OVERVIEW OF NASA'S UEET AND TBCC/RTA PROGRAMS

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Glenn Research Center
Cleveland, Ohio

Overview of the

Ultra Efficient Engine Technology (UEET) Program

Robert J. Shaw
Catherine L. Peddie

NASA Seal/Secondary Air System Workshop
October 23, 2002

Revolutionize Aviation Goal Emissions Objective

UEET Ultra Efficient Engine Technology

Reduce emissions of future aircraft by a factor of three within 10 years (2007), and by a factor of five within 20 years.

NASA Three Pillars for Success-1997

Reduce NOx emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline. Reduce CO_2 emissions of future aircraft by 25 percent and by 50 percent In the same timeframes (using 1997 subsonic aircraft technology as the baseline).

NASA Aerospace Technology Enterprise Strategic Plan-2001

UEET will be the responsible propulsion program for delivering on this objective!

Commercial Turbine
Engine Technology
Leadership for the
21st Century

NASA Glenn Research Center

UEET

Ultra-Efficient Engine Technology Program

The UEET Program will develop and transfer to the U. S. industry critical gas turbine engine technologies which will contribute to "enabling a safe, secure, and <u>environmentally friendly air transportation system"</u>.

Vision:

Develop and hand off revolutionary turbine engine propulsion technologies that will enable future generation vehicles over a wide range of flight speeds.

Goals:

Propulsion technologies to enable increases in system efficiency and, therefore, fuel burn reductions of up to 15 % (equivalent reductions in CO_2)

Combustor technologies (configuration and materials) which will enable reductions in LTO* NO_x of 70% relative to 1996 ICAO standards.

**** LTO - Landing/Take-off***

Program Technical Objectives

	Goal	Minimum Success Criteria
CO_2 Goal	15% fuel burn reduction for large subsonic aircraft	12% fuel burn reduction for large subsonic aircraft
	8% fuel burn reduction for small subsonic, small / large supersonic	4% fuel burn reduction for small subsonic, small / large supersonic
NO_x Goal	70% N0x reduction (below ICAO 96) for subsonic (large/ regional) combustors over the LTO cycle	65% N0x reduction (below ICAO 96) for subsonic (large/ regional) combustors over the LTO cycle

NASA's Technology Readiness Level (TRL) Scale

	TRL	General NASA Definition
System Test and Operations	9	Actual system "flight proven" on operational flight
	8	Actual system completed and "flight qualified" through test and demonstration
System/Subsystem Development	7	System prototype demonstrated in flight environment
Technology Demonstration	6	System/subsystem model or prototype demonstrated/validated in a relevant environment
	5	Component and/or breadboard verification in a relevant environment
Technology Development	4	Component and/or breadboard test in a laboratory environment
Research to Prove Feasibility	3	Analytical and experimental critical function, or characteristic proof-of-concept
Basic Technology Research	2	Technology concept and/or application formulated (candidate selected)
	1	Basic principles observed and reported

Industry Role

Government Role

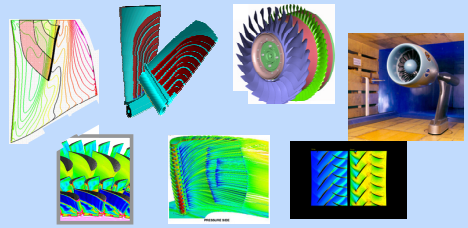
In partnership with DOD, industry

UEET

UEET Projects

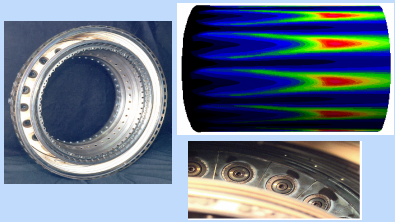
UEET Ultra Efficient Engine Technology

Highly Loaded Turbomachinery



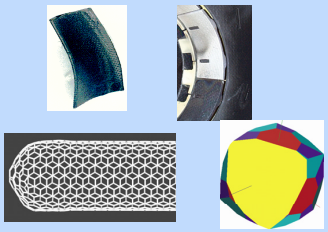
GRC Lead

Emissions Reduction



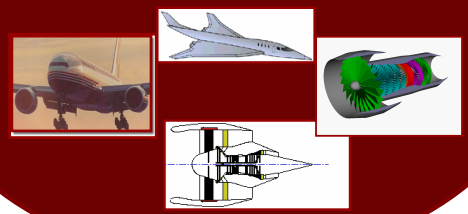
GRC Lead

Materials and Structures for High Performance



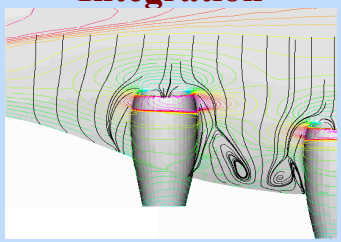
GRC Lead

Propulsion Systems Integration and Assessment



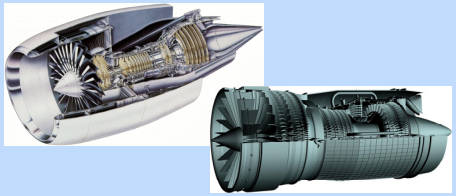
GRC Lead

Propulsion-Airframe Integration



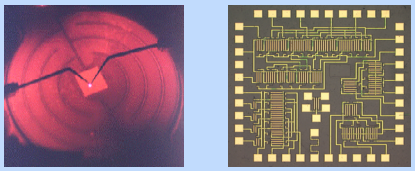
LaRC Lead

Integrated Component Technology Demonstrations



GRC Lead

Intelligent Propulsion Controls



GRC Lead

Baseline Vehicles for UEETP Technology Application Studies

Subsonic

Supersonic

Hypersonic

Commercial Vehicles

300 PAX
Large Subsonic Transport

50 PAX
Regional Jet Transport

500-600 PAX
Blended Wing Body (BWB)

300 PAX
High Speed Civil Transport (HSCT)

10 PAX
Supersonic Business Jet (SBJ)

These vehicles drive the technology investment strategy

Non-Commercial Vehicles

4 PAX
General Aviation Aircraft (GA)

Military Transport (C-17)

Unmanned Aerial Vehicle (UAV)

