Final Report
for the
Design and Manufacture
of
E1039 Target Supporting Frame and Insert Elevator

Submitted to:
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In fulfillment of:
Standard Research
Educational Institution or Nonprofit Organization
Subcontract Form of Agreement
[for Unclassified Work]
Subcontract No. 497957

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Introduction

In accordance with the statement/scope of work[1], New Mexico State University (NMSU) Physical Science Laboratory (PSL) successfully performed research and development work identified as "Design and Manufacture Target Supporting Frame and Insert Elevator". Specifically, NMSU PSL furnished the qualified personnel, equipment, material and facilities to perform all services necessary to design, manufacture and deliver the E1039 supporting frame and insert elevator.

The design and manufacture of the E1039 polarized target supporting frame was based on the conceptual design provided by Fermilab[2] and met all Fermilab and collaborator requirements. Likewise, the design and manufacture of the E1039 polarized target insert elevator was based on the conceptual design provided by Fermilab[2] and met all Fermilab and collaborator requirements. The E1039 polarized target supporting frame was delivered to the E1039 experiment site[3] at Fermilab on July 3, 2019. The E1039 polarized target insert elevator was delivered to the E1039 experiment site[3] at Fermilab on September 4, 2019.

In addition to providing details of the fulfillment of the subcontract, this document will provide details of the design, testing and strength analysis

[1] Appendix I of Subcontract 497957, May 30, 2018

[2] Frequent email/phone/online contact with James Brock (Jefferson Lab), Dustin Keller (Jefferson Lab) and Don Mitchell (Fermilab)

[3] SEAQUEST/NM4/KTEV FERMILAB, RICK TESAREK, KIRK RD AND PINE ST, BATAVIA, IL 60510, TRC Freight Bill #s 796-423401-0 and 745-096823-X.

Support Frame and Lifter Design

The overall design of the E1039 target support frame and insert elevator is shown in the image below:

Figure 1- Overall design of E1039 target support frame and insert elevator assembly

Referred to as the "E1039 PPT Support and Lifter Assembly"[4], the support and insert elevator ("lifter") assembly is comprised of 40 different sub-assemblies and mechanical parts. This top-level assembly, the various sub-assemblies and parts details are documented in the documents listed in the figure below:

Item	Document #
E1039 PPT Support and Lifter Assembly	TAS-017990-0100
E1039 PPT Bellows and Lifting Bar Assembly	SAS-017990-0100
E1039 PPT Lifting Bar Assembly	SAS-017990-0200
E1039 PPT Lifting Bar Weldment	SAS-017990-0210
E1039 PPT Bellows Support Detail	MDT-017990-0200-01
E1039 PPT Bellows Support Cap Detail	MDT-017990-0200-02
E1039 PPT Lifting Bar Detail	MDT-017990-0200-03
E1039 PPT Locking Collar Detail	MDT-017990-0200-04
E1039 PPT Lifting Bar Diagonal Detail	MDT-017990-0200-05
E1039 PPT Lifting Bar Stop Detail	MDT-017990-0200-06
E1039 PPT Bellows Assembly	SAS-017990-0300
E1039 PPT Bellows Lower Flange Detail	MDT-017990-0300-01
E1039 PPT Bellows Upper Flange Detail	MDT-017990-0300-02
E1039 PPT Positioning Arm Assembly	SAS-017990-0400
5164T850 Modification Detail	MDT-017990-0400-01
5164T510 Modification Detail	MDT-017990-0400-02
E1039 PPT Support Frame Assembly	SAS-017990-0500
E1039 PPT Support Upright Detail	MDT-017990-0500-01
E1039 PPT Support Upper Crossmember Detail	MDT-017990-0500-02
E1039 PPT Support Mid Crossmember Detail	MDT-017990-0500-03
E1039 PPT Support Lower Crossmember Detail	MDT-017990-0500-04
E1039 PPT Support Diagonal Detail	MDT-017990-0500-05
E1039 PPT Support Base Leg Detail	MDT-017990-0500-06
E1039 PPT Support Corner Bracket Detail	MDT-017990-0500-07
E1039 PPT Support Base Cap Detail	MDT-017990-0500-08
E1039 PPT Support Upright Simulator	MDT-017990-0500-09
E1039 PPT Lifter Assembly	SAS-017990-0600
E1039 PPT Lifter Support Assembly	SAS-017990-0700
E1039 PPT Lifter Support Top Plate Detail	MDT-017990-0700-01
E1039 PPT Lifter Support Base Plate Detail	MDT-017990-0700-02
E1039 PPT Lifter Support Angle Detail	MDT-017990-0700-03
E1039 PPT Step Motor Mounting Bracket	MDT-017990-0700-04
E1039 PPT Gear Box Mounting Spacer	MDT-017990-0700-05
E1039 PPT Lifter Lower Travel Stop	MDT-017990-0700-06
E1039 PPT Lifter Upper Travel Stop	MDT-017990-0700-07
E1039 PPT Lifting Plate Assembly	SAS-017990-0800
E1039 PPT Lifter Mid Plate Detail	MDT-017990-0800-01
E1039 PPT Lifting Bar Spacer Detail	MDT-017990-0800-02
E1039 PPT Roller Support Bar Assembly	SAS-017990-0900
E1039 PPT Roller Support Bar Detail	MDT-017990-0900-01
E1039 PPT Roller Support Angle Detail	MDT-017990-0900-02

