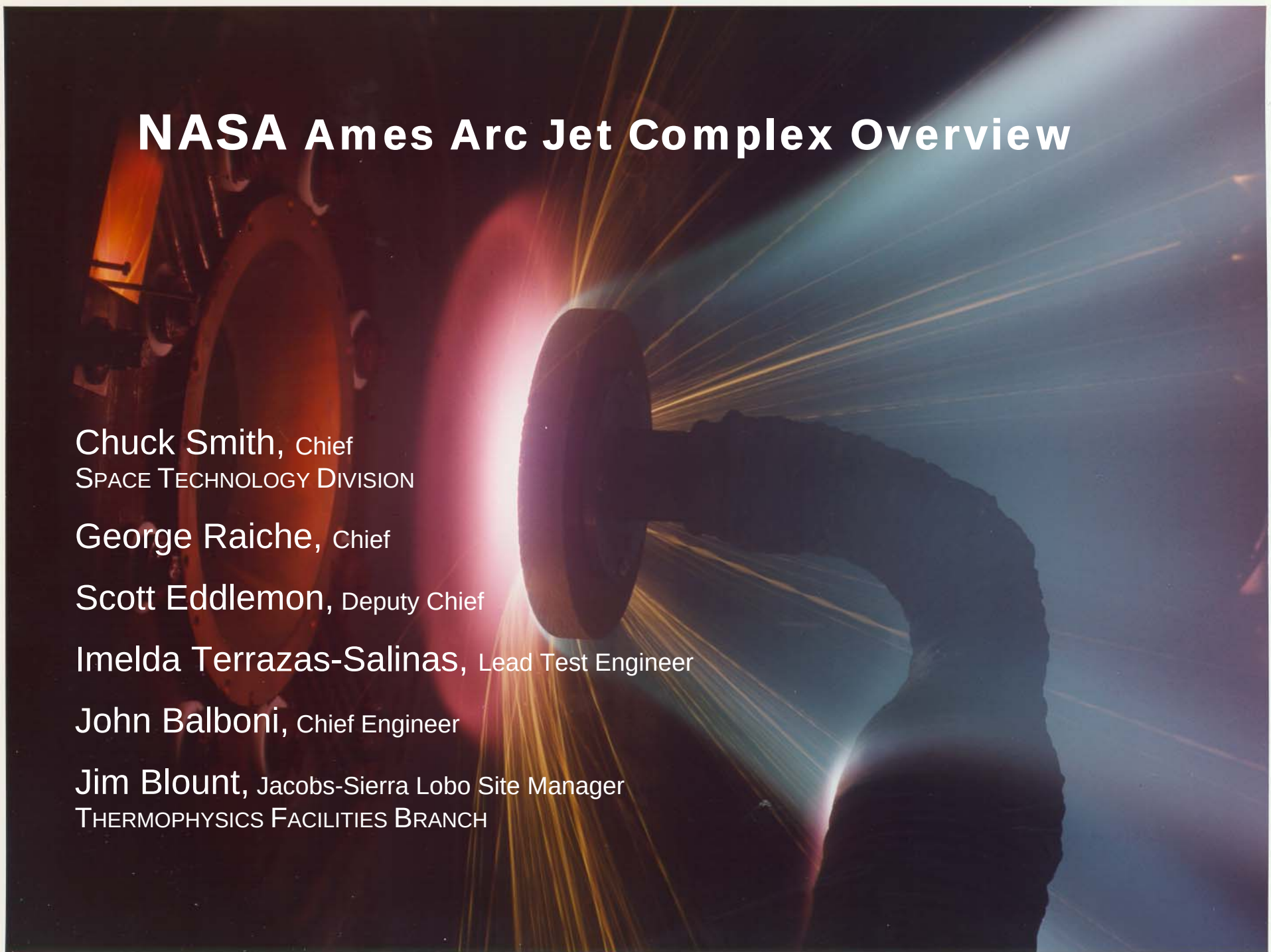
NASA Ames Arc Jet Complex Overview



Chuck Smith, Chief
SPACE TECHNOLOGY DIVISION

George Raiche, Chief

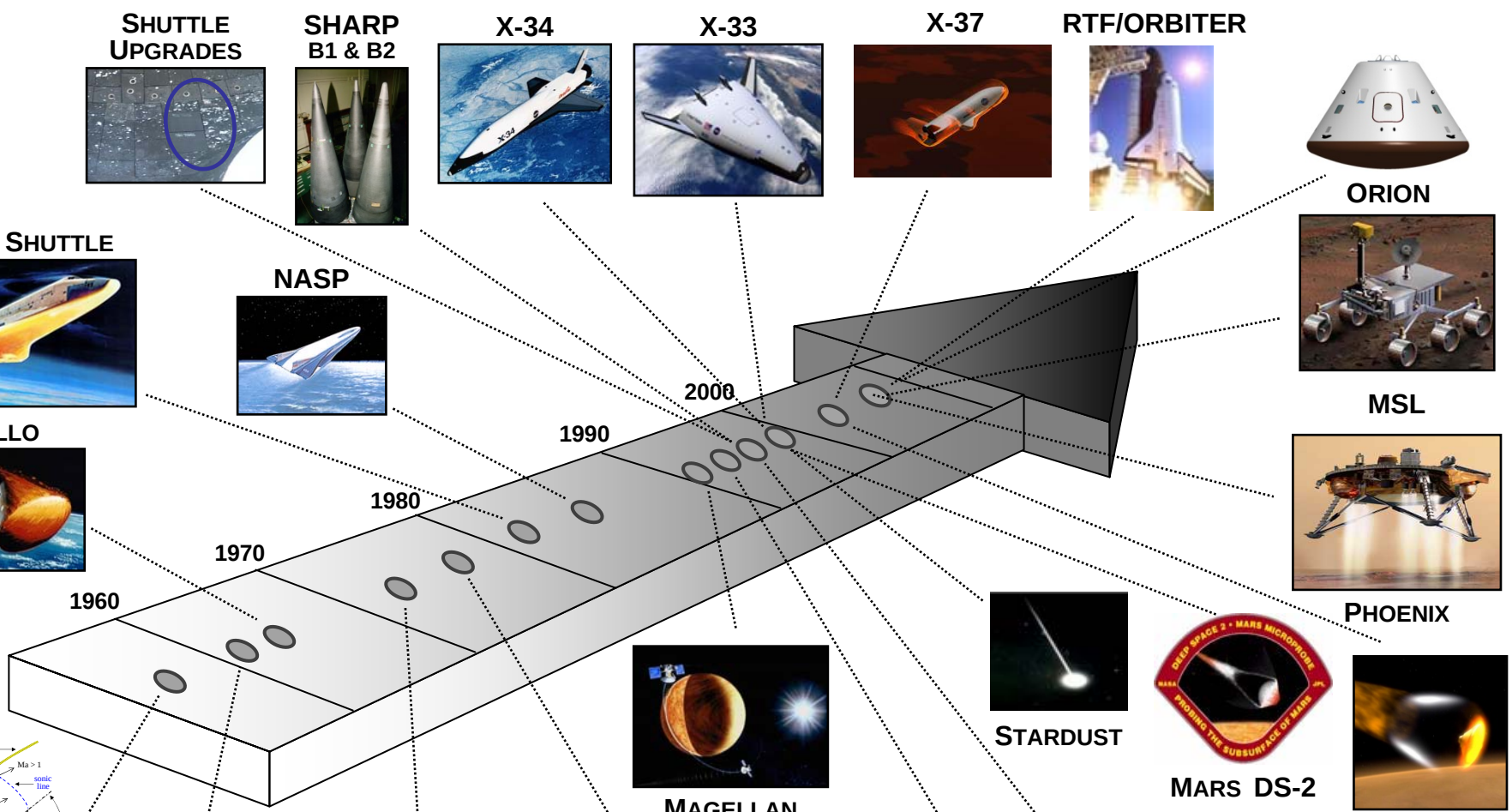
Scott Eddlemon, Deputy Chief

Imelda Terrazas-Salinas, Lead Test Engineer

John Balboni, Chief Engineer

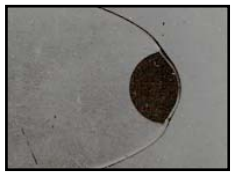
Jim Blount, Jacobs-Sierra Lobo Site Manager
THERMOPHYSICS FACILITIES BRANCH

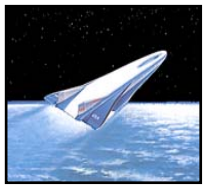
NASA Entry Vehicles/Missions Supported by Ames Arc Jets



Rationale for Arc Jet Testing

- **R&D:** *provide critical data for the research and development of thermal protection (TPS) materials*


PAET


NASP


SHARP B1 & B2


X-33


FALCON/CAV

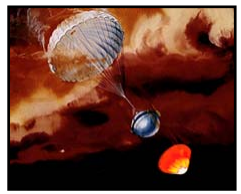

X-37

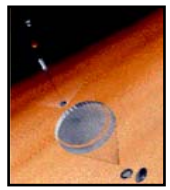
- **Flight Qualification/Sustaining Engineering:** *qualify/certify TPS materials and processes for National Programs*


