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# GLAST Tracker Corner Cables and Tower Assembly

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**Abstract**

The present design of the GLAST Tracker Tower Assembly uses four 0.024 inch diameter braided Vectran cables to hold the individual detector trays together in the stacked tower configuration. These cables are space qualified and significantly strong for their size. The procedure for assembling a tower assembly including cable preparation, tensioning, and termination is described in this technical document. Results from mechanical tests on the Vectran cables are also included.

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# Revision Log

| Revision | Date | Author | Summary of Revisions/Comments |
|---|---|---|---|
| OI | August 19, 1999 | S. Ney, E. Ponslet | Initial release. |
| A | April 12, 2000 | S. Ney | Updated document number, added Revision log |
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# 1. Summary

The purpose of this work is to document the procedure and fixtures used for stacking and tensioning the SLAC/GLAST beam test 99' tracker prototype tower. These procedures are similar to those developed in our Phase I NASA SBIR. Thicker Kevlar cables were used for the Phase I SBIR rather than the Vectran cables proposed for the GLAST tower assembly, but the procedures and fixtures developed are envisioned as being the same for the actual GLAST tracker assembly.

# 2. GLAST Tracker Tower Description

Figure 1 shows a sketch of the design for the GLAST beam test 99' tracker tower. Seventeen closeout trays carrying silicon wafer detectors are stacked one on top of the other with the detectors' direction alternated by 90 degrees from one tray to the next. Spacers are placed in the corners to maintain the correct spacing between the trays. In each of the four corners of the closeout trays, small holes allow for threading the tensioning cables through the entire tower stack. The process for assembling the tower is described in the next section.

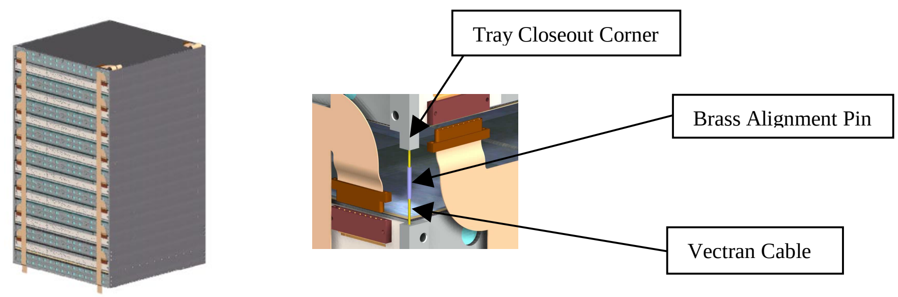



**Figure 1: GLAST tracker tower. (One side wall removed)**

# 3. GLAST Tracker Tower Assembly

## 3.1 Cable Selection and Design Load

Cable selection for the GLAST beam test 99' tracker tower was based on break strength, relaxation, Ultra-Violet (UV) light degradation resistance, abrasive resistance, and ease of termination. Three cables were considered: Kevlar B49/6x(2x195), Vectran LCP(6x400), and PBO BPBO(6x500). The PBO cable had the highest break strength of all three cables. However, the PBO fiber must be protected from UV light because the strength of the fiber decreases rapidly with increased duration of exposure. Also, the PBO cable braids are coated with a smooth, wax-like surface to help protect the fiber. The coating made terminations slip too easily, so it was difficult to get the full strength of the cable. (See appendix A for test results)

The Kevlar cable had excellent resistance to abrasion, and was very easy to terminate and get full pull strength out of the cable. However, the Kevlar is subject to pronounced relaxation, making it difficult to hold a predetermined load.

The Vectran cable had adequate strength, low relaxation, easy termination, excellent abrasion and UV degradation resistance, and the cable has a previous history of space applications. These qualities made the Vectran cable the most attractive of the three cables for this application. A series of pull tests were performed to determine what would be a safe design load for this cable. Based on these tests, 50 lb. is the maximum load that should be placed on a cable with terminations. Appendices A and B outline the tests done, and the results and conclusions made from these tests.

