P0201
Procedure for Assembly, Fiberoptic Switch for Charge Control
Rev A

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Gravity Probe B Relativity Mission

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NOTES:
Assembly to be performed only by Authorized Personnel listed: Wesley Rowe
All equipment used should be manufacturing certified.
All test results should be recorded in traveler.
All dimensions are in inches unless noted otherwise.

Note: Cleaning parts for the last time before assembly shall henceforth mean ultrasound with ethanol solution for a minimum of 15 minutes, with solution being replaced at least once during that time. The last solution should show no visible signs of contamination.

Note: also that consumable materials are specified in full detail in the respective assembly drawings.

1. Electromagnet Assembly

Electromagnet Assy Drawing 25654
Parts list:
1 Electromagnet (EM) End -- 25631-101
1 EM Core -- 25630-101
1 Washer, Flat -- 25667-101
Magnet wire, annealed copper, polyimide coated, .005" dia.
Epoxy, Tra-Bond 2143 – Verify material is not expired

1.1. Check (and modify) Washer fit (Outside of Cleanroom)

- The EM Core should fit snugly through the washer when inserted flat end first.
- The washer, an off-the-shelf-item, may have a within-spec i.d. which prevents insertion of the Core.
- If the core does not fit, remove the washer and use a .125 reamer, applied by hand using a chuck, to widen the hole.
- Test again, and then, if necessary, use a no.30 (.1285) drill bit to widen the hole further.
- Note that the hole should only be enlarged if the washer cannot be jammed on at all (with no regard for the force required, short of yielding washer).
- Use the edge of a metal file to cross-hatch the circumference of the Core within 1/16" of its flat end, where the End will be glued later.
- Use the same file to scratch surface of steel around circumference where the Washer will be glued later.

Completed by _____ Date: _____

Following steps should be performed wearing cleanroom grade latex gloves.

1.2. Clean parts

- Use ultrasonic cleaner and ethanol as solvent to remove oil and particles.

Completed by _____ Date: _____

1.3. Assemble EM End and EM Core

- Apply a small drop of epoxy to the cylindrical end of the Core (which does NOT have a flatted slot for mounting).
- Insert this end into the recess on the End which is the proper diameter for a slip fit.

- The amount of epoxy is sufficient only if it squishes up at every point around the circumference of the bond. Separate parts and apply more epoxy if needed.
- Remove excess epoxy with a spatula.
- Allow epoxy to harden with assy sitting on a flat surface, Core upright on top of End. Flatness of the bonded surfaces should be sufficient, along with gravity, to assure perpendicularity. Cure min. 3 hrs at 20C, or faster with heat.

Completed by _____ Date: _____

1.4. Assemble Washer onto EM Core

- Apply epoxy in a thin ring around the Core at the plane where the Washer should end up, as indicated on the drawing.
- Slide the washer to its proper position.
- Make sure that no epoxy is left on the exposed Core surface between Washer and flats on Core, as this might interfere with fitting into the winding chuck.
- Position Core horizontally in one of the slots of the teflon assembly jig.
- When all the assemblies in a given batch are glued and in place in the jig, apply the second half of the jig so that it clamps all the washers in a plane parallel to the Ends, normal to the Core axes.
- Allow epoxy to cure min. 12 hours at 20C or equivalent.

Completed by _____ Date: _____

1.5. Check Winder Direction

- Direction switch should be in the UP (A) position. Imagining the turning axis pointing to the left, the right-hand rule with thumb stuck into the chuck identifies this as the positive direction of revolution. Fingers curl in this same positive direction.

1.6. Wind magnet

NOTE that at no time during winding should the wire make a bend radius of less than .025".

