Mr. Frank Snow, Code 410.0
THEMIS Mission Manager
Goddard Space Flight Center
Greenbelt, MD. 20771

Subject: THEMIS Monthly Technical Report

Dear Frank,

Enclosed is a copy of the monthly technical report for the THEMIS project. Copies have been distributed as itemized below.

Additional details on the status of the program are available at any time at the THEMIS ftp site:

ftp://apollo.ssl.berkeley.edu/pub/THEMIS/1.1%20Management/REPORTS/

If you have any questions, please don't hesitate to call.

Sincerely,

Peter R. Harvey
THEMIS Project Manager
University of California, Berkeley

Cc: Brenda Brady, Contracting Officer, 214.4
Publications and Graphics Services Section, 253.1
Center for AeroSpace Information
Dr. Vassilis Angelopoulos, Principal Investigator
Dr. David Sibeck, Project Scientist

1 Summary Status and Accomplishments

1.1 Mission Management

Prime Contract Status. The NASA-UCB contract is continuing to be funded on a month-to-month basis. We continue to spend vast amounts of time needlessly extending subcontracts at all levels. These subcontracts are needlessly complicated by not having a prime contract signed and both cost & schedule impacts are possible in this configuration. UCB is ready to expedite a contract once it is delivered to the University Sponsored Project Office.

1.2 Systems Engineering

Reported by Ellen Taylor.

1.2.1. Reviews The Mission PDR was held in mid-November. As of the close of the period, the IIRT has not yet issued its RFAs. For the time being, we are working on preliminary information obtained verbally from the review team and from GSFC.

1.2.2. Requirements and Verification - UCB completed the MRD Verification Matrix (MRD Rev C.1), and is currently working on the Draft Verification Plan and Environmental Specification. We anticipate this will be ready for review in the next period.

1.2.3. Resource Budgets - Power, Mass and Data budgets continue to be tracked. New power allocation for Swales heater power is being considered.

1.2.4. System Design - IDPU harness and grounding diagrams have been completed and ready for review.

2 Space Segment Development

2.1 Instruments

2.1.1 Instrument Data Processor Unit

Boom Electronics Board (BEB).
Written by Stewart Harris.

1. Work on boom unit motor driver continued. The breadboard drive electronics for the brushless DC motor selected for the spin plane booms was critically tested and modified to improve switching characteristics and lower power consumption. The decision to proceed with a brush motor design made the motor drive board unnecessary, and further work was abandoned.

2. A preliminary design was developed for the BEB GSE. This support electronics will allow a level of automated testing and characterization of ETU and flight boards independent of other IDPU boards. Many of the parts required for the GSE were ordered and received. The BEB GSE will consist of an LVPS simulator, command-data interface box and analog characterization tools, such as waveform generator and analog-to-digital converters.

3. The pc board layout for the BEB ETU was started. This work was delayed due to resource conflicts, but the layout was started by the end of the period.

Planned activities for next period:

1. Layout of the BEB ETU is expected to be completed.
2. PC board fabrication and assembly will be started. This work is expected to be contracted outside SSL.
3. Design of the BEB FPGA will begin. The FPGA design is expected to be completed before it is needed for ETU testing.
4. Harness wiring definition for the EFI booms will be completed.

Digital Fields Board (DFB).
Written by Jim Westfall, LASP

Digital Signal Processing

1. The main accomplishment for November was the design and VHDL coding of the filter kernel. This kernel consists of the controlling state machine, the arithmetic logic unit, and the RAM interface block that are required to complete the filtering function. Several design approaches were investigated and the selected implementation was coded in VHDL. The selected implementation consists of an ALU that autonomously performs the processing of a particular sample while the state machine controls the filter, cascade, and number of iterations required. The basic structure of the kernel is there but some minor details such as register widths and the shift required in the filter banks IIR are still TBD. Also, the ALU has been implemented to execute in a single cycle but there are 16 clock cycle available so there is a considerable amount of optimization that is yet to be done to reduce FPGA logic resource utilization.
2. Started an update to the “Digital Filters” section of the FPGA implementation document.

