

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



LEVITATION OF GYROSCOPE IN GYRO ACCEPTANCE PROBE (GAF)

GP-B SCIENCE MISSION PROCEDURE

P0933 Rev -

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PREPARED

C. Gray, GMA RE

Date

APPROVED

B. Clarke, Gyro Test RE

Date

APPROVED

D. Ross, Quality Assurance

Date

APPROVED

Robert Brumley, Payload Tech. Manager

Date

1. SCOPE

This procedure is to be used every time a gyroscope is levitated in GAF. The first time a gyroscope is levitated in the probe with a given suspension system, there are certain steps which must be taken to ensure that the DDC is calibrated correctly, mechanical vibration is acceptable, etc. These sections are so noted in the procedure. Also, delevitation may happen long after the initial levitation. Finally, the suspension cables need to be connected and disconnected. Therefore this procedure has five major parts: (1) Initial Connection, (2) Levitation, (3) Initial Suspension Checkout, (4) Delevitation, and (5) Disconnection of Suspension System. Which portion of the procedure is to be done must be specified in the parent procedure that calls this document, or in a traveler. All sections were included in this single document so that the operator could gain a coherent understanding of the entire suspension process. Note that it is possible that only one section of operations may be performed at a given time. Therefore each operation section begins with an instruction to review the beginning non-operations part of the procedure. This is to ensure that the person performing the procedure is conscious of all hardware safety concerns, quality assurance requirements, etc.

The following table indicates which section covers the various operations related to DDC operation. This table is included for informational purposes only.

Name	Section #
Initial DDC Connection	6
Initial Levitation and Calibration	7
Levitation (after Initial)	8
Delevitation	9
DDC Disconnection	10

2. REFERENCES

2.1 Plans and Procedures

PO147 GPB Contamination and Control Plan

3. GENERAL REQUIREMENTS

3.1. Environmental Requirements

3.1.1 Cleanliness

This procedure may take place in the FIST-OPS cleanroom in the HEPL building. Note that all electrical connectors should be kept clean and free from any contamination that might interfere with the electrical contact.

3.1.2 Particulate Contamination

All parts and tools shall be cleaned at least to the cleanliness levels of the rooms where they are used for assembly or testing. All connectors must be inspected for particulate contamination that could potentially damage the part or interfere with a proper mating of the two connectors.

3.1.3 Magnetic Contamination

Not applicable

3.2 Integration and Test Personnel

3.2.1 Test Director

The test director for this procedure is Bruce Clarke, or his appointed replacement.

3.2.2 Personnel

The following personnel are qualified to perform this procedure:

- David Hipkins
- Bruce Clarke
- Chris Gray
- Ken Bower
- Robert Brumley
- Dr. William Bencze
- Dr. Sasha Buchman

See section 3.4 for details as to when Quality Assurance personnel are required to be notified and/or witness this procedure.

3.3 Safety

3.3.1 General

All participating personnel shall ensure they are aware of the specific and hardware safety concerns indicated in the safety requirements, cautions, and warnings in the procedure.

3.3.3 Hardware Safety

The high voltage switch on the DDC should never be thrown from off to on when the DDC is connected to the probe to avoid possible damage to the SQUIDs and gyro.

3.4 Quality Assurances

- *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.*
- *Russ Leese (or his 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 assembly or 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 Russ Leese, will certify her or his concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating his approval line at the end of the procedure.

3.5 Red-line Authority

Authority to red-line (make minor changes 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 Technical Manager shall be required if, in the judgement of the test director or QA Representative, experiment functionality may be affected. For procedures in the cleanroom, "redlines" shall be accomplished using red bold italics and "signatures" in black bold italics.

3.6 Electrical Connections

The DDC must always be connected or disconnected from the probe with the high voltage switch on. It is never permissible to throw the high voltage switch while the DDC is connected to the gyroscope.

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

- An grounded ESD strap must be worn by any person handling a connector on the probe.
- Inspect both connectors being mated to ensure that there are no particles that might interfere with the mate.

3.7 Gyroscope Delevitation

The delevitation of a gyroscope does not necessarily mean that the gyroscope fails the test altogether. 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 in accordance with this procedure
- Exploration of the housing (exact ranges may vary according the judgement of the MRB).
- New spindown test of the gyroscope (exact positions used and time spans used are at the discretion of the MRB).

