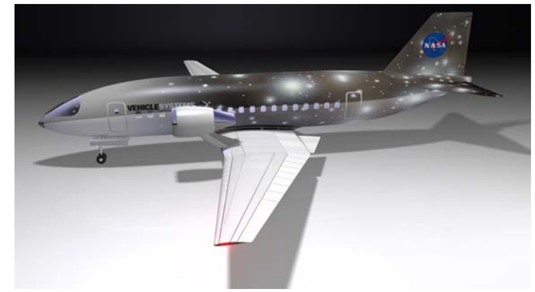
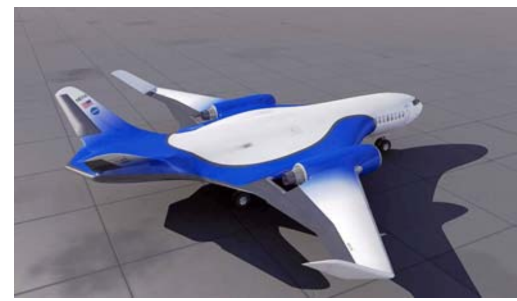
NASA's Subsonic Fixed Wing Project



October 7, 2008

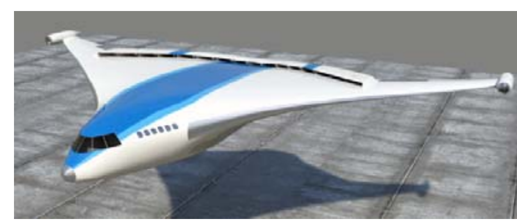
Fundamental Aeronautics Program

Annual Meeting



Fayette Collier

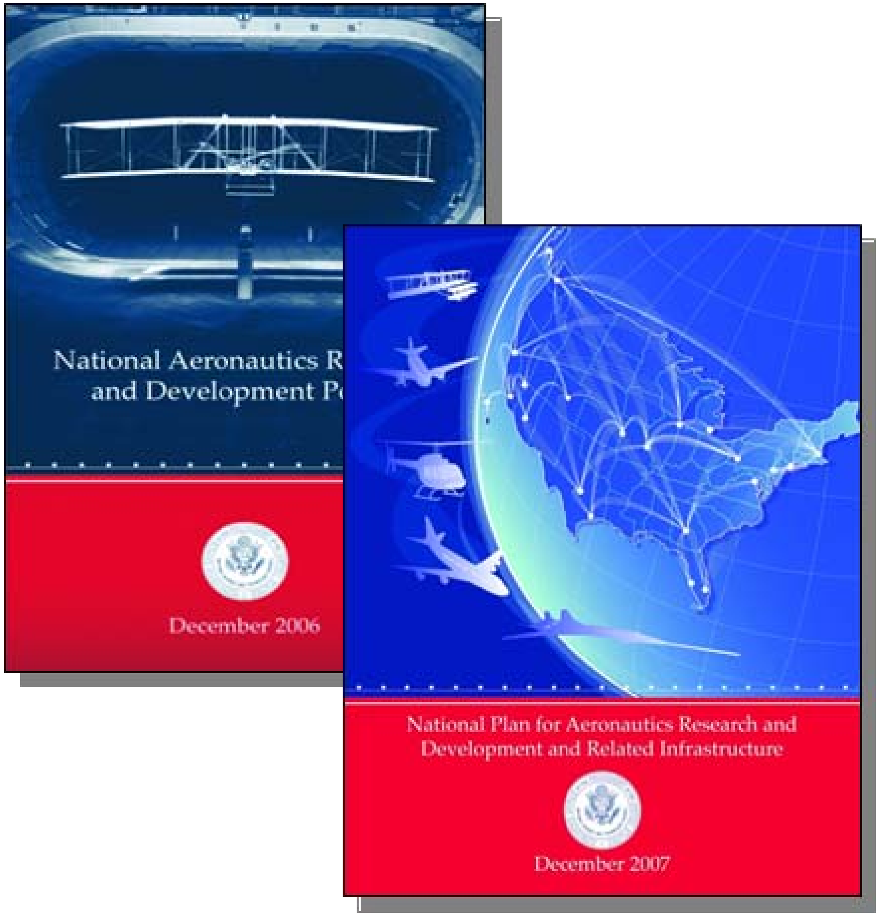
Principal Investigator, Subsonic Fixed Wing Project



National Aeronautics R&D Policy and Plan Objectives

- Policy
  - Executive Order signed December 2006
  - Outlines 7 basic principles to follow in order for the U.S. to “maintain its technological leadership across the aeronautics enterprise”
  - Mobility, national security, aviation safety, security, workforce, energy & efficiency, and environment

- Plan (including Related Infrastructure)
  - Plan signed by Pres. Bush December 2007
  - Goals and Objectives for all basic principles (except Workforce, being worked under a separate doc)
  - Summary of challenges in each area and the facilities needed to support related R&D
  - Specific quantitative targets where appropriate
  - More detailed document/version to follow later in 2008



Executive Order, Policy, Plan, and Goals & Objectives all available on the web

For more information visit: http://www.ostp.gov/cs/nstc/documents_reports

Subsonic Fixed Wing Project

.... technology for dramatically improving noise, emissions, & performance

- *Objectives*

  (1a) Development of prediction and analysis tools for reduced uncertainty in design process

  (1b) Development of concepts/technologies for enabling dramatic improvements in noise, emissions and performance characteristics of subsonic/transonic aircraft

- *Relevance*
  - Direct impact on future designs of a wide range of subsonic aircraft relevant to industry, DoD, and OGA
  - Direct impact on JPDO & NextGen operational and environmental goals and objectives

Organization of SFW Project

Principal Investigator
Fay Collier

Project Scientist
Rich Wahls

Project Manager
Rubén Del Rosario

Combustion
Dan Bulzan, API
Mary Wadel, APM

Acoustics
Ed Envia, API
Mary Wadel, APM

Aerothermodynamics
Jim Heidmann, API
Kevin Walsh, APM

SADO
Bill Haller, API
Mary Wadel, APM

System-Level Partnerships and Plans
- MDAO - Cynthia Naiman
- BWB - Dan Vicroy
- CESTOL - Craig Hange
- Quiet Technology - Charlotte Whitfield
- UHB Engines Tech - Chris Hughes
- Aero Efficiency - Dave Voracek
- JPDO/CLEEN - Fay Collier et al
- Green Prop. Initiative - Mike Nathal

