Subsonic Fixed Wing Project
N+3 (2030-2035) Generation Aircraft Concepts - Setting the Course for the Future

Presented by - Fay Collier, Ph.D.
PI, Subsonic Fixed Wing Project
Fayette.S.Collier@nasa.gov

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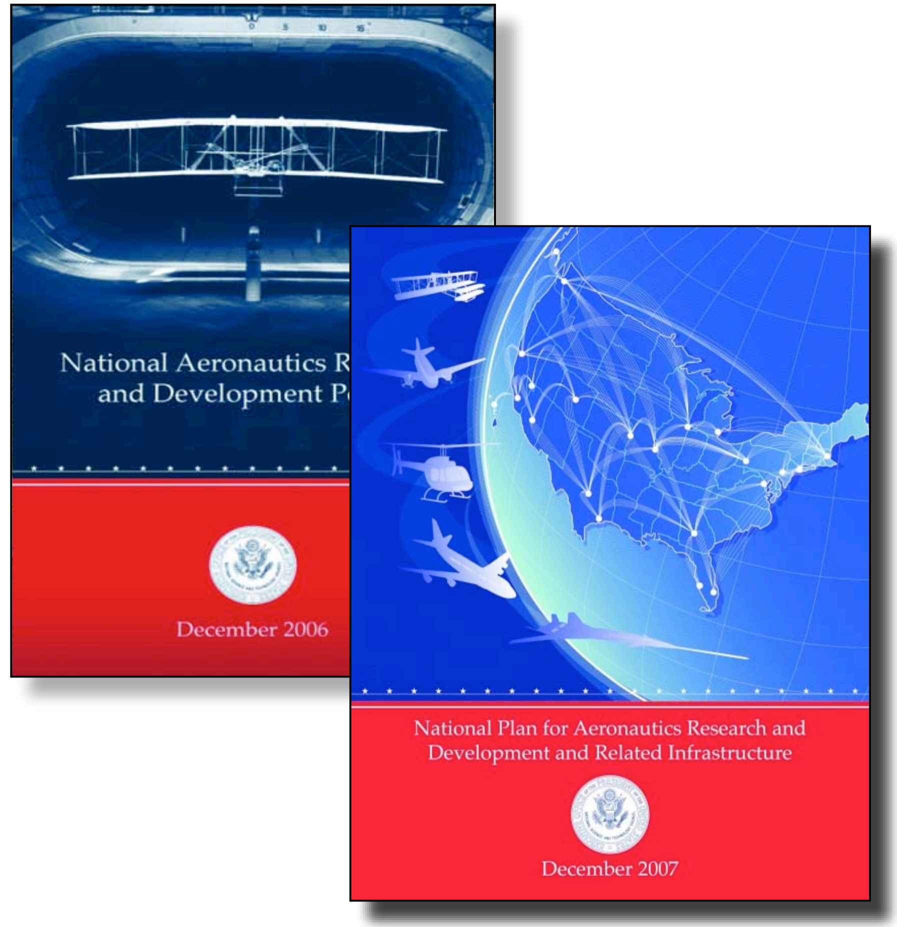
Outline

- US Policy on Aeronautics
- SFW System Level Metrics
- N+3 NRA Study Concepts
- N+3 NASA In-house Study Concepts
- Questions or Comments

National Aeronautics R&D Policy and Plan

- 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 President 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

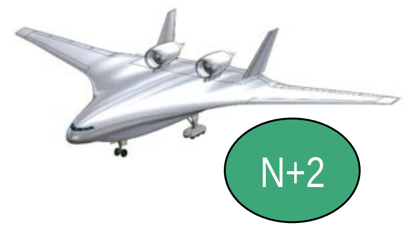
For more information visit: http://www.ostp.gov/cs/nstc/documents_reports

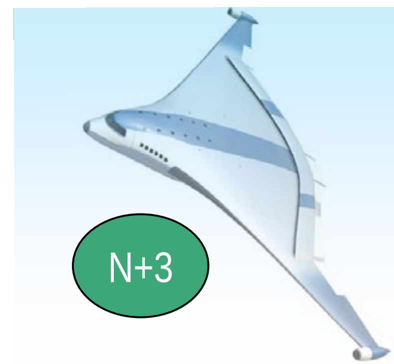
SFW System Level Metrics

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

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 multiple airports within the metropolitan areas
--- EIS = Entry Into Service; IOC = Initial Operating Capability