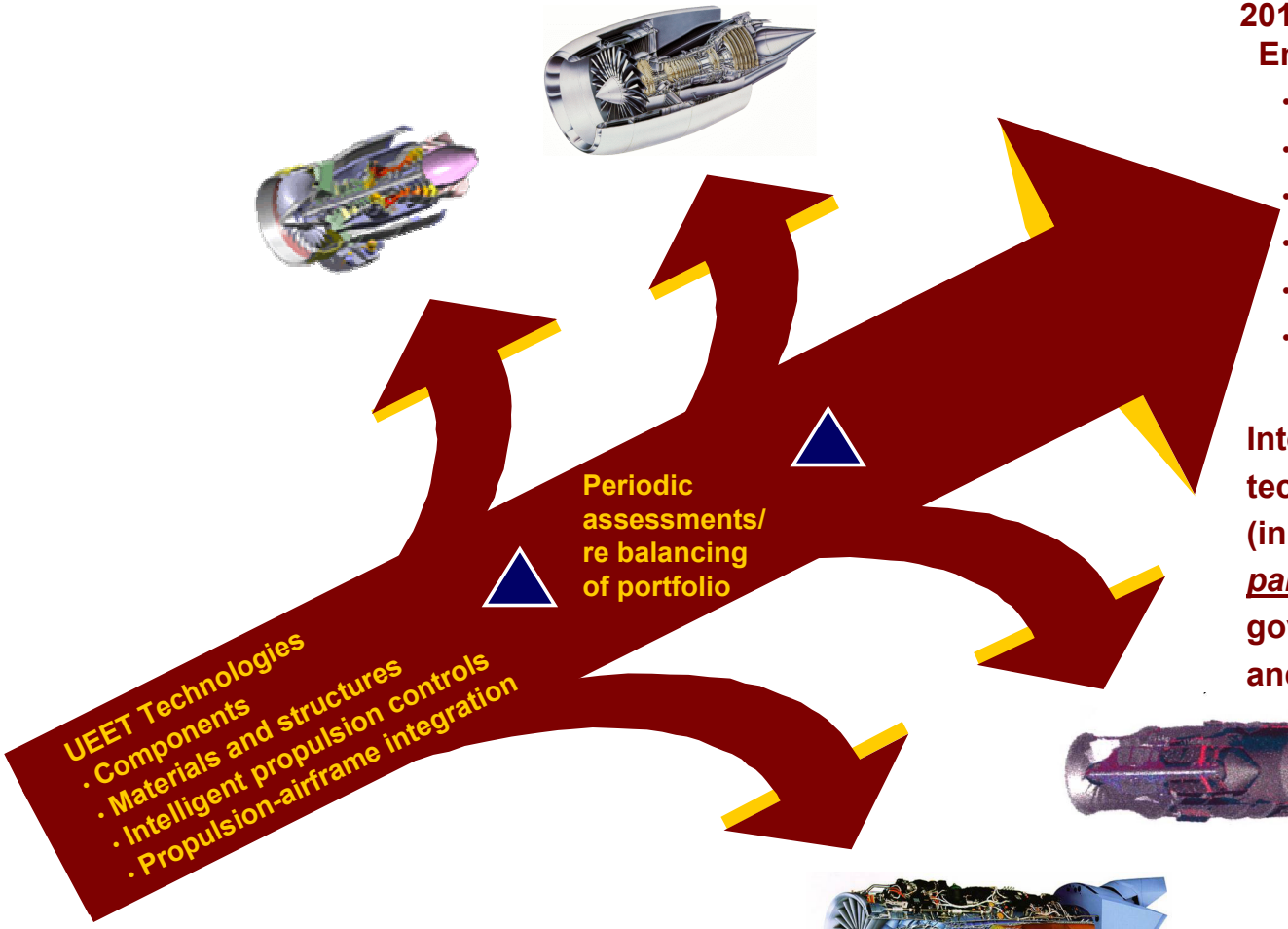
Advanced Fighter

Access-to-Space/High Mach Platform

These vehicles determine the technology synergies

The UEET "Roadmap"

UEET Ultra Efficient Engine Technology



2015 "Ultimate" Turbine Engine Systems

- Emissions
- Fuel burn
- Weight
- Noise
- Safety
- Reliability

Integrated component technology validations (in *cost-sharing partnership* with other government agencies and/or industry)

Vision

UEET Ultra Efficient Engine Technology

Develop and hand off revolutionary propulsion turbine engine technologies that will enable future generation vehicles over a wide range of flight speeds.

We support the vision and are committed to the success of NASA's Ultra Efficient Engine Technology (UEET) Program.

