PEAPOD

Pneumatically Energized Auto-throttled Pump for a Developmental Upperstage

Manufacturing Status Review

Customer: Special Aerospace Services
Chris Webber and Tim Bulk

Overview

- Project Overview
- Pump Manufacturing
- Pump Control
  - Valving
  - Electronics
  - Software
- Budget
- Conclusion

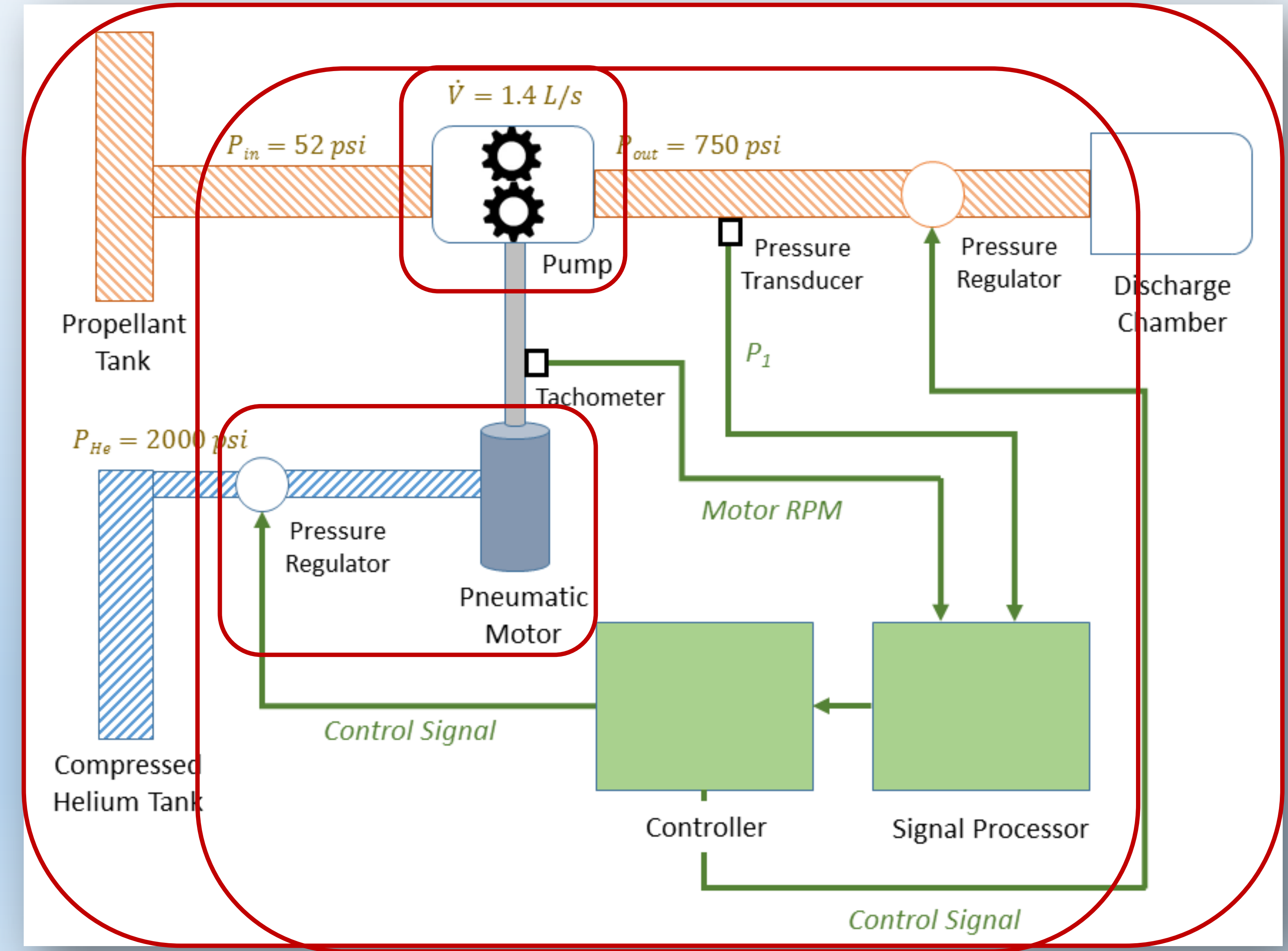
Project Motivation

- Design and manufacture a pneumatically powered pump system for use on an upper stage rocket engine or lander.
  - Proof of concept pump system for hypergolic propellants
  - 10%-100% throttleability
  - Pneumatically powered

Levels of Success

Level	Functional Success	Performance Success	Functional Requirement
1	• Pneumatic power • Digital control • Meets safety requirements	• 750 ± 15 psi outlet pressure • Structural FOS 2.5 • 120 seconds of operation • 75% efficiency of pump at full throttle	• **FR1** – System is pneumatically driven • **FR7** - FOS of 2.5 • **FR8** – 75% efficiency at full throttle • **FR3** – Pump outlet is at 750 ± 15 PSI
2	• Propellant stream throttling • All level 1 requirements	• 10-100% throttleability • 0-100% throttle in 2 seconds • All level 1 requirements	• **FR2** – Pump system is throttleable • **FR4** – Pump system can run through throttle profile • **FR5** – Pump is restartable
3	• Hypergolic compatible • All level 1 and 2 requirements	• 0-100% throttle in 1 second • All level 1 and 2 requirements	• **FR6** – System is built to hypergolic standards

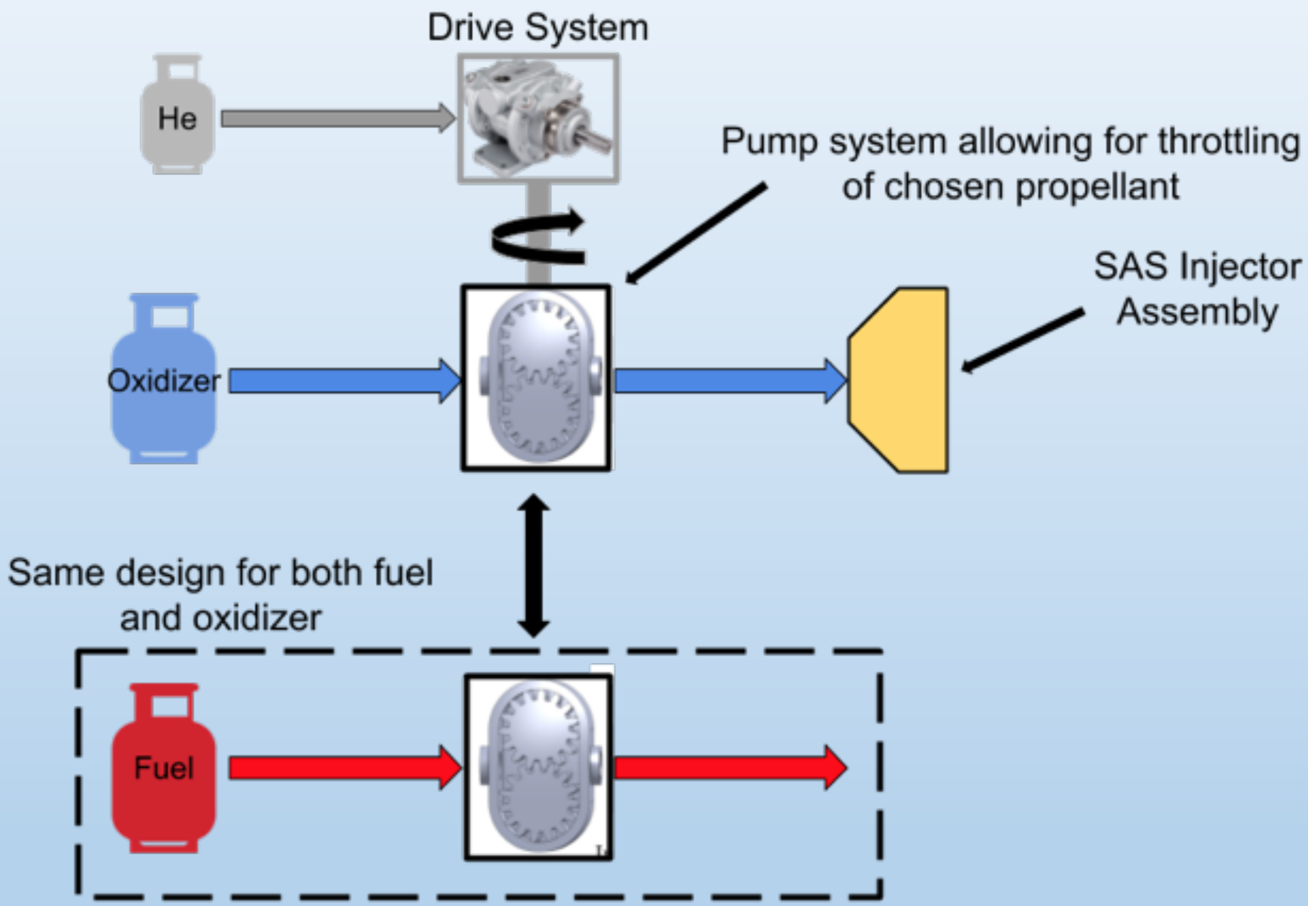
Functional Block Diagram



Subsystems

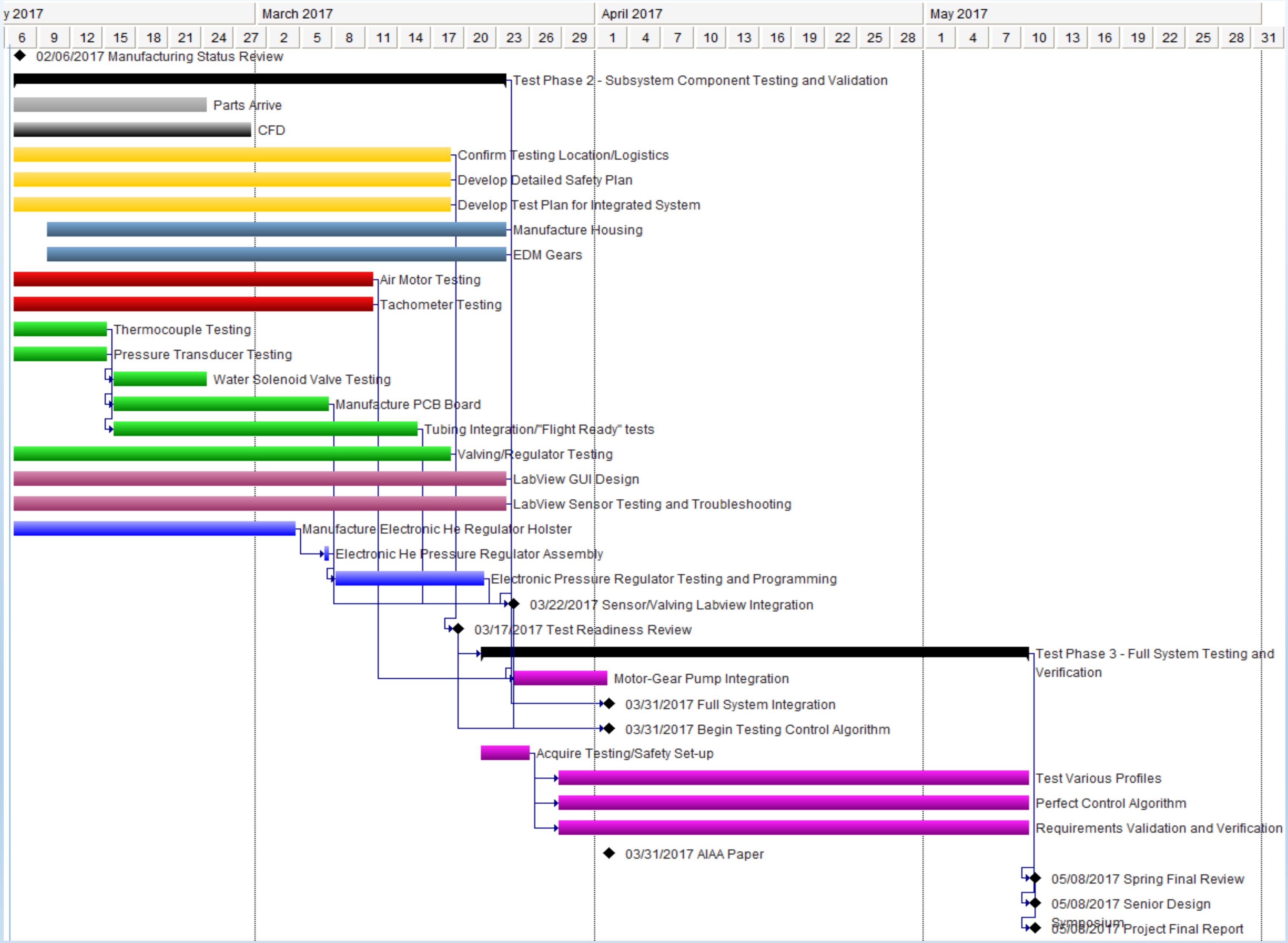
1. Pump
2. Drive System
3. Control
4. Test

CONOPS

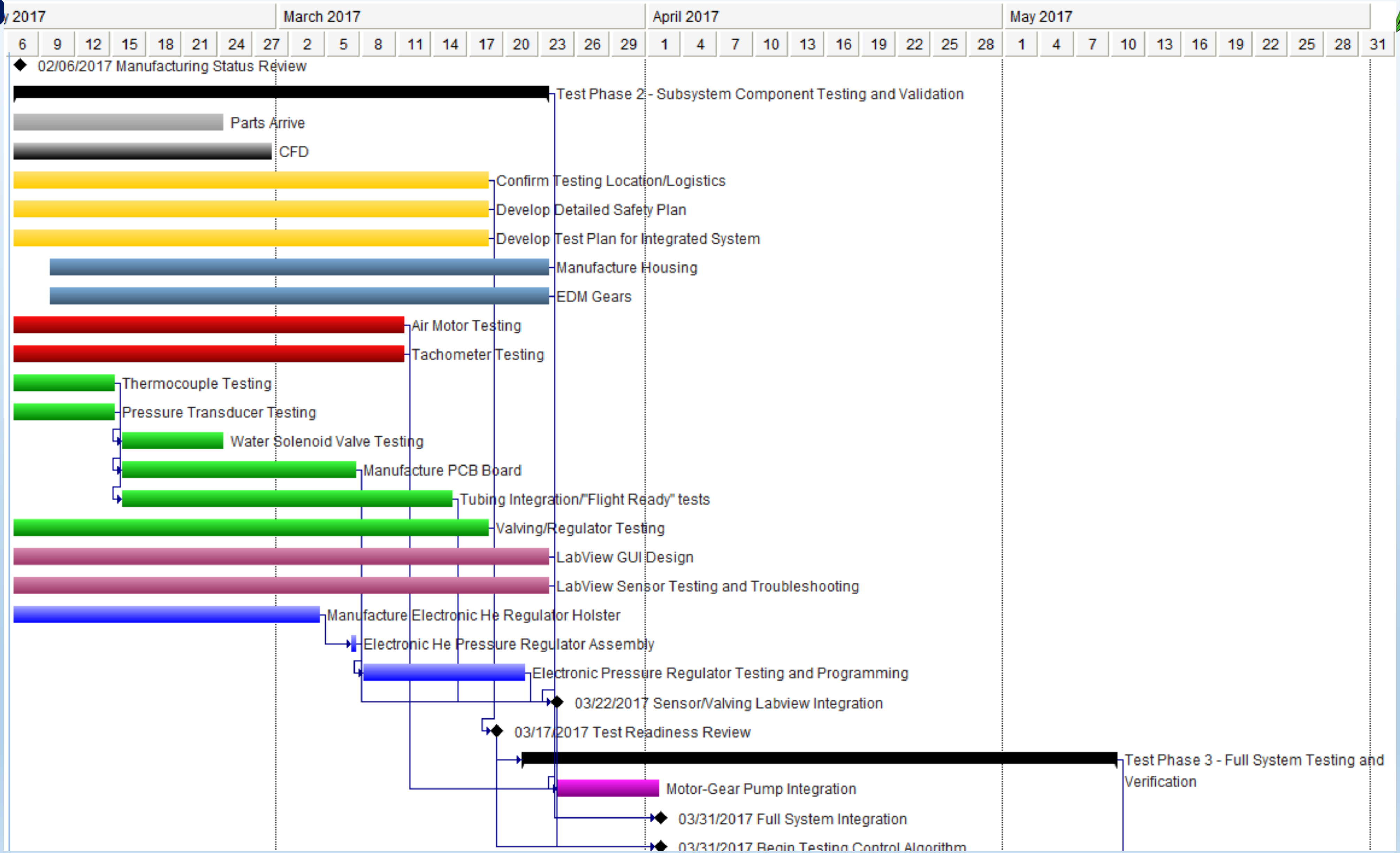


Drive System
He
Pump system allowing for throttling of chosen propellant
SAS Injector Assembly
Oxidizer
Same design for both fuel and oxidizer
Fuel

Current Schedule



Current Schedule



Manufacturing - Overview

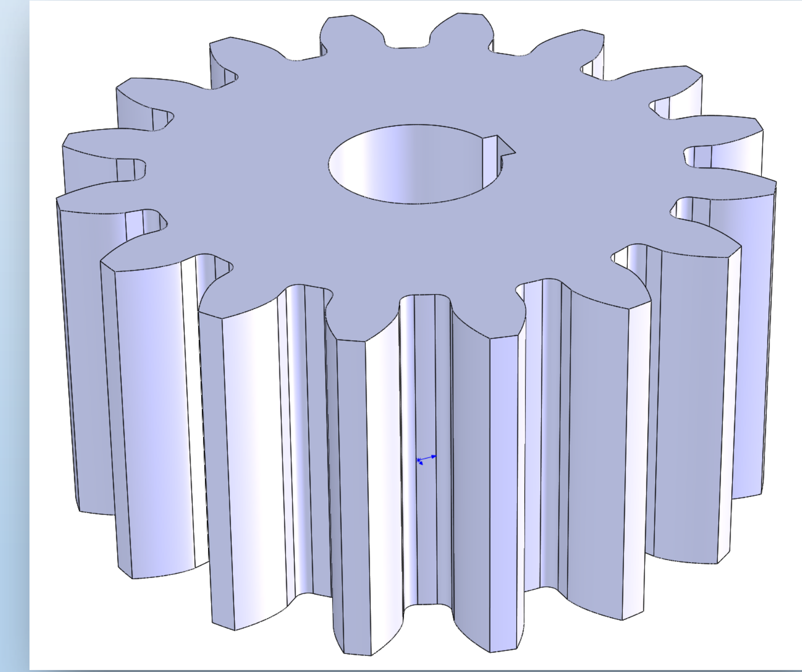
- What is included:
  - Housing
  - Gears
  - Driveshaft
  - Bearings
  - Seals
  - Assembly
  - Helium Regulator Holster

