MODIS DATA STUDY
TEAM PRESENTATION

September 8, 1989

AGENDA

1. Status of the MODIS Data Study Task
2. An Analysis of Uncompensated Momentum on MODIS Location Accuracy
3. Determination of Aerosol Size Distribution from Spectral Optical Depth Measurements
4. MODIS Science Requirements and Recommended Data Packet Structures
5. Considerations Regarding the Direct Broadcast of MODIS Observation Data

MODIS DATA SYSTEM STUDY
APPROVAL
ACCOMP.

Summary of Deliverables

Page 1 of 1

ORIG. APPVL. 06/24/88
LAST CHANGE 08/01/89
STATUS AS OF 09/01/89

	MILESTONES
01	Prel Data Requirements Doc
02	Non-Advocacy Review Materials
03	EosDIS/MIDACS I/F Comparison
04	Scenarios for Science Team
05	Prel TM Sci Prod Summary
06	Support MODIS Science Team Mtg
07	Input Data Attributes Report
08	Prel Core Prod Algorithm Rep
09	Prel TM Core Prod Analysis Rep
10	Core Data Proc Scenario Doc
11	Support MODIS Science Team Mtg
12	Prel MODIS Proc/Stor Req't Doc
13	Utility/Sup't Algo Req'ts Doc
14	MODIS SDST/ICT Requirem'ts Doc
15	Core Product Requirements Doc
16	
17	
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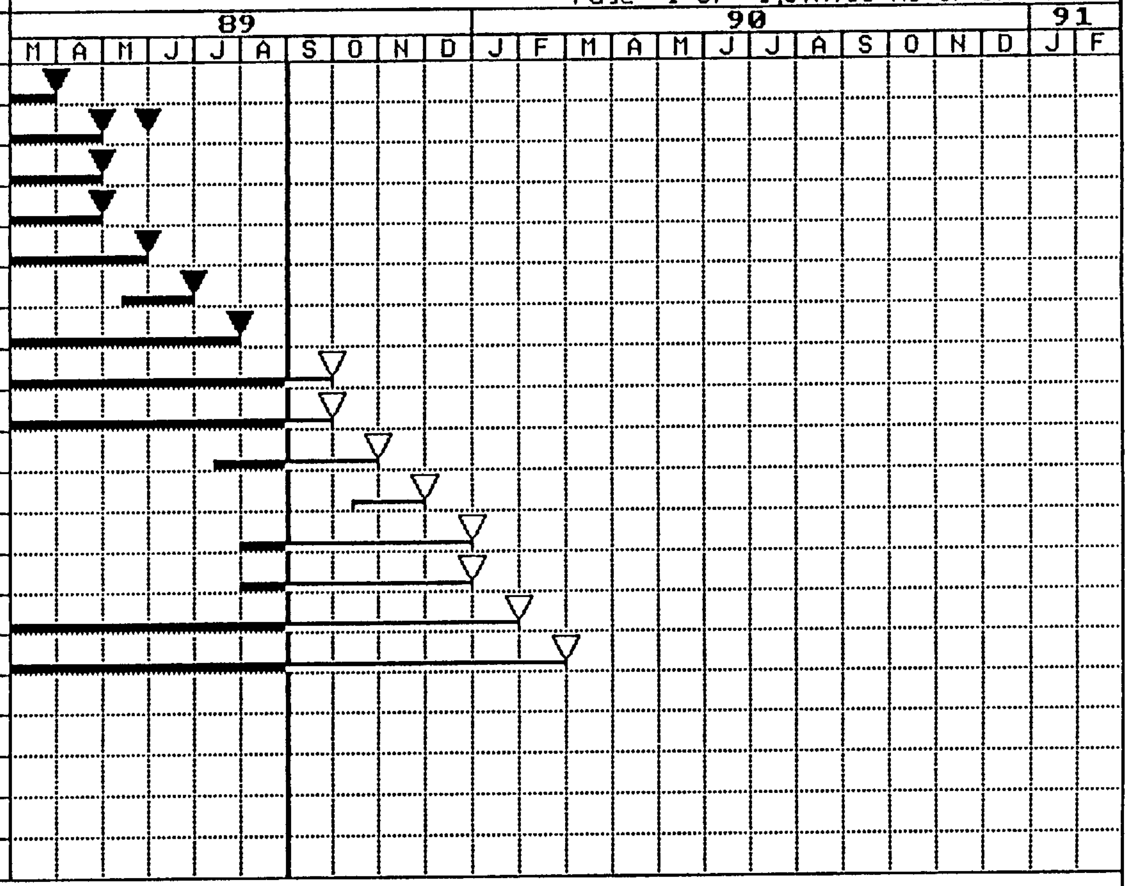


Note:

AN ANALYSIS OF UNCOMPENSATED MOMENTUM ON MODIS LOCATION ACCURACY

1. Statement of the Problem

The attitude of the polar platform carrying MODIS-N and MODIS-T will be perturbed about all three axes (pitch, yaw, and roll) due to internal sources of uncompensated angular momentum. These perturbations will occur at relatively high frequencies (e.g., 1 Hz) as instruments scan the Earth. Multiple scanning instruments will scan about different azimuths, and with varying phase relationships. If the attitude perturbation is significant (i.e., approaching 1/10 pixel), then the platform attitude must be sampled at least to the Nyquist frequency of the payloads (twice per scan) to resolve the effect. If the perturbation is negligible, then the operation of instruments on the platform can be neglected in defining the MODIS requirements for platform ancillary data.