## 3.2 Vectran Cable Termination

Figure 2 shows all the tools used to perform a cable termination. These include a spool of BUT/6X400 Vectran cable from Cortland Cable Company Inc., Thin Pro CA cyanoacrylate glue from Tower Hobbies Inc., a box of copper Nicopress stop sleeves (part # 871-32-B) and a combination Nicopress Tool (part #'s 17-BA & 17-2) from Ver Sales Inc., a measuring stick, scissors, a wipe cloth, and some sort of metal bench vice.


**Figure 2: Supplies for cable termination.**

To complete a cable termination, the cable is unwound from the spool piece and measured to the appropriate length of cable needed. At least 6 additional inches should be measured out on top of the length of cable needed to allow for preparation of the ends. Place ½ inch of one of the ends of the measured piece of cable in the bench vice and tighten the vice. Grab the cable about 5-6 inches from the end that has been placed in the vice and pull the cable taught between your hand and the vice. Enough tension should be used to see the braids and diameter of the cable tighten. Using your other hand, take the open bottle of glue and apply a small amount along about 1.5 inches of cable **starting at a ¼ inch from the vice**. Take the wipe cloth and remove the excess glue if any. (**Note: It is important to keep the cable taught the entire time that glue is being applied and wiped.**)

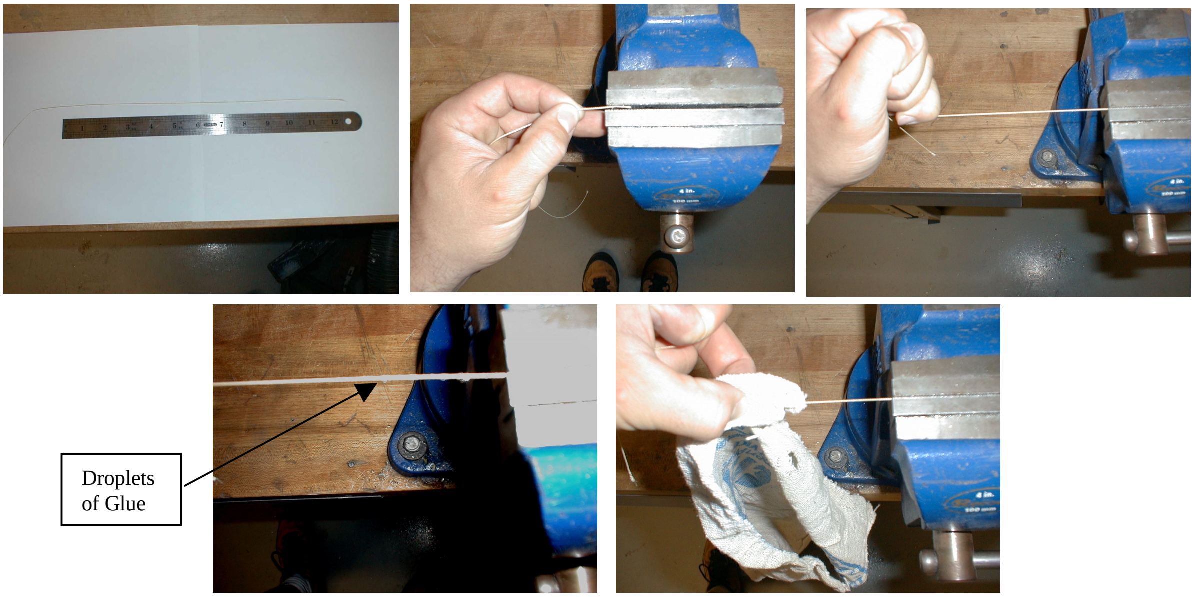



**Figure 3: Measure and stiffen cable with Pro CA glue.**

Hold the cable under tension for 5-10 seconds after wiping away the excess glue to let the glue left on the cable completely cure.

Now, take the scissors and while still holding the cable under tension, clip the cable halfway in the 1.5-inch section where glue was applied a few seconds ago. If the procedure was done correctly, you should have a very clean cable end. The stiffness of the dried glue in the cable allows the cable to be threaded through the stop sleeve as well as through the tray closeouts later on.