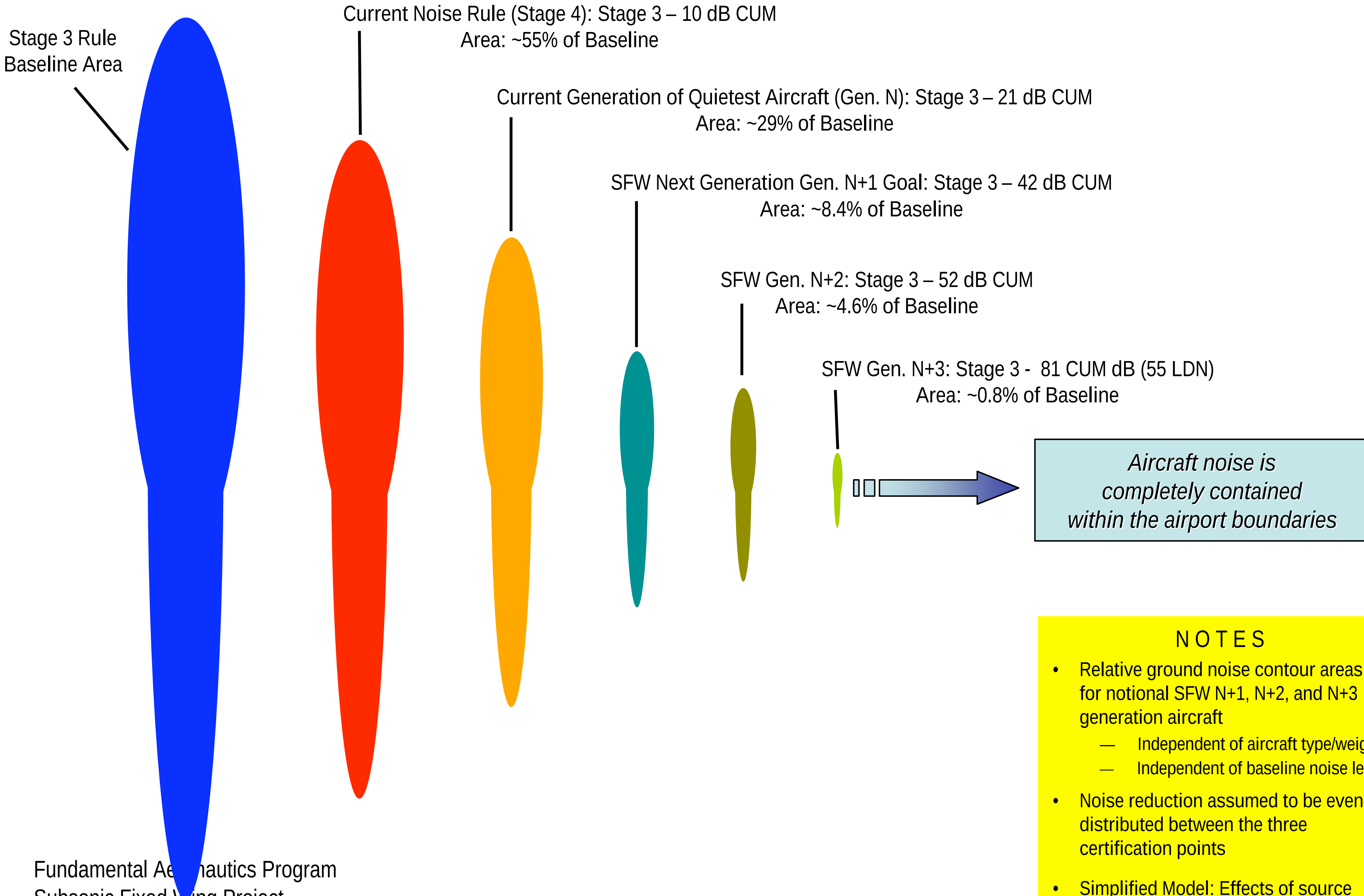




Approach

- *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*
- *Conduct Discipline-based Foundational Research*

Change in noise "footprint" area based on Subsonic Fixed Wing Project goals for a single landing and takeoff



NOTES

- Relative ground noise contour areas for notional SFW N+1, N+2, and N+3 generation aircraft
  - Independent of aircraft type/weight
  - Independent of baseline noise level
- Noise reduction assumed to be evenly distributed between the three certification points
- Simplified Model: Effects of source directivity, wind, etc. not included