1. Technical Approach for Multiple Instruments

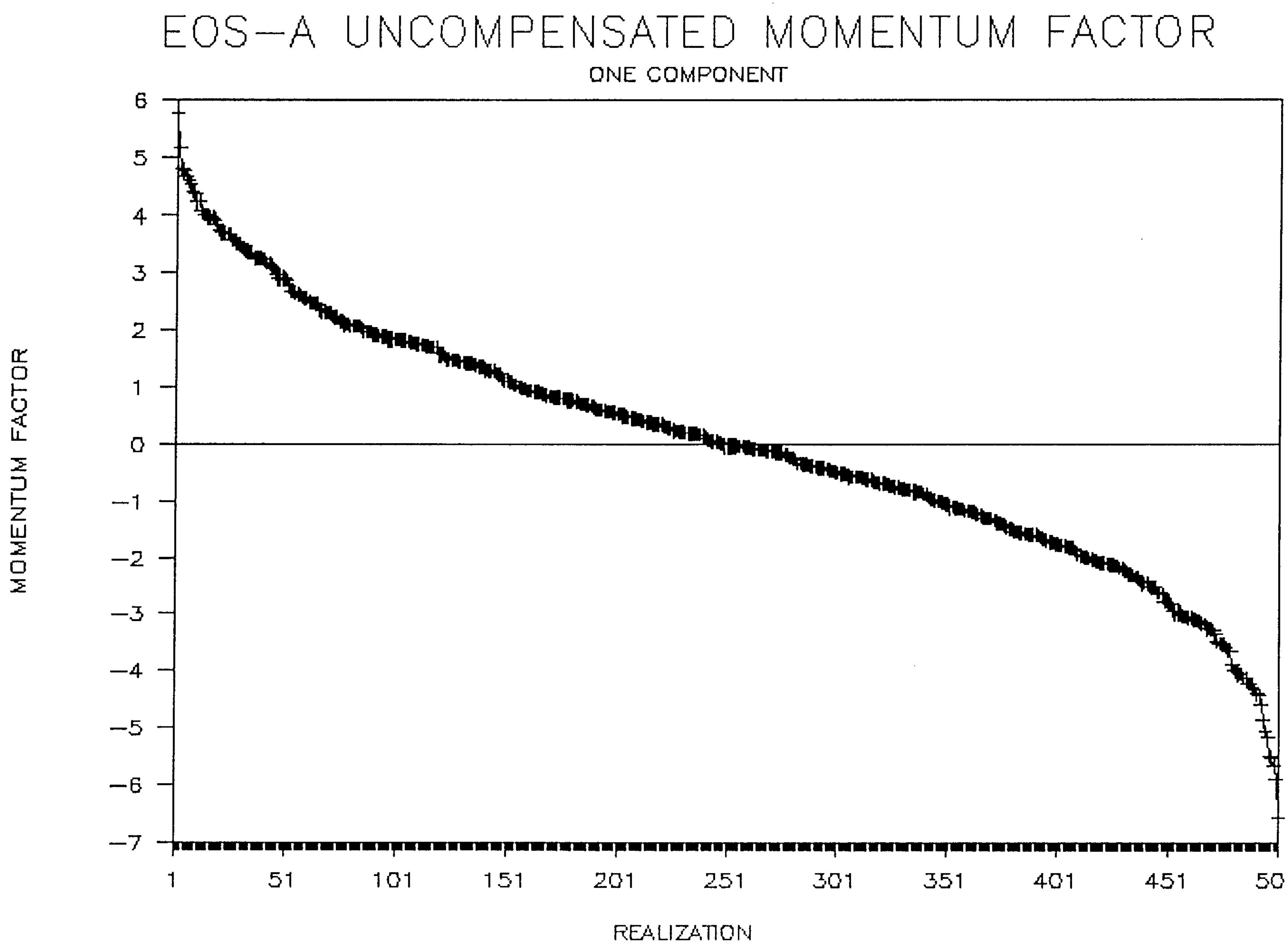
Two sets of simulation experiments were run to assess the joint effects of multiple scanning instruments. Complements of six and ten scanning experiments were considered. In each set of experiments, 500 realizations were run. In each realization, the individual instruments were assigned random scan azimuths. Each instrument was assumed to have an equal amount of uncompensated angular momentum along the scan azimuth. For each vector component, the maximum, minimum, mean, and standard deviation of the composite momentum was computed. The experiments were each repeated several times to check the consistency. A near-normal probability distribution was achieved, and the three standard deviation value was near the maximum value in all cases. For the case with six instruments, the standard deviation (relative to a unit value for a single instrument) ranged from 1.65 to 1.85. For the ten instrument case, a standard deviation of from 2.13 to 2.31 was obtained. The attached figure illustrates the results from one experiment for a ten instrument experiment.

