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Gravity Probe-B (GP-B) Relativity Mission

Gravity Probe B Mission Flight Rules

S0856, Rev. B

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Tom Langenstein 3/26/04 ITAR Assessment Performed, ITAR Control Req'd? Yes (No)

Changes from Reb A to Rev B for S0856 – Flight Rules

25-Mar-04

The only change made to the Flight Rules was to add rule 7.10, which reads:

SSR Playback Restriction

Rule: SSR Playbacks should not be scheduled during critical data collection periods.

Rationale: SSR playbacks cause 3 losses of data, each up to 30 seconds in duration. These losses of data occur due to transponder and IU configuration changes. Critical data collection periods such as Database Readouts, Snapshots, Memory Readouts, and critical sequences may lose potentially irreplaceable data

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1 Introduction

This document describes programmatic rules of flight operations for the Gravity Probe B mission. Hardware, software, and detailed technical operations related constraints are defined in the Constraints And Restrictions Document (CARD), an Appendix to the Flight Operations Handbook, MO-05.

2 Flight Rule Definition and Control

2.1 Definition

Flight Rules are high level operating policies that define "How GPB plans to run Mission Operations Center (MOC)." Frequently, Flight Rules will summarize an operations concept that is defined in greater detail in other documents, including: The Launch and Activation Plan, The Anomaly Resolution Plan, MOC Requirements, MOC Procedures, the Network Support Plan, P-Docs, S-Docs, and Position Handbooks.

2.2 Scope

All flight operations procedures, timelines, CSTOL scripts, support software, etc. must be consistent with these flight rules. If conflicts are found between documents, this document takes precedence.

2.3 Change to Flight Rules

All Flight Rules changes, additions or deletions must be approved by the PCB to ensure that all team members understand the implications and implementation of the changes.

2.4 Waiving of a Flight Rule

A flight rule may be waived only with the approval of a Mission Director, the Program Manager, or the Principle Investigator. The form at the back of this document is used to waive the Flight Rule and a copy of the waiver is maintained in a binder in the MOC.

2.5 Correcting a Flight Rule Violation

Any action that violates a Flight Rule without a prior waiver will be recorded into the Telemetry Quality and Status Monitoring (TQSM) Logbook. Each violation will be brought to the attention of the Program Manager who will then determine the appropriate corrective action. Corrective actions may include: changing the Flight Rules, updating processes and procedures, disciplinary action, etc.

3 MOC Rules

3.1 Certification

3.1.1 Rule: GPB will ensure that every person that works in the MOC or in a MOC support role will be certified in their position. This includes: Flight Directors, Console Operators, Mission Planners, Responsible Engineers, Orbit Determination Team, Data Processors, and Mission Directors.

3.1.2 Rationale: Proper certification will mitigate risk to the vehicle by assuring only qualified personnel will be in a position to affect the spacecraft.

3.2 Commanding Protocol

3.2.1 Rule: All typed commands will be verified by two certified MOC personnel prior to transmission to the vehicle.

3.2.2 Rationale: During IOC the Flight Director will approve all commands. The Flight Director can verbally waive this requirement for routine commands at their discretion. After IOC, the "second set of eyes" can be another controller. This Flight Rule is a standard procedure used by operations teams to mitigate human error.

3.3 Data Review

3.3.1 Rule: During IOC, each subsystem will be reviewed by an appropriate RE once per day prior to the All Hands Meeting. The review will consist of analyzing subsystem plots of the last 24 hours of data as a minimum.

3.3.2 Rationale: IOC for GPB is highly dynamic and automated limit checking should only be a back-up to RE verification of subsystem health.

3.4 Handling Limit Violations

3.4.1 Rule: All Limit Violations will be recorded into TQSM and the appropriate REs will be immediately notified. Limit Violations can be generated by OASIS, RTWORKS, or TCAD processing. Yellow Limit Violations will be reviewed and closure status assigned by the Daily All Hands Meeting. Red Limit Violations will be reviewed and closure assigned within 2 hours.

