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

# REMOVE PROBE VACUUM CAN

## GP-B SCIENCE MISSION PROCEDURE

2 December, 1998

PREPARED ______________________ ______________
A. Nakashima, Systems — Date

APPROVED ______________________ ______________
D. Bardas, Integration Manager — Date

APPROVED ______________________ ______________
J. Stamets, Integration Engineer — Date

APPROVED ______________________ ______________
J. Janicki, Safety Engineering — Date

APPROVED ______________________ ______________
B. Taller, Quality Assurance — Date

APPROVED ________________________________ ____________________
S. Buchman, Hardware Manager Date

# TABLE OF CONTENTS

# 1 SCOPE

This procedure describes the method used for removing the Probe Vacuum Shell from the Science Mission Probe. It assumes that the Probe starts off mounted horizontally on the Precision Manipulator (PM), in accordance with P0205(SM). The following tasks are covered in this procedure:

- Rotation of the Probe to Vertical
- Installation of Alignment Frame on PM
- Precision Alignment of Probe with PM travel Axis
- Removal of the Probe Vacuum Shell
- Rotation of Probe back to Horizontal

## 1.1 Acronyms

The following acronyms are used in this document

| | |
|---|---|
| PM | Precision Manipulator |
| VC | Probe Vacuum Can |
| ITD | Integration and Test Director |

# 2 REFERENCES

| | |
|---|---|
| P0059 | GPB Contamination Control Plan |
| P0057 | Stanford Magnetic Control Plan |
| P0205(SM) | Mount Probe onto Precision Manipulator |
| P0419 | Operations Manual for the Precision Manipulator |

# 3 GENERAL REQUIREMENTS

## 3.1 Environmental Requirements

This procedure will be conducted in the Stanford Class 10 Cleanroom in the HEPL facility.

### 3.1.1 Cleanliness

The Class 10 clean room where this integration takes place shall be maintained at the cleanliness levels per GPB Contamination Control Plan P0059. Certified Class 10 cloth garments shall be worn in the Class 10 clean room.

### 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. In addition, all flight parts shall be maintained at level 100 cleanliness per GP-B Contamination Control Plan (P0059). Take all necessary precautions to keep tools and handling equipment free of particulate contamination.

**To the maximum extent possible, personnel shall keep their bodies and garments downstream of the SIA, relative to the HEPA wall.**

3.1.3 Magnetic Contamination

All parts and tools shall be cleaned using methods consistent with achieving Mil Spec Level 100 cleanliness. In addition, all parts shall be maintained at level 100 cleanliness per GP-B Magnetic Control Plan, P0057. Take all necessary precautions to keep tools and handling equipment free of particulate contamination. Tools to be sprayed with Freon from Pressure can (filtered to < 0.2 micron) prior to use, or when contaminated.

## 3.2 Integration and Test Personnel

3.2.1 Integration and Test Director

The Integration and Test Director (ITD) shall be Dr. Doron Bardas or an alternate that he shall designate. The ITD has overall responsibility for the implementation of this procedure and shall sign off the completed procedure and relevant sections within it.

3.2.2 Personnel

All engineers and technicians participating in this procedure shall work under the direction of the ITD who shall determine which personnel are qualified to participate in this procedure. Participants in this procedure are expected to be D. Bardas, J. Stamets, G. Asher, G. Reynolds among others.

## 3.3 Safety

**Safety Engineering to be notified prior to start of this procedure.**

3.3.1 General

Personnel working in the Class 10 Cleanroom must be cognizant of the base of the Precision Manipulator, and take special care to avoid tripping or bumping into it.

3.3.2 Maximum Number of People in Cleanroom

Under normal operating conditions, there shall be no more than 5 people in the Class 10 Cleanroom. This is to avoid violating legal make up air requirements, and to provide an efficient workspace. Exceptions must be for short periods only, and approved by the ITD.

## 3.4 Quality Assurance

Integration shall be conducted on a formal basis to approved and released procedures. The QA program office shall be notified of the start of this procedure. A Quality Assurance Representative designated by B. Taller shall review any discrepancy noted during this procedure, and approve its disposition. The presently designated QA Representative is A. Nakashima. Upon completion of this procedure, the QA Program Engineer, B. Taller or P. Unterreiner, will certify his concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating in the designated place(s) in this document. Discrepancies will be recorded in a D-log or as a DR per Quality Plan P0108

### 3.5 Red-line Authority

Authority to red-line (make minor changes during execution ) this procedure is given solely to the ITD or his designate and shall be approved by the QA Representative. Additionally, approval by the Hardware Manager shall be required, if in the judgment of the ITD or QA Representative, experiment functionality may be affected.

