ABSTRACT

Dual-Spool Turbine Facility Design Overview

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The next generation of aircraft engines, both commercial and military, will attempt to capitalize on the benefits of close-coupled, vaneless, counter-rotating turbine systems. Experience has shown that significant risks and challenges are present with close-coupled systems in terms of efficiency and durability. The UEET program needs to demonstrate aerodynamic loading and efficiency goals for close-coupled, reduced-stage HP/LP turbine systems as a Level 1 Milestone for FY05. No research facility exists in the U.S. to provide risk reduction for successful development of close-coupled, high and low pressure turbine systems for the next generations of engines.

To meet these objectives, the design, construction, and integrated systems testing of a Dual-Spool Turbine Facility (DSTF) facility has been initiated at the NASA Glenn Research Center. The facility will be a warm (~1000°F), continuous flow facility for overall aerodynamic performance and detailed flow field measurement acquisition. The facility will have state-of-the-art instrumentation to capture flow physics details. Accurate and reliable speed control will be achieved by utilizing the existing Variable Frequency Drive System. Utilization of this and other existing GRC centralized utilities will reduce the overall construction costs. The design allows for future installation of a turbine inlet combustor profile simulator.

This presentation details the objectives of the facility and the concepts used in specifying its capabilities. Some preliminary design results will be presented along with a discussion of plans and schedules.

Dual-Spool Turbine Facility Design Overview

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Objective

- Next generation of engines, both commercial and military, will attempt to capitalize on the benefits of close-coupled, vaneless, counter-rotating turbine systems
- Experience has shown significant risks and challenges with close-coupled systems in terms of efficiency and durability
- Needed to demonstrate the UEET aerodynamic loading & efficiency goals for close-coupled, reduced-stage HP/LP turbine system (Level I Milestone for FY05)
- No research facility exists in the USA to provide risk reduction for successful development of closely-coupled, high and low pressure turbine systems for next generation of engines

Objective

- Design, construction, and integrated systems testing of a Dual Spool Turbine Facility (DSTF) at the Glenn Research Center (Engine Research Building No. 23, Cell W2)

- Warm (~1000° F) continuous-flow type facility for overall aero performance & detailed flow field measurement capability

- State-of-the-art instrumentation for flow physics details

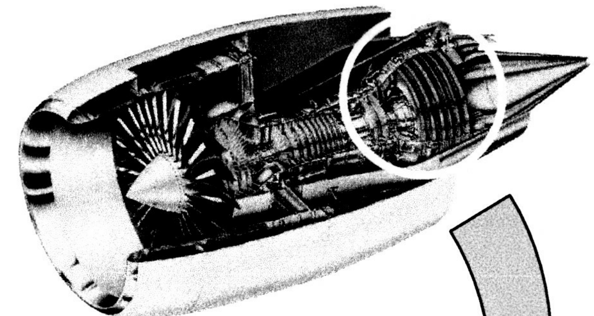
- Accurate speed control utilizing existing Variable Frequency Drive System (Building No. 23)

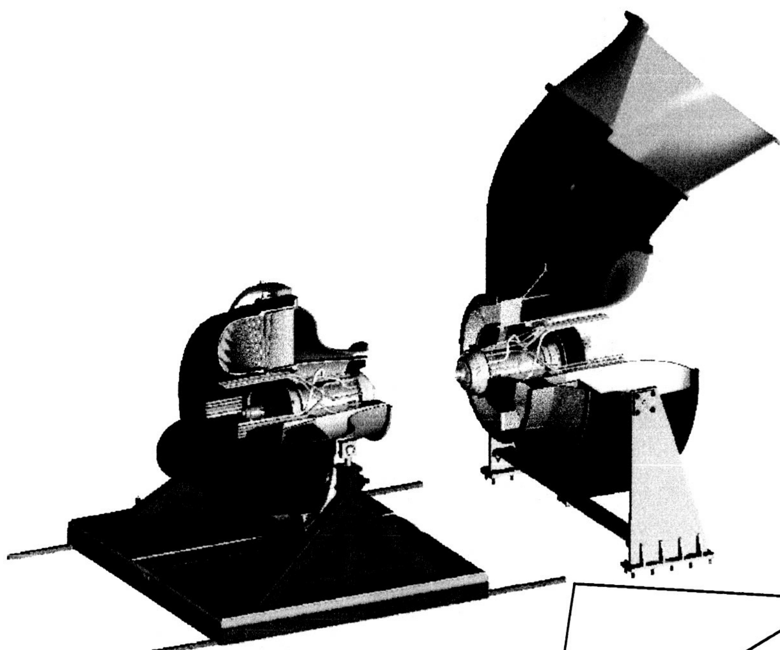
- Utilization of existing GRC centralized utilities reduces overall construction costs

- Configuration allows for future installation of a combustor profile simulator

Objective

Dual Spool Turbine Facility





- Research facility to provide validation data
- High pressure ratio capability (~twice the current capability at industry)
- Capacity to accommodate entire HP/LP turbine groups

Validation facility for CFD tools & models relevant to industry

Customer Support

Interfaced with Industry to Establish Facility Capabilities

Partner	Position
• GEAE	Supportive, since DSTF will have capabilities beyond their Cell A7 facility; Transmitted engine data for facility sizing.
• P&W	Supportive; offered military test articles; Transmitted engine data for facility sizing.
• Honeywell	Supportive, although concerned about suitability at small size end of product range; Transmitted engine data for facility sizing.
• AADC	Supportive; identified hardware for testing.
• AFRL	Supportive; complementary to TRF.

