MODIS DATA SYSTEM STUDY

TEAM PRESENTATION

February 17, 1989

AGENDA

1. MODIS Data Blocking Categories
2. Data Requirements Issues
3. MODIS Data System Scenario for Science Team Members (Preliminary Draft)

MODIS DATA BLOCKING CATEGORIES

The acquired MODIS data may be grouped in many different data blocks. Starting with a pixel, the table below lists the proposed blocks of data associated with MODIS. The data blocking categories follow a natural sequence going from the smaller less processed data blocks to the larger and more processed data blocks. Following the description of the data blocking categories, estimates of their sizes in megabytes is given. These estimates assume that only the observed Earth data is retained and that calibration data such as views of space or calibration sources have been truncated. Inclusion of the calibration data in the data blocks would increase their size by about 40%.

A granule is defined as the smallest orderable data block distributed by the DADS. For MODIS a granule may be a swath for Level 1 and 2 data products and a rectified image for Level 3 and 4 data products. The final choice of granule size is yet to be formally decided.

The data transmitted from the satellite comes in packets. If each packet consists of data from a single wavelength band, a series of packets will form a swath of data as defined below. Since it is not yet established that packets will be formatted in this manner, the packet is not further described here.

Proposed data blocking categories:

1) Pixel: A single monochromatic measurement from a single detector in the instrument.

2) Fiber: All the pixel measurements made during a single scan of a detector. Also a subset of a swath (defined below), being all the data produced in one swath by one detector.
   a) For MODIS-T, each fiber contains about 1200 pixels.
   b) For MODIS-N, each fiber contains from 1200 to 4800 pixels.

3) Swath: All data from a single instrument scan, for a single wavelength.
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T, it is 64 by about 1200 pixels or 64 fibers.
   c) For MODIS-N, it is 8 by about 1200 pixels (to as much as 4 to 16 times these numbers for 0.42 and 0.21 km resolution) or 8 to 32 fibers.
   d) Each pixel has a different cross-track footprint size.

4) Swath cube: All data from a single instrument scan, for all wavelengths.
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T, it is 64 by 64 by about 1200 pixels or 64 swaths.
   c) For MODIS-N, it is 8 by 8 by about 1200 pixels (to as much as 4 to 16 times these numbers for 0.42 and 0.21 km resolution) or 40 swaths.
   d) Each pixel has a different cross-track footprint size.

e) For MODIS-T, each swath cube contains 64 swaths or 4096 fibers.
f) For MODIS-N, each swath cube contains 40 swaths or 752 fibers. Since MODIS-N has more than one spatial resolution, we may need to define separate swath cubes for each resolution.

5) Path: All the swaths in one orbit of data
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T channels, it is about 625 swaths if data is gathered during the entire orbit.
   c) For MODIS-T channels, it is about 312 swaths if data is gathered over 180 degrees of the orbit.
   d) For MODIS-N thermal channels, it is about 5000 swaths.
   e) For MODIS-N visible channels, it about 2500 swaths.

6) Path cube: All the swath cubes in one orbit of data
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T channels, it is about 625 swath cubes if data is gathered during the entire orbit.
   c) For MODIS-T channels, it is about 312 swath cubes if data is gathered over 180 degrees of the orbit.
   d) For MODIS-N thermal channels, it is about 5000 swath cubes.
   e) For MODIS-N visible channels, it is about 2500 swath cubes.

7) Non-rectified image: All the data from several swaths, where it is assumed that an approximately square array (either in terms of number of pixels or spatially) of data is obtained. Also one wavelength from a non-rectified image cube, which is defined below.
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T, it is about 16 swaths.
   c) For MODIS-N, it is about 128 swaths.
   d) For MODIS-T and N, about 40 non-rectified images per orbit are obtained.

8) Non-rectified image cube: All data from several swath cubes, where it is assumed that an approximately square spatial array of data is obtained.
   a) This corresponds to a Level 1 or 2 data product.
   b) For MODIS-T, it is about 16 swath cubes.
   c) For MODIS-N, it is about 128 swath cubes.
   d) For MODIS-T and N, about 40 non-rectified image cubes per orbit are obtained.

9) Rectified image: One geophysical parameter or radiance value re-mapped or re-imaged onto a standard Earth grid with each pixel in the image having the same size footprint (e. g., 1 kilometer square). These images may be created by spatially truncating the non-rectified images or by mosaicking using adjacent orbits.
   a) The rectified image is a Level 3 or 4 data product.
   b) Data in this format has no residual instrument distortions.

c) With 1000 by 1000 kilometer images, 518 standard rectified images could map the entire Earth.
d) With 500 by 500 kilometer images, 2070 standard rectified images could map the entire Earth.
e) The rectified image be may be used in comparison to non-Eos data or as input to Geographical Information Systems or in other higher level analyses.

10) Rectified image cube: A collection of rectified images such as a group of related geophysical parameters which are overlaid on the same Earth grid.
   a) The rectified image cube is a Level 3 or 4 data product.
   b) Data in this format has no residual instrument distortions.
   c) With 1000 by 1000 kilometer images, 518 standard rectified image cubes could map the entire Earth.
   d) With 500 by 500 kilometer images, 2070 standard rectified image cubes could map the entire Earth.
   e) The rectified image cube may be used in comparison to non-Eos data or as input to Geographical Information Systems or in other higher level analyses.
   f) A MODIS data user may order a customized rectified image cube consisting of any number of MODIS geophysical or instrument parameters or other Eos geophysical parameters.

Other potential data blocking categories:

11) Rectified regional film strips: A time ordered series of 500 by 500 km. rectified images of a geophysical parameter which is stored or distributed as a single data product.
   a) The film strip is a Level 3 or 4 data product.
   b) Data in this format has no residual instrument distortions.
   c) If the geophysical parameter is a land or ocean surface property, such as a vegetative index, cloud covered areas may have their values replaced with interpolated values.
   d) 108,000 images could be stored on a standard 12 inch CAV videodisk. This corresponds to 1 parameter over 15 years for 20 regions assuming one image per day. Using a 5 inch videodisk, 2 regions over 15 years could be stored.
   e) This product is probably practical only if erasable videodisks are available. It is probably a custom made product.

12) Global or hemispheric maps or data sets: All of an average geophysical parameter available as an image or as a data set. The spatial resolution may be reduced.
   a) The map is a Level 3 or 4 data product.
   b) Data in this format has no residual instrument distortions.
   c) Polar stereographic, Mercator, and Mollweide are potential map projections.

d) Monthly, seasonal, or yearly time averages are probable means used for the maps.
e) The distribution media is TBD.
f) Regional maps could be created from these maps.

Sizes of data blocks (preliminary estimates):

1) For MODIS-T (64 wavelength bands):

a)	Pixel (14 bits)	2 bytes
b)	Fiber	2100 bytes
c)	Swath	0.13 MB
d)	Swath cube	8.6 MB
e)	Path	41.9 MB
f)	Path cube	2688. MB
g)	Non-rectified image	2.2 MB
h)	Non-rectified image cube	137.6 MB
i)	Rectified image (1K by 1K km)	1.8 MB
j)	Rectified image cube	variable

2) For MODIS-N at 0.84 km. resolution (30 wavelength bands):

a)	Pixel (12 bits)	2 bytes
b)	Fiber	1800 bytes
c)	Swath	0.12 MB
d)	Swath cube	3.5 MB
e)	Path	18. MB
f)	Path cube	540. MB
g)	Non-rectified image	1.2 MB
h)	Non-rectified image cube	45. MB
i)	Rectified image (1K by 1K km)	1.5 MB
j)	Rectified image cube	variable

3) For MODIS-N at 0.42 km. resolution (8 wavelength bands):

a)	Pixel (12 bits)	2 bytes
b)	Fiber	7200 bytes
c)	Swath	0.48 MB
d)	Swath cube	3.8 MB
e)	Path	72. MB
f)	Path cube	576. MB
g)	Non-rectified image	4.8 MB
h)	Non-rectified image cube	38.4 MB
i)	Rectified image (1K by 1K km)	6.0 MB
j)	Rectified image cube	variable

4) For MODIS-N at 0.21 km. resolution (2 wavelength bands)

a)	Pixel (12 bits)	2 bytes
b)	Fiber	28800 bytes
c)	Swath	1.9 MB
d)	Swath cube	3.8 MB
e)	Path	72. MB
f)	Path cube	144. MB
g)	Non-rectified image	19.2 MB
h)	Non-rectified image cube	38.4 MB
i)	Rectified image (1K by 1K km)	24.0 MB
j)	Rectified image cube	variable

DATA REQUIREMENTS ISSUES

Several issues affecting the functionality of the MIDACS have been identified during the preparation of the MODIS Data Requirements Document. Comment on the following issues is solicited:

1. <u>Archive-Data-Products-Release-Authorization</u>

The various MIDACS TMCFs are responsible for the original development of data products and for any experimental or developmental work required to improve existing products. At some stage in the development of original or improved products it becomes desirable for the TMCF to begin storing prototype products at the DADS. The original MIDACS thinking was that prototype products might be distributed with suitable caveats to other MODIS or Eos Team Members before products are released to the general public. To support this process, an Archive-Data-Products-Release-Authorization was defined. The Authorization would presumably allow general public access to the data. Questions: Who decides when a TMCF product is ready to be stored in the DADS? Are TMCF products stored at the DADS only after they are ready for distribution to some appropriate user community, or is data storage itself a valuable service that the DADS can perform in support of the TMCFs? How is caveat information distributed? Is it workable (or worthwhile) to allow Team Members access before access is granted to the general public?

Algorithm-Release-Announcement. As set up in our original data dictionary, the Algorithm-Release-Announcement announces that a new algorithm is in use. In the data flow diagrams, the information is shown flowing from [TMCF] Bubble 3.1, Develop and Maintain Science/Calibration Algorithms, to [TMCF] Bubble 3.3, Plan and Coordinate. It seems that the event that needs to be recorded in the archives is the actual algorithm implementation dates. If the algorithm is implemented at the TMCF, then the originator of an Algorithm-Release-Announcement is in a good position to record and announce such an event. But if a new algorithm is implemented at the CDHF, Team Members (at the TMCF) may not be in a good position to observe and announce the actual implementation of the new algorithm. It seems that the actual implementer should make the announcement. Do we need to add or change some data flows? Perhaps there are two separate flows of information involved. The actual designation of data blocks processed with the new algorithms is in the header information attached to each block. This information accurately reflects the actual implementation of the algorithm. The Algorithm-Release-Announcement would then only provide information for management purposes.

Production-Reports. According to present flow charts, Production--Reports go from the CDHF to the IMC to provide information that a user can use to track the availability of Standard-Data-Products (generated in the CDHF). Does the user (and the IMC) also need information on the availability of Specialized-Data-Products generated at the various TMCFs?

DQA-Report Routing. As presently shown in our data flow diagrams, the CDHF routinely checks the quality of data received from the instrument using algorithms supplied by the TMCFs. Our charts show DQA-Reports going back to the TMCFs, but no reports from the data quality checks going to the ICC. Is it possible that the data quality checks at the CDHF would detect instrument control errors that should be corrected as soon as possible? It would seem that perhaps at least some of the reports should be routed immediately to the ICC so that corrective measures can be taken. Would such information arrive so late that it would be of no consequence for instrument control? Or do we envision that the checks being made at the CDHF relate only to calibration and scientific issues and that results of these checks are of interest only to science team members? If there are checks that are of interest at the ICC, perhaps the algorithms to do these checks should be included in the original data system design and not developed by the TMCFs.

A separate but related issue has to do with the method by which DQA-Reports are made available to the end user. It is presumed that DQA information can be included in the header used to route data from the CDHF to the DADS and that DQA information will remain permanently available to the user in that form.

MODIS DATA SYSTEM SCENARIO FOR SCIENCE TEAM MEMBERS

Preliminary Draft Being Distributed for Review and Comment

February 17, 1989

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1. INTRODUCTION

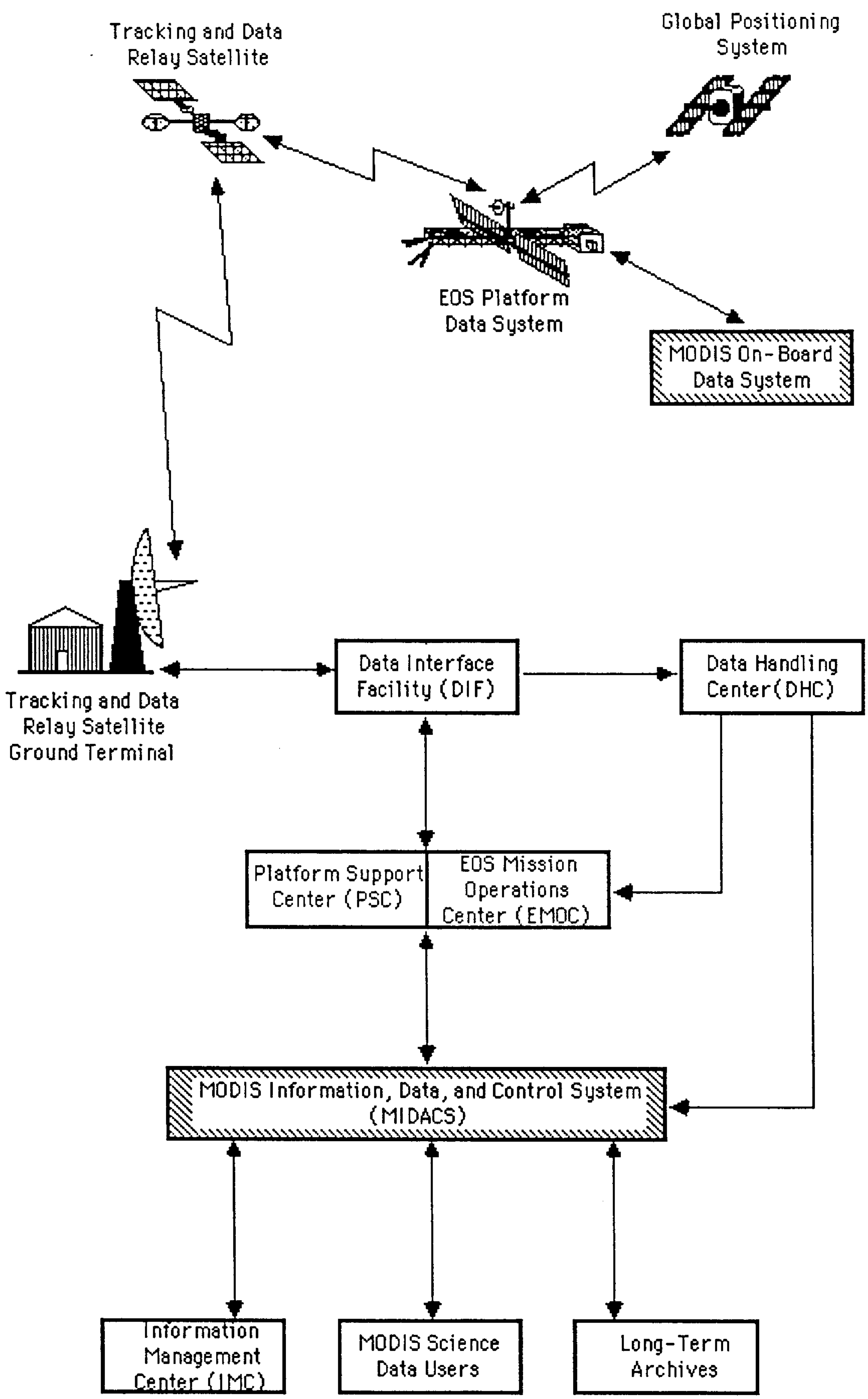
The Moderate Resolution Imaging Spectrometer (MODIS) has been designated as a facility instrument on the first NASA polar-orbiting platform (NPOP-1) as a part of the Earth Observing System (EOS) beginning in the mid-1990's. MODIS (Salomonson et al., 1987) will be composed of two whisk-broom scanning instruments: the MODIS-N for a 40 channel nadir-viewing scanner (Salomonson et al., 1988), and the MODIS-T, for a 64 channel "tiltable" scanner (Maymon et al., 1988). As currently planned, the MODIS instruments will provide data to the user community with at least ten-year, continuous terrestrial coverage. The NPOP-1 will be orbiting at a 705 km altitude and sun-synchronous orbit, with equator crossings at 1:30 AM/PM local time. The MODIS will scan ±45° (MODIS-T) to ±55° (MODIS-N) from nadir, will have a swath width of on the order of 1500 km, and will cover the entire globe at least once every two days. The combined 104 channels cover the visible, near-infrared, and thermal infrared spectral regions. The channels have been selected to provide terrestrial, oceanographic, and meteorological observations at spatial resolutions ranging from one kilometer to 250 meters at nadir.

