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Midcourse Space Experiment Data Certification and Technology Transfer

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Prepared for
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INTRODUCTION

The University of Alabama in Huntsville contributes to the Technical Management of the Midcourse Space Experiment Program, to the Certification of the Level 2 data produced by the Midcourse Space Experiment's suite of in-orbit imaging radiometers, imaging spectro-radiometers and an interferometer and to the Transfer of the Midcourse Space Experiment Technology to other Government Programs. The Technical Management of the Midcourse Space Experiment Program is expected to continue through out the spacecraft's useful life time. The Transfer of Midcourse Space Experiment Technology to other government elements is expected to be on a demand basis by the United States Government and other organizations. The University of Alabama Huntsville' contribution specifically supports the Principal Investigator's Executive Committee, the Deputy Principal Investigator for Data Certification and Technology Transfer team, the nine Ultraviolet Visible Imagers and Spectrographic Imagers (UVISI) and the Pointing and Alignment of all eleven of the science instruments. The science instruments effectively cover the 0.1 to 28 micron spectral region. The Midcourse Space Experiment spacecraft, launched April 24, 1996, is expected to have a 5 year useful lifetime with a 12 month lifetime for the cryogenically cooled IR sensor. A pre-launch, ground based calibration of the instruments provided a basis for the pre-launch certification of the Level 2 data base these instruments produce. With the spacecraft in-orbit the certification of the instrument's Level 2 data base is being extended to the in-orbit environment

SCOPE

This Final Report for Delivery Order 171 reports on the work done for the Midcourse Space Experiment between 30 September 1996 and 30 June 1997. A Final Report and Quarterly Reports for Delivery Order Number 153, Contract NAS8-38609, the predecessor Delivery Order, covers the work done for the Midcourse Space Experiment Program up to 29 September 1996.

BACKGROUND

All analysis and data products from the Midcourse Space Experiment are reviewed to ensure that misinterpretation and incorrect analytical results do not disseminate from the program. In the past, resources have been wasted as hurried analysis, misinterpreted results and incorrect conclusions were released by parties working on earlier space programs. This led to mistrust of the program's results, contradictory conclusions from the same data, and duplication of effort. The Midcourse Space Experiment program structure was designed to guard against this.

The Midcourse Space Experiment program structure was developed to ensure all

processes are reviewed from the collection of data to the analysis and interpretation of data. The Data Certification and Technology Transfer certification is part of the overall certification of all the scientific results of the Midcourse Space Experiment data. A Midcourse Space Experiment Data Management Teams verifies the flow of the data, the Data Certification and Technology Transfer Team certifies the processes which convert the bits to engineering units and a Principal Investigator Executive Committee peer reviews the analysis and the interpretations derived from the data. Thereby, all processes are reviewed from data collection to data interpretation which ensures that all Midcourse Space Experiment products benefit from the overall knowledge within the program.

The Data Certification and Technology Transfer team's data certification process provides the Midcourse Space Experiment Principal Investigator teams with reliable sensor and spacecraft data, provides future users valid databases and procedures for accessing and understanding the Midcourse Space Experiment's data, and the community with correct analysis of instrument performance data products

PHILOSOPHY

The Midcourse Space Experiment program is generating multi-tera-bytes of raw data. The Data Certification and Technology Transfer team cannot review each byte individually to certify this vast database. The Data Certification and Technology Transfer's review technique is similar to a method of process certification used in manufacturing. The Data Certification and Technology Transfer team certifies the sensor performance within its operational bounds as it operates within the environment encountered during ground calibration and in-orbit using a statistics based data analysis. Within the bounds, the sensor's operation and the process by which the sensor raw data is converted to scientific and engineering units, is certified by the Data Certification and Technology Transfer team. The data reduction process is called the CONVERT process. In-orbit measurements of standard calibration sources are used by the sensor engineering teams to improve the sensor's calibration and as a basis for modifications to the CONVERT process if necessary. The Data Certification and Technology Transfer team participates in any process modification, reviews the suggested changes, tests the altered process against standard data sets and certifies the changed process. The irradiance from the standard sources, both on the ground and in-orbit are certified by the Data Certification and Technology Transfer team. To certify a Virtual Level 2 database many processes must be understood, reviewed and analyzed by the Data Certification and Technology Transfer team members. The major technical areas of the Data Certification and Technology Transfer certification plan are the sensor's calibrations, the CONVERT software, and a verification the sensors operated within their respective operational

envelope.

At all stages through the certification process the Data Certification and Technology Transfer team reviews the error allocation budget. The error associated with the calibration process is divided up between all the calibration processes in order to meet the program's performance goals.

IMPLEMENTATION

The Data Certification and Technology Transfer allocates to a Watchdog each Midcourse Space Experiment scientific instrument or a suite of instruments. The Data Certification and Technology Transfer Watchdog is responsible for a detailed certification analysis of the single instrument or suite of instruments allocated. The Watchdog works with the individual instrument Performance Assessment Team. The Data Certification and Technology Transfer team, in turn, performs an independent data analysis and compiles a Certification Report to the Principal Investigators and to the Program Office.

DEPUTY PRINCIPAL INVESTIGATOR

MISSION PLANNING

Reviews of the Data Certification and Technology Transfer's Monthly Objectives and scheduled experiments are performed each four weeks. This time period is a Mission Month for Planning purposes. Specific options for the Data Certification and Technology Transfer Experiment plans being planned for that period are selected and formally provided to the Mission Planning Team. Periodically the Mission Planning Team meets with the Data Certification and Technology Transfer Watchdogs and the Science Instrument Performance Assessment Teams to adjust the data collection activities. At these meetings the Planned Data Certification and Technology Transfer Data Collection Events are updated as the mission progresses. Three updates were accomplished during the period reported by this document.

MISSION PLANNING TEAM MEETINGS

DECEMBER 4

A unique experimental opportunity to study contamination on-board an in-orbit spacecraft is presented by the SPIRIT III sensor's warm-up immediately upon the depletion of its cryogen. The loss of cryogen is expected to occur early in 1997, the precise date being uncertain. Also, optimal utilization of the spacecraft resources as well as the potential for contamination effects on the other sensors mandates a SPIRIT III sensor warm-up concomitant its cryogen depletion be well planned and coordinated. At this meeting the SPIRIT III End of Cryogen

Operation, an activity known as SECOT, planning began. Also at this meeting the progress, the status and potential issues of the UVISI instruments and the spacecraft pointing were discussed at individual meetings with certain members of the UVISI Performance Assessment Team and Data Processing Center and the Attitude Processing Center.

An opportunity to coordinate with the UVISI Data Processing Center and Performance Assessment Team personnel and the Attitude Processing Center staff presented itself upon the completion of the SPIRIT III End of Cryogen Operations Team meeting.

This December 4, 1996 Mission Planning Team - Performance Assessment Team - Data Certification and Technology Transfer team meeting exposed the need for the Principal Investigator teams to carefully review the Mission Month 12, 13 and 14, the period when the SPIRIT III sensor will reach its useful end of life due to cryogen depletion. The SPIRIT III sensor's end of useful life date and time is uncertain on the order of days to weeks. The principal factors which contribute to this time uncertainty are the sensor's increased noise, decreased dynamic range and increased responsivity as the focal plane array temperatures increase by fractions of a degree Kelvin. The total temperature span for the sensor's useful life time is on the order of 1.5 to 2 degrees Kelvin. There is significant variation, as large as a degree, in the FPA temperatures due to day to day operation of the sensor during Data Collection Events which look at or near the earth. Thermal models of better or lesser quality are used to estimate the temperatures and the temperatures are also monitored carefully. There are temperature sensor's epoxied on the hydrogen tank top and bottom. Down looking Data Collection Events can be used to estimate the respective model quality during warm-up. It will require approximately 44 mega-joules to raise the sensor to 220 K. It will take about 6 hours of tape recorder time to get the baffle to more than 140 K. The General Research International thermal model indicates it will take about 20,000 seconds to warm-up to 140 K using the hard earth. The model also indicates it will take about 2,000 seconds to warm-up to 100 K using the sun. It is desirable to expedite the warm-up to minimize the time taken from Data Collection Events by the other sensors. The out gassed contaminants return flux which might degrade the other sensors is predicted to be negligible compared to what was seen from the argon flux which of itself was negligible. Base line performance of the other sensor's just prior to and just after the warm-up experiment is essential.

The Johns Hopkins University Applied Physics Laboratory thermal model and the Space Dynamics Laboratory Utah State University thermal model will be coordinated by the first week in January. The experiments to support the warm-up experiment are to be identified and a first cut plan assembled. There will a SECOT telephone conference call at 1:00 P.M. EST on January 18. The next

SECOT meeting is scheduled for January 16 at Johns Hopkins University Applied Physics Laboratory.

The Contamination Principal Investigator has the lead responsibility to plan the SPIRIT III warm-up experiment. The Data Certification and Technology Transfer team responsibility is to assure a baseline of performance is established in concert with the warm-up experiment. The baseline of performance will include out-of-field-of-regard rejection, throughput and alignment for the other science instruments. Existing experiment plans will be redlined and implemented by the respective Performance Assessment Teams as appropriate. These inputs are needed by the Mission Planning Team as soon as possible to support the planning time line because the planning for the expected end of cryogen months, 12, 13 and possibly 14 begins 6 weeks prior to the start of month 12. That is soon.

UVISI Performance Assessment Team - Watchdog Meeting

The UVISI Data Processing Center will install a RAID data storage system over the Christmas holiday period. The Data Processing Center will be down for about three days. The data backlog should be caught up in a few days after the change over. It is noted the dark offset data is incorrectly gathered by the UVISI Pipeline process. Software changes to fix this problem will require all UVISI data to be rerun, possibly from the Level 1b. If done from the Level 1a, it will require running the data through the Pipeline. It is noted no seems to be using the DQI data as planned. Instead, Quick Time movies are being created. The quality of every frame of data rather than every fifth frame is being assessed. The initial user request some years ago when the Data Processing Center was being planned and built was for the DQIs only and the concept of assessing each data frame was rejected at that time. The IUN instrument has been flat fielded using the earths atmosphere as the source. The IUW flat field is being done also using the solar blind region of the earth's atmosphere. The wide field of view imagers need their response updated. The IVW response, the most inaccurate, is off by about three orders of magnitude. The updates will be made to the next version of the calibration files.

Pointing Performance Assessment Team - Watchdog Meeting

The Attitude Processing Notes format has been completed. The details are to be reported to Data Management. The format will be consistent with the MOC Data Products book's formats. The Data Collection Event DC.29.03 will use the Walker-Schlafer field number 72 instead of number 92 to preclude a glint problem for UVISI's IVN. The sun angle will be about 146° for field number 72. The Definitive Attitude reprocessing is planned to start December 16. The reprocessing will be done in chronological order unless other factors dictate a different order.