Component and Discipline NRAs and Foundational Research Plans

Aerodynamics
Mike Rogers, API
Craig Hange, APM

Materials and Structures
Karen Taminger, API
Rubén Del Rosario, APM

Aeroelasticity
Jennifer Heeg, API
Kevin Walsh, APM

Controls and Dynamics
Diana Acosta, API
Craig Hange, APM

Balanced, Integrated Plans & Associated Resources & Schedule

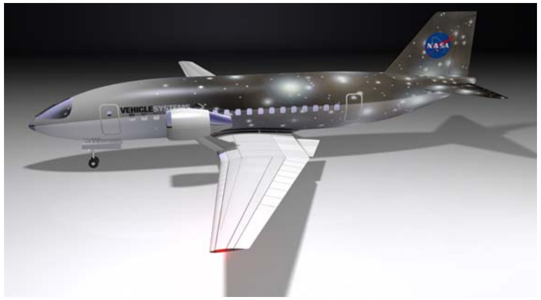
Technology Integration Manager - Anna McGowan
NRA Manager - Kim Pham
Lead Resource Analyst - Sarah Samples
Lead Scheduler - Mandy Eberwine

SFW System Level Metrics

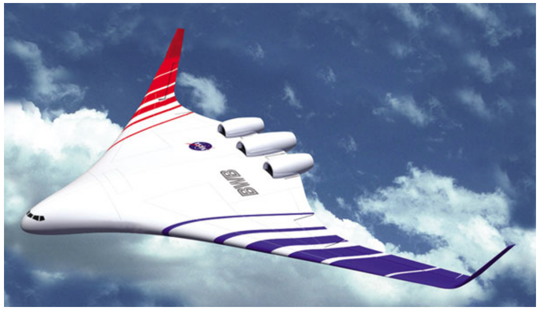
CORNERS OF THE TRADE SPACE	N+1 (2015 EIS) Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020 IOC) Generation Unconventional Hybrid Wing Body (relative to B777/GE90)	N+3 (2030-2035 EIS) Generation Advanced Aircraft Concepts (relative to user defined reference)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)	55 LDN (dB) at average airport boundary
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

** An additional reduction of 10 percent may be possible through improved operational capability
* Concepts that enable optimal use of runways at mutiple airports within the metropolitan areas
EIS = Entry Into Service; IOC = Initial Operating Capability

N+1 Conventional



N+2 Hybrid Wing/Body

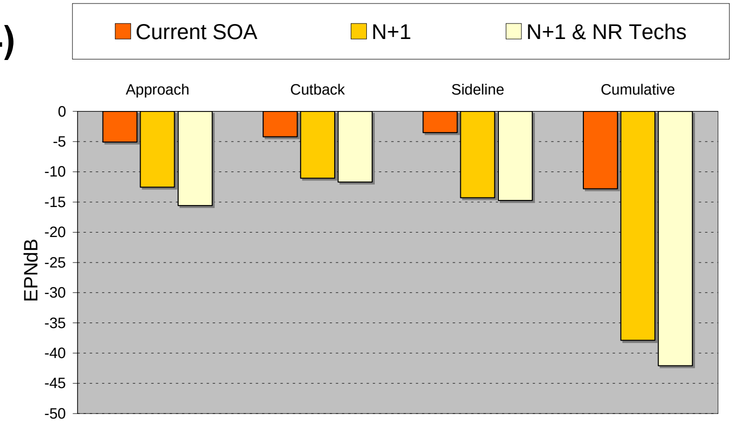


N+3 Generation

Noise Reduction

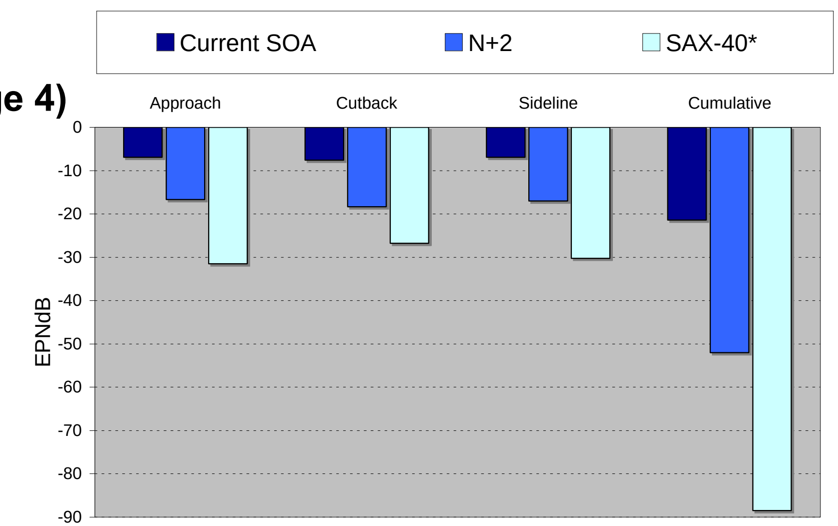
“N + 1” Conventional Small Twin

- 42 EPNdB cumulative below Stage 3 (32 wrt Stage 4)
- Target Next Generation Single Aisle (NGSA)
- Ultra-High Bypass (UHB) engines
- Noise Reduction (NR) technologies for fans, landing gear, propulsion airframe aeroacoustics
- Light weight acoustic treatment in multi-functional structures



“N + 2” Hybrid Wing/Body

- 52 EPNdB cumulative below Stage 3 (42 wrt Stage 4)
- Will achieve significant noise reduction from wing shielding of engines
- Drooped leading edge
- Continuous mold line flaps
- Landing gear fairings
- Long duct, low drag acoustic liners
- Distortion tolerant fans with active noise control



