

GOES I-M PRODUCT ASSURANCE PLAN

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EXECUTIVE SUMMARY

background

In early 1994, NOAA will introduce a new geostationary satellite series, GOES I-M that incorporates a completely new design of three axes stabilized spacecraft, new sensors, and a new ground data processing/distribution system. The new system is planned with capabilities to support NOAA programs, both operational and research to the year 2000. In particular, the new GOES will support the modernization of the National Weather Service (NWS) and its primary mission of providing warnings and forecasts. "GOES I-M and other new technologies will have an unprecedented impact on Weather Service operations" (Dr. Friday, GOES I-M Operational Satellite Conference, 1989).

purpose of plan

This NOAA GOES I-M Product Assurance Plan is necessary because there have been major changes in the spacecraft and ground systems and their impact on products must be understood. It is well known that the development of the GOES I-M system has experienced several technical problems. Many of those problems appear to have been overcome, however, certain portions of the system are still under development. There will, moreover, be no IR sensor data available for analysis before launch from a flight qualified imager or sounder; on-orbit spacecraft and sensor performance remain to be determined. The purpose of the plan is to assure the viability of GOES I-M day-1 products (equal to or better than the current GOES-7), to improve initial products and develop advanced products, and to ensure integration of the improvements into NWS and National Environmental Satellite and Data Information Service (NESDIS) operations. Product assurance must now receive high priority to bring it in step with the rest of the GOES I-M efforts.

This document details a five year program that will ensure that the opportunities offered by the new GOES system for supporting NOAA's mission will be realized. The plan is modelled on the successful NOAA Operational VAS Assessment (NOVA) program of 1983-85. It includes evaluation and validation of GOES-I and -J day-1 products, day-1 product enhancements, and evolution toward future products and sensor systems. Input has been coordinated within NOAA and NASA. Specifically, the GOES I-M Product Assurance Plan

specifics

- * Identifies the necessary linkages between NESDIS and the NOAA organizational elements using GOES I-M data, products, and services.
- * Defines GOES-I day-1 products, as well as the testing and evaluation necessary to ensure product quality.
- * Identifies procedures for user evaluation and feedback.
- * Identifies day-1 product improvements and the research and development necessary for advancing to day 2 products aimed at NOAA's high priority cross-cutting programs.
- * Defines special satellite schedules that will adequately support NOAA and national research projects such as the Mesoscale Research Program.
- * Presents a product management structure utilizing the NESDIS Product Oversight Panels and identifies the need for a multiagency Technical Advisory Committee.
- * Identifies the need to develop an active user training program.
- * Identifies additional resources above those in current NOAA program funding or staffing that may be needed to carry out this plan.

Efforts are focussed on data collection and product validation and user familiarization in the first year, technique development and new product generation in a demonstration mode for the NWS in the second year, and evaluation and incorporation of new techniques in the subsequent years.

management The overall management of all GOES I-M product assurance activities will reside with the "GOES Program Manager", assisted by a "GOES Scientist" and an "Product Coordinator". The Product Oversight Panels (POP) will see to the maintenance and evolution of the products. A Technical Advisory Committee (TAC) will provide guidance regarding priority and feasibility of future products and sensors.

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1. INTRODUCTION

1.1. Planning for Change

early history

Since the early 1960's, meteorological and oceanographic data from satellites have had a major impact on environmental analysis, forecasting and research in the United States and in other nations throughout the world. While polar orbiting satellites provided once or twice daily snapshots of various phenomena, it was not until 1967 that the ability to see weather systems in animation was realized with NASA's geostationary Applications Technology Satellites (ATS). The immediate success of ATS led to the launch of the first operational geostationary satellite with a spin scan stabilized camera in 1975. This evolved to the Geostationary Operational Environmental Satellite (GOES) that carried the VISSR (Visible and Infrared Spin Scan Radiometer), representing a major advancement in our ability to observe weather systems by providing frequent interval visible and thermal infrared imagery of the earth and its cloud cover. Weather systems within the satellites view could be monitored continuously day and night, and GOES data became a critical part of National Weather Service operations by providing unique information about emerging storms and storm systems.

By the early 1980's, the GOES system evolved to include an atmospheric temperature and humidity sounding capability with the addition of more spectral bands to the spin scan radiometer. This next evolution in the GOES system was termed GOES-VAS, VISSR Atmospheric Sounder. While the addition of channels represented a major improvement in satellite capabilities, instrument design also led to major compromises. Imaging and sounding could not be done at the same time, and a spinning satellite, viewing the earth only 5% of the satellite's duty cycle, makes it difficult to attain the instrument signal-to-noise needed for high quality soundings or the high spatial resolution infrared views of the earth needed to discern clear skies in and around clouds. Recognizing those shortcomings, NOAA began development of its next generation of geostationary satellites, GOES I-M, in 1982.

modern satellite era

The GOES I-M system promises to be a significant advancement in our national geostationary environmental satellite capabilities. All major portions of this system are new: (1) to improve spacecraft instrument performance, the satellite was designed to be earth oriented, i.e. three axes stabilized, so that its instruments could near continuously observe the earth and its cloud cover and not be limited to the 5% duty cycle of the forerunner GOES and ATS satellites; (2) new sensors were designed to improve multispectral imaging capabilities for cloud and storm diagnostics as well as multispectral sensing for atmospheric sounding; (3) the sounding and imaging functions were separated; (4) a new ground data processing system was developed to handle the high volume data that would flow from the satellite and be made into products for a variety of users; and, (5) different data transmission formats were devised for retransmission of raw data to direct receive users.

This new system must support U.S. geostationary environmental satellite requirements, both operational and research to the end of the 1990's. It is well known that the development of the GOES I-M system has experienced severe technical problems that have resulted in higher than anticipated costs and schedule delays. Much of this is due to the major design changes imposed by the transition from spinning to three axes stabilized spacecraft. Many of the technical problems appear to have been overcome, however, certain portions of the system are still under development and on-orbit spacecraft and sensor performance remain an unknown.

purpose of plan

This plan details a five year program that will ensure that the opportunities offered by the new GOES system for supporting NOAA's mission will be realized. This plan specifically addresses evaluation and validation of GOES-I and -J day-1 products, day-1 product enhancements and evolution toward future products and sensor systems. Input has been coordinated with the National Environmental Satellite and Data Information Service (NESDIS), the National Weather Service (NWS), and the Systems Program Office (SPO) in NOAA, and additional information was provided by NASA. A product assurance plan is necessary because of major changes in the GOES spacecraft, data format and ground system with the commencement of the GOES I-M era. The purpose of the plan is to: (1) assure that by the time the initial GOES-I and -J product stream is routinely available (six months after launch), it is at least equal to or better than what is available from GOES-7; (2) as

unique spacecraft characteristics become understood, enhance the initial product data sets to take full advantage of the GOES-I system's capabilities; and, (3) utilize the full capabilities of the improved GOES-I data stream to develop advanced meteorological and oceanographic products. It is modelled on the plan formulated ten years ago when NOAA began operational use of GOES-VAS: the NOAA Operational VAS Assessment (NOVA) program of 1983-85. NOVA involved the collaboration of NESDIS, NWS, and the Office of Oceanic and Atmospheric Research (OAR) in developing cost effective applications of geostationary remote sensing techniques to support improved atmospheric and oceanic forecasts and services. With the anticipated launch of GOES-I, such an effort is again required.

1.2. GOES I-M Support of NOAA Missions

NOAA missions

NOAA's mission includes the description, monitoring and prediction of conditions in the atmosphere and ocean, and the issuing of warnings against impending destructive natural events. In NOAA, there are five high priority cross-cutting programs: (1) climate and global change; (2) coastal oceans program; (3) modernization of weather programs; (4) management of environmental data; and (5) modernization of marine programs. These five programs are long-term commitments by the entire agency to address urgent problems of national concern. The GOES I-M system is an integral part of NOAA's modernized observing system and is designed to improve NOAA's ability to perform its mission.

GOES requirements

As was reported by the Government Accounting Office (1991): "In the early 1980's, the National Weather Service embarked on a broad modernization program to reduce staffing and costs and to improve weather forecasts. Design and production of GOES-Next was a part of this modernization." Among the NWS requirements that impacted the design of the GOES I-M series of spacecraft were:

- * independent imaging and sounding
- * multispectral imaging with improved spatial resolution
- * improved accuracy in atmospheric temperature and moisture soundings
- * improved image frame to frame registration accuracy
- * long term calibration accuracy
- * accurate earth location

weather modernization

The phased implementation of the NWS observing system has already begun. By the end of this century, the new modernized NWS will be entirely in place. This will include GOES and NOAA satellites, NEXRAD (Doppler) weather radars, wind profilers, automated surface observing stations (ASOS), and winds and temperatures along commercial aircraft routes (ACARS). Observational data, such as GOES images, will be automatically displayed on the Advanced Weather Interactive Processing System (AWIPS) in order to improve the flow of information to the forecaster. To ensure GOES data and imagery make an important contribution to the modernized NWS, the NWS has required these data to be precisely navigated, calibrated, remapped and distributed quickly. New products will need to be developed that rely on information from the partnership of these high technologies that will accompany NWS modernization.

NWS GOES Applications

The following paragraphs are taken from the presentation of Dr. E. W. Friday, Assistant Administrator for Weather Services, at the GOES I-M Operational Satellite Conference held April 3-6, 1989 in Arlington, VA. They summarize the expectations of the NWS regarding the new capabilities of the GOES I-M system of instruments.

"Geostationary satellites provide a unique instrument platform for obtaining information and coverage that encompasses all ground based observations. GOES I-M will provide many times more visual information than GOES-7 does today, and with added communication capacity, GOES I-M will provide access to observations from thousands more environmental data platforms. ...

Mesoscale analysis and forecast concepts of the 1990's demand

knowledge of storm environment parameters, such as local terrain effects, local low level moisture and vertical wind shear gradients, as well as the detection and tracking of unstable air mass boundaries, previous storm outflow boundaries, and the onset of convection. Geostationary satellite based imagery and sounding products with mesoscale location accuracy will have the opportunity to make a critical contribution to the warning and forecasting of hazards associated with convective storms.

GOES I-M observations will provide the forecaster with initial indications of the rapid development of convection. This is especially important in the mountainous west where radar coverage is severely restricted by terrain features. The improved temperature sensitivity for earth surface temperatures will allow meteorologists to more accurately determine the position of surface boundaries, such as dry lines that neither the radar nor surface data will adequately detect. Subsequently, using the GOES I-M imagery, the forecaster could more precisely delineate the formative areas of convective activity than is possible today.

A valuable tool in today's flash flood program is the ability to estimate rainfall amounts in data-sparse areas from satellite imagery. With improved earth location capability and greater IR temperature sensitivity, the satellite-derived rainfall estimates will be much more useful in flash flood prediction than those generated today.

Another valuable aspect of GOES I-M is the ability to produce satellite derived atmospheric sounding at frequent intervals. This feature will enable the meteorologist to locate areas of decreasing stability enhancing the ability to predict and subsequently alert the public as to the potential of severe storms. ...

The hurricane program will also benefit from GOES I-M products. Limited aircraft reconnaissance resources will continue to result in requirements for monitoring by satellite, the genesis, evolution, and track of hurricanes and tropical cyclones at sea. Improvements in the infrared image resolution are expected to help with nighttime tracking of the hurricane centers and changes in the storm's strength.

Large scale analyses and model output are used to forecast the future path of tropical cyclones. Conventional observations are few over the oceans and therefore, satellite imagery and derived products provide important information for depiction of weather in the analyses and model initialization fields. Improvements in image registration and location accuracy will contribute directly to improved synoptic scale tropospheric flow and storm environment wind analyses. In addition, soundings of the storm's eye have the potential for making significant contributions to estimates of storm intensity."