1.1 The MODIS Ground Data System

Based on the information compiled to date, we present here a set of scenarios identifying and describing the activities of the MODIS science team members within the MODIS ground data system. Based on the available science functional and performance requirements, the scenarios illustrate in both general and specific terms a preliminary concept of how the data system will support the activities of the team members. The interfaces between the science data processing facilities and the scientific users, particularly the MODIS science team members, will be emphasized.

1.1.1 The MODIS Data System in the EosDIS Environment

As a consequence of the design of MODIS, a high data rate and an extremely large data archive volume are anticipated. The instruments are expected to have a data rate of from two to nearly 20 (night versus day) million bits per second (Mbps). The average orbital data rate is anticipated to be about ten Mbps, deriving from a million observations taken every second, with on the order of a terabit of raw data acquired on a daily basis. Furthermore, specific aspects of the EOS Data and Information System (EosDIS) combine to shape the processing requirements for the MODIS data system; in particular, the release of certified data products in accessible archives within as little as 48 hours after observation. The EosDIS will be responsible for the end-to-end data flows, as shown in Figure 1, involving the EOS Platform Data System, the MODIS Instrument Data System on board the platform, the Tracking and Data Relay Satellite System (TDRSS) and its White Sands ground terminals, the various EOS ground systems, and the users.


Tracking and Data
Relay Satellite
Global Positioning
System
EOS Platform
Data System
MODIS On-Board
Data System
Tracking and Data
Relay Satellite
Ground Terminal
Data Interface
Facility (DIF)
Data Handling
Center (DHC)
Platform Support
Center (PSC)
EOS Mission
Operations
Center (EMOC)
MODIS Information, Data, and Control System
(MIDACS)
Information
Management
Center (IMC)
MODIS Science
Data Users
Long-Term
Archives

1.1.2 Context and Data Flows for the MODIS Data System

It is the responsibility of NASA to provide a MODIS data system which will control and monitor the operation of the MODIS instrument on board the platform and perform the data acquisition, processing, and distribution functions to serve the user community. NASA's Goddard Space Flight Center (GSFC) is responsible for the design and development of the MODIS data system. The system is being designed to fulfill the scientific functional and performance requirements identified by the members of the MODIS science team and other users, and will be operated within the context of the overall EosDIS (Figure 2). Because the science requirements will necessarily evolve now that the science team has been formed, as information is compiled and the instrument design developed, we anticipate some refinement to the design of the data system. Detailed information can be found in the reports by Han et al. (1988a, 1988b, 1988c) and Anderson et al. (1988).

It is important to keep in mind that the MODIS data system will not exist as a stand-alone entity. Rather, the MODIS Information, Data and Control System (MIDACS) represents, from strictly the MODIS viewpoint, what EosDIS is and what EosDIS does to service the needs of the MODIS science team. Thus, the MIDACS discussed here is part of a larger integrated scheme within EosDIS. Here, we will look at MIDACS from the science team member's point of view.

1.1.3 Functional Allocations within the MODIS Data System

The allocation of the individual data system functions at the next lower level is illustrated in Figure 3. The MODIS ground data system can be seen to be comprised of five components: (1) the Instrument Support Terminal (IST), whose primary function is observation planning; (2) the Instrument Control Center (ICC), whose primary function is controlling and monitoring; (3) the Team Member Computing Facility (TMCF), whose primary function is MODIS algorithm development and data analysis; (4) the Central Data Handling Facility (CDHF), whose primary function is the generation of standard MODIS data products; and (5) the Data Archive and Distribution System (DADS), whose primary function is the archival and distribution of the MODIS data. Through a consideration of the data flows in Figures 1, 2, and 3, the operations concept of the ground data system is revealed. The "upward" flow of information can be followed from a user, through the data system (the IST and ICC), to the MODIS instrument on board NPOP-1. Likewise, the "downward" flow of information can be tracked from the on-board MODIS data system, through the ground data system (the CDHF and DADS), and then to the user (perhaps through the long-term archives).

1.2 <u>The Team Member Computing Facility</u>

The MODIS science team members will perform their research within a distributed TMCF. The individual facilities will be distributed

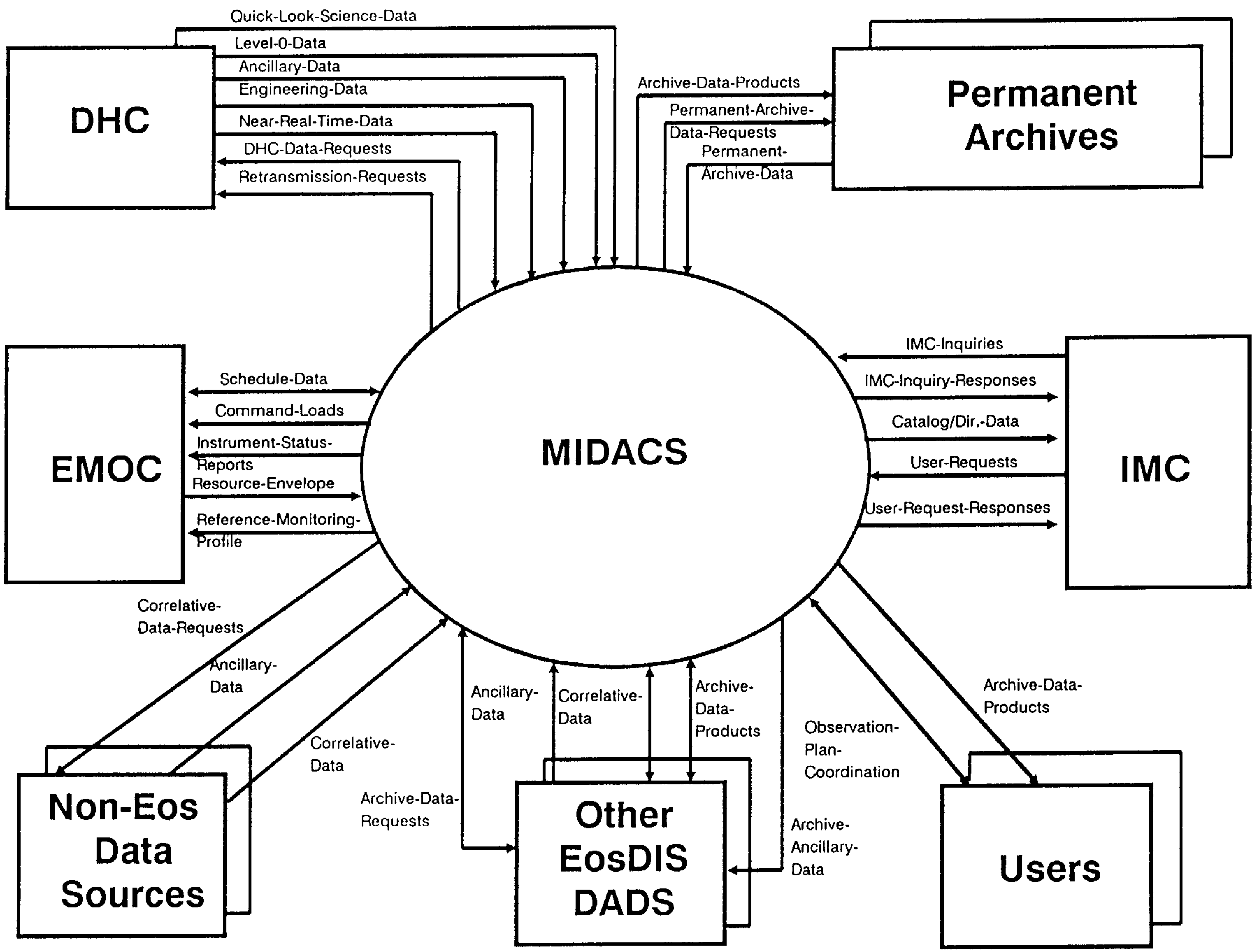


Figure 2. MIDACS Context Diagram

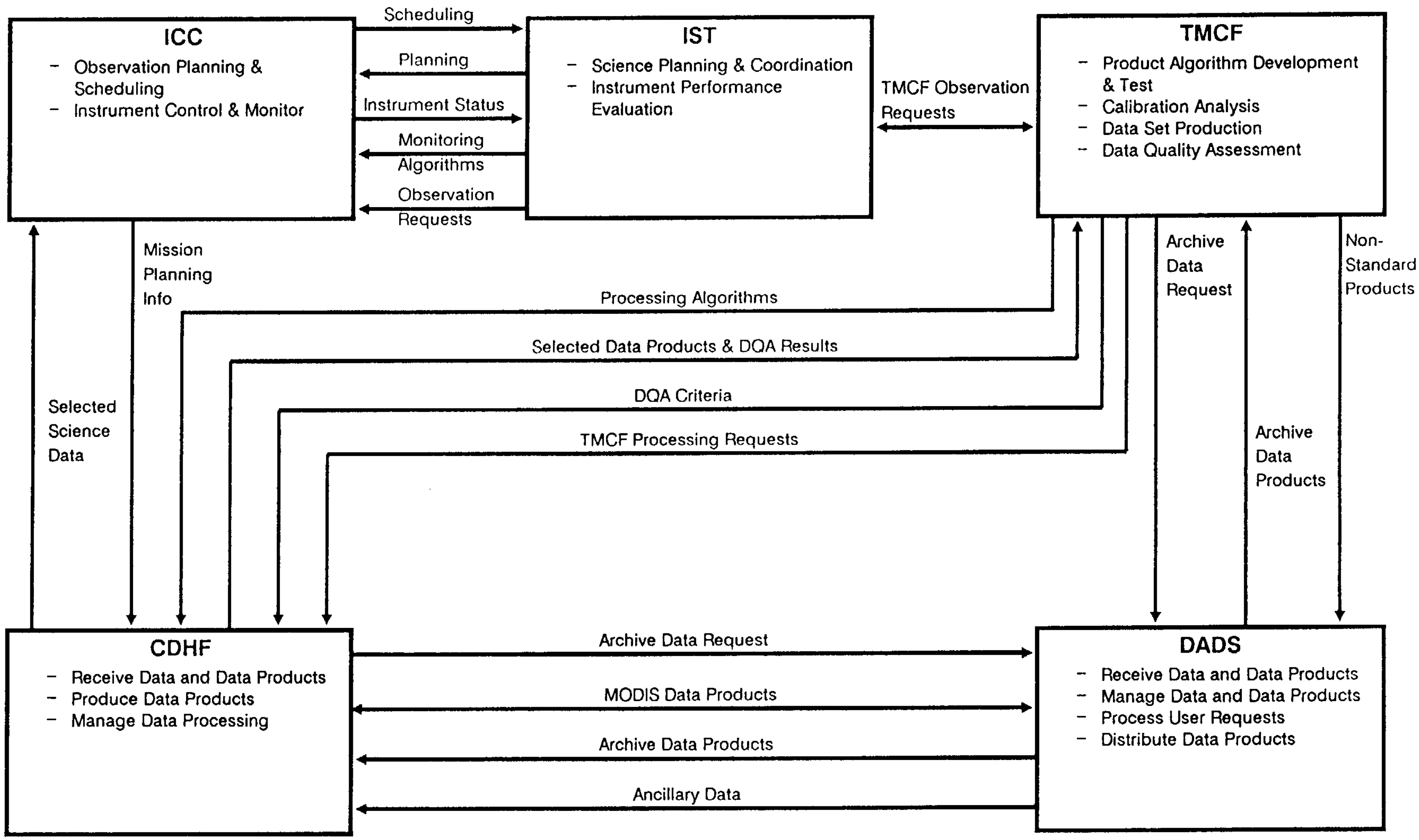


Figure 3. MIDACS Functional Allocation Diagram

nationally and internationally. Specific TMCFs may be designated to share in the generation of data products along with the CDHF. It is anticipated that the Calibration Support Team (CST) will reside in a TMCF located at GSFC.

1.2.1 Context and Data Flows for Team Member Computing Facility

Figure 4 is a context diagram of the TMCF. The TMCF is distributed and is composed of project-provided computing facilities used to develop scientific and calibration algorithms, verify and validate data, and to generate some specialized data sets. As an organizational unit, the TMCF is where the Science Team Leader provides planning and coordinating for the MODIS Science Team Members and for MIDACS. The TMCF is a distributed network of workstations at Science Team Member locations and perhaps temporarily at the site of a field experiment. The network node at GSFC is where several Science Team Members, including the Science Team Leader, will reside. Also resident at the GSFC will be the CST and a group of computer scientists engaged in making the algorithms developed by the Science Team Members more efficient and in developing software which would have general utility to all Team Members (the Science Data Processing Support Team, or SDPST). The GSFC TMCF node is central to the TMCF network and will probably have the greatest amount of project-provided computing facilities.

In addition to communications which may be required between the TMCF's computers, each TMCF will require communications with: 1) the CDHF, 2) the DADS, 3) the Information Management Center (IMC), and 4) non-EOS data sources. Communications will consist of textual messages (as with the IST), interactive database inquiries (as with the IMC), and the exchange of data products, browse data products, and algorithms (as with the CDHF and the DADS).

1.2.2 Functional Allocations within the Team Member Computing Facility

The TMCF consists of the team leader, the team members, the CST, and the SDPST. The allocation of their individual functions within the TMCF is illustrated in Figure 5.

