STANFORD UNIVERSITY
W.W. HANSEN EXPERIMENTAL PHYSICS LABORATORY
GRAVITY PROBE B, RELATIVITY GYROSCOPE EXPERIMENT
STANFORD, CALIFORNIA 94305-4085

(PTP) LT CHECKOUT OF GYROSCOPES IN PROBE C

GP-B SCIENCE MISSION PROCEDURE P0632 Rev B

24 July, 2001

PREPARED ________________________________ __________
R. Brumley, Gyroscope RE Date

APPROVED ________________________________ __________
B. Clarke, Gyroscope Verification Date

APPROVED ________________________________ __________
D. Ross, Quality Assurance and Safety Date

APPROVED ________________________________ __________
B Muhlfelder, Hardware Test Leader Date

REVISION HISTORY

Rev	Date	Comments
-	11/11/99	
A	10/23/00	Change title from 'Pre-Spinup Checkout of Gyroscopes in Probe C' to 'LT Checkout of Gyroscopes in Probe C' Change procedure to incorporate minor redlines from the previous run. Main structure of the procedure has not been changed. Include guidelines for handling the contingency where a gyroscope delevitates during the completion of this procedure. Update to reflect the new Gyro #4 (FQH58 + 95FH03)
B	07/24/01	Update Section 3.7 to include guidelines for the contingency where a gyroscope charges during the completion of this procedure.

1. SCOPE

This procedure is to be used to checkout certain aspects of gyroscope operation, namely:

- Levitation
- Freedom of Motion
- Gyroscope spindown rate in housing center
- Gyroscope spindown rate in spinup position
- Delevitation

It is assumed that the gyroscope under test is in an orientation consistent with three-axis levitation. Note that this procedure does not fundamentally verify any science mission requirements, but is intended as a double check on the health of the gyroscopes.

2. REFERENCES

2.1 Plans and Procedures

P0481	Levitation of Gyroscopes in Probe C
P0505	RT Spinup of Gyroscopes in Probe C
P0516	Low temperature spinup of gyroscopes in Probe C

3. GENERAL REQUIREMENTS

3.1 Environmental Requirements

3.1.1 Cleanliness

This procedure takes place in the FISTOPS cleanroom in the HEPL building. All activities taking place within this room must be in accordance with the guidelines established by the FISTOPS lab manager, Mike Taber.

3.1.2 Particulate Contamination

All connectors shall be inspected and verified free of particulate contamination before they are mated to Probe C. It is also desirable to keep the probe in general clean and free of particulate contamination.

3.1.3 Magnetic Contamination

This procedure takes place after the vacuum can is sealed and the probe has been inserted into the SM dewar, making the experiment much less sensitive to magnetic contamination. However, great care shall still be taken to avoid cross contamination between any magnetic (e.g. steel) item and the probe.

3.2 Test Personnel

3.2.1 Test Director

The test director for this procedure shall be Robert Brumley, or his appointed replacement.

3.2.2 Personnel

The following personnel have received extensive training in the testing of GP-B gyroscopes and are qualified to perform this procedure.

- David Hipkins
- Bruce Clarke
- Chris Gray
- Robert Brumley
- Dr. Sasha Buchman

See section 3.4 for details on the requirements for Quality Assurance notification and witnessing of this procedure.

3.2.3 Minimum Personnel

No activity shall be performed on the science mission probe without at least two people in the room, i.e. at least one person to perform the procedure and one person to observe the procedure.

3.3 Safety

3.3.1 Hardware Safety -- General

It is important to be cognizant at all times of the probe and the dewar. Be extremely careful not to accidentally bump into the probe. If any connector does not connect smoothly and securely, do not try to force it. Instead, remove the connector and inspect it to find the reason for the difficulty. Great care must be taken during at all times during the performance of this procedure.

3.3.2 Electrostatic Discharge

Grounded wrist straps shall be worn at all times when mating or demating to an electrical connector on Probe C.

3.3.3 Personnel Safety

All operations shall take place according to Stanford University safety guidelines. Any person observing a situation which they deem unsafe shall report the fact immediately to the test director. The Quality Assurance representative shall be responsible for monitoring that all activities are performed in a safe manner.

3.4 Quality Assurance

- Stanford QA must be notified at least one hour before beginning this procedure.
- ONR QA must be notified at least one hour before beginning this procedure.
- D. Ross (or her designate) must be present to monitor the completion of this procedure.

This procedure shall be conducted on a formal basis to its latest approved and released version. The QA Program Engineer shall be notified of the start of this procedure. A Quality Assurance representative designated by D. Ross shall review any discrepancy noted during test. Redlines shall be approved by the QA representative. The QA representative will nominally be Russ Leese. Upon completion of this procedure, the QA Program Engineer, D. Ross or R. Leese, shall certify his or her concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating the appropriate approval line at the end of the procedure.

