UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

ECLIPSE

Efficient Cryogenic Low Invasive Propellant Supply Exchange

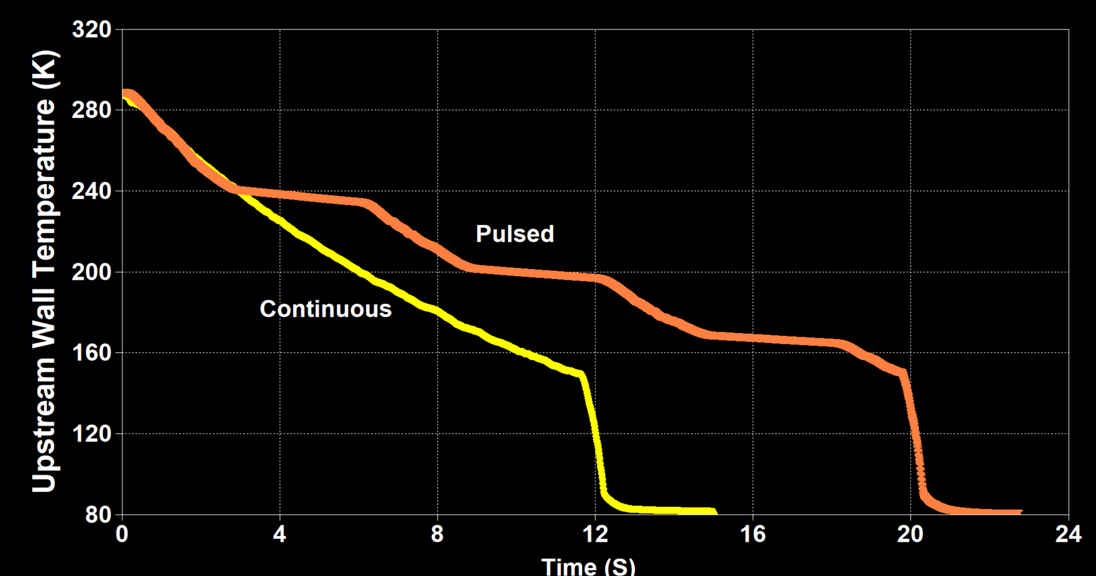
NASA HuLC HUMAN LANDER CHALLENGE

Primary Advisor: Dr. Vishwanath Ganesan

Cliff Sun | Charlie Cundiff | Braedyn Kim
Aneesh Ganti | Divij Garg
Thach Dang | Nate Vattana
Anna Rudenko | Justin Kotrba