Figure 2- List of assemblies, sub-assemblies and part details along with document numbers

Electronic copies (PDF drawings) of these documents are provided separately[5].

[4] Document TAS-017990-0100

[5] https://wiki.shanti.virginia.edu/display/SeaQuest/Target+Mechanics

Insert Elevator Proof Load Testing

Prior to delivery to Fermilab, the completed E1039 polarized target insert elevator (or “lifter”) was proof testing to a load of at least 157% (500 lbf) of the expected maximum service load (318 lbf).

Figure 3 - Test setup showing the crane scale readout with 500 lbf load

To verify the ability of the stepper motor to lift the maximum service load, a maximum load of 517 lbf was applied to the lifter by current-limiting the motor to 2.1 amps.

Support Frame Stress Analysis

The vacuum load to be supported is 318 lbf[6]. This vertical line of force is located a distance of 18.28" from the neutral axis (+Z, toward legs and diagonals) of the vertical frame members, resulting in a (318lbf * 18.28" =) 5813 in-lbf (484.4 ft-lbf) moment on the support frame.

In addition, a pump line analysis was provided[7] which provided the following pump line reaction locations:

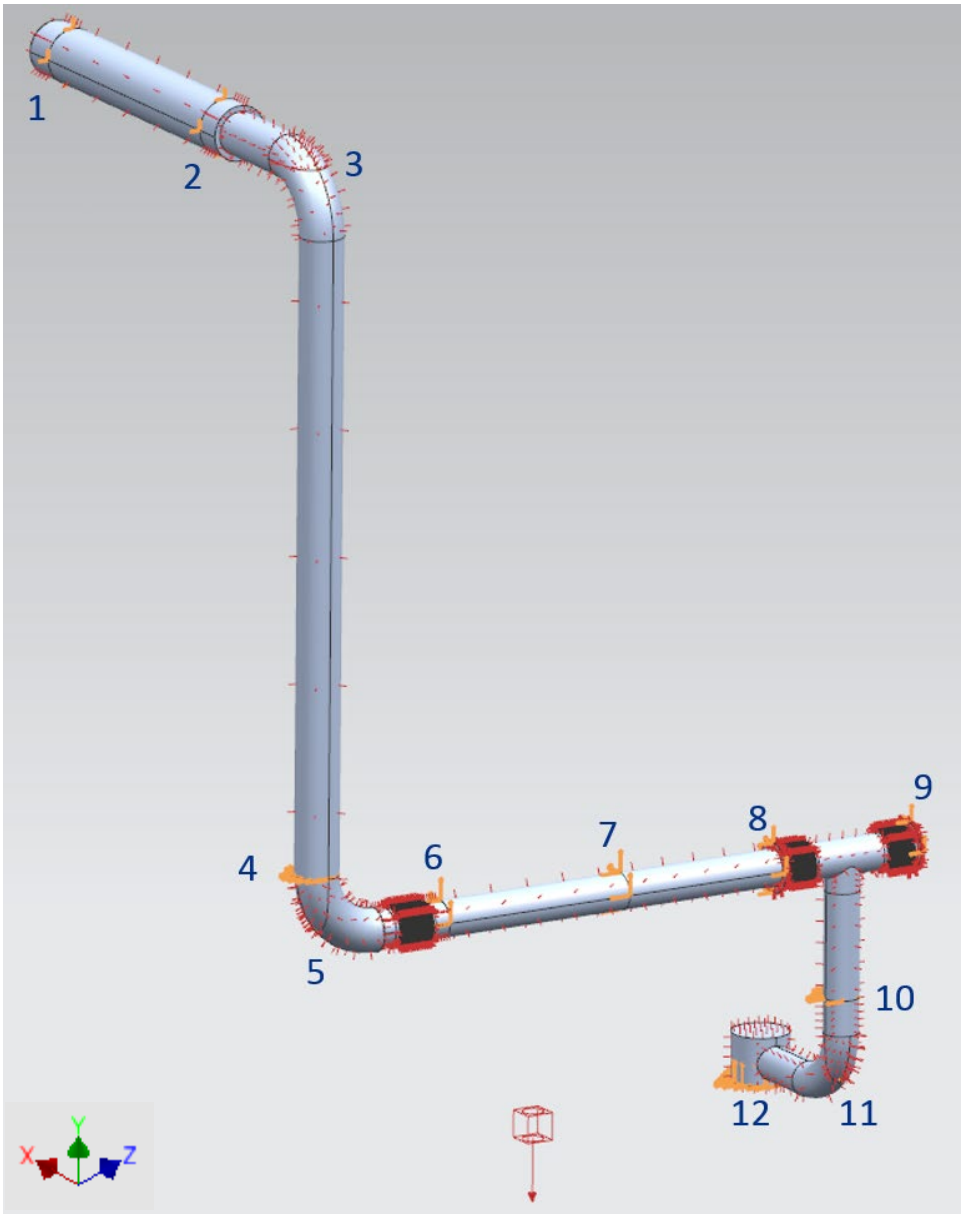

Figure 4- Reaction locations from Fermilab pump line analysis

[6] Email from Dustin Keller on August 29, 2018
[7] Email from Don Mitchell on May 29, 2018 and again on May 30, 2019

For each of these locations, reaction forces were provided as:

Pt #	X	Y	Z	Pounds
1	67.334	220.181	0	
2	-218.103	541.556	0	
3	8.618	0	0	
4	1621.378	0	-8.636	
5	0	908.49	0	
6	-911.906	114.115	0.021	
7	647.997	195.3	-0.009	
8	264.73	89.946	0.509	
9	-1471.83	30.853	0.454	
10	0.167	0	-39.026	
11	0	126.836	0	
12	-0.372	38.964	38.07	

Figure 5- Reaction forces from Fermilab pump line analysis

Of these reactions, the image of the Fermilab model below shows that only reaction #10 is attached to or supported by the support frame:

