Crafting a Complex Transition

By John Brohm, NAR#78048

For NARAM 59, The Flying I-Beam Kids entered a 1/10th size model of the Argo D-4 Javelin in the Team Scale category. The model was a fully functional three stage vehicle, the upper two stages electronically timed to fire successively, just like the real prototype. The model flew perfectly as planned, but unfortunately the 3rd stage/Payload section landed somewhere in a vast soy field adjoining the North East side of the launch site. Despite several hours of dogged searching by a determined recovery team, the 3rd stage/Payload section was never found.

Photo 1: 1/10th Size Argo D-4 Javelin; 1/1th Size Flyer

(Photo by Rod Schafer)

This unfortunate and empty-handed conclusion to an otherwise successful flight nevertheless provided the impetus to build a new 3rd stage/Payload section, and with that the opportunity to address some shortcomings that had been present in this section of the original model. Our particular focus here is the payload adapter, a conically-derived part very much like the transitions we make and use in our model rockets. While our models' payload adapter was correct in outline, color and certain details, it was still missing some features that had been left out due to the pressures of meeting the entry deadline. As well, further research revealed that the original model's adapter possessed several inaccuracies that had been implemented in the part. Building a new adapter offered the opportunity to correct these errors.

For those that may not be familiar with the Javelin, the Payload section is connected to the 3rd stage Nike booster with a short adapter that mates the two dissimilar diameters of these sections. The adapter is a busy part – it houses the payload section ignition and instrumentation equipment which is accessible by means of two diametrically opposed access panels; it possesses a port for an external umbilical attachment; and it has three equally spaced slots near the base of the adapter where access to the mating bolts to the Nike booster is provided. While our original model's payload adapter incorporated those three bolt access slots, it didn't include the two instrumentation access panels or the umbilical attachment port. As well, the length of the adapter base was wrong; at our scale factor the length of the base should have been 0.073" but instead was 0.060"; out of expediency I chose to use Styrene strips a standard 0.060" wide to form the adapter's base instead of strips cut to the correct width. Finally, additional research revealed that I had the shape of the bolt access slots wrong. A new Adapter was needed indeed.

References

The item in question can be seen on the prototype, and the following photo highlights the part, it being the olive drab section where the technician's hand is resting:

Photo 2: Payload Adapter

(NASA Photo 71HC362)

Examining closely, we can see one of the three bolt access slots directly above the technician's hand; there's also an umbilical cable attachment point on the top side of the transition (top side meaning as shown in this attitude). But if one looks really, really closely, one can just make out the outline of one of those instrumentation section panel covers. The technician's hand is actually resting on the panel's lower seam.

That panel cover is better seen in the prototype's cross-section blueprint, as follows:

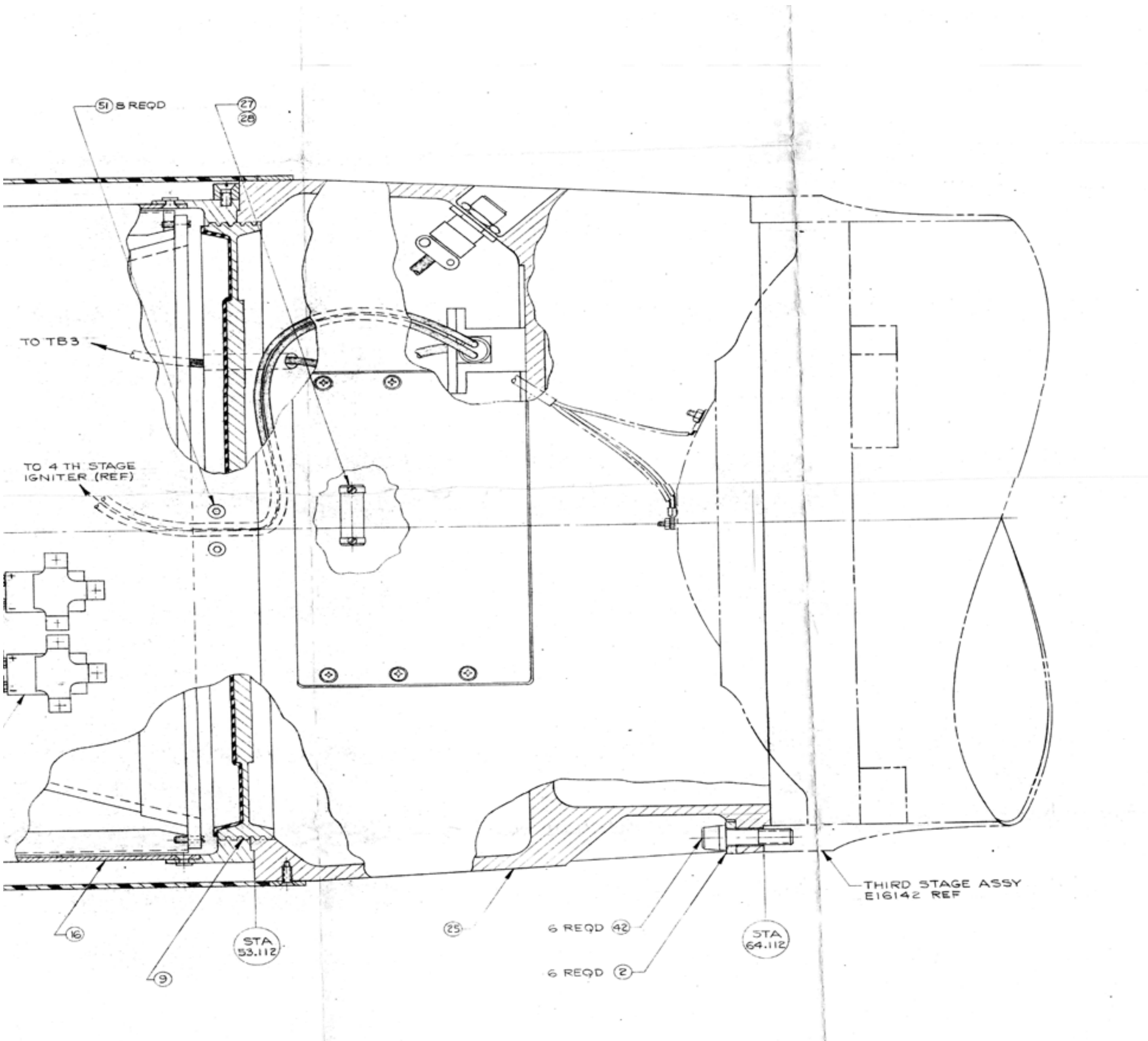

Figure 1: Payload Adapter Cross Section

One can also more clearly see that umbilical port in the top of the section view. Down in the lower right, we can see the cross-section cutaway of one of the bolt access slots.