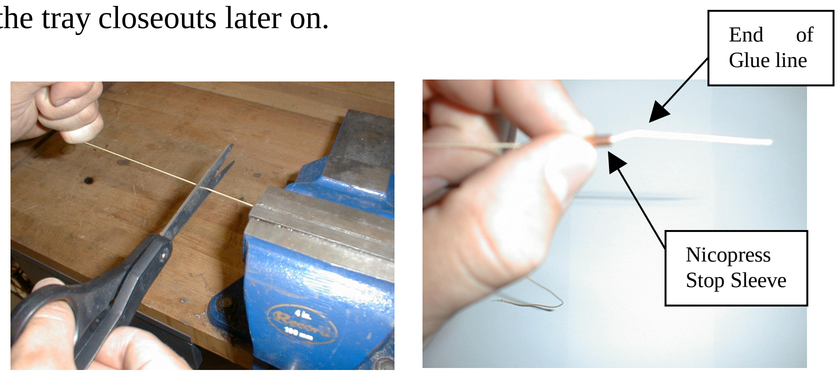
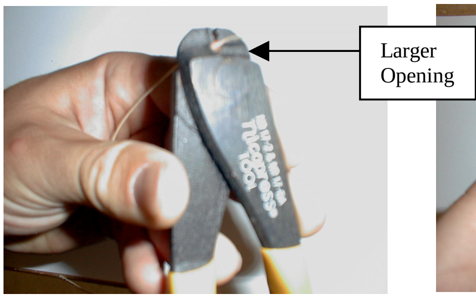



**Figure 4: Cut and thread cable through Nicopress stop sleeve.**

Next, take a copper Nicopress stop sleeve and thread the clean cable end through it. The copper Nicopress stop sleeve should be slid at least ½ inch past where the glue line (stiff section) in the cable ends. Taking the combination Nicopress tool, place the larger of the two openings in the tool around ½ of the sleeve. (**Note: Do not** let the stop sleeve move from its original position while placing the tool around the sleeve. It is very important that the stop sleeve be attached on an **unglued section** of the cable.

Attachment on the glued section will cause the cable to fail well below normal pull strength.) Press the handles of the tool together until the jaws of the tool are completely closed. Move the tool over to the other half of the sleeve, and rotate the cable and sleeve around until the tool is 90 degrees to the direction of the first press. Press the tool handles together again. If done correctly, you should see press lines from the tool on both halves of the stop sleeve at right angles to one another.



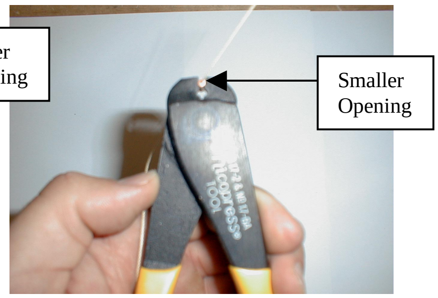




**Figure 5: Press Nicopress stop sleeve on cable; First using larger opening, and then using smaller opening in Nicopress combination tool.**

Start back at the first press with the press line oriented in the same direction as the jaws of the tool, but this time place the smaller opening of the Nicopress tool around the stop sleeve. We will press the sleeve two more times with the smaller opening to ensure adequate grip of the sleeve on the cable. **Press the stop sleeve only about halfway through the range of motion** of the tool. (**Note:** Pressing the stop sleeve more than halfway could cause damage to the fibers of the cable causing the cable to fail below normal pull strength.) Rotate the cable 90 degrees to the other half of the stop sleeve and finish pressing with the smaller opening of the Nicopress tool.

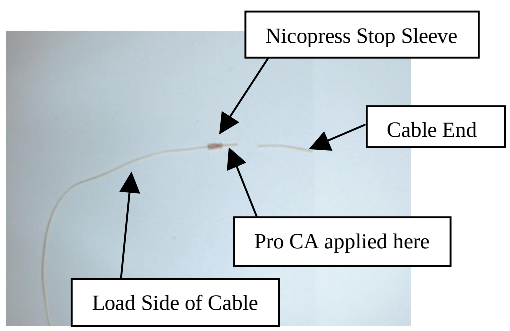



**Figure 6: Place some Pro CA glue on end of Nicopress stop sleeve to get a completed cable termination.**

The last step to terminate the cable is to place a couple of drops of Pro CA glue next to the stop sleeve on the side that is closest to the short end of the cable. Move the cable fibers around while applying the glue to insure proper absorption of the glue by the fibers of the cable. Wipe away excess glue. (**Note: Do not get glue on the other side of the stop sleeve.** Glue should be applied to the one side only. Glue on the other side **will**

**cause** the cable to fail below normal pull strength.) Trim cable on short end about ¼ inch from Nicopress stop sleeve.

