Agenda – Day 1

November 18, 2014 (Day 1)		
Time (CST)	**Topic**	**Presenter**
8:00-8:30 am	Registration, Welcome and Introductions	
8:30 – 9:15 am	History & Manufacture of EDU	Arthur Werkheiser
9:15 – 10:00 am	Multi-Layer Insulation (MLI)	Jessica Wood
10:00 – 10:15 am	BREAK	
10:15 – 11:30 am	Thermal Analysis of EDU	Tim Page
11:30 – 1:00 pm	LUNCH	
1:00 – 1:45 pm	Radio Frequency Mass Gauge (RFMG)	Greg Zimmerli
1:45 – 2:45 pm	Pressurization test results	Jonathan Stevens
2:45 – 3:15 pm	Fill model	Ali Hedyat
3:15 – 4:00 pm	Cryo Valves	Becky Crownover
4:00 – 4:20 pm	Liquid Acquisition Device (LADs)	Arthur Werkheiser
4:20 – 4:45 pm	TVS	Joe Zoeckler
4:45 – 5:00 pm	Success criteria & Wrap up	Arthur Werkheiser
	Adjourn to the Firehouse Pub	

Evolvable Cryogenics (eCryo) Project
Technology Workshop with Industry

Engineering Development Unit (EDU) Workshop

Success Criteria and Wrap-up

Arthur Werkheiser

Success Criteria
(Testing Score Card)

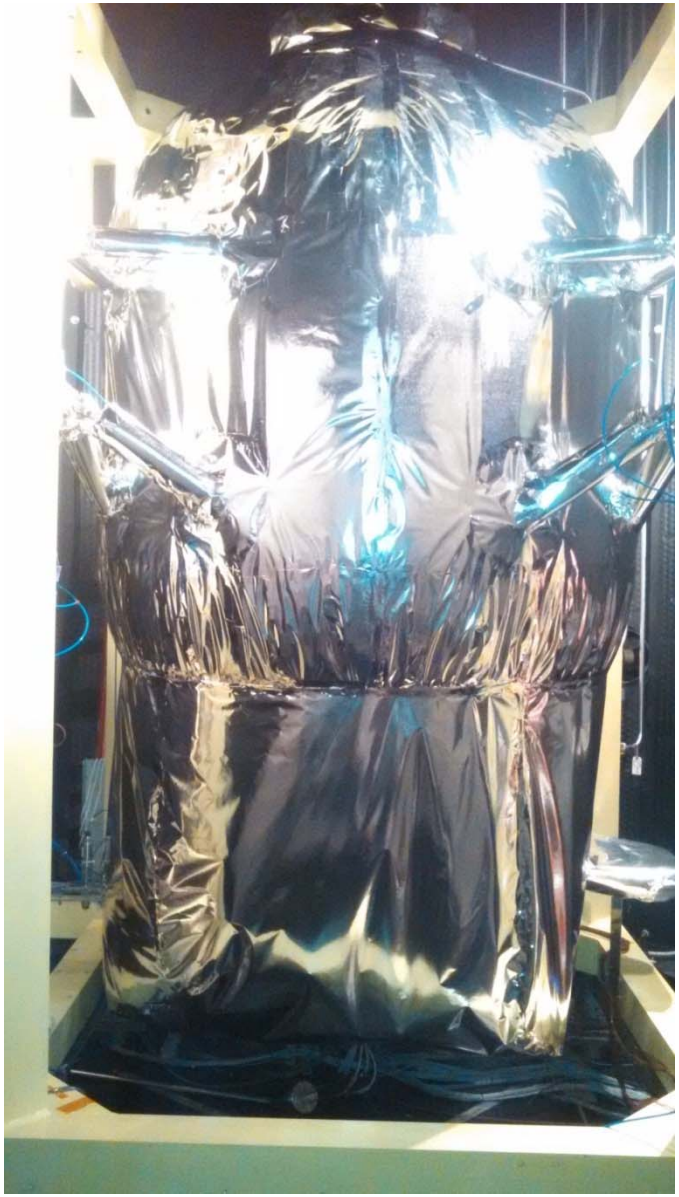
CPST – Cryogenic Propellant Storage and Transfer Project
(which has become)
eCryo – evolvable Cryogenics Project

Engineering Development Unit (EDU)

Arthur Werkheiser

October 2014

EDU and The Test Team



As Published – EDU LH2 Test Success Criteria

1. Safely load the EDU to 90% full with Liquid Hydrogen (LH2)
2. Operate Cryogenic Valves to manage the cryogenic fluid to mimic payload tank lockup mode
3. Evacuate TS300 chamber to vacuum conditions (1x10E-5 Torr or greater vacuum) with LH2 loaded
4. EDU Tank thermally reaches steady state conditions (- 0.5K change rate in 6hr)
5. Use Thermodynamic Vent System (TVS) to control (to a specified bandwidth) pressure in tank
6. Safely perform pressurization testing
7. Safely perform Liquid Acquisition Device (LAD) outflow testing
8. Conduct mass gauging measurements with Radio Frequency Mass Gaging Device (RFMG) and compare to liquid level information provided by temperature rake
9. Measure EDU Boil off for simulated on-orbit heat load
10. Data collection from above objectives