In anticipation of the GOES I-M system's impact on NWS Modernization, Dr. Friday added: "The new GOES I-M system is designed to make a significant contribution to our knowledge of the state of the atmosphere and how it is changing with time, ultimately leading to an improved warning and forecast process. The value of GOES I-M technology to the warning and forecast program will be fully realized when forecasters are efficiently using the data and products with other observations and in numerical forecast models to improve weather

NOVA heritage

operations and services." Later, in December 1991, Dr. Friday wrote to Mr. Pyke, Assistant Administrator for Satellite and Information Services requesting a GOES-I assessment plan: "Based upon the success of the NOAA Operational VAS Assessment program, I am requesting that NESDIS research and operational elements undertake a similar effort for improving the GOES-I program." With the implementation of the effort proposed in this document, the capabilities of the GOES-I system will come to fruition and the actions necessary to realize the anticipated improvement in NWS products and services will be initiated.

New data processing systems have been developed to accommodate the new opportunities offered by GOES I-M; an expanded NESDIS day-1 product suite is planned (the current list is summarized in Appendix C; it will be updated as necessary). New data processing and analysis systems will be in place at NWS National Centers (Meteorological Interactive Data Access Systems) and field offices (Advanced Weather Information Processing System) that will make it possible for the first time to exploit the full potential of a frequent interval observing system from geostationary satellites.

5 year plan

Establishing the means and methods of effectively integrating GOES I-M into operational service programs requires the coordinated and combined efforts of research, development and operational units within NOAA over the next 5 years (FY 93-97). This period covers the evaluation for the NWS Modernization and Restructuring (MAR) and the checkout of GOES-I and -J. As with the MAR, the new and improved products and services from the GOES I-M satellites are expected to make an important contribution to a number of important national programs. Foremost, among them, are NOAA's five high priority cross-cutting programs.

1.3. Major S/C and Instrument Change

GOES-7
comparison

Responding to user requirements for improvements in the GOES-VAS system, several instrument and spacecraft changes evolved with the GOES I-M program. Specifications called for performance improvements over GOES-7 (VAS) by factors of 2 to 4 in signal-to-noise and spatial resolution. This resulted in a different platform: a 3-axes earth-staring design, instead of the previous spin-scan design. This basic spacecraft design change leads to completely different scanning, navigation, calibration and thermal-control systems and potential problems for GOES I-M, with corresponding impact upon meteorological data products.

ongoing
instrument
characterization

The impacts of these differences on data quality and the ability to generate high quality products must be evaluated and assessed, and where the need arises fixes must be made. The delicately balanced navigation and calibration systems on GOES I-M will experience many periodic diurnal and annual forces that will require ongoing characterization of instrument performance and the effect on products. It is important to realize that data from the flight qualified instruments will not be available until after launch; in the interim, simulations and test data provide the basis for algorithm development.

separate imager
and sounder

The GOES I-M requirements resulted in separate sounding and imaging instruments that can be operated independently, improved IR resolution, 5 channels of image data, and 19 channels of sounder data. As a result a new data transmission format was devised to allow the GOES I-M data user to receive simultaneous operational data from the imager and the sounder, instead of alternately and experimentally as on GOES-7. Section 3.1.2 contains a summary of the expectations of GOES I-M versus performance of GOES-7 (VAS) with regard to radiometrics and navigation.

imager

The GOES I-M imager will provide visible data with the same 1 km resolution as GOES-7, but with a stable linear response and precision to 1 part in 1024, instead of a variable nonlinear response to 1 part in 64. Imagery is to be earth-navigated within a 1-2 km instead of 3-10 km, by using star positions in addition to traditional landmarks. The imager will also provide continuous infrared imagery simultaneously in four thermal channels, instead of the two or three channels available from the GOES-7. All but one of the GOES I-M imager's infrared channels are at 4 km horizontal resolution instead of 8 km. On-board calibration is to provide brightness temperatures with 1.0 K absolute accuracy and 0.3 K relative precision, and noise levels reduced 2 to 3 times over GOES-7.

sounder

The GOES I-M sounder will provide 18 thermal infrared channels plus a low-resolution visible channel, instead of the 12 infrared channels with visible on GOES-7. Several of the new channels are sensitive to temperature, moisture and ozone at wavelengths never before used in geosynchronous orbit. The GOES I-M sounder's design goal is to provide brightness temperatures with 1.0 K absolute accuracy and 0.3 K relative precision, and noise levels reduced 2 to 3 times over GOES-7.

1.4. Need for a Product Assurance Plan

The purpose of the NOAA GOES I-M Product Assurance Plan is assure the viability of GOES I-M day-1 products, to improve initial products and develop advanced products, and to ensure integration of the improvements into NESDIS and NWS operations. These efforts will make the new GOES I-M capabilities available to both public and private sector users in an efficient, effective and timely manner.

plan fills void

The current NESDIS GOES I-M project plans end with post-launch data checkout (e.g. the Operational Ground Equipment (OGE) checkout plan has been written by the GOES I-M Ground Systems Project) and production of the initially defined day-1 products (e.g. the software implementation plan is being written by the Satellite Services Division). Other NOAA programs have plans to use and archive the new GOES data and products (Satellite Services Division is working on a draft). However, no formal procedures or approved plans are in place for GOES-I data and products in three key areas:

- * scientific evaluation;
- * user assessment;
- * product evolution.

needs high priority

This plan will fill this void, but, since the organizations involved are part of several NOAA Line Offices (LO), the process for accomplishing this is complex. For this reason priorities for the integration of GOES I-M into NOAA programs need to be established at the Assistant Administrator level to assure that appropriate resources are made available to accomplish the initial assessment with additional money available for new product development and training. Specifically this plan:

contents of plan

- * Identifies the necessary linkages between NESDIS and the NOAA organizational elements that will use or benefit from GOES I-M data, products, and services.
- * Defines GOES I-M day-1 products and services, the testing and evaluation procedures necessary to ensure day-1 products are of a quality at least comparable to those of GOES-7, and identifies the responsible parties.
- * Identifies procedures for user evaluation and feedback.
- * Identifies day-1 product improvement and the necessary development activities that lead to advanced day 2 products aimed at NOAA's high priority cross-cutting programs.
- * Defines special satellite schedules that will adequately support product assurance and evolution as well as and research projects such as the Mesoscale Research Program.
- * Presents a product management structure utilizing the NESDIS Product Oversight Panels and identifies the need for a multiagency Technical Advisory Committee.
- * Identifies user requirements for data and product documentation and

the need to develop an active user training program.

- * Identifies additional resources above those in current NOAA program funding or staffing that may be needed to carry out this plan.

updates expected

Periodic updates to this plan are envisioned as the work progresses. Section 2 reveals the strategy for product assurance, while section 3 presents the testing and development activities in some detail. Section 4 indicates how the integration into operations will occur. Section 5 discusses the evolution to improved products and instruments. Appendix A indicates the government and university laboratories plus the resources that will be required to assure effective utilization of GOES I-M products and services. Appendix B outlines the management plan. Appendices C and D list the products and the individual responsible for product assurance. Appendices E and F list available references and plan user informational documents and activities. Appendices G and H suggest satellite schedules for checkout, research, and operations. An acronym list occupies Appendix I.

2. STRATEGY FOR PRODUCT ASSURANCE

2.1. Product Quality

There are two basic categories of products provided to the user community: (1) data, such as a raw satellite image or image loop animations; and (2) derived products, such as winds, soundings and combined radiometric products. Product quality will be measured relative to:

evaluation
criteria

- * current levels of performance for GOES-7;
- * specified performance requirements for GOES I-M
(as indicated in the NWS GOES-NEXT Requirements, 1983);
- * user response.

2.2. Prelaunch Tests and Simulations

GOES-I
changing til
launch

Throughout the long process of instrument testing, analyses of simulations of the instrument data at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), the Cooperative Institute for Research in the Atmosphere (CIRA), and other locations have confirmed the utility of the data for product generation. The prelaunch characterization of signal to noise, calibration accuracy, navigation stability and accuracy as conducted by the NASA GOES Project at Goddard Space Flight Center (GSFC) are important input to prelaunch algorithm development and product expectations. Inevitably, however, questions about the ultimate form of the on-orbit data (hence products) have arisen as the instrument testing has revealed and continues to reveal changes in instrument performance. Thus it is likely that the product algorithms will need adjustment after experience with real data.

assuming stable
GVAR

Likewise it is acknowledged that although the GOES ground systems tests are proceeding well, they were never intended as an indicator of product performance. What will be tested by that effort is the flow of the GOES Variable (GVAR) format data through the system, access of the GVAR with its embedded earth location parameters by the product systems and the exercise of the product algorithms on the simulated GVAR. The uncertainty is caused by the facts that the GVAR format is itself evolutionary due to instrument changes and that the ground system will not be able to simulate the updated GVAR before spring of 1993. It is not yet clear what changes to product processing software will be required by the GVAR modifications; this plan assumes a stable GVAR system once the flight instruments are integrated on the spacecraft.

simulations

Prelaunch simulations of image quality as a function of noise, jitter, and misregistration will continue at CIMSS and CIRA and other laboratories; as instrument tests reveal new characteristics, further simulations will reveal their impact and results will be shared with the NASA GOES Project. Impact on derived products will also continue to be studied.

2.3. Post-launch Checkout

checkout plans

Plans currently exist in the NASA GOES Project for post-launch evaluations of system performance with respect to a number of parameters (e.g. calibration, navigation, registration) crucial to successful product generation. In addition to the data necessary for these activities, product assurance requires special modes of instrument operation and acquisition of ancillary data from selected platforms such as the NOAA demonstration profiler network, next generation radar, model output, aircraft remote sensing, polar satellite data, and other geostationary satellite data (more details are provided later in this plan). GOES I-M data quality will be inspected as it affects each product; algorithms will be developed to mitigate undesirable qualities in the data. GOES I-M products will be compared to those from the ancillary sources to assure GOES-7 level of performance at a minimum. Assimilation of GOES I-M products with other available sources of information will be done to reveal the impact of those products (e.g. soundings with radiosondes and model predictions). These activities will begin during the intensive post-launch instrument checkout period of six months, but will continue during initial routine operations.

quick feedback
essential

The preparation for day-1 products will involve direct cooperation of algorithm developers with users in the NWS; this will include users both at the National Centers and the local Forecast Offices. Efficient feedback mechanisms are mandatory so that the product can quickly evolve and achieve acceptance. The post-launch checkout schedules suggested in Appendix G provide the necessary data flow for evaluation. After operational turn on, day-1 products will be the responsibility of the Product Oversight Panels; Appendix B suggests a management hierarchy and a template for a detailed management plan for each product.

science data
gathering

The evolution to day-2 products will depend on experience with day-1 products and scientific developments through case studies. The post-launch checkout is the only opportunity for more ambitious data gathering (e.g. very rapid interval imaging and sounding); thus Appendix G also includes a post-launch schedule for investigating future products. The case studies developed at this time will be the focus of considerable scientific endeavor.

3. EVALUATION/VALIDATION

Evaluation/validation of instrument performance, image quality, and imager and sounder products will ensure that NOAA realizes improved services through the effective use of the new remote sensing capabilities provided by the GOES I-M satellite series. The characterization of instrument performance will be accomplished largely through the efforts of the NASA GOES Project with NOAA participation from NESDIS, NWS, and SPO. The product assurance through evaluation and validation efforts will be accomplished largely within NESDIS, NWS, and ERL with university collaboration. Overall supervision will be accomplished by the "GOES Program Manager" with assistance by an "Office of Research and Application (ORA) GOES Scientist" and an "Office of Satellite Data Processing and Distribution (OSDPD) Product Coordinator". As the products become mature and operational, the responsibility for maintaining and improving the products will reside within the Product Oversight Panels (POPs) of NESDIS. Appendix B presents more details.

supervision

A five-year effort is anticipated consisting of data collection and product validation and user familiarization in the first year, technique development and new product generation in a demonstration mode for the NWS in the second year, and evaluation and incorporation of new techniques in the subsequent years.