NOx Emissions Reduction

Conventional Small Twin: N+1

70% LTO NOx reduction below CAEP/2

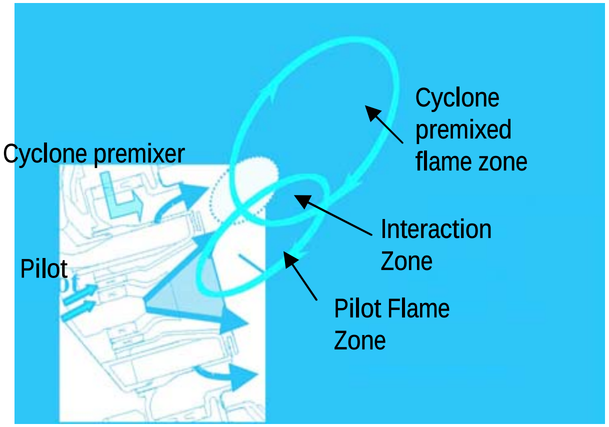
Target Next Generation Single Aisle (NGSA)

Annular combustor TAPS (GE)

- Improved fuel/air mixers

TALONX (P&W)

- Optimized quench section for improved mixing
- Improved fuel/air mixing in rich zone



Cyclone Main with Pilot Concept

Hybrid Wing/Body: N+2

80% LTO NOx reduction below CAEP/2

Improved CFD Modeling

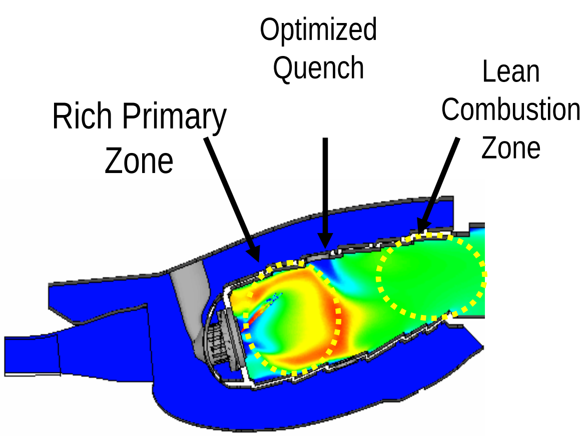
Advanced combustor concepts

Advanced fuel/air mixers

Active combustion control

High temperature liners

Alternative fuels



Rich Burn Quick Quench Lean Burn Concept

Lean Direct Injection Multipoint Concept

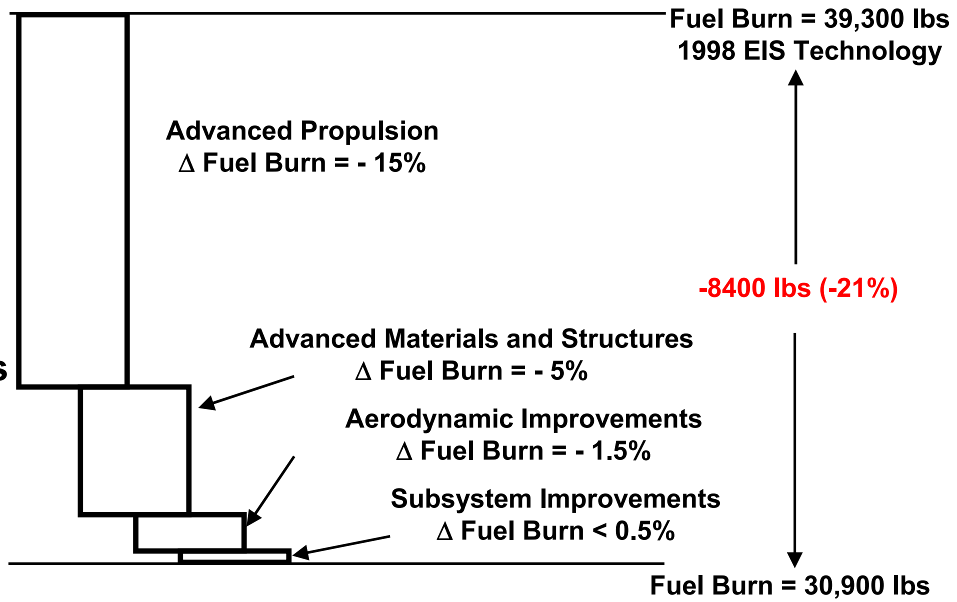
Performance - Fuel Burn - N+1

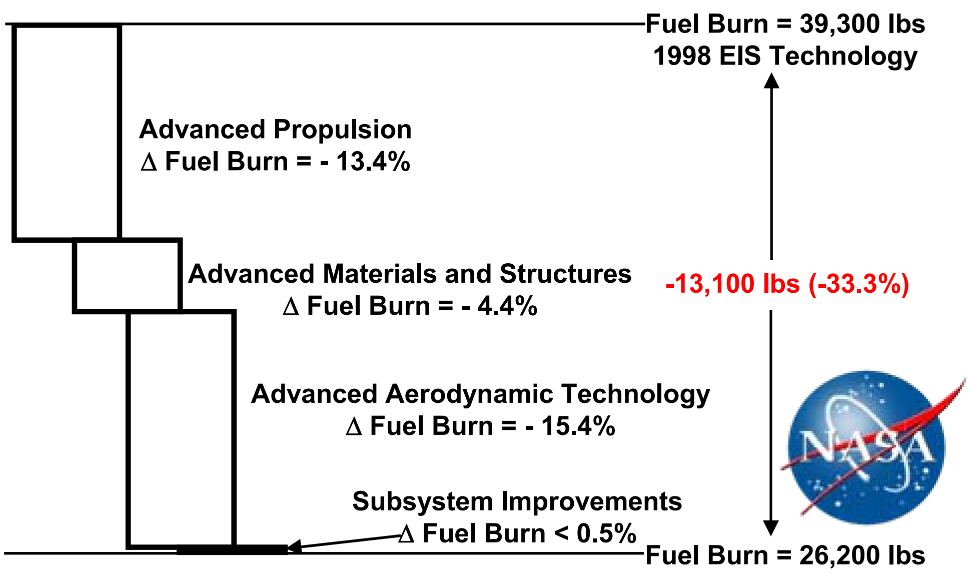
“N + 1” Conventional Small Twin

- 162 pax, 2940 nm mission baseline
- Ultra high bypass ratio engines, geared
- Key technology targets:
  - +1 point increase in turbomachinery efficiencies
  - 25% reduction in turbine cooling flow enabled by: improved cooling effectiveness and advanced materials
  - +50 deg. F compressor temperatures (T3)
  - +100 deg. F turbine rotor inlet temperatures
  - -15% airframe structure weight
  - -1% total vehicle drag
  - -15% hydraulic system weight