3. Assumptions and Fundamental Constants

Platform weight:	15,000 kg
Platform length:	16 m
Platform width:	4 m
Maximum uncompensated momentum:	0.1 N m sec
Number of instruments:	10
Platform altitude:	700 km
Three sigma factor:	6

4. Technical Approach for Developing the Navigation Error

Assuming that the system conserves total angular momentum, then $L = \Sigma_n \; m_n \; (\mathbf{r}_n \times \mathbf{v}_n)$, where L is the total angular momentum, n is the n'th component, and **r** and **v** are position and velocity of each component. Two components can be considered, the platform (a) and the composite scanning effect (b). The system can be considered


EOS-A UNCOMPENSATED MOMENTUM FACTOR
ONE COMPONENT
MOMENTUM FACTOR
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
1
51
101
151
201
251
301
351
401
451
501
REALIZATION

at two times (L_1 and L_2), for which the total angular momentum will be identical. We have $m^b_1\ r^b_1\ v^b_1 = m^a_2\ r^a_2\ v^a_2$. Knowing that the angular velocity (Ω) and momentum (L) are related by $v = \Omega\ r$, we have for the roll axis 6×0.1 kg m^2 sec = 15,000 kg $(1\ m)^2\ \Omega$, or $\Omega = 4 \times 10^{-5}\ sec^{-1}$.

5. Conclusions

At an altitude of 700 km, the effect is approximately 30 m in terms of relative horizontal displacement over one second near nadir. Because this perturbation in the Earth location approaches 1/10 pixel, we conclude the platform attitude must be monitored in such a manner that the effects of instrument scans can be resolved. A 100 millisecond sampling rate would yield an acceptable 3 m error, and a 50 millisecond rate would reduce the effect to about 1 m at nadir.

Determination of Aerosol Size Distribution from Spectral Optical Depth Measurements

This discussion is based on a working fully automated algorithm developed by Dr. Michael King. The details of the algorithm are contained in the references provided by Dr. King. The algorithm is a constrained, linear, recursive, least-squares inversion. The constraint is applied by requiring the solution to be everywhere non-negative. The solution method is linear while the problem is non-linear so recursive iterations are required to obtain an acceptable solution. The "best" solution is that which minimizes the least-squares difference between the observed and calculated solution.

The input data for this solution is aerosol optical depth as a function of wavelength. The errors on the optical depth are also required. The input data must be corrected for effect of Rayleigh scattering and molecular absorption. Dr. King states that the radius range of the particle determination depends on the wavelength range of the optical depths. Increasing the number optical depth determinations improves the quality of the radius determination.

The algorithm assumes that all the aerosol particles have a single index of refraction. The index of refraction must be supplied as an input to the algorithm. Fortunately, the particle size distribution is not very sensitive the assumed index of refraction. The smallest and largest particle radius to be solved for must also be specified.

The assumption is made that the particles are properly described using Mie scattering theory which is rigorously correct for spherical particles. The result of the algorithm is an integrated column size distribution usually presented in units of $dN/d(\log r)/cm^2$.

The initial guess for the size distribution is a power law with the exponent determined by fitting the input optical depths. The problem is initialized by using the assumed index of refraction and Mie scattering to calculate the extinction coefficients for the range of particle radius and wavelengths.

The distribution function is split into two parts, i.e., $n(r) = f(r)h(r)$ where f varies "slowly" and h is the "rapidly" varying part of the function. f is taken as a constant over a narrow range of r and the integral done over h. The result is a matrix equation for the observed optical depths (see the references for the mathematical detail). An improved estimate of f is obtained by matrix inversion. A new estimate of h is made by taking $h1 = f1*h0$. The process is then iterated.

A smoothing term is added to the matrix equation to improve the numerical stability of the inversion process. The amount of smoothing is controlled by using a Lagrange multiplier. In Dr. King's algorithm, the Lagrangian multiplier is varied over the range 0.001 to 5.0. The smallest value is used first, i.e. the least smoothing. The matrix inversion is done and the fs estimated. The solution is physically meaningful only if all of the fs > 0.0. If this is not true, the value of the multiplier is doubled and the process iterated. This process will take at most 13 iterations over various values of the multiplier. If not all fs are positive at the largest value of the multiplier, an interpolation is done between the positive values to make all of the fs positive. The determination of a set of fs can be term a minor cycle.

After each minor cycle, the quality of the solution is checked by calculating the expected optical depths. The difference between the calculated and observed optical depths is squared, weighted by the errors on the observations and, compared to the expected error. Another minor cycle is done if the resulting error exceeds the expected error.

In Dr. King's algorithms, this major cycle is done no more than 8 times. The current algorithms repeats the entire procedure for three different initial power laws. The "best" solution is the one which has the smallest observed minus calculated error. Dr. King has observed that the final result varies only slightly with the initial power law.

