Capsule Structural Tester

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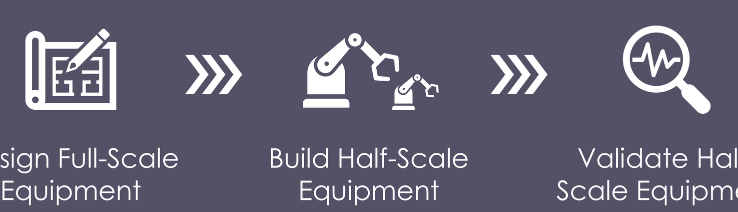
1. PROJECT OBJECTIVE

Design, build, and validate a **robust** and **scalable** test fixture for compressive structural testing of a space capsule and other rocket components.



2. DESIGN

Structural

The full-scale test fixture (Figure 5) design adheres to industry standards for applying compressive loads to test material and structural properties: dual-column, made of structural steel I-beams.

The half-scale prototype (Figure 1) was designed with beams suitable in size and strength for reuse at full-scale.

FIGURE 5: Full-Scale Capsule Structural Tester

The testing plate (Figure 4) is a composite with a stiffened steel surface supported by plywood. The structure base is an I-beam selected to withstand internal bending forces. This beam is attached to a plywood base designed to withstand shear according to OSHA standards.

Mechanical

Hydraulic actuation is the primary method of force application. The main components (Figure 6) of the hydraulic circuit are a hydraulic cylinder rated for 58000 lb-f, a hydraulic power unit powered by a 1.5 kW motor, a manual flow valve, and a pressure transducer.

The cylinder mounts to the T-bar on the structure by two clevis pins (Figure 2).

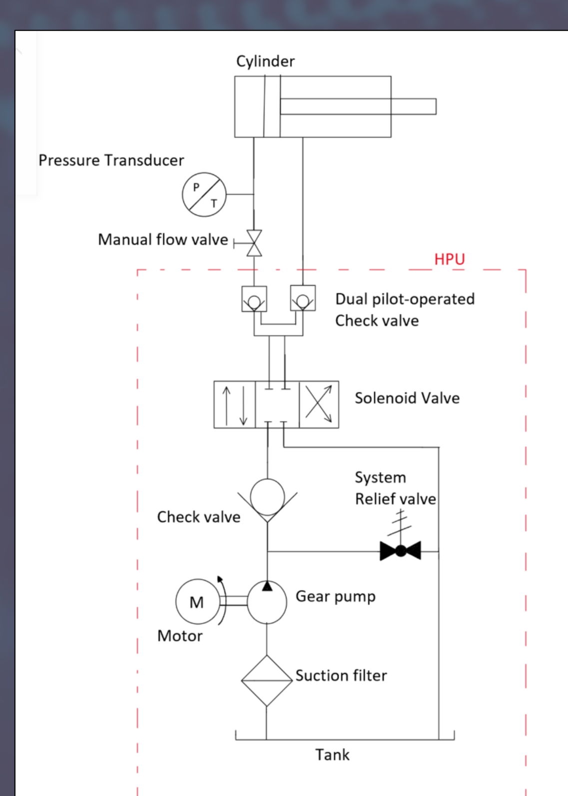


FIGURE 6: Hydraulic Instrumentation Diagram

The end effector (Figure 3) is the interface between the cylinder rod and the test subject. It is composed of two parts bolted together; a cylindrical aluminum sleeve and a flat square steel alloy slab. The end effector assembly attaches to the cylinder by a clevis pin.