Evaluated – EDU LH2 Test Success Criteria

1. Safely load the EDU to 90% full with Liquid Hydrogen (LH2)

   Achieved – We filled to 90% 5x times: Test Day 1 (Jun 12) 17:16,

   Day 9/13:27, Day 14/09:45, Day 19/09:59, and Day 20/14:23

2. Operate Cryogenic Valves to manage the cryogenic fluid to mimic payload tank lockup mode

   Achieved – We had four valves, 1401, 1402, 1404 and 1444. They were used for Fill/Drain(01), AJ JT Flow(02), LAD JT Flow(04), He Press(44). The cryo-valves performed their function well. Becky will have more details.

3. Evacuate TS300 chamber to vacuum conditions (1x10E-5 Torr or greater vacuum) with LH2 loaded

   Achieved – This one took while. We spent most of the test in the low 1.3 to 1.5 x 10e-5 Torr. Which was good enough to break convective heating for our test but did not quite hit the measurement. We did get to 10e-6 once the tank was drained low. On Day 18/23:06 we measured 6.7x10e-6 Torr.

Evaluated – EDU LH2 Test Success Criteria

4. EDU Tank thermally reaches steady state conditions (- 0.5K change rate in 6hr)

Achieved – This one maybe up for some scrutiny. Tim Page is the expert. We did not have "Cold Walls" in the tank for EDU. This causes the environment to drag us around as the sun rises/falls. Therefore the time averaging had to be expanded past the 6hr mark. Tim Page did declare "steady state" or as close as we were going to get under the conditions on Thursday June, 19 (test Day 8) at 13:00.

5. Use Thermodynamic Vent System (TVS) to control (to a specified bandwidth) pressure in tank

Not Achieved (maybe a little) – There are three pieces…

LAD Joule-Thompson device, Axial Jet Joule-Thompson device and the Axial Jet Pump. Of those three, the only part that worked correctly, was the pump. We were able to control the ullage pressure (lower the pressure) with the pump and that was only once we had a Helium Ullage. The Axial Jet line was blocked. It actually flowed two times. The second time got to liquid temps after 45 minutes. It never flowed again after that. The LAD JT device never got cold enough to get liquid to the LADs even though we let it run overnight. It could not overcome the heat in the line.

Evaluated – EDU LH2 Test Success Criteria

6. Safely perform pressurization testing

Achieved – We did perform this testing more than was planned with both the submerged and non-submerged diffusers. Day 12: High Pressure, High fill level, Forward (HT-48, B & C [cold He]) and Aft (HT-51 &B [cold He]) diffuser. Day 13: High Pressure, Med fill level (40%), (HT-48D, 47E ,51C) Low Fill Level 22% (48F, 51D)

7. Safely perform Liquid Acquisition Device (LAD) outflow testing

Achieved – We had planned 4 tests and performed 5. Day 19/11:22 first Out flow using top diffuser, 19/13:44 2nd Out flow using top diffuser, 19/16:30 3rd Outflow using bottom diffuser, 20/10:34 4th Outflow using bottom diffuser, 20//15:03 5th Outflow using top diffuser. BONUS – Nucleation Boiling Test 19/10:24

8. Conduct mass gauging measurements with Radio Frequency Mass Gaging Device (RFMG) and compare to liquid level information provided by temperature rake

Achieved – The RFMG appeared (from my close interaction) to be very successful and accurate, as compared to the Temperature Rake, the Sierra Lobo CryoTracker and the Capacitance Probe. Dr. Greg will have more.

Evaluated – EDU LH2 Test Success Criteria

9. Measure EDU Boil off for simulated on-orbit heat load

Achieved – We were able to measure the Boil off during loading (twice!) 1/17:11) and during steady state (both steady states. Second Steady state may be the more accurate measurement as we had the flow meters figure out by then.)

10. Data collection from above objectives

Achieved – All data from all Test stand sensors was recorded at 1hz (or 10Hz for a short period) and uploaded to Windchill under the EDU Test folder. Also the Cryotracker, Customer Logs and Daily Summaries were uploaded to windchill as well. Due to the nature of the RFMG files (many), they did not lend themselves to windchill use. They were “zipped” and emailed to Dr. Zimmerli directly. Archiving will be his responsibility.

