Environmentally Responsible Aviation Technical Overview

Presented by

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Contributors

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Meeting of Experts

Aeronautics and Space Engineering Board Meeting

National Research Council

Washington, DC

May 14-15, 2009

Outline

- Overview
  - Vision, Mission, Scope, Goals
  - Alternate Vehicle Concepts and Technologies

- Technical Approach
  - Project Framework/Schedule
  - Critical Technology Areas

- Concluding Remarks

ERA Project Framework

- Vision
  - ERA will expand the viable and well-informed trade space for vehicle design decisions enabling simultaneous realization of National noise, emissions, and performance goals
  - ERA will enable continued aviation growth while reducing or eliminating adverse effects on the environment
- Mission
  - Perform research to explore/assess the feasibility, benefits, interdependencies, and risks of vehicle concepts and enabling technologies identified as having potential to mitigate the impact of aviation on the environment
  - Transfer knowledge outward to the aeronautics community, and inward to NASA fundamental aeronautics projects
- Scope
  - N+2 vehicle concepts and enabling technologies
  - System/subsystem research in relevant environments

ERA Project Context

National Plan for Aeronautics R&D

- Mobility, Security/Defense, Safety, Energy & Environment
  - Enable growth in Mobility/Aviation/Transportation
  - Dual use with Security/Defense
  - Safety and Cost Effectiveness are pervasive factors
- Energy and Environment goals are central to ERA
  - Energy Diversity
    - use of alternative fuels, not creation of alternative fuels
  - Energy Efficiency
  - Environmental Impact
    - reduction of impacts, not reducing scientific uncertainties of impacts

Subsonic Fixed Wing System Level Metrics

…. technology for improving noise, emissions, & performance

CORNERS OF THE TRADE SPACE	**N+1 (2015)*** Generation Conventional Configurations relative to 1998 reference**	**N+2 (2020)*** Generation Unconventional Configurations relative to 1998 reference**	**N+3 (2025)*** Generation Advanced Aircraft Concepts relative to user-defined reference**
Noise	-32 dB (cum below Stage 4)	-42 dB (cum below Stage 4)	-71dB (cum below Stage 4)
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

***Technology Readiness Level for key technologies = 4-6

** Additional gains may be possible through operational improvements

* Concepts that enable optimal use of runways at multiple airports within the metropolitan area

Approach

- Enable Major Changes in Engine Cycle/Airframe Configurations

- Reduce Uncertainty in Multi-Disciplinary Design and Analysis Tools and Processes

- Develop/Test/ Analyze Advanced Multi-Discipline Based Concepts and Technologies

Alternate Configuration Concepts

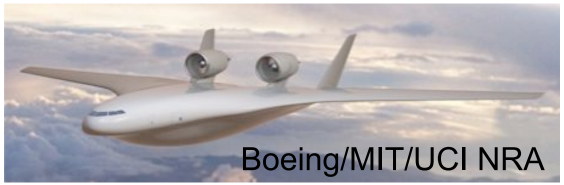
Many ideas, but…

What combination of configuration and technology can meet the goals?

What is possible in the N+2 timeframe?

Airbus
Aviation Week 1/15/01

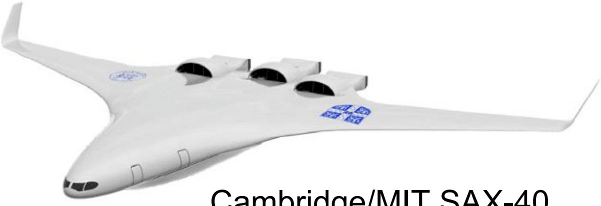
Boeing NRA
FAP Annual Mtg 10/08



Boeing/MIT/UCI NRA
Aviation Week 2/2/09

Airbus
Aviation Week 1/15/01

NASA VSP
2003



Cambridge/MIT SAX-40
1/07

easyJet ecoJet
Reuters 6/14/07

NASA- M Moore
2009

RAeS Concept
Greener By Design, 2006

Underlying Technology

- Technology enablers - <u>broadly applicable</u>
  - less visible than configuration features
  - applicable to alternate and advanced conventional configurations
  - Noise: continuous mold lines, increasing ducted BPR
  - Emissions: low NOx combustion, reduced fuel burn technologies
  - Fuel Burn: lightweight structure, reduced drag, and reduced SFC

$$\text{Aircraft Range} = \frac{\text{Velocity}}{\text{TSFC}}\left(\frac{\text{Lift}}{\text{Drag}}\right)\ln\left(1 + \frac{W_{fuel}}{W_{PL} + W_{O}}\right)$$

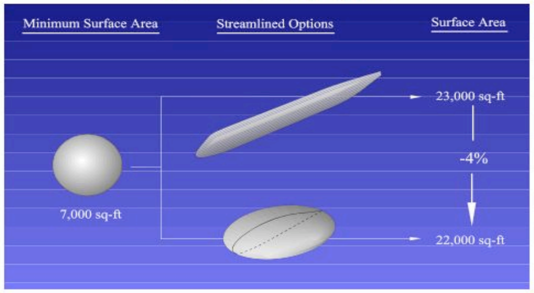
- Engine Fuel Consumption
- Aerodynamics
- Empty Weight

Alternate Configuration Concepts

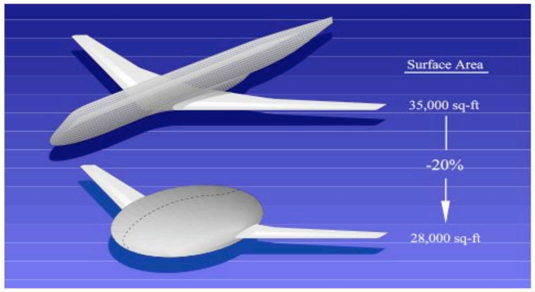
a case study to show what is possible

- Many ideas, but most concepts remain on paper
  - Hybrid Wing Body (HWB) concept has been explored in more detail
  - 1989 Origins: NASA Advanced Concepts Workshop challenges aeronautics community
  - 1990s System Concept Studies, Technology Challenges identified

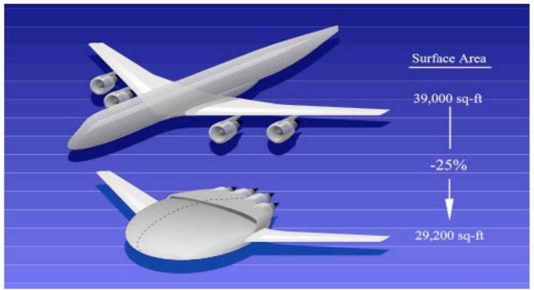
Effect of Body Type



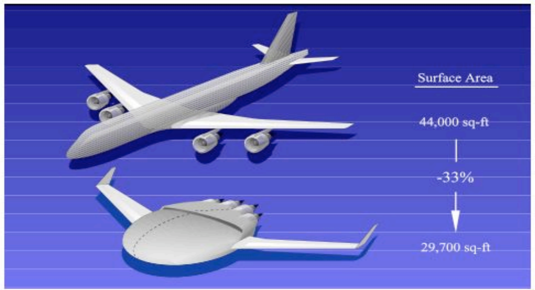
Effect of Wing/Body Integration



Effect of Engine Installation



Effect of Controls Integration



33% wetted area reduction
offers huge viscous drag reduction potential

Benefits

- Greater fuel efficiency
- Reduced Environmental Impact
- Operational Flexibility

Challenges

- Noncylindrical pressure vessel
- Edge-of-the-envelope flight dynamics
- Propulsion-Airframe Integration (PAI)

Liebeck, AIAA-2002-0002

Alternate Configuration Concepts

a case study to show what is possible

- Many ideas, but most concepts remain on paper
  - Hybrid Wing Body (HWB) concept has been explored with more detail

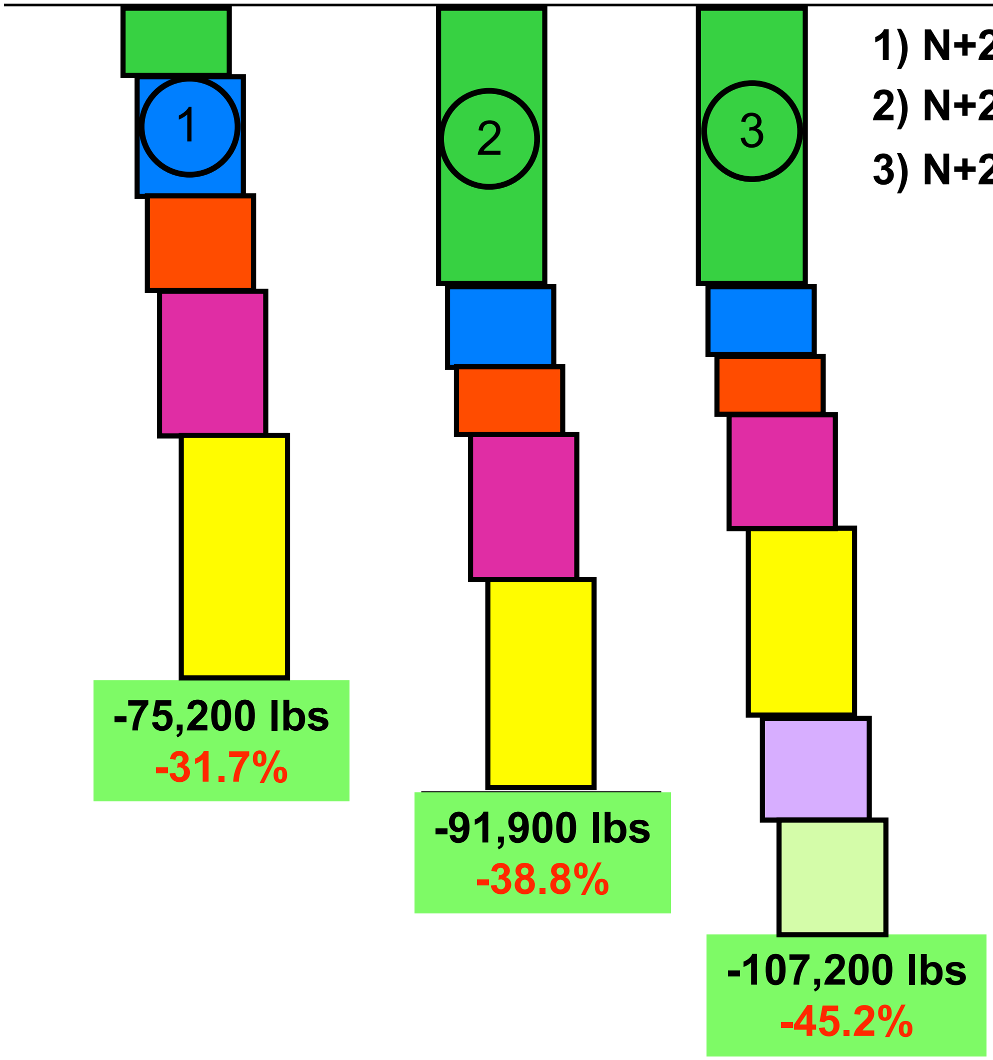
  - 2000s
    Research addressing technology challenges, ongoing system studies
    - Provides a framework for advancement of broadly applicable technologies

