Portfolio of Projects

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1 Hot Gas Purge System

The purpose of this project was to design a housing for a solenoid that would be controlled by SDSU Rocket Project's Electronic Systems Bay (ESB).

1.1 Background

When firing the LR101 engine on the Galactic Aztec Heavy Mark II vehicle, the team was experiencing hard starts on the engine. To help alleviate this, the necessity for a way of purging gases from the combustion chamber before firing was created. The solenoid is controlled by the ESB and feeds nitrogen gas into the combustion chamber.

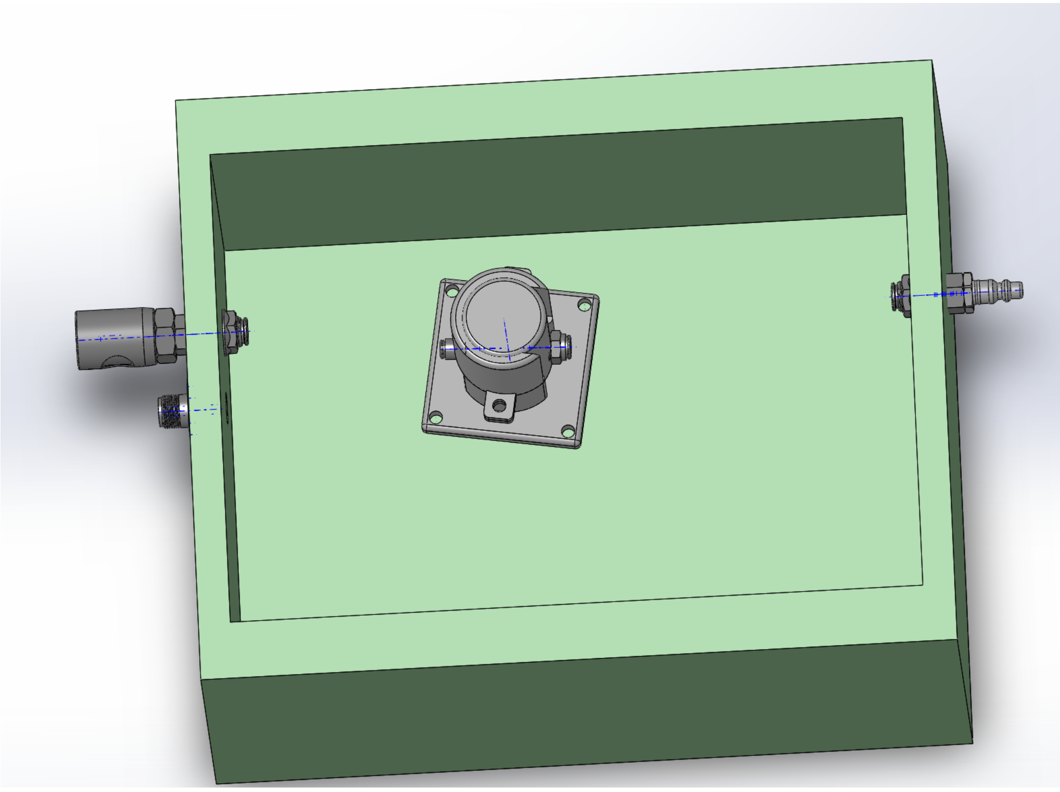


Figure 1: First project freshman year attempting a 3D CAD of the system. Full photos of the system were not took and the system was updated to house the camera systems switch on the test rig.

Figure 2: This was the solenoid that we used for the system. I was measuring to create a CAD model of the solenoid

2 Galactic Aztec Heavy Mark II Lower Airframe

The purpose of this project was to design a lower airframe for a LR101 engine and connect to the tanks of the Galactic Aztec Heavy Mark II vehicle.

2.1 Background

Galactic Aztec Heavy Mar II was a 26ft long liquid bi-propellant LOX/Kero rocket. The Lower Airframe (LAF) experienced the full thrust of the 1000 lbf engine. It needed to also house the Main Propellant Valves and their actuation structure. The LAF was the connection point for avionics and all the controls ground systems.

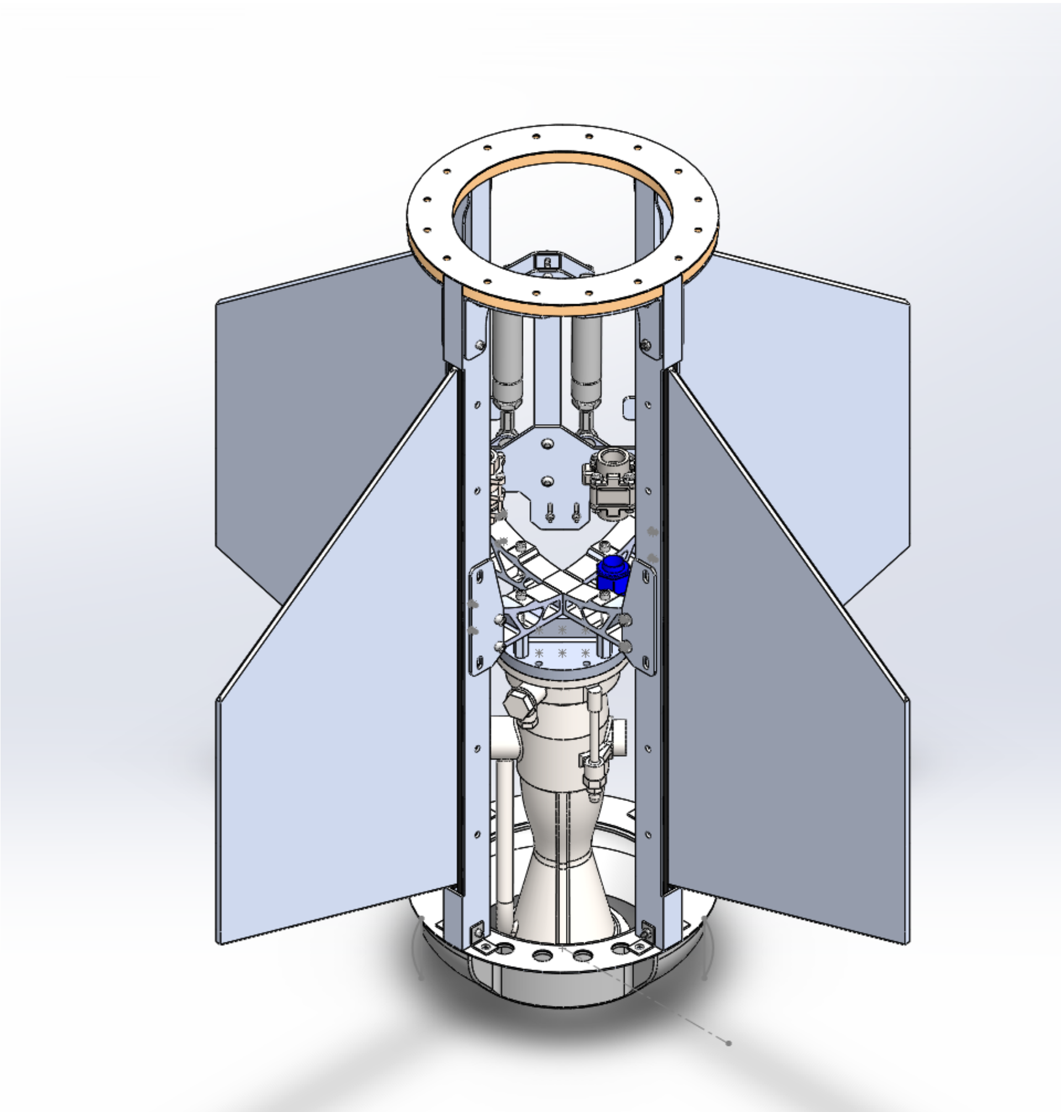


Figure 3: Isometric view of the LAF structure.

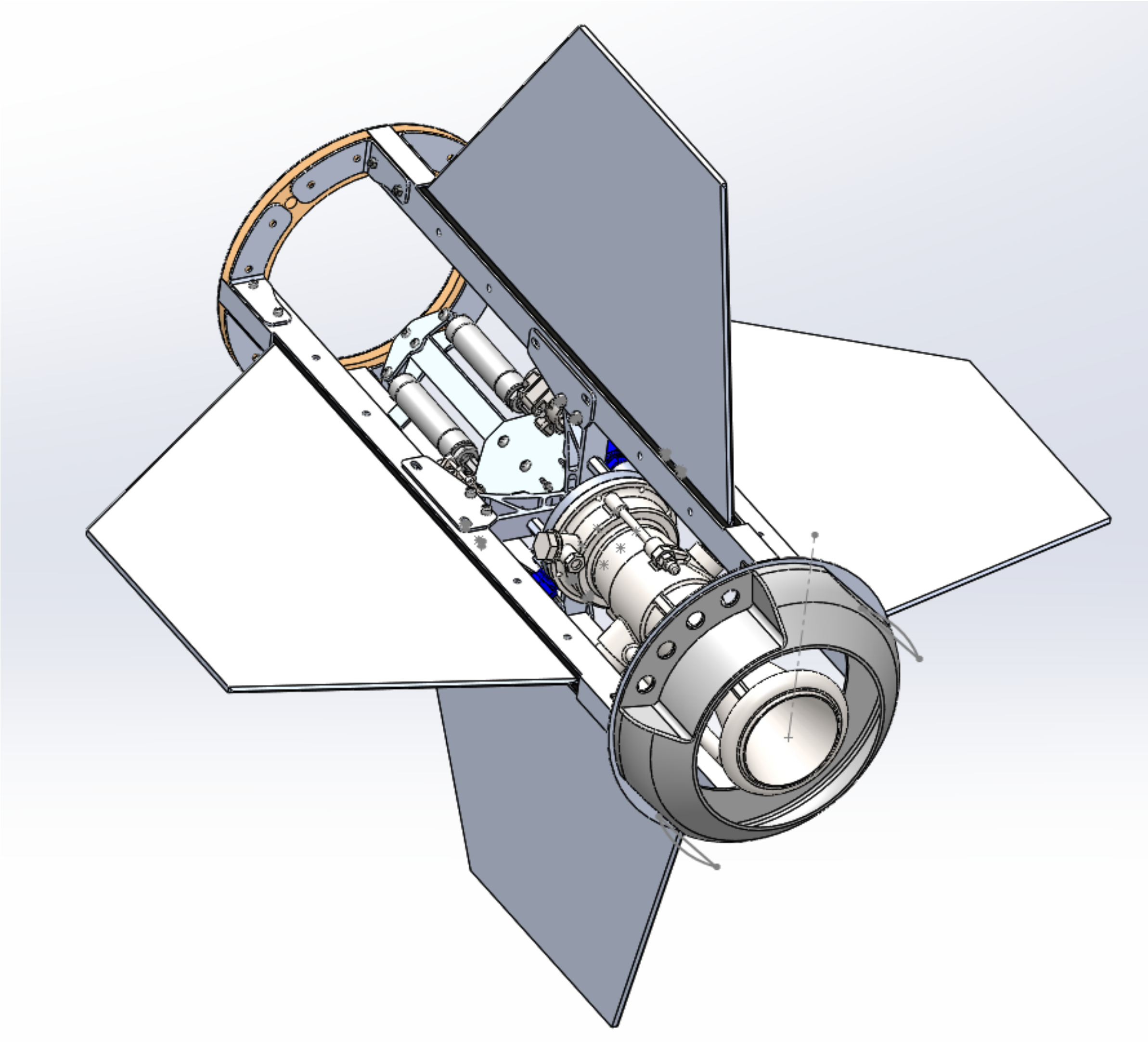


Figure 4: Side view of the LAF structure.

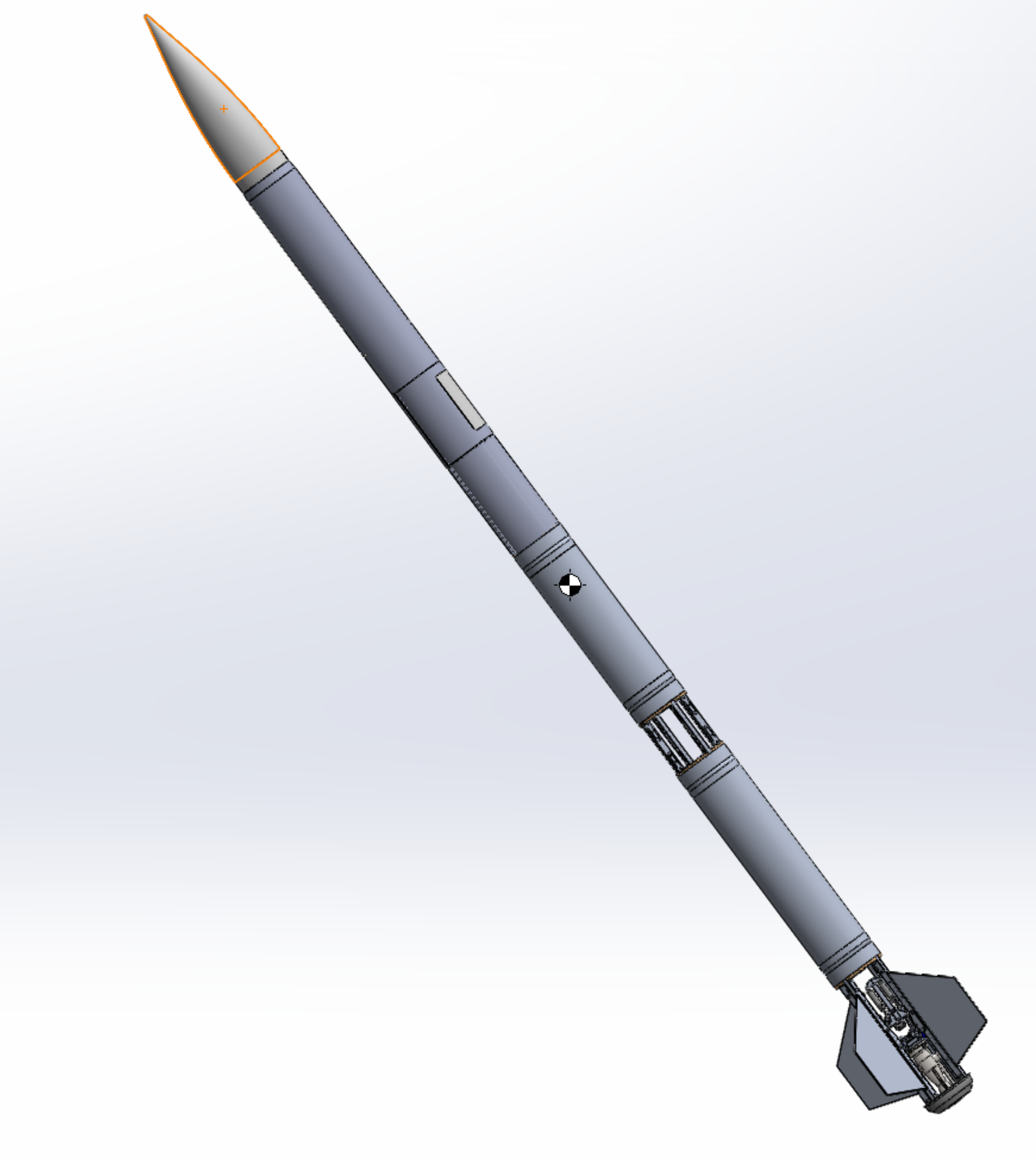


Figure 5: Model of Galactic Aztec Heavy Mark II

Figure 6: Photo before the launch attempt of the assembly.

Figure 7: A photo from inside our "Blockhouse," the original room we built rockets in.

3 Electronic Systems Bay 2.0

The purpose of the electronics systems bay 2.0 was to create a electronics controls housing on the cryogenic test stand. It housed data acquisition units and ports for pressure transducers, thermocouples, load cells, and ignition systems.

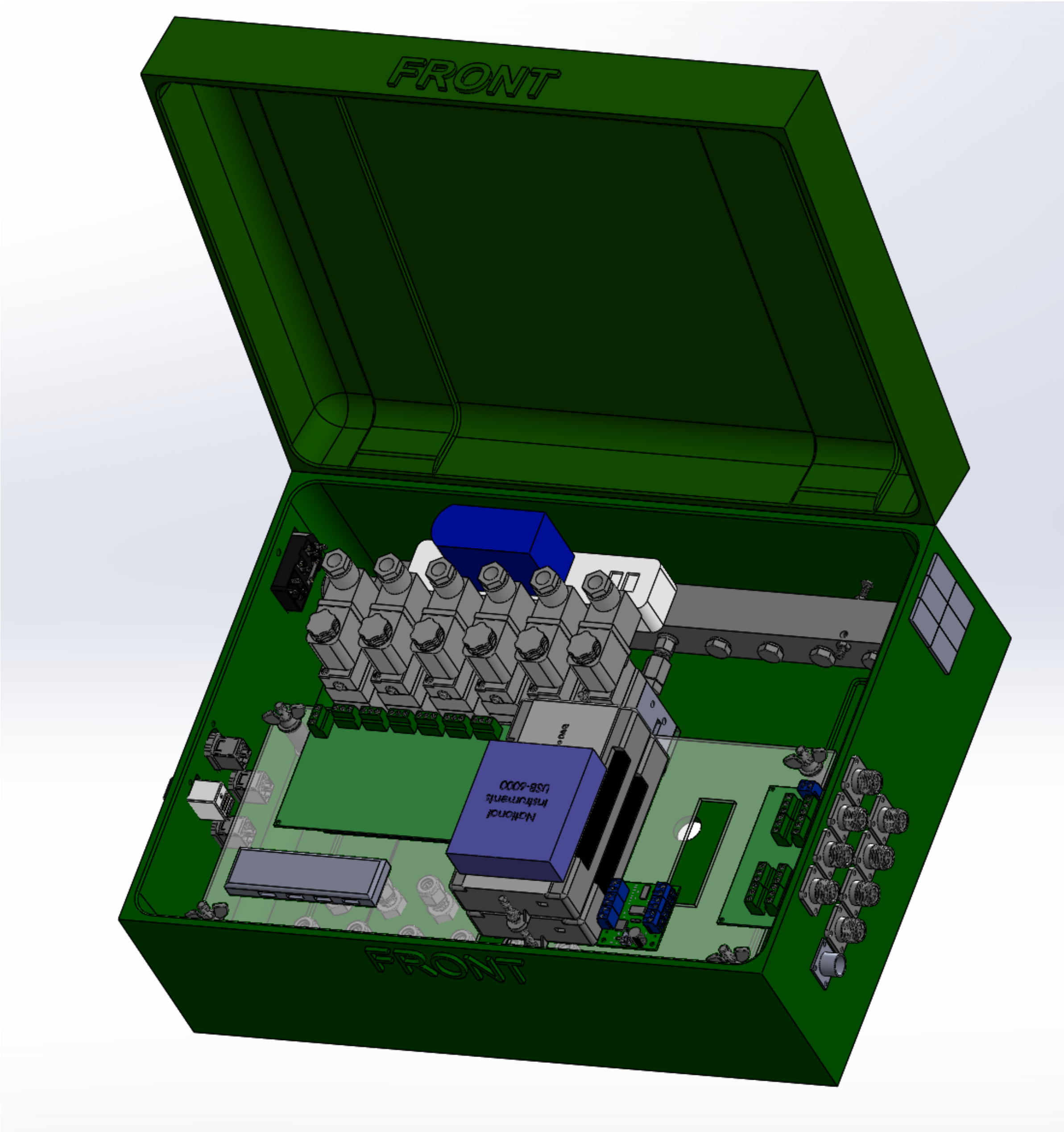


Figure 8: This is the CAD model of the electronics housing. We used it to make sure the electronics would fit and designate locations for them to be housed.

Figure 9: This is an image of the system being checked on the vehicle while on the test stand.

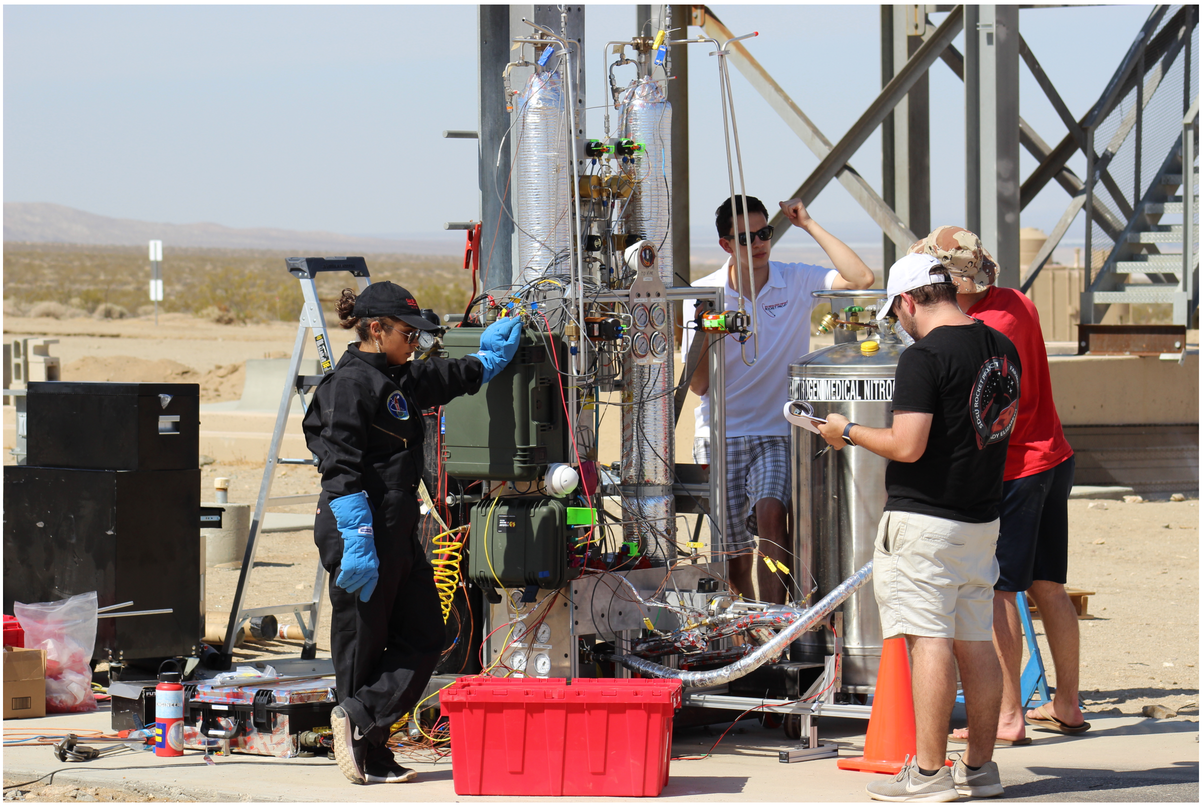


Figure 10: This is an image of the system being checked on the vehicle while on the test stand.

4 Automated Recycling Sorting Prototype

The purpose of this project was to design a prototype machine that automated sorting of recycling, designed to the local La Mesa recycling volume data as criteria. The vehicle was designed and tested during fall of 2017.

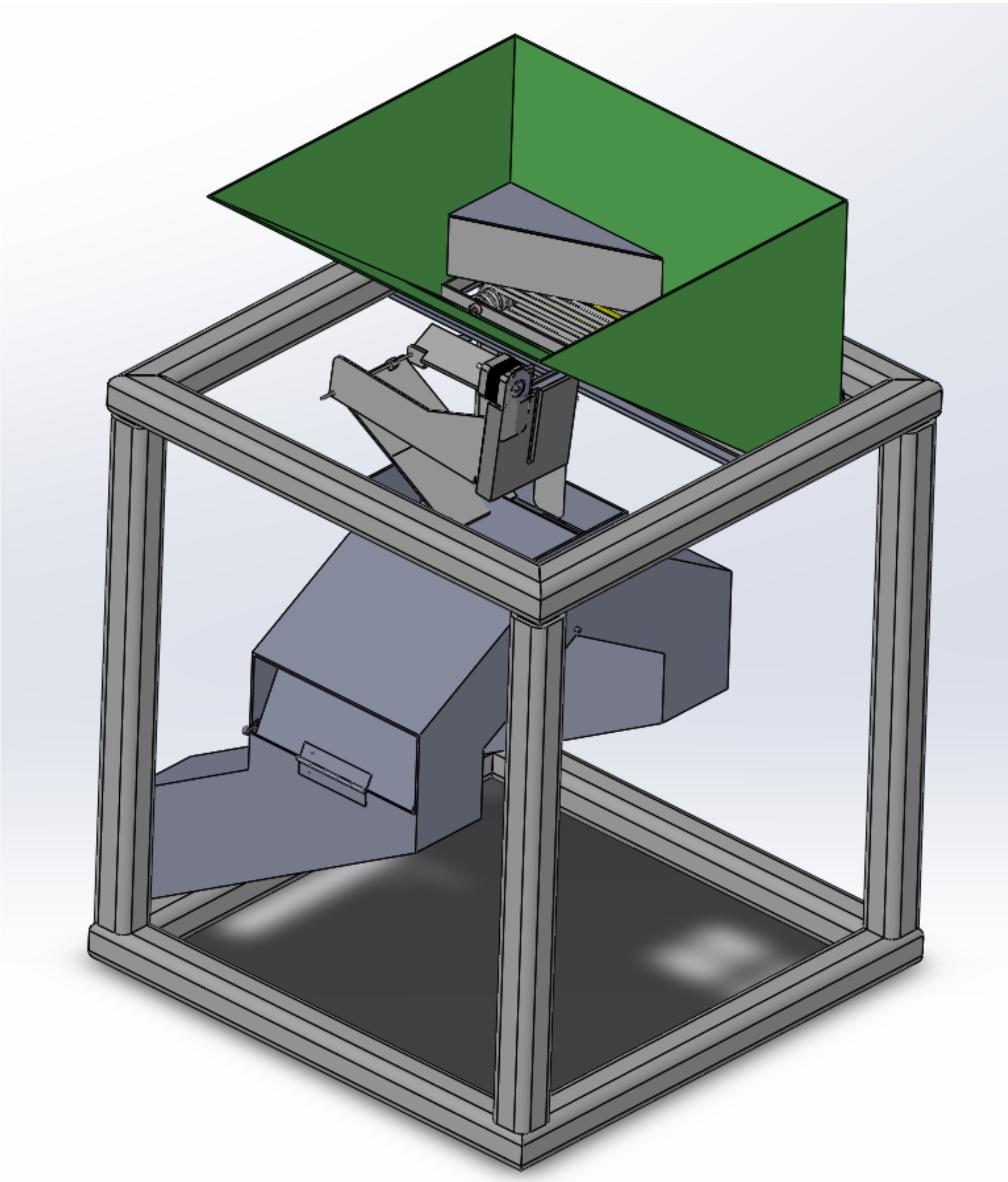
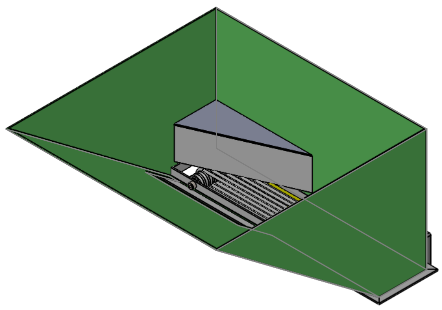


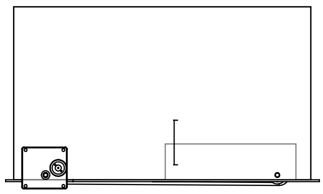
Figure 11: This is the CAD model of the recycling machine prototype assembly.

