

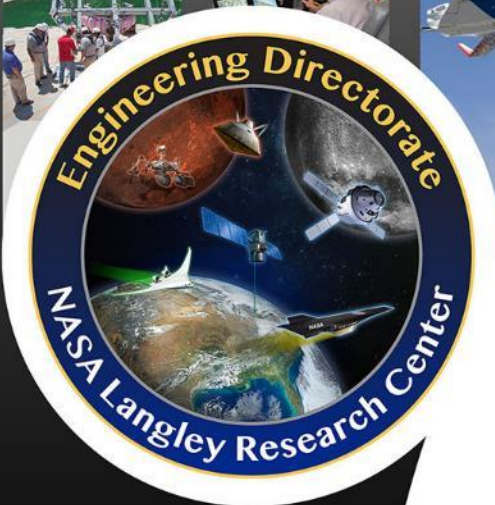


National Aeronautics and
Space Administration



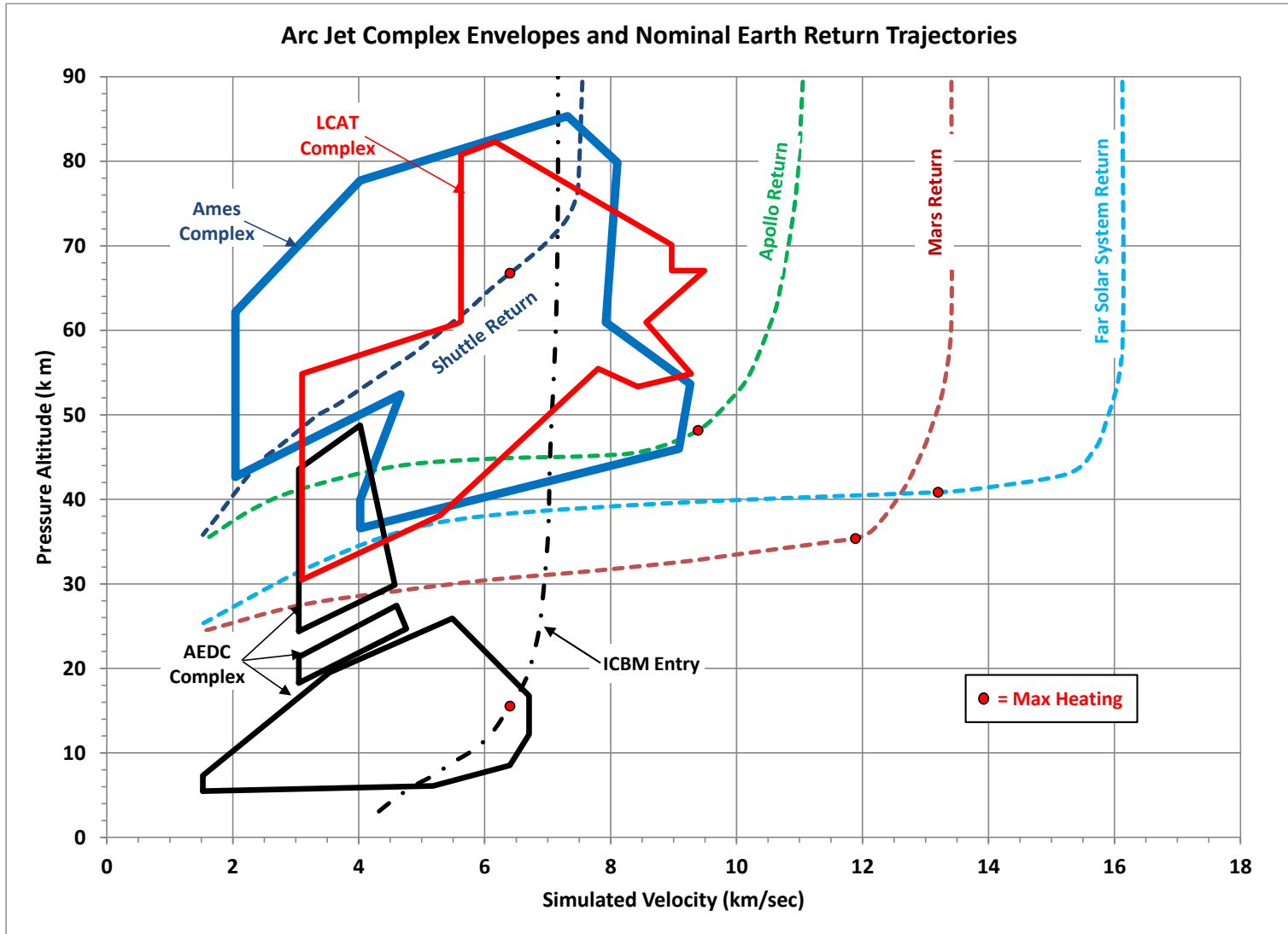
Conducting Tests at Boeing LCAT and AEDC Arc-jet Facilities

