NORTHROP GRUMMAN

Passive Deployable Hinge Mechanism

ME189 – Team 2

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Abstract

Due to the confining holding bays of launch vehicles, satellites are often designed to be launched in a stowed configuration then deploy into a functioning configuration. The success of the mission depends on the success of the deployment mechanisms. Teamed with Northrop Grumman, this project concentrated on producing a simulative passive deployable hinge mechanism designed to function in a typical satellite mission environment. A design was developed through extensive research, modeling, and prototyping. With analysis and physical testing, our product proved to meet all design requirements set forth by our industry partner.

	Requirement	Verification Method
Stowed & Launch	Stowed Angle = 0°	Inspection
	Min. Stowed Natural Frequency = 30 Hz	Analysis
	Max Fastener Load Imparted on Spacecraft ≤ 5000N (Shear or Pullout)	Analysis/Testing
	Survive & Meet Requirements with Launch G-Load (X,Y,Z) = (±6g, ±6g, ±13g)	FEA
Deployment & On-Orbit	Min. Deployed Natural Frequency = 3 Hz	Analysis
	Survive & Meet Requirements with Deployment & On-Orbit Loads	FEA
	Deployment Angle (SC Theta X) = 90°	Testing
	Deployment Latch-up Angular Errors = <+/-0.5> Degrees Max Error	Analysis/Testing
	Maximum Latch-up Base Moment Imparted to Spacecraft ≤ 500 N-m	Analysis/Testing
	Overcome Payload Electrical Harness Resistance Torque = 0.2 N-m	Analysis/Testing
	Deployment Torque Margins > 100% Measured Statically at All Points	Analysis/Testing
	Latch Up Torque ≥ 15 N-m	Analysis/Testing
General	Mass ≤ 0.375 Kg	FEA/Testing

Table 1. Project Requirements and Methods of Verification.

Design Approach

The hinge design had to passively achieve the design requirements highlighted in Table 1. After researching existing mechanisms in achieving passive deployment, two design solutions were created: a Pin and Groove design and a Clevis and Boom design. Through conceptual prototyping and analysis, the Clevis and Boom approach was chosen as the pursuant design.

The Clevis and Boom design efficiently and effectively accomplishes the deployment requirements through its locking tooth design:

- Sloped interfacing surfaces eradicates overshooting
- Tapered teeth provide negligible slop and accurate deployment position
- Locking tooth approach surpasses latch-up torque requirements EDIT EDIT

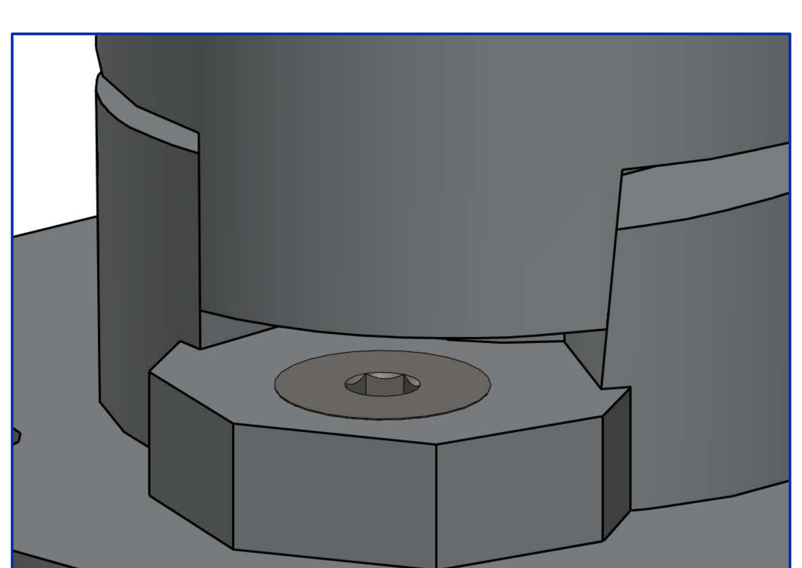


Figure 1. Tapered Teeth Design.