The team leader, who is also a team member, has all the functions of a team member plus duties related to planning and coordination, instrument control and monitoring, CST and SDPST management, and membership in working groups such as the Investigator Working Group (IWG). He is responsible for developing a Science Management Plan (SMP), using planning input from all the team members, which places priorities on the science goals and on the use of supporting ground facilities. This plan expresses the overall objectives of the experiment and is periodically reviewed and updated. The Instrument Operations Plan (IOP) is concerned primarily with the spacecraft operations and the near-term and long-term instrument operations objectives. This plan is consistent with the Science Management Plan. Part of the IOP is a

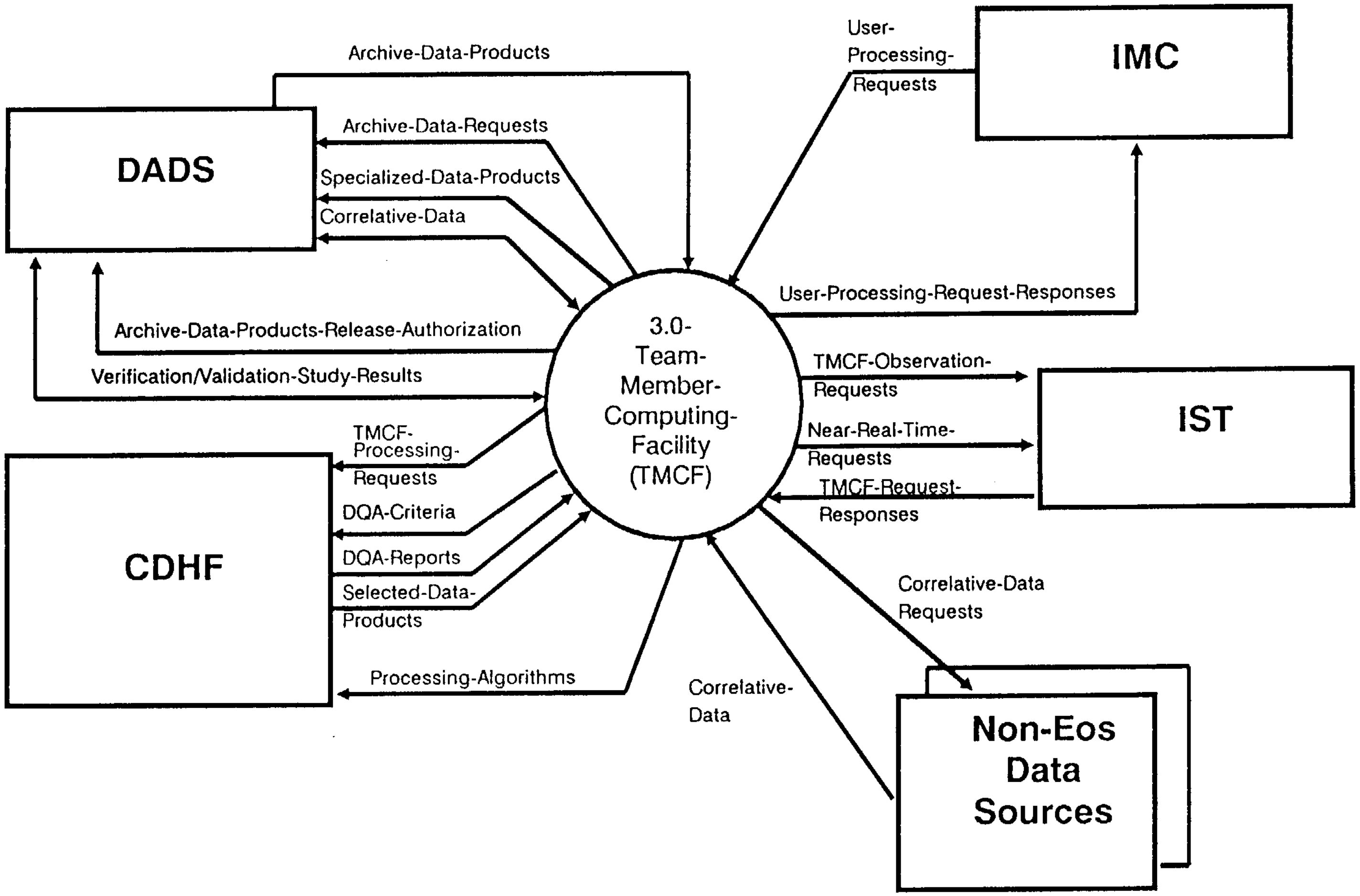


Figure 4. The TMCF Context Diagram

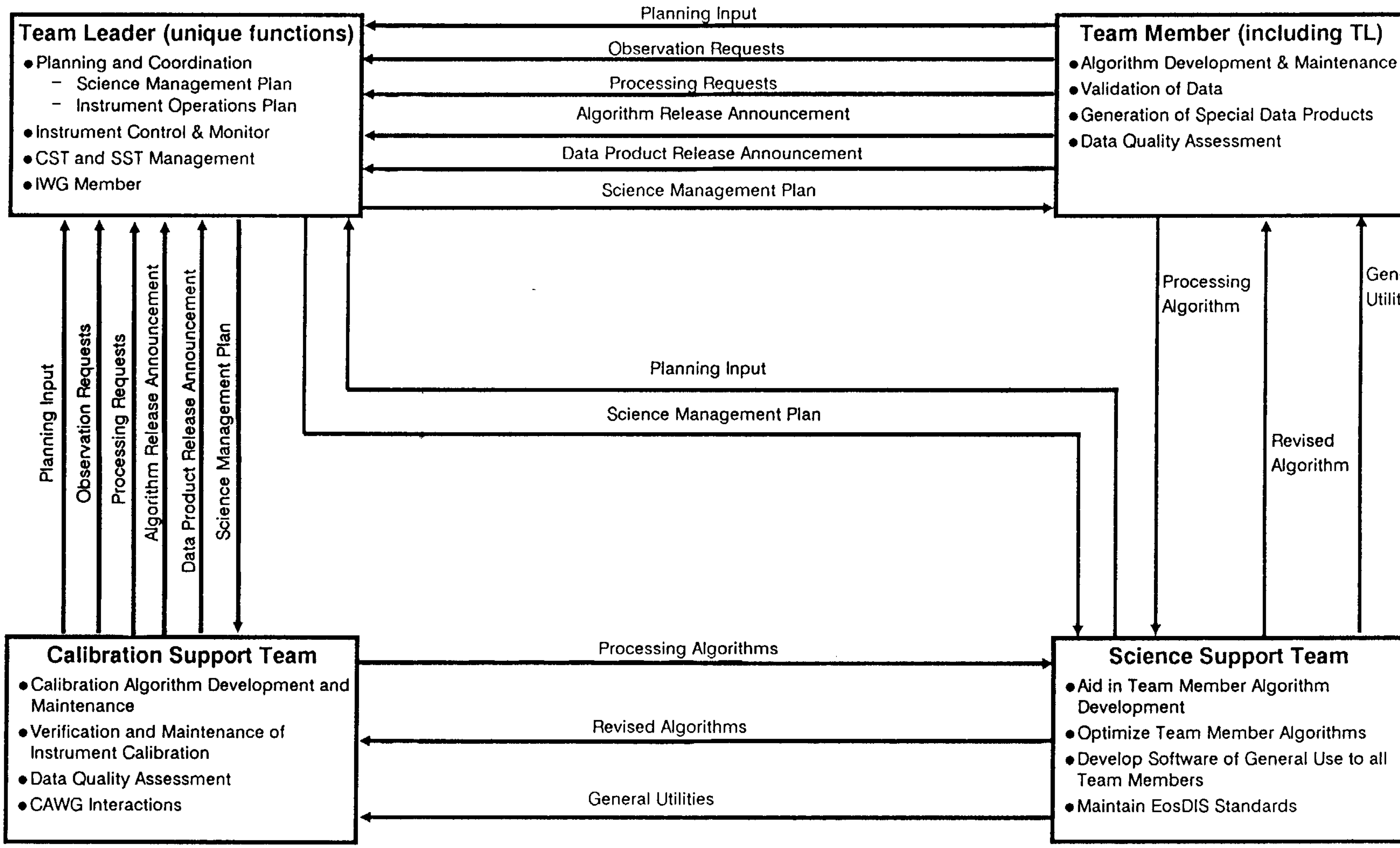


Figure 5. TMCF Functional Allocation Diagram

weekly operations plan, which gives one week's worth of detailed plans.

A team member (TM) is responsible for algorithm development, the validation of data generated by these algorithms, the generation of special data products, and data quality assessment. To achieve these goals, he provides planning input to the team leader, and may also request observations, data processing, and data products. These requests will go to the team leader for his information and for approval, if they have an impact upon MIDACS operations. A working algorithm or a finished data product will be accompanied by an Algorithm Release Announcement or a Data Product Release Announcement. These announcements keep the team leader, the other team members, and the scientific community informed of developments.

The CST's functions are similiar to the TM's, except it concentrates on the instrument calibration, including the development of calibration algorithms. Several TM's with their supporting staffs may be members of the CST. One or more TM's or their designates will also be a member of the Calibration Advisory Working Group (CAWG). The CST may be viewed as a supporting group for the team members, which assures that the instrument calibrations are correct and maintained.

The SDPST is another support group, concerned primarily with supporting algorithm development within MIDACS. They will aid team members in making their code efficient, so that whatever the architecture of the CDHF it will be optimally utilized. This could include vectorization of code or the development of software for efficient I/O, for example. Since many team members will probably want to develop algorithms which accomplish nearly identical goals, such as plotting subroutines or other general utilities, the SDPST will identify these common goals and either develop code to reach the general team member objectives or evaluate the competing codes so that the team members can decide which code is best. The SDPST will also insure that EosDIS language standards and data product standards are met. These SDPST functions mean that the SDPST will have some input in the planning process.

2. MODIS SCIENCE TEAM MEMBER ACTIVITIES

[PHIL]

2.1 Team Member Planning and Coordination

MODIS-N will collect data from 15 thermal-infrared channels at all times and from the 25 reflected-energy channels during daytime. MODIS-N will have a simple operations schedule due to its duty cycle and constant scan operation. MODIS-T will take data from 64 reflected-energy channels on a 100% duty cycle during the daytime only. MODIS-T, due to its design permitting tilt operations forward or backward with respect to the orbital velocity while scanning or staring at a fixed Earth target, will necessitate a more complicated operations concept to meet the science requirements. The routine planning and scheduling of MODIS-N and MODIS-T will be dynamic in response to platform and communications changes, instrument anomalies, or activities unknown at this time.

Science planning and coordination involves implementing MODIS observation data planning information in the form of Science Plan objectives from the IWG and data acquisition and processing request which are generated by Team Members. This information is coordinated, prioritized, and integrated into an observation plan which is compatible with the high level MODIS science policies. It is anticipated that once routine operations are implemented, the planning and coordination activities of the Team Member will become minimal.

2.1.1 Planning and Coordination Organization

The hierarchical levels of science planning and coordination encompass the International Investigator Working Group (IIWG), Investigator Working Group (IWG), and the Team Members. The organization of the international scientific efforts of EOS is centered around the IIWG, formed to coordinate research and operations among the EOS Polar Platforms. The IIWG is the primary science element of the international EOS mission and will formulate the international observing policy and overall science objectives for all EOS platform activities. They will also develop science plans to accommodate special windows of opportunity. The NASA IWGs are the primary science elements of the NASA EOS Project and play the leading role in the overall optimization of the science return. IWG activities are coordinated with the IIWG and receives policy, guidelines, and overall science objectives from the IIWG. The IWG will provide high-level science mission guidance to the EOS Project, establish science mission priorities and develop the long term detailed science plan (updated as required), and evaluate proposals for observations submitted to the science teams.

The MODIS Team Leader will be a member of the IWG, providing the science plan and policies to the Team Members. Team members will be organized under the direction of a Team Leader who will coordinate and prioritize data acquisition and processing request. The Team Leader will also coordinate changes or additions to the MODIS science plan.

2.1.2 Science Team Roles and Responsibilities

The MODIS science Team Leader is a member of the IWG and it is through this interface that changes to the MODIS Science Plan are conveyed to the MIDACS. The Team Leader will develop a MODIS science management plan in accordance with the IWG MODIS science plan and input from other Team Members. The science management plan will be established for setting of priorities. This plan will outline prudent use of observation time and instrument resources, supervision of ongoing studies, dissemination of results, and monitoring of the instrument health. The science Team Leader will have the responsibility for transmitting a request via the IST to the appropriate facility. The science Team Leader will established the guidelines for the submittal of observation request to the ICC. After submission of request becomes routine, he may be involved only by exception or conflict. He will receive and catalog all Team Member and general user acquisition, data processing, and data product request.

The Team Member will be responsible for the continued application of MODIS to complete the assigned study. As the instrument becomes more predictable and new areas of science studies are discovered, the Team Member will generate data acquisition request and send them to the Team Leader for approval. The Team Leader transmits these request via the IST to the ICC for implementing the respective commands. A data acquisition request, as opposed to an outright change to the science plan, may request unique instrument commanding, which is necessary for the ingest of data required for a particular science objective. This request may or may not become a routine instrument operation.

2.1.3 Science Plan Implementation

The Team Member will develop a request for controlling the MODIS instrument to acquire data and for the processing of the collected data. These request are discussed below.

2.1.3.1 Data Acquisition Request; Instrument Control

Science Team Members will generate a data acquisition request (DAR) for their planned science investigations. The information included in this DAR is used to control the MODIS instruments. The DAR can be divided into the following areas of information with several examples given for each:

Geophysical/Environmental Information:

Observation Times
Target Location
Cloud Cover Parameters
Surface Types

Science Information:

Science Objective
Science Products
Monitoring Requests

Instrument Information:

Tilt (MODIS-T) control
Gain control
Calibration sequence

Duty Cycle Control
On-Board Processing (if any)
Thermal requirements
Power requirements

Synergism:

Other Instruments Required
Other data required
Timeliness

A DAR may also include information for the scheduling of observation data for support of field experiments, targets of opportunity, and calibrations. For example, field experiments may require calibrated radiances from 15 MODIS-N and/or -T channels at specific target locations, as well as the production of level-4 products, which must be processed by the CDHF in near-real-time (within three to eight hours of the observation). The field experiment information will then be incorporated into the baseline DARs for planning and coordination. Emergency situations may be handled in the same way with possible pre-generated commands.

2.1.3.2 Data Processing Request

As part of the planning and coordination, a Team Member may need to arranged for the routine or special processing of collected data, the generation of algorithms, and the distribution of processed data or results from the CDHF or DADS. This planning and coordination (see figure ***) is performed independently from the aforementioned instrument control DARs. The planning and coordination of data processing will take place between the Team Member, Team Leader and the CDHF and requires a conflict resolution procedure for the prioritizing the processing needs of each Team Member. The Team Member needs to coordinate the processing of MODIS data collected per his instructions in the DAR. This coordination involves the collection and request of MODIS and other instrument data, platform ancillary data, engineering data, and other correlative or in-situ data. This data will be found in EOS or Non-EOS data sources. The Team Member's need for this data may be time or analytically critical depending on the intended use.

2.1.4 Data Acquisition Conflict Resolution

Once a DAR is submitted to the Team Leader, the Team Leader will merge the MODIS planning information with other request to identify conflicts with the science plan. The Team Leader will check the resource requirements of the instrument against the operations allocation and guidelines of the original planning input to the ICC. Conflicts may be caused by differences in requirements for individual scientific objectives, operating channels, by conflicts between science goals and system maintenance or communication schedules, by anomalous behavior of instruments or systems, or by near real-time requirements.

Conflicts at this stage will be resolved iteratively in the science team domain by the application of the above guidelines and science priorities. If necessary, higher levels of resolution based on the long term science plan and the IWG policies will be invoked. The prioritizing of processing request will also be coordinated by the Team Leader and will undergo a conflict resolution process.

A second level of DAR conflict resolution occurs in the ICC. The observation requests are checked against environmental models (orbit, attitude, Sun, and scene) to determine the feasibility of the request. For example, the required orbital geometry versus the predicted for support of a field experiment. The instrument resource requirements are modeled to the extent that the operations envelope is allocated by the EMOC. This envelope will provide guidelines for MODIS operation times and resources such as power.

It will be the science Team Leader's responsibility to convey the appropriate modeling parameters to the IOT. As the performance of the instrument becomes better known, the Team Member or leader will provide the IOT, via the IST, with changes to any instrument models. If IOT checks result in violation of the allocated resources, the IOT will inform the science Team Leader, via the IST, of the violation. The Team Leader and members will then resolve the conflict and a new or updated DAR will then be resubmitted. A candidate instrument schedule request is generated by the IOT if no violations are found and is sent to the EMOC for approval. All approved scheduling information is sent to the Team Leader by the IOT via the IST.

2.1.5 Planning and Coordination Tools

Support tools will be provided by the IST, the TMCF, or through the IMC for access to a planning database to assist the Team Member in generating valid DAR and data processing request. The level of assistance is TBD and will depend on the user requirements, the system design, and the software developed. These tools may be portable so that the Team Member can access the MIDACS from any location. They should provide for off-line generation of the DAR and data processing request before being sent to the Team Leader for coordination and approval.

2.1.6 Planning and Coordination Interfaces

The Team Member or Leader, can generate and submit a DAR and data processing request from any TMCF location that has the appropriate tools. To optimize this activity, a standard format will be agreed upon for delivery of requests. A DAR may be electronically transmitted to the Team Leader in two ways, either directly through an on-line interface or via the IMC. The IMC will provide the appropriate communication service, (communication lines and menu driven displays) for transmission of the request to the IST. The Team Member may be able to submit a request by phone or mail services if necessary. In all cases, a coordinated observation request made up of individual DARs will be sent through the IST to the ICC under the control of the Team Leader. Data processing request will be handled separately using a TBD interface with the CDHF and DADS.

