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National Shipbuilding Research Program (NSRP)
Cable Pulling Panel Project

Final Report

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The authors would like to thank for their contributions the members of the Integrated Project team (IPT), specifically Ben Zavitz and Greg Stevens of Bath Iron Works (BIW), and Dave Brookman of Newport News Shipbuilding (NNS). The authors would also like to thank Jason Farmer of Ingalls Shipbuilding (Ingalls) for his participation and support as Program Technical Monitor and Electrical Technologies Panel Chair.

MTS/jmm

EXECUTIVE SUMMARY

In ship construction, the installation of electrical cable, or cable pulling, is an expensive, labor intensive and injury-prone operation. Millions of feet of cable must be installed for each ship, in sizes ranging up to 4″ diameter and weighing upwards of 12 lbs. per foot. Most are in the overhead position with difficult to access locations that create many ergonomic, safety, and protection issues as well as added labor costs to install. Pulling cable is a very physical task that has resulted in hundreds of injuries that cost millions of dollars. With an aging workforce, pulling cable will be a major concern. The Navy's emphasis on improved quality, less tolerance of repairs/rework and fewer labor hours to build ships creates an opportunity to integrate existing best practices and equipment with new technology that will reduce ergonomic/safety risks, labor hours and overall ship costs.

This project for the Electrical Technologies panel of the National Shipbuilding Research Program has developed a number of simple and durable tooling concepts that will be effective in reducing the costs and injury rates for cable installation on board Navy ships. This report presents these concepts, along with an outline of the efforts taken to develop them, and recommendations going forward.

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1.0 INTRODUCTION

In ship construction, the installation of electrical cable, or cable pulling, is an expensive, labor intensive and injury-prone operation. New methods and requirements for cable installation are being added that will make it even more difficult. For example, DDG 1000 will be the most complex surface combatant ever constructed with approximately 2.8 million feet of complex cable routing and segregations (55% more than DDG 51). The cables range from ½" to 4" in diameter with larger diameter cables weighing upwards of 12 lbs. per foot. 80% of the cable runs are in the overhead with difficult to access locations, due to ship structure and more complex outfitting completed earlier in construction, that create many ergonomic, safety and cable protection issues. In addition, a human cannot physically fit into many of the spaces to grab the cable for pulling.

Historically, pulling cable is a very physical task that has resulted in hundreds of injuries that cost millions of dollars. With a shrinking and aging workforce, pulling cable will be a major concern with ship construction. The Navy's emphasis on improved quality, less tolerance of repairs/rework and fewer labor hours to build ships creates an opportunity to integrate existing best practices and equipment with new technology that will reduce ergonomic/safety risks, labor hours and overall ship costs.

To realize this opportunity, the Electrical Technologies panel of the National Shipbuilding Research Program (NSRP) approved this project to examine the current cable installation processes utilized at Newport News Shipbuilding (NNS) and Bath Iron Works (BIW), and to develop tooling concepts to reduce the labor costs and the potential for injury associated with shipboard cable installation. This report documents the work performed under this project.

2.0 OBJECTIVE

The objective of this project was to develop concept ideas to improve the current method of cable pulling, in order to reduce the overall process cost through labor reductions and avoidance of worker injury. The participating shipyards defined obtainable system requirements, provided periodic input to the design concepts and down-selected the concepts with the most potential for future technology commercialization and implementation. The objective was met; the selected and developed concepts are presented in Appendices A and B of this report.

3.0 TECHNICAL APPROACH

3.1 TASK 1: ON-SITE INSPECTIONS AT SHIPYARDS

Early in the project, on-site visits were made to both BIW and NNS to witness in-process cable installation on board ships under construction. The BIW visit that occurred on 9 February 2012 included large diameter cable installation in a section of DDG 1000 located in the Ultra Hall, as well as some installations on board a DDG 51 that was located pier side. The project team also had several beneficial meetings with designers and craft management personnel to discuss issues and expectations for the project. The project team gained a first-hand understanding of the challenges for cable installation, including the interferences that can be involved and the difficulty that the numerous bends in cable runs pose to the installation process. Photographs of in-process cable installation operations were taken at BIW and reviewed for release by BIW under Distribution Statement D; these were provided to the Integrated Project Team (IPT) and the Program Technical Representative (PTR) in September 2012.

The NNS visit took place on 8 March 2012 and included large diameter cable installations in several locations on board CVN 78. The installation process on this platform and yard were very similar to that at BIW, with the noted differences being the amount and length of cables involved, including the process of “re-eighting” cables before and after the cable is pulled through the selected zone. (Re-eighting refers to the method of storing and positioning cable not yet installed.) As with cable pulling operations at BIW, a significant amount of manpower was dedicated to installing large diameter cable, and the numerous direction changes in the cableways presented the same challenges as at BIW.

3.2 TASK 2: CABLE PULLING DESIGN REQUIREMENTS

Based on the observations and discussions held during on-site inspections, a preliminary list of design requirements was developed and promulgated to the IPT. These were discussed and approved at an IPT teleconference on 7 June 2012. These design requirements served as guiding principles for development and selection of concepts going forward. The design requirements for cable pulling concepts were as follows:

- Improvements to cable pulling operations may be used to:
  - Pull an entire cable evenly
  - Pull portions of the cable intermediate distances until routing the full length of cable
  - Reduce the amount of effort required to route cable through bends
  - Reduce cable friction to decrease the overall effort required to route lengths of cable.
- Provisions to improve cable pulling must be:
  - Simple
  - Ergonomically designed
  - Small and lightweight
  - Easy to carry throughout the ship
  - Easy to install and operate (at varying height or location)
  - Reliable
  - Require minimal or no tools to install and operate.
- Different types of tools and hardware may be used for various cable sizes and routing conditions.
- Manual or power-assist (120VAC or air) rollers are permitted as long as they are well-controlled to prevent potential injury or cable damage (injury and cable damage must be avoided with all improvements).
- Any modifications to cable hangers are preferably made prior to or during hanger installation.
- Technical Warrant Holder approval may be required for permanent modifications (e.g., using tape or rollers to reduce friction), but this should not deter the team from developing concept ideas.
- The improvements should focus on cables that are 1″-diameter and larger

3.3 TASK 3: BENCHMARKING RELATED INDUSTRIES

Based on the design requirements established for the project, an effort was made to identify existing tooling or practices in related industries to establish best practices or tooling that could be applicable to shipboard installation of cables. No relevant industry practices could be identified as the application on ships involves open cable hangers (as opposed to conduit or continuous trays) with many changes in direction. Additionally, permanent Navy shipboard cable installations are required to pass shock loading, which is unique among the industries examined. The majority of tooling for commercial construction or utility installations was either too large or focused on pulling very long, straight runs of cable, and was therefore unsuited for shipboard applications. However, there were several commercially available tools that could be used or modified for use in shipboard applications. These were included in concept formulation and selection.

