Subject: GLT Fiber Optic Cable Disassembly & Reassembly Plan	**Date:** 2020-08-20 DK001-2020-RevNC	**From:** Derek Kubo
To: Ming-Tang Chen	**cc:** T. Norton, S. Matsushita, P. Oshiro	**Location:** Hilo Office

1. Current Fiber Cable Configuration in Thule Air Base

The Greenland Telescope utilizes single-mode fiber optics for all communications between the telescope itself and the three primarly facilities that consist of: Control Trailer, VLBI Trailer, and Maser House. *Figure-1* describes the fiber cable routing currently in place in Thule Air Base. There are 12 individual cables consisting of 4 fibers each, for a total of 48 fibers. Note that cable W12 which carries the Local Oscillator signal is routed through the Azimuth axis (avoids spiral Azimuth cable wrap) and into the receiver cabin via the Elevation axis (avoids Elevation cable wrap).

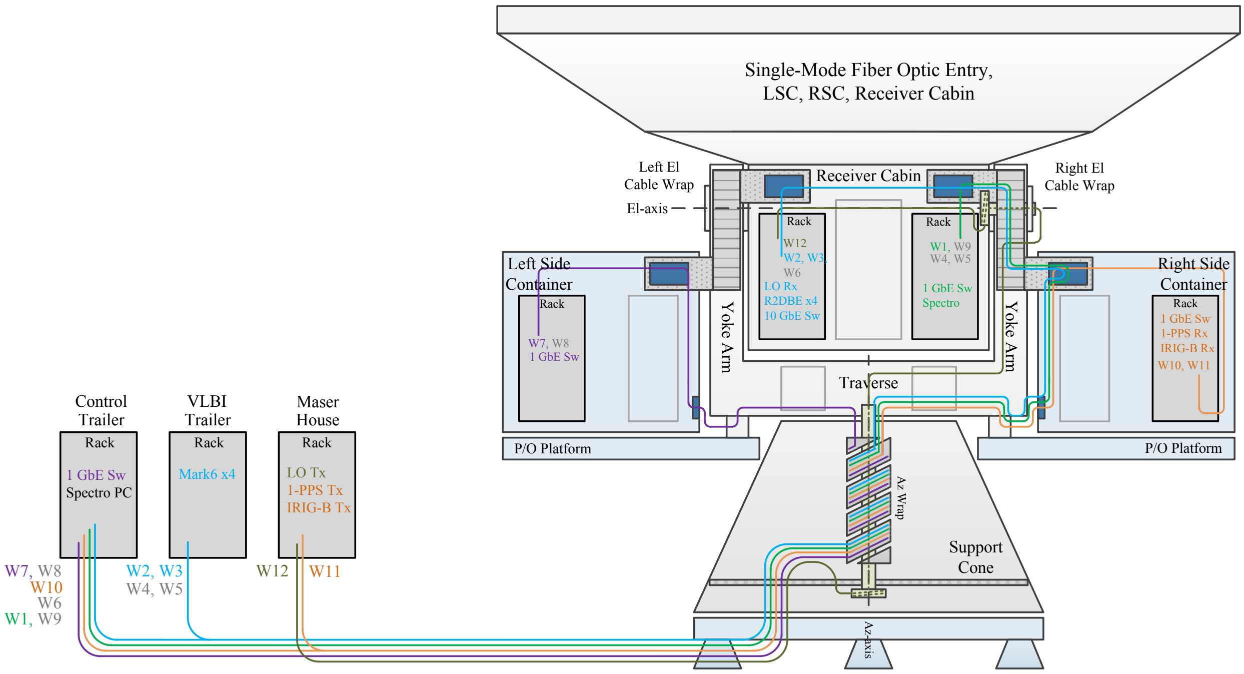


Figure 1 – Fiber optic cable routing between the three facilities and the telescope. There are 12 individual cables, W1 through W12, each carrying 4 fibers. Note cable W12 takes a different physical route through both the Azimuth and Elevation passages.