APOLLO


SPACE SHUTTLE

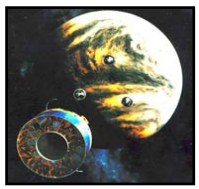

VIKING

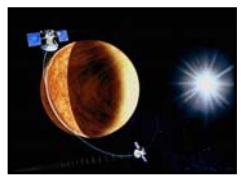

GALILEO


MARS PATHFINDER

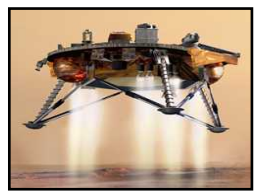

MER


Orion


PIONEER-VENUS


MAGELLAN

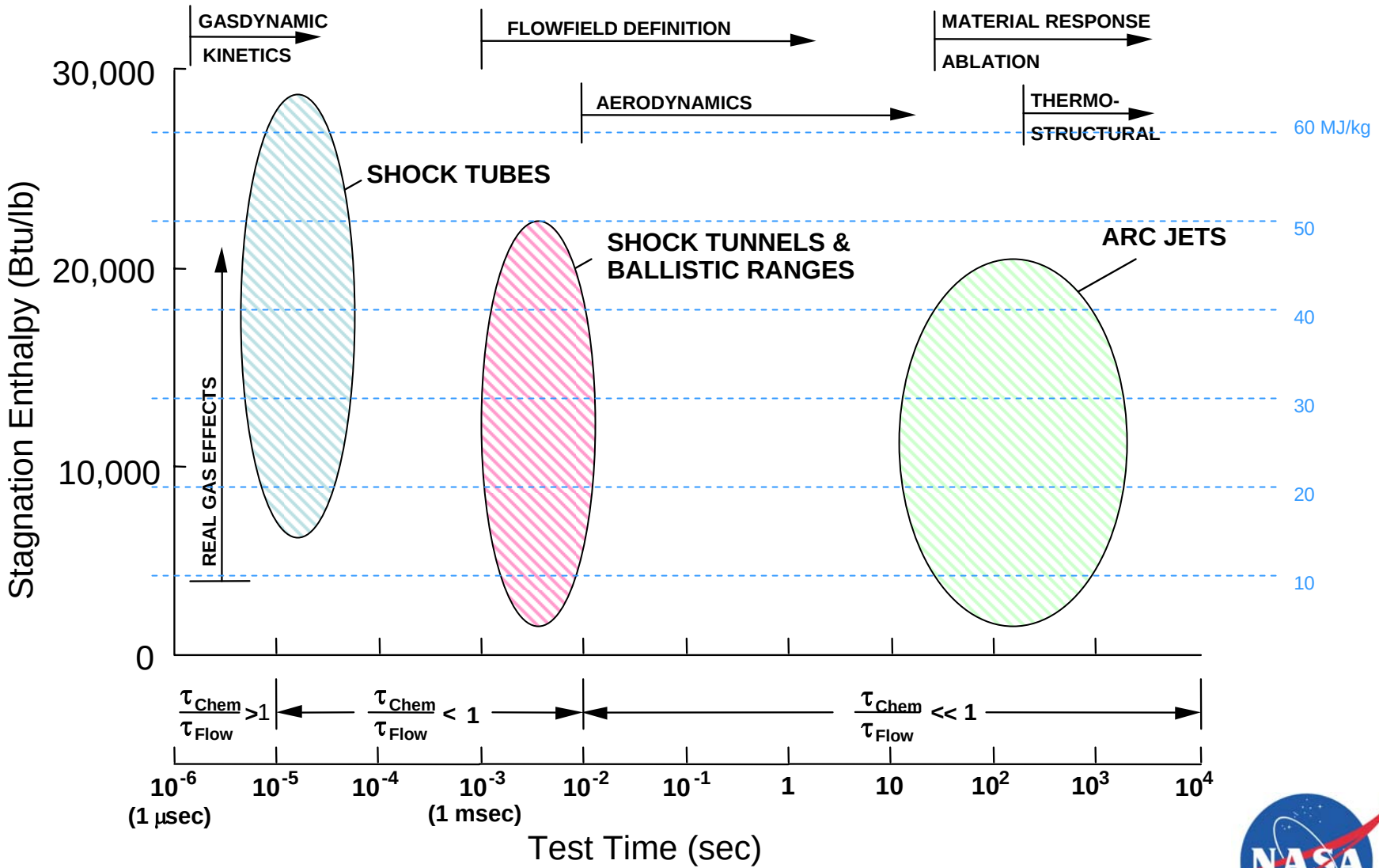

STARDUST


PHOENIX

- **Instrumentation:** *Develop surface and in-depth instruments and sensors*

- **Space Ops:** *Support TPS damage assessment and verification of repair techniques for crewed spacecraft*

Stagnation Enthalpy and Flow Duration Domains for Hypervelocity Simulation Facilities



Comparison of TPS Facility Types by Capability

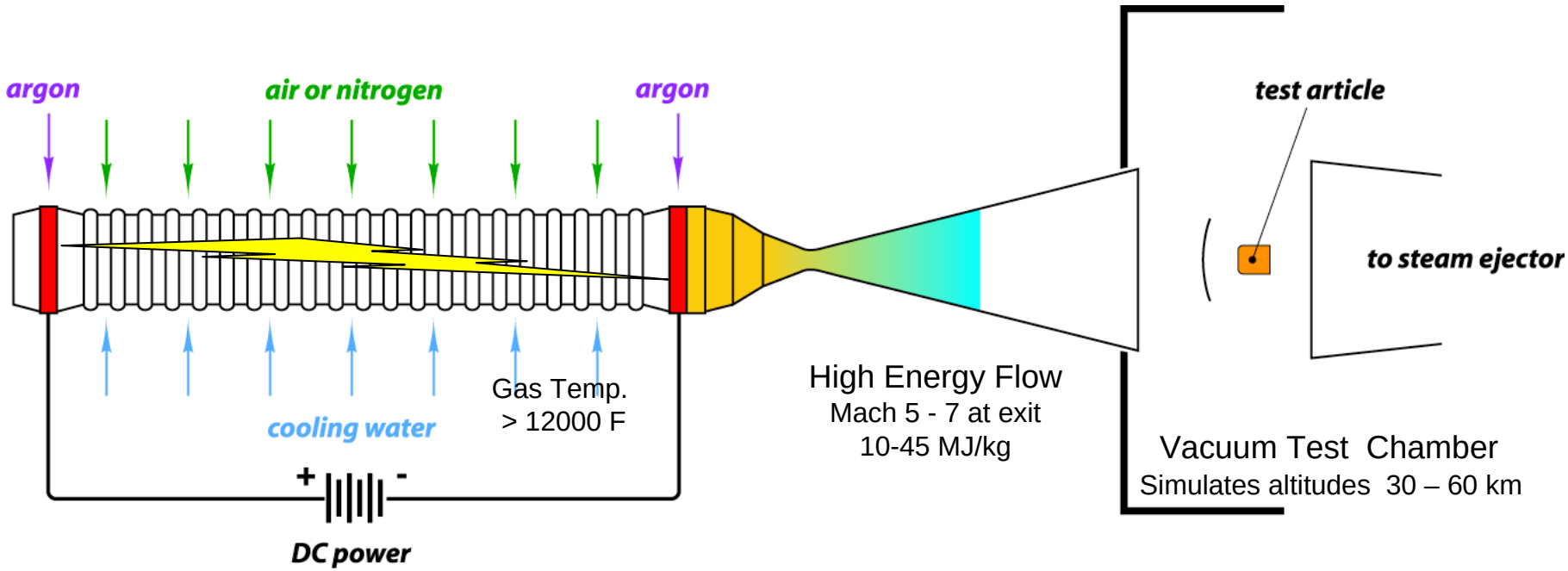
THERMAL PROTECTION SYSTEMS Test Facility Type vs. Capability	Heat Flux	Convective-Radiative Coupling	Gas Chemical Physics	Pressure	Aerodynamic Shear	Mass Transfer	Test Time
Arc Jets	F		F	F	p	F	F
Combustion Facilities	p		p	p	p	F	F
Radiant Lamps	F						F
Laser	F						F
Torch	p		p				F
Furnace			p				F