3.4 TASK 4: CONCEPT GENERATION AND SELECTION

With the design requirements and observation of the shipboard cable routing process for guidance, teams of Concurrent Technologies Corporation (CTC) designers were tasked to generate multiple tooling concepts to assist in cable pulling operations. An internal review eliminated several unworkable concepts or those outside of the requirements. The remaining concepts were then sorted into two groups: "powered" and "non-powered." In all, 27 different concepts were presented to the IPT for review, with the evaluation criteria set as the original design criteria. Concepts were reviewed and discussed in an IPT meeting on 28 August 2012.

The selected concepts were further developed, illustrated and presented to the IPT in two meetings held on 10 October 2012 for powered concepts and on 25 October 2012 for non-powered concepts. The powered concepts were further categorized as either drive devices or attachment methods; these are provided in Appendix A. The non-powered concepts were categorized as either low friction or hand tools and are provided in Appendix B.

SharePoint file sharing, hosted by CTC, was utilized for each of the IPT reviews and is the repository for all of the concepts reviewed and discussed. It is a very useful tool for projects such as this one, with potentially large file sizes and multiple viewers/contributors that are dispersed geographically. No major issues were noted with SharePoint users at BIW, NNS, or Ingalls.

3.5 TASK 5: IDENTIFY OPPORTUNITIES FOR FUTURE DEVELOPMENT

Prior to initiation, this project was briefed at the NSRP panel meeting held at ShipTech in Orlando, Florida on 15 February 2012. The project was also briefed at the Electrical Technologies panel meetings in Baltimore, Maryland on 17 July 2012 and in San Diego, California on 06 December 2012. Presentation materials are available through the NSRP website (http://www.nsrp.org/6-Panel_Presentations.html). The project was also showcased during the NSRP Day at the Washington Navy Yard on 27 September 2012.

Following the award and initiation of this NSRP panel project, a separate Navy Metalworking Center (NMC) project (Improved Cable Routing Tools, S2472) was initiated under the Manufacturing Technology Program with General Dynamics Electric Boat (GDEB) as the implementing shipyard. Due to restrictions on submarine cable installation, only non-powered tooling concepts are being considered under this project. Nevertheless, the effort to improve upon submarine cable installation operations has benefitted greatly from the efforts of this NSRP project. A number of the non-powered concepts initially developed on the NSRP project have been further refined and fabricated as preliminary prototypes used to validate the concepts in a shipyard environment at GDEB. The NMC project will continue to improve upon these non-powered concepts based on user feedback from GDEB as a means to reduce labor costs and the potential for injury while routing cables on Virginia Class submarines. The non-powered prototype tooling, subject to the temporal needs of the current NMC project, is generally available for trials or demonstration at any US shipyard. Contact any of the authors of this report for arrangements.

A second candidate NMC cable routing project is currently under review for FY14. This project will focus on surface ship applications, specifically on further refinement of the powered tooling concepts that were developed on this NSRP project. The implementing shipyards for that project are anticipated to be Ingalls (engagement facilitated by the PTR) and NNS, both for new construction and carrier overhaul divisions.

4.0 APPENDICES

4.1 APPENDIX A – POWERED CONCEPTS

DRIVE CONCEPT – ROLLER DRIVE

The Roller Drive concept, depicted in Figure 4-1 below, utilizes a drive roller and an idler roller to guide and squeeze the cable, thus providing friction to move the cable. The drive roller is coupled to a shaft, which can be turned by hand (via a torque wrench), or by powered means (via a cordless drill/driver) to feed the cable. The device is designed to install over a standard cable hanger mounting channel, or through a variety of other attachment methods such as cable mounting, as illustrated in Figure 4-6.