Pump Manufacturing

- Gear pump is made up of:
  - Gears – To be Manufactured
  - Housing – To be Manufactured
  - Close-out panel – To be Manufactured
  - Driveshaft – To be finalized, will be keyed and altered
  - Alignment Shaft – To be finalized, will be keyed and altered
  - Seals – Purchased; Geometry is being triple checked
  - Main bearings – Purchased; Thrust and roller bearings to be purchased
  - Coupler – To be Purchased
  - Collar – To be Purchased

Gears

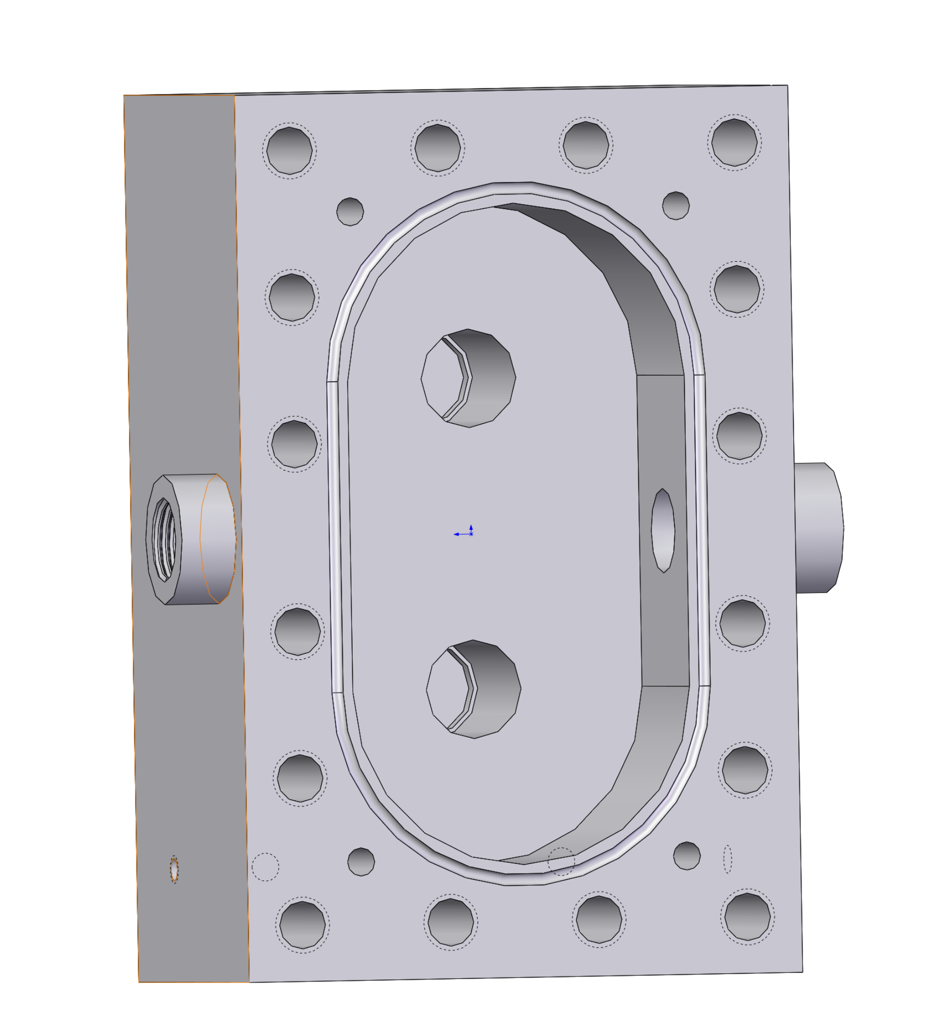
- Wire EDM profile with ground faces
- Finalizing stock requirements (17-4 PH Stainless)
- CFD results may dictate minor changes
- No post machining with decided manufacturer
  - Delivery 4 weeks ARO

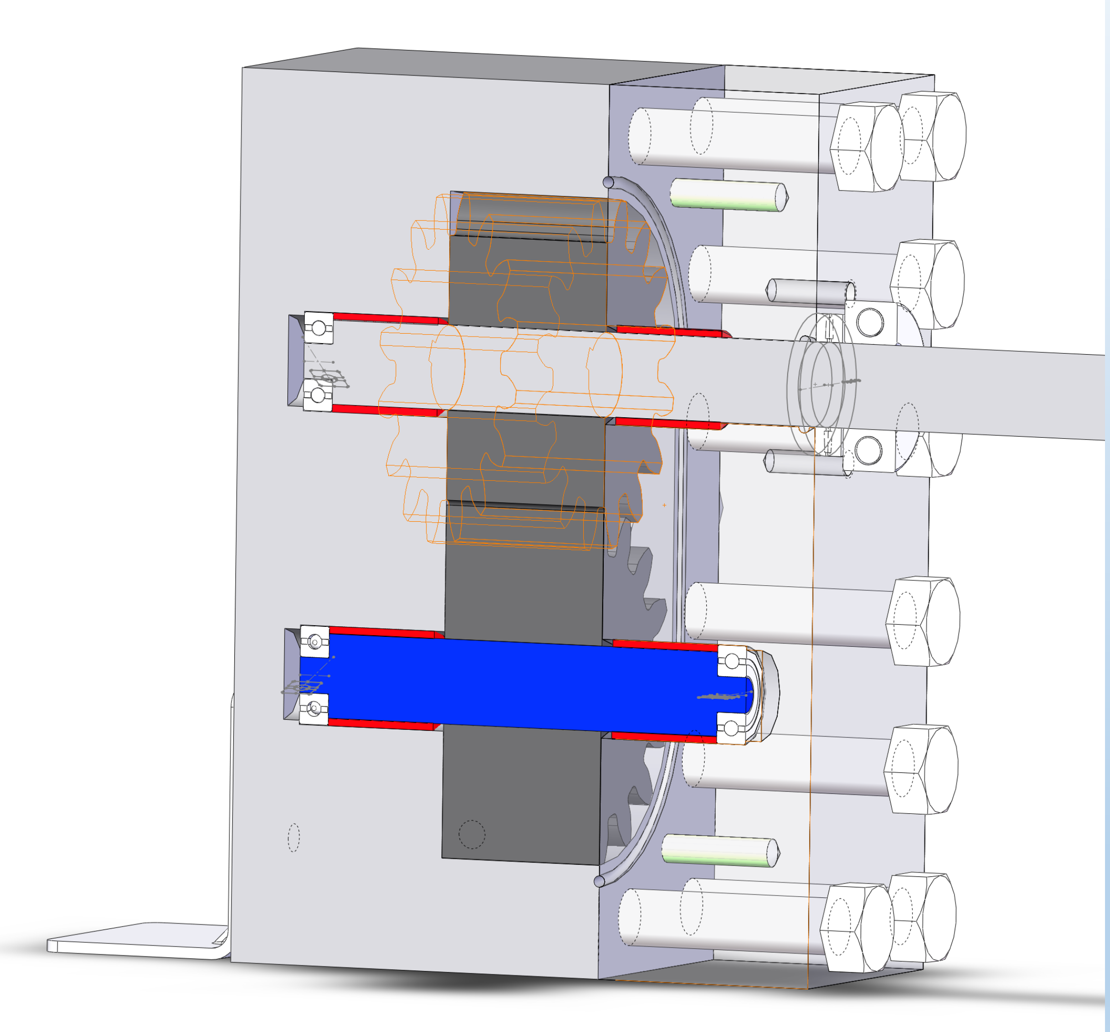


Pump Housing

- CNC here at CU, use a rough cut first to minimize time on CNC
- Benefit – working from our model
- Based off of continued CFD results, a second housing with looser tolerances may be made – perhaps here or at SAS
  - This gives us a back up
  - Must continue to move forward and complete CFD concurrently
- Time frame: 4 weeks
- Concerns: Depth of extruded cut, maintaining the profile, materials, special tools to manufacture

Housing

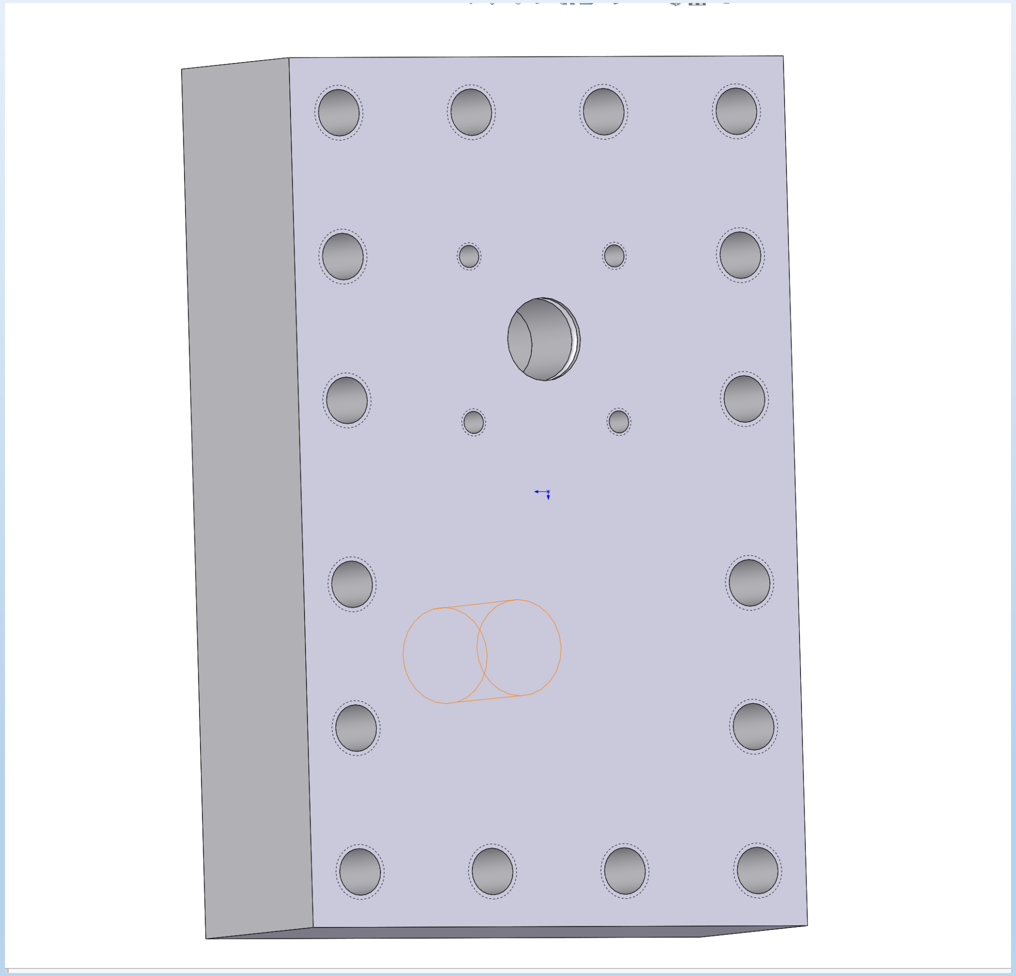




Close-Out Plate

- CNC here at CU
- Based off of continued CFD results, a second housing with looser tolerances may be made – perhaps here or at SAS
  - This gives us a back up, singular plate may work for both housings TBD
- Time frame: 4 weeks lead time
- Drawing to be finalized: still awaiting relief grooves, seal groove geometry may change for optimal performance
- Concerns: material, special tools to manufacture, rotary shaft seal and geometry

Close-Out Plate



Pump Manufacturing

- Seals
  - 1 large O-ring for faceplate and housing
  - 1 O-ring shaft seal
  - Groove geometry is being triple checked; May utilize a double seal
  - Ready for pick-up in Denver
- Bearings
  - Bearing manufacturer that commonly supplies bearings for gear pumps is sending 'samples' for free (shipped, awaiting arrival)
  - This is putting constraints on our shafts – metric options may solve this
  - Thrust bearings are outside of working fluid and work with a collar to retain the drive shaft
  - Roller bearings are included to avoid wear on the inside of the housing and necessitate post-machining of the shafts

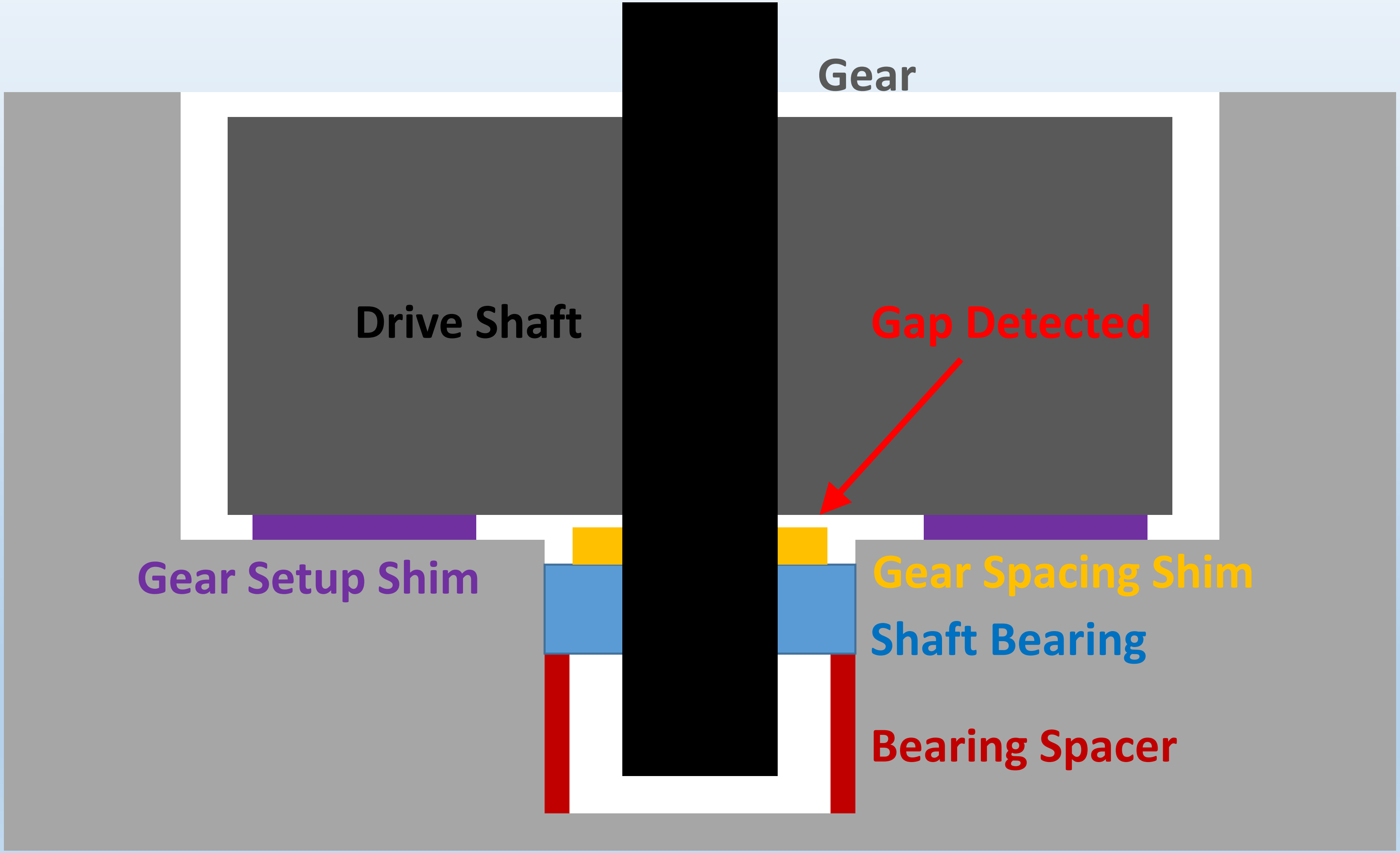
Pump Manufacturing

- Driveshaft and placement
  - Post-machine here
  - We can key in the shop here, allows for proper contact and sizing to maintain integrity of housing
  - Metric options are being explored to obtain proper undersizing for the performancing sleeve bearings
  - Timeframe: 20 hours

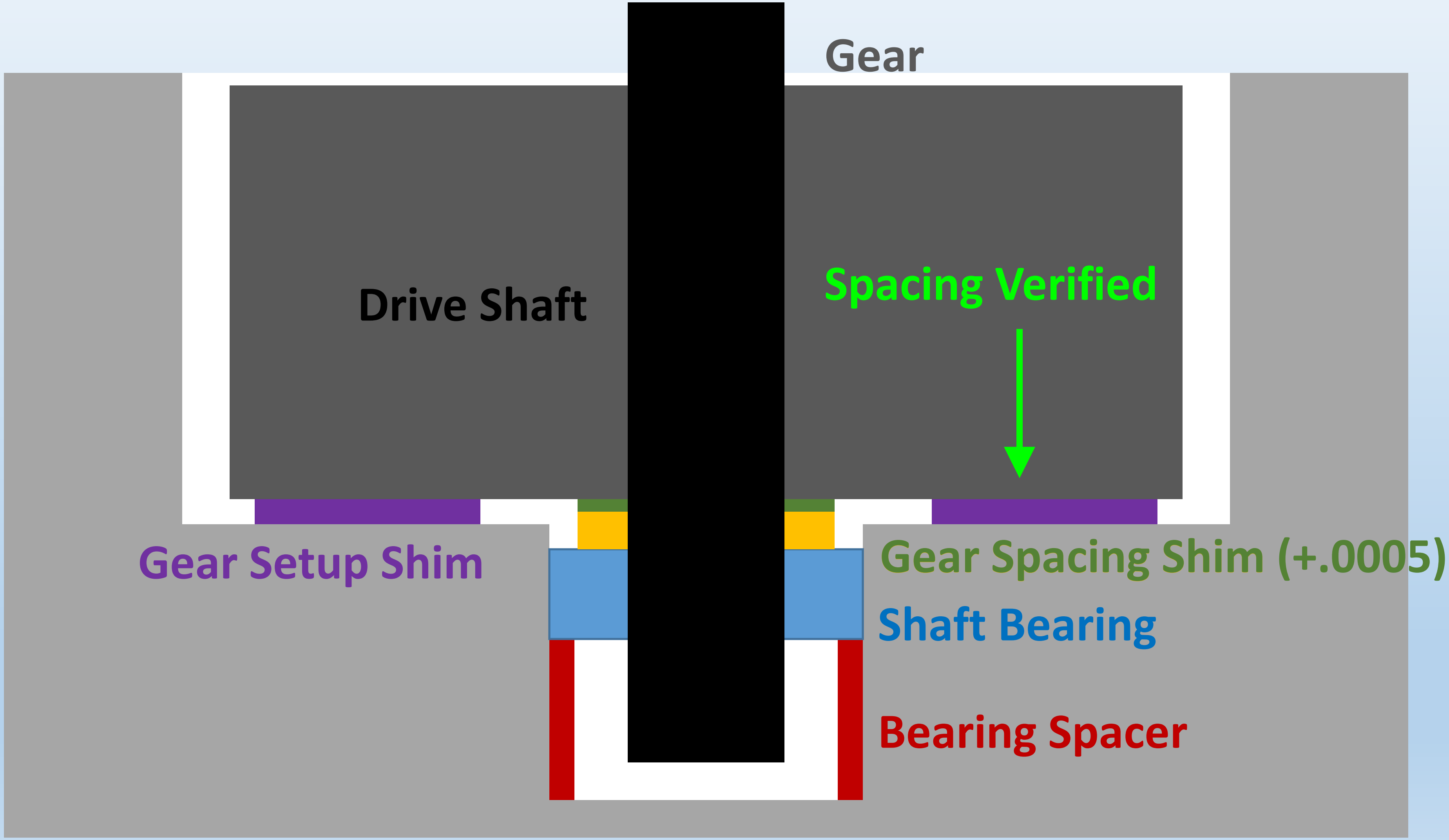
Overall Timeframe

- Seal groove geometry will be finalized by Tuesday COB
- Meeting with Matt Rhode Tuesday to nail down logistics – proper material and special tools
- Order and get materials and tools by Feb. 13th
- Start machining ASAP Feb 13th or 14th