Andrew J. Brune, Ph.D.
NASA Langley Research Center

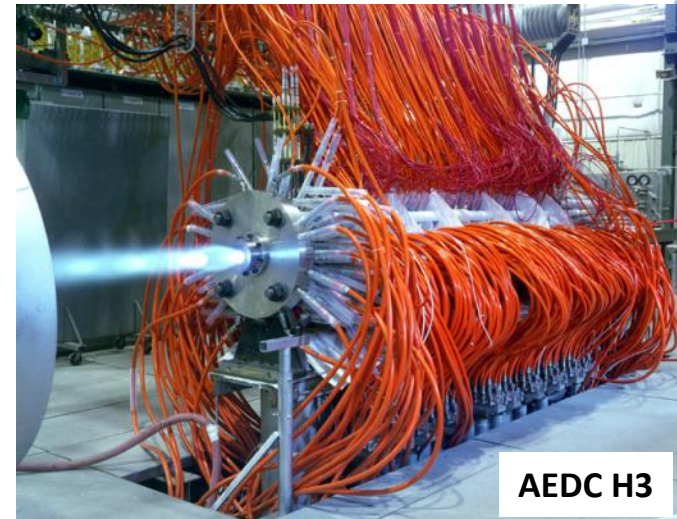
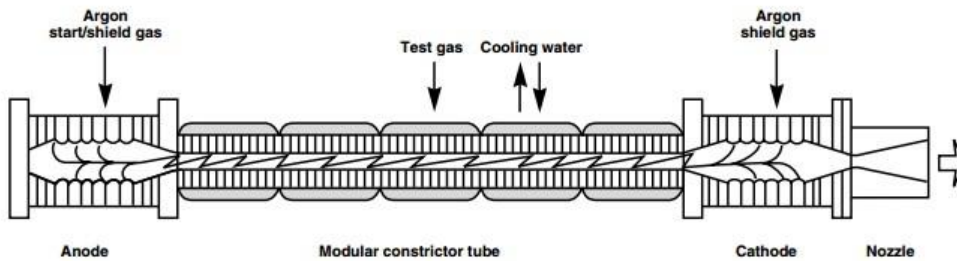
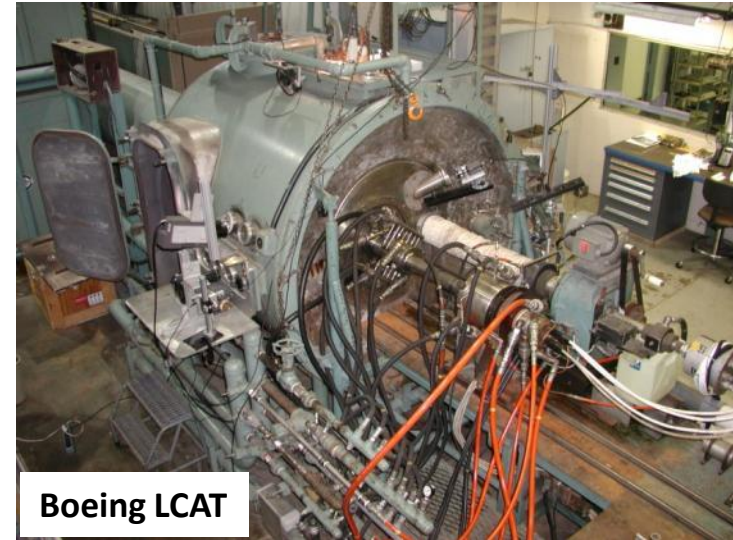
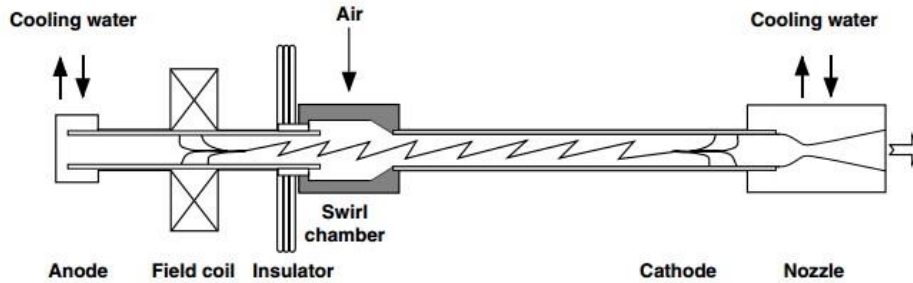