2.1.7 Planning and Scheduling Timeline

The science plan and policies determined by the IIWG and IWG will be done months in advance of DAR. To ensure that a DAR can be honored, it is necessary to enter a DAR into the IOT's planning and scheduling process one month ahead of the planned observation time. This DAR will therefore undergo the coordination, authorization, and approval process at the discretion of the Team Leader from one to three months before the observation time. After transmission of this request to the ICC, the ICC scheduling process continues for approximately three weeks and is iterated with the EMOC, and with the Team Members if conflicts arise, until approval about one week prior to command loading. Approximately one week ahead of the observation time, the request is considered scheduled. The Team Members may update their request at any point of this timeline up to two orbits before the execution of the command load by the instrument. The update should follow the same conflict resolution hierarchy as before. If the request is due to a target of opportunity or emergency need, the most expeditious method available may be pursued to accommodate the request.

A request for processing of data in a timely manner and the need for ancillary data from EOS and Non_EOS data sources must be known at a TBD time before the MODIS or other instrument data is collected.

2.2 Data Acquisition

The data collected by the MODIS instruments will be transmitted to the Data Interface Facility (DIF) on the ground via TDRSS. The data received by the DIF will be separated for each instrument and sent to an appropriate Data Handling Center (DHC) At the DHC, the data will be processed to Level-0. Bit errors that occur during transmission may be corrected at the DHC. In addition to Level-0, the DHC will collect and transmit ancillary data, such as platform ephemeris and platform attitude data, to the CDHF, where standard data products are produced. Level-0 and ancillary data will be available within 24 hours of observation.

In addition to these routine instrument operations to collect science data, there will be two special modes of operation: instrument calibration-related observations and special-event monitoring operations. The instrument calibrations will be performed to ensure the accuracy of the observations. The calibration of the MODIS-N and -T instruments will be maintained throughout the mission lifetime. Instrument operations to monitor calibration sources can be included as part of an observation, or may be dependent upon internal or external calibration sources.

Science team members and other users may request special observations for their planned science investigations. Observation requests may include information for the scheduling of observation data for support of field experiments. Field experiments may require calibrated radiance data as well as higher-level products, at specific target locations in near real-time (within three to eight hours of the observation).

Level-0 data will be further processed at the CDHF. Ancillary data will be merged with Level-0 data to produce Level-1A data. Earth locations are computed and radiometric calibrations are performed on the Level-1A data to produce Level-1B data. The radiometric calibration algorithm will be provided to the CDHF by the Science Team. The members of Science Team will also provide standard data product generation algorithms to the CDHF. Using these algorithms, Level-2 data will be produced from Level-1B data and other necessary data. These Level-2 data, as well as Level-1B data, will be used to produce Level-3 data, which are maps on fixed Earth grids. Level-1 data will be available within 48 hours of observation, Level-2 and Level-3 data will be available within 72 and 96 hours of observation, respectively. Browse data and metadata will be available with the same timeliness as the standard products.

The standard and special data products archived at the DADS will be available to users upon request. The users' access to the DADS is centralized and handled by the IMC. The IMC will store the most recent information on data production status, as well as catalogs of the MODIS data products. Small amounts of browse data may be available at the IMC. The users will specify their needs and place orders, and the IMC will route the requests to the appropriate DADS. The DADS will copy and send the requested data to the user via the requested method, which may be either electronic or on some physical media. In most cases, the data will be sent within 24 hours of receipt of the request.

Some of the data will be transferred to long-term archive centers. In this case, the IMC will provide the user with information describing where the data may be found.

As presented below data acquisition encompasses the Science team member's requests for MODIS datasets, non-MODIS Eos datasets, and non-Eos datasets. Figure 4 illustrates the data resources and flows available to the TMCF.

2.2.1 Requesting MODIS Datasets

MODIS-N and MODIS-T Levels 1-4 datasets will be requested through the IMC or directly from the DADS. These TMCF requests will be entered either interactively or executed as standing orders. The requested datasets will be retrieved either from DADS storage or from the permanent archive facilities, and sent electronically or on off-line media to the requesting science user. TMCFs can also request browse, catalog, and/or metadata from the IMC or DADS.

2.2.2 Requesting non-MODIS Eos Datasets

Non-MODIS Eos datasets will be requested through the IMC or directly from the DADS. Facility instruments providing this data include the Atmospheric Infrared Sounded (AIRS), Geodynamics Laser Ranging System (GLRS), High Resolution Imaging Spectrometer (HIRIS), Laser Atmospheric Wind Sounder (LAWS), and Synthetic Aperture Radar (SAR). P/I instruments providing this data include the Dynamics Limb Sounder (DLS), Tropospheric Emission Spectrometer (TES), Lightning Imaging Sensor (LIS), Positron Electron Magnet Spectrometer (PEMS), High Resolution Research Limb Sounder (HRRLS), Ionospheric Plasma and Electrodynamics Instrument (IPEI), Thermal Infrared Ground Emission Spectrometer (TIGES), Energetic Neutral Atom Camera for EOS (ENAC), Stratospheric Wind Infrared Limb Sounder (SWILS), GPS Geoscience Instrument for Eos and Space Station, X-Ray Imaging Experiment (and Optional Particle Detectors), Tropospheric Radiometer for Atmospheric Chemistry and Environmental Research (TRACER), The Solar Stellar Irradiance Comparison Experiment, Spectroscopy of the Atmosphere Using Far-IR Emission, Earth Observing Scanning Polarimeter (EOSP), An Active Cavity Radiometer Irradiance Monitor Experiment, and, Microwave Limb Sounder (MLS).

These requests will be entered either interactively or as standing orders. There will be two types of availability for these datasets. The first type will refer to datasets already in existence. The second will refer to datasets produced only when requested, for example, HIRIS datasets. In the first instance the DADS will request the datasets be sent from another Eos DADS or a permanent storage facility. In the second instance the DADS will forward a request for the datasets. When they are available (either at the time of the request or when generated) they will be sent by the other Eos DADS to the DADS electronically or on off-line media. Upon arrival at the DADS these datasets will be forwarded on the specified media to the requesting science user.

2.2.3 Requesting non-Eos Datasets

The science user will provide TMCF access to any desired non-Eos data. Data products resulting from these inputs can be sent to the DADS for cataloging and eventual access by other users. The Non-Eos satellites and/or instruments expected to be sources of this data include GOES (I-M), NOAA Polar Orbiters (such as AMSU and AMRIR), SeaWiFS, LANDSAT, SPOT, and the Japanese Earth Resources Satellite.

2.3 Develop and Maintain Algorithms

The science team members are responsible for developing science algorithms to process the MODIS data. This section describes the overall process by which this developmental work is accomplished within the MIDACS environment from the point of view of the team member. First, a background section on computer architectures is included since these architectures have a strong influence on the methods of developing algorithms and the final algorithms themselves. Given this background, the next section describes the science team member's interaction with MIDACS in general terms, emphasizing who interacts, where they interact in MIDACS, and when and how they interact. The final section describes the SDPST and its functions.

2.3.1 Background on Computer Architectures

It is a safe assumption that the computer architecture at the TMCFs will generally be quite different from the computer architecture at the CDHF; in fact, the architectures of individual TMCFs may be quite different from each other.

The architecture of computers can be described in many ways. There are two main catagories of architecture: serial and parallel architectures. Within parallel architectures we can distinguish those with switched processors from those with a network of processors. Switched processor computers can be further subdivided into those with shared memory and those with distributed memory. Network computers can be divided into those with mesh, cube, hierarchical, or reconfigurable networks of combined processors and memories.

The MODIS instrument, as with any cross-track scanner, generates image type data. To compute calibrated radiances or geophysical parameters, the same mathematical operations are performed on each pixel within the image. This suggests that the use of parallel architecture computers may be the most efficient approach as computations for all of the pixel elements can be performed simultaneously. The alternative of serial type computations (where all the computations are performed on one pixel, and then repeated on the next pixel, and so forth) would appear to be an inefficient approach.

Consider then two extremes: 1) The TMCF workstations as serial type computers. 2) The CDHF computer as a massively parallel processor using a cube network. In this case, software developed on the workstations may not efficiently run on the parallel processor. In fact, since parallel processors often require that ANSI standard languages have extensions to them for parallel data input and output, it is possible that the TMCF software might not run on the CDHF computer at all. One solution is to forbid parallel processors from being employed. (This may implicitly occur if ANSI language standards are strictly adhered to). A second solution is to wait for ANSI standards to be modified to account for recent technical developments.

If the CDHF computer is a massively parallel type, it is probably more efficient for algorithm development work to be done on the mainframe computer rather than at workstations whose architecture will undoubtedly be quite different. If the CDHF computer is a more conventional serial design or even a switched processor design, most of the algorithm development can be done on separate workstations. The choice of the CDHF computer architecture will have major effects on the TMCF network and hardware just as it will affect the development of software. Within the MIDACS, there is a need for a central software development group to convert code developed on the TMCF computers to code which efficiently utilizes the architecture of the CDHF computer. This group could be part of GSFC TMCF node.

In summary, the CDHF computer architecture will have major implications on the TMCF potentially altering the coding of the software and the TMCF hardware choice.

2.3.2 Team Members and Algorithm Development

A MODIS science team member will develop a science algorithm using either his own computing facilities or project provided computing facilities. Since the team member computing facilities may differ from one another and from the CDHF in their computing architecture, all the science algorithms will be tested and run on the CDHF (or duplicate facility) to see if they 1) compile, 2) execute and generate results meeting certification criteria, and 3) are efficient. At this point, the SDPST will examine the code and modify it as required to make it efficient and to meet EosDIS standards. The team members will have the opportunity to examine these changes to see that the accuracy and other requirements have not been compromised. Assuming an efficient working version of the algorithm is developed and has been certified as correct, the team member will write an Algorithm Release Announcement containing information on the algorithm and its data products. The announcement will be reviewed by the team leader before general release.

Algorithm development is an on-going process and will follow the general outline above throughout the MODIS experiment. A scenario which gives a chronological summary of this procedure is given in section 3.6.

2.3.3 Science Data Processing Support Team (SDPST)

The SDPST consists of computer scientists and other supporting personnel whose functions are fourfold: 1) revising team member computer code to be more efficient without any sacrifice in accuracy, 2) developing computer code of general utility to all team members, 3) assuring that the code developed meets EosDIS language standards, and 4) assuring that MODIS data products conform to EosDIS standards.

The science team members using the TMCF are responsible for the development of calibration and science algorithms. Input/ output algorithms and plotting and imaging algorithms which are of use to all science team members will be developed either by the SDPST or will be purchased from commercial sources. The code will, of course, be in a high level language such as Fortran 77 so that it can be developed on a workstation and transported to mainframe computer. If the CDHF acquires a computer which incorporates vector processing or parallel computing, the ANSI Standard languages require modifications since the input/output is handled differently. These language extensions, which take advantage of the parallel nature of the computer, may have effects on the choice of the science team member workstations and may change the way code will be developed and tested.

Algorithms such as input/output algorithms, plotting and imaging algorithms, or even calibration algorithms may be of general utility to all team members. Rather than have several team members develop code which accomplishes the same task, the SDPST can be used to develop this code. The SDPST therefore is a resource in MIDACS for the use of all team members. They will also have expertise on the CDHF computers so they can aid team members in the resolution of problems they may have in developing or implementing science algorithms.

EosDIS is expected to establish computer language standards and data product standards. These standards will probably adhere to some international standards. Their objective will be to have transportable and maintainable code and to generate data products that can be compared to other EOS products or to non-EOS data products, without a considerable overhead of effort. The SDPST will be familiar with these standards and examine the MODIS algorithms to ensure that the EOS objectives are being maintained. They will aid the algorithm developers in reaching the EOS standards.

2.4 Produce and Archive Special Data Products

It is likely that there will be a significant amount of processing that is done by MODIS team members. The current working definition is that a Special Data Product is anything not routinely produced in the standard product generation on the CDHF. By this definition, almost anything done by a TM will result in a Special Data Product.

This section will contain a discussion of four specific types of Special Data Products.

a. Non-standard products.
b. Preliminary products.
c. Level-4 science products.
d. Interactive products.

The presentation will consider only scientific or geophysical analysis. This report contains additional discussion of this topic in the sections on algorithm development and calibration.

Non-Standard Products

MODIS TMs be responsible for the production of, at least some, science products that will not be routinely generated during standard processing. This could involve the production of science products which are required only infrequently or in special circumstances.

For the support of field experiments, TMs may produce special science products that are roughly equivalent to standard products. As an example, the chlorophyll content of the tropical ocean could be determined by combining MODIS data with data from a geosynchronous satellite and a NOAA platform. It might not be possible to obtain all of this data and do the processing within the several hours required to support the field experiment.

The field experiment would be supported by a TM who makes a less accurate estimate using only Level-1B MODIS data. This product would be passed to a TM in the field, or perhaps generated in the field. This product would not be sent to the DADS since a more accurate product will be produced in 4 days by the standard processing.

Preliminary Product

During algorithm development, there will be a point at which the product being produced is correct and of scientific value. There could still be a substantial amount of work to be done before the algorithm could be implemented on the CDHF. This could be either software development or validation studies. As an example, an algorithm may be producing good science but be far from conforming to software standards.

How this situation is to be handled will depend on the demand for the data. It may be possible to wait till the algorithm is fully certified and then produce the product on the CDHF by reprocessing data. If there is immediate demand for the product, the results could be distributed as an uncertified product. (We are not aware of a mechanism for the distribution of uncertified data products.)

Level-4 Science Products

Level-4 Processing is not well defined at this time. In particular, it is possible that all Level-4 Processing will be nonstandard. This may place a severe load of the TM computing facilities.

Some, at least, of the Level-4 processing will be done by TMs. There will be Level-4 products produced only rarely or perhaps just once. As an example, following a volcanic eruption such as occur at Mt. St. Helens a Level-4 product could be produced which shows the spatial and temporal evolution of the dust cloud.

It will be necessary to archive and distribute Level-4 products. At this time, it is unclear how this will be done. It clearly will be necessary to produce products that conform to all of the Eos standards.

Interactive Processing

Certain types of processing are done interactively, i.e., a trained operator examines a preliminary or partial data product and guides the processing based on his expertise. It will be possible to automate some of this type of processing, e.g., check for cloud cover before determining surface properties.

The CDHF will not permit interactive processing; there will not be real-time interaction with a TM. Any processing that must be done interactively will be done by a TM. This is likely to involve the use of a graphics work-station, and may require significant computer resources. In addition, this type of processing will probably be done to support field experiments.

Interactive processing will produce data products that will be difficult to document and certify. When interactive processing is done, the result depends on the decisions made during the processing. Two different TMs will make different decisions which will result in different results. The differences can be significant. It is not difficult to document the decisions made by the operator and thus generate a detailed history of the data product. It is very difficult, if not impossible, to assess the quality of the final data product when a scientist's subjective judgments plXy a part in the processing.

2.5 Perform Correlative and Modeling Studies

The MODIS science team will perform correlative and modeling studies to validate and determine the accuracy of MODIS science products. This effort will involve the analysis of correlative data to determine the correctness of the MODIS data products and statistical modeling of both the MODIS instrument and the data products to determine the accuracy of the results.

Correlative Studies

Correlative data will be obtained to verify/validate the performance of the MODIS instrument. Correlative data are defined as any geophysical parameter that is not a MODIS data product. This will include data products from other instruments on the MODIS platform, data from instruments on other EOS platforms, and data from non-EOS sources.

EOS data will be requested by a Team Member from the DADS through a TMCF node. This data will be routinely available in at least one active archive in a time period of at most days. It will be possible to obtain this data simply by issuing a data request.

The data to be obtained from non-EOS sources will often be "ground truth" observations. Examples are upper air meteorological radiosonde data, rainfall data collected at a ground-truth network, and cloud cover as observed from a vessel in the Pacific Ocean.

The team member will decide what non-EOS data are needed, determine if the data are available, and arrange to obtain the data. The details of how this will be done is TBD. It is clear that non-EOS data may not be available without significant delay. In-situ data from an ocean cruise might not be available until the ship returned to port, i.e., a delay of several weeks.