“N + 1” Advanced Small Twin

- All technologies listed above plus:
  Hybrid Laminar Flow Control
  67% upper wing,
  50% lower wing,
  tail, nacelle
  Result = -17% total vehicle drag



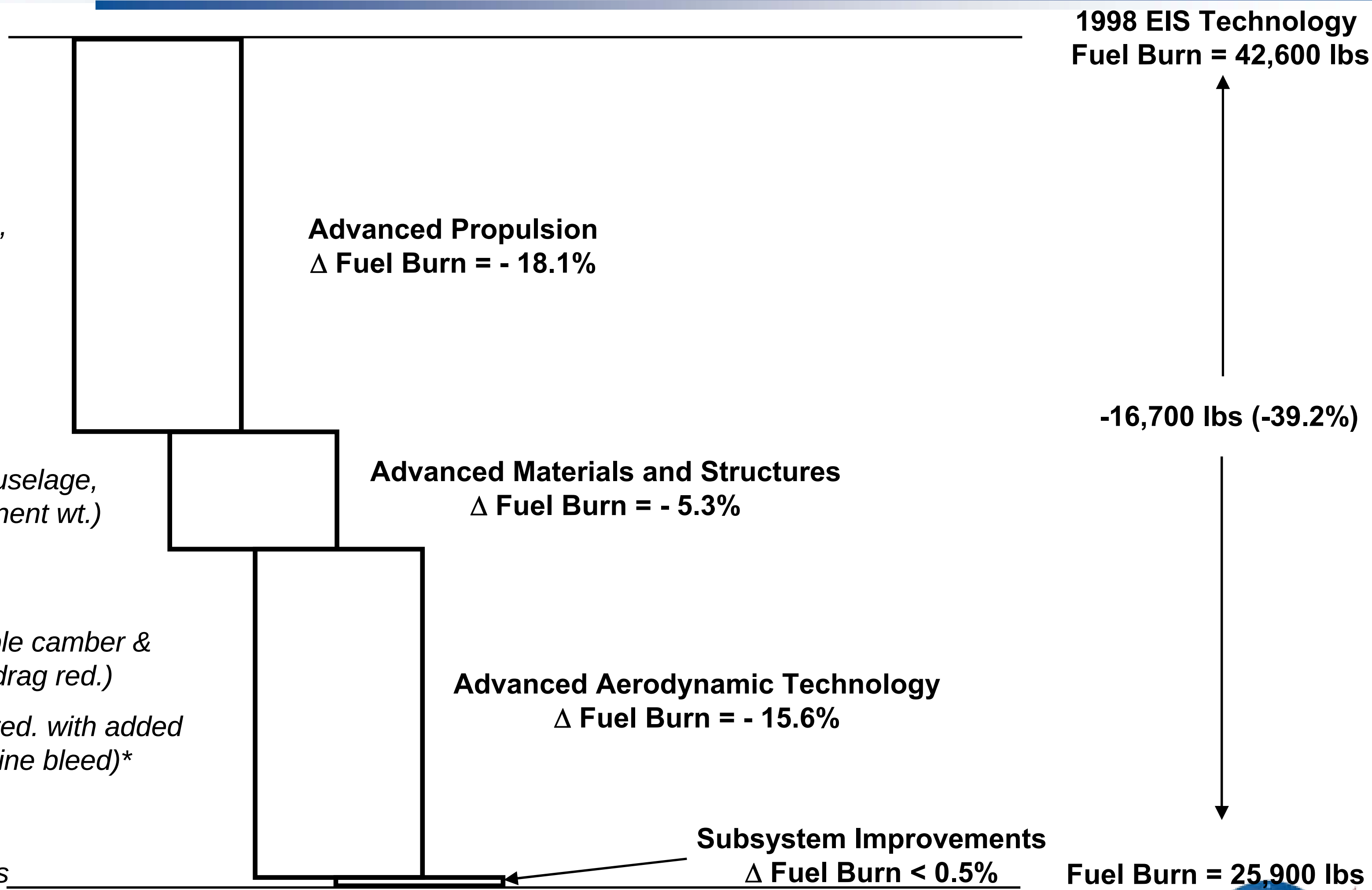


Performance - Fuel Burn - N+1

"N+1" Single Aisle Transport - **Optimized Solution**

(Design Mission: 162 Passenger, 3250nm)

- *Geared, FPR=1.5, OPR=42*
- *Composite wing, fuselage, tails (-15% component wt.)*
- *Trailing edge variable camber & drag clean up (1% drag red.)*
- *HLFC (~17% drag red. with added system wt. and engine bleed)**
- *5000 psi hydraulics*



*HLFC benefits applied only at cruise

Performance - Fuel Burn - N+2

Hybrid Wing Body - 300 pax, 7500 nm

Dominant Configuration - Tube and Wing 1997 Baseline

Fuel Burn = 237,000 lbs
1997 EIS Technology

Hybrid Wing Body configuration with composite fuselage
Δ Fuel Burn = - 10%

Advanced Propulsion (Podded) and Airframe Technologies (composite wings)
Δ Fuel Burn = - 10%

-95,900 lbs (-40%)

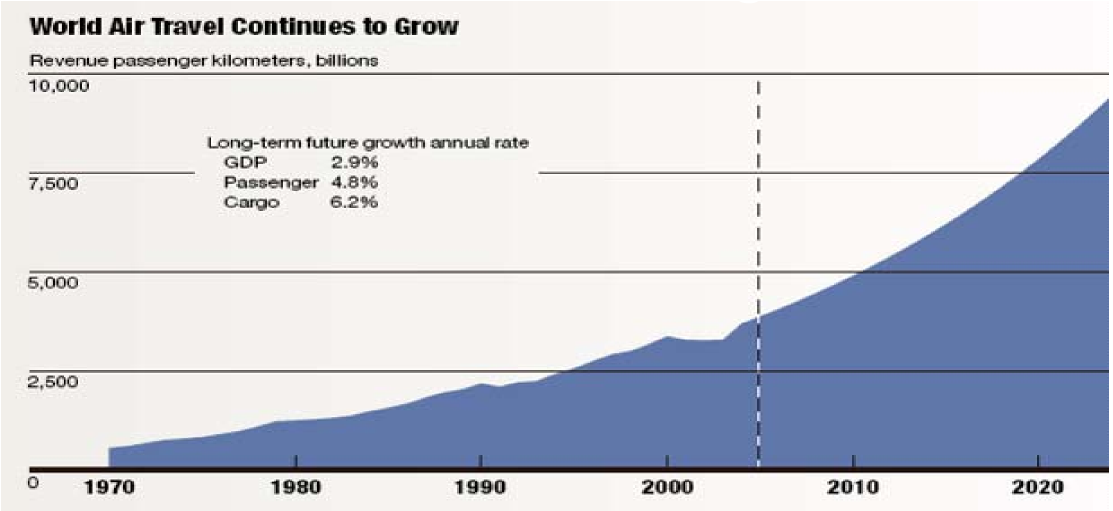
Advanced Propulsion (Embedded) and BLI inlets
Δ Fuel Burn = - 14%

