Third Quarterly Progress Report on CESDIS Contract S.C. 550-80

A Planetary Version of PC-McIDAS

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SUMMARY

This is the third quarterly progress report on CESDIS contact S.C. 550-80 towards work on a planetary version of McIDAS. Progress continues to be made in support of analysis of the Planetary Data System CD-ROM volumes in the McIDAS environment. The support for importing and analysis of planetary data from the CD-ROM volumes published by the Planetary Data System now includes the Voyager images of the giant planets and their satellites, Magellan radar images of Venus surface reflectivity, Magellan Altimeter data and Mars Digital Image Models. Remaining data types among the PDS CD-ROM volumes for which support needs to be extended include only the Viking Orbiter images of Mars and the Galileo SSI images of Venus, earth and the moon.

Magellan data related programs continue to get tested to make sure that they work in the same manner with the entire dataset produced over the life of the mission despite small differences in some of the file structures.

Details of the progress made in the preceding quarter towards the development of McIDAS for planetary applications in software development, documentation and user interface development are described here.

INTRODUCTION

This is the third quarterly progress report on CESDIS contact S.C. 550-80 towards work on a planetary version of McIDAS. Progress continues to be made in support of analysis of the Planetary Data System CD-ROM volumes in the McIDAS environment. By now the published data volumes include 12 volumes of Voyager data (3 CD-ROM's each of Uranus, Jupiter, Saturn and Neptune imaging data), over 70 CD-ROM volumes of Magellan Venus surface radar imaging data, a dozen or so CD-ROM volumes of Magellan data, one volume of global topography, emissivity and slope data for Venus from Magellan, twelve volumes of Viking Orbiter images of Mars and nearly a dozen volumes containing processed Mars images, and five volumes of Galileo images of Venus, Earth and the Moon. Software applications are being developed to provide support for using these different data within McIDAS. By now tools exist to import Voyager images of the giant planets, Magellan radar imagery, Magellan altimeter data and Mars processed monochrome images (Mars Digital Image Model).

Software development for Galileo Solid State Imaging (SSI) data, Magellan global data products (GxDR's), Viking Orbiter images is awaiting the receipt of the pertinent CD-ROM volumes from NSSDC which have been ordered.

In the preceding quarter we have tested the Magellan data importing programs (GETMGN, GETALT) with different data types (F-, C1, C2 and C3 MIDR's and different versions of ARCDR data files) with the help of Dr. Saunders, who is a co-investigator for this effort. Several anomalies were discovered regarding the precise format of some of the data types that caused the importing programs to fail unexpectedly. In most cases these were traced to slight differences in the file names such as different version numbers or extra digits as were added in the course of the systematic processing. In some cases the VICAR labels and PDS labels reflect somewhat different pieces of information such as the navigation information for the browse images-- the VICAR label reefers only to the data for the first tile in the browse set whereas the PDS label is valid for the entire browse image. Affected McIDAS programs are being modified to accommodate such differences in data files.

Work has also begun towards developing a Graphical User Interface for the planetary software so that a novice user need not know the command language before using the system. Most of the work continues to be developed on the IBM RISC-6000 system, although a Silicon Graphics Workstation (Indigo XZ 4000) has been acquired to test the portability of the code and to have a workstation with 24-bit graphics for 3-color display and animation capability.

Some of the problems encountered with the Extended Attribute Records (XARs) found on some of the PDS CD-ROM volumes have been resolved for the AIX operating system, although some others still pose a problem. The GxDR CD-ROM was formatted according to the ISO 9660 level 1 Interchange Standard and file attributes are specified by XARs. For operating systems that recognized the XARs, the access to the CD-ROM is straightforward--the disk appears identical to a file system of directories, sub-directories and files. Other operating systems that do not support XARs were expected to ignore them or append the XAR to the beginning of the file (512 bytes). Unfortunately, neither is the case with the IBM AIX operating system. Specifically, the latest release of the AIX operating system still does not support the XARs found on the GxDR volume containing Magellan data on surface emissivity, topography, slope and RMS slope, and the result is a hung workstation. We continue to work with the vendor (IBM) and have enabled the responsible people to access the specific CD volume when mounted on our workstation for diagnostic purposes, and it is likely that a solution will be available soon. Only then can we begin work with the GxDR datasets which require different program to be read because of the different directory structure. The GxDR's also present four new data types (local slope, rms slope, emissivity, and elevation) distinct from the radar reflectivity images and hence new data calibrations.

NEW APPLICATIONS

A major accomplishment in the preceding quarter was the initial development of the effort to provide calibrated data listing on demand from the user for Magellan and other data types. Normally the data calibration process in McIDAS is dependent only on the data type and the line documentation. However, in the case of Magellan radar imagery, the calibration also depends on the location of the data as the radar data needs the incidence angle before the conversion from data number to reflectivity can be made. This unfortunately poses a fundamental problem in terms of commonalty of code within the McIDAS environment as the MIDR is the only data type that requires the image coordinate of the data before the calibrated value can be obtained. In order to impact on low level McIDAS code an alternate approach to provide the same output has been found and that is to place the data conversion capability to calibrated units in different application programs that need it rather than at a very low level as is customary.

Figure 1 shows an example of a line plot (**LP** command) between two points in a Magellan radar image which shows the variation of the radar reflectivity along the surface straight line path between those two points in calibrated units. In general, the **LP** command will plot the data in its own calibrated units by default rather than just the digital brightness number. Similarly, as long as the image being scanned is navigated, the distance is given in km rather than pixels.

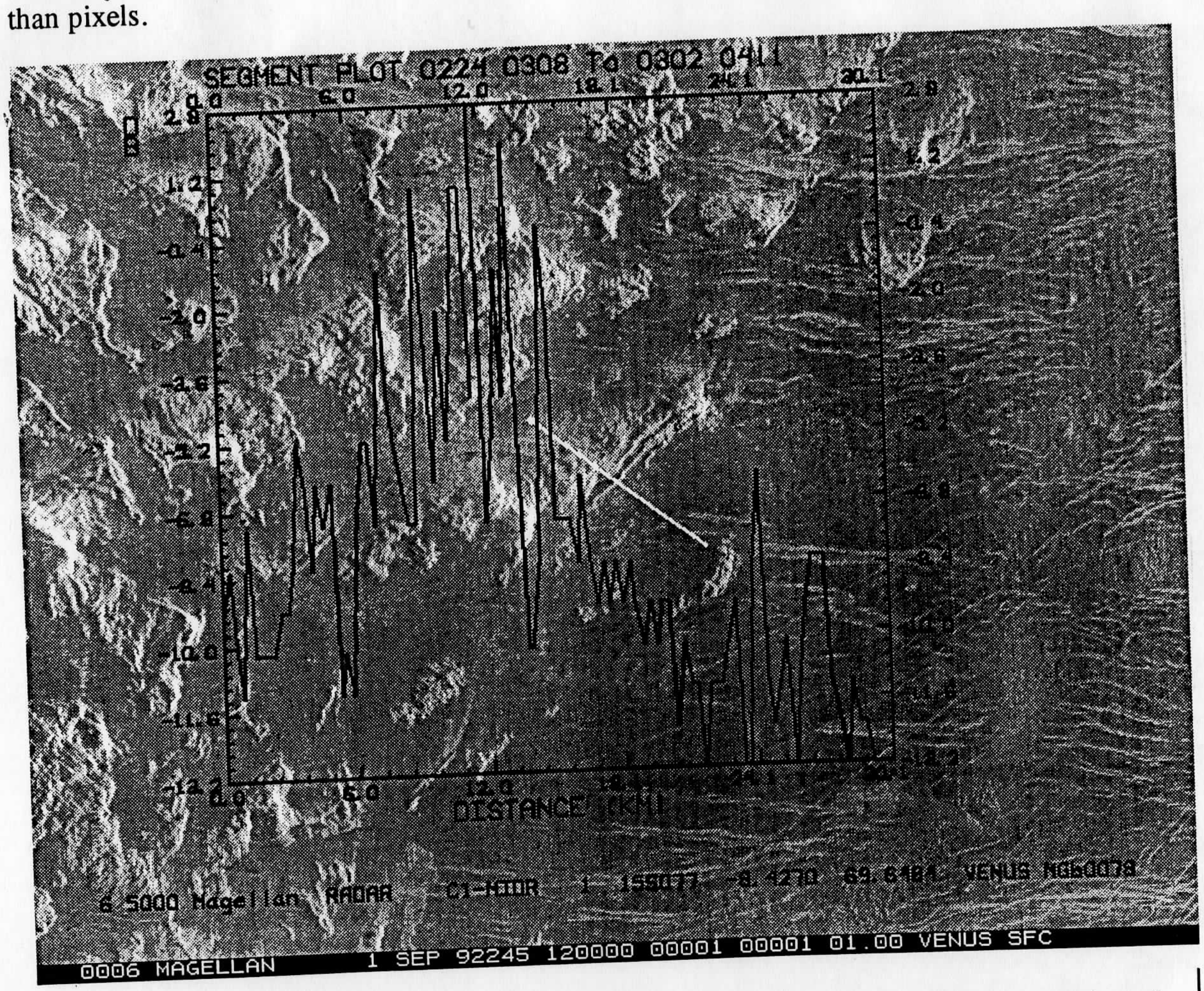


Figure 1. A line plot along two points in a Magellan radar image showing the variation of radar reflectivity along the path.

Once the GxDR CD-ROM volume can be read then the calibrations to convert the raw digitial numbers into calibrated units for those will be added to the suite of applications that use it it.

DOCUMENTATION

A User Guide to the planetary commands added to McIDAS is being developed, a preliminary version is attached as Appendix I. The User Guide which will eventually be accessible on-line from within McIDAS will allow new users to learn to use the system with greater ease and will contain sections on different PDS data types and summaries of typical processing of those data as well as include help on how to use specific commands and include a glossary of terms.

The documentation regarding the format of the McIDAS-X area formats and the Data Description Block (DDB) has been made available on-line. A McIDAS-X key-in EXPDOC provides access to this documentation by invoking the standard UNIX editor, vi with the documentation file which can be manipulated using the vi commands (except replacing it in edited form!)