Several pull tests were done with and without the Nicopress stop sleeves to determine the best way to do the cable termination steps described above to maximize the pull strength of the cable. The Vectran cable pull test results are listed in Appendix A.

### 3.3 Tensioning of GLAST Tracker Tower

Figure 7 shows the NASA SBIR Phase I tower in the tensioning fixture. The process and fixtures for tensioning the GLAST Tracker Tower should be similar. To tension a tower, first the tower must be assembled on the tensioning fixture base plate.

**Figure 7: NASA SBIR Phase I tower in tensioning fixture.**

The base plate is placed on its side and three support columns are attached for holding the upper plate. Four Vectran cables with Nicopress stop sleeves on one end are also threaded through small holes located on the bottom side of the bottom GLAST tray closeout. The base plate is reoriented vertically, and the bottom GLAST tray closeout is placed on the base plate and aligned to the base plate by the same bolt pattern used to attach the GLAST tracker tower to the grid on the satellite. Special recesses on the bottom of the corners of the bottom tray closeout will allow the pressed stop sleeves on the cable to sit in these recesses while the tray is attached to the base plate.

Note that a special bottom tray closeout was not used in the NASA SBIR Phase I tower. Instead tightly toleranced brass tubes and spacer blocks aligned the bottom tray closeout to the base plate. Figure 8 shows the first SBIR Phase I tray closeout being placed on the tensioning fixture. The four Vectran cables are threaded through the tray closeout corners.

Spacers are then threaded onto each of the corners of the tray closeout with the same brass locating tubes. The process starts over again with the next tray closeout until all 17 trays for the tracker tower are stacked on top of one another as seen in Figure 9.

Next, the upper plate is placed over the three support columns and slid down until it rests on three heavy hex nuts and washers. Nicopress stop sleeves are added to each of the cables, but are not pressed onto the cable until later when the cables are placed under tension. The cables are then threaded through the upper plate, through wire die springs, and each spring's top hat as can be seen in Figure 7. Last thing done once the cables have been routed through the entire tensioning fixture is to press the stop sleeve at the top end of each cable just above each spring's top hat.

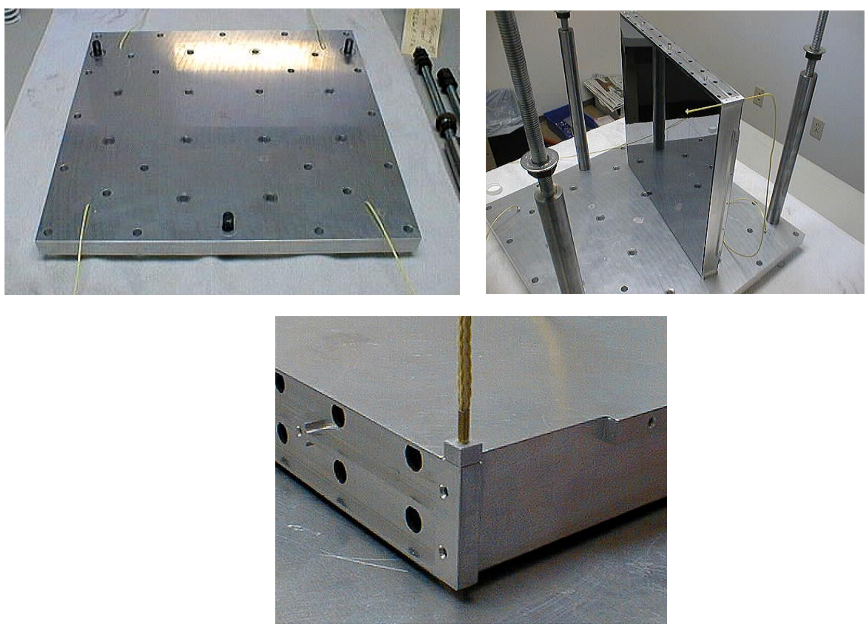


**Figure 8: Progression of placing first tray closeout on tensioning fixture base plate; (a) threading cables through base plate, (b) threading cables through first tray closeout, (c) threading spacer and brass locating tube on for the next tray closeout.**