FIGURE 2: Cylinder Mounting

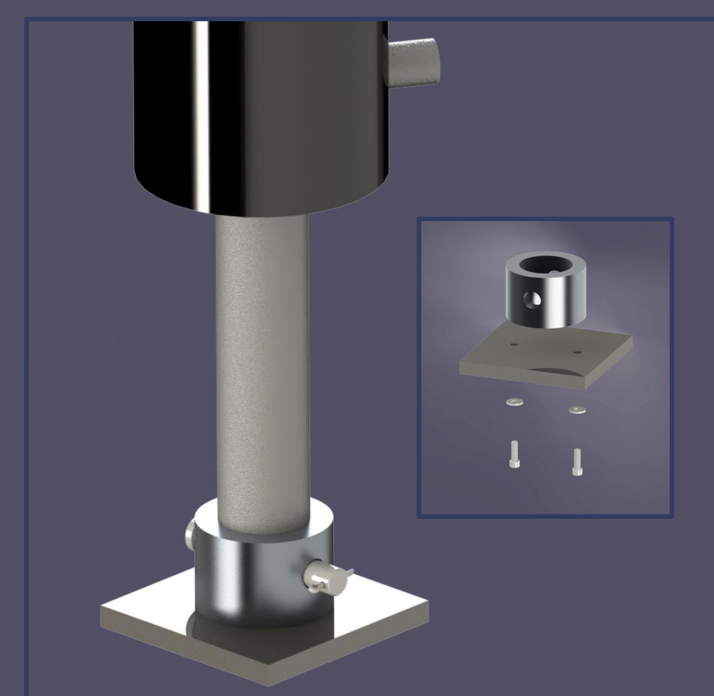


FIGURE 3: End Effector

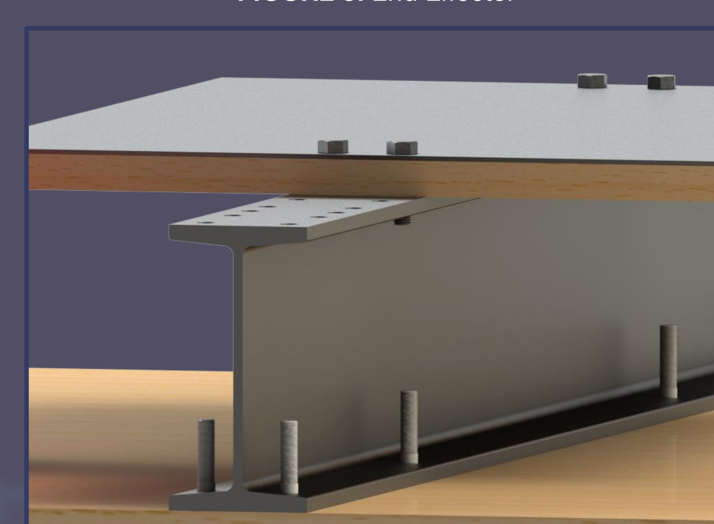


FIGURE 4: Composite Test Surface

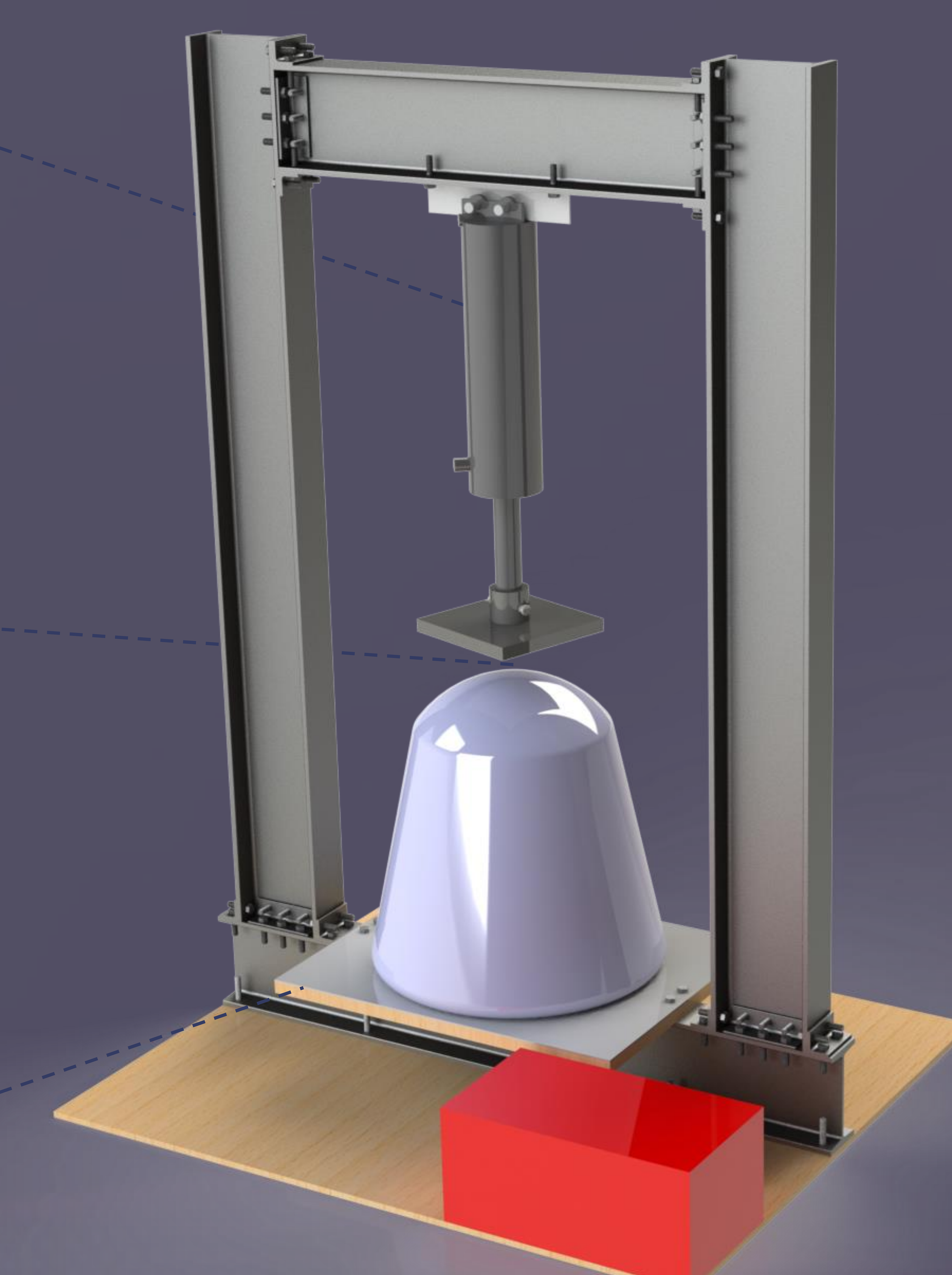


FIGURE 1: Half-Scale Capsule Structural Tester

3. MODELING

Finite Element Analysis (FEA)

SolidWorks FEA was used to model the structural design and verify that expected maximum stress remained less than yield stress for every structural component.

The cylinder mount T-bar (Figure 7) experiences the highest stress from compressive loading.

Other stress concentrations occur in the crossbar, also from compression, and in the steel test plate for both point loads (Figure 8) and distributed loads (Figure 9).

A point load induces more stress in the base I-beam. Since the I-beams were selected for the higher loads applied at full-scale, they are sufficient with redundancy for our half-scale use case.