FEBRUARY 26

The Definitive Attitude Version 03 process introduces virtual spacecraft motion that is greater than is tolerable for most data analysis. A plan to use either an interpolated and reformatted on-board attitude solution or a further changed Definitive Attitude process to produce a tolerable Definitive Attitude File compatible with the respective CONVERTs has been implemented. The status of the Pointing and Alignment for the spacecraft and the science instruments presented to the Mission Planning Team - Data Certification and Technology Transfer team - Performance Assessment team attendees shows the work in progress.

The Pointing Performance Assessment Team plans to meet Friday, March 7, at the Applied Physics Laboratory. The DC.29.03.00003.01 Data Collection Event is the experiment which the spacecraft and the science instrument teams have been asked to use as the basis for their respective analysis of pointing and alignment stability. One additional variation of a DC-29 Data Collection Event, planned to provide a data set to refine the gyro to star camera alignments, is identified for the Mission Planning Team. The SPIRIT III sensor's cryogen was depleted as of the day of this Mission Planning Team - Data Certification and Technology Transfer team - Performance Assessment Team meeting, February 26, 1997. Because of this the DC-29 on the schedule for execution February 28 is preempted by the Contamination Team's end-of-cryo experiments. A new date for the DC-29 remains to be determined. It is forecast only one more DC-29 is required to completed the Pointing and Alignment data set. This one is tentatively planned to provide the data set to complete the gyro to star camera alignment.

APRIL 24

A Phase One of spacecraft operations ended when the cryogen expired and the SPIRIT III sensor ceased to be functional February 26, 1997 and Phase Two of spacecraft operations began. The Phase Two operations are to be more routine with less planning required. A cost effective, timely transition requires careful planning by those who will continue to use the spacecraft to collect data. The pointing and alignment of the science instruments remains the program's top level unresolved issue.

The Pointing and Alignment data collection events, the DC-29s, are critical to resolving the pointing issue. The need to conduct these Data Collection Events periodically until the pointing issues are resolved is critical.

The Pointing and Alignment data collection events are scheduled to occur each Saturday for Phase Two operations. This has minimal impact on the science, space surveillance and calibration maintenance events routinely conducted in Phase Two.

SPIRIT III CERTIFICATION

Meetings with Space Dynamics Laboratory Utah State University SPIRIT III Performance Assessment Team provide an opportunity to set priorities for the SPIRIT III Calibration data analysis and to coordinate the schedules for the CONVERT and Pointing CONVERT Software's completion and release to the Principal Investigator teams.

CONVERT VERSION 4

The Data Certification and Technology Transfer team and the SPIRIT III Performance Assessment Team completed the CONVERT 4.1 Certification Letter at a meeting which preceded the April 24, 1997 Mission Planning Team - Data Certification and Technology Transfer team - Performance Assessment Team meeting. This letter provides the certified radiometric performance of the SPIRIT III radiometer and interferometer and the goniometric performance. The letter is distributed in conjunction with the CONVERT Version 4.1 distribution from the Background Data Center. The SPIRIT III Certification letter was successfully completed and distributed from the Data Certification and Technology Transfer's offices to the Background Data Center.

PRINCIPAL INVESTIGATORS EXECUTIVE COMMITTEE

MEETINGS

OCTOBER 28

The Data Certification and Technology Transfer team's Post-launch Certification analysis of the UVISI Instrument's data is essentially complete. A peer review of the Certification by the Principal Investigator's Executive Committee is scheduled for October 31. The Data Certification and Technology Transfer team's preparations, by all the parties involved in this analysis, is essential to identify unresolved issues and the plans to resolve them.

The Principal Investigator's Executive Committee continued to plan for a technical exchange between the MSX personnel and the SBIRS Low (formerly the SMTS) personnel of the work being accomplished by the MSX Program and of the technical requirements being developed for the SBIRS Low program. The Definitive Attitude analysis and reprocessing status was reviewed. The Contamination Team's work is planned for a peer review at this meeting. The UVISI Certification is planned for review at this meeting.

The Data Certification and Technology Transfer's thorough UVISI Certification analysis review identified technical issues. This work was done at the General Research Corporation International, Danvers, Massachusetts, as preparation for the Peer Review one day later at the Massachusetts Institute of Technology

Lincoln Laboratory, Lexington, Massachusetts.

The Principal Investigator's Executive Committee reviewed the Data Certification and Technology Transfer's Certification of the UVISI Instruments as well as the UVISI Performance Assessment Team's recommendations to address the issues revealed by the certification analysis.

The Definitive Attitude reprocessing status was reviewed with the Principal Investigator Executive Committee. The improvements made thus far indicate the Definitive Attitude may meet performance requirements. Each Principal Investigator's team needs the reprocessed Definitive Attitude to expeditiously proceed with their analysis.

A presentation made to the Principal Investigator's Executive Committee which documents the Definitive Attitude reprocessing status is attached to the trip report for the meeting. A second round of revisions to the Definitive Attitude filter have been made. Revised Definitive Attitude files produced with this revised filter are being distributed to selected Data Processing Centers and Data Analysis Centers for analysis. A Pointing Performance Assessment Team meeting is scheduled for November 22 to review the analytical results of the effects of the changes made to the filter. A final decision to initiate reprocessing of the spacecraft's Definitive Attitude since launch depends upon the analytical findings. The findings are to be reviewed at the November 22 Pointing Performance Assessment Team Meeting.

The UVISI Certification Analysis is formally documented and distributed to the Backgrounds Data Center by the Data Certification and Technology Transfer team from the General Research Corporation International office. The UVISI CONVERT 3.2c Point Source Extraction algorithm needs to be improved. The operational envelope settings as well as other Data Quality Indices within the Pipeline process for each instrument need to be reviewed and improvements made. A plan to resolve these newly opened issues identified during the Certification was presented by the UVISI Performance Assessment Team.

NOVEMBER 19

The Principal Investigator's Executive Committee met at the Johns Hopkins University Applied Physics Laboratory to address End-of-Cryogen and Post-Cryogen Mission Planning, to conduct a Peer Review of the Short Wavelength Terrestrial Backgrounds work and to review the Data Certification and Technology Transfer team's plans for the SPIRIT III CONVERT Version 4.0 and UVISI CONVERT Version 3.2C Certifications. The MSX Program Office published the meeting minutes.

JANUARY 20

The Principal Investigator's Executive Committee completed a peer review of the Early Midcourse team's work and the Earthlimb team's papers and the normal work agenda. The SPIRIT III's solid hydrogen cryogen is nearly depleted and it is timely to initiate post-cryogen phase program level planning. The Early Midcourse team's work and papers by the Earthlimb team are ready for peer review.

FEBRUARY 18

The Principal Investigator's Executive Committee met to Plan the joint IRIS Specialty Group and MSX Meeting scheduled for June 2 - 5, 1997, review abstracts for the American Geophysical Union Meeting, peer review four papers by the Surveillance Principal Investigator's team, report on the individual teams work and plan post-cryogen operations of the spacecraft.

The initial concept for MSX Phase II, post-cryogen, mission planning is to use routine Surveillance and Celestial Data Collection Events as the guide. Discussions indicated this would be a viable solution for Operations, the Surveillance, the Earthlimb and the Celestial Principal Investigators and the Mission Planning Team. The Data Certification and Technology Transfer events will be handled by the respective instrument teams with the Data Certification and Technology Transfer Data Collection Event's sandwiched in as appropriate. The morning and afternoon cluster of spacecraft passes over Applied Physics Laboratory are adequate to accommodate the up- and down-link time required. Target missions would be special events for the planning and execution process and the Celestial, Earthlimb and the Surveillance Data Collection Event's would be planned around them.

MAY 5

The Principal Investigator's Executive Committee met to peer review the Early Midcourse Test and Evaluation Team's automated data processing and to plan for the MSX Program's Interim Results Review. An Interim Results Review is planned jointly with a Space Surveillance Meeting, IRIS, June 2-3 and 4-5 respectively, at the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland.

Pointing Performance Assessment Team conference calls were made on May 5, 8, 12, and 15 and calls to specific individuals addressed the Definitive Attitude issues.

MSX Program conference calls were made on May 6 and 13.

The Early Midcourse Test and Evaluation Teams automated data processing passed its peer review.

A SBIRS IPT met with the Principal Investigator's Executive Committee and coordinated data and technology transfer between the SBIRS and the MSX programs.

The Early Midcourse Test and Evaluation Team's automated data process was approved. Details are in the MSX Program Office's published minutes of this meeting.

Three versions of a Pointing and Alignment Status briefing for the Interim Results Review in June were peer reviewed. This resulted in an acceptable version of the briefing which is to be reviewed by the co-author, T. E. Strikwerda, prior to its presentation at the planned Interim Results Review in June.

SBIRS HIGH & LOW

SBIRS LOW CRITICAL DESIGN REVIEW

The technology, the data and the analysis of the MSX Program can play an effective risk and cost reduction role as the SBIRS program progresses. The SBIRS Low Critical Design Review provided an opportunity for the MSX's Technical leaders to gain further insight to the SBIRS Low technical design and approach. Concomitantly, this occasion also provided an opportunity for the MSX's Technical leaders to collectively identify those aspects of the MSX Program's technology, data and analysis which can most effectively contribute to the SBIRS Low program, essentially in real time. The identified results can be provided to the SBIRS Low personnel at a future, mutually agreeable time

The MSX Principal Investigator's Executive Committee and key representatives from the MSX Operations staff actively attended the SBIRS Low Critical Design Review, Critical Design Review at the Hughes Aircraft Corporation, El Segundo, California, December 12-13, 1996 . The MSX Principal Investigator Executive Committee, the program's technical leaders, met the day before and each evening after the Critical Design Review presentations to discuss the presented material and to identify those aspects of the MSX Program's technology demonstrations, data analysis and operations which can be most effectively applied to enhance the SBIRS Low technical progress, thereby reducing the SBIRS Program's risk and cost.

The preparations for a Technical Exchange Meeting between the MSX Program and the major participants in the SBIRS Program, both Low and High, were coordinated with the SBIRS management. A tentative date for this Technical Exchange Meeting was set for February 21 and 22 at Hughes Aircraft Company and at Lockheed Missile and Space Company respectively.

During the after hours meetings the drafted technical contents of the Early Midcourse, Cooperative and Theater, the Contamination, the Earthlimb, the Short Wavelength and Terrestrial Background and the Data Certification and Technology Transfer Principal Investigator's material which had been prepared to support the Technical Exchange Meeting were reviewed, discussed, analyzed and revised.