Were one to ignore all of these prototypical details, construction of the adapter transition would be a fairly straightforward affair – a solid balsa transition would work, as would a paper shroud-based transition. On the other hand, adding in all of those details, might, in this modern age, encourage one to consider drafting the part in a 3D file and then having the part 3D printed. But as Scale is a Craftsmanship event, we'll endeavor to build that adapter the Old School way with a paper-based transition shroud, while capturing all of those prototypical features.

To help us precise, as the French would say, the details and their location on the adapter, we need some dimensions. Happily, we have a drawing for that:

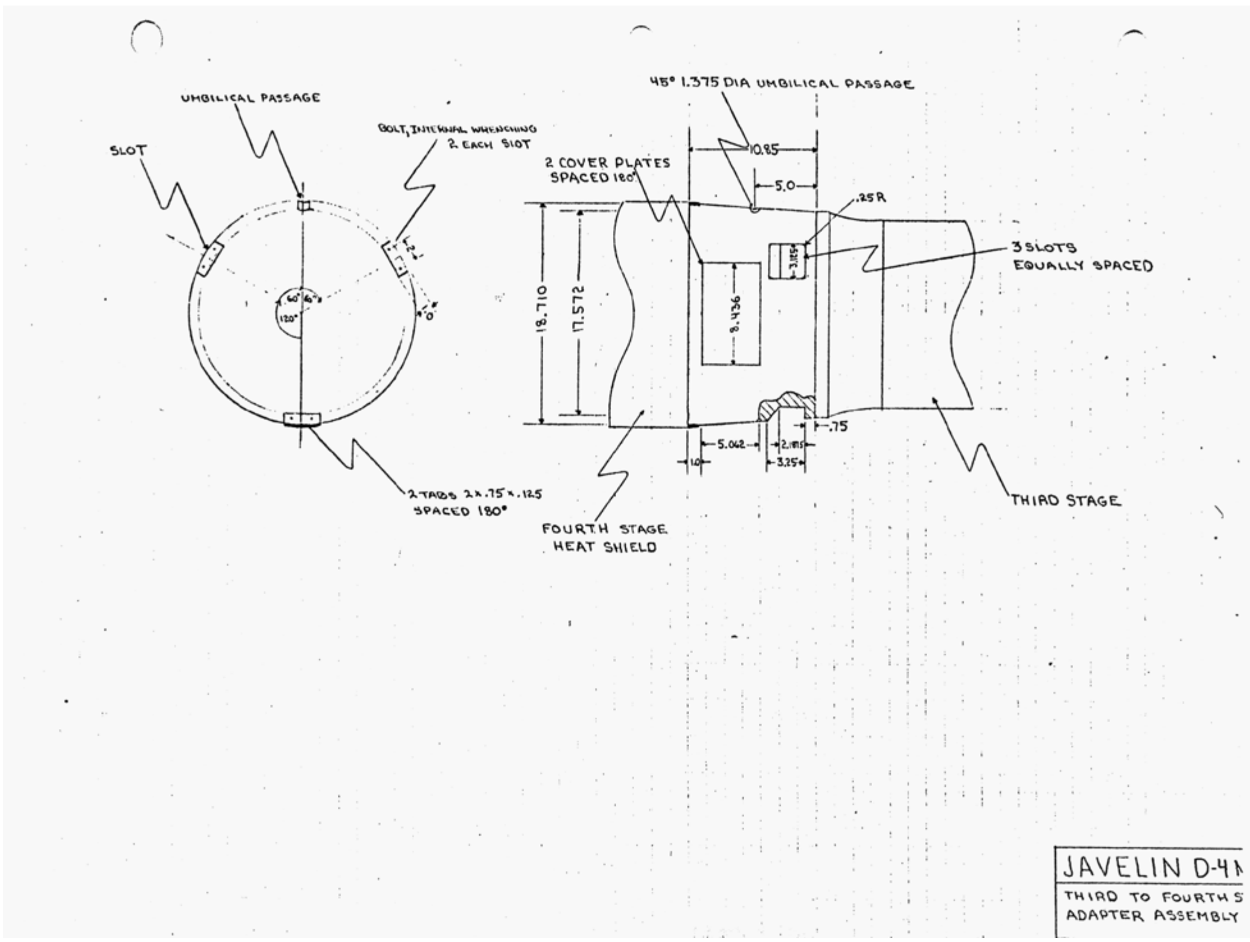

Figure 2: Payload Adapter

(Drawing by Jon Randolph)

Here we can see that the three bolt access slots are located 0.75" above the bottom edge of the prototype adapter. Our model's precise scale factor is 10.32, so that real-life 0.75" becomes 0.073" on the model. One can also see in the top view that the bolt access slots are shaped rectangularly; this is wrong for this adapter version, as in fact these slots are machined to follow the radial curve of the part. The sides of the slots are in fact angled to the face by 45 degrees, and are not perpendicular as the drawing suggests. The following photo highlights these features.

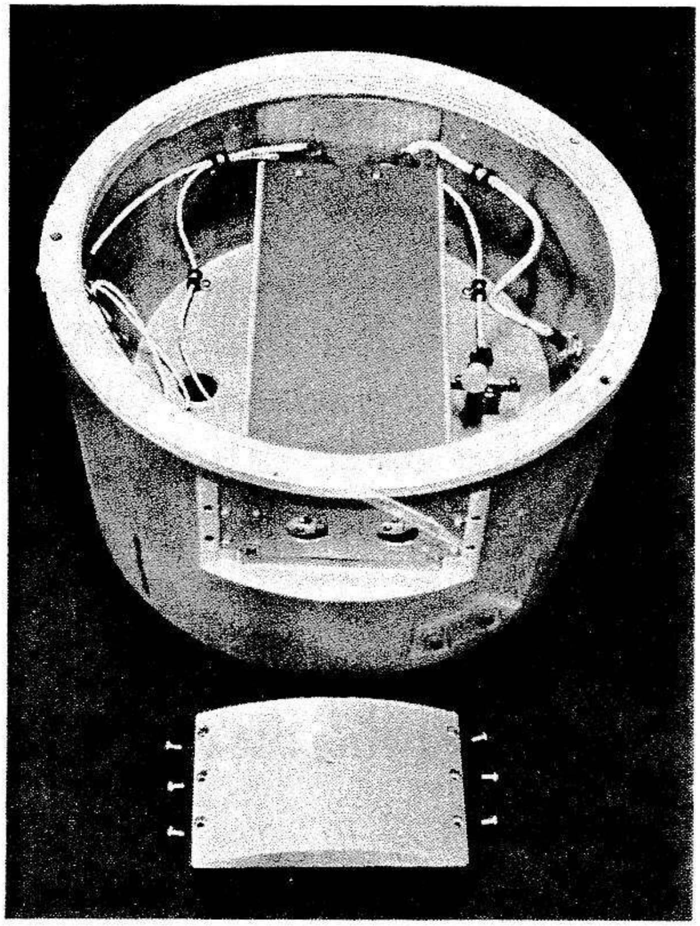

Photo 3: Prototype Adapter

The dimensions in the Randolph drawing also reveal another error that had crept into the original model. I had elected to fashion the original model's adapter to be flush with the OD of the aft end of the payload section; in fact, the dimensions show that that the forward end of the adapter has a diameter smaller than the aft end of the payload section – 18.710" versus the 19.04" of the Payload section. Something else to be corrected.