Aerodynamic Improvements (Hybrid Laminar Flow Control)
Δ Fuel Burn = - 6%

Fuel Burn = 147,595 lbs

Performance - Field Length

NextGen ATS to enable 2-3x growth in air travel by 2025

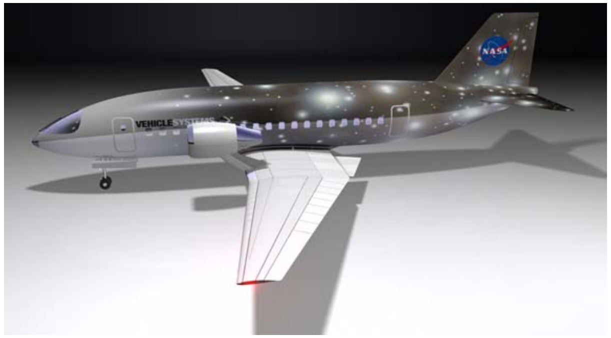


<u>Barriers to Growth</u>

- Noise
- Emissions
- Capacity

<u>Cruise Efficient STOL Aircraft Concepts</u>

<u>N+1</u>



<u>N+2</u>

<u>Key Aircraft Capability</u>

•STOL with low noise and efficient high-speed cruise (Mach 0.8+)

<u>Key Partnership for Tool & Technology Development</u>

•NASA/OGA/Industry - AF, Boeing PW, LM, Northrop Grumman

<u>Key Aircraft Technology</u>

•Powered Lift/Flow Control Concepts for Reduced Field Length

<u>Key Tools</u>

•3D Flow Control Prediction Tools (CFD)

Key Milestones and Deliverables

<u>FY07</u>

- Baseline state-of-the-art analysis methods and tools to address aeronautics challenges within the hypersonic, subsonic (for rotary and fixed wing vehicles), and supersonic flight regimes (completion in FY08)
- Blended wing/body X-48B low-speed, flight controls validation (extended to FY09)

<u>FY08</u>

- Develop and test concepts for conventional aircraft configurations that establish feasibility of achieving Stage 3-42 EPNdB (cum) noise reduction
- Develop and test concepts for unconventional aircraft configurations that establish the feasibility of achieving short take-off and landings on runways less than 3000 ft.
- Complete GEN 1 integrated multi-disciplinary design, analysis and optimization (MDAO) tool set

Subsonic Fixed Wing
Major Activities - FY08/FY09

UHB Geared Turbo Fan Tests (Noise, Performance and Alternate Fuels)

Partner = Pratt and Whitney

UHB Open Rotor Tests (Planning Phase Currently)

Partner = GE Aviation

Airframe and engine noise tests

Partner = Gulfstream and Honeywell

Cruise Efficient STOL Concept Tests

Partners = AFRL and Northrop Grumman, Boeing PW, LM

BWB X-48B Low Speed Vehicle Flight Tests, Acoustic Testing, and System Studies

Partners = AFRL/Boeing Phantom Works

Laminar flow strategy and tests

Partners = AFRL and US Industry

Green Propulsion Initiative

Partners = AFRL

MDAO strategy, framework and requirements documents complete

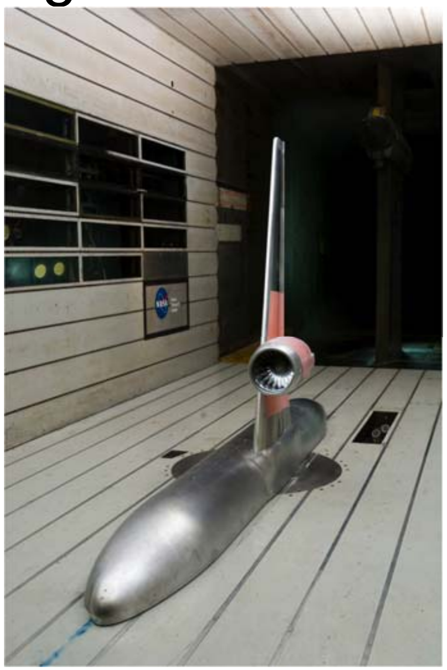
Validated GEN 1 Capability - low to medium fidelity (FY09)

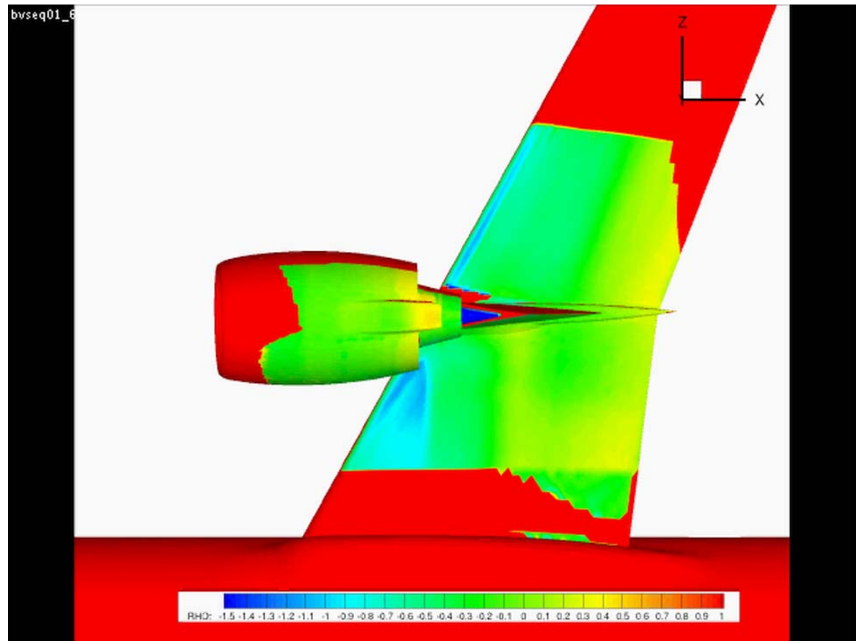
Validated GEN 2 Capability - medium to high fidelity (FY11)