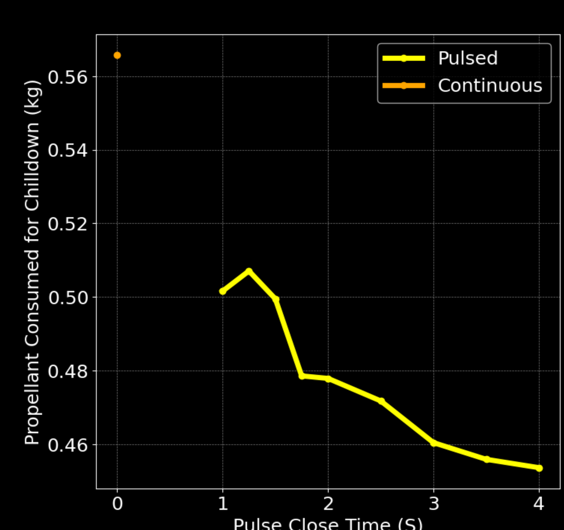
PULSED FLOW

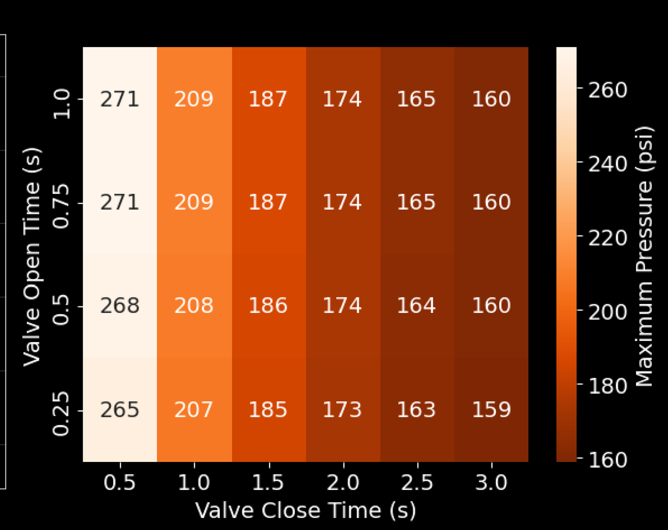
- Pulsed flow is *advantageous* in line chilldown compared to continuous flow



Comparison of pulsed flow and continuous flow during line chilldown

- Pulse close time is adjusted to *decrease* propellant consumed. See Fig. (1)
- Valve close time is chosen to *dampen* hydraulic shock. See Fig. (2)



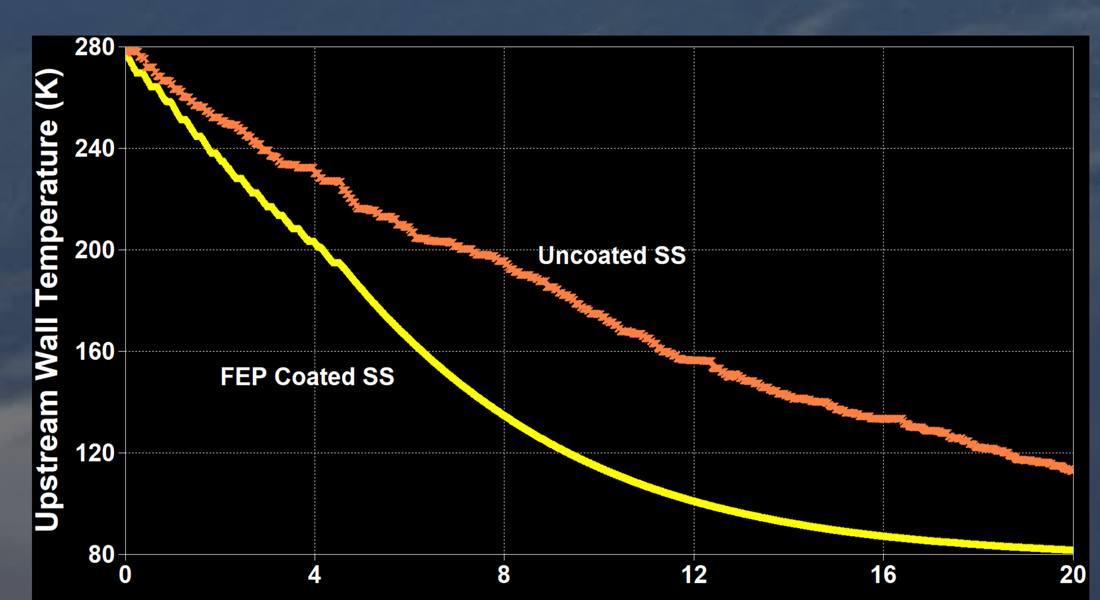


(1) Propellant consumed vs time the valve is closed for.

(2) Heat map of pressure spikes versus valve open and close times

MICROFILM COATINGS

- A microfilm coated line is *advantageous* in line chilldown compared to an uncoated line
- Developed technique to model microfilm coatings in NASA's GFSSP software
- FEP selected as microfilm material due to coefficient of thermal expansion (CTE) matching stainless steel & flexible coating techniques

