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Gravity Probe B Relativity Mission

ATC ADP Review – Final Issue Close Out

(ACE, Magnetometers, Thrusters, Coarse Sun Sensor, Magnetic Torquer Rods, Control Gyros, TIVs, Star Sensors)

S0752, Rev. -

January 21, 2003

Close Out Certification

The ATC data package* has been reviewed by Stanford University. MSFC and the IRT have been requested to identify any flight risks from any review to the Stanford University review chairman. The chairman, having assessed all inputs received as of the review date of 20 January 2003, finds the ATC components reviewed acceptable for the GP-B flight mission contingent on the acceptable closure of the action items and acceptable system level testing.

* the following items were reviewed: ACE, Magnetometers, Thrusters, Coarse Sun Sensor, Magnetic Torquer Rods, Control Gyros, TIVs, Star Sensors

ADP Review Chairman and GP-B Program Manager:

Gaylord Green — **Gaylord Green**

14 Feb 2003 — **Date**

Concurrence:

Richard Whelan — 14 Feb 2003

Systems Engineering — **Date**

Concurrence:

Jorrene Pon — Feb 14 2003

Quality Assurance — **Date**

ITAR Assessment Performed — **Tom Langenstein**

2/14/03

ITAR Control Req'd? ☐ Yes ☒ No

ATC ADP data Review (telecon) and Issues Resolution Meeting Minutes:

Location: Stanford University, HEPL Conference Room, 1 pm, January 21, 2003
Minutes prepared by: Richard Whelan

References:
LM / P480699, ATC Component ADP Closeout Presentation, Jon Kirschenbaum, January 21, 2003
LM EM ATCS 342, ATC Response to Hardware Acceptance Review Questions, Jon Kirschenbaum, January 20, 2003
[note: references are ITAR / U.S. Export Controlled documents]

Attendees:
MSFC (telecon): ....Byron Bartlow, Ralph Kissel, Howard Estes, Don Hedigar, Morris Hammer
MSFC (at SU): .....Charlie Dischinger, Marv Nowlins, Terry Koelbl, Jim Looney
SU: .....Gaylord Green, Dorrene Ross, Bill Bencze
LM: .....Bob Schultz, Rich Whelan, Jon Kirschenbaum, Dave Steele, Mike Miranda
IRT: .....Jerry Nurre, Virgil Young

Background:
In November 2002, Stanford began a review of several ATC component Acceptance Data Packages with the goal of achieving a Stanford "endorsement" of the component level data provided by Lockheed Martin, and subsequently submitted to Marshall Space Flight Center.
The process got off to a quick start with Stanford reviewing ACE, Magnetometers, Thrusters, Coarse Sun Sensor, and Magnetic Torquer Rods in the first round, then reviewing Control Gyros, TIVs, and Star Sensors in the second round. Questions and issues were forwarded to LM (Jon Kirschenbaum), which became the basis of the LM Engineering Memorandum and the focus of the Issues Resolution Meeting.

Overview / Summary:
Jon Kirschenbaum presented an overview of previous ATC reviews and a forward look at ATC hardware in Space Vehicle test. At the end of the presentation was a brief discussion regarding a Star Tracker anomaly investigation currently being conducted (no conclusions available, but Star Tracker B was removed from the vehicle and will be tested in the ITF, since no testing can be performed on the vehicle without the PDU).
Following this overview, the responses contained in EM ATCS 342 were reviewed, then the latest MSFC review comments were addressed. 3 action items resulted.

Action Items
1. Star Tracker - based upon discussion regarding current anomaly: Check if Star Tracker has been EMI tested or if the production unit was verified by similarity. *Answer: Ref: RL160 and EM ATCS 232 of 14 August 2001. EMI/EMC was done by similarity, as shown in the star sensor FDR, May, 1997.*

2. Actions for / with Jeff Vanden Beukel:
   a. Participate in telecon for resolution / addressing RL 444. Work with Rich Whelan and / or Drew Costantino. Interested parties include Jerry Nurre and Morris Hammer.
   b. Address the following MSFC question regarding Thruster component data:'
   The meaning of "reverse leak" is not clear & lacks correspondence to other leakage data in this section; no definition of testing for "reverse leaks."
3. Control Gyro: issue about maximum misalignment allowed / measured will be address in future submittal of E15 data book (defined per SCIT-01 part 3B). This databook has been assigned the LM document number P480558.

All other MSFC issues were discussed and closed at the meeting

Additional notes:
1. Information regarding spare units vs. flight units are available in S0664 Rev A. (Thruster units F001 and F015 are spares, TIV units SN006 and SN018 are spares.)
2. Star Tracker B is the redundant unit.
3. Flow testing of Thrusters was performed at one level since multiple levels had been tested at the component level.
4. 2 new sets of data have been sent to MSFC for the TIVs -- Qual Data, and post ATP heater install retest data. MSFC has already reviewed the TIV ATP data which is still valid.