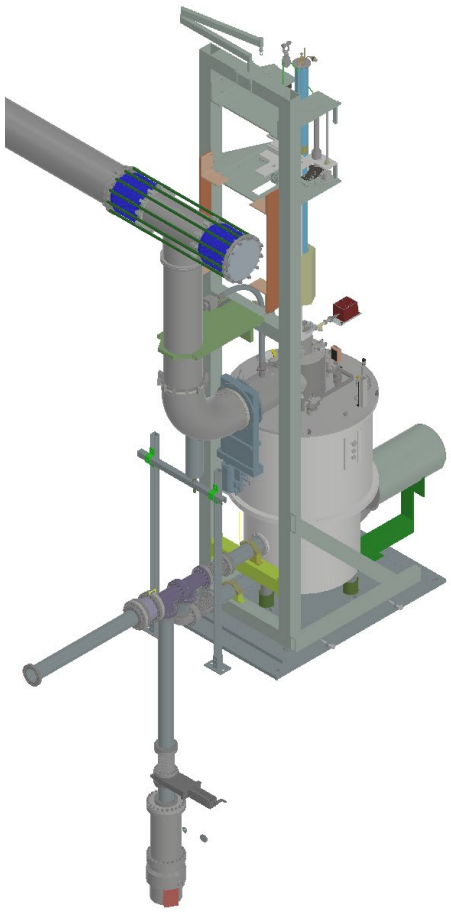

Figure 6 - Fermilab model showing attachments to support frame

These loads (vacuum load and pump line reactions) were applied to a finite element model of the support frame and the resulting static stresses are shown below:

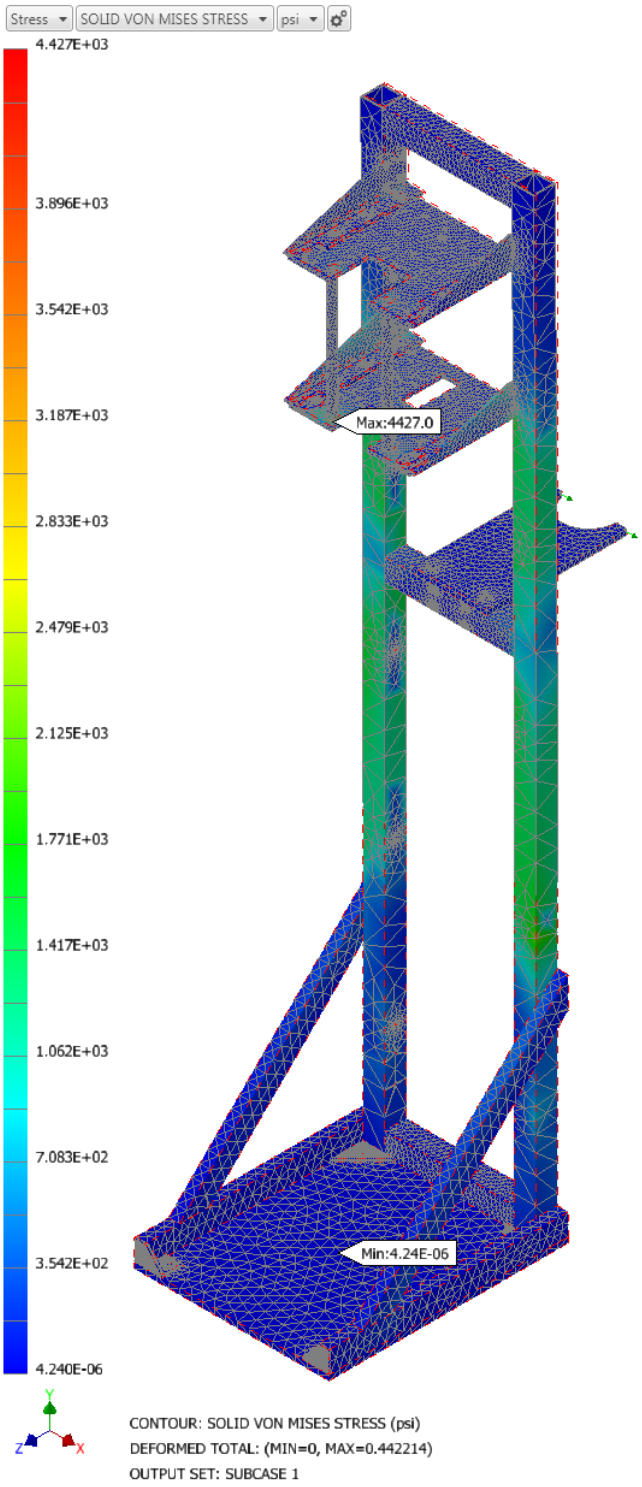

Figure 7 - Stress results for support frame and elevator

With a yield stress of 35ksi, this represents a minimum margin of safety (FoS-1) of 6.9.

