APPENDIX A

REPORT ON THE INSTALLATION OF THE NATIONAL CORS PROTOTYPE MONUMENT

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This report documents the procedures, materials, and costs involved in the setting of a prototype National CORS (Continuously Operating Reference Station) monument, as directed by the Executive Steering Committee in the Team Charter of Process Action Team 20 (PAT 20). The prototype monument was set to verify the recommendations developed by PAT 20 and to determine if any modifications were required to those recommendations.

The installation of the prototype for the National CORS monument took place on November 23 and 24, 1999, at the Instrumentation and Methodologies Branch's location in Corbin, Virginia. PAT 20 members overseeing the installation of the monument were Miranda Chin, Orland (Audie) Murray, and Dennis Hoar. Assisting were Shep Cofer, Richard Male, and Bill Rindal of the Instrumentation and Methodologies Branch and Mark Eckl of the Global Positioning System Branch.

The Team prepared for the installation of the monument by arranging with contractors to inspect for underground utilities, to drill the hole, and to deliver 2 cubic yards of concrete made from Type IIIA portland cement. The Team procured, in advance, the materials for the construction of the antenna mount, the reinforcement rod assembly, and the monument form. The materials were purchased from various local and mail order vendors and were stored at the Corbin facility.

"Miss Utility" (an organization comprised of utility companies) was contacted and arrangements were made for them to mark the location of any underground utilities in the area chosen for the installation of the monument. It is a requirement of the Commonwealth of Virginia (most states have a similar requirement) to contact "Miss Utility" at least 48 hours in advance of any digging. This is a free service provided by the utility companies. "Miss Utility" did not locate any underground utilities near the site selected for the installation of the monument.

Rappahannock Electric Cooperative was contracted to drill the hole for the monument. Locating a contractor to do this work required more time than the Team had anticipated. Several local contractors had equipment that could drill up to a 12-in.-diameter hole, but only one had equipment that exceeded the 18-in. minimum diameter that the Team recommends. The Team requested an auger capable of drilling a 24-in.-diameter hole to a minimum depth of 10 ft. Rappahannock Electric Cooperative said that they could meet the Team's requirements; however, the diameter of the auger on the truck that arrived at the site was only 21 in. The Team decided that a 21-in.-diameter hole would be adequate because it exceeded the minimum specifications recommended by the Team.

Rowe Concrete (Spotsylvania Plant) was contracted for the concrete. Locating a contractor to deliver the concrete was straightforward, since Type IIIA portland cement is a standard mixture for many large concrete companies. Type III portland cement provides high strength in an earlier time period than other mixes. This is important if the weather is cold or if the structure will need to be used quickly. The "A" in Type IIIA means the concrete is air-entrained. Air-entrainment adds small air bubbles to the concrete, which significantly improves a structure's resistance to freezing and thawing. The delivered concrete had a 3/4- to 1-1/2-in.-size aggregate, which satisfied the requirement that the maximum size of the aggregate should not exceed three-fourths the clear space between individual reinforcing rods or similar members such as the legs of the antenna mount. The 2 cubic yards of concrete that the team calculated as being the amount of concrete required for the monument was less than the contractor's minimum load quantity of 4 cubic yards, so they charged an additional fee for the "short load."

Arrangements were made with Rappahannock Electric Cooperative to drill the hole on November 23 and with Rowe Concrete to deliver the concrete on November 24. The Team decided to have the drilling and concrete delivery done on consecutive days to allow time to resolve any unexpected problems that might occur during the drilling process.

The antenna mount, the reinforcement rod assembly, and the monument form were fabricated at the Corbin facility using the materials purchased from local and mail order vendors. These monument components were fabricated prior to the drilling of the monument hole. The materials purchased for the monument components included:

1 - 6-in.-diameter by 1-in.-thick piece of Delrin polymer plastic plate, rough cut into a circular shape

1 - 1-in.-diameter by 9-ft.-long Delrin rod (3 ft. required)