### 3.6 Procedure Computerization Special Requirements

Because of cleanliness requirements in the Class 10 room, and to conveniently record data directly into the procedure thus generating the "as-built" document, the procedure will be handled in a paperless fashion until completed. A Laptop computer containing an electronic version of this procedure will be operated by the ITD or QA Representative and data shall be recorded by typing directly into the electronic file.

Following completion of the procedure, a hard copy of the "as-built" procedure shall be printed ***and signed off by all the designated parties***. It shall then be filed including an electronic copy into the data base.

The electronic editing of this document shall be as follows:

- Data will be inserted into the document using normal font, i.e. non-bold, non-italic
- "Signatures" shall be designated by **BLACK CAPITAL BOLD LETTERS**.
- "Redlines" shall be in ***RED BOLD ITALICS*** to make them distinguishable both on the Laptop screen and on the hard copy printout.
- Digital pictures shall be inserted into the document where appropriate.

# 4 REQUIRED EQUIPMENT

Flight Hardware

| Hardware | Part Number | Quantity |
|---|---|---|
| Probe-C Assembly, Without Sunshade | 1C34115-102 Rev – | 1 |

Note: Probe has Windows 1 and 2 and their baffles installed by LMMS. Window 3 still needs to be installed but due to a problem with its connector wires, it will be installed at a later time when it becomes available the probe is again horizontal. This work-around does not affect probe integrity or future probe functionality.

Ground Support Equipment

*Note: Precision calibration certification of these equipment and Tools is optional and not required because this procedure does not produce data needed to verify SM requirements.*

Precision Manipulator (PM)

PM Alignment Frame

Probe Vacuum Shell Stand

Delrin Cup for Stand

Delrin Cover for Probe Vacuum Shell

Tools and Miscellaneous

Allen Wrench, various

Ratchet Wrench for Probe Tilt Yoke

Dial type torque wrench (To be provided by LMMS) Cal Date: ___________

Fluke 77 Multimeter, or equivalent

Starrett No.25-441, 1 mil resolution dial (2 per ring, 4 total) for measuring alignment

SPI Protracto Level Cal Date: **10/19/98**

## 5 ROTATION OF PROBE TO VERTICAL

Started ___________ at _________ Signed: ______________________________
date time ITD or QA Representative

a) Raise the probe on the Precision Manipulator such that the bottom of the tilt worm gear assembly of the probe STA200 yoke is approximately 6 inches higher than the brackets on the sides of the PM which are used to attach the alignment frame. Use Precision Manipulator in accordance with P0419.

b) Using the ratchet socket wrench on the Hex Nut on the Probe Yoke Ring Collar, tilt the Probe from horizontal to vertical taking care to raise the probe sufficiently to ensure that the Vacuum Can comfortably clears the floor.

c) While periodically holding the SPI Protracto inclinometer against North or South side of the Vacuum Can, set the probe vertical* in the plane parallel to the HEPA filter wall by adjusting the tilt of the Probe Yoke Ring Collar. This is readily accomplished within ± 0.1 degrees, the resolution of the inclinometer.

d) While periodically holding the SPI Protracto inclinometer against East or West side of the Vacuum Can, set the probe to vertical* in the plane perpendicular to the HEPA filter wall. This is done by adjusting the PM tilt plate by turning its acme thread bolt in the appropriate direction. Verticality can readily be accomplished within ± 0.1 degrees.

** Note that it is **not** essential that the probe be exactly vertical. This part of the procedure facilitates the attachment of the alignment frame and other procedures which follow and a precision aligning the probe's <u>longitudinal</u> axis with the <u>direction</u> of motion of the PM. This minimizes rubbing between the QBS and the Vacuum Can during disassembly.*

Completed ________ at _________ Signed: ______________________________
date time ITD or QA Representative

## 6 INSTALL AND CENTER ALIGNMENT FRAME

Started ___________ at _________ Signed: ______________________________
date time ITD or QA Representative

a) Raise the probe so that the bottom of the Vacuum Can is about 6" higher than the level of the top mounting slots, on each side of the PM, for the Alignment Frame.

b) Fully assemble the Alignment Frame, i.e. the two circular rings should be complete.

c) Ensure that the dial indicators are locked in their outboard position, and that the micrometers are also fully retracted. The protective Delrin tips should be in place.