USER INTERFACE

We have begun testing and evaluating different Graphical User Interfaces (GUI) in order to make use of McIDAS simpler for novice users. McIDAS and McIDAS-eXplorer make use of the command window to execute applications and to control the screen display. There are numerous commands to accomplish these tasks. A menuing system or a GUI provides a means of providing access to such tasks while minimizing or eliminating the requirement for any expertise in using the system, and therefore useful. There are several factors to be considered in evaluating and implementing the GUI -- ease of use and development, maintenance required when the application programs are modified, an expert route to bypass the GUI for quicker access to McIDAS tools as well as portability to different flavors of UNIX and other operating systems that McIDAS may work under such as OS/2.

Function Keys

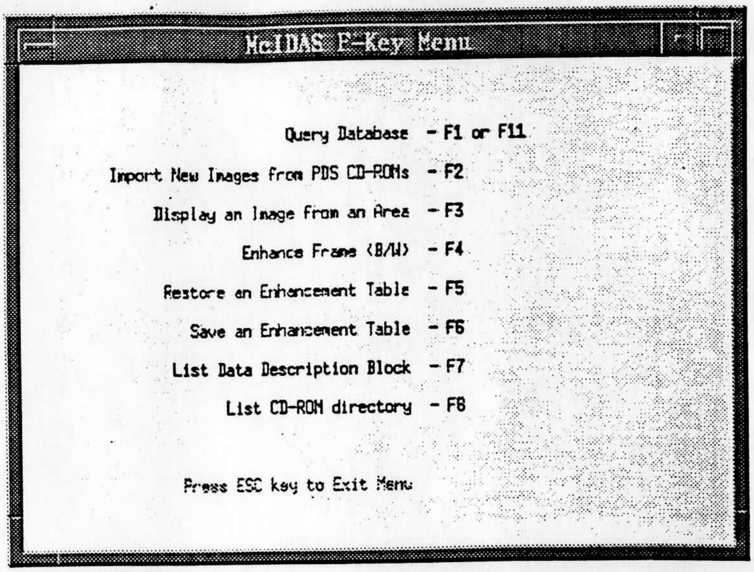
Among the ones considered is a function key based interface that has been used in the past and is portable to both X- and OS/2 workstations. The window screen tells the user of the current choices available with the function key setup. These keys can be programmed to cascade into more choices as appropriate. Figure 2 shows several examples of how the function keys can be used to provide access to McIDAS commands.

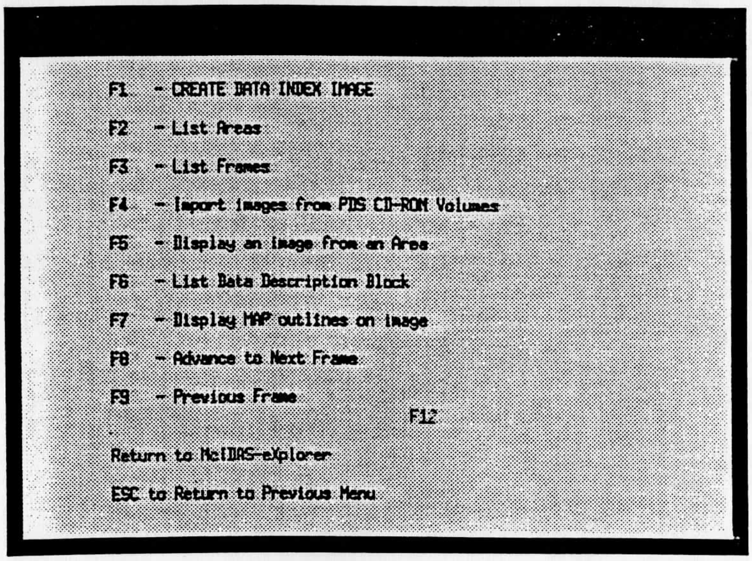
The function key based menu system is easy to program and the programming can be done by the end user. However, this menu system offers only limited choices and flexibility as only the function keys (and the escape key) are used, and is not easily gerneralized to provide access to all the applications in an elegant manner. Any text input solicited from the user is obtained by invoking a Motif window outside of the existing command window. Unfortunately the process of opening this input window causes a slight delay that is at present an annoyance. Other options are being considered to remedy the situation.

Programmable Buttons

Another possibility for a GUI is a "programmable button" approach using Motif window manager for X-workstations. The buttons can be programmed using the string table environment of McIDAS to activate specific commands. The buttons can control the McIDAS display using buttons to step a frame, loop or switch off the display. Figure 3 shows an example of such GUI that shows VCR style control buttons for controlling the frame display.

Figure 2. An example of a Function key based menu to provide access to McIDAS applications. Commands can still be entered directly into the Command window.





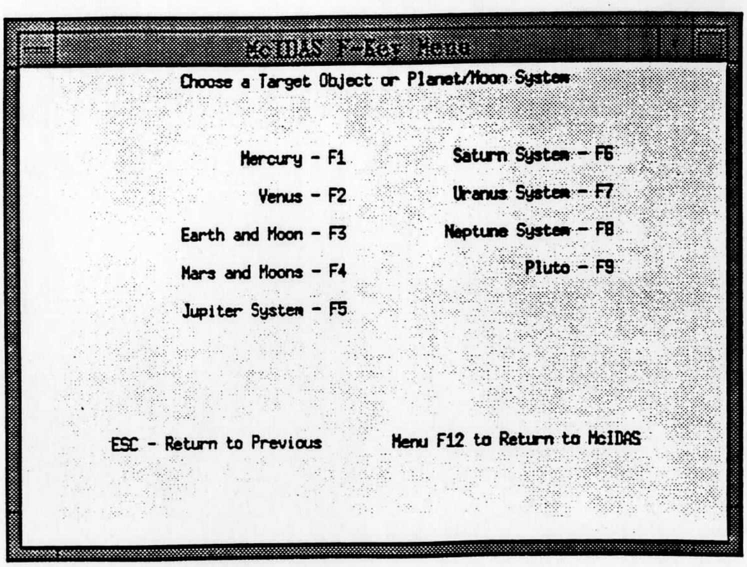
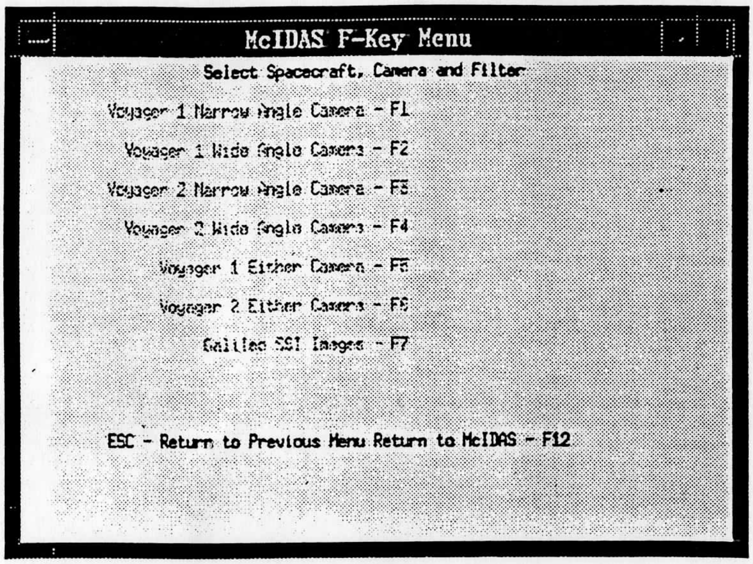


Figure 2 (contd.) An example of a Function key based menu to provide access to McIDAS applications. Commands can still be entered directly into the Command window.



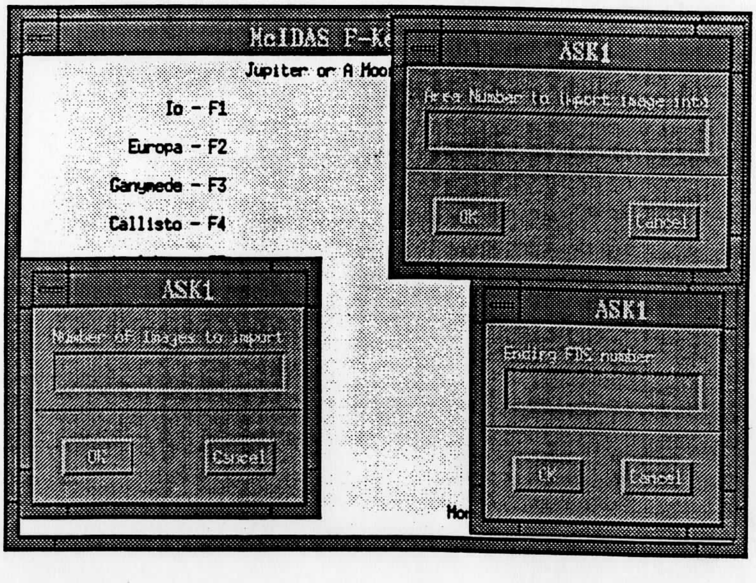
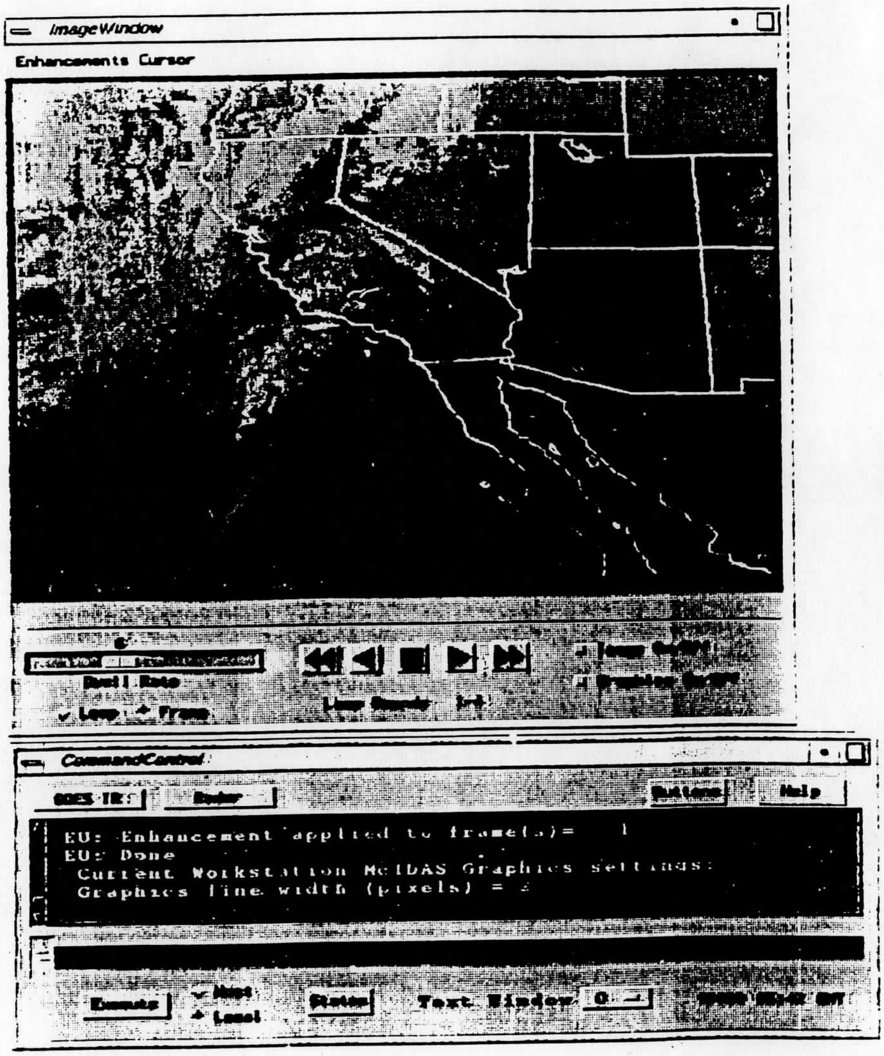