As Published – EDU LH2 Test Priorities (App I)

The following Test Objectives were developed in the last few weeks before the test; documented in App "I" of the Test Plan. They were developed by consensus from the EDU community, however, Maureen Kudlac and Chris Popp were some of the significant voices in creating the list and the priorities. Some of these objectives are data driven and will take more time (weeks/months) to evaluate success. Red means Not Achieved

A. Steady State Heat Load Performance

B. AJ/TVS Pressure Control

C. Pressure Rise Rate

D. Calibrated Heat Load

E. LAD Out Flow

F. Safely perform pressurization testing

G. Heat Load Due to Penetrations

H. Ghe Press on AJ/TVS

I. LADS TVS

J. Ground Heat Load during loading

K. Submerged/Dry Diffuser

L. Transient Heat Load

M. Facility Temps

N. TVS Clogging

EDU LH2 Test Priorities

A. Steady State Heat Load – Achieved. Tim Page is the owner of this Objective. He must be the declarant. We had two opportunities at this. The first opportunity was terminated inadvertently at test day 7/06:40. (June 18). The following day, Tim chose to declare “steady state”. We were able to pursue steady state again (second time) from Day 14/10:15 to 19/09:35 (5 full days) due to the TVS failure.

B. AJ/TVS Pressure Control – Not Achieved. There are three parts to TVS. The first is the Axial Jet. The Axial Jet Joule-Thompson line was blocked. It did work on the initial check out, but not long enough to get to liquid temps. Day 1/18:34. It worked one more time after that and did get to liquid at 45 minutes. It never worked again after that time. The second, the LAD Joule-Thompson line, was run over 12 hours and never got down to liquid temps. The third, the Mixing Pump, was quite a story. We spent 2 or 3 days troubleshooting and finally got it working with the “old” Sumitomo pump controller, but without the JT cooling, it was not very effective. Maureen was here for the troubleshooting and the one day of operations.

EDU LH2 Test Priorities

C. Pressure Rise Rate – Achieved. We did this a few times. Test day 9/21:35 (no Helium in system). Test day 19/18:00 Let rise over night from Ambient to 28 PSIA (helium in system, Fill level 34%).

D. Calibrated Heat Load – Not Achieved. The Heater worked during the Nitrogen testing and checkouts prior to the actual introduction of Liquid Hydrogen. During the initial tanking however, the Heater showed a continuity issue.

E. LAD Out Flow – Achieved. 5 tests performed. General Conclusion: The Aft Diffuser allowed the Pressurizing Helium to become cold enough such that a significant column of liquid could be held in the LAD. If the Forward Diffuser was used, the Ullage gas was too warm (over 200K) to allow any significant Column to be supported, even if a liquid Nitrogen intercooler was used to pre-chill the Helium

F. Safely perform pressurization testing - Achieved – We did perform this testing more than was planned with both the submerged and non-submerged diffusers. Day 12: High Pressure, High fill level, Forward (HT-48, B & C [cold He]) and Aft (HT-51 &B [cold He]) diffuser. Day 13: High Pressure, Med fill level (40%), (HT-48D, 47E ,51C) Low Fill Level 22% (48F, 51D)

EDU LH2 Test Priorities

G. Heat Load Due to Penetrations – Data collected, Achieved (Probably). This will take a few months to evaluate. This is in Tim Page's arena.

H. Ghe Pressurant on AJ/TVS Performance – Not achieved due to the fact that the Axial Jet Joule-Thompson Line was blocked. We did get the Mixing pump to operate with Helium in the ullage; so maybe this is not a complete zero.

I. LADS TVS – Not Achieved. We ran the LADs TVS from test day 8/20:06 to 9/09:39 (over 12 hours). The temperature in the LADSs never got below 78.5K. This is not even Liquid Temperature for Hydrogen (closer to 20 depending on pressure).

J. Ground Heat Load during loading – Achieved. We were able to measure the Boil off during loading. Step HL-9. (twice) 1/17:11 4000 actual liters per minute and 1/17:52 3900 actual liters per minute

K. Submerged/Dry Diffuser - Achieved. We did perform this testing more than was planned with both the submerged and non-submerged diffusers. Day 12: High Pressure, High fill level, Forward (HT-48, B & C [cold He]) and Aft (HT-51 &B [cold He]) diffuser. Day 13: High Pressure, Med fill level (40%), (HT-48D, 47E ,51C) Low Fill Level 22% (48F, 51D)

EDU LH2 Test Priorities

L. Transient Heat Load – Achieved. We gathered the boil off data from the first test day 1/19:30 to the end of the steady state test (actually throughout the test). Which can be converted into heat load data. This is Tim Page's arena

M. Facility Temps – Achieved. All data from all Test stand sensors were recorded at 1hz (or 10Hz for short periods) and uploaded to Windchill under the EDU Test folder. Also the Cryotracker, Customer Logs and Daily Summaries were uploaded to Windchill as well.

N. TVS Clogging – Achieved. We were not sure if this was possible even if the test was performed many times. However, we were only able to perform the test once due to TVS blockage early on. During the only test, we were not able to clog the Visco jet.

EDU LH2 Test Scorecard

- EDU Operational Objectives (from Whitepaper)
- 9.2 out of 10

- EDU Data-centric objectives
- 10 out of 14

- Thanks for your attention today
- IF you are going on the tour of the SOFI facility and the Test Stand 300, meet in this very parking lot at 8:30 Wednesday, Nov 19th.
- I will have a 11 person van or you can follow.
- We should be done at or before 11AM, at which time we will come back to this location.