1 - 12-in.-diameter by 12-ft.-long Sonotube

1 - Standard rotating tribrach adapter

1 - 5-in.-diameter by 1-ft.-long PVC pipe

1 - 10-32 by 1-1/2-in.-long stainless steel socket head cap screw

3 - 5/16-in.-diameter by 1-1/2-in.-long bolts

4 - 5/8-in.-diameter by 5-ft.-long Delrin rods

6 - 18-in.-long wooden stakes

8 - 8-ft.-long 2x4 lumber

- miscellaneous screws and plastic ties

Shep Cofer performed the machining of the materials for the antenna mount (Figure 1). A lathe was used to smooth the edges of the 6-in.-diameter Delrin plate. The 1-in.-diameter Delrin rod was cut into three 1-ft.-long legs. Threads were machined at one end, a point machined at the other, and groves machined in the sides to provide a place for the concrete to grip the legs. Holes for the legs and studs were drilled and tapped into the 6-in.-diameter plate. Three studs were machined from the 5/16- by 1-1/2-in.-long stainless steel bolts. The legs and studs were screwed into the plate. The feet were removed from a standard rotating tribrach adapter, the tribrach adapter was then placed onto the studs, and the set screws were tightened. The standard locking screw was removed from the adapter and replaced with a 10-32 by 1-1/2-in.-long stainless steel socket head cap screw. This will allow for tightening the locking screw after the antenna is in place. This antenna mount was placed in the top of the concrete pier.

A form (Figure 2) for the 5-ft.-long pier portion of the monument was constructed out of a 12-in.-diameter, 12-ft.-long Sonotube (12 ft. is the shortest standard length available). The height of the pier was limited to 5 ft. not only to ensure that the center of gravity remained well below ground but also to allow precise levels to be used in determining the orthometric height of the top of the antenna adapter, i.e., the antenna reference point (ARP). Thus, a 5-ft. length and a 1-ft. length were each cut from the Sonotube. Six pieces of 2x4 lumber were cut into 30-in. lengths with one end beveled at 60 degrees. Three each of these 2x4 lengths were attached in a triangular shape to the top and bottom of the 5-ft.-long form. These constructions were used to attach braces to the form to hold it in place during the pouring and curing of the concrete. The 1-ft. section of Sonotube was used to mark the approximate center of the mass of concrete poured into the ground. This simplified the process of placing the 5-ft. form in the correct position.

A reinforcement rod assembly (Figure 3) was constructed out of the 5/8-in.-diameter, 5-ft.-long Delrin rods and 5-in.-diameter PVC pipe. Four rings, each approximately 1-in. wide, were cut from the PVC pipe. Four pairs of holes, about 1-in. apart, were drilled into each of the four rings at about a 90-degree spacing. Plastic ties were used to connect the four 5-ft.-long sections of 5/8-in. Delrin rod to the four PVC rings, which were spaced at about even intervals along the rods. A potential problem was discovered when we noticed that the rings slid easily down the rods. The smooth surface of the rods did not provide enough resistance for the plastic ties to hold the rings in place. To remedy this, grooves were cut in the rods with the lathe. The plastic ties were placed in the groves and through the holes drilled in the PVC rings. This formed a reinforcement rod assembly having a diameter of 6 in. and a length of 5 ft. This assembly was placed in the monument to provide shear strength at the point where the poured concrete monument structure was to be reduced to a diameter of 12 in. at ground level.

The auger truck arrived 8:10 on November 23 at the selected monument site that was pre-approved as a safe location to dig by “Miss Utility.” The truck is owned by the Rappahannock Electric Cooperative and was outfitted with a 21-in.-diameter flight auger capable of drilling a hole to a depth of 15 ft. The truck was manned by a two-person crew of which one person operated the auger while the other directed the position, angle, and depth of the drilling. It took about 10 minutes for them to set up the rig and to attach the flight auger (Figure 4). The drilling process (Figure 5) took only 15 minutes to reach a depth of 11 ft., 4 in. (Figure 6). This time period included the operator stopping the drilling to occasionally lift the auger out of the hole to clear away excess soil from the hole and flight augers. The ease with which the hole was drilled is attributed to the local soil composition of loam, sand, and clay. The top 1 ft. was loam, followed by a layer of sand, and the remaining soil was clay. This soil composition was soft and dry, but contained enough moisture that the surrounding soil did not collapse into the hole. The diameter of the finished hole was 22 in. The water table was of sufficient depth that water did not seep into the hole, even after setting overnight. This was an unexpected bonus since the presence of water would have complicated the pouring of the concrete. The truck departed at 8:45, for a total of 35 minutes on site.