Validated GEN 3 Capability - high fidelity (FY13)

NASA/Pratt & Whitney GTF Collaboration

Integration and Interference Test in the ARC 11-ft Tunnel





Fan Performance and Alternative Fuels Test on Demo Engine

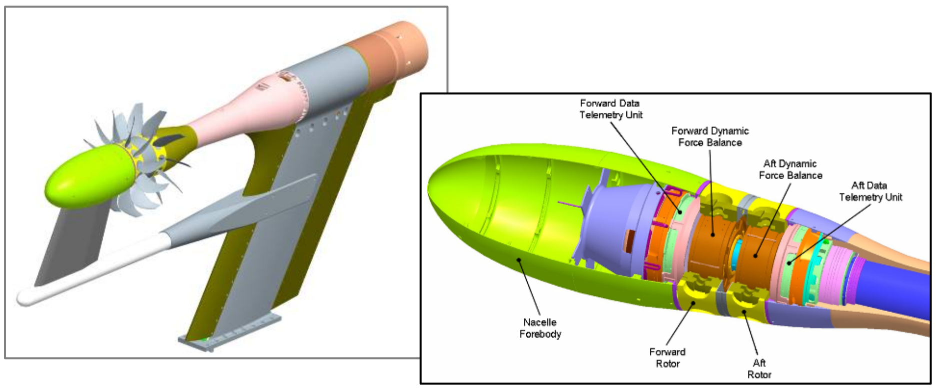
Pratt & Whitney’s Geared Turbofan™ Engine Demonstrates Alternative Fuel Capabilities

SINGAPORE AIR SHOW – February 19, 2008 – Pratt & Whitney’s Geared Turbofan demonstrator engine has successfully operated using an alternative fuel blend during Phase I ground testing in West Palm Beach, Fla. Pratt & Whitney and engineers from the National Aeronautics and Space Administration (NASA), in a partnership under the NASA Fundamental Aeronautics program, completed the test using a synthetic fuel blend as part of a program comparing potential emissions benefits for future aircraft applications.

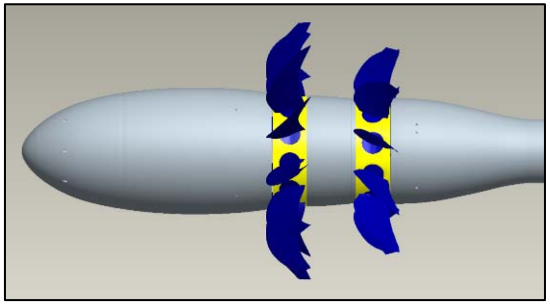
NASA/GE Open Rotor Collaboration

– Unlike the 1980s, the challenge is to uncover propulsion technologies that not only reduce fuel burn, but also meet current environmental regulations with regard to noise and emissions

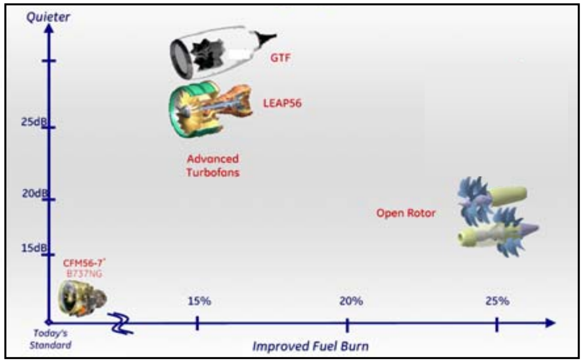
– The current NASA / GE Aviation collaborative partnership program is focused to investigate concepts that address those concerns

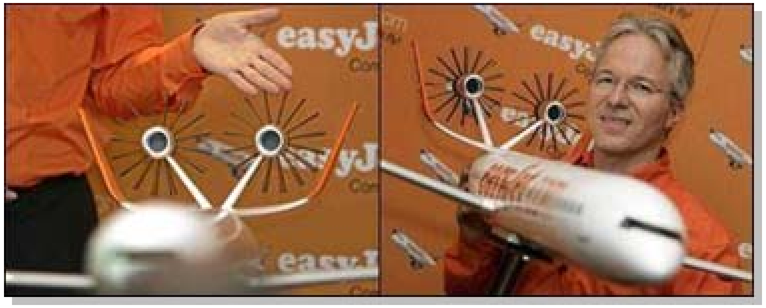


NASA Open Rotor Propulsion Rig, Aft Pusher Configuration



Possible Design Considerations for Environmental Concerns
- *Reduced Aft Rotor Diameter compared with Forward Rotor*
- *Large Rotor-to-Rotor Spacing*
- *Uneven Number of Blades between Forward and Aft Rotors*