Construction

The scratch-building challenge here is crafting a way to incorporate all of these features in a paper-based transition shroud. We'll do this by realizing these features as a set of pockets built into the skeleton of the transition. Then, when the skeleton is covered by a cardstock-derived transition shroud, we'll cut out the openings and finish up with some careful filling, filing and sanding.

The underlying transition skeleton actually needs to serve two purposes – accommodate the aforementioned pockets, but also provide structural support to the cardstock transition shroud that covers it. We'll synthesize the skeleton from a set of rings, each ring having an outer diameter that just makes contact with the shroud at each ring's location. A bit of trigonometry readily reveals those ring diameters; with some drafting, we arrive at a cross-section view of the structure we intend to build:

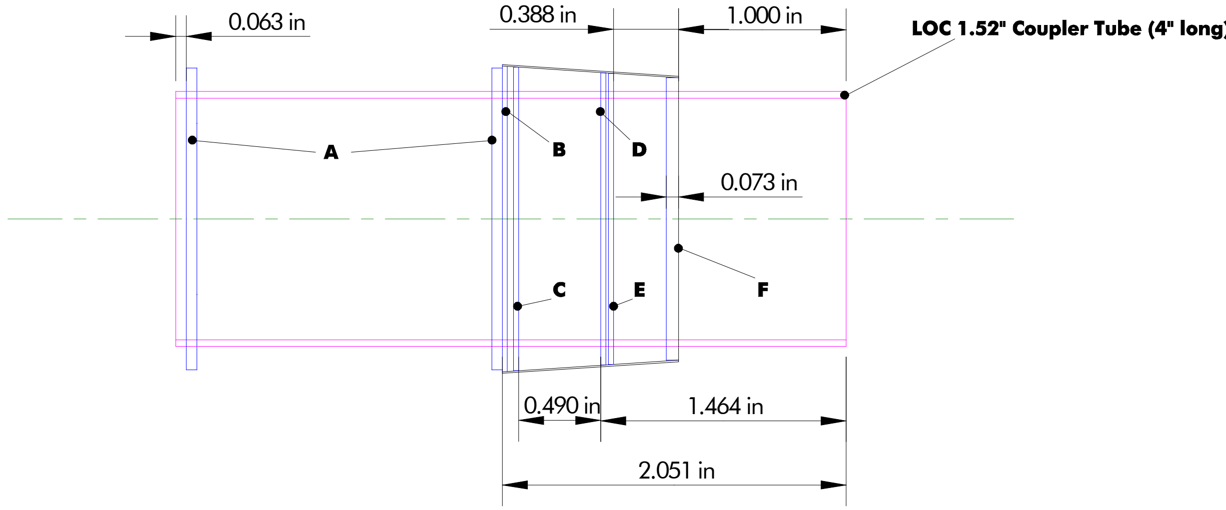

Figure 3: Payload Adapter Layout

Before I go on much further, I should say a word about the tube used to fabricate the adapter – the sketch in Figure 3 calls it out as a LOC 1.52″ Coupler Tube. What drives this choice is the airframe tube used for the Nike booster. At our scale factor (10.32), coupler tubing for BT-60 (or JT-60, in Estes parlance) turns out to be exact scale to represent a Nike booster (a prototype Nike booster has an OD of 16.46″, and at our scale factor this becomes 1.595″, exactly the OD of JT-60 coupler tubing). Since the Payload section must couple with the 3rd stage Nike booster, we'll need to find a tube to use as a coupler to join these two sections of the model. As it turns out, somewhat serendipitously, LOC/Precision 38 mm coupler tubing happens to be a very close, but slightly loose, fit as a coupler tube for JT-60. So our Payload Transition/Adapter is built up on this LOC coupler tube, as shown in Figure 3, above.

Figure 3 shows some precise spacing of the rings; this spacing sets the vertical dimensions of the bolt access and instrumentation panel pockets at precisely scale size. One might well ask why I would want to have so many rings so close together; why not just use one thick ring at the front and in the mid-section? Well, it's mainly because it's difficult (at least for me) to cut a ring from a thick material and then sand its edge such that it properly and smoothly conforms to the angle of the conical transition (3 degrees). The last thing we want are bulges in the shroud; thin rings help obviate that problem.

Construction begins by marking the coupler tube with the center lines for the various pockets and the locations for the rings.

As for the base ring, since no commonly available material exists that is precisely 0.073″ thick, we'll build up that ring with Styrene strips cut 0.073″ wide. We need to build out a base ring diameter of 1.685″ (which allows for the thickness of the outer cardstock shroud at the base) so we'll realize this with successive strips of 0.020″ thick Styrene cut 0.073″ wide followed by a final strip of 0.010″ thick Styrene. I used contact cement to adhere the strips, and I found I had to adjust the final outer strip thickness to account for the thickness of the intervening layers of glue. This is why the last strip is only 0.010″ thick. All up, I arrived at a base ring OD virtually spot on.