Analog Filters and Breadboard

1. Completed ICD which now is a controlled document.
2. Completed the design of the "programmable ETU" board--waiting for authorization to send it for layout.

3. Submitted a complete parts list for the DFB to Jorg.
4. Completed a Monte Carlo analysis of the EFI and SCM filters and differential amplifiers--submitted to John and Ellen for review and comments.

December Objectives:

1. Complete layout of DFB ETU and begin assembly drawings.
2. Develop BB and ETU test fixtures including start development of Labview code.
3. Complete update to FPGA implementation document "Digital Filters" section.
4. Begin optimization of filter ALU.
5. Complete FFT kernel design, optimization, and VHDL coding.
6. Begin update to FPGA implementation document "FFT" section.
7. Implementation of other data path elements depending on estimated arrival time of the reprogrammable ETU.

Schedule Update:

The DFB schedule has been modified to show changes in the baseline for the DFB BB layout. We will attempt to gain back some of the lost time by accelerating the layout, PWB fabrication and assembly. We've also combined two of the Digital Filtering development tasks, slow survey and fast survey, into a single task, digital filters. This combination better represent the new filter bank design. The changes are commented in the attached schedule.

Initial Data path connectivity is lagging behind since Ken redirected his efforts to the digital filter bank design. He will catch back up in this area, as we get closer to having a BB to work with. The digital filter kernel has been implemented but the design has not been optimized or verified.

This schedule still only shows tasks through ETU test. The DFB flight schedule remains unchanged from the THEMIS master schedule.

Technical Performance Metric (TPM) tracking:

With the completion of the Fields Instrument PDR, we will start reporting the following TPMs:

1. Power
2. Mass
3. FPGA Resource Utilization

We may add signal processing performance metrics once we have started DFB breadboard testing. At this time no processing metrics have been identified that are a concern and require tracking.

The Power and mass estimates are as reported at PDR. We will update those estimates as more of the FPGA modules have been coded and we have better estimates of the C/S cell utilization.

The FPGA resource utilization estimates are currently based on a small amount of non-optimized VHDL code for the digital filters. The bulk of the estimates are based on conservative assumptions for the remainder of the DSP modules. The modules being tracked and the current assumptions are attached below.

Based on the current estimates, the DFB will require three RT54SX72S FPGAs. While this estimate is consistent with order request that was placed with UCB Parts Group, it is not our goal. The DFB goal is to embed the entire design in two FPGAs.

The FPGA resource estimates are very preliminary and they will change. We are using these estimates as a tool to predict and respond to concerns before they become risks.

Data Controller Board (DCB)
Written by Dorothy Gordon.

1. Board Level Schematics: Released to Rev. A. Finalized DCB circuitry and integrated ETC section.

2. Parts: Substituted new items for some DCB Parts (such as the linear regulator and 3.3V Transceiver) which were unavailable. Parts list is now complete and the DCB-ETU parts are on order (or already in stock).

3. DCB PCB Layout: Winter Design is handling the layout. We have started the component definitions/placement and expect layout to be completed by the end of December. The fabrication and population of the DCB Boards as well as the "DCB Debug board" will also be handled by Winter Design, with parts kits supplied by UCB.(Winter Design has quoted for this work, but is still awaiting the actual Purchase Order.)

4. DCB-FPGA: The DCB-FPGA work is ongoing (about 30% complete) and will progress in parallel with the PCB Layout/Fabrication/Population.

2.1.2 Electric Field Instrument (EFI)

Written by John Bonnell.

2.1.2.1 Electronics Design

The EFI team participated in the Mission PDR in mid-November.

The EFI custom cable order to Gore was finally completed in late November 2003, after much wrangling over terms and conditions. Expected delivery time is 12 weeks. The FrangiBolt order for AXB and mag boom actuators was completed in mid-November, with expected delivery in late January 2004, in time for ETU assembly.