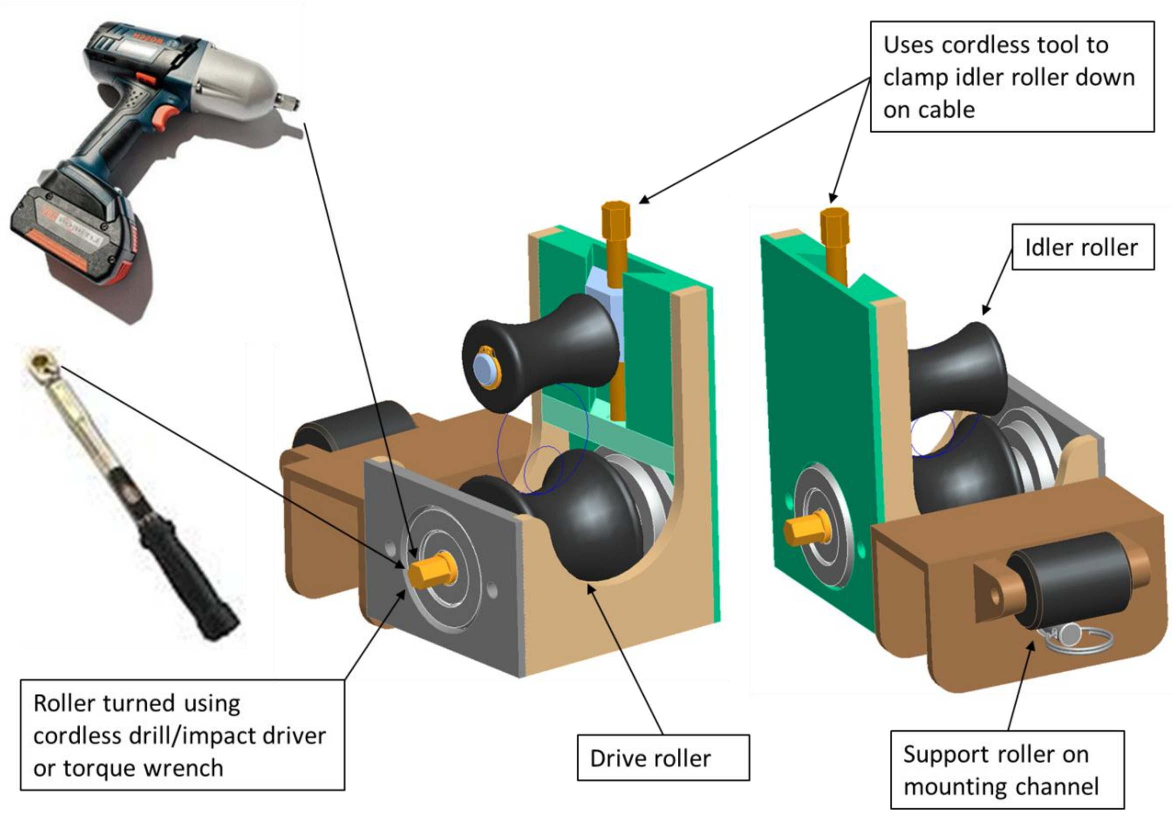

Figure 4-1. Roller Drive Concept

DRIVE CONCEPT – LINEAR DRIVE

The Linear Drive concept leverages a design from a currently available pulling product, which utilizes a ratchet motion to move the cable by hand as shown in Figure 4-2. The Linear Drive concept is powered using a cordless drill/driver to turn a lead screw and move a guided carriage to feed the cable. A small gearbox allows drive access from multiple directions. The device is designed to install over a standard cable hanger mounting channel, or through a variety of other attachment methods such as transit mounting, as illustrated in Figure 4-5, and cable mounting, as shown in Figure 4-6.

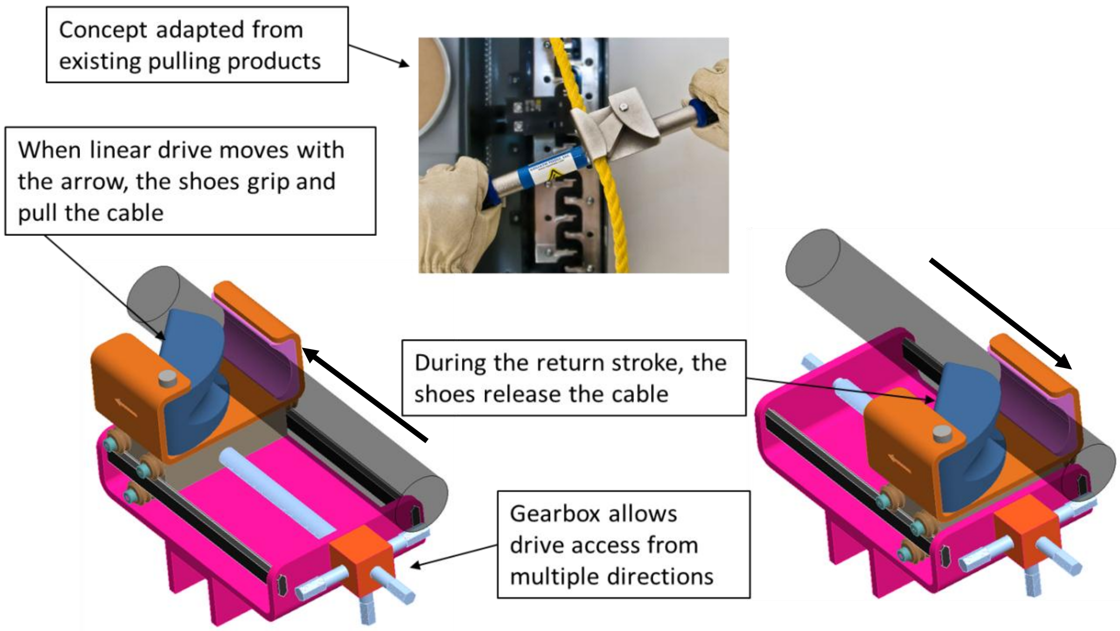

Figure 4-2. Linear Drive Concept

The Linear Drive concept could also be implemented using an air cylinder, as shown in Figure 4-3, in place of the drill/driver. The use of an air cylinder would allow the device to be cycled at a faster rate and allow remote operation, which would be convenient when the device is out the reach of the drill/driver.

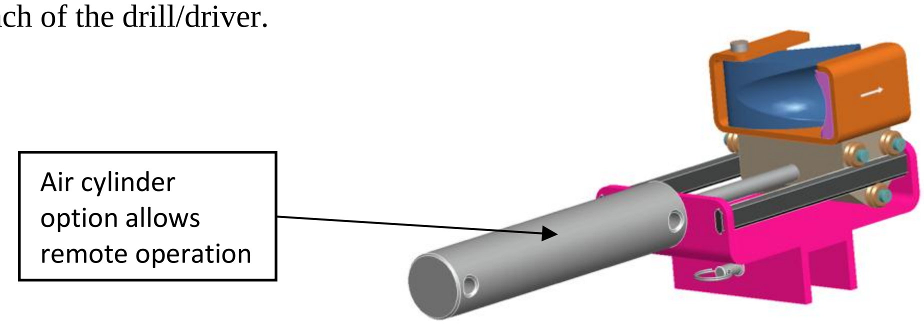

Figure 4-3. Linear Drive Concept with Air Cylinder

ATTACHMENT CONCEPT – HANGER STUD MOUNTING

In addition to the two drive concepts identified above, ideas to attach the drives were conceptualized. The Hanger Stud Mount concept depicted in Figure 4-4 shows hardware that will allow mounting of the drive in areas between the hangers, which in many cases may increase accessibility. The apparatus utilizes a magnet and quick release pins (just a few examples of attachment methods) to facilitate installation and folds for storage and transport. The concept is shown using the Linear Drive concept but can also be used for the Roller Drive concept or any future drive types that might be developed.