Objective

Establishing DSTF Facility Capabilities

Facility sized to meet…

- Industrial partner's needs
  DSTF capabilities "must exceed those of existing facility"

- UEET goals (55:1 OPR engine)
  UEET engine configuration data obtained from
  Airbreathing Systems Analysis Office (ASAO)

- Research objectives:
  - Detailed data
  - Accuracy
  - Spatial resolution

DSTF Facility Sizing Methodology

Given engine cruise and take-off parameters

(Diameters, power, speed, temperatures, pressures, flow)...

Match engine parameters…

- Reynolds number
- Mach number
- power coefficient

Subject to facility sizing constraints on…

- Inlet and exhaust air mass flows
- Power absorption
- Rotational speed
- Temperatures
- Pressures
- Cost

Sizing variables…

- geometric scale
- inlet temperature

Highly Loaded Turbomachinery, Dual-Spool Turbine Facility

DSTF Torque vs. Speed Curves

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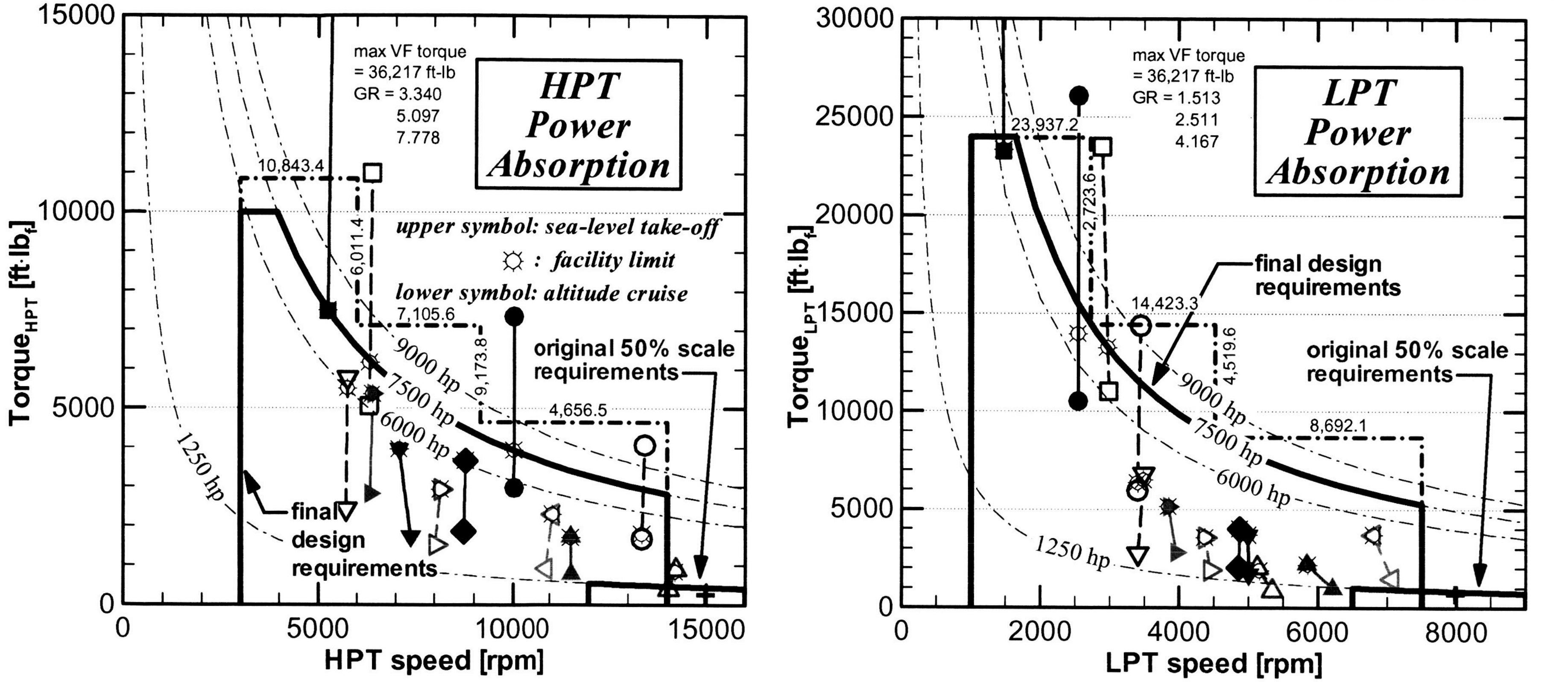
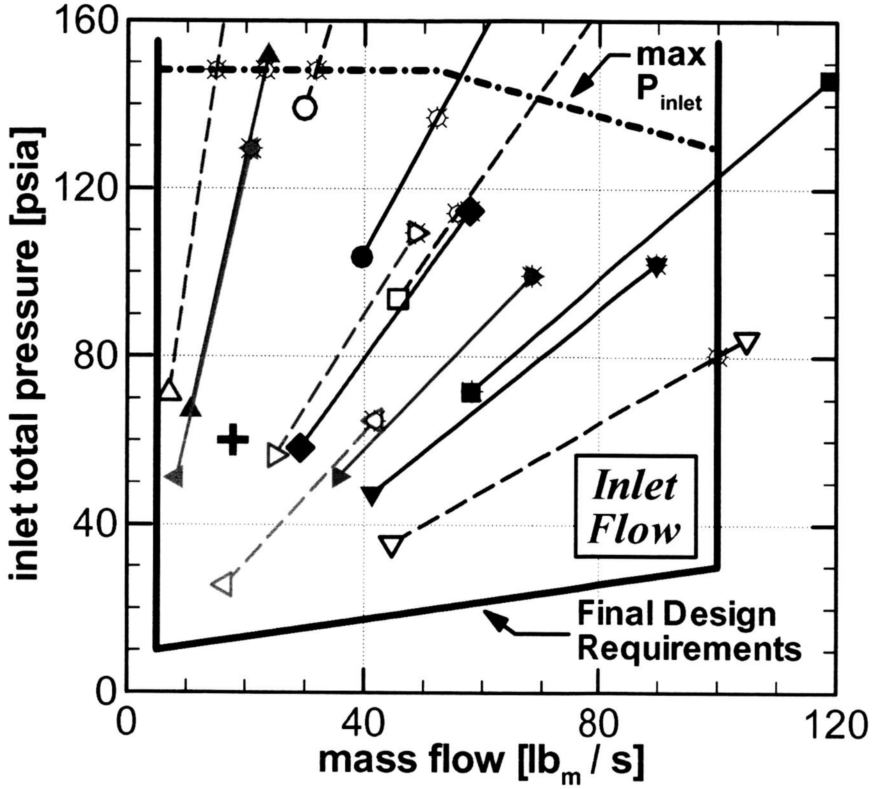
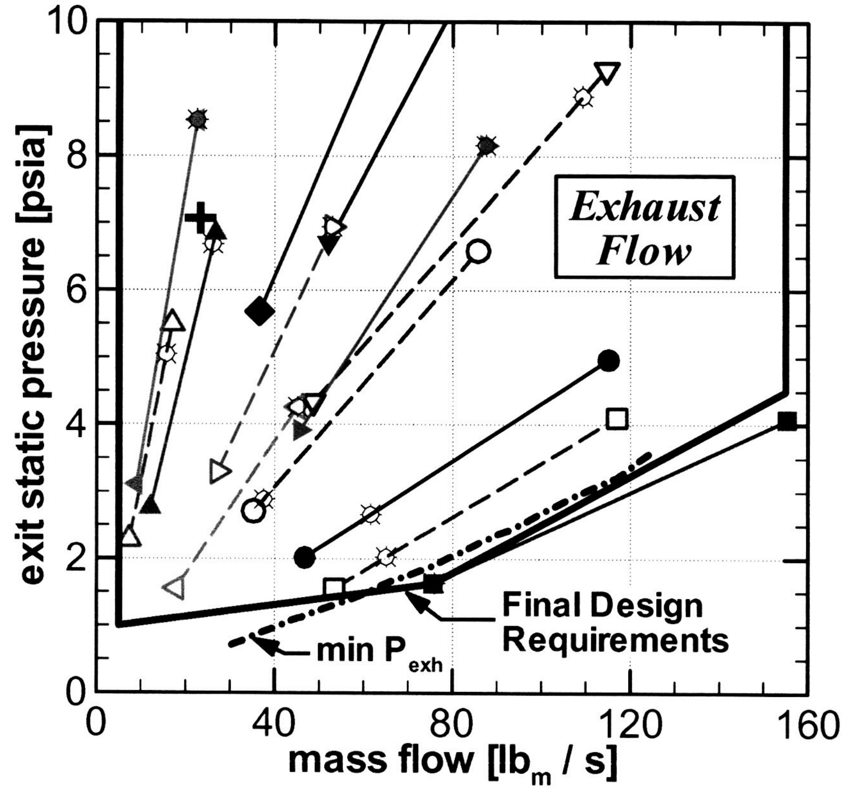