d) Slide the arms of the Alignment Frame into the respective slots on each side of the PM. Level it with the SPI to $\pm 0.2^{\circ}$ and center it on the PM approximately. Secure it to the PM with four bolts and custom washers midway in the rear slot of each arm.

e) Lower the probe carefully through the two rings until the lowest part of the yoke tilt mechanism (the housing for the worm gear) is about 1" above the top of the frame. While lowering the Vacuum Can through the rings, ensure that the probe is approximately concentric with the two rings and that there is no interference with either the dial indicators or micrometers. If necessary, loosen the frame's bolts and adjust.

f) Finally, when the probe is at its specified lowest position, adjust the frame so that the rings are concentric to the longitudinal axis within 1/8" of the probe. When satisfied that the rings are level and concentric, lock the frame by tightening the bolts securely.

g) The finished assembly of Probe and Alignment Frame should look like Figure 1 below.

Completed ________ at _________ Signed: ______________________________
date time ITD or QA Representative

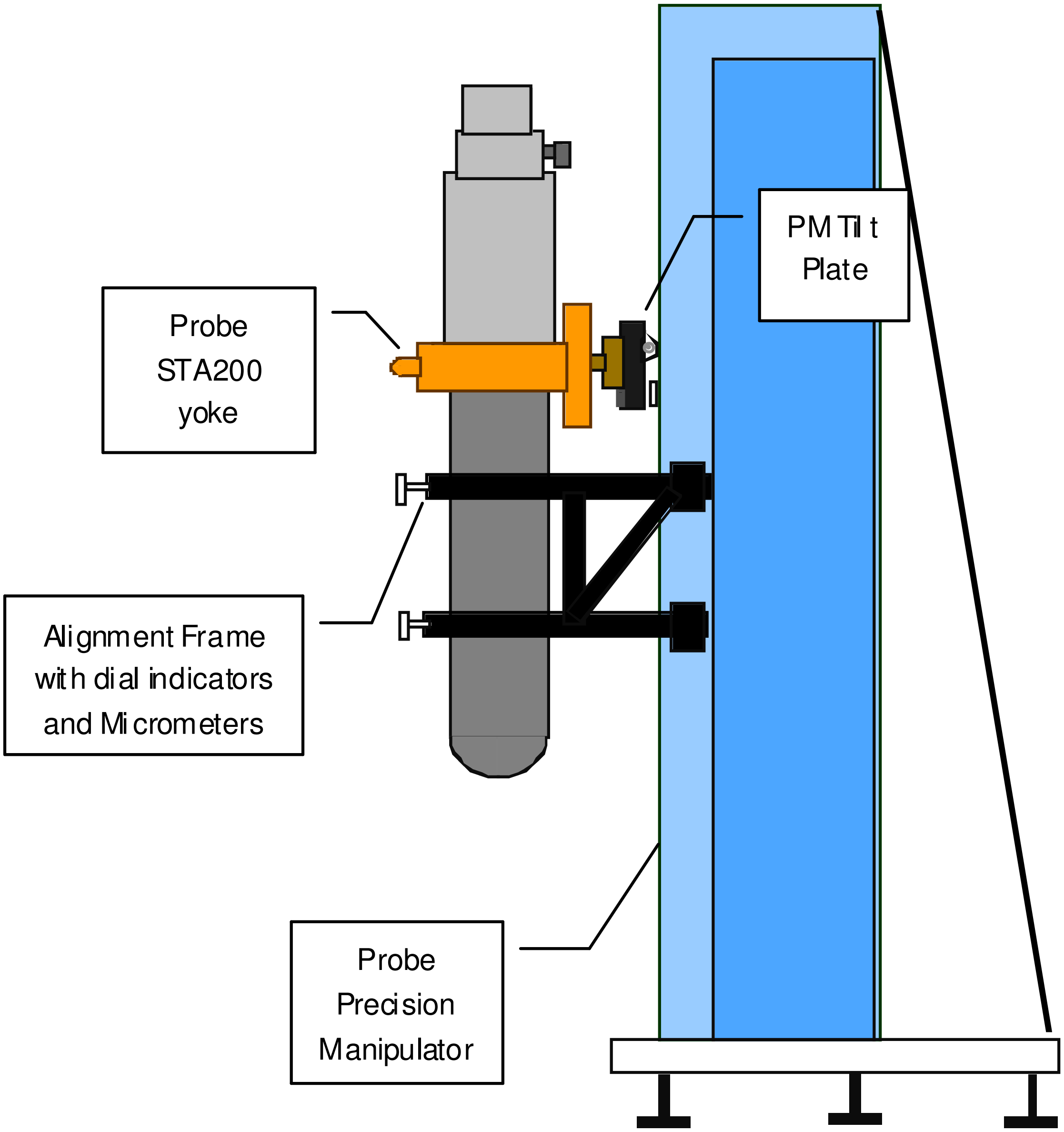


**Figure 1. Probe on Precision Manipulator with Alignment Frame**

## 7 ALIGN PROBE AXIS PARALLEL TO PM AXIS

Started ___________ at _________ Signed: _____________________________
date time ITD or QA Representative

a) Remove the constraints holding the stems of the two dial indicators on the top ring only and ease them radially inwards so that their Delrin tips touch the Vacuum Can.

*NOTE: One of the dials reads displacement of the Can due to tilt of the probe around the STA200 yoke axis, while the other dial indicator reads displacements due to tilt of the PM mounting plate.*

b) Turn the fiducial markers on each dial indicator's window to match the dial's fine scale. Record the actual complete reading of each dial indicator.

Probe DOWN:

Yoke tilt = $N_d$ mils PM plate tilt = $M_d$ mils

c) Raise the Probe until the contact points of the dial indicators are approximately 2" above the bottom of the cylindrical section of the Vacuum Can (i.e. 2" above the dome weld). Record the actual complete reading of each dial indicator.