KEY F **Full Capability** p **Partial Capability**

Arc Jet Schematic

Objective: Simulate entry heating in a ground-test facility

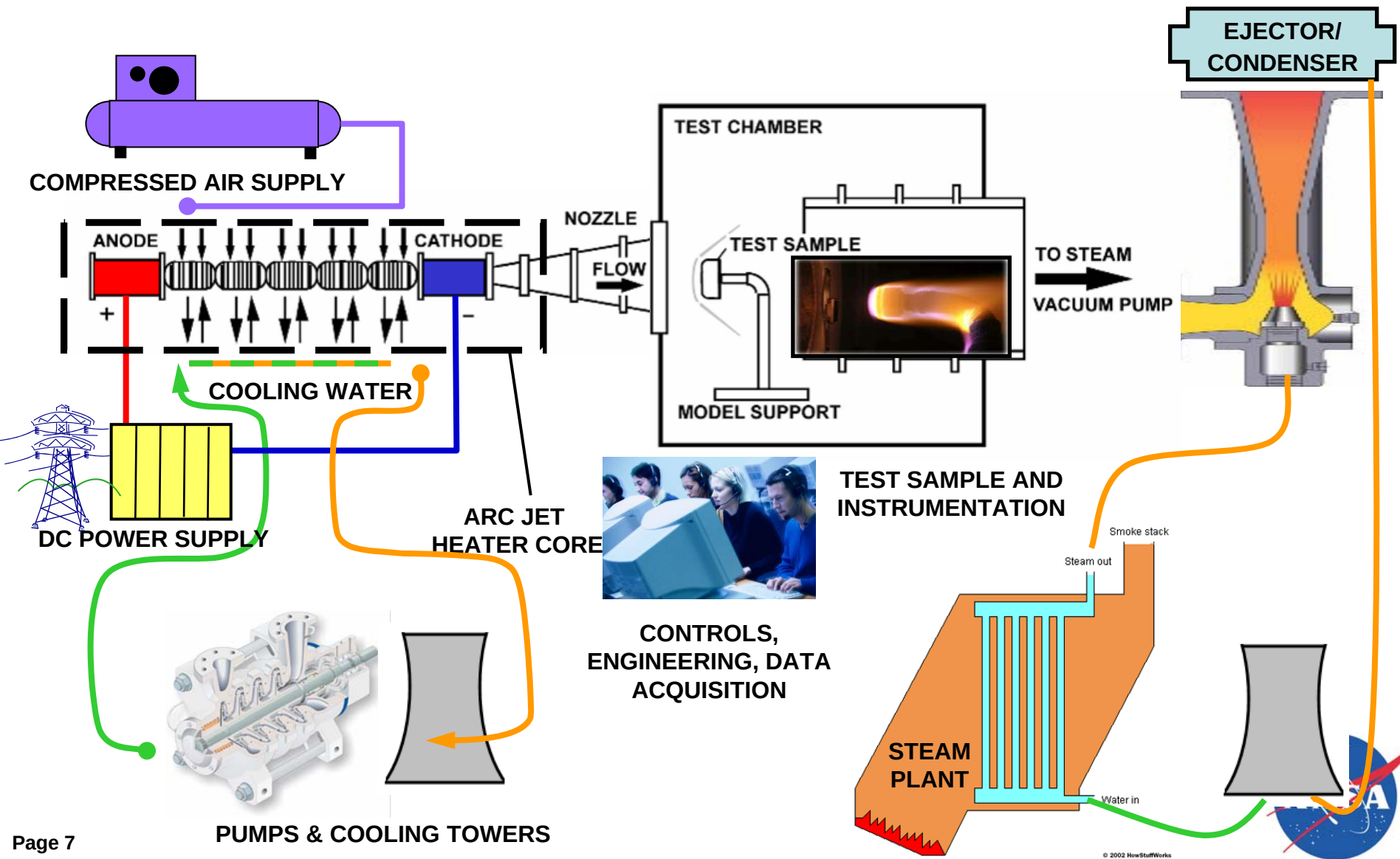
Goal: Verify a thermal protection material/system design before flight; support continuing engineering during operations