Comments on the SBIRS Critical Design Review are provided to the MSX Program Office and they in turn compiled a program response to the SBIRS Program Office. A dominant impression from the SBIRS Critical Design Review is the need to make sure all the Flight Demonstration System instruments, both those from Hughes Aircraft Company and the one from Rockwell International, are well characterized, calibrated and the data reduction processes are well documented and well reviewed. Without this effort the instruments will produce less than meaningful data with which to design an Objective System. The challenge is going to be how to do the calibrations, characterizations and documentation with a design to cost program. There is a need to carefully identify the specific issues to which the Flight Demonstration System instruments can contribute data and to emphasize the calibration, characterization and documentation efforts to support those specific issues. Any calibrations, characterizations or documentation are not excluded but rather it is necessary to prioritize those elements of calibration, characterization and documentation which will be done to support the key, fundamental issues which the Objective System design must meet.

SBIRS LOW & HIGH TECHNICAL EXCHANGE MEETING

The MSX Program respectively held, January 21 and 23, a Technical Exchange Meeting with the SBIRS High and the SBIRS Low programs staffs. A Technical Exchange Meeting agenda was completed at both the Hughes and the Lockheed Martin Companies, the respective SBIRS High and the SBIRS Low contractor. Multiple member of the SBIRS High and the SBIRS Low program staffs as well as members of the MSTI program staff participated in both of the Technical Exchange Meetings. The Principal Investigator presentations were made and insight to the SBIRS High and the SBIRS Low programs requirement's for data and analysis thereof was obtained. Comments on the Technical Exchange Meeting were provided to the MSX Program Office under separate cover.

NIST'S ANNUAL BALLISTIC MISSILE DEFENSE ORGANIZATION REVIEW

The MSX Program of the Ballistic Missile Defense Organization has been represented at the Ballistic Missile Defense Metrology Project Review, held annually at the National Institute of Standards and Technology for the past six

years. The National Institute of Standards and Technology work has directly supported the MSX Program's Reference Sphere material properties characterization, spectral emittance measurements are still outstanding, with the National Institute of Standards and Technology Low Background Infrared Facility and the Infrared Detector Standards work has helped to characterize the unexpected dark offset temperature behavior of the SPIRIT III infrared detectors. The Ballistic Missile Defense Organization representative reported on three PMAs, Theater Missile Defense, National Missile Defense and the Low Background Infrared facility which support the on going Ballistic Missile Defense Organization's technical work. The Ballistic Missile Defense Organization priority for this work is Theater Missile Defense first, National Missile Defense second and technology third.

The National Institute of Standards and Technology work reviewed is listed on the Agenda, see "proceedings of the BMD Metrology Review", December 17-18, 1997, the National Institute of Standards and Technology. Current work of particular current interest to Ballistic Missile Defense Organization is the development of the Medium Background Infrared Calibration chamber, the spectral capability now operational in the Low Background Infrared Calibration chamber, the Infrared Filter Measurements and Standards and a National Institute of Standards and Technology initiative to establish a Radiometric Calibration Standards capability in space using either or both the International Space Station or the MIR. The United States interest may well be in support of the SBIRS High and Low programs, the Ballistic Missile Defense Organization's Theater Missile Defense, National Missile Defense and technology development, NASA's Mission to Planet Earth as well as that of basic science.

The agenda topics, op cit, are all applicable to and essential for the continued optical sensor developments used in Ballistic Missile Defense. Both near term and longer term specific benefits from this work are directly applicable to the SBIRS program. Near term areas are the Medium Background Infrared chamber, the Infrared Filter Measurements and Standards and the Portable Cryogenic Spectral Radiometer. A longer term effort is Space-based Radiometry and Standards. In addition the MSX Program still awaits their reference sphere material's spectral emittance measurements in the Low Background Infrared chamber, a capability which has finally come on-line.

The National Institute of Standards and Technology radiometric physics metrology capabilities supported by the Ballistic Missile Defense Organization plays a vital role and can assure accurate radiometric data is produced by the SBIRS Low Flight Demonstration Systems sensors. This National Institute of Standards and Technology capability is especially important to the SBIRS Low Flight Demonstration System because of the program's resource limitations and

because the sensor data to be acquired is to support an Objective System's design. This means the Flight Demonstration System must provide as high a quality result as cost and schedule permit. Specifically, National Institute of Standards and Technology can measure the optical, spectral filter transmittance both in-band and out-of-band precisely, at operational temperatures and with operationally equivalent optical conditions, even when the out-of-band transmittance is many orders of magnitude less than the in-band transmittance. This is an important technical result for a system which is to collect data for analysis. The SBIRS Low Critical Design Review specified a number of optical filters to characterize the "seeing" when the sensors are flown. It is essential these filters be characterized in as nearly an operational configuration as possible. The optimal situation would be to do the characterization with the senors in-orbit. Since this isn't practical we do what is sensible. The National Institute of Standards and Technology Infrared Filter Measurements and Standards capability to characterize the spectral and spatial characteristics of these filters makes sense.

The radiometric calibration of the Flight Demonstration System sensors will probably be done at separate chambers, Hughes new chamber (their paper was withdrawn from this review), the POST chamber at Boeing's North American Rockwell or the 7V chamber at the Arnold Engineering Development Center. National Institute of Standards and Technology's Portable Cryogenic Spectral Radiometer can provide a common basis for the calibrations done in these multiple chambers. Also, the Medium Background Infrared chamber at the National Institute of Standards and Technology provides a means of calibrating a sensor whose operational temperature makes a calibration in a low background chamber nonsense. The nonsense aspect is because the sensor itself will radiate into the low background chamber and illuminate baffles and structure which will spatially corrupt calibration signals.

A longer term capability, a new and evolving idea, discussed at this review is Space-based Radiometry and Standards. With National Institute of Standards and Technology as the leader in such an activity the political and parochial biases induced by multiple institutions and contractors can be mitigated. Raju Datla, National Institute of Standards and Technology, led an Open Forum: Discussion of Space-based Radiometry for On-orbit Calibrations of Sensors. The National Institute of Standards and Technology goal is an observatory on the International Space Station or MIR, the Russian Space Station, which can be used to ensure radiometric calibrations of orbiting sensor systems. The idea is to achieve an exo-atmospheric radiometric standards or calibration capability afforded by these Space Stations. What immediately comes to mind is the fact that a very limited quality, the word poor in a certain context could be considered to be applicable, knowledge of the spectral radiometric flux from celestial sources at the top of the atmosphere exists in the technical literature. The ability to have radiometric

standards which could be used in-orbit to measure, characterize and to transfer calibrations to celestial sources, all done outside the earth's atmosphere, and to also be able to return the standards to the ground for episodical re-characterization and calibration is deemed an extremely valuable capability for the ballistic missile defense community as well as for the general astronomical and earth sciences communities. The personnel at this Metrology review expressed a general agreement such a capability should be developed. It appears to this author to be a good idea worth further discussion. The United States interest in such a capability may well be in support of the Ballistic Missile Defense Organization's Theater Missile Defense, National Missile Defense and technology development as well as that of basic science. National Institute of Standards and Technology anticipates a permanent site. Dr. V. Sapritsky stated the Russian Space Agency has sent a letter to NASA, it is thought to be to Mark Sistilli at NASA Headquarters, which offers the use of the MIR. Space-based Radiometry requirements, at the moment unclear, need to be clearly identified and stated. Should there be reference spheres ejected as needed? What kind of ground based radiometric standards should be on an orbital platform? How are these standards used to transfer calibrations to celestial sources? How do orbiting senors use the standards? These are but a few of the many questions which must be addressed before a meaningful plan can be put into action. National Institute of Standards and Technology is taking the lead on a study activity. Thoughts expressed at the forum discussion indicated a few man years of effort are necessary to conduct such a study activity. The study topics must include ARM site access, fields of view for instruments, celestial sources and the technology for unmanned sources also. A National Institute of Standards and Technology white paper, "NIST Reference Radiometry using Space Station Instrumentation" discusses the need for space based radiometry and the potential use of the International Space Station to support such an activity.

The spectral capability for the Low Background Infrared facility has completed its initial test and evaluation. This facility is now ready to make the final set of measurements, the spectral emittance, of the MSX Program's emissive reference sphere materials. This work remains on the Low Background Infrared facility schedule and the tooling to support the measurements is still on loan from the Massachusetts Institute of Technology Lincoln Laboratory. The scheduled time for these measurements is early 1998, a date which could be improved if resources became available to support it. It is recommended support be provided. The spectral emittance used for the Data Certification and Technology Transfer's analysis of a sphere's radiance is based upon one minus the reflectance to get an emittance. Taking the difference in two numbers of nearly equal magnitude, the emittance is nearly one, provides a limited accuracy emittance. Massachusetts Institute of Technology Lincoln Laboratory has on loan to National Institute of Standards and Technology the fixtures that had been used to measure the total emittance of the reference spheres and sphere material. Spectral emittance was not

measured directly when the spheres were being built because the Low Background Infrared facilities spectral capability was still in work. It is now in place and functional. Raju Datla, National Institute of Standards and Technology, states the reference sphere material's spectral emittance is still on the schedule, January, 1998, even though the Massachusetts Institute of Technology Lincoln Laboratory is no longer involved. The quality of the Data Certification and Technology Transfer's sphere radiant intensity analysis would be improved with the reference sphere material's spectral emittance measured directly in the Low Background Infrared facility.

ISSEG MEETING

The ISSEG meets periodically to review work in progress such as the MSX Program and to make recommendations to the Department of Defense. Members of the ISSEG Panel are from multiple institutions and the United States Government. A briefing was prepared and presented at the March 11, 1997 meeting to document the status of the MSX Program's Data Certification effort. The briefing is part of the Panels records.

The MSX Program's Principal Investigator teams are dependent upon adequately calibrated data as an input to their respective analytical work. The Pointing and Alignment of the science instruments is still plagued by anomalous inaccuracies which anomalously appear. Also, the SPIRIT III and the UVISI CONVERTs have remaining biases which are being corrected by Versions of the respective CONVERTs which are in work at the respective Data Processing Centers. The message to the ISSEG Team is the Certification Effort is close to being complete. While a certain level of performance is realized with the current data inaccuracy, a cost benefit to all future data users accrues with the completion of the CONVERT changes and their respective certifications. The Certification effort schedule shows completion of the new versions of CONVERTs by the second quarter of fiscal year 1998.

CALIBRATION SYMPOSIUM

An approved paper, "A Benefit of Radiometric Standards in Space", presented at the Seventh Space Dynamics Laboratory Utah State University Symposium on Infrared Radiometric Sensor Calibration appears in the Symposium Proceedings. It was decided to not submit this paper for inclusion in an upcoming issue of the SPIE Optical Engineering. A future paper is planned to document the global minimization of calibration errors, a task for which this initial paper provides an insight to the use of the SPIRIT III sensor as a transfer standard of radiometric accuracy. The SPIRIT III sensor was used to observe the calibration stars and the calibration spheres.