This algorithm requires that a matrix inversion be done up to a maximum of 13*8*3 = 312 times. While the matrices are typically not very large, this requires significant computation. The efficiency of this algorithm would be greatly improved by having a good first guess for the initial iteration.

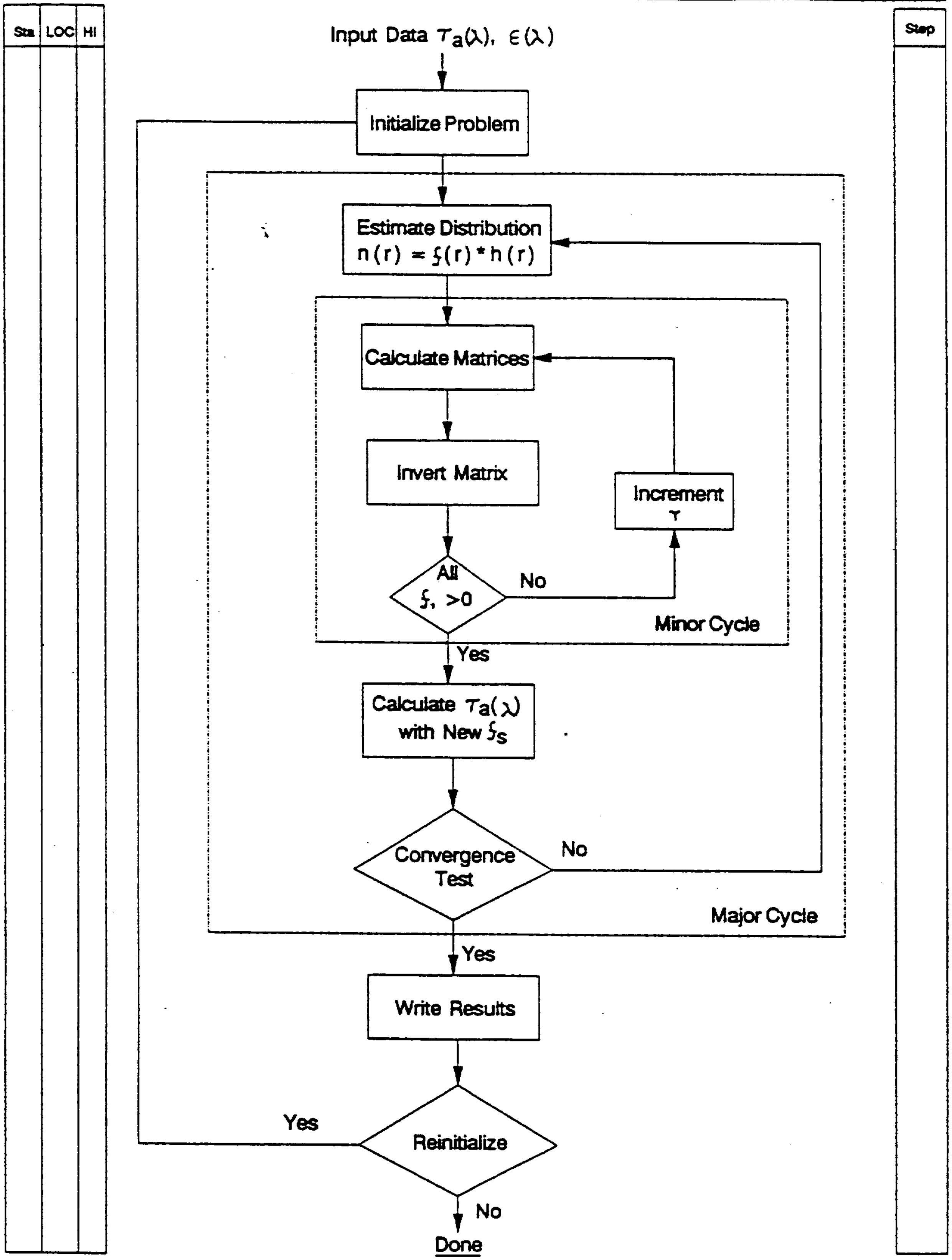
This may be possible in the Eos era. This will be a standard Level-2 core data product. It is reasonable to assume that a aerosol climatology will be available to the CDHF. The previous observations of aerosol size distribution can be used as first guess in the algorithm to allow convergence in fewer iterations. This should work well unless the composition of the aerosols changes dramatically.

The determination of aerosol size distribution will be done with the same resolution as the aerosol optical depth data which is required for input. It is not known whether the optical depth can be determined with full instrument resolution. The aerosol size distribution will be used as input for aerosol mapping and aerosol climatology products.

The aerosol size distribution is required to calculate the aerosol single scattering albedo which is required to atmospherically correct the data. Hence, this calculation may be required before the atmospheric correction of data can be done. This determination will be done only with MODIS-N data since the atmospheric discipline group does not think the wavelength coverage of MODIS-T is sufficient to determine the aerosol characteristics. This suggests that is may be desirable over even necessary to use MODIS-N data to atmospherically correct data from MODIS-T.