Method: Heat a test gas (air) to plasma temperatures by an electric arc, then accelerate into a vacuum chamber and onto a stationary test article

Arc Jet Facility Components

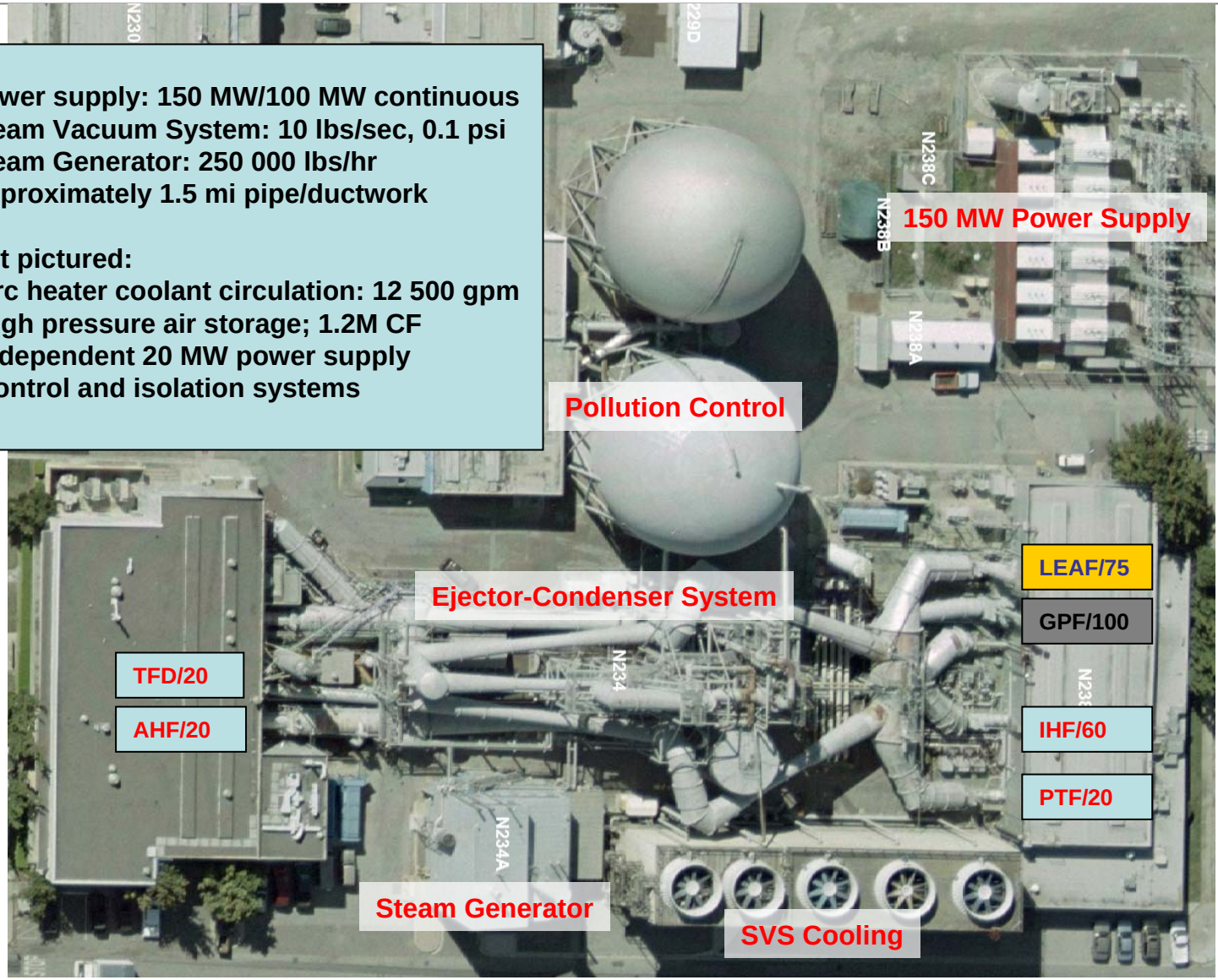
EACH ARC JET LEG IS SUPPORTED BY COMMON FACILITY INFRASTRUCTURE



Arc Jet Facility Overview

Power supply: 150 MW/100 MW continuous
Steam Vacuum System: 10 lbs/sec, 0.1 psi
Steam Generator: 250 000 lbs/hr
Approximately 1.5 mi pipe/ductwork