Richard Hill, Air Force Research Laboratory

Gerald Brines, Allison-Rolls Royce

Mahmood Naimi, Boeing Commercial Airplane Company

Fred Krause, General Electric Aircraft Engines

Dimitri Mavris, Georgia Tech

Vinod Nangia, Honeywell

Tom Hartmann, Lockheed-Martin

Robert J. Shaw, NASA Glenn Research Center

Robert D. Southwick, Pratt & Whitney

Scott Cruzen, Williams International

UEET Partnerships

UEET Ultra Efficient Engine Technology

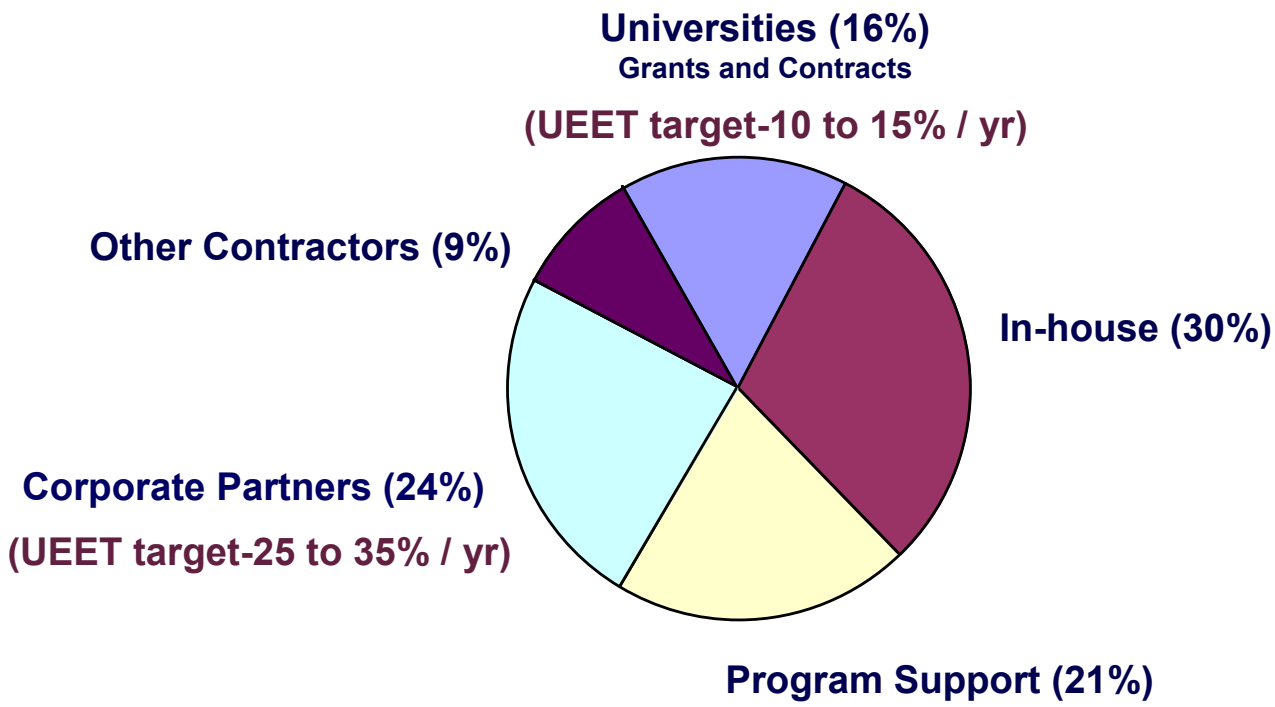
Partner	Comments
Boeing, Lockheed-Martin, GE, P&W, Honeywell, AAD/RR, Williams, Georgia Tech	On track to provide >$50M of direct in kind contributions to overall UEET Program
NASA Quiet Aircraft Technology (QAT) Program	Shared development of fan technologies
NASA Advanced Space Transportation Program (ASTP)	Technology insertion opportunities on TBCC/RTA demonstrators
NASA Propulsion and Power Program (APP)	Shared responsibility in simulation tool development; revolutionary lower TRL technologies
EPA	Environmental compatibility of technologies
FAA	Pre certification “issues” of technologies
DOD (IHPTET/VAATE)	Technology insertion on IHPTET/VAATE demos; collaboration on materials development/studies; support for Dual Spool Turbine facility (DSTF)
DOE	Technology insertion on ground power demos
National Technology Transfer Center (NTTC)	Technology transfer to non aerospace community
QinetiQ (UK)	Emissions modeling validation data sets

UEET is all about partnerships!

The UEET Team

UEET Ultra Efficient Engine Technology

UEET Investment Portfolio (FY00-02)

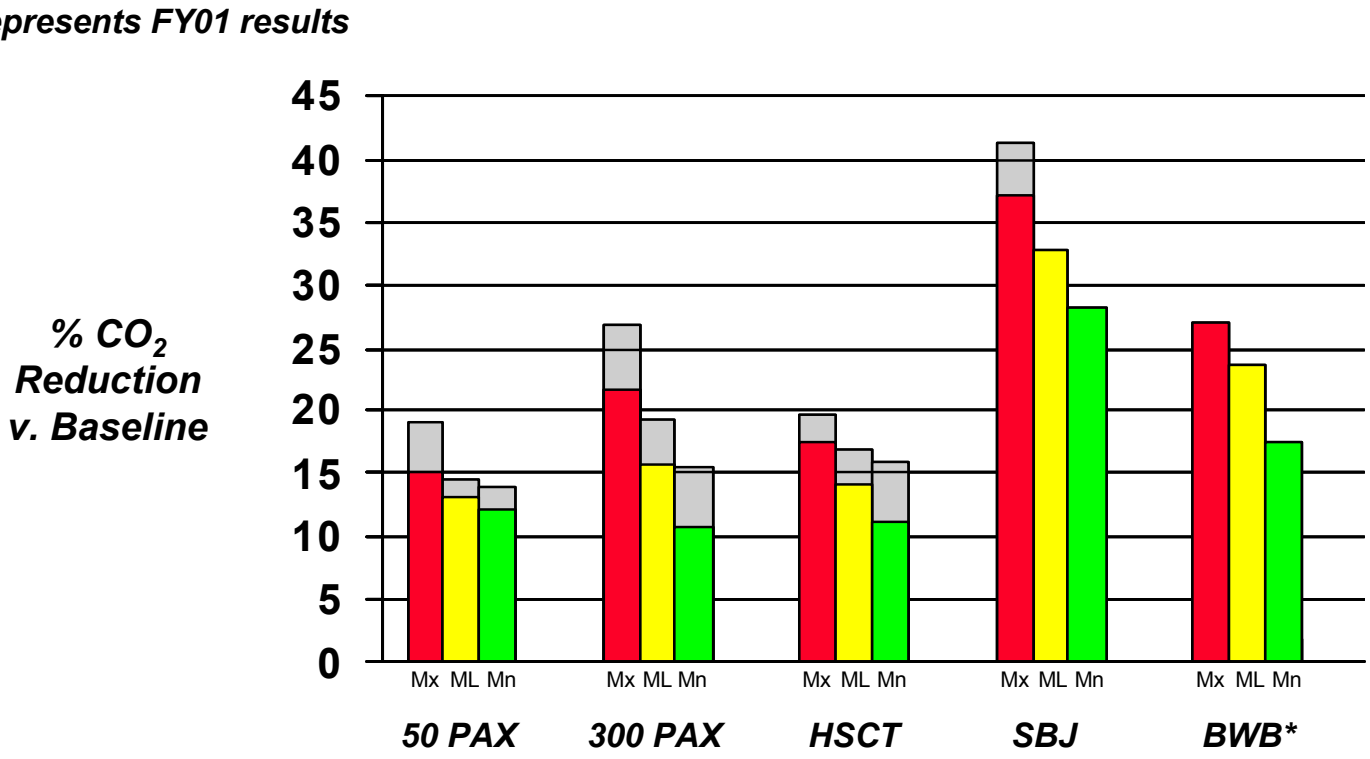


Program Status

October 2002

Goal	Status	Remarks
15% fuel burn reduction for large subsonic	22% projected for 300 PAX	Systems studies projections of combined impacts of UEET technologies.
8% fuel burn reduction for small subsonic, small / large supersonic	15% for 50 PAX 17% for 300 PAX HSCT 37% for 10 PAX SSBJ	Limited test data (TRL2-3+ range)
70% N0x reduction (below ICAO 96) for subsonic (large regional) combustors over the LTO cycle	Initial industrial sector tests give confidence that at least the min success will be achieved (TRL = 3+)	Initial sector tests completed

Potential CO_2 Reduction
(Using "Core" Set of Technologies)