2. Fiber Selection

All fibers in the GLT system consist of 9/125 um single-mode optical fiber to support wideband communications. Two critical physical requirements include dynamic operation (bending/twisting) at low temperatures of -65C and tight bend radii of 33 mm static and 132 mm dynamic. These requirements apply specifically to the fibers residing in the telescope itself where it sees simultaneous low temperature and dynamic movement.

To satisfy the requirements we chose a custom cable provided by AFL, specification DNS-12215. This cable utilizes a stainless steel tube that encases 4 Verrillon VHS100 polyimide coated single-mode fibers. The stainless steel tube is protected by twelve 316 stainless steel wires and is covered by a black HDPE jacket with an OD of 3.8 mm. Refer to *Figure-2* below.

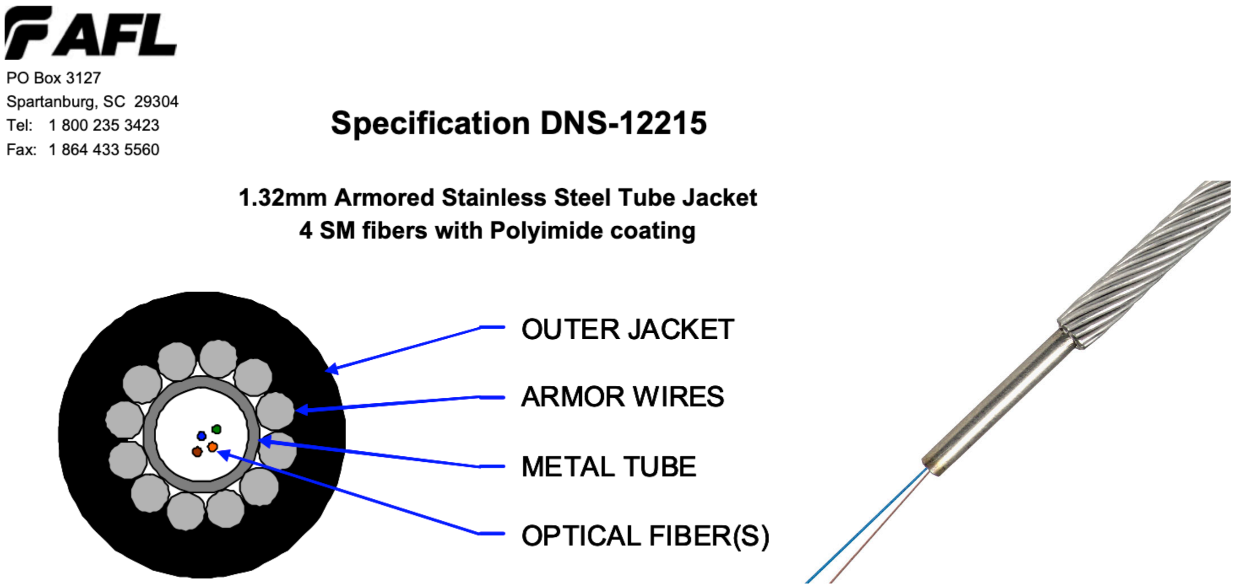


Figure 2 – Fiber optic cable routing between the three facilities and the telescope. Note that there are 12 individual cables, each carrying 4 Verrillon VHS100 fibers.

3. Fiber Terminations

Each of the 12 fiber cables consisting of 4 individual fibers for a total of 48 fibers. Each of these fibers are fusion spliced to SC/APC pigtails and are protected in a Fibercom 1U or 2U splice chassis as shown in *Figure 3* and *Figure 4*. There are a total of 96 fusion splices and connectors.

Figure 3 – Right Side Container splice chassis for W9 and W10 from control room, and W11 from maser house.