Probe UP:

Yoke tilt = $N_u$ mils PM plate tilt = $M_u$ mils

d) As a result of the dimensions shown in Figure 2, a calculation based on nulling out both probe tilt angle misalignments, relative to the PM direction of travel, results in adjusting the tilt in each direction by (probe in UP position):

Yoke tilt adjustment: $= (N_d - N_u) \times (59/44) =$ mils

PM plate tilt: $= (M_d - M_u) \times (59/44) =$ mils

e) Turn the fiducial markers on each dial indicator's window to match the dial's fine scale. Record the actual complete reading of each dial indicator.

Probe UP:

Yoke tilt = $N_u$ mils PM plate tilt = $M_u$ mils

f) Lower the Probe until the contact points of the dial indicators are approximately 2" below the bottom of the yoke worm gear housing. Record the actual complete reading of each dial indicator.

Probe DOWN:

Yoke tilt = $N_d$ mils PM plate tilt = $M_d$ mils

g) As a result of the dimensions shown in Figure 2, a calculation based on nulling out both probe tilt angle misalignments, relative to the PM direction of travel, results in adjusting the tilt in each direction by (probe in DOWN position):

| | | |
|---|---|---|
| Yoke tilt adjustment: | $= (N_u - N_d) \times (15/44) =$ | mils |
| PM plate tilt: | $= (M_u - M_d) \times (15/44) =$ | mils |

h) Repeat steps 7(b) through 7(g) (ending in the probe DOWN position) until the displacements $(N_u - N_d)$ and $(M_u - M_d)$ are less than 2 mils each. *The longitudinal axis of the probe is now sufficiently parallel to the direction of travel of the PM.*

i) Retract and lock the dial indicator shafts.

j) Advance the 3 ea. micrometers on each alignment ring until their Delrin tips just touch the surface of the Vacuum Can. Back each one off 1 mil and lock.

*Note: The line through centers of the two circles defined by the tips of the six micrometers is the longitudinal axis of the probe. Thus when the PM lifts the QBS out of the Vacuum Can, these items should be well co-aligned, and thus internal contact is minimized.*

Completed ________ at ________ Signed: ____________________________
date time ITD or QA Representative