EOS data will include Data Quality Assessments (DQA) which will indicate the statistical accuracy of the parameter measurement. This factor combined with timeliness considerations make it clear that, wherever possible, the correlative studies will be done with EOS data. For example, MODIS may produce a data product that estimates the fractional cloud cover in 1 km pixels. This product could be checked by examining HIRIS data. This would probably be quicker and more accurate than using ground observations of fractional cloud cover.

While the data from non-EOS sources may not be of the same quality as EOS data, it will still be necessary to obtain ground truth observations to verify the correctness of the MODIS results. For example, it will be necessary to measure surface temperature in-situ to insure that accurate values are obtained. Consistency within all of the EOS instruments is not sufficient, the quantity determined must be correct and tested.

The need for correlative studies is expected to decrease during the lifetime of the MODIS instrument. Immediately after launch, it will be necessary to test the correctness of all of the data products being produced. There may be a reduced need for this type of study in later years.

Modeling Studies

Modeling studies will be required to determine the accuracy (i.e., statistical errors) on the MODIS data products.

There may be some MODIS data products which can be more accurately measured with other EOS instruments, e.g., AIRS may more accurately determine temperature profiles. For these products, the errors can be modeled by comparing the MODIS results with the more sensitive measurements of the other instrument.

The accuracy of some products may be monitored by taking repeated observations of a quantity which is constant or slowly varying over a period of time. An example might be the surface temperature of the Arctic Ocean. A time series of observations of the same geophysical parameter could be examined and modeled to determine the accuracy of the MODIS data.

It is likely that the accuracy of some of the MODIS data products will be determined from pure modeling studies, i.e., Monte Carlo or computer system simulations. For any geophysical parameter, the known errors on the input data and the recovery algorithm can be used in simulations to estimate the accuracy of the parameter. This method will require knowledge of the statistical errors on the calibrated data, which will be determined by the calibration procedures.

It is possible that the result of both the correlative and modeling studies will be an instrument performance model. The performance model would contain information on the statistical errors on the MODIS data products as a function of the relevant parameters. This model would be an important tool in long-term monitoring of the MODIS instrument.

One of the things that should be included in this model is the pointing accuracy. It is how the pointing will be monitored and how the data will be processed to correct for pointing errors and uncertainties.

2.6 Maintenance of the MODIS Calibration

Several science team members are interested in the calibration of the MODIS instruments in the sense that a major portion of their efforts will be directed towards maintaining an accurate instrument calibration. All these team members and their supporting staff are expected to be members of an entity called the CST. The CST is expected to be involved in all aspects of calibration. MIDACS is involved with the data system aspects of MODIS. The account of the CST given here is thus not a definition of the team, but rather a treatment of its role in regard to calibration data products and data processing within the MIDACS environment.

Section 2.6.1 highlights some of the ways science team members who are not part of the CST can become involved in calibration data processing. Section 3.5, giving a MODIS calibration scenario, provides a guide to these members of how the calibration data processing proceeds.

Section 2.6.2 on the CST within MIDACS is included as background and is taken from an earlier document called the Preliminary MODIS Calibration Data Products Plan. This section is written from the point of view of the team members who are part of the CST and describes how they interact with other elements within the MIDACS.

2.6.1 Team Members who are not CST Members

Science team members may have questions about the instrument calibration. The CST's responsibilities include providing answers to these questions. The CST will keep a log of these questions and the answers provided. The CST will provide a user's guide to document the MODIS calibration procedures. The CST is a resource within MIDACS for any activity associated with calibration procedures and algorithms.

2.6.2 Team Members who are also CST Members

For the calibration to be as accurate as expected by the science team, it is anticipated that early in the Phase-C stage of the MODIS instrument development a CST will be formed. The MIDACS Functional Requirements Document defines some functions of the CST and the MIDACS Operations Concepts Document provides information on how the CST operates within MIDACS. This team will be composed of science team members and supporting staff which includes physicists, instrument engineers, and computer scientists. Its primary responsibilities prior to launch will be assuring that the ground calibrations are properly performed and provide continuity in the calibrations between the pre-launch and in-flight periods. The CST will also develop the calibration algorithms in the pre-launch period. After launch, its primary responsibilities will be providing the calibration coefficients and algorithms to the CDHF. This latter duty requires a host of supporting responsibilities which include monitoring, analysis, and assistance. The operation and responsibilities of the CST are reviewed below. Information on external interactions of the CST is followed by a review of the its supporting internal functions.

1. CST/CDHF Interactions

A primary responsibility for the CST is developing calibration algorithms and supplying them to the CDHF. These algorithms will remain relatively stable and only occasionally require updates. If an update is required, the CDHF will be supplied with the new algorithm. Approval of this procedure will be made by the team leader and the science team.

The primary in-flight responsibility of the CST is providing the CDHF the necessary calibration coefficients so that Level-1 data can be generated on schedule. The CST will probably accomplish this task by acquiring Level 1A data from the CDHF which includes embedded calibration information. This data will be analyzed to see if the calibration of any of the detectors has changed sufficiently so that they need to be changed. If they have changed, the CDHF will be provided with new calibration coefficients so that can proceed to process Level 1 data. If the coefficients remain the same, then the CDHF will use its current coefficients.

The CST will acquire special subsets of Level 1A data from the CDHF, in some cases to analyze views of selected earth targets, or data involving the use of the solar diffuser plate to monitor the instrument calibration.

On occasion the CST may send the CDHF a processing request, such as a request to perform calculations which the CST does not have the resources to perform.

DQA reports are defined as the results of routine data quality assessments associated with data receipt and data product operation. The CST will acquire the DQA reports in order to perform the calibrations correctly. The CST will also provide DQA criteria which are used to assess data quality.

2. CST/IST/ICC Interactions

A primary responsibility is providing the ICC via the IST a request for a special operation mode for MODIS when it is needed for calibration. The team leader at the IST will determine the priority of these calibration requests, along with the science requests, prior to relaying them to the ICC.

3. CST/DADS Interactions

At the same time the CDHF is provided with new calibration coefficients or algorithms, the DADS will also receive copies of them for archiving.

The CST will provide special data products to the DADS which document the history of the calibration of the instrument. Sample data products are 1) calibration scenes, 2) night views (visible channels), 3) history of lamp outputs, 4) history of blackbody outputs, 5) history of spectral calibrator, and 6) history of the lamp monitoring detectors.

4. CST/Instrument Contractor Interactions

Prior to launch, the calibration performed by the instrument contractor will be overseen so that the science team goals are met. The team members and the CST will be the primary people performing these tasks.

The CST and the team members will be satisfied that the instrument's calibration is traceable to NIST standards.

5. CST/Non-EOS Data Sources Interactions

For verification studies, the CST will request and receive correlative data from non-EOS sources.

6. Internal Functions of the CST

A primary responsibility of the CST is the on-going monitoring of the calibration of the MODIS instruments. The CST will meet the time schedule and quality assurance requirements of the MIDACS for the generation of Level 1B data products.

The CST will build a mathematical model of the instrument in order to interpret changes in the instrument performance and to develop calibration algorithms. Documentation of these models through technical reports or scientific papers are data products associated with this activity.

The instrument calibration coefficients may be a function of time. The CST will monitor the trends in the coefficients and based upon these analyses provide updated coefficients.

The CST will conduct on-going studies of the calibration algorithms.

The CST may require the MODIS instrument to operate in special modes from time to time to check the calibration. Such modes may be, for example, looking at selected Earth targets, looking at the moon, using a stereo view mode, and so forth.

The CST will have the capability to determine the causes of changes in the instrument calibration, so that changes in the calibration can be corrected based upon solid physical principles. The mathematical model for the instrument is one basis for these studies.

As a further check on the instrument calibration, comparisons of the calibrated MODIS instruments with themselves or with other calibrated satellite and in-situ measurements is a necessary activity of the CST. The CST will have the capability to participate in instrument intercomparisons in an on-going program to verify the MODIS calibration.

The CST will be in contact with the contractor during the Phase C/D studies. Continuity of the Calibration Group and Instrument Group from Phase C/D through launch will be maintained by the CST.

The CST will collaborate with science team members and evaluate the relative merits of different calibration algorithms.

3. SPECIFIC MODIS SCIENCE TEAM MEMBER SCENARIOS

[PHIL]

3.1 <u>Specific Scenario Illustrating Routine Interactions</u>

The following scenario presents the routine interactions of the Team Member and Team Leader with other segments of the MIDACS. This scenario for the routine production of land, ocean, and atmosphere data is presented here as an example of a general type of planning and coordination, and data processing and storage. Three areas of scientific specialty are combined into the routine interactions of the MIDACS. Although they are shown separately to clarify the interactions within the MIDACS, processing of each is considered to take place concurrently.

3.1.1 ROUTINE PLANNING AND COORDINATION

The planning and coordination of three scientific areas of specialty is discussed below and, as shown in Figures 6, 7, and 8, is performed within the box marked MODIS science team on each

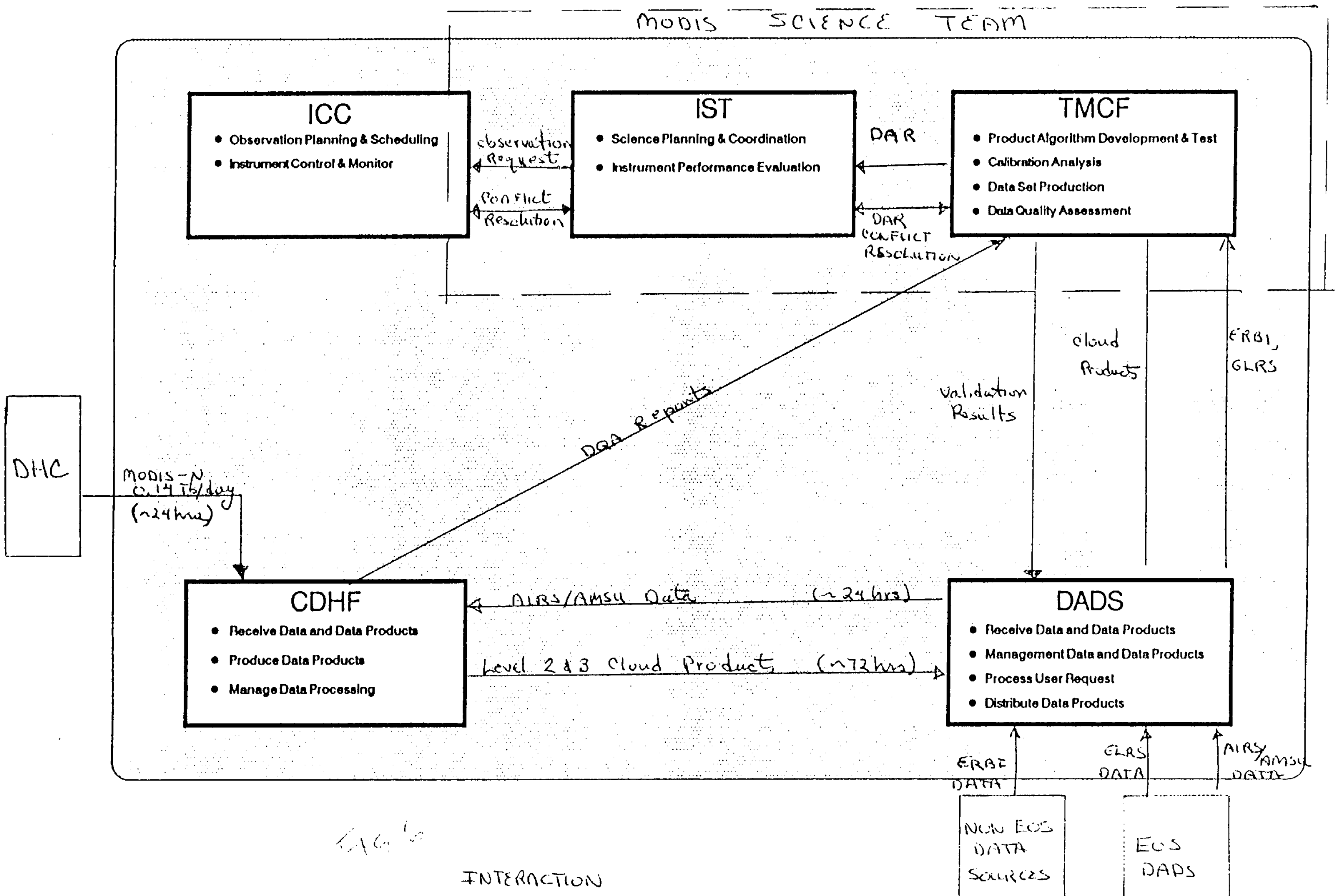
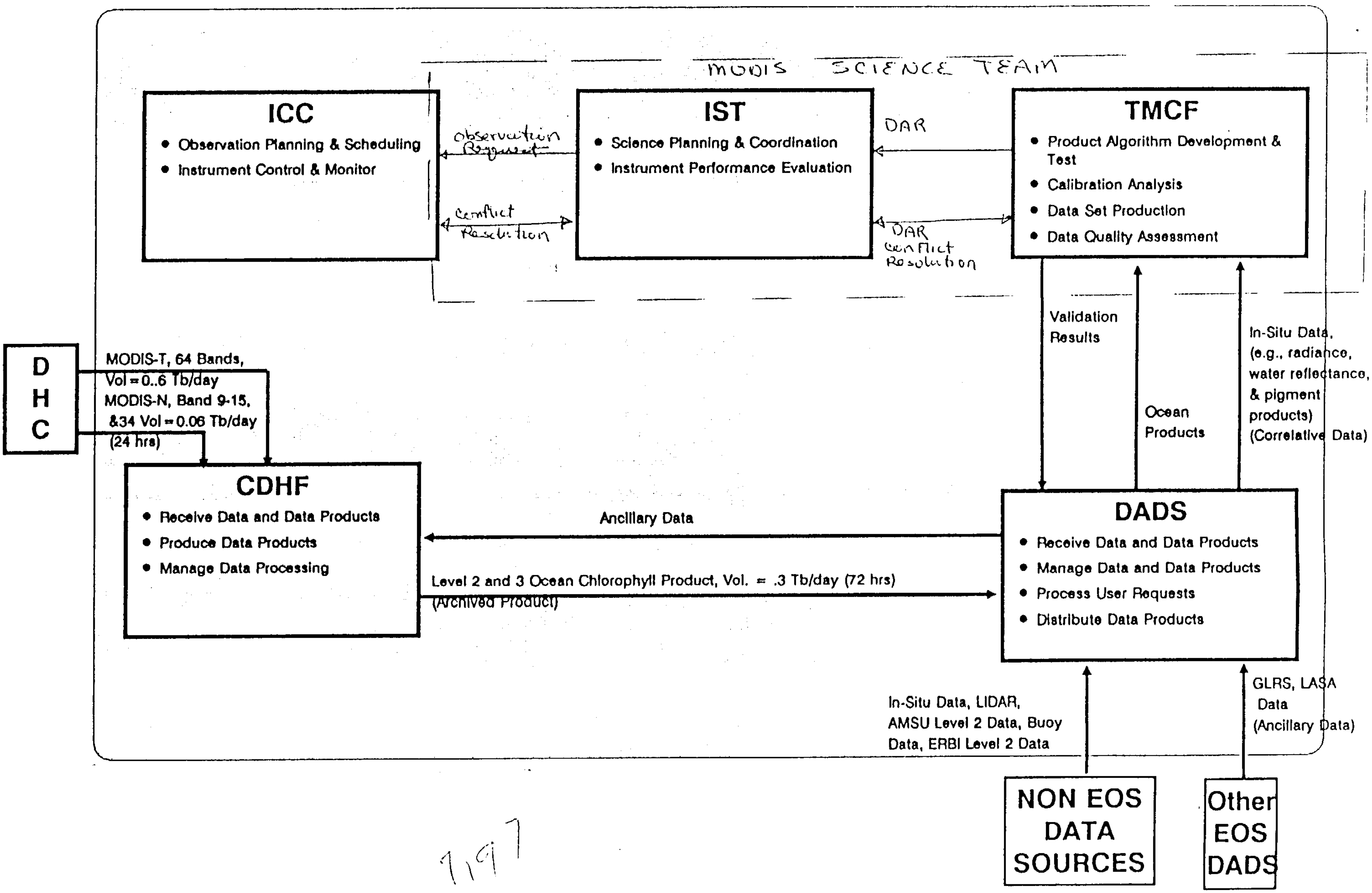