Preamp PWB fabricated, some errors in layout discovered and accommodated for ETU testing. ETU and Flight parts procured. Initial electrical testing of preamp ETU board begun, both with cable simulator and cable.

Final BEB schematics completed, and BOM created. Actual BEB ETU PWB layout begun, but postponed several times because of STEREO precedence on resources (to be resolved mid-Dec 2003).

Hardware for EFI/BEB GSE procured, and initial version of data acquisition system completed.

Activities for the next period will include:

- Assemble and test preamp ETU.
- Initial testing of combined preamp-BEB prototype circuits.
- Refinement of GSE design, specification of GSE program structure.
- Completion of SPB and AXB ETU designs and machining vendor selection.
- Magnetic testing of SPB motors and design of shielding to comply with EMC requirements.

2.1.2.2 Spin-Plane Boom Mechanisms

Requirements. A new mission requirement on the placement of the center of gravity was generated (the CG must be closer to the center of the pair of boom units than a distance of 1 part in 100 of the radial distance to the root of the SPB cable); this requirement is driven by an alignment requirement on the fine wires in the SPB sensors and the systematic error in electric field arising from that misalignment. The ESC specification was completed.

Design.. The SPB overall assembly was repackaged successfully achieving a 90/90 degree configuration on on the Probe. This was verified by Swales mechanical lead and is a huge success. The SPB to Probe Interface Control Document Rev 'D' was submitted to Swales at the end of the period.

Tests/Analyses. Fine wire load testing was completed successfully during the period.

Motors. The Globe Brushless Motor was replaced by Globe Brushed Motor, since the Brushed Motor Lead Time was 4 weeks instead of 20 weeks for brushless. This order is expected to go out in mid-December. The brush motor design had many

advantages, including a mass advantage as well as simplified enable plug (just 2 wires not 8). Next period we'll probably find out that the brushless motor has a smaller magnetic moment, too!

ETU Fabrication. Engineering model fabrication quotes have been received and we expect to have SPB machined parts in house in mid-January.

Issues. Array Shadowing. The SPB protrusion through the solar array causes a minor shadow on the cells when the Z-axis is off the ecliptic normal by more than 20 or 30 degrees. In order to help Swales deal with the array shadowing problem, UCB looked into the possible design trade which could minimize the protrusion. Unfortunately, UCB concluded this path was not possible.

2.1.3 Electro Static Analyzer (ESA)

Written by Paul Turin

Detector ETU part are on order and expected December 24. Purchased parts for the ETU have been ordered and are either on hand or expected by December 24. The prototype release plate assembly was received and evaluated this month. We determined that a dual (redundant) actuator design was required along with a torsion spring to replace the compression spring in the first prototype. In addition the cam shape for the actuator power cutoff switch was redesigned to provide more travel and allow use of a cam follower on the switch. All of these changes were incorporated in a new solid model and new parts and drawings generated.

All parts were ordered with a January 5 delivery date promised. The redesigned actuators based on the NanoMuscle's mechanical parts were designed and prototyped. The new design has a Vespel SP3 frame and PEEK clamping plate. Test parts survived the GEVS-SE shake test at 14.1 g for 4 minutes in each axis. We are now preparing to start life cycle testing. Design of the electronics housing has commenced and is 30% complete. Design of the mounting to the IDPU has also commenced and is 25% complete.