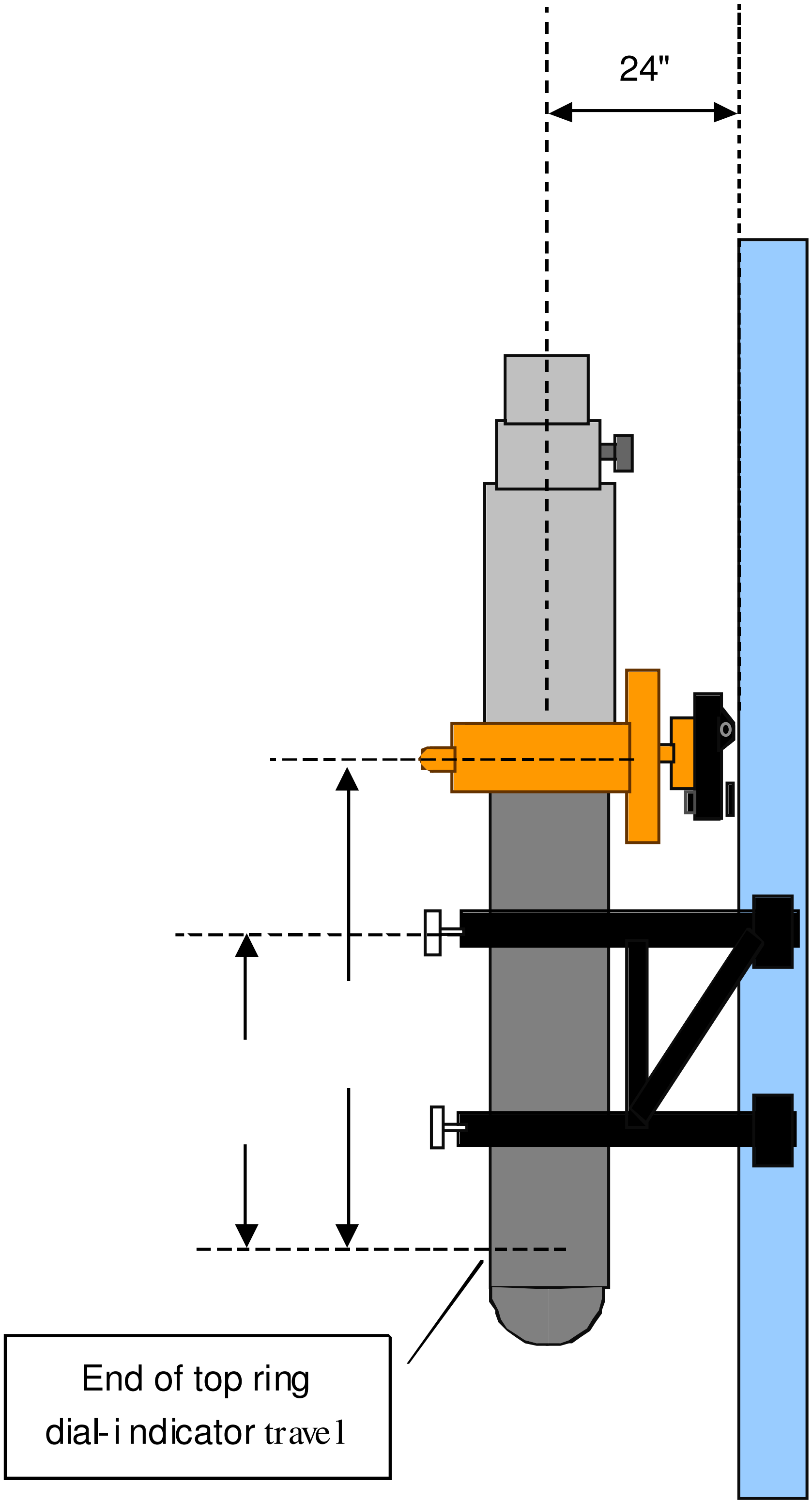


**Figure 2. Alignment Setup Showing Essential Dimensions**

**Section 7 Completed:**

Integration Engineer(s) ______________________________ Date ______________

______________________________ Date ______________

______________________________ Date ______________

Discrepancies if any:

Disposition./.sign-off: ______________________________ Date ______________
ITD

Concurrence: ______________________________ Date ______________
QA Designated Representative

*Take a picture (if digital, imbed in this document)*

## 8 REMOVE THE PROBE VACUUM SHELL

Started ___________ at _________ Signed: ______________________________
date time ITD or QA Representative

a) Position the Probe Vacuum Shell Stand under the probe. Center the Delrin cup on the Stand base under the Probe Vacuum Can. After positioning the Stand, lower the jacks to raise the Stand off its wheels to prevent it from rolling.

b) Lower the Probe until it is about 1/8" above the Delrin puck on the Vacuum Can Stand.

c) Near STA200 mark the clocking of the Vacuum Can to the Probe with small pieces of cleanroom tape at two azimuthal positions approximately 90° apart. Take care to not touch or put tape on the indium coated surface at STA200.

d) Using the back of the non-magnetic calipers and a known thickness of thin film material to protect the STA200 indium surface, e.g. 5 mil Kapton or similar material, measure and record the depth from the STA200 surface to the back of the Vacuum Can flange in four places, adjacent to the ±X* and ±Y* axes.