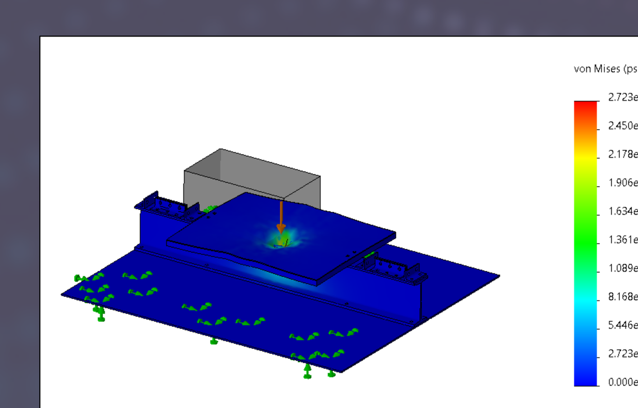


FIGURE 8: Base Plate Point Force

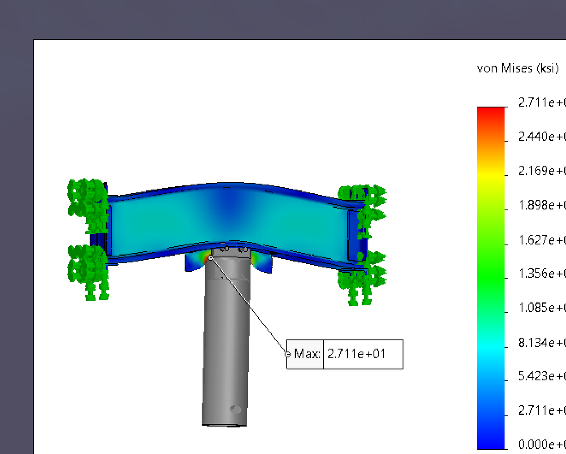


FIGURE 7: Crossbar FEA

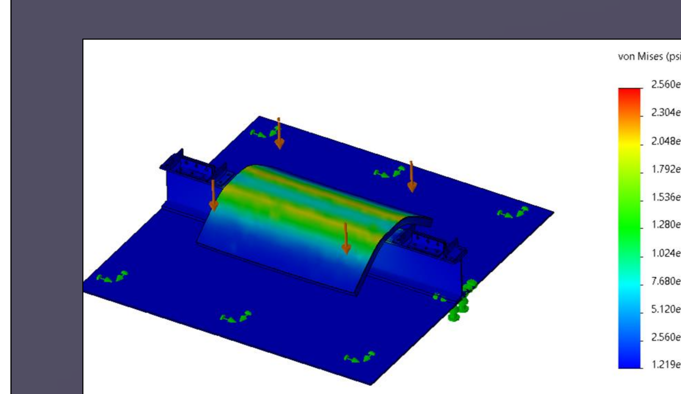


FIGURE 9: Base Plate Distributed Load

4. ELECTRICAL & DATA ACQUISITION

The heart of the system is a Arduino Uno microcontroller. A pressure transducer sends feedback to the controller, which in turn actuates the cylinder to apply force until the desired application force is achieved.

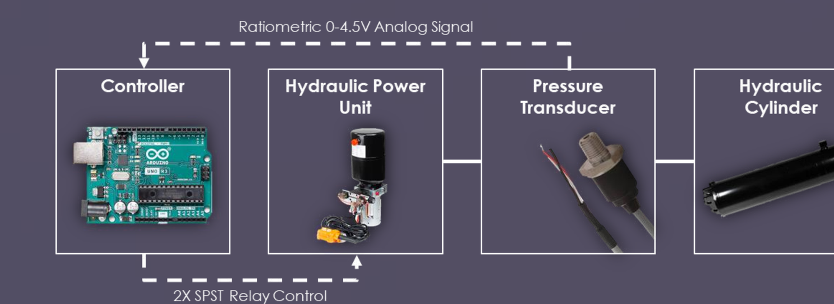


FIGURE 10: System Architecture

The control panel (Figure 11) utilizes a 16x2 LCD screen that displays force setpoint (FSP) and force process variable (FPV) values, as well as information on machine status. An adjustment knob allows the operator to change the FSP value, and pushbuttons serve as RUN and STOP buttons.

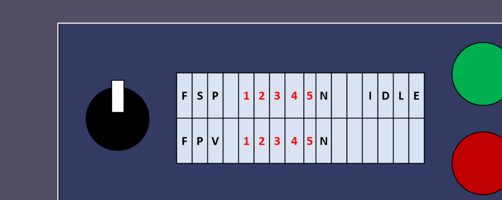


FIGURE 11: Control Panel Interface

Digital Image Correlation (DIC)

DIC works by applying a pattern to the test subject which is monitored with cameras during compression. The pattern is then tracked in software in post and gives various deformation values.

The pattern application quality & consistency is critical for data resolution.

The set up will include two cameras positioned perpendicular to each other.

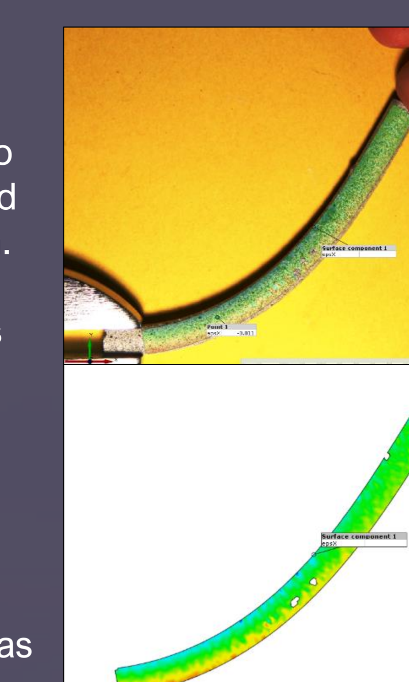
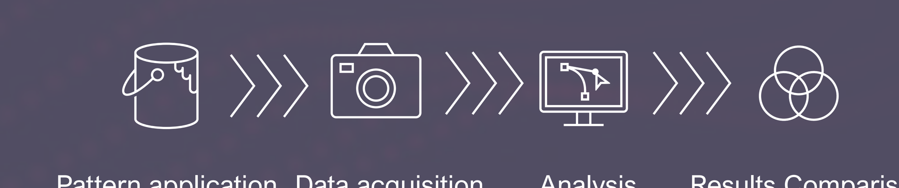


FIGURE 12: Sample DIC Data



5. RECOMMENDATIONS

1. Implement dedicated and modular 12VDC power architecture for HPU and electronics with safety relay system
2. Design and implement structural supports in the full-scale design to stabilize cylinder against radial forces caused by eccentric loading
3. Proceed with full-scale build to validate full-scale space capsule.