The Determination of Aerosol Particle Size Distribution from Optical Depth

Level 1



Algorithm Status

O - Operational
D - Development
C - Conceptual

LOC

Lines of Code

Current Human Intervention

A - Autonomous
H - Some Human
M - All Manual

MODIS SCIENCE REQUIREMENTS AND RECOMMENDED DATA PACKET STRUCTURES

1. BACKGROUND

Recently, Tom Magner (Code 717.3) has stated that, in the current MODIS-T design, sensor and ancillary data will be inserted into data packets on a "first-come, first-served" basis as data is read from the CCDs. However, the MODIS data team has advocated the creation of specialized packets, and has identified a number of desirable MODIS data packet types. These include an engineering data packet for health-and-safety monitoring of the MODIS instrument at the ICC, possibly a separate MODIS ancillary data packet, and a unique data packet for each spectral band of MODIS-N and MODIS-T (though not for each detector). All data packets will be time tagged at generation.

Tom Magner also indicated that, although there will be memory available to form the packets (on the order of 70% of the MODIS-T data in each scan must be buffered to provide a uniform output rate), the simplest (and cheapest) possible instrument is being designed. He stated that, since his group has no requirement to design specialized data packets, they weren't.

There are specific applications for which specialized data packets offer decided advantages: instrument monitoring in the ICC/IST, near-real-time data transmission and processing, and possibly real-time direct broadcast. In each case, the formation of a unique data packet for each spectral band would permit the isolation of data for specific required channels over specified time intervals.

Here, we state the advantages in creating specialized data packets within the MODIS instrument, provide one possible scenario for use, and outline the suggested data packet structures.

2. POSSIBLE SCENARIO FOR USE

One situation where specialized types of data packets are needed is field experiments. Here we present a possible scenario for the use of the one-band-per-packet capability to support either the priority processing (in near-real-time) or the direct broadcast (in real time) of field experiment data.

The Application Process ID, included in each data packet's primary header and set by the MODIS instruments, can indicate the destination and processing priority for the data contained in the packet, as well as the type of data the packet contains. A specific setting for the ID could indicate to the platform data system that the data packet should be routed to the direct broadcast system, and copied to the platform tape recorder. Alternatively, the ID could indicate that the data within the packet should receive priority processing. Provided that individual packets contain information from a single MODIS band, the user could customize his real-time or priority data request by orbital segment and spectral coverage. Depending on available bandwidth, single or multiple spectral bands could be selected.

Since the orbit for the polar platform is easily predicted 16 (one repeat cycle) or more days in advance, the following scenario is possible:

The team member supplies the team leader with a near-real-time or direct broadcast request, establishing the required bands and temporal coverage (GMT start and stop times). This information is combined with other team member requests and forwarded to the ICC/EMOC. Appropriate commands are uplinked to the platform and the MODIS instrument. During the specified intervals, the application process ID of the affected data packets is revised to reflect a near-real-time or direct-broadcast requirement and the platform data system routes the data packets accordingly. Ground processing at CDOS and EosDIS would also be directed by the packet IDs.

3. APPLICABLE STANDARDS

The Consultative Committee for Space Data Systems (CCSDS) has published several standards that are applicable for MODIS data transmission and processing. The primary documents governing telemetry include:

"Telemetry Concept and Rationale", CCSDS 100.0-G-1, Issue 1, Green Book, Consultative Committee for Space Data Systems, December 1987

"Packet Telemetry", Recommendation CCSDS 102.0-B-2, Issue 2, Blue Book, Consultative Committee for Space Data Systems, January 1987.

Two newer documents also contain provisions affecting telemetry:

"Advanced Orbiting Systems, Networks and Data Links, Concept, Rationale and Performance", CCSDS 700.00-G-1, Issue 1, Green Book, Consultative Committee for Space Data Systems, June 1989

"Advanced Orbiting Systems, Networks and Data Links, Architectural Specification", CCSDS 701.00-R-3, Issue 3, Red Book, Consultative Committee for Space Data Systems, June 1989

The second document is still under review and is issued as a "Red Book". Once the review is complete and all provisions of the recommendation have been accepted, the document will be revised and reissued as a standard "Blue Book" recommendation.

The following CCSDS documents also contain provisions affecting the formatting and handling of MODIS data:

"Telemetry Channel Coding", CCSDS 101.0-B-2, Issue 2, Blue Book,

Consultative Committee for Space Data Systems, January 1987

"Time Code Formats", CCSDS 301.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, January 1987
"Radio Metric and Orbit Data", CCSDS 501.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, January 1987

"Space Data Systems Operations with Standard Formatted Data Units, System and Implementation Aspects", CCSDS 610.0-G-5, Issue 5, Green Book, Consultative Committee for Space Data Systems, February 1987

"Standard Formatted Data Units - Structure and Construction Rules", CCSDS 620.0-B-1, Issue 1, Blue Book, Consultative Committee for Space Data Systems, February 1988

4. IMPLICATIONS OF CCSDS RECOMMENDATIONS

The recently introduced "Advanced Orbiting Systems" standards provide a number of new types of data transmission but maintain upward compatibility with the original Version 1 telemetry packet embodied in earlier CCSDS standards. It appears that MODIS telemetry needs are well served by the original Version 1 packet, so that the implications of the new standard for MODIS are minimal.

