Processing Overview of the MODIS Level-1A and Level-1B Data Products

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MODIS Level-1A and Level-1B Data Products are generated from MODIS-N and MODIS-T instrument data and spacecraft position and attitude data. Each data product has an accompanying set of metadata. Each MODIS Level-1 data product is self-contained, including all instrument science, engineering and housekeeping data, and a complete data set header. The metadata includes the information in the MODIS data set header and additional information added by the MODIS processes and other processes such as the Information Management System (IMS). This document describes the production of the Level-1A and Level-1B data products which will be available to the user community. The MODIS Level-1 processing assumptions are given at the end of this overview.

Introduction. The Earth Observing Satellite (EOS) Moderate Resolution Imaging Spectrometer - Tilt (MODIS-T) instrument generates three types of data: daylight, night time, and housekeeping. These data types correspond to the operating modes of the instrument. The details and size of each type of data are summarized in the accompanying table labeled "MODIS-T Data Types". MODIS-T data is used for illustration purposes in this document.

The collection of all the MODIS data associated with one complete across-track scan is called a scan cube. At Level-1A, this concept is illustrated in Figure 1. The scan cube is composed of detector data frames (see Figure 2) and separate frames of engineering and housekeeping data. Each detector data frame is represented as a two dimensional array of sensor data with tilt position, scan angle, and time tag appended. One dimension corresponds to along-track pixel location, while the second dimension corresponds to the wavelength bands or channels. All data within a given frame are recorded simultaneously. As the scan mirror rotates through one scan, the recorded sequence of data frames generates a scan cube (which includes engineering and housekeeping data, such as voltages, currents, thermistor readouts, status bits, etc.).

Each data frame is buffered inside the instrument and sent to the spacecraft communications system as packets. A packet is assembled to Consultative Committee for Space Data Systems (CCSDS) specifications and has less than 8192 bits (less than one KByte). A MODIS-T data frame is stored in two CCSDS telemetry packets. Each packet starts with an identifier (packet ID), then

MODIS-T Data Types

	daylight	night	housekeeping	(modes)
pixels along track	30	30	30	picture elements
science channels	32	32	32	bands
dark current	2	2	2	bands
pixel precision	13	13	13	bits per pixel
tilt angle	18	18	18	bits per frame
scan angle	18	18	18	bits per frame
time tag	64	64	64	bits per frame
	1,670	1,670	1,670	(Bytes per frame)
ground frames	1,007	16		frames per swath
dark frames	5	5		frames per swath
calibration frames	12	12	1	frames per swath
..total science portion	13,680,640	440,880	13,360	bits per scan
	1,710.08	55.11	1.67	(KBytes per scan)
electronic reference	390	390	390	(30 * 13 bits)
thermistors	48	48	48	Bytes per frame
photo diode	48	48	48	bits per frame
diffuser	4	4	4	bits per frame
aperture	8	8	8	bits per frame
relays	256	256	256	bits per frame
voltages/currents	96	96	96	Bytes per frame
..total engr portion	1,858	1,858	1,858	bits per frame
	232.25	232.25	232.25	(Bytes per frame)
..total scan cube size	13,682,498	442,738	15,218	bits per scan cube
	1,710.312	55.342	1.902	(KBytes per cube)
packet header (.68%)	93,041	3,005		bits (overhead)
..total data size	13,775,539	445,743	15,218	bits per scan cube
scan mirror speed	6.6	6.6	6.6	rev/min
scan cube time	4.545	4.545	13.636	seconds
maximum data rate	3.031	0.098	0.001	megabits per second
orbital average	40	60	100	percent of coverage
orbital period	98	98	98	minutes per orbit
orbital data volume	891.002	43.246	0.82	MegaBytes per orbit
	517.44	776.16	143.733	scan cubes per orbit
daily data volume	13.092	0.635	0.012	GigaBytes per day