3.5 Red-Line Authority

Authority to red-line (make minor chances during execution) this procedure is given to the qualified personnel listed in section 3.2.2. All redlines must be approved by the QA representative. In addition, approval by the Hardware Manager shall be required if, in the judgement of the test director or the QA representative, experiment functionality may be affected.

3.6 Electrical Connections

When mating to any flight connector, the following items are required:

- A grounded ESD strap must be worn by any person handling a connector on Probe C

- Inspect both connectors being mated to ensure that there are no particles that might interfere with the mate.

- Each mate and demate of flight connectors must be logged in that connector's mate/demate log sheet. Note that these log sheets have already been started for all suspension lines.

3.7 Gyroscope Testing in 1 g

Testing gyroscopes in a one-g environment requires very large voltages (on the order of 1000 V to achieve levitation, and approximately 620 V to maintain levitation in the center of the housing). These high voltages introduce the potential for additional complications when conducting a ground-based gyroscope test which are not issues for on-orbit gyroscope operation. Specifically, there is the potential for charging and gyroscope delevitation. These contingencies are discussed in more detail below.

Note that suspension voltages are much lower on orbit, so that the concerns about gyro delevitation and charging due to high voltage on the electrodes are not a concern.

3.7.1 Gyroscope Charging

Gyroscope charging on the ground is dominated by field emission due to the high one-g voltages. Gyroscope charging may be indicated when there is a mismatch in the control efforts such that the X and Y axes move in one direction (e.g. get larger), and the Z axis moves in the other (e.g. gets smaller). This is because the lifting electrode on the Z axis has a different sign than on the X and Y axes.

As noted above, the mechanism for gyroscope charging which exists in one g does not exist on orbit, and therefore gyroscope charge is not cause for concern in evaluating on-orbit gyroscope performance. However, gyroscope charge above a certain level (approximately 20 V) will start to reduce the stability of the gyroscope suspension. In the event that the gyroscope begins to charge at any time during the test then, at the discretion of the suspension system operator, the gyroscope may be delevitated. An attempt at re-levitation may only be started with the concurrence of QA and the Gyroscope RE. Gyroscope charging alone is not sufficient reason for the gyroscope to fail the performance checkout. However, in the event that significant gyroscope charging is observed, a report shall be generated to record the details of the gyroscope performance. As always, a Discrepancy Report may be opened if, at the discretion of Quality Assurance, it is warranted given the specifics of the situation.

3.7.2 Gyroscope Delevitation

If a gyroscope delevitates during the completion of this procedure, all work shall cease and the configuration shall not be broken. Work may only continue under the guidance of the MRB. A Discrepancy Report shall be immediately opened recording the details of what happened. The immediate concern of the investigation should be to determine whether the GSE was at fault in the delevitation, and it should usually be re-tested on non-flight gyroscopes prior to attempting levitation on a flight gyroscope. The exceptions to this are cases where it is abundantly clear that the delevitation was due to gyroscope charging.

The delevitation of a gyroscope does not necessarily mean that the gyroscope fails the room temperature test. The voltages necessary for ground levitation cause an extreme over-test, and it is expected that arcs due to field emission may occur from time to time. However, if a gyroscope does delevitate it will be necessary to conduct a certain amount of penalty testing. The exact nature of this penalty testing will depend on the details of the gyroscope delevitation, and therefore can not be indicated here (it will be under the control of the MRB). However, the following shall be used as a guideline for a standard set of penalty testing:

- Relevitation according to P0481
- Exploration of the housing according to P0178 (exact ranges may vary according the judgement of the MRB).
- New spindown test of the gyroscope according to P0178 (exact positions used and time spans used are at the discretion of the MRB).

Finally, note that gyroscope delevitation during the performance of P0481 (Gyroscope Levitation) is not necessarily a discrepancy. This is the procedure where the gyroscope undergoes initial levitation and the suspension system is tuned to the gyroscope. If, while the parameters are still be adjusted, the gyroscope delevitates then it is likely the cause was improper suspension parameters. The operator is allowed to attempt relevitation with different parameters in order to achieve a stable levitation. Formally, this point is reached at the time the levitation section of P0481 is signed off. However, based on the specifics of the situation, QA still has the option for opening a Discrepancy Report if they feel it is justified.

4. REQUIRED EQUIPMENT

4.1 Flight Hardware

- Probe C assembly with vacuum can installed, no sunshade.

4.2 Ground Support Equipment

The following equipment is necessary to perform these tests.