UVISI WATCHDOG

PERFORMANCE ASSESSMENT TEAM MEETINGS

The Performance Assessment Team meets periodically to assess progress, coordinate activities and to identify and resolve issues.

OCTOBER 23

The UVISI Instrument's Certification is scheduled for October 29, 1996. Potential issues identified during the Data Certification and Technology Transfer's certification evaluation and analysis were discussed with the UVISI Performance Assessment Team to clarify the cause, the effect and the development of plans to resolve the issues identified.

The Data Certification and Technology Transfer Principal Investigator, the Deputy Principal Investigator, the UVISI Watchdog, the UVISI Performance Assessment Team and a Co-Investigator from the Short Wavelength Terrestrial Background team reviewed the UVISI Instrument's Data Certification and Technology Transfer's Certification analysis. The Certification is to be peer reviewed by the Principal Investigator Executive Committee at its October 29, scheduled meeting. Two potential issues raised at the Data Certification and Technology Transfer UVISI Performance Assessment Team meeting of October 16, an apparently degraded radiometric performance at low instrument gate settings and a large number of decertified flags being set by the Pipeline DQIs, have been analyzed by the UVISI Performance Assessment Team since that prior meeting.

The gate setting analysis shows the gate calibration is correct down to gate settings as low as 25 (see the published UVISI Calibration Reports). The gate settings are specifically not the cause of the increased radiometric uncertainty at the low gate settings.

A Pipeline code walk-through conducted October 17 concluded the Point Source Extraction algorithm is in need of additional study to understand the details of how it functions. This Point Source Extraction algorithm is now believed to be the cause of the increased radiometric uncertainty at the low gate, less than about 50, settings. A correction to the Point Source Extraction algorithm is a high priority technical issue. It requires additional analysis by the UVISI Performance Assessment Team and the UVISI Data Processing Center to resolve it.

A significant number of Data Collection Events were excluded from the Data Certification and Technology Transfer's Certification analysis because decertified

flags were activated during the data reduction process. These flags are being set with calibration data from well designed experiments with carefully selected instrument settings well within the operational envelope. These flags nominally would not be expected to occur under these conditions. There also seems to be a large number of them. For example, five of the six Pointing and Alignment Experiments, DC-29, were excluded from the Data Certification and Technology Transfer's certification analysis.

The scale factor for the normalized radiometric spectral response of the four UVISI Imagers ranges is incorrect. The magnitude of the error in these instruments radiometric accuracy ranges from about thirty percent to more than two orders of magnitude. This is the next highest priority issue for resolution.

Each instrument's Earth Centered Inertial Pointing is still being limited by the Definitive Attitude quality. The Definitive Attitude is being improved by the Pointing Performance Assessment Team.

The UVISI Performance Assessment Team plans to implement a Point Source Extraction algorithm consistent with physics based models. Changes to the CONVERT 3.2b code will be made dependent upon what further investigation indicates needs to be done to bring the code into agreement with the plan. The Performance Assessment Team plans to make a recommendation on the values implemented as operational envelope certification boundaries to the Data Certification and Technology Transfer Watchdog.

DATA CERTIFICATION AND TECHNOLOGY TRANSFER PIPELINE

The Data Certification and Technology Transfer's Pipeline process steps are outlined below. These are the steps necessary to reduce each instrument's data and to populate the database from which the respective instrument's certification statistics are created.

<u>IMAGER POINT SOURCE PIPELINE PROCESSING STEPS</u>

1) Receive Level 1B data tape from UVISI Data Processing Center.
2) Load Entire Level 1B data onto hard drive.
3) Run UVISI CONVERT on all Level 1B data.
4) Erase Level 1B data.
5) Run POINT on all Level 2 files.
6) Backup Imager Level 2 and Imager PSRC2A data.
7) Erase Imager Level 2 data.
8) Are there more Data Collection Events? If YES, then return to STEP 2.

9) Run IMPSRC Pipeline.
10) Generate Certification numbers/tables.
11) END

SPIM POINT SOURCE PIPELINE PROCESSING STEPS

1) Receive Level 1B data tape from UVISI Data Processing Center.
2) Load Entire Level 1B data onto hard drive.
3) Run UVISI CONVERT on all Level 1B data.
4) Erase Level 1B data.
5) Run POINT on all Level 2 files.
6) Run SPSXT on SPIM Level 2A data.
7) Backup SPIM Level 2A and SPIM PSRC2A data.
8) Erase SPIM Level 2A data.
9) Are there more Data Collection Events? If YES, then return to STEP 2.
10) Merge observations of the same star from multiple Data Collection Events into 1 file for each SPIM.
11) Run clipping software to keep only those point sources totally in slit.
12) Run SPPSRC Pipeline.
13) Run certification number generating routines.
14) END

EXTENDED SOURCE PIPELINE PROCESSING

1) Receive Level 1B data from UVISI Data Processing Center.
2) Load 1 entire Data Collection Event onto hard drive.
3) Examine IVN Level 1B data to find uniform scenes.
4) Do enough uniform scenes exist? If NO, then return to STEP 2.
5) Run UVISI CONVERT on only those frames which show uniform scenes.
6) Erase Level 1B data.
7) Backup Level 2 data.
8) Generate truth for each set of frames.
9) Are there more Data Collection Events? If YES then return to STEP 2.
10) Run Extended Source Pipeline Tools for either Imagers or SPIMs.
11) Generate Certification Numbers/tables.

POINTING & ALIGNMENT WATCHDOG

POINTING REQUIREMENTS

GOAL ⇨ RECONSTRUCTED, POST MISSION:

- SINGLE FRAME
  - -SPIRIT III, < 9 μr (1/10 PIXEL)

-UVISI NFOV IMAGERS, < 45 μr (½ PIXEL)
-UVISI WFOV IMAGERS, < 450 μr (½ PIXEL)
-UVISI SPIMS, <450 μr (½ PIXEL)

- MULTI-FRAME
  -SBV: BORESIGHT POINTING, 2 μr (1/30 PIX) & STAR FIT, 6 μr (1/10 PIXEL)
- SPACECRAFT:
  - JITTER < 9 μr / 700 ms
  - OPEN LOOP POINTING < 0.1 DEG (1.7 mr)

STATUS

- PRE-LAUNCH
  - Pointing Alignment Verification Test of the Process was successful.
  - 9 μr Pointing is feasible

- POST- LAUNCH POINTING ESTIMATE
  - SPIRIT III and UVISI pointing derived from CONVERT and Definitive Attitude File
    - Result is 100 - 300 μr
  - SBV (Does not rely on Definitive Attitude)
    - Boresight < 2 μr
    - Star Fit Over Frame < 6 μr

- SPACECRAFT MEETS SPECIFICATIONS
  - JITTER < 9 μr / 700 ms
  - OPEN LOOP POINTING < 0.1 DEG (1.7 mr)

- DEFINITIVE ATTITUDE AN ISSUE
  - Reconstructed pointing estimate in error
  - ~ 300 μr over a data collection even

POINTING PERFORMANCE ASSESSMENT TEAM

The Pointing Performance Assessment Team meets periodically to assess the pointing and alignment of the spacecraft and the science instruments and to devise a plan of action to resolve issues when they arise.

MEETINGS

OCTOBER 16

The Pointing Performance Assessment Team met October 16 at the Johns Hopkins

University Applied Physics Laboratory building 23, room 23-305.

This fifth working level meeting assessed the revised Definitive Attitude process performance. Revised Definitive Attitude files for selected Data Collection Events supplied to the Celestial, Earthlimb, Data Certification and Technology Transfer, Early Midcourse teams and the respective instrument Data Processing Centers show the Earth Centered Inertial pointing, both the precision and the accuracy, have improved. The current changes produce a nominal post-Data Collection Event reconstructed Earth Centered Inertial pointing precision on the order of 10 micro-radians and an accuracy on the order of 100 micro-radians. The improvements are a result of using the quaternion difference from the gyros instead of their rate vectors, a higher weight (nominally the on-board weight for the Attitude Determination System) for the star camera's input to the Definitive Attitude filter process and an adjustment of the Definitive Attitude filter's gains. Although un-quantified as of this review, the Definitive Attitude appears to provide a "smoother" function than does the on-board attitude. This remains the expectation. The Definitive Attitude is expected to be a better estimate of attitude than the on-board attitude. One more iteration of revised Definitive Attitudes for selected Data Collection Events is planned. Gene Heyler published by E-mail the list of those selected. New ones are noted. The Attitude Processing Center investigation team requested longer attitude history files for the selected Data Collection Events to assist with the Definitive Attitude filter process refinement and analysis. A meeting is to be scheduled as soon as the next round of Definitive Attitudes have been distributed to and analyzed by the respective teams. It is requested each team notify D. B. Pollock or T. E. Strikwerda as soon as their next round of processing and analysis is sufficiently complete to proceed. More and more Definitive Attitudes are piling up to be reprocessed.

The Definitive Attitude performance limitation (in a sense a noise equivalent angle) is expected to be the noise on the gyros and the star camera's output and the distortion correction of the star camera, i.e. its calibration or both. Also, a reconstructed Earth Centered Inertial pointing may be limited by instrument to star camera alignment variations. There is some thought the instrument to instrument alignments may be more stable than the instrument to star camera alignment. This is to be investigated by the Attitude Processing Center. If we should fail to achieve an adequate Definitive Attitude with these performance limitations during the next Definitive Attitude iteration, then there is one more round of performance improvement anticipated.

The improvement may derive from either an in-orbit star camera calibration update or a modified alignment bias removal process or both. An initial experiment design indicates the star camera's distortion correction can be updated with an in-orbit calibration. An alignment bias perturbation correction with stars

observed serendipitously during a Data Collection Event appears to be a feasible, modified bias removal process. A decision as to whether or not to proceed with either the star camera calibration or the alignment perturbation removal or both is to be made after the next iteration on the Definitive Attitude reprocessing.

SELECTED Data Collection Events
EM.12.01.00002.01
EL.02.01.00089.01
DC.43.01.00018.01
CB.03.01.00017.01
DC.44.02.00008.01
DC.17.01.00008.01 (NEW)
DC.33.02.00008.01 (NEW)

The hardware aspects of the Definitive Attitude reprocessing have progressed but are as yet incomplete. Also, the next round of Definitive Attitude filter improvements and an evaluation of performance with these Definitive Attitudes will be assessed before the complete Definitive Attitude reprocessing can begin.