Figure 3. An example of a MOTIF based GUI that allows control of the McIDAS display through VCR like buttons.



Programmable Tool Bars using Tk-Tcl Scripting Language

Tk-Tcl is a scripting language developed at University of California-Berkeley that allows a tool-bar type graphical user interface development decoupled from the McIDAS code. It will allow commands to be created using cascading windows and transmitted to McIDAS. Utility of this for creating GUI's to enable McIDAS-eXplorer use is being investigated.

APPENDIX I

Draft Version of the User Guide

1.0 INTRODUCTION

This document describes **McIDAS-eXplorer**, a set of planetary analysis tools designed for the McIDAS environment. McIDAS is Man Computer Interactive Data Access System developed by the Space Science & Engineering Center (SSEC) of the University of Wisconsin-Madison (Suomi et al., 1983). Somewhat earlier, in late 1960's a similar facility was being born at the Jet Propulsion Laboratory (JPL) called Video Information Communication and Retrieval (VICAR) for analyis of the data being returned from the space probes such as the Mariner 6 mission to Mars (Castleman, 1979; Seidman, 1977). McIDAS originated as a tool for providing interactive access to the earth weather satellite data during the 1970's when there was a dearth of adequate hardware and software tools. While specific hardware elements are a key part of McIDAS, it is primarily the suite of software tools that has made it particularly useful in national and international operational weather facilities for integrating vastly different data weather sources and providing a coherent access to the user. Many of these capabilities are also applicable to the analysis of the planetary data returned by NASA's solar system missions of the past (Viking, Voyager, Magellan), current such as Galileo and Mars Observer and future such as and Cassini or the Pluto Fast Flyby. However, because of the different nature of the data and target objects, many adaptions or modifications are necessary. PDADS constitutes these adaptions and includes other specific tools for analysis of the planetary data.

Describing McIDAS is analogous to the story of the five visually impaired persons describing an elephant by feeling. McIDAS is different things to different specialists. But there are a few key features that distinguish McIDAS and McIDAS-eXplorer that will become more apparent after a brief consideration of the differences in the data and applications as described below.

1.1 Data are data... or are they?

While it may appear that the remote sensing data such as images returned from LANDSAT or SPOT satellites and data from weather satellites have much in common, and hence the same analysis tools (e.g. many of the Geographic Information Systems packages) can suffice, the differences between the two are apparent in the way these data are utilized as well as in their content. These differences can be illustrated by the presence of clouds in the satellite data-- for geographic remote sensing applications the presence of clouds is a hindrance to the analysis of the underlying surface data, yet the presence of the same clouds in weather applications is used for determining the atmospheric flow and radiation budget or storm development. Further, the information for geographic applications is concentrated in the spatial and spectral domain whereas for meteorological applications the information is contained primarily in the time domain and in spatial and spectral domain for climate applications. The spatial resolution of the data as well as coverage is also a distinguishing factor. For geographic and geologic applications highest achievable spatial resolution is desirable whereas for weather and climate applications ***global*** and ***temporal*** coverage is more important than high spatial resolution.

Planetary data in general differ from both the geographic satellite remote sensing data and the terrestrial weather satellite data in several key aspects. First of all while some data is analyzed in near real time for mission sequencing and public affairs reasons, much of the scientific analysis is carried out later. The data is usually acquired over a limited period of time and is often unique. Thus while we have global weather satellite data for nearly two decades, we have less than two days worth of images of Venus from Galileo and for several weeks each year from the Pioneer Venus Orbiter. At the other extreme we have the radar investigation of the surface of Venus from Magellan at a resolution of 120 meters providing mapping of a planet that is unmatched even by the data available about our own planet due to difficulties of mapping the ocean bottom.

1.2 What is McIDAS?

Very briefly, McIDAS provides a multitasking software and hardware environment for multiframe display and analysis of and interactive access to any multi-dimensional data. Data is rendered onto the two-dimensional display device of the user workstation on as many frames as the hardware capabilities allow. A user interface allows as many analysis tasks as practical (limited by the workstation resources) and animation.

Currently three different flavors of McIDAS are supported by SSEC. They are McIDAS-MVS that runs under on mainframe computers capable of running the MVS operating system (i.e. IBM or compatibles), McIDAS-OS2 for IBM compatible personal computers capable of running the OS/2 operating system, and IBM-X for UNIX workstations that support the X-windows environment. The MVS environment also typically includes satellite data ingestors for earth satellite data and a variety of inputs through other communication networks to ingest other types of data such as weather forecast model outputs, conventional surface and upper air station data, surface radar data, lightning data etc. These ingestion capabilities are of course not required for analysis of planetary data. The other hardware element of McIDAS-MVS and McIDAS-OS2 versions is a SSEC designed workstation called the "Wide Word Workstation" (WWW). This workstation is controlled by an IBM PS/2 personal computer and is capable of storing displaying up to 1500 image/graphic frames in its video memory allowing animation at video refresh rates. The interface to this workstation does not yet exist for the RISC-6000 series computers although it is technically possible.

For reasons of technology and price vs. performance, the UNIX workstations from different vendors such as Silicon Graphics, IBM (RISC-6000 series), Sun Microsystems and Hewlett Packard, McIDAS software has been ported to the X-Window environment which is supported by these workstations. At the moment all of the new planetary code has been developed for the McIDAS-X environment, however, it can be easily ported to the OS2 environment.

Finally, a general observation about McIDAS is in order. By comparison with many of the commercial applications, particularly in the McIntosh and Windows 3.1 domains, the user interface used by McIDAS may seem dated. The primary reason why the interace has not yet changed is that McIDAS is used at many operational meteorological facilities throughout the world as well as colleges and univeristies in the US. The hardware environment McIDAS is used under ranges from IBM compatible personal computers based on Intel 80386 (or later processors), UNIX workstations and mainframe computers running MVS operating system (with SSEC designed and built workstations). The existence of a diverse user community implies user support and performance across platforms. As the port to the X-environment matures the interface will be eventually modernized as more and more users move to the X-Windows environment.

1.3 What is McIDAS-eXplorer?

McIDAS-eXplorer is a software enhancement package for McIDAS (currently only for the X-version). This is intended to provide support for analysis of planetary data acquired by NASA's numerous solar system missions. As the missions to different planets have different instrument systems, the planetary data spans a large range in terms of data quantity, type and global coverage. It is neither possible nor desirable to provide support for all types of data. The strength of McIDAS is in its ability to interact with satellite data for geophysical applications such as multispectral imagery, surface network data and atmospheric soundings. To that extent the enhancements described here provide support for planetary image data from missions such as Mariners, Vikings, Pioneer, Voyagers and Magellan as well as from Hubble

Space Telescope. In addition, other planetary data such as Magellan altimetry data, Pioneer and Mariner 9 Mars occultation profiles, Voyager IRIS can also be accessed and processed.

The tools developed to ingest the different data into McIDAS and specific planetary applications are described herein. Thus the user also needs access to the McIDAS-X User handbook to be able to utilize the standard McIDAS capabilities.

In the past the different missions usually provided the data in the form of Experiment Data Record (EDR) tapes. Supplementary navigation data required to analyze these data were provided as Supplementary Experiment Data Record (SEDR) tapes. The process of using these data for analysis required custom software for each mission and each instrument. Fortunately the situation is much improved now with the advent of the CD-ROMS. Much of the planetary data is now being made available through the Planetary Data System on CD-ROMS which allows at least some commonality to accessing these data. However, the SEDR data such as trajectory, pointing etc. are not yet available for all the CD-ROMS although limited data are available as SPICE kernels.

There are many capable software products available which unfortunately can be used only with specific data, particularly terrestrail data. With many successful missions to the solar system targets we now have an immense amount data collected at numerous objects that are as diverse as the airless moon or Mercury to rings of Neptune as well as comets and asteroids. The only thing common about these objects is that they have vastly different physical properties besides the fact that the opportunities to collect data on these targets from space probes are limited. One of the goals of has been to provide a unified approach to the analysis of the target dependent data by accounting for the differnces in their physical characteristics such as size, shape, etc. To this end, the Navigation Ancillary Information Facility's (NAIF, at JPL) approach of assiging a unique identification tag to each object (and spacecraft for that matter) is adopted within McIDAS-eXplorer with some enhancements.