2 1

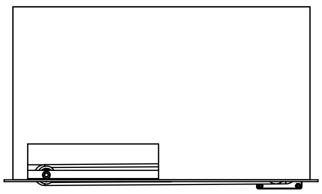
B B



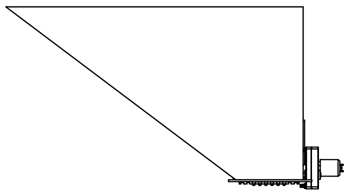
Back View



Front View



Side View



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		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
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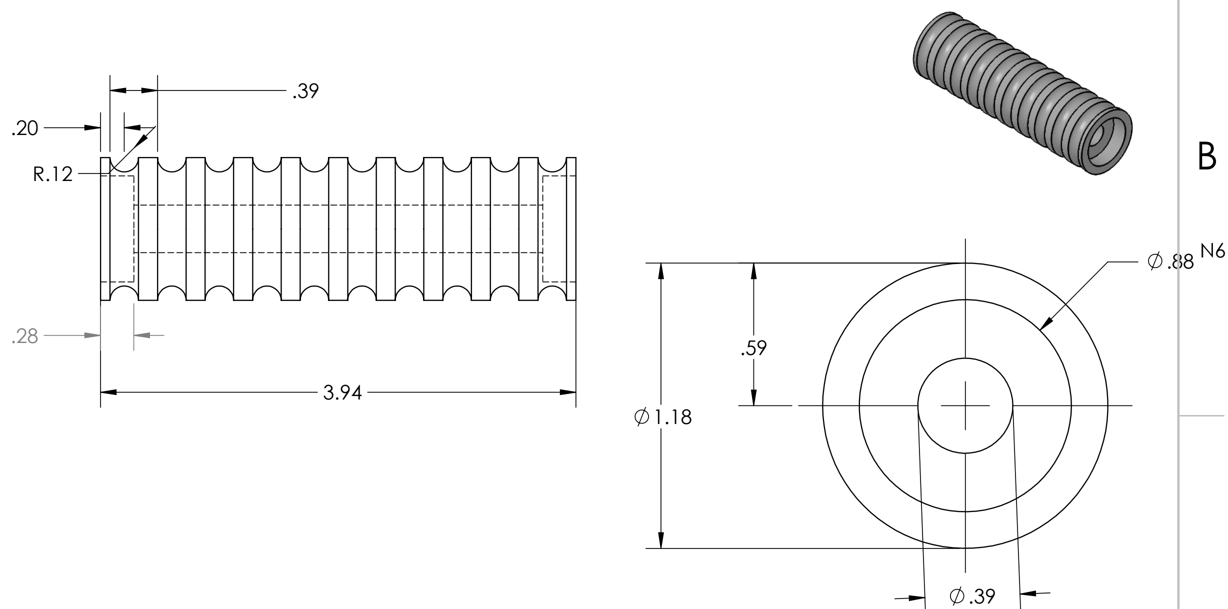
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

TITLE:

SIZE	DWG. NO.	REV
A	Hopper Assembly Drawing	
SCALE: 1:1	WEIGHT:	SHEET 1 OF 7

2 1



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Q.A.		
COMMENTS:		

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Hopper Assembly Drawing

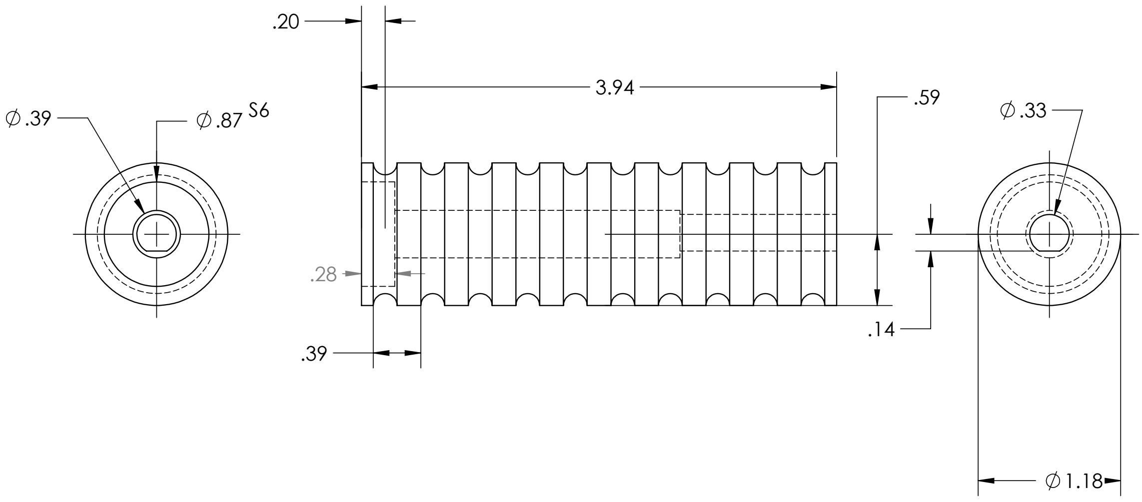
SIZE	DWG. NO.	REV
A		

SCALE: 1:1 WEIGHT: SHEET 2 OF 7

2 1

2 1

B B



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		MATERIAL	COMMENTS:		
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APPLICATION		DO NOT SCALE DRAWING			

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Wheel B

SIZE	DWG. NO.	REV
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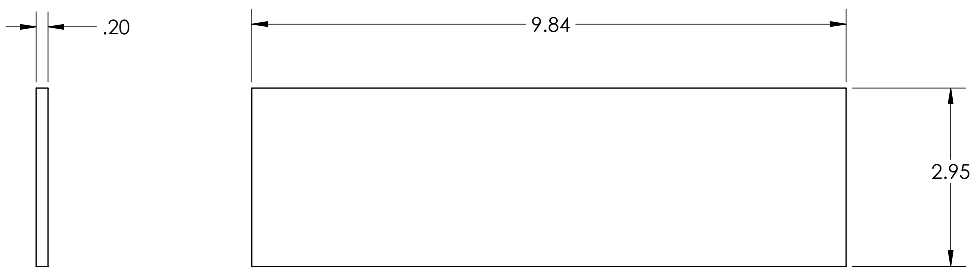
2 1



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FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

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	NAME	DATE
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ENG APPR.		
MFG APPR.		
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COMMENTS:

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APPLICATION	

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TITLE:

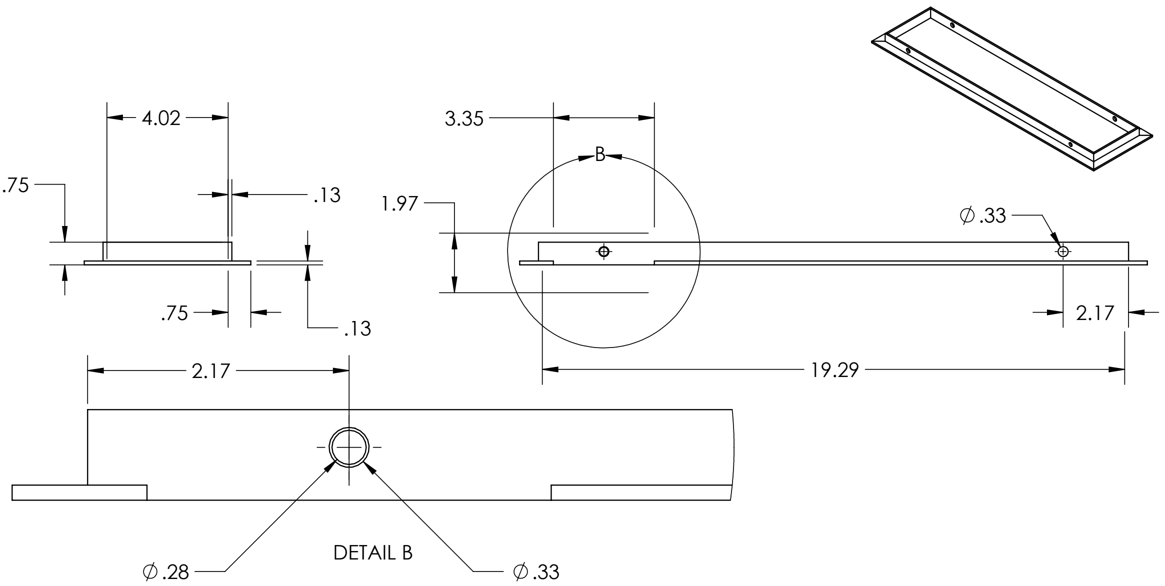
Angled Plate

SIZE **A** DWG. NO. REV

SCALE: 1:1 WEIGHT: SHEET 4 OF 7

2 1

B B



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			MFG APPR.			
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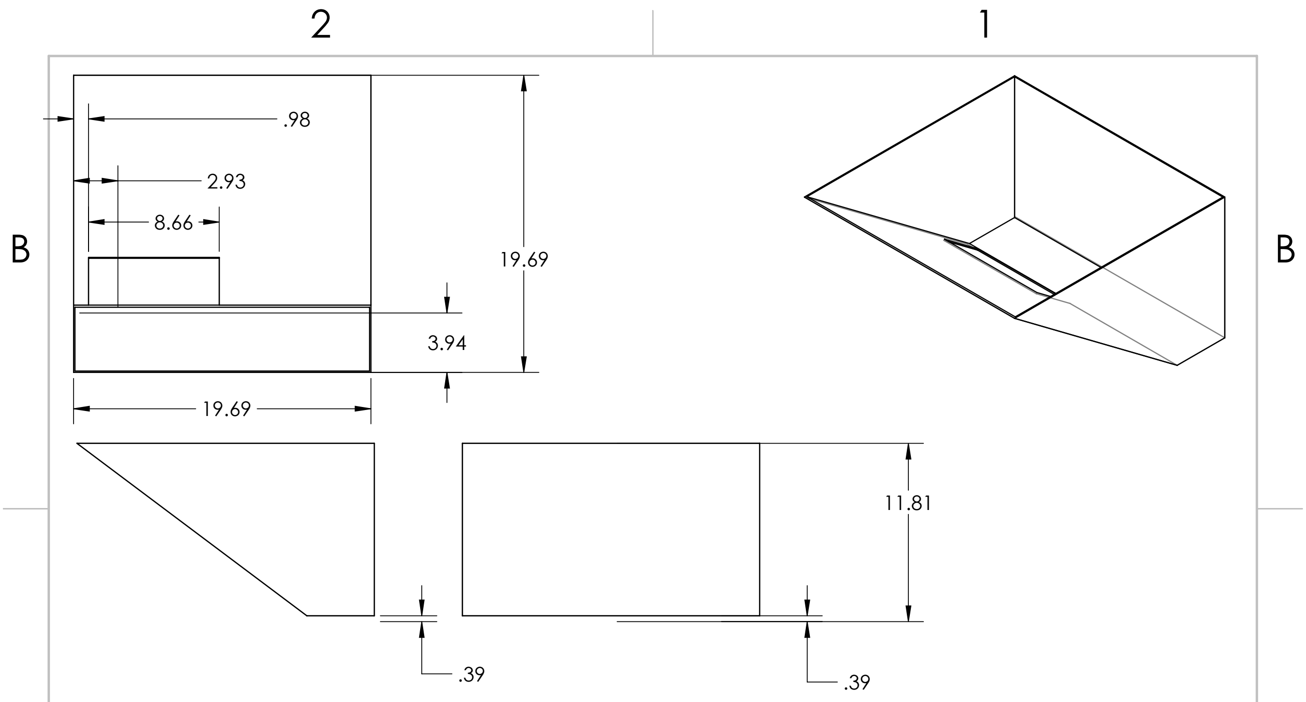

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

NEXT ASSY | USED ON

APPLICATION

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ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

Hopper

SIZE A | DWG. NO. Hopper Assembly Drawing | REV

SCALE: 1:1 | WEIGHT: | SHEET 6 OF 7

2 1

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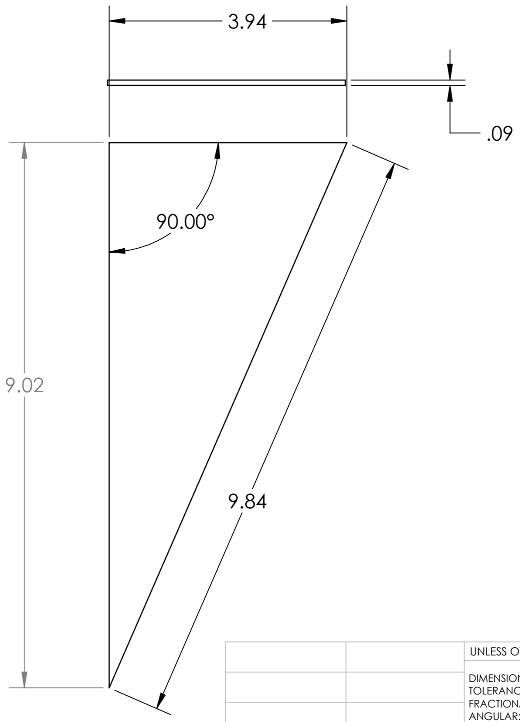

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			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

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TITLE:

Bottle Trap Cover

SIZE	DWG. NO.	REV
A	Hopper Assembly Drawing	

SCALE: 1:1 WEIGHT: SHEET 7 OF 7

2 1

5 Safety Procedure for Cryogenic Engine Test Stand

These are the procedures for SDSU Rocket Project's Cryogenic Test Stand that is used to operate the vehicle safely and from a bunker. The procedure was written in order to best create repeatable operation of the vehicle and allow for multiple operators (myself and the CTO/Treasurer) to run the operation. In the event that one person stepped away, the next person was able to keep moving from each step. Each step was labeled with a number system that could be called on radio and repeat what step and how far the team was through the testing procedure. Each black box marked a pausing point and the time labeling allowed for studying speed after working through the procedure.

5.1 Failure Scenarios

The last section of the procedure has a system of failure scenarios and what move to make given the circumstances. This allowed for calm movement and step by step procedures to safely move forward with the vehicle. The failure scenarios were printed and put on the wall of the bunker for reference.

5.2 Annotated from Cryogenic Test

This is a copy of the procedure that was used during one of the last cryogenic tests. Notes were taken on improving the procedure and errors that occurred.

Test Stand SHF/Cryo Test Procedure

John's Copy

This document will serve as the overall procedure for a static hot fire or cryogenic test using our test stand. It will be organized into the following sequential sections: Testing Specifics, Acronym List, Arrival, Setup, Dry System Testing, Helium System Pressurization Testing, Leak Testing Tank System, Helium System Depressurization, LOX Tank LOX Loading, CH4 Tank Conditioning, CH4 Tank LNG Loading, Helium Loading, Pre-Terminal Sequence, Terminal Sequence, Failure Scenarios, and Safety Approach.

Testing Specifics - Specify Test Number to Your Right (Options: "1", "2", or "Cryo")			Cryo
Test 1 Specifics	Option "1"	Value	Unit
	O/F Ratio	2.2	
	CH4 Tank Pressure	1485.00	psi
	LOX Tank Pressure	1474.00	psi
	Burn Time	10.00	seconds
	CH4 MPV Lead	0.50	seconds
Test Notes			
Test 2 Specifics	Option "2"	Value	Unit
	O/F Ratio		
	CH4 Tank Pressure	24567.00	
	LOX Tank Pressure	1500.00	
	Burn Time		
	CH4 MPV Lead		
Test Notes			
Current Test Tank Pressures		Value	Unit
	CH4 Tank Pressure	1000	psi
	LOX Tank Pressure	1000	psi

Acronym List			
1	Helium Isolator Valve	HI Valve	
2	Main Proellant Valve	MPV	
3	Vent Valve	VV	
4	Electronic Systems Bay	ESB	
5	Mission Control	MC	
6	Avionics Laptop	AvTop	
7	Thermocouple	TC	
8	Pressure Transducer	PC	
9	Dome Loaded	DL	
10	Failure Scenario - Number - Page Number	FS-#-##	

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Arrival**	Void	[illegible]
1.01		Truck/Trailer to requested I-Beam		
1.02		Unload tables and EZ-Up		
1.03		Unload all "Pad" crates at I-Beam		
1.04		Unload LN2 dewar		
1.05		Unload all Cylinders		
1.06		Unload Test Stand		✓
1.07		Unload all "Bunker" crates at bunker		
1.08		Bring LOX Dewar to shade		
2.00		**Setup**	Time:______________ Void	[illegible]
2.01		Power ON and charge radios		
2.02		Position Pressurant Cylinders at I-Beam (At least 1 He for pressurization and 1 N2 for Cylinder for Purge must be secured)		✓
2.03		**Horizontal Configuration**	☑ Use ☐ Void	✓
2.04		*Roll up and secure to I-Beam*		✓
2.05		**Verticle Configuration**	☐ Use ☑ Void	[illegible]
2.06		*Position Test Stand and Secure to I-Beam*		
2.07		*Begin Assembling Engine mount to I-Beam after Test stand is mounted*		
2.08		*Begin mounting engine for plumbing*		
2.09		*Once engine is mounted, begin plumbing line to engine*		
2.10		*Position Blast Deflector*		
		Insert Engine Specific Set-Up Procedure Here		

Step #	Callout	Step Description	Notes/Comments	Check Box
2.11		Place Air Compressor next to Test Stand		✓
2.12		Prepare regulators and hoses for Air Compressor and N2 Purge	redo fitting	✓
2.13		Prepare Igniters		
2.14		**Propellant Igniter**	☐ Use ☐ Void	
2.15		Do not connect igniter line to igniter box		
2.16		*Attach e-match leads to connectors and crimp*		
2.17		*Attach breakwire leads to green connector and ESB*		
2.18		*Connect igniter to igniter line*	VOID	
2.19		*Have igniter placed safely near I-Beam and ready to mount to engine*		
2.20		**Spark Igniter**	☑ Use ☐ Void	✓
2.21		*Ensure DC Power Supply Splitter is NOT connected*		
2.22		*Plug in AC/DC Converter*		✓
2.23		*Attach cables together and secure*		✓
2.24		*Connect ethernet into ESB 3.0*		✓
2.25		*Continuity Test*		✓
2.26		*Have igniter placed safely near I-Beam and read for igniter test*		✓
				✓
2.27		**Connect all data lines:**		
2.28		*Begin Setting up avionics in bunker*		✓
2.29		*Run extension cords to I-Beam for ESB 3.0, Purge, & Compressor*		✓
2.30		*Confirm ESB 3.0 has power source connected and battery pack is on*		✓
2.31		*Restart all computers before test and plug in computer power sources*		
2.32		*Plug in secondary monitor to AvTop and ensure visual*		✓
2.33		*Connect Ethernet from ESB 3.0 to AvTop Computer*		✓
2.34		*Verify umbilicle between Junction Box and ESB is connected*		✓
2.35		*Connect Valvestate Monitoring Line from Purge System to Reo Link Computer*		✓
2.36		*Ensure all camera ethernet cords are connected to switch*		✓
2.37		*Connect Load Cell to Junction Box*		✓
2.38		*Boot ESB 3.0*		✓

Verify new capacitor

Confirm secure

Step #	Callout	Step Description	Notes/Comments	Check Box
2.11		Place Air Compressor next to Test Stand		✓
2.12		Prepare regulators and hoses for Air Compressor and N2 Purge	redo fitting	✓
2.13		Prepare Igniters		
2.14		**Propellant Igniter**	☐ Use ☐ Void	
2.15		*Do not connect igniter line to igniter box*		
2.16		*Attach e-match leads to connectors and crimp*		
2.17		*Attach breakwire leads to green connector and ESB*	VOID	
2.18		*Connect igniter to igniter line*		
2.19		*Have igniter placed safely near I-Beam and ready to mount to engine*		
2.20		**Spark Igniter**	☑ Use ☐ Void	✓
2.21		*Ensure DC Power Supply Splitter is NOT connected*		✓
2.22		*Plug in AC/DC Converter*		✓
2.23		*Attach cables together and secure*		✓
2.24		*Connect ethernet into ESB 3.0*		✓
2.25		*Continuity Test*		✓
2.26		*Have igniter placed safely near I-Beam and read for igniter test*		✓
2.27		**Connect all data lines:**		
2.28		*Begin Setting up avionics in bunker*		✓
2.29		*Run extension cords to I-Beam for ESB 3.0, Purge, & Compressor*		✓
2.30		*Confirm ESB 3.0 has power source connected and battery pack is on*		✓
2.31		*Restart all computers before test and plug in computer power sources*		
2.32		*Plug in secondary monitor to AvTop and ensure visual*		✓
2.33		*Connect Ethernet from ESB 3.0 to AvTop Computer*		✓
2.34		*Verify umbilicle between Junction Box and ESB is connected*		✓
2.35		*Connect Valvestate Monitoring Line from Purge System to Reo Link Computer*		✓
2.36		*Ensure all camera ethernet cords are connected to switch*		✓
2.37		*Connect Load Cell to Junction Box*		✓
2.38		*Boot ESB 3.0*		✓

Verify new connections

Confirm secure

Step #	Callout	Step Description	Notes/Comments	Check Box
2.39		Turn ON NI and ReoLink Client		
2.40		**Camera start sequence:**		
2.41		*Start Desktop Client*		✓
2.42		*Start Each Camera with play button*		✓
2.43		*Verify live feed with each camera with hand wave*		✓
2.44		**Test Stand ESB 3.0 National Instruments (NI):**		
2.45		*Check NI Max for complete connections*		✓
2.46		*If unsucessful, click reset*		✓
2.47		*Open Main NI Panel*		✓
2.48		*If sucessful, verify physical ethernet port*		✓
2.49		*Verify all valves are instantiated into a closed state*		✓
2.50		*Tare Load Cell and Verify Load Cell is reading*		✓
2.51		There should be no pneumatic pressure so no valves should physically change state		✓
2.52		*Verify all TCs and PTs are live*		✓
2.53		*Set new offsets to 0*		✓
2.54		*Save settings*		✓
2.59		Confirm all data is live: Cameras and NI		✓
2.60		Ensure no hands are near actuators		✓
2.61		**Supply pneumatic source to Junction Box:**		✓
2.62		*Only VVs will change state if all valves were properly closed at previous test.*		✓
2.63		*Verify pneumatic pressure is set to ~100 psi*		✓
2.64		*Verify no leaks throught pneumatic system of closed state valves*		✓
2.65		*Verify valve states are set to closed*		✓
2.66		**Supply N2 to Purge System:**		✓
2.67		*Open valve on regulator and adjust pressure to ~100 psi*		✓
2.68		*Verify no leaks until solenoid*		✓
2.69		Record time	Time: 11:34	
3.00		**Dry Systems Testing**	Time: 11:36	
3.01		Distrubute Radios, if not already done so.		✓
3.02		Confirm all data is live:	Cameras, NI	✓

Step #	Callout	Step Description	Notes/Comments	Check Box
3.03		**Cycle all pneumatic valves and verify actual states can be read (not just "there is movement"):**		
3.04		LOX Vent:		
3.05		*CLOSE*		✓
3.06		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.07		*OPEN*		✓
3.08		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.09		CH4 Vent:		
3.10		*CLOSE*		✓
3.11		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.12		*OPEN*		✓
3.13		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.14		Vent Valves		
3.15		*CLOSE*		✓
3.16		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.17		*OPEN*		✓
3.18		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.19		*CLOSE*		✓
3.20		**Valve Safety OFF**	Includes spark igniter	✓
3.21		LOX MPV:		
3.22		*OPEN*		✓
3.23		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.24		*CLOSE*		✓
3.25		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.26		CH4 MPV:		
3.27		*OPEN*		✓
3.28		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.29		*CLOSE*		✓
3.30		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.31		MPVs (Launch Button):		
3.32		*OPEN*		✓
3.33		*Verify valve state: Camera/Reed Switch/Visual*	Check MPV Lead Time	✓
3.34		*CLOSE*		✓
3.35		*Verify valve state: Camera/Reed Switch/Visual*	Check MPV Lead Time	✓
3.36		LOX HI		
3.37		*OPEN*	Ensure valves are at correct speed. Repeat step as necessary.	✓
3.38		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.39		*CLOSE*		✓
3.40		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.41		CH4 HI		
3.42		*OPEN*	Ensure valves are at correct speed. Repeat step as necessary.	✓
3.43		*Verify valve state: Camera/Reed Switch/Visual*		✓
3.44		*CLOSE*		✓
3.45		*Verify valve state: Camera/Reed Switch/Visual*		✓

* Dump Valve
* Purge checks

Step #	Callout	Step Description	Notes/Comments	Check Box
3.46		Abort		
3.47		**Change states to Unsafe State:**		
3.48		*VVs CLOSE*		✓
3.49		*HI's OPEN*		✓
3.50		*MPV OPEN*		✓
3.51		Hit Abort Button and Ensure Test Stand Enters Safe State		✓
3.52		CLOSE VV		✓
3.53		**Confirm MPVs CLOSED and Valve Safety ON**		
3.54		**Igniter**		
3.55		**Propellant Igniter:**		
3.56		**Igniter Box and Continuity Test:**		
3.57		*Plug in igniter to igniter box*		✓
3.58		*Power on igniter box*		✓
3.59		*Perform continuity test of igniter box*		✓
3.60		*Verify breakwire is intact at DataQ*		✓
3.61		**Ignition Test:**		
3.62		***Ensure everyone is safetly 10ft away***		✓
3.63		*Igniter safety OFF and red cover up*		✓
3.64		*Prepare timer for test*		✓
3.65		*Begin countdown from 5 and ignite*		✓
3.66		*Record time it takes to burn through ignitier*	Time: ~50s	✓
3.67		*Ensure igniter is off*		✓
3.68		*Ensure we can read the breakwire is broken*		✓
3.69		*Igniter safety ON*		✓
3.70		*Power down box and unplug one lead on the bunker side*		✓
3.71		**Spark igniter:**		
3.72		*Ensure igniter relay is OFF*		✓
3.73		*Plug in DC Power Supply Splitter*		✓
3.74		***Ensure everyone is safely 10 ft away***		✓
3.75		*Turn OFF Valve Safety*		✓
3.76		*Give 5 second countdown for Spark Igniter Test*	Fail + Fail	✓
3.77		*Ensure spark igniter works reliabily and turn OFF*		✓
3.78		*Give 5 second countdown for Spark Igniter Test again*		
3.79		*Ensure spark igniter works reliabily and turn OFF*		
3.80		*Disconnect DC power Supply Splitter*		
3.81		*Prepare igniter for actual SHF Test*		
3.82		**Purge System Testing:**		
3.83		*Remove caps on Engine*		✓
3.84		*Actuate Purge Solenoid*		✓
3.85		*Verify air flow*		✓
3.86		*CLOSE Purge*		✓
3.87		*Verify purge regulator is still at nominal pressure*	~100 psi	✓

Fail: Short
Spark ignition cap.