The large pile of soil was then removed from around the hole (Figure 7). Eric Murray of the U.S. Geological Survey volunteered to operate his agency's front end loader to assist in the removal of the soil. This greatly reduced the amount of manual labor required to accomplish this task. It took almost twice as long (1 hour) to remove the soil as it did to drill the hole. The soil was hand shoveled into the bucket of the front end loader to minimize the possibility of soil falling back into the hole. The soil was then spread over low areas near the monument to smooth out the grounds.

The concrete truck arrived at the site at about 9:05 on the morning of November 24, 1999. Because the location of the monument is an open area and the soil conditions were dry, the driver of the concrete truck had no problems in maneuvering his vehicle into position to pour the concrete. The chute of the concrete truck was positioned directly over the hole, and the concrete was poured slowly to minimize the knocking of loose soil into and thereby contaminating the concrete (Figure 8). The pouring was halted every 2 to 3 ft. so a concrete vibrator could be inserted into the concrete to compact the mix (Figure 9). Care was taken to place the concrete vibrator in the mix for only a few seconds each time so as to not remove the air-entrainment nor segregate the aggregate.

This process was repeated until the hole was filled to within a couple of feet of the ground surface. At this point the reinforcement rod assembly was centered into the hole and pushed down into the concrete until approximately 2 ft. of the assembly was above the ground level (Figure 10). The pouring was resumed until the concrete was within a couple of inches of the ground surface. The 1-ft.-long section of Sonotube was placed over the rod assembly and, after measuring to ensure that the rod assembly was in the center, was gently pushed down into the concrete just enough to make a small indentation that could serve as a guide for centering the 5-ft.-long form (Figure 11). The 1-ft. piece of Sonotube was then removed and replaced with the 5-ft. form (Figure 12). Wooden stakes were driven into the ground next to the bottom wooden triangle that was attached to the form, and a 24-in.-long hand level was used to level the form before securing the triangular sides to the stakes using sheet rock screws (Figure 13). Long 2x4s were then attached to the top wooden triangle and secured to stakes (Figure 14). This arrangement was designed to hold the form securely in place while it was filled with concrete. The pouring of the concrete resumed at an even slower pace to ensure that the level would be maintained. The operator of the concrete truck advised against using the concrete vibrator inside the form as there would be a good chance that the force of the vibrator settling the concrete would rupture the form. A section of a 2x4 was used instead of the vibrator to tamp down the concrete after about 2 ft. of concrete had been poured into the form. This process was repeated until the concrete was about 1 in. higher than the form (Figure 15). The bracing worked as intended, as the form did not move out of level. This concluded the concrete pouring phase of the monument construction. The concrete truck departed the Corbin facility at about 10:00, for a total of about 1 hour on site.

The concrete mix was not as stiff as the Team had desired, causing some of the concrete to ooze out around the bottom of the form. (For durability, a maximum water-to-cement ratio by weight of 0.50 is recommended for concrete exposed to freezing and thawing in a moist environment.) This “oozing” at the bottom of the form did not appear to jeopardize the integrity of the monument, but the Team nevertheless decided to let the concrete firm up for an hour before troweling the top of the monument and inserting the antenna mount. After the delay, the top of the monument was troweled, forming a slight dome shape to prevent water from accumulating on the top of it. The antenna mount was then inserted into the center of the dome (Figure 16) and pushed down until the 1-in.-thick plate was imbedded about 1/2 in. into the concrete (Figure 17). This should prevent water from getting under the plate and potentially freezing and thereby separating the antenna mount from the concrete. The top of the monument was troweled smooth, and an arrow pointing toward true north was then inscribed into the top of the concrete pier (Figure 18) to help with the aligning of GPS antennas during observations. The concrete was allowed to cure for 16 days before the bracing and form were removed from the monument (Figure 19). The bracing and form could have been removed after 7 days; however, because of the cold weather, the team thought it prudent to allow extra curing time. The level of the antenna mount was checked (Figure 20) after the bracing and the form were completely removed, and it was found to be the same as when the monument was installed. The monument installation was completed (Figure 21) except for painting the exterior and installing PVC pipe to protect the antenna cables.