Although McIDAS-eXplorer is general enough to be utilized for most types of data, its strength is in analysis of multispectral images or data that can be visualized as a two dimensional image. McIDAS-eXplorer also has tools for analysis of atmospheric data such as temperature profiles which although are one-dimensional individually, are typically available globally for planets such as Mars, Venus. The Infrared Radiometer Interferometer Spectrometer (IRIS) instrument on Voyager 1 and 2 provides spectra for the giant planets from which temperature profiles have been derived.

Object Identification

The (NAIF) software developed at JPL uses an identification number for each solar system object for ephemeris purposes. This same number is used within McIDAS-eXplorer but with a small modification. This identification process serves another purpose besides naming the object in the image-- it is used to retrieve the object's physical constants (radii, length of day etc.). In most cases the planetary data refers to a single target object such as a planet or its satellite or ring system. Occasionally however there can be multiple objects in a single frame such as the images of a planet and its ring system or a satellite in the same frame. In such cases the decision on which NAIF identification number to use within McIDAS-eXplorer is made on the basis of which single object is being analyzed in that frame.

Another complication arises in investigating images of bodies with extended atmospheres such as Venus or Titan. The visible or infrared images of these planets do not "see" the surface but only the cloud-top level, which is about 65-70 km above the surface for Venus and nearly 300 km for Titan. Thus the effective radius for such objects needs to be different for the purpose of not only image navigation (the process of relating the image co-ordinates to the planet's co-ordinates and vice-versa), but also for measuring distances etc. For this reason McIDAS-eXplorer distinguishes between the solid surface and the cloud level. Further, this level can be different at different imaging wavelengths such as for Saturn, therefor allowance is made for having as many as 9 separate radii for different levels for objects with atmospheres. The NAIF identification code for an object is entered as a four-digit number rather than as a three digit number. with the rightmost digit denoting the level for which the radius is defined. Thus, for Venus, the NAIFID value of 299 is modified to 2990 for the solid surface, and 2991 for the cloud level at the first wavelength, 2992 at the second wavelength etc. The pnemonic identification is also suitably modified as appropriate, for example, to Venus_sfc or Venus_atm.

Object specific physical constants are required for analysis are obtained through a single subroutine BODCON. This subroutine contains the most-recent published values of the triaxial radii and the length of the day for solar system objects. If any of the data need to be updated, then this subroutine needs to be recompiled after the required changes, and all of the planetary code needs to be relinked as well. This is done as a matter of precaution to ensure that the fundamental constants are not changed inadvertently (as is possible if the constants were loaded from a data file-- there is no simple accountability if the file gets modified).

1.4 McIDAS-eXplorer Workstations

The foremost requirement for McIDAS-eXplorer is to have convenient acces to the current and future planetary datasets. Data from missions such as Voyager (giant planets), Viking (Mars) , Galileo (Earth and Venus) and Magellan (SAR imagery of Venus and surface altimetry, reflectivity, emissivity) data are available on CD-ROM's through the Planetary Data System. The workstations required to use McIDAS-eXplorer are the ones that can run McIDAS-X with the exception that a CD-ROM reader needs to be available either locally or over a Local Area Network (LAN). A typical configuration is a UNIX based workstation (SUN, SGI, IBM/RISC-6000, HP) with 32 mb or more memory, 1 Gb or larger capacity disk, and a DAT or an Exabyte tape drive in addition to the CD-ROM reader. A color display, preferably with 24-bit display capability is desired but 8-bit display support is adequate for many applications. Similarly, a CD changer such as the Pioneer DRM-604X can also be useful to provide access to as many as 6 CD's simultaneously (not synchronously of course), but not necessary, and of course can be expnaded through the SCSI interface to handle as many as 48 CD's on-line, up to 8 of the minichangers (daisy-chained to the SCSI port) simultaneosuly.

1.5 McIDAS-X User Environment

McIDAS-eXplorer is a set of specific commands or applications programs that can be run under McIDAS-X and familiarity with McIDAS-X workstation environment is useful. McIDAS-X capabilities, installation notes can be found in the Users Guide available from SSEC. For novice users a brief introduction to the McIDAS concepts is given here.

Starting and ending a McIDAS session

At the console login, enter the user ID and the password to log onto the workstation. The user ID and the password are created by the system administrator. At the system prompt type McIDAS to start a McIDAS session. To close a McIDAS session, i.e. to log off, press CTRL-ALT Backspace keys on the keyboard by pressing and holding down the CTRL and ALT keys simultaneously and then pressing the Backspace key. Follow with CTRL-D key sequence to finish the log off procedure.

If the X-server is not running, start it with xinit. To start McIDAS, simply enter at the prompt:

```
mcidas
```

from your home directory. This initiates execution of the mcidas profile file which sets the display environment flags such as # of bits displayed, number of frames created at start-up, size of the display frames etc. The contents of the profile are described in the McIDAS-X User's Guide. Note that it is when starting a McIDAS session that the frame size and the number of gray levels displayed gets set (leave it at 128 unless the workstation has more than a sinlge 8-bit diaplay plane).

Note that the frame size defined here is the McIDAS display frame size. The X-window within which this display appears is initially set to this size and should normally not be changed. Once the McIDAS session has started, expanding or shrinking the display window (or the "image" window for McIDAS) has no real effect on the amount of data displayed by McIDAS in that window. Thus the frame size should be set to the largest size of the image that needs to be seen at the full resolution since by integer sub-sampling larger images can be seen in a small display frame.

McIDAS-X creates several "windows" when a session is started, typically, four. One of these is a "command" window which also includes a status line (Figure 1) and is the primary user interface to McIDAS. There are two text windows ("1" and "2") which are made active by clicking in the particular window or from the numeric-keypad by pressing "1" or "2" key. These two text windows contain output from McIDAS commands. The fourth window is the image display which is sized according to the frame size specified in the start-up procedure.

McIDAS Display

Since the prime motive behind McIDAS is the analysis of data acquired in the temporal domain, animation is a key feature, and thus McIDAS uses multiframe display capability. The image data are displayed on a "frame" which can contain either image or graphic data. The frames can be any size as desired and each one can be of a different size. If the frame size is larger than the screen size then the screen provides a scrollable window into the displayed frame and can be moved with the mouse. Frames can also be dynamically added to a session (as allowed by available system memory), but at the moment they cannot be unloaded to free up memory without exiting a McIDAS session. On UNIX workstations the number of frames to configur and their sizes are specified by the user (in the profile) as constrained primarily by the amount of random access memory (RAM) available in the workstation.

The user controllable frame size is useful to optimize the number of display frames for the specific data being analyzed in that session. Even if animation may not be a desire, a large number of frames are still immensely useful in streamlining an analyis session by eliminating the need to erase and re-draw graphics as well as by keeping them around for reference. The planetary image data available on PDS CD-ROMs range in size from 800 x 800 for Voyager and Galileo to 1024 x 1024 or larger for Magellan products, a considerable difference in frame size and memory requirements.

The display frame contains much more information than just the visible image in McIDAS environment. For each frame that contains an image, McIDAS keeps track of the image source, its calibration, and, most important, the navigation. Overlay graphics can be drawn which can also be dynamically saved in separate graphics files for re-display later. This is particularly useful in the X-environment wherein "peelable" graphics are not yet possible or implemented on most workstations. Thus, if any changes are required in the graphic frame, the entire contents have to be erased and re-displayed.

McIDASese - Not quite a language but a syntax of its own

At its core, McIDAS and McIDAS-eXplorer are command driven and not menu-driven. A certain familiarity with the command syntax is thus necessary. In future versions the emphasis on command language is hoped to be minimized through the use of windowed choices. Until then the grammar needs to be understood.

Typically a process can be performed with a command entered in the command window from the workstation key-board. A command may or may not have any arguments, have positional parameters or keywords or both. The positional parameters are generally restricted to certain "obvious" situations (but that is peculiar to the programmer!) while keywords are used to specify other specific inputs. Such keywords are used by typing the keyword exactly (ALWAYS in upper case) followed by a comma or the equality sign ("=") followed by the value. A keyword may accept as few as one or as many as 32 values entered consecutively on the command line. The McIDAS-eXplorer commands are expected to check the specified keywords for validity, if any are misspelled or extraneous to the command, an error message is printed out and the process is not executed. The keywords come in two varieties- global and command specific. The "global" keywords are generally recognized system-wide, and share some commonality in use. Examples are DAY= and TIME= or DEV*ice*=. Generally the global keywords require only the first three characters, but command specific keywords may check the entire keyword.

> Caution: In McIDAS-X the commands name can be entered in lower case (although not recommended) but all keywords **must** be entered in UPPER CASE!

The positional parameter is most often used to indicate to an applications program the *area#* containg an image of interest. Often it is desired to modify one image by some process and retain the original as well. The syntax most often used (and almost invariably in McIDASese) is to specify in input area# first and the output area# second. For example a command with a syntax given as:

REMAP *from_area to_area* and entered as
REMAP 101 102

will remap the image contained in the file specified by the positional parameter *from_area* (area# 101 in this example) and write the output in the file specified by the second positional parameter *to_area* (area# 102) using the navigation transforms defined for the two areas. The actual file names for the two areas are AREA0101 and AREA0102, but the user seldom needs to worry about the exact names except for system administration purposes.