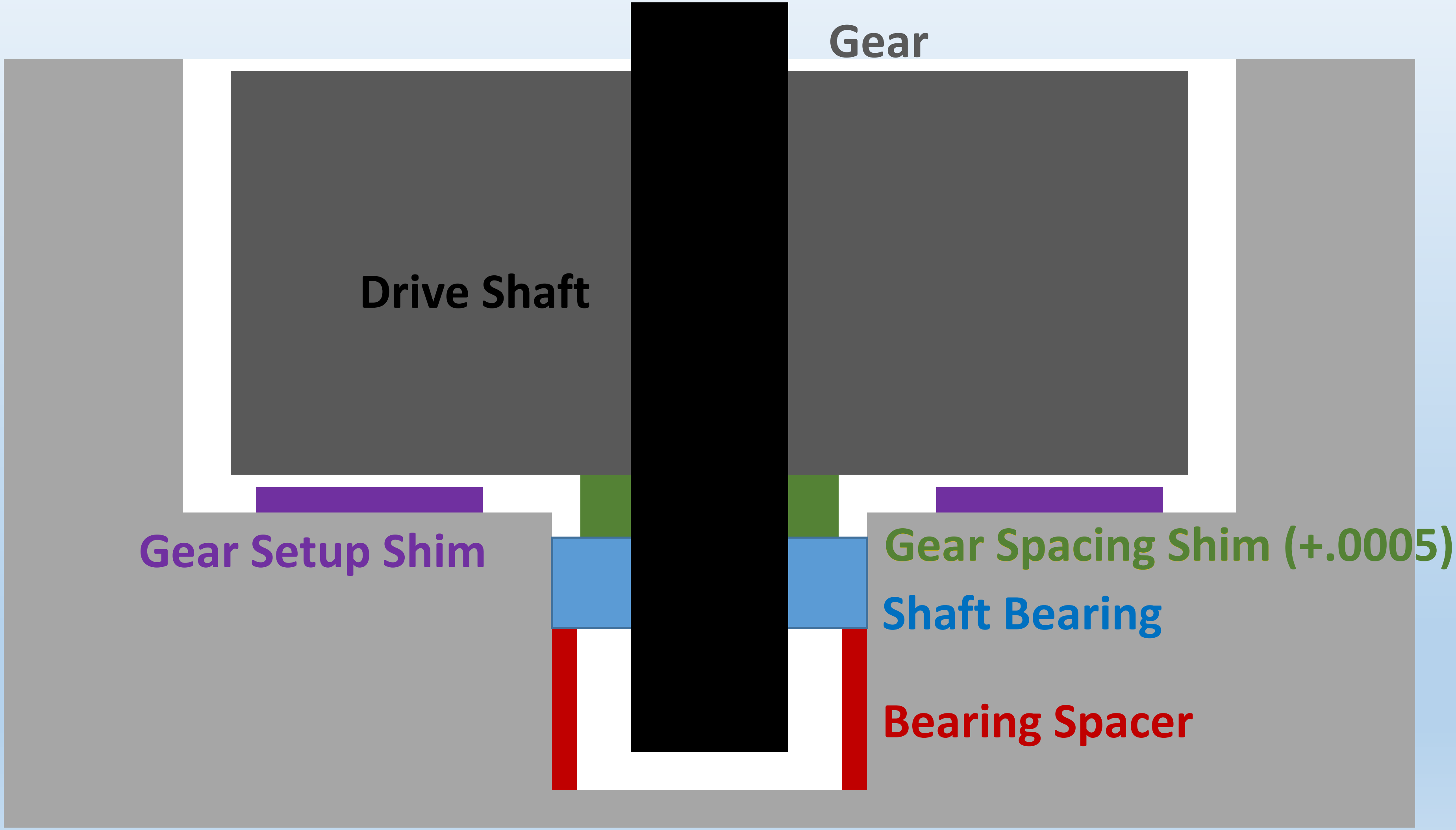
Pump Assembly



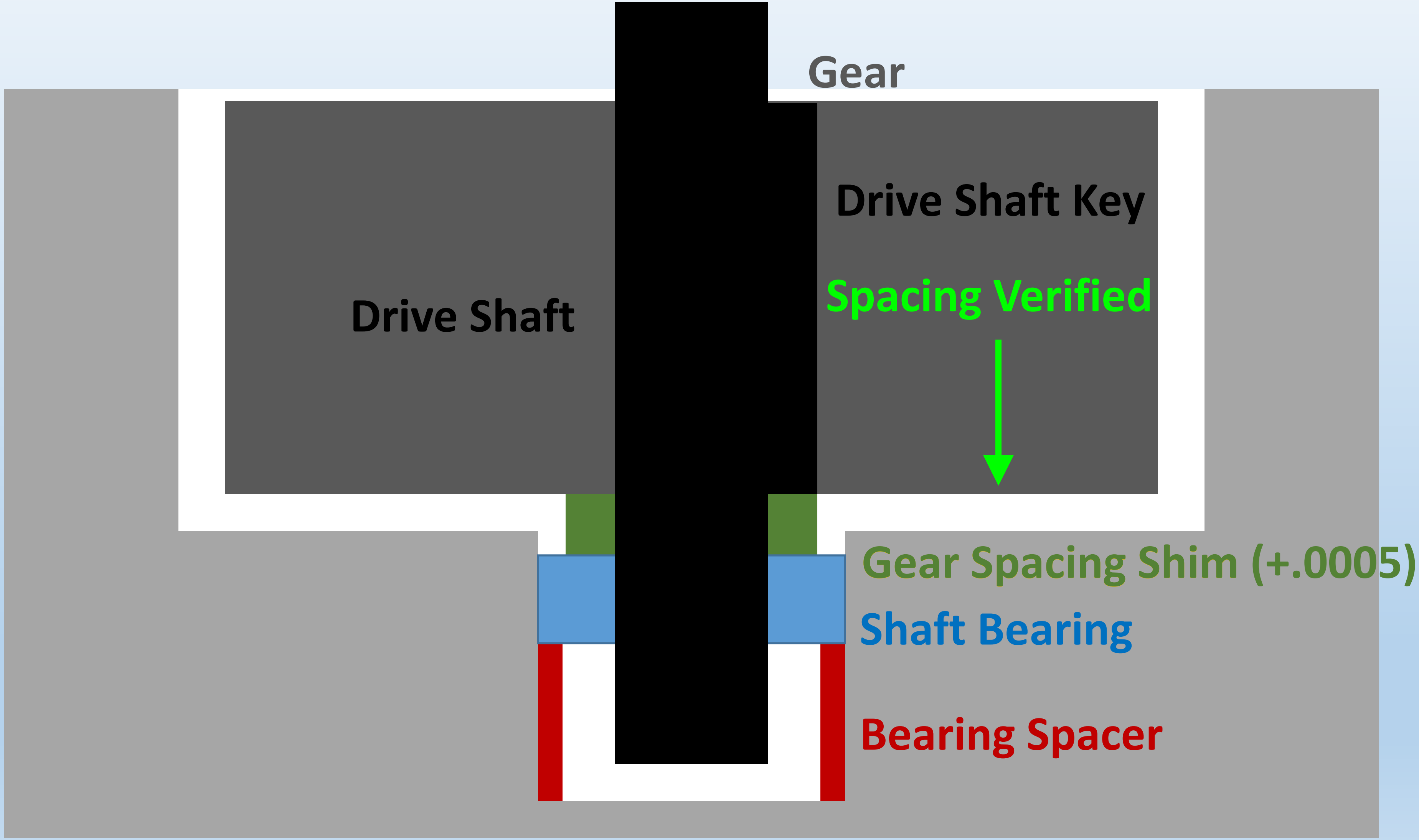
Pump Assembly



Pump Assembly

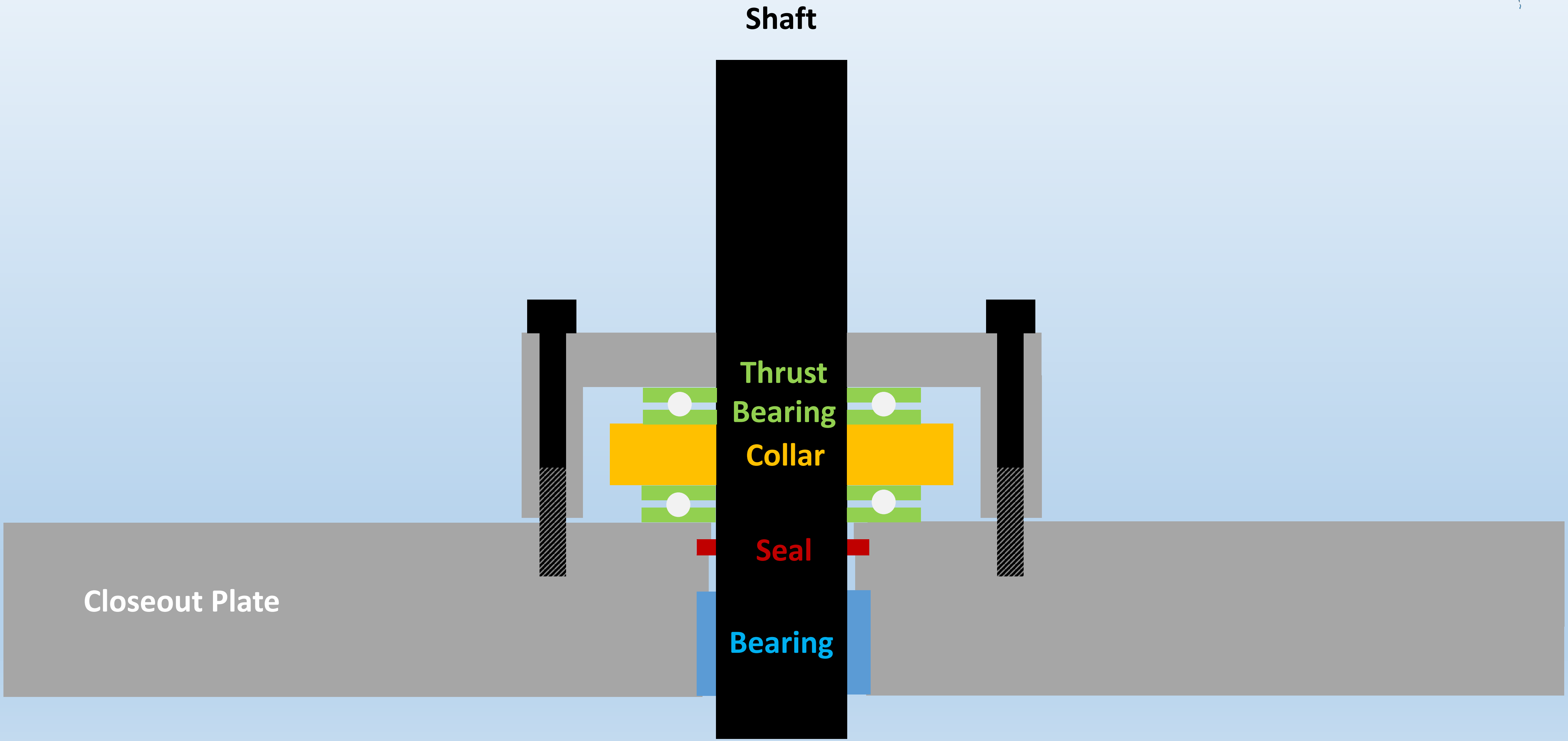


Pump Assembly



Timeframe: 1 week for assembly

Pump Assembly



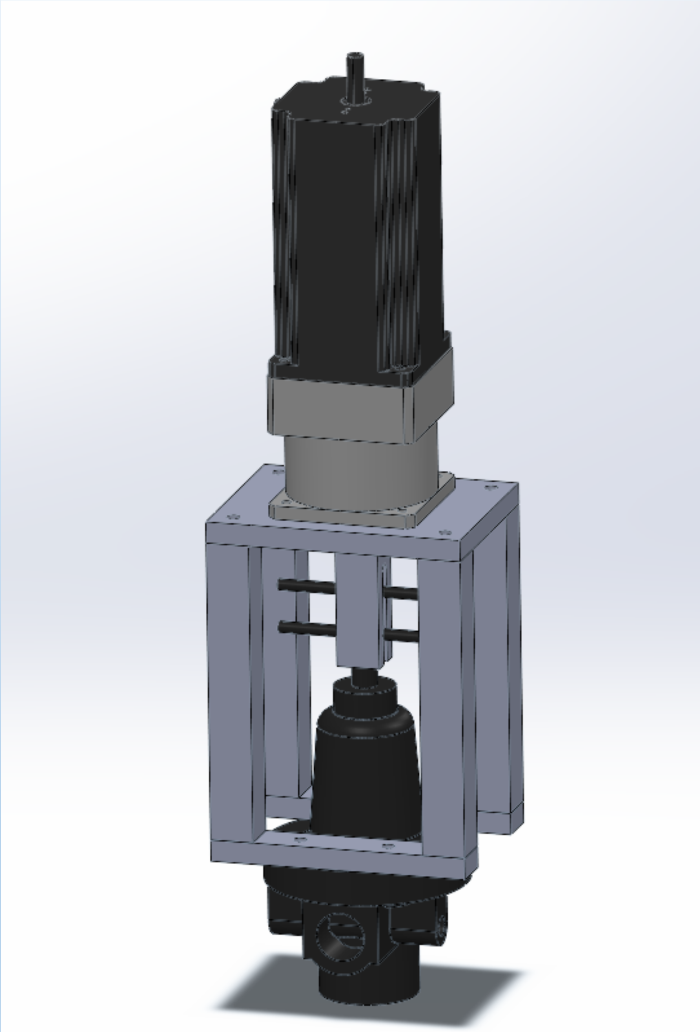
Timeframe: 1 week for assembly

Electronic He Regulator

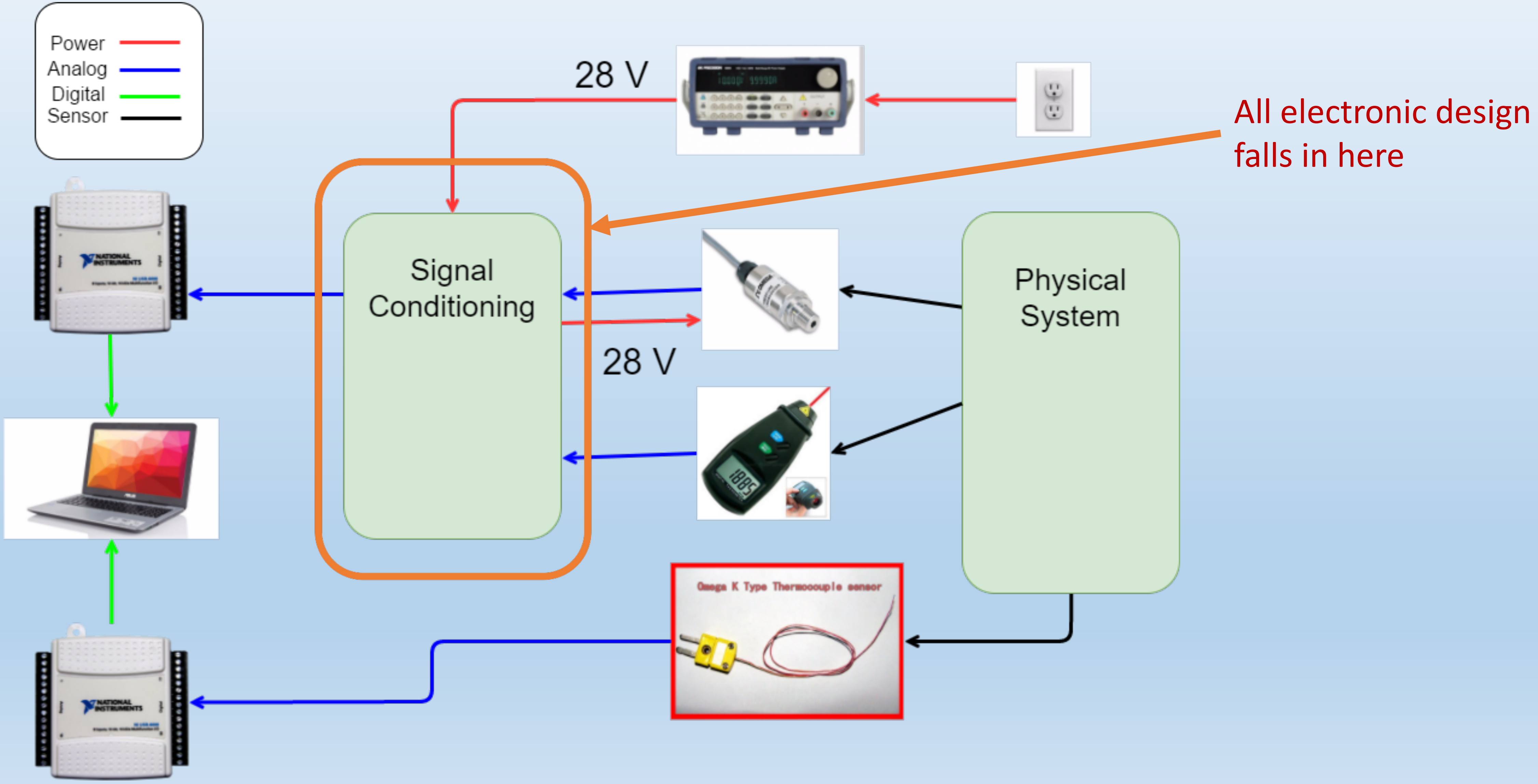
- Constructing an Electronic Helium Regulator
  - To control the drive system
- Manufacture a holster to house the stepper motor
- Timeframe: 80 hours