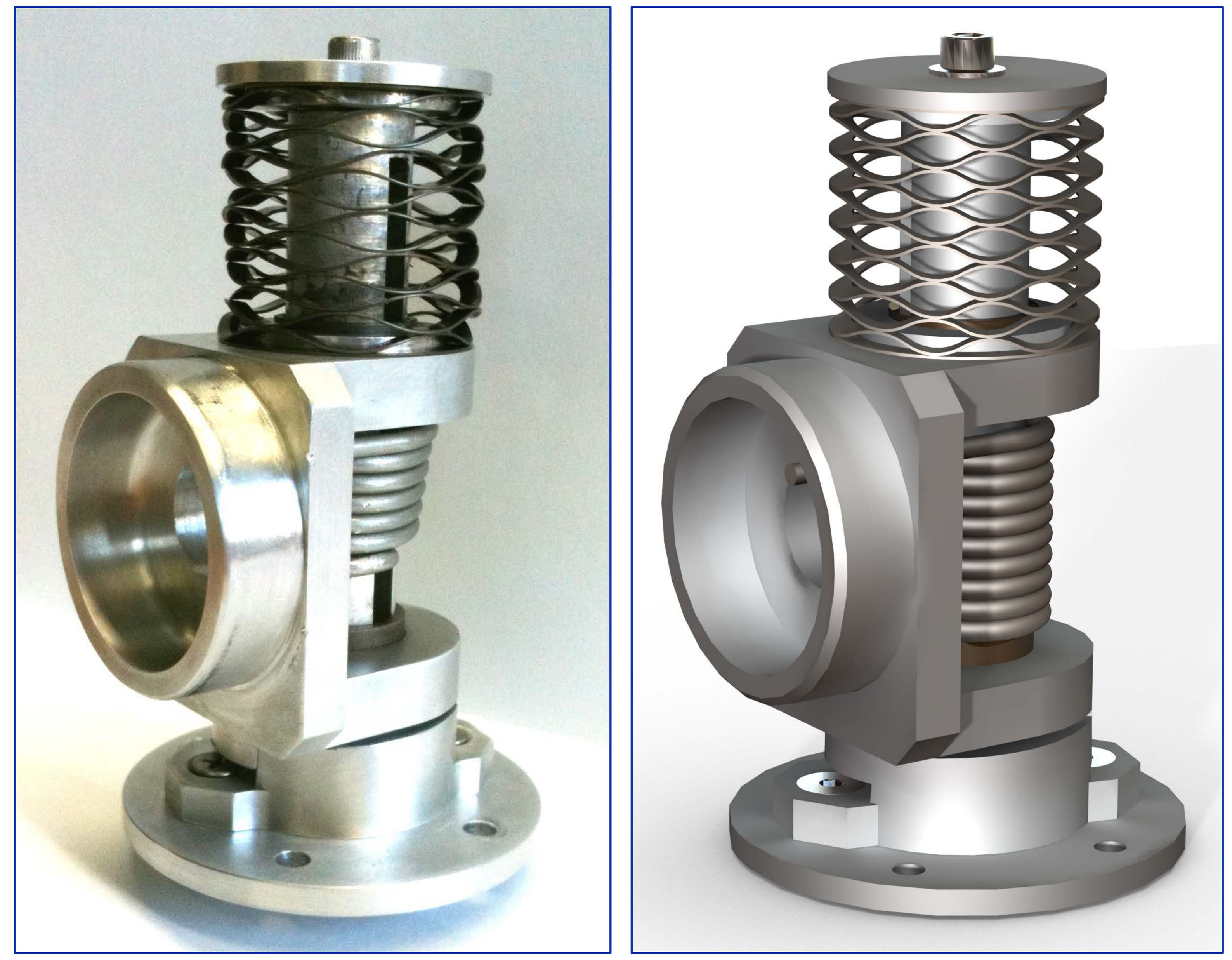