  - Today
    Continues to show potential of simultaneously meeting the N+2 goals

Potential Reduction in Fuel Consumption

Reference Fuel Burn = 237,100 lbs

1997 Technology Large Twin Aisle Vehicle “777-200ER-like”



1) N+2 Advanced "tube-and-wing"

2) N+2 HWB

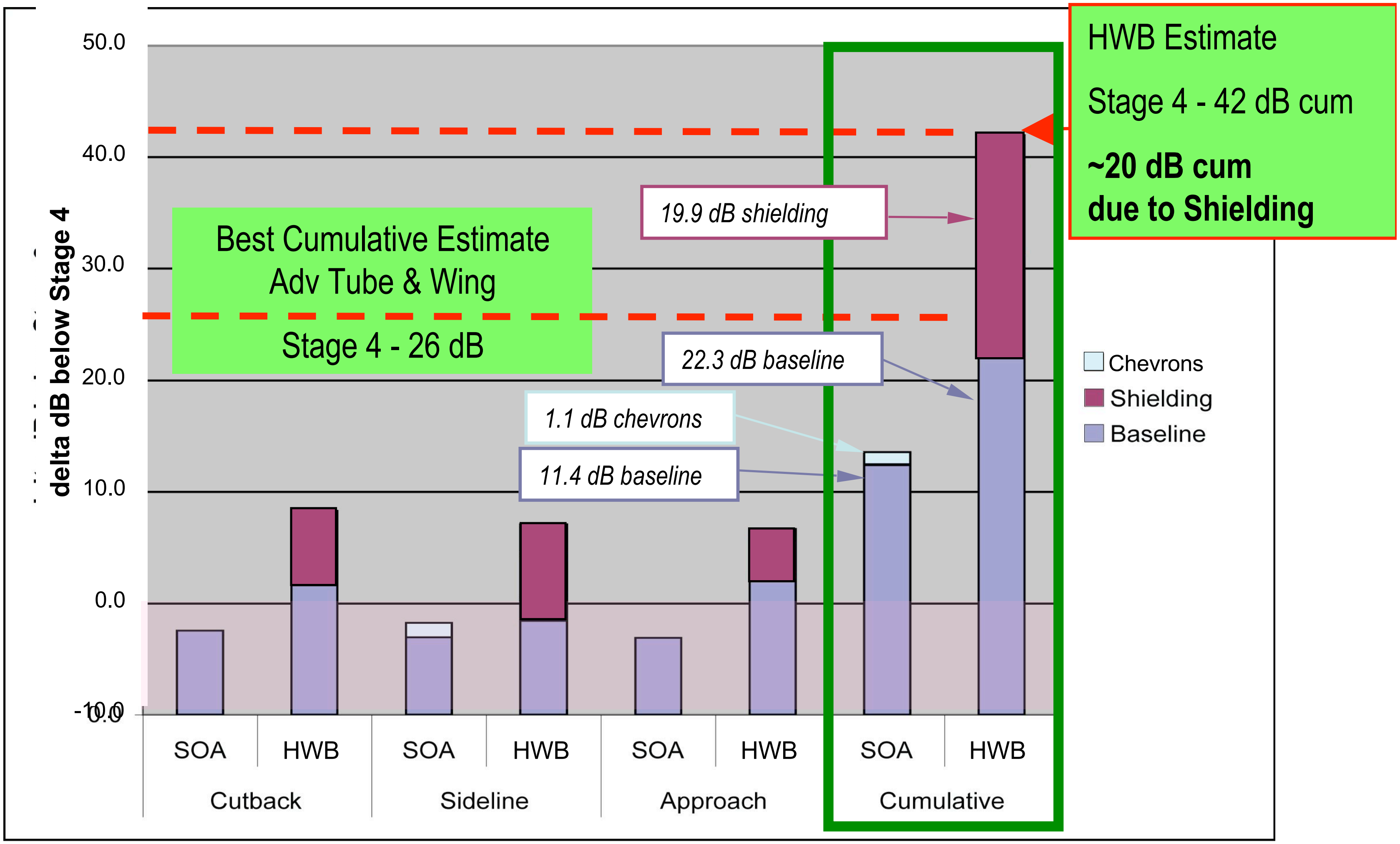
3) N+2 HWB + more aggressive tech maturation

- 🟩 **Fuselage – composite + config**
- 🟦 **Wing – composite + adv subsystems**
- 🟧 **Adv Composite Concept**
- 🟪 **Adv Propulsion**
- 🟨 **HLFC - wing/nacelle**
- 🟪 **Embedded engines with BLI**
- 🟩 **LFC - centerbody**

Nickol, et al 2009

N+2 Potential Noise Reduction

Includes estimate of maximum propulsion noise shielding



Best Cumulative Estimate
Adv Tube & Wing

Stage 4 - 26 dB

HWB Estimate

Stage 4 - 42 dB cum

~20 dB cum
due to Shielding

Thomas, Berton, et al

Market Needs and Design Trades

A sweet spot for noise and fuel burn

…but lower cruise speed may change technologies

…as might payload/range (vehicle size)

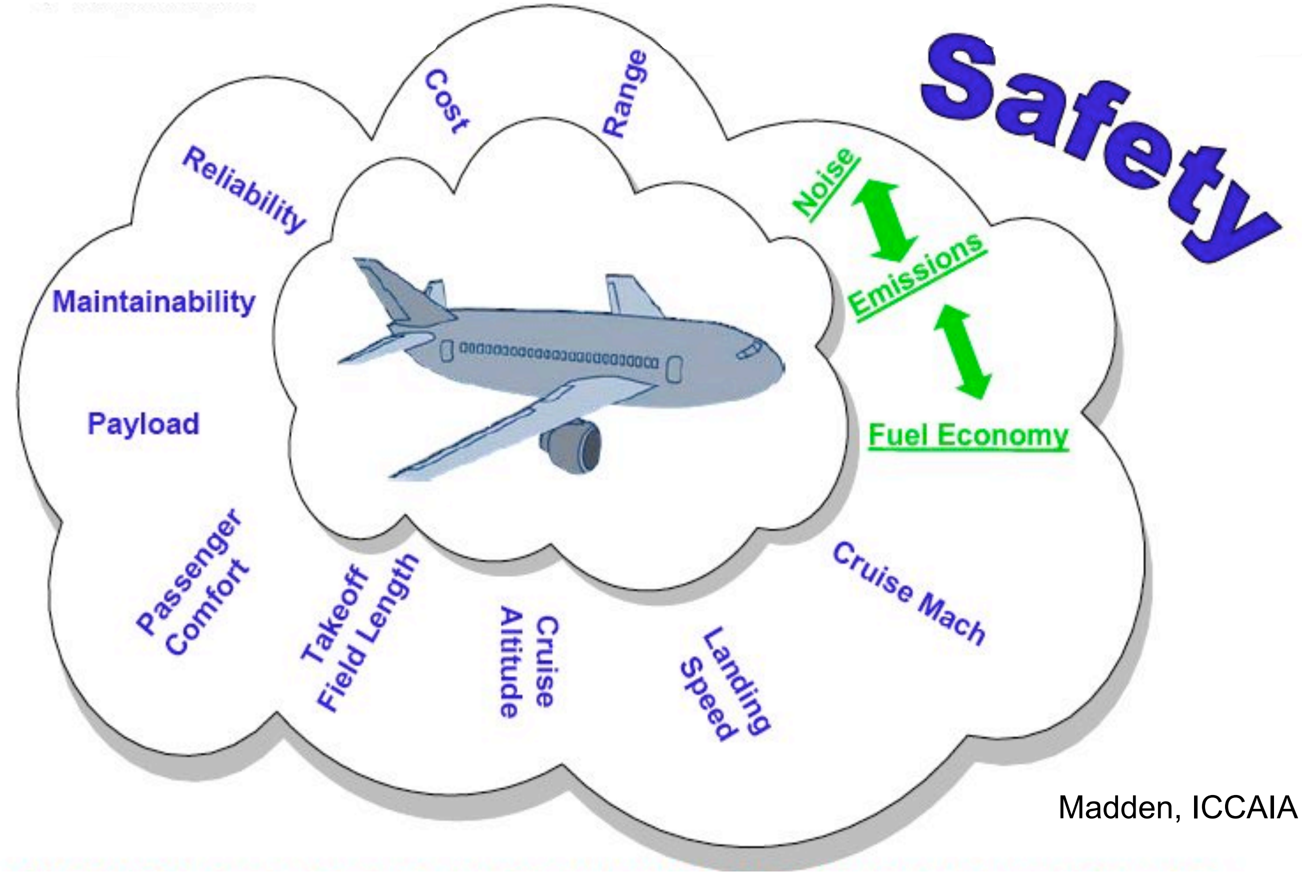
… or relative emphasis on noise & fuel burn

Market will ultimately determine outcome

…but concepts and technologies enable options

Design Trades and Dependencies

Our focus is Noise, Energy Efficiency, and Emissions
…but airplane design is a balance among many factors