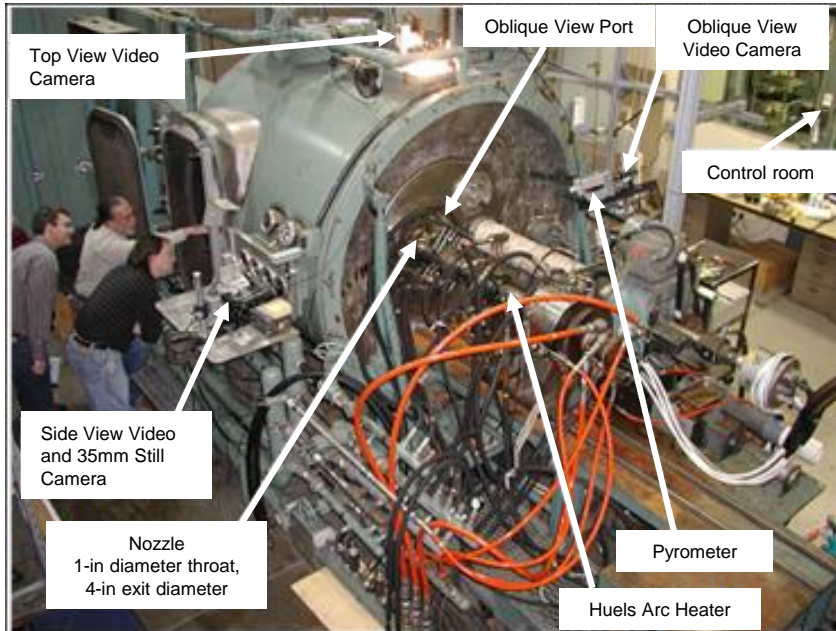
Arc Jet Facility Capabilities



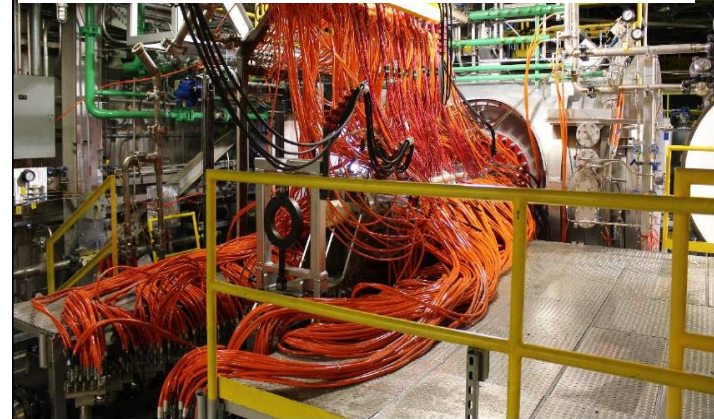
Huels (Hüls) vs. Segmented Arc Heaters



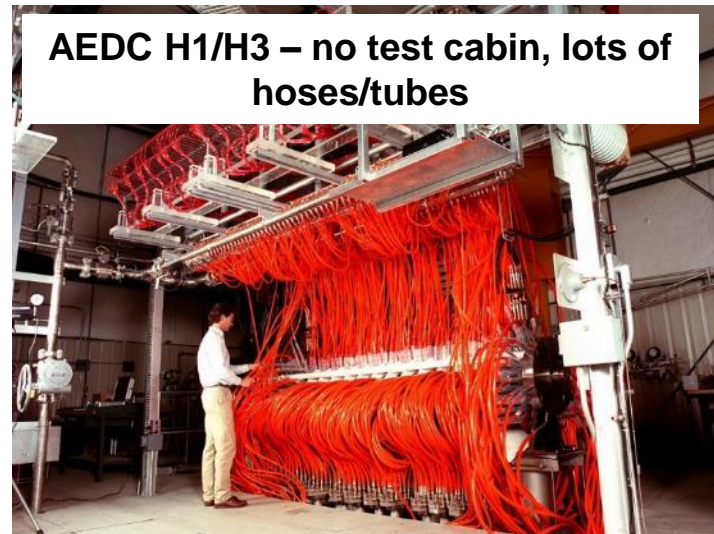
Boeing LCAT – test cabin, limited hoses/tubes, steam ejector exhaust



AEDC H2 – test cabin, lots of hoses/tubes, mechanical pump exhaust



AEDC H1/H3 – no test cabin, lots of hoses/tubes



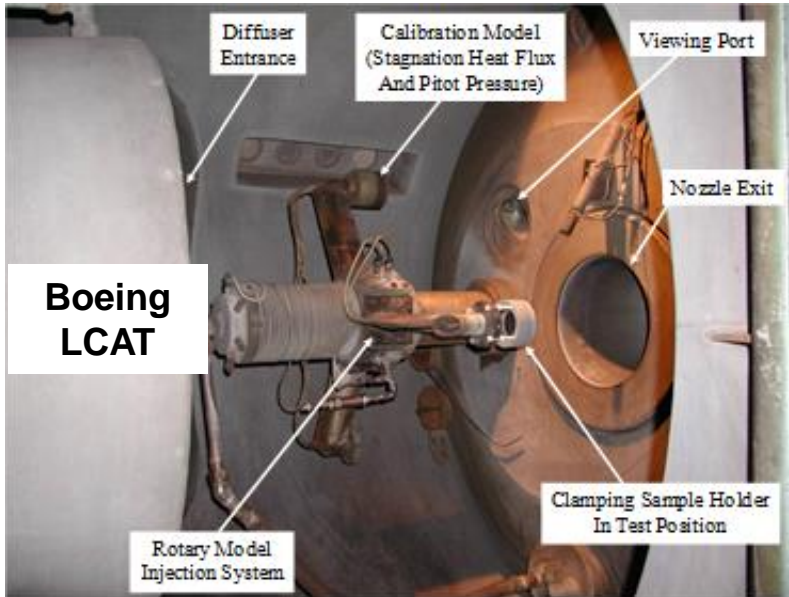


Arc Jet Facility Overview (2/2)

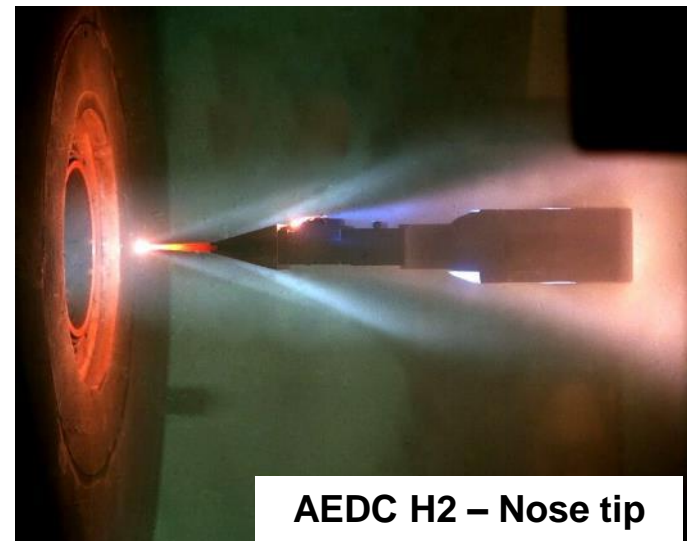
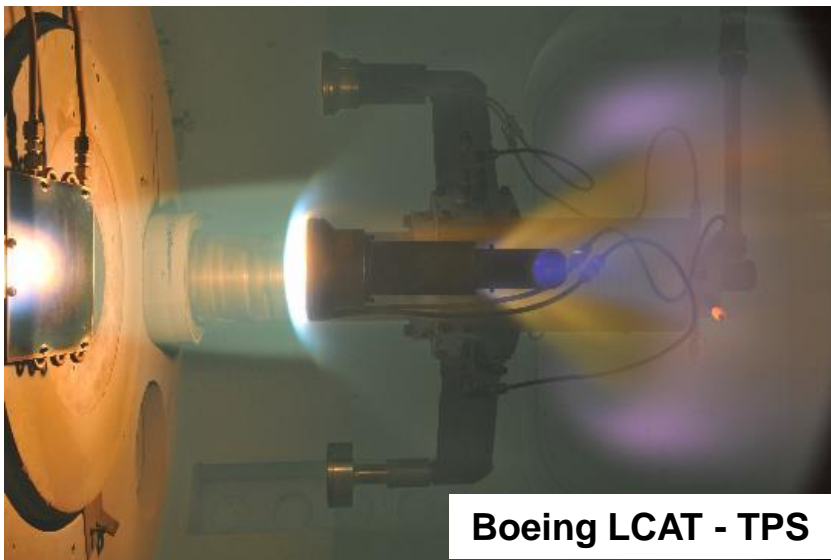
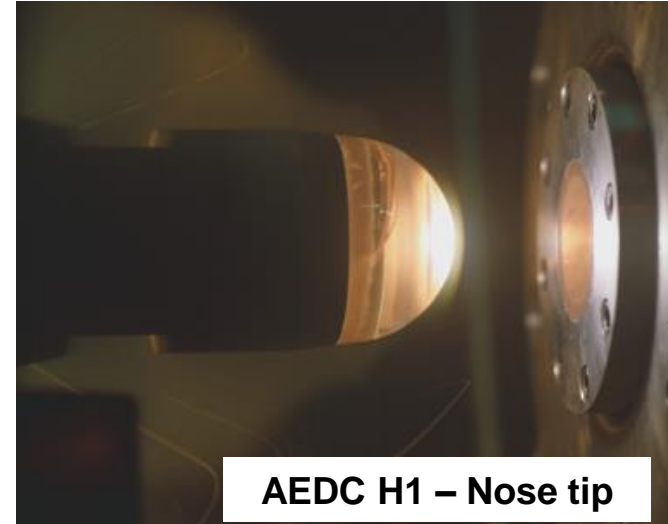
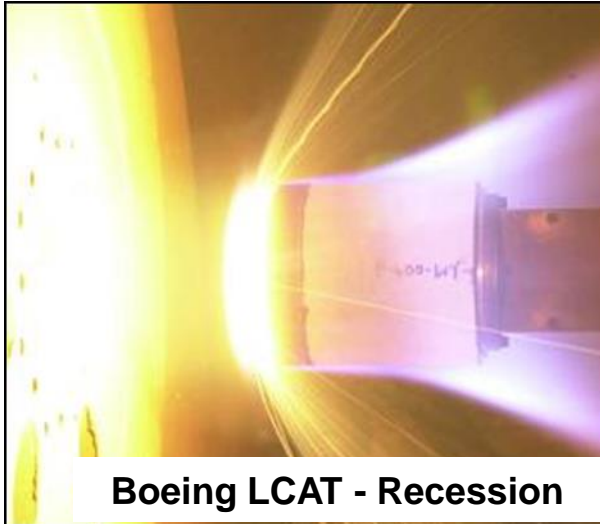


