LANSCE Wire Scanning Diagnostics Device Mechanical Design

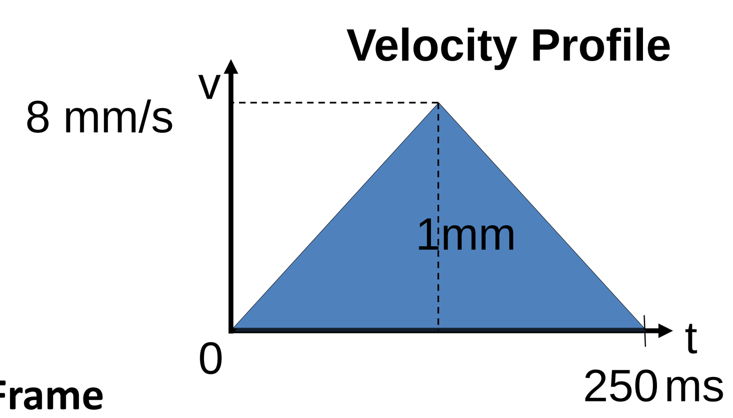
S. Rodriguez, B. Smith, D. Gilpatrick, M. Gruchalla, J. Sedillo, C. Pillai, Y. Batygin

INTRODUCTION

The Los Alamos Neutron Science Center (LANSCE) is one of the major experimental science facilities at the Los Alamos National Laboratory (LANL). The core of LANSCE's work lies in the operation of a powerful linear accelerator, which accelerates protons up to 84% the speed of light. These protons are used for a variety of purposes, including materials testing, weapons research and isotopes production. To assist in guiding the proton beam, a series of over one hundred wire scanners are used to measure the beam profile at various locations along the half-mile length of the particle accelerator. A wire scanner is an electro-mechanical device that moves a set of wires through a particle beam and measures the secondary emissions from the resulting beam-wire interaction to obtain beam intensity information. When supplemented with data from a position sensor, this information is used to determine the cross-sectional profile of the beam. The designs of current wire scanners vary making it difficult to keep spare parts that would work on all designs. Also many of the components are custom built or out-dated technology and are no longer in production.

DESIGN CRITERIA

The first design criterion is that the wire scanner should be constructed with as many commercially available off-the-shelf components as possible. This will facilitate having spare parts that can fit multiple wire scanners. This is similar to the wire scanner design of the Oak Ridge National Laboratory (ORNL) Spallation Neutron Source (SNS) wire scanner. The second criterion is that the wire scanner should be capable of 1mm movements at 4Hz (1mm in 250ms) with a triangular velocity profile as illustrated in Figure 1. Notice that for the area under the curve to be 1mm, the peak velocity must be 8mm/s half way through the motion. This yields an acceleration of 64mm/s² (Note: 1g = 9807mm/s²). Third, the position of the wires at the end of the "fork" must be known within ±1mm with respect to an external monument. Also, the repeatability of the system must be within ±0.1mm. Fourth, the motor must be powered off while taking a measurement at each bin location. Lastly, the wire scanner should be designed to accommodate as many existing beam structures as possible.



Frame

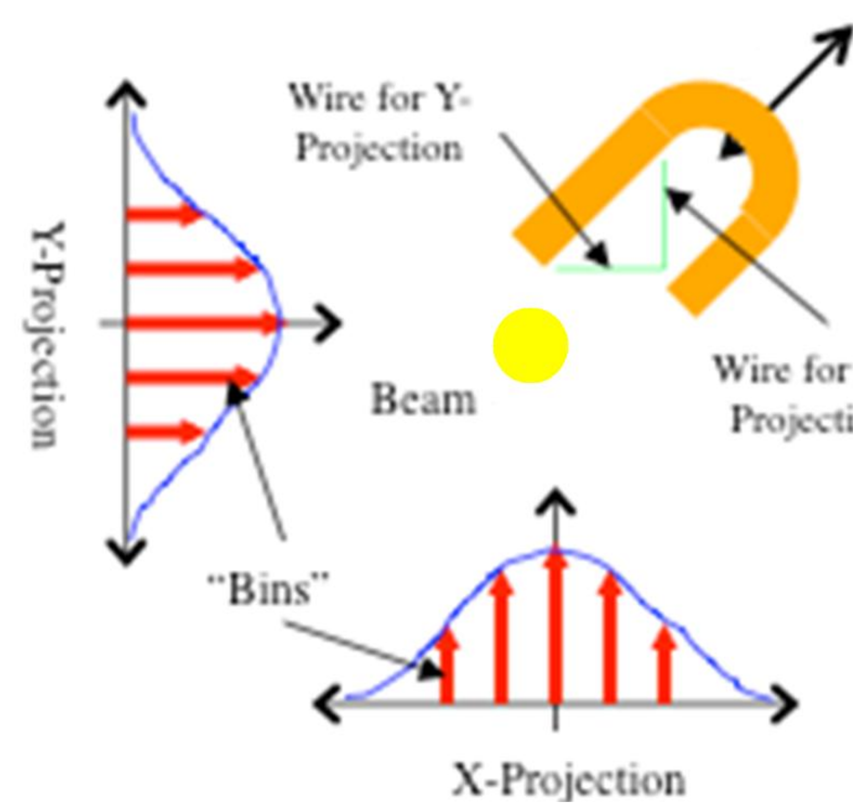
The frame is composed of four components: the front plate, back plate, top of the frame, and bottom of the frame; all made from 6061 aluminum alloy. The top and bottom of the frame have been designed in such a way that the top of the frame can be removed to gain access to the internal components while maintaining the bottom of the frame in place.