Notes:
• no power recieved

Step #	Callout	Step Description	Notes/Comments	Check Box
3.88		**Test ESB 3.0 Power Loss:**		
3.89		*Change Valves to Unsafe State: VV Closed, HI's Open, MPV's Closed*		✓
3.90		*Pull power to ESB 3.0 and Ensure Test Stand Enters a Safe State*		✓
3.91		**Test Pneumatic Pressure Loss:**		
3.92		*Change Valves to Unsafe State: VV Closed, HI's Open, MPV's Closed*		✓
3.93		*Pull pneumatics and Ensure Test Stand Enters a Safe State*		✓
3.94		**Valve Safety On**		✓
3.95		Review Valve Failure Scenarios, as necessary.		✓
3.96		Record Time	Time:__________	NA
4.00		**Helium System Pressurization Testing:**	Time: 12:30	
4.01		Remove all caps		✓
4.02		Verify HI's are CLOSED		✓
4.03		Verify Vent Valves are CLOSED		✓
4.04		Verify hand loaded regulators are unloaded		✓
4.05		Connect Helium Source while source is CLOSED		✓
4.06		Verify leak test is at the ready		✓
4.07		Verify pressure transducer data is live		✓
4.08		Inform team about to pressurize and to stand clear		✓
4.09		Open Helium K Bottle		✓
4.10		Leak check Helium Input System		✓
4.11		Verify Input He Gauge matches input Ducer	Issue	✓
4.12		Input Pressure Settings - Stage 1:		✓
4.13		***Adjust LOX Inline Regulator and bring output pressure to: 1700 psi***		✓
4.14		*Adjust CH4 Inline regulator and bring output pressure to: 1700 psi*		✓
4.15		*Set Lock nuts to hand tight*		✓
4.16		Input Pressure Setting - Stage 2:		✓
4.17		*Test psi is determined by managers or senior engineers:*		✓
4.18		*Tank psi should be set to ~250 psi for Leak Testing Tank System*		✓
4.19		*Tank psi should be set to Test 1 Specifics for SHF Test, if leak test is already checked.*		✓
4.20		*Adjust LOX Hand Loaded Regulator to desired pressure.*		✓
4.21		*Verify LOX DL output is 250 psi on gauges and ducers*		✓
4.22		*Adjust CH4 Hand Loaded Regulator to 250*		✓
4.23		*Verify CH4 DL output is 250 on gauges and ducers*		✓
4.24		*Verify no pressure is leaking past HI Valves*		✓
4.25		Verify there are no leaks prior to HI Valves		✓
4.26		Record Time	Time: 12:41	✓

Step #	Callout	Step Description	Notes/Comments	Check Box
5.00		**Leak Testing Tank System (If already done, skip).**	Time:____________	
5.01		Announce that we are moving on to leak testing tanks and they will be pressurized.		✓
5.02		Begin/Confirm DAQ		✓
5.03		Read out all pressures and valve states		✓
5.04		Confirm LOX and CH4 DL pressures are ~250 psi	LOX/CH4 DL:____/_____	✓
5.05		Cameras Live		✓
5.06		Notify all personnel Test Stand is ready to pressurize	"All Clear Inside/Outside"	✓
5.07		CLOSE LOX and CH4 Vents		
5.08		CLOSE MPVs		
5.09		Announce Reverse Procedure (RevP):		
5.10		*CLOSE HI Valves*		
5.11		*OPEN Vents*		
5.12		Ask for CH4 DL Pressure	CH4 DL psi: 250	✓
5.13		Announce CH4 DL Pressure as intended CH4 Tank Pressure		✓
5.14		Ensure one person is monitoring Data Aqu Client and are watching for pressure increases during HI Valve Opening		✓
5.15		Valve Safety OFF		✓
5.16		Countdown from 3 Seconds		
5.17		OPEN CH4 HI Valve	☑ Open ☐ Fail: RevP	
5.18		If loud leaks are detected or fitting blows off, commence reverse procedure.		✓
5.19		Confirm CH4 Tank Pressure	☑ ~250 ☐ Fail	
5.20		Valve Safety ON		✓
5.21		Confirm safe to approach for leak test		✓
5.22		Leak Test CH4 System		✓
5.23		Ask for LOX DL Pressure	LOX DL psi: 250	✓
5.24		Announce LOX DL Pressure as intended LOX Tank Pressure		✓
5.25		Ensure one person is monitoring data aqu client and are watching for pressure increases during HI Valve opening		✓
5.26		Valve Safety OFF		✓
5.27		Countdown from 3 seconds		✓
5.28		OPEN LOX HI Valve	☑ ~250 ☐ Fail: RevP	✓
5.29		Confirm LOX Tank Pressure		✓
5.30		Valve Safety ON		✓
5.31		Confirm safe to approach for Leak Test		✓
5.32		Leak Test LOX System		✓
5.33		Record Time	Time: 12:53	✓

if leaking, close HI valve

Step #	Callout	Step Description	Notes/Comments	Check Box
6.00		**Tank System Depressurization (If leak tested):**	Time:______	
6.01		Valve Safety OFF		
6.02		CLOSE HI Valves		✓
6.03		Announce Tank Pressures		✓
6.04		Annouce we are going to depressurize		✓
6.05		*Ensure everyone is clear*		✓
6.06		OPEN Vents		✓
6.07		Verify Tank pressures are 0 psi		✓
6.08		Valve Safety ON		✓
6.09		Record Time	Time: 12:55	✓
7.00		**Helium System Depressurization:**	Time:______	
7.01		*Detail: There is no way to vent helium systems without using the tanks venting system. This requires opening the HI and Vent Valves.*		✓
7.02		**Verify LOX DL and CH4 DL pressures are reading less than 1000**		✓
7.03		Tank pressure should be raised to Test 1 Specifics if planned test after fueling. The pressure set should be seen again during Helium loading.	800 LOX: ~~1000~~ /CH4: 1000	✓
7.04		Tank pressure set should be less than 300 psi in tanks if simply venting system.		✓
7.05		CLOSE He Cylinder		✓
7.06		Ensure both Vent Valves are OPEN		✓
7.07		Verify everone is a safe distance away from Test Stand		✓
7.08		Valve Safety OFF		✓
7.09		OPEN LOX HI Valve		✓
7.10		Read pressures dropping		✓
7.11		OPEN CH4 HI Valve if necessary (If LOX regulator is closed)		✓
7.12		Read pressures are 0 psi on entire system		✓
7.13		CLOSE HI's and Vent Valves		✓
7.14		Valve Safety ON		✓
7.15		**Ensure enough Helium for Test**		✓
7.16		Stop Camera Recording and Export File	☐ USE ☒ VOID	
7.17		Record Time	Time: 13:03	
8.00		**Pre-Hot Fire Test Preparation:**	Time:______	
8.01		Install igniter into engine:		
8.02		*If Spark Igniter, ensure DC power supply is NOT plugged in*		
8.03		*If Propellant Igniter, ensure wires are shorted in bunker*		✓
8.04		Test Spark Igniter:	If necessary	✓
8.05		*Verify Valve Safety is ON*		✓
8.06		*Plug in Spark Igniter to DC Power Supply*		✓
8.07		Ensure Breakwire is connected and NI is reading correctly if Propellant Igniter		
8.08		Rehearse Terminal Sequence and Failure Scenarios before LN2 Loading		

CH4: @800-Reach
LOX: @650~

Step #	Callout	Step Description	Notes/Comments	Check Box
6.00		**Tank System Depressurization (If leak tested):**	**Time:**________	
6.01		Valve Safety OFF		
6.02		CLOSE HI Valves		✓
6.03		Announce Tank Pressures		✓
6.04		Annouce we are going to depressurize		✓
6.05		*Ensure everyone is clear*		✓
6.06		OPEN Vents		✓
6.07		Verify Tank pressures are 0 psi		✓
6.08		Valve Safety ON		
6.09		Record Time	Time: 12:55	✓
7.00		**Helium System Depressurization:**	Time:________	
7.01		*Detail: There is no way to vent helium systems without using the tanks venting system. This requires opening the HI and Vent Valves.*		✓
7.02		**Verify LOX DL and CH4 DL pressures are reading less than 1000**		✓
7.03		Tank pressure should be raised to Test 1 Specifics if planned test after fueling. The pressure set should be seen again during Helium loading.	LOX: ~~1000~~ 800 /CH4: 1000	✓
7.04		Tank pressure set should be less than 300 psi in tanks if simply venting system.		✓
7.05		CLOSE He Cylinder		✓
7.06		Ensure both Vent Valves are OPEN		✓
7.07		Verify everone is a safe distance away from Test Stand		✓
7.08		Valve Safety OFF		✓
7.09		OPEN LOX HI Valve		✓
7.10		Read pressures dropping		✓
7.11		OPEN CH4 HI Valve if necessary (If LOX regulator is closed)		✓
7.12		Read pressures are 0 psi on entire system		✓
7.13		CLOSE HI's and Vent Valves		✓
7.14		Valve Safety ON		✓
7.15		**Ensure enough Helium for Test**		✓
7.16		Stop Camera Recording and Export File	☐ USE ☒ VOID	
7.17		Record Time	Time: 13:03	
8.00		**Pre-Hot Fire Test Preparation:**	Time:________	
8.01		Install igniter into engine:		
8.02		*If Spark Igniter, ensure DC power supply is NOT plugged in*		✓
8.03		*If Propellant Igniter, ensure wires are shorted in bunker*		
8.04		**Test Spark Igniter:**	If necessary	✓
8.05		*Verify Valve Safety is ON*		✓
8.06		*Plug in Spark Igniter to DC Power Supply*		
8.07		Ensure Breakwire is connected and NI is reading correctly if Propellant Igniter		
8.08		Rehearse Terminal Sequence and Failure Scenarios before LN2 Loading		

CH4: @800-read
LOX: @650 ~

Step #	Callout	Step Description	Notes/Comments	Check Box
8.09		Reset Offsets Again		✓
8.10		Go get trucks		✓
8.11		Clean up Pad		✓
8.12		All Personnel must move over 100 feet away from Test Stand		✓
8.13		**Fueling Team Get Prepared:**		✓
8.14		PPE		✓
8.15		Inform fueling team about Spark Igniter		✓
8.16		LOX:		✓
8.17		*RED_O2 on ground with Test Stand and T-Spinner*		✓
8.18		*RED_O1 on truck ready for opeing LOX Dewar Globe Valve*		✓
8.19		LN2:		
8.20		*RED_F3 ready to receive LOX Tranfer Hose*		✓
8.21		CH4:		
8.22		*RED_F2 with T-Spinner of CH4 Hose*		✓
8.23		*RED_F1 at CH4 Dewar*		✓
8.24		*Move LNG Dewar far away from LOX and begin venting*		✓
		Record Time:	Time:________________	✓
9.00		**LOX Tank LOX Loading:**	Time: 1:24	
9.01		*Note: 4 Red Team Operators, President, Carl, FAR Representative only for this step*		
9.02		Ground vehicle to test stand		✓
9.03		Confirm with FAR that we are permitted to load LOX		✓
9.04		Ensure proper PPE is on		✓
9.05		Ensure Valve Safety is ON		✓
9.06		Ensure Camers are live		✓
9.07		Ensure HI Valves are CLOSED		✓
9.08		Ensure LOX Fill CLOSED		✓
9.09		Vent LOX Dewar to 30 psi		✓
9.10		OPEN Test Stand LOX Vent		✓
9.11		Remove cap and connect transfer hose to Test Stand and Dewar		✓
9.12		OPEN Test Stand LOX Fill Valve		✓
9.13		Ensure NI TC's and PTs are reading		✓
9.14		Ensure NI is recording		✓
9.15		OPEN LOX Dewar globe valve to begin fill		✓
9.16		Confirm NI TC Temp Change		✓
9.17		Begin cycle LOX Vent	~ Every 20 seconds	✓
9.18		Ensure no leaks through LOX MPV		✓
9.19		Continue to fill until LOX Liquid is discharged from LOX Vent		✓
9.20		CLOSE LOX Dewar Globe Valve		✓
9.21		Allow 60 second tank cold soak		✓
9.22		OPEN LOX Dewar Dewar globe valve for LOX Tank top-off		✓
9.23		Continue fill until LOX liquid is discharged from LOX Vent		✓
9.24		CLOSE LOX Dewar Globe Valve		✓
9.25		CLOSE Test Stand LOX Fill Valve		✓

Step #	Callout	Step Description	Notes/Comments	Check Box
9.26		Vent line		✓
9.27		Disconnect transfer hose an give to RED_F3		✓
9.28		Loosely cap LOX Fill		✓
9.29		Prepare Test Stand Cameras		✓
9.30		Unlatch Ground		✓
9.31		Send LOX Dewar away		✓
9.32		Record Time	Time: [illegible]	
10.00		**CH4 Tank Conditioning:**	Time:____________	✓
10.01	RED_F3	Receive LOX Transfer Hose from LOX Truck		✓
10.02		Attach LOX Transfer Hose to LN2 Dewar and jacket		
10.03		Crack OPEN LN2 Deware Globe Valve		✓
10.04		Record Time	Time	
11.00		**CH4 Tank LNG Loading:**	Time: [illegible]	
11.01		*Note: 3 Red Team-F Operators, President, Carl, FAR Representative only for this step*		✓
11.02		Ground vehicle to Test Stand		✓
11.03		Confirm with FAR that we are permitted to load LNG		✓
11.04		Ensure proper PPE is on		✓
11.05		Ensure HI Valves CLOSED		✓
11.06		Ensure CH4 Fill CLOSED		✓
11.07		Vent LNG Dewar to 30 psi		✓
11.08		Ensure cameras are live		✓
11.09		OPEN Test Stand CH4 Vent		✓
11.10		Remove Cap and Connect transfer hose to Test Stand and Dewar		✓
11.11		OPEN Test Stand CH4 Fill Valve		✓
11.12		OPEN LNG Dewar Globe valve to begin fill		✓
11.13		Begin cycle LOX *and* CH4 Vents	~ every 20 seconds	✓
11.14		Ensure no leaks through CH4 MPV		✓
11.15		Continue to fill until LNG liquid is discharged from CH4 Vent		✓
11.16		CLOSE LNG Dewar Globe Valve		✓
11.17		Allow for 60 second tank cold soak		✓
11.18		OPEN LNG Dewar Globe Valve for CH4 Tank top-off		✓
11.19		Continue fill until LNG liquid is discharged from CH4 Vent		✓
11.20		CLOSE LNG Dewar Globe Valve		✓
11.21		CLOSE Test Stand CH4 Fill Valve		✓
11.22		Vent line		✓
11.23		Disconnect Transfer Hose		✓
11.24		Test Stand Go-Pro Cameras Recording		✓
11.25		Loosely Cap CH4 Fill		✓
11.26		CLOSE LN2 Dewar Globe Valve		✓
11.27		Unlatch Ground		✓
11.28		Send all Dewars away		✓
11.29		Record Time	Time____________	✓
12.00		**Helium Loading:**	Time:____________	
12.01		*Note: Carl Tedesco and RED_F1 only*		
12.02		NI is live and recording		✓

Step #	Callout	Step Description	Notes/Comments	Check Box
12.03		Cameras Recording and Live		✓
12.04		Turn on all screen recording software		✓
12.05		Verify igniter cords are all plugged in at pad		✓
12.06		Ensure pneumatic pressure is ~120 psi		✓
12.07		Ensure purge pressure is ~100 psi		✓
12.08		**Verify LOX and CH4 HI Valves are CLOSED**		✓
12.09		Verify all personnel are safely distant from Test Stand		✓
12.10		Ensure we have permission to pressurise with HI's CLOSED		✓
12.11		Open Helium Bottles		✓
12.12		Verify all pressures are nominal		✓
12.13		Record Time:	Time: 7:12	
13.00		**Pre-Terminal Sequence:**	Time:________	
13.01		Confirm with FAR that we are permitted to pressurize		✓
13.02		Turn off all excess radios in bunker		✓
13.03		**Begin/Confirm NI**		✓
13.04		*Set new offsets if necessary*		✓
13.05		Tare Load Cell		✓
13.06		Read out pressures for Helium In, DL's, and pressurants.		✓
13.07		Ensure bunker camera is recording		✓
13.08		Notify all personnel Test Stand is ready to pressurize	☑ All clear	
13.09		CLOSE LOX and CH4 Vents (Stop Vent Cycling)		✓
13.10		Announce Reverse Procedure for this scenario		✓
13.11		*CLOSE HI Valves*		✓
13.12		*OPEN Vents*		✓
13.13		Announce CH4 DL Pressure		✓
13.14		Announce to Bunker and Radio: CH4 Tank will be pressurised to: 1000		✓
13.15		Valve Safety OFF		✓
13.16		Countdown from 3 seconds (on radio)		✓
13.17		OPEN CH4 HI Valve	☐ Open ☒ Fail: FS-10-19	
13.18		If loud leaks are detected or a fitting blows off: Commence Reverse Procedure		✓
13.19		Confirm CH4 Tank Pressure	CH4 Tank psi:________	✓
13.20		Announce LOX DL Pressure		
13.21		Announce to Bunker and Radio: LOX Tank will be pressurized to: 1000		

pop

Step #	Callout	Step Description	Notes/Comments	Check Box
13.22		Countdown from 3 seconds (on radio)		
13.23		OPEN LOX HI Valve	☒ ☐ Open Fail: FS-10-19	
13.24		Confirm LOX Tank Pressure	LOX Tank psi: 675	
13.25		Valve Safety ON		✓
13.26		Propellant Igniter:	☐ ☒ Use Void	
13.27		*Confirm Igniter Safety ON*		
13.28		*Plug in Ingiter Box*		
13.29		*Igniter Box Power ON*		
13.30		*Continunity Test*		
13.31		Spark Igniter	☒ ☐ Use Void	
13.32		*Standby*		
13.33		Start NI DAQ		✓
13.34		Take a deep breathe and DO NOT RUSH		✓
13.35		Ensure "Bunker Personnel" are ready for terminal sequence: Personnel Glance (No need to call out each)		
13.36		Av_1 at MC		✓
13.37		P_3 at Propellant Igniter		✓
13.38		Av_3 at Reolink Computer		✓
13.39		Av_4 at Countdown		✓
13.40		Op_1 at Procedure		✓
13.41		P_1 at Engine Computer, P_2 standby		✓
13.42		Carl as Supervisor		✓
13.43		Reminder: Propellant Igniter at 2s for P_3. Av_1 to call out "Launch"		✓
		Pre-Terminal Sequence complete. Proceed to Terminal Sequence.		✓

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
		Connect New Engine. See engine specific setup.		
14.00		**Reset Test Setup**		
14.01		Prepare Igniters		
14.02		**Propellant Igniter**	☐ Use ☒ Void	
14.03		*Do not connect igniter line to igniter box*		
14.04		*Attach e-match leads to connectors and crimp*		
14.05		*Attach breakwire leads to green connector and ESB*		
14.06		*Connect igniter to igniter line*		
14.07		*Have igniter placed safely near I-Beam and ready to mount to engine*		
14.08		**Spark Igniter**	☐ Use ☒ Void	
14.09		*Ensure DC Power Supply Splitter is NOT connected*		
14.10		*Plug in AC/DC Converter*		
14.11		*Attach cables together and secure*		
14.12		*Connect ethernet into ESB 3.0*		
14.13		*Continuity Test*		
14.14		*Have igniter placed safely near I-Beam and read for igniter test*		
14.15		Reset GoPro Cameras for next test		
14.16		**Check pressurant tanks to make sure enough left over for secondary test**		
14.17				
14.18				
14.19				
14.20				
14.21				
14.22				
14.23				
14.24				
14.25				
14.26				
15.00		**Helium System Pressurization Testing:**	Time: 14:28	
15.01		Verify HI's are CLOSED		✓
15.02		Verify Vent Valves are CLOSED		✓
15.03		Verify hand loaded regulators are unloaded		✓
15.04		Connect Helium Source while source is CLOSED		✓
15.05		Verify pressure transducer data is live		✓
15.06		Inform team about to pressurize and to stand clear		✓
15.07		Open Helium K Bottle		✓

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
15.08		Verify Input He Gauge matches input Ducer		
15.09		Input Pressure Settings - Stage 1:		
15.10		*Adjust LOX Inline Regulator and bring output pressure to: 1700 psi*		
15.11		*Adjust CH4 Inline regulator and bring output pressure to: 1700 psi*		
15.12		*Set Lock nuts to hand tight*		
15.13		Input Pressure Setting - Stage 2:		
15.14		*Test psi is determined by managers or senior engineers:*		
15.15		***Tank psi should be set to Test 2 Specifics for SHF Test, if leak test is already checked.***		
15.16		*Adjust LOX Hand Loaded Regulator to: 1500*		
15.17		*Verify LOX DL output is 1500 psi on gauges and ducers*		
15.18		*Adjust CH4 Hand Loaded Regulator to: 24567*		
15.19		*Verify CH4 DL output is 24567 psi on gauges and ducers*		
15.20		*Verify no pressure is leaking past HI Valves*		
15.21		Verify there are no leaks prior to HI Valves		
15.22		Record Time	Time	
16.00		**Helium System Depressurization:**	Time:_____________	
16.01		*Detail: There is no way to vent helium systems without using the tanks venting system. This requires opening the HI and Vent Valves.*		
16.02		**Verify LOX DL and CH4 DL pressures are reading less than 1500**		
16.03		Tank pressure should be raised to Test 2 Specifics if planned test after fueling. The pressure set should be seen again during Helium loading.		
16.04		CLOSE He Cylinder		
16.05		Ensure both Vent Valves are OPEN		
16.06		Verify everone is a safe distance away from Test Stand		
16.07		Valve Safety OFF		
16.08		OPEN LOX HI Valve		
16.09		Read pressures dropping		
16.10		OPEN CH4 HI Valve if necessary (If LOX regulator is closed)		
16.11		Read pressures are 0 psi on entire system		
16.12		CLOSE HI's and Vent Valves		
16.13		Valve Safety ON		

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
16.14		Ensure enough Helium for Test		
16.15		Stop Camera Recording and Export File	☐ USE ☐ VOID	
16.16		Record Time	Time:________	
17.00		**Pre-Hot Fire Test Preparation:**	Time:____________	
17.01		Install igniter into engine:		
17.02		*If <u>Spark Igniter</u>, ensure DC power supply is NOT plugged in*		
17.03		*If <u>Propellant Igniter</u>, ensure wires are shorted in bunker*		
17.04		Test Spark Igniter:	If necessary	
17.05		*Verify Valve Safety is ON*		
17.06		*Plug in Spark Igniter to DC Power Supply*		
17.07		Ensure Breakwire is connected and NI is reading correctly if Propellant Igniter		
17.08		Rehearse Terminal Sequence and Failure Scenarios before LN2 Loading		
17.09		Reset Offsets Again		
17.10		Go get trucks		
17.11		Clean up Pad		
17.12		All Personnel must move over 100 feet away from Test Stand		
17.13		**Fueling Team Get Prepared:**		
17.14		PPE		
17.15		Inform fueling team about Spark Igniter		
17.16		LOX:		
17.17		*RED_O2 on ground with Test Stand and T-Spinner*		
17.18		*RED_O1 on truck ready for opeing LOX Dewar Globe Valve*		
17.19		LN2:		
17.20		*RED_F3 ready to receive LOX Tranfer Hose*		

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
17.21		CH4:		
17.22		*RED_F2 with T-Spinner of CH4 Hose*		
17.23		*RED_F1 at CH4 Dewar*		
17.24		*Move Dewar far away from LOX and begin venting*		
		Record Time:	Time:_______	
18.00		**LOX Tank LOX Loading:**	Time: 2:35	
18.01		*Note: 4 Red Team-O Operators, President, Carl, FAR Representative only for this step*	✓	✓
18.02		Ground vehicle to test stand	✓	✓
18.03		Confirm with FAR that we are permitted to load LOX	✓	✓
18.04		Ensure proper PPE is on	✓	✓
18.05		Ensure ~~Valve~~ Safety is ON	✓	✓
18.06		Ensure Camers are live	✓	✓
18.07		Ensure HI Valves are CLOSED	✓	✓
18.08		Ensure LOX Fill CLOSED	✓	✓
18.09		Vent LOX Dewar to 30 psi	✓	✓
18.10		OPEN Test Stand LOX Vent	✓	✓
18.11		Remove cap and connect transfer hose to Test Stand and Dewar	2 ✓	✓
18.12		OPEN Test Stand LOX Fill Valve	✓	✓
18.13		Ensure NI TC's and PTs are reading	✓	✓
18.14		Ensure NI is recording	✓	✓
18.15		OPEN LOX Dewar globe valve to begin fill	✓	✓
18.16		Confirm NI TC Temp Change		✓
18.17		Begin cycle LOX Vent	~ Every 20 seconds ✓	✓
18.18		Ensure no leaks through LOX MPV	✓	✓
18.19		Continue to fill until LOX Liquid is discharged from LOX Vent	✓	✓
18.20		CLOSE LOX Dewar Globe Valve		✓
18.21		Allow 60 second tank cold soak		✓
18.22		OPEN LOX Dewar Dewar globe valve for LOX Tank top-off		✓
18.23		Continue fill until LOX liquid is discharged from LOX Vent		
18.24		CLOSE LOX Dewar Globe Valve	✓	✓
18.25		CLOSE Test Stand LOX Fill Valve	✓	✓
18.26		Vent line	✓	✓
18.27		Disconnect transfer hose an give to RED_F3		✓
18.28		Loosely cap LOX Fill	✓	✓
18.29		Prepare Test Stand Cameras	✓	✓
18.30		Unlatch Ground	✓	✓
18.31		Send LOX Dewar away	✓	✓
18.32		Record Time:	Time: 2:44	

tim: 3:26

Camera for HI valve not Live

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
19.00		**CH4 Tank Conditioning:**	Time:________________	
19.01		Receive LOX Transfer Hose from LOX Truck		
19.02		Attach LOX Transfer Hose to LN2 Dewar and jacket		
19.03		Crack OPEN LN2 Deware Globe Valve		
19.04		Record Time:	Time:________________	
20.00		**CH4 Tank LNG Loading:**	Time:________________	
20.01		*Note: 2 Red Team-F Operators, President, Carl, FAR Representative only for this step*		
20.02		Ground vehicle to Test Stand		
20.03		Confirm with FAR that we are permitted to load LNG		
20.04		Ensure proper PPE is on		
20.05		Ensure HI Valves CLOSED		
20.06		Ensure CH4 Fill CLOSED		
20.07		Vent LNG Dewar to 30 psi		
20.08		Ensure cameras are live		
20.09		OPEN Test Stand CH4 Vent		
20.10		Remove Cap and Connect transfer hose to Test Stand and Dewar		
20.11		OPEN Test Stand CH4 Fill Valve		
20.12		OPEN LNG Dewar Globe valve to begin fill		
20.13		Begin cycle LOX *and* CH4 Vents	~ every 20 seconds	
20.14		Ensure no leaks through CH4 MPV		
20.15		Continue to fill until LNG liquid is discharged from CH4 Vent		
20.16		CLOSE LNG Dewar Globe Valve		
20.17		Allow for 60 second tank cold soak		
20.18		OPEN LNG Dewar Globe Valve for CH4 Tank top-off		
20.19		Continue fill until LNG liquid is discharged from CH4 Vent		
20.20		CLOSE LNG Dewar Globe Valve		
20.21		CLOSE Test Stand CH4 Fill Valve		
20.22		Vent line		
20.23		Disconnect Transfer Hose		
20.24		Test Stand Go-Pro Cameras Recording		
20.25		Loosely Cap CH4 Fill		
20.26		CLOSE LN2 Dewar Globe Valve		
20.27		Unlatch Ground		
20.28		Send all Dewars away		
20.29		Record Time:	Time:________________	