A simpler example of the positional parameter is when only a single parameter is required, such as in the LA command to list the directory for a given area (so one can find out what the contents are!):

LA 101

which produes a single line of output in the text window like:

If this is not sufficient, one can make use of the keywords for this command to produce additional output by keying in:

LA 101 FORM=AUDIT

which queries the area to produce the audit trail for the image contained in the Area 101 and the output may look like:

```
area  ss  yyddd hhmmss  lcor  ecor lr er zr  lsiz  esiz z    bands
---- ---- ----- ------ ----- ----- -- -- -- ----- ----- -    -----
 101  48  89214  83159     1     1  1  1  1   800   800 1 1...............
   proj:     0 created: 93048 191147  memo: ---CDROM DECOMPRESS---
   type:VISR      cal type:BRIT
   area offsets:  data= 9040 navigation=  256 calibration= 2816
   doc length:  36   cal length:   0   lev length:   0 PREFIX=  36
   valcod:             0 zcor:  1 band-8: NA  reel#:*****
 -Audit Trail
   yyddd hhmmss
   ----- ------
    PICNO= 0338N2-023                                    TARGET= NEPTUNE
    FDS=  10706.02      CAMERA= NARROW ANGLE             SPACECRAFT= VOYAGER
    SHUTTER TIME=  89214   83159          NAONLY
    FILTER= GREEN  (5)   EXP=  15.3600SEC.               GAIN=  LOW
    LINES= 800    ELEMENTS= 800                          SCAN=  5:1     EDIT=

   VCDROM: Internal Parameters and Defaults:
    SOURCE        =  /cdrom/neptune/c1070xxx/c1070602.imq
    FDS-START     =  1070600
    FDS-END       =  1070700
    TARGET        =  neptune
    CAMERA        =
    FILTER        =
    SEARCH_INDEX=  0
    OUTPUT_AREA =  101
   93048 191155 VCDROM FDS= 10706.00 10707.00 AREA= 101 TARGET= NEPTUNE
   93119 175624 RF 101
   93119 175657 FILLO 101
   93119 175727 RF 101
   93119 175813 SEDRIN 101
```

Some commands which require no arguments at all. One example is **EXIT** which shuts down an active McIDAS session and closes all active McIDAS windows. Then there are some single-letter commands which can be alternately entered using the ALT-key simultaneously with another key. These commands do not require a [CR] if entered using the ALT key, and generally control the display state. Examples are the 'A' and 'B' key commands which respectively advance or back-up the display to the next frame in the sequence.

McIDAS also makes use of user defined string tables to facilitate simpler input to application programs as well as argument passing between different application programs. These string tables are created by a simple string editor and stored in the user profile and can be saved and deleted. Multiple versions can be stored under different names for different applications and can be shared with other users Besides the single command execution or action of application tools, McIDAS applications can be executed in a sequence for repetitive tasks in one of two distinct ways. One of them is as a macro command that is precompiled. A McIDAS macro program accepts as input standard FORTRAN statements with some exceptions and can call other McIDAS applications. Once compiled, the application executes the sequence described within the macro.

The second way of simplifying repetitive tasks is to use the REPEAT command, which executes a command string a given number of times with any number of numeric arguments. For example:

TE "MAPIT !1 !2 MERGE=YES; DF !2 1

REPEAT MAPIT 100 TO 200 BY 1 300

will map images contained in areas 100 to 200 and map into into a given projection and merge the output into a single output area (# 300) and display the result after the addition of each image on frame 2. This sequence is useful for making mosaics from Magellan framelets or tiles.

Hardcopy Text or Image output

There are several ways of obtaining hardcopy text and image (gray-scale or color) output from McIDAS-X. The simplest means of otaining a print copy of the McIDAS comannd output is to use the redirect capability offered by the DEV keyword. The output can be directed either directly to the workstation printer, or to a file, simply by appending any command by **DEV = P**, or **DEV = F** *filename* respectively. The text file can then be printed from the X-window by any of the methods. Note that this file is an LW file (which really means that it lacks the carriage-return LineFeed sequence) and must be converted to a DOS or a text file by using **DOSTOLW** command and then sent to the printer. One possible is to use *enscript*:

(In the McIDAS Command Window):

DOSTOLW *filename text_file*
OS *"enscript -2rG filename*

which will print the file as facing pages in the landscape format.

If a complete log of the McIDAS worksession is desired, user key-ins and the McIDAS output can be also be copied to a log file using the **TFILE** command to open and close the log files at appropriate times as desired:

TFILE OPEN *filename*

.

.

.

TFILE CLOSE

The file can then be printed as before from the X-window using the operating system commands.

A third means is to use a screen capture device to print out the screen display which may or may not include gray-scale or color images using such as a TOYO printer which is connected to the display device of the workstation.

Finally, the image dispalayed on a McIDAS frame can be printed by saving it as a .GIF format file using the **SVGIF** command. The .GIF file can then be saved as a PostScript file using the **XV** utility from a X-Window session, either as a color image or as a black and white image. The PostScript file containing the image can then be sent to the system laser printer to get either a black and white gray-tone image, or to a color printer such as the Tektronix to obtain a color print:

lpr -Prgb *filename*

The .GIF file can also be exported to other systems such as high resolution cameras or image editing programs to add annotation, change color balance etc.

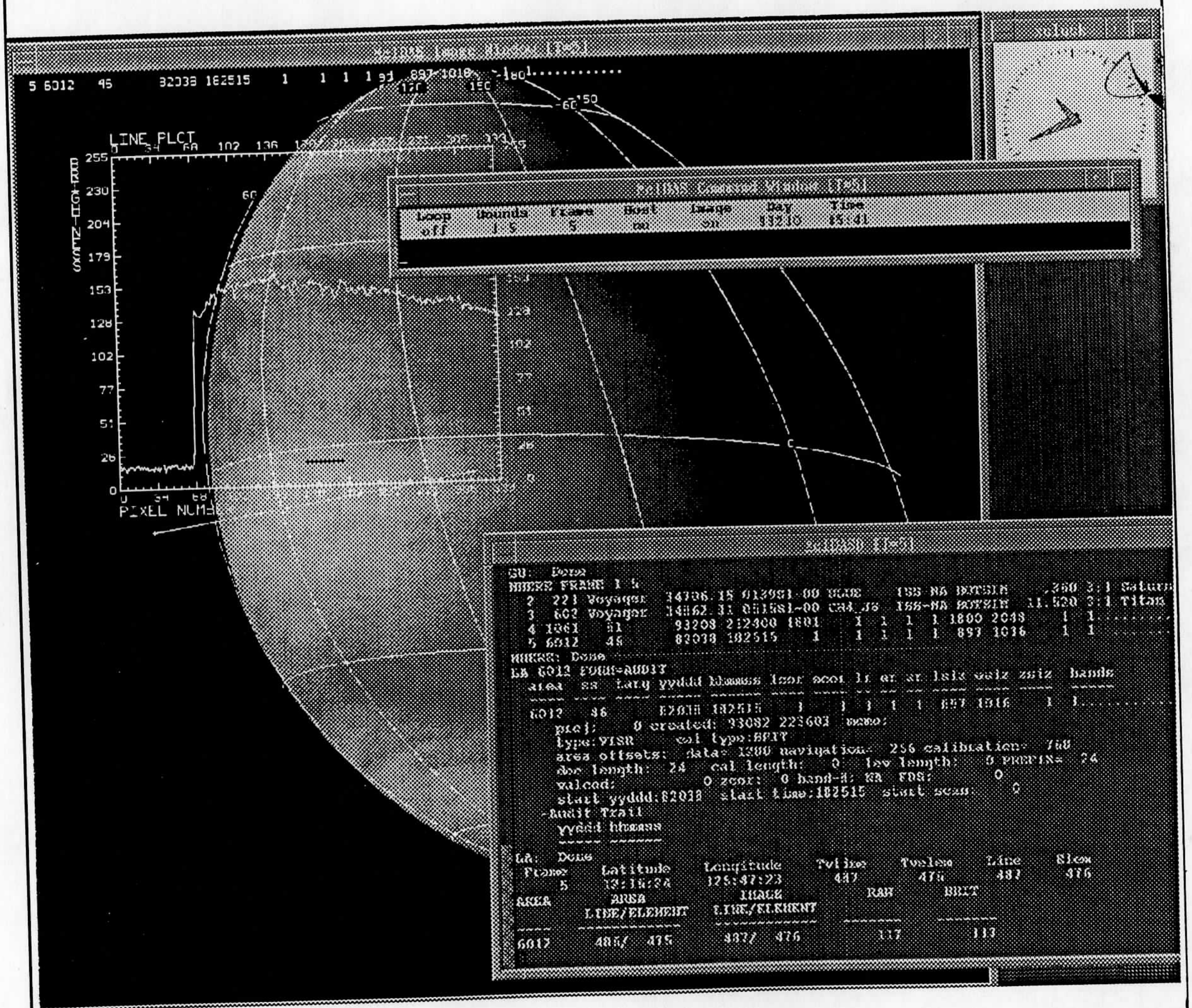


Figure 1. A view of the McIDAS-X screen

Frequently an X-window is also required for direct interface to the operating system, although most commands can also be sent to the operating system from the McIDAS command window through the OS command followed by a string (i.e. preceded by the double quote symbol, ") containing the operating system command syntax. Exceptions are commands that require authentication, as the "su" command.

OS "pwd *(queries the system for the current directory).*

The output is directed to the current McIDAS text window:

```
/u1/mcidas/data
```

McIDAS-eXplorer adheres to the general McIDAS-X conventions for the file system. Thus the data ingested normally resides in the /mcidas/data directory and the source is in /mcidas/src directory, etc. Specific formats for storing and accessing the data are specified under McIDAS-X such as image data (two or three dimensional), gridded data (two dimensional gridded data sets e.g. output of numerical models) which is usually much more granular than the image data, and other single dimension data types such as time series, etc. The exact implementation of the different formats are dependent on the native operating system, but McIDAS-X provides a transparent and a common interface between the applications software and the native operating system. The basic file system is called the Large Word array or LW format. Both the digital image data and the grid-data formats are based on the LW file system. For both the gridded and the image data sets a directory service is provided to query the contents of the file. McIDAS-eXplorer uses certain extensions for planetary applications which are compatible with McIDAS-X.

System Status

As McIDAS-X is a multitasking environment, several one application programs can be executed simultaneously. The respective output can be directed to separate text windows or files. Some of the applications, such as multispectral classification of large images require significant processing time even on fastest workstations. It is useful in such instances to determine the active applications. A command provides a current snapshot of the processing load at any instance, and an abort mechanism also exists to abort a user process from within McIDAS-X.

Scheduler

McIDAS-X has a scheduler capability to execute a sequence of commands at a predetermined time in the future. Although this is most useful in real-time environments for acquisition of data, the facility is useful to schedule processing resources intensive tasks at times when the workstation may be otherwise idle or less stressed.

Batch mode operation

A facility to execute commands from a file allows systematic, repetitive processing of data effortlessly. Any McIDAS command can be entered in a text file just as it would be entered from the key-board. The file can be executed using the scheduler capability.

2.0 IMPORTING DATA into McIDAS-eXplorer

Most of the planetary data analysis takes place from "archived" data as opposed to "real time" data which is more typical with earth meteorological satellite environments. The most common format now for the archived planetary data is the CD-ROM. Appendix I contains a list of the data available through PDS in this format. One noteable exception is the HST WF/PC data which is available only on 9-track or Exabyte tapes.