SFW N+3 NRA Objectives

- Identify advanced airframe and propulsion concepts, as well as corresponding enabling technologies for commercial aircraft anticipated for entry into service in the 2030-35 timeframe, market permitting
  - Advanced Vehicle Concept Study
  - Commercial Aircraft include both passenger and cargo vehicles
  - Anticipate changes in environmental sensitivity, demand, & energy
- Results to aid planning of follow-on technology programs

N+3 Advanced Concept Study NRA

- 29 Nov 07 bidders conference
- 15 Apr 08 solicitation
- 29 May 08 proposals due
- 2 July 08 selections made
- 1 Oct 08 contract start
- Phase I: 18 Months
  - NASA Independent Assessment @ 15 months
- Phase II: 18-24 Months with significant technology demonstration

SFW N+3 NRA Requirements

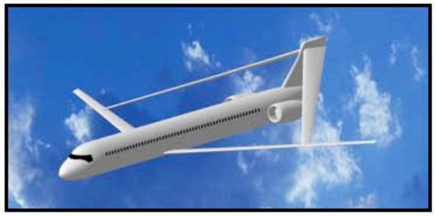
- Develop a Future Scenario for commercial aircraft operators in the 2030-35 timeframe
  - provide a context within which the proposer's advanced vehicle concept(s) may meet a market need and enter into service.
- Develop an Advanced Vehicle Concept to fill a broad, primary need within the future scenario.
- Assess Technology Risk - establish suite of enabling technologies and corresponding technology development roadmaps; a risk analysis must be provided to characterize the relative importance of each technology toward enabling the N+3 vehicle concept, and the relative difficulty anticipated in overcoming development challenges.
- Establish Credibility and Traceability of the proposed advanced vehicle concept(s) benefits. Detailed System Study must include:
  - A current technology reference vehicle and mission
    - to be used to calibrate capabilities and establish the credibility of the results.
  - A 2030-35 technology conventional configuration vehicle and mission
    - to quantify improvements toward the goals in the proposer's future scenario due to the use of advanced technologies, and improvements due to the advanced vehicle configuration.
  - A 2030-35 technology advanced configuration vehicle and mission

Boeing

Subsonic Ultra-Green Aircraft Research (SUGAR)

A Wide Variety of Concepts Will Be Considered

Engineering, Operations & Technology | **Phantom Works** **Platform Performance Technology**