Electronic He Regulator

- Solenoid regulator was too expensive
- Manufacturing from aluminum
- Houses stepper motor
- Need 8 Nm of torque to turn the pressure regulator at its lowest settings
- Similar setup for back pressure regulator



Electronics FBD



Electronics

- Signal Conditioning
  - Design will be tested in a breadboard
  - PCB board will be designed based on the breadboard
  - PCB board will be populated
- Testing
  - Component testing will be done on the breadboard
  - Integration will be done with the PCB board

Electronics Integration

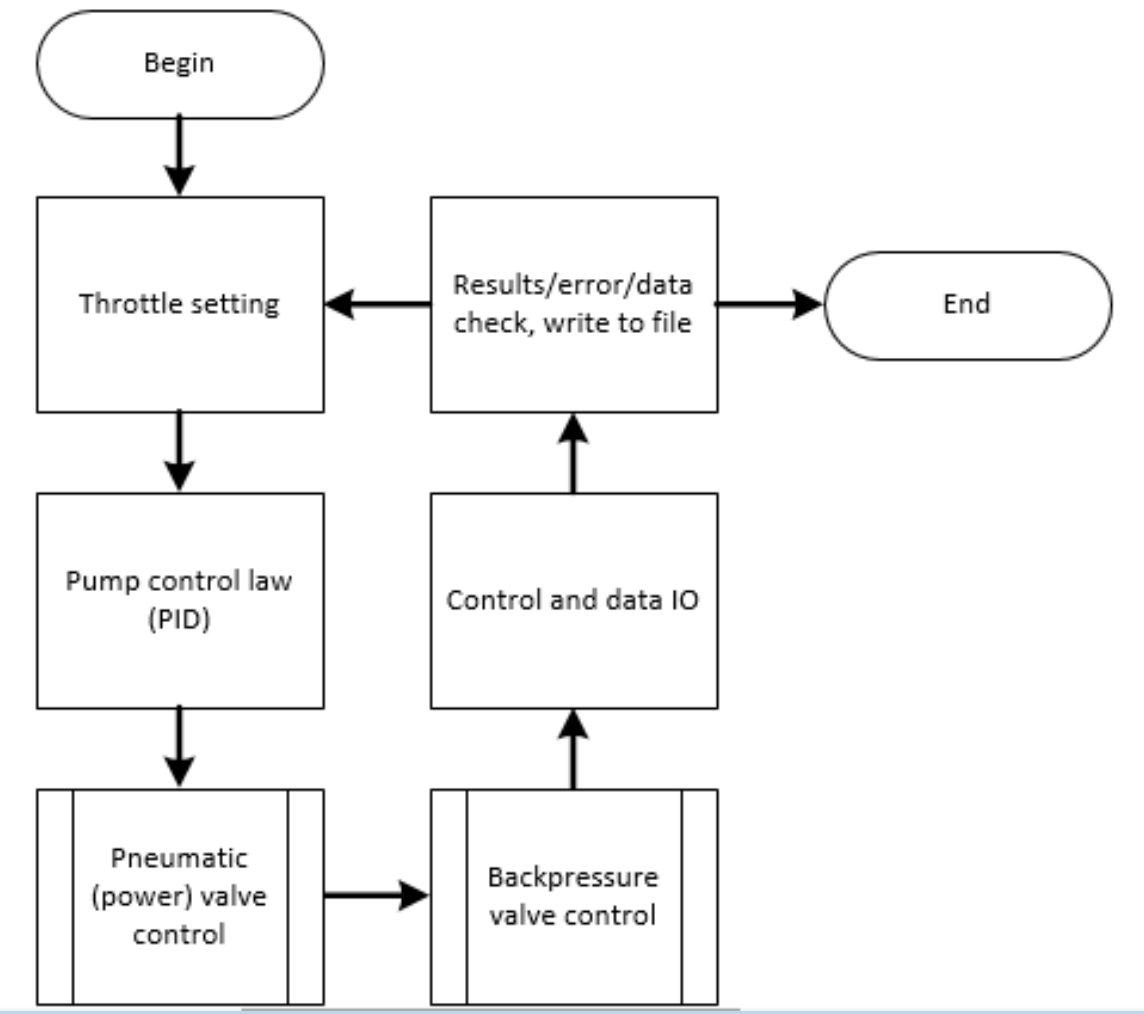
- Electronics
  - Sensors
  - DAQs
    - NI 9211 (temperature readings)
    - NI 9205 (pressure readings, similar to NI 6002 but more powerful)
      - will use NI 6002 for final tests
  - 100 hours left for all testing and integration

Software

- Software
  - LabVIEW
    - Development order:
      - File system - complete
      - Component tests/DAQ system – in progress (~10 hours, <1 week)
      - Control systems – model, simulate, implement – in progress (~45 hours, 4 weeks)
      - Full system tests - TBD (~60 hours, 5 weeks)
  - DAQ Software Drivers
    - Already have
  - Post test analysis - MATLAB (file read functions complete)

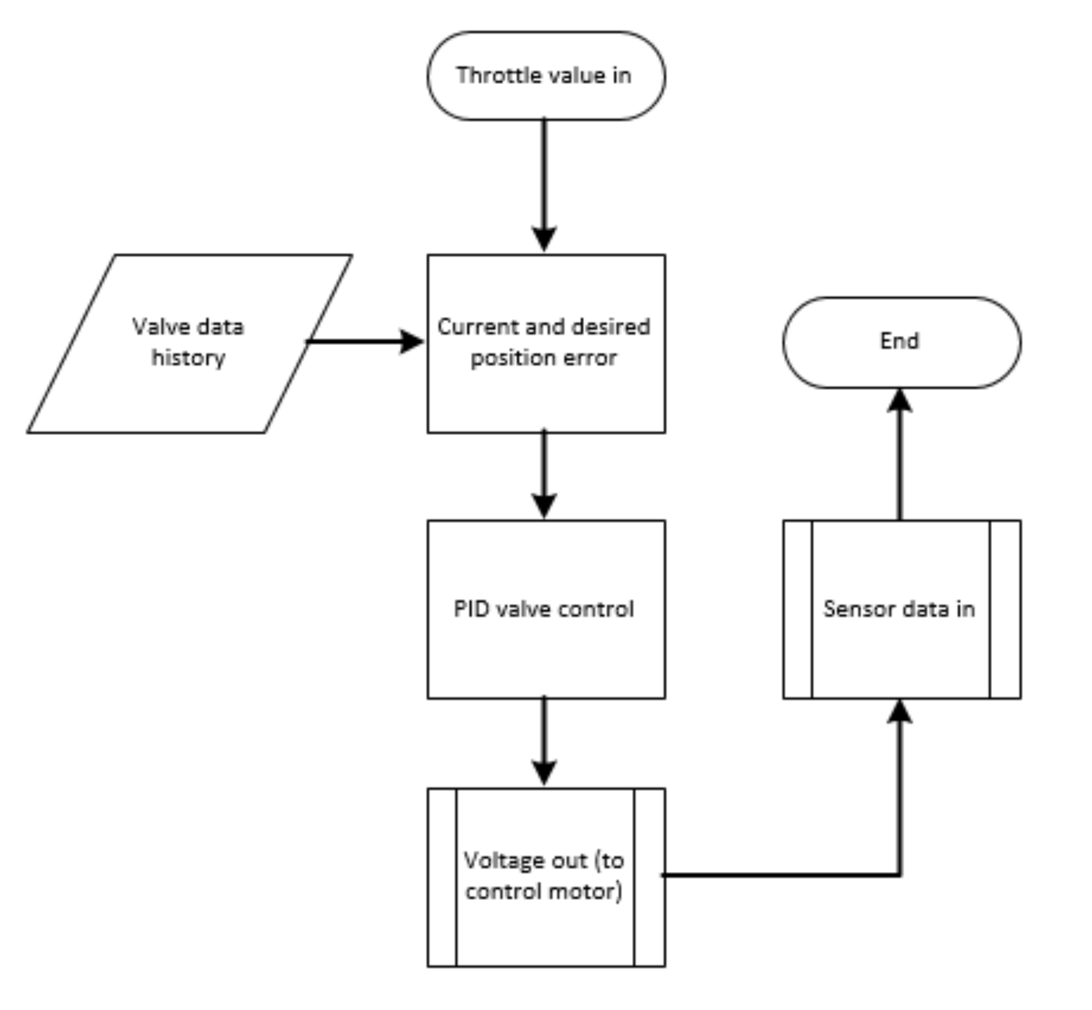
Software

- Control code overview:
  - Safety implicit to error check
  - Throttle manual or automatic
  - Backpressure faster than power - prevent oscillation



Software

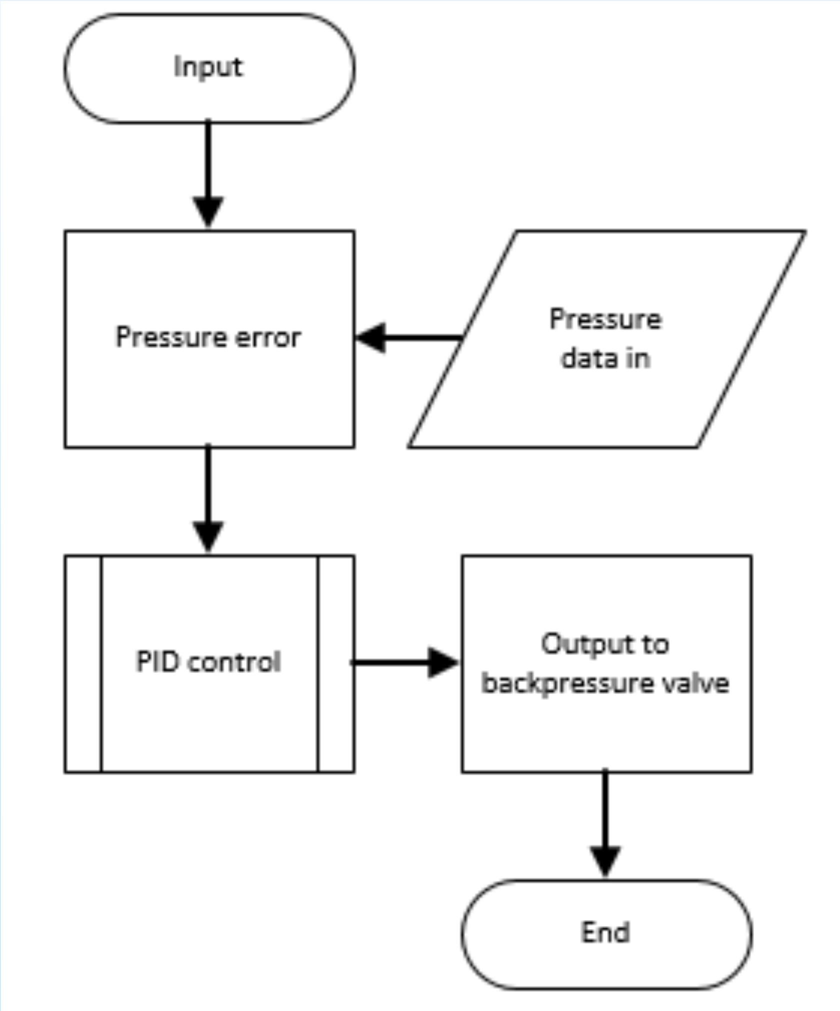
- Pressure valve control:
  - Some data kept in memory – check valve position