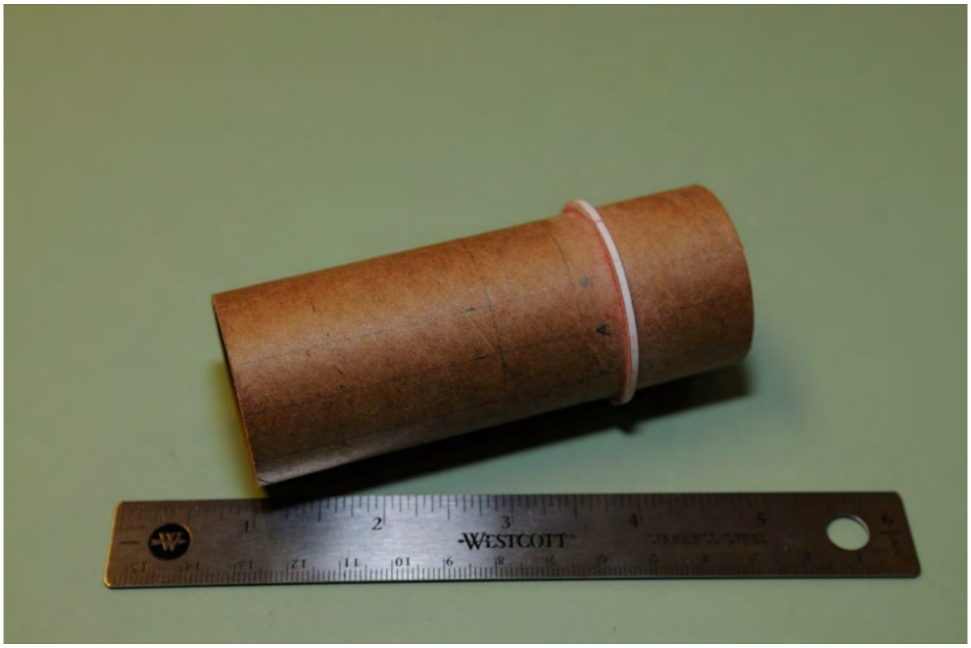

Photo 4: Coupler Tube with Built Up Base Ring

Next, we'll locate the various rings that form the vertical structure for the pockets; these 1/32" thick ply rings were laser cut by fellow teammate Rod Schafer, which contributed significantly to the accuracy of the build.

Figure 3 shows a very small space between the first two rings; trying to install that second ring by eyeball would risk introducing some seating error, so we help ourselves by installing some Styrene spacers of the right thickness on the first ring. Now the second ring will be located in the right place, and will be seated with the same axial perpendicularity as the first ring; best get that first ring right!

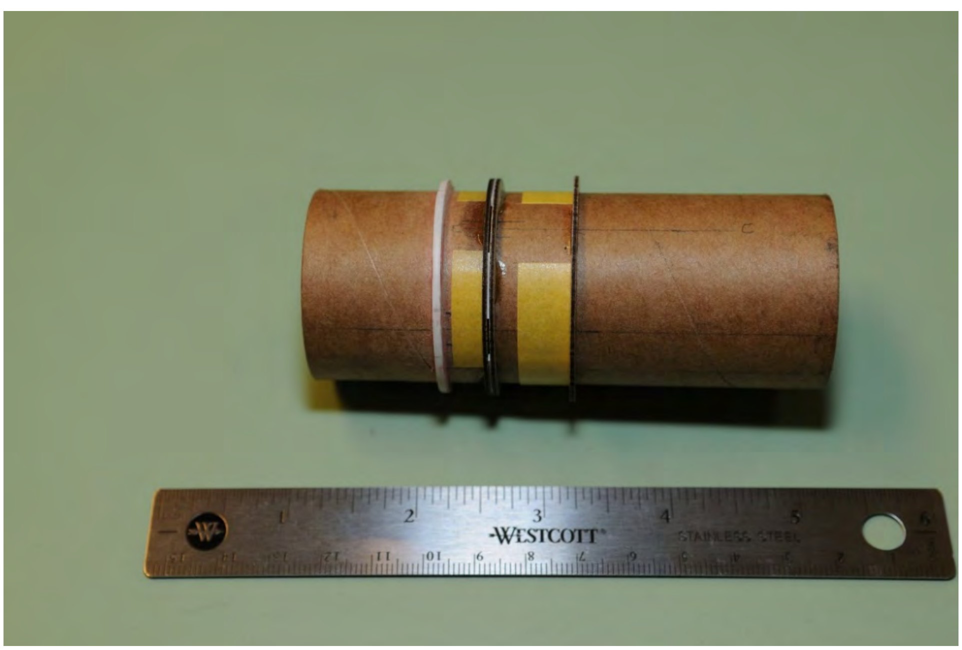

Photo 5: Ring Installation

One must also pay attention to where glue is placed for the rings; we don't want any glue in the areas where the pockets will be placed.

Installation of the rings continues, including spacers between the last two rings as Figure 3 also shows, and once completed, and assuming we have everything in the right place, we should have a nice smooth conical transition skeleton. We can check for that with a straight edge; everything should be tangent, with no gaps.

Photo 6: Tangent Rings

Now that the rings are in place, we can construct the slot sides. These are fashioned from pieces of Styrene sheet, and are installed at a 45-degree angle relative to the rear face of the slot. This is replicated for each of the three bolt access slots.

Photo 7: Bolt Access Slot Sides

At this point, one might be tempted to try a transition shroud fit, but before we do that, we should install the umbilical port first. We'll fashion that item from some Styrene tubing of the right diameter, and with a bulkhead installed for the umbilical connector. We need to locate it in the right place, and on a 45-degree angle, as indicated in the blueprint.

While laying out the location of the umbilical port on the adapter I discovered I would need to cut into the middle ring so that the end of the port would seat correctly. Accordingly, a little trimming and gluing, and we have the port installed.

Photo 8: Umbilical Port

One more thing to take care of before we try the transition shroud: all those pockets and ports are going to create a lot of edges in the shroud, and to make sure the smooth conical form of the transition is preserved, we'll need a way to securely tack all those edges down. So some balsa scraps are used to infill the relevant areas to provide a gluing surface for all of those edges.