Fig 6

ROUTINE INTERACTION SCENARIO FOR ATMOSPHERE



ROUTINE ~~MIDACS~~ INTERACTION SCENARIO FOR OCEAN
~~(Esaias, Ocean Chlorophyll)~~

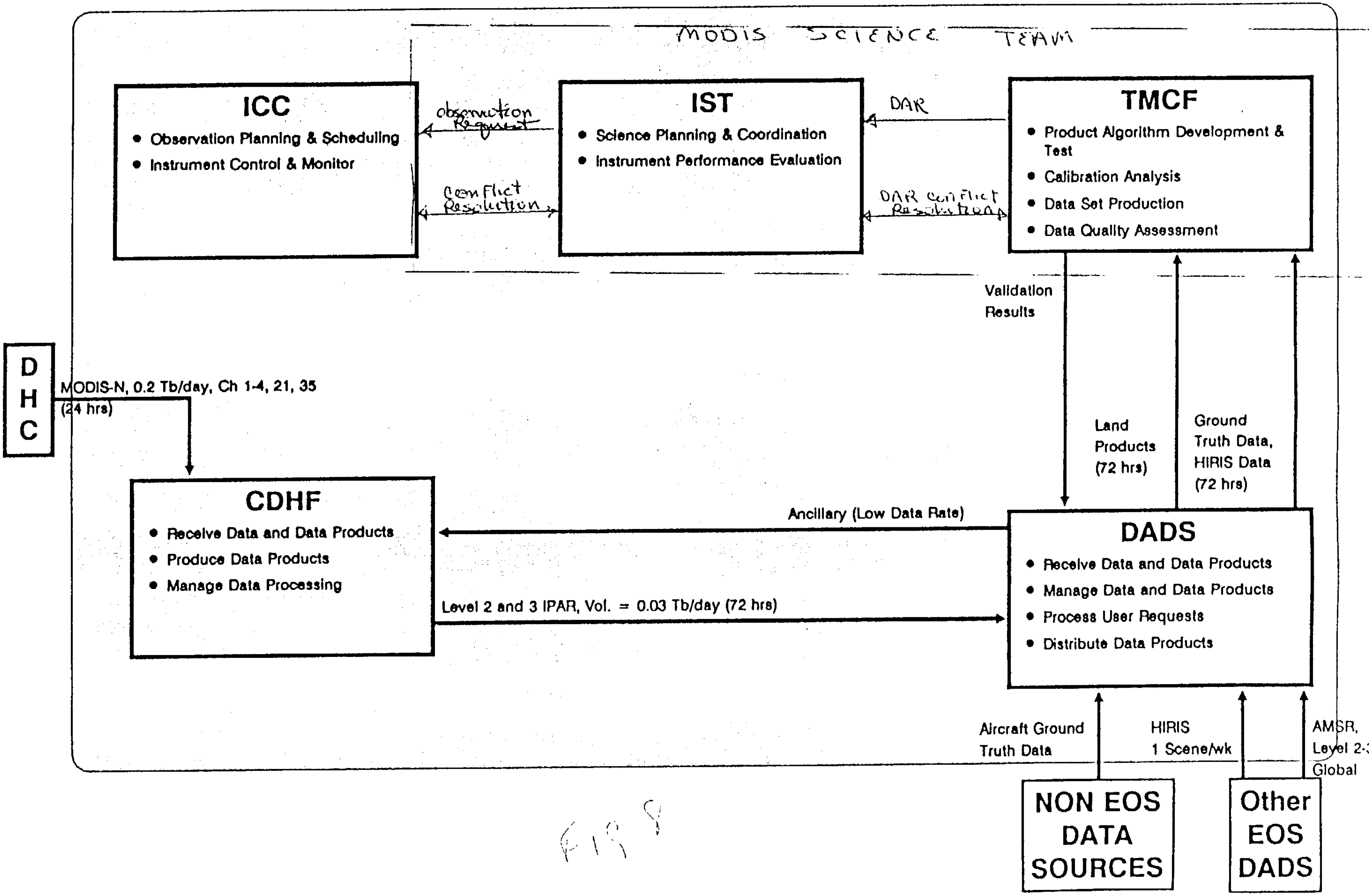


Fig 8

ROUTINE MIDACS SCENARIO FOR LAND
(Salomonson, Biomass/IPAR)

figure. It is assumed that the instrument models used by the ICC have already been tested and approved by the Team Members and are in-place at the ICC. It is anticipated that once the routine operations are implemented, the planning and coordination activities of the Team Members will be minimal if performed at all.

3.1.1.1 Routine Team Member Participation

The Team Members have previously decided on a routine observation plan to pursue. In this routine scenario, each Team Member from the land, ocean, and atmosphere scientific areas of interest propose the use of the MODIS instruments to collect data for their research. Since this is a routine scenario, the planning and coordination activities have been completed following the procedures discussed in section 2 and the Team Member is not required to submit another plan unless he wishes to update or change the routine instrument operations.

3.1.1.2 Routine MIDACS Participation

Using the IST, the Team Leader will have previously submitted an observation request to the instrument operations team (IOT) located at the ICC for weekly conflict resolution and command load generation. The MIDACS wi6l use the routine observation plan, the supplied instrument models, and EosDIS resource envelops to ensure allocated resources are not exceeded. If a conflict exist which prohibits the use of the MODIS, such as a tilt command for a portion of the requested observation time, a notification of the conflict and related information is then sent back to the Team Leader via the IST. The Team Leader resolves the conflict with the respective Team Member. This is shown in the figures by the data flow marked conflict resolution. Upon approval of the schedule by the EMOC, the IOT generates the command loads for this request and they are implemented at the appropriate time.

The routine planning and coordination of the MODIS is simplified by the nature of the instrument and the number and type of commandable instructions. Since the duty cycle of MODIS -N and -T are 100% (50% for the reflected energy channels) and 50%, respectively, a set of commands such as those for pointing (tilt), gain, and day/night mode switching can be routinely uploaded. For the routine observations using MODIS-N, there are no special observation sequences needed for this scenario other than the duty cycle and on/off modes of operation based upon the IWG plan and guidelines. For the Ocean observation using the MODIS-T instrument, as presented below, a request for a tilt or stare mode of operation of MODIS-T was included in the observation request sent to the ICC.

3.1.2 ROUTINE DATA ACQUISITION

It is assumed in these scenarios that the Team Member has developed and tested the processing algorithms on the TMCF resources which are again tested in final form on the CDHF prior to implementation in routine processing. It is also assumed that the observation request has been honored and that MODIS data is available to the CDHF from the DHC for processing.

3.1.2.1 Routine Data Processing

Routine processing of the MODIS data takes place at the CDHF. This processing requires three basic interactions to be performed; ingest of MODIS science data and MODIS ancillary data from the DHC, ingest of additional ancillary data from other data sources such as other EOS DADS, and the processing of this data to provide the Team Member with his product. This scenario assumes that the Level 1-3 processing is done in sequence.

The routine scenario for atmosphere, Figure 6 incorporates the routine processes for the generation of cloud parameters, requiring the coprocessing of data from two different types of instruments: the AIRS and the AMSU which provide specific observations at a coarser resolution. The Team Member then generates and sends a request for these data to be sent to the CDHF from storage on a routine basis. The request is made either by direct communication with the DADS or through the IMC. These data will have already been processed to derive atmospheric temperature and water vapor profiles and surface temperatures and were stored in the respective DADS. Level 1-3 data sets are routinely produced by the CDHF using the MODIS-N earth located and radiometrically calibrated data and ancillary data. As part of the routine processing, cloud products are sent to the DADS after generation at the CDHF. The Team Member request that this data be sent to him along with other selected data. Again, this may be a standing request and will be filled by the DADS, possibly in a automatic operation mode, at a requested time interval.

The routine scenario for Ocean, Figure 7, shows the routine processing for the generation of ocean chlorophyll. Both MODIS-N and -T data are required for this product. This scenario requires the use of other instrument data to generate the product required by the Team Member. After the ocean product has been generated, it is sent to the DADS for dissemination to the Team Member at his request as stated above.

Figure 8 presents the routine scenario for the generation of biomass/IPAR. MODIS-N data is required along with ancillary data. The Team Member has also previously requested that related products be sent to him for future validation of the processed data.

During and after the data processing, the Team Member receives data quality assessment reports (DQRs) from the CDHF on the processing of the requested data. The DQR contain statistical and quality assessment of the data and processing system.

3.1.2.2 Routine Data Storage

All products generated by the CDHF are sent to the DADS for storage. The Team Member accesses his data by requesting it either directly or through the IMC using a TBD (menu driven) system. The data is sent routinely to the Team Member either electronically or via mail on a physical medium. The Team Member can request data from other studies through the IMC or DADS which enable him to validate and verify his results. This may be a routine operation that is performed at the Team Member's discretion. These results are then sent to the DADS for subsequent release to the public.

3.1.3 Summaries

The following table presents some basic Team Member activities. Some of these activities may only occur as an exception once the observations and processing become routine. The Team Member may chose to receive his data either electronically or on a physical medium.

3.1.3.1 Activities

Team Member Action
Reason/link

Submit DAR Propose observation plan,
(also conflict resolution) implemented for coordination Electronic link from TMCF to Team Leader

Submit Observation RequestGeneration of commands and EOS resource conflict resolution Electronic Link from IST to ICC
Submit Data Processing RequestSelect and prioritize data essing Electronic link from TMCF or IST to CDHF

Submit Data Request To
Receive MODIS and other archived data Electronic link to DADS or IMC

Receive data electronically or on physical medium

3.1.3.2 Timeline

The following table presents a routine timeline of activities.

Activities	Timeline	FROM/TO
1. Plan/Coordinate	Weeks-Months before routine operations	
Observation		TMCF/ICC
Synergism		TMCF/ICC
Other Data		TMCF/CDHF-DADS

2.	Receive MODIS data	Within 24 hours from the DHC	DHC/CDHF
	Receive ancillary data	At time interval specified by Team Member	Data Sources/ DADS DADS/CDHF
3.	Process Data Level-2 & Up	Within 8 hours after receiving data Within 72-96 hours after receiving data	CDHF/CDHF
4.	Receive MODIS data	After processing of data, 72-96 hours or at Team Members discretion	CDHF-DADS/TMCF

3.2 Specific Scenario Illustrating Targets of Opportunity

Dynamic phenomena, such as explosive volcanic eruptions (EVE), insect infestations, and human produced or related events, will be detected by MODIS. These events represent targets of opportunity for scientists and require a quick response both by the scientist and MIDACS to study these phenomena. The scientist, presented in this scenario as a science team member, will notify the science team leader of an ongoing event. Specific information necessary to operate the MODIS instruments to study this event will result in the generation of command or observation request by the science team leader which is sent to the ICC via the IST. These requests will impact the current schedule at that time. Figure 9 illustrates the target of opportunity scenario for EVE.

Planning

Since the majority of EVE events are not predictable, the following scenario discusses MIDACS operations for an unpredicted event. The request does not follow the current instrument schedule. The science team member delivers a request to the science team leader at the TMCF, the IST or the IMC for intensive observation of the explosive volcanic eruption. Since the MODIS science team leader is responsible for science planning and the overall stewardship of the experiment and since the team member request has a significant impact upon the present plan and instrument schedule, the team member must present his case for alterations of the plan to the team leader. Since an EVE is of wide scientific interest, the team member's request is expected to be approved. Because of the wide scientific interest of the EVE, the team leader will probably be presented with multiple requests for MODIS operations. The time pressures for immediate data acquisition may place the team leader in a position where he will be unable to consult all team members before arriving at a decision as to which mode of operation MODIS should be placed in. In this case, the team leader will decide which course of action to take. The Science Manage-

This time!

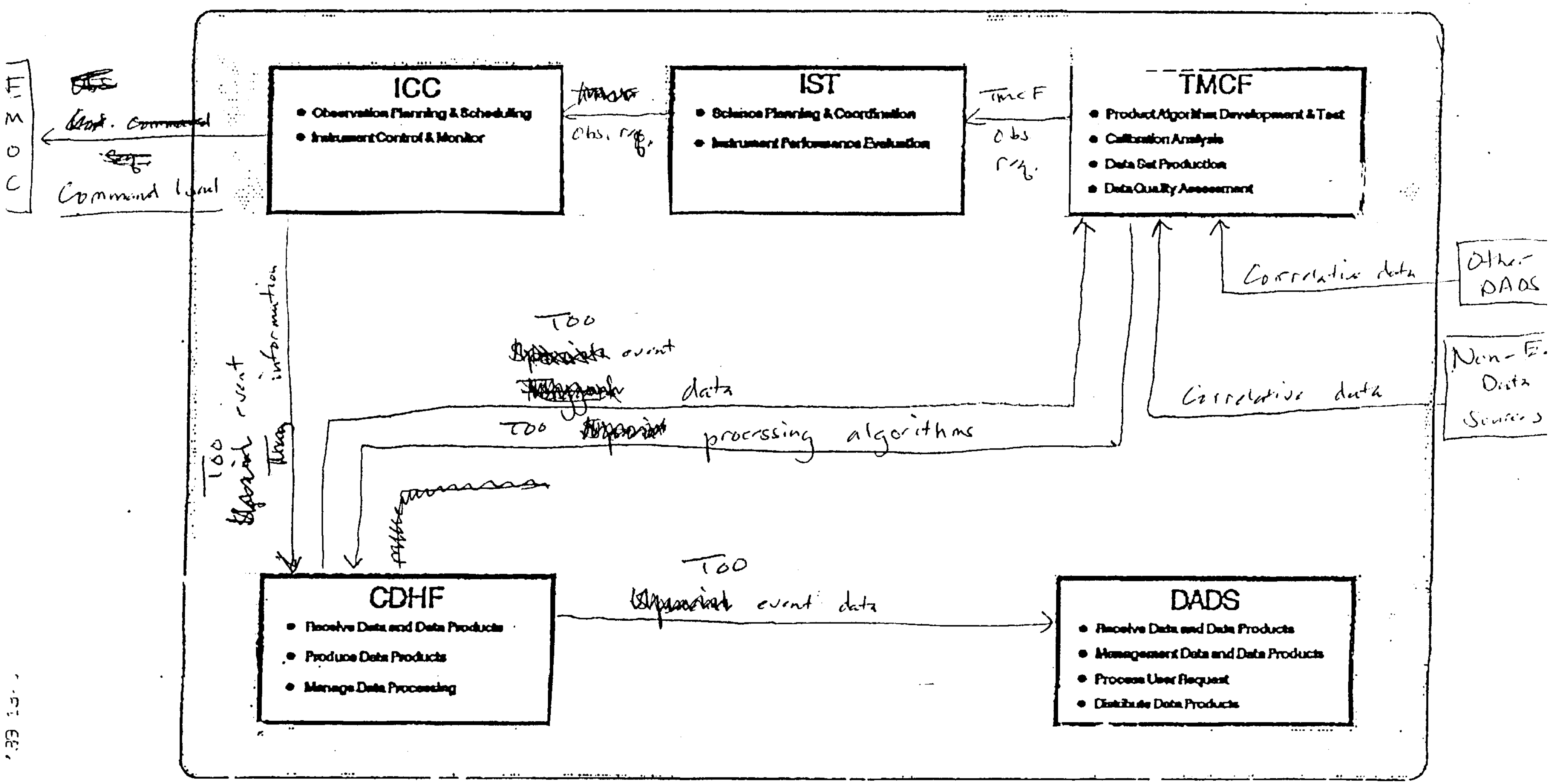


FIG 9

ment Plan may provide a pre-determined and agreed upon plan of action for EVE's and other contingencies. Whatever the course of action, an approved observation request is then transmitted via the IST to the ICC. As an example, this observation request may contain the following information.