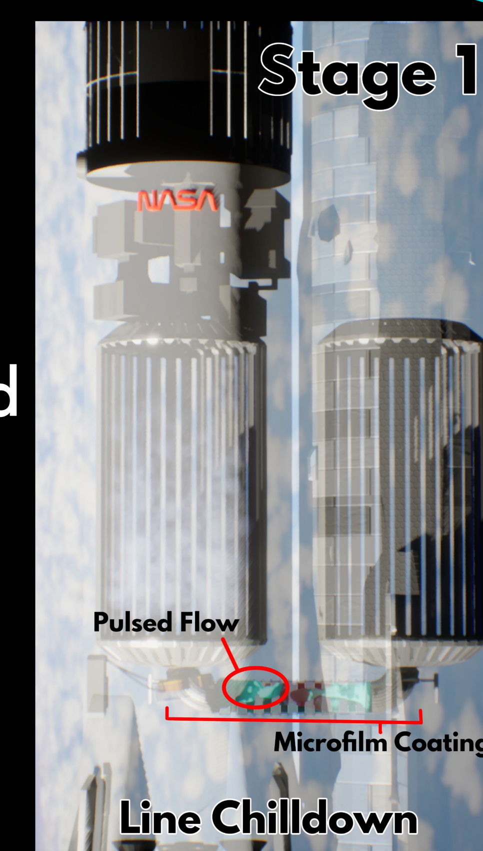


Comparison of a microfilm coated line and an uncoated line during continuous flow line chilldown

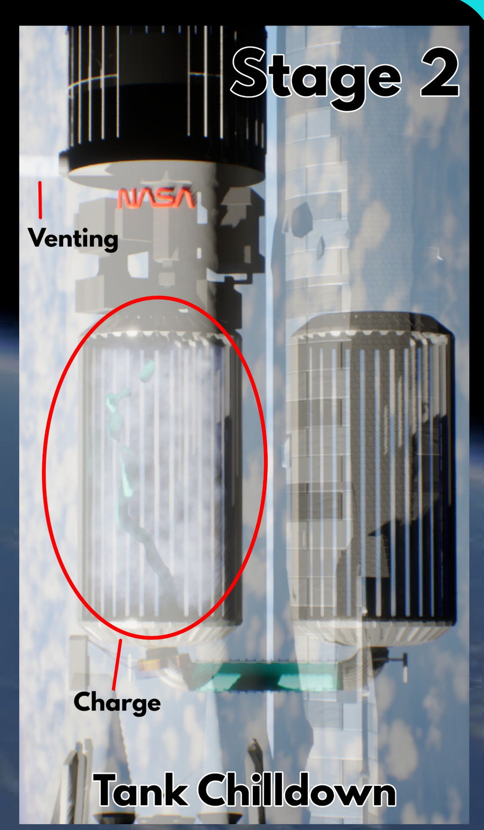
KEY TAKEAWAYS

- Pulsed flow reduces up to 24% propellant consumed during line chilldown
- Microfilms reduce chilldown time by 50%
- Charge-Hold-Vent (CHV) to No-Vent-Fill (NVF) minimize tank over-pressurization risks
- Two-phase flow regimes identified using statistical moments computed from capacitance signal
- CHV-NVF transition triggered by tank maximum temperature sensor

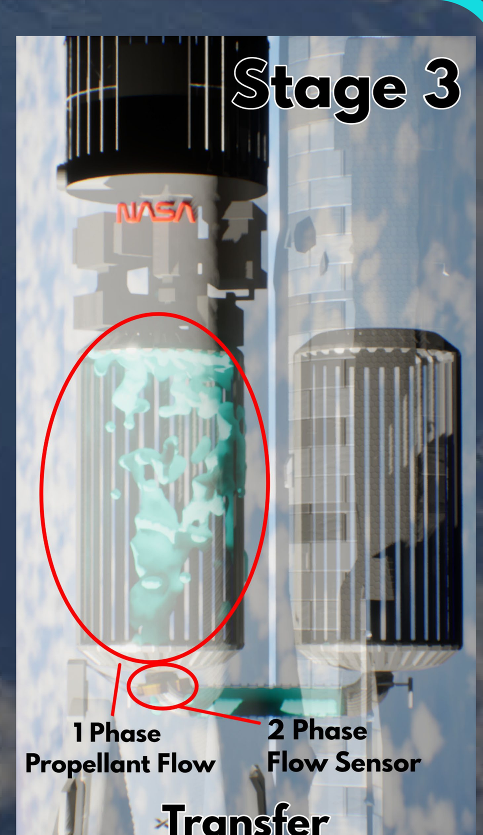
STAGE 1: Prior to single-phase liquid propellant transfer, the line must be chilled down. To minimize propellant losses during this stage, ECLIPSE leverages pulsed flow and microfilm coatings. The pulsed flow topology is optimized to maximize heat transfer efficiency while being mindful of hydraulic shock caused by the valve operations.