5 year effort

3.1. Characterization of Instrument Performance

This plan assumes that calibrated and navigated radiances will be available for the scientific evaluation. However, since the products are vulnerable to unexpected or out-of-specification instrument performance characteristics, algorithms and techniques will have to be adjusted accordingly and possibly even new ones may have to be developed. A close working relationship between the NASA GOES Project and the scientific evaluators will be accomplished through the office of the GOES Program Manager using the structure outlined in Appendix B. The NASA GOES Project post-launch evaluation of the instrument is focussed on adequately characterizing its performance; that information will be used to determine the effects on the day-1 products and guide evolution to improved day-2 products. The instrument performance will be evaluated against specified performance levels by the NASA GOES Project. The GOES I-M data will be compared against data from the VAS (VISSR Atmospheric Sounder) on GOES-7 and the HIRS (High resolution Infrared Radiation Sounder) and the AVHRR (Advanced Very High Resolution Radiometer) on the NOAA polar orbiting spacecraft by the scientific user community. The radiometric quality will be analyzed and catalogued by the appropriate Product Oversight Panels.

instrument
uncertainty

3.1.1. Validating Specified Performance

GOES I-M is a totally new system whose behavior must be carefully assessed. The delicately balanced navigation and calibration systems will experience many periodic forces, such as high frequency modes associated with scanning, diurnal modes associated with earth-facing operation, annual modes associated with insolation on the "north polar cap" detector cooler plates, and beginning-of-life and end-of-life modes associated with outgassing and component degradation. Analyses to determine impacts on product quality as a function of diurnal changes, seasonal changes, and spacecraft aging must continue throughout the lifetime of the spacecraft. The new ground system that prepares GOES-I data for transmission to the user will help characterize the quality of the GOES-I data by tracking recent behavior to calculate current navigation and calibration.

validation
ongoing

Currently expectations are that the GOES-I imager will meet or exceed its radiometric requirements, with the exception of precise infrared calibration, where there will be some line-to-line, channel-to-channel and scene-to-scene brightness variations. Pre-launch estimates are being made of the magnitude of these GOES-I calibration errors, that are not expected to be larger than on GOES-7. The principle radiometric error is expected to be random zero-point drifts for a few seconds between space-looks, due to the lack of an infrared chopper in the GOES-I imager. The effects of periodic radiometric perturbations upon data products will require post-launch evaluation of the actual magnitudes, ground system adjustments, and repeated evaluations.

imager
expectations

The GOES-I imager should meet its pointing requirements over the continental United States (CONUS) sector, although the actual effects of on-orbit weightlessness coupled to a strong diurnal thermal cycle are

impossible to assess with confidence before launch. Line-to-line jitter in the visible imagery is likely to be worse from the delicately balanced GOES-I imager than from the spin-stabilized GOES-7 resulting in some additional errors in cloud-tracked winds and decreases in the utility of imagery for computer animated loop analyses. Furthermore, the effect on data quality of zig-zag scanning coupled with instrument spatial weighting function smearing is unknown. On the other hand, the GOES-I image navigation system is expected to provide superior earth location resulting in imagery that can be remapped with confidence.

sounder
expectations

The GOES-I sounder is now expected to exceed its radiometric noise requirements in the shortwave channels, meet the requirements in the midwave channels, and be below requirements in the longwave channels. Prelaunch calibration performance is not yet assessed but should meet requirements because the short-term random drifts in the sounder's infrared signal are suppressed by frequent looks at the filter wheel housing (performing the function of beam chopping).

The GOES-I sounder pointing accuracy requirements are not as stringent as those of the imager, and are expected to be met by the same high precision star-tracking methods used with the imager. Channel-to-channel registration has been difficult to achieve in the GOES-I sounder's multi-beam design; it remains to be verified before and after launch.

3.1.2. Comparison to GOES-7 (VAS)

This section summarizes some expected performance characteristics of GOES-I compared to GOES-7, that will be verified in the post-launch checkout. More details are in the NASA GOES Project document of April 1992. The major areas include: radiometric performance, INR (Image Navigation and Registration) performance, and time and image area coverage trade-offs.

Image navigation and registration (INR) performance for GOES-I was summarized in April 1992 as being close to specifications, thus making it as good as, and in some respects better than, GOES-7. A few comments from that summary follow.

INR

* imager INR

IR/IR coregistration

28 urad (thermal distortion)

28 urad VIS FOV near midnight

42 urad frame-to-frame reg.

42 urad within-frame reg.

OGE correction is VIS/IR only

Scan mirror thermal distortion

Servo and motion compensation

EOL degradation

* sounder INR

IR/IR coregistration 22 urad.

84 urad within-frame reg.

Thermal distortion in optics

Changed to 3000 km sector

Frame time performance is a little slower. With new scan clamps to assist calibration, the full disk requires 26.6 minutes; the full disk GOES-7 takes only 18.2 minutes.

GOES-I should exceed GOES-7 in radiometric performance with these (effects):

* imager visible performance

radiometrics

FOV	(resolution) equivalent except near midnight?
Signal to Noise	(detail) much better
Quantization	(contrast) much better
MTF	(edge response) better
Normalization	(striping) much better
Overshoot	(edge response) comparable
Pixel Registration	(distortion) possibly worse?
Linearity	(dynamic range) much better

* imager infrared performance

NEDT	(detail) better
FOV	
Bands 2,4,5	(resolution) better
Band 3	(resolution) slightly worse
Quantization	(contrast) comparable
MTF	(edge response) comparable
Normalization	(striping) TBD
Imager Stability	(distortion) comparable
Calibration	(radiance) better

* sounder infrared performance

Long-wave NEDT	(soundings) not as good, not meeting specs
Mid-wave NEDT	(soundings) better
Short-wave NEDT	(soundings) better
MTF	(edge response) comparable
FOV	(resolution) comparable
Calibration	(radiance) better

3.1.3. Calibration

The calibration algorithm of the infrared radiances will be validated as part of the scientific evaluation. To validate the IR radiances, the GOES-I measurements will be compared to collocated radiance measurements from other sensors (on board the geostationary GOES-7 and Meteosat as well as the polar orbiting NOAA series) and with forward calculations based on radiosondes or model analyses. Diurnal and seasonal changes in the infrared calibration will be investigated routinely by the NESDIS Satellite Operations Control Center (SOCC) with assistance by the Physics Branch. Additionally, a relative calibration of the visible detectors will be done routinely over the life of the spacecraft to correct for long-term sensor drift. The techniques in use for the AVHRR Pathfinder activity, using periodic measurements of a desert whose reflectance is assumed constant in the long term, will be applied to the GOES I-M visible data. A target data base has been developed that will supply the data arrays (daily, hourly, seasonally) for selected sites that will serve for the visible calibration. The utility of bright clouds for visible reference is also under consideration. The NESDIS Physics Branch is assuming responsibility for the visible calibration. The Calibration Oversight Panel will work with the NASA GOES Project Calibration Working Group and coordinate these activities.

cal

3.1.4. Navigation

The navigation of GOES I-M images will be evaluated through deviations in landmark registration; these will be catalogued diurnally and seasonally, with corrections suggested to the Operational Ground Equipment periodically. The Navigation Oversight Panel will coordinate this activity.

nav

3.2. Evaluation/Validation of Derived Products

3.2.1. Image, Cloud, and Aerosol

The GOES I-M imaging system will have the capability of providing a wider variety of image products. The five channels planned for GOES I-M imagery are:

- (1) .55-.75 um (vis) used for imaging clouds, snow and ice, and land features:
- (2) 3.9 um (shortwave infrared window) used for identifying fog/stratus, cloud vs snow, fires/volcanoes, and sea surface temperature (SST) determination:
- (3) 6.7 um (water vapor channel) used for synoptic analysis, upper tropospheric humidity, and finding convection:
- (4) 10.7 um (longwave infrared window) used for cloud tracking, locating cloud tops, and SST determination: and,
- (5) 12.0 um (split window) used primarily for low level moisture identification and SST determination.

Facilities with direct receive capabilities such as the NWS National Centers (the National Severe Storm Forecast Center (NSSFC), the National Hurricane Center (NHC), the National Meteorological Center (NMC)), NESDIS, the Forecast Systems Laboratory (FSL), the Cooperative Institute for Research in the Atmosphere (CIRA), and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) can receive OGE calibrated and navigated data directly through the GVAR data stream. At NESDIS GOES I-M images will be produced in either full disk, partial disk or sectorized format for transmission to field users. There will be two basic image formats: (1) the GOES projection for transmission over the existing GOES-TAP and FAX/WEFAX system; and, (2) remapped imagery to be made available to the National Weather Service (NWS) via a new mode to be known as GOES I NOAA-PORT Interface (GINI). Although AWIPS will not be fully implemented at the beginning of the GOES I-M era, some facilities will be in place to evaluate the GINI products.

GOES-TAP and FAX/WEFAX images should closely resemble those currently produced for GOES-7. The sectors will cover areas with equivalent resolutions of 1 km, 4 km and 8 km. The sectors will be about 32% larger in area than those for GOES-7, in order to maintain the same data format for transmission to existing facsimile equipment, this will result in a slight reduction of the maximum resolution normally available. Although five image channels are available from GOES I-M, only three are planned for day-1 transmission on the GOES-TAP system, along with one composite type image (e.g. combined visible and infrared window image). The same limitation of image frequency now existing (30-minute interval) will still apply.

enhanced images

Enhancement of the imagery will still be provided, based on user requirements. Post-launch evaluation includes comparison of GOES-I enhanced data sets resulting from enhancement curves with similar ones from VAS and correction for possible diurnal effects. A matched set of enhancement curves to those used operationally by GOES-7 must be available for all GOES-TAP and AWIPS sectors. Diurnal or seasonal characteristics of GOES-I IR data may require subsequent versions of each enhancement curve to be applied to outgoing data to assure that observed changes are not an artifact of the satellite sensors. Enhancement curve subsets may have to be developed and integrated into the operational data stream. Further evolution will include multispectral products. Several multispectral products, particularly those using the 3.9 um channel are being developed and may be viable in the near term for application to volcanic ash cloud monitoring, tropical storm eye locations, aviation forecasting, etc. Work in these areas will continue at the Physical Sciences Branch with the new GOES-I data.

sectors

Image sectors for the AWIPS system will be produced for the continental U.S. (one eastern and one western) and for the Hawaii, Puerto Rico and Alaska forecast areas. AWIPS imagery will be remapped into a Lambert Conformal projection for most sector types, except for Alaska sectors that will be in the Polar Stereographic projection. All image channels plus 3 composite images will be available at any time at full resolution. From the full resolution sectors, individual AWIPS sites will extract sectors for larger scale applications (full sector), regional scale applications (2000 or 1500 km by km sectors), or local scale applications (750 or 500 km by km sectors).

The frequency of the AWIPS images will depend on the particular mode of operation in effect. Three operating scenarios are planned: Normal, Alert, and Warning. In the Normal mode most imagery will be produced at 30-minute intervals. In the Alert mode, image frequency increases to twice per half hour. In the Warning mode, severe weather, five images will be available every half hour; one of those five images will satisfy the CONUS east or west coverage requirements. Full earth disk imagery will be available every 30 minutes during Normal mode operations but will be reduced to 3 hourly intervals in the Alert and Warning mode. The latter time interval is the minimum required by international agreement. It is required that at 6 hourly synoptic times, a sequence of three consecutive full disk images will be needed for producing global winds for inclusion in numerical models.

composite imagery

Composite imagery on GOES-TAP will be of two types, multi-channel and multi-satellite composites. Two types of multi-channel composite images are planned: (1) a visible/infrared and (2) water vapor/infrared combinations. VIS/IR images now widely used by the NWS and others will be a Day-1 image product. The maximum resolution of each image type will be retained. VIS/IR images combine the best features of both types of imagery: the temperature structure of cold, precipitating cloud systems and high resolution depiction of mesoscale processes such as low level inflow, cloud line mergers, etc. They also provide a smooth transition from daytime to nighttime monitoring of convection. The water vapor/IR composite is planned as a day-2 product. Important upper air features such as jet streaks, troughs and vorticity maxima are often well defined only in water vapor images.

polar projection

In the AWIPS era, imagery from GOES-East and GOES-West will be combined into one polar stereographic image covering most of the northern hemisphere. The images will be produced in three separate channels; visible, infrared window, and water vapor. Each image pixel will consist of an average brightness over an 8 km x 8 km area. This new day-1 product will not be available during the Warning Mode.

image evaluations

The imagery transmitted through GINI and GOES-TAP will be used for individual picture interpretation (e.g. cloud type identification, fruit frost forecasts) and for observing changes in weather systems with animated image sequences (e.g. thunderstorm development, vorticity center location). CIRA will be conducting image evaluations of GOES-I, GOES-7, and NOAA AVHRR capabilities to identify features; they have already begun the development of algorithms for the comparison of GOES-7 and AVHRR imagery. NSSFC, NHC, and selected WSFOs will evaluate the quality of imagery for their specific concerns. Additionally, FSL will evaluate GOES-I satellite imagery in its hourly Local Area Prediction System (LAPS).