Symbol	Configuration	T'_{in}	T_{exit}	N_{HPT}	N_{LPT}
●——●	Mid Commercial, scale=0.8734	1200	455	10016	–2540
○------○	Mid Commercial, scale=0.6551	1200	458	13327	–3384
■——■	UEET 300 PAX, Current Tech.	1100	454	5252	1474
□------□	UEET 300 PAX, UEET Tech.	1200	457	6328	2987
▲——▲	UEET 50 PAX, Current Tech.	1460	699	11550	6216
△------△	UEET 50 PAX, UEET Tech.	1460	664	14031	5339
✚	Original 50% Scale Mil. Config.	800	500	15000	–8000
▼——▼	HSCT, Current Tech., 50% scale	800	500	7388	5004
▽------▽	HSCT, UEET Tech., 75% scale	800	485	5727	3407
▶——▶	SBJ, Current Technology	1000	553	6339	3959
▷------▷	SBJ, UEET Technology	1000	524	8024	4448
◀——◀	Small Commercial, scale=1.0	1460	787	21791	14143
◁------◁	Small Commercial, scale=2.0	1460	787	10896	7072
◆——◆	Mil. Fighter, Current Tech.	1200	709	8741	4856

Highly Loaded Turbomachinery, Dual-Spool Turbine Facility

DSTF Mass Flow Requirements





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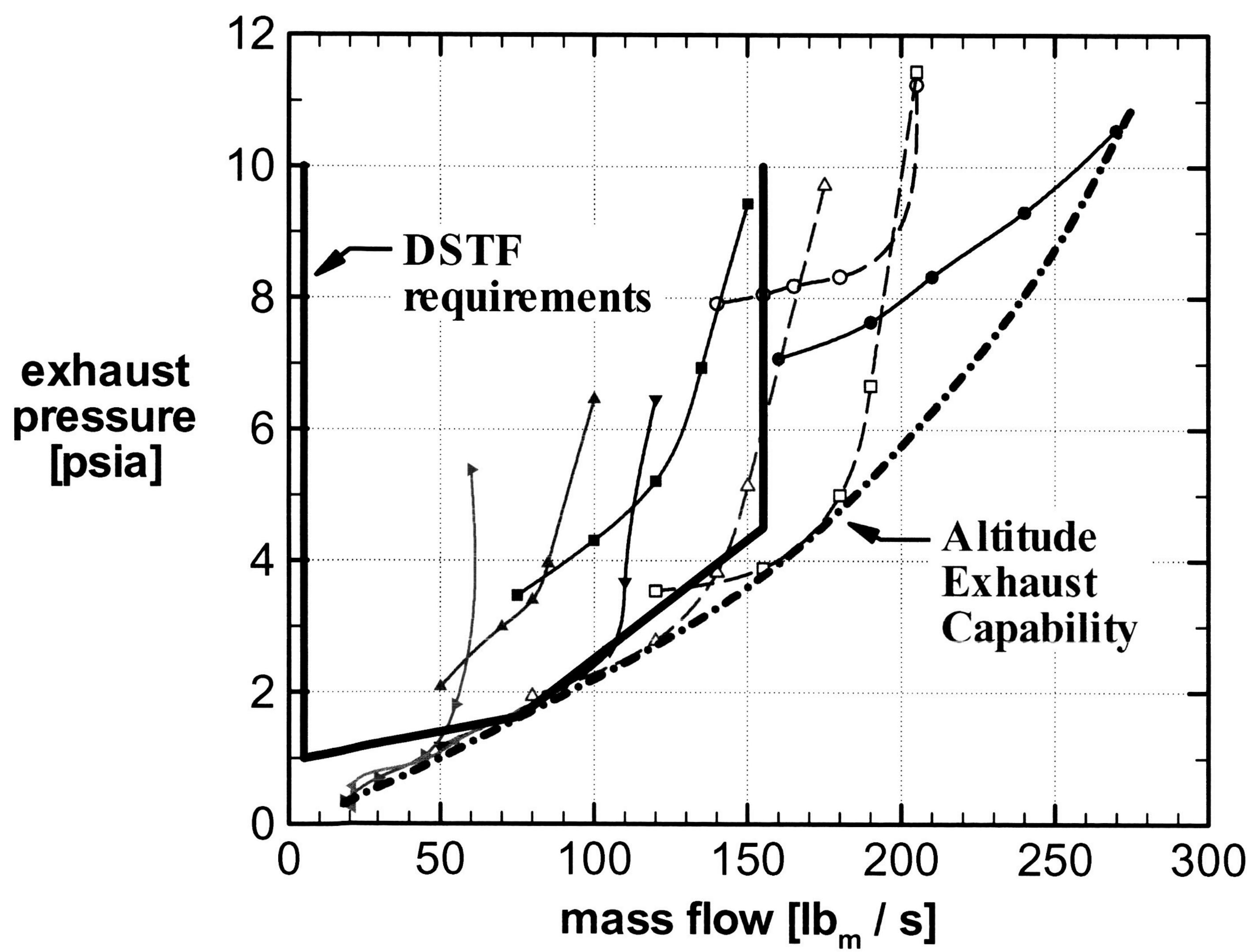
GRC Altitude Exhaust Capability and DSTF Requirements



