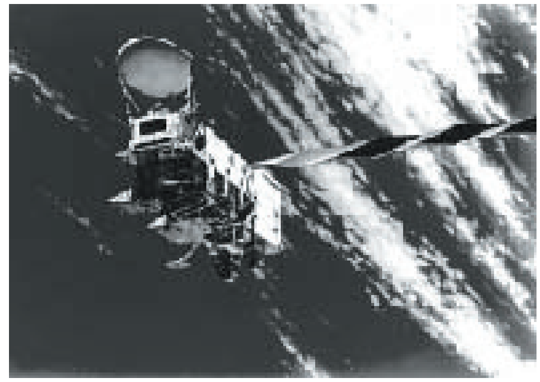
The Earth Observer, May/June, 1997, Vol. 9 No.3

PM Science Working Group Meeting on Spacecraft Maneuvers



--Claire L. Parkinson, clairep@neptune.gsfc.nasa.gov
PM Project Scientist, Goddard Space Flight Center

The EOS PM Science Working Group met on May 6, 1997, to examine the issue of spacecraft maneuvers. The meeting was held at NASA Goddard Space Flight Center and was attended by the Team Leaders of all four instrument science teams with instruments on the PM-1 spacecraft, additional representatives from each of the four teams, the PM Project management, and random others. The meeting was chaired by the PM Project Scientist and open to all.

The meeting was called in order to untangle some of the concerns raised over the past several months regarding whether or not the PM-1 spacecraft should undergo spacecraft maneuvers to allow the instruments to obtain deep-space views. Two of the Science Teams, those for the Moderate-Resolution Imaging Spectroradiometer (MODIS) and the Clouds and the EarthÍs Radiant Energy System (CERES), had strongly expressed the need for deep-space views in order to calibrate their instruments properly and conveniently. The other two teams, those for the Advanced Microwave Scanning Radiometer (AMSR-E) and the Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU), and the Humidity Sounder for Brazil (HSB), had expressed concerns that the maneuvers involve risks to the instruments and undesired gaps in the data sets.

The meeting began with introductory statements by the PM Project Scientist, Claire Parkinson, the PM Project Manager, Marty Donohoe, and the EOS Program Scientist, Ghassem Asrar. Parkinson opened the meeting by briefly summarizing the basic positions of the four teams and expressing the desirability of coming to a resolution on the maneuver issue early, so that each team can proceed accordingly. Donohoe explained that the spacecraft contractor’s (TRW’s) specifications include the possibility of a maneuver, and that the Project management will task TRW to study whatever consensus maneuver the scientists decide upon. Asrar reiterated the importance of the maneuver issue, explained that he is anxious to hear the arguments of each of the teams, and mentioned that we cannot ignore the international dimension and must be particularly sensitive to concerns the Japanese have raised concerning the AMSR-E instrument that they are providing for the PM-1 mission. All other instruments on the PM-1 spacecraft are from the U.S. with the exception of the HSB, which is being provided by Brazil.

The introductory statements by Parkinson, Donohoe, and Asrar were followed by a short presentation by the AIRS/AMSU/HSB (or AIRS for short) Team Leader, Mous Chahine, laying out what he sees as the appropriate metric for making a decision. In particular, although he is convinced that the MODIS and CERES calibrations will be helped by a maneuver, Chahine feels that the decision on whether or not to have a maneuver should be based, in part, on the quantitative impact on the accuracy of the derived geophysical parameters, specifically the Level 2 products. Bruce Barkstrom, the CERES Team Leader, indicated that it would be best to add Level 3 products to the metric, and Chahine readily agreed.

The setting-the-scene presentation by Chahine was followed by presentations by each of the four science teams, detailing their respective positions.

The MODIS Team Position

The MODIS Team Leader, Vince Salomonson, began the MODIS presentation by explaining that he and his team have been considering whether they need a maneuver for quite some time and are convinced that a maneuver is essential for them in order to meet their most visible Level 1 requirement, which is to obtain sea surface temperatures (SSTs) to an accuracy of 0.3-0.5 K. The MODIS Project Scientist, Bob Murphy, then explained the flow-down from the SST requirements to the MODIS instrumental requirements and indicated that a simple single-axis nighttime maneuver taking 40 minutes would meet most of the MODIS needs. Murphy stepped through a schematic of the maneuver sequence and showed, using several relevant plots, that, with the maneuver, the MODIS instrument will meet the specifications for absolute radiometric uncertainty for most of the MODIS bands.