Specific areas of investigation will include: (1) diurnal and seasonal characterizations; (2) comparison of 6 and 10 bit visible imagery; (3) low light visible capabilities; (4) differences in 4 and 8 km infrared imagery; (5) image clarity; (6) near spacecraft midnight effects on imagery; (7) effects of zig-zag scanning and spatial smearing on product quality; (8) effects of within frame registration errors and jitter on computer animated loop analyses; (9) investigation of combined image products, such as the CIRA developed combined vis/IR imagery; and (10) evaluating the utility of the different spectral band applications.

day-2

In preparation for day-2 enhancements, CIRA will also be studying cloud height assignment from shadows and stereographic techniques. Additionally, multispectral techniques to identify cloud phase will be investigated and will also be done with the sounder. The Physics Branch, in response to a request from the NWS Office of Hydrology, will develop an operational insolation product for the CONUS using the visible data; a focus on insolation and albedo in the Mississippi drainage basin is expected in 1995.

ASOS cloud product

CIMSS and the Physical Sciences Branch have already begun evaluation and validation of a GOES-7 cloud product through comparison with ground observations; this will be continued for GOES-I with NWS participation. The algorithm will be adjusted as necessary to accommodate the GOES-I observing characteristics and possibly be simplified for imager use as well. This cloud activity is motivated by the NWS introduction of the Automated Surface Observing System (ASOS) nationwide; there already are a limited number of ASOS sites in the midwestern United States. ASOS uses automated equipment to provide near continuous observations of surface weather data including cloud height and amount that are currently obtained by NWS observers. The cloud information from the ASOS equipment is limited to altitudes below 12,000 feet, thus the GOES I-M will be expected to provide supplemental information about cloud cover above 12,000 feet. The combined ASOS/satellite (ASOS/SAT) system is expected to depict cloud conditions at all levels. Because observations are required every hour, the satellite cloud product must be derived from the geostationary spacecraft data. The satellite cloud information is derived using sounder data with the CO₂ slicing technique, which calculates both cloud top pressure and effective amount from radiative transfer principles. It also reliably separates transmissive clouds that are partially transparent to terrestrial radiation from opaque clouds in the statistics of cloud cover. For a given ground observation site, the algorithm uses radiation measurements from an area of roughly 50 km by 50 km centered on the site.

WSFO involved

The NWS WSFO at Milwaukee/Sullivan will participate in the evaluation/validation of the ASOS/SAT system. There are already ten ASOS units installed in Wisconsin and the Milwaukee/Sullivan WSFO has already been involved in the first steps of the local ASOS augmentation tests. The Milwaukee/Sullivan WSFO will work with CIMSS, the developers of the satellite technique, to provide a local evaluation; this activity is enhanced by their close proximity.

The Image, Cloud, and Aerosol POP will coordinate activities in this area.

3.2.2. Soundings

There are several GOES products that come under the category of soundings. From the sounder, they include the clear field of view (FOV) brightness temperatures, profile retrievals of temperature and moisture, as well as their layer mean values, lifted indices, and thermal wind profiles. Additionally from the imager, there are derived product images of precipitable water and lifted indices. A brief description follows.

T(p)

Vertical temperature profiles from sounder radiance measurements are produced at 40 pressure levels from 1000 to 0.1 mb using a simultaneous, physical algorithm that solves for surface skin temperature, atmospheric temperature and atmospheric moisture. Also, estimates of surface emissivity and cloud pressure and amount are obtained as by products. The retrieval begins with a first guess temperature profile that is obtained from a space/time interpolation of fields provided by the NWS forecast models. Hourly surface observations are also used to provide surface boundary information. Soundings are produced from a 5x5 array of FOVs whenever 9 or more FOVs are determined to be either clear or "low cloud". The FOVs are "cloud filtered" and co-registered to achieve an homogeneous set. The location (latitude and longitude) of the retrieval is assigned to the mean position of the filtered sample. A "type" indicator is included in the archive to indicate if the sounding represents "clear" or "low cloud" conditions. A quality indicator is included to indicate if the retrieval has failed any internal quality checks.

q(p)

Vertical moisture (specific humidity) profiles are obtained in the simultaneous retrieval, and thus are provided at the same levels as temperature up to 100 mb. Since the radiance measurements respond to the total integrated moisture above a particular pressure level, the specific humidity is a differentiated quantity rather than an absolute retrieval. Geopotential height profiles are derived from the full resolution temperature and moisture profiles. Layer means of either temperature or moisture can also be derived (although there are no plans to do so presently). Layered precipitable water may be integrated from retrievals of specific humidity. Only the total precipitable water is provided in the standard archive.

The channel brightness temperatures for the available channels are archived with each retrieval. These values are filtered from the 5x5 arrays of FOVs used to produce a single retrieval. Only heterogeneous cloud

T_b contamination is removed. The values are not limb corrected, nor has solar contamination (if present) been removed. The brightness temperatures may represent either "clear" or low "uniform cloud" conditions. A cloud product representative of the 5x5 array will also be derived, though exact details for its archival have not been formulated. In all probability, it will follow (and perhaps replace) the gridded ASOS cloud product.

LI The lifted index for each retrieval is also derived. The lifted index is an estimate of atmospheric stability. It represents the buoyancy that an air parcel would experience if mechanically lifted to the 500 mb level. The lifted index expresses the difference in temperature between the ambient 500 mb temperature and the temperature of the lifted parcel. A negative value (warmer than the environment) represents positive buoyancy (continued rising); whereas a positive value denotes stability (returning descent). The formulation used to derive LI is a thermodynamical relationship requiring the 500 mb temperature and a mean pressure, temperature, and moisture for the boundary layer. These quantities are all available from the retrieved profile.

z The geopotential height of the pressure level as derived from a 1000 mb height analysis (from the NMC forecast supplemented with hourly data), a topography obtained from a library (10 minute latitude/longitude resolution) and the retrieved temperature and moisture profile are contained in the archive of each retrieval. Thickness can be calculated from this profile.

gradient winds Thermal winds are provided with each profile. These are derived from objective analyses of the geopotential profiles calculated with each retrieval. The objective analysis is a 3-dimensional, univariate recursive filter that uses as a background the same fields that provide the first guess to the temperature retrieval algorithm (NMC forecasts and surface analyses). The analyses are performed on a 1 degree latitude/longitude grid. Gradient winds are calculated using finite difference operators that involve surface-fitting over 5x5 gridpoints centered at the gridpoint closest to each retrieval. Wind estimates are provided from 700 to 400 mb. Verification studies with observed winds have shown that this product from VAS depicts the temperature gradient consistently more accurately than the NMC forecast. It will be verified that the GOES-I product is even better, and with expanded geographical coverage.

derived product images Derived product imagery can be produced from either the imager or the sounder. Data from the former is limited to the longwave split window, the shortwave window, and the 6.7 um water vapor channels. However, the day-one GOES I-M derived product imagery, total precipitable water and lifted index, can be produced using only these channels with acceptable results. Derived product imagery is formed from pixel-by-pixel retrievals of atmospheric temperature and moisture profiles wherever the atmosphere is quasi-clear. The derived product is scaled to the major part of the 6-bit quantization of the image area. The high order bits of the image are used to store "bright" 11 um window values when cloud contamination is sensed. Thus the images appear as the derived product with the cloud cover superimposed. A major effort of the early GOES-I derived product image evaluation will be to determine if the multiple bands of the sounder offer a significant improvement over the imager.

The day-1 derived product images are total precipitable water in the atmosphere, a standard retrieval product adapted to the image format, and an additional image of the lifted index. It should be added that the processing software has provision for a third derived product image that may be defined during the evaluation.

product assurance Product assurance with regard to soundings will come from the following activities. During the post-launch checkout period (1) collect all satellite data and generate products with existing algorithms to evaluate their performance, (2) develop improved algorithms for selected case study days utilizing the new spectral capabilities of the GOES-I, and (3) investigate methods to determine the boundary layer temperature and fluxes. These activities will be focussed at CIMSS, while selected investigations such as sounding via radiance clustering and structure function analyses will be undertaken at CIRA. It is anticipated that the data collection period for the evaluation will overlap with several special field programs (e.g. the U. S. Weather Research Program) so that the extensive ground based profiler and special sonde network will be available for intercomparison and assimilation.

first year

In the first year, day-1 products generation will be assured. The day-1 retrieval processing system has been defined, but real data checkout will probably require further modification. At CIMSS, close collaboration with the Sounding Implementation Branch will enable efficient implementation of changes to the sounding software. After the launch and checkout of the GOES-I and -J satellites, it is assumed that the satellite will be scheduled for special research data gathering from both the imager and the sounder for a number of case studies. The sounding and imaging data will be processed to generate special data sets of temperature and moisture retrievals, derived product images, and experimental products such as surface flux. In support of these special case studies, the NASA ER-2 high altitude aircraft will also be used to obtain high spectral resolution data with the High resolution Interferometer Sounder (HIS). The HIS has already been successfully used to verify and compare radiances from VAS and AVHRR satellite sensors.

second year

The second year of the effort will consist of an evaluation and comparison of GOES-I and -J imager and sounding data/products collected during the previous year. This will involve exchange of data sets within the evaluation team. Additionally, further improvements to the retrieval process will take advantage of progress in the interactive sounding joint project of NESDIS/NWS/NASA to ensure maximum compatibility between polar orbiting and geostationary sounding. Also investigation will be undertaken into the GOES I-M ability to depict boundary layer properties that may be influencing the development of convective activity. Techniques will be developed utilizing the shortwave channels on GOES I-M to provide improved surface skin temperature and lower layer moisture determinations. The net flux divergence and the inferred cooling rate will be determined on the mesoscale; these can be used to describe the radiative processes over terrain inhomogeneities surrounding atmospheric instabilities. As techniques show promise, the Techniques Development Unit at the NSSFC, the NWS MAR sites, and the Experimental Forecast Facilities (EFF) will be included in the evaluation through pilot demonstration programs.

next 3 years

In the following three years, comparisons with the past satellite capabilities and other current systems will be performed to assess the relative usefulness of the new data and the improved capabilities with the new instrumentation. At this time, day-2 algorithms and products should be defined. Throughout this activity, close collaboration with NMC will be maintained and data impact studies with NWS numerical forecasts will be conducted. This work will be conducted primarily by the CIMSS, in collaboration with the CIRA, the NESDIS Sounding Implementation Branch, and the NMC Development Division. The Soundings POP will coordinate activities in this area.

3.2.3. Winds

operational winds

Currently, operational winds are derived four times daily from imager data, from a sequence of 3 half hourly images. The winds are calculated by a three-step objective procedure that will be applied to GOES-I images with minor modifications. The initial step selects targets, the second step assigns pressure altitude, and the third step derives motion. An initial altitude is assigned based on a temperature/pressure derived from radiative transfer calculations in the environment of the target. That assignment is determined by using a pressure-temperature profile obtained from NMC forecasts, time and space interpolated to the location of the target. An initial guess motion is used, based on NMC wind forecasts at the estimated cloud level. The cloud motion is derived by a pattern recognition algorithm that locates a "target area" in one image within a "search area" in the second image. For each target two winds are produced representing the motion from the first to the second, and from the second to the third image. The first guess motion, the consistency of the two winds, the precision of the cloud height assignment, and the pattern recognition feedback are all used to assign a quality flag to the "vector" (which is actually two vectors). The horizontal density of the vectors is controlled by the target selector. Initial height assignments are made using the CO2 slicing technique (with GOES-I this will be replaced by a H2O intercept method). These initial height assignments are quality controlled and some are adjusted by an autoeditor. This objective quality control attempts to minimize a penalty function where the cloud tracer temperature, height and velocity are compared with ancillary data (e.g. the 6 hour model forecast and aircraft wind reports). A quality flag is also assigned to the vector at this stage.