Overview | Pump Manufacturing | Pump Control | Testing/ Schedule | Budget

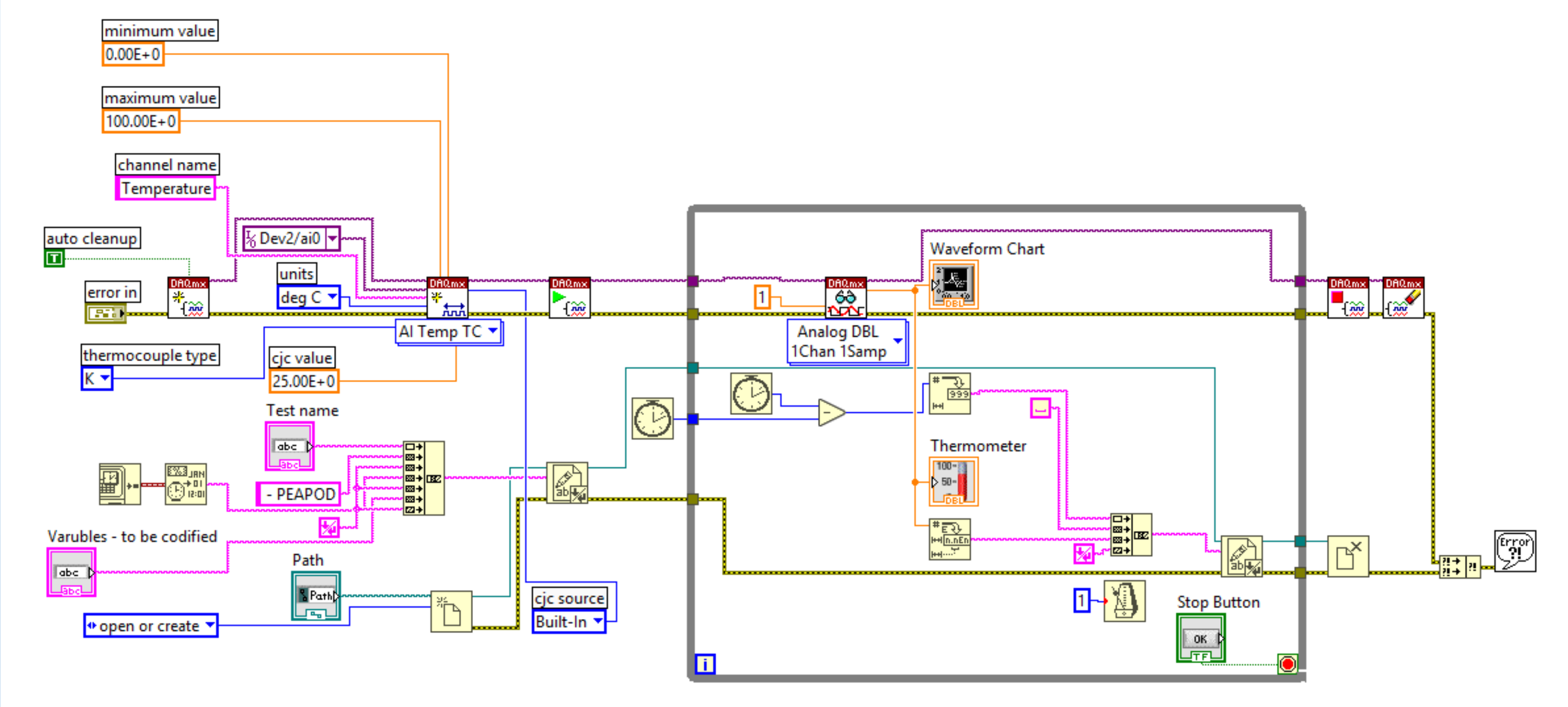
Software

- Backpressure control:
  - Fastest control component



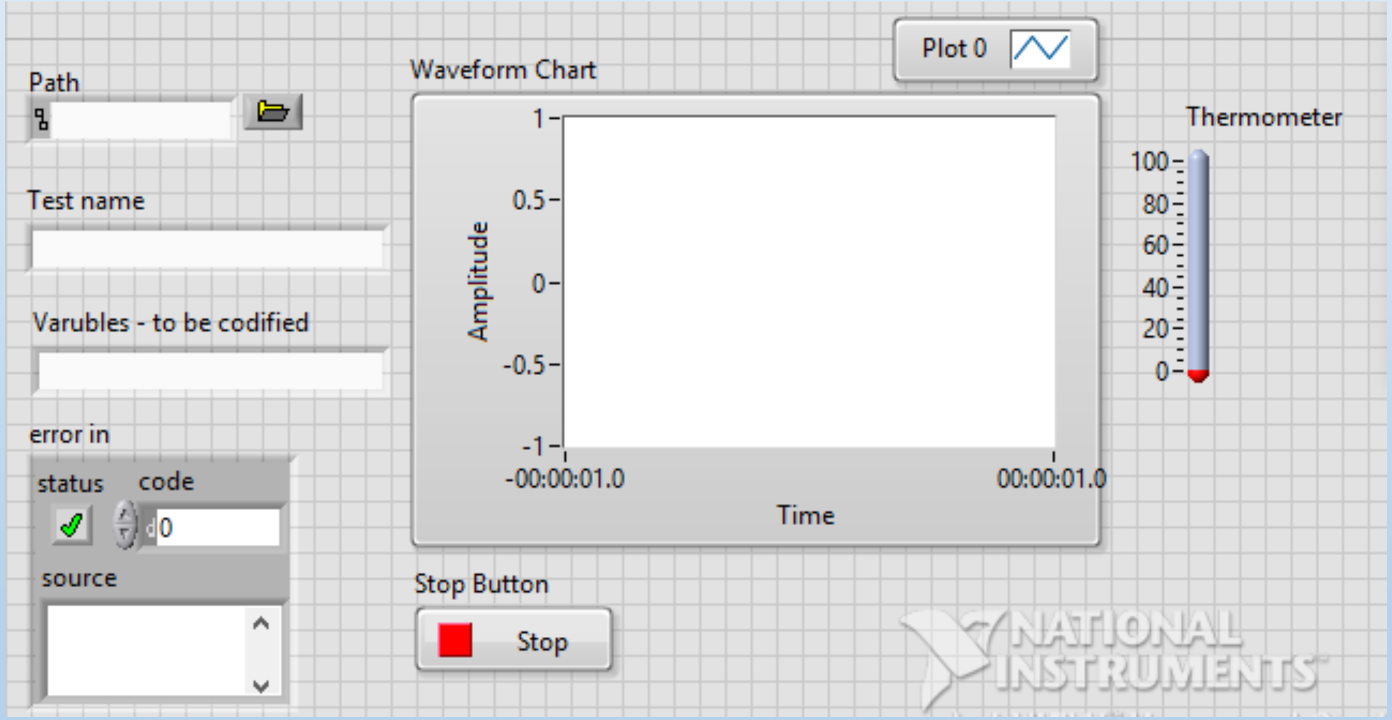
Software

- Software – thermocouple test block diagram



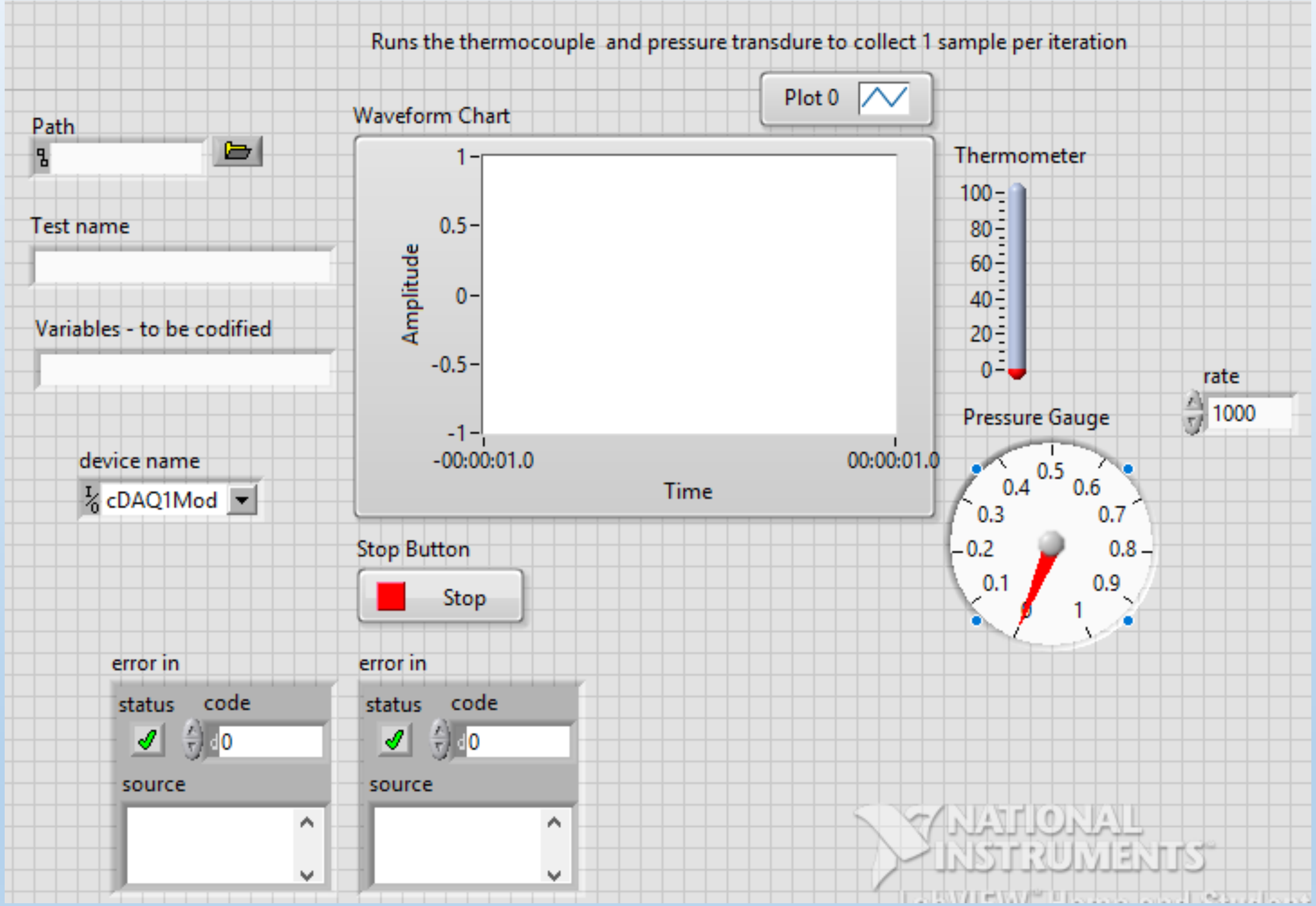
Software

- Software – thermocouple test user interface



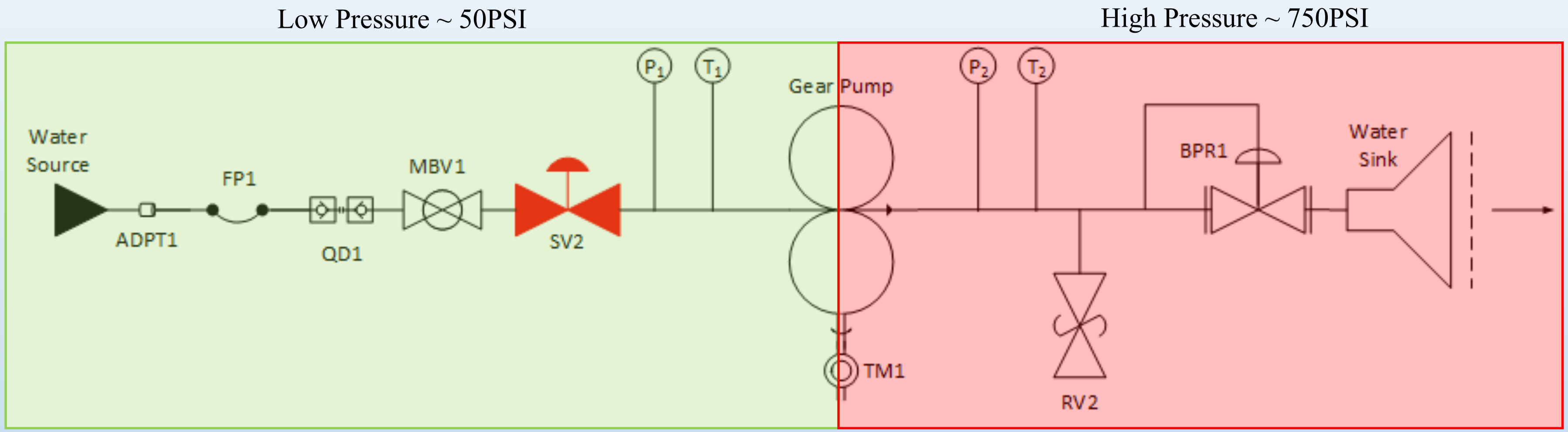
Software

- Combined pressure and temperature user interface
- 115 hours remain

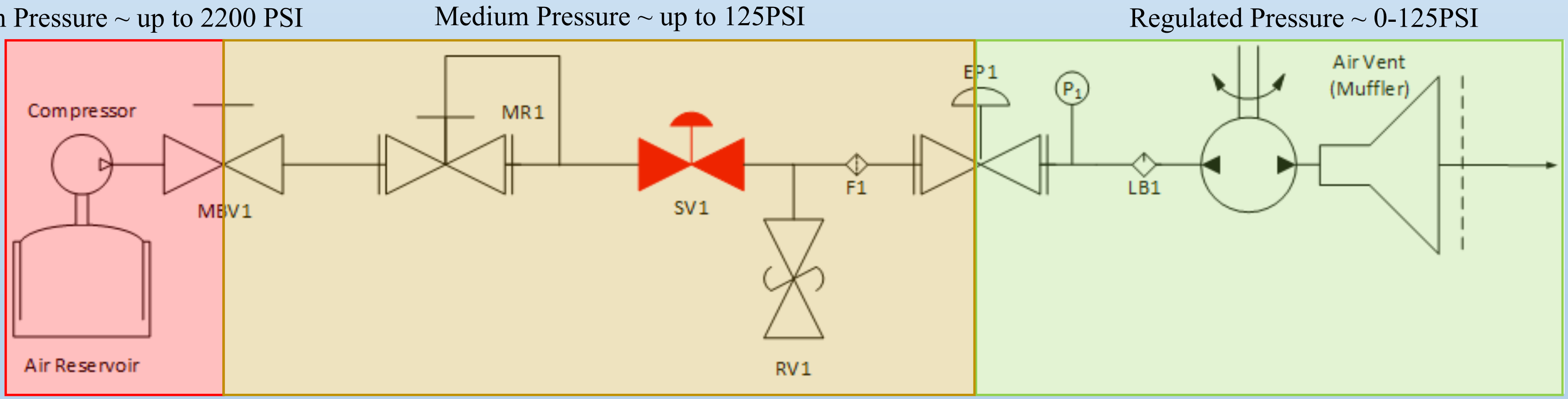


Piping Assembly

Water Pipe Size: ¾"NPT
Pressure Ranges: 50-800PSI
Max Flow Rate: 22Gal/min



Air Pipe Size: 1"NPT
Pressure Ranges: 0-2200 PSI
Max Flow Rate: 45CFM



Nomenclature
SV = Solenoid Valve RV = Relief Valve MBV = Manual Ball Valve MR = Manual Regulator EP = Electronic Pressure Regulator BPR = Back Pressure Regulator TM = Tachometer BD = Burst Disk LB = Lubricator F = Air Filter P = Pressure Transducer T = Temperature Sensor ADPT = GHT to NPT FP = Flexible Pipe QD = Quick Disconnect

Testing Timeline

Component Testing – QC and Calibration

Component	Testing to be Conducted	Man Hours	Status
Pressure Transducer (Air P1, Water P1)	Calibration through ranges of known shop air pressures	6 Hours : 1.5*(2*1 + 2*1 + 2*1)	50%
Air Pressure Regulator (EPR)	Operation through 0-110PSI to calibrate outlet pressure/thread engagement	10.5 Hours : 3*1 + 3*1.5 + 3*1	0%
Water Back Pressure Regulator (BPR)	Operation through 0-750PSI to calibrate inlet pressure/thread engagement	10.5 Hours : 3*1 + 3*1.5 + 3*1	0%
Thermocouples (T1, T2)	Calibration at known temperatures (Ice bath, boiling…)	4 Hours : 2*0.5 + 2*1 + 2*0.5	100%
Manual Ball Valve (Water MBV1)	Verify correct operation (on/off) and no leaking	25 Minutes : 1*0.2 + 1*0.1 + 1*0.2	0%
Solenoid Valve (Water SV1, Air SV2)	Correct opening and closing upon energization and de-energization	1.5 Hours : 2*0.5 + 2*0.25 + 2*0.5	0%
Tachometer	Calibration at known RPMs	6 Hours : 2*1 + 2*1 + 2*1	0%
Manual Air Regulator (MR1)	Calibration to ranges 100-125 with known shop air pressures	7 Hours : 2*1.5 + 2*1 + 2*1	0%
Full Air Assembly	Torque Verification @ RPM, conducted with friction test, fan test	13.5 Hours : 3*2 + 3*1.5 + 3*1	0%

Timing

Personnel: Operators required

Hours: Time required to prepare and assemble test

Hours: Time required to conduct test

Hours: Time required to disassemble test and save results

Multiplier: Repeat test for identical sensor /component

*Subsystem Testing included in backups

Total Man Hours: 113.4

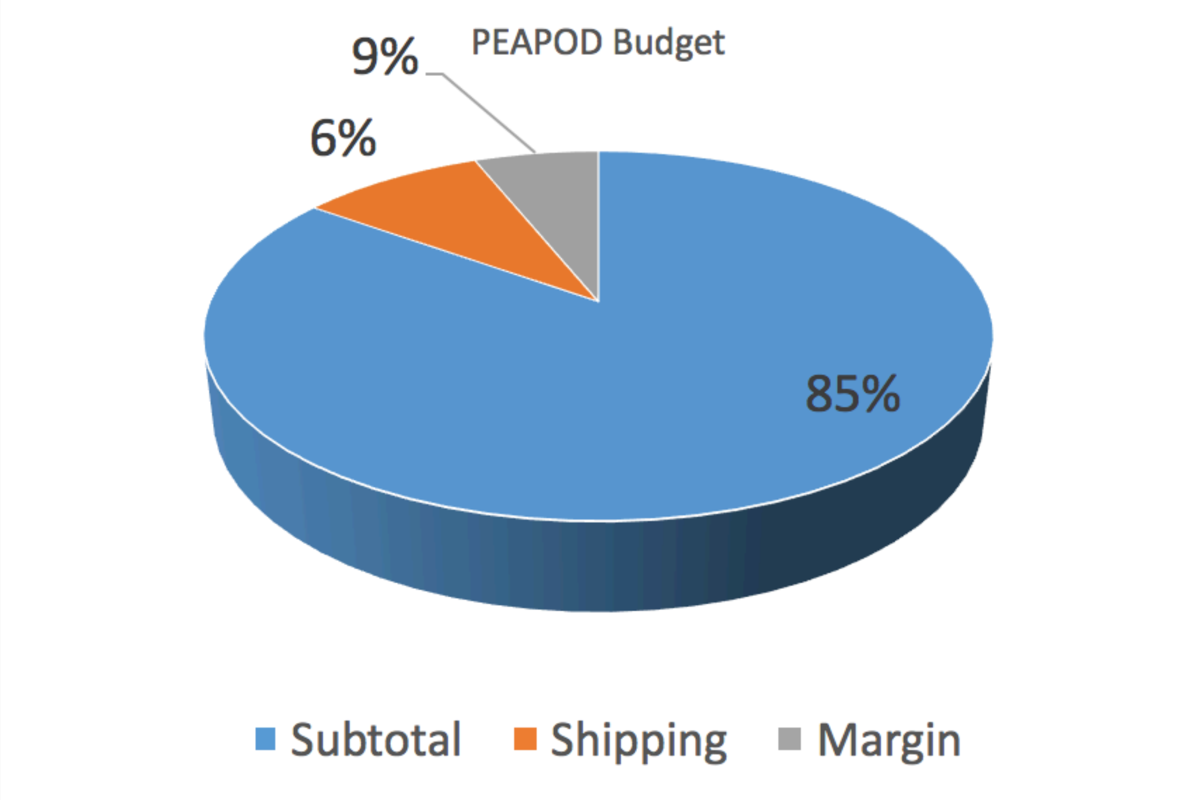
Scope

- **Electrical**
  - Create Signal Conditioning on Breadboard
  - Develop a PCB Board
  - Populate the PCB Board
- **Software**
  - Component test
  - Control systems
  - System test
- **Manufacturing**
  - Valving/Piping
  - Housing
  - Driveshaft
  - Gears
  - Bearings/Seals

Integration

Budget

Subtotal	$ 6,792.57	85%
Shipping	$ 721.17	9%
Margin	$ 486.27	6%



Total	$ 7,513.74
Budget	8000
margin	6.078%

Progress	73%	(by part #)
	34%	(by $ Value)

Budget

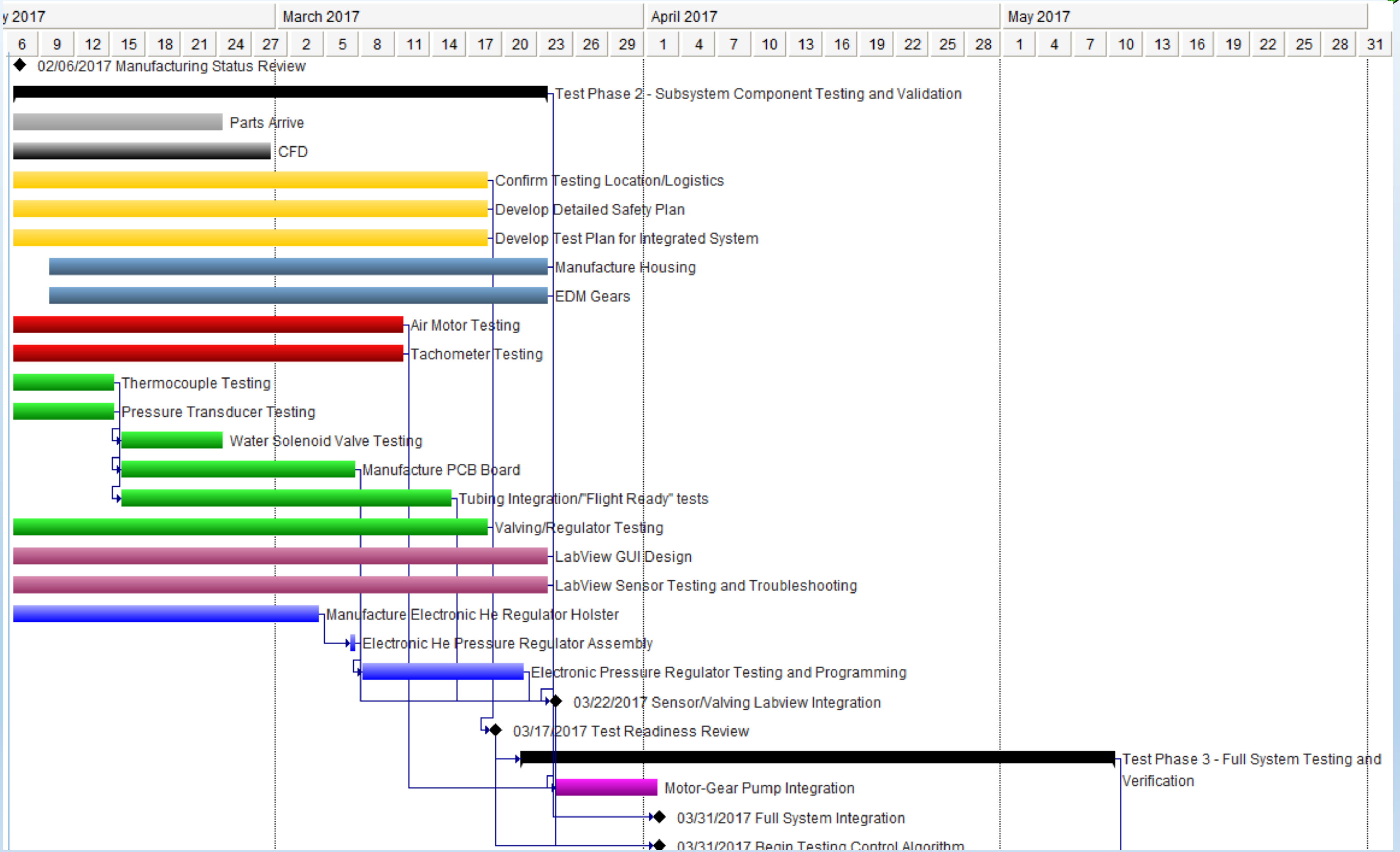
Received	Ordered	Part	part number	price	Quantity	sub total	shipping	Total
x	x	Globe Motor	VA10J	$ 1,238.00	1	$ 1,238.00	$ 125.00	$ 1,363.00
x	x	Tachometer	A2108	$ 349.00	1	$ 349.00	$ -	$ 349.00
x	x	Reflective Tape	205t	$ 5.00	1	$ 5.00	$ -	$ 5.00
x	x	reflective tab	205ts	$ 5.00	1	$ 5.00	$ -	$ 5.00
	x	Water pipe	t53480	$ 29.44	1	$ 29.44	$ 21.90	$ 51.34
	x	Hose2Pipe adp	4kg88	$ 4.81	2	$ 9.62	$ 5.00	$ 14.62
x	x	Air Regulator	21U842	$ 228.00	1	$ 228.00	$ 33.21	$ 261.21
x	x	Pipe tee	4429K229	$ 14.27	2	$ 28.54	$ 15.30	$ 43.84
x	x	Air Filter	3248T11	$ 78.10	1	$ 78.10	$ -	$ 78.10
x	x	lubricator	8520T19	$ 82.58	1	$ 82.58	$ -	$ 82.58
x	x	lube	1298K2	$ 24.47	1	$ 24.47	$ -	$ 24.47
	x	steel pipe	4457K42	$ 14.72	1	$ 14.72	$ 27.21	$ 41.93
	x	pipe nipple	4830K194	$ 3.93	1	$ 3.93	$ -	$ 3.93
	x	Brass Valve	4629K44	$ 18.53	1	$ 18.53	$ -	$ 18.53
	x	Steel pipe	4464K355	$ 7.78	1	$ 7.78	$ -	$ 7.78
	x	3 port ball valv	4017T14	$ 35.83	1	$ 35.83	$ -	$ 35.83
	x	bushing adapte	4464K399	$ 8.56	1	$ 8.56	$ -	$ 8.56
	x	Hose 1	7454T12	$ 12.00	1	$ 12.00	$ -	$ 12.00
	x	Hose 2	7454T15	$ 12.33	1	$ 12.33	$ -	$ 12.33
	x	pipe	4813K63	$ 79.72	1	$ 79.72	$ -	$ 79.72
	x	bushing adapte	4464K151	$ 13.76	1	$ 13.76	$ -	$ 13.76
	x	inline tee	44605K627	$ 8.68	2	$ 17.36	$ -	$ 17.36
x	x	stepper motor		$ -	0	$ -	$ -	$ -
		EDMing		$ 1,100.00	1	$ 1,100.00	$ -	$ 1,100.00
		BPRegulator		$ 1,600.00	1	$ 1,600.00	$ 240.00	$ 1,840.00
		Housing block		$ 90.00	4	$ 360.00	$ 54.00	$ 414.00
		gear block		$ 90.00	2	$ 180.00	$ 27.00	$ 207.00
		brackets		$ 100.00	1	$ 100.00	$ 15.00	$ 115.00
		coupler		$ 25.15	2	$ 50.30	$ 7.55	$ 57.85
		Tooling for gears		$ 500.00	1	$ 500.00	$ 75.00	$ 575.00