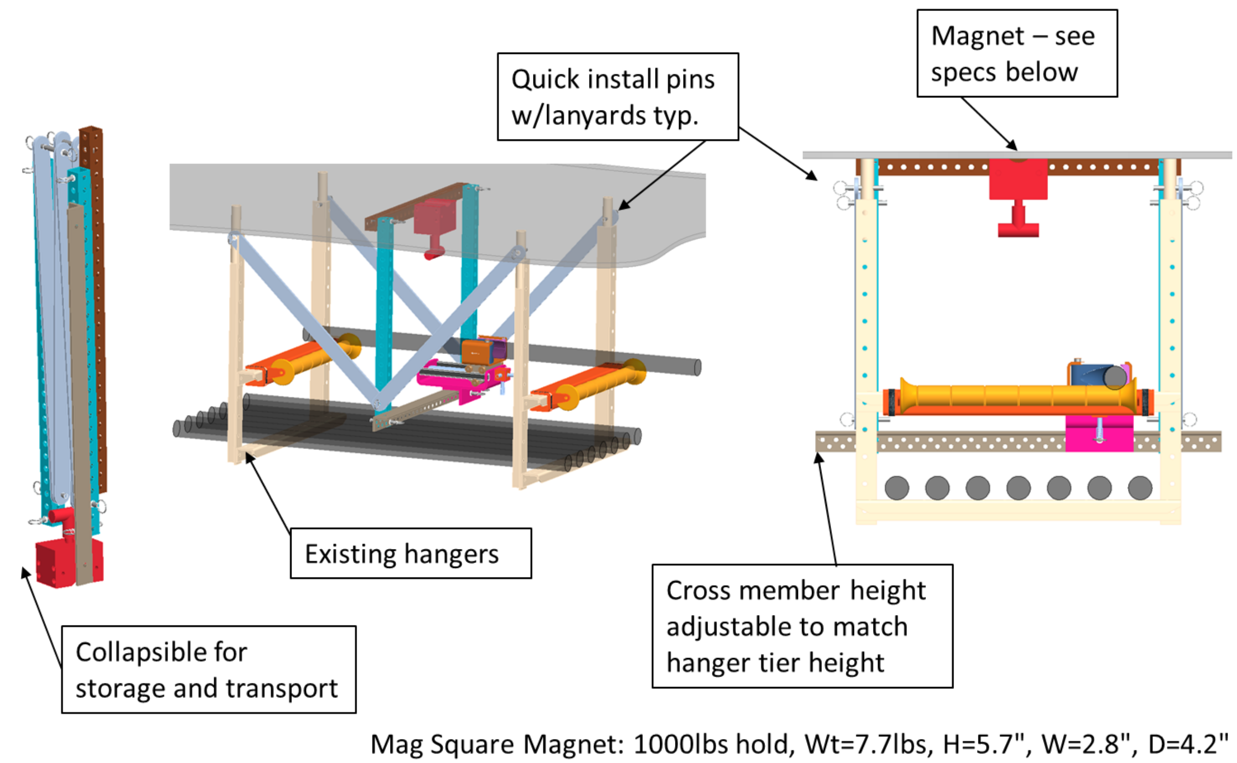

Figure 4-4. Hanger Stud Mount Concept

ATTACHMENT CONCEPT – TRANSIT MOUNTING

Figure 4-5 depicts a conceptual method for attaching the Linear Drive to a transit opening through a bulkhead. The idea can be extended to the Roller Drive concept as well as others.

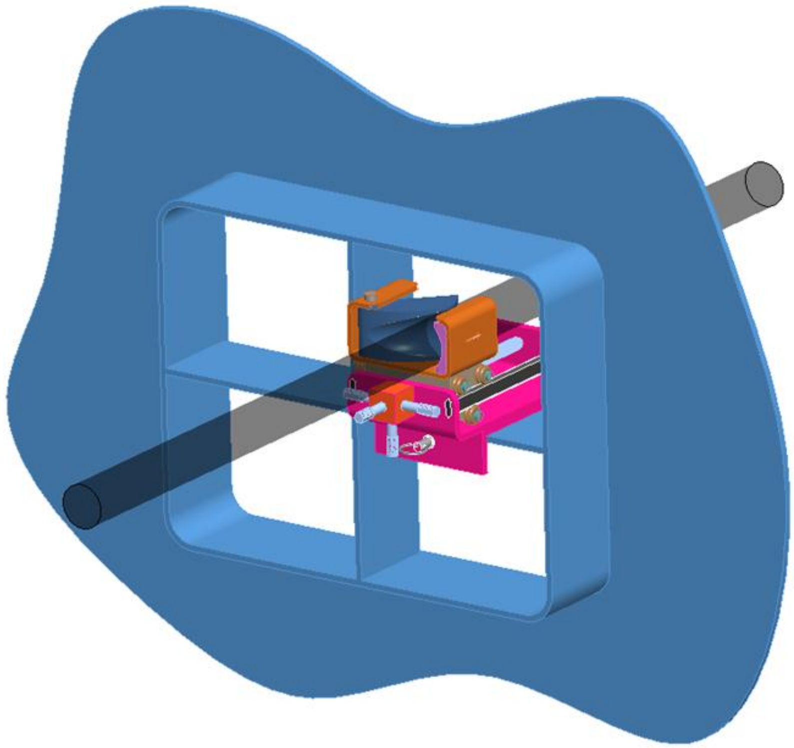

Figure 4-5. Transit Mounting Attachment Concept

ATTACHMENT CONCEPT – CABLE MOUNTING

Figure 4-6 shows yet another drive attachment concept, the Cable Mounting concept. This method takes advantage of previously routed large diameter cables, and uses them as an attachment point for pulling additional cables. The concept utilizes an adapter that connects from the drive to the cable to route cables parallel to existing ones. The drive is also able to be attached perpendicular to the cable for routing cables at right angles. The Cable Mounting attachment method can also be used for the Roller Drive and Linear Drive concepts.

