Update on the Status of the MISR and AirMISR Experiments

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Abstract -- The Multi-angle Imaging SpectroRadiometer (MISR) instrument is scheduled for launch in 1998 aboard the Earth Observing System (EOS) AM spacecraft. MISR consists of nine pushbroom cameras, and will provide global coverage in four visible/near-infrared spectral bands. This measurement strategy provides systematic multi-angle imagery of the Earth for studies of aerosols, surface radiation, and clouds. AirMISR, an airborne MISR simulator fabricated using a spare MISR camera, has flown on NASA ER-2 aircraft during 1997 and 1998 and obtained a number of multi-angle image sets.

INTRODUCTION

The MISR instrument was delivered in May 1997 by the Jet Propulsion Laboratory (JPL), the instrument builder, to Lockheed Martin Missiles and Space, the EOS-AM spacecraft contractor in Valley Forge, PA. EOS-AM is scheduled for launch in 1998 and will be placed into a 16-day repeat 705-km sun-synchronous orbit, with a 10:30 am equator crossing time.

MISR has been designed to provide multiple-angle, continuous imagery of the Earth in reflected sunlight. It will use nine separate charge coupled device (CCD)-based pushbroom cameras to observe the Earth at nine discrete angles: one at nadir, plus eight other symmetrically placed cameras that provide fore-aft observations with view angles, at the Earth's surface, of 26.1°, 45.6°, 60.0°, and 70.5° relative to the local vertical. The sample spacing on the ground is 275 m and can be averaged, in flight via ground command, up to 1.1 km. Each camera contains four detector line arrays, each overlain by a spectral filter.

Some of the ways in which the multi-angle viewing strategy of MISR will be used include: (1) three-dimensional cloud field and vegetation canopy structure characterization; (2) stereoscopic cloud height and wind retrieval; (3) aerosol composition and size identification; (4) aerosol optical depth retrieval; (5) cirrus detection and characterization; (6) scene-dependent albedo determination; and (7) surface classification.

MISR INSTRUMENT

A summary of several as-built performance characteristics of MISR is shown in Table 1. Additionally, view angles at the Earth's surface, calculated from the measured camera orientations, are within 0.2° of the nominal angles quoted above [1].

Thermal vacuum testing of the EOS-AM spacecraft with its complement of five instruments occurred February - March 1998. No thermal anomalies were observed for the MISR instrument and the results were consistent with data obtained during thermal-vacuum testing at JPL prior to instrument delivery.

Over 900 GB of packetized MISR data were obtained over a high-speed data link from Valley Forge to JPL. All data packet types, including CCD science and calibration, engineering, test, on-board calibrator, and motor current, were placed through automated analysis software to determine the instrument performance and health. The test was successful in establishing the instrument's flight worthiness.

MISR GROUND SOFTWARE

Spatial co-registration of the 36 channels of data from the instrument is an essential requirement of all of the MISR geophysical retrievals. This is accomplished during ground data processing. A common grid for the georectified radiances is established to provide the required co-registration. Space-Oblique Mercator (SOM) is used for this grid because its projection meridian nominally follows the spacecraft ground track and a constant distance scale is preserved along that track, thus minimizing distortion and resampling effects. The map resolution of the projection is matched to the horizontal sampling mode of each camera channel.

A separate projection will be established for each of the paths of the 233 repeat orbits of the EOS 16-day cycle. The SOM-gridded images and geophysical data constitute an intermediate step to the Earth-based map projections to be used for global mapping at higher processing levels. Two types of SOM projection will be used for MISR data: terrain projection, in which the images are mapped to a surface defined by a digital elevation model (DEM) in order to account for angle-dependent topographically induced misregistrations; and ellipsoid projection, in which the images are mapped to a surface defined by the WGS84 ellipsoid.

The MISR Science Computing Facility (SCF) at JPL and Distributed Active Archive Center (DAAC) at NASA Langley Research Center represent the primary entities in which the functions of MISR science data processing will be implemented. The DAAC, which is shared with several other

Table 1. MISR instrument system requirements and as-built specifications

Parameter	Requirement	As-Built
Spectral Bands (solar weighted in-band response)	443 ± 2 nm (Blue) 555 ± 2 nm (Green) 670 ± 2 nm (Red) 865 ± 2 nm (Near-Infrared)	446.4 nm (Blue) 557.5 nm (Green) 671.7 nm (Red) 866.4 nm (Near-Infrared)
Spectral Bandwidths (solar weighted in-band response)	≤ 30 nm (Blue) ≤ 20 nm (Green) ≤ 20 nm (Red) ≤ 60 nm (Near-Infrared)	41.9 nm (Blue) 28.6 nm (Green) 21.9 nm (Red) 39.7 nm (Near-Infrared)
Polarization Sensitivity	≤ 1%	< 1%
Absolute Radiometric Uncertainty	≤ 3% of absolute radiance at full signal	2%
Signal-to-Noise Ratio (SNR)	≥ 700 at full signal at highest spatial resolution	986
Data Rate (orbital average)	≤ 3.8 Mbps	3.3 Mbps
Quantization	Established by SNR requirements	14 bits linear, square-root compressed to 12 bits
Swath width (9-day global coverage)	≥ 360 km	389 km

EOS instruments, is the facility at which software incorporating MISR science algorithms will operate in a high volume, real-time mode to produce standard science data products.