Depth at: +X* = +Y* = -X* = -Y* =

e) Using a similar technique, measure the depth to the top of the head of each of the bolts. Record the data in Table 1 with Bolt 1 on the +X* axis and proceeding counterclockwise looking in the –Z* direction.

**Table 1. Depth from STA200 Surface to Top of Bolt Heads (inch)**

| Bolt # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Bolt # | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | | | | | | | | | | |
| Bolt # | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| | | | | | | | | | | |

f) Use the dial readout type torque wrench to determine the breakaway torque of each bolt except for three approx. 120° apart next to the jacking screw locations, at the Can to STA200 interface. Work in a star pattern. Record the breakaway torques in Table 2 with Bolt 1 on the +X* axis and proceeding counterclockwise looking in the –Z* direction.

**Table 2. Breakaway Torque for Vacuum Can Bolts (in-lb)**

| Bolt # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Bolt # | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | | | | | | | | | | |

| Bolt # | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

g) Using the BeCu wrench remove these 27 bolts, leaving the vacuum can supported by three bolts. Bag and tag the bolts.

h) Back off the remaining 3 mounting screws two turns each, recording their breakaway torques in Table 1. Bag and tag the bolts.

i) Install 3 mounting screws into the 3 jacking screw holes to break the seal and allow the vacuum can to settle onto the remaining 3 mounting screws.

j) Incrementally unscrew the remaining three bolts. Guide the Vacuum Can to gently drop into the Delrin puck.

k) Raise the probe so that the STA200 ring is approximately 3 inches above the Vacuum Can Flange.

l) Disconnect the three heater connectors from the probe and carefully stow.

m) Attach one lead of the Fluke 77 Multimeter to the Vacuum Can Flange and the other to the PM structure. *The PM is shorted to the QBS via the metal to metal interfaces through the tilt plate and the Probe Yoke.*

n) Set the Multimeter to the short circuit alarm mode; a beep sounds when a short occurs.

o) Begin raising the probe while watching the Multimeter for shorts. Should a short circuit be indicated, stop the probe's upward motion and back off each micrometer by 0.005", adjust the can position to eliminate the short, reset the micrometers to a gap of 0.001 from the new position of the Vacuum Can surface.

p) Continue raising the probe until the QBS Spider (with all its hardware) has cleared the top of the Vacuum Can by about 2 inches.

q) Once the probe is clear of the Vacuum Shell, attach the Vacuum Can Stand clamp loosely around the Vacuum Can. Back off all the Alignment Ring micrometers.

r) Remove the “half-circle” of each alignment ring and set aside.

s) Tighten the Vacuum Can Stand clamp and roll the Vacuum Can cart away.

t) Remove the used C-seal from the vacuum can flange groove.

u) Examine the inside of the Vacuum can for contaminants and note here:

v) Place the Delrin cover plate on Vacuum Can flange to protect it from contaminants.

w) Roll the Vacuum Can Cart with the Vacuum Can into the Class 1000 cleanroom.

x) Remove the rest of Vacuum Can alignment GSE from the PM and store in CL 10 room.

Completed ________ at ________ Signed: ______________________________
date time ITD or QA Representative

*Take a picture (if digital, imbed in this document)*

## 9 ROTATE PROBE TO HORIZONTAL

Started: ___________ at _________ Signed: ______________________________
date time ITD or QA Representative

a) Lower the probe and tilt so that it is horizontal with the Birdcage end facing the large observation window.

b) Adjust the height so that the probe is approximately 4 feet above the floor.

c) Place a stainless steel work table underneath the Birdcage end of the Probe.

Completed ________ at _________ Signed: ______________________________
date time ITD or QA Representative

## 10 PROCEDURE COMPLETION

The results obtained in the performance of this procedure are acceptable:

Integration Engineer ______________________________ Date _______________

ITD ______________________________ Date _______________

The information obtained under this assembly and test procedure is as represented and the documentation is complete and correct:

QA Representative ______________________________ Date ______________

QA Program Engineer______________________________ Date ______________

Copy discrepancies to D-Log and open Discrepancy Reports when required.

Hardware Manager ______________________________ Date ______________

Systems Engineering ______________________________ Date ______________

## 11 DATA BASE ENTRY

The following data shall be entered into the GP-B Data Base:

a) Name, number and revision of this procedure
b) An electronic copy of this document
c) A copy of the "as-built" procedure with data and pictures, when completed.