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
21.00		**Helium Loading:**	Time:	
21.01		*Note: Carl Tedesco and RED_F1 only*	✓	✓
21.02		NI is live and recording	✓	✓
21.03		Cameras Recording and Live	✓	✓
21.04		Turn on all screen recording software	✓	✓
21.05		Verify igniter cords are all plugged in at pad		
21.06		Ensure pneumatic pressure is ~120 psi	72psi	✓
21.07		Ensure purge pressure is ~120 psi	✓	✓
21.08		Verify LOX and CH4 HI Valves are CLOSED	✓	✓
21.09		Verify all personnel are safely distant from Test Stand	✓	✓
21.10		Ensure we have permission to pressurise with HI's CLOSED	✓	✓
21.11		Open Helium Bottles	1000psi	✓
21.12		Verify all pressures are nominal		✓
21.13		Record Time:	Time: 2:47	
22.00		**Pre-Terminal Sequence:**	Time:	
22.01		Confirm with FAR that we are permitted to pressurize	✓	✓
22.02		Turn off all excess radios in bunker	✓	✓
22.03		Begin/Confirm DAQ, wait on NI	✓	✓
22.04		*Set new offsets if necessary*	✓	✓
22.05		Tare Load Cell		
22.06		Read out pressures for Helium In, DL's, and pressurants.	✓	
22.07		Ensure bunker camera is recording	✓	✓
22.08		Notify all personnel Test Stand is ready to pressurize	☑ All clear	
22.09		**CLOSE LOX and CH4 Vents (Stop Vent Cycling)**		
22.10		Announce Reverse Procedure for this scenario		
22.11		*CLOSE HI Valves*		
22.12		*OPEN Vents*		
22.13		Announce CH4 DL Pressure		✓
22.14		Announce to Bunker and Radio: CH4 Tank will be pressurised to: 24567		✓
22.15		Valve Safety OFF		—

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
22.16		Countdown from 3 seconds (on radio)		
22.17		OPEN CH4 HI Valve	☑ Open ☐ ~~Fail: FS-10-19~~	✓
22.18		If loud leaks are detected or a fitting blows off: Commence Reverse Procedure	4000	✓
22.19		Confirm CH4 Tank Pressure	CH4 Tank psi: 850	✓
22.20		Announce LOX DL Pressure		✓
22.21		Announce to Bunker and Radio: LOX Tank will be pressurized to: 1500		✓
22.22		Countdown from 3 seconds (on radio)		✓
22.23		OPEN LOX HI Valve	☑ Open ☐ Fail: FS-10-19	✓
22.24		Confirm LOX Tank Pressure	LOX Tank psi: 850	✓
22.25		Valve Safety ON		✓
22.26		Propellant Igniter:	☐ Use ☒ Void	
22.27		*Confirm Igniter Safety ON*		
22.28		*Plug in Ingiter Box*		
22.29		*Igniter Box Power ON*		
22.30		*Continunity Test*		
22.31		Spark Igniter	☐ Use ☒ Void	
22.32		*Standby*		
22.33		Start NI DAQ		✓
22.34		Take a deep breathe and DO NOT RUSH		
22.35		Ensure "Bunker Personnel" are ready for terminal sequence: Personnel Glance (No need to call out each)		
22.36		Av_1 at MC		
22.37		Av_2 at Data Acq		
22.38		P_3 at Propellant Igniter		
22.39		Av_3 at Reolink Computer		
22.40		Av_4 at Countdown		
22.41		Op_1 at Procedure		
22.42		P_1 at Engine Computer, P_2 standby		

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
22.43		Carl as Supervisor		
22.44		Reminder: Propellant Igniter at 2s for P_3. Av_1 to call out "Launch"		
		Pre-Terminal Sequeince complete. Proceed to Terminal Sequence.		

make it work

Terminal Sequence: Propellant Igniter

Time	Call out	Response	Role	Check	Description
T- 30s	"Countdown Start at 30 Seconds"		Op_1		Intervals of 5 until 10 Seconds
		"Countdown Started"	Av_4		
		"Hold Countdown"	Av_4		
T- 25s	"Igniter Safety off"		Op_1		Igniter Key turned and Red Cover up
		"Igniter Safety Off and Armed"	P_3		
		"Hold"	P_3		
T- 20s	"Valve Safety Off"		Op_1		MPV, Launch and HI Buttons Active
		"Valve Safety Off"	Av_1		
		"Hold	Av_1		
T- 15s	"Purge On"		Op_1		Press Purge Button
		"Purge On"	Av_1		
		"Hold	Av_1		
T- 2s	"Igniter"		Op_1		Flip Switch
		Ign1 Flip Switch	P_3		
		"Hold"	P_3		
0s	"Breakwire Status"		Op_1		Verify Digital broek signal and announce launch.
		"Launch"	Av_2		
		"Hold" ... FS-9-19	Av_2		
T+ 10s	"Close MPV and Confirm"		Op_1		MPV Closed Announced and Visually Confirmed
		"MPV Closed"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-3-16	Av_1		
T+ 15s	"Close HI's and Confirm"		Op_1		Repeat
		"HI's Closed"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-10-19	Av_1		
T+ 20s	"Open Vents and Confirm"		Op_1		Repeat
		"Vents Open"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-2-16	Av_1		
T+ 25s	"Valve Safety On"		Op_1		Safety on for MC
		"Valve Safety On"	Av_1		
		"Hold"	Av_3		
T+ 30s	"Ingiter Off and Igniter Safety On"		Op_1		Igniter Swith OFF and Key out
		"Igniter Off"	P_3		
		"Hold"	P_3		
T+ 35s	"Purge Off"		Op_1		Purge OFF
		"Purge Off"	Av_1		
		"Hold"	Av_1		
	"Save all Files"				
	RED_F1 and Carl leave bunker				
	Close He Cylinder Valve				
	Approach Test Stand				

Terminal Sequence: Spark Igniter

Time	Call out	Response	Role	Check	Description
T- 20s	"Countdown Start at 20 Seconds"		Op1		Intervals of 5 until 10 Seconds
		"Countdown Started"	Av4		
		"Hold Countdown"	Av4		
T- 10s	"Valve Safety Off"		Op1		MPV, Launch and HI Buttons Active
		"Valve Safety Off"	Av1		
		"Hold	Av1		
T- 5s	"Igniter"		Op1		Press Igniter Button
		"Igniter On"	Av1		
		"Hold"	Av1		
T- 0s	"Go for Launch"		Op1		Press Launch Button
		"Launch"	Av1		
		"Hold" ...FS-5-17	Av1		
T+ 10s	"Close MPV and Confirm"		Op1		MPV Closed Announced and Visually Confirmed
		"MPV Closed"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-3-16	Av1		
T+ 15s	"Close HI's and Confirm"		Op1		Repeat
		"HI's Closed"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-10-19	Av1		
T+ 20s	"Open Vents and Confirm"		Op1		Repeat
		"Vents Open"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-2-16	Av1		
T+ 25s	"Igniter Off"		Op1		Toggle Igniter Button
		"Igniter Off"	Av1		
		"Hold"	Av1		
T+ 30s	"Valve Safety On"		Op1		Safety on for MC
		"Valve Safety On"	Av1		
		"Hold"	Av1		
	"Save all Files"				
	RED_F1 and Carl leave bunker				
	Close He Cylinder Valve				
	Approach Test Stand				

Fail: Close HI
Open VU
Open Dump

Failure Scenarios

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Frozen Vent Valve (Frozen OPEN)**		
1.01		Troubleshoot and verify no avionics failures		
1.02		CLOSE HI Valves or verify they are CLOSED		
1.03		Verify Helium supply valve is CLOSED	If safe to approach	
1.04		OPEN non-frozen vent valve or verify that it is set to OPEN		
1.05		**Perform dump Sequence:**		
1.06		*Ensure dumping is safe with Carl*		
1.07		*OPEN Dump on frozen vent valve tank*		
1.08		*Ensure enough time has passed since dump*		
1.09		*CLOSE Dump frozen vent valve tank*		
1.10		CLOSE or reverify helium supply valve is closed		
1.11		Evaluate Valve		
2.00		**Frozen Vent Valve (Frozen CLOSED)**		
2.01		CLOSE HI Valves or verify they are closed		
2.02		OPEN non-frozen vent valve or verify hat it is set to open		
2.03		Verify Helium supply valve is closed	If safe to approach	
2.04		**Perform dump Sequence:**		
2.05		*Ensure Dumping is safe with Carl*		
2.06		*Dump frozen vent valve tank*		
2.07		*Ensure enough time has passed since dump*		
2.08		*Dump frozen vent valve tank*		
2.09		CLOSE or re-verify helium supply valve is CLOSED		
2.10		Evaluate valve		
3.00		**Frozen MPV**		
3.01		CLOSE MPV's or verify MPVs are set to CLOSED		
3.02		CLOSE HI Valves or verify they are CLOSED		
3.03		Vent both tanks, OPEN Vents	If VV Frozen: See FS-4-17	
3.04		Approach Test Stand		
3.05		CLOSE Helium supply valve		
3.06		Move safely away from test stand		
3.07		**Perform dump Sequence:**		
3.08		*Ensure Dumping is safe with Carl*		
3.09		*Dump frozen MPV tank if MPV Valve can open at higher pressure*		
3.10		*Ensure enough time has passed since dump*		
3.11		*Dump frozen vent valve tank*		
3.12		If time permits, remove frozen valve and try and dry it		
3.13		Replace Valve, restart sequence over (Start at Step 1)		

Failure Scenarios

4.00		**Vent Valves and MPV are frozen**		
4.01		Hold and communicate with President, Carl Tedesco, and FAR for best course of action		
5.00		**No Propellant Ignition**		
5.01		MPV Closed		
5.02		Helium isolation valve CLOSED		
5.03		OPEN Vents		
5.04		Verify ignitor system is OFF		
5.05		Verify methane plume does not catch the test stand on fire		
5.06		*Note: If test stand is on fire, let it burn out.*		
5.07		Ground version 2 igniter if necessary		
5.08		CLOSE He Cylinder		
5.09		Evaluate propellant amount remaining:		
5.10		**If aborted BEFORE 3 seconds of open MPV:**		
5.11		*Replace ignitor (If Propellant)*		
5.12		*Check Consumables*	Restart at He System Depressurization to use new k-bottle	
5.13		*If okay, proceed with test*		
5.14		**If aborted AFTER 3 seconds of open MPV**		
5.15		Evaluate safety of test stand		
5.16		Replace ignitor		
5.17		Restart at Helium System Depresurization to use new k-bottle		
5.18		After returning to desirable state, proceed with test		
6.00		**Engine Melts or Explodes**		
6.01		Verify MPV CLOSED		
6.02		Verify HI Valves CLOSED		
6.03		Verify Vent Valves OPEN		
6.04		Go through depressurizing sequence		
6.05		Go through fuel dumping sequence		
6.06		Give engine sufficient amount of time to cool off		
6.07		Evaluate safety before approaching test stand		
6.08		Replace engine with second engine, if available.		
6.09		Replace ignitor		
6.10		Go through pressurizing sequeince and fueling sequence.		

Failure Scenarios

7.00		**Total ESB Power Loss in Fueling State**		
7.01		Fueling Valve States:		
7.02		*HI CLOSED*		
7.03		*VV OPEN*		
7.04		*MPV CLOSED*		
7.05		Unplug Extension Cord and Data Aqc USB		
7.06		Verify all valves are in or return to default positions	HI Open, VV Open, MPV Closed	
7.07		Notice error message on MC		
7.08		Close all sessions (MC, Server, Data)		
7.09		Reboot ESB	Verify no valves changed state	
7.10		Perform Test Stand Pi and MC Start Sequence		
7.11		Inform team that VV should CLOSE, His should CLOSE, MPV should remain CLOSED once connected.		
7.12		Perform Sequence		
7.13		Perform Data Acq Start Sequence		
7.14		Perform Reolink Start Sequence		
7.15		Confirm VVs OPEN, HIs CLOSED, MPV remain CLOSED		
8.00		**Total ESB Power Loss in Firing State**		
8.01		Firing Valve States:		
8.02		*HI OPEN*		
8.03		*VV CLOSED*		
8.04		*MPV OPEN*		
8.05		Unplug extension cord and Data Acq USB		
8.06		Verify all valves are in or return to default positions	HI's OPEN, VV OPEN, MPV CLOSED	
8.07		Notice error message on MC		
8.08		CLOSE all sessions (MC, Serve, Data)		
8.09		Reboot ESB	Verify no valves changed state	
8.10		Perform Test Stand Pi and MC Start Sequence		
8.11		Inform team that VV should CLOSE, His should CLOSE, MPV should remain CLOSED once connected.		
8.12		Perform Sequence		
8.13		Perform Data Acq Start Sequence		
8.14		Perform Reolink Start Sequence		
8.15		Confirm VVs OPEN, HIs CLOSED, MPV remain CLOSED		

Failure Scenarios

9.00		**Igniter Fails to Ignite**		
9.01		CLOSE HI's		
9.02		OPEN Vents		
9.03		Confirm MPV's are set to CLOSE		
9.04		Valve Safety ON		
9.05		Igniter OFF and box unpowered		
9.06		If safe to approach test stand, CLOSE He Supply		
9.07		Inspect Igniter and replace		
9.08		Restart pre-terminal sequence once people are safely away		
9.09		**If unsafe, perform dump sequence:**		
9.10		Ensure dumping is safe with Carl		
9.11		Dump MPV tank if MPV Valve can open at higher pressure		

Safety Approach

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Both Tanks Full**		
1.01		Vent Valves confirmed OPEN	Check Camera/last command	
1.02		HI Valves confirmed CLOSED	Check Camera/last command	
1.03		MPV Valves confirmed CLOSED	Check Camera/last command	
1.04		Only Carl Tedesco and Designated Senior Engineer [Av4] are approved for this approach at SHF		
2.00		**One Tank Full**		
2.01		Vent Valves confirmed OPEN	Check Camera/last command	
2.02		HI Valves confirmed CLOSED	Check Camera/last command	
2.03		MPV Valves confirmed CLOSED	Check Camera/last command	
2.04		Dump CH4:		
2.05		*Only CH4 Valve state is to be actuated*		
2.06		*Verify with Carl Tedesco it is safe to dump*		
2.07		*OPEN CH4 MPV valve*		
2.08		*Wait for 5-30 min for all CH4 to empty and disperse*		
2.09		Only Carl Tedesco and Designated Senior Engineer [Av4] are approved for this approach at SHF		
3.00		**Pressurized Empty Tanks**		
3.01		Review tank depressurization procedure		

5.3 Original Copy of Procedure

Test Stand SHF/Cryo Test Procedure

This document will serve as the overall procedure for a static hot fire or cryogenic test using our test stand. It will be organized into the following sequential sections: Testing Specifics, Acronym List, Arrival, Setup, Dry System Testing, Helium System Pressurization Testing, Leak Testing Tank System, Helium System Depressurization, LOX Tank LOX Loading, CH4 Tank Conditioning, CH4 Tank LNG Loading, Helium Loading, Pre-Terminal Sequence, Terminal Sequence, Failure Scenarios, and Safety Approach.

		PRIMARY ROLE:	RED_F2
		SECONDARY ROLE:	leak check
	Testing Specifics - Specify Test Number to Your Right (Options: "1", "2", or "Cryo")		1.00
Test 1 Specifics	Option "1": Regen	Value	Unit
	O/F Ratio	2.2	
	CH4 Tank Pressure	1450	psi +- 100
	LOX Tank Pressure	1450	psi +- 100
	Burn Time	10.00	seconds
	CH4 MPV Lead	0.50	seconds
	CH4 tank relief pressure		PSI
	LOX tank relief pressure		PSI
Test Notes			
Test 2 Specifics	Option "2": Ablative	Value	Unit
	O/F Ratio	2.00	
	CH4 Tank Pressure	367.48	psu
	LOX Tank Pressure	356.68	psi
	Burn Time	10.00	seconds
	CH4 MPV Lead	0.00	seconds
Test Notes			
Current Test Tank Pressures		Value	Unit
	CH4 Tank Pressure	1450	psi +- 100
	LOX Tank Pressure	1450	psi +- 100
Acronym List			
1	Helium Isolator Valve	**HI Valve**	
2	Main Propellant Valve	**MPV**	
3	Vent Valve	**VV**	
4	Electronic Systems Bay	**ESB**	
5	Mission Control	**MC**	
6	Avionics Laptop	**AvTop**	
7	Thermocouple	**TC**	
8	Pressure Transducer	**PC**	
9	Dome Loaded	**DL**	
10	Failure Scenario - Number - Page Number	**FS-#-##**	

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Arrival**		
1.01	Driver	Truck/Trailer to requested I-Beam		
1.02	LOG_1	Unload tables and EZ-Up		
1.03	LOG_1	Unload all "Pad" crates at I-Beam		
1.04	LOG_1	Unload LN2 Dewar		
1.05	LOG_1	Unload all Cylinders		
1.06	LOG_1	Unload Test Stand		
1.07	LOG_1	Unload all "Bunker" crates at bunker		
1.08	LOG_1	Charge Drones and Verify Firmware (check SD card capacities)		
1.09	RED_O1	Bring LOX Dewar to shade		
2.00		**Setup**	Time:_______________	
2.01	LOG_1	Power ON and charge radios		
2.02	RED_F3	Position Pressurant Cylinders at I-Beam (At least 1 He for pressurization and 1 N2 for Cylinder for Purge must be secured)		
2.03	OP_1	**Horizontal Configuration**	☐ USE ☐ VOID	
2.04	LOG_1	*Roll up and secure to I-Beam*		
2.05	OP_1	**Vertical Configuration**	☐ USE ☐ VOID	
2.06	LOG_1	*Position Test Stand and Secure to I-Beam*		
2.07	P_1	*Begin Assembling Engine mount to I-Beam after Test stand is mounted*		
2.08	P_1	*Begin mounting engine for plumbing*		
2.09	P_1	*Once engine is mounted, begin plumbing line to engine*		
2.10	P_1	*Position Blast Deflector*		
		Insert Engine Specific Set-Up Procedure Here		
2.11	RED_F3	Place Air Compressor next to Test Stand		
2.12	RED_F3	Prepare regulators and hoses for Air Compressor and N2 Purge		
2.13	P_1	Prepare Igniters		
2.14	P_1	**Propellant Igniter**	☐ USE ☐ VOID	
2.15	P_1	*Do not connect igniter line to igniter box*		
2.16	P_1	*Attach e-match leads to connectors and crimp*		
2.17	P_1	*Attach break wire leads to green connector and ESB*		
2.18	P_1	*Connect igniter to igniter line*		
2.19	P_1	*Have igniter placed safely near I-Beam and ready to mount to engine*		
2.20	P_1	**Spark Igniter**	☐ USE ☐ VOID	
2.21	P_1	*Ensure DC Power Supply Splitter is NOT connected*		
2.22	P_1	*Plug in AC/DC Converter*		
2.23	P_1	*Attach cables together and confirm secure*		
2.24	P_1	*Connect ethernet into ESB 3.0*		
2.25	P_1	*Verify New Transformer and Continuity Test*		
2.26	P_1	*Have igniter placed safely near I-Beam and read for igniter test*		

Step #	Callout	Step Description	Notes/Comments	Check Box
2.27	AV_1	**Connect all data lines:**		
2.28	AV_1	*Begin Setting up avionics in bunker*		
2.29	AV_1	*Run extension cords to I-Beam for ESB 3.0, Purge, & Compressor*		
2.30	AV_1	*Confirm ESB 3.0 has power source connected and battery pack is on*		
2.31	AV_1	*Restart all computers before test and plug in computer power sources*		
2.32	AV_1	*Plug in secondary monitor to AvTop and ensure visual*		
2.33	AV_1	*Connect Ethernet from ESB 3.0 to AvTop Computer*		
2.34	AV_1	*Verify umbilical between Junction Box and ESB is connected*		
2.35	AV_2	*Connect Valve state Monitoring Line from Purge System to Reo Link Computer*		
2.36	AV_2	*Ensure all camera ethernet cords are connected to switch*		
2.37	AV_1	*Connect Load Cell to Junction Box*		
2.38	AV_1	*Boot ESB 3.0*		
2.39	AV_2	Turn ON NI and ReoLink Client		
2.40	AV_2	**Camera start sequence:**		
2.41	AV_2	*Start Desktop Client*		
2.42	AV_2	*Start Each Camera with play button*		
2.43	AV_2	*Verify live feed with each camera with hand wave*		
2.44	AV_1	**Test Stand ESB 3.0 National Instruments (NI):**		
2.45	AV_1	*Check NI Max for complete connections*		
2.46	AV_1	*If unsuccessful, click reset*		
2.47	AV_1	*Open Main NI Panel*		
2.48	AV_1	*If successful, verify physical ethernet port*		
2.49	AV_1	*Verify all valves are instantiated into a closed state*		
2.50	AV_1	*Tare Load Cell and Verify Load Cell is reading*		
2.51	AV_1	There should be no pneumatic pressure so no valves should physically change state		
2.52	AV_1	*Verify all TCs and PTs are live*		
2.53	AV_1	*Set new offsets to 0*		
2.54	AV_1	*Save settings*		
2.55	AV_1	Confirm all data is live: Cameras and NI		
2.56	OP_1	**Ensure no hands are near actuators**		
2.57	RED_F3	**Supply pneumatic source to Junction Box:**		
2.58	RED_F3	*Only VVs will change state if all valves were properly closed at previous test.*		
2.59	RED_F3	*Verify pneumatic pressure is set to ~100 psi*		
2.60	RED_F3	*Verify no leaks through pneumatic system of closed state valves*		
2.61	RED_F3	*Verify valve states are set to closed*		
2.62	RED_F3	**Supply N2 to Purge System:**		
2.63	RED_F3	*Open valve on regulator and adjust pressure to ~100 psi*		
2.64	RED_F3	*Verify no leaks until solenoid*		
2.65	OP_1	Record time	Time:_______________	

Step #	Callout	Step Description	Notes/Comments	Check Box
3.000		**Dry Systems Testing**	Time:_______________	
3.001	LOG_1	Distribute Radios, if not already done so.		
3.002	AV_1/AV_2	Confirm all data is live:	Cameras, NI	
3.003	AV_1	**Cycle all pneumatic valves and verify actual states can be read (not just "there is movement"):**		
3.004	AV_1	LOX Vent:		
3.005	AV_1	*CLOSE*		
3.006	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.007	AV_1	*OPEN*		
3.008	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.009	AV_1	CH4 Vent:		
3.010	AV_1	*CLOSE*		
3.011	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.012	AV_1	*OPEN*		
3.013	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.014	AV_1	Vent Valves		
3.015	AV_1	*CLOSE*		
3.016	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.017	AV_1	*OPEN*		
3.018	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.019	AV_1	*CLOSE*		
3.020	AV_1	**Valve Safety OFF**	Includes spark igniter	
3.021	AV_1	LOX MPV:		
3.022	AV_1	*OPEN*		
3.023	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.024	AV_1	*CLOSE*		
3.025	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.026	AV_1	CH4 MPV:		
3.027	AV_1	*OPEN*		
3.028	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.029	AV_1	*CLOSE*		
3.030	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.031	AV_1	MPVs (Launch Button): Both MPV's OPEN with CH4 Lead Time		
3.032	AV_1	*OPEN*	Check MPV Lead Time	
3.033	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.034	AV_1	*CLOSE*	Check MPV Lead Time	
3.035	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.036	AV_1	LOX HI		
3.037	AV_1	*HI Safety off*		
3.038	AV_1	*OPEN*	Ensure valves are at correct speed. Repeat step as necessary.	
3.039	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.040	AV_1	*CLOSE*		
3.041	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.042	AV_1	CH4 HI		
3.043	AV_1	*OPEN*	Ensure valves are at correct speed. Repeat step as necessary.	
3.044	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.045	AV_1	*CLOSE*		
3.046	AV_1	*Verify valve state: Camera/Reed Switch/Visual*		
3.047	AV_1	Abort		
3.048	AV_1	**Change states to Unsafe State:**		
3.049	AV_1	*VVs CLOSE*		
3.050	AV_1	*HI's OPEN*		

Step #	Callout	Step Description	Notes/Comments	Check Box
3.051	AV_1	*MPV OPEN*		
3.052	AV_1	Hit Abort Button and Ensure Test Stand Enters Safe State	MPV CLOSE, VV OPEN, HI CLOSE	
3.053	AV_1	CLOSE VV		
3.054	AV_1	CH4 Dump		
3.055	AV_1	*Verify valve in closed state*	Should be normally closed	
3.056	AV_1	*OPEN Dump*		
3.057	AV_1	*Verify valve in OPEN state*		
3.058	AV_1	*CLOSE Dump*		
3.059	AV_1	*Verify valve in closed state*		
3.060	AV_1	**Confirm MPVs CLOSED and Valve Safety ON**		
3.061	P_3	**Igniter**		
3.062	P_3	Propellant Igniter:		
3.063	P_3	Igniter Box and Continuity Test:		
3.064	P_3	*Verify igniter box voltage (15-18VDC)*		
3.065	P_3	*Plug in igniter to igniter box*		
3.066	P_3	*Power on igniter box*		
3.067	P_3	*Perform continuity test of igniter box*		
3.068	P_3	*Verify break wire is intact at DataQ*		
3.069	P_3	Ignition Test:		
3.070	OP_1	***Ensure everyone is safely 10ft away***		
3.071	P_3	*Igniter safety OFF and red cover up*		
3.072	P_3	*Prepare timer for test*		
3.073	P_3	*Begin countdown from 5 and ignite*		
3.074	P_3	*Record time it takes to burn through igniter*	Time:______________	
3.075	P_3	*Ensure igniter is out and switch is off*		
3.076	P_3	*Ensure we can read the break wire is broken*		
3.077	P_3	*Igniter safety ON*		
3.078	P_3	*Power down box and unplug one lead on the bunker side*		
3.079	P_3	Spark igniter:		
3.080	P_3	*Ensure igniter relay is OFF*		
3.081	P_3	*Plug in DC Power Supply Splitter*		
3.082	P_3	***Ensure everyone is safely 10 ft away***		
3.083	P_3	*Turn OFF Valve Safety*		
3.084	P_3	*Give 5 second countdown for Spark Igniter Test*		
3.085	P_3	*Ensure spark igniter works reliably and turn OFF*		
3.086	P_3	*Give 5 second countdown for Spark Igniter Test again*		
3.087	P_3	*Ensure spark igniter works reliably and turn OFF*		
3.088	P_3	*Disconnect DC power Supply Splitter*		
3.089	P_3	*Prepare igniter for actual SHF Test*		
3.090	AV_1	**Purge System Testing:**		
3.091	RED_F3	Remove caps on Engine		
3.092	AV_1	Actuate Purge Solenoid		
3.093	RED_F3	Verify air flow		
3.094	AV_1	CLOSE Purge		
3.095	leak check	Perform Leak check, if necessary, of all systems past the MPV's using Purge pressure and plugging engine.		
3.096	RED_F3	Verify purge regulator is still at nominal pressure	~100 psi	
3.097	AV_1	**Test ESB 3.0 Power Loss:**		
3.098	AV_1	*Change Valves to Unsafe State: VV Closed, HI's Open, MPV's Closed*		
3.099	RED_F3	*Pull power to ESB 3.0 and Ensure Test Stand Enters a Safe State*		
3.100	AV_1	*Reset NI Max*		
3.101	AV_1	**Test Pneumatic Pressure Loss:**		