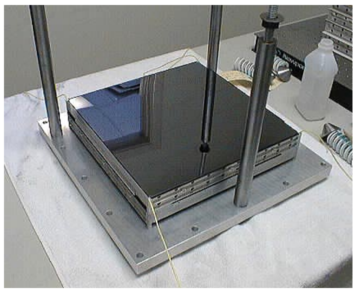
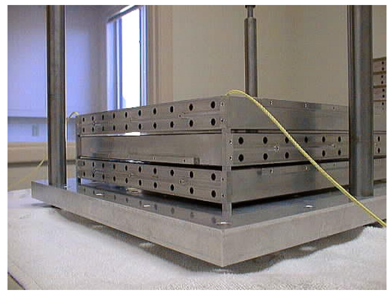
 

**Figure 9: Placing second and third tray closeout on tensioning fixture base plate.**

Once the upper-most stop sleeve is in place on each cable, the upper plate can be raised by turning the heavy hex nuts on each column. The upper plate will compress the calibrated springs against the cable termination just above each top hat thus placing each cable in tension. The four springs were chosen from a batch of 10 springs to get the closest match of spring rates. Spring rates were around 258 lb./inch for the cables used on the SBIR Phase I. Cable tension for the SBIR Phase I was about 200 lb., but the cable was a thicker Kevlar cable rated for much higher pull strength than the Vectran cables for the GLAST tracker tower.

For the Vectran cables, maximum allowable tension should be 50 lb. This number is based on pull tests in appendices A and relaxation tests in appendices B. The correct load is reached by measuring the compressed length of the springs. The tower should then sit for a day to allow for any relaxation in the cables. The next day the compressed length of the springs should be checked again and adjustments made to the heavy hex nuts underneath the upper plate.

After tightening the tension in the cables, the stop sleeves that are sitting loose on top of the tower can be pressed in place. The tension in the cables makes it difficult to get Pro CA glue into the cable fibers on the appropriate side of the stop sleeves, but tapping the cable does help get some glue in them. Once the glue has had time to dry, the cables can be released from tension by lowering the upper plate. This should place the tower in compression. The cables will have to be cut to remove the tower from the fixture. In case adjustments are needed later on, the cable should be cut such that as much length as possible is left. This will insure that they can be re-threaded and re-tensioned in the fixture.

# 4. References

1. E. Ponslet, S. Ney, W.O. Miller, *Innovative, Low-Mass, Passively Cooled, All Composite Material Tower Structure for High Resolution Charged Particle Tracking in a Gamma-Ray Space Telescope*, HYTEC Inc., Los Alamos, NM, NASA SBIR #97-1 17.01-5179, October 1998.

## 5. Appendix A

Table 1 gives the results of the cable pull tests without cable terminations. Three different cables were selected for comparison based upon manufacturer's listed pull strength, relaxation, abrasive resistance, chemical resistance, and aerospace applications.

| **Sample #** | Kevlar Cable B49/6x(2x195) | Vectran Cable LCP(6x400) | PBO Cable BPBO(6x500) |
|---|---|---|---|
| | Pull Strength (lbf) | Pull Strength (lbf) | Pull Strength (lbf) |
| Sample #1 | 64 | 77 | 118 |
| Sample #2 | 63 | 74 | 115 |
| Sample #3 | 67 | 74 | 113 |
| **Average** | **65** | **75** | **115** |

**Table 1: Cable pull tests without cable terminations.**

The PBO cable performed the best overall, but the cable was difficult to grab with the pull fixture on our load frame due to a wax type coating that is applied during fabrication of the cable. This wax coating made it very difficult to grab the cable with the Nicopress stop sleeves. Also, the fibers degrade rapidly in Ultraviolet light. These two factors made the Vectran fiber more attractive for our application.