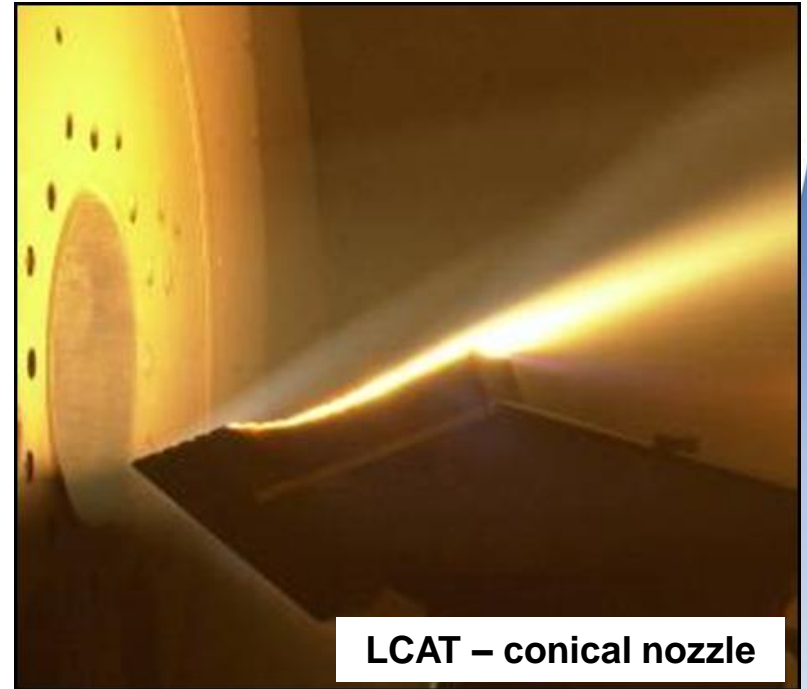
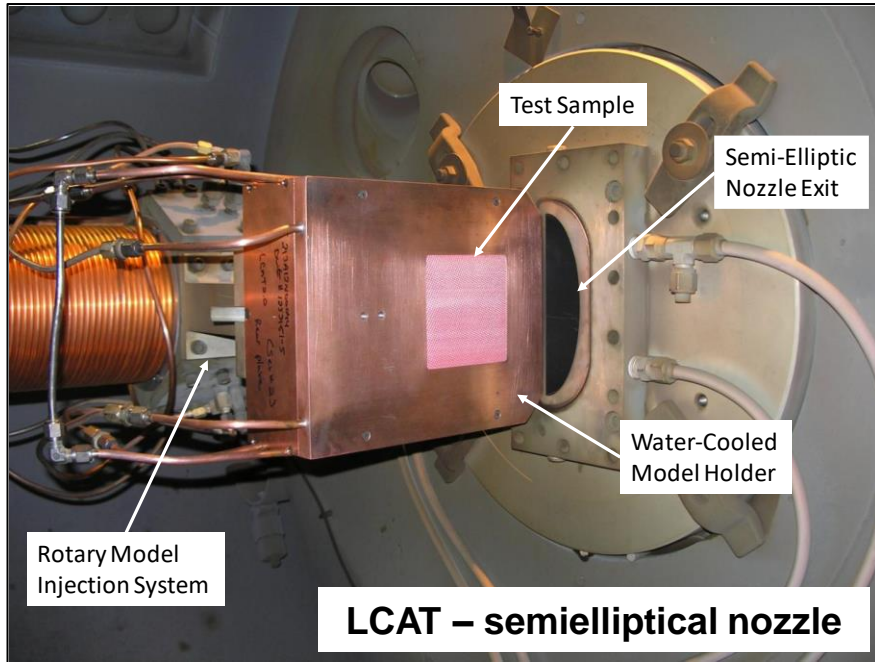
Facility Name	LCAT	AEDC H1	AEDC H2	AEDC H3
Facility Type	Subatm. Exhaust	Atm. Exhaust (Freejet)	Subatm. Exhaust	Atm. Exhaust (Freejet)
Maximum Run Time (minute)	5-200	1-2	3-30	1-2
Nozzle Types	Conical Semi-elliptical	Conical	Conical	Conical
Nozzle Mach Number	3.7 to 8.5 (conical) 2.5 to 5.7 (semi-elliptical)	1.8 to 3.5	3.4 to 8.3	1.8 to 3.5
Nozzle Exit Diameter/Dimensions (in)	4.0 to 20.0 (conical) 0.82 x 2.14 to 3.3 x 13 (sei-elliptical)	0.75 to 3.0	5.0 to 24.0	1.4 to 4.5
Stagnation Pressure (atm)	Up to ~1	Up to ~100	Up to ~10	Up to ~100
Inferred Stagnation Enthalpy (BTU/lbm)	Up to ~15,000	Up to ~8,500	Up to ~5,500	Up to ~8,500
Mass Flow Rate (lbm/sec)	0.05-2	0.5-8	2-10	3-25
Facility Power (MW)	Up to 5	Up to 30	Up to 45	Up to 70