Step #	Callout	Step Description	Notes/Comments	Check Box
3.102	AV_1	*Change Valves to Unsafe State: VV Closed, HI's Open, MPV's Closed*		
3.103	RED_F3	*Pull pneumatics and Ensure Test Stand Enters a Safe State*		
3.104	AV_1	**Valve Safety On (call out on radio)**		
3.105	AV_1	Review Valve Failure Scenarios, as necessary.		
3.106	OP_1	Record Time	Time:_______________	
4.00		**Helium System Pressurization Testing:**	Time:_______________	
4.01	RED_F2	Remove all VV Caps		
4.02	AV_2	Verify HI's are CLOSED		
4.03	AV_2	Verify Vent Valves are OPEN		
4.04	RED_F2	Verify hand loaded regulators are unloaded (loose)		
4.05	RED_F2	Connect Helium Source while source is CLOSED		
4.06	Leak Check	Verify leak test is at the ready		
4.07	AV_1	Verify pressure transducer data is live		
4.08	OP_1	Inform team about to pressurize and to stand clear		
4.09	RED_F2	Open Helium K Bottle		
4.10	Leak Check	Leak check Helium Input System		
4.11	RED_F2	Verify Input He Gauge matches input Ducer		
4.12	RED_F2	Input Pressure Settings - Stage 1:		
4.13	RED_F2	*Adjust LOX Inline Regulator and bring output pressure to: 1700 psi*		
4.14	RED_F2	*Adjust CH4 Inline regulator and bring output pressure to: 1700 psi*		
4.15	RED_F2	*Set Lock nuts to hand tight*		
4.16	RED_F2	Input Pressure Setting - Stage 2:		
4.17	RED_F2	*Test psi is determined by managers or senior engineers:*		
4.18	RED_F2	*Tank psi should be set to ~250 psi for Leak Testing Tank System*		
4.19	RED_F2	*Tank psi should be set to Test 1 Specifics for SHF Test, if leak test is already checked.*		
4.20	RED_F2	*Adjust LOX Hand Loaded Regulator to desired pressure.*		
4.21	RED_F2	*Verify LOX DL output is 250 psi on gauges and ducers*		
4.22	RED_F2	*Adjust CH4 Hand Loaded Regulator to 250*		
4.23	RED_F2	*Verify CH4 DL output is 250 on gauges and ducers*		
4.24	Leak Check	*Verify no pressure is leaking past HI Valves*		
4.25	Leak Check	Verify there are no leaks prior to HI Valves		
4.26	OP_1	Record Time	Time:_______________	
5.00		**Leak Testing Tank System (If already done, skip).**	Time:_______________	
5.01	OP_1	Announce that we are moving on to leak testing tanks and they will be pressurized.		
5.02	AV_1	Begin/Confirm DAQ		
5.03	AV_1	Read out all pressures and valve states		
5.04	AV_1	Confirm LOX and CH4 DL pressures are ~250 psi	LOX/CH4 DL:____/_____	
5.05	AV_2	Cameras Live (reolinks)		
5.06	OP_1	Notify all personnel Test Stand is ready to pressurize	"All Clear Inside/Outside"	
5.07	AV_1	**CLOSE LOX and CH4 Vents**		
5.08	AV_1	**CLOSE MPVs**		
5.09	OP_1	Announce Reverse Procedure (RevP):		
5.10	OP_1	*CLOSE HI Valves*		
5.11	OP_1	*OPEN Vents*		

Step #	Callout	Step Description	Notes/Comments	Check Box
5.12	OP_1	Ask for CH4 DL Pressure	CH4 DL psi: __________	
5.13	OP_1	Announce CH4 DL Pressure as intended CH4 Tank Pressure		
5.14	OP_1	Ensure one person is monitoring Data Acq Client and is watching for pressure increases during HI Valve Opening		
5.15	AV_1	Valve Safety OFF		
5.16	AV_1	Countdown from 3 Seconds		
5.17	AV_1	OPEN CH4 HI Valve	☐ OPEN ☐ FAIL: REVP	
5.18	AV_1	If loud leaks are detected or fitting blows off, commence reverse procedure.		
5.19	AV_1	Confirm CH4 Tank Pressure	☐ ~250 ☐ FAIL: REVP	
5.20	AV_1	Valve Safety ON		
5.21	OP_1	Confirm safe to approach for leak test		
5.22	leak check	Leak Test CH4 System	If leaking, CLOSE HI	
5.23	leak check	Check for leaks past VV's and MPV's		
5.24	OP_1	Ask for LOX DL Pressure	LOX DL psi:__________	
5.25	OP_1	Announce LOX DL Pressure as intended LOX Tank Pressure		
5.26	OP_1	Ensure one person is monitoring data acq client and are watching for pressure increases during HI Valve opening		
5.27	AV_1	Valve Safety OFF		
5.28	AV_1	Countdown from 3 seconds		
5.29	AV_1	OPEN LOX HI Valve		
5.30	AV_1	Confirm LOX Tank Pressure	☐ ~250 ☐ FAIL: REVP	
5.31	AV_1	Valve Safety ON		
5.32	AV_1	Confirm safe to approach for Leak Test		
5.33	leak check	Leak Test LOX System		
5.34	leak check	Check for leaks past VV's and MPV's		
5.35	OP_1	Record Time	Time:______________	
6.00		**Tank System Depressurization (If leak tested):**	Time:______________	
6.01	AV_1	Valve Safety OFF		
6.02	AV_1	CLOSE HI Valves		
6.03	OP_1	Announce Tank Pressures		
6.04	OP_1	Announce we are going to depressurize		
6.05	OP_1	*Ensure everyone is clear*		
6.06	AV_1	OPEN Vents		
6.07	AV_1	Verify Tank pressures are 0 psi		
6.08	AV_1	Valve Safety ON		
6.09	OP_1	Record Time	Time:______________	

Step #	Callout	Step Description	Notes/Comments	Check Box
7.00		**Helium System Depressurization:**	Time:_______________	
7.01		*Detail: There is no way to vent helium systems without using the tanks venting system. This requires opening the HI and Vent Valves.*		
7.02	RED_F2	**Verify LOX DL and CH4 DL pressures are reading less than 300 PSI**	When tanks are empty, it can be damaging to the system if the DL pressures are too high and vented through the tanks	
7.03	OP_1	**Evaluate pressures of entire system and determine if depressurization should be done from the bunker or at the PAD**		
7.04	RED_F2	**Tank pressure should be raised to Test 1 Specifics if planned test after fueling. The pressure set should be seen again during Helium loading.**	LOX: 1450 +- 100 psi CH4: 1450+- 100 psi	
7.05	RED_F2	Tank pressure should be set to less than 300psi if venting empty tanks.		
7.06	RED_F2	CLOSE He Cylinder		
7.07	AV_2	Ensure both Vent Valves are OPEN		
7.08	OP_1	Verify everyone is a safe distance away from Test Stand		
7.09	AV_1	Valve Safety OFF		
7.10	AV_1	OPEN LOX HI Valve		
7.11	AV_1	Verify pressures dropping		
7.12	AV_1	OPEN CH4 HI Valve if necessary (If LOX regulator is closed)		
7.13	AV_1	Verify pressures are 0 psi on entire system		
7.14	AV_1	CLOSE HI's and Vent Valves		
7.15	AV_1	Valve Safety ON		
7.16	RED_F2	**Ensure 2 He K-bottles are hooked up for test (2200 PSI)**		
7.17	AV_2	Stop Camera Recording and Export File	☐ USE ☐ VOID	
7.18	OP_1	Record Time	Time:_______________	
8.00		**Pre-Hot Fire Test Preparation:**	Time:_______________	
8.01	P_1	Install igniter into engine:		
8.02	P_1	*If Spark Igniter, ensure DC power supply is NOT plugged in*		
8.03	P_1	*If Propellant Igniter, ensure wires are shorted in bunker*		
8.04	P_1	Test Spark Igniter:	If necessary	
8.05	P_1	*Verify Valve Safety is ON*		
8.06	P_1	*Plug in Spark Igniter to DC Power Supply*		
8.07	AV_1	*If any changes were made to the LabView Program, perform full dry systems test now. No alterations are allowed to the code after this point.*		
8.08	AV_1	Ensure Break wire is connected and NI is reading correctly if Propellant Igniter		
8.09	OP_1	Call for Radio Silence. End all non-Safety Critical conversations.		
8.10	OP_1	Rehearse Terminal Sequence and Failure Scenarios before LN2 Loading		
8.11	LOX Driver/ CH4 Driver	prepare trucks for fueling and verify fueling equipment is ready.		
8.12	LOG_1	Clean up Pad		
8.13	LOG_1	All non-essential Personnel must move 100 feet away from Test Stand		
8.14	CH4 driver	*Move CH4 Dewar far away from LOX and begin venting (30 PSI)*		
8.15	RED_O1	Disperse PPE To Essential Personnel		
8.16	AV_1	Inform fueling team about Spark Igniter		

Step #	Callout	Step Description	Notes/Comments	Check Box
		Fueling Team Get Prepared:		
		LOX:		
	RED_O2	*RED_O2 on ground with Test Stand and T-Spinner*		
	RED_O1	*RED_O1 on truck ready for opening LOX Dewar Globe Valve*		
		LN2:		
	RED_F3	*RED_F3 ready to receive LOX Transfer Hose for LN2 jacket*		
		CH4:		
	RED_F2	*RED_F2 with T-Spinner of CH4 Hose*		
	RED_F1	*RED_F1 at CH4 Dewar*		
9.00		**LOX Loading:**	Time:________________	
9.01		*Note: 4 RED_O Operators, President, Carl, FAR Representative only for this step*		
9.02	OP_1	**Check with other FAR participants to ensure we can proceed with fueling**	**IMPORTANT: Once given the OK to proceed, SDSU will not be able to pause for other universities unless instructed by the FAR director**	
9.03	LOG_1	Prepare Test Stand Cameras		
9.04	LOG_1	begin recording of at least 1 GoPro camera for fueling		
9.05	LOX driver	Ground vehicle to test stand		
9.06	OP_1	Confirm with FAR that we are permitted to load LOX, Fuel and pressurize		
9.07	OP_1	Confirm proper PPE is on (LIST OF PROPER PPE)		
9.08	AV_1	Ensure Valve Safety is ON		
9.09	AV_2	Ensure Cameras are live		
9.10	AV_2	Ensure HI Valves are CLOSED		
9.11	RED_O2	Ensure LOX Fill CLOSED		
9.12	RED_O1	Vent LOX Dewar to 30 psi		
9.13	AV_1	OPEN Test Stand LOX Vent		
9.14	RED_O2	Remove cap and connect transfer hose to Test Stand and Dewar		
9.15	RED_O2	OPEN Test Stand LOX Fill Valve		
9.16	AV_1	Ensure NI TC's and PTs are reading		
9.17	AV_1	Ensure NI is recording		
9.18	RED_O1	OPEN LOX Dewar globe valve to begin fill		
9.19	AV_1	Confirm NI TC Temp Change in LOX tank		
9.20	AV_1	Begin cycle LOX Vent	~ Every 20 seconds	
9.21	RED_O2	Ensure no leaks through LOX MPV		
9.22	RED_O1	Continue to fill until LOX Liquid is discharged from LOX Vent		
9.23	RED_O1	CLOSE LOX Dewar Globe Valve		
9.24	RED_O1	Allow 60 second tank cold soak		
9.25	RED_O1	OPEN LOX Dewar globe valve for LOX Tank top-off		
9.26	RED_O1	Continue fill until LOX liquid is discharged from LOX Vent		
9.27	RED_O1	CLOSE LOX Dewar Globe Valve		
9.28	RED_O2	CLOSE Test Stand LOX Fill Valve		
9.29	RED_O1	Vent line		
9.30	RED_O2	Disconnect transfer hose from test stand and Dewar		
9.31	RED_O2	Loosely cap LOX Fill		
9.32	RED_O2	Unlatch Ground		
9.33	LOX Driver	Send LOX Dewar away		
9.34	OP_1	Record Time:	Time:________________	

Step #	Callout	Step Description	Notes/Comments	Check Box
10.00		**CH4 Tank Conditioning:**	Time:________________	
10.01	RED_F3	Receive LOX Transfer Hose from LOX Truck		
10.02	RED_F3	Attach LOX Transfer Hose to LN2 Dewar and jacket		
10.03	RED_F3	Crack OPEN LN2 Dewar Globe Valve		
10.04	OP_1	Record Time:	Time:________________	
11.00		**CH4 Tank LNG Loading:**	Time:________________	
11.01		*Note: 3 Red Team-F Operators, President, Carl, FAR Representative only for this step*		
11.02	RED_F2	Ground vehicle to Test Stand		
11.03	OP_1	Confirm proper PPE is on (LIST OF PROPER PPE)		
11.04	AV_2	Ensure HI Valves CLOSED		
11.05	RED_F2	Ensure CH4 Fill CLOSED		
11.06	RED_F1	Vent CH4 Dewar to 30 psi		
11.07	AV_2	Ensure cameras are live		
11.08	AV_1	OPEN Test Stand CH4 Vent		
11.09	RED_F2	Remove Cap and Connect transfer hose to Test Stand and Dewar	Verify attached to "liquid out" on the Dewar	
11.10	RED_F2	OPEN Test Stand CH4 Fill Valve		
11.11	RED_F1	OPEN CH4 Dewar Globe valve to begin fill		
11.12	AV_1	Begin cycle LOX *and* CH4 Vents	~ every 20 seconds	
11.13	RED_F2	Ensure no leaks through CH4 MPV		
11.14	RED_F1	Continue to fill until LNG liquid is discharged from CH4 Vent		
11.15	RED_F1	CLOSE CH4 Dewar Globe Valve		
11.16	RED_F1	Allow for 60 second tank cold soak		
11.17	RED_F1	OPEN CH4 Dewar Globe Valve for CH4 Tank top-off		
11.18	RED_F1	Continue fill until CH4 liquid is discharged from CH4 Vent		
11.19	RED_F1	CLOSE CH4 Dewar Globe Valve		
11.20	RED_F2	CLOSE Test Stand CH4 Fill Valve		
11.21	RED_F1	Vent line		
11.22	RED_F2	Disconnect Transfer Hose		
11.23	LOG_1	**ALL cameras recording**		
11.24	RED_F2	Loosely Cap CH4 Fill		
11.25	RED_F3	CLOSE LN2 Dewar Globe Valve		
11.26	RED_F2	Unlatch Ground		
11.27	LOX Driver/ CH4 Driver	Send CH4 and LOX Dewars away	*Optional Time to Top of LOX*	
11.28	OP_1	Record Time:	Time:________________	
12.00		**Helium Loading:**	Time:________________	
12.01		*Note: Carl Tedesco and RED_F1 only*		
12.02	AV_1	NI is live and recording		
12.03	LOG_1	Cameras Recording and Live		
12.04	AV_1	Turn on all screen recording software		
12.05	P_1	Verify igniter cords are all plugged in at pad		
12.06	AV_1	Ensure pneumatic pressure is ~120 psi		
12.07	AV_1	Ensure purge pressure is ~100 psi		
12.08	AV_2	**Verify LOX and CH4 HI Valves are CLOSED**		
12.09	OP_1	Verify all personnel are in bunkers		
12.10	RED_F1	Open Helium Bottles		
12.11	AV_1	Verify all pressures are nominal		
12.12	OP_1	Record Time:	Time:________________	

Step #	Callout	Step Description	Notes/Comments	Check Box
13.00		**Pre-Terminal Sequence:**	Time:_________________	
13.01	OP_1	Turn off all excess radios in bunker		
13.02	AV_1	Begin/Confirm NI		
13.03	AV_1	*Set new offsets if necessary (* REMOVE STEP? changes should not be made at this point.)		
13.04	AV_1	Tare Load Cell		
13.05	AV_1	Read out pressures for Helium In, DL's, and pressurants.		
13.06	OP_1	Ensure bunker camera is recording		
13.07	OP_1/ AV_4	Notify all personnel Test Stand is ready to pressurize (over FAR PA system)	☐ ALL CLEAR	
13.08	AV_1	**CLOSE LOX and CH4 Vents (Stop Vent Cycling)**		
13.09	OP_1	Announce Reverse Procedure for this scenario:		
13.10	OP_1	*CLOSE HI Valves*		
13.11	OP_1	*OPEN Vents*		
13.12	AV_1	Announce CH4 DL Pressure		
13.13	OP_1/ AV_4	Announce to Bunker and PA system: CH4 Tank will be pressurised to: 1450		
13.14	AV_1	Valve Safety OFF		
13.15	OP_1/ AV_4	Countdown from 3 seconds (on radio/ FAR PA system)		
13.16	AV_1	OPEN CH4 HI Valve	☐ OPEN ☐ FAIL: FS-10-19	
13.17	AV_1	If loud leaks are detected or a fitting blows off: Commence Reverse Procedure		
13.18	OP_1	Confirm CH4 Tank Pressure	CH4 Tank psi:__________	
13.19	AV_1	Announce LOX DL Pressure		
13.20	OP_1/ AV_4	Announce to Bunker and PA system: LOX Tank will be pressurized to: 1450		
13.21	OP_1/ AV_4	Countdown from 3 seconds (on radio/ FAR PA system)		
13.22	AV_1	OPEN LOX HI Valve	☐ OPEN ☐ FAIL: FS-10-19	
13.23	OP_1	Confirm LOX Tank Pressure	LOX Tank psi:__________	
13.24	AV_1	Valve Safety ON		
13.25	OP_1	Propellant Igniter:	☐ USE ☐ VOID	
13.26	AV_1	*Confirm Igniter Safety ON*		
13.27	P_3	*Plug in Igniter Box*		
13.28	P_3	*Igniter Box Power ON*		
13.29	P_3	*Continuity Test*		

Step #	Callout	Step Description	Notes/Comments	Check Box
13.30	OP_1	Spark Igniter	☐ USE ☐ VOID	
13.31		*Standby*		
13.32	AV_1	Start NI DAQ		
13.33	OP_1	Take a deep breathe and DO NOT RUSH		
13.34	OP_1	Ensure "Bunker Personnel" are ready for terminal sequence: Personnel Glance (No need to call out each)		
13.35	OP_1	Av_1 at MC		
13.36	OP_1	P_3 at Propellant Igniter		
13.37	OP_1	Av_3 at Reolink Computer		
13.38	OP_1	Av_4 at Countdown		
13.39	OP_1	Op_1 at Procedure		
13.40	OP_1	P_1 at Engine Computer, P_2 standby		
13.41	OP_1	Carl as Supervisor		
13.42	OP_1	Reminder: Propellant Igniter at 2s for P_3. Av_1 to call out "Launch"		
		Pre-Terminal Sequence complete. Proceed to Terminal Sequence.		

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
		Connect New Engine. See engine specific setup.		
14.00		**Reset Test Setup**		
14.01		Prepare Igniters		
14.02		**Propellant Igniter**	☐ Use ☐ Void	
14.03		*Do not connect igniter line to igniter box*		
14.04		*Attach e-match leads to connectors and crimp*		
14.05		*Attach breakwire leads to green connector and ESB*		
14.06		*Connect igniter to igniter line*		
14.07		*Have igniter placed safely near I-Beam and ready to mount to engine*		
14.08		**Spark Igniter**	☐ Use ☐ Void	
14.09		*Ensure DC Power Supply Splitter is NOT connected*		
14.10		*Plug in AC/DC Converter*		
14.11		*Attach cables together and secure*		
14.12		*Connect ethernet into ESB 3.0*		
14.13		*Continuity Test*		
14.14		*Have igniter placed safely near I-Beam and read for igniter test*		
14.15		Reset GoPro Cameras for next test		
14.16		**Check pressurant tanks to make sure enough left over for secondary test**		
14.17				
14.18				
14.19				
14.20				
14.21				
14.22				
14.23				
14.24				
14.25				
14.26				
15.00		**Helium System Pressurization Testing:**	Time:_______________	
15.01		Verify HI's are CLOSED		
15.02		Verify Vent Valves are CLOSED		
15.03		Verify hand loaded regulators are unloaded		
15.04		Connect Helium Source while source is CLOSED		
15.05		Verify pressure transducer data is live		
15.06		Inform team about to pressurize and to stand clear		
15.07		Open Helium K Bottle		
Step #	**Callout**	**Step Description**	**Notes/Comments**	**Check Box**
15.08		Verify Input He Gauge matches input Ducer		

15.09		Input Pressure Settings - Stage 1:		
15.10		*psi*		
15.11		*psi*		
15.12		*Set Lock nuts to hand tight*		
15.13		Input Pressure Setting - Stage 2:		
15.14		*Test psi is determined by managers or senior engineers:*		
15.15		*is already checked.*		
15.16		*Adjust LOX Hand Loaded Regulator to: 356.68*		
15.17		*Verify LOX DL output is 356.68 psi on gauges and ducers*		
15.18		*Adjust CH4 Hand Loaded Regulator to: 367.48*		
15.19		*Verify CH4 DL output is 367.48 psi on gauges and ducers*		
15.20		*Verify no pressure is leaking past HI Valves*		
15.21		Verify there are no leaks prior to HI Valves		
15.22		Record Time	Time:_______________	
16.00		**Helium System Depressurization:**	Time:_______________	
16.01		*the tanks venting system. This requires opening the HI and Vent*		
16.02		**356.68**		
16.03		after fueling. The pressure set should be seen again during		
16.04		CLOSE He Cylinder		
16.05		Ensure both Vent Valves are OPEN		
16.06		Verify everone is a safe distance away from Test Stand		
16.07		Valve Safety OFF		
16.08		OPEN LOX HI Valve		
16.09		Read pressures dropping		
16.10		OPEN CH4 HI Valve if necessary (If LOX regulator is closed)		
16.11		Read pressures are 0 psi on entire system		
16.12		CLOSE HI's and Vent Valves		
16.13		Valve Safety ON		
Step #	**Callout**	**Step Description**	**Notes/Comments**	**Check Box**
16.14		Ensure enough Helium for Test		
16.15		Stop Camera Recording and Export File	☐ USE ☐ VOID	
16.16		Record Time	Time:_______________	
17.00		**Pre-Hot Fire Test Preparation:**	Time:_______________	
17.01		Install igniter into engine:		
17.02		*If <u>Spark Igniter</u>, ensure DC power supply is NOT plugged in*		
17.03		*If <u>Propellant Igniter</u>, ensure wires are shorted in bunker*		
17.04		Test Spark Igniter:	If necessary	
17.05		*Verify Valve Safety is ON*		
17.06		*Plug in Spark Igniter to DC Power Supply*		
17.07		Propellant Igniter		
17.08		Loading		

17.09		Reset Offsets Again		
17.10		Go get trucks		
17.11		Clean up Pad		
17.12		All Personnel must move over 100 feet away from Test Stand		
17.13		**Fueling Team Get Prepared:**		
17.14		PPE		
17.15		Inform fueling team about Spark Igniter		
17.16		LOX:		
17.17		*RED_O2 on ground with Test Stand and T-Spinner*		
17.18		*RED_O1 on truck ready for opeing LOX Dewar Globe Valve*		
17.19		LN2:		
17.20		*RED_F3 ready to receive LOX Tranfer Hose*		
Step #	**Callout**	**Step Description**	**Notes/Comments**	**Check Box**
17.21		CH4:		
17.22		*RED_F2 with T-Spinner of CH4 Hose*		
17.23		*RED_F1 at CH4 Dewar*		
17.24		*Move Dewar far away from LOX and begin venting*		
		Record Time:	Time:_________________	
18.00		**LOX Tank LOX Loading:**	Time:_________________	
18.01		*Representative only for this step*		
18.02		Ground vehicle to test stand		
18.03		Confirm with FAR that we are permitted to load LOX		
18.04		Ensure proper PPE is on		
18.05		Ensure Valve Safety is ON		
18.06		Ensure Cameras are live		
18.07		Ensure HI Valves are CLOSED		
18.08		Ensure LOX Fill CLOSED		
18.09		Vent LOX Dewar to 30 psi		
18.10		OPEN Test Stand LOX Vent		
18.11		Remove cap and connect transfer hose to Test Stand and Dewar		
18.12		OPEN Test Stand LOX Fill Valve		
18.13		Ensure NI TC's and PTs are reading		
18.14		Ensure NI is recording		
18.15		OPEN LOX Dewar globe valve to begin fill		
18.16		Confirm NI TC Temp Change		
18.17		Begin cycle LOX Vent	~ Every 20 seconds	
18.18		Ensure no leaks through LOX MPV		
18.19		Continue to fill until LOX Liquid is discharged from LOX Vent		
18.20		CLOSE LOX Dewar Globe Valve		
18.21		Allow 60 second tank cold soak		
18.22		OPEN LOX Dewar Dewar globe valve for LOX Tank top-off		
18.23		Continue fill until LOX liquid is discharged from LOX Vent		
18.24		CLOSE LOX Dewar Globe Valve		
18.25		CLOSE Test Stand LOX Fill Valve		
18.26		Vent line		
18.27		Disconnect transfer hose an give to RED_F3		

18.28		Loosely cap LOX Fill		
18.29		Prepare Test Stand Cameras		
18.30		Unlatch Ground		
18.31		Send LOX Dewar away		
18.32		Record Time:	Time:_________________	
Step #	**Callout**	**Step Description**	**Notes/Comments**	**Check Box**
19.00		**CH4 Tank Conditioning:**	Time:_________________	
19.01		Receive LOX Transfer Hose from LOX Truck		
19.02		Attach LOX Transfer Hose to LN2 Dewar and jacket		
19.03		Crack OPEN LN2 Deware Globe Valve		
19.04		Record Time:	Time:_________________	
20.00		**CH4 Tank LNG Loading:**	Time:_________________	
20.01		*Representative only for this step*		
20.02		Ground vehicle to Test Stand		
20.03		Confirm with FAR that we are permitted to load LNG		
20.04		Ensure proper PPE is on		
20.05		Ensure HI Valves CLOSED		
20.06		Ensure CH4 Fill CLOSED		
20.07		Vent LNG Dewar to 30 psi		
20.08		Ensure cameras are live		
20.09		OPEN Test Stand CH4 Vent		
20.10		Dewar		
20.11		OPEN Test Stand CH4 Fill Valve		
20.12		OPEN LNG Dewar Globe valve to begin fill		
20.13		Begin cycle LOX *and* CH4 Vents	~ every 20 seconds	
20.14		Ensure no leaks through CH4 MPV		
20.15		Continue to fill until LNG liquid is discharged from CH4 Vent		
20.16		CLOSE LNG Dewar Globe Valve		
20.17		Allow for 60 second tank cold soak		
20.18		OPEN LNG Dewar Globe Valve for CH4 Tank top-off		
20.19		Continue fill until LNG liquid is discharged from CH4 Vent		
20.20		CLOSE LNG Dewar Globe Valve		
20.21		CLOSE Test Stand CH4 Fill Valve		
20.22		Vent line		
20.23		Disconnect Transfer Hose		
20.24		Test Stand Go-Pro Cameras Recording		
20.25		Loosely Cap CH4 Fill		
20.26		CLOSE LN2 Dewar Globe Valve		
20.27		Unlatch Ground		
20.28		Send all Dewars away		
20.29		Record Time:	Time:_________________	

