MVAS Preliminary Design Review

Overview:

- Background
- Research Summary
- Needs and Requirements
- Proposed Design(s)
- Design and Analysis Plan

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Background

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Problem Definition

At the latest test fire, a main oxidizer valve was unable to open, resulting in the liquid natural gas to combust with little oxygen, resulting in minimal thrust produced. In order to prevent this from occurring in future test fires, the current system's existing hardware must be investigated while the MVAS team will design an entirely new system with commercial off-the-shelf components.

Problem Statement

The objective of the MVAS team is to develop an actuation system that will allow two mechanically linked valves to open simultaneously and deliver the propellants into the injector at their desired pressures.

Speaker: Vanroy

Research Summary

Where did we start?

We split up the project into chunks that each of us could work on:

- Cory: Actuator selection
- Vanroy: Valve selection
- Jeffrey: Linkage design

Resource(s) used:

- Discussed potential solutions with UCIRP team leads
- Reached out to Mark Holthaus from FAR
- SolidWorks models from the team GrabCAD
- Several websites to look for OTS components (McMaster-Carr, Amazon, REGO, etc.)
- Huzel, Huang - *Design of Liquid Propellant Rocket Engines*, NASA
- Pressure loss code

Links to documentation:

- Client Statement
- MVAS 189 Final Report

Speaker: Vanroy

Needs and Requirements

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Design Parameters

- System must be capable of withstanding 600 PSIA
- System must maintain a 0.625” inner diameter for optimal fluid flow
- Components must be capable of handling cryogenic fluids and gases
- System should significantly reduce weight from existing system (34lbs)
- System should maintain a safety factor of 1.5
- The system should ensure that the valves are mechanically linked
- The valves should actuate, from full open to full closed, in less than 0.5 seconds
- The system should cost less than $600
- The system should also be compatible with existing avionics hardware and communications
- The system should draw less than 30A at 16.8V
- The system should should fit well within the rocket fuselage and be mounatable to main structure

Speaker: Vanroy

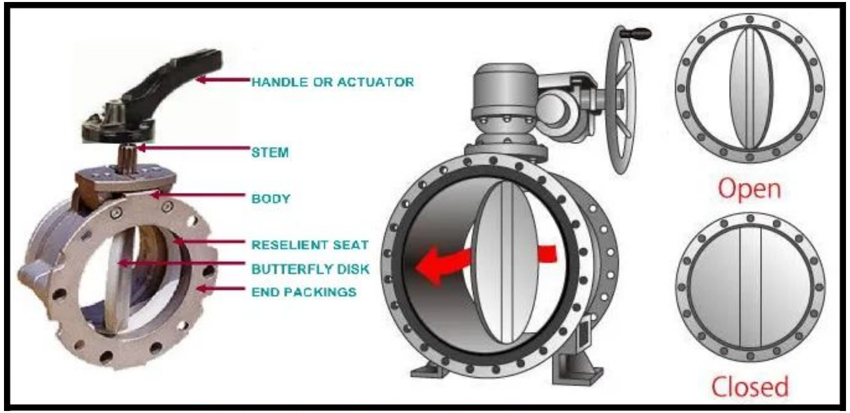
Valve Selection

Types of propellant valves commonly used on rockets

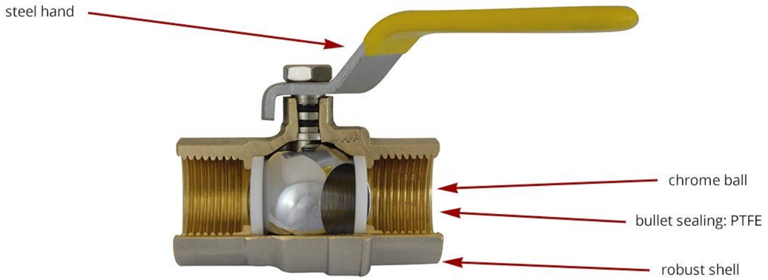
- Butterfly valves
- Ball valves
- Poppet valves
- Venturi valves
- Gate valves
- Needle valves

All these valve types were considered in the selection process. Choices were limited to off-the-shelf products.