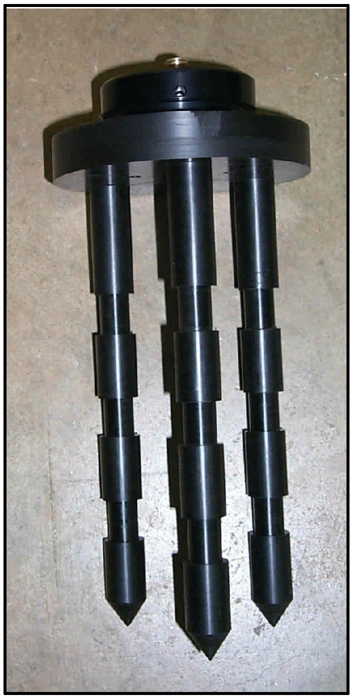

Figure 1

Figure 2

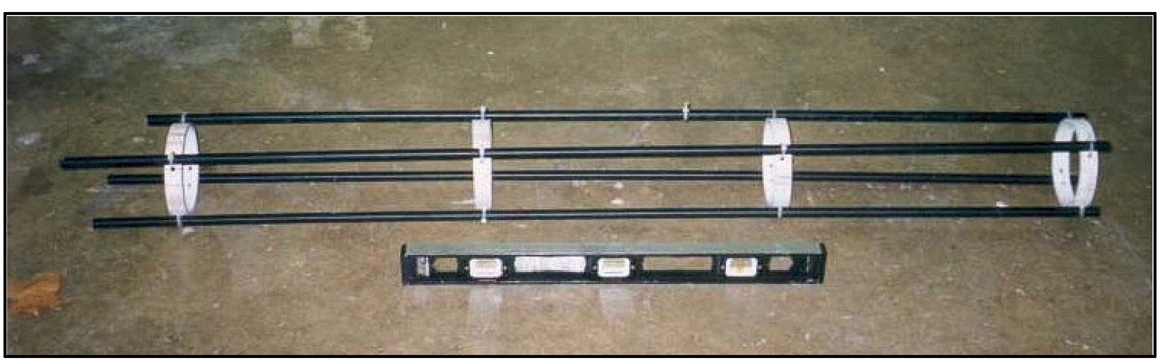

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

Figure 17

Figure 18

Figure 19

Figure 20

Figure 21

The installation of the prototype National CORS monument went more easily than PAT 20 had anticipated. The drilling of the hole and the pouring of the concrete took less time than was scheduled, meaning that both operations could have been completed in a single day. The Team recommends, however, that two days be scheduled between the two contractors to allow for the resolution of unanticipated problems, such as the presence of an underground ledge or of water in the hole.

The Team’s experience with the installation of this prototype monument led to only one major component being changed from the original recommendations. This change involved the material and length of the reinforcement rod assembly. The Team, based on the problem of the PVC rings sliding down the Delin rods during construction of the rod assembly, did additional research and found a company that manufactures a product called C-Bar. C-Bar is a reinforcing rod made of a polymer composite material that has a raised surface that will allow the PVC rings to be tied to the rods without having to machine grooves into the surface. C-Bar is non-metallic, is available in a variety of diameters and lengths, and is less expensive than Delrin. C-Bar resembles standard rebar in appearance and performs the same reinforcement function. The Team also increased its recommended length of the reinforcement rod assembly from 5 ft. to 8 ft. This will allow the rod assembly to extend 4 ft. into the above-ground pier and 4 ft. into the concrete below ground, thereby making a more solid monument.

There were two tasks that were not completed at the time of the monument installation due to the onset of cold weather. One task was to paint the pier with a white, waterproof concrete paint to seal the exterior from moisture. The other task was to place PVC pipes underground to protect the antenna cables that will run from the pier to the building that houses the GPS receiver. These tasks were completed in February 2000 after the air temperature remained above the freezing point.

PAT 20's Team Charter did not require that a geodetic position be determined for the prototype monument. The Team determined, however, that it would be necessary to establish a position of Order A accuracy for the monument in order to monitor its long term stability. This was done during the Virginia Federal Base Network (FBN) GPS project that took place from February to March 2000. Additional GPS observations will be done whenever there is a project in the area. This will allow for periodic monitoring of the stability of the monument. It is the recommendation of PAT 20 that the prototype monument be established as a National CORS. This would provide continuous, long-term tracking of the monument’s stability.

In conclusion, the installation of the prototype National CORS monument verified PAT 20's research that indicated a concrete pier is a design (Figure 22) that is low-cost, is relatively easy to install, and meets all known technical criteria for a benign GPS signal environment.