Highly Loaded Turbomachinery, Dual-Spool Turbine Facility

Planned Use of GRC Central Services for DSTF

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most likely

↑

less likely

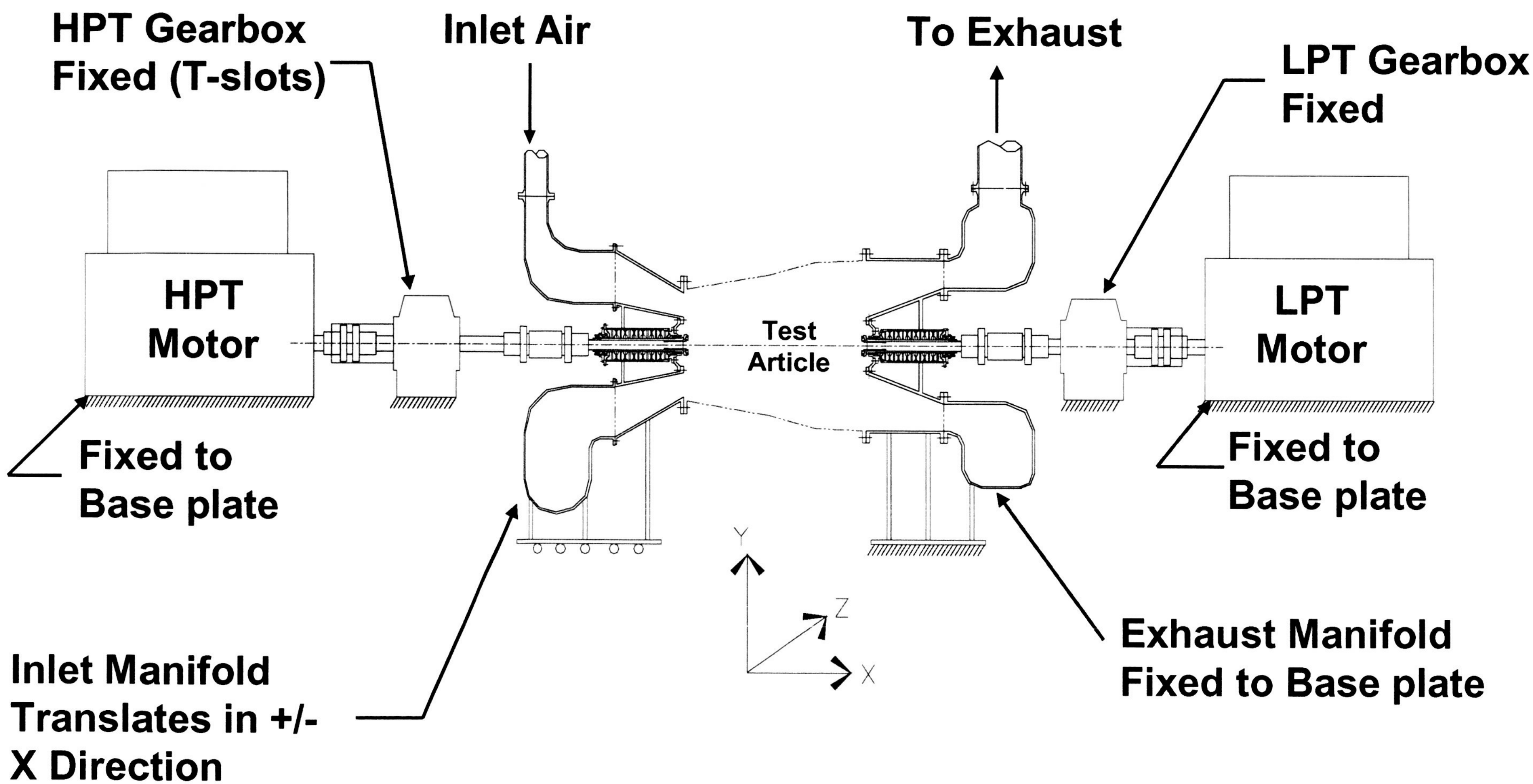
Test Article	Variable Frequency*	150 psig Comb. Air	Altitude Exhaust
Mid. Commercial, 87% Scale	B - [redacted]	C	C
Mid. Commercial, 66% Scale	B	C	C
Military Fighter, Current Tech.	B	C	C
Small Commercial, Scale=2.0	C - B	C	C
UEET 50 PAX, Curent Tech.	C - B	C	C
UEET 50 PAX, UEET Tech.	B	C	C
UEET 300 PAX, Current Tech.	[redacted]	C	C
UEET 300 PAX, UEET Tech.	[redacted]	C	C
SBJ, Current Tech.	B	C	B
SBJ, UEET Tech.	C - B	C	C
HSCT, Current Tech.	B	B	B
HSCT, UEET Tech.	B	B	B

[redacted]

B: DSTF requires 40% to 80% of GRC Capability

C: DSTF requires less than 40% of GRC Capability

Converters Available		
FY04 - FY05	FY06 - FY07	FY08 - FY09
10	11	12 *

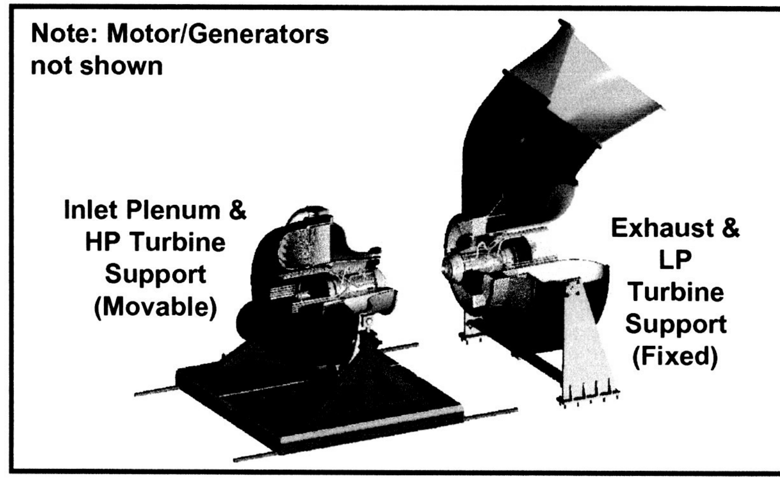


DSTF Free Body Diagram

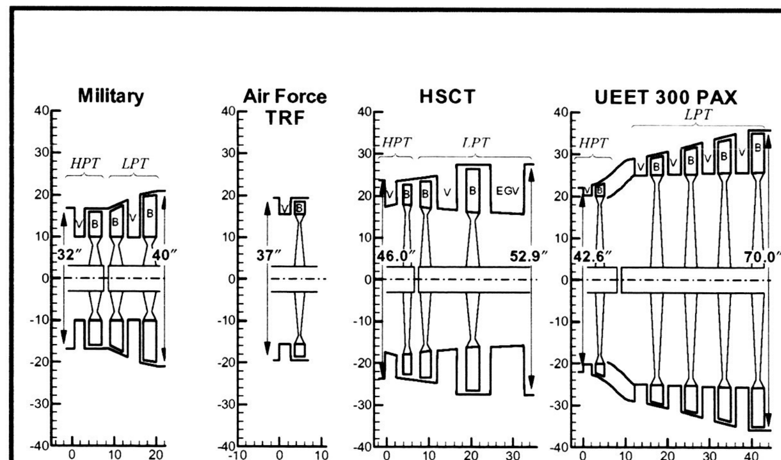
Highly Loaded Turbomachinery, Dual-Spool Turbine Facility