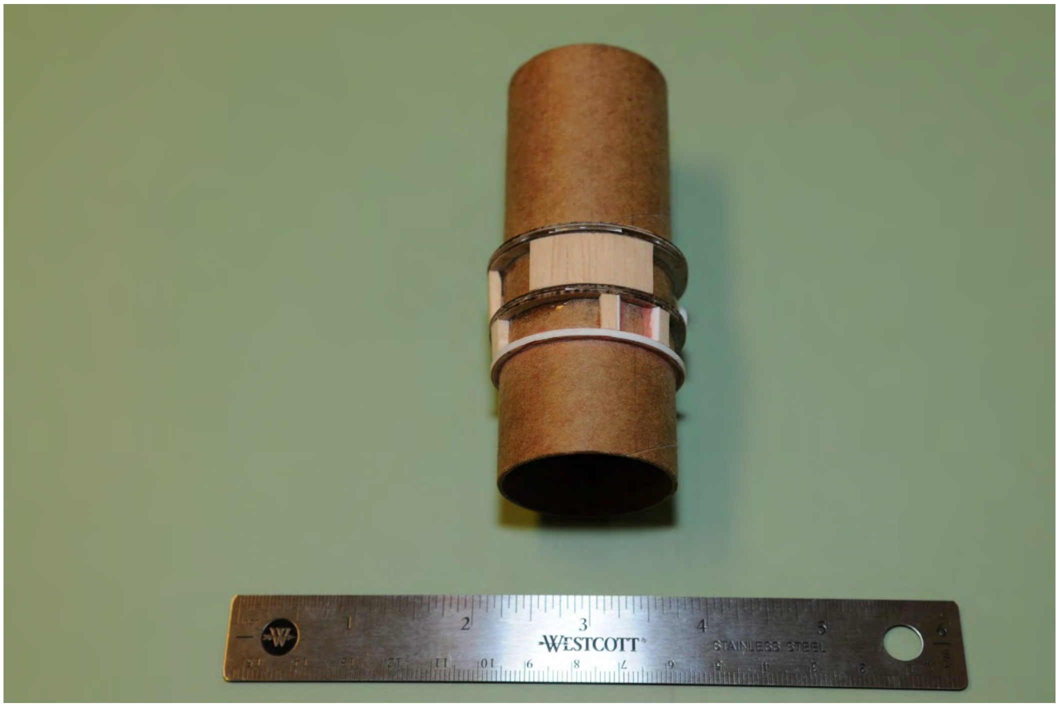

Photo 9: Balsa Infill

After some careful sanding to ensure that the balsa infill and the various Styrene pocket and port pieces all smoothly conform to the compound curves of the transition, we can now try a shroud fit. It took me three attempts to arrive at a shroud that fit perfectly.

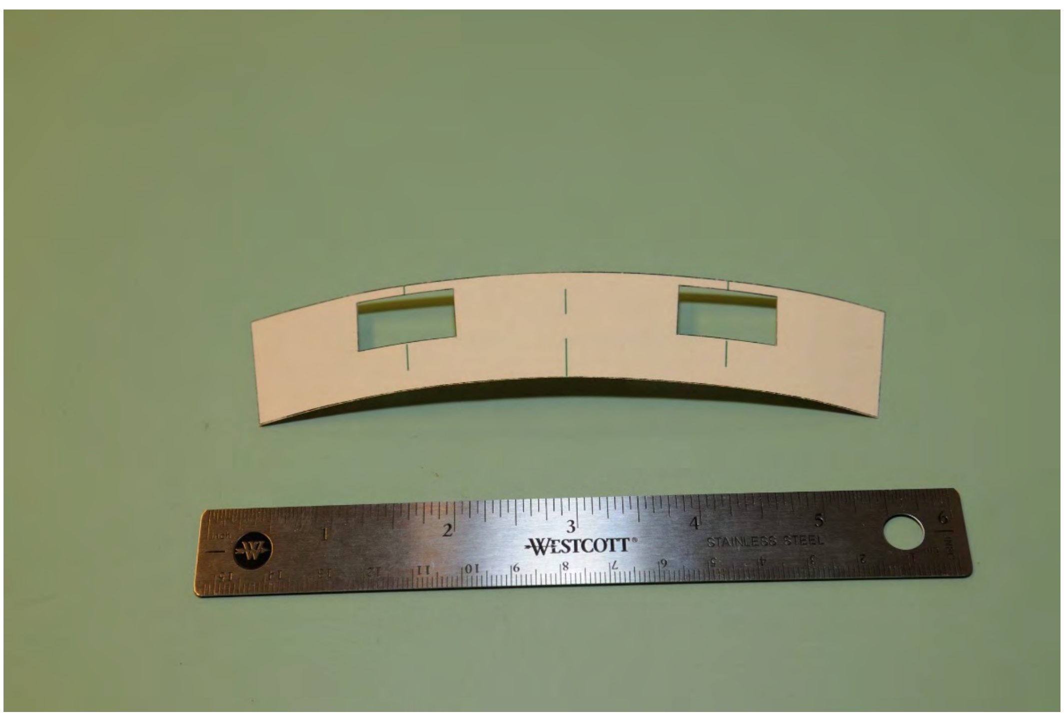

Photo 10: Transition Shroud

The shroud material I like to use is 67lb cardstock. I've found this to be a good weight to work with, and it stiffens up quite well, and sands and finishes well, when saturated with CA.

As Photo 10 shows, the instrumentation section panels were cut out before installation, as it would not be possible to do this after the shroud is installed due to the balsa infill in those areas.

Normally when I prepare a shroud, I do like everyone does, and prepare a joiner strip that's glued in behind the two adjoining edges of the shroud. But in this case a joiner strip would create a bulge in the shroud once installed, due to all those rings in behind. To solve this problem, I infilled the joint area with balsa, formed the shroud and then joined it on the outside with a temporary piece of Scotch tape. Applied some glue in all of the right places (don't forget those areas where the edges will rest), slid the shroud into place, and then lifted the tape once the glue had set. The result was a tight, smooth joint, as the following photo shows.