ATC Questions / Issues from MSFC:

Subsystem	MSFC Reviewer	Findings/issues	Finding resolution
Control Gyroscope (KFT99006 & KFT99007)	Feltner	When the alignment of the two internal gyros in each pkg was attempted at the vendor acceptance testing, specifications could not be met. Ensure that the misalignment at the ctrl gyro level is compensated as the gyros are installed on the spacecraft. This is to avoid saturation by cross-coupling of the roll rate into the pitch & yaw axes.	Answer documented in EM ATCS 231, 29 July 2002 (ref. RL 155 closed). Alignment errors within bias compensation. Alignment will be covered in Alignment Databook, E15 (P480558). CLOSED here. Remains open programmatically until E15 is delivered to MSFC.
Magnetic Torque Rods (ITH98007)	Feltner	There is a mismatch between the Torqrods and the ACE such that the maximum current possible from the ACE cannot generate the required maximum torque. Only 194 A-m2 can be generated, while the spec is 230 A-m2.	Answer documented in EM ATCS 231, 29 July 2002 (ref. RL 155 closed). The ACE can generate adequate current for the mission need. CLOSED.
Thrusters (8A00090), (F001 - F0018, F001 & F015 are spares), and Thruster Isolation Valve (TIV) (SN001-018, SN006 & SN018 are spares)	Hammer	(cd: reviewer is not from GP-B team) Apparently, data pkg addresses at least 18 TIVs & 18 Thrusters. The GP-B system consists of 16 thrusters & 16 TIVs. Therefore, two of these components must be spares. (cd: It is not clear which are being addressed. Data pk is voluminous and not organized.) Rqmts & specs the components are to meet are not defined.	Answers about spares contained in S0664 and shown in column 1 to the left. CLOSED.
		The reviewer finds it difficult to discern the pertinent data; no map of test to expected results.) The meaning of "reverse leak" is not clear & lacks correspondence to other leakage data in this section; no definition of testing for "reverse leaks."	See info below*
		For ambient functional tests, mass flow rqmts are not defined. No rationale is given for use of only one P level (12.5 torr).	At the SV level, on one flow rate was used. Multiple flow rates were used at the component level. CLOSED.
		Propulsion performance parameters (e.g., thrust, Isp) not addressed.	At these low thrust levels, the thrust is defined by pressure and mass flow rate. Additional analysis can be found in SU Theses SUDAAR 538 and 624. CLOSED.
		No insight as to acceptable performance variability between thrusters.	See info below*
		No evidence that P transducer calibration and feedback response have been evaluated; important to proper thruster performance.	Transducers have calibration data from the vendor which is used in the CCCA.
		Data tables express raw current in mV and mass flow in sccm.	Yes. CLOSED.
		For thruster S/N F015, following data are missing: Interim Ass'y., Hot/coldLeakage Test, Hot/cold Functional Test, Thruster Gain Data (for sw).	F015 is a spare, not installed flight hardware.
Star Sensor/Tracker (HDS 990013 - 990020)	Feltner	Anomalous power-up behavior: excessive power dissipation. Satisfactory explanation received.	Answer documented in EM ATCS 231, 29 July 2002 (ref. RL 155 closed). No further closure action required.

* Thruster Questions to Jeff Vanden Beukel:

1) "The meaning of 'reverse leak' is not clear and lacks correspondence to other leakage data in this section; no definition for 'reverse' leaks."

Response: From the thruster spec:
"4.2.2.2.9 Reverse Leakage
With the nozzle cap assembly (LMMS Drawing 8A00178-GSE) installed, the thruster shall be evacuated using a helium leak detector. All mechanical joints and 100 percent of the surface shall be checked using helium."

In other words, the thruster is tested for leakage with an internal vacuum, and helium sprayed on the external surface. The term reverse is used since this is the opposite of the direction of pressure differential during operation, i.e. helium pressure inside the thruster, and an external vacuum. In general, leak testing in either "direction" is considered equivalent for detecting leaks. However, the thruster is tested with a positive internal pressure during the "Hot/Cold Leak" test, as defined in the thruster spec:

"4.2.2.2.5 Hot/Cold Leakage
The thruster inlet shall be pressurized with gaseous helium to 6895 Pa (1.0 psia) while the thruster is in a vacuum of 1.33 Pa (10^{-2} torr) or lower. All mechanical joints and 100 percent of the thruster surface shall be checked using a helium leak detector at the minimum and maximum temperatures specified in 3.2.5.2.1. For protoqualification Hot/Cold Leakage, the thruster shall be tested at the minimum temperature specified in 3.2.5.2.1, and at 10 K (18 °F) above the maximum temperature in 3.2.5.2.1."

2) No insight as to acceptable performance variability between thrusters.

Response:
Each thruster is required to meet minimum and maximum mass flow (thrust) level requirements over the range of operating conditions.

There is not a requirement on performance variability between thrusters. This is because each thruster is individually characterized over the range of possible inlet pressures and temperatures. These data are then used by the Attitude Control and Software group to generate curve fits for each thruster. These constants, for both open and closed loop modes, are database items in the flight software. The flight software uses this information to generate the proper thrust/mass flow command for each thruster.