Lifting Bar Stress Analysis

The lifting bar was analyzed to determine the stress induced by the vacuum load of 318 lbf with the roller support in the raised and lowered positions:

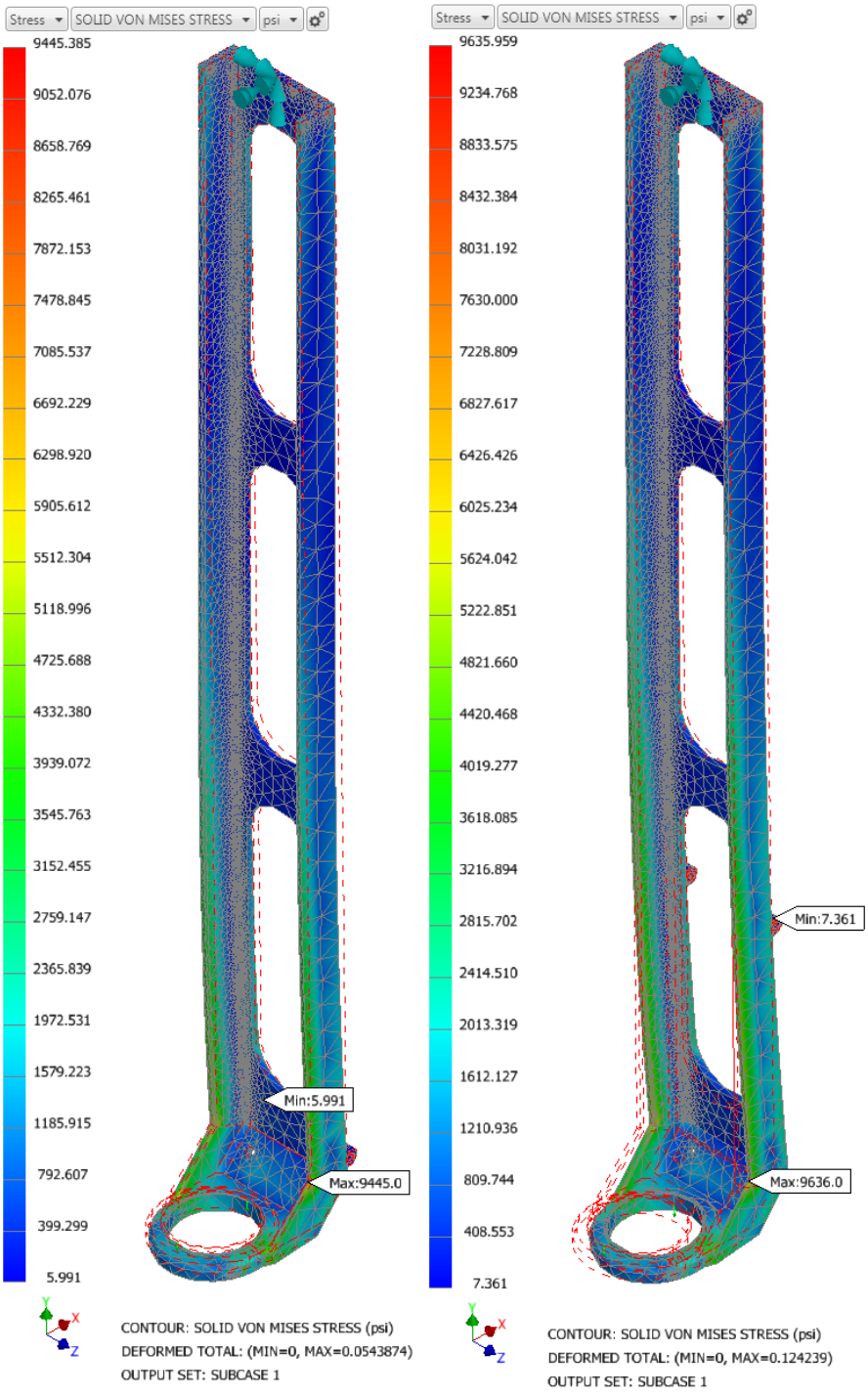

Figure 8- Lifting bar stress from vacuum load and roller support in 2 positions

With a yield stress of 35ksi, this represents a minimum margin of safety (FoS-1) of 2.63.