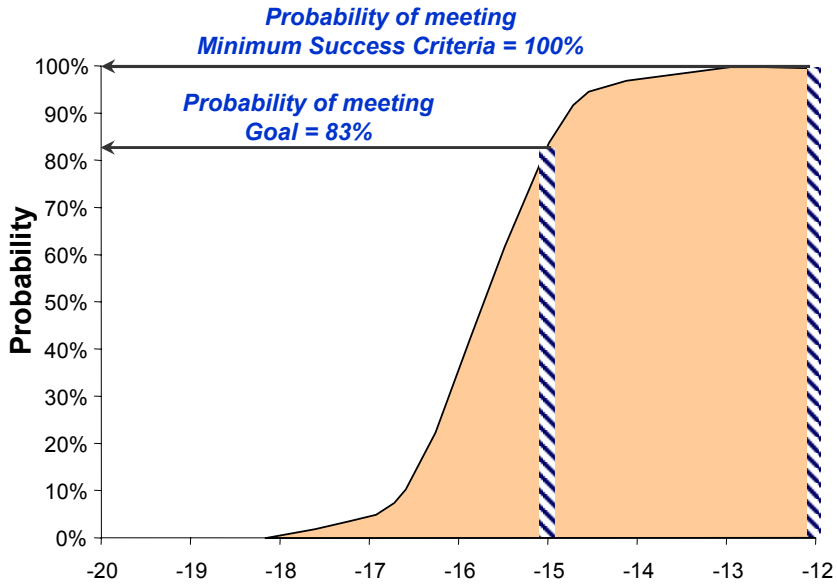


* Same engine for all cases only Active Flow Control benefit varied

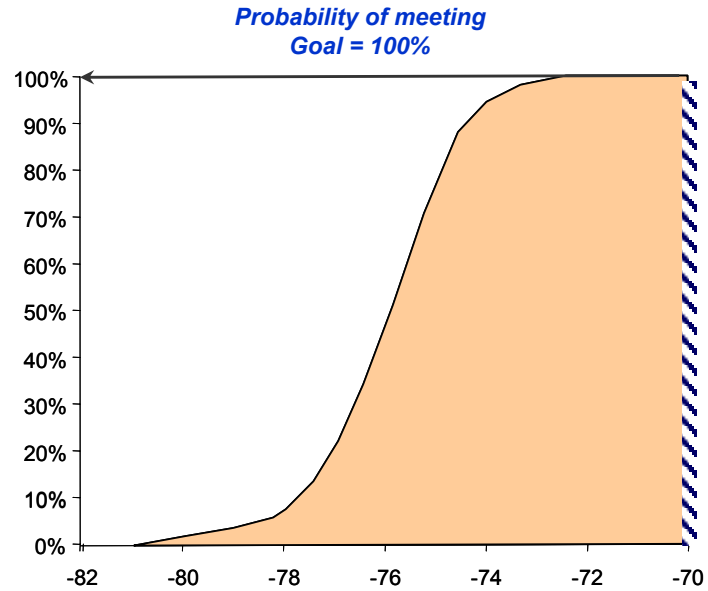
Probability Distribution for Meeting UEET Program Goals

UEET

% Change in CO_2/ASM from Baseline for GT Best



% Below LTO NO_x Rule for GT Best

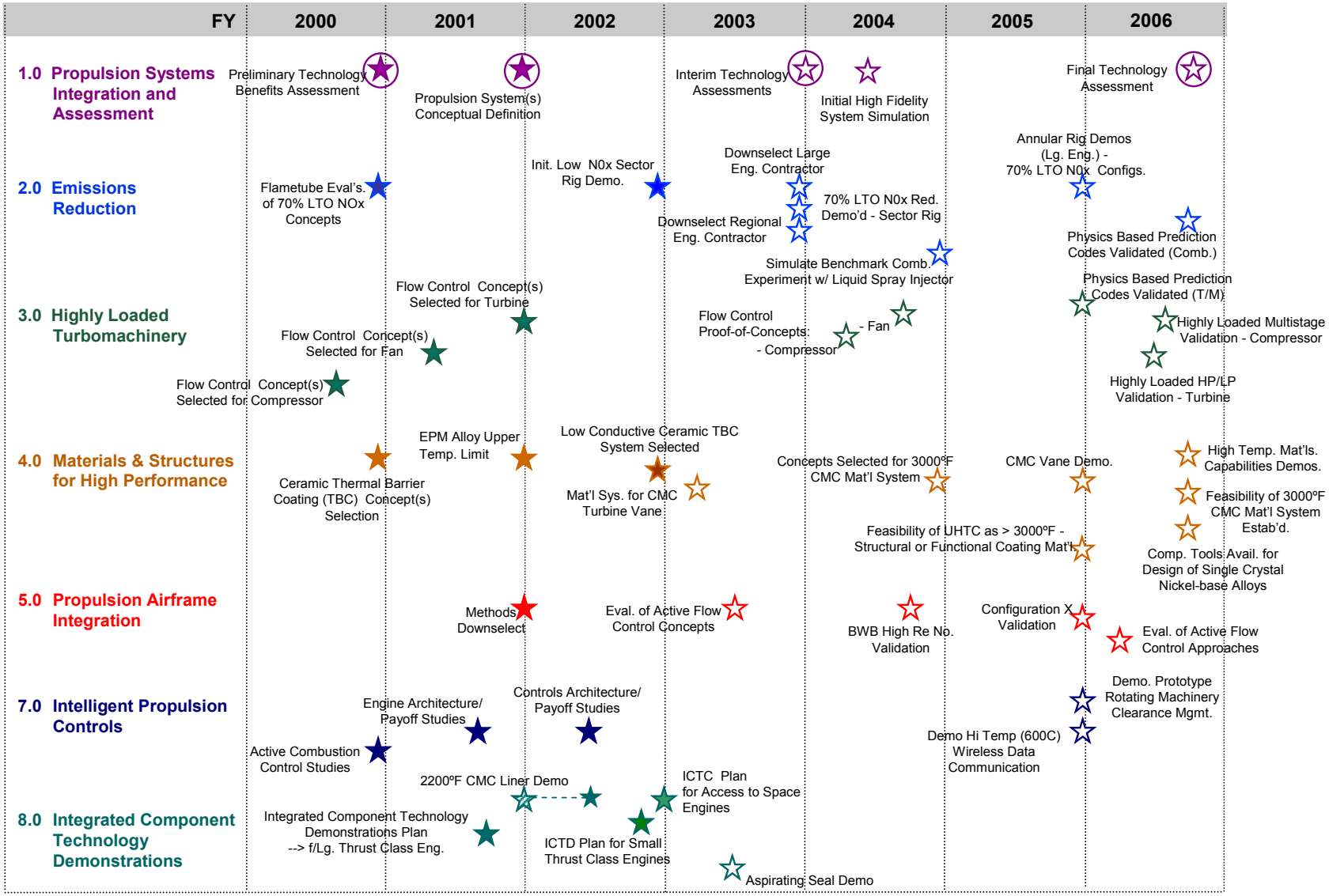


- **UEET Program Goal of -70% LTO NO_x can be achieved with a 100% confidence with the identified best set of technologies**
- **UEET Program Goal of -15% CO_2 can be achieved with a 83% confidence**