WV winds

Winds from moisture imagery (6.7 μm , 7.2 μm) are derived by the same methods used with cloud drift imagery. However, the images are separated by a full hour rather than a half hour. Heights are assigned from

the water vapor brightness temperature. An attempt is currently made to exclude cloud targets from the target data set. However, research at EUMETSAT indicates that this may not be desirable, and the question will be addressed during the evaluation.

deep layer means Combined cloud drift, moisture drift, and thermal gradient winds have been studied by the Atlantic Oceanographic and Meteorological Laboratory and the National Hurricane Center in the context better depiction of hurricane trajectories. CIMSS has coordinated production of these deep layer mean wind fields for the past ten years and participated with AOML in validation through aircraft dropwindsondes and evaluation in model impact studies. The deep layer mean wind field has shown considerable promise and is a day-1 product.

winds product assurance Product assurance will focus on several activities. The accuracies of satellite winds are limited by the accuracies of the instrument calibration and earth location. It is therefore required that quantitative post-launch measurements of those accuracies be made available to the product validators. These should include, but not be limited to: image to image landmark (LM) motions, within-image LM to LM distances, earth edge measurements (IR), comparisons of window channel temperatures with known SST's and cloud top temperatures. These measurements should come from the initial earth location and calibration activities in SOCC and be available before the start of the product validation effort and in real time during the validation. One meaningful validation requires a concurrent operational satellite for comparison; this is especially true for low-level winds that in general are valid only over the oceans where no other data are available. Another validation will include comparisons of satellite derived wind vectors with profiler, Doppler radar, aircraft, radiosonde wind determinations and ground sky camera stereo estimates of cloud motion. Absence of an operational spacecraft (especially GOES-7) would make such additional comparisons for validation mandatory. These efforts will be undertaken at CIRA, CIMSS, and the University of Chicago. Impact of satellite winds on numerical models will continue to be tested by periodic parallel runs of the model with and without the satellite motion information. This will be done by NMC and AOML in close collaboration with CIMSS.

day-1 Initial efforts will focus on getting the day-1 winds product established; this will involve collaboration of CIMSS, the Sounding Implementation Branch, and the Product Systems Branch. Validation will include direct comparisons of colocated computed cloud motions and cloud brightness temperatures, as well as profiler and cloud drift wind comparisons. This would be done in the context of past satellite to satellite comparisons of which there is a long history. Additionally, comparisons of motion measurements of a target from one image to the previous and following images in the operational winds will be used in the validation as an indication of image-to-image stability (and would be especially valuable in the absence of an operational spacecraft).

day-2 Evolution of the wind products will require review of the wind tracking process. Historically, problems (e.g. apparent slow bias in upper level satellite-derived winds) impede successful use of the data in forecasting operations. The recent Workshop on Wind Extraction from Operational Meteorological Satellite Data (Sep, 1991) suggested several new approaches, that include (1) further improvement in methods of height assignment for the wind vector including stereoscopic techniques (to augment the recent progress with the CO2 slicing technique), (2) tracking features in more images with shorter time separations, (3) development of tracking techniques with visible imagery, complemented by both short and long wavelength infrared imagery, (4) improved integration with other data sources (e.g. numerical forecasts and profiler observations), and (5) tracking features in the retrieval fields rather than the radiance observations. This will be an ongoing activity largely centered at the two NOAA cooperative institutes, CIMSS and CIRA, working closely with NMC. The Winds POP will coordinate activities in this area.

3.2.4. Precipitation

three product areas The GOES I-M era offers exciting possibilities for the development and implementation of improved precipitation products. The present Interactive Flash Flood Analyzer (IFFA) will be converted to the new Interactive Data Utilization Center (IDUC), which will allow the implementation of an automatic precipitation estimation technique. Three product areas are discussed below; IFFA, precipitation histograms, and moisture bogus. The activities outlined in this section will be performed largely by the NESDIS Physical Sciences Branch and will be coordinated with the Precipitation POP.

IFFA

IFFA precipitation validation involves comparison with ground-based observations. Because of the mesoscale nature of heavy convection and the sparsity of the raingauge network, it is difficult to get good verification of satellite rainfall techniques. Nevertheless, baseline statistics of IFFA accuracy are currently being developed from NMC 24 hour data bases. Plans are underway to access 3- and 6- hourly rainfall amounts to refine and examine the quantitative IFFA amounts. Pre-launch validation includes recoding the IFFA software for GVAR data; this needs to be tested periodically for operability with each McIDAS upgrade. Additionally, a standard must be developed for comparison of GOES-I precipitation estimates. DMSP/SSMI precipitation algorithms, Meteosat VIS and IR, NOAA VIS and IR, and NEXRAD will be used. Diurnal affects on IR data and resultant estimates must be evaluated. Navigation, parallax corrections, and remapping must be examined for accuracy.

tuning to new
GOES

Post-launch evaluation will include inspection of all available parallel data sets listed above. Higher IR resolution will require fine tuning of decision tree coefficients/factors. Tropical, continental, and warm top convective systems must be evaluated for a least one year to assure IFFA estimates are equal or better than current accuracy levels. Selected NWS offices will evaluate the IFFA precipitation on a local scale; mesoscale observations and NEXRAD data will be available for validation. The WSFO at Milwaukee/Sullivan is one of several offices nationwide that is participating in a quantitative precipitation forecast risk reduction exercise; their evaluation of IFFA estimates will help support both these risk reduction activities and the GOES I-M product assurance.

automation

Day-2 product development will move towards automation. The IFFA remains a manually intensive product to generate. Only one or two areas of the US can be monitored at any time. The Convective Stratiform Technique (CST), an automated precipitation estimation program, has been developed and tested. This would serve as a first guess to monitor all convective systems over the US. It also would allow NESDIS to satisfy NMC requests for hourly estimates for the MAR mesoscale models. CST has been converted to McIDAS format. GVAR data operability must be established. Currently VDOC processing restraints prohibit operational parallel testing. Implementation of CST will improve the heavy precipitation "watch" and target selection, particularly with the higher resolution IR data. A blended microwave, IR, and visible (tri-spectral) product is considered the best approach and will be under development. NMC mesoscale model impact tests will be needed.

Validation of the precipitation histogram involves similar activities as baseline IFFA estimates, but navigation and parallax issues are of little concern to this product. Post-launch evaluation must include assuring IR calibration and cloud top temperature accuracy. Likewise diurnal and annual variability of sensor data must be established for product corrections. This is a climate product thus long-term consistency is vital.

moisture bogus

Moisture bogus techniques are nearly 20 years old and need major revamping. Utilization of moisture estimates is minimal by the NMC even though this information is of great interest to NMC. New approaches are currently being examined ranging from the Japanese Meteorological Agency approach that uses pattern recognition and 50 or so classes to a blended geostationary and polar product. Currently this is a manually intensive and very subjective technique that relies on a analyst to determine the cloud type and meteorological situation after which a moisture bogus category is assigned. Prelaunch validation will focus on developing a new analytical technique. One based on IR and water vapor data is being explored. Since the current technique relies only on imagery at reduced resolution, the accuracy of IR temperatures and navigation are of less concern than with other products. Post-launch evaluation must involve NMC model impact studies.

3.2.5. Surface Products

sfc

There are currently no day-1 surface products from GOES-I. However, based on knowledge acquired from AVHRR and experiments with GOES-7 there are a number of potential day-2 products. Among those products are insolation and clear sky land surface temperature. These are the responsibility of the NESDIS Land Sciences Branch and will be coordinated with the Surface Products Oversight Panel.

3.2.6. Ocean Products

ocean

There are currently no day-1 ocean products from GOES-I. However, based on knowledge acquired from AVHRR and experiments with GOES-7 there are a number of potential day-2 products, specifically sea surface temperature. The inflight imager calibration accuracy, stability, and line-to-line, channel-to-channel, and scene-to-scene variations will have to be evaluated to decide whether imager performance is sufficient for SST calculation. If the performance is acceptable, a cloud-filtered temporal composite SST product for the U. S. coastal areas would be an asset to the CoastWatch part of the Coastal Ocean Program. A development effort spanning three years would be necessary to bring an operational product on line. Development of these products would be the responsibility of the NESDIS Physical Sciences, Marine Applications, and Ocean Sciences Branches. Their activities will be coordinated with the Ocean Products Oversight Panel.

3.2.7. Earth Radiation Budget

ERB

There are currently no day-1 earth radiation budget products from GOES-I. However, based on knowledge acquired from HIRS, AVHRR, ERBS, and experiments with GOES-7 there are a number of potential day-2 products. Potential activities include investigations of climate phenomena with large diurnal variations and the continued development of global products of the International Satellite Cloud Climatology Project. The NESDIS Atmospheric Sciences Branch participates in ISCCP; activities in this area will be coordinated with the Earth Radiation Budget Products Oversight Panel.

3.2.8. Ozone

ozone

There are currently no day-1 ozone products from GOES-I. However, GOES-I sounder has an ozone sensitive channel at 9.6 um. Development of future products in this area is the responsibility of the NESDIS Physics Branch; activities will be coordinated with the Ozone Products Oversight Panel.

4. INTEGRATION OF EVALUATION/VALIDATION RESULTS INTO OPERATIONS

4.1. Role of the POPs

Product Oversight Panels (POPs) will play a key role in the pre- and post-launch activities. They have representatives from the user communities, and can be enlarged to include "consultants" or representatives to ensure all interests are covered. Since POPs are co-chaired by operations and research, they are the conduit for identifying problems, testing out proposed solutions, and bringing the improvement on line. Identifying problems appears to be aptly handled through user participation at the POPs: the users are on the forefront and can inform NESDIS promptly of problems. Monthly reporting to the GOES Program Manager will assure that management is informed of progress within each POP. Testing improvements and implementing them in a timely fashion remains the biggest challenge to the POPs; computer and people resources must be identified and allocated. It is the responsibility of the individual POP co-chairs to identify those necessary resources. Additionally, a strong management commitment to ensure highest priority is prerequisite.

4.2. Role of the SPRB

POPs report to the Satellite Products Review Board (SPRB) every month. The SPRB reviews user acceptance of products and progress on new product implementation; technical and resource problems are presented and solutions are suggested whenever possible.

4.3. Role of the TAC

TAC advises

The Technical Advisory Committee (TAC) is an advisory body that is composed of representatives from agencies using and developing GOES data products. The TAC provides a mechanism for community-wide coordination of GOES product research and development. The TAC will be responsible for (1) setting priorities for GOES product research and development, (2) providing technical guidance on feasibility and difficulty of new GOES product efforts, and (3) soliciting technical advice from outside the GOES community when necessary. They will work with the GOES Program Manager to guide product development and to prioritize resource allocation. Outside users should route new product requests through the TAC. NESDIS will chair the committee which has representatives from NESDIS, SPO, NWS, ERL, NASA, DOD, FAA, and the university community; two meetings a year are suggested. The idea is borrowed from the NEXRAD program, which has been served well by their TAC.

4.4. NWS participation

NWS needs SOO

The user evaluation within the NWS will be coordinated at each of the National Centers, NWS MAR sites, Experimental Forecast Facilities (EFF), and selected field offices. As techniques show promise, Science Operations Officers (SOO) at appropriate NWS locations will be included in the evaluation through pilot demonstration programs. People at these locations will be responsible for providing feedback on product timeliness and utility. Strong interaction through AWIPS is expected. Algorithms will be adjusted based on NWS recommendations to the POPs and the SPRB.

4.4.1. NSSFC

derived products
for TDU

The GOES I-M is expected to significantly enhance the utility of satellite data in severe weather forecasting beyond GOES-7. The improved 10 bit visible digitization will show greater details of cloud features as will the improved 4 km resolution of the infrared imagery. The 4 um channel will enable forecasters to see small clouds near the ground at night as well as distinguish ice clouds from water clouds. The split window will allow monitoring of low level moisture. The independent operation of the sounder will produce more timely and higher quality soundings and derived product images (e.g. total precipitable water and lifted index). Forecasters of the Techniques Development Unit at NSSFC will be working with scientists from NESDIS, CIMSS, and CIRA to explore these new opportunities.