> EVE: Eruption of Mt. St. Helens
> EVE start time and duration: 1998, July plus six weeks
> EVE location: State of Washington, USA
> Timeliness requirement: Daily, each observation opportunity for the next 6 weeks
> Near Real-time requirements: First day (day to day decisions thereafter)
> Instrument Unique Operations: MODIS-T in stare mode in each pass over the site

All of the team members, as well as the requesting team member, will be kept informed of the changes in the observation plans by the science team leader. From the point of view of the requesting team member, the MODIS science team leader is the point of contact for all follow-up information and for additional status requests. The science team leader may have a designated assistant to perform most of these mission related duties. The designated assistant might be viewed as an ombudsman for the team members where most routine inquiries can be directed. The ombudsman would allow the science team leader to focus his attention on the overall strategic science planning issues.

In addition to observation requests from MODIS, the team members may also wish to acquire data from other platform instruments for synergistic studies. If these EOS data products are routinely generated, he can contact the IMC to acquire the necessary data. For non-EOS data, the team member will need to acquire it on his own from other data centers.

Scheduling and Commanding

The IOT at the ICC will respond in an appropriate manner to the request. To minimize turnaround time, the ICC may use pregenerated commands developed for such an event or generate the commands from a simulation of the request. The latter may be a shortened process due to the nature of the request. The command load is then verified and sent to the EMOC for resource conflict review. The commands are then uploaded to the instrument according to standard procedures during the next available TDRSS contact. If the event is to be observed in near real-time, the data will be flagged in the DHC so near-real-time processing can be performed at the CDHF. Alternatively, the near-real-time data packets will be assigned a unique process application process ID by the on board MODIS instrument data system in response to a set of stored or real-time commands. Either of these two methods for identifying and seletively acquiring near-real-time data appear to be functionally equivalent from a MODIS science team members point of view. Once the EVE event is over or the duration time span of the observation request to monitor the EVE is exceeded, commands will be issued by the IOT to resume the current weekly schedule that was interrupted.

Monitoring

The ICC will notify the CDHF of the request in order for the CDHF to provide the appropriate processing functions and will notify the science team leader of the status of the request. The IOT will monitor the engineering and science data to ensure that the instrument is responding to the command load. If an anomaly is discovered in the operations, corrective action will be taken by the IOT upon approval by the science team leader.

Data Processing And Archiving

Processing of observation data for explosive volcanic eruptions will follow near real-time processing requirements closely. The CDHF will contain or be provided with an automation code to provide the near real-time processing for the event as requested. An EVE event with MODIS-T in a stare mode during a portion of many orbits may require special processing at the CDHF. Presumably an event of this nature will be planned for and algorithms will have already been developed to study the EVE. These algorithms will be submitted to the CDHF, probably by the SDPST, along with the raw EVE data. A special data product may result, such as the production of a film of the eruption plume using many flybys of the event. The DADS will be notified by the science team leader to anticipate the receipt of the EVE data as soon as it is processed. The DADS verifies, stores, and transmits the data to the originator of the request.

3.3 Specific Scenarios Illustrating Field Experiments

[PHIL and MIKE]

3.4 Specific Scenarios Illustrating MODIS Calibrations

The scenario presented here, Figure 10, provides a chronological summary of how calibration operations may proceed in the event that a science team member wishes to have the MODIS instrument undergo a special calibration. The scenario attempts to identify who will be involved and how they will interact. Since the scenario assumes that routine calibration planning is done in one week blocks, most of the steps in the scenario will be occurring simultaneously as each of the weekly plans progresses through the system. In this particular scenario, we assume that a particular science team member has reason to believe the MODIS calibration may be in error. The team member first wishes to test the instrument by putting the instrument in a special operations mode. Simultaneously we assume he wishes to acquire a set of calibration coefficients and other data, but is not certain exactly what procedure to follow. His point of contact in MIDACS for a study of this nature is the calibration scientist who leads the CST.

Calibration Scenario

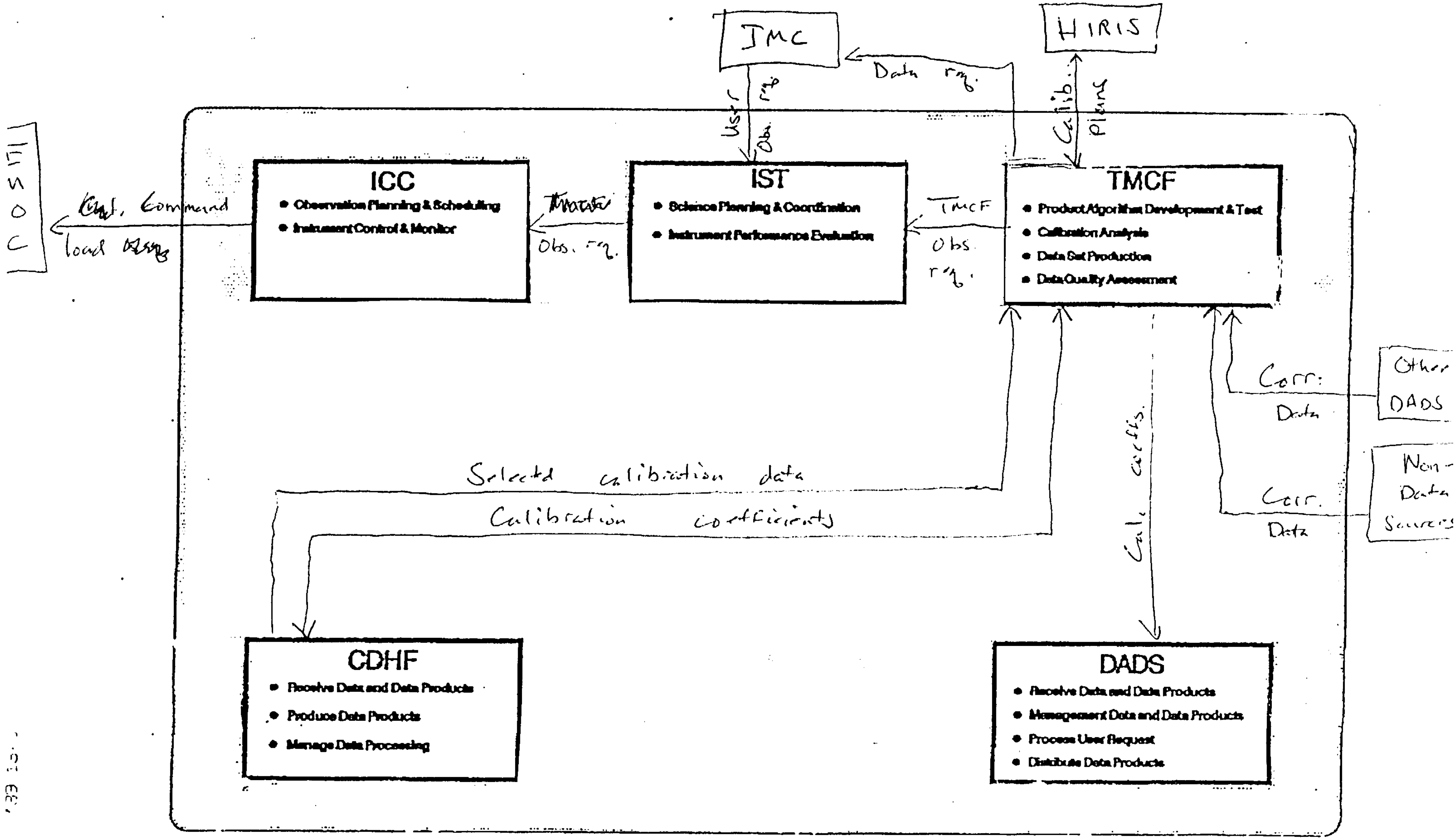


Fig 10

The CST normally maintains and evaluates the instrument calibration. It is a resource within MIDACS for all issues concerning calibration.

The time T in the scenario below is the time that a calibration sequence is actually performed.

T minus 6 weeks: The science team member notifies the CST of his concern with the MODIS calibration and requests that a particular calibration sequence be performed to test his hypothesis. The CST concurs and adds the requested test to its next planning meeting in one week.

T minus 5 weeks: The CST as part of its normal operating procedures consults with the HIRIS CAL and with other calibration teams of instruments on the EOS platform, informing them of the upcoming calibration plans. The science team member request has been incorporated in the MODIS calibration plan. The calibration observation plans of the two or more instruments are coordinated so that instrument comparisons are possible.

T minus 4 weeks: The CST decides on a schedule of observations that they want for a one week period, four weeks in the future. They wish to examine intensively their Earth targets of opportunity as a response to the team member request. The calibration scientist, or his designate in the CST, using an interactive menu-driven program developed jointly with the IOT, determines the times (GMT) and orbit numbers when the EOS platform will be over the selected targets within 10 degrees of vertical during the week in question. The CST incorporates this derived information in the proposed observation plan, an example of which follows.

Initially Proposed Weekly Schedule

All days: Deploy solar diffuser plate on one orbit each day as satellite crosses the Earth's terminator (nearest 00 GMT).

Day 1: Normal operations. No special mode changes.

Day 2: Observe Earth targets: White Sands, the central Sahara, the Atacama desert, and Greenland during orbits n, n+3, n+4 and n+9.
MODIS-T in nadir position.
During a night orbit, sequence lamps through 3 levels.
Tag all special data sets for CDHF/TMCF.

Day 3: Observe Earth target: South Pacific region.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 4: Night time orbit: observe dark side of Earth, perform spectral calibration, and perform electronics calibration.
Tag data for CDHF/TMCF.

Day 5: Observe targets: White Sands, the central Sahara, the Atacama desert, the South Pacific region, and a second South Pacific region.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 6: Observe targets: the Arabian peninsula, Alice Springs, and the Kalahari Desert.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 7: Observe targets: White Sands, the central Sahara, and the two South Pacific regions.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Scheduling and Commanding

T minus 3 weeks: The science team leader received the proposed calibration plan from the CST one week ago. He also received proposed observation plans from several other science team members and from other users via the IMC. As part of the initial screening process, the plans are entered into an expert system on a computer which identifies possible conflicts in observations. The science team leader and science team members are provided with copies of the list of observation conflicts. The science team leader in consultation with the science team members reviews the conflicts. The CST proposal to observe the Atacama desert on days 2 and 5 requires MODIS-T to be in the nadir position which conflicts with proposed ocean chlorophyll observations requiring MODIS-T to be in a tilt position. The science team leader decides ocean chlorophyll measurements have higher priority based upon IWG guidelines and eliminates the Atacama desert observations from the CST observation plan. The conflict free plan is sent to ICC using the IST.

T minus 2 weeks: ICC tests the plan on their simulator and finds no problems. ICC in consultation with EMOC reviews the impact of the plan on the platform operations. In this case we assume a conflict is found requiring the CST to cancel or re-schedule the night observations of the lamps scheduled on day 2. ICC notifies the science team leader who in turn notifies the CST of the conflict. The CST revises their plan to have the night observations on day 3 rather than day 2. The conflict resolution procedure described above is repeated with no further observation changes required in the second go-round. The HIRIS CAL and other instrument calibration teams are kept informed of all developments within MIDACS relating to the coordinated calibration plan.

T minus 1 weeks: The ICC writes the command sequences which will be executed in the following week. These command sequences will include a tag which will be appended to the header of the data requested by the CST so that they can easily identify the data sets that they requested. An alternative scenario would require the CST to simultaneously notify CDHF of the observations plan and require CDHF to somehow extract the requested data from the data stream.

T plus hours: However the data are extracted, the CDHF writes the data to a disk on an account maintained by the CST at the CDHF. A mail message is sent to the CST notifying them that new data have arrived. The CST downloads the new data to their TMCF for more detailed analysis. A copy of a subset of the calibration data acquired as a result of the science team member's earlier request is transferred to his TMCF either electronically or by overnight mail as appropriate.

T plus 1 day: The CST uses the newly acquired data to derive gains for the detectors. Based upon this analysis, the CST decides that several detectors have changed sufficiently that revised calibration coefficients are required. The science team member who requested the special calibration sequence is informed of these developments. This team member may also have performed his own independent analysis and he can compare results with the calibration scientist. An updated table of coefficients is sent to CDHF with the time at which it becomes effective. The CDHF uses the coefficients in its routine processing of Level-1 data. Simultaneously, the CST sends this information to the DADS for archiving.

Usually the calibration coefficients are automatically derived using the CDHF and normally there is no additional examination of the data by the CST. It is likely that one entire orbit's worth of calibration data will be used to derive the calibration coefficients.

T plus 3 days: The CST contacts the IMC and requests the HIRIS data taken in the plan be sent from their DADS to the CST.

T plus 5 days: The CST receives the HIRIS data.

T plus 1 week: Both the CST and the interested science team member use the Earth TOO data for more detailed analysis of the MODIS instrument performance. Much of this analysis may be of the form of interactive image processing using a version of the Land Analysis System (LAS) software of Landsat or PACE (the software package used by the Canadian Centre for Remote Sensing). Typically the HIRIS spatial and spectral resolution would be degraded to match the MODIS resolution and then the differences between the two equivalent images would be studied. These analyses may confirm previously observed instrument changes have occurred, may lead to reprocessing, or the development of new calibration algorithms.

3.5 Specific Scenarios Illustrating Algorithm Development and Implementation

Algorithm development and implementation will be occurring both prior to launch and after launch. In this scenario, we list some of the steps that may be encountered in a typical developmental program with a typical time line.

An algorithm developer will have several points of contact within MIDACS. First will be the science team leader and other science team members. At science team meetings and through the Science Management Plan, all developers will be kept informed of what algorithms are being developed. A second point of contact is the SDPST. The SDPST will be polling the team members to determine if there are certain algorithms that they should develop so that several team members will not unnecessarily duplicate each others work. The SDPST will examine the computer code developed by the team members and, if necessary, will modify it so as to most efficiently use the computer architecture of the CDHF. The SDPST will also keep the team members informed of EosDIS programming standards and EosDIS standards for data formats. They will aid the science team members in meeting EOS goals.

T in this scenario is the algorithm implementation date and possibly the launch date.

T minus 5 years: The science team member receives sufficient computing resources from the MODIS Project Office so that he can start algorithm development.

T minus 2 years to T minus 2 months: A prototype algorithm is developed and debugged by a science team member. It is submitted to the CDHF for timing tests. Computer scientists at the GSFC TMCF node and CDHF (the SDPST) begin examination of the software code and look for methods to increase the efficiency such as vectorization. The SDPST also provides the science team member with some subroutines which aid in his algorithm development, such as some data input/output and plotting subroutines. Finally the SDPST keeps the algorithm developer informed about EosDIS data format standards and programming language standards. The science team member continues to check the accuracy and validity of the algorithm.

T minus 2 months to T minus 1 month: Using lower-level MODIS data generated by the CDHF and using the CDHF computers, the science team member and computer scientists have interacted to increase the code efficiency, with runs requiring about 1/3 to 1/100 the computer time that the initial code required. No loss in accuracy has occurred and the CDHF computer architecture is fully exploited.

T minus 1 month: The algorithm is formally delivered to the CDHF by the science team member, along with all certification and DQA criteria needed for autonomous processing.

T minus 1 week: The CDHF automated/expert system processing code is updated to bring the new algorithm on line. The science team leader issues an Algorithm Release Announcement, which states the algorithm will be implemented in one week and gives information on what standard data products will be produced. All team members and the EOS Project Office among others will be kept informed this way.

T: The algorithm is applied to Level-1A or -1B data and generates a Level-2 product. Browse, metadata, and catalog data are generated. The certification criteria are tested.