Butterfly-Type Valves



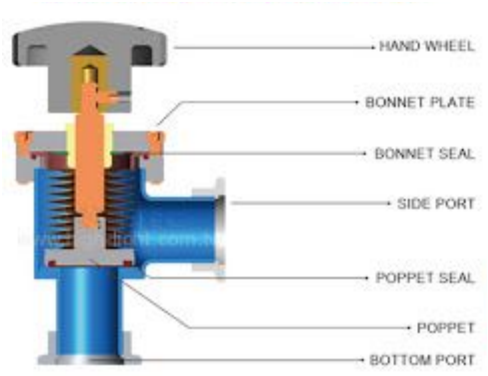
Ball-Type Valves



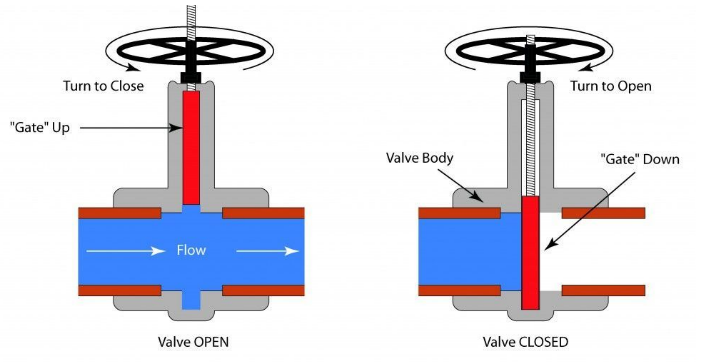
Speaker: Vanroy

Valve Selection

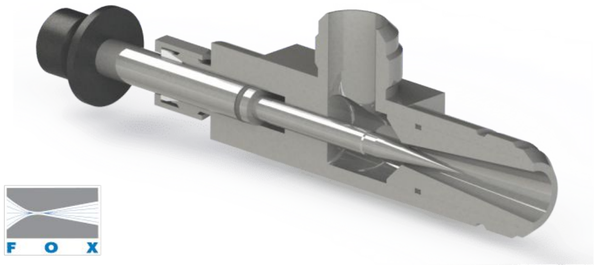
Poppet-Type Valves



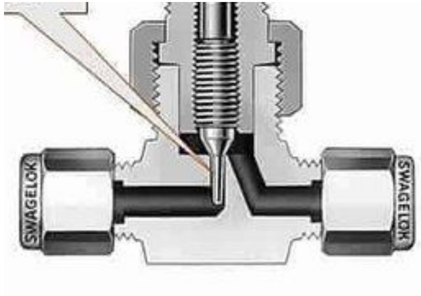
Gate-Type Valves



Venturi-Type Valves



Needle-Type Valves



Speaker: Vanroy

Valve Selection

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Main valve choices:

Valve	Specifications	Price	
Liquid Nitrogen Valve - Stainless Steel, Vented Ball Valve	• Cryo rated • 2000 psi rating • ¾” FNPT	$611.99/each	
Goddard 306 Series Bronze Gate Valve	• Cryo rated • 600 psig rating • Cv = 36 • ¾” FNPT	$284.33/each	
McMaster-Carr Ultra-Corrosion Resistant Full-Port On/Off Ball Valve	• Not cryo rated (needs modifications) • 1000 psi rating • Cv = 35 • ¾” FNPT • PTFE seal	$47.86/each	

Speaker: Vanroy

Valve Selection

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Things to note:

- All extended bonnets should still be able to fit inside the rocket (assuming 12” ID)
- For cryogenic modification, we need to clean/degrease valve components very well and relube with Krytox
- Ball valve will need to be vented (⅛” diameter vent hole)
- Need to test modified ball valve design with LN2 in a controlled environment before integrating to Cold Brew or PTR

We have chosen to use the McMaster-Carr ball valve and will modify it for cryogenic operations.

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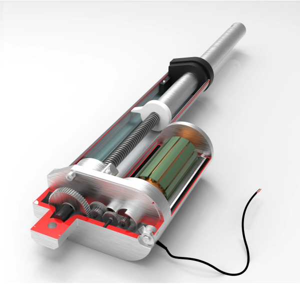
Proposed Design(s)

Motor Actuation Methods



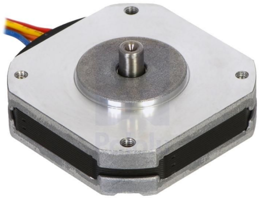
Linear actuators (off the shelf product)
- High torque/low speed
- LA within budget use stepper or brushed
- Fully integrated solution

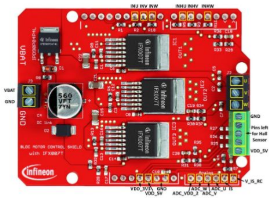
Brushless
- High Starting Torque
- Speed/Position Feedback (EMF)
- Resilient to environmental factors

Brushed
- Low Cost
- Simple to control
- Low starting torque

Drive Component
- Brushed motors can be driven directly by the avionics payload
- Brushless and stepper motors require additional drivers and, depending on design, an additional microcontroller

Stepper
- HIgh torque
- Precise control
- Low speed





Speaker: Cory Hague

Proposed Design(s)

Pneumatic Actuation Methods

Air cylinders
- High Force/Speed
- Limited amount of actuations
- Simple to control