3.4.2 Rationale: This limit violation policy is set to ensure that the limits database is accurate, that REs have a method to review and close violations rapidly, that a record of limit violations is maintained, and to ensure the timely prevention or recovery of vehicle problems.

3.5 On-Call Personnel

3.5.1 Rule: The MOC will use On Call personnel to respond to issues that occur outside of normal business hours.

3.5.2 Rationale: The MOC will not be staffing an engineering staff 24/7. To ensure potential vehicle problems are averted and critical data is reviewed in a timely manner, On-Call personnel must be able to respond as specified in Handling Limits Violations (above). Responsible Engineers are also required to sign Mission Planning Loads which may also occur at odd hours.

3.6 Handovers

3.6.1 Rule: The MOC will utilize both position and team handovers at every shift change.

3.6.2 Rationale: Handovers should uniformly inform the entire team about any recent position or mission specific issues.

3.7 Logbook

3.7.1 Rule: MOC personnel will use an on-line logbook to permanently capture pertinent operations information.

3.7.2 Rationale: An on-line logbook will ensure the entire team has access to all relevant operations material in a timely manner. The on-line logbook should be TQSM but a Logbook or ReadMe file in the current Oasis run directory can serve as a backup. Relevant information for the logbook includes limit changes, equipment limitations, ground station issues, timeline progress, subsystem performance issues, product availability, up-coming areas of concern, summaries of closed issues, etc.

3.8 Integrated Test Facility (ITF) Status

3.8.1 Rule: The ITF will be kept in working order with no downtime exceeding 24 hours during the GPB Mission.

3.8.2 Rationale: The ITF is used to verify command templates, command sequences, and to develop contingency procedures in the event of an anomaly. Since recovery from an anomaly should occur within 3 days, no more then 1 day should be lost to ITF maintenance.

3.9 Launch Day Activities

3.9.1 Rule: GPB will use an extensive Pre-Launch Checklist to ensure proper: vehicle configuration, software images, SPC loads, launch products, console documentation, launch procedures, communications, MOC hardware status, MOC interfaces, and personnel.

3.9.2 Rationale: The extensive list of "one time" only activities and products associated with launch, the timing rigors of launch-day, and the number of people involved requires special consideration.

3.10 Telemetry Format Loads

3.10.1 Rule: No telemetry format shall be reloaded while it is active.

3.10.2 Rationale: The active format controls what is down-linked to the ground or recorded on the SSR. If the transient format is active when a reload takes place, the telemetry output will be incorrect, and due to possible indexing errors, the flight software may fail.

3.11 Database Readouts

3.11.1 Rule: When a data base readout is in progress, another request for a new data base is not permitted.

3.11.2 Rationale: Requesting a data base readout while one is already in progress will corrupt the original request.

3.12 Security Word Changes during IOC

3.12.1 Rule: There shall be no changes to the Security Word during IOC.

3.12.2 Rationale: The risk of getting the ground system out of sync with the spacecraft and the subsequent delays to commanding is higher than the risk of unauthorized commands being sent to the spacecraft during this period. Note that commands are still security coded; the security code will just remain the same throughout IOC.

4 STORED PROGRAM COMMAND (SPC) LOADS

4.1 Transmission of SPCs

4.1.1 Rule: The Mission Operations Center (MOC) shall send only pre-tested, approved SPC templates. Testing in the ITF is required. An analysis of the validity of the testing shall be provided with the template.

4.1.2 Rationale: Sending untested or unapproved SPC templates may cause unintended vehicle configurations, delays in the mission timeline, or violation(s) of a Constraints and Restrictions Document (CARD). As the ITF may not be able to test the template's functionality, the supplemental analysis will allow the project to assess the risk in the sequence transmission.

4.2 CSTOL Procedures

4.2.1 Rule: The MOC shall use only pre-tested, approved CSTOL procedures when commanding the Space Vehicle (SV). Testing in the ITF is required. Sending benign realtime commands such as: setting global variables for abort sequences, clearing the event supervisor, switching telemetry formats, resetting safemode tests/macros are pre-approved as long as two people verify the commands prior to transmission

4.2.2 Rationale: Use of untested or unapproved real-time command procedures may allow erroneous commands to be transmitted to the Space Vehicle (SV), causing unintended vehicle configurations, delays in the mission timeline, or the violation of a CARD. Realtime commanding that is not benign should be built into an SPC and pre-run in the ITF to ensure accuracy.