Technical Results

- Preliminary Design Report completed (Jan 01).
- Detailed Design contract initiated Aug 01 (ASE/Belcan).
- 30% design of Dual Spool Turbine Facility was completed, reviewed.
- Separate PDR was held (Apr 02).
- PDR team included industry, NASA, and DoD personnel.
- PDR recommendation resulted in gov't redirection of inlet plenum/bearing support design, facility instrumentation design.
- 60% final design completed Dec 02.
- Detailed design will continue to completion.
- IST hardware will continue to be defined.
- 90% Design due end of May 02.



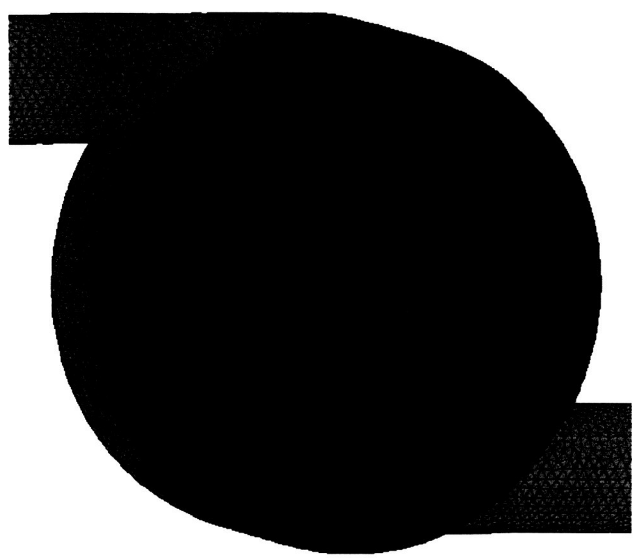
Most recent PDR concept for DSTF



Capability for Proposed Test Articles

Aero Performance Design

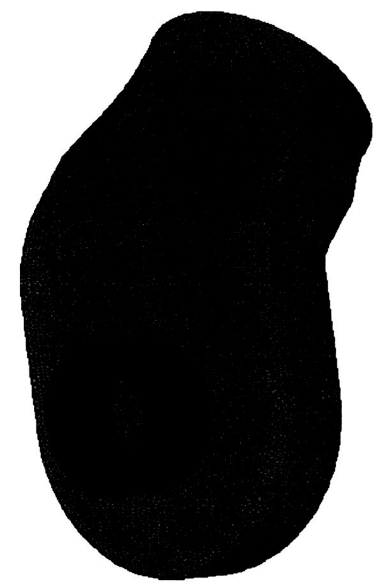
For the DSTF



Inlet Manifold & Transition Piece

Flow Path Definition

CFD Analysis Performed to Define Flow Path (Ensure uniform Airflow Velocity, Pressure, and Temperature Profiles Into the Inlet of the High Pressure Turbine)