The SPIRIT III Data Processing Center reported the precision of sensor observations of Alpha Lyrae, DC.44.02.00008.01 are nominally less than 9 micro-radians in both the cross- and the in-scan directions. The in-scan bias is reduced to less than 5 micro-radians from a nominal 74 micro-radians while the cross scan bias has remained essentially unchanged at about 80 micro-radians. The in- and cross-scan directions are essentially along the spacecraft's Z and Y axes.

The Earthlimb team reports an apparent 15 km tangent height drift over the CD.03.01.00017.01 Data Collection Event's duration is reduced to something on the order of 2 km with the new Definitive Attitude. (Post meeting analysis at the Attitude Processing Center indicates the 2 km offset may be attributable to different alignment files having been used and an apparent pointing drift during the Data Collection Event is attributable to gyro drift combined with an absence of star camera measurements.)

The Early Midcourse team reports the new Definitive Attitude gives a nominal 10 micro-radian precision for the EM.12.01.00002.01. They, as well as the Attitude Processing Center team looked also at the DC-43. A poorer position for the second half of the Data Collection Event observations of Beta Pegasi, about 400 micro-radians are found. This is attributed to an incorrect Definitive Attitude file for this, the second half of the DC-43 observations. A correct file was sent out but received too late to be included in the analytical results discussed. The observations of Alpha Lyrae, the first half of the DC-43 observations, gives a result that is consistent with the improved precision and bias numbers.

A plot of the DC-43 Alpha Lyrae star position observed by SPIRIT III as the star was drifted along the cross-scan direction clearly indicates a smoother attitude for the Definitive Attitude than the attitude produced by the ADS (see Gene Heyler's plots attached to the meeting report).

A cross-correlation analysis done by the Celestial Team using the CB.03.01.00017.01 data processed with the improved Definitive Attitude indicates there may be a nominal 250 micro-radian bias introduced by the revised Definitive Attitude. This potential bias is being investigated by the Attitude Processing Center team during the next Definitive Attitude iteration.

The UVISI Performance Assessment Team has developed an improved alignment process for the SPIMs. In principle each SPIM is aligned to the IVN which is aligned to the star camera. This process utilizes the DC17 data sets and is documented in the attachments to the meeting report.

The formalized configuration control process for the Definitive Attitude and the Sensor Alignment Estimation file processes is reported by Data Management to be working.

OCTOBER 23

A meeting with the Pointing Performance Assessment Team Chairman reviewed the progress made with the Definitive Attitude filter process refinements, the in-orbit calibration of the star camera and recent pointing results obtained from the Early Midcourse team after the Pointing Performance Assessment Team meeting October 16.

Pointing performance results produced by the Early Midcourse team, received after the recent Pointing Performance Assessment Team meeting, show a number of stars were observed by SPIRIT III during the MDT II (EL.12.01.00002.01) experiment execution. These results obtained with the "old" Definitive Attitude, the Definitive Attitude used since the spacecraft has been in-orbit, provide little insight to the improvements associated with a "newer" Definitive Attitude. Newer refers to the first iteration Definitive Attitude which all the Co-Investigators used to obtain the analytical results presented at the Pointing Performance Assessment Team Meeting last week, October 16. However, enough stars were seen long enough, as many as 8 stars, with 13 observations on one star, to warrant a feasibility analysis. The analysis is to investigate using serendipitous star observations as a SPIRIT III sensor alignment update for the MDT II Data Collection Event. The requirement to complete this investigation depends upon the SPIRIT III sensor's Pointing performance after the Definitive Attitude estimation process refinements are completed and an alignment stability analysis, instrument to instrument to spacecraft, is completed.

The SPIRIT III sensor alignment update would be based upon the currently used approach to estimate alignments with the Pointing and Alignment Experiment Plan DC-29. A series of unit vectors in the SPIRIT III instrument frame, one for each star observed in each frame, along with the star identification, sent to the Attitude Processing Center are used to estimate the instrument frame to spacecraft fiducial frame quaternions.

An iterative estimation process is planned to reduce the star camera's residual calibration errors. A large enough sample of star observations over the camera's 8 by 8 degree field of view to provide a statistically significant data set is being sought out. Two types of Data Collection Events are being considered. One is a pole to pole scan of the celestial sphere and the other is a stellar occultation. The spacecraft's inertial scan orientation is rotated 90° between these two types of Data Collection Event. The scan orientation which provides the more comprehensive data set will be used. The star camera uses five stars to estimate attitude. The five star location and spacing over the camera's field of view affects the quality of the attitude estimate.

One more iteration of the Definitive Attitude refinements is to be reviewed before the Definitive Attitude reprocessing begins. It is anticipated the reprocessing should begin before November 15 and would be completed by the end of November.

The Attitude Processing Center personnel also plan to improve the star camera's calibration in-orbit. A search for appropriate data sets has been initiated. This activity is an ongoing effort which will take months to bring to fruition. Another refinement to the Definitive Attitude estimation process would be implemented once the calibration activity is completed. Previously completed Data Collection Events would take advantage of an improved Definitive Attitude on a case by case basis.

Summarily stated the changes implemented in the Definitive Attitude Processing have significantly reduced the artificially induced virtual spacecraft motion. The goniometric precision is frequently less than 9 micro-radians but additional refinements are necessary to remove residual biases, on the order of 100 micro-radians, before a 9 micro-radian goniometric accuracy goal can be realized.

FEBRUARY 4

The Pointing Performance Assessment Team met February 4 at The Johns Hopkins University Applied Physics Laboratory in Building 23, room 23-327. Only a portion of the expected analysis with the reprocessed Definitive Attitude Files were adequately complete to support the discussions at this meeting and a morning session was adequate to complete the agenda. As usual a copy of all

presentations is attached along with an attendance list to the meeting report.

The primary purpose of this seventh working level meeting, to investigate the causes for the remaining pointing and alignment errors, made little progress. The magnitude of the remaining pointing and alignment inaccuracies is still on the order of 100 to 500 micro-radians. This inaccuracy continues to appear to be either virtual spacecraft motion induced by the Definitive Attitude process or virtual alignment shifts induced by the alignment process, or both. The cause(s) of the inaccuracy remains unknown.

An analysis of a limited number of DC-44 Data Collection Events by the SPIRIT III team show an improved short term pointing precision, nominally 10 micro-radians for both in-scan and cross-scan, with Definitive Attitude File Version 03, see attached Space Dynamics Laboratory Utah State University Presentation by M. Larsen. But, the pointing accuracy is insignificantly changed, if changed at all. It remains on the order of 100 micro-radians. Short term here means the duration of a Data Collection Event. The reported performance is based upon five DC-44 Data Collection Events performed since the Version 03 Definitive Attitude Files began being used on January 2, 1997. Their summary states the Definitive Attitude File is improved significantly for the in-scan precision for four of the five Data Collection Events processed. Data for the unimproved one, the fifth one, has been provided to the Attitude Processing Center for further analysis as to why it didn't improve. They also, looked at the autocollimator's output and conclude that it provides null information to support or disprove a "flexure" theory.

An analysis using UVISI Performance Assessment Team tools gives a pointing accuracy on the order of 200 micro-radians with Definitive Attitude File Version 03 and a new, unpublished alignment and on the order of 600 micro-radians with Definitive Attitude File Version 01 and a published alignment, see UVISI ALIGNMENT STATUS attached to the meeting report. The bias and the precision are co-mingled. Two Data Collection Events, DC.29.03.00003 and DC.29.03.00002 respectively, were used for each of these results. These are the step stare options for this Data Collection Event. Note that Performance Assessment Team analysis tools rather than Point CONVERT was used for the analysis.

An analysis using UVISI CONVERT and Point gives a pointing accuracy on the order of 600 micro-radians for a single star, the DC.29.03.00002 data and 8 different alignment files, see UVISI ALIGNMENT AND POINT ANALYSIS attached to the meeting report. This accuracy value is dominated by a nominal 500 micro-radian bias in RA.

The persistent inaccuracy, hundreds of micro-radians in magnitude, still appears

to be related to the star camera's data, the Definitive Attitude File's Kalman filter and possible alignment variations. The Definitive Attitude File continues to provide our best estimate of post-Data Collection Event pointing pending a further resolution of the issues.

The technical issues: is there significant spacecraft flexure; are there real and significant alignment shifts; if there is either, then which instrument is shifting or flexing and what is the magnitude and the time period; under what conditions does a shift or flex occur; does the star camera need to be re-calibrated in-orbit; do SBV, IVN, SPIRIT III and the star camera all give the same pointing solution for the DC.29.03s; are the SPIRIT III pointing errors comparable in EL and MS mode; does the Definitive Attitude File Kalman filter need another parameter or existing parameter weights adjusted further; what is the improvement magnitude when a smoother is implemented; all remain unanswered.

It was pointed out in the meeting notice that an analysis of the recently revised Pointing and Alignment Data Collection Event, known as DC.29.03, designed to provide insight to the remaining issues cited above and to provide additional data for the star camera re-calibration had been executed twice well prior to this meeting. The first Data Collection Event, DC.29.03.00002, was 96:12:27 and the second Data Collection Event, DC.29.03.00003, was 97:01:02. For this Data Collection Event the spacecraft is incrementally rolled one star camera field of view. Between each roll maneuver there is a stare at a constant point in space. Each science instrument has demonstrated quality performance as a star camera provided the spacecraft is staring. The individual and distinct star camera fields of view provide independent measures of the star camera's attitude performance. The data for the individual instrument stares can be used to check each instrument's pointing as well as its relative alignment to the star camera and the other instruments, at least over the duration of each Data Collection Event. The star camera data can also be used to correct any residual optical distortion, if that proves to be necessary. None of this was done. The insight to be gained from these analyses awaits their completion.

The Attitude Processing Center did receive separate DC.29.03.02 Attitude History Files one for each segment and one more which is for all the segments combined, from the SPIRIT III and the IVN instruments as requested. The SBV team had found only one frame of data from both Data Collection Events as of the meeting. (It has been confirmed since the meeting there is in fact data for SBV.) The available resources were adequate only to get the alignment quaternions for DC.29.03.00003 for the SPIRIT III and partially for IVN, see H. L. Fisher's material attached to the meeting report.

It was requested each of the three instrument teams use their last alignment update

to evaluate the DC.29.03 results for their respective instruments as preparation for this meeting . The Attitude Processing Center was asked to use each DC.29.03 staring segment statistically as a lesser population of the total population, all the segments, and in principle compute a mean and a variance for the lesser populations. It should be within the statistical bound for the entire population of this Data Collection Event. None of this was done.