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
21.00		**Helium Loading:**	Time:________________	
21.01		*Note: Carl Tedesco and RED_F1 only*		
21.02		NI is live and recording		
21.03		Cameras Recording and Live		
21.04		Turn on all screen recording software		
21.05		Verify igniter cords are all plugged in at pad		
21.06		Ensure pneumatic pressure is ~120 psi		
21.07		Ensure purge pressure is ~120 psi		
21.08		Verify LOX and CH4 HI Valves are CLOSED		
21.09		Verify all personnel are safely distant from Test Stand		
21.10		Ensure we have permission to pressurise with HI's CLOSED		
21.11		Open Helium Bottles		
21.12		Verify all pressures are nominal		
21.13		Record Time:	Time:________________	
22.00		**Pre-Terminal Sequence:**	Time:________________	
22.01		Confirm with FAR that we are permitted to pressurize		
22.02		Turn off all excess radios in bunker		
22.03		Begin/Confirm DAQ, wait on NI		
22.04		*Set new offsets if necessary*		
22.05		Tare Load Cell		
22.06		Read out pressures for Helium In, DL's, and pressurants.		
22.07		Ensure bunker camera is recording		
22.08		Notify all personnel Test Stand is ready to pressurize	☐ All clear	
22.09		**CLOSE LOX and CH4 Vents (Stop Vent Cycling)**		
22.10		Announce Reverse Procedure for this scenario		
22.11		*CLOSE HI Valves*		
22.12		*OPEN Vents*		
22.13		Announce CH4 DL Pressure		
22.14		367.48		
22.15		Valve Safety OFF		

Secondary Test Insert

Step #	Callout	Step Description	Notes/Comments	Check Box
22.16		Countdown from 3 seconds (on radio)		
22.17		OPEN CH4 HI Valve	☐ Open ☐ Fail: FS-10-19	
22.18		If loud leaks are detected or a fitting blows off: Commence Reverse Procedure		
22.19		Confirm CH4 Tank Pressure	CH4 Tank psi:___________	
22.20		Announce LOX DL Pressure		
22.21		356.68		
22.22		Countdown from 3 seconds (on radio)		
22.23		OPEN LOX HI Valve	☐ Open ☐ Fail: FS-10-19	
22.24		Confirm LOX Tank Pressure	LOX Tank psi:___________	
22.25		Valve Safety ON		
22.26		Propellant Igniter:	☐ Use ☐ Void	
22.27		*Confirm Igniter Safety ON*		
22.28		*Plug in Ingiter Box*		
22.29		*Igniter Box Power ON*		
22.30		*Continunity Test*		
22.31		Spark Igniter	☐ Use ☐ Void	
22.32		*Standby*		
22.33		Start NI DAQ		
22.34		Take a deep breathe and DO NOT RUSH		
22.35		Personnel Glance (No need to call out each)		
22.36		Av_1 at MC		
22.37		Av_2 at Data Acq		
22.38		P_3 at Propellant Igniter		
22.39		Av_3 at Reolink Computer		
22.40		Av_4 at Countdown		
22.41		Op_1 at Procedure		
22.42		P_1 at Engine Computer, P_2 standby		

Step #	Callout	Step Description	Notes/Comments	Check Box
22.43		Carl as Supervisor		
22.44		"Launch"		
		Sequence.		

make it work

Time	Call out	Response	Role	Check	Description
T- 30s	"Countdown Start at 30 Seconds"		Op_1		Intervals of 5 until 10 Seconds
		"Countdown Started"	Av_4		
		"Hold Countdown"	Av_4		
T- 25s	"Igniter Safety off"		Op_1		Igniter Key turned and Red Cover up
		"Igniter Safety Off and Armed"	P_3		
		"Hold"	P_3		
T- 20s	"Valve Safety Off"		Op_1		MPV, Launch and HI Buttons Active
		"Valve Safety Off"	Av_1		
		"Hold	Av_1		
T- 15s	"Purge On"		Op_1		Press Purge Button
		"Purge On"	Av_1		
		"Hold	Av_1		
T- 2s	"Igniter"		Op_1		Flip Switch
		Flip Switch	P_3		
		"Hold"	P_3		
0s	"Breakwire Status"		Op_1		Verify Digital broek signal and announce launch.
		"Launch"	Av_1		
		"Hold" ... FS-9-19	Av_1		
T+ 10s	"Close MPV and Confirm"		Op_1		MPV Closed Announced and Visually Confirmed
		"MPV Closed"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-3-16	Av_1		
T+ 15s	"Close HI's and Confirm"		Op_1		Repeat
		"HI's Closed"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-10-19	Av_1		
T+ 20s	"Open Vents and Confirm"		Op_1		Repeat
		"Vents Open"	Av_1		
		"Confirmed"	Av_3		
		"Hold" ... FS-2-16	Av_1		
T+ 25s	"Valve Safety On"		Op_1		Safety on for MC
		"Valve Safety On"	Av_1		
		"Hold"	Av_1		
T+ 30s	"Ingiter Off and Igniter Safety On"		Op_1		Igniter Swith OFF and Key out
		"Igniter Off"	P_3		
		"Hold"	P_3		
T+ 35s	"Purge Off"		Op_1		Purge OFF
		"Purge Off"	Av_1		
		"Hold"	Av_1		
	"Save all Files"				
	RED_F1 and Carl leave bunker				
	Close He Cylinder Valve				
	Approach Test Stand				

Time	Call out	Response	Role	Check	Description
T- 20s	"Countdown Start at 20 Seconds"		Op1		Intervals of 5 until 10 Seconds
		"Countdown Started"	Av4		
		"Hold Countdown"	Av4		
T- 10s	"Valve Safety Off"		Op1		MPV, Launch and HI Buttons Active
		"Valve Safety Off"	Av1		
		"Hold	Av1		
T- 5s	"Igniter"		Op1		Press Igniter Button
		"Igniter On"	Av1		
		"Hold"	Av1		
T- 0s	"Go for Launch"		Op1		Press Launch Button
		"Launch"	Av1		
		"Hold" ...FS-5-17	Av1		
T+ 10s	"Close MPV and Confirm"		Op1		MPV Closed Announced and Visually Confirmed
		"MPV Closed"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-3-16	Av1		
T+ 15s	"Close HI's and Confirm"		Op1		Repeat
		"HI's Closed"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-10-19	Av1		
T+ 20s	"Open Vents and Confirm"		Op1		Repeat
		"Vents Open"	Av1		
		"Confirmed"	Av3		
		"Hold" ... FS-2-16	Av1		
T+ 25s	"Igniter Off"		Op1		Toggle Igniter Button
		"Igniter Off"	Av1		
		"Hold"	Av1		
T+ 30s	"Valve Safety On"		Op1		Safety on for MC
		"Valve Safety On"	Av1		
		"Hold"	Av1		
	"Save all Files"				
	RED_F1 and Carl leave bunker				
	Close He Cylinder Valve				
	Approach Test Stand				

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Frozen Vent Valve (Frozen OPEN)**		
1.01		Troubleshoot and verify no avionics failures		
1.02		CLOSE HI Valves or verify they are CLOSED		
1.03		Verify Helium supply valve is CLOSED	If safe to approach	
1.04		OPEN non-frozen vent valve or verify that it is set to OPEN		
1.05		**Perform dump Sequence:**		
1.06		*Ensure dumping is safe with Carl*		
1.07		*OPEN Dump on frozen vent valve tank*		
1.08		*Ensure enough time has passed since dump*		
1.09		*CLOSE Dump frozen vent valve tank*		
1.10		CLOSE or reverify helium supply valve is closed		
1.11		Evaluate Valve		
2.00		**Frozen Vent Valve (Frozen CLOSED)**		
2.01		CLOSE HI Valves or verify they are closed		
2.02		OPEN non-frozen vent valve or verify hat it is set to open		
2.03		Verify Helium supply valve is closed	If safe to approach	
2.04		**Perform dump Sequence:**		
2.05		*Ensure Dumping is safe with Carl*		
2.06		*Dump frozen vent valve tank*		
2.07		*Ensure enough time has passed since dump*		
2.08		*Dump frozen vent valve tank*		
2.09		CLOSE or re-verify helium supply valve is CLOSED		
2.10		Evaluate valve		
3.00		**Frozen MPV**		
3.01		CLOSE MPV's or verify MPVs are set to CLOSED		
3.02		CLOSE HI Valves or verify they are CLOSED		
3.03		Vent both tanks, OPEN Vents	See FS-4-17	
3.04		Approach Test Stand		
3.05		CLOSE Helium supply valve		
3.06		Move safely away from test stand		
3.07		**Perform dump Sequence:**		
3.08		*Ensure Dumping is safe with Carl*		
3.09		*pressure*		
3.10		*Ensure enough time has passed since dump*		
3.11		*Dump frozen vent valve tank*		
3.12		If time permits, remove frozen valve and try and dry it		
3.13		Replace Valve, restart sequence over (Start at Step 1)		
4.00		**Vent Valves and MPV are frozen**		

4.01		for best course of action		
5.00		**No Propellant Ignition**		
5.01		MPV Closed		
5.02		Helium isolation valve CLOSED		
5.03		OPEN Vents		
5.04		Verify ignitor system is OFF		
5.05		Verify methane plume does not catch the test stand on fire		
5.06		*Note: If test stand is on fire, let it burn out.*		
5.07		Ground version 2 igniter if necessary		
5.08		CLOSE He Cylinder		
5.09		Evaluate propellant amount remaining:		
5.10		**If aborted BEFORE 3 seconds of open MPV:**		
5.11		*Replace ignitor (If Propellant)*		
5.12		*Check Consumables*	System	
5.13		*If okay, proceed with test*		
5.14		**If aborted AFTER 3 seconds of open MPV**		
5.15		Evaluate safety of test stand		
5.16		Replace ignitor		
5.17		Restart at Helium System Depresurization to use new k-bottle		
5.18		After returnign to desirable state, proceed with test		
6.00		**Engine Melts or Explodes**		
6.01		Verify MPV CLOSED		
6.02		Verify HI Valves CLOSED		
6.03		Verify Vent Valves OPEN		
6.04		Go through depressurizing sequence		
6.05		Go through fuel dumping sequence		
6.06		Give engine sufficient amount of time to cool off		
6.07		Evaluate safety before approaching test stand		
6.08		Replace engine with second engine, if available.		
6.09		Replace ignitor		
6.10		Go through pressurizing sequeince and fueling sequence.		
7.00		**Total ESB Power Loss in Fueling State**		
7.01		Fueling Valve States:		
7.02		*HI CLOSED*		
7.03		*VV OPEN*		
7.04		*MPV CLOSED*		
7.05		Unplug Extension Cord and Data Aqc USB		
7.06		Verify all valves are in or return to default positions	MPV Closed	
7.07		Notice error message on MC		

7.08		Close all sessions (MC, Server, Data)		
7.09		Reboot ESB	changed state	
7.10		Perform Test Stand Pi and MC Start Sequence		
7.11		should remain CLOSED once connected.		
7.12		Perform Sequence		
7.13		Perform Data Acq Start Sequence		
7.14		Perform Reolink Start Sequence		
7.15		Confirm VVs OPEN, HIs CLOSED, MPV remain CLOSED		
8.00		**Total ESB Power Loss in Firing State**		
8.01		Firing Valve States:		
8.02		*HI OPEN*		
8.03		*VV CLOSED*		
8.04		*MPV OPEN*		
8.05		Unplug extension cord and Data Acq USB		
8.06		Verify all valves are in or return to default positions	OPEN, MPV CLOSED	
8.07		Notice error message on MC		
8.08		CLOSE all sessions (MC, Serve, Data)		
8.09		Reboot ESB	changed state	
8.10		Perform Test Stand Pi and MC Start Sequence		
8.11		should remain CLOSED once connected.		
8.12		Perform Sequence		
8.13		Perform Data Acq Start Sequence		
8.14		Perform Reolink Start Sequence		
8.15		Confirm VVs OPEN, HIs CLOSED, MPV remain CLOSED		

9.00		**Igniter Fails to Ignite**		
9.01		CLOSE HI's		
9.02		OPEN Vents		
9.03		Confirm MPV's are set to CLOSE		
9.04		Valve Safety ON		
9.05		Igniter OFF and box unpowered		
9.06		If safe to approach test stand, CLOSE He Supply		
9.07		Inspect Igniter and replace		
9.08		Restart pre-terminal sequence once people are safetly away		
9.09		**If unsafe, perform dump sequence:**		
9.10		Ensure dumping is safe with Carl		
9.11		Dump MPV tank if MPV Valve can open at higher pressure		
9.12		Ensure enough time has passed since dump		
9.13		Dump frozen vent valve tank		
9.14		Inspect Igniter and replace		
9.15		Restart sequence at LOX Loading		
10.00		**HI Valve: No actuation**		
10.01		Attempt to close HI Valves. Verify their state.		
10.02		OPEN Vent Valves		
10.03		CLOSE or Verify HI Valves are in CLOSED position		
10.04		Verify Pressurant is at ~100 psi		
10.05		Troubleshoot Avionics		

Step #	Callout	Step Description	Notes/Comments	Check Box
1.00		**Both Tanks Full**		
1.01		Vent Valves confirmed OPEN	Check Camera/last command	
1.02		HI Valves confirmed CLOSED	Check Camera/last command	
1.03		MPV Valves confirmed CLOSED	Check Camera/last command	
1.04		Only Carl Tedesco and Designated Senior Engineer [Av4] are approved for this approach at SHF		
2.00		**One Tank Full**		
2.01		Vent Valves confirmed OPEN	Check Camera/last command	
2.02		HI Valves confirmed CLOSED	Check Camera/last command	
2.03		MPV Valves confirmed CLOSED	Check Camera/last command	
2.04		Dump CH4:		
2.05		*Only CH4 Valve state is to be actuated*		
2.06		*Verify with Carl Tedesco it is safe to dump*		
2.07		*OPEN CH4 MPV valve*		
2.08		*Wait for 5-30 min for all CH4 to empty and disperse*		
2.09		Only Carl Tedesco and Designated Senior Engineer [Av4] are approved for this approach at SHF		
3.00		**Pressurized Empty Tanks**		
3.01		Review tank depressurization procedure		

6 Hall Effect Sensor Mount

The purpose of this project was to develop a mount that housed a hall effect sensor and connected it to a rotary actuator. The hall effect sensor relayed the state of the valves on the rocket to the bunker to tell what state the rocket was in at any time.

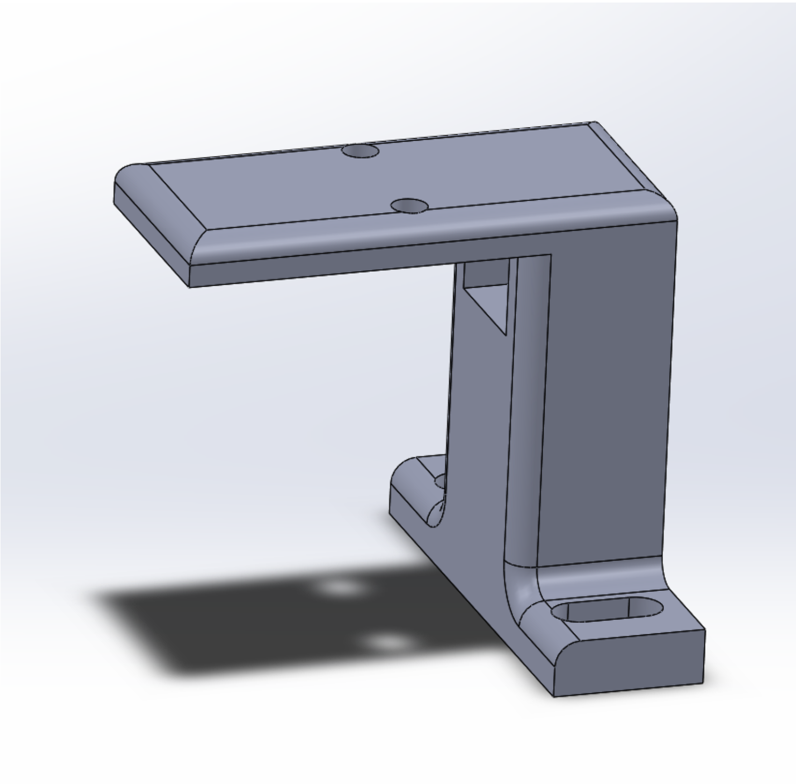

Figure 12: This is the CAD model of the part used to hold the sensor above the actuator.

Figure 13: This is me checking the fit of the part on the actuator before installing it.

7 Linear Actuated Telescoping Variable Intake System (LATVIS)

Designed with a team as a capstone project, this design was created to optimize the volumetric efficiency of the AR 20 Aztec Racing FSAE vehicle. I developed the controls and electronic system that read the RPM from the CAN line that went around the car and fed into a custom designed PCB that interpreted the CAN bus data and filtered for the RPM. It then used the RPM to calculate the optimum length of the intake and set the length of the actuator in real time.

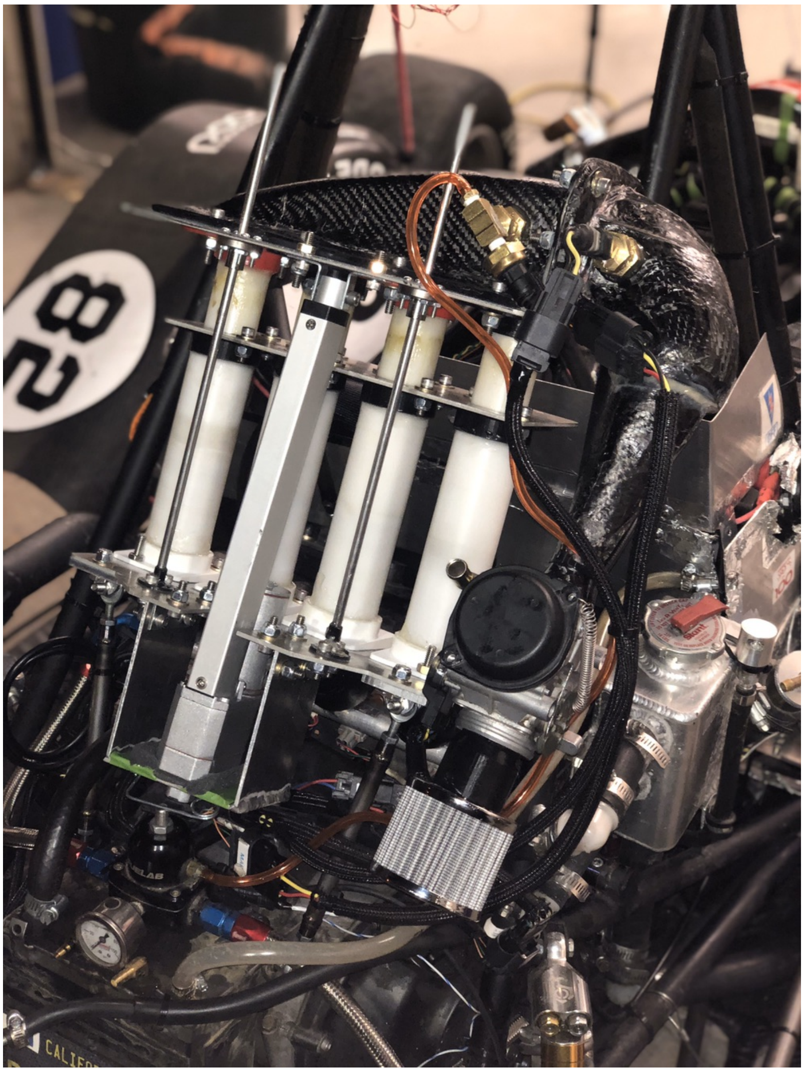

Figure 14: This is the assembly on the FSAE AR 20 Vehicle.

Figure 15: This is the assembly on the FSAE AR 20 Vehicle.

8 Static Interactive Display

The purpose of this project was to design a interactive display tool that simulated the CAN signal that was being sent over the FSAE aztec racing vehicle. During design day, the car could not be ran indoors to demonstrate the project so I created a box that simulated the CAN signal that the car would be transmitting to the box. The design being displayed was the LATVIS system as described above. The pontentiometer in the middle selected and displayed the RPM and corresponding determined length.

Figure 16: This is the Static Interactive Display tool with labeled notches.

9 CANVAS Project

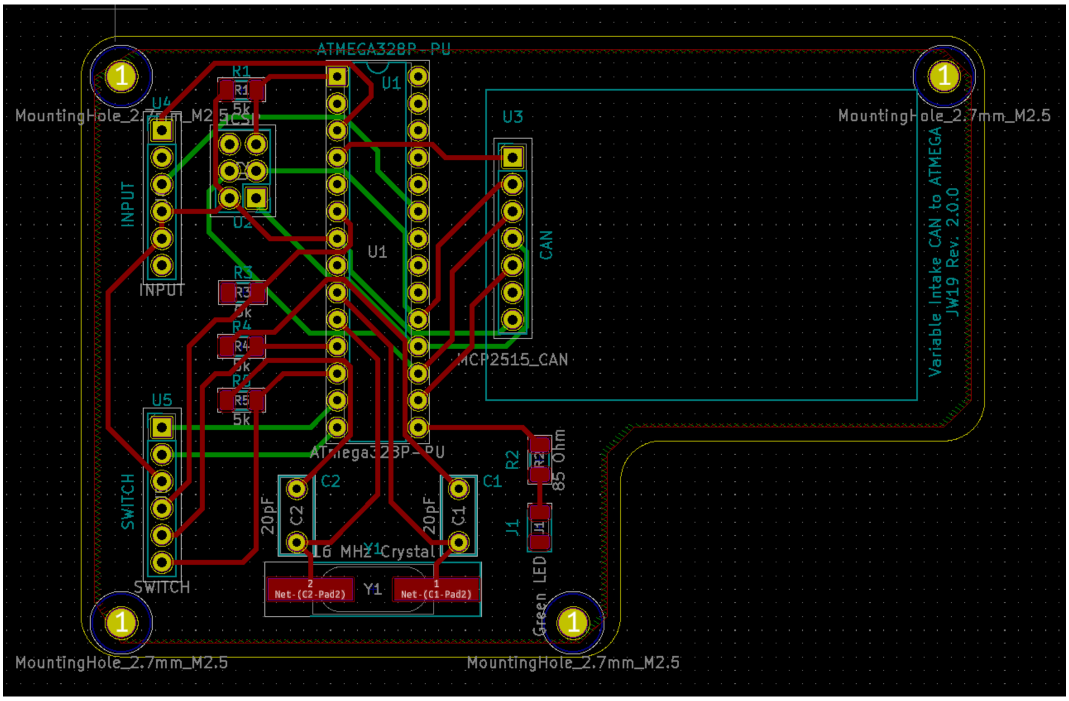

Figure 17: This is the CANVAS PCB in 2D done in KiCAD.

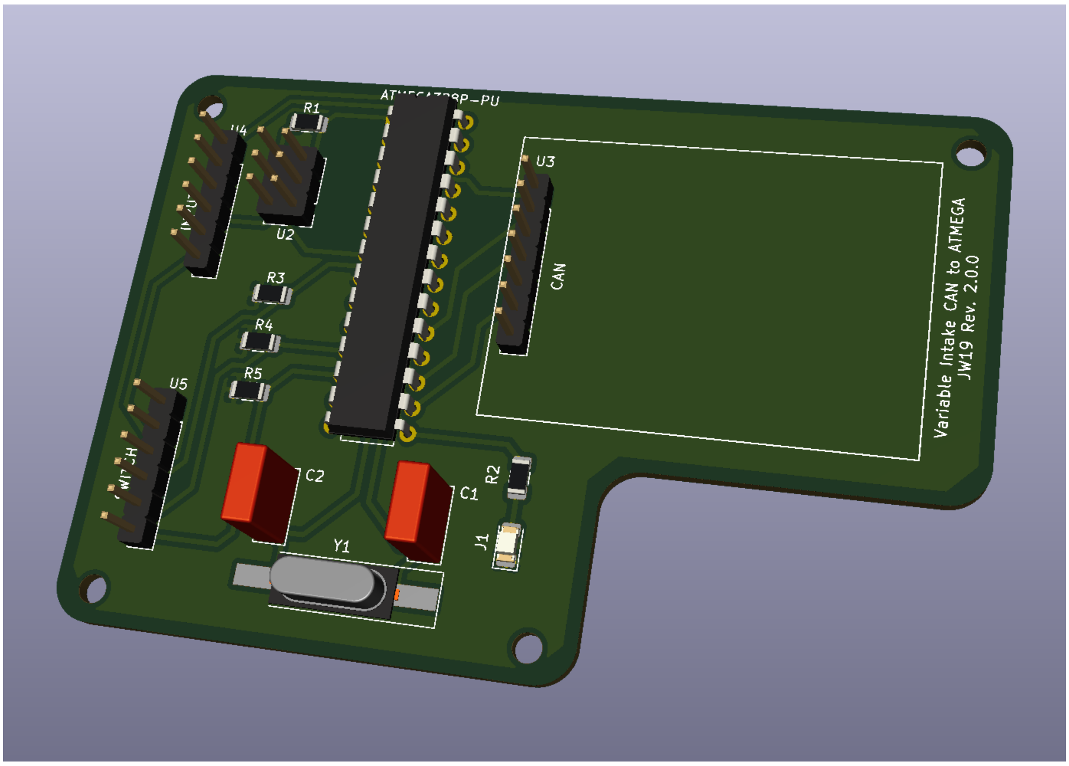

Figure 18: This is the CANVAS PCB in 3D done in KiCAD.