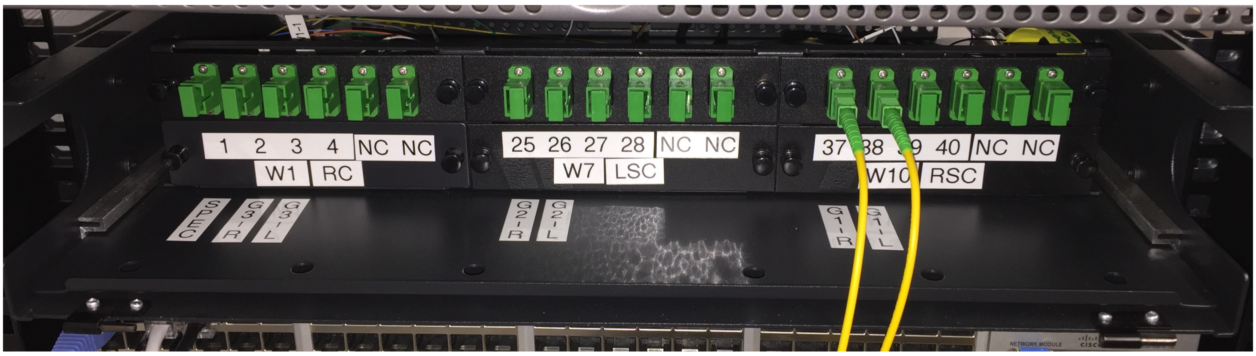


Figure 4 - Control trailer splice chassis for W1 to Rx cabin, W7 to Left Side Container, and W10 to Right Side Container.

4. Fiber Optic Cable Disassembly

It is my recommendation that we start by cutting off all SC/APC terminations at each end of the 12 cables (96 connectors) and remove the strain reliefs that secure the cables to the rack structures. This will permit the cables to be pull out one at a time and coiled for reuse. If a cable appears physically damaged (abraded or kinked) then we should label it as such and set it aside. We ordered a total of 1.5 km of DNS-12215 (described above) that consisted of 4 Verrillon VHS100 fibers at a cost of $29.43k USD in April of 2017.

5. Future Fiber Cable Configuration at Summit Station

The physical arrangement of the telescope and operation trailers are envisioned to be separated by approximately 5 km (3.1 miles). Refer to preliminary diagram in *Figure 5*. We plan to utilize the same low temperature AFL 4-fiber cable within the telescope as shown in *Figure 6*. 48 fusion splices will be used to connect the low temperature AFL fiber to a single armored 48 fiber cable that traverses the ~5 km distance. Similarly, at the other end of this cable, 48 fusion splices will be used to connect back to the low temperature 4-fiber cable (previously used) for distribution.