- Insert washer end of Core into chuck of winder so that washer butts up against chuck jaws.
- Tighten moderately, so that core is held, but not so tightly that the oddly stressed jaws don't spit assembly back out. Overtightening also tends to knock the assembly off-center. Whole assembly should turn evenly.
- Magnet wire spool should turn easily at some point convenient to winding. Ideally the spool should require no attention from the operator.
- Thread magnet wire end through the slot in the core and draw out 4-6". This tail shall henceforth and in later procedures be called "TAIL A", and will be easily identifiable by its location near the Washer end. Wrap this tail around the chuck such that it will not present a hazard during winding. (Threading through slot helps prevent unwinding during handling.)
- Wind as smoothly as possible, making smooth passes along the whole length of the core. Especially during the first ten layers, any imperfections in the winding should be backed off and remedied as soon as they occur.
- Wind until the cylinder defined by the outside diameters (.312") of the Washer and End is entirely filled by magnet wire (lay off a little immediately next to End). It shouldn't be necessary, but up to .029" of wire may be added to the cylinder radius, with the exception of the region within .25" of the End, which must still remain within the o.d. of the End. The outside diameter of this extra region is not to exceed .370". Note that this extra winding does not

appear on the assembly drawing.

- Clip the magnet wire and tie off near the End by tucking the tail under the last wrap and pulling tight; then temporarily stick it through the slot in the Core to prevent loosening of the coil. It must only stay tight until it can be glued later. The tail should be 4-6" long, and it will henceforth be called "TAIL B".
- Remove completed assembly from chuck.
- Scrape insulation from ends of tails and measure resistance of coil.
- Remove wire if necessary until the resistance is between 50 and 53 Ω.
- Set aside and continue winding EM assys until batch is complete.

Completed by _____ Date: _____

1.7. Clean EM Assy, in clean environment

- Clean in ultrasonic and ethanol for 10 minutes, occasionally changing orientation of assy w.r.t. gravity.
- Replace solution with ethanol and ultrasonic clean for 10 more minutes.
- Remove from ethanol and let drip onto cloth.
- Enclose in foil to protect from particles in oven (there must be significant vent gaps).

Completed by _____ Date: _____

1.8. Bake out (preferably done as 1 batch)

- Bake in low temp vacuum oven for at least 24 hours at 100 C. Because of the amount of solvent boiling off initially, pump must be on continuously.
- Allow to cool in vacuum.
- Remove and return to storage in clean room.

Completed by _____ Date: _____

Lot Date Code: _____

QA: _____

RE buy-off: _____ date: _____

2. Block Assembly

Block Assy Dwg 25655

Parts list:

2 Fiber Clamp -- 25637-101
1 Left Alignment Block -- 25635-101
1 Right Alignment Block -- 25636-101
2 Flathead Screw, 0-80 x .125 -- 25662-102
2 Fiber Assy -- 25657-**101** (16" long)
Epoxy—Tra-Bond 2413 – Verify that material is not expired
Teflon Sleeve (Spaghetti, 24 AWG)
Teflon Tubing, 18 AWG

All steps take place in a Class 1000 (or better) cleanroom.

2.1. Clean all metal parts at the start with ultrasonic and ethanol; they should be free of oil and particles.

Completed by _____ Date: _____

2.2. Teflon Sleeve

- Cut length of spaghetti such that, when slid over fiber and inserted about 0.3" into SMA connector, it shall leave a .25" length of fiber exposed beyond teflon.
- Wipe teflon tube with ethanol and lint-free cloth repeatedly until no signs of contamination show on the cloth.
- Puncture Sleeve approximately every 1" to allow gas to escape easily in vacuum.
- Slide Sleeve over Fiber Assy.

2.3. Strain Relief

- For each Fiber Assy cut a length of the larger Teflon Tubing to length as indicated on the assembly drawing cross-section.
- Optional: Slit the Teflon Tubing (#18) along part or all of its length if necessary.
- Clean all tubing in ultrasonic ethanol.
- When dry, slide Teflon tubing into position over Fiber and Sleeve.