Both the primary and the secondary ring laser gyros have been providing angular rate data since January 2. Number two is rotated 50 degrees to Number one. The Attitude Processing Center team was asked to use this data to address the flexure issue and to compare motion indicated by the gyro(s) vs the star camera attitude change; also look for flexure on a short time scale (i.e. during the maneuvers between segments). This didn't happen either. But, an "Error from Commanded", see G. Heyler's presentation, does show relatively large values for the star camera (labeled sid-z) as compared to the raw, ads (attitude determination system), gyro only and the Definitive Attitude File with different star camera weights for the filter.

The SPIRIT III pointing performance in the Earthlimb mode with the Version 03 Definitive Attitude File is believed to be essentially the same as it was for an earlier test version of the Definitive Attitude File process. The performance with the earlier version was reported at the previous Pointing Performance Assessment Team meeting. However, the SPIRIT III Earthlimb mode pointing performance will be supported by data after a Version 03 Definitive Attitude File is processed by the Celestial Team and the pointing performance analyzed. The incremental changes made to the Definitive Attitude File processing between the test version and the Version 03 reportedly would not change the results significantly.

The Attitude Processing Center requests to the SPIRIT, the UVISI and the SBV for long, i.e tens of frames or more, attitude history files in support of the alignment estimation process was accomplished for SPIRIT III and UVISI's IVN. The SBV team located one frame of the DC.29.03 data sets. Only the SPIRIT III and the IVN alignment trends were partially updated by the Attitude Processing Center, see H. L. Fisher's work attached to the meeting report. It is difficult to understand the available alignment trend results. The apparently changing alignments may again be a virtual effect rather than a real one. Please recall that the alignment estimation process requires each instrument function as an independent star camera to estimate its own attitude. The Definitive Attitude File is not an element of this process. Any problems with an attitude estimate, be it star camera or science instrument, will show up in the alignment trends.

An Attitude Processing Notes file is now in place although it is currently an empty file. An initial contents identification is planned by the next Pointing Performance

Assessment Team Meeting.

A smoother will improve the Definitive Attitude estimate, but, it may well be a more precise estimate of an incorrect solution. The reason is we appear to have a bias in our Kalman filtered result, i.e the statistics used in the filter are not Gaussian. For example, see the Space Dynamics Laboratory Utah State University M. Larsen chart with the heading "DC.44.03.00024.01" attached to the meeting report. The units are micro-radians for both axes. The commanded spacecraft motion for this Data Collection Event should cause a star's image to appear to move in a straight line 0.4 degrees in length across a focal plane array in the cross-scan direction. The data points noted by the squares shows there is a nominal 140 or so micro-radians meander to the desired straight line as observed by the SPIRIT III sensor. However, when the Definitive Attitude is used to project these same observations on to the focal plane an obvious bias is introduced, see the data points noted by the circles. Is the SPIRIT III sensor the only instrument to see this bias?

The search is still on for the cause of the rather large, hundreds of micro-radians pointing inaccuracy.

FEBRUARY 18

Ongoing analysis has shown the Definitive Attitude's improved precision provides a poorer pointing solution than is acceptable for radiometric data analysis. The issue is a bias which varies with time. The pointing solution has errors whose magnitude is on the order of hundreds of micro-radians. There is a limited data analysis which suggests a residual mis-alignment of the on-board gyros to the star camera is the cause of this problem. A meeting between the Pointing Watchdog, the Chairman of the Pointing Performance Assessment Team Chairman and the scientist responsible for the star camera discussed the potential causes of the virtual spacecraft motion induced by the Definitive Attitude process. Three critical areas identified are the residual gyro-to-star camera mis-alignment, star camera residual distortion correction which may also be spectrally dependent and relative movement between the science instruments themselves and the star camera. A plan to focus technical attention on these critical areas developed at a meeting rapidly convened while the principals were all available.

The Data Certification and Technology Transfer Watchdog, the Pointing Performance Assessment Team Chairman, the Applied Physics Laboratory Program Manager and the MSX Chief Scientist met and developed a plan of action to resolve the Definitive Attitude issues. Two alternatives discussed are reformatting the on-board data to Definitive Attitude format and resolution of the technical issues which are introducing virtual relative motion between the science instruments and the star camera.

At a meeting of the Applied Physics Laboratory MSX Manager, the MSX Chief Scientist, the Data Certification and Technology Transfer's Pointing Watchdog and the Pointing Performance Assessment Team Chairman a plan of action to recover the pointing performance in the Definitive Attitude Files was developed. It was agreed to stop reprocessing the Definitive Attitude File Version 03 pending resolution the residual virtual spacecraft motion being introduced by the Definitive Attitude process. An interim solution for a Definitive Attitude is to interpolate the on-board attitude and reformat it. The work to identify and remove the virtual spacecraft motion from the Definitive Attitude was assigned to individuals present at this meeting. Principal Investigator selected Data Collection Event's are to be used as test cases for a revised Definitive Attitude process.

The Definitive Attitude Version 03 is still a better solution than the original Definitive Attitude and reprocessing of the already selected files will continue. About two-thirds of the thirty three Definitive Attitude files selected for a priority reprocess are completed. The remaining one-third have a problem such as the file needs to be retrieved from the Backgrounds Data Center Level 1 tape or a similar type of issue. It is expected the issues will be easily resolved and the files reprocessed faster than the Mission Processing Center can assimilate and deliver to the Background Data Center for distribution to the Principal Investigators. At the current assimilation and distribution rate about three to four months will be required to complete the total mission reprocessing.

There is a need to modify the DC-29 Pointing and Alignment Experiment plan to gather gyro alignment data. A new time line which points the spacecraft in orthogonal directions is to be prepared and executed.

MARCH 7

The Midcourse Space Experiment Program's Pointing Performance Assessment Team met to review the results of modifications made to the Pointing and Alignment Experiment Plan, DC-29. The respective science instrument's Earth Centered Inertial pointing continues to be less than requirements. The modifications to the Experiment Plan were designed to provide data which would support analysis to identify the causes of the reduced performance.

This seventh working level meeting answered the primary specific question, why does the Definitive Attitude File introduce virtual spacecraft motion? Also, a plan to reduce the virtual spacecraft motion to acceptable levels is to "fly" the Definitive Attitude File on the gyros and scale the Definitive Attitude attitude to the ADS solution to remove bias. This plan is being implemented by the Attitude Processing Center. How the Definitive Attitude File introduces virtual spacecraft motion can be understood from a comparison of the star camera, the SBV, the SPIRIT III, the IVN, the ADS and the Definitive Attitude File pointing. These

comparative analysis are based upon data from the DC-29s, DC-43s and DC-44s. The spacecraft rolls about the spacecraft fiducial to force the star camera to accept a new set of stars to estimate attitude and then stares while the science sensors collect data for the DC.29.03.00002 and DC.29.03.00003. The spacecraft repeats three of the stares for the DC.29.03.00004. For the DC-43s and DC-44s the star camera's eight degree field of view nominally uses a single set of 5 stars to estimate attitude. The spacecraft pointing changes nominally one degree for the DC-43s and DC-44s and the star camera would nominally use the same star set to estimate attitude.

The on-board spacecraft pointing solution input from the star camera can and does change randomly on the order of 150 to 200 micro-radians, see G. Heyler's presentation, attached to the meeting report. These changes are smoothed by the spacecraft's control loop which uses input from the gyros as well as the star camera to estimate attitude and to point the spacecraft. The data used to make Heyler's plots came from a DC-44, a Data Collection Event where the spacecraft was commanded to slowly move a star from -0.2 to + 0.2 degrees, bottom to top, cross-scan direction, in the plane of the SPIRIT III's boresight for a star one and for a star two. Star two is greater than one star-camera-field-of-view away from star one. The "raw" trace on Heyler's plots is from the SPIRIT III sensor. (The nominal 10 micro-radian steps on this trace are attributed to a minor timing error in the SPIRIT III data reduction process and is being fixed.) The "ads" trace is in effect the error in the on-board pointing control loop from the commanded attitude. The "gyro" trace is self explanatory and the "g/a" is for the gyro's alignment refined. The "sid" trace is for the star camera. The "daa(50,1e-8)" is the definitive attitude adjusted, i.e. star camera de-weighted.

Supporting Analysis

The star camera clearly shows a biased attitude solution between segment 1 and 7 of DC.29.03.00004, see D. Haley's work attached to the meeting report. There are a series of charts which show the angular separation star one to each of the four other star camera stars as a function of time. Another series shows the five star positions in the star camera's focal plane coordinates for each segment of the Data Collection Event. Line 1, Line 2, etc refer to star one, star two, etc. There are also a set of scatter plots in star camera focal plane coordinates. A star camera pixel is about 270 micro-radians square (512 pixels in 8 degrees). Catalog and observed star positions are over plotted for segment 1 and segment 7. Note the quantization and the apparent biases between segment 1 and segment 7 for all 5 stars. A summary chart titled "Stars, Segment 1, dc(2)90304", shows the bias between segment 1 and segment 7 is different in magnitude and direction dependent upon the star. The chart titled "ADS to Commanded Attitude Errors (microrad)" shows the spacecraft X, Y and Z components are reasonable. The subsequent charts of

the Definitive Attitude-to-gyro errors for all seven segments indicate the estimated alignment of the gyros will reduce the bias but some bias across the entire Data Collection Event remains. Additionally RA and DEC versus time, UVISI's IVN and Definitive Attitude, for six of seven segments of DC.29.03.00003 are shown. Note that Segment 1 of Haley's work is Orientation 0 of Carbary's work, an attachment to the meeting report which follows Haley's. The time period of Carbary's Orientation 6 mismatched the time period of Haley's Segment 7. Haley's work is for the six Segments (1 through 6) where his time periods do match with those for six of Carbary's Orientations (0 through 5).

The UVISI IVN analysis, see Carbary's work attached to the meeting report, agrees with Haley's work and supports the conclusion the star camera is the culprit. For the DC.29.03.00003, annotated as ivn_DC2903_0301, the analysis shows the respective difference between the mean RA and the mean DEC, mean over a respective segment, ranges from a low of 10 to a high of 140 micro-radians. The Table 2. "Mean Differences, MSX boresight (Star - DAF)", see the chart titled "Direct Comparison Statistics, ~DAF to Star Boresights", is interpreted as a representative measure of the pointing error magnitude which can be induced by the star camera in the Definitive Attitude. Note these analysis are independent of UVISI CONVERT and Point as are Haley's analysis.