There is another format of data input/output from Digital Audio Tape (DAT) cartridges available from within McIDAS-X. If a DAT drive is available on the system, then McIDAS areas can be saved as individual files on these cartridges and restored later. This is a fairly attractive method for short/long term archiving of processed data as these cartridges can hold up-to 8 Gbytes (compressed) of data. Thus as the McIDAS work-space gets full, the image areas can be stored and restored as desired.

McIDAS-X stores image data in files called "areas" all of which have names of the form "AREAxxxx" where xxxx is a four-digit number. Each "area" contains one single image which can be multibanded. As many as 9999 areas can be accessed by McIDAS from the "/u1/mcidas/data" sub-directory. This sub-directory can be thought of as workspace for McIDAS-X, and needs to be large enough to accept the data to be accessed as well as for any output created, and typically this is the largest directory.

2.1 Reading data from CD-ROM's: Mounting and Unmounting CD's

Most versions of UNIX require that a CD-volume be mounted before it is recognized by the system, and McIDAS-X is no exception. Here is how to mount and unmount the CD's:

changecd

(physically remove the CD-ROM in the drive if there is any) and insert a new CD into the CD-ROM reader, and then click with the left mouse button in the active text window to finish the mount process. The CD-drive light should go on to read the directory which indicates that the command has taken effect

At this point the data from the particular CD inserted into the reader is accessible from within McIDAS-eXplorer though specific commands.

2.2 McIDAS-eXplorer Commands

A variety of tools are available to manipulate the data within McIDAS-eXplorer. For solar system image data these include geometric and radiometric calibration, filters of various types, navigation and cartographic projections, image enhancement, multispectral classification, time series analysis, area and distance measurements, cross-sections etc. Map outlines and gazetteer files provide ability to visually identify the geographic features. General purpose utility applications provide housekeeping functions and for data migration.

Two dimensional irregularly spaced data can be objectively analyzed onto grids and gridded data themselves can be graphically displayed via contour plots and cross-section plots as well as rendered into images. A basic spread sheet capability allows arithmetic operations on the gridded data to compute other derived quantities.

Spectral data can be displayed, averaged and staged for further processing as desired for temperature retrievals or other analysis.

McIDAS-eXplorer Tools

When fully developed, McIDAS-eXplorer will have tools to import, process and analyze planetary images from PDS CD-ROM volumes. Curently Voyager images of the giant planets and their satellites and ring systems, Magellan SAR images of Venus surface, Pioneer Venus Orbiter Cloud Photopolarimeter images of Venus clouds can be calibrated (shading and geometry) and navigated. Support for other data products such as Galileo SSI images and hopefully Mars Observer will be added in the near future. Once these data are imported within McIDAS-eXplorer, they can be gridded, map projected, animated, brightness normalized and filtered. Three color composites and multispectral classification of up to six bands are possible. Calibrated and navigated image data can be used for for areal, cloud motion and other measurements using general tools.

Although many of these commands are quite general in that they can be used for data from any solar system object or spacecraft mission, some of them are very specific to a particular mission and data. For example, there are a set of specific commands that are limited to data from Voyager 1 and 2 missions to perform tasks related to the analysis of the images which have very specific properties requiring specific processing. Similarly the Magellan SAR and topography data have a set of commands that are not useful to any other data. Such mission specific commands are to be described in Section 3.

The commands available currently are described in Section 4 in detail. A brief summary of what these commands do is given below.

ASTAT - Measure image statistics from a displayed image e.g. histograms, outlines, etc.

BOTSIM - Navigate simultaneous Wide-Angle/Narrow-Angle Voyager Image pair with one of them navigated.

CALCMA - Calculates Transform Matrix for Planetary Navigation for framing camera image navigation. Currently it is set up for Voyager images only.

CHANGECD - Unload/load or load/unload CD-ROM in the CD-ROM drive from within McIDAS. **The disk of course has to be manually removed and replaced!**

CONFIT - Fit a general conic to a set of points stored in a limb points file created using the key-in **LIMBPT**. Primarily useful for planet center determination if the pointing data is accessible. Constrained fits are also used if the planet orientation and size are known.

COMBIN - Make a multiband area from several single band area. May also be used to reduce 2-byte data to 1-byte data using the calibration constants in the area directory. Useful for multispectral classification, remapping of multi-filter images such as Voyager or Viking.

DSTNCE - Measure distances on any navigated solar system image either between a pair of points or along a trajectory to determine the cumulative distance and segment lengths.

EDGES - Determine the location of the bright limb of a planetary image using the maximum local brightness gradient method and write the locations in a file (LIMBxxxx, where xxxx is the four digit area number. Usually a first step in image navigation (see **IMGCTR** and **PLANAV**).

ELLIPS - Draw signature ellipses from a USCLAS spectral classification to see the spectral class distribution.

EXPDOC - List the User guide and command help documentation in an X-Window that can be scanned using vi editor commands.

FILLO - Fill in the alternate line data compression gaps in Voyager 2 images of Uranus and Neptune by interpolation across lines for each missing element.

FINDALT - Determine on which PDS CD-ROM volume Magellan Altimeter data from a particular orbit can be found. *As yet there is no command to determine the orbit number corresponding to a given Venus location.*

FINDFF - Locate Magellan MIDR framelets containing a given geographic feature or a latitude-longitude region

FINDVGR - Search the CD-ROM index file(s) for a Voyager image to determine which CD-ROM & sub-directory it resides on. The index is in /mcidas/data/ sub-directory.

FILLO - Interpolate zeroes in scan lines due to data compression in Voyager Uranus/Neptune images which are compressed using the alternate side compression scheme, by interpolation across lines.

GETCPP - Import Pioneer Venus Orbiter Cloud Photopolarimeter (OCPP) images from NSSDC tape archive files into McIDAS areas.

GETFITS - Import an image stored in a FITS format file into a McIDAS area. Useful for importing earth-based telescopic images of solar system targets.

GETMAG - Import a Magellan Mosaic Image Data Record (MIDR) image from CD-ROM into a McIDAS area.

GETVGR - Import compressed Voyager 1 or 2 images from CD-ROM and write a McIDAS area containing that image.

GETVO - Import Viking Orbiter 1 & 2 Mars images from CD-ROM into McIDAS areas.

HSTTOMC - Import Hubble Space Telescope WF/PC image from a FITS format tape-file into a McIDAS area.

HSTKNIT - Combine the 4 panels (800 x 800) of a HST WF/PC image into a single one (1600 x 1600) using specified co-ordinates.

IMGCTR - Determine the center of a planetary image for which limb points have been written to a file (LIMBxxxx, where xxxx is the area #) using the EDGES command (or any other process if the file conforms to the format) by using a geneal conic fit. The image center, the two axes, the orientation of the ellipse and the eccentricity of the ellipse are returned. These values can be used in the PLANAV key-in to attach navigation to an image (e.g. ground based for which SPICE kernels may not be available) if applicable.

IMGTS - compile or display a file containing a time series of data from digital areas

LIMBPTS - Locate the planet's bright limb interactively using directional derivatives from displayed image and store the points in a file. Primarily useful for planet center determination (CONFIT) for the purpose of image navigation.

LIMBSCAN - Plot radial scans of data from a planetary images from the planet center to the planet limb

LP - Line-plot of Image Data at Cursor Location or between any two points on a displayed image.

LISCOM - Lists contents of PLAN navigation common from navigation blocks. Useful for debugging navigation programs.

LISTAUD - List audit trail for a McIDAS area.

LISTDDB - List the various Data Description Blocks (DDB) such as planetary SPICE navigation block, etc. for an area.

LOCATE - Plot as an overlay graphic on a navigated image display the co-ordinates of points from a text file.

MAPDEF - Version of MAKNAV that is linked to planetary navigation.

MRACD - Read Magellan Radar Altimeter CD-ROM (ARCDR's) Altimetry Data Files (ADF's) and plot the data (along the orbit track) on a displayed Magellan SAR image.

MCLIMB - Simulate view from orbit of a planet from a nadir looking instrument and plot instrument IFOV's.

MDCLAS - Spectrally classify a multi-band image
- MDM CLASSIFICATION USING .SIG STATISTICS ---

MINFIT - Determine Minnaert scattering Coefficients (I_O and β) for a navigated planetary image ($I = I_O \mu\mu^{\beta}$) by both least squares and minimum absolute deviation methods.

NAVCHG - Poke parameters manually into the PLAN navigation block. Mostly used for de-bugging navigation code.

PAA - Export a McIDAS area without the extended Data Directory Block (DDB) into another area with the DDB. Used with "old" areas or those imported from the mainframe. AA now serves the same capability, PAA has fewer features.

PCROP - Trim the spline-sized rectangular edges at the limb of a remapped planetary image.

PHYSCON - Program to obtain the Physical constants of an object. Either the NAIF ID (preferred) or its name (capitalized) can be entered. Radii and length-of-day are currently listed.

PLAEDG - Determine a limited number of limb points for a planetary image for the purpose of navigation.

PLANAV - Create a general perspective view navigation codicil for a given area for any object.

PLAREV - Flip the longitude convention for the navigation created using PLANAV. *This is required for earth views because of the McIDAS longitude system convention which is opposite to the general planetary longitude convention.*

POLEN - Refine the C-matrix for a Voyager image by using a known star which can be located in the image. Will also optionally determine the pole position for Neptune.

REDISP - Re-display a displayed frame from the original given area at the cursor co-ordinates on the same or another frame using an integer blow-up or blow-down factor. Similar to BU on the McIDAS-MVS system.

RESEAU - Lists and/or plots reseau data for Voyager spacecraft

RESREM - Remove the reseau marks in Voyager images by interpolation of brightness from their immediate neighbourhood.

RF - Determine the locations of the reseaus in a Voyager image which may or may not be displayed

SEDRIN - Reformat SEDR data into navigation block for raw image

SEDRRD - Load Voyager SEDR tape file records into LW file

SPICEIN - Reformat SPICE data into navigation block for planetary image)

STRIPX - Strip or fuse an area into or from the DDB and image data component files (DIRCxxxx and IMAGxxxx, where xxxx is the original 4-digit area number. Currently used for data compression experiments.