5 COLLECTING DATA FROM THE VEHICLE

5.1 Software, Database, and Calibration Loads

5.1.1 Rule: Anytime a software load is performed (MSS, GSW, SSW, SUS, EEPROM) or a database or calibration level is changed the MOC will dump an image for permanent archival at the ground.

5.1.2 Rationale: The ground needs to know the state of the vehicle at any given instant. By ensuring this "dump after change" rule, a record of the most recent values can be maintained in the MOC for documentation, configuration control, analysis, and troubleshooting.

5.2 EEPROM Loads

5.2.1 Rule: When uplinking EEPROM loads to the SSR or CCCA, the MOC shall verify the loads via memory dump and compare prior to activating them for use.

5.2.2 Rationale: It is prudent to verify the EEPROM load against a known, good ground image prior to activating the load.

5.3 GSS and SRE Loads

5.3.1 Rule: Always dump and verify the GSS and SRE EEPROM after loading from the SSR before attempting to execute the load.

5.3.2 Rationale: The application PP_Host has been known to repeat packets of data being sent to the GSS. This causes bad loads with unpredictable results.

6 REAL-TIME OPERATIONS

6.1 MOC Staffing for Real-Time Contacts

6.1.1 Rule: During IOC the MOC shall minimally staff at least one certified controller and one certified Flight Director during every real-time contact with the vehicle. After IOC, two certified controllers will be sufficient.

6.1.2 Rationale: On-site staff will be better able to troubleshoot issues with the ground support equipment; GN, SN, NASCOM equipment. Real-time support will also ensure that vehicle health and safety checks are done in a timely manner.

6.2 Timing Real-time Commands

6.2.1 Rule: Sending real-time commands to the SV must be compared against the progress of the current SPC load and the orbital events file for Vehicle Mode Select (VMS) macro activations before they are sent to avoid mailbox collisions.

6.2.2 Rationale: Transmission of certain commands while certain SPCs or VMS macros are actively executing may cause a mailbox collision or CPU timeout resulting in dropped commands or possible safemode test failures.

6.3 Real-time Command Verification

6.3.1 Rule: All real-time commands sent to the vehicle will be verified for success in real-time. All commanding errors will be documented for the permanent MOC record.

6.3.2 Rationale: Flight Director approval of commanding ensures 2 people verify that typing is accurate, use of CSTOLs are appropriate, and correct loads are used; this is done to mitigate human error. Ensuring that commands are received properly prevents delays in the timeline associated with the safemodes SPC List Exhaust or No Ground Commands Received in 12 Hours. The incremental command reject counter must be recorded to ensure accurate analysis of command reception.

6.4 Special Macros

6.4.1 Rule: The timeline must be checked before sending commands to activate Special Macros that contain SRM_Processing application commands or Telemetry application commands.

6.4.2 Rationale: The timeline has embedded command sequences that use the same application. The potential for mailbox collisions and the loss of commands could lead to unexpected results.

7 SCHEDULING

7.1 Critical Sequences

7.1.1 Rule: All sequences which may require a real-time contingency procedure shall be scheduled to execute during real-time contacts with both a forward and return link.

7.1.2 Rationale: The flight team must be able to see the potential cause for the contingency procedure in real-time as well as have a commanding link to execute that procedure.

7.2 Component Activation

7.2.1 Rule: All sequences that activate a component for the first-time will be scheduled during real-time contacts with both a forward and return link whenever possible.

7.2.2 Rationale: Real-time coverage mitigates the risk associated with first time component turn-on. Activation sequences that occur during initial ascent that are not in view are exempt from this rule.

7.3 State of Health and Data Recovery

7.3.1 Rule: The program will ensure a command is sent to the vehicle every 12 hours.

7.3.2 Rationale: By sending a command every 12 hours the program ensures that a command link is available for commanding as well as ensuring a real-time state of health is performed.