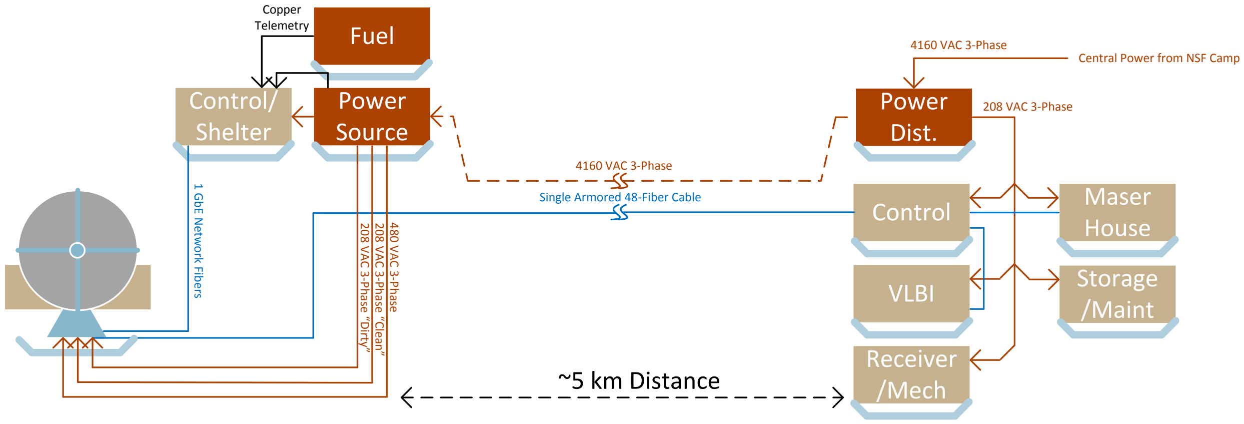


Figure 5 – Summit Station configuration. Note the telescope is located approximately 5 km distance from the support camp and necessitates a long fiber run.

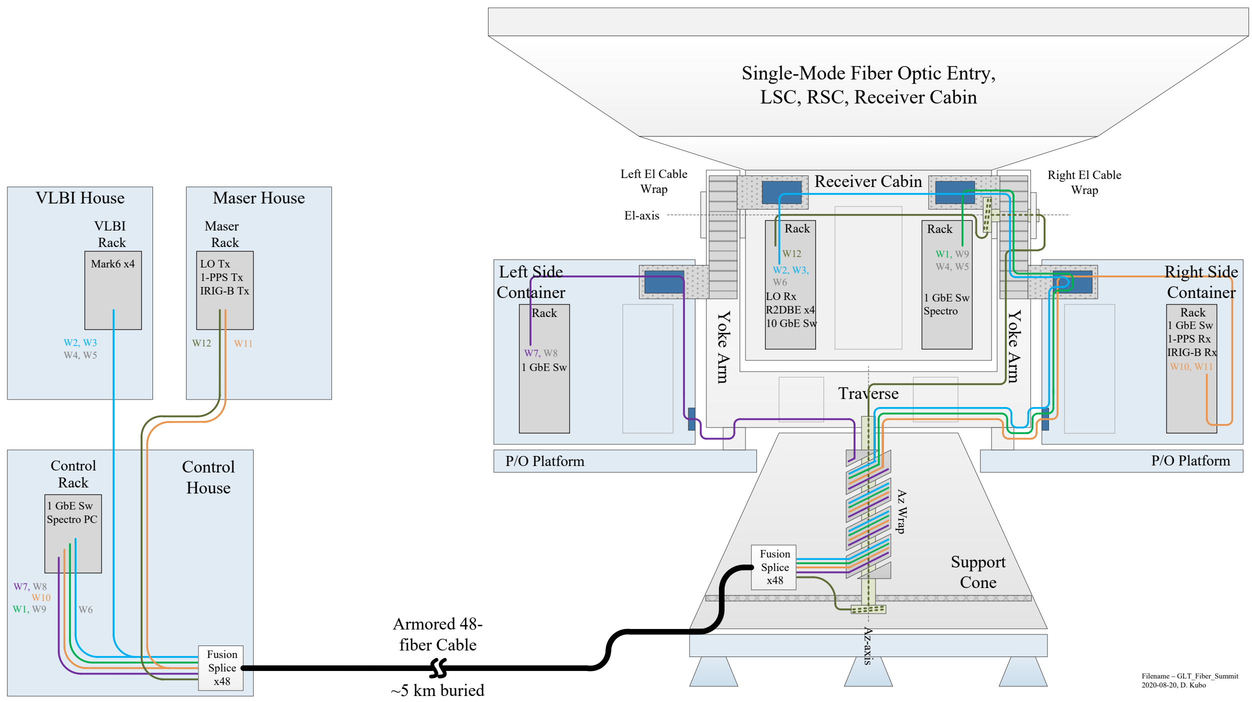


Figure 6 – Summit Station fiber description. Low temperature AFL fiber cables will be used with the telescope (same as today) and at the support camp facilities. AFL offers a standard armored 48-fiber cable for the ~5 km run

6. Preparation for Summit Station

There is much to do in preparation for the summit fiber infrastructure. A key element is to perform a site survey to determine the precise locations for the telescope and the support camp facilities. And for the actual laying of the ~5 km fiber cable (and 4,160 VAC 3-phase power?) we should establish a contract with Polar Field Services. For our ASIAA procurement I've listed some items below that we can begin purchasing when the budget becomes available.