Linear Actuated Variable Intake System (LATVIS)

John Wiggins

December 2019

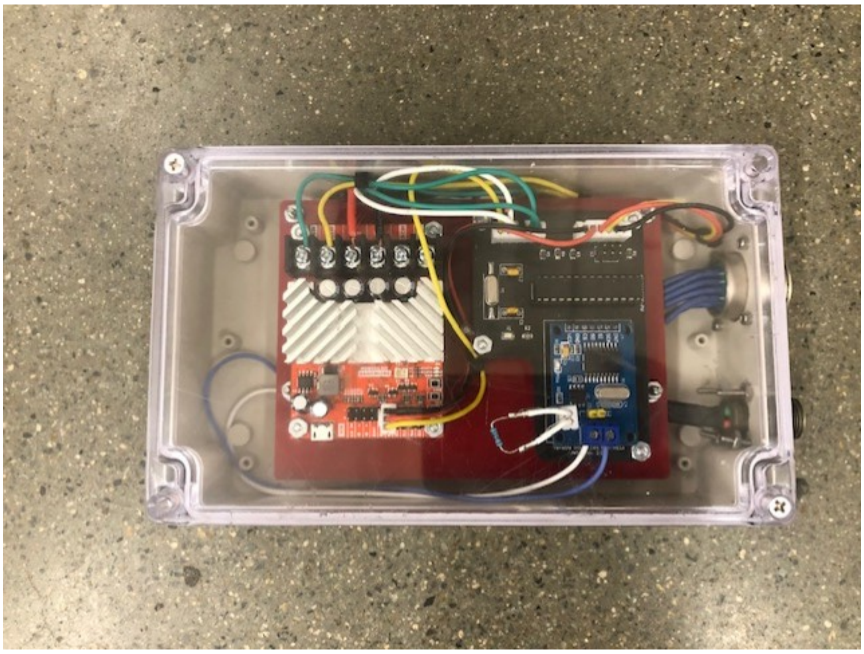

Figure 1: Electronics Housing Assembly

1 Introduction

The goals of this project were to develop a lightweight electronics housing system that could communicate via CAN bus. The RPM of the AR 20 vehicle would be then logged onto a microprocessor and converted to length, via the Helmholtz relationship between length and RPM.

2 Components

This project was split into two major subsystems. The first subsystem is the On-Board controller housing that lives in the Side-Pod. The second subsystem is the Simulated Interactive Display (SID) that allowed for tuning of the electronics system without the car running.

2.1 On-Board systems

The on-board system has two main components: The roboclaw motor controller and the custom CAN to SPI conversion Micro-Controller, known as CAN Variable Actuation System (CANVAS).

2.1.1 RoboCLaw

The RoboClaw motor controller controls the actuator's DC motor via a PWM signal from the CANVAS board.

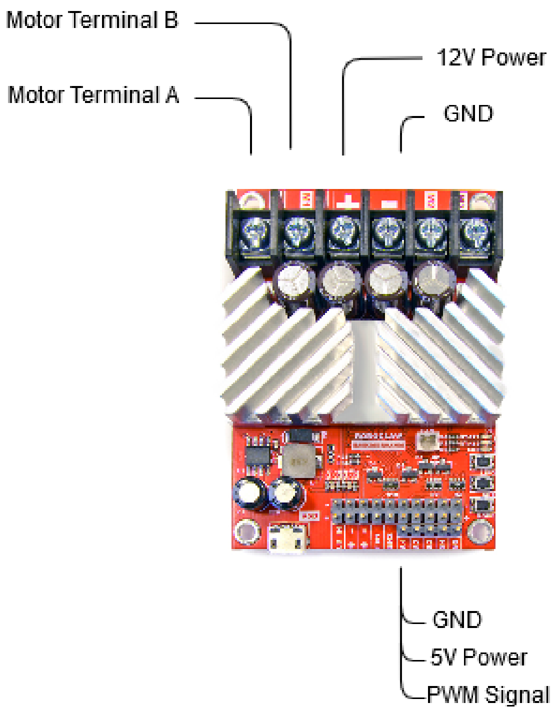

Figure 2: RoboClaw Project Wiring Diagram

These are a few notes about the modes and operation of the RoboClaw:

- The board is set to be in ANALOG MODE 3 for PWM interpretation.
- The board regulates the power for the CANVAS board down to 5V which is is the primary source of power for the board. It saved the project having to add an external voltage regulator or separate power source for the CANVAS board.
- The rapid indicator flashing notes that it is receiving signals.
- Do not attempt to use serial for communication with the RoboClaw for this project. There was success using serial, however, the CANVAS board was having trouble with dual serial communications and worked more reliably using PWM.

2.1.2 CANVAS PCB

The CANVAS PCB operates as the MCU for the on-board system. With an integrated CAN Bus converter, the board operates as the interface between the vehicle and the motor controller. For more information on the board, refer to the CANVAS PCB Design section.

Figure 3: CANVAS Board upon initial completion

3 CANVAS PCB Design

3.1 v0.0.1

The first version of the PCB was designed in Altium. The main goal of the board was to route the pins from the NiRen MCP2515 CAN to SPI PCB and to put 3 pull down resistors on the lines dedicated to switches. To program the board, the original idea was to flash it on a pre-set breadboard.

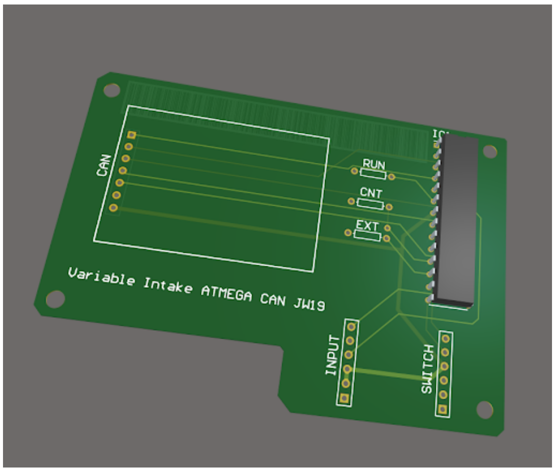

Figure 4: v0.0.1 of the CANVAS board

This board had a few issues. First, the terminals that are reserved for the switches were going directly to ground, not routed to the pins on the ATMEGA328P that is supposed to read low when active. Thus the pull down resistors were just connecting those terminals to ground directly, making that functionality null. The board also ran only at 8Mhz instead of the 16Mhz needed to use the arduino library to code. These issues were noted and prompted a v.1.0.0.

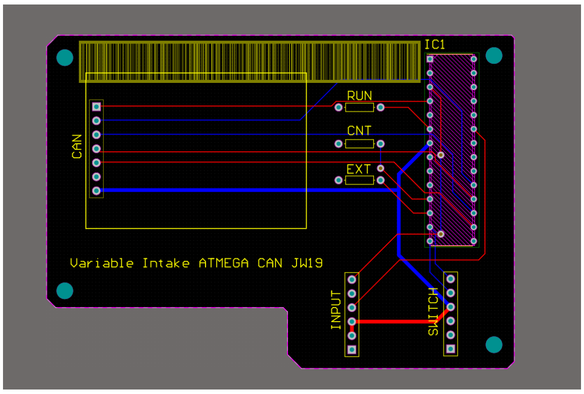

Figure 5: v0.0.1 of the CANVAS board

3.2 v1.0.0

This version of the board was designed using KiCad. The switch to KiCad was made to allow easier version control and use across multiple devices. All project files were backed up on GitHub.

This version presented a few large fixes:

- Addition of programming pin headder
- Reorientation of NiRen PCB to align CAN terminals with edge of board
- 16Mhz clock and corresponding 22 pF capacitors
- Indicator LED
- Handful of components turned to SMD footprints

These fixes allowed for a much more versatile board to be used for the project.

4 CAN Communication Notes

This section will go into detail on the CAN communication notes for this particular project. CAN communication within the few systems prooved itself to be a challenge and here are some notes that helped the project overcome these.

4.1 Parameters

The project parameters were found via sniffing the line with a Saleae Logic Analyzer and Motec documentation. Here are is a list of data points that were logged:

Motec Baud Rate	1 Mbps
Mask	0xFF
Channel	0x520
Type of CAN	Standard
Array Length	8
Byte to RPM Conversion Factor	x100

4.2 Hardware and Testing

The hardware use to convert the CAN signal to SPI was the NiRen MCP2515 Can breakout board. This board uses the MCP2515 chip as the main processing IC and allows for easy integration of the breakout board into any test system.

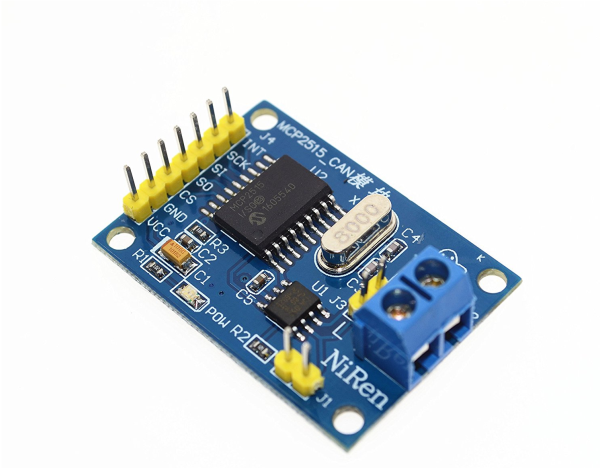

Figure 6: NiRen MCP2515 CAN Breakout Board

The first step that was taken was using the example code found on the MCP2515 Seeed-Studio library to verify the boards worked. The library can be found here on github. The set-up looked as the following:

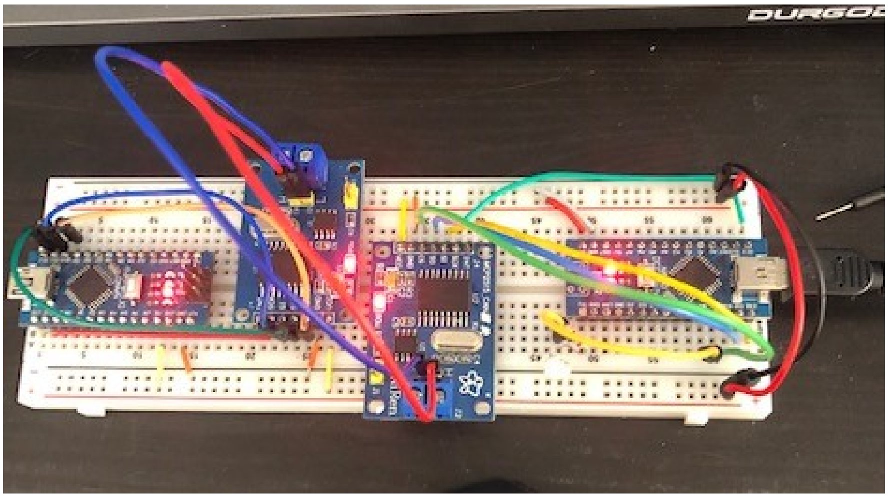

Figure 7: CAN Communication Test Setup

There were three errors that occurred with the setup in Figure 5 that needed to be adjusted in order to obtain communication between the two boards. The two notable changes were:

- **Terminating Resistor:** Add 120 Ohm terminating resistor to at least one side of the communication. It does not matter which side you add it to, however the system must have one to obtain communication. One was added to the board to ensure there was always one in the loop.
- **16 Mhz Clock:** In order to use the arduino MCP2515 Library, the boards require a 16 Mhz clock. The NiRen boards to not come assembled with one, but rather a 8 Mhz clock. Replacing the clock to a 16 Mhz clock solve this communication issue.

- **CAN Wires Have a Max Length:** During testing, a 5 ft long cable was used to test communication across the two boards, due to the distance between the test computer and the test bench. The signal could not complete this length without developing errors and a switch to a shorter length fixed this issue. According to the National Instruments website, at 1 Mbit/Sec, while the Bus Length can go up to 131 ft, the max Cable Stub Length, which is what this system is concerned with, is 1 ft. Thus, using an extended cable was not going to work and a shorter cable did resolve this issue.

After making these adjustments, the communication issues were resolved and the boards were able to send the sample messages across.

The next step was to test the CAN communication to the CANVAS board. This involved running jumpers to the boards CAN terminals and rewriting the buffer array to have all zeros except the 0-th byte, which contained anywhere between a 0 to 255.

$$\text{buf}[8] = [150, 0, 0, 0, 0, 0, 0, 0];$$

Multiplying this value by the RPM conversion factor of 100, converts, for example, a 42 to 4200, which would be the example RPM. Thus, sending a 150 would be 15000 which is close to the max value the vehicle would be sending and a good test value for a fully contracted verification of communication.

4.3 Library and Coding

The MCP Can library used had a few key functions that helped send/receive messages.

4.3.1 Receiving Messages

Below is an example of Receiving Messages that comes with the library. It covers the the main calls and setup of checking a received code. This was also the same code used to sniff the line on the AR-20 Vehicle and verify the data was being received. The code was slightly altered to reflect the parameters of the vehicle, using the masks and filters. Remove these and reset the baud rate for any system.

```
// demo: CAN-BUS Shield, receive data with check mode
// send data coming to fast, such as less than 10ms, you can use this way
// loovee, 2014-6-13


#include <SPI.h>
#include "mcp_can.h"                             //Initializes the Library


unsigned char Flag_Recv = 0;
unsigned char len = 5;                           //Defines the Length of the data
unsigned char buf[8];                            //Defines the size of the Array
char str[20];

MCP_CAN CAN(10);                                 //Set CS to pin 10

void setup()
{
    Serial.begin(500000);

START_INIT:

```

```
    if(CAN_OK == CAN.begin(CAN_1000KBPS))   //init can bus : baudrate = 1Mbps
    {
        Serial.println("CAN BUS Shield init ok!");
    }
    else
    {
        Serial.println("CAN BUS Shield init fail");
        Serial.println("Init CAN BUS Shield again");
        delay(100);
        goto START_INIT;
    }
    CAN.init_Mask(0,0,0xFF);                   //Sets the Mask to be 0xFF
    CAN.init_Mask(1,0,0xFF);                   //Sets the Mask to be 0xFF
    CAN.init_Filt(0,0,0x520);                  //Filters for 0x520 Address
}


void loop()
{
  int canId = CAN.getCanId();
  if(CAN_MSGAVAIL == CAN.checkReceive())       // check if data coming
    {
            CAN.readMsgBuf(&len, buf);         // read data,  len: data length, buf : data buf
            Serial.print(buf[0]);              //Prints the first indicies
            Serial.print("\t");
            Serial.println();
            return;
    }
}
```

4.3.2 Sending Messages

Below is an example of Sending Messages that also is accompanied with the library. It displays the structure on sending a test code that was used to simulate the signal from the vehicle.

```
// demo: CAN-BUS Shield, send data
#include <mcp_can.h>
#include <SPI.h>

MCP_CAN CAN(10);                                        // Set CS to pin 10

void setup()
{
    Serial.begin(115200);

START_INIT:

    if(CAN_OK == CAN.begin(CAN_1000KBPS))                    // init can bus : baudrate = 500k
    {
        Serial.println("CAN BUS Shield init ok!");
    }
    else
    {
        Serial.println("CAN BUS Shield init fail");
        Serial.println("Init CAN BUS Shield again");
        delay(100);
        goto START_INIT;
    }
}
```

```
void loop()
{
  unsigned char stmp[8] = {250,5,25,155,0,0,0,0};
    // send data:  id = 0x00, standrad flame, data len = 8, stmp: data buf
    CAN.sendMsgBuf(0x540, 0, 8, stmp);
    Serial.println(stmp[0]);
    delay(100);                       // send data per 100ms
}
```

4.4 Noise in the Line

During the testing phase, a distict amount of noise was found on the line. The noise was repeating and allowed for a 1 line fix of the code, that filtered out the values. If the system read one of these 4 values, it read the message again and took that value as the input. The following are the before and after filter graphs generated from the data.

5 Static Interactive Display (SID)

One of the goals during the design phase of this system was to generate a simulated CAN bus signal that the on-board housing would interpret identically as the messages received from the Motec ECU. Originally, a simple breadboard set-up was planned, connecting the terminals of the on-board housing with the terminals on the breadboard. However, since the testing environments were going to be dynamic, a more robust system was called for. Thus the idea of the Static Interactive Display (SID) was generated. The goals of the project were as follows:

- Have an interactive display piece for the design presentation that moved the actuator.
- Have a setting that shows the full extension of the system.
- Have a setting that shows the full contraction of the system.
- Be in a sturdy and robust travel case.
- Be able to clip into the same CAN bus terminals that come from the on-board system.

The housing was chosen from the inexpensive Pelican-like-Case's from Harbour Freight ($20 vs the $150+ name brand boxes) and

6 System Requirements and Constraints

6.1 System Requirements

System Requirements were assigned by the main purpose of this experiment and design, to optimize the volumetric efficiency of an internal combustion engine using a variable length intake control system. For this design, the system requirements were as follows:

- The size of the actuation needed to fit within the competition vehicle envelope.
- The actuator needed to push a minimum of 15 lb-f.
- The whole system needs to be as lightweight as possible.

- The system needed to respond to the RPM autonomously.
- The system needed to shut off via the main vehicle power safety switch.

6.2 Vehicle Constraints

Along with the requirements, the system needed to be compliant with the vehicles physical and electrical constraints:

- The system needed to be powered by the 12V coming from the on-board battery.
- The actuator needed to read the RPM from the Motec System Can BUS.
- The system needed to use the 0x520 Hex address for the RPM CAN message.
- The CAN bus needed to keep the CAN loop closed and not effect the current configuration.

7 Manufacturing

The assembly of this PCB was done in house. The PCB was made at JLCPCB and hand soldered by myself. It took about 3-4 tries to get the PCB manufactured and cleaned the way I was looking for. More information to be updated here in a future push on the techniques used.

8 Operation

In order to operate the system safely, please follow these steps on powering up, powering down, and controlling the system.

8.1 Powering Up

8.1.1 Normal Driving Operation (NDO)

Normal Driving Operation (NDO) is used when vehicle is to be driven around.

1. Verify all connections are secure on the vehicle (Under-Dash CAN, Actuator Clip, and Side-Pod Terminals).
2. Turn the power safety clip on the drivers right hand side of the vehicle to the ON position.
3. Wait for power on sequence. (NOTE: Actuator will move to lowest position).
4. System is ready to drive.

8.1.2 Bench Power and Simulated RPM

Bench Power is for when the vehicle is static and power does not want to be drained from on-board battery. To move actuator, use of the SID will be needed.

1. Lift and secure Side-Pod on the side of the vehicle.
2. Remove screws from top acrylic cover of actuator casing.
3. Remove the 2-Prong Power connectors to the vehicle on the lower left side of the casing. This keeps the rest of the vehicle from getting power and turning on the built in CAN bus system from the Motec ECU.
4. Verify bench power supply is *NOT* connected to the vehicle.
5. Turn ON bench power supply and verify the output voltage is set to 12V.
6. Turn OFF bench power supply.
7. Reach under dash and disconnect CAN bus terminals.
8. Connect the CAN bus terminal going to the sidepod to the SID CAN bus line.
9. Connect the power and ground terminals of the Roboclaw to the bench power supply.
10. Connect the SID to power via Mini USB.
11. Power on bench power supply.
12. Wait for startup sequence.
13. System is ready to simulate.

8.2 Powering Down

8.2.1 Normal Driving Operation (NDO)

To power down, turning off power to the vehicle will shutdown the system immediately.

NOTE: If the operator wishes the actuator to go to the fully contracted position, power cycling the car will trigger the boot up sequence, which sets the actuator to the fully contracted position. Do NOT turn the vehicle back on once it is in this position as it will move the actuator automatically to the the optimized intake length for the given RPM.

8.2.2 Bench Power and Simulated RPM

1. Move the actuator to the fully contracted position, for storage and quality maintenance of actuator.
2. Power off the bench power supply. This guarantees the actuator is no longer able to move.
3. Power off the SID.
4. Reconnect the dash CAN bus clip to the built in vehicle terminal.
5. Reconnect the Side-Pod housing to the built in vehicle power terminals.
6. Verify all connections are restored for driving operation and close and secure Side-Pod.

8.3 Control via Static Interface Display (SID)

For operating the SID, please follow these steps.

8.3.1 Boot Up Sequence

The SID has a boot up sequence that initialized the CAN bus inside the box. When the boot is set, the LCD monitor will display that the CAN bus has been initialized. Press the MODE button to move into the operating modes. The indicator LED will begin to glow to reflect the current user mode.

8.3.2 RPM Tuning

The RPM Tuning mode is controlled by the potentiometer in the middle of the base panel. The RPM is displayed on the LCD as well as the intended length and position of the actuator. This mode will run until the MODE button is pressed, indicating the mode to jump out of it's loop and upon a second press of the MODE button, will move onto the next MODE of operation.

8.3.3 Fully Extended

Fully Extended mode moves the actuator to the longest length the on-board Side-Pod housing controller allows. Upon arrival at this location, the user can press MODE again to jump out of the movement of the actuation and upon a secondary press, can change to the next MODE.

NOTE: Do NOT click the MODE button while the actuator is moving. This will lock the movement of the actuator causing it to over extend and could damage the machine. Currently working on fixes for this issue, however for the time-being, please be aware of this and use with caution.

8.3.4 Fully Contracted

Fully Contracted mode move the actuator to the shortest length the on-board Side-Pod housing controller allows. Upon arrival at this location, the user can press MODE again to jump out of the movement of the actuation and upon a secondary press, can change to the next MODE.

8.3.5 Range of Actuation Demo

The Range of Actuation Demo allows for the demonstration of the continuous range of motion the actuator allows. This mode will toggle between fully extended and fully contracted.

NOTE: To move on from this mode, hold the MODE button down until the actuation changes direction then quickly press the MODE button a second time to move onto the next position in the loop of Modes.

9 Coding

The coding for this project was done in C. I used atmel studio to write and flash the programs onto the PCB. The biggest challenge was identifying the lines in the code to initialized the clock speed that the PCB was going to be running at. The examples of the written code are below.

10 Appendix

10.1 On-Board Code

```
//Define the clock speed
#define F_CPU 16000000UL

//Included libraries and header files
#include <avr/io.h>
#include <util/delay.h>
#include "Servo.h"
#include "Arduino.h"
#include "SoftwareSerial.h"
#include "RoboClaw.h"
#include "SPI.h"
#include "mcp_can.h"

SoftwareSerial serial(10,11);       //Defines the SoftwareSerial class "serial"
Servo claw;            //Defines the servo class "claw"

//LED Pint and PinMode initializing of variables
int ledPin = 9;
float val = 0;
int valPerc = 0;
int potPin = A0;
float pos = 0;
int threshold = 1;
float setPoint = 0;
int spiCSPin = 10;
float raw;
int motor = 6;              //PWM pin is pin 6

MCP_CAN CAN(spiCSPin);          //Defines the class CAN as the can bus name and set it to transcieve data via SPI on the spiCSPin == pin 10

void setup() {
  claw.attach(motor);       //Defines the servo class claw
  serial.begin(38400);        //Begins the serial connection
  pinMode(ledPin, OUTPUT);      //Initializes the ledPin to be an output
  pinMode(potPin, INPUT);       //Defines the potentiometer pin as an input
  pinMode(motor,OUTPUT);        //Defines the pin connecting the PCB to the Roboclaw (PWM channel, in the servo class claw) as output
  threshold = 10;          //Sets the threshold value to read in between
  while (CAN_OK != CAN.begin(CAN_1000KBPS)) { //Initializes the CAN connection at 1 Mbps
    Serial.println("CAN BUS Init Failed");
    delay(100);
  }
  Serial.println("CAN BUS Init OK!");   //Feedback that the CAN bus has been initialized (Requires 120 ohm terminating resistor)

  CAN.init_Mask(0,0,0xFF);      //Sets mask for CAN to read
  CAN.init_Mask(1,0,0xFF);
  CAN.init_Filt(0,0,0x520);     //Filters for channel 520

  claw.writeMicroseconds(2300);     //Sets the actuator to go full contraction on startup
  delay(7000);
}

void loop() {
```

```
  digitalWrite(ledPin, LOW);      //Set integrated PCB indicator LCD to low
  unsigned char len = 0;        //Initialized the length indicator
  unsigned char buf[8];       //Initialize the buffer array of size 8
  if(CAN_MSGAVAIL == CAN.checkReceive()) {  //Run the check on the CAN bus line. It verifies that signal is being received
    CAN.readMsgBuf(&len, buf);    //Saves the length of the data to integer 'len' and the data array to the buffer array 'buf'
    unsigned long canId = CAN.getCanId(); //Reads each CAN address and assigns it to the unsigned long val canId
    val = analogRead(potPin);   //Reads the voltage of the potentiometer and assigns it a value between 0 and 1023
    pos = val;         //Gets the position of the actuator by mapping the value read from the potentiometer between 0 in to 8 in
    raw = buf[0];       //Stores the value at indices 0 of the buffer array to the integer 'Raw'
    //raw = 127;
    setPoint = map(raw, 0, 255, 0, 530);  //Remaps the read value from the buffer indices to read as a length that maximizes at the maximum actuation length of the system
  }
              // TODO: Replace Bang-Bang control loop with PID
  //setPoint = rpmL(raw);       // TODO: Update to reflect relationship of RPM to inches. Remove above setpoint when this change occurs.

  //Begin Bang-Bang control loop
  if (pos >= (setPoint - threshold) && pos <= (setPoint + threshold)) { //If read length is inside the threshold, send 1500 == STOP
    claw.writeMicroseconds(1500);
    delay(50);
    Serial.print(pos);
    digitalWrite(ledPin, HIGH);
  } else if (pos > (setPoint - threshold)) {  //If it is greater than the setPoint, go backwards at full speed
    claw.writeMicroseconds(2300);
    delay(50);
    Serial.print(pos);
  } else if (pos < (setPoint + threshold)) {  //If it is greater than the setPoint, go forwards at full speed
    claw.writeMicroseconds(1000);
    delay(50);
    Serial.print(pos);
  }
}

/* void rpmL(raw){
  float rpm = map(raw, 0, 255, 0, 15353);
  float inch = rpm/10000;       // TODO: Replace with the correct relationship to RPM
  int digi_inch = map(inch, 0, 8, 0, 1023);
  return digi_inch;

} */
```

10.2 SID Code

```
#include <SoftwareSerial.h>
#include <SPI.h>
#include <mcp_can_dfs.h>
#include <mcp_can.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