4.4.2. NHC

winds for NHC

The NHC uses both the imagery and the derived winds provided by the GOES system. High density cloud drift winds (and water vapor drift) are produced from imager movie loops. Thermal gradient winds in the subtropics produced with the sounder have recently been found to be providing good information on atmospheric motion in non cloudy skies. The combination of the imager and sounder winds is used to infer mean atmospheric motions associated with tropical cyclones and their steering currents. NHC forecasters will continue to work with NESDIS, NMC, AOML, CIRA, and CIMSS scientists to utilize the improved GOES-I imagery and to evaluate the impact of the new wind sets on their forecast procedures and their model initializations.

4.4.3. NMC

NMC model
impact studies

An extensive effort is underway at NMC to develop the Regional Data Assimilation System (RDAS), which will be capable of accepting data on frequent (e.g. 3 hourly) cycles for both level and layer parameters. Thus NMC will be in position to exploit the spatial and temporal information available from the GOES I-M products (e.g. cloud-tracked winds, temperature retrievals, layer moisture retrievals, cloud top temperatures). Cloud-tracked winds from short interval (e.g. 15 minutes) imagery in regions where other observations are sparse will receive increasing attention; however the upper level slow bias must be understood and accounted for. Temperature retrievals will be valuable especially over oceanic regions, but they must be competitive with those from the TOVS (within 2.5 C rms of radiosondes). Layer moisture retrievals, hopefully improved by the additional moisture channels on GOES I-M, should provide a good bound on several moisture layers for a large area of the western hemisphere. Cloud top temperatures and effective cloud amount should indicate cloud type and location. Additionally products such as snow and ice cover, surface temperature, and water vapor tracked winds will provide information that cannot be provided by other sensors. All parameters, as well as thermal gradients expressed as gradient winds, will also be used by the Global Data Assimilation System (GDAS), but on a 6-hour cycle.

Impact of a given GOES product will be measured by the Development Division of NMC in a series of tests where the RDAS (and/or GDAS) is run with and without the GOES information. Close coordination with assimilation efforts at FSL, CIMSS, and CIRA will be required. These tests will be scheduled with the appropriate Product Oversight Panel (POP) and will typically run ten to twenty days. Feedback from these tests will be funnelled through the POPs and appropriate product availability will be arranged or the desired product adjustment pursued.

4.4.4. FSL

images and
models

The Forecast Systems Laboratory (FSL) will support this plan through several activities: (1) evaluate data quality over ISPAN through interaction with the forecast office and the NWS; (2) test various remapping algorithms to assure equivalent product quality from GOES-I; (3) work with CIRA in comparing analysis strategies with those developed for GOES-7; and (4) check GOES-I data using LAPS (Local Area Prediction System) surface temperature, cloud, and moisture analyses. FSL has been working with GOES data for the past 10 years in a number of areas. They include the testing and refinement of algorithms (e.g., split-window VAS moisture product, GOES soundings and derived image products), participation in the NOVA program, and collaboration with CIRA in improving satellite products targeted for AWIPS. FSL will continue this interaction. In addition, FSL will continue working with the (NWS Denver) operational forecast office to test new satellite products and applications and refine existing ones. In the mid-1990's, ERL will move into a new building that also houses the NWS Denver forecast office. FSL will occupy offices next to the weather service allowing direct interaction between operational forecasters and FSL researchers and algorithm developers.

The major vehicle to get satellite data to the future operational offices will be through GINI processed data distributed through NOAA-PORT. FSL receives ISPAN distribution now and plans to test the data by using it as input in both analysis and product generation. Additionally, FSL will have a GVAR ground station. With

ISPAN vs.
GVAR

both ISPAN and direct received GOES-I data, as a day-2 activity FSL will determine improvements to the ISPAN data feed and assess its value compared with data from GOES-I GVAR ingest. FSL has "operational" experience using GOES-7 data in the local analysis and prediction system (LAPS) and meteorological display algorithms. Further, depending on the impact of the activities mentioned above, FSL can perform satellite data impact experiments by comparing forecast model output based on initialization made with and without satellite data.

4.4.5. NWS Field Offices

During the checkout period, CIRA will be coordinating evaluation activities with the NESDIS Satellite Services Division at selected GOES-TAP sites receiving GOES-I data through the NESDIS/NWS "No-GOES" contingency facilities and those sites receiving imagery from GINI. Candidate sites include the NWS-EFF and field offices with a SOO.

Milwaukee/
Sullivan

In addition, CIMSS and the nearby Milwaukee/Sullivan WSFO will collaborate in the evaluation of the new satellite data and the derived products. This will take advantage of the local availability of NEXRAD, ASOS, and Profiler data as well as bringing together operations and development personnel to plan further product enhancements.

4.4.6. Informing the User Community

need active
training
programs

With the transmission of data through GVAR and processed products through GINI and GOES-TAP, information and training will be required for the broad user community. Some of those activities must begin prior to the launch of GOES-I. This is the responsibility of NWS and NESDIS using input from the Training and Information Services Branch and the Ground Systems Division, as well as CIRA and CIMSS. Prior to the launch of GOES-I, selected technical memoranda must be updated for the user community. These are summarized in Appendix F, as well as other NWS and NESDIS plans for providing information to the user community. There remains a need for an active user training program coordinated within NOAA; such a program was a fundamental part of the NEXRAD integration into the NWS.

5. EVOLUTION TO IMPROVED PRODUCTS AND INSTRUMENTS

While much of the initial focus for product validation is on GOES-I, the important issues of changes to the GOES I-M series and the future beyond GOES-M should be addressed also. This section discusses each of these issues as a logical progression of knowledge from this GOES I-M Product Assurance Plan.

5.1. Evolution of Products

day-2
possibilities

Products will evolve as experience is gained with the new GOES spacecraft configuration and its improved capabilities. In Appendices G and H, meteorological target scenarios have been suggested for both post-launch checkout and operational modes. At these times of data collection, it will be possible to look at new products and their usefulness to the NWS and other users. The day-1 products have been listed in Appendix C. Opportunities for gathering data sets for day-2 products occur largely during the post-launch checkout; operational constraints will inhibit more ambitious data gathering at other times. Possibilities for day-2 products include mesoscale winds from very rapid image intervals, cloud products like fog and cloud emissivity from the imager, gridded cloud information from the sounder, automated precipitation estimates from the imager and the sounder, sea surface temperature from the imager, ozone from the sounder, and land surface or radiation budget flux values from the sounder.

procedure for
introducing
day-2

The exact process of evolving from day-1 to day-2 products will rely on scientific research, a demonstration program for the NWS, coordination with the appropriate POP, approval by the SPRB, and implementation by the Office of Satellite Data Processing and Distribution (OSDPD). This plan requests funding for this procedure. This process will be enhanced if there is a working group which meets periodically to discuss and encourage product developments.

5.2. Establishing a Working Group

GOES working
group

Since 1983 the International TOVS Working Group has been studying the quality and applicability of satellite derived temperature and moisture profiles for operational purposes. The meetings of this group have proven to be a successful venue for exchange of information and algorithms. More recently in 1991, an initial meeting of the International Winds Working Group convened the international producers of satellite derived atmospheric motions to share information on cloud and water vapor drift winds and the associated height assignments. There is a need for a GOES Working Group that functions in much the same way.

Such a group would start with the community having GOES/VAS or NOAA/TOVS experience and expand to include new GOES I-M users. International participation would be encouraged. Working group meetings would provide a venue for geostationary experts to discuss progress and goals, as well as a sounding board for new products and instruments. It would facilitate validating day-1 products, getting day-2 products tested and made operational sooner, and evolving the GOES instruments for future needs.

5.3. Potential Impacts on GOES L-M

The schedule to build instruments and spacecraft does not permit time for significant changes with GOES-I and -J. There is more time and hence flexibility with regard to GOES K-M. Improvements fall into three categories; instrument manufacture, reliability, and design changes for better performance.

GOES L-M

In June 1992, the NASA GOES Project identified 31 reliability and manufacturing changes, adding a total cost of about \$22 million dollars. These are currently being prioritized and some changes are anticipated to GOES K, L and M. Some of these changes should result in improved products, but the impact must be verified. The major instrument/spacecraft change considered to date is an interferometer on GOES M to provide the sounding function. While this would improve spectral resolution, thus adding the potential for exciting new products like trace gases, it would be a major cost and schedule driver. No decision has been made about the interferometer as of this date.

5.4. Implications for GOES-N

GOES-N is the designation given to the next generation of geosynchronous weather satellites after GOES-M. The first GOES-N will be needed in December 2004 to replace GOES-L, assuming the anticipated 5-year life for each satellite in the GOES I-M series. GOES-M is scheduled for a December 2003 launch.

What capabilities will be available from the new generation of weather satellites? Experience points to two important principals: (1) GOES-N should evolve from more careful trade-offs and analysis of user requirements; and (2) the future generation should be more "robust" than the current systems allowing for flexibility and no risk of lack of coverage (i.e. only one satellite) meaning that spacecraft spares will be important. The benefit of returning to 3-year lifetimes instead of 5 or 7 years should be considered also.

paths to GOES-N Options for the future GOES program are being discussed. This will lead to an integrated strategy evolving from GOES-I to the next generation. There may be a need for more flexibility and robust spacecraft configurations. There are at least three paths by which this can happen; they are not necessarily independent.

* Path One: Continue the extrapolation path of making larger and more complex spacecraft and instruments. Improved spatial and spectral resolution is sought, but at the increased cost and risk of very difficult pointing accuracy and ground control (including data processing). All satellites are the same.

* Path Two: Consider a fleet of geostationary satellites with different missions, sizes, and instrument configurations. For example it might be best to have spinning imagers for synoptic coverage at east and west coast U.S. locations, with a larger satellite stationed over the central U.S. for higher resolution imaging and soundings. Design of a microwave and IR instrumented geostationary satellite should be considered to do measurements of, and through, clouds for improved precipitation measurements and thermodynamic soundings in cloudy areas.

* Path Three: Reduce operational risk by testing research versions of operational instruments in space, before generating an operational series of these instruments. A microwave sounder, IR interferometer, lightning mapper, and new solar imaging instruments need space testing before operational commitments can be made. NASA and NOAA could team effectively to fly smaller spacecraft with vital research instruments. This test capability would lead to leadership data products faster in the future and with greater user requirements.

guidance from TAC This GOES-I Product Assurance Plan provides a path for improved weather products from the current GOES I-M series, but only if work continues beyond the few critical weeks or months after GOES-I launch. The Technical Advisory Committee can also play a key role in defining the future GOES requirements and identifying possible robust satellite configurations to fulfill them. The next generation GOES should not be a high-risk step function, but should be continuous, well-tested, and incremental. For the future GOES program, continuity of coverage is a key necessity, but not the only one. Designers may look for innovative instruments to provide continued data coverage and improved data for advanced products.

This GOES-I Product Assurance Plan takes the first step toward the future generation. The second step is to move steadily toward day-2 products. Step three must recommend even better ways to fulfill user requirements by analysis and improvement of current data. This in turn leads to recommendations for new instruments and possible new satellite configurations.

APPENDIX A. Responsibility and Cost

Product assurance responsibilities and costs are outlined in this section. More detailed budgets will be expected in the individual proposals to the GOES Program Manager from the participating laboratories. Recurring science development costs beyond FY 1997 are not included. Costs required to implement and maintain these products in the Office of Satellite Data Products and Distribution are not included.

A.1. Responsibility

Product	NOAA SAL/ SRL	NSSFC	NHC	NMC	WSFO	FSL	AOML	Coop CIMSS	Inst CIRA	Univ Chi	NASA GSFC
Images	X	X	X		X	X		X	X		X
Clouds	X				X			X			X
Soundings	X	X	X	X		X	X	X	X		X
Winds	X		X	X			X	X	X	X	X
Precip	X			X	X						X
Other ^a	X			X							X

^a This refers to the day-2 product activities in surface products, ocean products, earth radiation budget, and ozone.