2.1.4 Solid State Telescope (SST).

Written by Paul Turin

Mechanical Design

- Updated drawing of DFE circuit board based on new component layout
- Updated magnet-cage assembly to accommodate larger magnets and yokes to meet science performance requirements
- Continued design of attenuator-cam assembly to be used in actuator life test
- Support structure modified to accommodate new magnet-yoke assembly

- Finalized flex circuit and beryllium-copper component designs with input from electrical engineers and scientists
- Detector dimensions and pixilated stay-out regions fully defined

Engineering Test Unit:

- Ordered flex circuits for detector board assembly (ETA: mid December)
- Ordered beryllium-copper contact rings and spring plates (ETA: late December)
- PEM circuit board fasteners ordered (received 12/8/03)
- Detectors for THEMIS in production at Lawrence Berkeley National Laboratory
- Created drawings for magnet-cage assembly components which were then submitted to various vendors for quotes
- Created drawings for DFE detector stack assembly components which were then submitted to various vendors for quotes

ICD for Integration with Bus:

- Updated ICD with latest SST dimensions

2.1.5 Search Coil Magnetometer (SCM).

Written by : Abdel Bouabdellah, Christophe Coillot, Bertrand Delaporte, Olivier Lecontel, Alain Roux

2.1.5.1 Sensors

Manufacturing of the sensors has begun :

- All parts have been procured
- Winding will start in december (CETP/TECHNOPOINT).

2.1.5.2 Preamplifier voltage regulator :

Components has been procured by CETP.

2.1.5.3 Preamplifier

Calibration function :

Calibration function behaviour has been successfully tested :

- Generation of the calibration signal : spectrum analysis is compliant with our requirement (analysis of the transfer function from 10Hz to more than 200Hz)
- Calibration command has been checked.

Components list of calibration function is fixed.

80% of components have been procured. No critical issue on this procurement.

PCB routing :

PCB routing is finished but is under validation.

Preamplifier box.

Housing design (PA box) continues.

Reduction of the PCB size allows to save mass.
Mass budget for PA will be respected.

Mechanical structure of tri axis antennas.
Numerical computation for thermal, shake and shock behaviour continues (GDTECH).

2.1.5.4 Harness SCM to PA

No change.

2.1.6 Magnetometer Booms

Written by Paul Turin

Design

- Prepared for and presented at Mission Preliminary Design Review on Nov 13.
- Redesigned mag booms to for new harness routing plan. Half the parts were redesigned to accommodate harness running inside the mag boom.
- Completed new releases of ICDs for deck to FGM/SCM mag booms. Held in-depth discussion with Swales regarding mag booms base hinge and connector attachments.
- Designed process for making composite AXB flange.

Fabrication

- Evaluated prepreg for purchase.
- Ordered adhesive.
- Clean up and major renovations to accommodate table roller equipment in Bldg 151, Richmond Field Station completed.

Others

- Helped to test and characterize mechanical strength of EFI wire booms.

2.2 Probe and Probe Carrier

See Reference : ftp://apollo.ssl.berkeley.edu/pub/THEMIS/1.1 Management/REPORTS/thm_monthlyreport_0311_ppc.pdf

3 Ground Segment Development

Written by Manfred Bester

3.1 Mission Operations

3.1.1 Mission Design

The THEMIS flight dynamics team generated additional IDL code that, in conjunction with GTDS, facilitates the development of detailed orbit placement strategies for all five probes, independent of the launch date. The orbit placement

strategies for all five probes were completed for the first tail season, based on a nominal launch date of 21-Aug-2006. The orbit placement was optimized for a minimum number of maneuvers, minimum fuel consumption and minimum operational complexity while allowing for various contingencies. Additional efforts concentrated on maximizing conjunction time.

Members of the flight dynamics team met with Conrad Schiff of AI Solutions to review ongoing mission design work as well as maneuver planning strategies and associated software options.

3.1.2 Orbit Determination Accuracy

A Carrier Doppler Measurement System (CDMS) and Track Data Formatter (TDF) on loan from the Wallops Flight Facility was used to determine Doppler accuracies as a function of signal-to-noise ratio and demodulator loop bandwidth for both BPSK and PM modulated signals. Two-way Doppler tests were performed in loop-back mode and with the FAST spacecraft to establish a baseline for planning the number and distribution of tracking arcs for THEMIS orbit determination. The tests demonstrated that the Berkeley Ground Station will be able to provide Doppler tracking data with a quality similar to those obtained at equivalent NASA ground stations. A CDMS and TDF identical to the Wallops system will be procured and installed permanently in the Berkeley Ground Station.