TGET - Restore one or more McIDAS area files from tape to disk (i.e. in /mcidas/data sub-directory) from a DAT or an Exabyte cartridge written using **TPUT**.

TILES - Displays the framelets or tiles that make up a Magellan browse image created from C1-MIDR's as a grid pattern and numbers the tiles. Normally started by MCDROM during retrieval of browse and full resolution images. Will scale the displayed image to the frame size by integer sampling appropriately.

TLST - Lists areas on a tape written by TPUT. SCSI tape drives only (either DAT or EXABYTE). Use TGET to restore data from tape to disk in the /u1/mcidas/data sub-directory.

TPUT - Save one or more McIDAS area files from disk to tape (i.e. in /mcidas/data sub-directory).

USCLAS - Spectrally classify a multi-banded image using unsupervised multispectral classification. Currently assumes 1-byte per spectral band data. 2-byte data can be used after using COMBIN to use the calibration to convert to 1-byte data.

VENUSF - LISTS & PLOTS Planetary Feature names on displayed images.

WHERE - List frame and area contents in the text screen using data specific information.

2.3 McIDAS-eXplorer Files

A number of data files are required by some of the commands that form McIDAS-eXplorer in addition to those files required by the core McIDAS. These files exist in /mcidas/data sub-directory. McIDAS generally uses standard prefixes (always UPPER CASE!) for its standard data files. The convention is as follows:

Digital images	AREAxxxx
Gridded data files	GRIDxxxx
Random ordered data	MDxxxxxx

In addition, McIDAS-eXplorer uses similar convention for the files used in some solar system applications programs. They are:

LIMBxxxx	Image edge points
xxxx.ET	Enhancement tables created by USCLAS
xxxx.LOG	A log file of the USCLAS multispectral classification program

There are many data files associated with specific missions and instruments that are useful in more efficient operation of McIDAS-eXplorer commands. These are also in /mcidas/data sub-directory. Their names and brief description are given below.

file_name	*Remarks*
gazetter.tab	Gazetteer table for Mars from the USGS Digital Image Map CD-ROM Volumes.
geo.tab	An ASCII file containing the names of the geographic features on Venus. This file is found on all PDS Magellan CD's through Volume MG0067.
ibmints	NGDC global topography and bathymetry file with 10 minute resolution.
jupitertapes	A catalog of Voyager 1 and 2 Jupiter EDR tape cartridges. Each cartridge contains 240 images (10 1600-bpi original EDR tapes).
mcumdir.tab	Magellan Mission cumulative directory for the MIDR data (PDS CD-ROM Volumes MG0001 through MG0067). This is the version from MG0067 CD.
neptapes	A catalog of Voyager 2 Neptune EDR tape cartridges. Each cartridge contains 240 images (10 1600-bpi original EDR tapes).
orbele.pvo	Pioneer Venus Orbiter orbital elements file (text).

pck00003.tpc The NAIF kernel file containing the planetary physical constants and other data used by NAIF software. Other NAIF data files are also copied into this directory.

pvocpp.img Catalog of Pioneer Venus Orbiter Cloud Photopolarimeter images (text).

RESEAUS This is a binary file containing nominal reseau locations for Voyager 1 and 2 NA and WA cameras. The strucutre of this file is described elsewhere. Used by **RF** and **RESEAU** commands.

uranustapes A catalog of Voyager 2 Uranus EDR tape cartridges. Each cartridge contains 240 images (10 1600-bpi original EDR tapes).

(This list is incomplete)

2.4 Planetary Data supported under McIDAS-eXplorer

The following data are planned to be fully supported for analyis in terms of navigation and data calibration. In addition to the following, earth based telescopic images of solar system targets can also be readily imported and analyzed using McIDAS-eXplorer if the data are available in a standard format such as FITS or TIFF.

Earth

Data from all US civilian meterological satelllites as well as METEOSAT and GMS (European and Japanese geosynchronous satellites).

Venus

Magellan Mosaicked Image Data (C- and F-MIDR's) on PDS CDs MIDRCD.01 - MIDRCD.67 and Altitude and Radiometry Data CDs on Volumes ARCDRCD.001 through ARCDRCD.015.

Pioneer Venus Orbiter Cloud Photopolarimeter (OCPP) images

Mars

Mapped Image Data Products: MDIMS volume 1-6
Viking Orbiter Images: PDS Volumes VO_1001 through VO_1006.

Jupiter and Satellites

Voyager 1 and 2 images on EDR tapes and PDS CD-ROM Volumes 6-8. Hubble Space Telescope images of Jupiter.

Saturn and Satellites

Voyager 1 and 2 images on EDR tapes and PDS CD-ROM Volumes 4-5. Hubble Space Telescope images of Saturn

Uranus and Satellites

Voyager 2 images on EDR tapes and PDS CD-ROM Volumes 1-3.

Neptune, Rings and Satellites

Voyager 2 images on EDR tapes and PDS CD-ROM Volumes 9-12.

2.5 McIDAS-eXplorer Data Structures

Although the CD's offer a convenient means of archival of image data, the speed of access is less than desirable. For this reason and for reasons of compatibility with the McIDAS environment as well as efficiency, the image data is imported into the McIDAS environment as files. At the same time a Data Description Block is created that provides a roadmap to the navigation, calibration information for the image data. While there is some commonality between various formats, mission and science instrumentation differences result in mission specific variations. These are accomodated by classifying the DDB's into specific models such as one for framing cameras, one for spin scan imagery, one for nadir pointing scanning instruments etc. The Magellan SAR and altimetry data are exceptions in that the image products are available only as mapped productes (various compressions achieved through sampling) while the latter is mostly available along orbit tracks.

The datafile structure is described in detail in Appendix I for the different models used.

3. VOYAGER DATA ON GIANT PLANETS AND THEIR SATELLITES

The two Voyager spacecraft carrying seven experiments each (an imaging system consisting of a wide and a narrow angle camera (ISS), an infrared Radiometer Interferometer and Spectrometer (IRIS), a Plasma Wave Spectrometer (PWS), a Magnetometer were launched in 1978 August and 78 respectively. Voyager 1 observed the Jovian system in 1979 and the Saturn system in 1980. Voyagre 2 also observed the Jovian and Saturn systems in 1979 and 1981 and then travelled further into the outer solar system to encounter the Uranus system in 1986 and finally the Neptune system in 1989. The data from the ISS and the IRIS experiments collected in these six encounters can be analyzed with McIDAS-eXplorer tools.

The tools for IRIS data analysis are limited to the display of individual spectra, location of the data based on pointing refined by simultaneous imaging observations (IRIS and ISS fields of view are bore-sighted), and averaging. These spectra are useful for a variety of applications that are too specialized to be of much general use, but the required tools can be imported or developed within McIDAS-eXplorer environment. Examples of such applications include temperature retrievals and trace gas abundance determinations for atmospheres of Jupiter, Saturn and Titan.

3.1 VOYAGER IMAGES

The imaging system on each of the two spacecraft was nearly identical- each carried a wide and a narrow angle vidicon camera. Each camera was equipped with a filter wheel with eight filters. The filters on the two spacecraft were nearly the same with the exception of a methane band filter on the Voyager 2 wide angle camera that replaced the blue filter on the Voyager 1 filter wheel. The faceplate of each of the caemras was etched with a pattern of 202 reseaux marks that were nominally 3 x 3 pixels wide. Their positions were measured to a ± 0.001 mm accuracy on the ground. The details of the imaging system and the calibration of the data can be found in the report by Benesh and Jepson (1978). The camera characteristics are summarized in Table 1 for completeness.

Table 1

Voyager Imaging System Characteristics

Spacecraft Camera	VGR 1 Narrow Angle	VGR 1 Wide Angle	VGR 2 Narrow Angle	VGR 2 Wide Angle
Focal Length,mm	1502.38 ± 1.37	200.47 ± 0.39	1503.49 ± 0.39	200.77 ± 0.23
Frame Size	800 x 800	800 x 800	800 x 800	800 x 800
FOV*	0.44989x0.44989	3.34888x3.34986	0.45022x0.45022	3.36174x3.36745*
Pixel Size** (μrad)	9.12	68.34	9.11	68.23
Filters	6	5	6	5
	Clear	Clear	Clear	Clear
	Violet	Violet	Violet	Violet
	Blue	Blue	Blue	Blue
	Green	Green	Green	Green
	Orange	Orange	Orange	Orange
	UV	-	UV	-

*Average over the entire frame (measured from reseaus)

**Central 100 pixels only (after Danielson et al., 1981)

The vidicon images obtained from Voyager cameras suffer from geometric and radiometric distortations. Before much of the quantitative analysis can be carried out it is necessary to correct the data for these distortions. The removal of the geometric distortations requires the use of the geometric distortion indicated by the known locations of the reseaus and their image locations. The radiometric distiortion removal requires the shading files that contain tables of the vidicon response at each pixel for a given exposure.

3.2 PRE-PROCESSING OF THE VOYAGER 1 AND 2 IMAGES OF THE GIANT PLANETS AND THEIR SATELLITES

The images acquired from the Voyager vidicons suffer from two kinds of distortions: (a) photometric, and (b) geometric. The photometric distortions correspond* to the non-linear response of the brightness read-out across the image for a uniform incident illumination. This non-linearlity actually is from two distinct sources- (i) non-linear response of the vidicon itself, and (ii) the development of dark current on the vidicon as soon as the image is shuttered. The geometric distortion arises from optical distortions due to the magnetic focussing used in the vidicon system for reading out the image brightness data and results primarily in a barrel type distortion. It is possible to remove both of these distortions to a large degree as described below.

The systematic processing of Voyager images can be streamlined by using a macro command that daisy chains the steps described below as the processing steps need to be sequential. See the macro **DOVGR** for example which will begin with a either Wide or Narrow angle camera images acquired with a specific filter and will sequentially process it to fill the data compression gaps, determine reseau locations, correct for shading including dark noise subtraction using an appropriate dark noise file, perform geometric rectification, and determine a preliminary set of limb points for interactive navigation, all in a single command. Optionally, multiple images can be processed in exact same manner, sequentially.