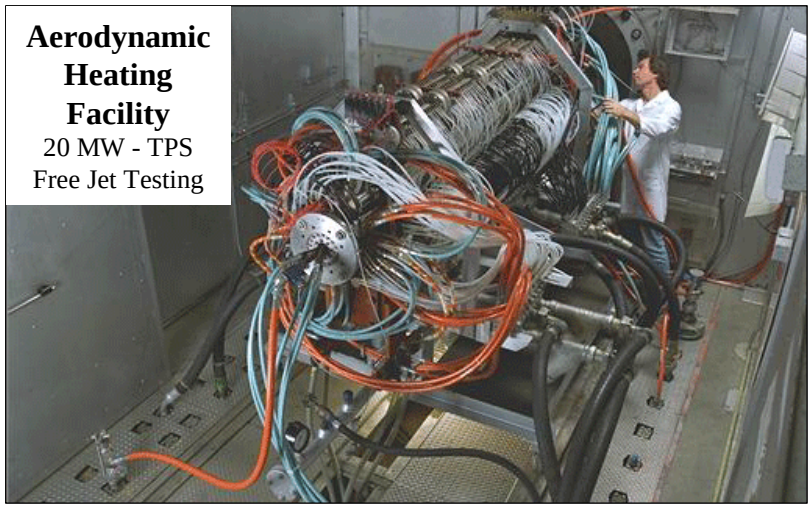
Not pictured:
- **Arc heater coolant circulation: 12 500 gpm**
- **High pressure air storage; 1.2M CF**
- **Independent 20 MW power supply**
- **Control and isolation systems**



FOUR ACTIVE TEST LEGS; ONE SET OF SHARED UTILITIES

Ames Arc Jet Legs

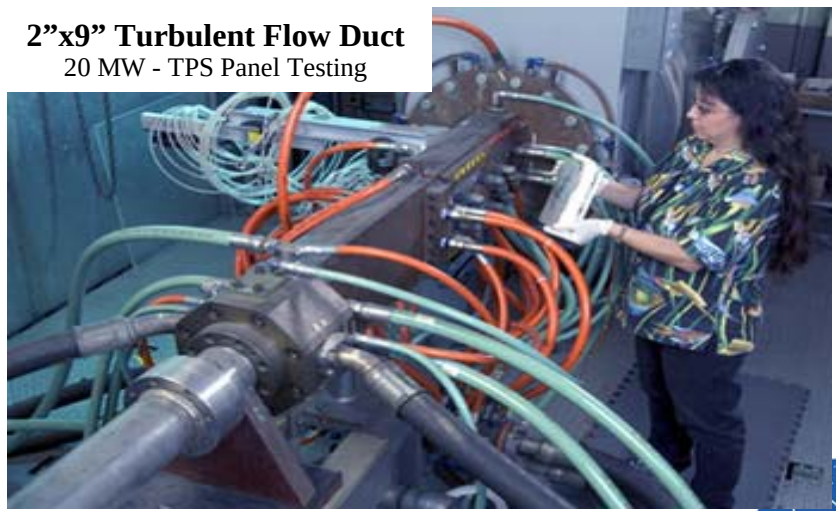
Aerodynamic Heating Facility
20 MW - TPS Free Jet Testing