Madden, ICCAIA Fuel Burn Workshop
March 2009

The Way Forward

- System research to bridge the gap between fundamental research (TRL 1-4) and product prototyping (TRL 7)
  - Identify vehicle concepts with the potential to simultaneously meet National goals for noise, emissions, and fuel burn in the N+2 timeframe
  - Understand the concept and technology feasibility/risk vs potential benefits
  - Understand the concept and technology trades and interdependencies at high fidelity in relevant environments
  - Determine safety implications of new technologies and configurations

- Technology investments guided by
  - matured in fundamental program and worthy of more in-depth evaluation at system level in relevant environment
  - systems analysis indicates most potential for contributing to simultaneous attainment of N+2 goals
  - identified through stakeholder input as having potential for contributing to simultaneous attainment of N+2 goals

Outline

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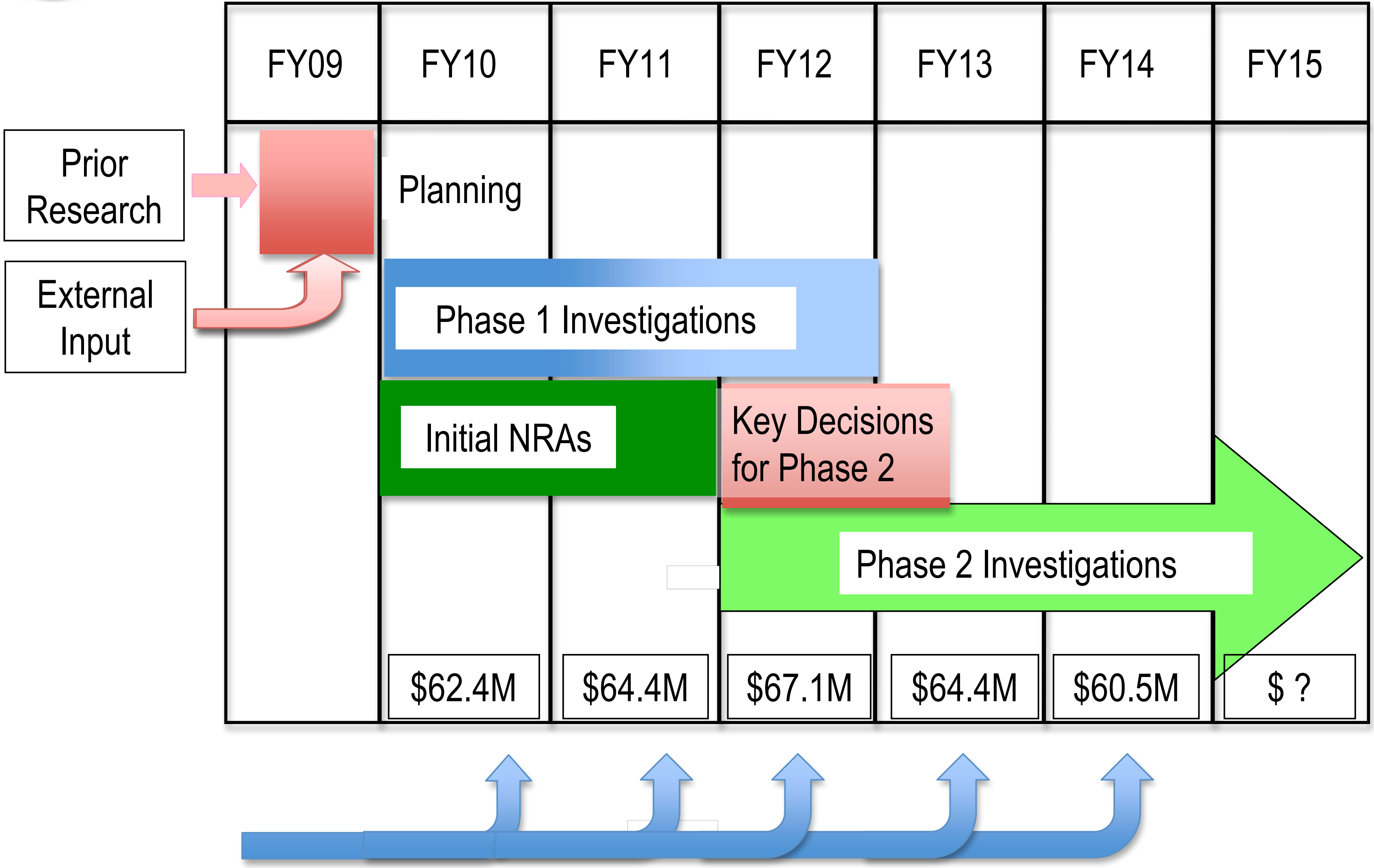
Research Focus Areas

1.0 Project Management	**Natural Metrics**
2.0 Airframe Technology	**ML/D, Empty Weight, Airframe Noise**
2.1 Lightweight Structures	investigations where propulsion system is not 1st order effect
2.2 Flight Dynamics and Control	
2.3 Drag Reduction	
2.4 Noise Reduction	
3.0 Propulsion Technology	**SFC, Engine Noise, Emission Index**
3.1 Combustor Technology	investigations where airframe system is not 1st order effect
3.2 Propulsor Technology	
3.3 Core Technology	
4.0 Vehicle Systems Integration	**ML/D, Weight, SFC, Emission Index, Noise**
4.1 Systems Analysis	investigations where propulsion/airframe interaction is 1st order effect
4.2 Propulsion Airframe Integration	
4.3 Propulsion Airframe Aeroacoustics	
4.4 Advanced Vehicle Concepts	

ERA Project Flow



Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov't Agencies

Initial NRA Topics Under Development

- Topic 1 - N+2 Advanced Vehicle Concepts
  - Concept development and technology roadmaps
  - Scope key system Investigations to inform Phase 2 decisions

- Topic 2 - Low NOx Combustors
  - Concept development and technology roadmaps
  - Initial flametube experiments
  - Inform Phase 2 decisions

- Topic 3 - Quick-Start System Research Investigations
  - Complementary to Phase 1 investigations
  - Early technical progress/results toward ERA goals
  - Inform Phase 2 decisions

Bidders Conference Prior to Solicitation

Phase 1 Investigations

- Scope
  - Concepts and technologies from fundamental projects ready for system experimentation
  - System integration and multidisciplinary risks/barriers
  - 2-3 years

- Critical Technology Focus
  - Stitched composite technology for low weight and damage tolerance
  - Laminar flow technology for drag reduction
  - Flight dynamics & control technology enabling alternate configurations
  - Combustor technology for low emissions
  - Propulsion technology and integration for SFC and noise reduction
  - Propulsion shielding for noise reduction

- Outcome
  - Selected concepts and technologies explored/assessed with respect to feasibility, benefits, interdependencies, and risks - uncover unexpected multidisciplinary interactions
  - New and/or refined ideas emerge
  - Detailed information to update systems studies, and for prioritization and selection of Phase 2 investigations

Phase 2 Investigations

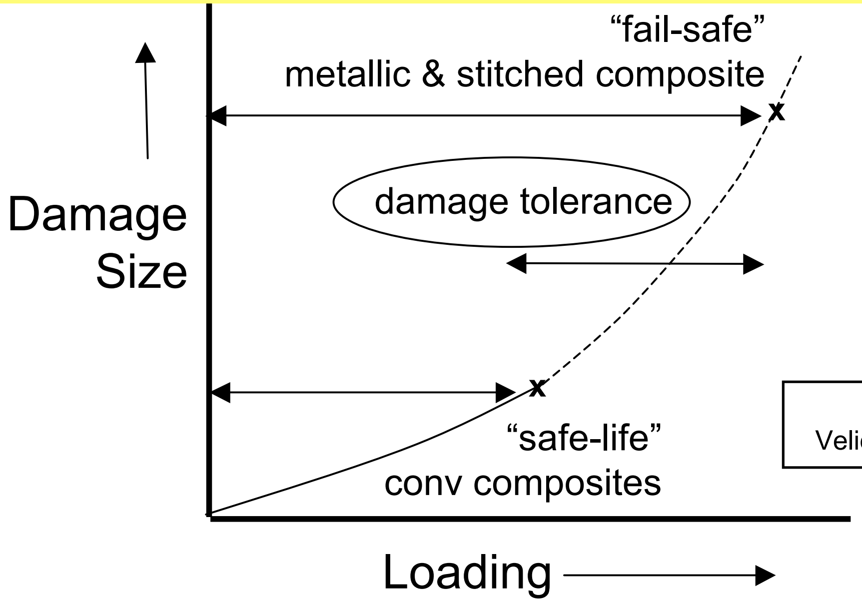
- Key Decisions
  - FY12 timeframe plus/minus 1 year - not a specific point in time
- Scope
  - Similar to Phase 1, plus further exploration of Phase 1 concepts and technologies as appropriate
  - 3-4 years
- Technology Focus
  - Informed by Phase 1 progress/results, system studies, stakeholder input
  - Envision investigations which integrate results from Phase 1, NRAs, other sources
- Outcome
  - Selected concepts and technologies explored/assessed with respect to feasibility, benefits, interdependencies, and risks - trade space understood

Energy Efficiency

Lightweight Structures

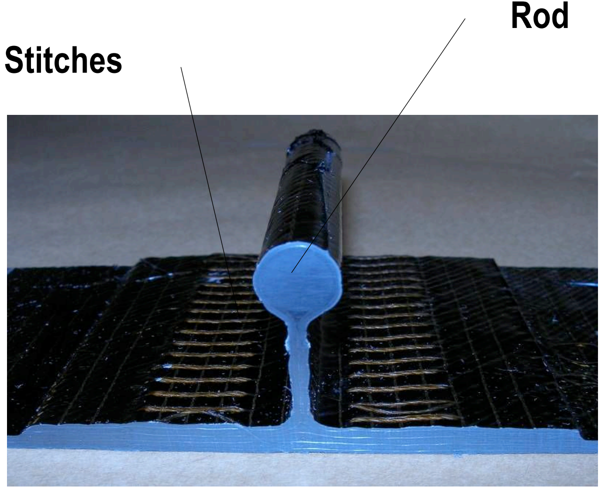
Stitched Composites - enabling weight reduction with load limits of metals