4. REQUIRED EQUIPMENT

4.1 Hardware

Gyro Acceptance Probe. Vacuum can is on, and vacuum system is pumping on the probe. Acceptance probe is at $\sim 4^\circ$ K

4.2 Ground Support Equipment

The following equipment is necessary to perform these tests:

Item	Quantity
DDC Digital Suspension System Rev B or Rev C	1
GAF MHV-MHV Suspension Cables	6
386i Workstations with FFT Program	1
Oscilloscope (no calibration required)	1

4.3 Tools and Miscellaneous

Fluke meters, capacitance meters

OPERATIONS

5.0 DDC Prelevitation Qualification

5.1 Gyro-Cart Checkout

Any DDC used to levitate gyroscopes in the Gyro Acceptance Probe must have been used to levitate a gyroscope in a gyro cart for at least 6 hours prior to being connected to Gyro Acceptance Probe. This checkout is intended to be rough and qualitative, but *must have been concluded with an 'Operator Shut Down (OSD)' within 3 weeks of the initial levitation attempt of the gyroscope.* It is preferable that this checkout be done in the same room as Gyro Acceptance Probe, so that no significant moving of the DDC needs to be done between this checkout and levitation of the gyroscope in the Gyro Acceptance Probe.

Levitation of a gyroscope in the Gyro Acceptance Probe concluding with an OSD within the past 3 weeks may also be used to satisfy this requirement.

Confirm Requirements of Sect. 5.1 have been met: _____ (please 4)

Notes: _____

6.0 Initial DDC Connection

Note: Please review sections 1-5 before completing this section. They contain information and warnings vital to the successful completion of this procedure.

Note: Do NOT complete this section if the DDC is already connected to the probe. If a traveler or other document asks for the connection, but visual inspection shows the DDC is already properly connected, then steps 6.1.5 and 6.1.6 should be skipped.

6.1 Initial Setup

Start Date: _____

Start Time: _____

Item	Data
Gyroscope Position	
DDC Serial Number	
DDC Code Revision	
Vertical Probe Axis	
DDC Control Gain	
DDC Sensor Bias [X Y Z]	
DDC Sensor Gain [X Y Z]	
Sample Rate (3501 Hz)	
Electrode Configuration (e.g. PPM)	

6.1.1 Make sure the probe pressure is less than 5×10^{-5} torr and that the pumping system has been pumping on the probe for at least 12 hours. Record the pressure below:

Vacuum Can Pressure (torr): _____

6.1.2 Make sure that the DDC has at least 300 Megabytes of free disk space. If necessary, backup old files and delete. _____

6.1.3 If using optional suspension system adapter boxes, connect these to the science mission probe now. Use of these is not required for suspension, but can improve SQUID performance. _____

6.1.4 Make sure DDC DSP is reset, position values are being updated in the software, and that the DDC is **NOT** in high voltage calibration mode. _____

6.1.5 Make sure the DDC cables are **NOT** connected to the probe. Turn on DDC High Voltage Switch. If DDC is already connected, skip this step. _____

6.1.6 Connect DDC Cables to MHV connections on connector adapter box. Connections are color coded (i.e. connect red to red, purple to purple, etc.) If DDC is already connected, skip this step. _____

6.1.7 Record Indicated Rotor Position (μ in) _____

X Position:

Y Position:

Z Position:

6.1.8 Swap DDC cables on each axis at the back of the DDC.

X1 → X2 Y1 → Y2 Z1 → Z2
X2 → X1 Y2 → Y1 Z2 → Z1

6.1.9 Record Indicated Rotor Position (μin)

X Position:

Y Position:

Z Position:

6.1.10 Calculated Desired Rotor Position R_D according to these rules:

- The absolute value of R_D is the average of the absolute values of the numbers recorded in 6.1.7 and 6.1.9
- The sign of R_D is the sign of the positions in 6.1.7

R_D (X):

R_D (Y):

R_D (Z):

6.1.11 Adjust the sensor bias until the indicated rotor position is equal to the positions indicated above (6.1.8). New Sensor Gain:

Sensor Bias (X):

Sensor Bias (Y):

Sensor Bias (Z):

6.1.12 Return the DDC Cables to their original positions _____

6.1.13 Record the new indicated position: _____

X Position (μin):