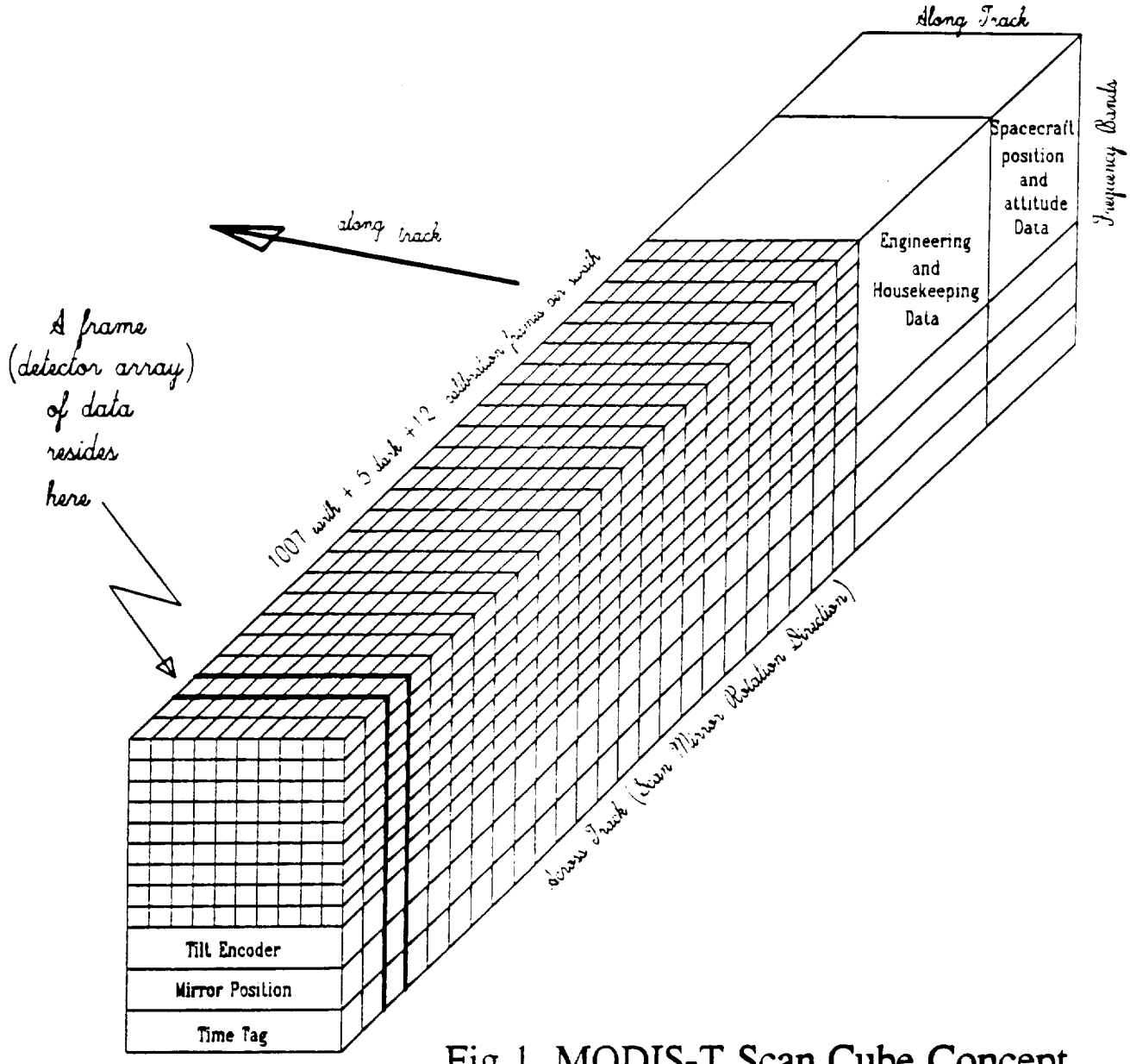

Fig 1 MODIS-T Scan Cube Concept

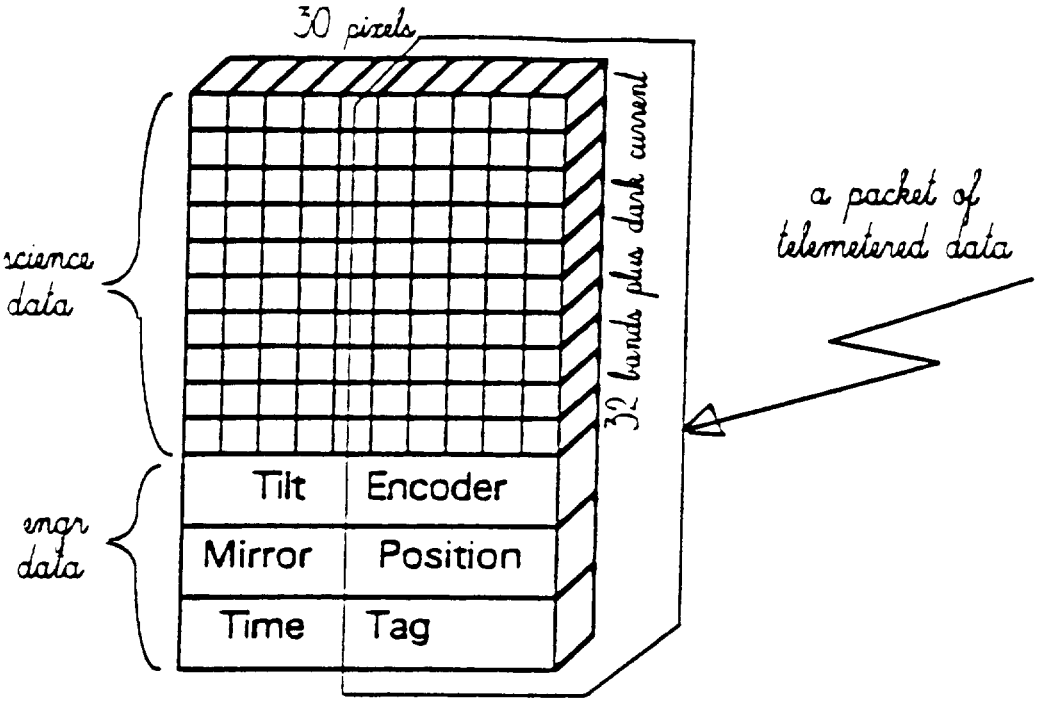

Fig 2. Data Frame

ID	instrument data (science and engineering)	CRC

Fig 3. Packetized Data

data from the source, followed by error detection and recovery codes (CRC, etc.) (see Figure 3)

The spacecraft position and attitude data are contained in separate data packets that are sent down at the same time as the instrument data. This data is computed ten times per second on board the spacecraft. (This is a change from previous practice. On board the spacecraft is the only place where spacecraft position and attitude are computed for use in producing the MODIS data products.) All telemetry packets are archived by the Data Archive and Distribution System (DADS).

MODIS Level-1A Data Products. Two MODIS Level-1A data products are produced: the product containing the scan cubes, and the separate Level-1A metadata product. The metadata is a super set of the data product header. It also contains information appended by other processes such as the IMS. The MODIS scan cube data product will not be altered or replaced by any process other than the MODIS program by which it was generated. The metadata, however, will have information appended by other processes, provided that the original information is not destroyed.

The Level-1A product is derived from two input data streams: Level-0 instrument data packets and the position and attitude data packets. Level-0 is defined to be the instrument data in packetized form, time ordered with duplicates removed (except, possibly, in the case of quick look data). The MODIS Level-1A program receives the packets from the DADS. MODIS processing places the packets of data into computer memory, represented as instrument scan cubes. The scan cube is illustrated in Figure 1. The MODIS program appends spacecraft platform position and attitude information to each scan cube. The position and attitude information is generated ten times per second. Note that 45 or more spacecraft position and attitude data values are appended to each scan cube. This information is not altered or interpolated to instrument scan time.

The scan cubes are placed into the MODIS data product structure, ordered by time, as illustrated in Figure 4. The appended data product header contains the algorithm version numbers, data synopses and descriptors, etc. Each individual scan cube contains data quality, data completeness indicators, and other items required for further processing. The Level-1A data will not be unpacked (13 bits into 16 bits) or altered in any way. The Level-1A data product is limited to the raw instrument data (with duplicate packets removed) and the appended position and attitude data.