Damage Tolerance, Durability, Flexibility, Cabin Noise



Adapted from
Velicki 2009 Aging A/C Conf

Advanced Stitched Composite Concept

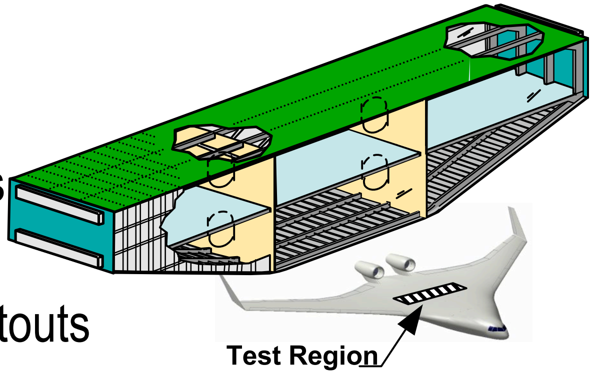


Pultruded Rod Stitched Efficient Unitized Structure
PRSEUS

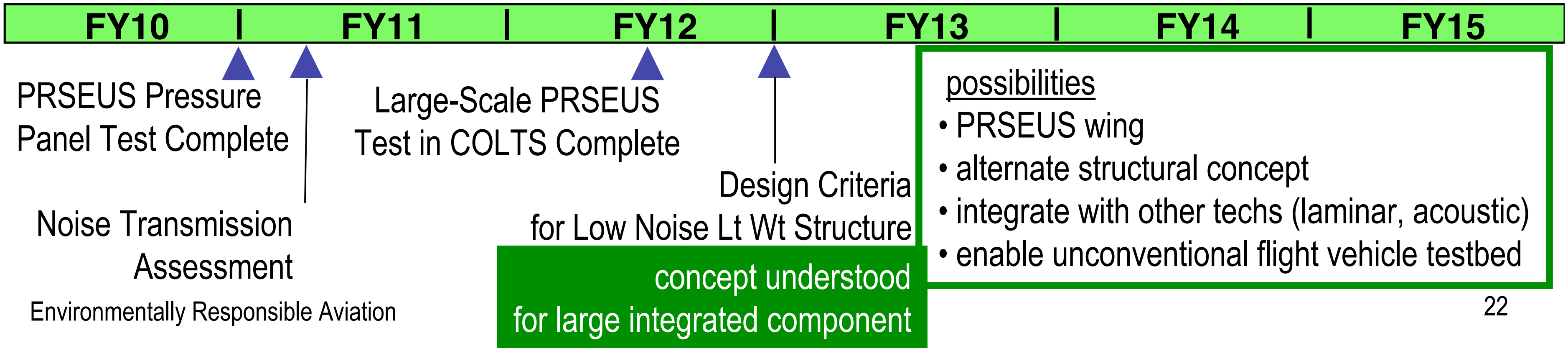
- Can the same load limits as metal be applied to a lower weight composite concept?
- Can structural weight be reduced while meeting certification/safety requirements?
- Can cabin noise be acceptable with lightweight structure, particularly in the context of propulsion noise shielding?

Energy Efficiency

Lightweight Structures



- **Objective**
  - Explore/validate/characterize/document new stitched composite structural concept under realistic loads
- **Approach**
  - Building block experiments on sub components, joints, cutouts
  - Explore repair/maintenance, NDE methods
  - Large scale pressurized multi-bay fuselage section under combined load
  - Incorporation of IVHM sensors in large scale COLTS test
- **Benefit**
  - Validate damage-arresting characteristics under realistic loads. Expected 20% reduction in weight and cost of conventional composite structural concepts. Extensible to wings, etc.



PRSEUS Pressure Panel Test Complete

Noise Transmission Assessment

Large-Scale PRSEUS Test in COLTS Complete

Design Criteria for Low Noise Lt Wt Structure

concept understood for large integrated component

possibilities
- PRSEUS wing
- alternate structural concept
- integrate with other techs (laminar, acoustic)
- enable unconventional flight vehicle testbed

Enabling

Flight Dynamics & Control

Flight Controls - enabling alternate vehicle concepts

Handling/Ride Quality, Safety of Flight

Unconventional Vehicle Concepts provide unique challenges

? Regulatory acceptance

? Market acceptance

? Performance benefit

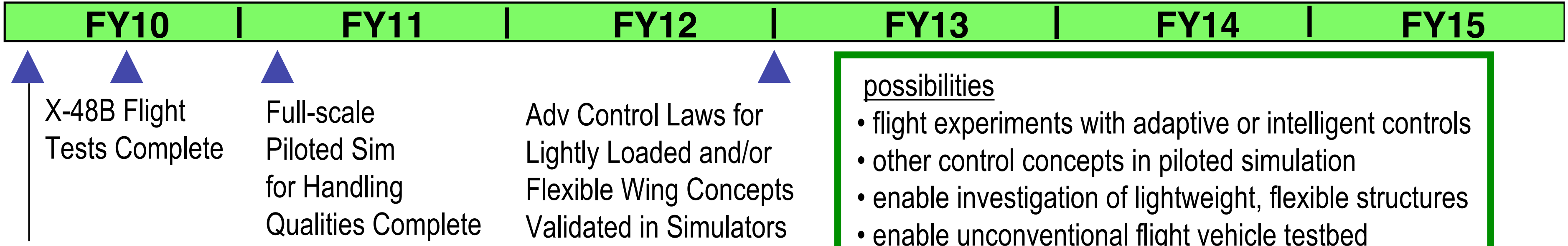
- Can alternative vehicle concepts meet Federal airworthiness requirements without negating performance/acoustic benefits?
- Can alternative vehicle concepts meet passenger ride quality expectations without negating performance/acoustic benefits?
- Can advanced controls enable performance and safety improvements beyond simply enabling a new vehicle concept?

Enabling

Flight Dynamics and Control

Piloted Sim

- **Objective**
  - Explore/assess dynamics and control design space for unconventional, flexible wing vehicle, w/ extensibility to other advanced aircraft designs
- **Approach**
  - Utilize extensive HWB database to develop full-scale piloted motion-based simulation for advanced HWB concept; establish control system design requirements and guidelines for HWB aircraft
  - Complete X-48B flight test
  - Explore/assess a broad range of handling, ride quality, control authority and allocation, gust load alleviation, upset recovery, aero-servoelastic control concepts/challenges
- **Benefit**
  - Advanced/adaptive control law technology for handling, ride quality, and safety of flight, extensible to a range of advanced vehicle concepts



FY10 | FY11 | FY12 | FY13 | FY14 | FY15

X-48B Flight Tests Complete

X-48C Tests In 30x60 Complete

Full-scale Piloted Sim for Handling Qualities Complete

Adv Control Laws for Lightly Loaded and/or Flexible Wing Concepts Validated in Simulators

possibilities

- flight experiments with adaptive or intelligent controls
- other control concepts in piloted simulation
- enable investigation of lightweight, flexible structures
- enable unconventional flight vehicle testbed

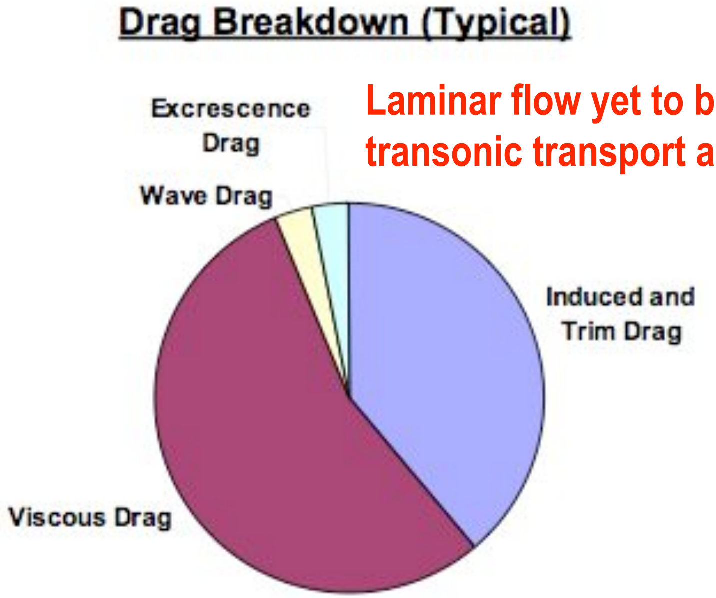
full envelop HWB control and dynamics understood; advanced controls explored

Energy Efficiency

Drag Reduction

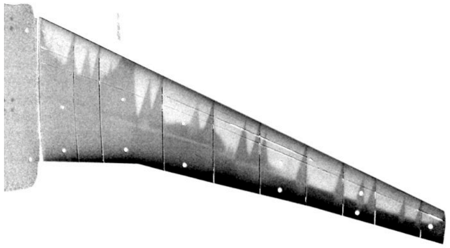
Laminar Flow - breaking down technical barriers to practical laminar flow application

System integration trades, robustness, pre-flight assessment



Laminar flow yet to be exploited on transonic transport aircraft

Active and Passive Concepts

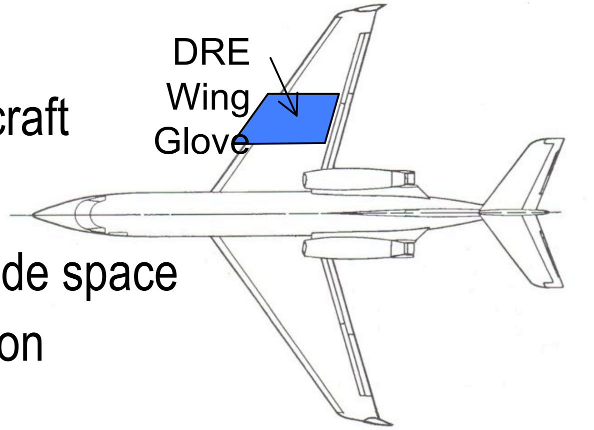


- Aerodynamic/drag benefits are known, and depend on application (config, size, regions)