Otis Brown, in collaboration with Peter Minnett, presented the rationale for SST accuracy requirements, made comparisons with earlier instruments, and gave details on the MODIS scan mirror characteristics and the usefulness of the maneuver to the SST accuracies. Typical SST anomalies, for instance for El Nio, are on the order of 2 K, guiding the desire for an SST error of less than 0.5 K. The Advanced Very High Resolution Radiometer (AVHRR) currently in operation obtains such accuracies on a global basis without the need for a spacecraft maneuver. However, because of the differing scan geometries and mirror coatings, MODIS will not be able to obtain the same accuracies without the desired deep-space view. (A Denton coating was selected for the MODIS mirror because of the wide spectral range to be covered, although it would not be the ideal choice if the only channels were the infrared channels used in the SST calculations.) The uncertainties in the MODIS mirror properties cannot be compensated by routine in-flight calibration, but should be compensated by the deep-space view, as recently demonstrated with the Geostationary Operational Environmental Satellite (GOES), which also has a Denton mirror coating. Efforts preparatory to the MODIS SST validations have confirmed the ability to obtain in situ skin surface temperatures to an accuracy of 0.1 K.

The next portion of the MODIS presentation was given by Chris Moeller, who, in collaboration with Paul Menzel, is developing a cloud mask for the MODIS data. A good cloud mask is essential for obtaining accurate MODIS-derived SSTs. Moeller explained the experience with GOES and its Denton mirror coating, as well as the impact of scan mirror uncertainty on both the MODIS radiances and the MODIS cloud mask. Comparisons between the water vapor measurements from radiosondes and GOES have quantified the value of the GOES scan mirror correction. Data from the MODIS Airborne Simulator (MAS) suggest a loss in accuracy of about 0.6 K due to the uncertainties in the scan mirror emissivity. Results for one case study show that, with the current cloud mask, about 1% of the pixels change classification after removing the scan-error uncertainty, although final fine-tuning of the cloud mask will have to await satellite MODIS data. Moeller warned that there could be major delays in data processing if no maneuver is performed, as in that case corrections will probably be made using an Earth-scene regression that is time-consuming and not as reliable as the deep-space view.

Murphy summarized the MODIS position by stating that a maneuver at the start of the PM-1 mission is essential in order to bring the MODIS performance to required levels and allow the SST, land surface temperature, and atmospheric algorithms to meet their required accuracies. Experience with the AM-1 mission will help determine whether subsequent PM-1 maneuvers are also desired.

Extensive discussion occurred during the MODIS presentations. One highlight was the analysis by Ghassem Asrar that, consequent to the convincing argument by Otis Brown, Earth observations alone will not be sufficient to eliminate the largest uncertainty in the MODIS data, i.e., the scan error emissivity bias; it becomes critical either to perform the maneuver or to devise an alternative strategy for removing the uncertainty. Chahine indicated that alternative strategies might be possible.

The CERES Team Position

The CERES Team Leader, Bruce Barkstrom, presented the CERES Team position, which, like the MODIS Team position, also includes a very strong desire for deep-space observations. The CERES Team has had extensive experience with the Earth Radiation Budget Experiment (ERBE), which flew on the Earth Radiation Budget Satellite (ERBS) with a spacecraft maneuver and on NOAA 9 and NOAA 10 without a spacecraft maneuver. Barkstrom estimates that the NOAA 9 ERBE data set required approximately one yearÍs extra data processing because of not having the calibration benefit of a deep-space view. The agonizing experience with the NOAA 9 ERBE data has led to a very strong desire of the CERES Team to make sure that the PM-1 spacecraft obtains the needed deep-space view. The CERES Team will produce ERBE-like data products from the PM-1 data as well as the more-advanced CERES/MODIS products incorporating the cloud property identification from the MODIS radiances.