```

```
int demo = 5;
int contr = 4;
int ext = 6;
int potPin = A0;
int spiCSPin = 10;
int val = 0;
unsigned char pos = 0;
const int btn = 2;
const int tuning = 3;
int selector = 0;
boolean isPressed = false;
unsigned char buf[8];

SoftwareSerial serial(10,11);
LiquidCrystal_I2C lcd(0x27,16,2);                         //I2C address of 0x27
MCP_CAN CAN(spiCSPin);                                    //Initializes the CAN pin to be spiCSPin = pin 10

void setup() {
  lcd.init();                                             //Initialize the library to use the LCD
  lcd.backlight();                                        //Turns on the backlight on the screen (optional)
  lcd.home();                                             //Sets the cursor home location
  Serial.begin(38400);                                    //Sets the baud rate of the serial communication
  pinMode(btn, INPUT_PULLUP);                             //Sets the button pin to be an input with a pull up
  pinMode(tuning, OUTPUT);                                //Sets the tuning pin as an output
  pinMode(ext, OUTPUT);                                   //Sets the ext pin as an output
  pinMode(contr, OUTPUT);                                 //Sets the contr pin as an output
  pinMode(demo, OUTPUT);                                  //Sets the demo pin as an output
  pinMode(potPin, INPUT);                                 //Sets the potentiometer pin as an input
  while (CAN_OK != CAN.begin(CAN_1000KBPS)) {             //Sets the baud rate for the CAN bus to be 1Mbps
    lcd.print("CAN BUS Init Failed");                     //Provides feedback to the LCD to print
    delay(100);                                           //Slows down the print speed so it is readable
  }
  lcd.print("CAN BUS Init OK!");                          //Feedbacks that the initialization is set
}

void loop ()
{
  if (digitalRead(btn) == LOW && isPressed == false )     //Button is pressed AND this is the first digitalRead() that the button is pressed
  {
    isPressed = true;                                     //Set to true, so this code will not run again until button released
    doSwitchStatement();                                  //A call to a separate function that performs the switch statement and subsequent evoked code
    selector++;                                           //This is done after the doSwitchStatement(), so case 0 will be executed on the first button press
    if (selector > 3) {                                   //Resets the selector
```

```
    to go back to 0 after it gets to 3
      selector = 0;
    }
    // selector = (selector+1) % 4;                          // does the same, without if-statement (Alternative suggested method)
  } else if (digitalRead(btn) == HIGH)                       //If the button is not pressed, it will read high
  {
    isPressed = false;                                       //button is released, variable reset
  }
}

void doSwitchStatement() {                                   //Sets up the switch statments to select between the cases (Settings on the device)
  switch(selector) {
  case 0:                                                    //Runs the RPM Tuning Mode
    digitalWrite(contr, LOW);                                //All the subsiquent LOW settings are to turn off LED's for each mode. Without it, all LED's will slowly turn on as modes are toggled
    digitalWrite(demo, LOW);
    digitalWrite(ext, LOW);
    digitalWrite(tuning, HIGH);                              //Sets the tuning pin HIGH
    lcd.clear();                                             //Clears the LCD
    delay(250);
    doRun();
    break;
  case 1:                                                     //Fully Extends the actuator
    digitalWrite(contr, LOW);
    digitalWrite(demo, LOW);
    digitalWrite(ext, HIGH);
    digitalWrite(tuning, LOW);
    lcd.clear();
    lcd.print("Fully Extended");
    delay(250);
    doExtend();
    break;
  case 2:                                                      //Fully Contracts the actuator
    digitalWrite(demo, LOW);
    digitalWrite(ext, LOW);
    digitalWrite(tuning, LOW);
    digitalWrite(contr, HIGH);
    lcd.clear();
    lcd.print("Fully Contracted");
    delay(250);
    doContract();
    break;
  case 3:                                                       //Runs the boundary demo of the actuator
    digitalWrite(ext, LOW);
    digitalWrite(tuning, LOW);
    digitalWrite(contr, LOW);
    digitalWrite(demo, HIGH);
    lcd.clear();
    lcd.print("Boundary Demo");
    delay(250);
    doDemo();
    break;
```

```
  }
}

void doRun(){
      do {                                                         //Runs the RPM loop 10,000 times, unless the button is pressed
          val = analogRead(potPin);

          pos = map(val, 0, 1023, 0, 255);                         //
          unsigned char buf[8] = {pos,0,0,0,0,0,0,0};
          CAN.sendMsgBuf(0x520, 0, 8, buf);

          lcd.setCursor(0,0);
          lcd.print("RPM: ");
          float  RPM_Test = map(pos, 0, 255, 15350, 0);
          lcd.print(RPM_Test);

          lcd.setCursor(0,3);
          float len = map(val, 0, 1023, 0.000, 5.000);
          lcd.print("Length: ");
          lcd.print(len);
      } while (digitalRead(btn) == HIGH);
  return;
}

void doExtend(){
  do{
  unsigned char buf[8] = {255,0,0,0,0,0,0,0};
  Serial.print(buf[0]);
  CAN.sendMsgBuf(0x520, 0, 8, buf);
  lcd.setCursor(0,3);
  lcd.print("Length: 5in    ");
  } while (digitalRead(btn) == HIGH);
  return;
}

void doContract(){
  do{
  unsigned char buf[8] = {0,0,0,0,0,0,0,0};
  CAN.sendMsgBuf(0x520, 0, 8, buf);
  lcd.print(buf[0]);
  lcd.setCursor(0,3);
  lcd.print("Length: 0in    ");
  } while (digitalRead(btn) == HIGH);
  return;
}

void doDemo(){
  do{
    unsigned char buf[8] = {255,0,0,0,0,0,0,0};
    Serial.print(buf[0]);
    CAN.sendMsgBuf(0x520, 0, 8, buf);
    lcd.setCursor(0,3);
    lcd.print("Length: 5in    ");
    if(digitalRead(btn) == LOW){
      return;
    }
    delay(3000);
    unsigned char buf_2[8] = {0,0,0,0,0,0,0,0};
    CAN.sendMsgBuf(0x520, 0, 8, buf_2);
    lcd.print(buf[0]);
    lcd.setCursor(0,3);
```

```
    lcd.print("Length: 0in     ");
    if(digitalRead(btn) == LOW){
      return;
    }
    delay(3000);
  }while(digitalRead(btn) == HIGH);
  home();
  return;
}

void home(){
  do{
  unsigned char buf[8] = {0,0,0,0,0,0,0,0};
  CAN.sendMsgBuf(0x520, 0, 8, buf);
  lcd.setCursor(0,3);
  lcd.print("Homing Actuator     ");
  }while(digitalRead(btn) == HIGH);
  return;
}
```

10 Little Devil Project

The little-devil is a custom designed printed circuit board that is designed with development in mind using the ATSAMC21G18 processor. The board offers standardized pin packages allowing for this board to act as a breakout board and direct communication with the main hardware. The PCB offers 3 optional power supply methods: 3.7V battery, 2 pin header, or micro USB.

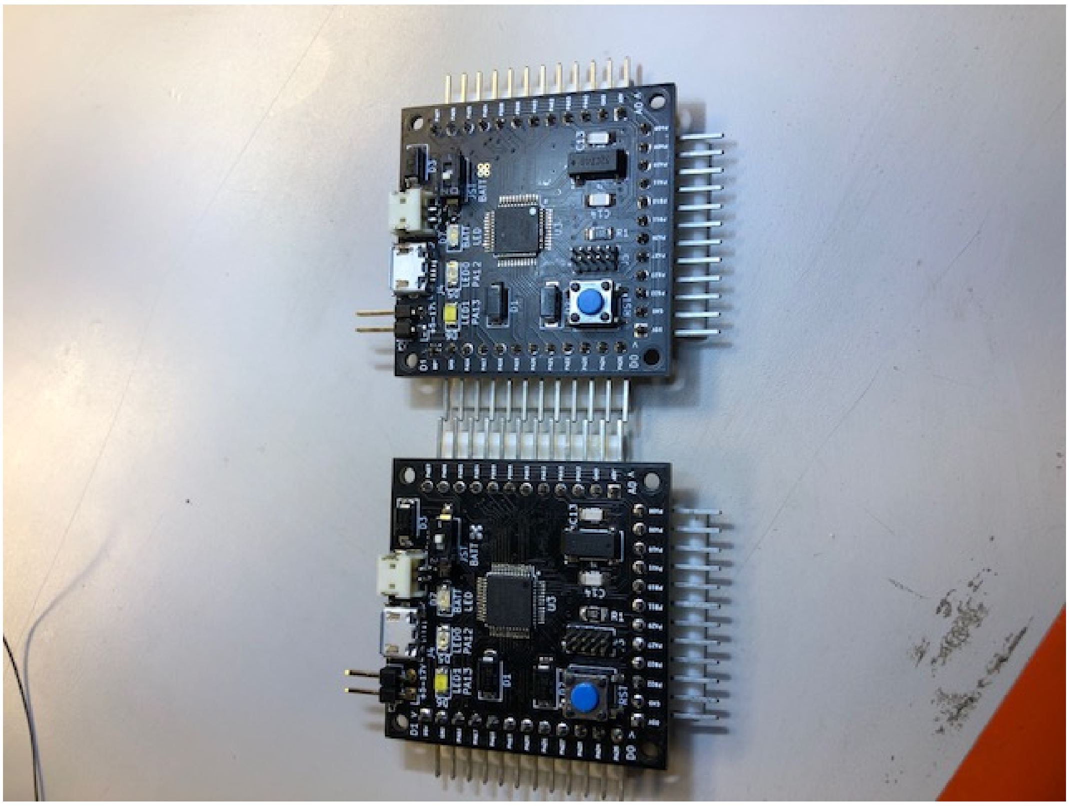

Figure 19: This is the competed board, both sides.

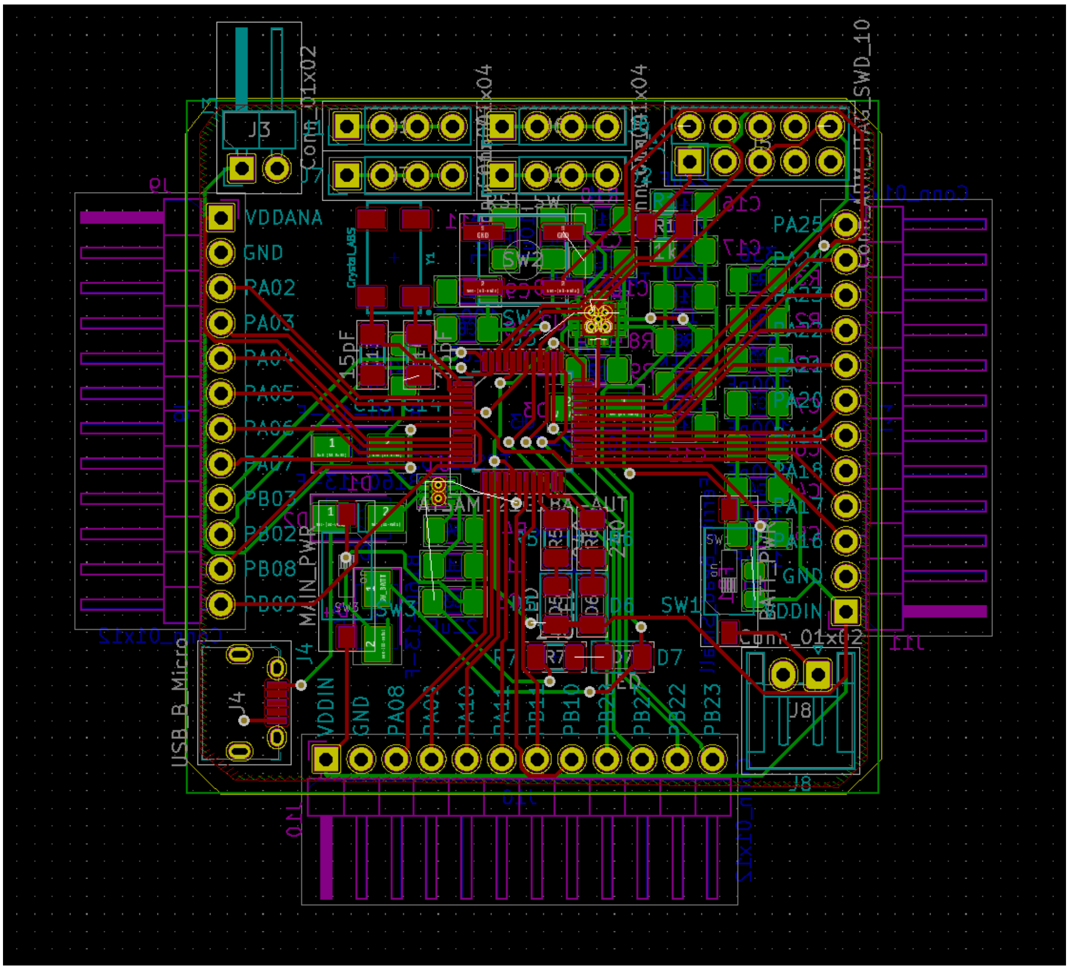

Figure 20: This is the KiCAD 2D layout of the board. It was designed in 2 layers.

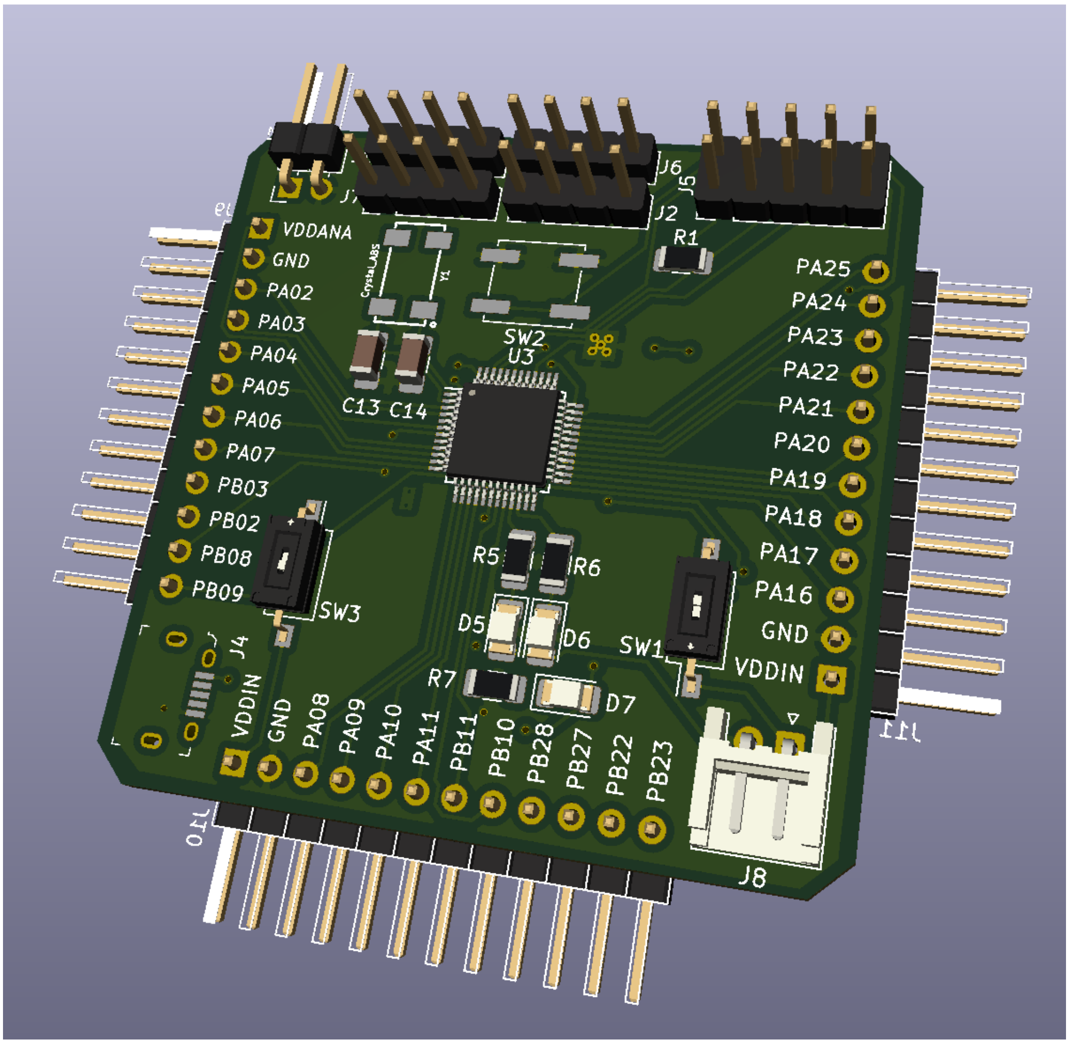

Figure 21: This is the KiCAD 3D rendering of the board.

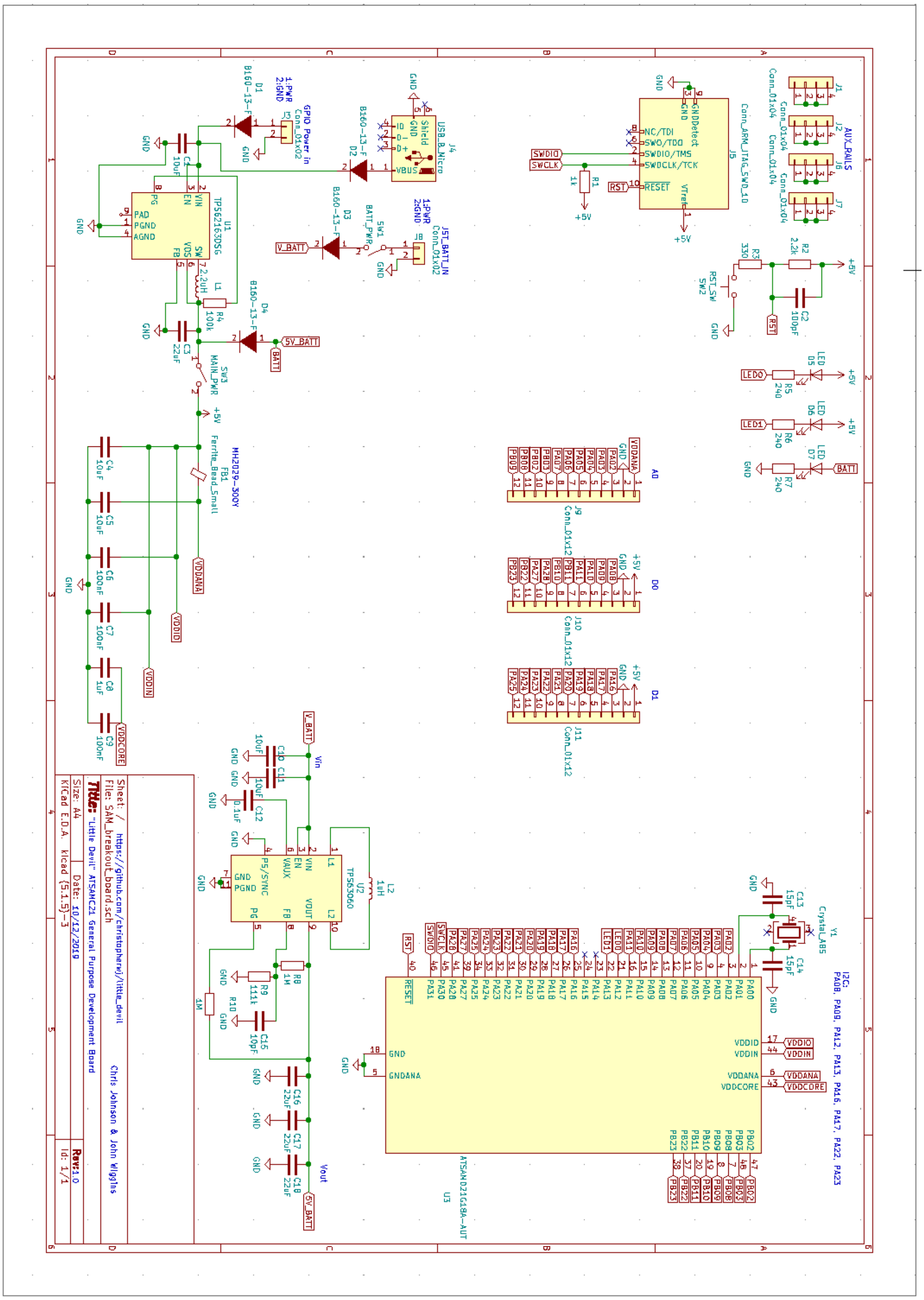

Figure 22: This is the KiCAD schematic of the board.

11 SPACE Lab: Turtlebot Project

I am currenting working on research on landing drones on moving platforms in the SPACE lab on campus. This is the current image and code of the setup being programmed. Not pictured yet are the drones landing on the platform. We are using parrot drones as our flying vehicles.

Figure 23: This is the SPACE lab turtle bot that I am currently coding.

```
close all;
clc; clear;
rosshutdown
ipaddress = '192.168.1.3';
rosinit(ipaddress);

%Set velocity
velocity = 0.1;
%resetOdometry(ipaddress);

%Create publisher
robot = rospublisher('mobile_base/commands/velocity');
odom = rossubscriber('/odom');
velmsg = rosmessage(robot);

velocity = 0.25;
i = 1;

%Set forward motion
velmsg.Linear.X = velocity;
Npts = 100;
    odomdata = receive(odom,3);
    pose = odomdata.Pose.Pose;
    x0 = pose.Position.X
    y0 = pose.Position.Y
waypoints = [x0-1 y0]; % [x y] in meters
dx = 100;
dy = 100;
tol = 0.01; % meter
Pos = [];
Vel = [];
Velx = 0;
Vely = 0;
Kx = 0.1;
Ky = 0.1;
figure('units','normalized','outerposition',[0 0 1 1])
%Send message in loop
while abs(dx) > tol || abs(dy) >tol
    odomdata = receive(odom,3);
    pose = odomdata.Pose.Pose;
    x = pose.Position.X;
    y = pose.Position.Y;
    odomList(i,:) = [x y];
    t1 = clock;
%       velmsg.Linear.X = Velx;
    velmsg.Linear.Y = Vely;

    send(robot,velmsg);
    dt = etime(clock, t1);
```

```
    odomdata = receive(odom,3);
    pose = odomdata.Pose.Pose;
    xn = pose.Position.X;
    yn = pose.Position.Y;

    Dx =  xn - x;
    Dy =  yn - y;
    Vx = Dx/dt;
    Vy = Dy/dt;

    Pos = [Pos; x y];
    Vel = [Vel; Vx Vy];
    i = i+1;
    grid on;
    plot(x,y,'-db'); hold on
    pause(0.008)

    dx = (xn - waypoints(1));
    dy = (yn - waypoints(2));

    Velx = -Kx*dx;
    Vely = -Ky*dy;

%      if abs(Velx)>1
%          Velx = Velx/abs(Velx);
%      end
%      if abs(Vely)>1
%          Vely = Vely/abs(Vely);
%      end
end

%Plot the data
Dx =  odomList(end,1) - odomList(1,1);
Dy =  odomList(end,2) - odomList(1,2);

Vx = Dx/Npts;
Vy = Dy/Npts;

speed = sqrt(Vx.^2+Vy.^2)
% figure;
% plot(odomList(:,1),odomList(:,2));

%plot(odomList(:,1), speed)
axis equal
clear tbot
```

12 Kero/LOX Rocket

This is my current project, I am designing a LOX/Kero rocket that will use a LR101 engine. This rocket's research will lie in the avionics. We plan to use FPGA's to control the terminal sequence and safety of the rocket. They will also log data as the flight occurs. This rocket looks to cost around $15,000

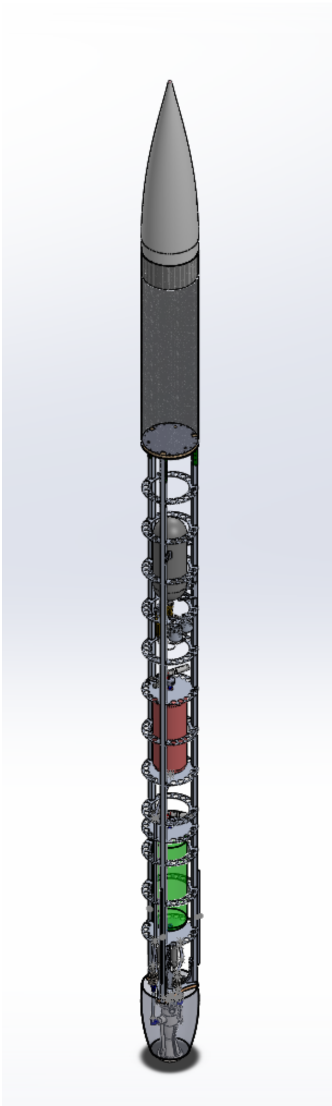

Figure 24: This is the current design of the "Sparky" rocket.

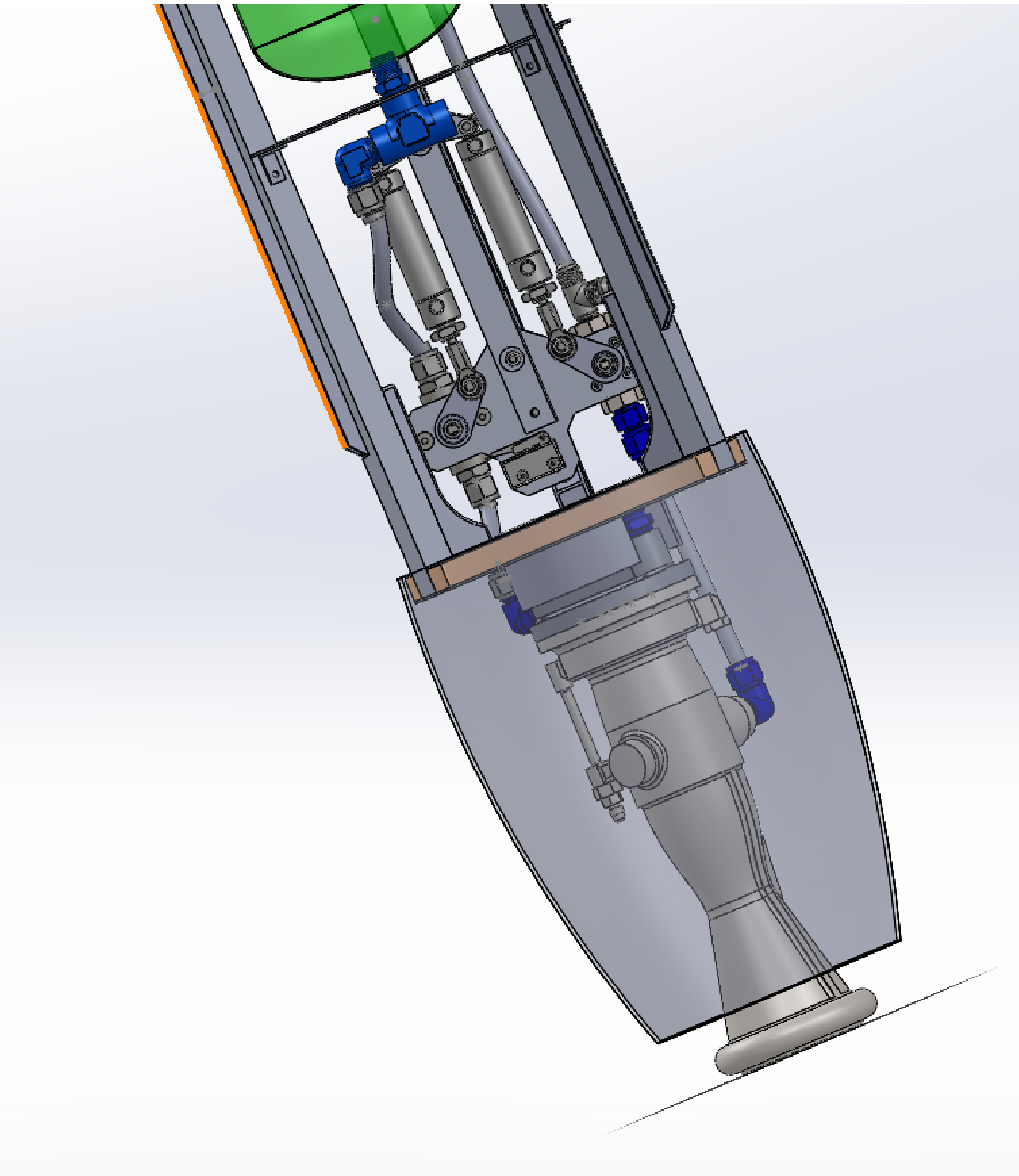

Figure 25: This is the Lower Airframe of the Sparky Rocket.