Preliminary results

UEET Level I Milestone Schedule

May 2002 Rebaseline



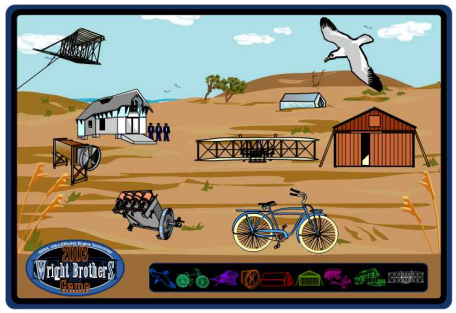
Notes: 1) PCA milestones are denoted by ☆
2) WBS 6.0 reserved for Program Mgmt. functions

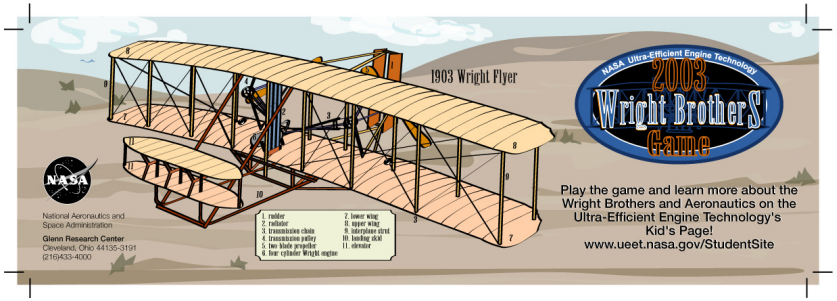
Education/Outreach Activities

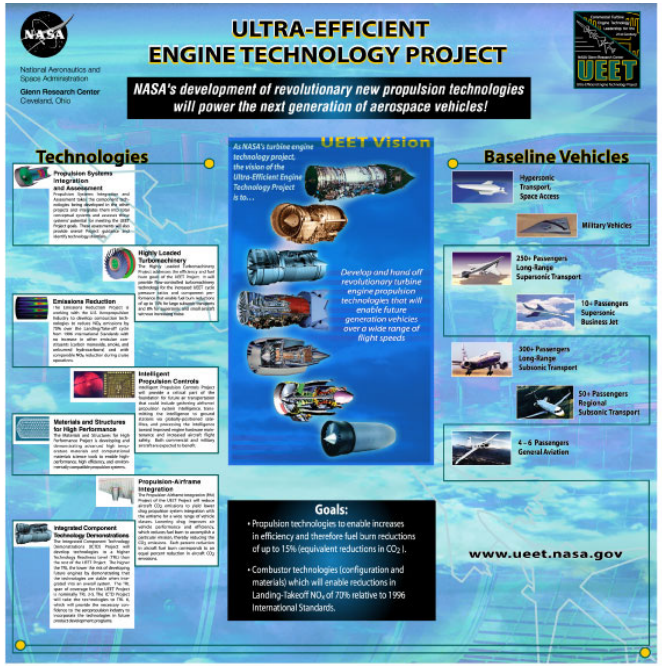
UEET Ultra Efficient Engine Technology

Wright Brothers Game for the Web

Targeted to grades 5-8, this educational game encourages students to browse the museum and learn facts about the Wright Brothers and their journey to discover the secret of powered flight, then answer questions for points on Kill Devil Hills near Kitty Hawk. The game has been posted to the UEET Website: http://www.ueet.nasa.gov/StudentSite





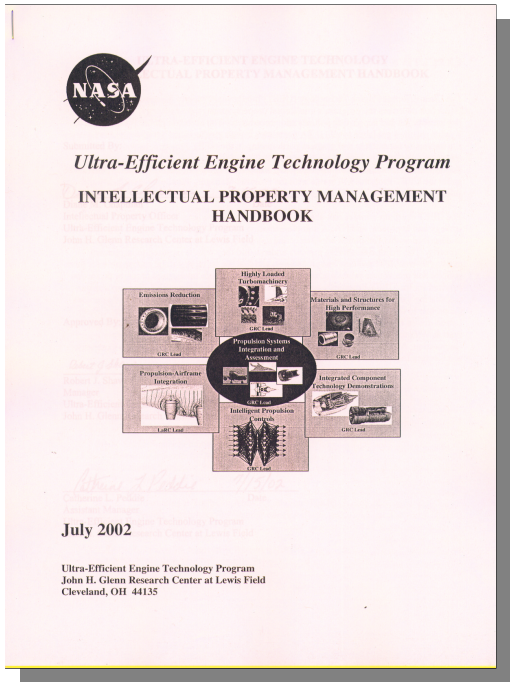


UEET Outreach Display

This 8ft x 10ft display was created to represent UEET to the technical community and the general public. It was debuted at the Integrated High Performance Turbine Engine Technology (IHPTET) Symposium in Dayton, Ohio on September 9, 2002.

Intellectual Property Management Handbook

- Handbook signed July 2002 after <u>extensive</u> interactions with industry
- Training module has been developed in co-operation with National Technology Transfer Center (NTTC) for NASA employees (including on site PBC's)
- Training module (and trainers) have been offered to corporate partners



Technology Transfer Partnership

UEET Ultra Efficient Engine Technology

We are committed to working together in partnership to actively seek out non aerospace opportunities for transfer and commercialization of all appropriate technologies being developed through programs and projects being managed by the Ultra Efficient Engine Technology (UEET) Office.

Joseph Allen
President, National Technology Transfer Center
Wheeling Jesuit University

Robert J. Shaw
Chief, UEET Office
NASA Glenn Research Center

Larry Viterna
Chief, Commercial Technology Office
NASA Glenn Research Center

Commercial Turbine Engine Technology Leadership for the 21st Century
NASA Glenn Research Center
UEET
Ultra-Efficient Engine Technology Program

Commercial Technology Office

Robert C. Byrd National Technology Transfer Center

Final Major Technology Deliverables (1)

Propulsion Systems Assessment and Integration:

Systems studies assessment of impact of UEET technologies towards meeting NO_X and CO_2 goals.

Emissions:

Annular rig validation test (TRL5) of combustor configurations that will meet or exceed 70 % Landing Take-Off NOx goal.