STAGE 2: The storage tank must also be chilled down prior to transfer. To minimize the risk of tank over-pressurization, ECLIPSE implements Charge-Hold-Vent (CHV) to No-Vent-Fill (NVF). The CHV-NVF transition is governed by a temperature sensor placed at the regions of highest thermal gradient. This sensor will measure the tank's peak temperature per CHV cycle.

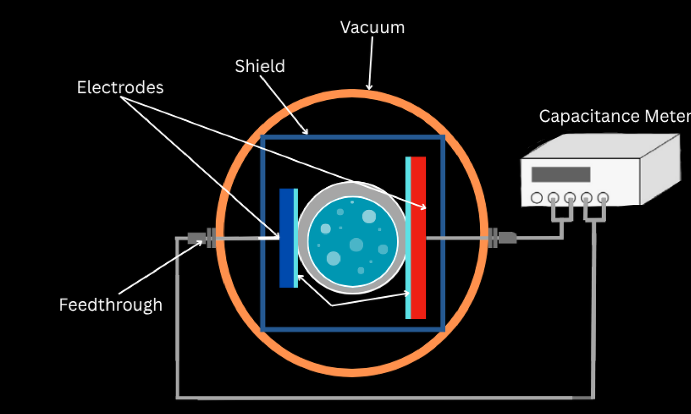


STAGE 3: Following line and tank chilldown, single-phase liquid propellant transfer is initiated. ECLIPSE monitors the health of the transfer operation by identifying flow-boiling regimes and measuring void-fraction at the end of the line. This informs the system of any potential heat leaks on-going during transfer.



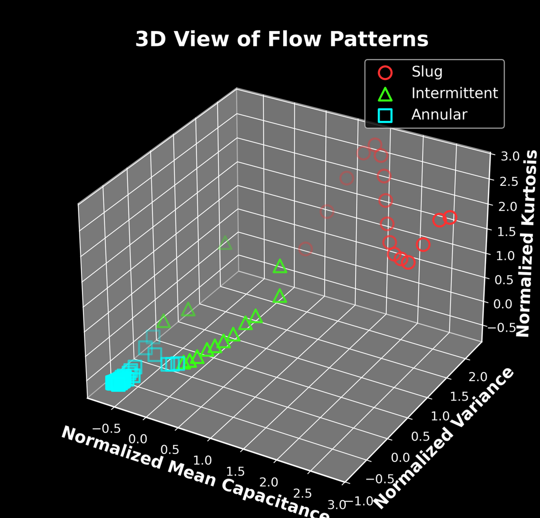
FLOW IMAGING

- Capacitance sensor extracts time-domain capacitance signal from 2-phase fluid
- Sensor Materials: Copper Electrodes, X-Aerogel insulator, Aluminum Shield