Interaction Heating Facility
60 MW - TPS Free Jet and Panel Testing

Panel Test Facility
20 MW - TPS Panel Testing

2”x9” Turbulent Flow Duct
20 MW - TPS Panel Testing



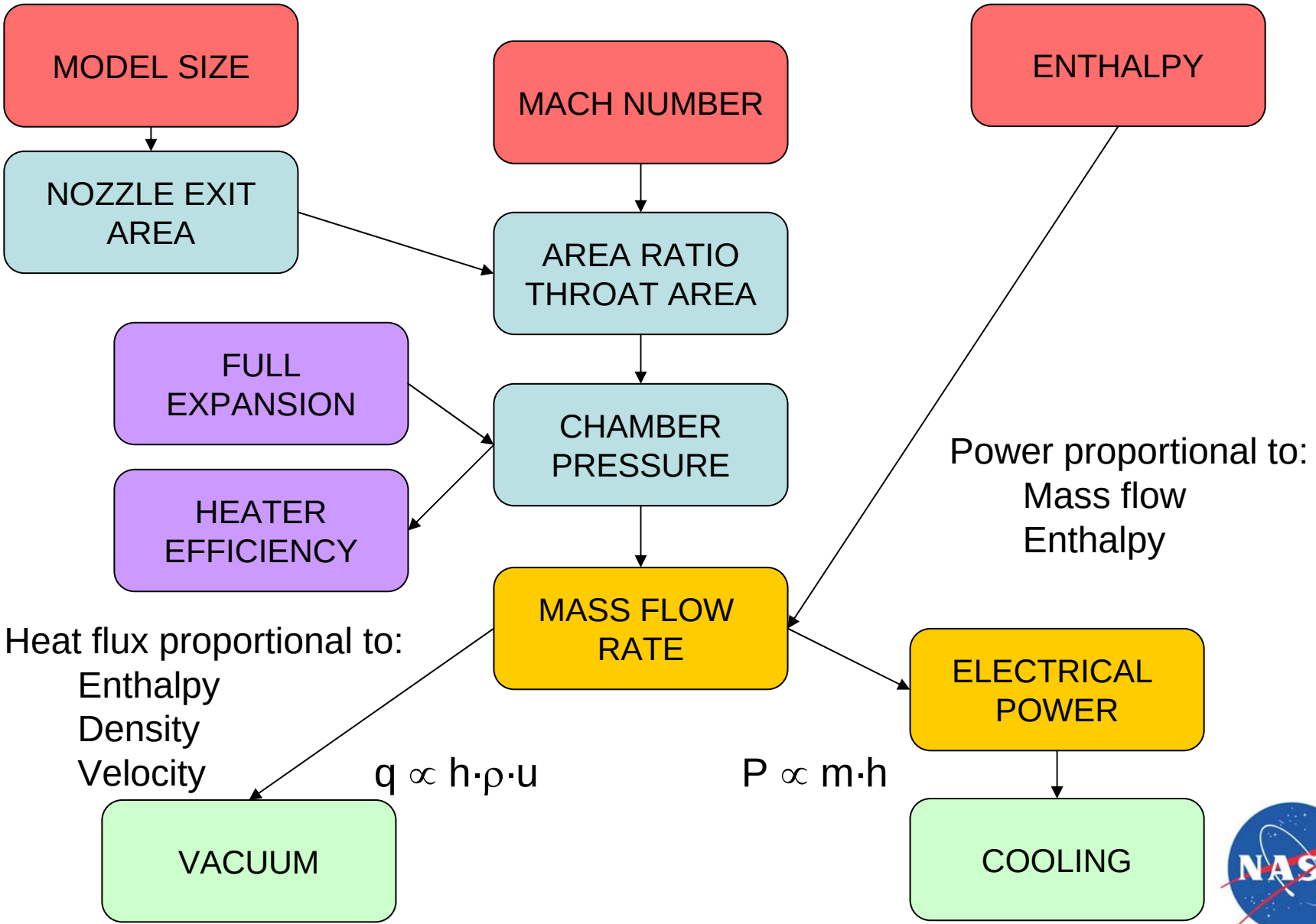
Ames Arc Jet FOMs

Facility	Gas	Input Power (MW)	Type of Test Article	Nozzle Exit (inches)	Mach Number	Bulk Enthalpy (Btu/lb_m)	Surface Pressure (atm)	Convective Heating Rates* (Btu/ft^2-sec)
AHF	Air N_2	**20**	Stagnation Point, Inclined	Conical 12, 18, 24, 30, 36 ∅	4-12	500 to 14,000	0.005 to 0.125, 0.001	20 to 225, 0.05 to 22
AHF/Huels	Air N_2	**20**	Stagnation Point, Inclined	Conical 12, 18, 24, 30, 36 ∅	4-12	1,500 to 4,500	0.02 to 0.3	20 to 225
IHF	Air	**60**	Stagnation Point, Inclined, Panel	Conical 6,13,21,30,41 ∅ Semi-elliptical 8 x 32	< 7.5 5.5	3,000 to 20,000	0.010 to 1.2, 0.0001 to 0.02	50 to 1500, 0.5 to 45
PTF	Air	**20**	Panel	Semielliptical 4 x 17	5.5	3,000 to 15,000	0.0006 to 0.05	0.5 to 30
Turbulent Flow Duct (2x9)	Air N_2	**12**	Panel	2 x 9	3.5	1,300 to 4,000	0.02 to 0.15	2 to 60

Arc Jet capabilities at Ames Research Center (US customary units)

*Heating rate is a cold wall, fully catalytic value on a 4-inch diameter hemisphere.