The Level-1A metadata product is created by the MODIS Level-1A program. It includes information from the CDOS packet switching facility, the MODIS Level-1A data product header, and additional data descriptors.

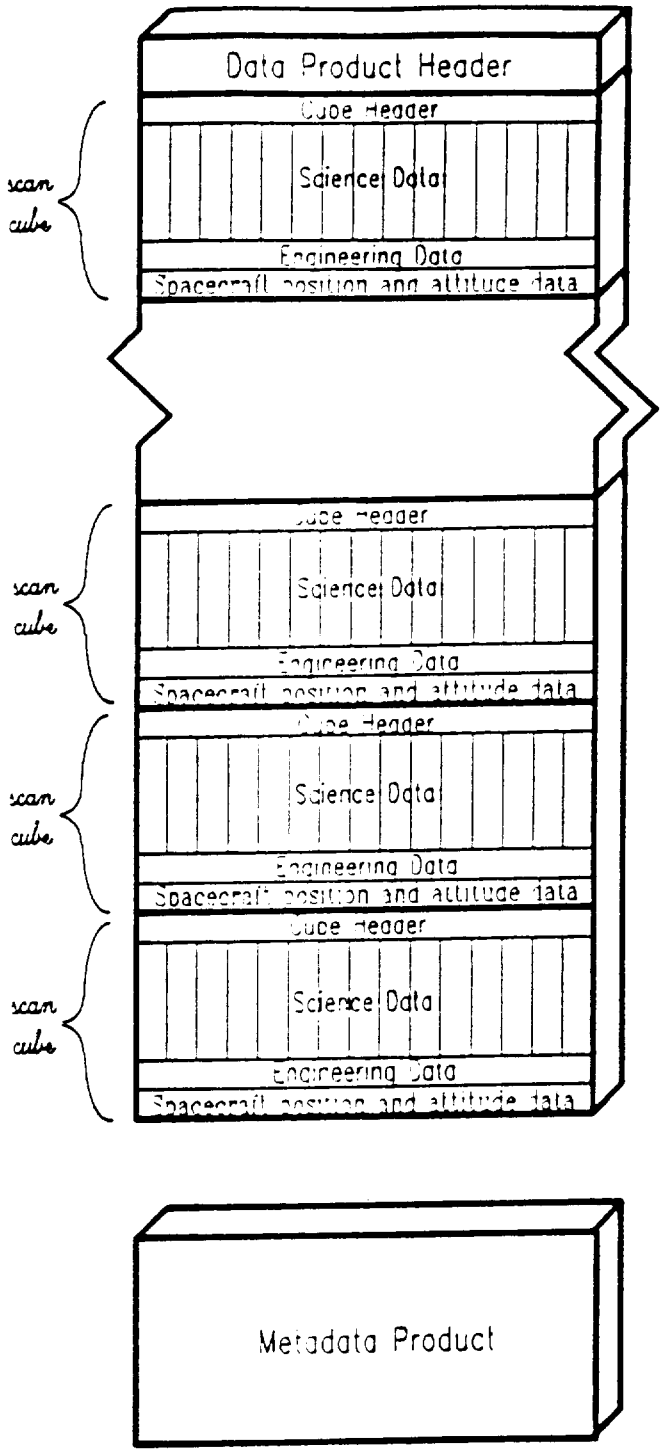

Fig 4 Data Products

Level-1B Data Product. At-satellite radiances are provided in the Level-1B Data Product. These radiances will be calibrated using an algorithm agreed upon by the MODIS Team members. The MODIS Characterization Support Team (MCST) will supply calibration algorithms and coefficients that will use the instrument engineering values as inputs. The calibration algorithm may include smoothing over a time period of several hours on either side of the data epoch.

Anchor points (ground locations) will be calculated for a subset of pixels within each scan cube. The anchor points will be appended to the data product using the WGS84 (or similar) ellipsoidal Earth model. This does not include a digital elevation model (DEM). Anchor point computations will be based on instrument geometry and spacecraft position and attitude. The expected ground location accuracy of these anchor points is approximately 500 meters (three sigma). Image registration techniques are being examined as a method of providing an additional set of ground locations to satisfy higher accuracy requirements.