Completed by _____ Date: _____

2.4. Clamp Block in vice

- Clamp Alignment Block (Rt or Lft) in vice with groove side up and fiber exit end at the edge of the vice jaws (to allow fingers maximum freedom).
- Insert Flathead screw through a Fiber Clamp and thread it into the hole. Only start threads; do not tighten.

2.5. Inspect Fiber tip

- If there are scratches or particles, resolve problems before proceeding.

Completed by _____ Date: _____

2.6. Getting the fiber in the groove

- Raise Clamp so that the fiber can be slid laterally under it and into the groove.
- DO NOT slide the fiber along the axis of the groove, since this will cause it to collect particles.

Note: The fiber tip should always stay between the planes formed by either side of the slot in the Block during this entire assembly phase. It must not touch anything.

2.7. Glue and tighten Clamp, Fiber

- Lightly tighten screw down so that the Clamp will temporarily hold the Fiber in place.
- Align fiber tip to midplane of slot in Block, where it should reside permanently.
- Tighten the screw down more firmly, but not so hard that it could crack the fiber.
- Use a spatula to force epoxy down between the Block and the Clamp along the entire length of the groove. Also apply a thin tab of epoxy to connect surface of Clamp and Screw to prevent later rotation. This tab must not project out from the surface so far that it will separate the Blocks when in position in the final assembly.
- Make sure that the nearest point on the Clamp is at LEAST .005" behind the fiber tip, well clear of the space through which the moving fiber will translate in the final assembly.

Completed by _____ Date: _____

2.8. Set assembly aside and let cure minimum 18 hrs at 20C, or equivalent.

Lot Date Code: _____

QA: _____

RE buy-off: _____ date: _____

3. Bellcrank Assembly

Bellcrank Assy Dwg 25658

Parts list:

1 Bellcrank -- 25628-101
1 Pivot -- 25634
1 Magnet -- 25633-101
1 Fiber Anchor -- 25632-101
1 Setscrew, 0-80 x .125 -- 25664-101
1 Flathead Screw, 0-80 x .375 -- 25662-101
1 Fiber Assy -- 25657-**102**
Ceramic Extension Tube
Strain Relief – Teflon tubing, 18 AWG
Teflon Sleeve (Spaghetti 24 AWG)
Epoxy—Tra-Bond 2413 – Verify that material is not expired

All steps take place in a Class 1000 (or better) cleanroom.

3.1. Clean all metal parts at the start, free of oil and particles, in ethanol. Keep Magnet separate from all steel parts during cleaning, drying.

Completed by _____ Date: _____

3.2. Assemble Bellcrank, Pivot

- Put a small amount of epoxy on .375" Flathead halfway down its length.
- Insert screw through countersunk hole in Bellcrank and thread on Pivot. Use screwdriver on screw but fingers on Pivot; make as tight as possible.
- Threads extending out of Pivot should be totally free of epoxy. If not, clean screw and start over.

3.3. Assemble Magnet, Setscrew onto Bellcrank

- Insert Magnet into its hole with the groove pointing towards where the Setscrew will be.
- Squeeze a small amount of epoxy into bellcrank hole intended for Setscrew, and thread setscrew.
- Tighten while verifying that the magnet groove is orented properly.
- The Setscrew should lodge at the bottom of the groove and be glued there.
- Apply torque using only the short lever arm of the allen wrench to avoid breakage of brittle permanent magnet material.

Completed by _____ Date: _____

3.4. Protective Teflon Sleeve

- Cut a piece of Strain Relief tubing to length as indicated on assembly drawing, and cut a slit in one wall along the entire length.
- Clean Fiber Assembly by brief ultrasonic ethanol on SMA and wiping fiber itself with ethanol.
- Cut Teflon Sleeve to a length 2.75" less than the length of fiber extending from the end of the SMA connector.
- This sleeve, when slid over the fiber of the Fiber Assy, must leave a minimum of 2.980" fiber extended past the end of the teflon; also, the sleeve should penetrate into the SMA far enough to provide some strain relief, approximately 0.30".
- Puncture walls of sleeve once every 1" or so to allow trapped gas to escape in vacuum.
- Slide Strain Relief tube over end of Sleeve, extending about .25" beyond end of sleeve.
- Slide sleeve onto Fiber Assy.