Overview of Arc Jet Design Considerations

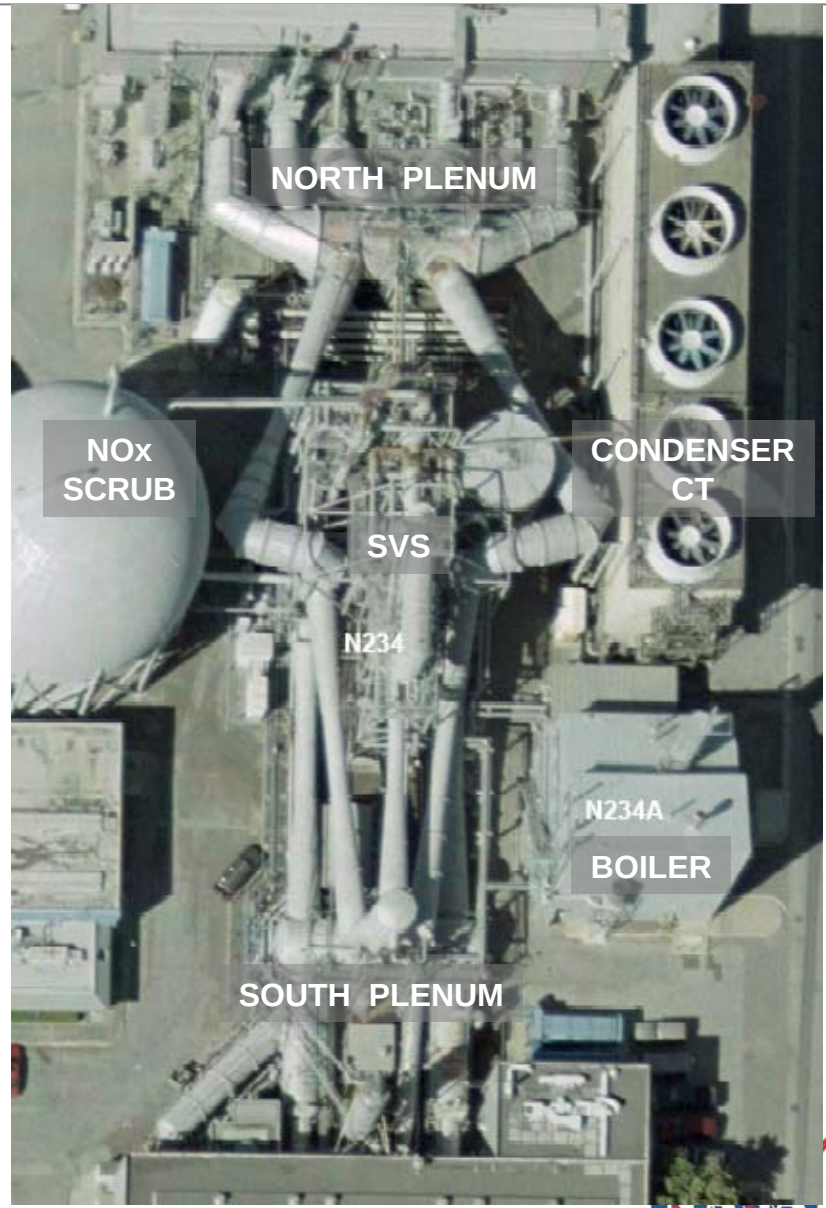


DC Power Supplies

- **Direct grid connection, 138 kV**
- **Two continuous DC rectifier power supplies 20 MW and 150 MW**
- **Typical output: 2.4 kA @ 6 kV (20 MW)**
  6 kA @ 7.2 kV (60 MW)
- **Interlocked access and distribution switching allows single facility control/operation from multiple control stations/test bays**
- **150 MW supply: three transformers, five operational rectifier modules**
- **Dedicated on-site support staff; widely respected experts**
- **Transformers are “original” equipment (mid-1970s)**
- **Recent CofF upgrades to rectifiers and expanded control monitoring**

Steam Vacuum System

- Vacuum for the Arc Jet complex is created by a five stage steam ejector pumping system Flow rates at plenums: 100 µHg @ 0.5 lb/sec; 5000 µHg @ 10 lb/s
- Steam Generator (Boiler)
  - Babcox and Wilcox M-type naval boiler recovered from USS Helena (CA-75; C. 1945; fabricated 1943)
  - Converted from diesel to natural gas burners at Ames
  - Ejection system: 5-stage steam jet system, 11 ejectors
  - 253,000 lb/hr capacity, 634 psig max, typically throttled to 300 psi
  - Annual inspection by National Board / CA State Inspector
- Pollution Control System scrubs effluents from Arc Jet exhaust prior to atmospheric release; compliant with all local regulations



ARC Arc Jet Facility Statistics

FY04

CHARGED SHIFT DAYS		DAYS POSSIBLE		SCHD/STBY/RUN DAYS AVAILABLE		UNSCH DOWN	AVAILABILITY		STARTS
2X9	0	2X9	217	2X9	217	0	2X9	1.00	
AHF	67	AHF	218	AHF	207	11	AHF	0.95	
IHF	118	IHF	220	IHF	207	13	IHF	0.94	
PTF	10	PTF	215	PTF	215	0	PTF	1.00	
TOTAL TO DATE:	**195**	TOTAL TO DATE:	882	TOTAL TO DATE:	858	24	TOTAL TO DATE:	**0.97**	310

FY05

CHARGED SHIFT DAYS		DAYS POSSIBLE		SCHD/STBY/RUN DAYS AVAILABLE		UNSCH DOWN	AVAILABILITY		STARTS
2X9	0	2X9	227	2X9	192	0	2X9	1.00	
AHF	126	AHF	227	AHF	213	14	AHF	0.94	
IHF	143	IHF	230	IHF	202	21	IHF	0.91	
PTF	1	PTF	227	PTF	227	0	PTF	1.00	
TOTAL TO DATE:	**270**	TOTAL TO DATE:	911	TOTAL TO DATE:	834	35	TOTAL TO DATE:	**0.96**	453

FY06

CHARGED SHIFT DAYS		DAYS POSSIBLE		SCHD/STBY/RUN DAYS AVAILABLE		UNSCH DOWN	AVAILABILITY		STARTS
2X9	8	2X9	62	2X9	27	0	2X9	1.00	
AHF	35	AHF	215	AHF	201	0	AHF	1.00	
IHF	114	IHF	210	IHF	145	39	IHF	0.79	
PTF	26	PTF	197	PTF	185	12	PTF	0.94	
TOTAL TO DATE:	**183**	TOTAL TO DATE:	684	TOTAL TO DATE:	558	51	TOTAL TO DATE:	**0.92**	331

FY07

OD		DAYS POSSIBLE		SCHD/STBY/RUN DAYS AVAILABLE		UNSCH DOWN	AVAILABILITY		STARTS
2X9	19	2X9	225	2X9	158	8	2X9	0.95	
AHF	96	AHF	225	AHF	206	14	AHF	0.94	
IHF	96	IHF	225	IHF	113	46	IHF	0.71	
PTF	37	PTF	225	PTF	181	8	PTF	0.96	
TOTAL TO DATE:	**248**	TOTAL TO DATE:	900	TOTAL TO DATE:	658	76	TOTAL TO DATE:	**0.90**	429

	Starts/ year	Models/ year	Injections/ year	Average OD/yr	Models/ OD	Insertions/ OD
AHF	120	161	440	81	1.98	5.43
IHF	230	224	414	117	1.9	3.51
AHF + IHF	350	385	858	198		
All legs	391			224		