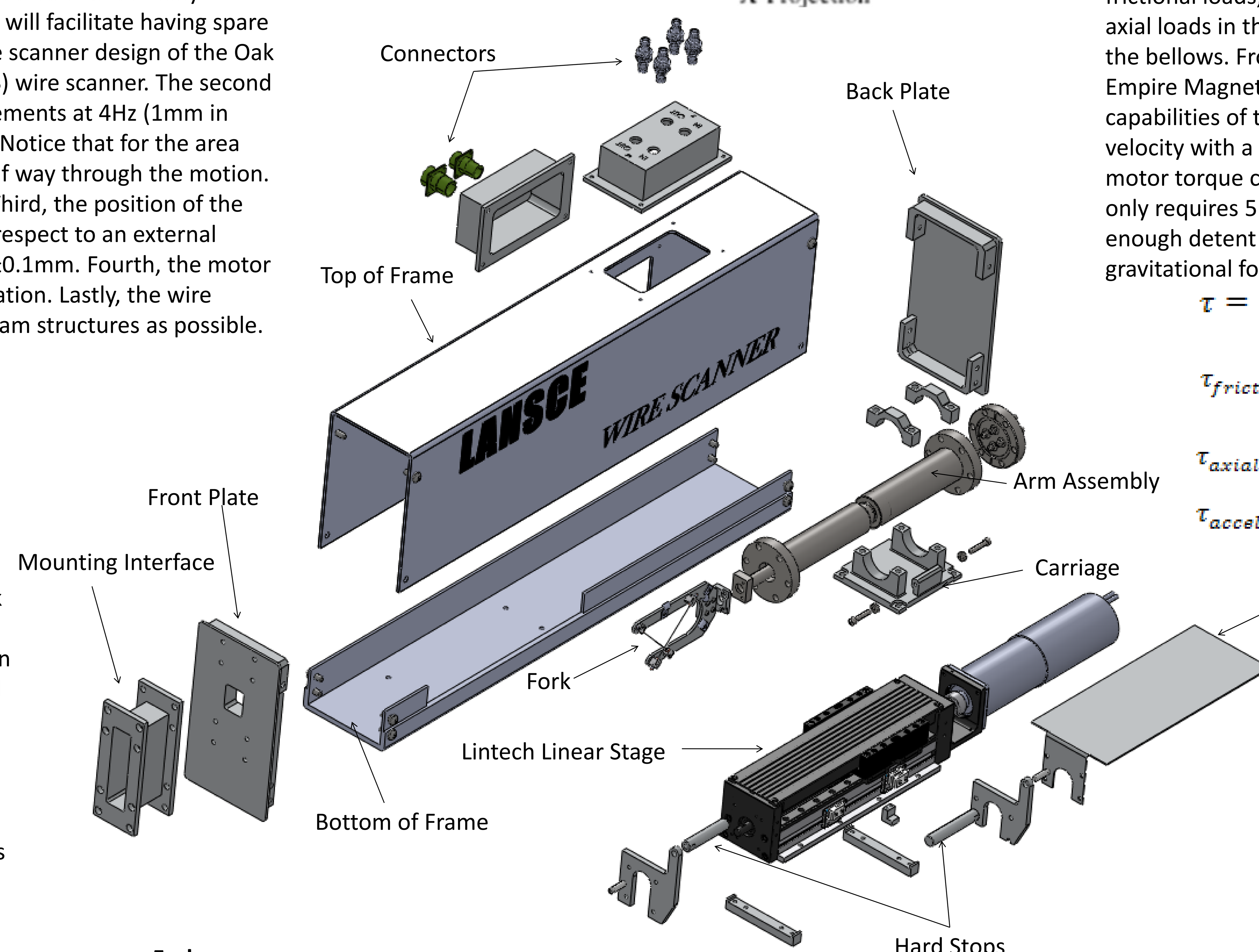
Drive System

The drive system is composed of a Lintech 100-series linear stage with a 10mm-lead ball screw and 6-inches of available travel. This stage comes fully assembled with a NEMA 23 motor mount and motor coupling. The slide table travels on two rails with a two linear bearings per rail. Each bearing has a dynamic load capacity of 775lbs rated for 2million inches of travel; the table is estimated to only travel 36,000 inches in a period of 20 years with a load of 7lbs at most. The maximum acceleration of these bearings is 19.6 m/sec² (2g's). Some additional features are two mounts for limit switches and a cover plate to protect the ball screw from dust and debris.