Y Position (μin):

Z Position (μin):

6.1.14 The above positions should match (to within a minus sign) R_D to better than 20 μin . If not, record the event in a D-Log (no DR is necessary) and repeat 6.1.5 – 6.1.11. If swapping cables does not provide consistent results (e.g. if cables are swapped several times without changing any settings yet significantly different positions are indicated) then it is likely there is a problem in the hardware. At this point notify the ITD and hardware manager. Disconnect the DDC per section 10 and begin troubleshooting the DDC. _____

6.1.15 Verify that the gyro ground plane is grounded. _____

6.1.16 Connect the oscilloscope to the 3 outputs of the oscillator on the DDC. Verify that the waveforms are of roughly equal magnitude and sinusoidal in shape. There should be no apparent clipping or obvious distortion of the signal. _____

Completion Date: _____

Completion Time: _____

7.1.2 Once the gyroscope is levitated, record the initial control effort from the screen (g's): _____

CE(X): _____ CE(Y): _____ CE(Z): _____ Net: _____

7.1.3 Record the following DDC Parameters:

Sensor Gain [X Y Z]:

Sensor Bias [X Y Z]:

Control Gain:

Lift Timeout: Gyro Gap:

Shutdown Radius:

Electrode Configuration (PPM, MMP, etc):

7.1.4 Look at the lift snapshot, which is automatically saved by the DDC. Record the magnitude of any oscillation which is present:

Oscillation (μ in peak to 0): _____

7.1.5 If the oscillation is greater than 20 microinches, then, at the test director's discretion, it is appropriate to take steps to try and reduce the magnitude of the oscillation, including rotor delevitation and relevitation if necessary. Record the event in the D-Log (a DR is not necessary). Document carefully the steps taken to reduce the vibration and all levitations and delevitations, and attach to this procedure.
Notes:

7.1.6 Before proceeding, wait at least 10 minutes. If there is any evidence of _____

charging or some other abnormality, record in a D-Log or DR, as determined by the Test Director and the QA representative.

7.2 Calibration of DDC

7.2.1 Take a DDC Snapshot

Filename:

7.2.2 Record the following by taking the mean of Vx1 through Vz2 (individually) and ux through uz (individually) in the snapshot taken above:

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

7.2.3 Use the Matlab m-file gyropos.m to determine the position of the rotor (in μin) and record below:

	X	Y	Z
Pos:	_____	_____	_____

7.2.4 Now adjust the sensor bias and sensor gain until the calculated position is within 20 microinches of the commanded position the following positions:

- [X Y Z] = [0 0 0] microinches
- [X Y Z] = [+200 +200 +200] microinches
- [X Y Z] = [-200 -200 -200] microinches

Record the operations and DDC snapshots necessary to achieve this in the table on the following page:

7.2.5 Record the final sensor gains and biases below: _____

	X	Y	Z
Bias:	_____	_____	_____
Gain:	_____	_____	_____

7.2.6 Make sure the rotor is commanded to the center position, and take a final snapshot.

Filename: _____

7.2.7 Record the following data by taking the mean of V_{x1} - V_{z2} and $u_x - u_z$ as recorded in the above snapshot. The DDC position is now calibrated. _____

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

Completion Date: _____

Completion Time: _____

7.3 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then 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 (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

8. Levitation of Gyroscope (after first levitation)

Note: This section is intended to be used when the DDC has already been used to levitate the gyroscope in question so that the correct levitation parameters are known. If there has been any servicing of the DDC since the last levitation, then sections 6 and 7 should be completed.

Note: Please review sections 1-4 before completing this section. They contain information and warnings vital to the successful completion of this procedure.

8.1 Operations

Start Date: _____

Start Time: _____

8.1.1 Make sure the probe pressure is less than 5×10^{-5} torr. Record pressure below:

Pressure (torr): _____

8.1.2 *If the DDC cables are already connected to the probe, check to see if the High voltage switch is on. **DO NOT TURN HIGH VOLTAGE SWITCH ON YET.***

If the high voltage switch is already on, proceed to step 8.1.5.

If the high voltage switch is not on, disconnect all suspension cables from the probe at the MHV connector, turn on the high voltage switch, then reconnect the cables to the probe. Note the mate and demate in the appropriate log.

