in a smooth sequence) are easy.

Data overlays were laboriously registered and related by hand for the camera. With IVAM, image-to-image registry is inherent and error free.

With the camera technique it is not possible to overlay a transparent color on a colored background without completely losing the background color. IVAM can blend or retain colors with complete freedom when different domains are overlaid.

We learned that great care must be exercised in selecting colors so that when the program is shown on black and white sets the information is not lost. The required gray scale-color rules will be incorporated in the IVAM logic to guarantee good black and white reception.

Mr. Terry Kelly, who served as our test presentation weathercaster, is a highly skilled professional meteorologist with some experience before a TV camera. He enjoyed using the simulated IVAM product, and found that it was much easier than he had expected. Mr. Kelly viewed the IVAM segments, making timing notes. From there he prepared cue cards and then ran the program. Neither Mr. Kelly nor the IVAM program people were satisfied with the results because it appeared flat and stilted. Mr. Kelly threw away the cue cards, and ran the show again ad-lib. The results are excellent. Based on this experience, Mr. Kelly is convinced that he could review the IVAM segments once or twice, and then present the show with no worries about timing problems. Discussions with the Weathercaster Advisory Panel members indicated the same attitude.

In making the cable TV presentation we experimented with the alphanumerics to find out size and length limitations. There is a rule in the TV industry that more than 36 characters in a line is a mistake. We found that using 24 characters per line allowed easy viewing from a distance 14 times the screen width, which is a reasonable standard. Also, the larger letter size of 24 characters looked better; i.e., suffered less confusion when placed over maps, etc.

A second video tape was produced in the spring of 1977. It consisted of two segments, #59 and #43. Both were produced for cable TV and represent typical cable TV format. Segment #43 was produced in two different test formats, and the tape also included a demonstration of how elements and domains are used to construct an image.

Creation of the video was made by the same steps that would be used for the eventual automatic operation of IVAM; i.e., storage of elements, smooth, scan convert, prepass, link, sort, pack, and fill-in as required. The major differences between production of these test segments and automatic operation were two: (1) The test segments were produced by manually stepping through the control functions, and (2) the McIDAS digital terminal was used for output assembly with its attendant limit of four colors and slow communication path at that time.

Conventional TV equipment was used to provide fade transitions and alphanumerics, since IVAM does not have the hardware required to produce such effects. However, the production sequence is still the same as that of IVAM in the sense that the segments are assembled in a serial fashion from data stored in files controlled by the software.

Segment #54 for cable TV represents an X-Y graphical display of temperature information. Data used for creation of the segment was actual Service A data from May 4, 5, and 6, 1977. Times of interest for temperatures were identified as: driving times to and from work, noon, and prior to bedtime. Data used for the forecast curve is not currently available in ready-to-use format, but can be derived straightforwardly from the data available.

Segment #43 was produced from a series of radar echoes over Jacksonville, Florida, and was recorded on May 8 and 9, 1977. The sequence depicts highly local information, and in test #1 uses a state map to orient the viewer to the area of coverage. Contours of accumulated rainfall were calculated via the uniform grid method from data supplied from point measurements in the Jacksonville area. Use of McIDAS equipment limited the choice of color combinations available, so two tests were made, each using different color sets.

Also included was a sequence of images which demonstrate the assembly of an output image. The sequence is produced by simply letting the video tape recorder run while the picture is being drawn, one element at a time. Manual control is used only to call files or initiate control functions. The rate of fill-in and line drawing was limited by the McIDAS communication channel used as output at that time.

A third demonstration tape was produced in early calendar 1978, using the latest software available in the IVAM system. The tape is a remake of parts of the first demonstration tape, but using actual IVAM output, drawn on the McIDAS terminal, instead of film simulation used in the original tape. The weather data used covers both the national scale and the Washington, D.C. area. The fine segments used provide the same general coverage as in the original broadcast demonstration tape.

Several developments in the IVAM software and hardware made this final tape more representative of final IVAM output. An earlier problem was finding a scheme for providing a see-through image, such as is needed for overlaying on cloud pictures. A fine-grained crosshatch gives this effect, although it appears differently for different colors, depending on the NTSC code representation of the hue and saturation. This final tape uses the crosshatch effect, not only for see-through color effects over the satellite picture (for indicating warm and cold air masses), but for open-shading of precipitation areas. Open-shading is desirable for locating precipitation to avoid misleading the viewer into thinking that the edge of the precipitation area is a distinct and precisely located line.

A "fast fill-in" hardware module was designed and built, and was added to the McIDAS system output. It received coded picture information from the IVAM system via the IVAM/McIDAS interface, and filled in and constructed the output picture from line number and pixel number start-stop information.

Grids on the satellite picture were drawn from the mapping module in the IVAM computer, not by the McIDAS as had been done earlier.

Production of each frame was done automatically by software which staged and assembled the picture by sequencing through a set of macro instructions. The output included some of the alphanumerics in the final product. They were stored as a library of character elements, then scaled, located, and included in the picture as called for by the macros.

Video taping was controlled by the IVAM computer which turned on the tape recorder when it was finished "creating" a frame of data. The receiver was controlled to tape a given amount (number of seconds) of a frame, then

stopped while the IVAM system called elements, displayed and colored them, and assembled the next picture. When assembled, the computer would again automatically turn on and record.

Since the IVAM output video assembler was only simulated to some extent by the McIDAS system, fading and dissolving between frames could not be done. To accomplish this, the tape, which consisted of thirty-second dwells of each frame, was edited by standard television studio equipment. Some alphanumerics were added at the studio, too, since the algorithms for scale, color, and location on the map were not developed for automatic inclusion by the IVAM computer.

Finally, the "IVAM output" was used with the project meteorologist, Terry Kelly, to simulate a 6:00 pm weather show as is normally included with the news. All of the final on-camera and narrative taping was done "ad-lib" after reviewing the pre-taped "IVAM output" once or twice. Scripts were not written or used, to provide a better example of how the IVAM output would ultimately be used in most broadcast TV situations.