A.2. Cost (in \$1000 units)

FY	Total	NOAA SAL/ SRL	NSSFC	NHC	NMC	WSFO	FSL	AOML	Coop CIMSS	Inst CIRA	Univ Chi	NASA GSFC
1993	635	110	55	55	A	A	60	B	175	140	40	C
1994	1485	289	57	57	A	A	157	B	459	361	105	C
1995	1620	364	60	60	A	A	165	B	482	379	110	C
1996	1306	318	63	53	A	A	139	B	405	318	---	C
1997	1371	334	66	66	A	A	146	B	425	334	---	C

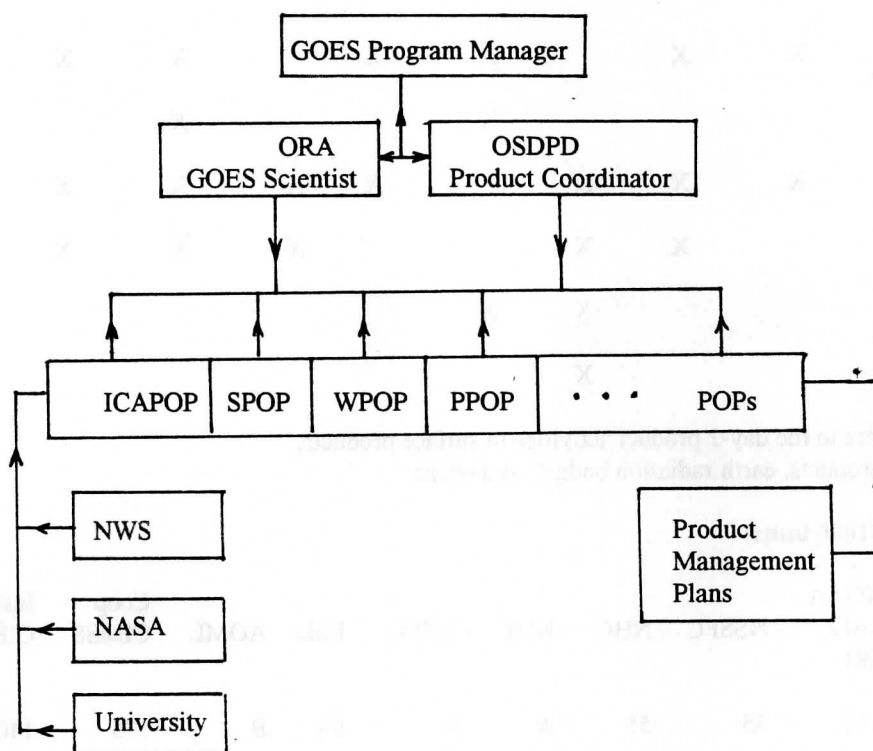
An inflation rate of 5% per year is incorporated; one FTE is assumed to cost \$55K

A implies this activity is covered under current NWS programs

B denotes that separate funding from NOAA is being sought to support these activities; C denotes separate funding from NASA.

APPENDIX B. Management Plan for Each Product

The management of all GOES I-M Product Assurance activities will be accomplished with a three tiered structure. Top leadership and overall responsibility resides with the "GOES Program Manager". In the second tier, an "ORA GOES Scientist" and an "OSDPD Product Coordinator" will be responsible to him to assure work is done, milestones met, and implementation accomplished. Finally, in the third tier, the Product Oversight Panels (POP) will see to the maintenance and evolution of the products. The POPs will report on progress at the monthly SPRBs and other venues, as requested by the GOES Program Manager. This management structure is depicted in the following diagram.



The POPs with their respective co-chairs (one from research and one from operations) are listed below.

- | | | |
|-----------------------|---------------|-------------|
| Image, Cloud, Aerosol | L. Stowe | B. Banks |
| Soundings | C. Hayden | E. Burdsall |
| Winds | D. Gray | G. Rutledge |
| Precipitation | R. Scofield | N. Lyles |
| Oceans | B. Pichel | J. Sapper |
| Ozone | W. Planet | D. Bowman |
| Surface | D. Tarpley | M. Matson |
| ERB | H. Jacobowitz | J. Sapper |
| Calibration | M. Weinreb | R. Lawrence |
| Navigation | K. Kelly | E. Harrod |

Progress on each product will be logged by the appropriate POP in a management plan; this will be used to track evaluation activities, product quality, and resource allocation. A template for a management plan for each GOES I-M product is given below.

Start Date of Plan:

Date of Last Entry:

* Product

Description

References from scientific literature

NOAA product since when

* Use of Product

Users (with phone numbers)

* Evaluators

Assessment of data quality as it affects product

importance of navigation

Approach for assessment of product

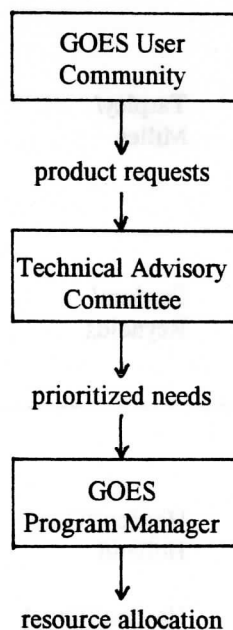
other data needed

Status of evaluation

* Resources required in each FY 93 through 97

* Comments

The GOES Program Manager is also served by the Technical Advisory Committee (TAC), which helps to guide GOES product research and development and to prioritize resource allocation. The TAC provides a mechanism for community-wide coordination and is composed of representatives from agencies using and developing GOES data products. Outside users should route new product requests through the TAC. NESDIS will chair the committee which has representatives from NESDIS, SPO, NWS, ERL, NASA, DOD, FAA, and the university community; two meetings a year are suggested.



APPENDIX C. Product List

This list is current as of summer 1992 and will be updated periodically to incorporate new information.

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
Cloud Parameters				
o Cloud Heights (Cloud Top Temp)	Imager/ VDUC	Menzel/ Rutledge	FD/ 1ph	FAA & NCs/ NMC
o Cloud Amount (ASOS)	Sounder/ VDUC	Menzel/ Rutledge	CONUS/ 1ph	WSFO & NCDC/ NWS
Enhanced Data Sets				
o GOES Projection (GOESFAX)	Imager/ GSS	Purdom/ Miller	sectors/ 2ph	NWS/ WSFO
o GOES Projection (WEFAX)	Imager/ DPSS	Ellrod/ Miller	FD/ 2ph	NWS/ NMC
o Lambert Conformal (AWIPS)	Imager/ CEMCSS	Purdom/ Miller	CONUS/ 2,4,12ph	NWS & NCDC/ MAR
			Hawaii/ 2,4,4ph	
			P. Rico/ 2,4,4ph	
o Polar Projection (AWIPS)	Imager/ CEMCSS	Tarpley/ Miller	Alaska/ 2,4,4ph	WSFO & NCDC/ NWS
			N Hemis/ 2,2,0ph	
o Stretched Data (real time)	Imager/ OGE	Purdom/ Reynolds	Normal, Alert, Warning	NWS/ NCs
Atmospheric Parameters				
o Vertical Temperature Profiles (deg K)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Layer Mean Virtual Temperatures (deg K)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
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Atmospheric Parameters (cont)

o Vertical Moisture Profiles	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Layer Precipitable Water (mm)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Total Precipitable Water (mm)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
	Imager/ VDUC	Hayden/(Gray) Holland	FD/ 1ph	NCs & NCDC/ NSSFC
o Channel Brightness Temps (deg K)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ ORA
o Lifted Index	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
	Imager/ VDUC	Hayden/(Gray) Holland	FD/ 1ph	NCs & NCDC/ NSSFC
o Geopotential Heights (m)	Sounder/ VDUC	Hayden/(Gray) Holland	CONUS+/ 8pd	NCs & NCDC/ NMC
o Thermal Wind Profiles (m/s)	Sounder/ VDUC	Hayden/ Rutledge	CONUS+/ 4pd	NCs & NCDC/ NMC & AOML
o Moisture Analysis (Interactive)	Imager/ VDUC	Brown/ Carney	PD/ 4pd	NMC/ NMC
o Precipitation Estimates	Imager/ VDUC	Scofield/ Lyles	CONUS+/ 8pd	NWS & NCDC/ NWS & NMC
o Precipitation Histograms	Imager/ DPSS	Scofield/ Hughes	30N-30S/ 8pd	NMC/ NMC

Data Bases

o Imager	Imager DPSS SSEC	Hughes Metcalf	FD/ 2ph	NCDC/ SDPD
o Sounder	Sounder DPSS SSEC	Hughes Metcalf	CONUS+/ 1ph	NCDC/ SDPD

PRODUCT	SENSOR/ SYSTEM	DEVELOPMENT/ IMPLEMENTATION	COVERAGE/ FREQUENCY	USER/ EVALUATOR
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Data Bases (cont)

o Vicarious Cal (IR and VIS)	S and I/ DPSS	Weinreb/ SOCC		
o Long Term Cal (IR and VIS)	S and I/ PM	Weinreb/ SOCC		all/ all

Winds

o Cloud Drift (low)	Imager/ NCCF	Hughes/(Gray) Schreitz	60N-60S/ 4pd	NCs & NCDC/ NMC
o Cloud Drift (high)	Imager/ VDUC	Menzel/(Gray) Rutledge	60N-60S/ 4pd	NCs & NCDC/ NMC
o Moisture Drift (mid)	Imager/ VDUC	Menzel/(Gray) Rutledge	60N-60S/ 4pd	NCs & NCDC/ NMC
o Deep Layer Mean	I and S/ VDUC	Velden/ Rutledge	hurricane/ 4pd	NHC & AOML/ NMC & AOML

notation:

ph - per hour
 pd - per day
 CONUS+ - CONUS and adjacent oceans
 FD - full disk
 PD - partial disk

APPENDIX D. NOAA and University Organizations Responsible for Product Assurance

The following table summarizes the various NOAA affiliates and universities that have specific responsibilities for product assessment. Activities at each site include, but are not limited to, the indicated areas of responsibility. Where possible, lead individuals are also identified.

D.1. Image, Cloud, and Aerosol

Atmospheric Sciences Branch (L. Stowe)	ICAPOP
Physical Sciences Branch (G. Ellrod)	WEFAX
	multispectral products
Physics Branch (N. Rao)	insolation
CIRA (J. Purdom)	image quality
(S. Smith)	multispectral products
CIMSS (A. Schreiner)	ASOS cloud products
(G. Wade)	multispectral products
Synoptic Analysis Branch (J. Lynch)	user feedback
WSFO Milwaukee/Sullivan (A. Siebers)	ASOS cloud evaluation
	multispectral product evaluation
NSSFC TDU (F. Mosher)	multispectral product evaluation
FSL (D. Birkenheuer)	LAPS impact studies

D.2. Sounding

CIMSS (C. Hayden)	SPOP
	profiles and gradient winds
	derived product images
Sounding Implementation Branch (D. Gray)	software
CIRA (D. Hilger)	clustering
Synoptic Analysis Branch (J. Lynch)	user feedback
WSFO Milwaukee/Sullivan (A. Siebers)	derived product evaluation
NSSFC TDU (F. Mosher)	derived product evaluation
FSL (D. Birkenheuer)	LAPS impact studies
EFF	derived product evaluation
NMC Development Division (W. Baker)	RDAS/GDAS impact tests

D.3. Winds

Sounding Implementation Branch (D. Gray)	WPOP
	software
Product Systems Branch (G. Hughes)	picture pair winds
CIMSS (S. Neiman)	upper level winds
(C. Velden)	deep layer mean winds
(P. Menzel)	cloud heights from H2O
CIRA (S. Smith)	storm relative flow
(P. Dils)	cloud heights from shadows
(J. Purdom)	mesoscale winds
University of Chicago (T. Fujita)	ground truth
Synoptic Analysis Branch (J. Lynch)	user feedback
NHC (H. Gerrish)	wind field evaluations
NMC Development Division (W. Baker)	RDAS/GDAS impact tests
AOML (B. Burpee)	model impact tests

D.4. Precipitation

Physical Sciences Branch (R. Scofield)
(D. Brown)
Synoptic Analysis Branch (J. Lynch)
NMC Development Division (W. Baker)

POPOP
CST improvements
improved moisture bogus
user feedback
model impact tests

D.5. Surface

Land Sciences Branch (D. Tarpley)