Model Injection System

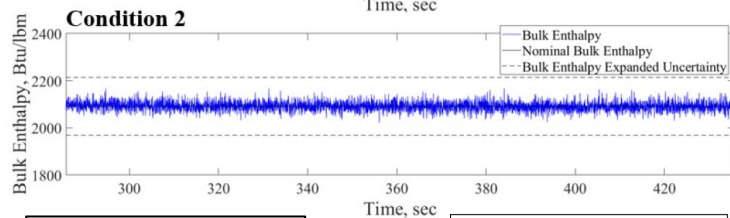
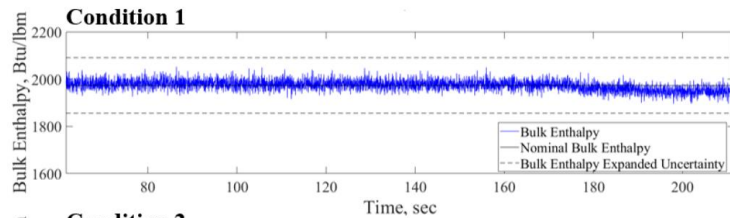
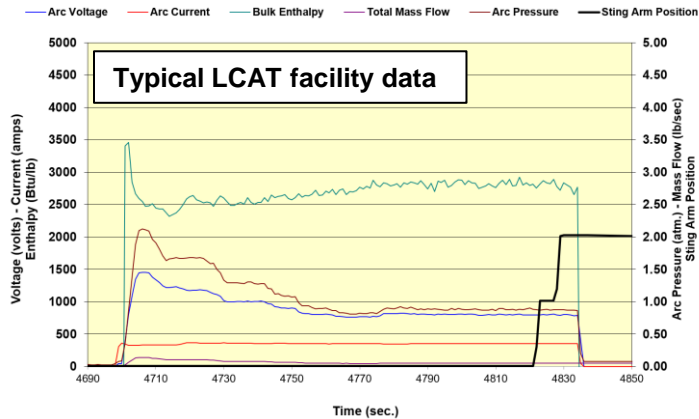


Stagnation Type Testing





Facility Conditions



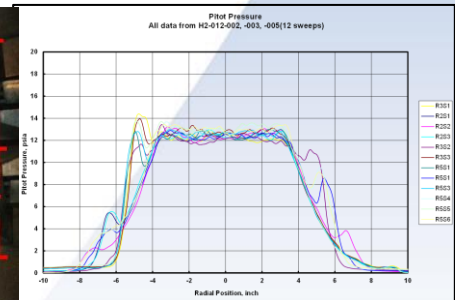
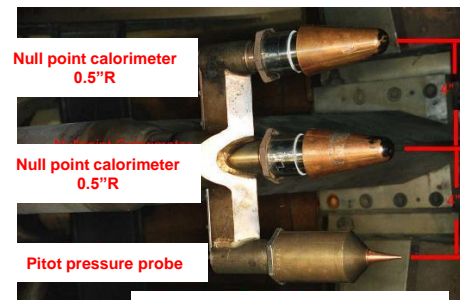
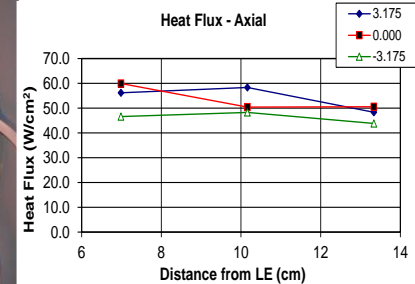
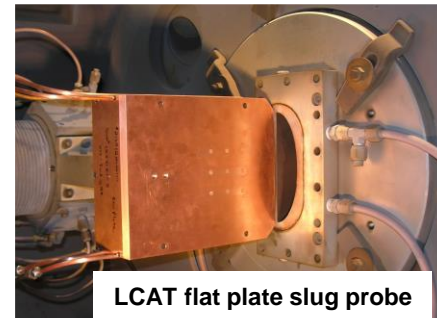
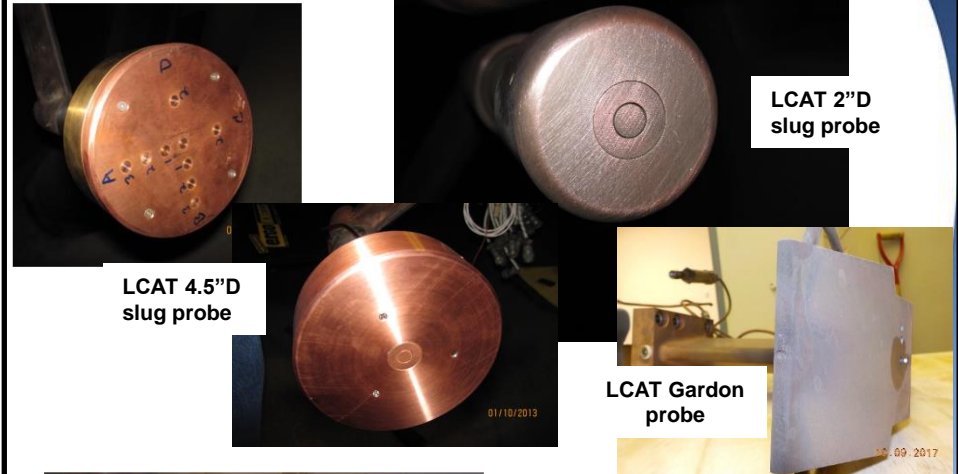
Typical AEDC bulk enthalpy data