Validated physics based simulation tools. (TRL4)

Highly Loaded Turbomachinery

Wind tunnel validation of wake flow control concept for efficient, low noise fan. (TRL4) Done in partnership with QAT.

Test rig validation of compressor flow control/management concept. (TRL4)

Test rig validation of turbine flow control/management techniques. (TRL4)

Validated physics based simulation tools. (TRL4)

Material and Structures

Rig test validation of high temperature turbine airfoil materials systems. (TRL3)

Rig test validation of 2700 deg F Ceramic Matrix Composite material system. (TRL3)

Develop and validate computational materials tools. (TRL2)

Final Major Technology Deliverables (2)

Propulsion-Airframe Integration

Wind tunnel validation of advanced flow and shape control technologies for propulsion system application. (TRL3)

Validated advanced CFD based design methods. (TRL4)

Intelligent Propulsion Controls:

Validated approaches for propulsion system active clearance management. (TRL3-6?)

Determine through laboratory tests attractive approaches for high temperature wireless data communications for propulsion system applications. (TRL3)

Integrated Component Technology Demonstrations

Demonstrate through engine tests (TRL6) in partnership with industry technology readiness for 2200°F Ceramic Matrix Composite Combustor liner and aspirating seal.

Concluding Remarks

- The UEET Program is comprised of a portfolio of technologies which are matured to a TRL of 3-6 and transitioned to industry for their use in future aerospace vehicles designs.

- The program goals/objectives are satisfied through systems studies assessments of the combined impact of the technologies on four vehicle classes.
    - Large subsonic transports
    - Regional subsonic transports
    - Large commercial supersonic transport
    - Supersonic business jet

- The ultimate measure of success of the UEET Program will be the impact of the technologies.

Overview of the

Turbine Based Combined Cycle (TBCC) Program

Robert J. Shaw
Catherine L. Peddie

NASA Seal/Secondary Air System Workshop
October 23, 2002

Vision and Mission

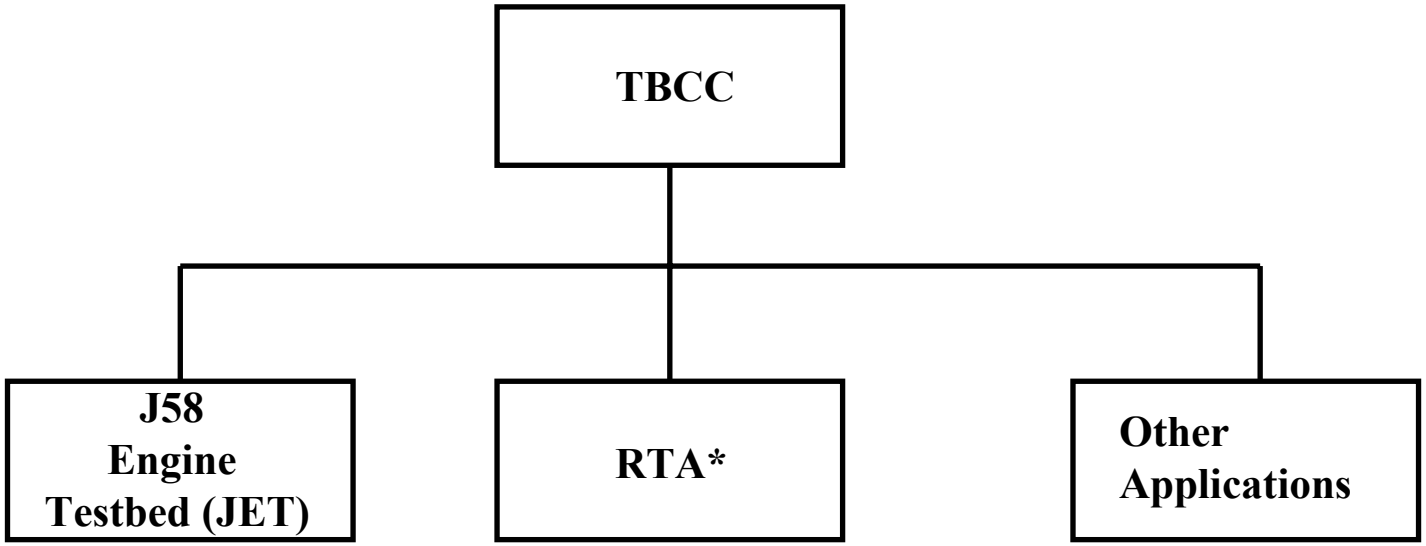
Vision:

Forging high mach turbine technologies for future transportation systems.

Mission:

Develop, demonstrate, and transition the enabling technologies required for future turbine based combined cycle propulsion systems for commercial and military applications including access-to-space and hypersonic cruise.

Project Organization

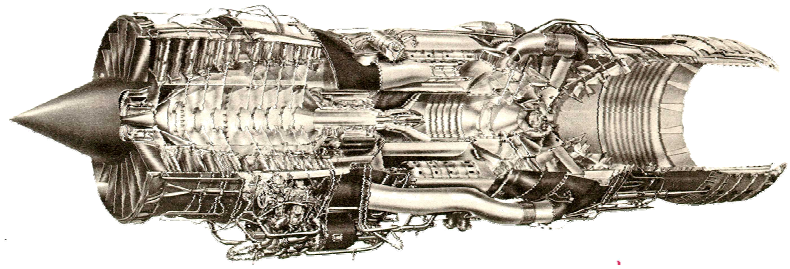


RTA-revolutionary turbine accelerator project
(funded by NASA ASTP)

State of the Art High Speed Turbine Application

Strategic Reconnaissance Aircraft
(High Speed Recon.)