POP
land surface temperature

D.6. Ocean

Ocean Sciences Branch (B. Pichel)
Physical Sciences Branch (E. Maturi)
Marine Applications Branch

POP
SST
SST

D.7. Earth Radiation Budget

Atmos. Sciences Branch (H. Jacobowitz)

POP

D.8. Ozone

Physics Branch (W. Planet)

POP

D.9. Calibration

Physics Branch (M. Weinreb)
SOCC
CIMSS (T. Schmit)
CIRA (P. Dils)
NASA GOES Project

POP
operational evaluation
cal intercomparisons
cal intercomparisons

D.10. Navigation

SOCC (K. Kelly)
NASA GOES Project

POP

APPENDIX E. References for further Information concerning GOES and GOES Products

- * NOVA Program Development Plan,
November 1982
- * NWS GOES-NEXT Requirements,
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- * NOAA Technical Report NESDIS 33
An Introduction to the GOES I-M Imager and Sounder Instruments
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- * NOAA Technical Report NESDIS 40
The GOES I-M System Functional Description
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- * Performance Specification for GOES-IJK/LM
GSFC Revision 2A
February 1989
- * GOES I-M Operational Satellite Conference Proceedings,
April 3-6, 1989
- * Purpose and Plans for the GOES Science Evaluation Working Group
June 1990
- * Positive Characteristics of Viewing from Geostationary Orbit,
7th Symposium of Meteorological Observations and Instruments,
January 1991
- * GOES-I Post-launch Test Plan,
January 28, 1991
- * GAO/NSIAD-91-252
Report on Weather Satellites to the Committee on Science,
Space, and Technology, House of Representatives
July 1991
- * Proceedings from the Workshop on Wind Extraction from Operational
Meteorological Satellite Data,
September 17-19, 1991
- * Preprints of the Sixth Conference on Satellite Meteorology and
Oceanography,
January 19, 1992
- * GOES I-M Performance Overview,
NASA GOES Project Briefing to Dr. Friday
April 1992

APPENDIX F. Plan for Providing Information to the User Community

The value of GOES I-M technology to the warning and forecast program will be fully realized when forecasters are efficiently using the data and products with other observations and in numerical forecast models to improve weather operations and services. User information will be available through conference presentations, publications in peer review journals, technical reports, and technical information messages. This will be the responsibility of the POPs.

F.1. Planned Conference Presentations

- * NWS Science and Operations Officers Conference, December 1992
- * American Meteorological Society Meeting, January 1993

F.2. Planned Technical Reports

- * GOES I-M Satellites and the Impact on Field Operations:
(invited article in Bulletin of AMS)
Initial: NWS/NESDIS/SPO
- * GOES Instrument Performance Summary for NWS and User
Community Researchers:
(invited article in Bulletin of AMS)
Initial: NWS/NESDIS/SPO
- * GOES I-M Instrument Performance:
(NASA GOES Project Report to be available six months after launch)
Initial: GSFC/NESDIS
Updates: NESDIS
- * GOES I-M Calibration:
(NOAA TM to be available at time of GOES-I launch)
Initial: ORA
Updates: ORA
- * GOES-I Day-1 Product Descriptions:
(NOAA TM to be available at time of GOES-I launch)
Initial: ORA/OSDPD
Updates: OSDPD/ORa
- * GOES-I Users Guide (GOES-TAP / NOAA PORT):
(NOAA TM to be published before service begins)
Initial: OSDPD
Updates: OSDPD
- * WEFAX Users Guide:
(update current edition dated Nov 1981)
Update: OSDPD
- * GOES-I Data Collection Users Guide:
(update current edition)
Update: OSDPD
- * GOES I-M Data User Guide (Archive data):

(publish before GOES-I launch)
Initial: NCDC
Updates: NCDC

- * GOES Application Information Notes:
(publish as required by training program)
Initial: ORA/NWS
Updates: ORA/NWS

F.3. Formalized Training Functions

- * Mechanisms need to be identified.

APPENDIX G. Post-launch Checkout Data Needed

The Post-launch Test (PLT) period is expected to last six months; a schedule of events is currently being planned. The needs for a proper scientific evaluation of the GOES I-M data is being factored into the PLT schedule. The requests for data will generally fall into three categories; a) data needed to prepare and test day-1 generation of operational products, b) data synchronized with the MAR, and c) data that can be used to investigate possible future operational products.

G.1. Schedule for Day-1 Product Preparation

The minimal schedule to test day-1 generation of operational products is briefly summarized as follows. Temporal overlap of the imager and sounder is implicit; synchronization with polar orbiter overpasses is highly desirable. If time allows each day should be repeated.

- * imager (6 days each separated by 3 to 5 days)
 - day 1: 5 consecutive full disk images, daylight
 - day 2: 5 consecutive full disk images, synoptic times
(00Z, 06Z, 12Z, 18Z)
 - day 3: 10 consecutive 15 minute interval images, synoptic times
(00Z, 06Z, 12Z, 18Z)
 - day 4: nominal schedule for imager, all day
(continuous half hourly full disk imaging)
 - day 5: alert schedule for imager, all day
(mix of nominal schedule and 15 minute images)
 - day 6: warning schedule for imager, all day
(mix of alert schedule and 5 minute images)

- * sounder (4 days each separated by 5 days)
 - day 1: 5 consecutive CONUS soundings, daylight
 - day 2: 8 consecutive CONUS soundings, centered around sunset
to detect surface cooling
 - day 3: 8 consecutive CONUS soundings, centered around local
midnight to investigate possible calibration effects
 - day 4: nominal schedule for sounder, all day
(24 consecutive CONUS soundings)

G.2. Schedule for Synchronization with MAR

A schedule that enables synchronization with the MAR focuses on six minute imager updates for NEXRAD compatibility and hourly sounder updates for the hourly roundups.

- * imager (hourly)
 - 6 min. coverage of CONUS plus
 - 24 min. full disk coverage
 - 12 min. partial disk past Puerto Rico
 - 6 min. coverage of CONUS plus
 - 6 min. coverage of CONUS plus
 - 6 min. coverage of CONUS plus

- * sounder (hourly)
 - 60 min. coverage of CONUS plus

G.3. Schedule for Investigating Possible Future Products

The schedule to investigate future products is more ambitious. Special schedules have been suggested by the GOES Science Evaluation Working Group (June, 1990) and have been modified due to research results since that document. It should be noted, that for all cases below, coordination of data taken with NOAA polar orbiting spacecraft and other components of MAR is desirable when possible. Among the topics to be investigated are (a) winds from cloud motions over water, land, and coastal regions, (b) temperature and moisture profiles, (c) hurricanes, (d) winter storms, (e) tornadic storms, (f) flashfloods, and (g) fog, pollution, and haze. The latter topics will receive priority as weather events dictate (i.e. if a hurricane occurs during checkout we will adjust our data gathering schedules to take advantage).

- * imager (3 hour repeat cycle with at least 9 hours duration)
 - 15 min. interval alert sector data for 30 min.
 - 3 min. interval data within alert sector for 30 min.
 - 10 min. interval reduced alert sector data for 30 min.
 - 2 min. interval data within reduced alert sector for 30 min.
 - 5 min. interval special sector data for 30 min.
 - 1 min. interval data within special sector for 30 min.

- * sounder (3 hourly repeat cycle up to 24 hours duration)
 - 0.1S dwell time in special sector for 30 min.
 - 0.1S dwell time in special sector for 30 min.
 - 0.1S dwell time in reduced special sector for 15 min.
 - 0.1S dwell time in reduced special sector for 15 min.
 - 0.1S dwell time in reduced special sector for 15 min.
 - 0.1S dwell time in reduced special sector for 15 min.
 - 0.2S dwell time in reduced special sector for 30 min.
 - 0.4S dwell time in reduced special sector for 30 min.

G.4. Coordination with the NASA GOES Project

The science team from NOAA, NASA, and the universities will be interacting with the post-launch checkout team through the NESDIS GOES Project Scientist to ensure that as many of these data sets are gathered as the checkout schedule allows.

A few comments regarding the post-launch test schedule follow; they indicate that more planning and coordination will be undertaken.

- * The engineering tests have not been integrated with the products/science applications thus it is likely that some product validation could be done along with post-launch engineering tests.

- * NOAA handover does not occur sharply at week 10, but could start as early as week 1 to 2 after power, outgassing, AOCS wheels etc. are shown to be working. Between weeks 2 and 10, there will need to be some product output if only on a "first glimpse" basis. Some products will begin to flow at week 10 with regularity. Most products are not due until as late as week 26.

- * The extent and measurement of "in spec" product validity interface needs to be defined.

- * The product evaluation assumes navigated and calibrated data; effects of both will be investigated in the quality of the final product. INR testing will require some time, therefore early product testing should not rely heavily on good navigation.

APPENDIX H. Probable Operational Schedules

Operational schedules for GOES I-M are still being drafted, and the final version will be dependent on the pre-launch instrument test results. However, all preliminary schedules include some elements of the following summary.

* imager

nominal mode: half hourly full disk
alert mode: 15 minute northern hemisphere
warning mode: five minute CONUS

* sounder

normal and alert modes: hourly CONUS coverage for ASOS and NWP
warning mode: three hourly duty cycle with
hour 1 and 2: repeat 15 minute coverage over active area
hour 3: one hour CONUS coverage
hurricane mode: three hourly duty cycle with
hour 1 and 2: repeat one hour CONUS coverage
hour 3: one hour hurricane coverage for thermal wind support

APPENDIX I Acronyms

AOML - Atlantic Oceanographic and Meteorological Laboratory
ASOS - Automated Surface Observing Stations
ATS - Applications Technology Satellites
AVHRR - Advanced Very High Resolution Radiometer
AWIPS - Advanced Weather Interactive Processing System
CEMSCS - Central Environmental Satellite Computer System
CIMSS - Cooperative Institute for Meteorological Satellite Studies
CIRA - Cooperative Institute for Research in the Atmosphere
CONUS - Continental United States
CST - Convective Stratiform Technique
DMSP - Defence Military Satellite Program
EFF - Experimental Forecast Facilities
EOL - end of life
ERL - Environmental Research Laboratory
ES - Earth sensor
FAA - Federal Aviation Administration
FSL - Forecast Systems Laboratory of ERL
FOV - field of view
GDAS - Global Data Assimilation System
GINI - GOES I NOAA-PORT Interface
GOES - Geostationary Operational Environmental Satellite
GSFC - Goddard Space Flight Center
GSS - GOES Sectorizer System
GVAR - GOES Variable (data format)
HIRS - High resolution Infrared Radiation Sounder
HIS - High resolution Interferometer Sounder
IDUC - Interactive Data Utilization Center
IFFA - Interactive Flash Flood Analyzer
IMC - image motion compensation
INR - Image Navigation and Registration
ISCCP - International Satellite Cloud Climatology Project
LAPS - Local Area Prediction System
LM - landmark
LO - Line Offices
MAR - Modernization and Restructuring
MMC - mirror motion compensation
MTF - modulation transfer function
NASA - National Aeronautics and Space Administration
NCDC - National Climate Data Center
NEDT - noise equivalent temperature
NESDIS - National Environmental Satellite and Data Information Service
NHC - National Hurricane Center
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
NOVA - NOAA Operational VAS Assessment
NSSFC - National Severe Storm Forecast Center
NWS - National Weather Service
OAR - Office of Oceanic and Atmospheric Research
OGE - Operational Ground Equipment
ORA - Office of Research and Applications
OSDPD - Office of Satellite Data Processing and Distribution
POP - Product Oversight Panel

RDAS - Regional Data Assimilation System
SAL - Satellite Applications Laboratory
SSMI - Special Sensor Microwave Imager
SOCC - Satellite Operations Control Center
SOO - Science Operations Officers
SPO - Systems Program Office
SPRB - Satellite Products Review Board
SRL - Satellite Research Laboratory
TDU - Techniques Development Unit (at NSSFC)
TOVS - TIROS Operational Vertical Sounder
VAS - VISSR Atmospheric Sounder
VISSR - Visible and Infrared Spin Scan Radiometer
WSFO - Weather Service Forecast Office