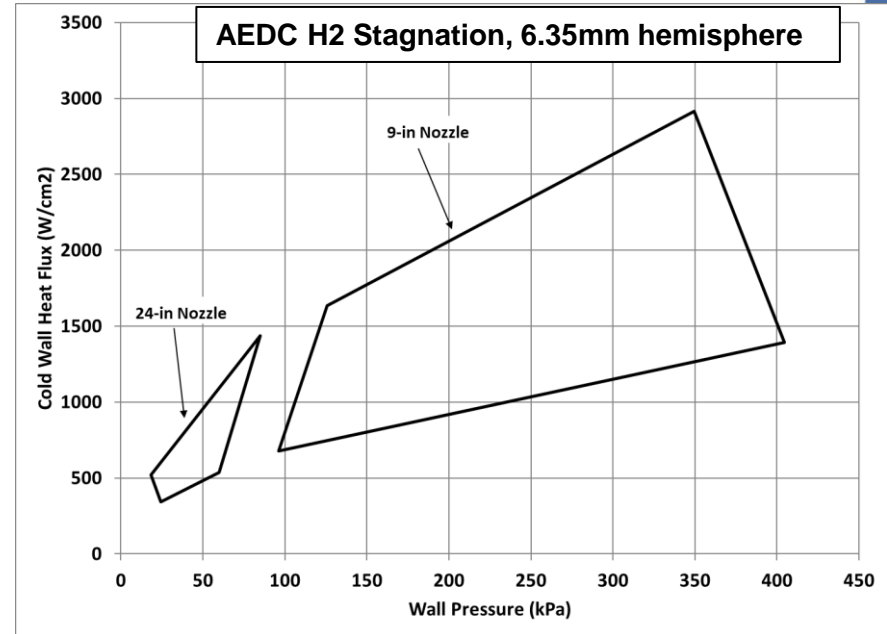
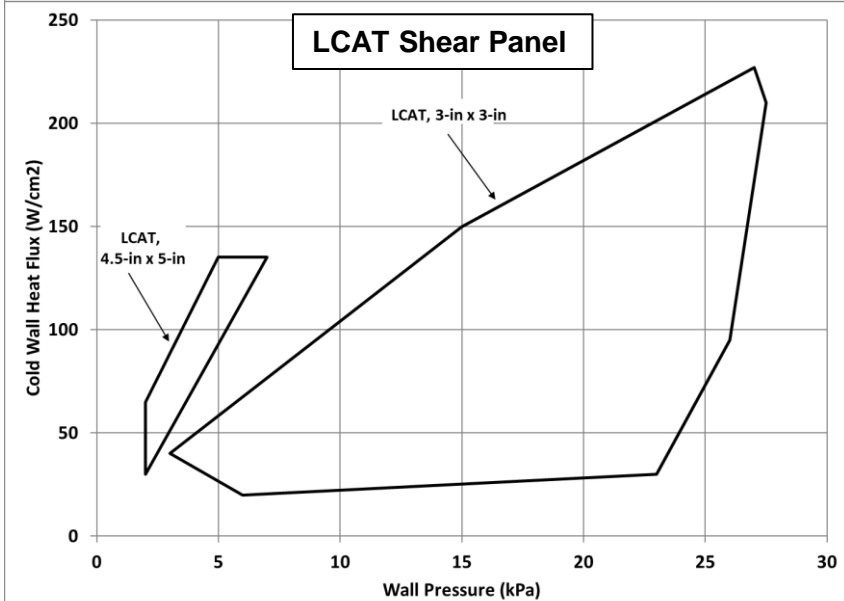
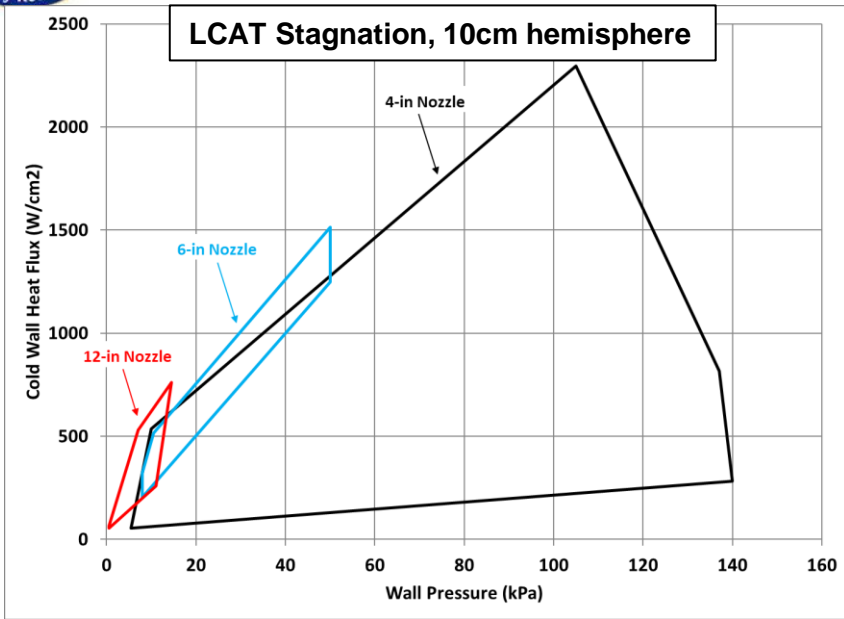
Bulk Enthalpy Calculation