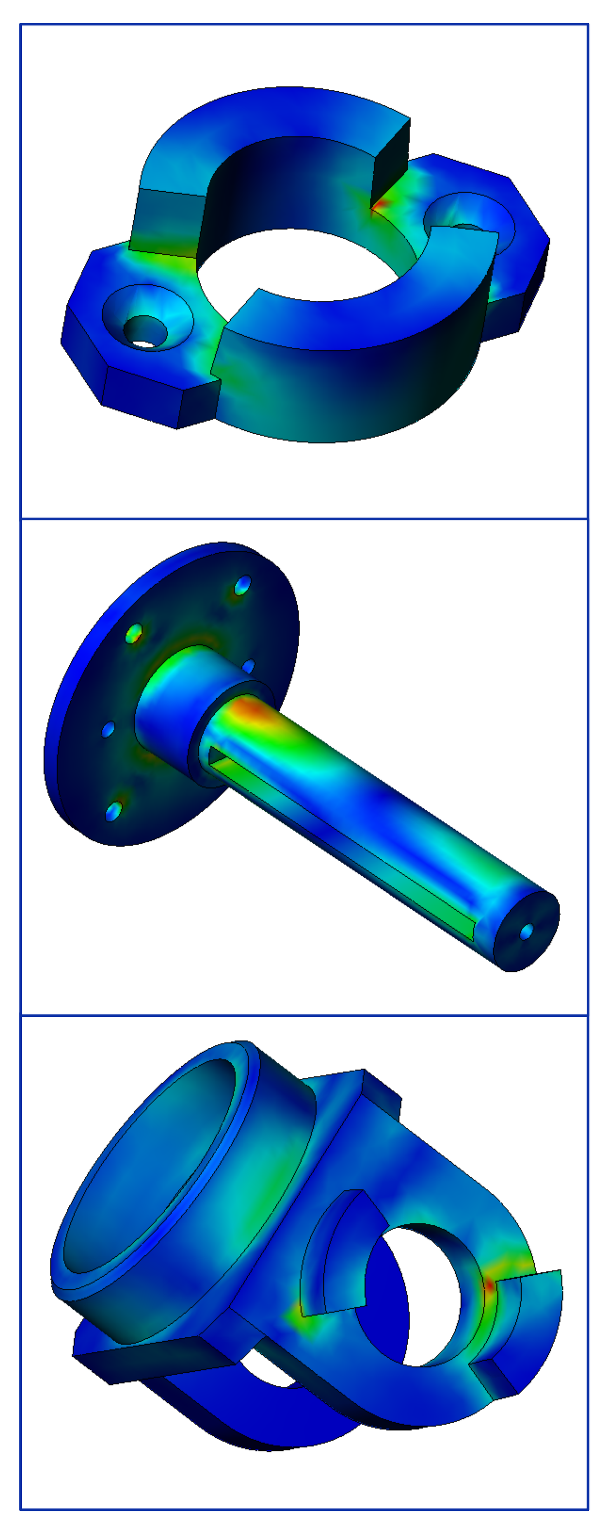