For reference, Figure 1 shows the packet format under discussion. The standard permits packets of any desired length but also provides machinery for the segmentation of long data packets into shorter (approximately 8 kilobit) packet segments that are more suitable for transmission over the spacecraft-to-ground data link. Note also the existence of a secondary header that may be used to send platform ancillary and instrument engineering data.

5. MODIS SCIENCE REQUIREMENTS

5.1 For routine processing of MODIS data at the CDHF, there are no major advantages to any particular packetization strategy.

5.2 To efficiently select data for direct broadcast, real-time TDRSS transmission, instrument monitoring, and perhaps priority (near-real-time) processing, it is desirable to select MODIS data packets by spectral band.

5.3 Packetization by spectral band permits the user to efficiently access the MODIS sensor data of interest without the need to access and decommutate 100% of the MODIS data stream.

5.4 Band-by-band packetization offers the ability to selectively handle specified bands for specified orbital segments on the platform, across the downlink, and within the ground processing. Selective handling is important for direct data broadcast, for near-real-time support of field experiments,

Major Field	Length (Bits)
Primary Header	48
Secondary Header	Variable (optional)
Source Data	Variable
Packet Error Control	Variable (optional)

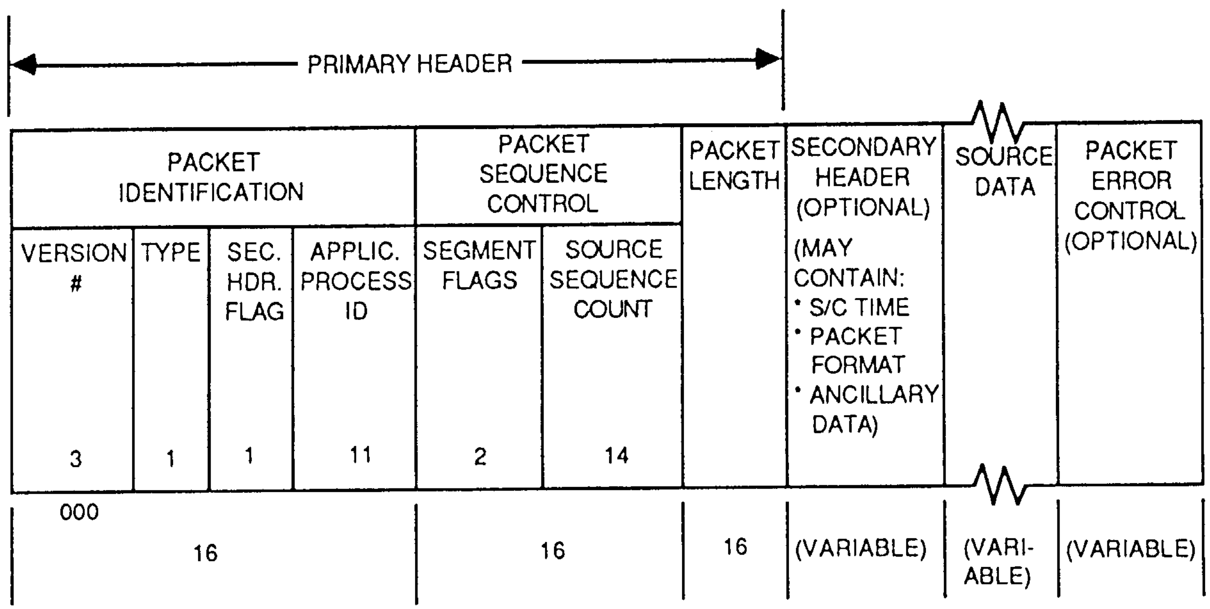


Figure 1: Version 1 "Source Packet" Format

and for instrument monitoring.

5.5 The trade-off between increased instrument design and fabrication costs for band-by-band packetization and more efficient and responsive data system capabilities must be considered.

6. MODIS INSTRUMENT DESIGN IMPLICATIONS

6.1 For the MODIS-T instrument, two types of engineering data will be generated.

6.2 One type is generated in synchronization with each detector frame readout and contains instrument tilt angle, the current scan mirror angle, a time tag, a set of instrument attitude angles, a set of instrument attitude change rates, and a block of reserved bits for future implementation.

6.3 The second type of engineering data is generated once for each instrument scan, and contains electronic reference values, thermistor readouts, platform position, a time tag, and instrument status bits.

6.4 The bit allocations for each item are shown in the Appendix.

7. SUGGESTED MODIS DATA PACKET STRUCTURES

7.1 The MODIS sensor data for a complete scan and for a single spectral band will be contained in one very long source data packet.

7.2 Each spectral band will generate its own unique data packet.

7.3 CCSDS Version 1 Source Packet Format will be utilized.

7.4 Source-Internal Segmentation, i.e. segmentation within the MODIS instrument, will be applied.

7.5 In this format, the Packet Length field directly indicates the length of the data in the packet segment, and the Source Sequence Count increments once for each segment to indicate the segment number of the data packet within the original very long source packet.