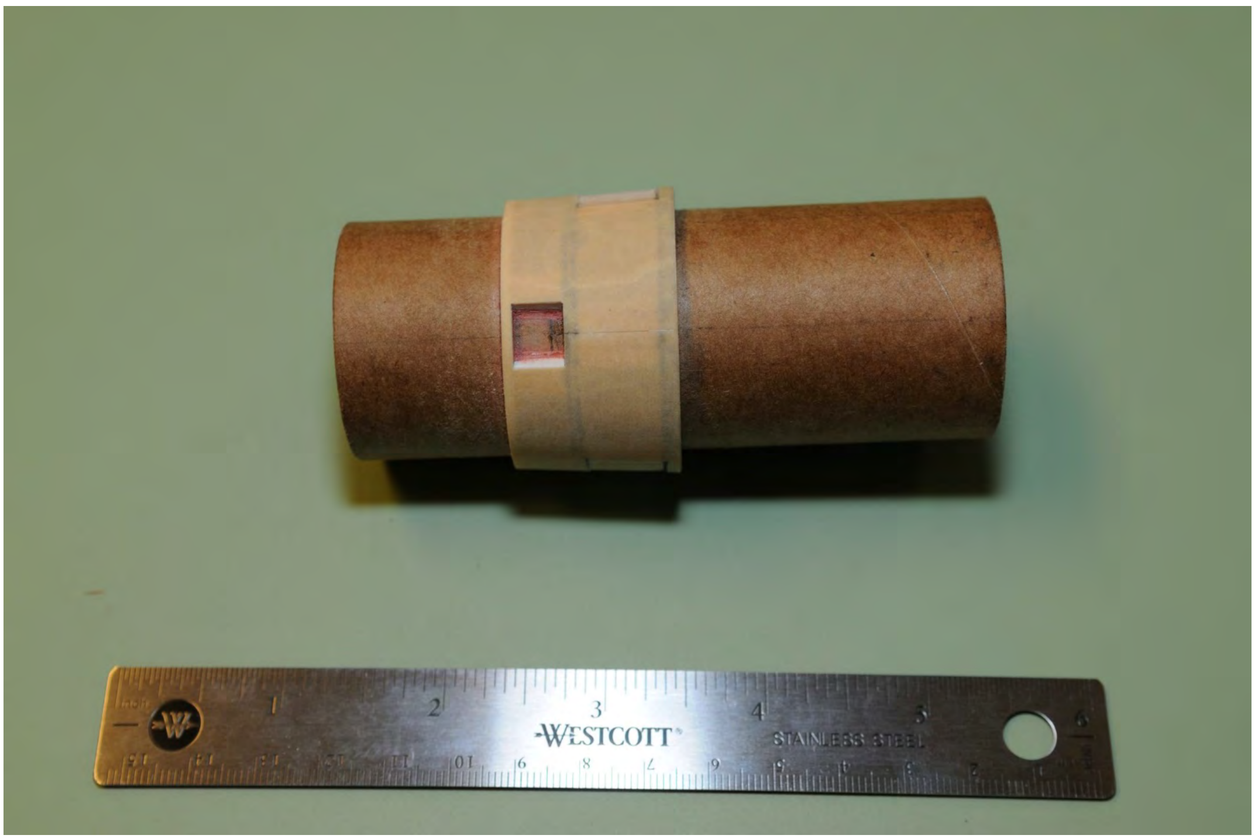

Photo 11: Shroud Joint

Sometimes shroud joints can be hard to disguise because of that backing joiner strip, but in this case, we don't have one; the conformally sanded balsa infill provides ample gluing surface to tack those joint edges down, keeping everything tight and smooth to the curve of the transition. As well, the joint is minimized by placing it in a position where some of it would be cut out, as Photo 11 shows.

After saturating the installed shroud with CA and letting this cure, a fresh sharp blade in the hobby knife was used to carefully cut out the various pockets and ports. These were fairly easy to find, as the CA renders the cardstock somewhat translucent. Photo 12 shows the result.

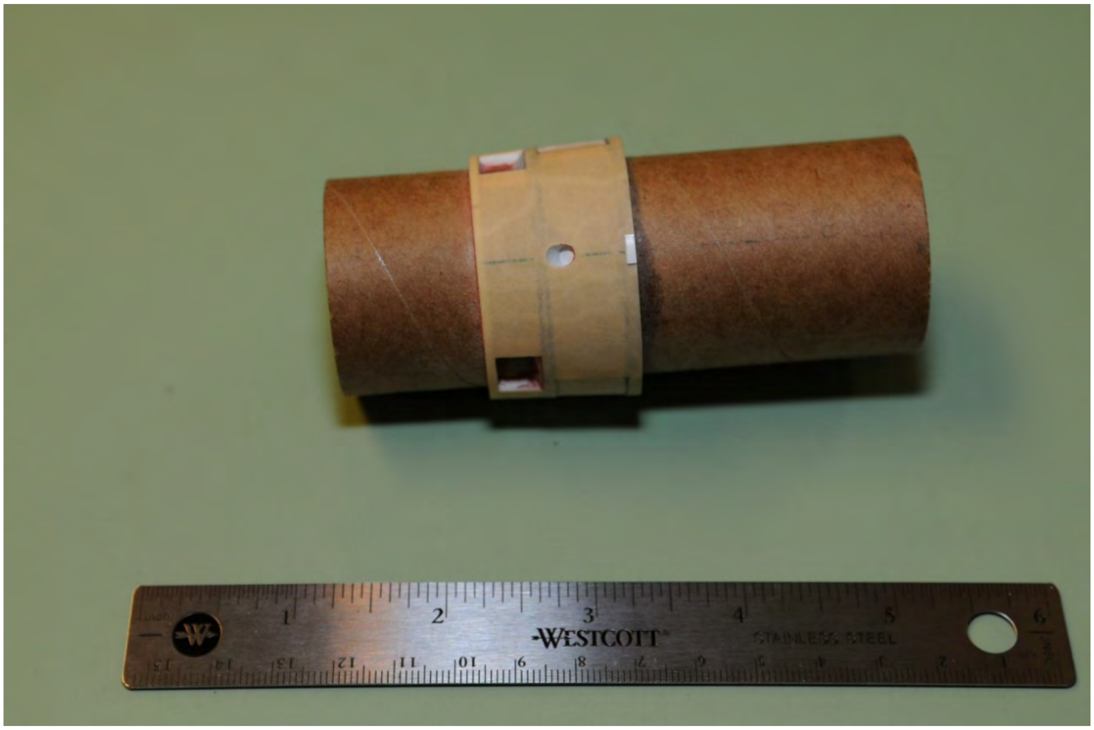

Photo 12: Pocket Cuts

Edges were checked for fit, sanding and filing where necessary, and some putty was used to create the top angled faces of the bolt slot pockets. Once ready, off to the paint shop for some primer.

