[RFS] E-3 Testing day(s)

What: E3 Cart Single Element CO2 flows

Where: RFS

Why is this critical?

- Need this data to place the order for the engine. The engine will be printed through one of our new sponsors, Addman. However, this sponsorship effectively expires after a year and not conducting these tests could ultimately lead to our team to not be able to take advantage of the full package of the sponsorship (worth $60k).
- Eureka-3 (Space Shot Rocket) project is on complete halt until then.

Goal:

- Collect data needed to determine injector orifice sizing for E-3, so design can be finalized for manufacture
- Validate orifice sizing simulations

Safety checks before then:

- total system leak check
- confirm all vent actuation (solenoids, emergency pneumatic vents, and slow remote vents)

Procedure:

- E-3 Template Procedures

General Logistics

Activity	Development CO2 single element flow of Eureka-3 cart • This test involves flowing a propellant substitute (CO2 instead of ethane/nitrous) through our system to collect performance data. • It is qualified as a development flow, given it will be for the purposes of data collection • Single element refers to using a ~1/60 scaled injector to calibrate flow rates at 1/60 the total performance of the system during an engine fire
Date	Monday Nov 20 - Tuesday Nov 21, 8am-5pm
Location	• System located in front of our RFS space • Only pad crew is allowed to approach the system during the first set of procedures. Once tank are pressurized, all personnel must be inside our RFS workspace, with the door closed shut. The system can be visually observed through our live camera system.

Operating staff	• 4 pad student staff (with EH&S training for pressure and cryo)
	  ◦ For operations before pressurization and fill
	• 4 dashboard student staff
	  ◦ Remotely checking the health of the system
	  ◦ Reading out procedures
	• Rest of the team helping with set up
	  ◦ Not operating with cylinders / cryogens / dashboard
	• Supervisors from COE and/or EHS
	  ◦ As many as recommended

Criteria for success	• Demonstrate CO2 fill procedures
	  ◦ Successfully fill CO2 to the expected 100% tank volume of 18L
	• Collect useful mass flow rate, temperature, and pressure data from both fuel-side and ox-side single element variants
	  ◦ Check data against simulations to compare reality to expectations and calibrate next tests accordingly
	• Test with at least 2 fuel-side single element orifices and at least 2 ox-side orifices
	  ◦ To get the most out of testing, use a total of 4 elements to get sufficient data with different injector geometries

Associated "hazards"	• High pressure gasses (GN2) • Compressed Liquids (CO2)
Summary of new safety measures	• No flammables, only CO2 will flow through our system • Presence of supervisor(s) • Standard work hours operations (8-5) • Safety reviews to verify our system and procedure before the actual test

Safety features overview

System / Team	Items

Avionics & Controls	• Procedure for filling, pressurization of tanks and flow automation sequence are **fully remote**
	• Ground station has 2 laptops running dashboard for redundancy, and dashboard is monitored by 2 or more people at all times
	• All system data (pressures, temperatures, continuity and current draw of actuators, status of actuators) is displayed on dashboard, in real time
	• All actuators on the system are controlled remotely through dashboard
	• Before using any pressure or cryogens with the system, we conduct a full checkout of every valve (tank vent solenoids, main valve solenoids, RBVs for fill, vents) and sensors (pressure transducers, motor encoders) on the system
	• Tank vent solenoids will automatically cycle to open and close if pressure in tanks exceeds maximums
	  ◦ Our tanks have been hydrotested to 900 & 1125 PSI, we vent at 600 and 750 psi
	• System has automated aborts:
	  ◦ In the case of tank overpressure
	  ◦ In beginning flow procedure
	• Avionics system has watchdogs, if communication is lost with the dashboard, vents will automatically open after 30 seconds

Propulsion	The propulsion system has numerous safe guards to keep personal safe. E3 Can be operated fully remotely. Once propellant bottles are opened, students can leave the system, and automation hardware will open and close valves to control the state of the system. CO2 Fill Procedures: Due to the way E3 works, we maintain pressures in the tank to keep our propellants at a certain temperature during fill. An automatically control loop controls this process, and monitors pressures in the system. This system does not have regulators designed to pressurize our propellants. They are allowed to warm up to approximately 600 and 850 PSI, and this causes them to flow. This means there is no risk of a regulator failure overpressurizing our tanks. In the case that our propellants warm up beyond expected operating temperatures and rise in pressure beyond acceptable limits, we have multiple systems in place designed to vent pressure. General System Hardware Safety • High flow rate COTS burst disks on system sized to exceed boil off rate of propellants at 100 degrees F • High flow rate COTS relief valves on system sized to exceed boil off rate of propellants at 100 degrees F • All lines operating at or below rated working pressure • Tanks operating at above rated pressure have been hydrotested and are only pressurized remotely

Pad	• **The system is fully remote. No pad team is necessary, except to initially open K bottles with CO2.**
	• The students wh do this will be wearing this PPE just in case.
	  ◦ Long sleeve anti-absorbent shirts
	  ◦ Googles and face shield
	  ◦ Cryo apron and gloves
	  ◦ Earplugs during fill
	  ◦ Note: we have additional PPE items for supervisors as needed
	• All pad crew staff has completed the EH&S cryo and high pressure training
	• All pad crew staff has completed similar procedures at least 20 times by now (around 14 cold flows and exactly 7 hotfires)

Procedure	E-3 Template Procedures