Completed by _____ Date: _____

3.5. Fiber Anchor

- Slide Fiber Anchor over Fiber Assy tip in proper orientation.
- Insert end of Strain Relief into the counterbore in anchor as far as possible.
- Now gently force Sleeve down into Anchor, being careful not to buckle it. This jams the Strain Relief outwards against the counterbore, holding it in place.

Completed by _____ Date: _____

STORE in cleanroom, protected from settling of particles, and totally separate from any parts or instruments which might be sensitive to magnetic fields.

Lot Date Code: _____

QA: _____

RE buy-off: _____ date: _____

4. Final Switch Assembly

Fiberoptic Switch Assy Dwg 25656

Parts list:

2 Electromagnet Assembly -- 25654-101
1 Block Assembly -- 25655-101
1 Bellcrank Assembly -- 25658-101
1 Base -- 25627-101
2 Bearing, Ball -- 25659-101
2 Clamp -- 25629-101
1 Lid -- 25638-101
1 Nut, Hex -- 25660-101
6 Screw, Socket Head, 0-80 x .25 -- 25661-101
4 Flathead Screw, 2-56 x .375 -- 25663-101
Epoxy—Tra-Bond 2413 – Verify that material is not expired
Stranded wire, 24 AWG, Teflon insulation
Solder—lead-tin, flight qualified
.112-40 UNC x .168 length Helical Coil Locking Thread Inserts, MIL spec, CRES steel

All steps take place in a Class 1000 (or better) cleanroom.

1. Clean all metal parts

- At the start with ultrasonic ethanol, they should be free of oil and particles. Subassemblies have been stored carefully and so are still clean.
- Make particularly sure that all tapped holes harbor no machining chips.

Completed by _____ Date: _____

2. Install Helical Coil Inserts

- Make sure that the last coil is installed completely clear of the mounting face.
- Break off tang and remove from hole.

Completed by _____ Date: _____

3. Mount the Bellcrank

- Place a Ball Bearing over the Pivot of the Bellcrank Assembly. Insert this into its counterbore on the top surface of the Base.
- Turn the Base over and complete its attachment with another Ball Bearing and the Hex Nut. A small drop of epoxy should be applied to lock the threads of the Nut. It must not come anywhere near the internal parts of the Bearing.
- **Finger tighten Nut** (with tweezers): Wiggle the Magnet up and down (perpendicular to plane of Base) as the Nut tightens until the point where there is no play left in the vertical direction but the Bellcrank still pivots freely. Back the Nut off between a sixth and a quarter of a turn, so that with little applied force the Magnet moves up and down about .010” peak-to-peak.

Completed by _____ Date: _____

4. Temporary Installation of Moving Fiber

Bellcrank and Ceramic Extension Tube

- Slide Fiber through Bellcrank.
- It is critical now that the fiber of the Bellcrank Assy not be allowed to back out through any of the parts into which

it has been inserted, for cleanliness.
- Break off appropriate length of Ceramic Tube (per dwg) and wash away particles with ethanol; let dry.
- Slide this over the fiber tip.

Inspect Fiber Tip

- Use microscope from polishing kit to check fiber tip.
- Use Ethanol and particle-free cloth to wipe off any particles.
- If any scratches are present, either try to polish them out in situ or else disassemble to polish.

Completed by _____ Date: _____

5. Temporarily Mount Subassemblies

Temporarily mount Block Assembly

- Attach Left and Right Alignment Blocks using two Socket Head Screws.
- Tighten each lightly at the middle of its adjustment range (the screw head is centered along the length of the slot in its Block).
- Make sure that the tip of the Moving Fiber is not damaged during this operation.
- Note: Do NOT use epoxy on the threads yet.