6.1 Order Low Temperature AFL Cable – We ordered a total of 1.5 km of DNS-12215 (described in *Figure 2*) that consisted of 4 Verrillon VHS100 fibers at a cost of $29.43k USD in April of 2017. I recommend that we order another 1 km of the same cable for use within the antenna and to reuse the old fiber cable for the summit camp interconnections.

6.2 ID and order Armored 48-fiber Cable – A preliminary investigation has shown that there are several sources for normal armored 48-fiber single-mode cable. Some are touted as direct burial and implies no conduit is required. The distance is currently estimated as 5 km straight line but the actual cable route will likely meander so my suggestion is to order 1.5x more cable than the straight distance.

6.3 Order Hermetic Fusion Splice Enclosures – We've already identified a suitable fusion splice enclosure and have one on hand and ordered an additional 3 for use in the support cone (refer to *Figure 7*). We will order another 4 for the summit camp entry.

6.4 ID and order Termination Hardware – 3 m SC/APC pigtails qty 130, protective sleeves qty 300, cleaners, etc. in preparation for the large number (192) of fusion splices.

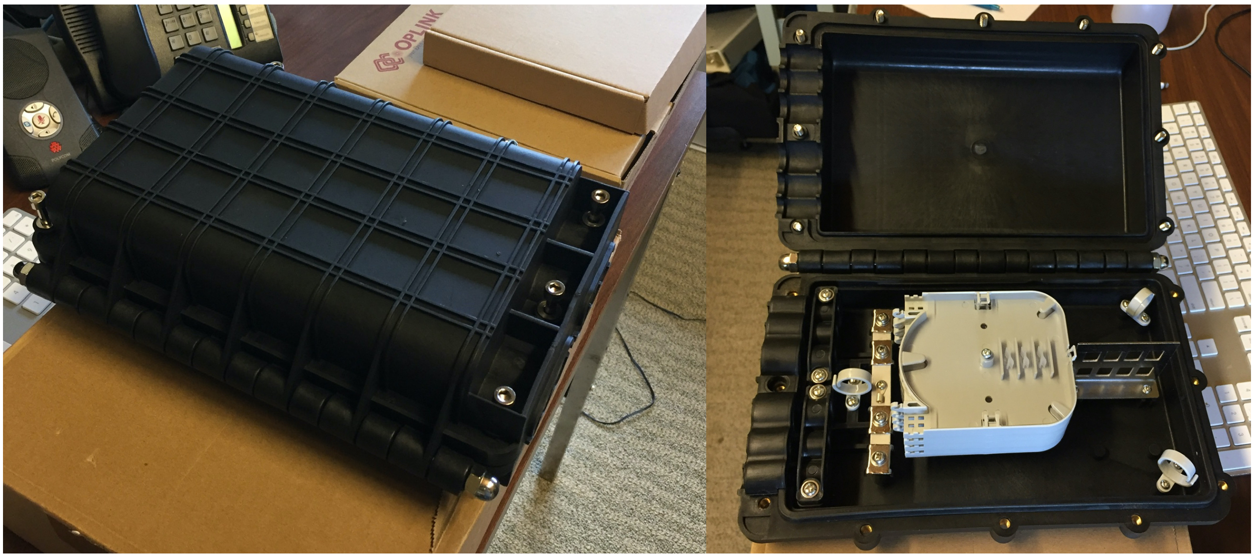


Figure 7 – Fibertronics HTB-502 hermitic fusion splice enclosure, $77 USD each.