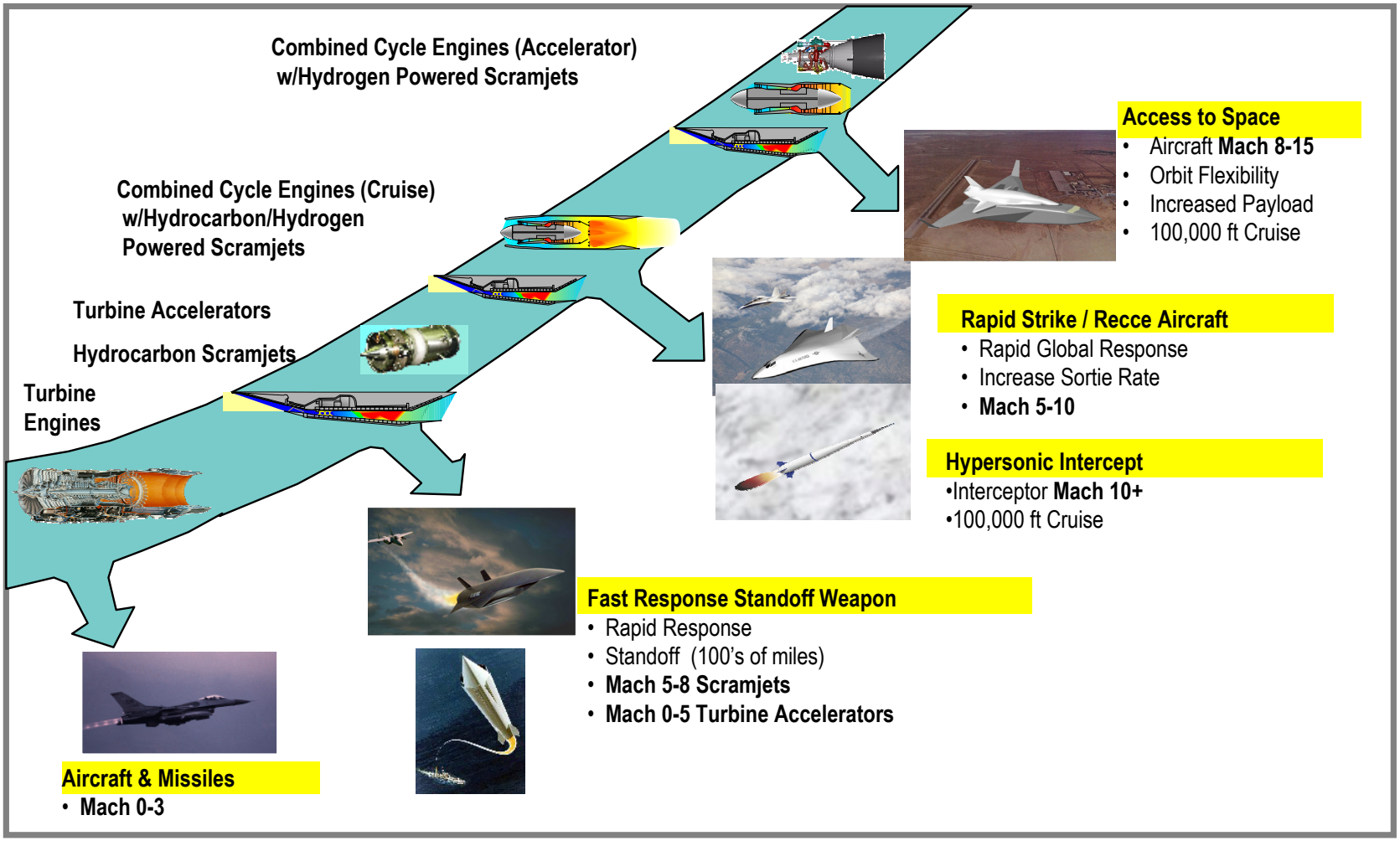
JT11D-20 (J58)



Variable Cycle ‘Turbine Bypass’ Turbojet

- ***Mach 3+ Cruise Applications***
- ***40+ year old technologies (some materials no longer made)***
- ***Requires frequent engine overhauls (every ~100 hrs)***
- ***T/W ~4:1***

RTA Bridges the Gap Between Mach 3 & Mach 5

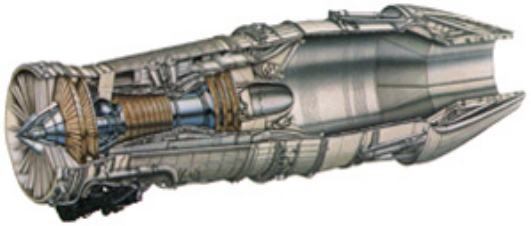


Today | Near-Term | Mid-Term | Far-Term

RTA Project Areas of Emphasis

Subscale Ground Based Testbed (GBT) Demonstrator (2001-2008)

- Develop & Demonstrate enabling turbine technologies required to meet ASTP objectives
- Demonstrate technologies on a proper scaled ground based testbed (GBT)
- Utilize GBT as a system to evaluate
  - Advanced Turbine Technologies
  - High Mach Operability (I.e., Thermal management)
  - The "ilities" (I.e.,Reliability, Durability, etc..)



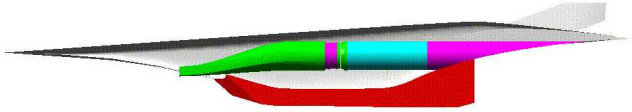
Ground Based Testbed (GBT)

X43-B Flight Demonstration Propulsion Systems (2001-2003)

- Limited design effort for TBCC system in support of X43-B downselect
  - Conceptual design of TBCC propulsion system (RTA plus Dual Mode Scramjet) that could be available for CY 2009 first flight
  - Effort builds upon DoD IHPTET results
  - First flight in 2009 requires a technology freeze in 2005
  - If effort were continued & flown on X43-B, the PAI technology challenges will be addressed

Small-scale RTA

Dual Mode Scramjet (DMSJ)



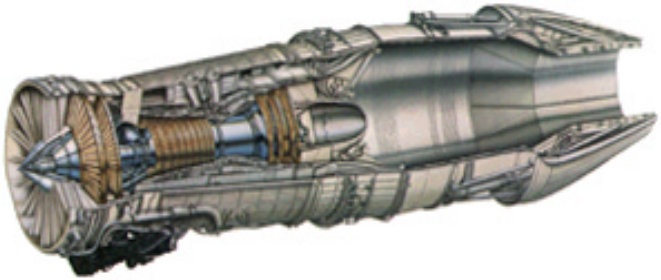
X43-B flight demo vehicle

RTA GBT Goals & Objectives

- **Mission:** **Develop & demonstrate a reusable turbine based propulsion system to meet future space access requirements (i.e., lower costs & increased safety)**

- **Goal:** **Develop and evaluate enabling technologies that significantly lower the cost for access-to-space and increase safety by providing performance margins which insure high reliability and durability.**

- **Approach:**
  1. **Develop & evaluate enabling technologies to improve performance above SOA.**
  2. **Incorporate and evaluate new advanced technologies (from ASTP as well as UEET, IHPTET, and VAATE) as they mature.**
  3. **Conduct investment studies for enabling technologies specific to RTA propulsion systems and use as key input to technology selection process**
  4. **Design and build a sub scale RTA ground based testbed (GBT)**
  5. **Utilize a combination of system studies & simulations to project propulsion system performance characteristics for both the demonstrator testbed and the full-scale vision propulsion system.**



UEET: ***Ultra Efficient Engine Technology program***
IHPTET: ***Integrated High Performance Turbine Engine Technology program***
VAATE: ***Versatile Affordable Advanced Turbine Engine program***