Temporarily mount each EM Assembly (EMA)

- Use one Socket Head Screw to mount each, without epoxy.
- Adjust them to flight-like positions: the fiber should be mildly stressed when lodged in its destination groove. In the ideal position the fiber returns to its position in the groove when pushed away by a finger (without the Bellcrank moving). In other words, the radius of curvature of the fiber in its stressed state is barely less than the radius the fiber would return to if the groove wasn't there to get in its way.
- The Magnet should be in contact with the EM End when in the latched position on a given side; the fiber should not be stressed enough to pull it away any distance.

Completed by _____ Date: _____

6. Temporarily mount Fiber Anchor:

- Use two Socket Head Screws.
- Make sure that strain relief teflon tubing is properly inserted into Anchor.

7. Grip Base in vice at the Anchor end

- Note that the force involved will not be great, so gravity could be enough if utilized properly.

8. Check Alignment motion

- It is also important at this stage to make sure that the fiber tip doesn't have trouble sliding along the walls of the grooves to reach its proper aligned position.
- If it doesn't align easily, rotate the moving fiber about its center axis and try again.
- If the moving fiber is very far out of its intended plane, this may be corrected when the ceramic tube is installed in the next step.

Completed by _____ Date: _____

9. Glue Moving Fiber in place

- Use a drop of glue to attach Ceramic Tube to Bellcrank.
- If in step 7 there was an alignment problem discovered, wait until the end of this step to glue the moving fiber to the Ceramic Tube.
- Position the fiber tip about .003" from the destination fiber tip opposite it.
- Flip switch back and forth with finger, making sure that the fiber moves in the plane of the groove vertices. If it doesn't, use clamping means like rubber bands to deflect the ceramic tube such that the fiber tip will move in the plane of the grooves.
- If fiber is unglued, allow Ceramic epoxy to cure, then retest alignment before gluing Fiber to Ceramic Tube.
- Let all epoxy cure minimum 18 hours at 20C before continuing.

Completed by _____ Date: _____

10. Finish gluing Moving Fiber in place

- Loosen EM Assys to hold Bellcrank in neutral (between blocks) position.
- DO NOT glue the fiber into the ass end of the Bellcrank; let it float free. Otherwise, fiber is too stiff for latching strength.
- Glue fiber into Fiber Anchor by sliding Anchor towards Bellcrank, putting drop of epoxy at point even with screw holes for Anchor attachment, and then returning Anchor to its position and screwing it down. Try to avoid epoxy filling the counterbore meant for teflon sleeve.
- Assure that the clearance between screws and holes in the Anchor is taken up such that the Anchor is oriented to the edges of the Base.
- Tip the Base up in the vice so that the moving fiber points to mocking Apollo on Olympus.
- Apply a small weight to the SMA connector (up to about ½ oz) to straighten the fiber out between Anchor and Bellcrank. A Lid works well for this.
- Let cure min. 18 hours at 20C.

Completed by _____ Date: _____

11. Solder all wires: to be carried out by a certified solder technician in Assembler's presence.

Prepare wires for soldering

- Strip about .2" of insulation from ends of all four magnet wire tails with a ceramic blade, under the microscope. Do not nick conductor.
- Tin exposed conductor with solder.
- Cut two 24" lengths of the 24 AWG wire, and use hot tweezers to strip the insulation off from about .2" at one end of each wire.
- Tin stranded conductor.
- Twist the tinned portion of Tail A lead from each EMA together, and likewise for Tails B.

Supervised by _____ Date: _____

Test actuation of the switch

- Identify the twisted leads (A or B) which, when taken to +5 V w.r.t. the other pair, switches to Channel L (which corresponds to the moving fiber lodging in the Left Alignment Block). Note that this depends on the north-south orientation of the Magnet in the Bellcrank, which was arbitrary at that stage of assembly. This is the "HIGH" pair.