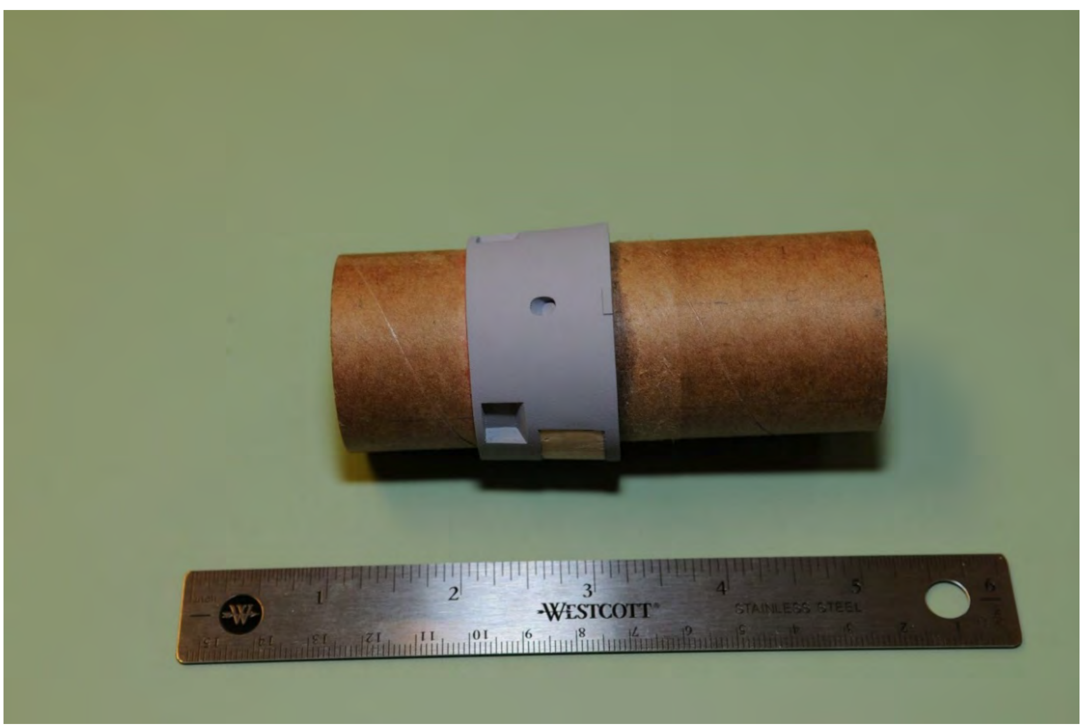

Photo 13: Primer

Now it's time to address the Panel Covers for the Instrumentation section. They had been left off for the first primer round to avoid excessive primer build up in the panel seams. With a miniature punch the correct scale-sized screw holes are placed in the covers. Then each cover is saturated with CA and allowed to dry. A bit of sanding and they're ready for installation.

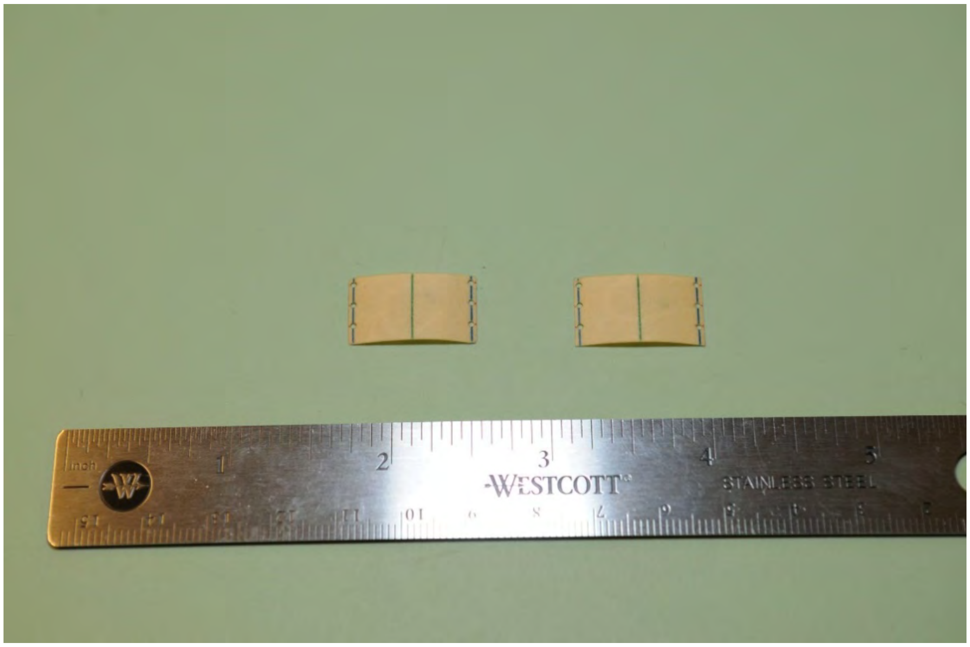

Photo 14: Panel Covers

Another primer application, and we'll also take the opportunity to try a trial fit of the mating bolts in the access slots to see how they look.

Photo 15: Mating Bolts Trial Fit

The mounting bolts are just miniature plastic socket head bolt heads; happily, they're near exact scale in size. While it's hard to see in the photo, there's also a Styrene disc placed underneath each bolt head representing its seating washer; these also were punched to scale size. These little assemblies will be glued into position as the last step just before painting the color coat.

One might ask whether the plan is to leave the screw holes vacant in the panel covers; one is tempted to do so, as at this size the empty holes lend definition to the part. But we're going to fill these in with miniature rivets to represent the screws that fasten the cover to the adapter. We have a rivet with a head sized to scale, and we'll press these into the underlying balsa so that the heads sit flush with the cover, just like the real screws did. Should look ok when done.

Altogether, some good progress towards completing the part, but as can be seen, the unit still needs some clean up before it's actually paint-ready. We'll work on that for a bit, and then move on to the Finishing stage.

Finishing

The adapter was primed with Rustoleum Automotive primer; any residual surface defects were filled with Squadron White Putty. Once satisfied with the surface, I installed the access slot bolt heads, and shot the assembly with Testors Olive Drab.