7. Fiber Installation at Summit Station

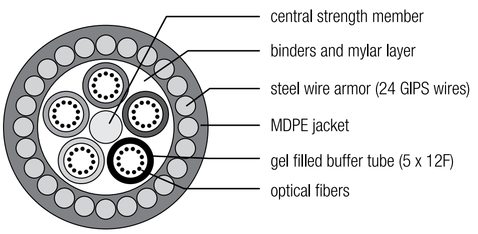
Though we have not determined the order of the assembly at Summit Station, it makes sense to build up the infrastructure prior to the arrival of the telescope. This includes the power station and the support facilities that consist of the Control, VLBI, and Maser Houses, along with the require workshops and storage facilities. With that completed we may begin with the installation of the previously used (removed from telescope in Thule) AFL DNS-12214 fiber infrastructure shown on right side of *Figure 5* and the left of *Figure 6*. There will be 12 separate fiber cables, W1-12, pulled from the fusion splice enclosures in the Control house to their various locations.

Installation of the 5 km long fiber cable can also proceed prior to the arrival of the telescope. I've preliminarily selected an AFL direct burial 48-fiber cable with specifications shown in *Figure 8*. We will have to consult with some experts to see if it is indeed feasible to direct bury in the snow and also how to route to accommodate ice movement.

High Strength Steel Wire (HSSW) Armored Fiber Optic Cable

AFL's High Strength Steel Wire (HSSW) Armored Fiber Optic cable provides the reliability needed for network backbones in harsh environment conditions. The high strength galvanized plow steel armor is enhanced and offers a significant improvement in mechanical performance as compared to traditional steel tape armored cables. With a near ten-fold improvement in tensile performance, a two-fold improvement in crush resistance, and a three-fold improvement in impact energy resistance, AFL's HSSW armored fiber optic cable provides the strength and durability needed for the most extreme conditions. Ideal for use as a direct buried cable in heavy construction zones including wind farm developments, pipelines, oil and gas fields, heavy industrial sites and a variety of additional harsh environments, AFL's HSSW armored cable meets or exceeds all requirements specified in Telcordia GR-20-Core.

Cable Components



Physical Properties

PARAMETER	VALUE
Fiber Count	1-60 *
Nominal Diameter	0.65 inches / 16.5mm
Nominal Weight	335 lbs/1000 ft. / 500 kg/km
Max Tensile Load	5,000 lbs/ 22.2 kN **
Minimum Bend Radius	13 inches / 33 cm
Termperature Range	Installation: -40 to + 70 degrees C Operation: -50 to + 70 degrees C ***

* Any combination of up to 60 fibers available
** Higher strength options available upon request
*** Expanded temperature ranges available upon request

Figure 8 – AFL armored direct burial 48-fiber cable. Fiber counts up to 60 and operation down to -50 C.

After the disassembled telescope has arrived at Summit Station via the GrIT transport, a significant effort will be placed in the reassembly and test of the telescope itself. We should consider establishing temporary network communications over the 48 fiber trunk to the support camp located ~5 km away.

The final segment of fiber installation can proceed once the telescope structure has been reassembled and completed. This will involve pulling of cables W1 through W12 using the newly purchased AFL DNS-12214 cable. The source and destinations within the telescope are indicated in the right half of *Figure 6* but please note that the physical configuration of the Receiver Cabin equipment will be changed in the near future to accommodate another science instrument. New details will be provided prior to commencement of the fiber work. Note that cable W12 which carries the critical Local Oscillator signals shall be routed through the direct Azimuth and Elevation axis (i.e., through both the Az and El encoders).

As a final note, our present fiber configuration in the receiver cabin has tens of meters of excess slack for each of the eight fiber cables, refer to *Figure 9*. It is my desire to minimize the excess slack within the Receiver Cabin to 2-3 m and to have additional excess slack located in the Support Cone where no motion takes place.

Figure 9 – View of excess fiber cable in Receiver Cabin looking toward the right Elevation Axis.