When the star camera uses essentially a constant star set as it would do for the DC-43s and DC-44s, see D. Garlick and M. Larsen, chart titled Stellar Benchmark Pointing Repeatability", (short term is the duration of a Data Collection Event), attached to the meeting report, the SPIRIT III pointing precision is 13 and 6.8 micro-radians in-scan and cross-scan respectively. However, using the DC.29.03.00004.01's, where the star camera is forced to select a new star set for each of the seven staring observations, non-anomalous data (non-anomalous data is bounded by the vertical bars on the time history plots) gives a precision which ranges from 14 to 43 and 6 to 14 micro-radians in-scan and cross-scan respectively, see D. Garlick and M. Larsen, chart titled "DC.29.03.00004.01", attached to the meeting report. Accepting on faith the sensor to spacecraft alignment changes insignificantly over the 20 minutes or so when the DC-29 data is collected, then the precision and accuracy errors for the DC-29 are dominated by the star camera's noise and residual errors. Note that the SPIRIT III CONVERT and Point are an integral part of this analysis.

The SBV analysis confirms the spacecraft does in fact provide stable, precise pointing (1 Hz) during each of the seven segments of the DC.20.03.00003 and the DC.29.03.00004 Data Collection Events. See the analysis by C. von Braun attached to the meeting report.

It is further recognized the star camera issues dominate the alignment process. We

have consistently aligned the science instruments to the spacecraft fiducial which is in fact the 20 degree rotated star camera boresight. The pointing uncertainties induced by the star camera's relationship to the spacecraft fiducial impose a significant uncertainty upon the alignment process we have used. This is seen in the Sensor Alignment Estimate History Plots, see H. Landis Fisher's work attached to the meeting report. There are alternative alignment processes we can use. The details and the implementation are a longer term solution to the issue at hand, which is provide an acceptably accurate pointing solution to the Principal Investigative teams as soon as possible. Bias removal (bias over the duration of a Data Collection Event) is expected to remain an issue, but an issue of lesser significance and tractable.

The analysis indicates an alignment uncertainty for an individual instrument to the star camera (the spacecraft's fiducial), is on the order of 50 to 60 micro-radians. The limitation derives from the star camera's time varying pointing solution. Time variation is measured with how often the star camera drops one of its five stars and adds a new one. The star camera's time dependent pointing solution depends also upon the relative star positions in the star camera's field of view. This is quite normal performance for the star camera and it meets its performance specifications. However, MSX is using the star camera in a non-normal way. The star camera is tipped 20 degrees to the spacecraft's fiducial (the +X) axis rather than being co-aligned with it. The star camera's time dependent errors in roll, i.e. rotation about its boresight, are coupled into the Z axis pointing solution. This is true for a spacecraft fiducial attitude estimate made from a spacecraft attitude history file, a time series of star camera observations, or for the definitive attitude estimate, a smoothed time series of star camera observations, two distinct processes. The spacecraft fiducial attitude estimate is from a star camera boresight attitude history file, star camera observations rotated into the spacecraft coordinates. Were the star camera aligned with the spacecraft fiducial, the way a star camera is normally used to estimate attitude, the time dependent roll errors would be orthogonal to both the spacecraft Y and Z axes and the errors would appear in neither the Y or the Z axis of the Definitive Attitude File nor the spacecraft attitude estimate used to deduce the science instrument alignments. However, the science instrument alignment process is still flawed because the star camera boresight is the fiducial to which the science instruments are aligned. Even when a science sensor's alignment to the star camera is based upon long, i.e tens of frames or more, attitude history files, it varies within a hundreds of micro-radians envelope from launch through the end of cryogen, see H. Landis Fisher's work attached to the meeting report. Note specifically his work shows all the science instrument alignments vary significantly for each of the seven segments of a DC.29.03.00003 and a DC.29.03.00004 and the repeated pointing segments do not give repeated alignments. This is difficult to accept as being true. Structural motion between each segment or within a segment may exist. But if it does then its

magnitude is being overwhelmed by the uncertainties being introduced by the star camera data.

Spacecraft structural motion induced changes to an instrument's alignment, either flexure or coefficient of thermal expansion related, over the time period of a Data Collection Event or of a much longer one, is yet to be experimentally extracted from the data and clearly demonstrated. A more precise alignment process is required to identify such motion. The one we are using is dominated by the star camera residual errors and uncertainties.

Status and summary presentations by Strikwerda and Pollock are attached to a trip report for this meeting. A suggested analysis, to assess the potential benefit of a smoothing process for the Definitive Attitude, by Robbins, is attached to the trip report also.

Errata - The notice for this Pointing Performance Assessment Team meeting contained an error. The notice should have stated -"Analysis of this data clearly shows the star camera (start delete), the ADS and the star camera (end delete) differ(s) from the commanded attitude by as much as 100 micro-radians over the nominal 20 minute duration of a DC-29 Data Collection Event." The commanded and the ADS attitudes agree within micro-radians, see Fisher's and Haley's work attached to the meeting report

APRIL 11

The Pointing Performance Assessment Team met at 9:00 A.M., April 11 at The Johns Hopkins University Applied Physics Laboratory in Building 23, Room 293 and completed their Agenda.

The primary purpose of this eighth working level meeting was to initiate a Definitive Attitude Validation process. At this meeting the Pointing Performance Assessment Team assessed the Version 4 process, i.e. "flying-on the gyros", as being of inadequate accuracy to produce Definitive Attitude Files. The primary specific issue, virtual spacecraft motion introduced by the Definitive Attitude Version 03 process, eliminated by the Version 04 process, unfortunately introduces a different virtual spacecraft motion. (Discussions and analysis since the meeting have shown gyro random walk is sufficiently large as to invalidate the concept of "flying on the gyros" during a Data Collection Event. A revised Version 03 process is being addressed as the Version 05 process.)

Analysis by the Celestial Background team and the SPIRIT III team found what appears to be a virtual spacecraft cross-scan motion, i.e. a rotation about the spacecraft's Z axis whose magnitude increases as the Data Collection Event proceeds. The presentations of M. Egan and M. Larsen, analysis of

CB.03.01.00017 and DC.33.02.00009.01 using the Version 04 Definitive Attitude process, show the virtual motion. Their presentations are attached to the meeting report. The IVN instrument is used by J. F. Carbary as pointing truth for an analysis using Definitive Attitude Version 04 for the DC.29.04.00002.01 Data Collection Event. This analysis shows no evidence of a virtual spacecraft cross-scan motion as seen for the CB-03 and the DC-33 events. An analysis of DC.44.03.00024.01, a SPIRIT III Band A observation of Beta Gem and Alpha CMa, shows no evidence of a virtual spacecraft motion with the Definitive Attitude Version 04. An analysis by G. Heyler of the CB-03 and the DC-33 Data Collection Events shows the development of a cross-scan bias for each Data Collection Event. For the CB-03 it is the delta quaternion between the Star Camera's (sid) attitude solution and the gyro's attitude solution. For the DC-33 it is between the raw SPIRIT III data (i.e. the observed star's distortion, scan mirror transfer function and column co-alignment corrected focal plane coordinates relative to the SPIRIT III bore sight) and the Star Camera's (sid) attitude solution for the star inversely transformed through the Definitive Attitude Version 04 and the SPIRIT III alignment into SPIRIT III focal plane coordinates.

An analysis of the DC.29.04.00002.01 by Dave Haley clearly shows what can be described as a consistency between the SBV pointing and the Definitive Attitude Version 04 pointing over the duration of this Data Collection Event. But there is inconsistency over the duration each of the Data Collection Event's six segments even when the bias for each respective segment is removed arbitrarily. An analysis by C. Von Braun shows the SBV's RA and DEC average periodic motion at the 1 Hz sample rate is less than 3 micro-radian and the average star fit is less than 5 micro-radian except for one segment for which the fit is 14 micro-radians for four of the six staring periods.

The longer attitude history files provided to the Attitude Processing Center successfully supported H. Landis Fisher's alignment history for the IVN and the SBV sensors within the segments of the DC.29.03.00002, the DC.29.03.00004 and the DC.29.04.00002 Data Collection Events. This shows there is progress yet to be made in the process whereby the sensors are aligned to the spacecraft fiducial. A different alignment solution is obtained for different segments. The magnitude of the difference is sufficiently large as to dominate a 9 micro-radian pointing accuracy requirement.

While the Early Midcourse team, Mark Gibney, analysis showed little performance change between the Version 03 and the Version 04 Definitive Attitude it is apparent that updates to the spacecraft orientation of a quarter of a degree or so and made during the MDT II mission probably induced apparent steps in the attitude solution. The magnitude of the change in attitude steps seen in

the analysis is consistent with the known error residuals for the SPIRIT III scan mirror transfer function, timing, optical distortion and column co-alignment. These errors are being reduced by improvements in the SPIRIT III sensor's calibration used in the CONVERT data reduction process.

Another revision to the Definitive Attitude process is required to achieve the 9 micro-radian accuracy goal. Hand processing by both the Attitude Processing Center and a Data Processing Center or a Data Analysis Center is still expected to be required for high value Data Collection Events to achieve a post-Data Collection Event 9 micro-radian pointing accuracy pending the validation of either a Definitive Attitude process which gives 9 micro-radian accuracy or a known cause as to what needs to be done to achieve it. How accurate the next Version Definitive Attitude will be is in work and will be assessed at the next Pointing Performance Assessment Team meeting. It will be scheduled as soon as practical.

Note that the Definitive Attitude process completes validation when the Validation Data Collection Event's Definitive Attitude Files have been evaluated by the Data Processing Centers and the Data Analysis Centers and they are acceptable to these Teams as well as the Attitude Processing Center team. The Definitive Attitude process code is being re-written in parallel with the hand processing of the Validation Data Collection Event Definitive Attitude Files.

The analytical results presented at this meeting are attached to the meeting report. The newly discovered virtual spacecraft motion is directly evident in the DC-33 analysis by the SPIRIT III team and the CB.03 analysis by the Celestial team. It increases nominally to hundreds of micro-radians cross scan error during the 20 to 30 minute time period of either Data Collection Event. The additional analyses provide little insight to cause of this newly identified virtual motion.

MAY 22

The Pointing Performance Assessment Team met at 9:00 A.M., May 22 at The Johns Hopkins University Applied Physics Laboratory in Building 23, Room 305. An attendance list, an agenda and the individual presentations are attached.

This eighth working level meeting concluded the Definitive Attitude File 04 process, i.e. initialize attitude and then fly the Data Collection Event on the aligned gyros, is an unacceptable process to create a Definitive Attitude. Although the gyro's 0.007 degree per root hour random walk and <0.02 degree per hour drift are well within specification, they are too large to be the sole basis for Definitive Attitude. Over a 20 to 30 minute Data Collection Event these can combine to produce several hundred micro-radian errors.