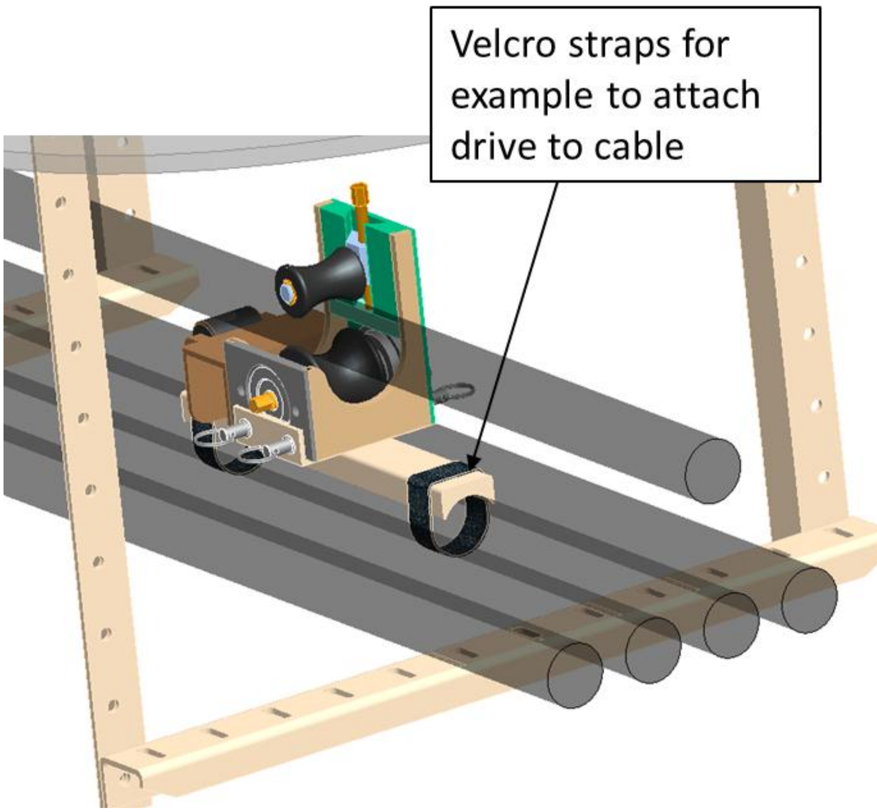

Figure 4-6. Cable Mounting Attachment Concept

4.2 APPENDIX B – NON-POWERED CONCEPTS

As mentioned in Section 3, Task 5, there is an NMC project underway (Improved Cable Routing Tools, S2472) to develop and implement non-powered tooling concepts to assist with the cable routing process on Virginia Class submarines. The tools were not designed to drive or pull cables; these concepts were developed to reduce friction while pulling cables, and to support, divert, and/or manipulate cables during routing on the ship. The first generation of these tools has been conceptualized, reviewed by the end users, and manufactured as prototypes. The tools will continue to evolve as feedback from the end users is incorporated, until a final production version is reached for implementation.

LOW FRICTION CONCEPT – TEMPORARY HANGER COVER

Figure 4-7 depicts the Temporary Hanger Cover concept made from Ultra High Molecular Weight (UHMW) plastic, which is designed to quickly install over existing cable hangers to reduce friction and make cable pulling easier.

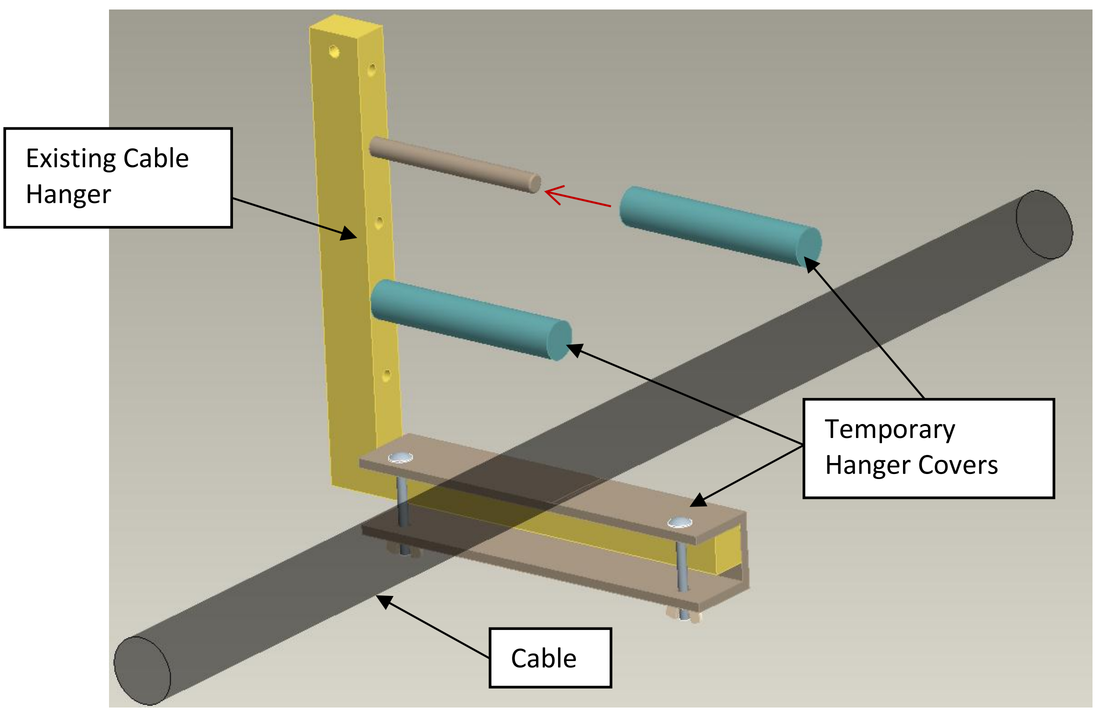

Figure 4-7. Temporary Hanger Cover Concept

LOW FRICTION CONCEPT – CABLE BEND SHOE

Figure 4-8 depicts the Cable Bend Shoe concept. This concept is designed to lower friction and help bend or turn a cable in strategic areas. The cable is routed through two low friction elbow halves as shown. The elbows can be 45°, 90° or other custom angles as needed. It is also possible to direct cable using a stick mounted elbow.