easyJet ecoJet Propfan-Powered Aircraft Concept incorporating Noise Shielding

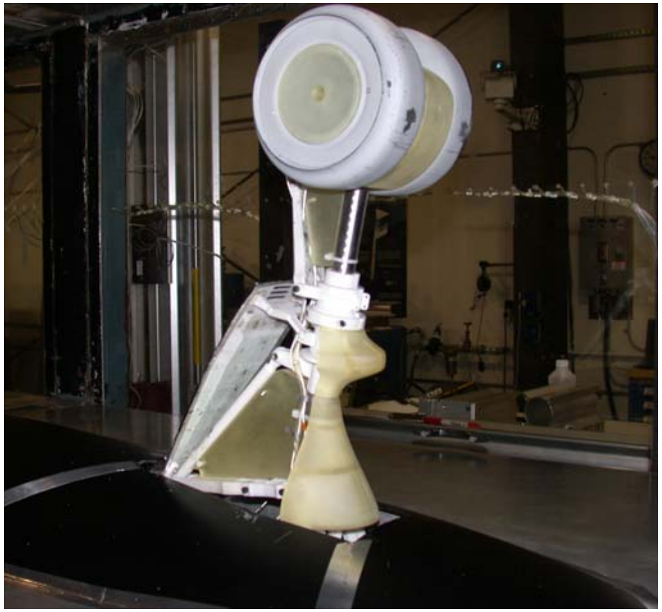
NASA/Gulfstream Collaboration

Nose Landing Gear (NLG) Conceptual Acoustic Fairings

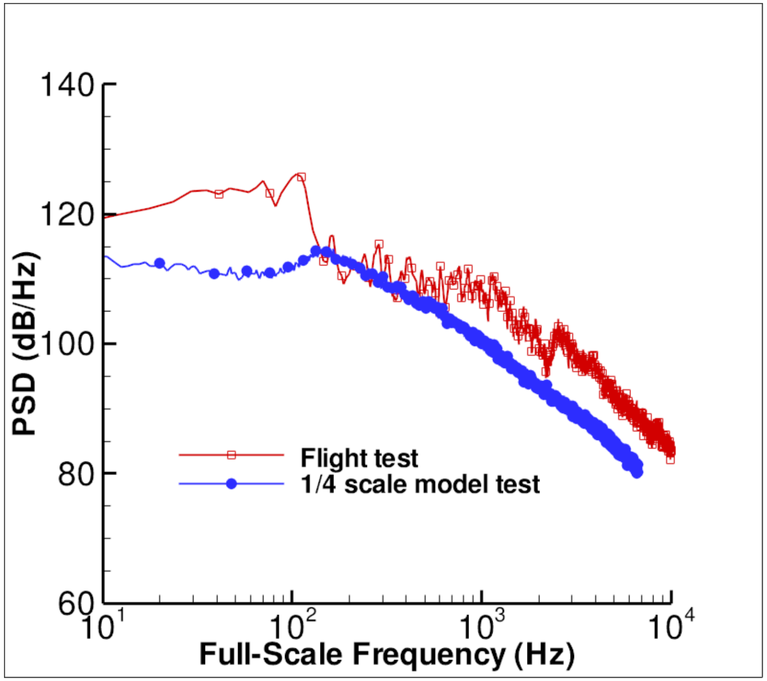
Noise reduction fairings were designed and fabricated by Gulfstream

Initial acoustic test were performed during spring 08 in the UFL tunnel

Preliminary steady & unsteady aerodynamic measurements were conducted in BART during August-September of 08



Ground to Flight Correlations



NASA/AFRL/Industry Laminar Flow Control Collaborations

NASA/AFRL/Boeing B757 HLFC Flight Experiment - 1990

NASA/Boeing HLFC Wing Model in 8-ft TPT Wind Tunnel - 1995

- Results
  - Flight demonstrated a practical HLFC system on a commercial transport, 31 flights, 150 flight test hours
    - LE Suction panel
    - Krueger high lift/insect shield
    - Hot air deicing
  - Routinely achieved laminar b.l. flow to rear spar
  - Measured 29% local drag reduction w/b.l. rake
  - Calibrated and identified limitations in prediction codes

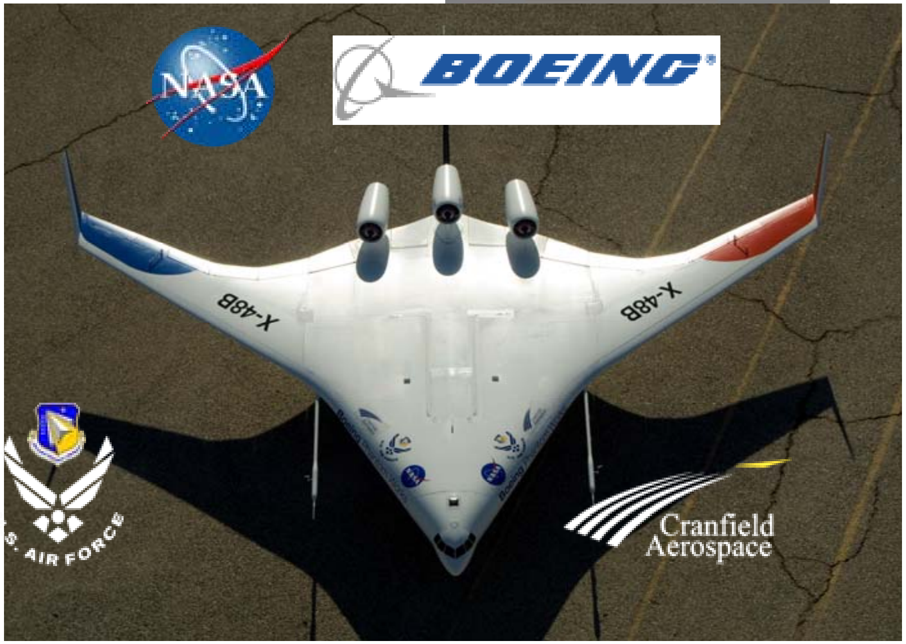
NASA/AFRL/Industry Laminar Flow Control Collaborations - FY08 Restart

- Ground test strategy
- Natural laminar flow
  - How far can we push Distributed Roughness Elements
  - Other approaches for passive control
- Relook at The HLFC “Crossflow Experiment” Database
- Develop flight test or demonstration strategies

NASA/AFRL/Boeing PM BWB Collaborations

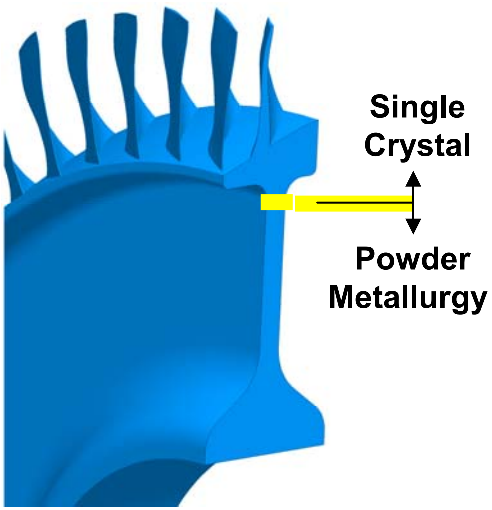
Description - Low-speed, flight controls experiment
First flight July 20, 2007
- X-48B flight test vehicle
- 500 lb, 21 ft wing span
- 31 minute flight