Time has become critical and it is agreed that reprocessing should start with a

Definitive Attitude File Version 05 process. It is to be implemented with the star camera Kalman filter weights "tuned" to the extent that a roll uncertainty of 30 micro-radians appears to be to small and a value of 50 micro-radians may be more appropriate. The Attitude Processing Center team will choose the value after further analysis. The Definitive Attitude File Version 05 process is expected to provide extended periods where the Definitive Attitude is precise to 9 micro-radians even though the accuracy may be as large as 50 to 100 micro-radians. Numerous DC-43s and DC33s, calibration and base line performance observations made with the SPIRIT III sensor in the mirror scan mode, have shown in-scan as well as cross-scan precision on the order of 7 to 14 micro-radians with a Definitive Attitude File Version 03 process. The Definitive Attitude File Version 03 process uses star camera Kalman filter weights on the order of 30 micro-radians.

A more accurate attitude than will be available from the Definitive Attitude File Version 05 process will require further analysis, if it is possible at all. Systematic errors as large as hundreds of micro-radians, which have been observed with all versions of the Definitive Attitude File process, haven't been explained and will affect the quality of some Data Collection Events.

Automated quality tests are to be implemented and their results reported in the Attitude Processing Notes file. The Definitive Attitude File Version 05 process development will include the use of these quality tests. The tests are still being defined. They are to be implemented in code, tested and made an element of the automated reprocess.

It is noted the "gyro1" and "gyro2" data can be compared to asses the estimated magnitude of the random walk attributed to either of them. Also, the estimated angular random walk error of either gyro system could be reduced by combining both gyro's output to obtain an estimate of angular rate. However, an improvement in definitive attitude accuracy is expected to be small. This is because the gyro random walk error is not the dominant error source which limits the pointing accuracy.

The algorithm to obtain the instrument-to-instrument and instrument to spacecraft alignment is to be revisited. A more accurate instrument-to-instrument alignment should be obtained by using one of the science instrument's boresight coordinate system, either SBV's or IVN's , as a reference instead. The one science instrument would then be aligned to the Spacecraft fiducial as specified by the star camera's boresight. The spacecraft fiducial is estimated by the star camera's body centered boresight. The star camera's roll uncertainty is cross-coupled into rotation uncertainty about the spacecraft Y-axis when the star camera boresight is transformed to the spacecraft body system. This creates an added uncertainty in

the spacecraft Y-axis attitude.

To enhance the removal of the residual SPIRIT III optical distortion and the residual scan mirror transfer function errors by the Calibration Team, eleven of the DC-33s and DC-35s are to have two definitive attitude files to be created. One will be by the Definitive Attitude File Version 05 process and the other by a gyros only process, i.e. the star camera weights are essentially zero. These are "hand processed events" in that they will be done as a high priority. The SPIRIT III Calibration Team requires these Definitive Attitude Files to correct the residual Scan Mirror Transfer Function and Optical Distortion errors. The instrument products which will result from these analysis need to be created and used in the CONVERT Version 5.0. The CONVERT release schedule precludes awaiting the automated Definitive Attitude File reprocessing.

The weekly Pointing Performance Assessment Team telephone conference calls will continue. The day is Thursday. They will continue until they are no longer serving a useful purpose.

An original list of 22 Prioritized Data Collection Events, see Steve McLaughlin's presentation material, to have Definitive Attitude Files quickly produced by the Version 05 process, has grown to 171 Data Collection Events. They are identified as High Priority for various reasons. These events will be processed on APC#3, Steve McLaughlin's PC, as resources permit. The Definitive Attitude File Version 05 reprocessing will be on APC#2, a dedicated machine. The APC#1 is to continue to handle the daily, operational Definitive Attitude File production.

JUNE 26

The Pointing Performance Assessment Team met at 9:00 A.M., June 26 at The Johns Hopkins University Applied Physics Laboratory in Building 36 Room 106. Attachments are an agenda, an attendance list, an updated DC-29 log, a draft Processing Notes File - Description and the material presented at the Meeting are attached to the meeting report.

Although the primary purpose of this ninth working level meeting, complete the Validation of the Definitive Attitude File Version 05 process, is a continued work, there were no surprises and the Definitive Attitude File Version 05 reprocess work continues as planned.

The differences between the Version 03 and the Version 05 process are an improved "gyro1" alignment estimate from the DC.29.04.00002.01, the star sigma weight is decreased from 50 to 30 arc-seconds, the initial filter covariance is reduced from 3 rad angle sigma and 1 rad/sec rate sigma to 20 arc-second and 200 micro-radian/second, the gyro random walk parameter is reduced from 0.07 to

0.007 deg/hr^0.5, covariance fudge factors are removed, only the primary gyro and more than one star measurement are retained (coarse instruments, the second gyro and single star measurements are neglected), statistics for the processing notes are collected, see L. Fisher's presentation material attached to the meeting report.

As scheduled, the first Operational tests with the Definitive Attitude File Version 5 took place on the CE.35.05 Data Collection Event run June 24, two days prior to the Pointing Performance Assessment Team Meeting. It was run on the Attitude Processing Center #1 hardware. Definitive Attitude File Version 05 will become operational, i.e. files released for distribution through Operations in accordance with the agreed upon Data Management system, as soon as the Attitude Processing Center staff validates the process. The previously prioritized list of 20 Data Collection Events (prioritized at a recent Principal Investigator Meeting) is being used for the validation. Validation implies the Attitude Processing Center Staff is satisfied that the Definitive Attitude Version 05 process software changes are correctly implemented.

The draft Attitude Processing Notes, see L. Fisher's, D. Haley's and G. Heyler's presentation material attached to the meeting report, includes fits to the slope between the gyro and star camera. The initial Attitude Processing Notes content reviewed at this meeting showed no surprises. The reprocess of all the Definitive Attitude Files is scheduled to begin on the Attitude Processing Center #2 hardware as soon as the process validation is completed by the Attitude Processing Center staff. A Data Certification and Technology Transfer Certified Pointing accuracy is expected to be improved over the 01 and the 03 processes, but, it will be numerically greater than the 9 micro-radian accuracy goal. The accuracy value will be available from the Data Certification and Technology Transfer Certification runs for the UVISI CONVERT 4.2 and for the SPIRIT III CONVERT 5.0. The Definitive Attitude Version 05 process is simply constrained by the pointing accuracy limitations imposed by the extant hardware and software implementation limitations. Analytical work continues in an effort to improve the pointing accuracy which can be achieved routinely by either an automated or a "hand" process. A hand processed Definitive Attitude File, i.e. one created by the analysis of data from multiple instruments, SBV, IVN as well as the star camera and gyros, has reportedly improved the MDT II Definitive Attitude accuracy. Only anecdotal results can be cited since limited resources precluded an Early Midcourse Test and Evaluation Team presence at this meeting. Hand processing remains a possibility for high value Data Collection Events. The limited number of Data Collection Events for which this is considered to be a feasible requirement are those for the Early Midcourse and the Cooperative Target teams, 2 Data Collection Events and 6 Data Collection Events to date respectively.

The preliminary results of an analysis supported by the SBV Data Analysis Center are reported herein, see M. Gaposchkin's work attached to the meeting report. However, the full meaning of these results awaits a more detailed discussion with the analyst, who was unable to attend the meeting but, who did support the meeting with a phone call and the faxed results attached. The analysis purpose is in support of as accurate an Earth Centered Inertial pointing as possible within the extant hardware, software and resource constraints.

ATTITUDE PROCESSING NOTES

A file is now prepared and included with the Definitive Attitude file distributed for each Data Collection Event. The name of the file is UA_eventid_ii.APN, following the naming convention in the MOC Data Products notebook. The file contents are unique items and each unique item in the file is prefaced by a two-digit code. This will facilitate machine reading of the file and communication and discussion of various items. Note that a Data Collection Event may be divided among one or more segments, depending on spacecraft tape-recorder usage. Item **01** is listed once and items **02-04** and **06 - 07** are listed once for each run of the Definitive Attitude program. The information and statistics for each of the segments is provided in time order following the **05** line. The data in the file documents the statistics created when the Definitive Attitude processing is done.

REPROCESSING

The star camera's orientation relative to the science instruments on the spacecraft has resulted in a cross coupling of errors in the Definitive Attitude solution. This is a residual design artifact recently identified by analysis. The effect is to limit the attitude uncertainty about the spacecraft's Y axis, what would be considered to be the in-scan direction for the science instruments, to something on the order of 150 micro-radians. The weights of the filter elements implemented to smooth the star camera data with the gyro data has been undertaken with the effect of improving the Definitive Attitude solution. The Definitive Attitude data up to a specific date when the routine process is changed, must be reprocessed for the Data Collection Events where a higher quality attitude is required.

Adjustments to the filter element weights is considered to be only an interim solution to the Definitive Attitude process. There is still an Ultimate solution. The distinction between the Interim and the Ultimate is the need for an Attitude Processing Center person to input star sightings at the beginning and-or end of a Data Collection Event or for a Data Processing Center Data Analysis Center analyst to remove biases. There are at least two possibilities for an Ultimate solution. One is the Version 4 Definitive Attitude process is used forever and ever and the Attitude Processing Center Data Processing Center Data Analysis Center analyst intervenes to remove biases. Two is a Version 5 Definitive Attitude

process where the Attitude Processing Center Data Processing Center Data Analysis Center analyst no longer intervenes. Version 5 is required to have an accuracy which is either a.) 9 micro-radians or b.) adequate to meet all pointing accuracy requirements but those for the Celestial, the Early Midcourse and the Cooperative Targets Principal Investigator's. It may prove to be that the Version 5, Option b.) requirements can be met with Version 4. The answer will come from obtaining data and doing analysis of the results. Data like how well the instruments stay relatively aligned from Data Collection Event to Data Collection Event and how well the gyros can be aligned to the spacecraft fiducial and how well they stay aligned. It is estimated there will be a need to modify the Version 4 process to make it work for Version 5, Option b.).

INTERIM RESULTS REVIEW

The Data Certification and Technology Transfer Pointing and Alignment Watchdog collaborated with the Pointing Performance Assessment Team Chairman to prepare and to present "Pointing Status" for the spacecraft and its multiple instruments at the MSX Interim Results Review held June 3, 1997 at the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland. The proceedings are published by the Program Office which contains the presentation.

AIAA CONFERENCE

The Data Certification and Technology Transfer and the Contamination team each had a dedicated session at the conference. This provided an opportunity to communicate the MSX Program's Data Certification, its Technology Transfer and its Contamination Plan and Models to a broad technical audience. Three papers were prepared for the AIAA's 35th Aerospace Sciences Meeting & Exhibit. "Spacecraft Pointing Design and Certification", paper number AIAA 97-0310, summarizes the attitude control system design, fabrication, assembly, test and the pointing performance certification of the MSX spacecraft and its science instruments. The paper was reproduced and entered into the AIAA process for publication and distribution at the conference. Questions from the audience indicated both the Data Certification and Technology Transfer and the Contamination team session were attended by personnel with an interest in the work done.