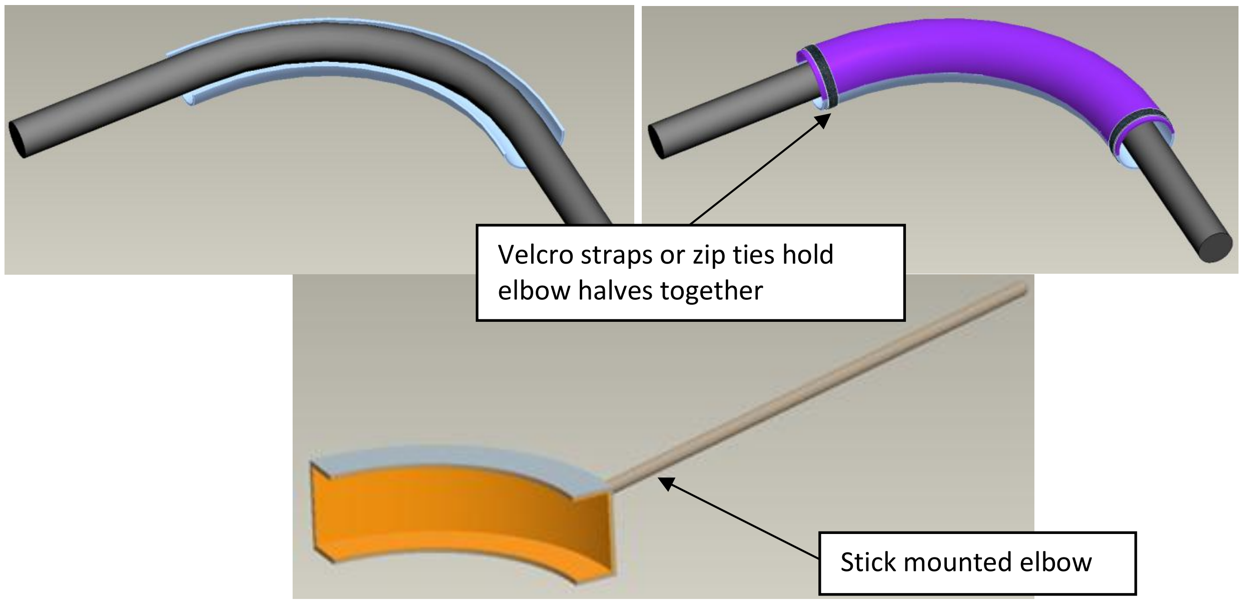

Figure 4-8. Cable Bend Shoe Concept

LOW FRICTION CONCEPT – TRANSIT ROLLERS

Figure 4-9 depicts several examples of a concept that not only reduces friction, but provides guidance and direction manipulation for the cable. Several small and large versions of these Transit Rollers are commercially available and could be used with and without modification. The rollers can be either clamped to an adjacent rigid structure, or attached via a removable magnet.

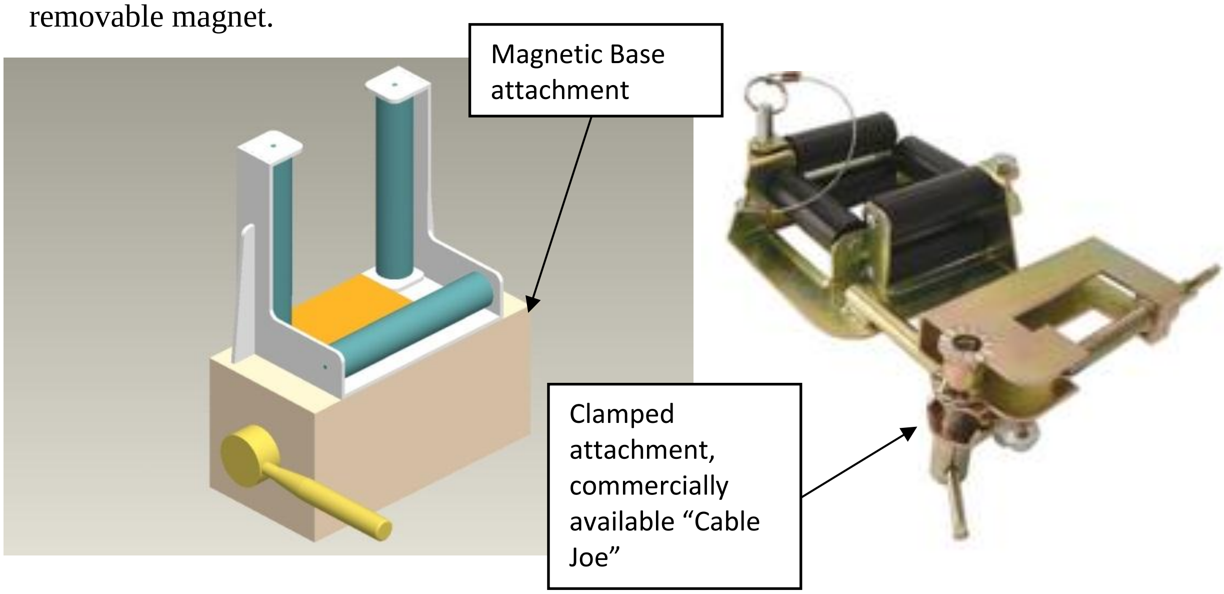

Figure 4-9. Transit Roller Concept

LOW FRICTION CONCEPT – LOW FRICTION PADDLES

Figure 4-10 illustrates a simple Low Friction Paddle concept. The paddle has a handle attached that can be used to position the paddle surface where needed, including places that might be out of hand reach. The handle also allows some leverage to be applied to adjust cable positioning. The paddle's flat profile allows it to be easily removed by sliding it out from the side, without having to lift the heavy cables.