Arm Assembly

The arm assembly acts as support for the fork as well as a vacuum boundary with an electrical feedthrough for the signal wires. The arm is a hollow ½ inch stainless steel tube, this allows for the signal wires from the fork to travel through it and gain access to the electrical feedthrough, which is composed of 4 double-ended SMA connectors on a CF 2.75 flange from Accu-Glass Products Inc. The bellows, which allows motion while maintaining vacuum on the inside, is welded to a CF 2.75 flange that bolts onto the front plate. This bellows assembly is provided by Metal Flex Welded Bellows Inc. This assembly is supported by a carriage and clamp assembly that mounts onto the linear stage.





Fork

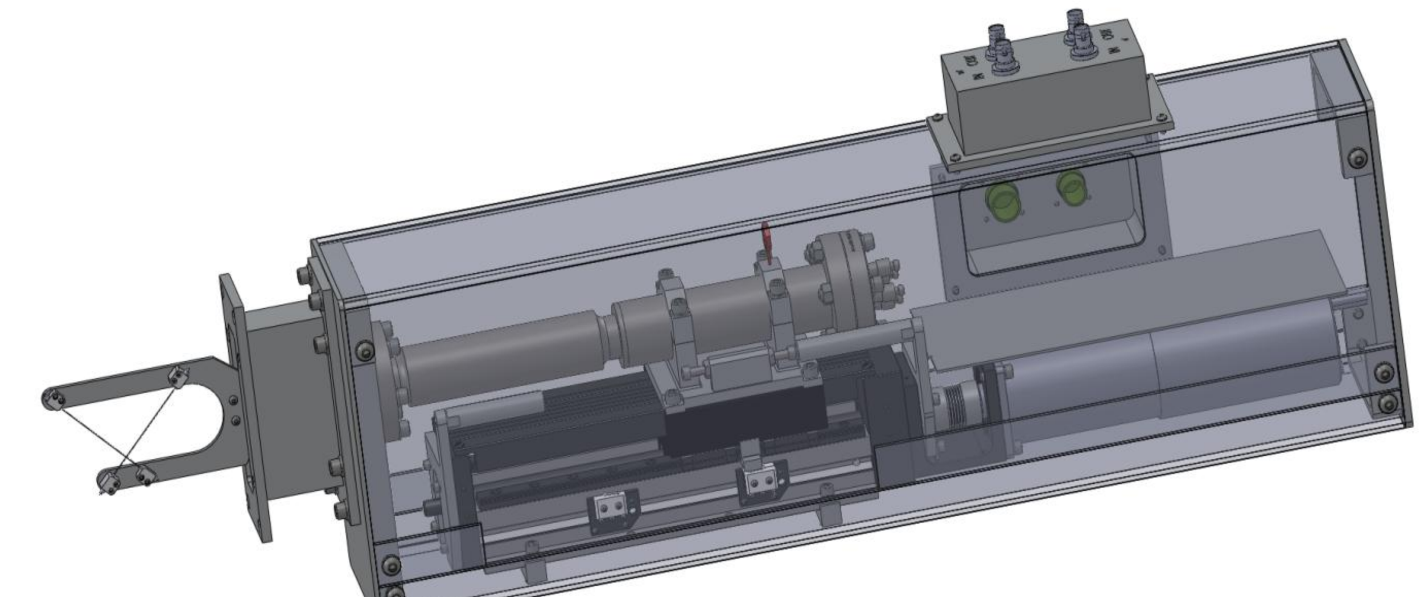
The fork assembly is designed such that two wires, positioned perpendicular from each other, act as X and Y beam profile indicators when mounted at ±45° from the horizontal. This assembly allows for the current to travel from the wires through the arm and exit through the electrical feedthrough. The fork and fork bracket are made from aluminum while the wire mounts are made from macor. The wire itself is typically 0.1mm diameter of tungsten, silicon carbide, or carbon fibers.