$$H_o = \frac{E * I * C_1 - C_2 * CW * C_p * \rho * \Delta T}{M_{Total}}$$

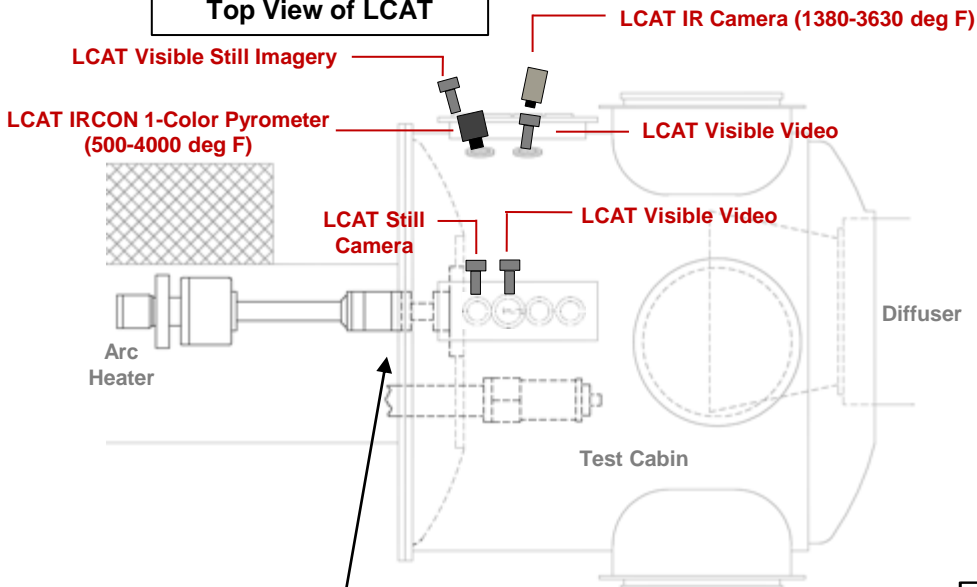
- H_o = Total bulk enthalpy, (MJ/kg)
- E = Arc heater voltage, (Volts)
- I = Arc heater current, (Amps)
- C_1 = 9.48 E-4 (Btu/s.W)
- C_2 = 2.23 E-3 (min. ft³/s.gal)
- CW = Cooling water flow, (LPM)
- C_p = Specific heat of water, (4.2 kJ/kg K)
- ρ = Water density, (1000 kg/m³)
- ΔT = Cooling water temp. difference, (K)
- M_{Total} = Total gas mass flow, (kg/s)

Flow-field Probe Measurements

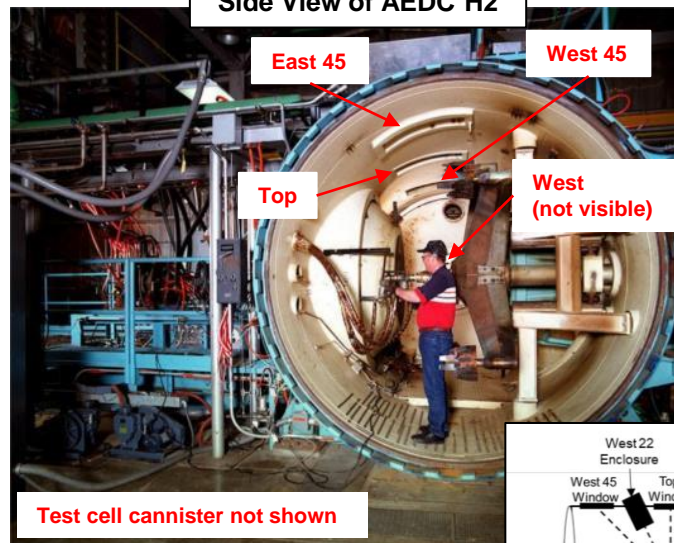




Top View of LCAT

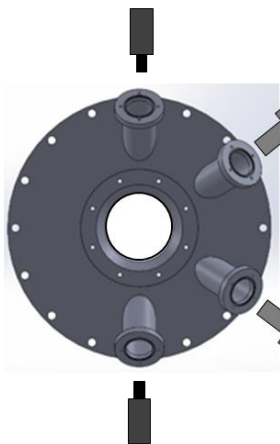


Side View of AEDC H2



4" Nozzle Upstream Ports

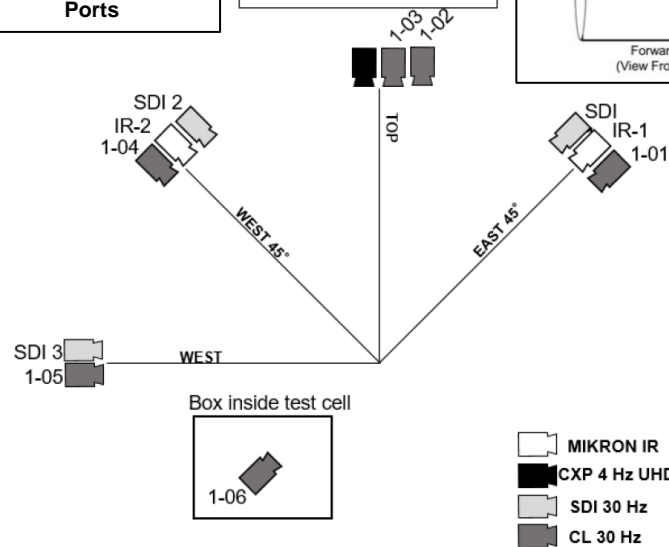
LCAT Low-Temperature Multiwavelength Pyrometer (570-3630 deg F)



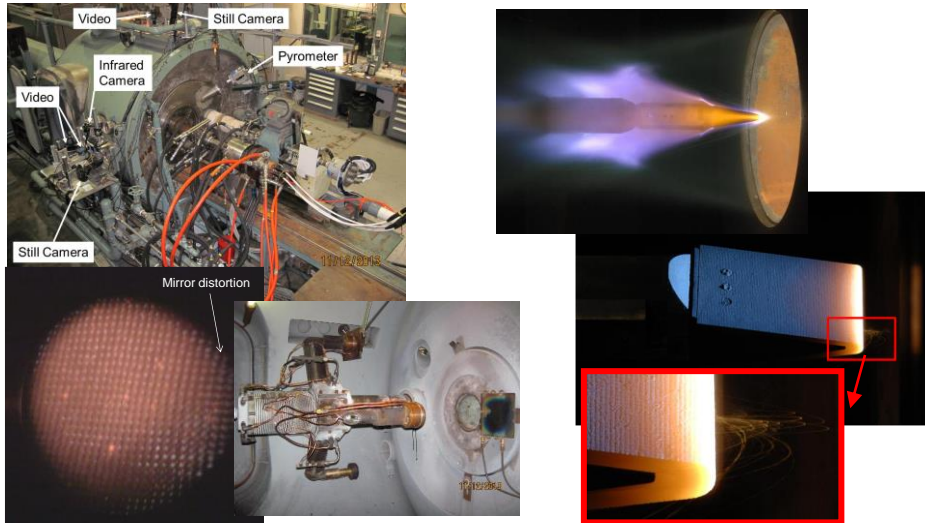
LCAT High-Temperature Multiwavelength Pyrometer (1470-4530 deg F)