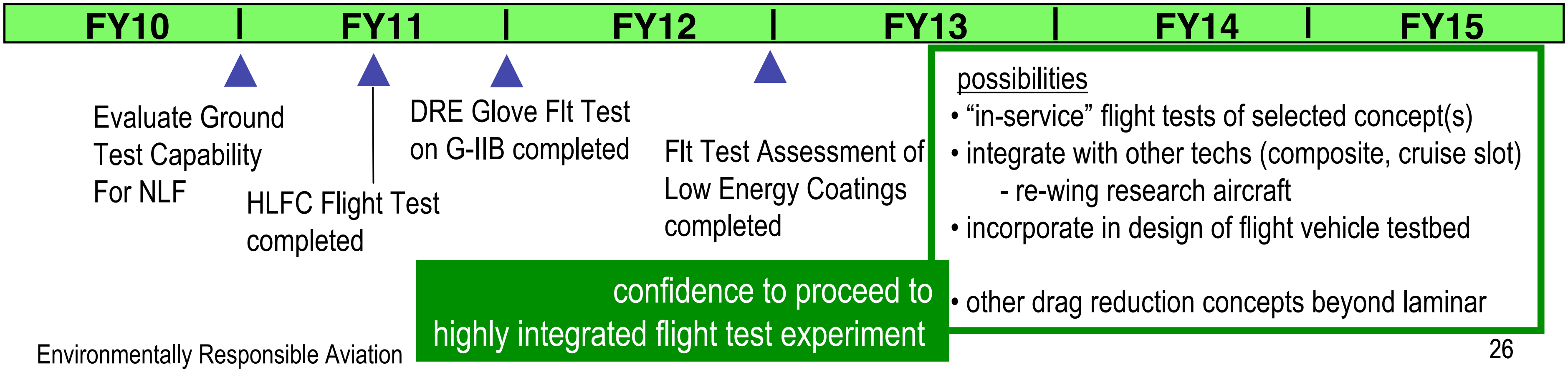
Challenges
- Integration trades for high-lift performance, and suction systems for HLFC in particular
- Robustness to contamination and structural/surface imperfection
- Ability ground test/assess across full flight envelop at relevant conditions prior to flight

Energy Efficiency

Drag Reduction



- **Objective**
  - Enable practical laminar flow application for transport aircraft
- **Approach**
  - Mature multiple approaches to laminar flow to enlarge trade space
  - Address critical barriers to practical laminar flow application
  - Explore synergy with other advanced technologies (e.g. composite structure, cruise slots, novel high lift systems, intelligent controls, etc.)
- **Benefit**
  - Validated passive and active drag control technologies capable of enabling 5-15+ % reductions in fuel burn. Expanded design trade space with higher fidelity trade information. Expanded database (higher Rn) for validation of transition models.



Evaluate Ground Test Capability For NLF

HLFC Flight Test completed

DRE Glove Flt Test on G-IIB completed

Flt Test Assessment of Low Energy Coatings completed

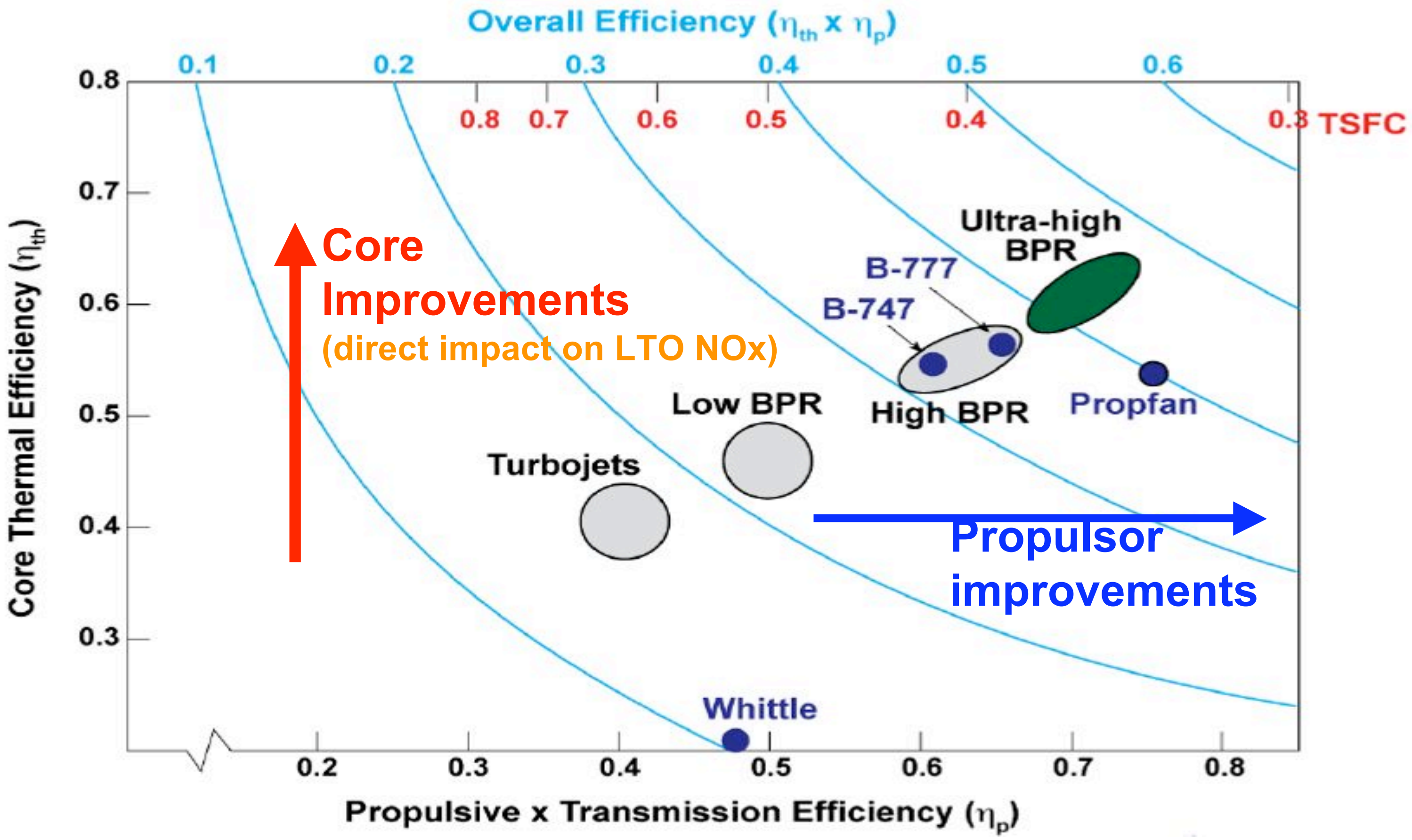
possibilities

- "in-service" flight tests of selected concept(s)
- integrate with other techs (composite, cruise slot)
  - re-wing research aircraft
- incorporate in design of flight vehicle testbed
- other drag reduction concepts beyond laminar

confidence to proceed to highly integrated flight test experiment

Propulsion Systems

Propulsion system improvements require advances in propulsor and core technologies



Core Improvements

(direct impact on LTO NOx)

Propulsor improvements

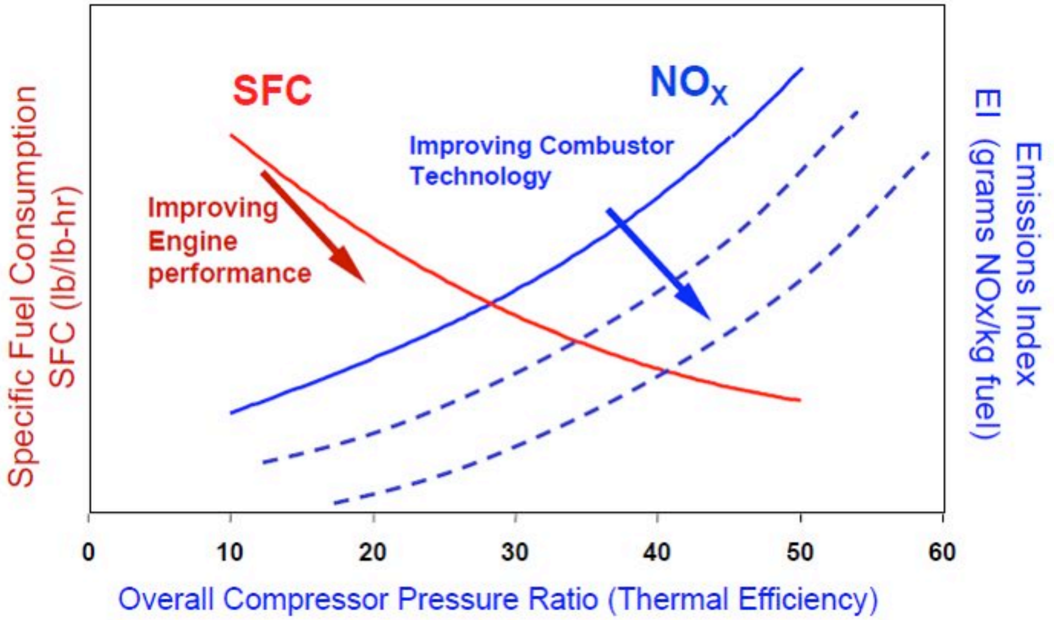
Alan Epstein
Pratt & Whitney Aircraft

LTO NOx

Core/Combustor Technology

Low NOx combustor concepts for high OPR environment

Increase thermal efficiency without increasing NOx emissions



Injector Concepts

- Partial Pre-Mixed
- Lean Direct Multi-Injection

Enabling Technology

- lightweight CMC liners
- advanced instability controls

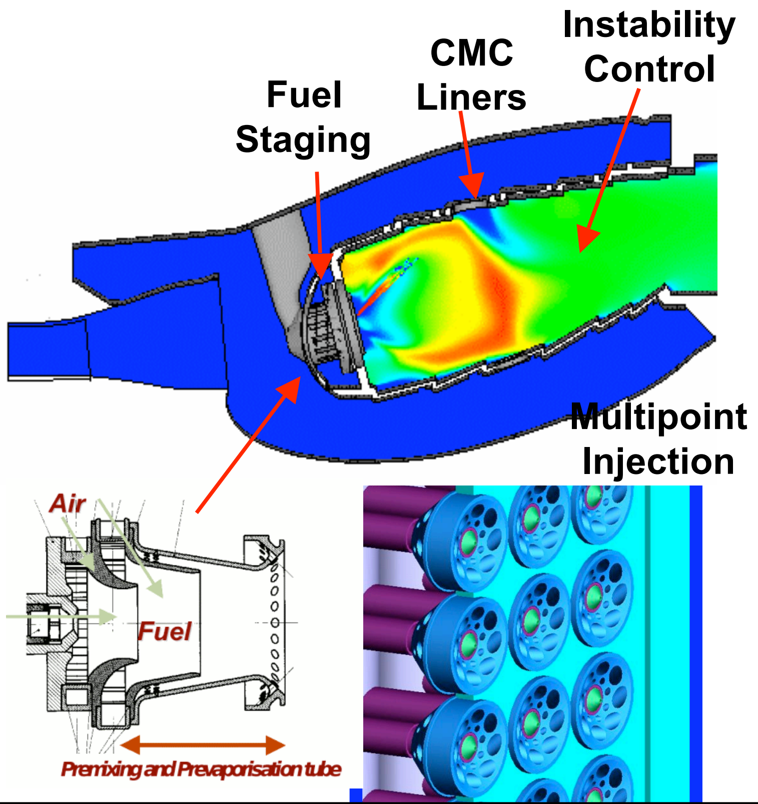
- Improved fuel-air mixing to minimize hot spots that create additional NOx
- Lightweight liners to handle higher temperatures associated with higher OPR
- Fuel Flexibility