Mounting Interface

The mounting interface serves as extra room for the fork to retrieve into away from the beam line. Additionally, it serves as the mounting interface between the beam structure and the rest of the wire scanner. This component is a solid rectangular piece of aluminum 6061 with two flanges on its ends. The flange that interfaces with the beam structure is flat while the one that interfaces with the rest of the wire scanner has a groove for an aluminum 1100 wire seal.

Hard Stops

The hard stops act as mechanical precautions in the case that the stage does not stop when the limit switches engages. These hard stops mainly protect the fork from over travel into the beam structure. Additionally, it protects the bellows from over extending or over compressing which may cause tearing and leaks.



Motor

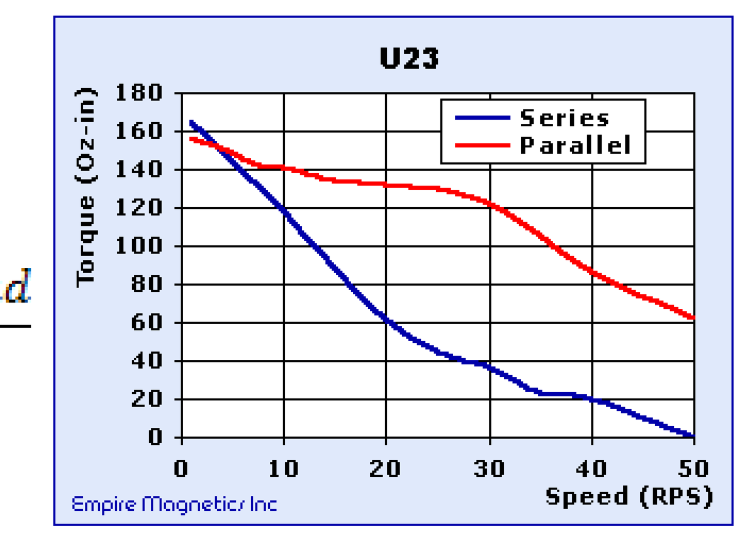
In order to determine if the desired velocity will be reached, the torque required to perform such action must be calculated. To do so, the equations below were used. The torque required for this task is composed of three parts, the torque to overcome axial loads, the torque to overcome frictional loads, and the torque needed to accelerate the ball screw to the desired velocity. The axial loads in this case would be the vacuum force, gravitational force, and the spring force due to the bellows. From the equations below we were able to size the motor correctly and chose the Empire Magnetics Inc. U23 stepper motor. The graph below shows the torque vs. speed capabilities of this motor. From the velocity profile, the peak velocity needed is only 8mm/s. This velocity with a 10mm-lead ball screw translate to 0.8 revolutions per second (rps). From the motor torque curve, the motor has 165 oz-in available. With the torque equations, the system only requires 5.78 oz-in. In addition to meeting the torque requirements. This motor provides enough detent torque to prevent back-driving of the system caused by the vacuum and gravitational forces acting on it.

$$\tau = \tau_{friction} + \tau_{axial} + \tau_{accelerate}$$

$$\tau_{friction} = \frac{\mu W sin(45) \times Lead}{2\pi e}$$

$$\tau_{axial} = \frac{(F_{vac} + W cos45 + F_{spring}) \times Lead}{2\pi e}$$

$$\tau_{accelerate} = (J_{load} + J_{screw} + J_{motor})\frac{\omega}{t}$$



Cable Guard

The Cable guard is designed to protect the signal wires that run from the electrical vacuum feedthrough to the BNC connectors. This cable guard allows for the wires to rest on it while the actuator is in its fully retracted position thus protecting them from getting tangled on any other component and at the same time preventing contact with the motor which may be hot.

Connectors

Connectors are needed to transfer signals from the wires intercepting the beam and also to interface with the motor, resolver, and limit switches. For the signal wires, four BNC bulkhead connectors are used in this design. For the motor, resolver, and limit switches, two MS connectors are needed. The motor requires 8 wires which would go on a 10-pin connector. The limit switches require a total of 9 wires and the resolver requires 6; these 15 wires would go onto a 19-pin connector. The mounting cases for these connectors are made from aluminum-6061 stock machined to specifications and are bolted onto the top and side of the frame.

Carriage

The purpose of the carriage is to hold the arm assembly to move with the linear stage. This is composed of a base and two arches that bolt over the arm assembly. Additionally, this carriage provides the impacting surface with the hard stops in the case of over travel.

Limit switches

For this design we will be using three limit switches, one for the in-limit and two on the out-limit. On the out-limit, one of the switches lets the operators know that the wire scanner is ready to perform. The other limit switch simply indicates when the wire scanner has fully retrieved from the beam line. The first switch to engage on the out-limit is the one that indicates that the wire scanner is fully retrieved, the other lets the operators know that the wire scanner is ready to run or if it is done.