Table 2 gives the results of cable pull tests with cable terminations.

| **Sample #** | Kevlar Cable B49/6x(2x195) | Vectran Cable LCP(6x400) | PBO Cable BPBO(6x500) |
|---|---|---|---|
| | Pull Strength (lbf) | Pull Strength (lbf) | Pull Strength (lbf) |
| Sample #1 | 62 | 64 | 49 (Termination started to slip) |
| Sample #2 | 69 | 62 | 53 (Termination started to slip) |
| Sample #3 | 65 | 59 | - |
| **Average** | **65** | **62** | **N/A** |

**Table 2: Cable pull tests with cable terminations.**

The Kevlar cable performed the best with cable terminations. This is due to the high abrasive resistance of the Kevlar fiber. The pressing action of attaching the Nicopress stop sleeves tends to pinch the fibers in the cables. When the cable is pulled in tension, the pinched fibers are slowly cut as the cable tries to slip through the stop sleeve. The Vectran cable was still very close in performance to the Kevlar cable. The PBO fiber could not be gripped properly with the cable terminations explaining its poor performance for these tests.

## 6. Appendix B

Relaxation results are presented in table 3 below.

| Relaxation Test with Cable Terminations | | | | | |
|---|---|---|---|---|---|
| Kevlar Cable B49/6x(2x195) | | Vectran Cable LCP(6x400) | | PBO Cable BPBO(6x500) | |
| Start | End | Start | End | Start | End |
| 6/12/99 | 6/13/99 | 6/13/99 | 6/14/99 | 6/14/99 | 6/15/99 |
| 9:45am | 9:45am | 11:00am | 11:00am | 11:10am | 11:10am |
| 40 lbf | 32.1 lbf | 40 lbf | 35.7 lbf | 40 lbf | 32.1 lbf |

**Table 3: Relaxation tests with cable terminations.**

The Vectran cable had the least amount of relaxation over a 24-hour period, so a long term relaxation test (1 month) was done with the Vectran cable to measure its relaxation curve. Figure 10 shows the curve for the Vectran cable.

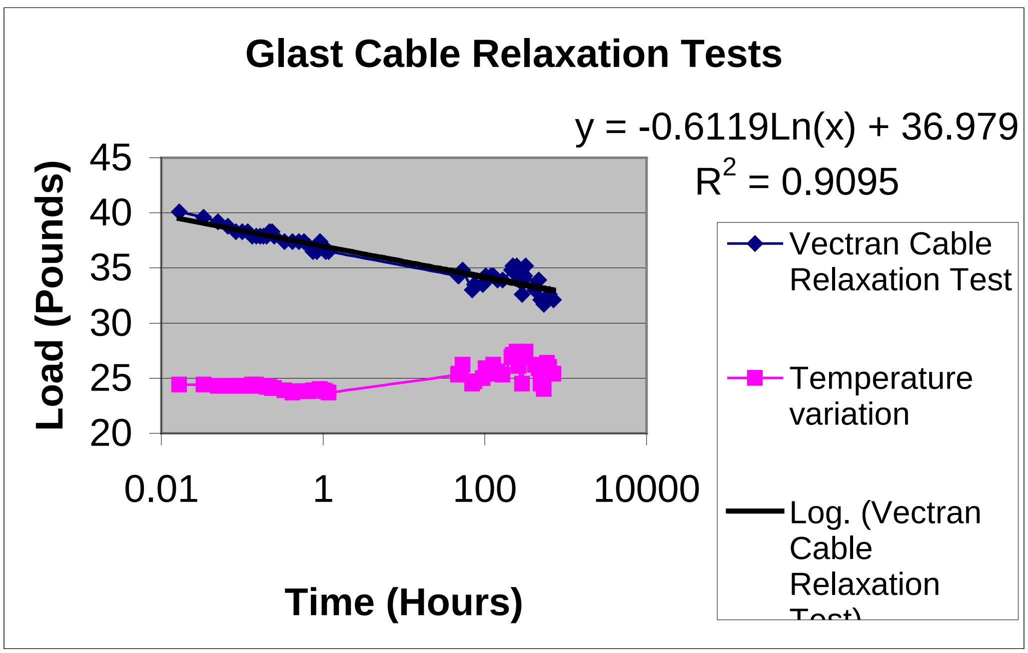



**Figure 10: Graph of relaxation curve for the Vectran cable.**