- DoD HEETE Program is developing higher OPR compressor technology
  …. ERA will focus on new combustor technology for reduced NOx formation

LTO NOx

Combustor Technology

- **Objective**
  - Extend maturation of technologies for reducing LTO NOx. Concepts must ensure fuel flexibility.
- **Approach**
  - Pursue 3 concepts: Lean Partial-Mixed Combustor, Lean Direct Multi-Injection, TBD from NRA.
  - Flametube, sector, and annular combustor tests.
  - Select single concept for engine tests.
  - Assume 50% cost share with industry.
- **Benefit**
  - Technologies to reduce LTO NOx by 75% below CAEP/6.



FY10 | FY11 | FY12 | FY13 | FY14 | FY15

- ▲ Initiate Low-NOx Combustor Concept Studies
- ▲ Select Low-NOx Combustor Concepts **(downselect 3 to 1)**
- ▲ Complete Flametube Experiments
- △ Complete Sector Tests
- △ Complete Annular Combustor Tests

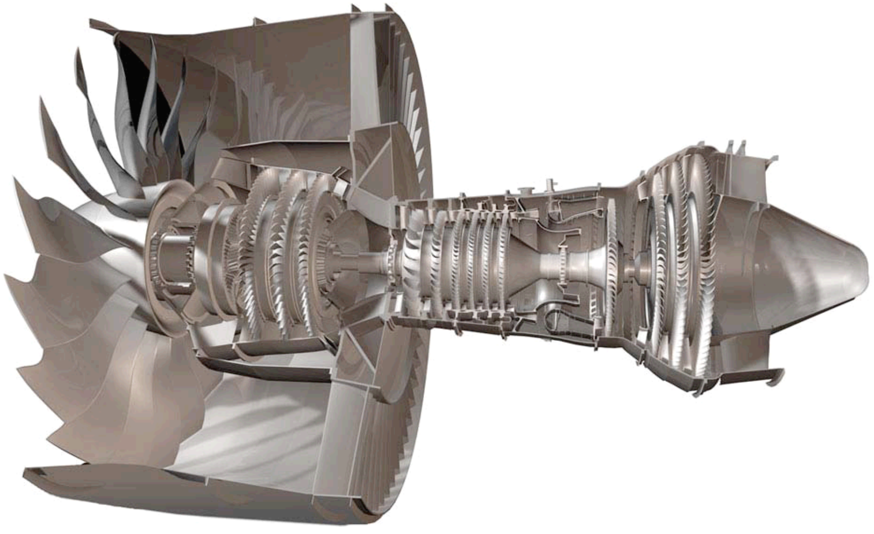
Increasing integration/complexity

Energy Efficiency

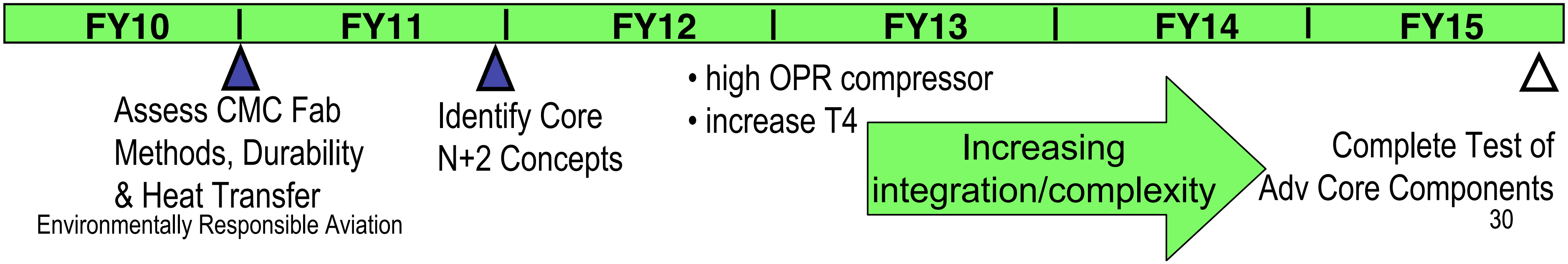
LTO NOx

Core Technology

- **Objective**
  - Explore core architectures and develop key technologies needed for N+2 propulsion
- **Approach**
  - Use NRA to explore core engine concepts; specific technologies TBD but will integrate existing work on high OPR compressors from VAATE, turbine cooling work in SFW.
  - Pursue technologies like Ceramic Matrix Composite (CMC) materials that will benefit any gas turbine engine concept; early work assesses fabrication methods for cooled vanes and nozzles
- **Benefit**
  - Technologies to increase thermal efficiency that enable higher BPR propulsion (either turbofans, open rotors, or embedded engines)



Advanced Core for UHB Turbofan (P&W GTF)



FY10	FY11	FY12	FY13	FY14	FY15

▲ Assess CMC Fab Methods, Durability & Heat Transfer

▲ Identify Core N+2 Concepts

- high OPR compressor
- increase T4

Increasing integration/complexity

△ Complete Test of Adv Core Components

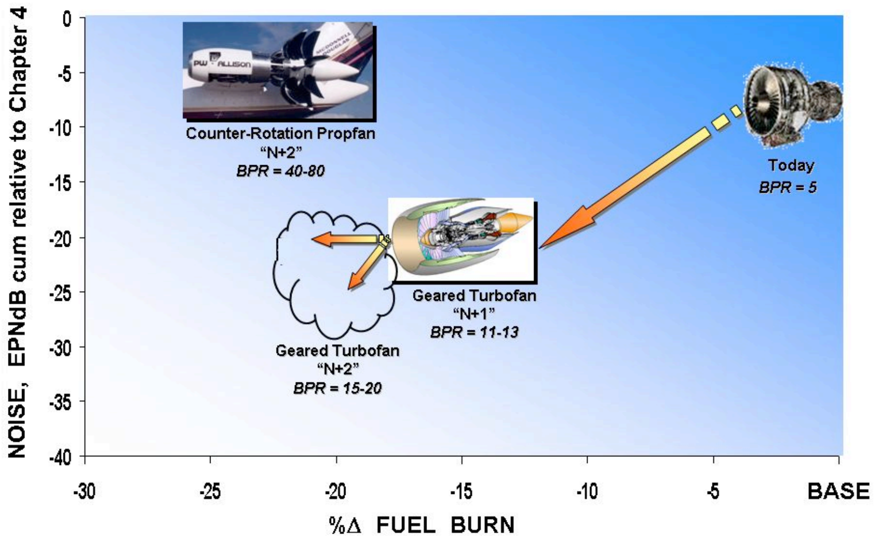
Energy Efficiency

Noise Reduction

Propulsor Technology

Ultra high bypass ratio propulsor

Ducted v Unducted trade, noise v efficiency

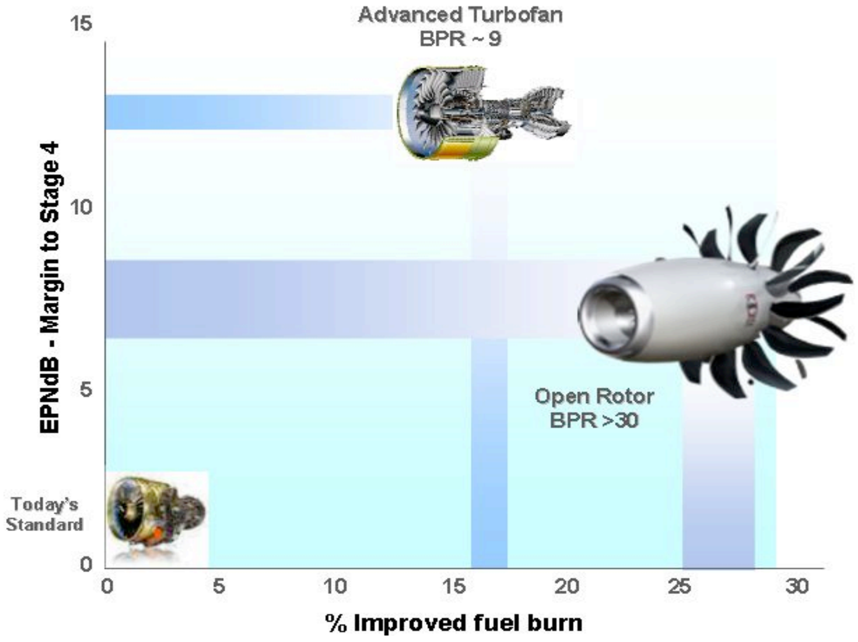


Concepts

- Ducted UHB
  - short inlets, laminar flow nacelles
  - SMA variable area nozzle
  - soft vane, over-the-rotor treatment
- Unducted UHB (Open Rotor)
  - increased rotor spacing, lower blade count
- Embedded for boundary layer ingestion
  - inlet flow control, distortion tolerant fan

Challenges

- Open Rotor - reduced noise while maintaining high propulsive efficiency
- Ducted UHB - nacelle weight & drag with increasing diameter



Energy Efficiency

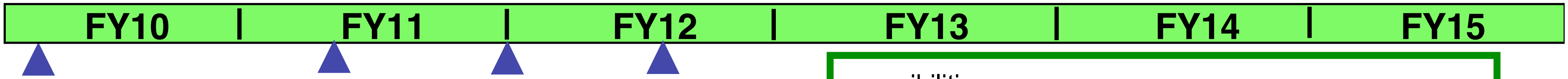
Noise Reduction

Propulsor Technology

- **Objective**
  - Explore propulsor (bypass flowpath) configurations for N+2 vehicle concepts to expand and better define the trade space between performance and noise reduction.
- **Approach**
  - Investigate feasibility of higher BPR propulsion systems: UHB Turbofans, Open Rotors and TBD Advanced Propulsor identified from NRA.
  - Evaluate UHB & Open Rotor for N+2; isolated and partially installed simulations in wind tunnel tests; Handoff to VSI for full installation experiments.
- **Benefit**
  - Propulsor concepts identified and validation data available for noise & performance trades.