3.1.3 Ground System Design

The design of the THEMIS ground data system is well on its way. The envisioned architecture for THEMIS is built on top of the exiting multi-mission operations environment already in place at the Berkeley MOC. Additional software tools will be implemented to streamline data flows, to generate constellation overview displays and to populate databases with probe telemetry points. The latter will allow efficient access to telemetry archives for data trending and event analyses. Discussions with Hammers regarding potential ITOS upgrades for multi-satellite support are part of the ongoing efforts.

A revised space allocation plan has been submitted to the SSL Space Committee. Expansion of the MOC in preparation of THEMIS ground system implementation is anticipated to commence in early 2004.

3.1.4 Ground Station Trade Study

The required trade study on ground station options, including number of stations, number of passes and associated costs was completed. A draft PSLA for THEMIS support via TDRSS and NASA/GN is under development. Corresponding ICDs are in the draft stage.

3.1.5 NTIA License

The Berkeley team worked with the GSFC Spectrum Management Office to prepare the application for the THEMIS NTIA license. Preliminary S-band frequencies were assigned to THEMIS. Upon approval by the DoD, which is expected by December 17, 2003, the GSFC Spectrum Management Office will file the Stage 2 application with the NTIA. Approval of the Stage 2 license is expected by mid-2004.

3.2 Ground Based Observations Developments

Written by Stewart Harris
Ground Based Observatories (GBO)

3.2.1 Mission PDR completed.

No RFAs were received.

3.2.2 ASI environnemental enclosure. Working with Allison Park Group, the prototype enclosure design was finalized with selection of materials, dome vendor and connectors. The ASI enclosure will be stainless steel, hermetically sealed construction with acrylic dome.

3.2.3 ASI lenses and cameras were received. All sky lenses and the MX716 cameras from Starlight Xpress for the entire GBO network were received.

3.2.4 Computer system environmental enclosure. Working with Moore Sailboats, the prototype enclosure design for manufacture process was completed. This involved taking the design concept and developing the fabrication process and tooling requirements. The Computer System enclosure will be fiberglass panel/foam core construction.

3.2.5 Subsystem parts ordered. The parts list for the GBO prototype system was completed and parts ordered in preparation for construction scheduled for next period. This included Campbell Scientific temperature controller, serial port switch, power switching components, heaters, temperature sensors and power supplies.

3.2.6 Temperature control software specification. The Campbell Scientific temperature control computer (CR10X) was received, and a specification for the control program was completed.

3.2.7 GMAG GPS selection revised. The Oncore GPS initially selected for use has not worked well with Linux. For this reason, the Trimble Accutime is being considered. It provides equal, or better, performance, and has established Linux compatibility.

Planned activities for next period:

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1. Fabrication of ASI enclosure will be completed.
2. Fabrication of Computer Enclosure will be started.
3. Construction of prototype GBO system will be in progress.
4. Temperature controller software will continue development.
5. Prototype GMAG interface electronics will be completed.

4 Education and Public Outreach

Respectfully Submitted,
THEMIS E/PO scientists Nahide Craig, Laura Peticolas

4.1 Formal Education:

L. Peticolas visited the Auk Bay Elementary Schools in Juneau, AK where she talked to two classes of 5th graders about the aurora and the Sun-Earth. The students had seen the aurora associated with the large October, 2003 CME events and they learned that this aurora was connected with the Sun, CMEs, and Earth's magnetic field.

4.2 Public Outreach:

The THEMIS E/PO web site is completed and reviewed and will be ready to be public in December.

4.3 Cross Cutting:

We presented the E/PO in a splinter session during the Mission PDR. Dr. Larry Cooper, a Program Planning Specialist for Education and Public Outreach from the NSA HQ, participated in the E/PO PDR with Solar B E/PO Lead and SECEF co-Manager in a splinter session on November 12. The local E/PO partners participated in person and the remote ones by telecon. The E/PO was also presented during the plenary Session on November 14th.