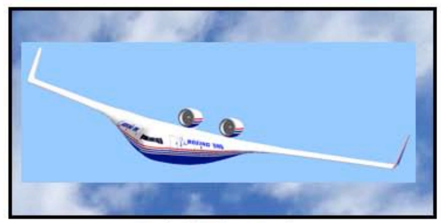


Joined Wing

Hydrogen Powered

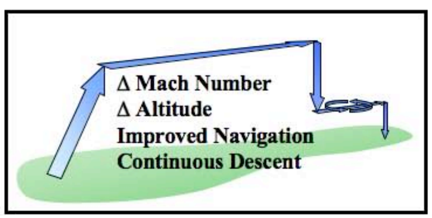
Strut-braced Wing

Aerial Refueling

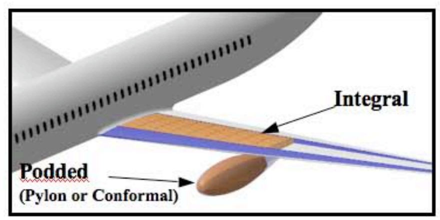


Hybrid Wing Body

Formation Flight



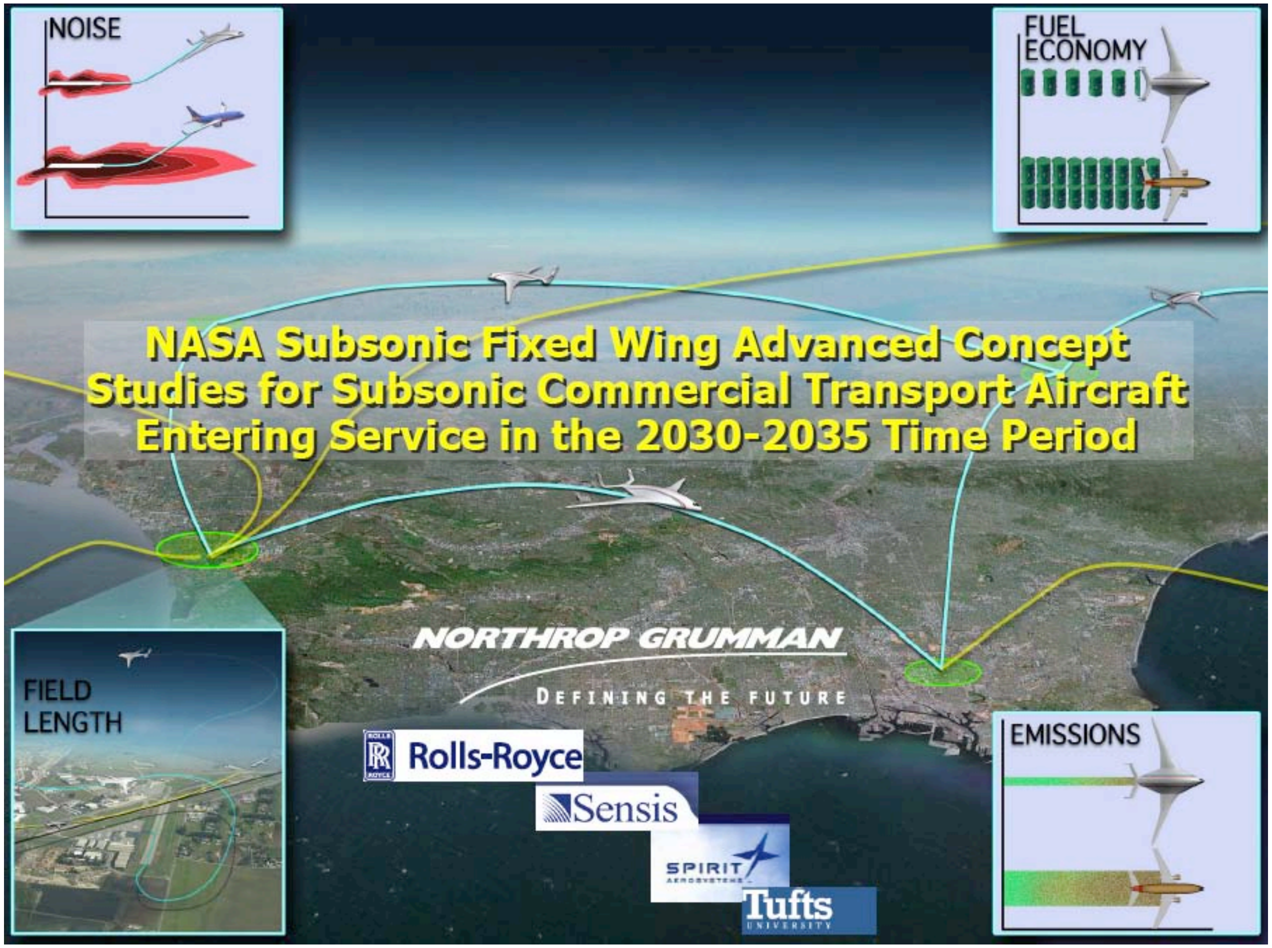
Changes in Mission & Operation



Podded or Integral Batteries

Other Concepts from Worksl

Northrop Grumman



Massachusetts Institute of Technology

Aircraft & Technology Concepts for an N+3 Subsonic Transport

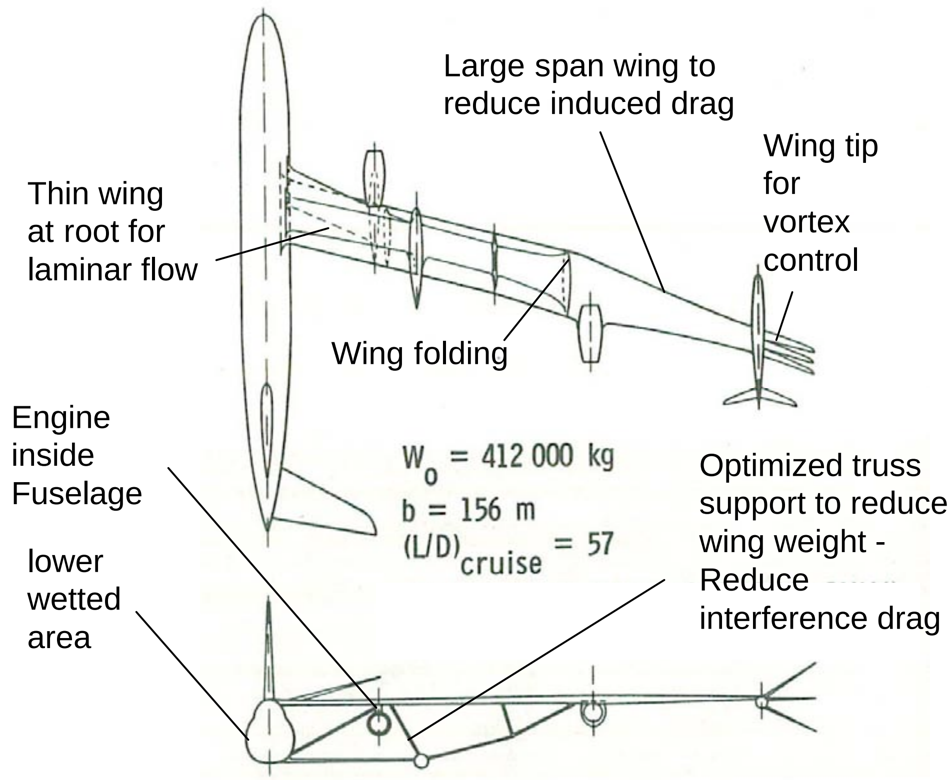
- MIT
- Aurora
- Aerodyne
- Pratt & Whitney
- Boeing PW

General Electric

Truss-Braced Wing (TBW) Research

NASA In-house, NIA, Virginia Tech, Georgia Tech N+3 Study

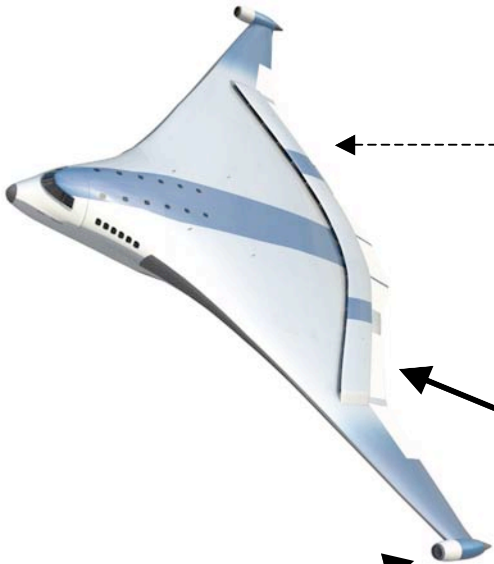
- What: Develop and design a revolutionary Truss-Braced-Wing (TBW) subsonic transport aircraft concept.
- Why: In 1988, Dennis Bushnell, Langley Chief Scientist challenged the aeronautic community to develop a passenger transport aircraft with Lift/Drag ratio of 40. BWB & Pfenninger's TBW have the potential to meet this challenge.
- How: Develop full Multidisciplinary Design Optimization (MDO) analysis tool for TBW design to increase span, reduce weight and drag with thin wing for natural laminar flow, reduced wetted area, folding wing & flight-control, vortex control, advanced composite, efficient engine in fuselage, bio-fuel.

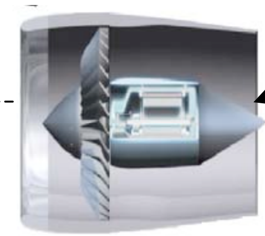


- Revolutionary: If successful, this design will Double the Lift/Drag ratio of a conventional transport aircraft

Distributed Turboelectric Propulsion Vehicle

NASA In-house N+3 Study (Workshop in progress at GRC)





Lightweight High Temperature Superconducting (HTS) Components

- Superconducting motor and generator structures
- Low-loss AC superconductor
- Compact cryocooler
- LH2 tankage (if desired)
- HTS electric power distribution components