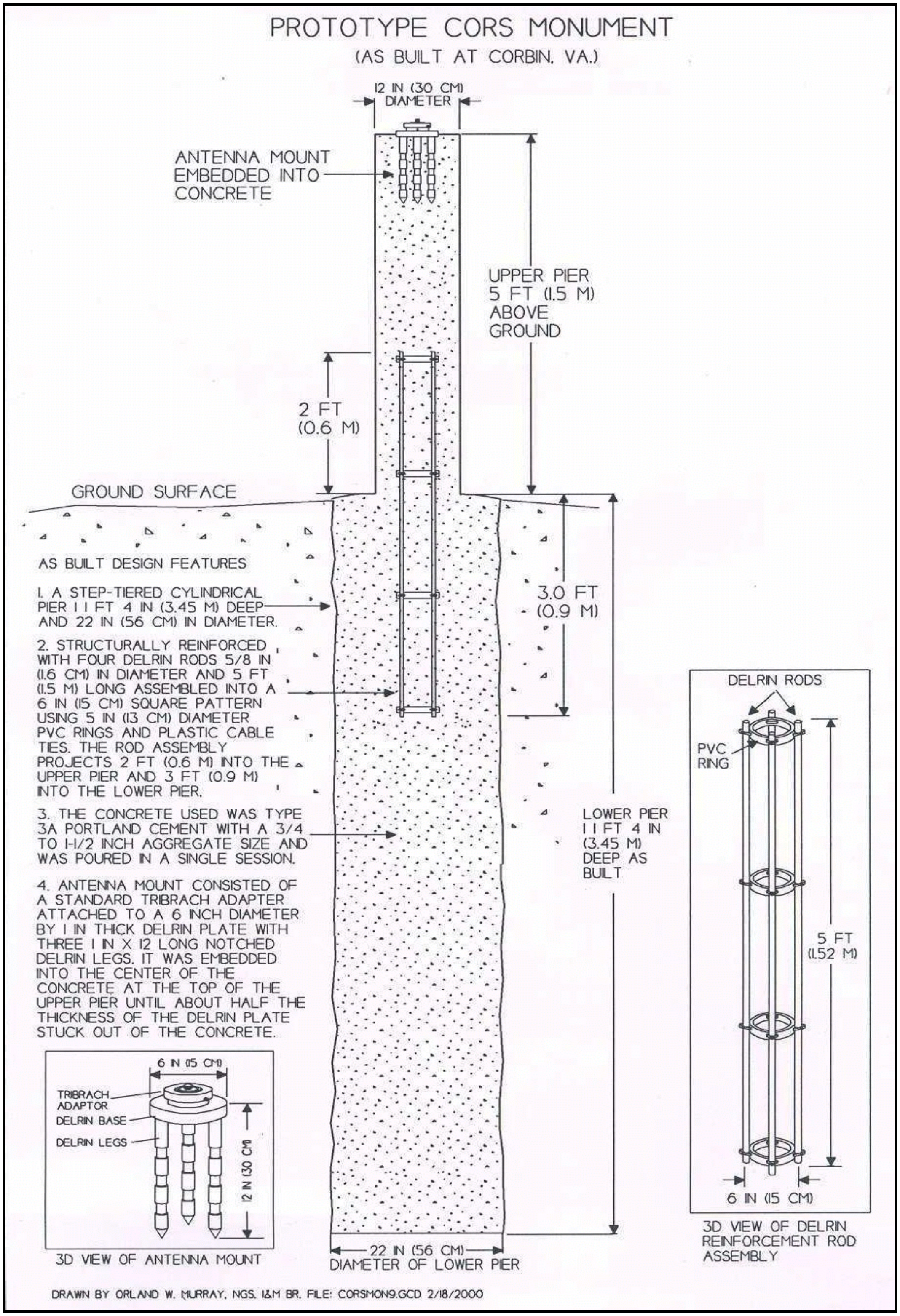
PROTOTYPE CORS MONUMENT
(AS BUILT AT CORBIN, VA.)
12 IN (30 CM) DIAMETER
ANTENNA MOUNT EMBEDDED INTO CONCRETE
UPPER PIER 5 FT (1.5 M) ABOVE GROUND
2 FT (0.6 M)
GROUND SURFACE
3.0 FT (0.9 M)
AS BUILT DESIGN FEATURES
1. A STEP-TIERED CYLINDRICAL PIER 11 FT 4 IN (3.45 M) DEEP AND 22 IN (56 CM) IN DIAMETER.
2. STRUCTURALLY REINFORCED WITH FOUR DELRIN RODS 5/8 IN (1.6 CM) IN DIAMETER AND 5 FT (1.5 M) LONG ASSEMBLED INTO A 6 IN (15 CM) SQUARE PATTERN USING 5 IN (13 CM) DIAMETER PVC RINGS AND PLASTIC CABLE TIES. THE ROD ASSEMBLY PROJECTS 2 FT (0.6 M) INTO THE UPPER PIER AND 3 FT (0.9 M) INTO THE LOWER PIER.
3. THE CONCRETE USED WAS TYPE 3A PORTLAND CEMENT WITH A 3/4 TO 1-1/2 INCH AGGREGATE SIZE AND WAS POURED IN A SINGLE SESSION.
4. ANTENNA MOUNT CONSISTED OF A STANDARD TRIBRACH ADAPTER ATTACHED TO A 6 INCH DIAMETER BY 1 IN THICK DELRIN PLATE WITH THREE 1 IN X 12 LONG NOTCHED DELRIN LEGS. IT WAS EMBEDDED INTO THE CENTER OF THE CONCRETE AT THE TOP OF THE UPPER PIER UNTIL ABOUT HALF THE THICKNESS OF THE DELRIN PLATE STUCK OUT OF THE CONCRETE.
LOWER PIER 11 FT 4 IN (3.45 M) DEEP AS BUILT
DELRIN RODS
PVC RING
5 FT (1.52 M)
6 IN (15 CM)
3D VIEW OF DELRIN REINFORCEMENT ROD ASSEMBLY
6 IN (15 CM)
TRIBRACH ADAPTOR
DELRIN BASE
DELRIN LEGS
12 IN (30 CM)
3D VIEW OF ANTENNA MOUNT
22 IN (56 CM)
DIAMETER OF LOWER PIER
DRAWN BY ORLAND W. MURRAY, NGS, I&M BR. FILE: CORSMON9.GCD 2/18/2000