Received	Ordered	Part	part number	price	Quantity	sub total	shipping	Total
		Tooling for gears		$ 500.00	1	$ 500.00	$ 75.00	$ 575.00
		Water drum		$ 500.00	1	$ 500.00	$ 75.00	$ 575.00
		Teflon Seal		$ -	0	$ -	0	$ -
		binding report		$ 100.00	1	$ 100.00	0	$ 100.00
x	x	Microsoft Office		$ -	1	$ -	0	$ -
x	x	Labview		$ -	1	$ -	0	$ -
x	x	Matlab		$ -	1	$ -	0	$ -
x	x	Solidworks		$ -	1	$ -	0	$ -
x	x	Gantter		$ -	1	$ -	0	$ -

Progress	73%	(by part #)
	34%	(by $ Value)

Total	$ 7,513.74
Budget	8000
margin	6.078%

Schedule



y 2017
March 2017
April 2017
May 2017
6 9 12 15 18 21 24 27 2 5 8 11 14 17 20 23 26 29 1 4 7 10 13 16 19 22 25 28 1 4 7 10 13 16 19 22 25 28 31
02/06/2017 Manufacturing Status Review
Test Phase 2 - Subsystem Component Testing and Validation
Parts Arrive
CFD
Confirm Testing Location/Logistics
Develop Detailed Safety Plan
Develop Test Plan for Integrated System
Manufacture Housing
EDM Gears
Air Motor Testing
Tachometer Testing
Thermocouple Testing
Pressure Transducer Testing
Water Solenoid Valve Testing
Manufacture PCB Board
Tubing Integration/"Flight Ready" tests
Valving/Regulator Testing
LabView GUI Design
LabView Sensor Testing and Troubleshooting
Manufacture Electronic He Regulator Holster
Electronic He Pressure Regulator Assembly
Electronic Pressure Regulator Testing and Programming
03/22/2017 Sensor/Valving Labview Integration
03/17/2017 Test Readiness Review
Test Phase 3 - Full System Testing and Verification
Motor-Gear Pump Integration
03/31/2017 Full System Integration
03/31/2017 Begin Testing Control Algorithm

Conclusions

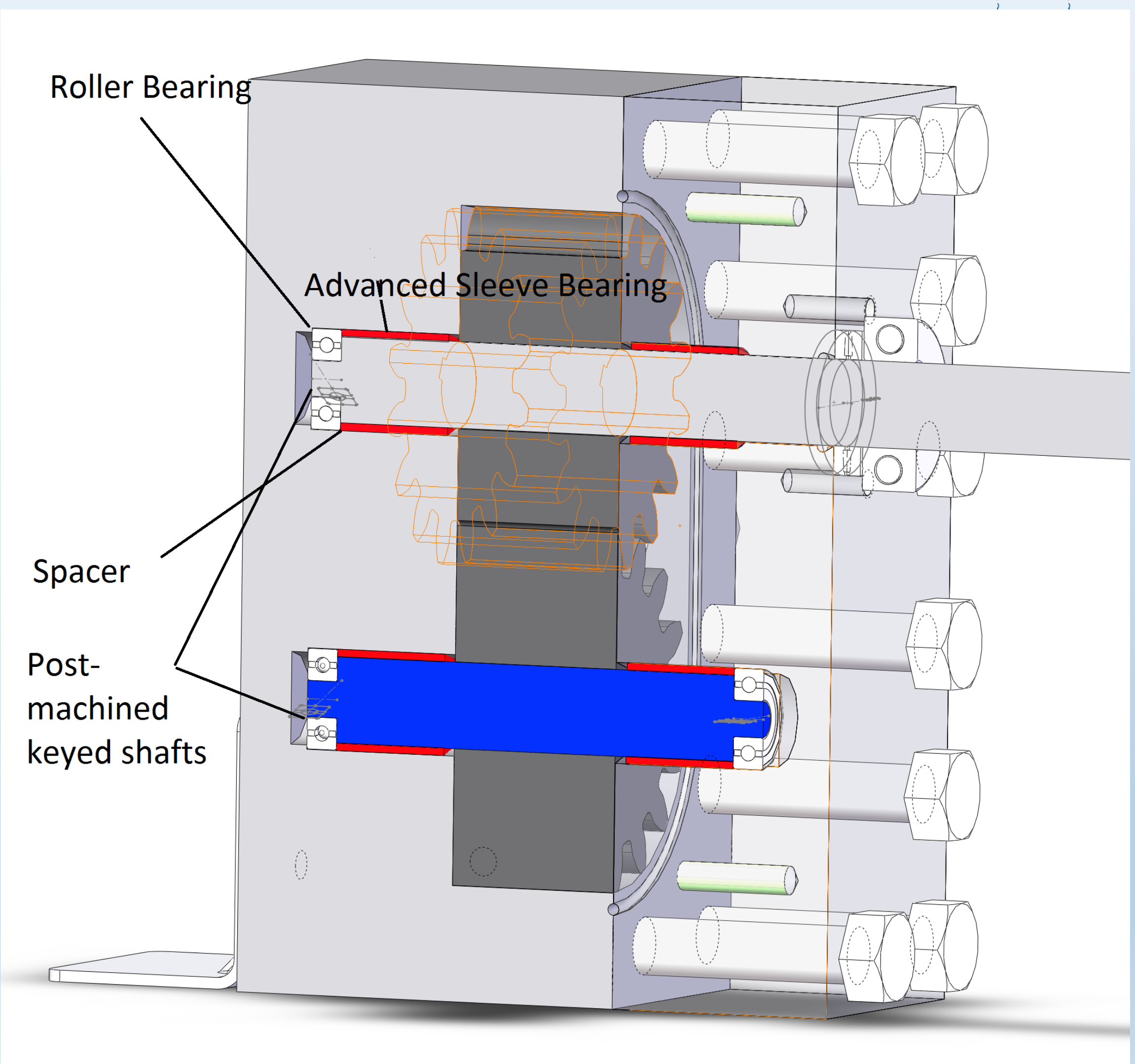
- We are slightly behind schedule (3 days – 1 week)
  - Encountered problems with pump manufacturing
  - Air motor testing
  - Unable to find cheaper parts resulted in manufacturing them
- Increase in team hours to accomplish sensor and integration tasks
- Moving Forward:
  - Increase in sub-component testing from all team members
  - Timeframe: ~100 hours for Electronics
    ~200 hours for Software
    ~100 hours for Manufacturing/Assembly
    ~150 hours for Testing

Questions?

Backup

Pump Housing

- Worries about shafts wearing into the housing necessitated this solution
- Possible to post machine down the ends to press fit into bearings and key in the proper locations for the gears and coupler



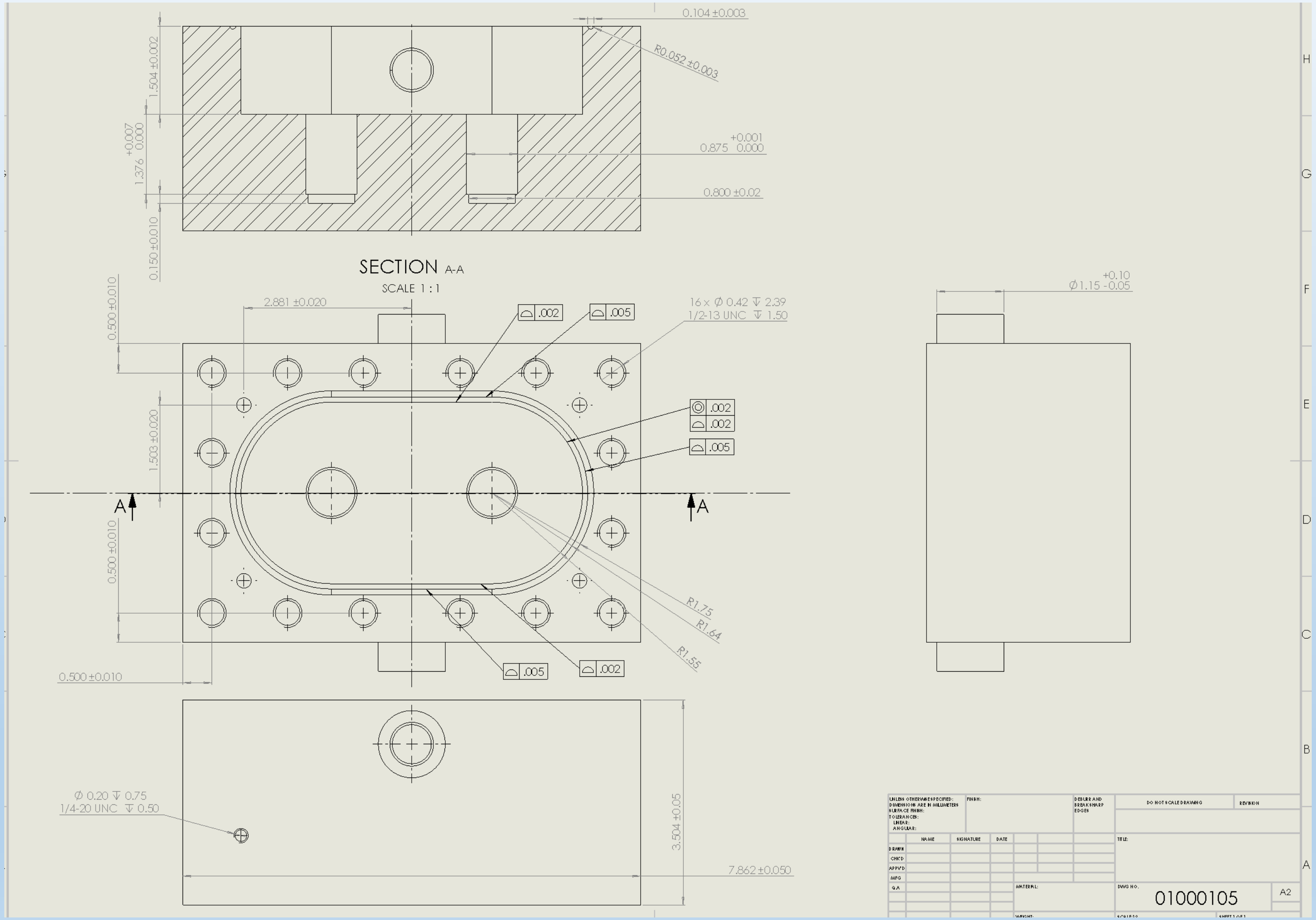
Pump Housing

- To prevent pressure pushing the driveshaft out, an extra retention method was included to prevent axial pushback since the shaft is essentially wedged between the mounted pump and mounted motor on the stand

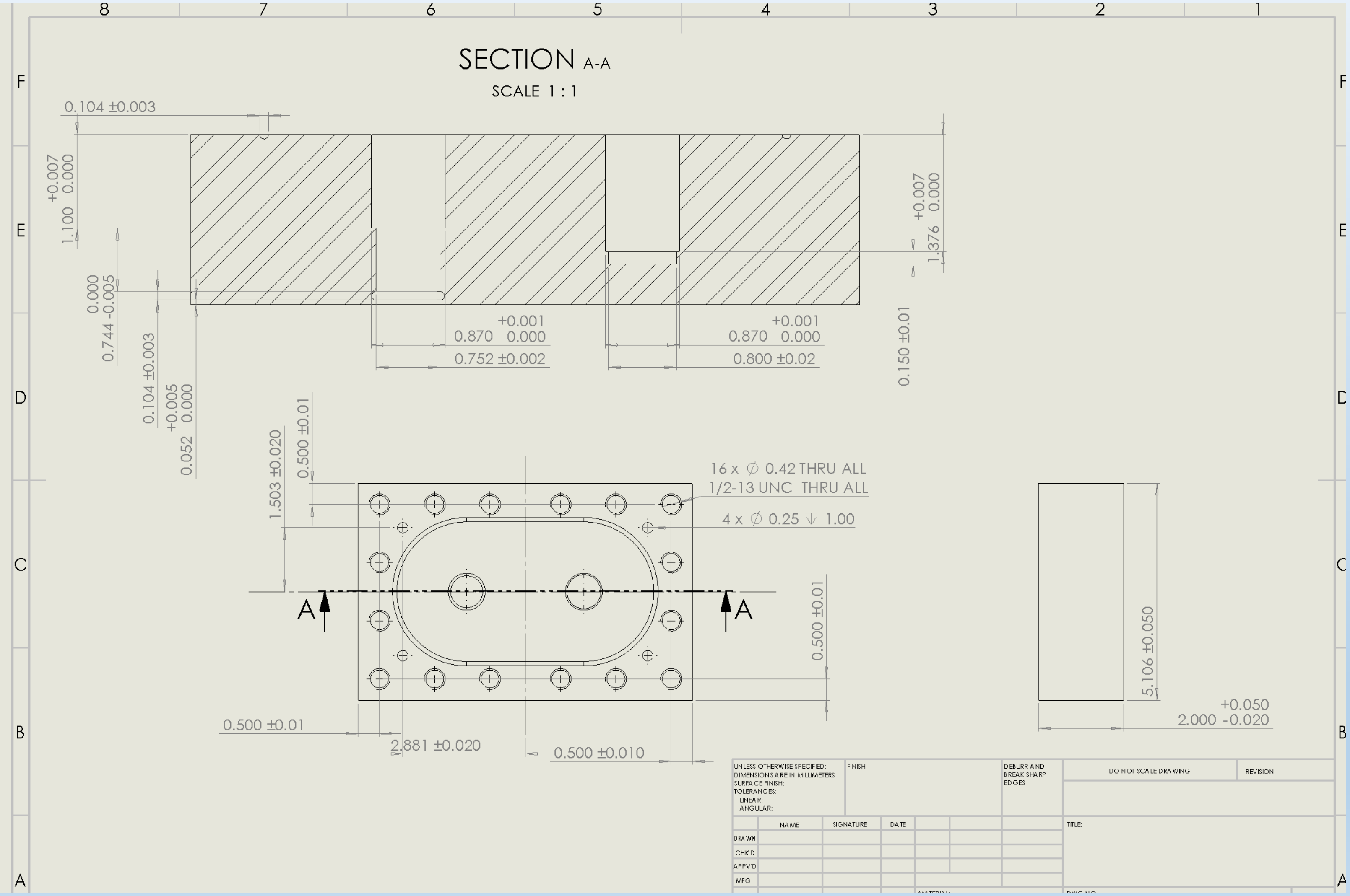
Pump Seals

- The geometry is being updated to optimal specs. Will be finalized/double checked by COB Tuesday
- May included a double seal to mitigate possible leaking as we enter testing