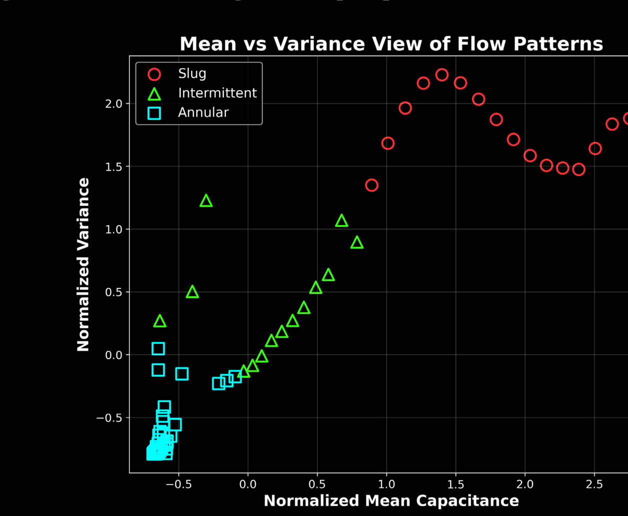


Sensor Depiction on Transfer Pipe

- Identifies two-phase flow regime based on measured capacitance mean, variance, kurtosis
- ML model balances # of points per flow regime
- Probabilistic clustering used to group points



3-D visualization of flow regime map

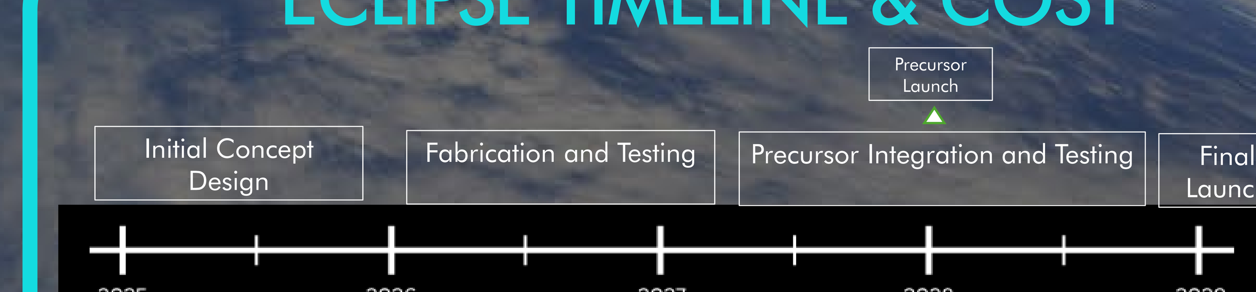


2-D slice of flow regime map

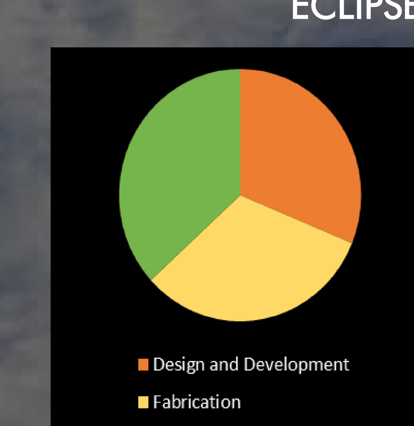
TANK CHILLDOWN

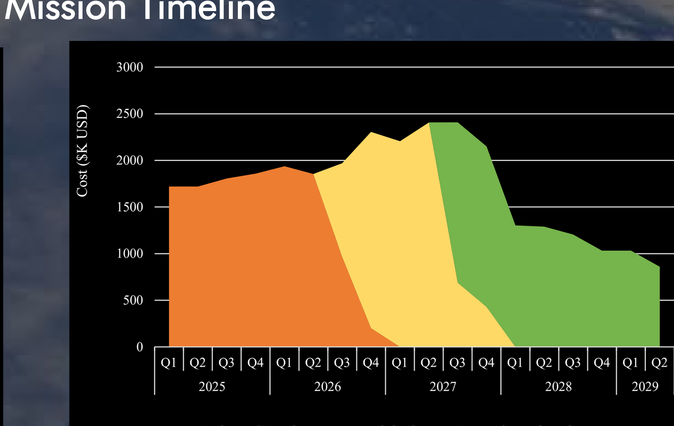
Sensors placed in locations of highest thermal conduction → Measure max tank temp → Tank max temp under target temp → Tank is fully conditioned → Trigger NVF

ECLIPSE TIMELINE & COST



ECLIPSE Mission Timeline





ECLIPSE Cost Analysis