5 Problems

5.1 Outstanding Problems

None from last period.

5.2 New Problems / Problem Avoidance

From the Instrument and Bus PDR's we found that there were a number of items needing attention. The most significant were:

1. GNCD funding. The THEMIS team at Guidance Navigation and Control Division was not operating due to the lack of a JON. We don't know if this is part of the overall funding issues between GSFC and UCB or not, but we made new requests for them to start supporting the project.

2. The EFI booms should be longer than the concept study. Based upon new data from Cluster, the recommendation from the peer review was to make the booms longer. (This problem will be solved next period.)
3. The SST sensor would not work to high enough energy given the magnetic initially conceived. This will be solved in the next period.
4. The Probe preliminary design does not meet its attitude requirements. Either the Z-boom has to get shorter or the X & Y booms need to get longer. (This solves problem #2 above! This will be solved in the next period.)
5. The Probe thermal design does not meet the goal of being able to point in any direction indefinitely. At the bus review, it was clear that the probe could not stand having the top deck pointed toward the sun for long periods. This will be aggressively attacked in the next month.
6. The Probe communication link depends upon a new technology to circularly polarize the antenna. This study has been undergoing at Ball Aerospace for some time and the results had not been delivered.
7. The IIRT believes that NASA Orbital Debris guidelines require that there is a 99% probability of successful flight termination. Since our Probes are single-string, we cannot possibly meet this requirement and hope that this is not a real requirement. We have prioritized submitting the Orbital Debris Assessment in the next period and hope to get this discussion going as soon as possible.

5.3 Resolved Problems

None.

6 Risk Management

GSFC will provide a Risk Management workshop at UCB and tailor the THEMIS plan on January 14-15th.

7 Performance Assurance

7.1 Requirements

During the period, GSFC asked for a change in Mission Assurance Requirements from GSFC-410-MIDEX-003 to 410-RQMT-0025. Buried in the initial draft of 410-RQMT-0025 was a change in parts requirements from 311-INST-001 to 311-INST-002. This is a non-trivial change in parts qualification and design assurance, and would surely bring substantial schedule and cost impacts to the project. It would essentially invalidate the concept study efforts. The final outcome of this discussion was to use 311-INST-001 for THEMIS parts requirements per the AO.

The Performance Assurance Implementation Plan Rev A dated 9/30/03 (CDRL-04) are still under review at GSFC.

The Level 1 Requirements document (CDRL-03) was sent to GSFC for review.

7.2 Parts and Materials

The preliminary Parts and Materials Lists were delivered to GSFC for review during the period (CDRL-30 and CDRL-31).

7.3 Contamination Control

Based upon inputs from the Instrument Preliminary Design Review packages, UCB developed the Preliminary Contamination Control Plan. This was modeled in large part on the FAST CCP which had the very same instrument contamination issues.

This plan was sent to Swales for review and comment, and delivered to GSFC for review (CDRL-32).

7.4 Software Assurance

Based upon a MOU between UCB, GSFC and IV&V (CDRL-06) defining the initial assessment activities, UCB, Swales and GSFC met with IV&V representatives to begin the Initial Assessment. This involved detailing the software functionality down to modules which could be sized and CPU performance requirements estimated. These multipage assessments covered the IDPU Flight Software, Probe Flight Software, and Mission Operations Software.

7.5 Configuration Management

During the period, UCB delivered its preliminary Configuration Management Plan (CMP) to GSFC for review (CDRL-56).

7.6 Systems Engineering Management Plan

During the period, UCB delivered its preliminary Systems Engineering Management Plan (SEMP) to GSFC for review (CDRL-55).

7.7 Safety Assurance.

After five months of iterations (unbelievable as that may seem), the THEMIS Safety Plan submitted to GSFC in November was approved by GSFC safety.