Within McIDAS-eXplorer environment, whenever the original data are being modified in some form, the application program will always retain the original area and create a new version of the data in another area and will copy the accompanying directory and DDB information as well as make an entry in the audit trail. The original can then be deleted if no longer necessary. Thus if an error is made at any step, the process can be repeated as desired. The individual steps are described below.

3.2.1 Removal of Geometric Distortion

To account for this distortion a network of 202 3x3 reseau marks is etched on the faceplate of the each of the vidicons and their positions on the faceplate were carefully measured (to a thousandth of a mm) on the ground before launch (Benesh and Jepsen, 1977). The locations of these marks are first measured in the images (using key-in **RF**) and their ground measured locations used to compute the transformation between the observed and expected object space locations. The coordinates for other points in the image are then obtained by bi-linear interpolation. In order to minimize the effect of round off or truncation error, the output images size is set to 1000 x 1000 pixels, 25% larger than the original size in either dimension. The **GEOM** command accomplishes the latter task.

The required key-ins are as follows:

RF source_area_# — *to measure and store the image locations of the reseaux marks. The spacecraft and camera information as well as the nominal*

---

reseau locations are retrieved within the program from the area DDB.

(If the data are also to be corrected for radiometric distortion, then the command SHADE9 should be used before removing the geometric distortion.)

GEOM source_area_# output_area# SMOOTH =

This step uses the measured locations of the reseaux marks and their object space locations to remap the input image into another area that has the distortion removed. The SMOOTH=YES option smoothes the output image by performing a local average of the immediate neighbours (2/3, 1/3 weighted). Note that typically the radiometric distortion is removed BEFORE this step as the shading correction files are useable only in the original (i.e. distorted) image. Further, the averaging is speeded up through the use of a look-up table that will currently handle DN values between 0-4095 only. The output of the shading correction program is generally 2-bytes and is within this range if the data are normalized using the IOF=1 default option. If the data are radiometrically calibrated to a greater dynamic range, then the SMOOTH option should be turned off as it will not produce proper averaging. If the resultant image is visually too granular, then it can be smoothed by running a low-pass filter with a small filter radius (e.g. 2x2).

3.2.2 Removal of Photometric Distortion

Photometric correction requires removal of the dark current signal or dark noise, and correction of the non-linear response of the vidicon. Both of these are image position as well as exposure time dependent. The dark current however has another cause and that is dependent on the rate at which the image is read out by the data system- the current starts building as soon as the image is exposed and keeps on increasing until the image is read out by the vidicon electronics. Thus, the lower the data rate the longer it takes to read out an image and the greater the dark current build up.

Dark Current Removal

The dark noise begins to build up on the vidicon faceplate as soon as the exposure begins, and is thus a function of the exposure time and the image readout time. The image readout time is determined by the data transmission rate. The rates used for transmission of data during the Voyager 1 and 2 encounters with the Saturn system typically used a 3:1 scan rate. The background brightness thus increases from the top of the image to the bottom and from the left to right. As may be expected, the dark noise has a quantization noise, so that there is a slight variation from frame to frame.

Typically the dark current is subtracted during the radiometric correction step (**SHADE9** command). Occasionally the dark current subtraction alone is desirable for quick-look analysis, in which case the McIDAS **MC** command can be used to subtract the dark noise frame from the Voyager image of interest.

Shading Correction

The non-linear vidicon response to uniform incident light manifests itself in differing output brightness levels across the image. The non-linearity of the cameras was determined by measuring the output brightness level in terms of data numbers (DN's) for nine exposures for each filter, and a coefficient determined for each pixel of the image that describes the response of the vidicon for the input brightness at for a given filter at that pixel and saved as a "shading file". Thus, given an image that is exposed at an expoure within the bounds of the shading files, the expected brightness at each pixel of the image can be interpolated from the actual vidicon response and the shading coefficients.

The shading correction files are voluminous, occupying nearly 12 mbytes per filter. Their names are of type VGRnXm, where n is 1 or 2 indicating Voyager 1 or 2 spacecraft, X is the camera identifier, N for narrow angle camera and W for wide angle camera, and m denotes the filter number on that camera. These files may be compressed to only about 24% of their original size using a loss-less compression scheme.

3.2.3 Image Navigation

Image navigation is the process of relating the image co-ordinates of a feature to their planetary coordinates or vice versa. For the Voyager images this step does not have the potential to add photometric "noise" to the image. Howevever, the procedures to bring out suble image features such as color composites or image normalization requrire a precise navigation. Thus navigation can indirectly add photometric noise to the processed image if the scattering angles are imprecisely or incorrectly computed. For Titan images the potential for such errors is not insignificant in view of the difficulty of navigating the Titan images precisely.

3.2.4 Center Finding

Because Titan is completely covered with clouds and no surface features (if any) are visible through this cloud cover, the navigation process relies on the observing geometry, the camera characteristics and the physical shape of Titan. The first task is to determine the location of the center of apparent disk of Titan. This is readily done for a spherical object by determining the position of the distinct periphery of the object, the "bright limb". Since the solid surface is not being imaged, the visbile limb does not have a sharp edge characterrized by sudden change in the brightness in a scan across the disk, but a gradual one and requires the use of an edge detection technique to locate the limb. The technique usually employed is the maximum brightness gradient one which usually is assumed to reflect the location of the level where the slant optical depth equals unity.

In the case of Titan this limb is several hundred km above the solid surface (determined from radio occultation data) and is known to be aspherical. Further, the height of the detectable limb has been measured to be different at different wavelengths from both Pioneer 11 observations (Tomasko and Smith, 1982) and our analysis of Voyager images. There is also evidence that the height of the detectable limb is considerably different at low (i.e. backward scattering) and high solar phase angles (i.e. forward scattering). The radii at different wavelengths that have been found previously from low phase angle images are given in Table 2. The dependence of limb location relative to the center of Titan on phase angle and wavelength has not yet been adequately investigated or measured.

3.2.5 Use of SPICE kernels

If available, the NAIF-SPICE kernels for an image can be utilized to attach navigation transform using the SPICEIN command. Utilities to modify the C-kernels to refine the navigation have not yet been released for use.

4. VENUS DATA from MAGELLAN and PIONEER VENUS MISSIONS

The Pioneer Venus mission and Magellan mission have returned a significant amount of imagery data. The Orbiter Cloud Photopolarimeter (OCPP) instrument acquired nearly 4000 images of Venus' cloud cover over a time approximately 7 years in reflected sunlight and filtered through a narrow band 365-nm filter. It also acquired many full disk polarimetry maps at 270, 365, 550 and 935 nm over a longer duration. These data can be imported into McIDAS-eXplorer and manipulated. Magellan mission has returned radar images of the surface and high vertical resolution topography data over nadir footprints along the Magellan orbit tracks. These data can also be imported into McIDAS-eXplorer and manipulated as described below.

4.1 MAGELLAN SAR IMAGERY and ALTIMETRY DATA

Magellan data is the largest component of the PDS CD-ROM data with nearly 60 volumes of radar imagery of Venus surface and 15 volumes of nadir altimetry and radar reflectivity data on the Venus surface. These two data can be linked in a displayed frame. There is also one CD-ROM volume containing a global mosaic of the radar altimetry and radiometry data. There are separate McIDAS-eXplorer commands to import these data for analysis. The radar images require no further systematic processing as the required processing has already been performed. The only exception is if the radar reflectivity in calibrated units is required, in which case a special command converts the image from raw data units into calibrated units.

The radar images are stored in three different formats as components of a global maps. The individual components are mapped in a sinusoidal projection and are available at three different resolutions. Each CD-ROM volume also contains a 8-X reduced resolution 'browse' frame to provide a larger context for a specific geographic location. The stpes in displaying a region of interest are described below.

FINDFF, GETMGN and **TILES**

These two commands enable the user to locate and import a radar image into McIDAS explorer. FINDFF searches the cumulative index (from the last MIDR volume, MG_0080 V1) to determine the CD-volume containing a region given by latitude and longitude.

Once the CD-ROM volume has been located and mounted in the CD-reader, GETMGN will import that frame into a McIDAS area from which it can be displayed using the DF command. If useful, the browse frame can be imported first, in which case the user is provided the option to import a full resolution image of one of the 56-component pieces (also called 'tile' or a 'framelet' or 'chip')of a browse frame by selecting a specific number from the displayed image. The tiles can be re-drawn using the **TILES** command.

FINDALT and **GETALT**

FINDALT searches the ARCDR index to locate a particular CD-ROM volume on which the altimetry and radiometry data corresponding to a given orbit is stored. The Magellan orbit number corresponding to a specific location on Venus is most readily determined by scanning the audit trail of an area containing a Magellan radar image (F or any C-MIDR) by using the LA *area_#* FORM=AUDIT command.

GETALT will retrieve the radiometry and altimetry data for that orbit and plot it on the screen over a displayed image of that region.

4.2 Pioneer Venus OCPP images

Pioneer Venus OCPP images are normally available from NSSDC on 9-track tapes. The individual files containing the images can be imported into a McIDAS-eXplorer workstation via any available means (local tape drive or over a network). Unlike majority of the images acquired by NASA's solar system missions, the OCPP images were obtained using the spin scan technique pioneered by the geosynchronous earth weather satellites and also used on Pioneer 10 and 11 spacecraft to reconnoitre Jupiter and Saturn in the 1970's. In the case of the OCPP images the spin of the spacecraft provides a swath across the disk of Venus and the orbital motion of the spaceraft translates the successive scans across the disk of Venus. A full disk image thus takes anywhere from 2.5 to 5 hours to acquire depending on the position of the Pioneer Venus orbiter in its highly inclined (105°) highly eccentric (0.8453) orbit. Consequently, NAIF SPICE kernels are not available for these images. Instead these images are navigated using the knowledge of the spacecraft orbit and imaging geometry. A single McIDAS-eXplorer command will import and navigate the raw roll-by-roll images into McIDAS areas as described below.

GETCPP

This command will import a Pioneer Venus OCPP image into a McIDAS-eXplorer area and attach the necessary navigation transform to it by retrieving the appropriate information from supplementary files stored within the /mcidas/data sub-directory. The image can then be manipulated , e.g. remapped, gridded or brightness normalized using the general McIDAS commands.