Figure 2. Prototype Model (left) and Solidworks CAD Model (right).

Analysis

The hinge was modeled using SolidWorks and FEA was performed using COSMOS. Models precisely emulating the physical hinge were developed and launch loads, stowed/deployed loads, and on-orbit loads were applied to simulate actual launch and deployment conditions.



Due to the complexity of the design and the explicit and drastic loads experienced during launch and operation, all load requirements were satisfied through FEA, shown in Fig. 3.

Energy calculations were utilized in the sizing of springs during the design phase and also used to compliment dynamic physical testing. Vibration analysis was performed to achieve natural frequency requirements.

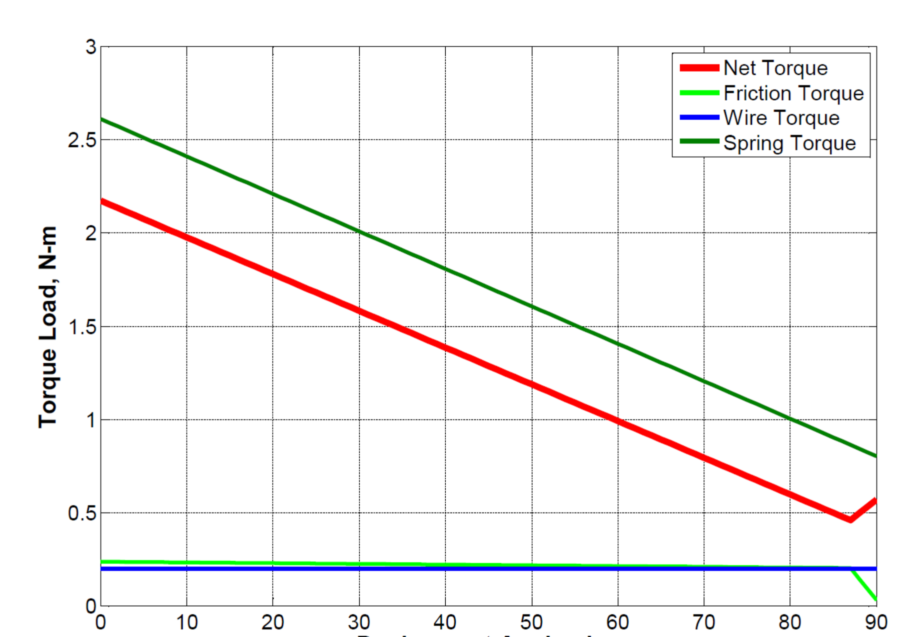
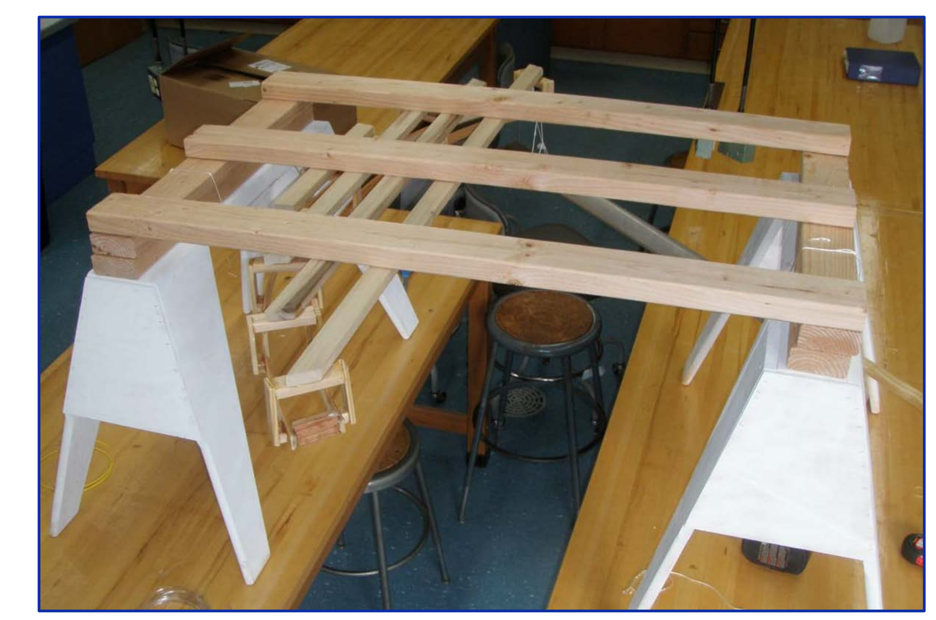


Figure 3. FEA Stress Results and Theoretical Torque Calculations.

Testing

In order to properly test our design, a test bench was constructed to offload the gravitational effects of the boom and mass while maintaining their inertial effects. With this test bench, a series of tests were performed that determined the static and dynamic attributes of the hinge.

A load cell was used to calculate latch-up torques, fastener loads, and deployment torque margins. A potentiometer was used to determine the slop of the hinge in the deployed state. Mass was also physically tested using a laboratory scale accurate to 0.001 grams.



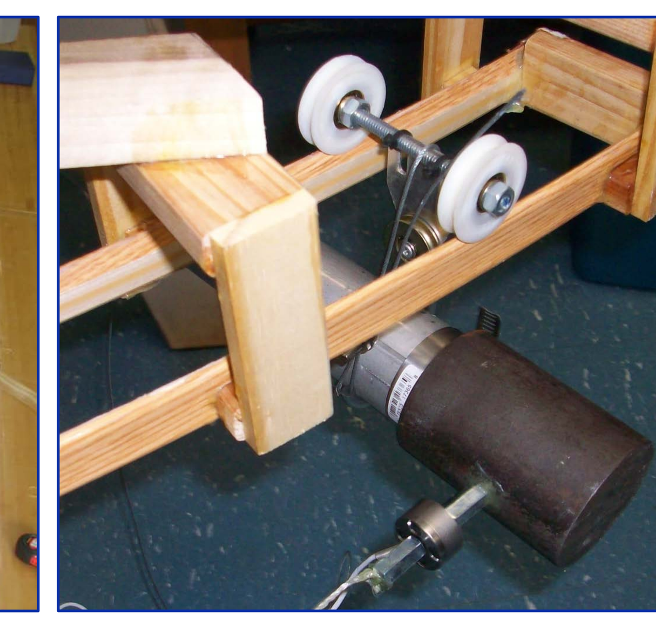


Figure 4. Angular Slop Test (top) and Test Bench Set-up (bottom).