7.4 SSR Data Recovery

7.4.1 Rule: The program will schedule at least 3 GN contacts per day to ensure all SSR data is recovered prior to it being overwritten on board the S/C. Contingency procedures will be used to ensure data recovery if a GN contact is lost

7.4.2 Rationale: The current mean duration of GN visibility requires at least 3 supports to ensure full data recovery from the solid state recorder. Contingency SSR procedures to recover data prior to its being overwritten pose little or no risk and are pre-approved for real-time implementation.

7.5 Scheduling Control Block Memory Dumps

7.5.1 Rule: The MOC will schedule a dump of the Control Block and SUS once a month to ensure no changes

7.5.2 Rationale: The main flight computer may not reboot if there are changes to the SUS or control block.

7.6 Orbit Determination Accuracy

7.6.1 Rule: The MOC will schedule at least four 15 minute coherent contacts per day during IOC with the SN to ensure the Flight Dynamics Facility can generate an accurate back-up orbit vector.

7.6.2 Rationale: In the event of a failure of the vehicle GPS system the back-up orbit vector must be used and it must be accurate.

7.7 Snapshot Restriction

7.7.1 Rule: Only one type of snapshot data, GSS or ST or SQUID or memory dump can be scheduled at a time.

7.7.2 Rationale: Only one type of snapshot data or memory dump can be inserted into the telemetry stream at a time. Scheduling multiple, concurrent snapshots wield only yield data from the last snapshot scheduled.

7.8 GPS Almanac Loads

7.8.1 Rule: The operations team shall load the current GPS Almanac into the CCCA every 2 weeks.

7.8.2 Rationale: Safemode Recovery or loss of lock on the GPS receiver will require a current version of the GPS Almanac in the CCCA.

7.9 Heat Pulse Meter Operation

7.9.1 Rule: Operating the heat pulse meter should be done only at the direction of a Dewar RE and the activity must be monitored in real-time.

7.9.2 Rationale: The heat pulse meter is run to test the remaining amount of cryogen within the Dewar which is needed in order to estimate when the mission will transition to the post science calibration phase. However, operating the heat pulse meter boils off helium which shortens the total mission life, thus the operation should only be ordered and monitored by the Dewar RE.

7.10 SSR Playback Restriction

7.10.1 Rule: SSR Playbacks should not be scheduled during critical data collection periods.

7.10.2 Rationale: SSR playbacks cause 3 losses of data, each up to 30 seconds in duration. These losses of data occur due to transponder and IU configuration changes. Critical data collection periods such as Database Readouts, Snapshots, Memory Readouts, and critical sequences may lose potentially irreplaceable data.

8 SAFEMODES

8.1 Safemode Protection

8.1.1 Rule: Except during special timeline activities, the vehicle shall be considered safe for 72 hours after any single point failure without any ground interaction.

8.1.2 Rationale: This flight rule defines the outer limit on how quickly the recovery process should begin after any anomaly as well how quickly the MOC must recover telemetry. Knowing the vehicle is safe for 3 days bounds the "rush to recovery" Those timeline activities that can put the vehicle at greater risk then safemodes can cover will have contingencies.

8.2 Operations While Safemode Protections Are Not Enabled.

8.2.1 Rule: If any Safemode protection is disabled after a system becomes operational and is verified, the operations team will schedule as near full real-time contact coverage as is possible.

8.2.2 Rationale: If the vehicle cannot protect itself from possible damage with the use of safemodes, the operations team must serve as the damage mitigation function until safemode protections can be restored.

9 MISSION PLANNING

9.1 Timeline Change Approval

9.1.1 Rule: All changes to the baseline timeline shall be approved by the timeline committee or the Mission Director.

9.1.2 Rationale: Unreviewed changes may cause unintended vehicle configurations, CARD violations, loss of proper data collection, or delays to the mission timeline.

9.2 SPC Load Approval

9.2.1 Rule: Entire SPC loads (ping/pong) need to be approved at the daily planning meeting by the appropriate Responsible Engineers (REs), the MD, and an operations representative.