Team Structure

Revolutionary Turbine Accelerator Technology Demonstration

Senior Leadership Team
D. Campbell (NASA)
M. Benzakein (GE)
R. Sparks (GE)
C. Caudill (GE)

Leadership Team
F. Krause (GE PM)
J. Shaw (NASA)
H. Maclin (GE)
J. Johnson (GE)
C. Cash (GE)
H. Cikanek (NASA)
A. Spence (NASA)
T. Curran (NASA)
R. Kastner (GE)

Core Management Team
D. Shafer (TTM)
P. Bartolotta (PM)
N. McNelis (DPM)
CAMs
K. Suder
J. Seidel
G. Bruening (USAF)

Business Management Team
J. Huth (CAM)
J. Barrett
A. Fisher
J. Ladd
D. Davis
Ed Yanosik
L. Boukalik (NASA) M. Neuzil (NASA)
K. Crandall (NASA) M. Groff (NASA)
J. Rybak (NASA) J. Moran (NASA)

Systems Engr/ Materials ITD Team
D. Shafer (CAM)
E. Krammer
S. Draper (NASA)
D. Utah
G. Srini
J. Heidmann (NASA)
J. Waltz (TK)
J. Mehta (TK)
H. Demel) (TK)
D. Edmunds (USAF)
G. Bruening (USAF)

Thermal Mgmt Sys ITD Team
T. Tucker (CAM)
N. Georgiadis (NASA)
G. Coffinberry (TK)
B. Bergholz
R. Boehm
B. Brown
A. Mancini
M. Meyer (NASA)

Test & Evaluation ITD Team
G. Paulis (CAM) /
R. Sorge (NASA)
J. Bradner
K. Gessner
B. Corcoran
D. Kampman
W. Maciag

Hyperburner/ Exhaust Nozzle ITD Team
L. Grammel (CAM)
J. Orr
R. Winslow
L. Pennekamp
J. Koshoffer
J. Lee (NASA)
R. Buerhle (NASA)

Controls ITD Team
M. Butz (CAM)
J. Hyer M. Butz
E. Condrac
D.K. Le (NASA)

Bearings, Seals, & Drives ITD Team
J. Laritz (CAM)
M. Proctor (NASA)

Core Engine ITD Team
J. Benson (CAM)
G. Royal
P. Wood
C. Lee
T. Watson
C. Flotner
R. Sorge (NASA)
J. Giriunas (NASA)
R. Wiedenmannott (NASA)

Fan & Core-Drive Fan ITD Team
D. Bedel (CAM)
G. Royal
M. Mielke
P. Wood
R. Zenon
M. Mielke
K. Suder (NASA)

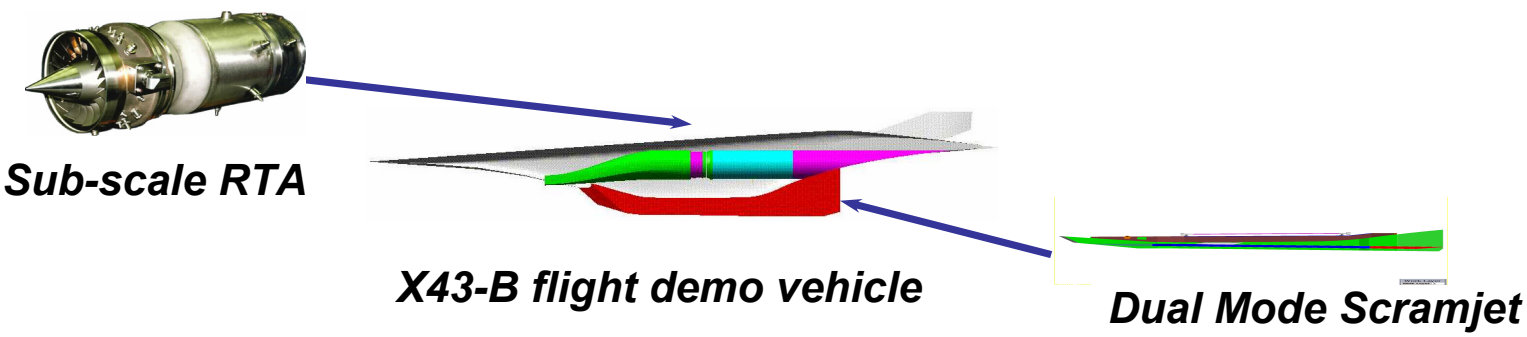
Performance/ Vehicle Integration/VPS ITD Team
J. Baughman (CAM) /
J. Seidel (NASA)
B. Powell
S. Bitter
D. Elliott
R. Porro (NASA)
T. Curran (NASA)
D. Mavris (Georgia Tech)
D. Dolvan (USAF/VA)
N. Georgiadis (NASA)

X43-B Flight Demonstrator Goals & Objectives

Mission: Develop and demonstrate a reusable turbine based propulsion system to meet future access to space requirements (i.e. lower costs and increased safety).

Goal: Develop and demonstrate a turbine based combination cycle propulsion system for the X43-B flight vehicle to evaluate propulsion/airframe integration and mode transition between low speed and high speed flow paths.

Approach: Mature to PDR level the design of a turbine accelerator and DMSJ flow paths for the X43-B flight demonstrator for a propulsion concept down-select in FY03 (program has slipped this decision to FY06.



RTA Technical Performance Metrics (Ground Based Testbed)

Metric	Current SOA	Goal	Minimum Success
M_{cruise}	3+	5	4
Thrust/Weight	4	20	10
Life	125 hrs	750 hrs	500 hrs

Rotating Components*

Compressor: Weight Reduction
High Mach Capability
Stage Loading

Turbine: Weight Reduction
Cooling Flow Reduction
Work Coefficient

Bearings: High Temperature
Life
Load Capacity

Rotating Seals: High Temperature
Leakage
Life

Non-Rotating Components*

Inlets: Pressure Recovery
Flow Quality
Mode Transitions

Combustors: High Temperature
Volume & Weight
Efficiency

Augmentors: Mixing Efficiency
Flame Stability
Length

Nozzles: High Temperature
Performance
Length & Weight

Advanced Technologies*

Materials: High Temperature
Lightweight
Durability
Processing Attributes

Thermal Management:
Weight
Volume

Fuels: Density & Stability
Heating Value
Heat Sink Capability

IVHM / Instrumentation:
TBD

Controls: TBD

** All sub-element metric values are TBD until after system cycle selection is complete.*

Note: Thrust, weight, and life will be projected values based on GBT data and acceptable analytical tools