UHB Turbofans

Open Rotor



Select UHB & Open Rotor Concepts

Select Adv. Propulsor Concept For N+2

Complete UHB Turbofan Tests

Complete Isolated Open Rotor Tests

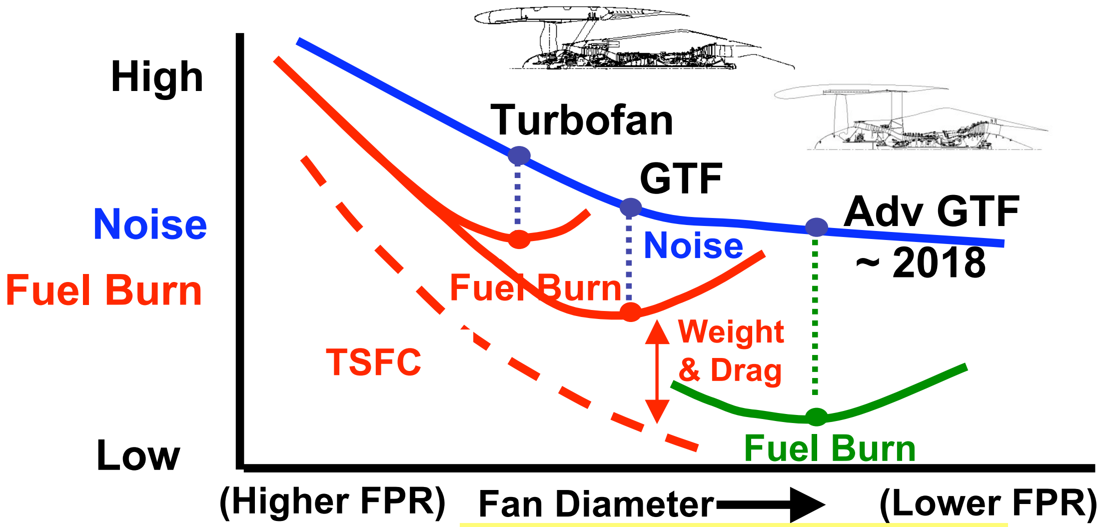
possibilities
- isolated and partially installed advanced propulsor ground tests similar to phase 1
- integrate with other techs (config, shielding)
- flight test propulsion concept
- incorporate in design of flight vehicle testbed

Energy Efficiency

Propulsion Airframe Integration

UHB Installation that minimizes or avoids performance penalties

Increased size of system may drive need for alternate configurations



Lord, Sepulveda, et al

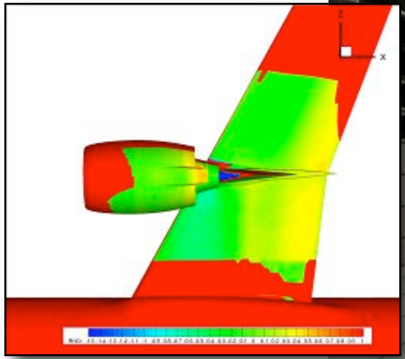
PAI Challenges Increase

- Increasingly large diameters present increasingly difficult installations for conventional low wing configurations, and may require alternate configurations/installations to take advantage of propulsive efficiency

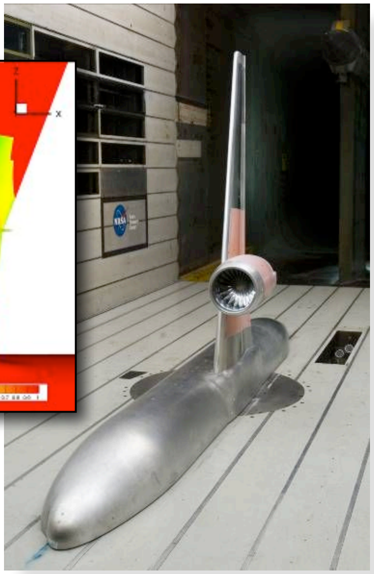
  …. significant vehicle level trade space to explore

Propulsion Airframe Integration

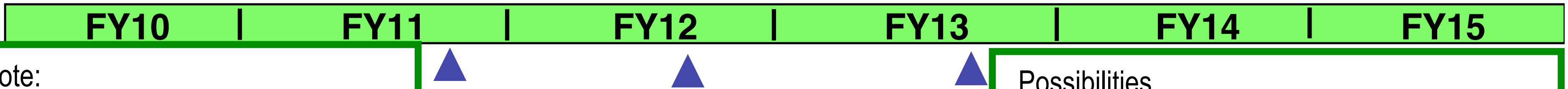
- **Objective**
  - Understand synergistic performance/efficiency coupling potential between advanced propulsor and airframe concepts
- **Approach**
  - Explore/assess (large-scale testing) performance benefits thru integration of advanced low noise/efficient open rotor and UHB propulsors
  - Quantify installed performance benefits of alternate engine airframe integrations (e.g. boundary layer ingestion)
- **Benefit**
  - Enlarged PAI design trade space with new open rotor and UHB propulsors (and integrations) with advanced N+2 airframes (15-25% fuel burn reduction)



Pressure Sensitive Paint results



Powered half-span model test in Ames 11' wind tunnel



Note:
- Advanced large scale isolated/proximity UHB and reduced noise OR propulsor experiments being conducted in 9x15. Results will feed integrated experiments.

HWB Low-Speed Performance Assessment

Performance Assessment of installed UHB

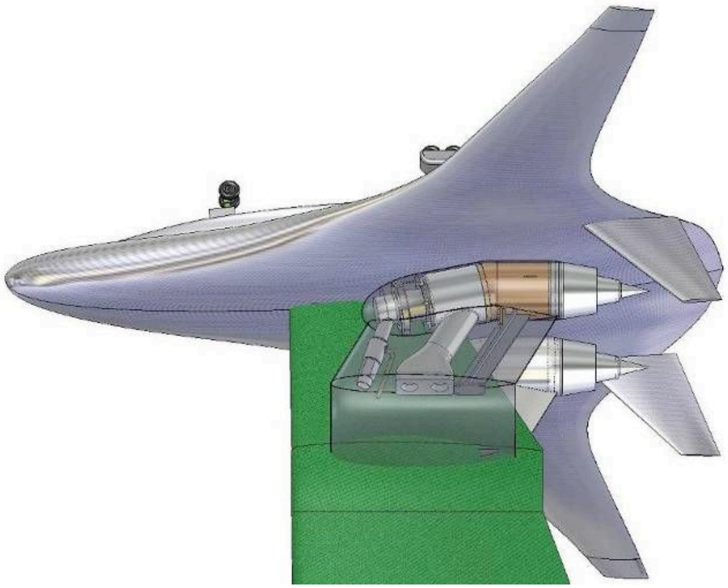
Performance Assessment of installed Open Rotor

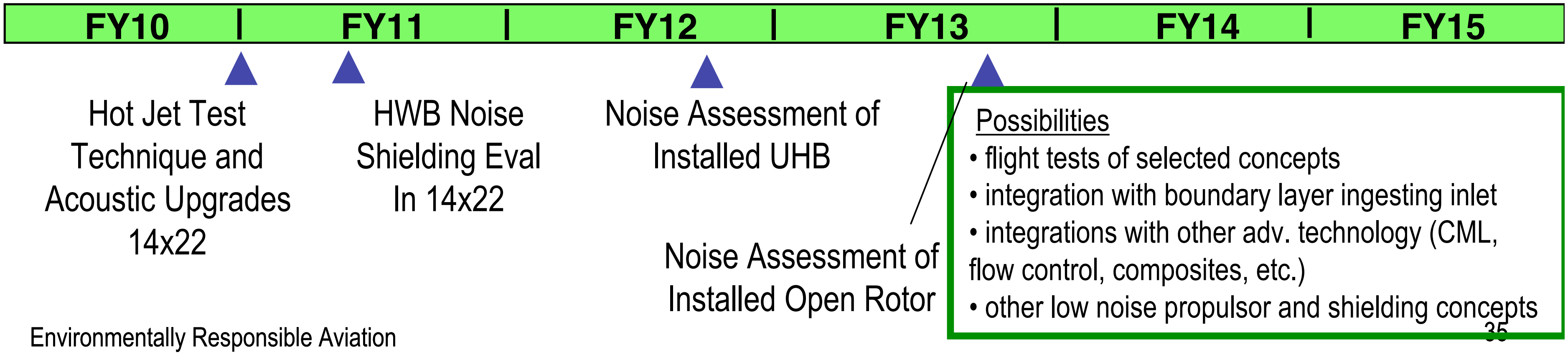
Possibilities
- flight tests of selected concepts
- integration of boundary layer ingesting inlet
- integrations with other adv. technology (CML, flow control, shielding, etc.)
- other low noise propulsor concepts

Noise Reduction

Propulsion Airframe Aeroacoustics

- **Objective**
  - Understand synergistic acoustic coupling potential between advanced propulsor and airframe concepts
- **Approach**
  - Explore/quantify (large-scale testing) airframe shielding benefits thru integration of advanced low noise/efficient open rotor and UHB propulsors
  - Quantify aeroacoustic benefits of alternate engine airframe integrations (e.g. boundary layer ingestion)
- **Benefit**
  - Enlarged PAA design trade space for new open rotor and UHB propulsors (and integrations) with advanced N+2 airframes (15-20 dB cum reduction to Stage 4)