9.2.2 Rationale: Prior testing of SPC templates will not catch issues associated with the timing and spacing of a series of templates. Also, final CARD reviews, data collection periods, real-time loading constraints, data formats, snapshots, and timeline objectives must be reviewed prior to sending any load.

9.3 Orbit Determination Products

9.3.1 Rule: The Orbit Analysts will deliver an orbit vector to the Mission Planning Team once a day though IOC and then once every 3-5 days thereafter.

9.3.2 Rationale: The Mission Planning Team needs accurate orbit information to correctly schedule contacts and the mission timeline.

10 DATA PROCESSING

10.1 SSR Data Availability

10.1.1 Rule: SSR dump data will be available for analysis within 3 hours of the playback pass.

10.1.2 Rationale: Operations depends on the timely processing of recorded data for timeline verification and vehicle health.

10.2 FrameX Data Availability

10.2.1 Rule: 2k and 1k FrameX data will be processed and available for analysis within 30 minutes of the Loss of Signal of the SN contact.

10.2.2 Rationale: Operations depends on the timely processing of real-time data for timeline verification as well as insight to vehicle health and the possible need for rapid contingency response.

10.3 Data Gaps

10.3.1 Rule: Data processing will deliver a report to the MOC detailing any gaps in telemetry immediately after processing each SSR data file.

10.3.2 Rationale: Realtime operations needs time to schedule additional GN SSR playback contacts prior to the data being overwritten on board the vehicle.

11 ORBIT DETERMINATION

11.1 Ephemeris Loads

11.1.1 Rule: The ephemeris data base on board the vehicle shall be updated every 2 days prior to launch, as needed during orbit trim, and every 3 to 7 days thereafter.

11.1.2 Rationale: If the GPS system fails the on-board propagated ephemeris will be used. To preserve science this ephemeris load must be accurate to within 100m and 1m/s. This loading frequency will ensure an accurate on board vector.

11.2 Leap Seconds

11.2.1 Rule: Leap second changes must be accounted for in the vehicle ephemeris loads.

11.2.2 Rationale: Inaccuracies in the vehicle ephemeris associated with an incorrect TAI-UTC generates an unacceptably large position error for science.

12 SCIENCE

12.1 Completion of Mission Phases

12.1.1 Rule: The science team will formally determine when the vehicle has completed the IOC phase and the science mission phase.

12.1.2 Rationale: There is a significant reduction in MOC staffing, mission planning, and scheduling associated with the end of IOC, and vehicle readiness for the science mission phase can only be determined by the science team. By performing periodic Dewar life calculations, the science team will also signal when to begin activities associated with post-science calibrations.

12.2 Vehicle Time Correlation

12.2.1 Rule: The vehicle clock will be synchronized to the ground clock just before launch. The vehicle clock will not be updated on orbit except in the case of an anomaly.

12.2.2 Rationale: Vehicle time (TAI time) will drift according to the accuracy of the on-board SRE reference oscillator. Timing drifts will be corrected post-mission by the science team.

13 CONTINGENCY OPERATIONS

13.1 Use of Contingency Procedures

13.1.1 Rule: The use of contingency procedures requires approval from the Mission Director. The only exceptions to this rule are the procedures used to re-establish command and telemetry with the vehicle, SSR management to ensure minimal data loss in the event of a GN problem, and all procedures that recover ground systems, which can be approved by the Flight Director.

13.1.2 Rationale: The risk associated with rushing a contingency sequence can be mitigated by insisting on approval from a non-MOC team member. Rapidly recovering the command and telemetry links poses little risk to the vehicle and outweighs the risk of not having visibility into vehicle health.

14 FLIGHT RULE WAIVER REQUEST FORM

Should the need arise that requires a flight rule to be waived, a Flight Rule Waiver Request Form shall be filled out by the requesting party and approved and signed by the Mission Director, Program Manager, or Principle Investigator. (See the next page for the form.)

Flight Rule Waiver Request Form

Waiver No. _____

Requestor: _____ Date:_____

Flight Rule Number: _____
Flight Rule Title: _____

Request:

When this should occur (date and sequence ID):

Justification for request:

Procedures/command templates affected:

CARD verification or change:

Approval:

_____
Mission Director