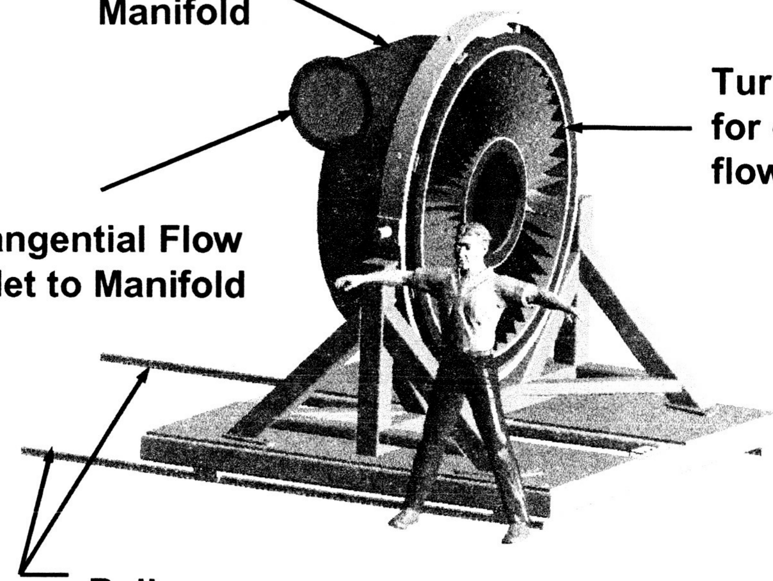


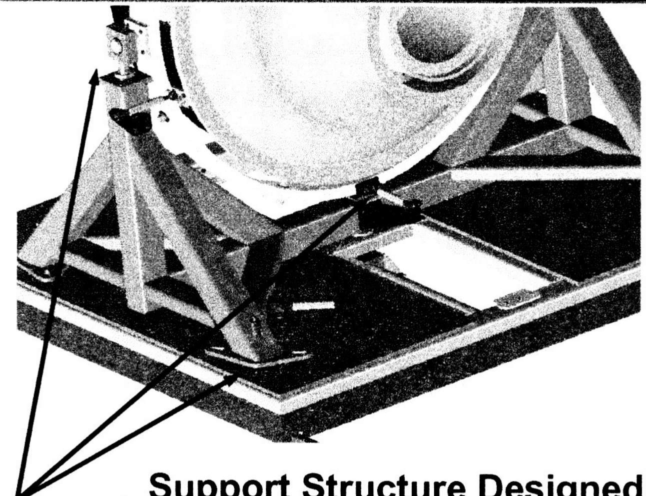
Exhaust Manifold & Transition Piece

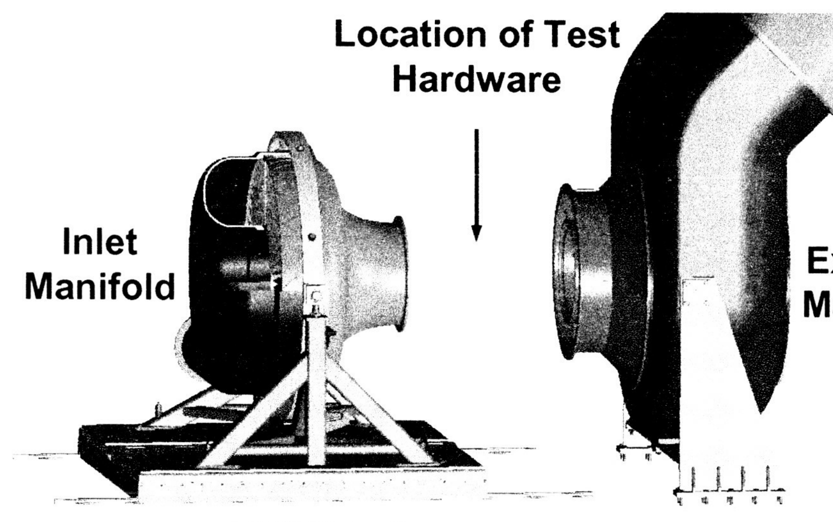
Flow Path Definition

CFD Analysis Performed to Define Flow Path (Ensure That There are no Backpressure Effects from the Exhaust Manifold)