Prelim Housing Drawing with GD&T

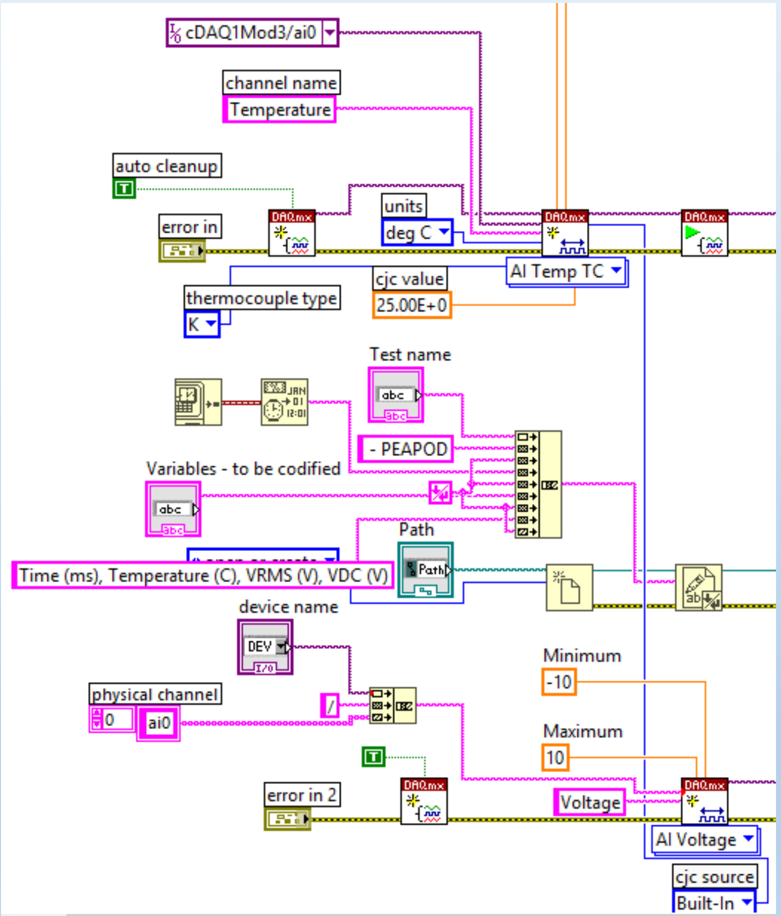


Prelim Close-out Panel Drawing with GD&T



Pump Control - Software

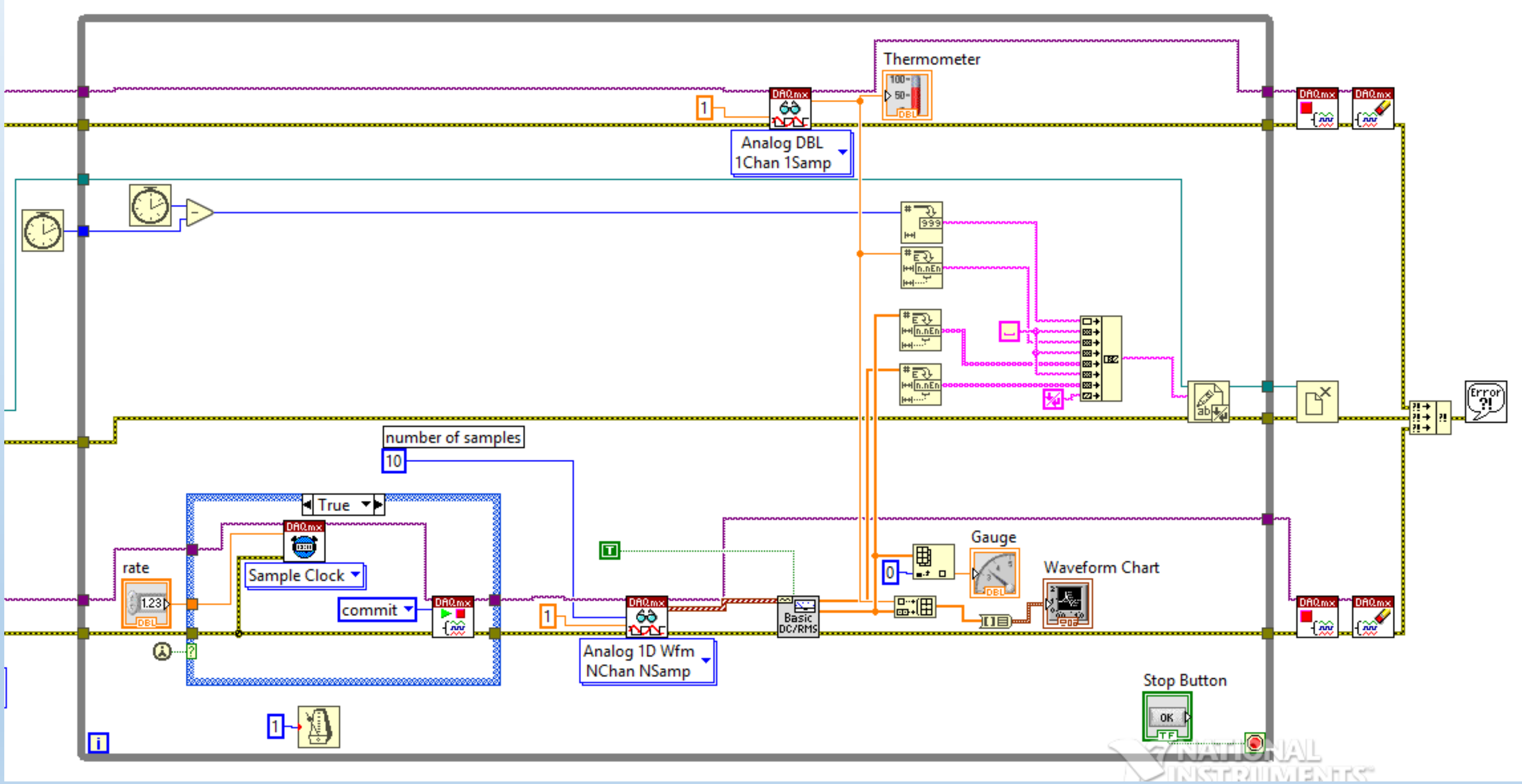
- Pressure and temperature combined test setup



Overview | Pump Manufacturing | Pump Control | Testing/ Schedule | Budget

Pump Control - Software

- Pressure and temperature combined test main loop



Overview | Pump Manufacturing | Pump Control | Testing/ Schedule | Budget

Phase 1 – Sensor Testing and Simulation

Electronic pressure regulator design

- Designing motor-regulator mechanical interface
- Designing pressure regulation through control of motor voltage

Sensor Testing

- Circuit Design: Power requirements, reading outputs
- Calibration: sampling rate, noise compensation, error rejection

Simulink Modeling

- Model Drive and Pump system
- Design control law for throttling pump flow rate
- Design realistic throttle profiles

LabView Design

- System circuit design
- Implementation of safety monitoring software

Key Results to obtained

- Completion of pressure regulating system, obtaining resulting accuracy, slew rate, power requirements
- Pressure Transducer performance
- Tachometer mounting and performance
- First iteration of electronics circuit design
- First iteration of system control law
- Estimate of system slew rate (startup and shutdown)
- Generation of various throttle profiles
- First iteration of DAQ design for both data acquisition and system control
- First iteration of system user interface
- Design of system monitoring software
- Confirming testing location

Phase 2 Functional Reqs. met – None

Phase 2 – Subsystem Testing

Drive System Testing

- Motor: RPM/Torque Test
- Motor: Helium Run Test
- Manual Regulator: Pressure Fluctuations
- Electronic Regulator: Calibration to hit maximum accuracy.
- Tachometer: Calibration to hit maximum accuracy
- Power-Off testing: Verifying that solenoid valve correctly closes in case of power loss.
- Throttling Test 1: Throttling from 10-100% using the electronic pressure regulator, confirming control with pressure transducer.
- Throttling Test 2: Fully assembling drive system components. Running through throttle profiles.

Pump System Testing

- Manual Regulator: Pressure Fluctuations
- Power-Off testing: Verifying that solenoid valve correctly closes in case of power loss.
- Electronic Back Pressure Regulator: Calibration to hit maximum accuracy

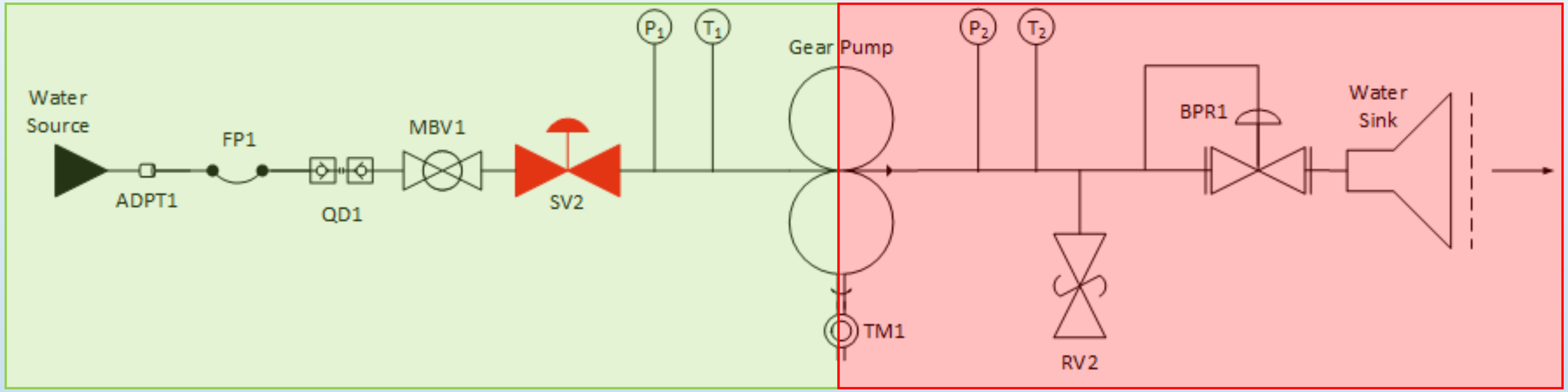
Key Results to be obtained

- Numerous iterations of throttling control software, monitoring software and electronic regulator software
- Assessment of unforeseen issues, correction of affected components
- Validation of component capabilities, allowing for full system assembly to occur

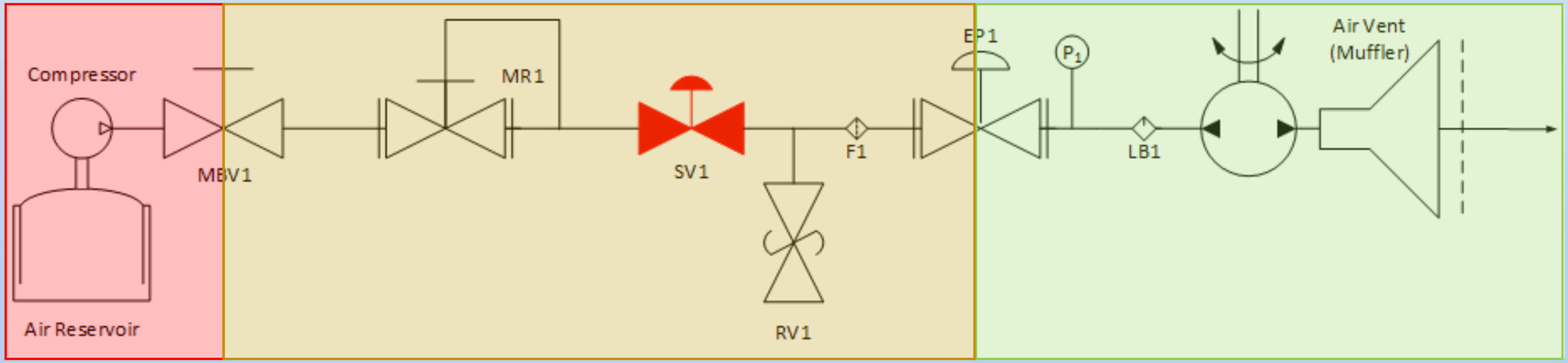
Phase 2 Functional Reqs. met – FR6, FR7

Piping Assembly

Water Pipe Size: ¾"NPT
Pressure Ranges: 50-800PSI
Max Flow Rate: 22Gal/min



Air Pipe Size: 1"NPT
Pressure Ranges: 0-2200 PSI
Max Flow Rate: 45CFM



Nomenclature

SV = Solenoid Valve
RV = Relief Valve
MBV = Manual Ball Valve
MR = Manual Regulator
EP = Electronic Pressure Regulator
BPR = Back Pressure Regulator
TM = Tachometer
BD = Burst Disk
LB = Lubricator
F = Air Filter
P = Pressure Transducer
T = Temperature Sensor
ADPT = GHT to NPT
FP = Flexible Pipe
QD = Quick Disconnect

Subsystem Testing Timeline

Water Testing – Subsystem Testing			
Component(s)	Testing to be Conducted	Man Hours	Status
Solenoid Valve Shut-Off	Simulate excessive pressure and/or temperature readings to initiate safety shutdown	9 Hours : (2*4 + 2*0.5 + 2*0.5)	0%
Adapter, Quick Disconnect, Flexible Pipe, Pressure Ducer	Quantify pressure losses (water) associated with pre-piping assembly	7.5 Hours : 2*1 + 2*1.5 + 2*1	0%
Pre-Pump pressure loss	Quantify pressure loss (water) of full assembly leading to pump inlet	10.5 Hours : 3*2 + 3*0.5 + 3*1	0%

Total Man Hours: 27

Timing

Personnel: Operators required

Hours: Time required to prepare and assemble test

Hours: Time required to conduct test

Hours: Time required to disassemble test and save results

Multiplier: Repeat test for identical sensor /component

Subsystem Testing Timeline

Air Testing – Subsystem Testing			
Component(s)	Testing to be Conducted	Man Hours	Status
Solenoid Valve Shut-Off	Simulate excessive pressure and/or temperature readings to initiate safety shutdown	4 Hours : (2*1 + 2*0.5 + 2*0.5)	0%
Pressurized Gas, Manual Regulator, Solenoid Valve (Air), Relief Valve, Filter, Pressure Transducer	Quantify pressure losses (air) associated with pre-regulator assembly	10.5 Hours : 3*1.5 + 3*1+ 3*1	0%
Full air system excluding Air Motor	Detection of pressure regulator miss-calibration/erroneous operation	13.5 Hours : 3*2 + 3*1 + 3*1.5	0%

Total Man Hours: 28

Timing

Personnel: Operators required

Hours: Time required to prepare and assemble test

Hours: Time required to conduct test

Hours: Time required to disassemble test and save results

Multiplier: Repeat test for identical sensor /component

Subsystem Testing Timeline

Air Testing – Subsystem Testing			
Component(s)	Testing to be Conducted	Man Hours	Status
Solenoid Valve Shut-Off	Simulate excessive pressure and/or temperature readings to initiate safety shutdown	9 Hours : (2*4 + 2*0.5 + 2*0.5)	0%
Pressurized Gas, Manual Regulator, Solenoid Valve (Air), Relief Valve, Filter, Pressure Transducer	Quantify pressure losses (air) associated with pre-regulator assembly	7.5 Hours : 2*1 + 2*1.5 + 2*1	0%
Full air system excluding Air Motor	Detection of pressure regulator miss-calibration/erroneous operation	10.5 Hours : 3*2 + 3*0.5 + 3*1	0%
Full Air Assembly, air motor connected to friction assembly			

Timing

Personnel: Operators required

Hours: Time required to prepare and assemble test

Hours: Time required to conduct test

Hours: Time required to disassemble test and save results

Multiplier: Repeat test for identical sensor /component

Total Man Hours: 27

Phase 3 – Full System Testing

Full scale testing to be conducted

- Drive Shaft Alignment
- Mass flow rate testing
- Throttle profile testing
- System startup and shutdown testing
- Emergency shutdown testing
- Restartability testing

Key Results to be obtained

- Determination of any misalignment of motor/pump driveshaft
- Pump performance: mass flow rate, back pressure, efficiency
- Observation of system under numerous throttle profiles
- Iteration on shutdown procedures to optimize restartability
- Iteration on control law to account for unaccounted system properties

Final Testing

Full scale testing to be conducted

- Throttle profile testing: (10 - 100% Throttle), slew rate testing.
- Quantifying magnitude of outlet pressure fluctuations
- Throttle profile testing (ran through various profiles)
- System startup and shutdown testing, with emergency shutdown and restart-ability

Key Results to be obtained

- Pump performance: mass flow rate, back pressure, efficiency
- Observation of system under numerous throttle profiles
- Iteration on shutdown procedures to optimize re-startability
- Iteration on control law to account for unaccounted system properties

Standard Testing Procedure - Example

Throttle Calibration Test

1. Pump is started up and commanded to throttle setting
2. The pump is run at throttle setting
3. Flow enters control volume for 10 secs
4. Flow is diverted back to regular vent
5. Pump is shutdown
6. Control volume is measured and recorded
7. Test is re-iterated as needed for other throttle settings

Critical Test Elements

- Pump-Drive system
- Control Volume
- Flow Bypass system
- 3 Team membersmonitoring test

Key Results to be obtained

- Validation of throttle model design
- Refinement of throttle model design
- Meeting of critical project element

Safety Set-Up

Worst Case Failures

1. Drive system flywheel – 225 J
2. Drive system casing – 16 J
3. Pump gears – 36 J

Cinder Block Housing Strength

- Chipping - 300 J
- Cracking - 600 J
- Penetration - 800 J
- Failure - 1000 J
- Complete destruction - >1300 J

Analog to Digital Conversions

- Converting from ADC to pressure

$$V_{ADC} = V_{out,max} \frac{MSMT}{2^{16}}$$

- Find the MSMT out of the ADC to get the Voltage into the ADC

$$V_{Press} = \frac{V_{ADC}}{G} + V_{offset}$$

- Find the pressure out of the Pressure transducer
- Find pressure by dividing it by the voltage per pressure ratio

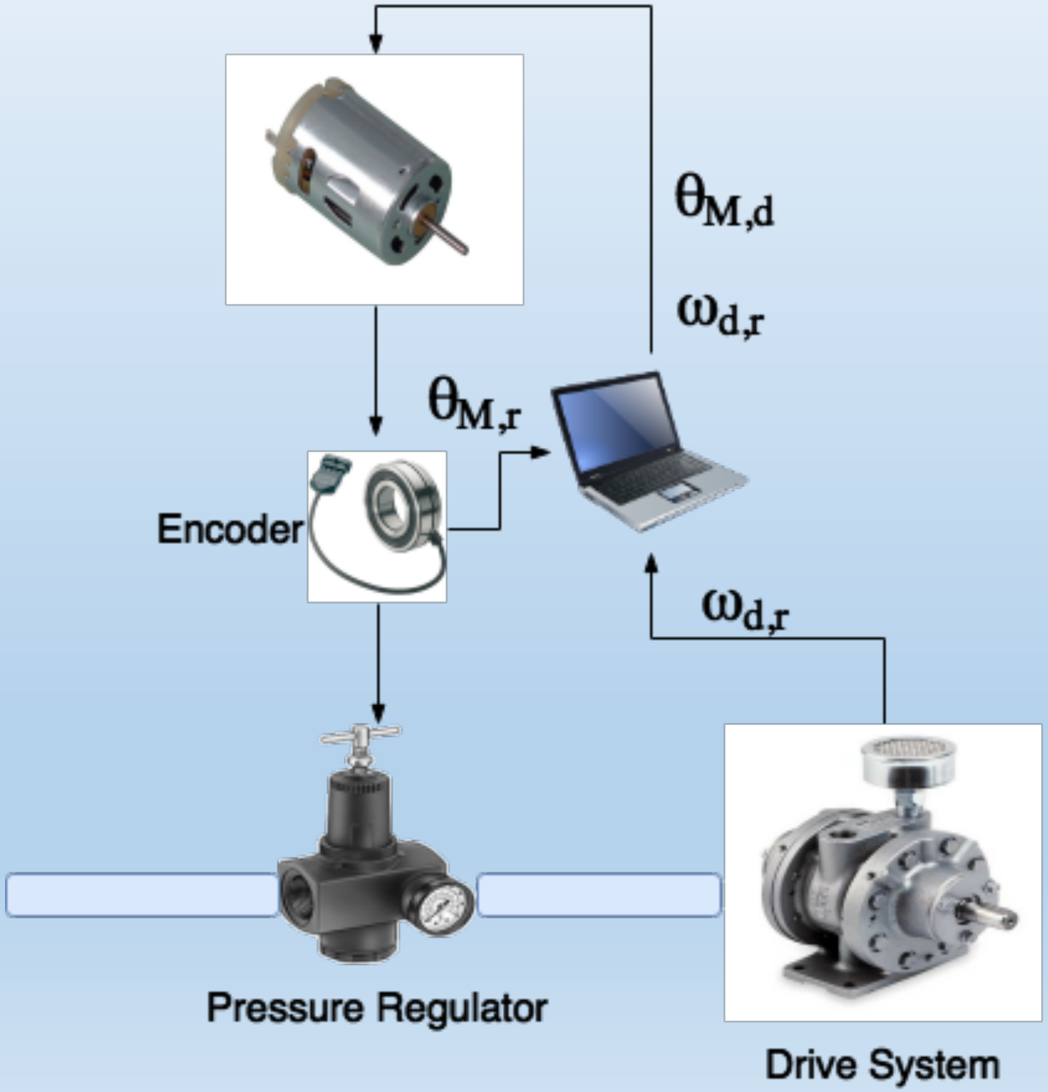
$$P = \frac{V_{Press}}{Ratio_{V2P}}$$

Automatic Pressure Regulator

- Electronic pressure regulators with high volume flow are not found, but manual do exists
- Combining a manual pressure regulator with an encoder and stepper motor
- Motor shall have a minimum angular velocity of 300 RPM
- No error, and time of settle of less than 1 second