- Verify that reversing the polarity switches back to Channel R.

Supervised by _____ Date: _____

Make solder connections

- Insert the tinned stranded wires through holes 2 and 4 from the Anchor end of the Base, as seen in the assembly drawing.
- Wrap the tinned, twisted portion of the HIGH pair onto the conductor of the wire nearer the Anchor (hole 2). If possible, wrap some insulated portion of this pair around the insulated portion of the stranded wire for strain relief away from the joint.
- Do the same for the other twisted leads.
- Apply solder to the joints per NASA requirements.

Supervised by _____ Date: _____

12. Inspect Solder Joints

- NASA certified Quality Assurance officer. Record results in traveler.

13. Affix wires

- Locate a spot on the insulation of the stranded wire just inside the wall of the switch, as per the assembly drawing, which will be epoxied.
- Scrape this spot of insulation in a crosshatching pattern with a scalpel. Be careful not to penetrate the insulation and damage the conductors.
- Repeat for both stranded wires.
- Epoxy both solder joints to the EMA as indicated in assembly drawings, well apart from each other to avoid shorting. Make sure that all uninsulated wire is covered with epoxy.
- Use epoxy to tack free magnet wires wherever they run. Lengths of magnet wire should run no more than 1" without support.
- Use a large drop of epoxy to pot insulated wires in their respective holes. There should be a little slack in the wire as it runs from solder joint to switch wall.

Completed by _____ Date: _____

14. Glue Anchor

- Remove the Screws holding Anchor and apply a small amount of epoxy to their threads. A dab under the head would be advantageous but not absolutely necessary.
- Replace Screws (still loose).
- Tug on moving fiber at a point 3" from the end of the switch and on a line with the bearings and the thru-hole of the Anchor, again with about 1 oz. of force. Tighten both screws down with a wrench set on maximum stun. Make sure the Anchor isn't moved by the torque of the screw head.
- Check that the Bellcrank does not show preference for one channel over the other. This may be caused by an asymmetry in the routing of the Moving Fiber. Rectify problems.

Completed by _____ Date: _____

15. Glue Block Assy

- Remove and replace screws with epoxy as in 13.
- Move Fiber to Left Block.
- Slide Block into position so that its destination fiber tip is positioned .003-.004" from the tip of the Moving Fiber.
- Tighten screw Very Tightly.
- Repeat for Right Block.

Completed by _____ Date: _____

16. Complete EM Assy

- Use a Flat Head Screw (2-56) to affix a Clamp over each EM as in the drawing, applying a drop of epoxy to the threads at its tip.
- Loosely tighten the Clamp down to hold the EM in position. Remove, glue, and replace Socket Head Screws as in 13.

Completed by _____ Date: _____

17. Final adjustment

- Loosen both screws holding the right EM down.
- Latch the magnet onto this EM and move it so that the bend in the Moving Fiber is ideal (as described in step 4). The EM should be in position still from previous placement; this is just a verification.
- Tighten the Socket Head Screw as much as possible.
- Make sure that the Clamp is in a position which does not interfere with motion of the Bellcrank, and then tighten it with a screwdriver very firmly (without yielding materials).
- Repeat for other EM.

Completed by _____ Date: _____

18. Conduct tests on functionality

- Conduct Acceptance Test Plan as laid out in P0343.

19. Buy-off

- Recorded in detail in traveler by serial number.

20. Attach Lid

- Thread Block Assy fibers into strain relief housing on Lid, and move Lid into place.
- Apply epoxy to tips of two Flat Head Screws (2-56) and use them to attach Lid. Screw it down firmly yet without causing deformation in the top surface.

Completed by _____ Date: _____

21. Package all switches in safe container for storage, transportation

- Switches should at the very least be double bagged, packed securely in foam in a strong brief-case type container, with fibers held carefully in a secure arrangement to prevent damage.

Completed by _____ Date: _____

- Whole package should go in a dry-box during storage.