8.1.3 *If the DDC cables are not connected to the probe, turn on the high voltage, then connect the cables. Note that the appropriate connections are detailed in Table A.*

8.1.4 Using the same parameters used during the previous levitation, levitate the rotor by pressing the lift button in the DDC software.

8.1.5 Write down the control efforts indicated in the DDC software window.

X-axis CE (g's): _____

Y-axis CE (g's): _____

Z-axis CE (g's): _____

Net CE (g's): _____

8.1.6 If, in the judgement of the DDC operator, the control efforts show indication of charge > 50V, delevitate the rotor, abort the procedure, and record the incident in a Discrepancy Report.

8.1.7 Take a DDC snapshot.

Filename: _____

8.1.8 Wait at least 10 minutes. If there is, in the judgement of the DDC operator, no indication of significant charging after this time, it is OK to proceed to the next operation.

Completion Date: _____

Completion Time: _____

8.2 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then 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 (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

9. Gyroscope Delevitation

Note: Normally Section 9.1 should be completed to delevitate the rotor. However, on occasion the DDC computer may stop responding in some way (which is usually due to a bug in the Windows 95 operating system, not a bug in the DDC software itself). If this happens, the DSP is still running so the gyroscope will not crash. The delevitation procedure, however, is somewhat different. Therefore, if the DDC computer has stopped responding in some way, complete Section 9.2 instead of Section 9.1.

Note: Please review sections 1-4 before completing this section. They contain information and warning vital to the successful completion of this procedure.

9.1 Normal Delevitation

Start Date: _____

Start Time: _____

9.1.1 Delevitation of the rotor is not permitted at spin speeds greater than 0.5 Hz. If necessary, spin down the rotor to <0.5 Hz using the appropriate signed procedure.

Record Final Spin Speed: _____

9.1.2 Take a DDC snapshot.

Filename: _____

9.1.3 If the rotor is not in the center of the housing, command it to the center and take another DDC snapshot.

Filename (if taken): _____

9.1.4 Delevitate the rotor by pressing the delevitate button in the DDC software window. When it asks if you really want to delevitate the rotor, press "Yes".

9.1.5 Note that it is not permitted to turn the high voltage switch on while the cables are connected to the probe. To avoid the possibility of someone turning on the high voltage with the cables connected to the probe, the user is discouraged from turning *off* the high voltage while the DDC is connected to the probe unless there is a very strong reason for doing so. _____

If the high voltage is turned off, then label a piece of paper “DO NOT
TURN HIGH VOLTAGE ON UNLESS DISCONNECTED FROM
THE PROBE” and tape it over the high voltage switch. _____

Completion Date: _____

Completion Time: _____

9.2 CONTINGENCY: Delevitation when DDC Computer has Stopped Responding

For use only if the DDC computer has stopped responding in some way. If Section 9.1 has already been completed, skip this section and go to 9.3.

Start Date: _____

Start Time: _____

9.2.1 If the DDC computer has stopped responding, the DSP should still be running, so the gyroscope will still be levitated. Therefore this is not an emergency. Note the fact that the DDC software has stopped responding in the D-Log, however (a DR is not necessary). _____

9.2.2 Delevitation of the rotor is not permitted at > 0.3 Hz spin speed without the authorization of the Hardware Manager. If necessary, spin down the rotor to < 0.3 Hz using the appropriate signed procedure. _____

9.2.3 Turn off the high voltage switch. The rotor is now down. _____

9.2.4 Disconnect the DDC cables from the probe. This is done to help ensure that the high voltage switch will not be turned back on the cables attached to the probe. _____

Completion Date: _____

Completion Time: _____

9.3 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then 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 (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

10. Disconnect DDC

Note: Please review sections 1-4 before completing this section. They contain information and warning vital to the successful completion of this procedure.

10.1 Operations

Start Date: _____

Start Time: _____

10.1.1 The rotor should already be delevitated. If necessary, complete Section 9 before proceeding to delevitate. _____

10.1.2 Disconnect all DDC cables at the MHV connection closest to the Probe. _____

10.1.3 If necessary, disconnect the MHV to filter adapters from the Probe. _____

10.1.4 Archive all files used in the previous levitation attempts. If the DDC disk space is <300 MB, delete the old files. _____

Completion Date: _____

Completion Time: _____

10.2 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then 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 (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)