Rotary Pneumatics
- High Torque/Speed
- Can be fixed (vane/rack & pinion) or continuous rotation
- Low Power
- Limited amount of actuations.
- Continuous actuators require substantial gas storage

Pressure Sources and Controls
- Require Extra Space
- Low Power
- Simple Control

Speaker: Cory Hague

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Proposed Design(s)

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Hydraulic and Spring Actuated Methods

Hydraulic Rotary and Linear Actuators
- Requires Onboard Pump
- Not weight efficient
- Slow actuation on a small scale
- Pumps require large battery discharge capability

Spring Mechanisms (Torsion/Tension/Constant Force)
- Only provides a single actuation without complex gear mechanisms
- Added risk in terms of actuation reliability
- Involves high mechanical potential energy that could present danger to operators and crew

Speaker: Cory Hague

Proposed Design(s)

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Actuator Type	Expected Torque/Force @ 0.5s Actuation	Weight	Power Draw	Cost	Lead Time	Control Complexity	Additional Hardware	Other Advantages	Other Disadvantages
Brushed Motor	2.1 ft-lb	0.5 lbs	20A-30A	$25-$60	1 week	Would interface directly with avionics	none	Readily available, low cost	High stall current, low starting torque
Brushless Motor	1.5 ft-lb (not at start)	0.8 lbs	20A-30A	50-$100	1 week	Requires at least one motor driver (PWM)	Motor Driver	Constant torque, waterproof	Additional control hardware required
Stepper Motor	0.6 ft-lb	2.2 lbs	7A	$50-$150	1-2 weeks	Requires motor drive and microcontroller	Motor Driver and microcontroller	High torque, integrated position control	Additional hardware required, low weight efficiency
Pneumatic Cylinders	40 lbs linear @ ¾" bore	1.1 lbs	0.5A	$30-$60	1 week	Direct avionics interface, digital	solenoid valve, air storage system	High force, low power, simple control	Requires extra volume for air storage, limited actuations
Pneumatic Rotary Vane	20 ft-lb	0.5 lbs	0.5A	$105-$255	1 week	Direct avionics interface, digital	solenoid valve, air storage system	High mechanical efficiency, high torque	Requires air storage, limited actuations
Pneumatic Rotary Rack & Pinion	20 ft-lbs	1,4 lbs	0.5A	$176-$300	1 week	Direct avionics interface, digital	solenoid valve, air storage system	High torque, fast actuation	Larger than vane designs, limited actuations, airstorage
Pneumatic Ratchets (continuous)	150 ft-lbs	2.9 lbs	0.5A	$50-$200	1 week	Direct avionics interface, digital	solenoid valve, air storage system	High torque, fast actuation	Large air flow, very limited number of actuations
Hydraulic Actuators	50 ft-lbs	~6 lbs	30A-50A	$300-$500	2 weeks	Direct avionics interface, digital	Solenoid valve, pressure pumps	High torque, simple control	Low speeds, weight, large power consumption
Spring Actuators	5 ft-lbs	1-2 lbs	N/A	$50-2$00	1 week	Direct avionics interface, digital	Latch mechanism, solenoid/motor	HIgh torque, low power	Danger to operators, limited to single actuation

Proposed Design(s)

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Actuation Methods

Motor
- Linear actuators (off the shelf)
- Brushed
- Stepper
- Brushless
- Drive Component

Pneumatic
- Cylinders
- Rotary tools
- Gas Storage

Springs
- Torsion
- Tension
- Constant Force
- Mechanism

Hydraulics
- Linear
- Rotary
- Pump

Proposed Actuators

Pneumatic Cylinder: McMaster-Carr 6498K154 - $40
- Simplified control
- Reliable
- High Actuation Force
- Low Weight
- Low Power Requirements
- Directly Compatible with Avionics

Pneumatic Rotary Vane: SMC NCRB1BW30-180S*(or 90S)* - $105
- Precise Rotational Control
- High Torque and Speed
- Large Range of Pressures
- Directly Compatible with Avionics
- Low Weight
- Low Power Requirements

Speaker: Cory Hague

Proposed Design(s)

Mechanical Linkage Methods

Gear Train using pneumatics or motors

- Pinion Gears
- Worm Gears
- Rack and pinion
- Bevel Gears

Screw

- Lead Screws
- Ball Screws

Bar linkages

- Four bar linkage

Rotational to Rotation (motors and rotary)

-motor to gear train

-rotary to gear train, fixed or continuous

-motor or rotary to a rack and pinion

Linear to Rotation (linear actuators/pneumatic)

-Pneumatic/linear actuator to rack and pinion

-Pneumatic/linear actuator to bar linkages

Speaker: Jeffrey Vuong

Proposed Design(s)

