**Cable management design for Inspection Robot**

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**Fermi laboratory Summer 2023**

**1. Abstract.**

The goal of the internship is to construct a secure safe and reliable cable management system that helps a cable network all around the Inspection robot connect and power a two-stepper motor system on a gantry designed and created on a previous internship. The way this was made possible was by integrating what are called “cable carriers” which are covers that can only bent in a specific direction in the existing two-actuator gantry, which sits on top of the drive train of the inspection robot, this attribute allows the cables to go inside this cover to evert the overstress of the cables in ways which they can overstretch, rip apart, as well as twist and tangle. In the design process during the internship, a series of brackets with screw clearance were 3D modeled in NX for easy installation and extra security for the cable carriers. Said brackets were printed out of PETG filament and installed on the two-actuator gantry allowing a safe and easy way for a cable network to be created and installed in said gantry for later use.

**2. Introduction.**

The main idea of the inspection robot or “Rover” project is so that it can replace the human factor when it comes to making diagnostics down in the accelerator where the levels of radiation can be dangerous for humans. Normally a team would be sent down to check the accelerator in order to infer what the problem is and should be done about it, however this can take an extreme toll on the team, because they can be subject of radiation which could be dangerous. This rover would take the job of going down to the accelerator with a camera or radiation sensor if needed that can be controlled by the Main Control Room staff remotely so they can visualize the problem that accelerator faces and plan accordingly. This rover would have to be extremely reliable implying that the need for a complex cable network should be an important priority since the place where Rover would be sent cannot be reached that easily. To ensure the reliability of the cable network, a cable management system is to be created as well. The cable management system is to be integrated on the two-actuator gantry which sits on top of the drive train where the brain resides and the connections for the cable network meet. This is the main goal of the internship: create, design and install a safe and reliable cable management system that would cover a cable network for later use. The way this cable system was successfully assembled was through 3D modeling on Fermilab platform NX, basically improving from previous internships models. Thanks to previous year interns, rover was modeled completely on NX so the new additions for the cable management were easily created, modeled, printed and assembled. Additionally, this system needed support all around to ensure maximum safety for the cable network which were also designed and assembled successfully using aluminum and PETG (polyethylene terephthalate glycol) filament instead of PLA (Polylactic acid) filament for stronger parts and security.

**3. Modeling of vertical cable management system.**

 The vertical actuator has a stepper motor at the top with a big gear that can move up and down. This stepper motor needed to be connected and powered to the drive train which sits under the gantry system. On the bottom of the actuator, there are three brackets. Two brackets were installed on the sides of the actuator and one bigger bracket was installed on the back as well for extra support. For the installation of the cable carrier, on the bottom brackets was redesigned so that it would have a three-hole screw clearance and a middle bracket that connects both vertical and horizontal actuator was also resigned as well for the same result. Both designs were printed out of PETG filament for extra strength and less rigidity. Nevertheless, the cable carrier pushed itself backwards as well forwards, so a back and front support were implemented. The back support was made of aluminum so the cable carrier would not push itself backwards, this back support was installed between the back of the vertical actuator and the bigger bracket on the back, however, the thickness of the back support made a gap between the actuator and bigger bracket so it would not sit flush for installation, therefore, a bracket spacer was designed, the only functions is to close the gap between the actuator and the bracket for installation. However, the cable carrier still pushed itself forwards, this was fixed by simply moving the area where the three-hole screw clearance was made so that I would not push itself forwards anymore. After the installation of the cable carrier on the vertical actuator, the length of said cable carrier was adjusted so that when the horizontal actuator was moved up with the help of the vertical actuator stepper motor, the cable carrier would not overpass the height of the vertical actuator creating more reliability issues.

**4. Modeling and installation of horizontal actuator.**

In the same fashion that the vertical actuator cable management system was installed, a horizontal version needed to be created and installed. However, this horizontal cable management system needed to be more resistant, since it carries two types of cables, as well as the fact that being horizontal demands an under support that would help the cable carrier not be dangling loose. This cable carrier would carry the cable that connects the stepper motor to the base of the rover, and it would also carry the cable that connects to the camera which has been installed there from previous internships. The way this was designed originally was with a single aluminum plate which would bend upwards from both ends at a 90-degree angle with screw hole clearance so it would attach itself to the actuator beam. This, however, could not be done in the time frame of the internship, because making such aluminum plate would have taken more than eight weeks. For that reason, a decision was made; so, instead of having an aluminum plate with two bents at the ends, the gantry system would have two 3D modeled brackets that would be mounted on the horizontal actuator and would also hold the aluminum plate which would be screwed from under the brackets. The idea was passed, and two brackets were modeled on NX and later printed. When it came to most prints during the internship, PETG was used instead of PLA. Though PETG needs a higher temperature to be printed and is not biodegradable as PLA, PETG has a stronger layer adhesion and is more flexible rather than PLA which is very rigid and can snap easier. This again was part of the reassurance and reliability aspect of the machine. These brackets were assembled on both ends of the actuator, one which was next to the camera and the other was on the other side of the actuator. When it came to the installation, the bracket that was next to the camera had two sets of holes. The set of screw holes closer to the edge are three-hole set of screws that would set the cable carrier in place, however, the second set of screw holes are way behind it. The reason behind this is because that is where the under place would be installed. And for this case the screws would have to be button head screws which stick out from the bracket making it hard if they happened to overlay with the cable carrier. In the other hand, the other bracket at the other end of the actuator, was way simpler than the other bracket since it only needed the two screw holes for the under plate to be assembled. Additionally, the cable carrier needed to be secured from a second place as well, this is where the middle bracket that connects both vertical and horizontal actuator comes into play again. The three-hole screw clearance exist on the top right corner of the bracket, for the support of the second actuator, below said the three-hole screw clearance, a tab would come out of it which would hold another set of the three-hole screw clearance allowing for the horizontal cable carrier to be secured. This took a little more redesigning since the tap did not have some sort of support and broke. Therefore, a chamfer was added to edges of said tab, allowing for extra strength and support of the tab so it wouldn’t break if anything happened during performance.

**5. Conclusion.**

Overall, the cable management system is something of outmost importance when it comes to the Rover project for inspection down in the accelerator for inspection and radiation detection. It is important the whole machine is completely reliable and strong enough so that the main control room can use it without any worries of failing at all. Furthermore, having a cable management system allows the safety and security of the whole cable network which is the way all the motor in the gantry is powered and the camera or sensor would be. The creation, design and installation were made possible by careful analysis and comprehension of the machine. It would not have been done also without the help of the mentos who have always been there of the interns.