No correction for atmospheric effects will be included or applied to the radiance values or the anchor point determination. Scene characterization flags (cloud, land, ocean, etc) will not be included in the Level-1B data product. These flags will be determined in the Level-2 and later processes. All metadata from Level-1A will be enhanced and appended to produce the Level-1B metadata. Previous metadata values are retained with new information added to produce the current metadata.

Conceptually, the MODIS Level-1B scan cube within the Level-1B data product is the same as the Level-1A scan cube illustrated in Figure 1. The data are byte aligned (unpacked) and will have the selected anchor points appended. The along-track coverage of the set of scan cubes contained within the data product is to be determined (TBD).

General Considerations. The MODIS processes will monitor preselected elements of instrument data and will generate appropriate messages. These messages will be transmitted to requesting processes or projects. The messages will provide information about problems or anomalies detected from the MODIS telemetry data. Messages will be sent to the scheduling activity (SCA) in response to status requests and to indicate completion of processing. In addition, entries will be made to the MODIS Processing Log covering all MODIS scheduling times, problems, and events.

Quick look processing, normal processing, and reprocessing will all be done with the same version of the algorithm. The same version of MODIS software will also handle all MODIS instrument modes. Production of a browse data set (once defined) will be a separate process which may be executed either concurrently or on demand (TBD). Browse products may be generated by subsampling,

either spatially, temporally, or in wavelength, and lossy compression may also be included. Browse products will not be used in further processing of the MODIS data.

Each MODIS process will be under configuration management (CM). Any revision to a program, including changes in calibration algorithms and coefficients, and earth location methods will require an update to the algorithm version number. The associated documentation and validation must also be updated. Software program changes will force a CM revision. Each MODIS data product will contain the version number of the software used in its production. MODIS data products will be under CM control once produced. The MODIS metadata will not be under CM control to allow other processes to append information.

MODIS Level-1 Processing Assumptions

compiled by the
MODIS Science Data Support Team

This list of assumptions is associated with the design of the MODIS Level-1 data processing. The assumptions may change as comments are received, and as refinements are made to the Level-1 processing system design. The numbering of items comes from a master list being tracked by the MODIS Science Data Support Team. Only those items which may be of interest to MODIS Science Team members are included in this abbreviated list.

Unpacking Data (016). MODIS data will not be unpacked (byte aligned) at Level-1A.

> Leaving the data in a packed form minimizes the size of the data set in the absence of data compression. It also minimizes the time and complexity of Level-1A processing. Unpacking the data at Level-1A could increase the probability of error in the basic level of permanently archived data.

Level-1A Navigation (017). Earth locations of MODIS pixels will not be determined at Level-1A.

> This function is contained in the Level-1B process.

Required Ancillary Data (042). All data required for MODIS Level-1B processing will be included in the MODIS Level-1A product (with the possible future exception of ground control point data).

> This assumption says that all data required to process to the Level-1B product (including metadata) will be contained within the Level-1A data product. With the possible exception of ground control point data, this means that no in-situ data is required, and that no auxiliary data sets are required (i.e. other instrument motions causing momentum effects, platform thermal deformation data not in the MODIS packets, etc.). See also: Engineering Data (044).

Platform Position and Attitude Knowledge (037). MODIS Level-1B processing will use the satellite position and attitude knowledge generated on board the spacecraft (and appended to the Level-1A data).

> The MODIS Level-1A processor appends the satellite position and attitude to the Level-1A data product. If subsequent processing leads to changes in the spacecraft position or attitude data after the MODIS

data product has been generated, it may be necessary to reprocess the data.

Position and Attitude Knowledge for Quick-Look (052). MODIS Quick-Look processing will use the best available satellite position and attitude data.

It is assumed that the position and attitude information generated on board the spacecraft will be available for MODIS quick look processing. The quick look data product will be produced with the appropriate data quality indicators.