7.6 Segmentation Flags will be used to indicate a first (01), continuation (00), or last (10) segment.

7.7 Information which describes a physical sequence count and length of the original very long packet (the scan number and the number of bytes taken during that scan by one band) will be placed into the data field (as part of the secondary header) of the first segment.

7.8 In each packet segment, the secondary header flag will be set to one, indicating that a secondary header exists. For the DHC or any other facility to perform level-0 processing on the MODIS data, it will be necessary to extract from the secondary header the physical sequence count (sequential scan number for the calendar day).

7.9 Consider the following possible scenario for MODIS-T:

34 bands (32 spectral bands plus 2 additional "dark" bands used for monitoring detector noise and stability) each are given their own data packet.

A 35th data packet could contain both detector-frame-readout and scan referenced instrument engineering data as described in Section 6.

The data volumes of each data packet would be similar (387,720 bits for packet types 1 to 34, and 401,634 bits per scan for packet type 35)[1].

Each of the 35 data packets generated by the MODIS-T instrument per scan would be segmented into on the order of 50 segments.

This process would be repeated every scan.

7.10 It is possible that an abbreviated form of data packet type 35 (type 36?) could be generated simultaneously for continuous real-time transmission to the ICC in support of basic health and safety monitoring.

7.11 The role of the Application Process ID must be further explored. We can anticipate distinctions between36 MODIS-T packet types and 40 MODIS-N packet types. Furthermore, we can anticipate four types of paths (direct broadcast, real-time TDRSS, priority processing, and routine procesing). Finally, we can anticipate at least two destinations (ICC and CDHF). This yields 608 possible permutations.[2] The 11 bits of the ID in the header allow 2,048 possibilities, and it is unlikely that MODIS will be allowed to use 30% of the possible values.

7.12 The packets designated for direct broadcast should also be

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[1]The total amount of overhead developed from Appendix A is approximately 17%.

[2]The Blue and Red CCSDS books regarding telemetry standards disagree as to whether the application process ID describes only the source, or the path including the destination as well.

sent via TDRSS to permit higher-level EosDIS processing. One bit of the application process ID could designate to the platform data system whether a packet is to be directly broadcast. Similarly, two bits would indicate to the platform data system and to the Level-0 processing facilities whether to treat the data as real time, priority playback (near real time), or routine.

7.13 If the capability to generate higher-level products wihin the MODIS instrument is provided, then the data packets generated for these products (presumably for direct broadcast) would have unique data identifiers as well.

1.1 km * single scan speed * 30 along track pixels

Revised on	28-Aug-89
	1.1 km along track IFOV
	1.1 km cross track IFOV
	single scan speed
	F3.1
ground frames	1,007
dark frames	50
calibration frames	20
total frames	1,077
detector	30 pix by 34 pix
slit FOV	1.1 km by 33 km
slit FOV	1.560 mrad by 46.809 mrad
slit FOV	5' 22" by 2° 40' 48"
detector pitch	161.7 µm by 220.5 µm
detector A reg size	4851 µm by 7497 µm
#bits/frame	
frame (12 bit A/D)	12,240
tilt	17
scan	17
time tag	64
Attitude angle	36
attitude rate	36
TBD	200
total bits/frame	12,610
#bits/swath	
frames	13,580,970
electronic reference	2,400
thermistors	384
POP Position	96
Time tag	64
Instrument status	200
Total #bits/swath	13,584,114
total scan time (sec)	4.615
scan mirror speed (rev/min)	6.501
transmitted data rate (bits/sec)	2,943,569
earth scan time (sec)	1.154
frame time (msec)	1.146
data generated during earth scan (bits)	12,698,270
earth scan data rate (bits/sec)	11,006,457
earth scan data rate (pixels/sec)	917,205

Considerations Regarding the Direct Broadcast of MODIS Observation Data

Recently within the Eos project there is renewed interest in the possible use of direct broadcast to transmit observational data from the orbiting Eos platforms to appropriate ground receiving stations located around the earth. In addition to conventional data downlink through the Tracking and Data Relay Satellite System (TDRSS), data could go directly from the satellite to ground receiving stations without the intervening services of TDRSS. Service at a given ground location would be limited to those time intervals when direct radio communication can be maintained between the orbiting platform and the receiving earth terminal. Interested parties with access to appropriate receiving facilities could potentially have direct access to some or perhaps all of the MODIS observation data.

In its role as an intermediary between the MODIS Science Team and the EosDIS community, the MODIS Data Team receives basic science requirements from the MODIS Science Team and documents and interprets these requirements for use by data system designers. This document is a first attempt to lay out issues that the Science Team must address to define science requirements for the use of direct data broadcast. Without a firm statement from the science team regarding the science requirements for direct broadcast, there will be no direct broadcast capability.