AEDC H2 Test Cell Ports

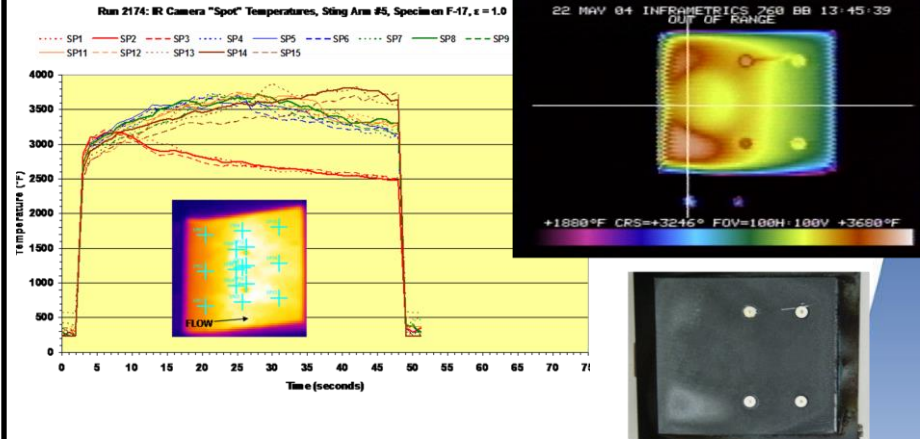
FORWARD LOOKING AFT



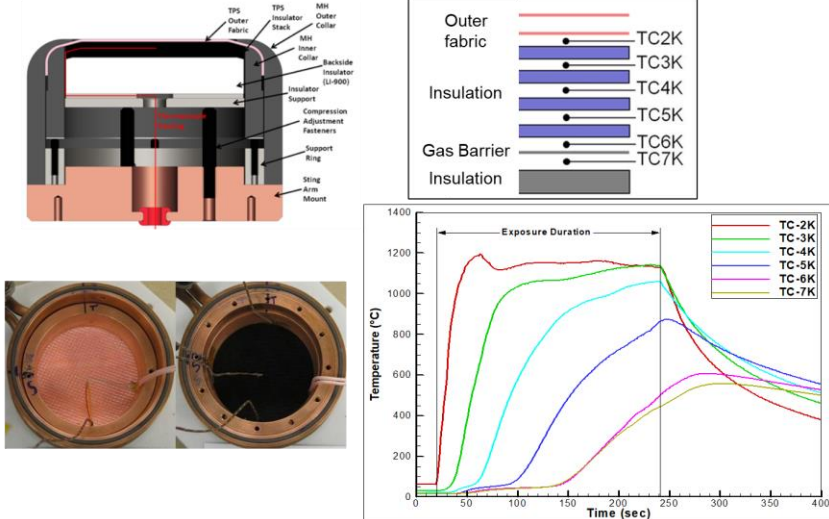
In-test Photos/Videos



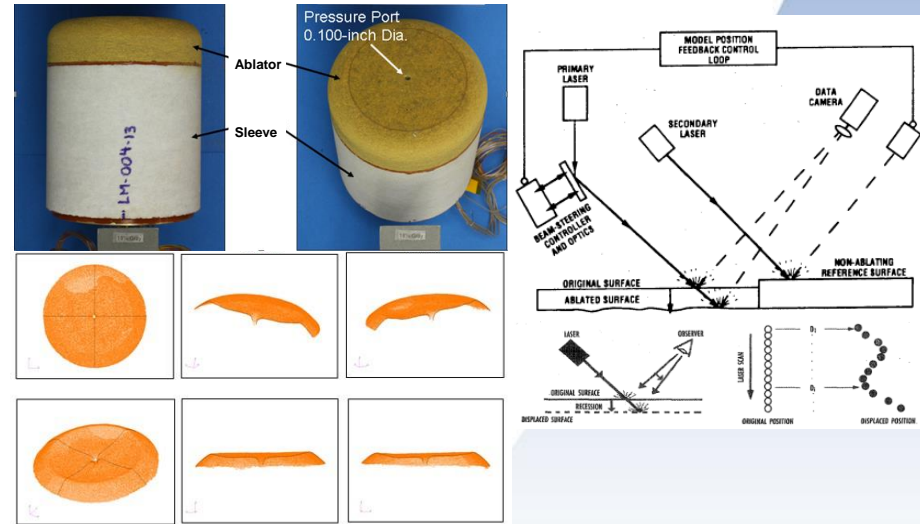
Surface Temperatures (IR camera, pyrometry)



In-depth Temperatures (thermocouples, heat flux gages)



Recession/Recession Rates





LCAT Considerations and Contact Information



- **Personnel have experience performing work for many external customers (NASA, AFRL, SBIR contractors)**
- **Lab staff has flexible test scheduling, conditions and set-ups with users to assure test objectives are achieved within established budget**
- **Customer typically handles test plan development and readiness reviews**
- **LCAT facility availability varies considerably – averages ~50%**
- **All contract work is priced as fixed-cost**
- **Contact John Simms for further information:**
 - John.r.simms@boeing.com
 - **Phone: 314-234-9185**



AEDC Considerations and Contact Information



- Personnel have experience performing work for government and external customers (DoD, NASA, private sector, etc.)
- Staff requires customers to complete the following to assure test objectives are achieved within established budget
 - Test Requirements Document, Test Matrix, Statement of Capability agreement, including safety/security requirements, material safety data sheets
- Staff will handle test plan development and facility-required analyses/reviews prior to testing
- Plan early – AEDC facility is usually booked 12-18 months out
- Plan for potential delays – facility maintenance and unforeseen issues can add additional 3-6 months to schedule
- Work under agreement is priced per run based on facility, complexity, and number of runs per campaign
 - Additional product services: Computational modeling, surface profilometry, etc.
- Contact one of the following Test Managers for further information:
 - Rick Rushing: richard.rushing@us.af.mil
 - Sherry Stovall: sherry.stovall.ctr@us.af.mil
 - Rylan Cox: jon.cox.ctr@us.af.mil