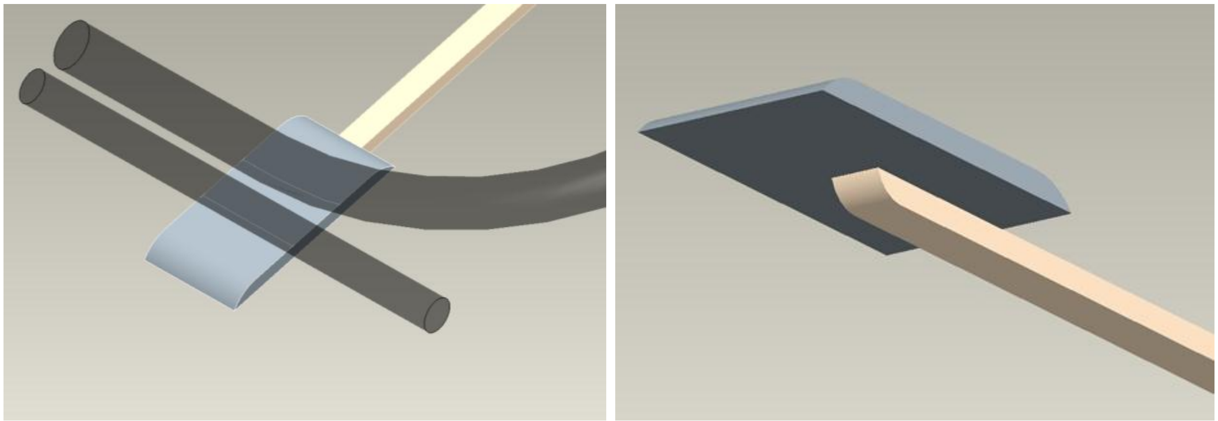

Figure 4-10. Low Friction Paddle Concept

LOW FRICTION CONCEPT – MAGNETICALLY ATTACHED BLOCKS

Figure 4-11 shows several examples of using a magnet to hold low friction shapes that can support and guide cables during pulling. The hinged UHMW block allows the cable to be captured during pulling, then released anywhere along the cable length. The magnet shown is commercially available and is typically used to support steel pieces for weld fixturing. The magnet is activated and released by turning the handle. The magnet shown is capable of up to 1,000 pounds of holding force and is available in a variety of shapes, sizes and hold strengths.

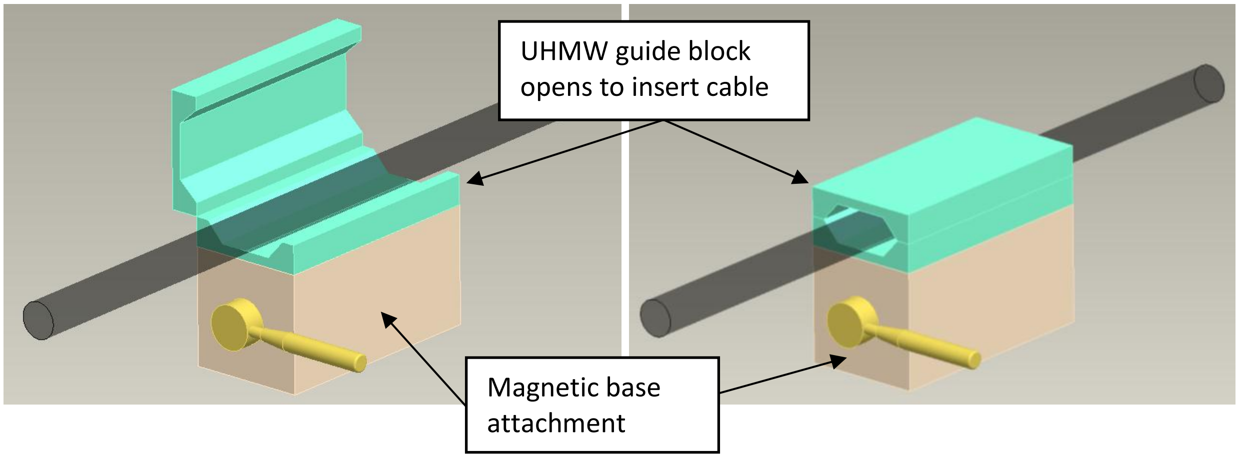

Figure 4-11. Magnetically Attached Blocks Concept

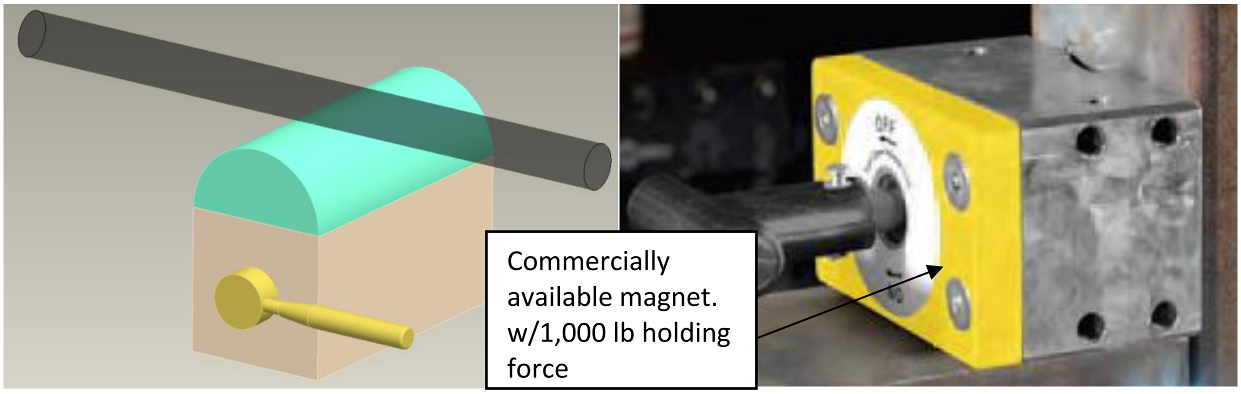

Figure 4-11. Magnetically Attached Blocks Concept (Cont.)