Coordinate System (031). Coordinates will be represented in the geodetic latitude-longitude coordinate system on a standard ellipsoid.

Coordinate transformations from the EOS platform coordinate system to the ground based geodetic latitude-longitude coordinate system will be performed by the MODIS process using standardized transformation routines. Latitude will be given in the geodetic coordinate system.

Anchor Point Selection (032). For each scan, a set of anchor points will be selected for interpolating the ground locations of pixels within the scan.

See the report "An Analysis of MODIS Anchor Point Accuracies for Earth Location", MODIS Data Study Team, Revised: April 5, 1991 for details of the anchor point method. The ground locations of the selected pixels are determined solely from the satellite position, attitude, and instrument geometry without the use of ground control points.

Anchor Point Parameters (033). The following parameters will be provided in the Level-1B data set for each anchor point: earth location (geodetic latitude-longitude) of the pixel, satellite slant range, satellite azimuth and zenith angles, and solar azimuth and zenith angles (all with respect to the pixel).

The zenith angles are relative to the normal to the local geodetic surface at the pixel.

Land/Ocean Flags at Level-1A (024). Land/Ocean, Cloud, or other derived flags will not be included in the Level-1A data product.

The scan data is in uncalibrated digital (raw) count form thereby precluding the use of any cloud detection algorithm at Level-1A.

Land/Ocean Level-1A Products (025). The Level-1A product will be supplied without separation into land/ocean or other categories.

> Navigation is not performed in the Level-1A process. Therefore, earth referencing information is not available to allow a land/ocean flag to be generated.

Level-1B Cloud Flags (051). Cloud flags will not be included in the Level-1B data product.

> Cloud flags are a Level-2 function. These flags are based upon the properties of the atmosphere which are not a consideration for at-satellite radiances. These flags may also be an interdisciplinary function that occurs at later stages in the MODIS processing. Multi-instrument registration may also be required.

Level-1B Land/Ocean Flags (039). Land/Ocean flags will not be included in the Level-1B data product.

> The current Level-1B design contains no provision for data flags. Generating a land/ocean flag may be a part of the Level-2 process.

Land/Ocean Level-1B Products (040). The Level-1B product will not be divided into a land data set and an ocean data set.

> Level-1B MODIS data products will not be categorized by spatial parameters. Headers and metadata, however, will contain indicators of this characterization based on spacecraft position and attitude data.

Level-1B Elevation Correction (036). There will be no terrain elevation correction (beyond the reference ellipsoid) to earth location at Level-1B.

> Any use of a Digital Elevation Model (DEM) will be performed in follow-on processing upon the determination of a DEM procedure and appropriate model.

Atmospheric Correction (038). No atmospheric correction of any kind will be applied in the MODIS Level-1B data.

> The definition of MODIS Level-1B data is at-satellite radiances, uncorrected for atmospheric effects such as absorption, scattering, and refraction.

Level-1A Browse (026). There will be no Level-1A browse product.

> It is assumed that browse data derived from raw packed instrument counts with no earth referencing would be of very limited use.

Level-1B Browse (041). Level-1B browse product will be generated by a separate process.

> Any required browse products will be generated by a separate browse process in order to take advantage of future technology advances without compromising the main data product processing. This allows technologies to be used as they are developed without changing the basic Level-1B product generation function. This also allows for the concept of 'on the fly' or demand browse to be implemented.

Calibration (043). Calibration algorithms and coefficients will be provided by the MCST.

> Both algorithms and coefficients will be provided by the MCST. They will be incorporated into the Level-1B software by the SDST.

Engineering Data (044). MODIS Level-1B processing will extract instrument engineering values from each Level-1A scan cube individually.

> The engineering values from the instrument will be used as parameters by the calibration equations supplied by the MCST. The parameters used to calibrate a scan cube of data will be obtained from within the same scan cube plus Level-1A data taken within a time interval of several hours on either side of the Level-1B scan cube time.

Quality Checks (010). Quality checks will be built into every stage of the MODIS processing.

> An integrated set of quality checks from all sources, including team members, will be built into the MODIS algorithms.