Standard product generation at the DAAC is dependent on calibration parameters and other look-up data, such as threshold datasets, atmospheric climatologies, aerosol and surface model datasets and the like. These are produced at the SCF. Updates to these data structures occur infrequently compared to the rate of standard product generation, and therefore fit into the more limited processing capabilities of the SCF. Other essential functions that have activities at the SCF include quality assessment, algorithm and data product validation, software development, and instrument operations.

Delivery of MISR data processing software and ancillary data sets to the Langley DAAC is scheduled for mid-April 1998, to be followed by upgraded versions in mid-summer.

AirMISR INSTRUMENT

In 1996 the EOS Project Science Office at the NASA Goddard Space Flight Center (GSFC) approved the construction of an airborne MISR simulator, designated AirMISR. The NASA ER-2 is the preferred platform for AirMISR because its high flight altitude of 65,000 feet (20 km) places it above more than 90% of Earth's atmosphere. AirMISR is a pushbroom imager utilizing a single camera in a pivoting gimbal mount [2]. The computer-controlled gimbal provides images at all nine MISR angles during a 13-minute flight line. A data run is divided into nine segments, each at a specific MISR look angle. The gimbal pivots aft between segments to repeat the pushbroom data acquisition of the same area on the ground from the next angle. This process is repeated until all nine look-angles of the target area are collected.

MISR brassboard, protoflight spares, and existing ground support equipment were adapted for the camera optics, electronics, and data system. The use of a single camera to provide coverage at all nine angles is made possible since we are not attempting to obtain continuous, global coverage, as is the case from EOS. The swath width is governed by the camera field-of-view, and varies from 11 km in the nadir to 32 km at the most oblique angle. The along-track image length at each angle is dictated by the timing required to obtain overlap imagery at all angles, and varies from about 9 km in the nadir to 26 km at the most oblique angle.

Several engineering flights spanning the time interval April - November 1997 were flown out of NASA Ames Research Center. The first complete set of good images was obtained on August 25. A pair of forward and aftward red band images of Moffett Field is shown in Fig. 1. Geometric corrections have been applied only in the roll direction. During the August 25 flight, aircraft yaw tests conducted by the pilot showed that the

Figure 1. AirMISR red band images of Moffett Field, CA (August 25, 1997). Left: 26° forward. Right: 26° aftward.

airspeed indicator from the pitot tube "downwind" of the AirMISR drum became highly variable, with deviations up to 20 kts compared to the pitot tube in the clean airstream. As this is a flight safety issue, a structural extension of the pitot tubes was recommended, and the aircraft manufacturer (Lockheed) completed the requisite design and fabrication. A test flight was conducted on November 4, 1997. The pitot tube extensions improved the airspeed reliability as hoped, and AirMISR was declared to be flight qualified.

In mid-November 1997 the ER-2 aircraft were relocated to the NASA Dryden facility at Edwards Air Force Base in the Mojave Desert, CA. Additional flights have been flown from this site, including runs over Rogers Dry Lake and Pasadena, CA. A flight to Alaska is planned for May 1998.

AirMISR GROUND SOFTWARE

MISR-equivalent pixels can be constructed by binning raw pixels in the ground data processing, taking into account the full resolution and frequency updates of aircraft-supplied navigation and attitude data. From ER-2 altitude, the AirMISR camera has an instantaneous footprint of 7 m cross-track x 6 m along-track in the nadir view and 21 m x 55 m at the most oblique angle. Lines of image data are acquired every 40.8 msec, resulting in an along-track sample spacing, regardless of view angle, of 8 m for an aircraft ground speed of 200 m/sec. Thus, it is possible to generate samples which match MISR pixel dimensions at any view angle, and to compensate for the variable footprint dimensions with angle in the ground data processing. It is also possible to make use of the higher resolution imagery. Image geolocation and registration software that maps the AirMISR multi-angle data to a common resolution of 27.5 m, ten times finer than the MISR resolution, is currently being applied to the data.

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For further information about the MISR and AirMISR experiments, the reader is invited to peruse our World Wide Web site at *http://www-misr.jpl.nasa.gov*.