Figure 22

COST OF INSTALLING THE PROTOTYPE NATIONAL CORS MONUMENT

Materials for Antenna Mount

1 - rotating Tribrach Adapter ....$ 82.00
3 - 5/16-in.-diameter by 1-1/2-in.- long stainless steel bolts ....$ 2.00
1 - 10-32 by 1-1/2-in.-long stainless steel socket head cap screw ....$ 0.50
1 - 6-in.-diameter by 1-in.-thick Delrin plate @ $29.00 ea. ....$ 29.00
1 - 1-in.-diameter by 3-ft.-long Delrin rod @ $3.00 per ft. ....$ 9.00
Shipping and handling ....$ 5.25

Subtotal $127.75

Materials for Pier

1 - 12-in.-diameter by 12-ft.-long Sonotube form..$ 25.91
4 - 5/8-in.-diameter by 5-ft.-long Delrin rods @ $1.88/ft. ....$ 37.60
Shipping and handling ....$ 12.07
2x4 lumber, wooden stakes, PVC pipe, misc screws & plastic ties ....$ 43.81

Subtotal $119.39

Contracted Services

2 - cu. yds. of Type IIIA concrete @ $74.00/cu. yd. $148.00
Short Load Fee ....$ 75.00
1 - Drilling of a 22-in.-diameter by 11-ft. 4-in. -deep hole $184.01

Subtotal $407.01

Rental

1 - Electric concrete vibrator with 8-ft. whip ....$ 34.65

***Total Cost $688.80**

*(costs exclude the salary and per diem of the NGS employees involved in the installation)

Contractors and Supply Companies

Concrete Company

Rowe Concrete (Spotsylvania Plant)
Fredericksburg, VA
Contact: Jeff - Ph: 540-710-0075
Sales: Sonotube and other supplies
Contact: Kevin - Phone: 540-538-1978

Delrin Supplier

Piedmont Plastics
Richmond, VA
website: www.piedmontplastics.com
Phone: (800) 266-7898
Fax: (804) 271-6798

Drilling Company

Rappahannock Electric Cooperative
Bowling Green, VA
Contact: Kevin Jordan - Phone: (804) 633-5011

Rental Company (concrete vibrator)

Fredericksburg Supplies & Rentals
Fredericksburg, VA
Phone: (540) 891-8244

For future Reference:

C-Bar Supplier

Marshall Industries Composites, Inc
Website: www.c-bar.com
Phone: (904) 443-6022