Design Constraints and Basic Implementation Issues

Since direct data broadcast has not been considered in-depth by the MODIS Science Team, the initial questions to be asked relate to the scientific utility of new system options that this feature could potentially support. Basic scientific needs must dictate the data system features that are implemented. In this spirit, we shall, at first, de-emphasize the technical and cost constraints associated with direct data broadcast, and we shall instead consider the potential scientific utility of this feature.

Depending on receiving station resources available within the user community, the direct broadcast link could be implemented in any of several frequency bands. Since Landsat 4 and 5 use the X-band and a network of ground terminals already exists to serve Landsat needs, it is often thought that the X-band may be an optimum choice.

Other frequency bands could also be implemented, including several that could support low-data-rate links to simplified ground terminals that do not require the large financial outlay associated with an X-band ground receiving station. Low cost ground stations running on an IBM PC and MacIntosh SE are presently capable of picking up direct broadcast real-time FM data from the NOAA polar orbiters, GOES, Meteor, Meteosat, and other polar and geostationary spacecraft. Also, ground terminal capabilities presently exist to receive APT and HRPT data from NOAA polar orbiters.

Much will depend on the required data throughput capability of the direct broadcast link. Team members should consider all possibilities, including the possible return of all MODIS data as well as selected portions thereof. If selected data is to be returned, appropriate data selection criteria must be specified.

Data might be downlinked either in real time as they are collected, or if science requirements justify, perhaps data could be retrieved from the on-board tape recorder. Because of the additional complexity introduced, compelling scientific justification would likely be required for implementation of tape retrieval.

Depending on science requirements, direct broadcast could be implemented either with or without on-board data processing. If on-board processing is specified, the required processing capability should be achievable within the physical confines of the MODIS instrument, i.e. it is not expected that Eos platform computing resources will be available for MODIS use.

Illustrative Direct Broadcast Scenario #1

The following scenario is offered as an illustration of the potential usefulness of direct data broadcast. None of the system features assumed in this scenario have been agreed to (or even suggested) by members of the MODIS Science Team, so this scenario is provided only as a stimulus for additional thought. The real usefulness of alternative direct broadcast features will be appraised by the members of the MODIS Science Team.

For illustration, it will be assumed that direct data broadcast is implemented in one of the low-data-rate bands that allows direct data receipt by the end-user with access to a personal computer and minimal receiving equipment. It will be assumed that data is continuously transmitted and is available only in real-time, i.e. data retrieval from on-board tape recorders is not implemented. It will also be assumed that limited MODIS data processing is available on-board the platform and that the end-user is primarily interested only in data for his own local region.

Data products available might be as follows: for MODIS-N, the Normalized Difference Vegetative Index (NDVI), a measure of surface brightness, and image output from one of the thermal channels, and for MODIS-T, three visible band images, one each in the red, green, and blue regions. Depending on the throughput capabilities of the downlink, composite pixels containing data for more than the usual one-by-one kilometer pixel may be generated to reduce the downlink data rate. If averages over many pixels (as sensed by the instrument) are used, "texture" or some other measure of component variability may also be generated to measure the spread or variability of averaged parameters.

To support the selection of useful data from the usual EosDIS distribution channels, the data system may also provide data quality indicators and other suitable measures of data usefulness. Since the absence (or presence) of cloud cover is critical for many observations, an image showing cloud cover would obviously be helpful.

The potential users of the described direct broadcast data might include MODIS Science Team Members and other researchers who could use the direct broadcast data to screen the full MODIS data set for suitable data on selected features, as well as local investigators who may develop their own applications for the data. Examples of such investigators might include university people from around the world who may use the data to support regional investigations of local phenomena. If suitable products become available from the research community, then it may ultimately become possible for the non-specialist to obtain data products relevant to his own local interests, such as extent of gypsy moth infestation, extent of drought affected crops, etc.

Illustrative Direct Broadcast Scenario #2

A simpler alternative would allow a team member to designate an orbital segment and set of spectral bands for MODIS observational data to be transmitted. Operation might be as follows:

The requesting Science Team Member supplies the Science Team Leader with a request for real-time direct broadcast data, designating start and stop times and required spectral bands for the data. The request is combined with other team member requests and forwarded to the ICC/EMOC. Appropriate commands are uplinked to the platform and, ultimately, to the MODIS instruments. At the designated start time, the application process ID of affected data packets is revised to a new value that indicates a direct-broadcast requirement, and, accordingly, the platform data system routes the data to the direct broadcast system.

Questions for Science Team Members

Since design requirements for the MODIS-T instrument will soon be finalized, Science Team responses to the following questions are urgently needed. Short comments are acceptable; for each question, you may want to indicate both a minimum requirement and a desired level of implementation.

1. What data is needed, i.e. what type or types of data should be directly broadcast?

2. Will on-board processing be required to generate the needed MODIS direct broadcast products?

3. How much data is needed, i.e. what is the required on-board data processing capability for direct broadcast products and what is the required data throughput capability of the direct broadcast link?

4. Should the direct broadcast system support only the real-time transmission of data as observations are made, or should data for direct broadcast be retrievable from the on-board tape recorder?

5. Should data be broadcast continuously, whenever the satellite is within range of a known ground terminal, or only on request?