Item	**Quantity**
DDC Digital Suspension System Rev B	2
230 pF MHV - MHV Suspension Cables	14
MVH to Reynolds Interface Units	14
386I Workstations with FFT programs	2
Optical Readout System	4
Probe C to Optical Readout System Interface Cable	4

4.3 Software

Item	**Revision**
DDC Software	1.07
FFT Spin speed monitoring program	1.41

4.4 Tools and Miscellaneous

Fluke meters and capacitance meters shall be readily available should the need to trouble shoot arise.

5. GUIDELINES FOR OPERATIONS

- Testing shall proceed according to the room-temperature testing travel sheet.
- Gyroscopes 3 and 4 may be tested in parallel
- Gyroscopes 1 and 2 may be tested in parallel
- It is preferred, but not required, that Gyroscopes 3 and 4 be tested *prior* to the beginning of the testing of Gyroscopes 1 and 2.

6. OPERATIONS

6.1 Pre-Testing Checklist

6.1.1 Enter the following data:

Start Date: ____________________

Start Time: ____________________

Gyroscope #: __________________ ___________

6.1.1 Verify that the pumping system is on and pumping on the probe. ___________

6.1.2 Verify that probe pressure is less than 1×10^{-5} torr ___________

6.1.3 Verify that the DDC is already connected to the probe. If not, then connect it per P0481, Section 6 ___________

6.1.4 Verify that all necessary optical cables are connected to the probe. ___________

6.1.5 If it is desired to perform a spinup prior to delevitating, open the spinup valve as outlined in P0516 section L2 (optional). ___________

6.1.6 If it is desired to cycle the VAT valve on the probe after levitation, verify that the VAT controllers are connected. ___________

6.1.7 If it is desired to take any SQUID readings after levitation, make sure the cable to the SQUID is connected. ___________

6.1.8 Make sure all the desired instrumentation cables (e.g. heater, pressure) are connected. ___________

6.1.9 Complete a final inspection of the probe and surrounding area as a final confirmation to make sure all is as desired. ___________

6.2 Initial Gyroscope Levitation

Verify that the gyroscope has been levitated with the DDC per P0481, Section 7. Note that this section includes a calibration of the rotor's position. ___________

6.3 Rotor Freedom of Motion

This step verifies that the rotor has proper freedom of motion in the cavity. In most cases, the freedom of motion will be verified to the same level that it was verified in room temperature commissioning of the gyroscope. Some gyroscopes were commissioned early enough that we did not have a good method for calibrating the DDC *in situ*. For these gyroscopes, a slightly different commanded position is required. The following values are recommended for the freedom of motion verification.

Gyroscope #1 (FQH61 + 96FH17)

Single-Axis Displacement: 400 µinches

Three-Axis Displacement: 350 µinches

Gyroscope #2 (FQH46 + 96FH06)

Single-Axis Displacement: 400 µinches

Three-Axis Displacement: 350 µinches

Gyroscope #3 (FQH44 + 96FH09)

Single-Axis Displacement: 400 µinches

Three-Axis Displacement: 350 µinches

Gyroscope #4 (FQH58 + 95FH03)

Single-Axis Displacement: 400 µinches

Three-Axis Displacement: 350 µinches

Note: The ITD may, at his discretion, redline these values should experimental needs dictate a change.

6.3.1 Make sure the rotor is in the center position and take a DDC snapshot. Record the filename, mean voltages, and control efforts in the table below. ____________

Filename: ____

	X	Y	Z
V1:	___________	___________	___________
V2:	___________	___________	___________

CE: __________ __________ __________

Net CE: __________

6.3.2 Using the Single-Axis Displacement values listed above, command the rotor to the following positions. If the gyroscope does not delevitate, then put a check mark in the appropriate box.

+X Single Axis: __________ -X Single Axis: __________

+Y Single Axis: __________ -Y Single Axis: __________

+Z Single Axis: __________ -Z Single Axis: __________

+

6.3.3 Command the rotor position so that all axes are at the positive Three-Axis displacement listed above. Take a DDC snapshot. Record the mean voltages, control effort, and filename below.

Filename:____________________________________

	X	Y	Z
V1:	__________	__________	__________
V2:	__________	__________	__________
CE:	__________	__________	__________

Net CE: __________

6.3.4 Command the rotor position so that all axes are at the negative Three-Axis displacement listed above. Take a DDC snapshot. Record the mean voltages, control effort, and filename below.