LOW FRICTION CONCEPT – LOW FRICTION TAPE

Figure 4-12 shows the application of Low Friction Tape to a simple painted surface. Low friction tapes are a very versatile solution with a wide range of applications for cable installation, and they can be easily combined with several of the concepts proposed here. The product is currently used in high-wear applications such as feed chutes and conveyor guide rails. 3M provided several samples for consideration, including product #5451 shown in Figure 4-12, and #5425, a UHMW-backed product that contains no PTFE (Polytetraflouroethylene).

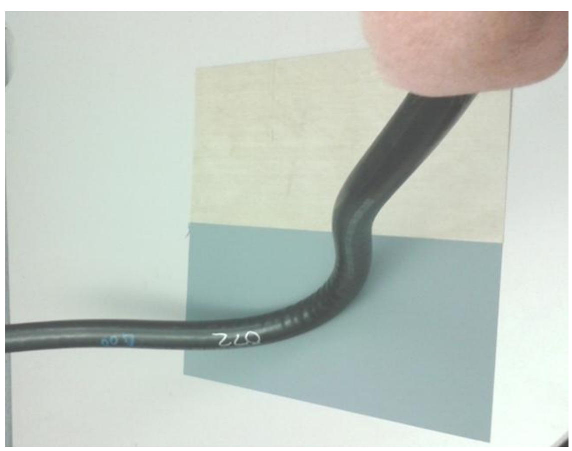

Figure 4-12. Low Friction Tape Concept

NON-POWERED CONCEPTS – END EFFECTORS ON A STICK

In order to reach remote areas where cables need to be routed, turned, or moved, several varieties of tooling may be useful when mounted at the end of a stick. A series of stick-mounted tools were conceptualized to specifically help manipulate the cable, as well as provide friction reduction. The individual concepts shown in Figure 4-13 fall into the category called "End Effectors," and include rollers, hooks, saddles and hour-glass shapes.

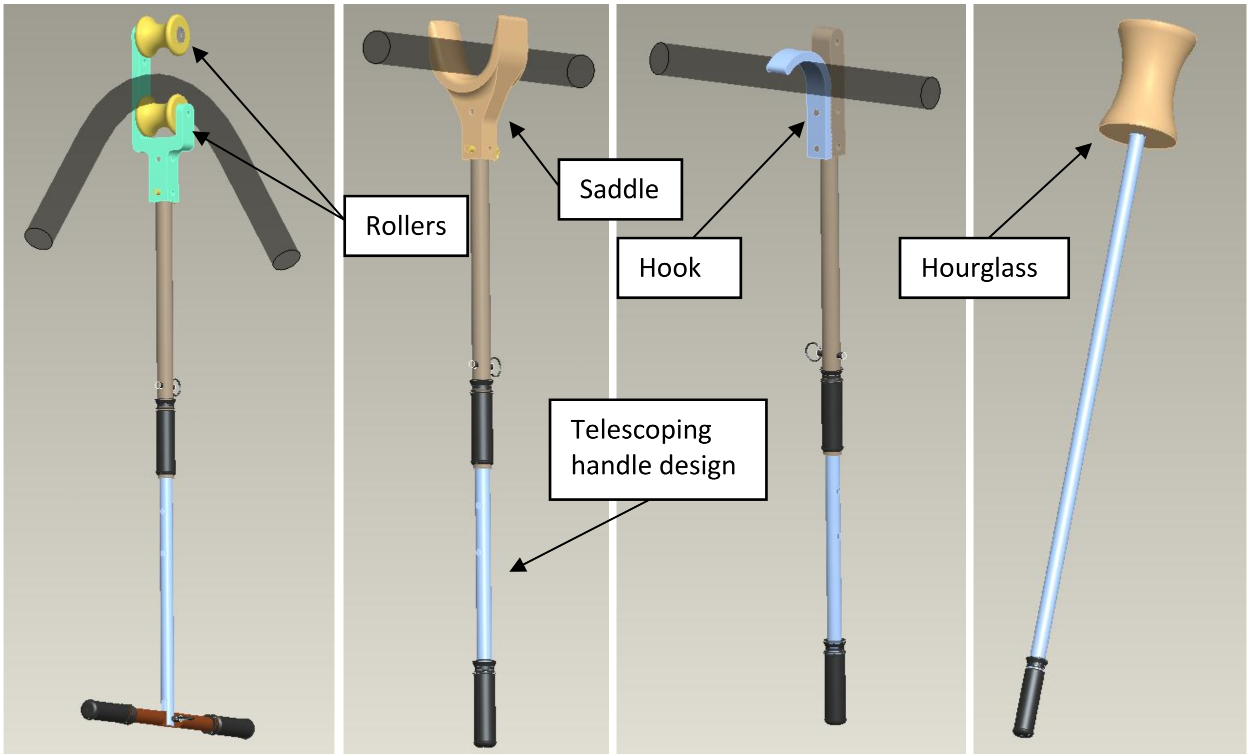

Figure 4-13. End Effectors on a Stick Concept

4.3 APPENDIX C – ELECTRONIC DISTRIBUTION

Names	**Copies**
External Distribution	
Jason Farmer, Ingalls	1
Justin Montague, SCRA	1
Ben Zavitz, BIW	1
Greg Stevens, BIW	1
Dave Brookman, NNS	1
Internal Distribution	
Mark Smitherman, CTC	1
Timothy Freidhoff, CTC	1
Alan Baum, CTC	1