Status - 30 Flights Completed, in block 3 of 5 flight test blocks
Expect to meet all Phase I objectives by March 09



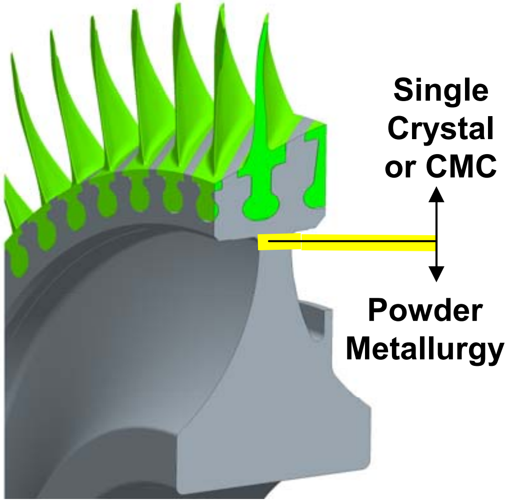
NASA/AFRL Green Propulsion Initiative Collaborations

Develop high temperature, lightweight engine materials for improved fuel efficiency & reduced emissions



- Basic concept employs 3rd generation powder metallurgy (PM) disk alloy bonded to single crystal (SX) alloy optimized for this application
- GRC patented SX low density superalloys demonstrated excellent creep resistance at 1500°F for hybrid disk rim
- High pressure compressor disk using blisk configuration Rim and blading cast/machined from one piece SX ring, operable at compressor discharge temps. (T~1500°F)

- High pressure turbine disk will employ traditional "fir tree" blade attachment
- HPT blades will initially be SX with potential growth to CMC blade, allows elevated turbine blade temperatures (T>1800°F)



NRA Status

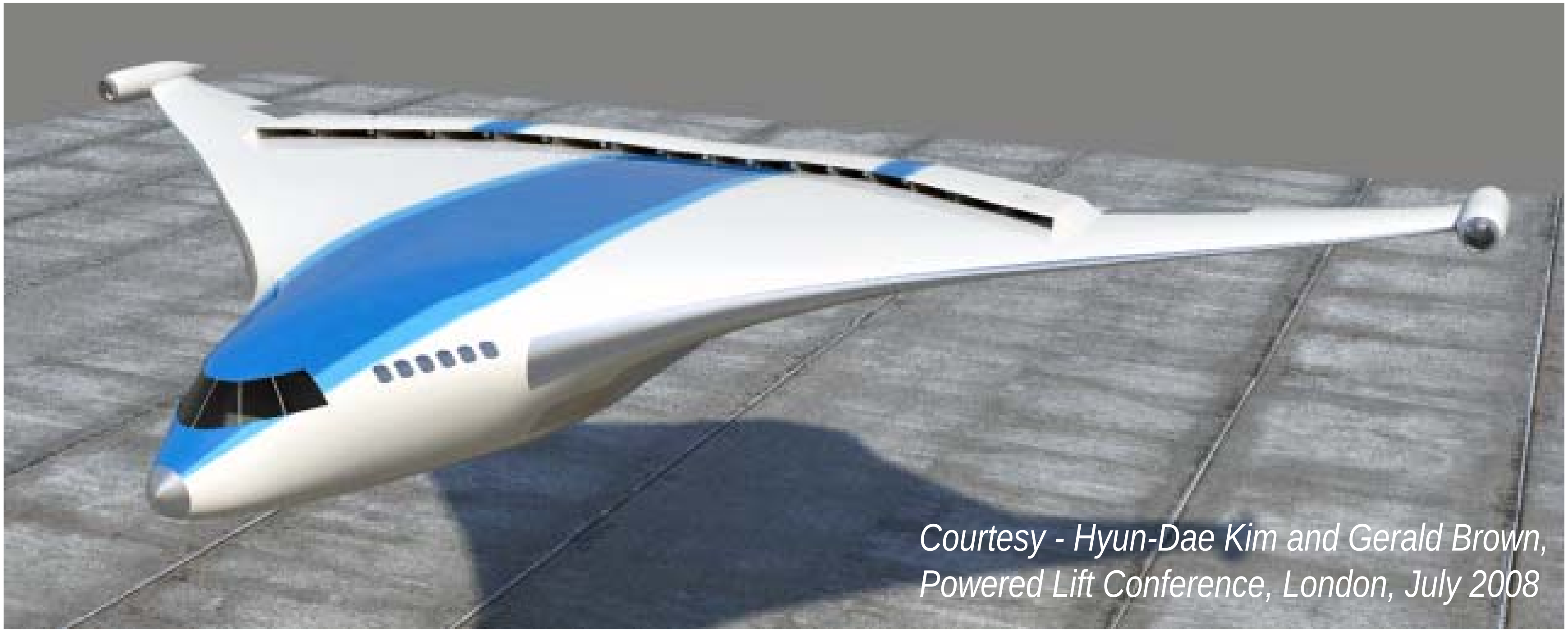
	Proposals	Awards	# Publications	Invested (to date)
Round 1	176	30	119	$15.0M
Round 2	76	19	27	$10.8M
Round 3	10	4	0	$5.0M
From 3 NRA Rounds	**262**	**53**	**146**	**$30.8M**

SFW	FY06 ($K)	FY07 ($K)	FY08 ($K)	Total Invested ($K)
NRA Budget, $K	**5,193**	**15,050**	**10,556**	**30,799**

SFW Sessions

- Tuesday PM - Session 1 - Advanced Engines …
- Wednesday AM - Session 2 - CESTOL …
- Wednesday PM - Session 3 - Open + One-on-One
- Thursday AM - Session 4 - Tools & Capabilities …
- Thursday PM - Session 5 - HWB …

Questions or Comments



__Recent and Coming Events__

NRA Round 2 Year 1 Review - Williamsburg, Sept 08

Fundamental Aeronautics Annual Meeting - Atlanta, Oct 08

AIAA Aerospace Sciences Meeting - Orlando, Jan 09

NRA Round 1 Year 2 Review - Orlando, Jan 09