Filename:____________________________________

	X	Y	Z
V1:	__________	__________	__________
V2:	__________	__________	__________

CE: __________ __________ __________

Net CE: __________

6.3.5 Return the rotor to the center. Take a DDC snapshot. Record the mean voltages, control effort, and filename below.

Filename: ____________________________________

	X	Y	Z
V1:	__________	__________	__________
V2:	__________	__________	__________
CE:	__________	__________	__________

Net CE: __________

6.3.6 Confirm that the CE values do not differ by more than 15% from those recorded in Section 6.3.1.

If the values do differ by more than 15%, then record the event in a D-Log entry and notify Robert Brumley or the Hardware Manager. Delevitate the rotor using P0481 Section 9, then relevitate with P0481 Section 8. The procedure may be continued at that time. ___________

6.3.7 Cycle the leakage gas VAT valve on the probe while observing the position trace on the DDC. Verify the rotor does not move too much while this valve is cycled. Less than 100 mV out of the bridge is acceptable. (optional) ___________

6.3.8 Cycle the exhaust gas VAT valve on the probe while observing the position trace on the DDC. Verify the rotor does not move too much while this valve is cycled. Less than 100 mV out of the bridge is acceptable. (optional) ___________

6.4 Rotor Spindown in the Center of the Cavity

6.4.1 Verify that optical readout systems are on and connected to Probe C. If possible, connect one optical readout system to each fiber optic connections for each gyroscope (i.e. 2 per gyro). ___________

6.4.2 Verify the DC offset on the optical readout systems is less than 0.1 V. If necessary adjust using the screw labeled "DC Bias" on the optical readout system. ___________

6.4.3 It is optional to use bandpass filters to improve the quality of the optical readout system. If using the bandpass filters, verify the settings at this point. The low-frequency cutoff should be between 0 and 0.1 Hz, and the high-frequency cutoff should be from 50 - 200 Hz. ___________

6.4.4 Start the FFT spin frequency-monitoring program (version 1.41). Data should be recorded at least every 5 minutes. ___________

6.4.5 Using a function generator, input a signal into the "Electrical In" BNC on the optical readout system. Verify that a signal at that frequency appears in the FFT window. ___________

6.4.6 Spin the gyroscope to approximately 0.3 Hz using P0516. Monitor the rotor spindown in the center position for at least 4 hours. Record the average spindown rate below, and attach a copy of the spindown with this procedure.

Experiment Start Date and Time: ___________________________

Experiment Stop Date and Time: ___________________________

Gyroscope Spindown Rate: _________________________ mHz/Hr ___________

6.5 Rotor Spindown Offcenter

6.5.1 Make sure the rotor spin frequency is greater than 0.2 Hz. If necessary, spin the rotor to approximately 0.3 Hz using P0516. ___________

6.5.2 Move the gyroscope off-center to the position indicated below. ___________

Gyroscope #1 (FQH61 + 96FH17)

[X Y Z] = [-225 –225 -225] µinches

Gyroscope #2 (FQH46 + 96FH06)

[X Y Z] = [-200 –200 -200] µinches

Gyroscope #3 (FQH44 + 96FH09)

[X Y Z] = [-250 –250 -250] µinches

Gyroscope #4 (FQH58 + 95FH03)

[X Y Z] = [-275 -275 -275] µinches

Note: The ITD may, at his discretion, redline these values should experimental needs dictate (e.g. due to vibration).

6.5.3 Take a DDC snapshot. Record the mean voltages, control effort, and filename below.

Filename: ____

	X	Y	Z
V1:	__________	__________	__________
V2:	__________	__________	__________
CE:	__________	__________	__________
Net CE:	__________		

6.5.4 Monitor the rotor spindown in the off-center position for at least 4 hours. Record the average spindown rate below, and attach a copy of the spindown with this procedure.

Experiment Start Date and Time: ____________________________

Experiment Stop Date and Time: ____________________________

Gyroscope Spindown Rate: __________________________ mHz/Hr

6.5.5 Return the rotor to the center of the housing. ___________

6.5.6 Take a DDC Snapshot. Record the mean control efforts and voltages in the table below.

Filename:____

	X	Y	Z
V1:	__________	__________	__________
V2:	__________	__________	__________
CE:	__________	__________	__________

Net CE: __________

6.6 Final Status

6.6.1 At the conclusion of this procedure, the gyroscope is still levitated and spinning. Either additional testing may be done, or the gyroscope may be delevitated as appropriate per the travel sheet and authorized procedure. ___________

7. PROCEDURE COMPLETION

Record completion of this procedure in the traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, open a Discrepancy Report to document the event.

This test has been completed according to the procedure contained herein. All redlines used have been integrated into this document.

Test Director: (print)	(sign)
(optional) **Test Engineer:** (print)	(sign)
(optional) **Test Engineer:** (print)	(sign)
QA Representative: (print)	(sign)