Rack and Pinion

- Long range
- Higher speeds
- Backlash

Ball Screws

- Less friction
- Screw whip
- Lower speeds

Bar Linkage

- May not be able to withstand high torque

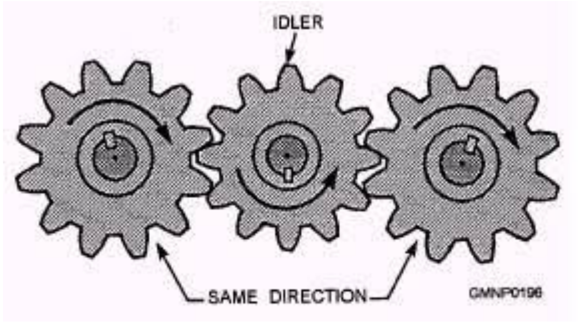
Proposed Linkage Mechanisms

Three Pinion Gears with a pneumatic rotary vane

- Two to one gear ratio
- Higher power transfer efficiency

Rack and Pinion with linear pneumatic actuator

- Higher speeds
- Helical rack, less friction, smoother, higher forces



Speaker: Jeffrey Vuong

Proposed Design(s)

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Potential Mechanical supplies needed:

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Linkage Mechanism		Estimated Cost
Pinion Gears	Mcmaster-carr	$20-$50 each
Ball/lead screw	Mcmaster-carr	$15-$50 each
Bar linkages	To be manufactured	TBD
Rack	Mcmaster-carr	$40 each
Worm Gear	Mcmaster-carr	$10-$40 each

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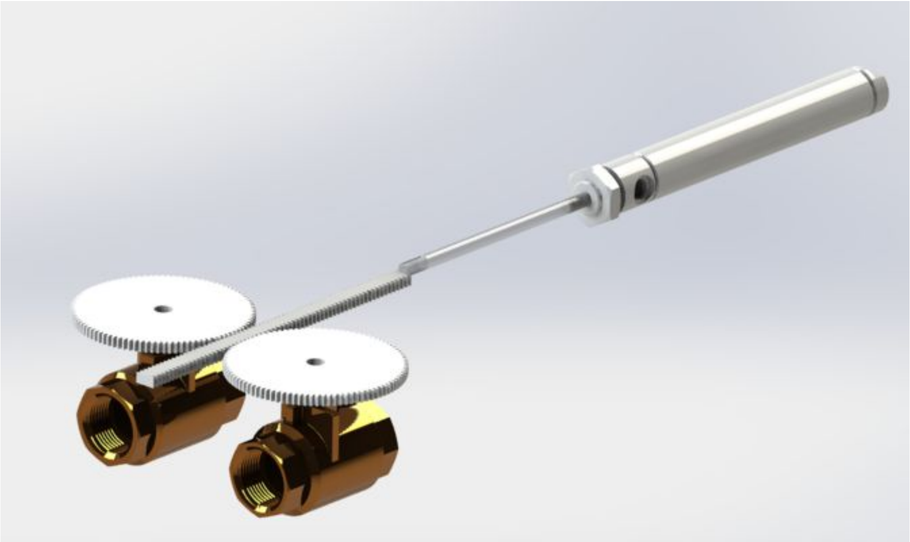
Proposed Design(s)

Solidworks Render Models



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Design and Analysis Plan

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Design/Analysis Plan

- Create CAD designs for proposed design concepts (digital twin)
- Perform analysis on components to ensure they meet requirements (thermal, stress, motion study, flow simulation, etc.)
- Perform in-lab pressure and force tests with nitrogen on modified ball valve (safety permitting)
- It is possible to prototype this design using on-hand equipment, additional materials and components required
- Once manufactured this system may be tested using inert high-pressure liquids and later integrated on the Cold Brew system for fully integrated testing.

Speaker: Jeffrey Vuong

Project Timeline

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Week 5: Decide on final design of actuation system. This includes final valve selection, actuator selection, and linkage design. Present preliminary design review to UCI Rocket Project and project advisor.

Week 6: Develop CAD models of hardware and circuit diagrams for verifying compatibility with existing electronics. Start doing preliminary analyses of final design. This includes thermal analysis, stress analysis, and motion study.

Week 7: Present critical design review to UCI Rocket Project and project advisor. Verify that final design meets all specifications and requirements.

Week 8: Start ordering part to begin manufacturing process. Present final design review to UCI Rocket Project and project sponsor. Validate the logistics of the design.

Week 9: Start building component. Test component with liquid nitrogen to ensure reliability under cryogenic operation.

Week 10: Turn validated design over to UCI Rocket Project. Complete other necessary documentation to close out the project.

Speaker: Jeffrey Vuong

Any questions?