T plus 1 day: DQA indicates a change in the algorithm is needed. For the purposes of this scenario, we assume that the initial validation tests indicate a problem exists with the algorithm and that the certification criteria are not being met. The CDHF withdraws the algorithm from routine processing. The defective data are sent to the DADS as uncertified and are only available to the science team.

T plus 2 months: The science team member has located the problem in the code and fixed it. The revised algorithm is resubmitted to the CDHF and the CDHF reinstalls it in its Level-2 processing stream.

T plus 2.2 months: Archival of the geophysical parameter starts since it is now a certified standard product. The science team leader, based upon the most recent validation studies, certifies the algorithm and issues an Algorithm Release Announcement. Simultaneously, retrospective processing on the backlog of data, taken prior to the implementation of the algorithms, is used to derive the new standard product. The required input data are acquired from the DADS and sent directly to the CDHF for processing at twice the MODIS acquisition rate.

T plus : As the MODIS experiment continues, the scientific algorithm is updated and maintained as required. The maintenance of algorithms is an ongoing aspect of the experiment.

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APPENDIX A
DESCRIPTION OF STANDARD DATA PRODUCTS

All collected MODIS data will be processed to scientifically usable data levels. The data will be routinely processed to higher-level data at a central data processing facility. These data are called standard data products. The descriptions of the processing levels at which standard data products will be produced are given below:

Level-0: Time-ordered instrument data, redundancies removed, bit-error corrected, and quality-assessment annotated.

Level-1A: Instrument data with ancillary and engineering data needed to complete processing appended. Earth locations are computed and reversible radiometric calibrations have been applied. The highest level of data to be reversible to Level-0 data.

Level-1B: Level-1B data are irreversibly processed from Level-1A, and will only be produced if the MODIS Level-1 processing generates data products from which Level-0 data cannot be recovered. Under these circumstances, both Level-1A and -1B products will be produced and archived.

Level-2: Geophysical parameters derived from Level-1B data, and at the same resolution as Level-1B data. A list of candidate parameters is included in Appendix A.

Level-3: Radiances or other geophysical parameters that have been geometrically rectified and resampled onto space-time grids.

Level-4: Model or analysis results of lower-level products from the MODIS instrument and products from other instruments or sources.

There will be other types of standard data produced from the above data products. These data will contain summaries of products, coarse resolution data, or other information, and include:

Browse Data: Browse data products accompany all archived data products and are provided to assist data users in selecting data that is suitable for their purposes. They are not meant to be used as input to processing algorithms that produce higher-level parameters from lower-level products. In addition, the date or dates of observations, instrument type designators, product type designation, spectral band, and instrument tilt angle for each image may be displayed on the browse images.

Metadata: All MODIS data delivered to the archives may be handled in blocks, or "granules;" each granule will have appended a descriptive header describing the data within the block. In the archive, this header data will be used in a data base management system (DBMS) to facilitate a user's access to the full-resolution and browse-resolution MODIS data for display and ordering purposes.

In addition to standard data products, there will be other types of data products archived and available to users. These special data products are considered to be part of a specific research investigation and are produced for a limited region or time period. New or experimental products may eventually be accepted by the research community as standard products and will then be processed routinely. The special data products should meet the same requirements as the standard data products.

APPENDIX B

MODERATE RESOLUTION IMAGING SPECTROMETER (MODIS) SCIENCE TEAM MEMBERS BY DISCIPLINE WITH A PRELIMINARY PARTIAL LISTING OF ASSOCIATED SPECIALIZED AND STANDARD DATA PRODUCTS

ATMOSPHERIC SCIENCES

ATMOSPHERIC AEROSOLS:

1. Yoram J. Kaufman, Science Systems & Applications, Inc., Seabrook, MD; "Global Monitoring of Aerosols Properties - Aerosol Climatology, Atmospheric Corrections, Biomass Burning, and Aerosol Effect on; Clouds and Radiation."

   Candidate Data Products:

   a. Aerosol climatology
   b. Atmospheric corrections
   c. Biomass burning
   d. Aerosol effect on clouds and radiation.

2. Michael D. King, GSFC, Greenbelt, MD; "Determination of Cloud and Aerosol Radiative and Microphysical Properties from MODIS-N."

   Candidate Data Products:

   a. Aerosol optical thickness
   b. Aerosol size distribution
   c. Aerosol index of refraction
   d. Aerosol single scattering albedo

3. Didier Tanre, Univ. des Sciences et Techniques de Lill, Villeneuve d'Ascq, FRANCE; "GLobal Aerosols Monitoring Experiment from Space G.A.M.E.S. (Transport and Radiative Properties)."

   Candidate Data Products:

   a. Aerosol radiative properties
   b. Aerosol transport processes

CLOUDS:

1. W. Paul Menzel, NOAA/NESDIS, Madison, WI; "The Investigation of Cloud Properties with MODIS-N."

   Candidate Data Products:

   a. Cloud properties with MODIS-N

2. Joel Susskind, GSFC, Greenbelt, MD; "Determination of High Resolution Atmospheric and Surface Parameters from MODIS-N."

Candidate Data Products:

a. Effective cloud fraction
b. Cloud top pressure
c. Outgoing longwave radiation
d. Longwave cloud radiative forcing

RADIATIVE TRANSFER MODELS:

1. Alan H. Strahler, Boston University, Boston, MA; "Mapping Spectral Directional Radiance, Spectral Directional Surface Radiance, and Spectral Bidirectional Reflectance; Distribution Functions for Land Surface Covers using MODIS-T."

   Candidate Data Products:

   a. Spectral directional radiance
   b. Spectral directional surface radiance
   c. Spectral bidirectional reflectance
   d. Distribution functions for land surface covers using MODIS-T

<u>LAND SCIENCES</u>

VEGETATIVE PROPERTIES:

1. Christopher O. Justice, UMd, College Park, MD; "Monitoring Global Vegetation Dynamics using MODIS-N."

   Candidate Data Products:

   a. Vegetation index
   b. Vegetation dynamics
   c. Atmospheric corrections

2. Vern Vanderbilt, ARC, Moffett Field, CA; "Estimation of Photosynthetic Capacity using MODIS Polarization."

   Candidate Data Products:

   a. Photosynthetic capacity using MODIS polarization.
   b. Polarized leaf reflectance

CARBON AND OTHER BIOLOGICAL CYCLES:

1. Frank E. Hoge, Wallops Flight Center, Wallops Island, VA; "Species Variability and Improved Carbon and Nitrogen Cycling Determinations."

   Candidate Data Products:

   a. Species variability
   b. Improved carbon and nitrogen cycling determinations

2. Alfredo R. Huete, UAz, Tucson, AZ; "Determination of Dynamic Vegetation - Soil - Organic Carbon Interactions with MODIS Instrument Observations."

Candidate Data Products:

a. Determination of dynamic vegetation - soil - organic carbon interactions

3. Steven W. Running, University of Montana, Missoula, MT; "Canopy Carbon and Water Fluxes from Terrestrial Vegetation: Development of EOS/MODIS."

Candidate Data Products:

a. Canopy carbon fluxes
b. Canopy water fluxes
c. Normalized difference vegetation index

PHYSICAL PROPERTIES:

1. Jan-Peter Muller, University College London, London, England, UK; "Mapping the Composition and 3D Structure of Terrestrial Surfaces from a Synergistic use of EOS Instruments and Numerical; Simulation Models."

Candidate Data Products:

a. Composition of terrestrial surfaces
b. 3D structure of terrestrial surfaces
c. Simulation modelling

2. MODIS Team Leader - Vincent V. Salomonson, GSFC, Greenbelt, MD; "The Dynamics of Snow and Ice Cover Over Large Areas and Relationships to Surface Radiation Balance Components as Observed; by MODIS N and T."

Candidate Data Products:

a. Snow and ice cover
b. Surface radiation budget components
c. Dynamics of snow cover

3. Zhengming Wan, Institute of Remote Sensing Application, Beijing, CHINA; "Land Surface Temperature Measurements from EOS/MODIS Data."

Candidate Data Products:

a. Land surface temperature measurements

<u>OCEAN SCIENCES</u>

GLOBAL BIOLOGICAL PROPERTIES:

1. Mark R. Abbott, OSU, Corvallis, OR; "Studies of Primary Production in the World Ocean Using Data from the Moderate Resolution Imaging Spectrometer (MODIS)."

   Candidate Data Products:

   a. Primary production in the world ocean

2. Wayne Esaias, GSFC, Greenbelt, MD; "Oceanic Productivity and Photosynthetic Efficiency."

   Candidate Data Products:

   a. Ocean chlorophyll
   b. Diffuse attenuation coefficient
   c. Oceanic productivity
   d. Photosynthetic efficiency

3. Otis B. Brown, UMiami, Miami, FL; "Infrared Algorithm Development for Ocean Observations with EOS/MODIS."

   Candidate Data Products:

   a. Infrared algorithm development for ocean observations
   b. Multiple orbit averages with reduced spatial resolution
   c. Mesoscale oceanic phenomena

4. Howard R. Gordon, UMiami, Coral Gables, FL; "Algorithm Development for Ocean Observations with EOS/MODIS."

   Candidate Data Products:

   a. Algorithm development for ocean observations
   b. Raleigh scattering calculations

5. Robert H. Evans, UMiami, Miami, FL; "Processing and Calibration for Visible Ocean Observations with EOS/MODIS."

   Candidate Data Products:

   a. Processing algorithms for visible ocean observations
   b. Multiple orbit averages with reduced spatial resolution
   c. Mesoscale oceanic phenomena

REGIONAL BIOLOGICAL PROPERTIES:

1. Kendall L. Carder, University of South Florida, St. Petersburg, FL; "High Spectral Resolution MODIS-T Algorithms for Ocean Chlorophyll in Case II Waters."

   Candidate Data Products:

a. Ocean chlorophyll in case II waters

2. John Parslow, CSIRO, Hobart, Tasmania, AUSTRALIA; "Ocean Color Algorithm Development and Processing of MODIS-T Data for Australian Waters."

   Candidate Data Products:

   a. Ocean color for Australian waters

PHYSICAL PROPERTIES:

1. Ian Barton, CSIRO, AUSTRALIA; "The use of MODIS-N Data in the Derivation of Accurate Global Sea Surface Temperature Data Sets."

   Candidate Data Products:

   a. Global sea surface temperature

2. Dennis K. Clark, NOAA/NESDIS, Washington, DC; "Marine Optical Characterizations."

   Candidate Data Products:

   a. Marine optical characteristics

<u>CALIBRATION STUDIES</u>

1. MODIS Team Leader - Vincent V. Salomonson, GSFC, Greenbelt, MD; "The Dynamics of Snow and Ice Cover Over Large Areas and Relationships to Surface Radiation Balance Components as Observed; by MODIS N and T."

   Candidate Data Products:

   a. MODIS-N calibration
   b. MODIS-T calibration

2. Robert H. Evans, UMiami, Miami, FL; "Processing and Calibration for Visible Ocean Observations with EOS/MODIS."

   Candidate Data Products:

   a. Calibration for visible ocean observations

3. Philip N. Slater, UAz, Tucson, AZ; "Absolute Radiometric Calibration of MODIS-N and other EOS Imaging Sensors."

   Candidate Data Products:

   a. Absolute radiometric calibration of MODIS-N

APPENDIX C
ADDITIONAL CANDIDATE LEVEL-2 PRODUCTS

LAND SURFACE COMPOSITION (soil types, rock types, available soil moisture, soil thermal inertia, and soil particle size).

LAND SURFACE BIOLOGICAL ACTIVITY (reflected near-infrared radiation, reflected photosynthetically active radiation, leaf-area indices, plant and crop types, ecological zone classifications, plant temperature, plant productivity, plant stress, photosynthesis rate, and canopy state).

OCEAN CIRCULATION (velocity vectors, areal extent of eddies, sea surface temperature, and suspended sediment concentration).

OCEAN AND LAKES BIOLOGICAL ACTIVITY (primary production rate, pigment concentration or groups, suspended sediment concentration, gelbstoffe concentration, chlorophyll concentration, phalophatin concentration, marine humus concentration, fulvic acid concentration, species composition, phytoplankton biomass, and chlorophyll fluorescence).

AEROSOLS (optical depth at specified wavelengths, aerosol size distribution, aerosol height distribution).

CLOUD PROPERTIES (cloud-top height, fractional cloud cover, cloud albedo and optical depth, cloud-top temperature, cloud emissivities, precipitation rate, amount, and latent heat flux, and the identification of cloud-free areas for other instruments).

EARTH RADIATIVE BUDGET (planetary albedo, surface albedo, surface temperature and emissivity, outgoing longwave radiation, upward and downward net surface longwave radiation, sensible heat flux and the Bowen ratio, heat flux into Earth, net radiation at atmospheric top, net, shortwave, and longwave cloud-radiative forcing, and the rate of entropy production).

ATMOSPHERIC TEMPERATURE AND COMPOSITION (temperature and specific humidity at a number of levels, total ozone content, carbon dioxide content, and total precipitable water).

SNOW AND ICE COVER (snow and ice extent, albedo, age, emissivity, and surface temperature, bidirectional reflectance models, and polynya area).

APPENDIX D
ISSUES RELATED TO REQUIREMENTS ON DATA

To ensure that the science team members' requirements relating to the MODIS data are properly addressed, certain fundamental issues must be considered, some of which may directly impact the design of the MODIS instrument and the polar platform itself.

1. One of the data requirements is the location of a pixel with an error of less than 10% of the pixel size (which ranges 250 to 1000 m) at nadir. This requirement can be met only through the accurate determination of the sub-satellite position and accurate attitude information. The current platform design will result in more than a 100 arc second uncertainty in attitude and 50 m of uncertainty in sub-satellite position determination, which will not meet the requirement. So, MODIS must have its own star tracker which can determine the attitude within 4 arc seconds, and will require the platform to determine the sub-satellite position uncertainty to less than 10 m.

2. Another requirement on the data is that, after corrections are made, the bit error rate (BER) should be less than 10^{-8}. At a BER of 10^{-12}, on average only one bad MODIS bit will be encountered every day. However, at a BER of 10^{-8}, 10^{4} bad bits will be encountered daily. The packets with uncorrectable errors will be flagged as such by the DHC. Each packet will consist of up to 10^{4} bits. In general, it will not be possible to identify the bad bit in a flagged packet. As a result, it may be necessary to reject up to 10^{8} bits of MODIS data per day; this is the equivalent of ten seconds of data out of 86,400. The current Grade II service of the TDRSS will meet this BER requirement.

3. A third requirement describes the completeness of MODIS data coverage. The MODIS instrument is capable of operating simultaneously in two modes. These have been termed the "survey instrument" mode and the "observatory instrument" mode. The survey instrument takes continuous observations and regularly observes the entire Earth. The observatory instrument acquires data only in response to a user's data acquisition request (DAR). Each of these modes will have a different level of allowable data loss.

   When data collection is dictated by a response to a DAR, there is a specific requirement for the data. The need for the data may be critical (e.g., supporting and directing aircraft flights), or alternate data may be acceptable (e.g., from two days later). It must be assumed that a 100% coverage requirement applies to the DAR, and that none of the requested MODIS data may be lost. Should a conflict arise that will result in the loss of the data covered by the DAR, then the MODIS science team leader must be involved in the resolution of the conflict.

When data collection is not dictated by a response to a DAR, the extent of lost MODIS data will be driven by the science requirements on the accuracy of the geophysical parameters (including the radiances). These requirements have not yet been formally stated, and will no doubt vary from parameter to parameter. It may be necessary to conduct system simulation studies to assess the impact of data gaps on the product accuracies. However, it is clear that no spatially systematic gaps in data coverage will be tolerable. Only non-systematic (random) data losses will be allowable.

At present, the requirement on the data coverage is not specified. To help to understand this requirement, consider the following computation: completeness to only the 99% level would result in a loss of 15 minutes of coverage per day. At the 6.5 km per second velocity of the satellite, this is about 51° in latitude, or about a 5600 km along the orbit with the full swath. Because MODIS data will be used to produce products with global coverage, missing data will degrade the quality of the final product. The Science Team may require that no systematic MODIS data losses occur.