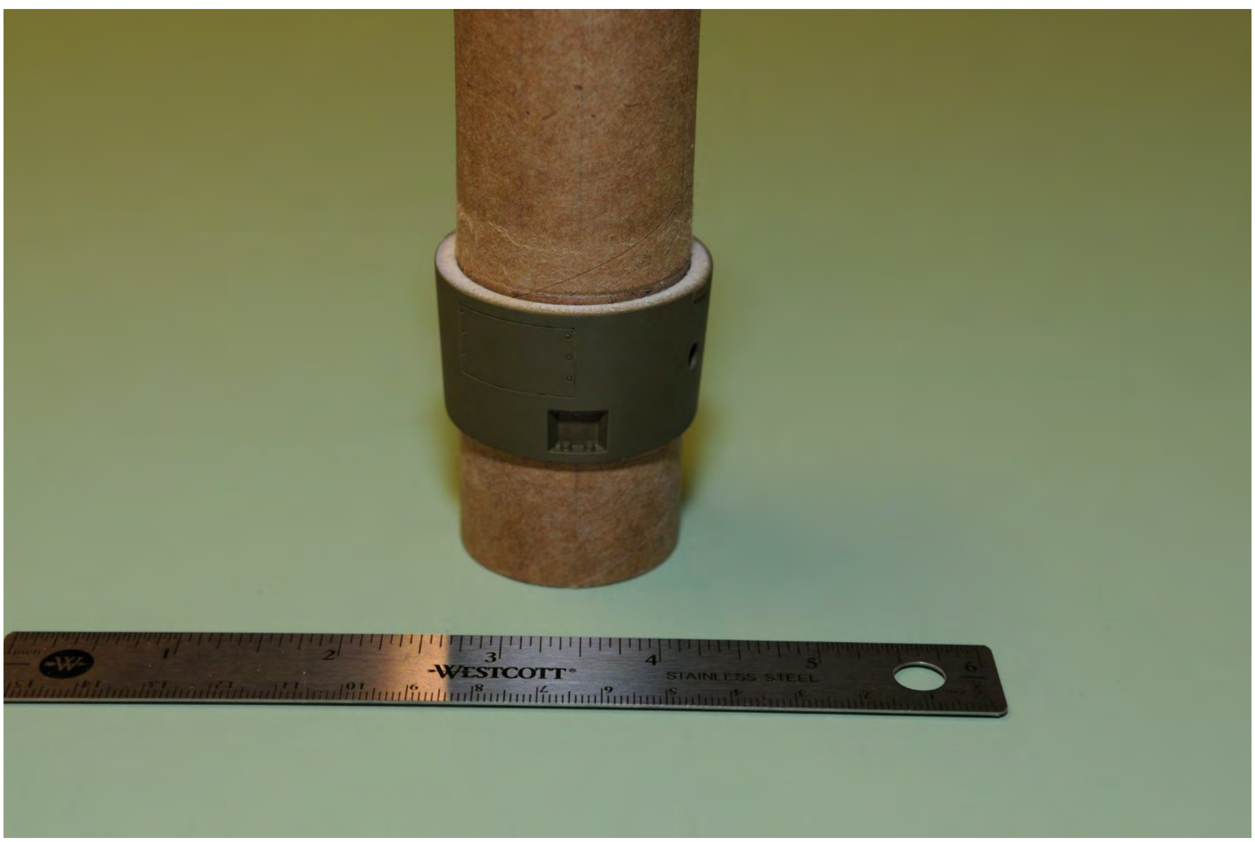

Photo 16: Payload Adapter - Painted

The next photo allows us a closer look, and we can see that the panel screws have also been installed.

Photo 17: Panel Screws

Almost done. There remains one last detail to add, that being the umbilical connector located in the umbilical port. We can see what this part looks like in the blueprint provided in the earlier Figure 1. I scaled the length and diameter of the connector (it's a Deutsch connector, but I've been unable to discover the actual part number used in the prototype) from the drawing, and found that at our scale factor, one of those plastic bolt heads I had used in the access slots was a close match (slightly smaller, but close). But we can also see that the connector is fastened to the bulkhead with a hexagonal nut; I again scaled its size from the drawing, and fashioned one from sheet Styrene.

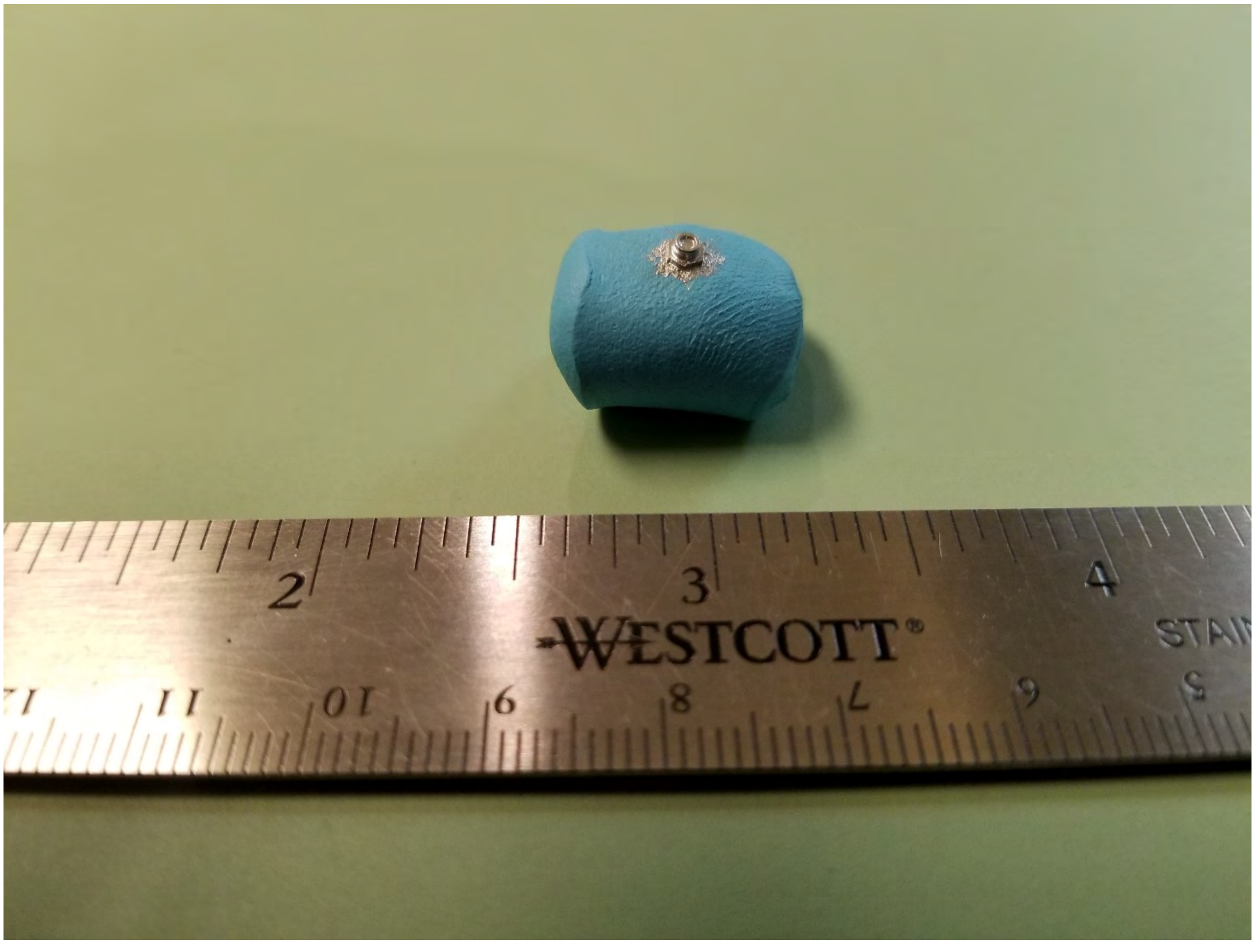

Photo 18: Umbilical Port Connector

I chose to paint this tiny assembly silver – this was an assumption made on my part, as I imagined that the connector was either installed after the adapter had been painted, or at the very least had been masked to protect the internal contacts in the connector while the adapter was being painted. Either way, it ought to provide some good contrast on what is otherwise a very drab assembly. Once the paint had dried, the simulated connector was installed with a dot of Humbrol Poly Cement.

Photo 19: Umbilical Connector Installed

And there you have it – an updated and accurate Javelin payload adapter, ready for scale action. Now we just need to build the payload section to go with it!