FY10 | FY11 | FY12 | FY13 | FY14 | FY15

Hot Jet Test
Technique and
Acoustic Upgrades
14x22

HWB Noise
Shielding Eval
In 14x22

Noise Assessment of
Installed UHB

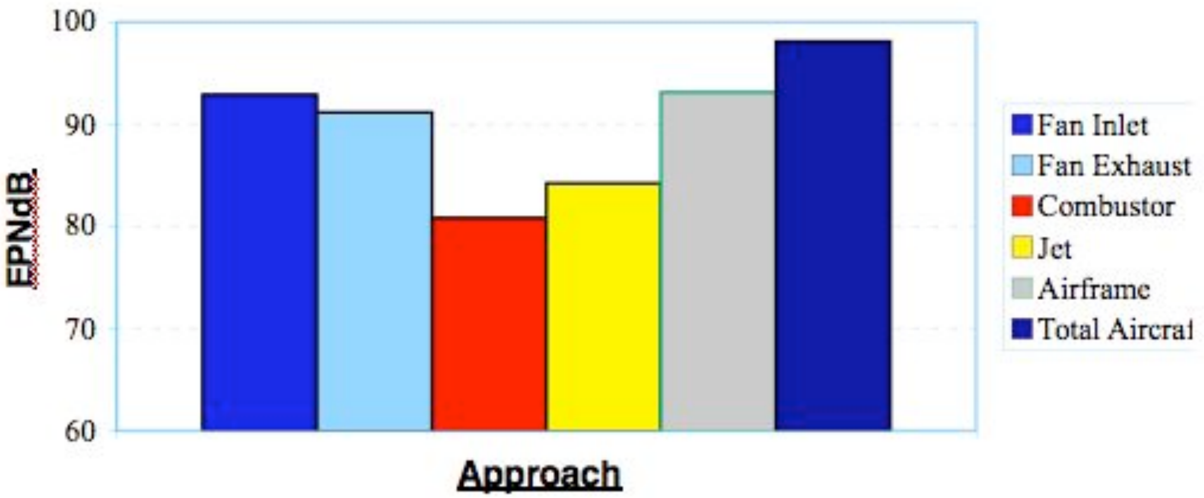
Noise Assessment of
Installed Open Rotor

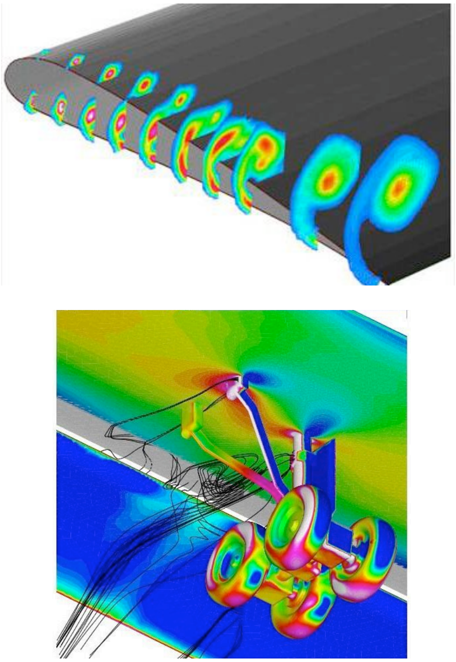
Possibilities
- flight tests of selected concepts
- integration with boundary layer ingesting inlet
- integrations with other adv. technology (CML, flow control, composites, etc.)
- other low noise propulsor and shielding concepts

Airframe Noise Reduction

Quiet flaps and landing gear without performance penalties

Low airframe noise technologies conflict with low drag/weight





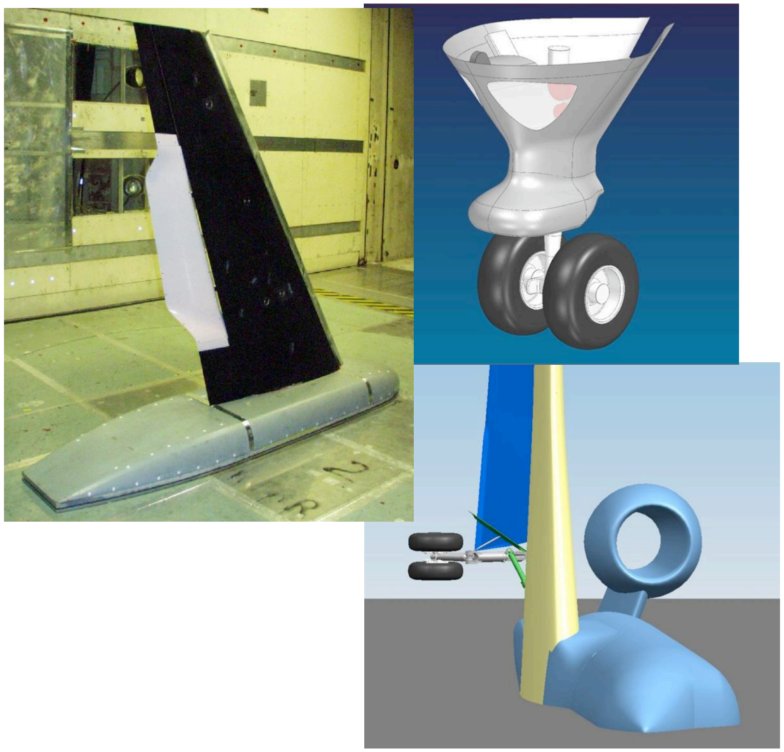
- Landing gear designed for performance/weight, but generate much more noise
- High lift system gaps and exposed flap edges help performance, but generate noise

- Currently cannot accurately account for all aircraft sources, interactions with other components, and installation effects

Noise Reduction

Airframe Noise Reduction

- **Objective**
  - Understand/research synergistic coupling/multidisciplinary aspects of integrated adv. airframe noise reduction technologies
- **Approach**
  - Flight test of CML flap on NASA G-IIB aircraft
  - Wind tunnel and flight test campaign on large business jet (LBJ) targeting landing gear and flap edge noise as well as gear/flap interactions. Improved microphone array technology.
- **Benefit**
  - Quantified technologies for airframe noise reduction on the order of 5-10 dB cum; enlarged design trade space for adv. low noise configurations



FY10 | FY11 | FY12 | FY13 | FY14 | FY15

Low Noise Concepts
on LBJ in 14x22

Assess CML
Perf & Acoustic
Benefits on G-IIB

Valid. Adv. Low Noise Gear and/or
Flap Edge Noise Concepts
on LBJ Flt Test

Possibilities
- Characterize & simulate aeroacoustic loads on large-scale multi-bay composite structure
- Large-scale or flight experiments on low noise vehicle with adv. NR technologies (e.g. landing gear fairings or low noise designs, slat cove fillers, flap edge devices, etc.)

Phase 2 Investigations - Revisited

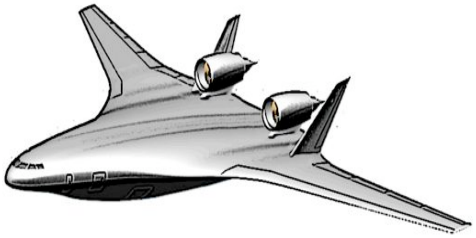
- Key Decision Point(s) for Phase 2 in the FY12 timeframe
- Noted several times today the idea of an experimental vehicle testbed (XVT) as centralizing focus for integrated systems research on an unconventional configuration
- The XVT would (very) likely require a significant budget increase and/or significant cost sharing partnerships
- Initial NRA Topic 1 may inform us as to the possibilities

XVT - Experimental Vehicle Testbed

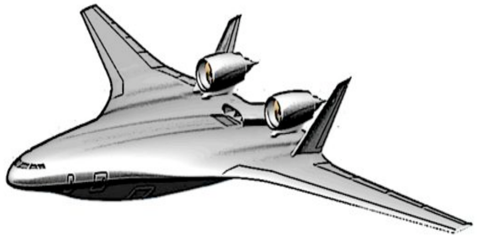
- Drivers for a (large) Flight Research Vehicle
  - Appropriate scale for aerodynamics validation
    - High Reynolds number to minimize scaling issues
    - High speed - compressibility effects
    - Geometric fidelity
  - Appropriate scale for acoustics flight test
    - Geometry fidelity
    - Physics of the noise sources require they be of the same type to scale properly
    - Scale required to understand noise attenuation and shielding
  - Appropriate scale for aero-elasticity and flight dynamics
  - Capability to assess advanced flight controls concepts

XVT - Experimental Vehicle Testbed

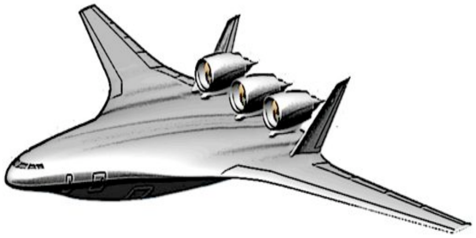
- Additional Benefit of a Flight Research Vehicle
  - Validate simultaneous progress toward N+2 goals through technology integration on a vehicle testbed
    - Gain understanding of technology interdepencies/interactions and hardware integration issues
    - Ability to validate multiple off-nominal data points through full envelope testing
    - Flight Reynolds number with real world effects
  - Produce and disseminate high quality data for technology characterization and design method validation
  - Collect actual flying qualities, passenger ride quality, and cabin noise data
  - Ability to operate in the National Air Space for integration Airspace/Operations projects
  - Testbed for future technology concepts including propulsion systems
- AN IDEA ….



Baseline Aircraft



Embedded Engine



Advanced Engine Technology

Concluding Remarks

- Explore/demonstrate the feasibility, benefits, and risks of vehicle concepts and enabling technologies identified to have potential to mitigate the impact of aviation on the environment

- Expand viable and well-informed trade space for vehicle design decisions enabling simultaneous realization of National noise, emissions, and performance goals; identify challenges for foundational research

- Alternative configurations w/ advanced technology will be needed to simultaneously achieve the N+2 goals; technologies will be broadly applicable and tradable

- Systems research in relevant environment