The CERES Team desires for a deep-space view include: (1) limb-to-limb observation of deep space at all azimuths, and (2) timing the observations to occur on the dark side of the Earth. The team has no requirement on the maneuver mechanism but would like to divide the maneuver into segments of about 10 minutes at each of three scan positions. The most critical need is for a maneuver early in the mission, at about 45 days after launch, but they could also benefit from a second maneuver one year later and will know better after experience with AM-1, following its 1998 launch, whether additional maneuvers will be desired. The deep-space view will reduce the time needed both for CERES validation and for getting the CERES data products to EOSDIS.

The AMSR-E Team Position

The AMSR-E Team Leader, Roy Spencer, explained that he and the other AMSR-E Team members might be able to derive a small calibration benefit from a maneuver if the AMSR-E were operating during it, but that this potential benefit might become irrelevant, because the AMSR-E might have to be turned off in the event of a maneuver. The Japanese providers of the instrument (along with the AMSR-E Team and the PM Project management) are concerned about the risks involved in having the spacecraft turn over while the 220-kg mass of the spinning portion of the AMSR-E is in its spinning mode, rotating at 40 revolutions per minute with a 1.6-m antenna. Further study is needed regarding whether the instrument and the satellite could withstand the torques imposed by a maneuver carried out with the AMSR-E operating. Until such studies can be done and confirm the safety of the procedure, the Japanese have indicated that they would want to spin down the AMSR-E prior to any maneuver, followed by spinning it back up after the maneuver. They estimate that the combined spin-down/spin-up procedure would result in approximately a two-week data gap centered on each maneuver. Facing two-week data gaps, the AMSR-E Team would be very adverse to having a maneuver any more frequently than once a year. They are not adverse, however, to a single maneuver at the start of the mission to satisfy the major needs of the MODIS and CERES Teams.

The AIRS Team Position

The AIRS Project Scientist, George Aumann, presented the AIRS Team position. He emphasized that from what is known about the AIRS instrument as of May 1997, the AIRS does not need a deep-space view and that, because of the data losses and risks involved with a maneuver, the preference of the AIRS Team is that no maneuver be done. He explained three significant differences in the AIRS and MODIS situations in spite of their both having a Denton coating:

1. AIRS uses a Denton coating only on the scan mirror, with all other AIRS mirrors being gold-coated. Furthermore, the AIRS scan mirror is used at a fixed angle of 45Á. In contrast, the MODIS mirrors are all Denton coated, and the MODIS scan mirror is used at angles of incidence ranging from -11 to +65 degrees.

2. The required absolute calibration accuracies for the two instruments differ significantly, that for AIRS being 3% and that for MODIS being 0.5%.

3. The AIRS data processing uses routine daily checking of the calibration and, on a monthly timescale, tuning of geophysical parameters relative to a global set of co-located radiosondes.

In response to a query on whether the AIRS would be turned off in the event of a maneuver, Aumann replied that this would not be done. The maneuver itself, if executed as planned, might not pose a risk to the AIRS instrument, but it is expected to shift the spectral response of the AIRS outside the range permissible for normal

Level 2 data processing. Aumann fears that the resulting disruption of the data processing would likely appear as an artifact in the long-term AIRS Level 2 data record, a situation that would not be acceptable for the AIRS mission objectives.

Decision and Remaining Issues

By the end of the meeting, it was agreed to request that the PM Project have TRW do a feasibility study for having a single maneuver at about day 45 of the mission, after turning on the MODIS and CERES instruments but prior to turning on the AIRS and AMSR-E instruments. All parties agreed to this as an appropriate first step, recognizing that the issue will have to be readdressed later, after additional information is obtained. In addition to the TRW study, the Japanese will be examining the issue further for the AMSR-E instrument, and the AIRS Team has decided to undertake a study of the AIRS mirror similar to the study done by the MODIS Team for the MODIS mirror, with the possibility that the AIRS Team position could thereby be revised. Also, both the MODIS and CERES Teams will have a better handle on the value of the maneuver and the desired frequency after the EOS AM-1 spacecraft is launched, and they have a chance to analyze the effects on their data sets of the AM-1 maneuvers.

At the end of the meeting, David Starr, the EOS Validation Scientist, briefly discussed the major steps in the upcoming validation planning exercise for PM-1. Draft plans are due from the AIRS and AMSR-E Teams on August 15, following which a workshop will be held in September and revised plans will be due in December. An NRA for validation studies, specifically for PM-1, can be expected to be released in about two years.