Mechanical Design of Inlet & Exhaust Manifolds for the DSTF

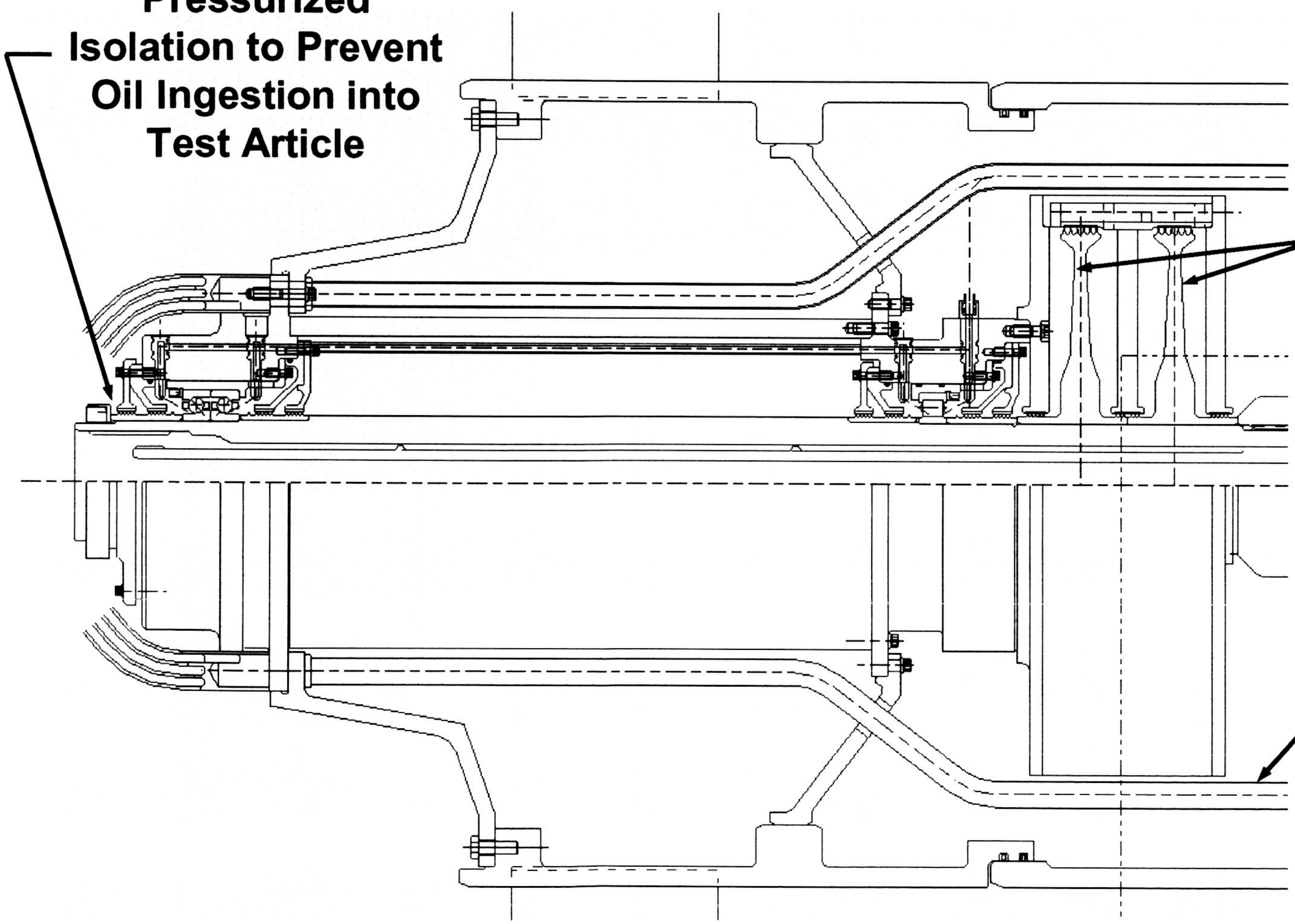


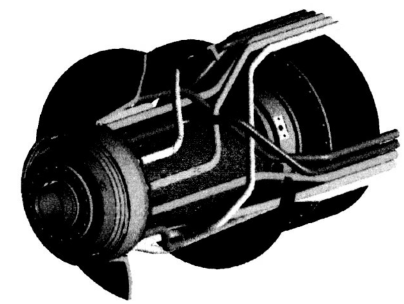




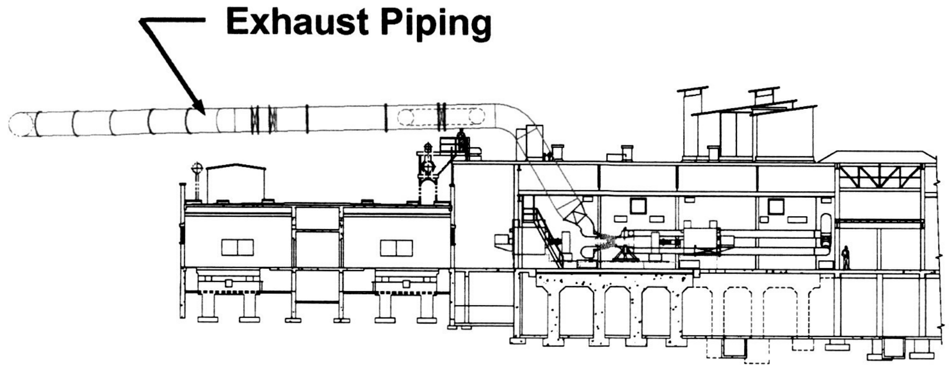
Facility Inlet Hardware Mounted on Translating Cart to Simplify Test Hardware Assembly Procedures

HPT/LPT Bearing Cartridge Design Details



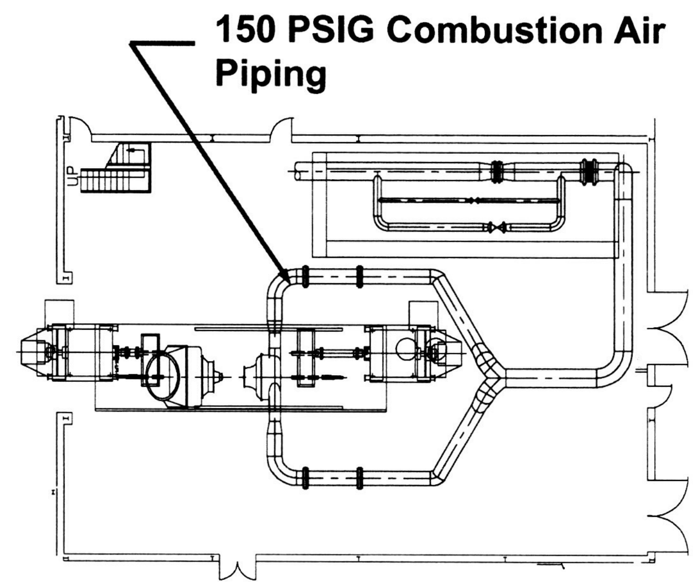


DSTF Facility Piping Design



Bldg. 23, Cell W2 Sectional View

Exhaust Piping (Shown in Green) Exits Through the Roof of Cell W2, Runs Above SW Wing, Ties Into Existing Altitude Exhaust Header



Bldg. 23, Cell W2 Plan View

150 PSIG Combustion Air Piping (Shown in Blue) Splits and Two Feeds Supply the DSTF Inlet Manifold

Highly Loaded Turbomachinery, Dual-Spool Turbine Facility

Plans for Next Year & Beyond

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Calendar Years

Event	Duration
Final Design	**9/01 - 7/03**
60% Review Meeting	10/22/2002
Motor Procurement Package	4/03 - 6/03
Heater Procurement Package	4/03 - 6/03
90% Review Meeting	6/03
100% Submittals	7/03
Constr. Procurement	**7/03-11/03**
CBD Announcement	7/03 - 8/03
Solicitation	8/03 - 10/03
Award Contract	11/03
CoF Construction	**12/03-4/05**
Need Heater	7/15/2004
Need Motors	7/15/2004
Collector Delivery (best)	8/15/2004
Bearing Cart. Deliv. (best)	8/15/2004
Integrated Syst. Test	**4/05-11/05**
Subsystems Tests	4/05 - 8/05
Rotating Hardware	8/05 - ...

2002				2003				2004				2005			
Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4

Conclusion

- No Technical or Other Barriers Preventing Completion of Final Design

- Industry Partners Involved in Design (Helped Solve Technical Issues)

- Industry Partner to Furnish Rotating Hardware for Use During Integrated Systems Testing (IST)

- Phased Research Test Article SOW Development underway.