Results

Through the testing and analysis performed, we confidently met all requirements. The overall mass was found to be 8 grams under the maximum, torque margins were determined to well exceed the minimum requirements, fastener loads and latch-up base moments were significantly lower than specified, and all margins of safety were positive. EDIT EDIT EDIT

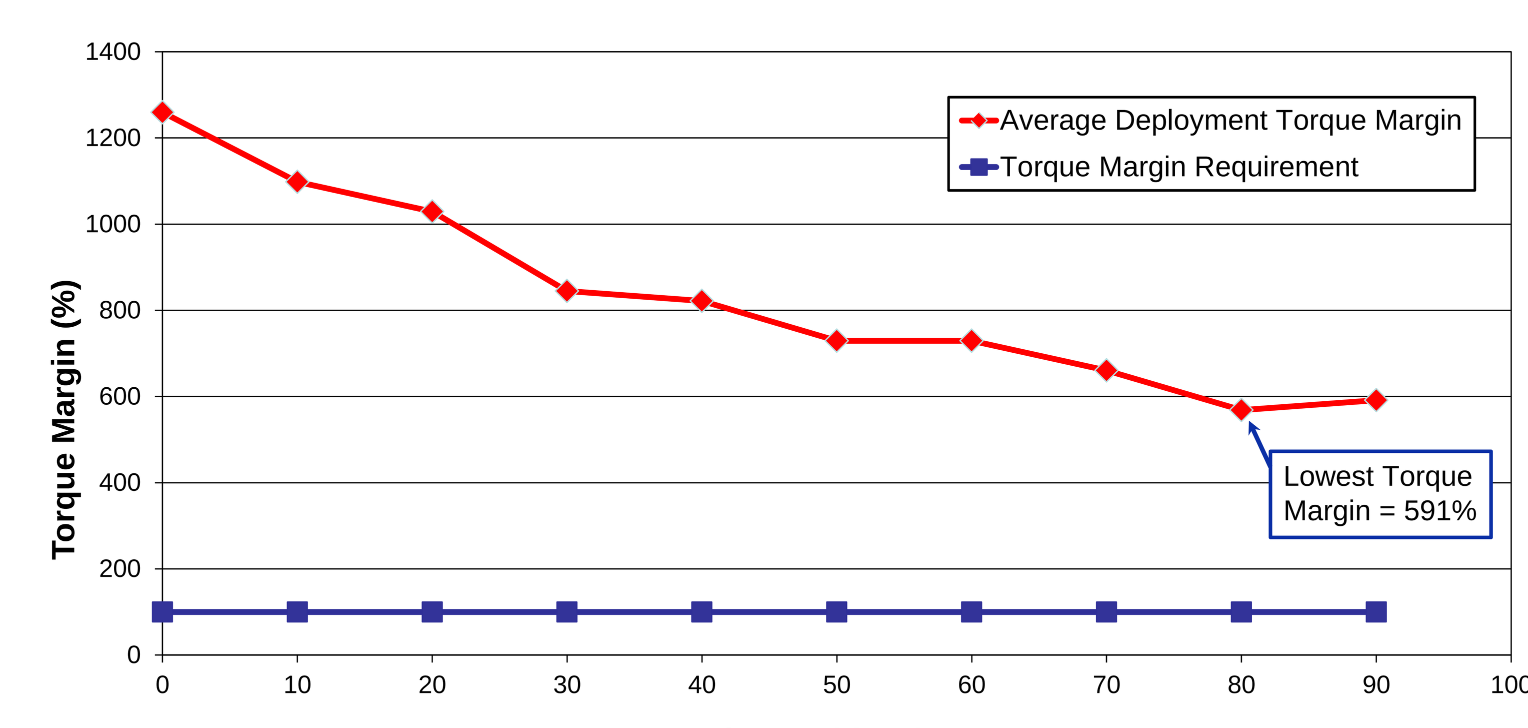


Figure 5. Results of Deployment Torque Testing.

Acknowledgments

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