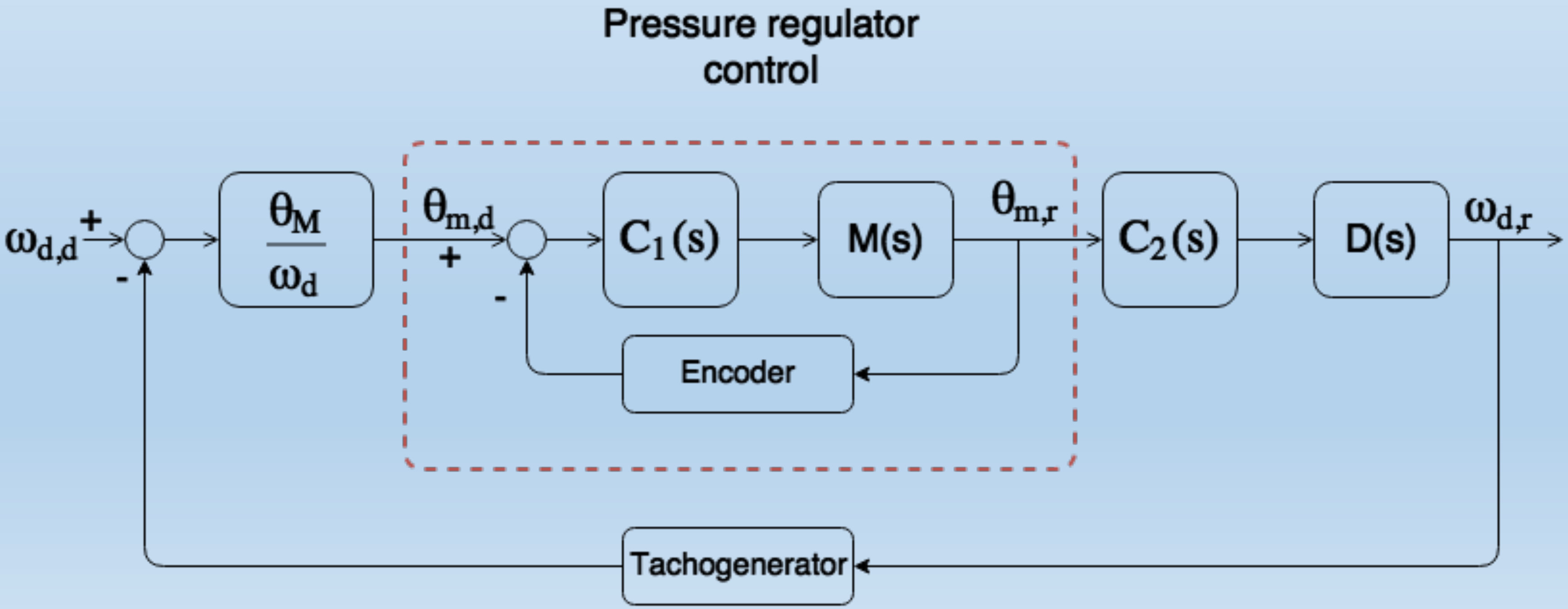
Automatic Pressure Regulator FBD

- Controlling a stepper motor based on the position
- This position will allow the output pressure



Automatic Pressure Regulator Diagram

- Control points of view for the pressure regulator
- Can be simplified by combining both plants
- Needs to be tested to find the correlation of angular position with output RPM



Automatic Pressure Regulator

- This can be simplified by combining
  - the drive system transfer function and
  - the motor transfer function

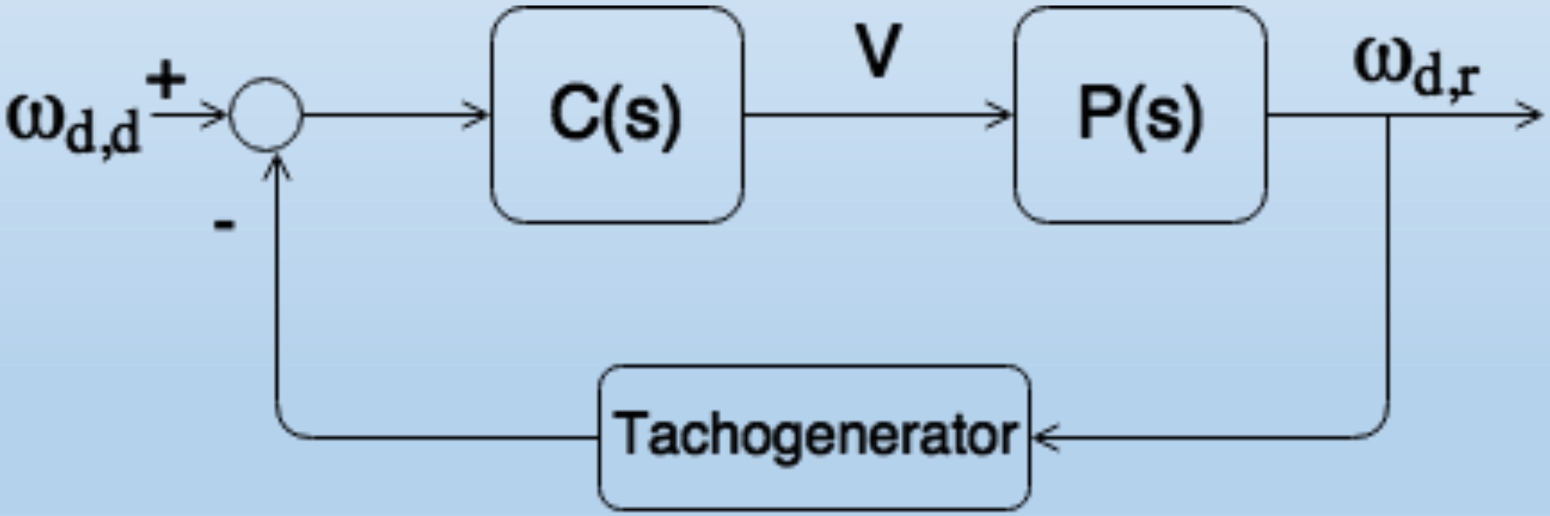
$$D(s) = \frac{\Omega_D(s)}{\Theta_{pr}(s)} = \frac{1}{Is + f_v} \quad [\frac{RPM}{rad}]$$

$$P(s) = \frac{\Omega_D(s)}{V(s)} = \frac{K}{s((Js+b)(Ls+R)+K^2)(Is+f_v)} \quad [\frac{RPM}{V}]$$

$$M(s) = \frac{\Theta_{pr}(s)}{V(s)} = \frac{K}{s((Js+b)(Ls+R)+K^2)} \quad [\frac{rad}{V}]$$

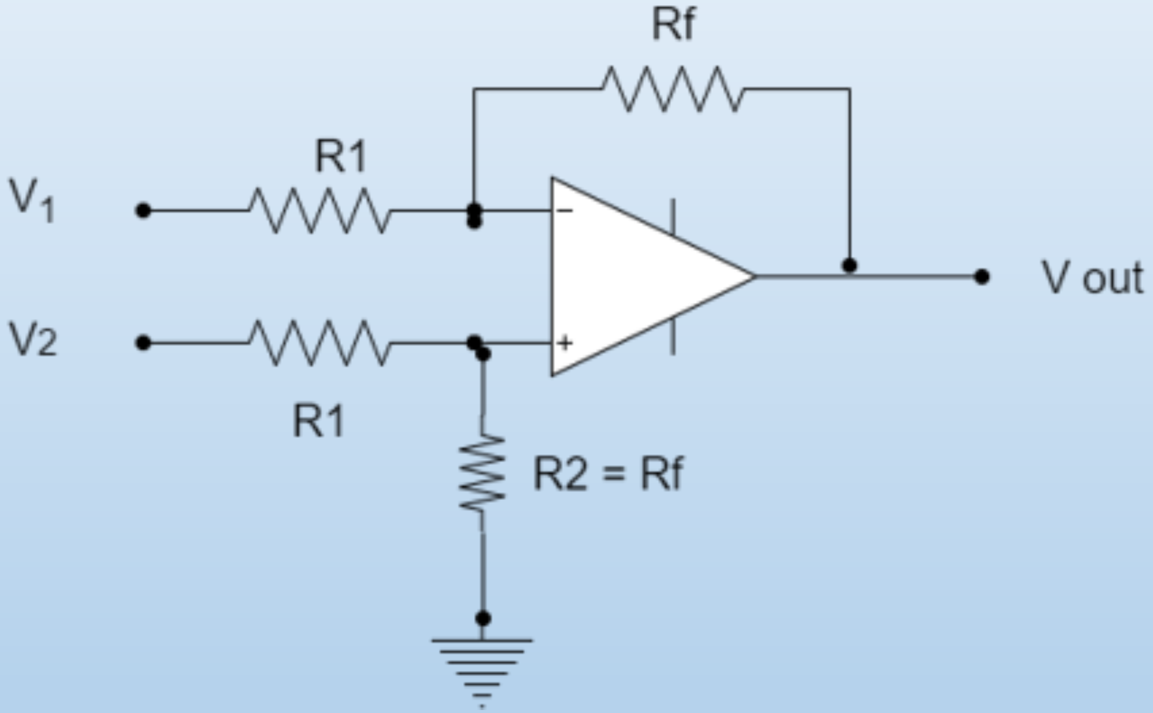
Automatic Pressure Regulator

- Simplified version of the model
- Allows to control the drive system based on the voltage input



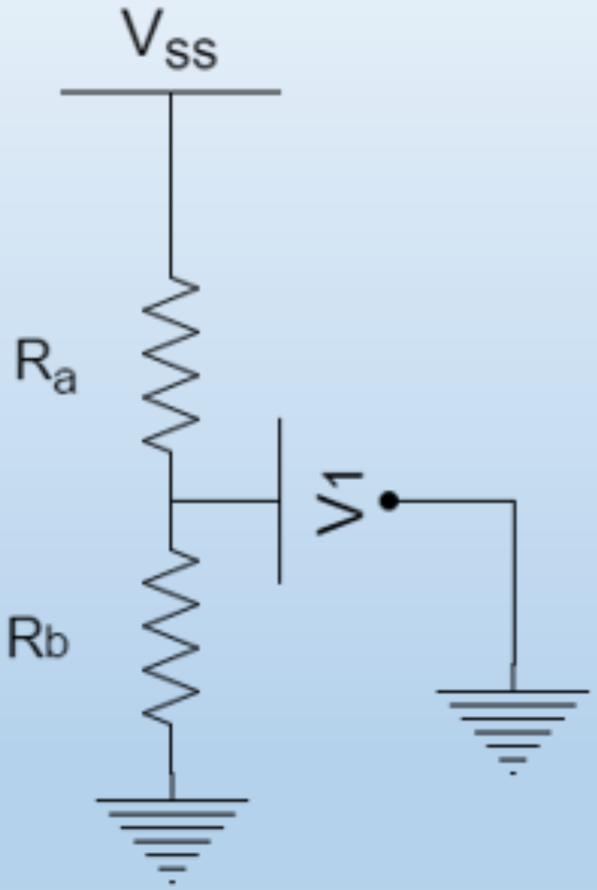
Signal Processing – Differential Amplifier

- Use for creating an offset and applying a gain to the voltage out of the pressure transducer
- This will allow us to look at a range from 600 – 800 psi a with higher accuracy.



Signal Processing – Voltage divider

- Being able to from 28 V to .6 V
- The output will be used to provide the offset needed for V1



Signal Processing – Noise Mitigation

Low pass filter Vs Sallen-key filter

Low pass filter

- Easy to make
- First order filter
- Only one pole

$$T = \frac{1}{1 + sRC}$$

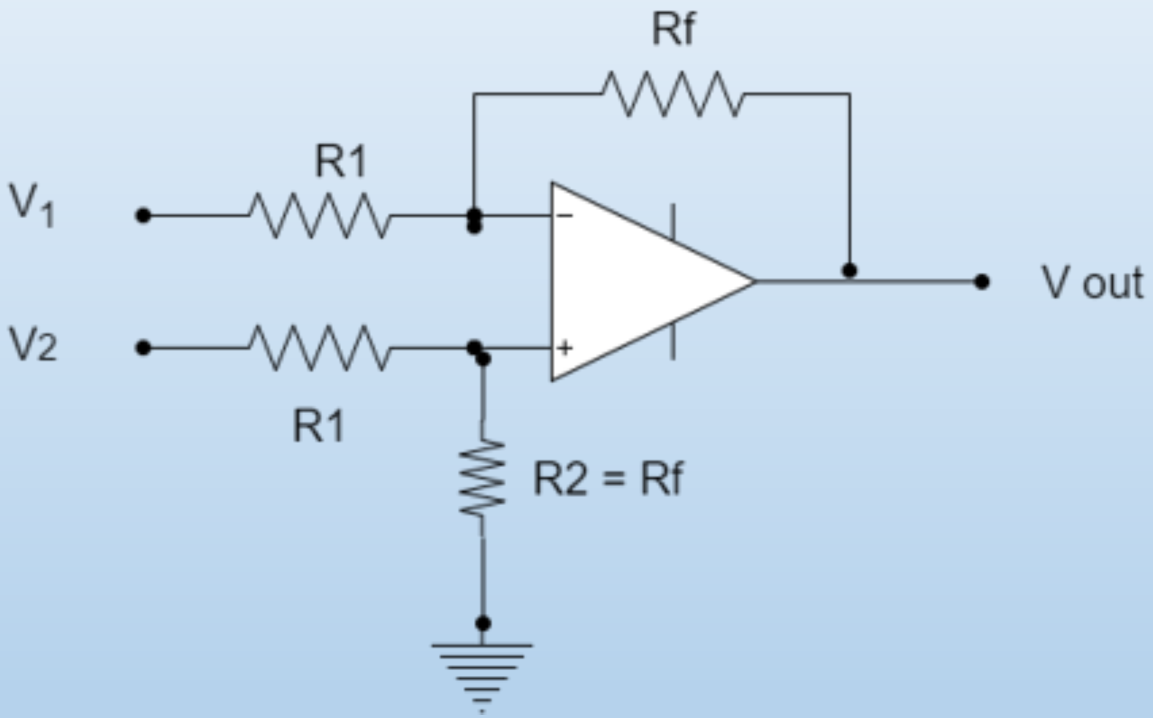
Sallen-key filter

- Harder to make
- Second order filter
- Two poles

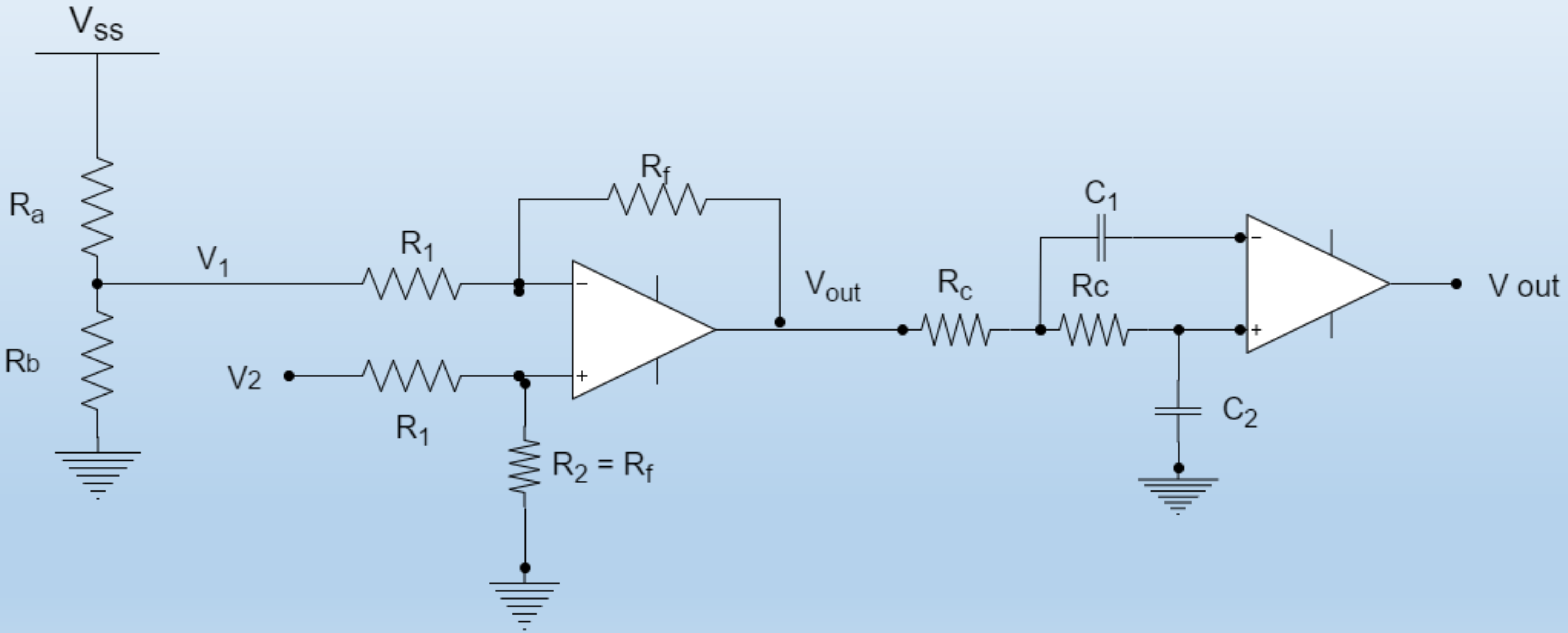
$$T = \frac{\omega_0^2}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2}$$

Signal Processing – Noise Mitigation

- Prevents to look at high frequencies that are irrelevant
- This will have a cutoff frequency at 2 kHz



Signal Processing – Electronic diagram



Electronic Test