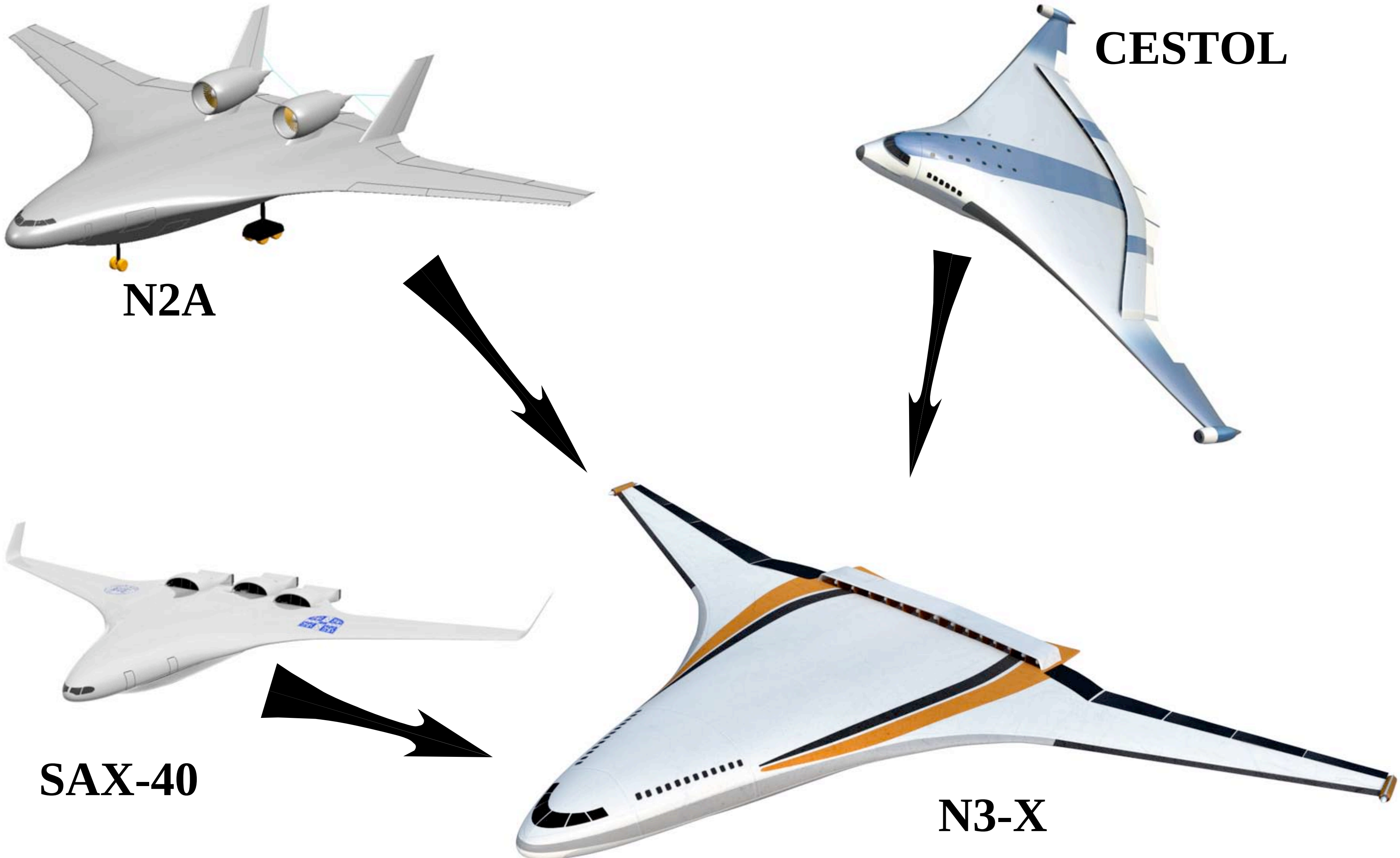
Turboelectric Engine Cycle

- Decoupling of the propulsive device (fans) from the power-producing device (engine core) -> High performance and design flexibility of aircraft
- High effective bypass ratio -> High fuel efficiency due to improved propulsive efficiency and maximum energy extraction from the core
- Distributed power to the fans -> Symmetric thrust with an engine failure

Propulsion Airframe Integration

- Large BLI high aspect ratio short inlet and vectoring nozzle
- Distributed fan noise reduction through wing and jet-to-jet shielding
- Engine core turbomachinery noise suppression
- Direct spanwise powered lift
- Aircraft control using fast response electric fan motor and/or vectoring nozzle
- Wing-tip mounted engine core/generator
  - Aeroelasticity, tip vortex interaction

N3-X Turbo-electric Distributed Propulsion



Felder, Kim, Brown

N3-X Distributed Turboelectric Propulsion System

Superconducting motor driven fans in a continuous nacelle

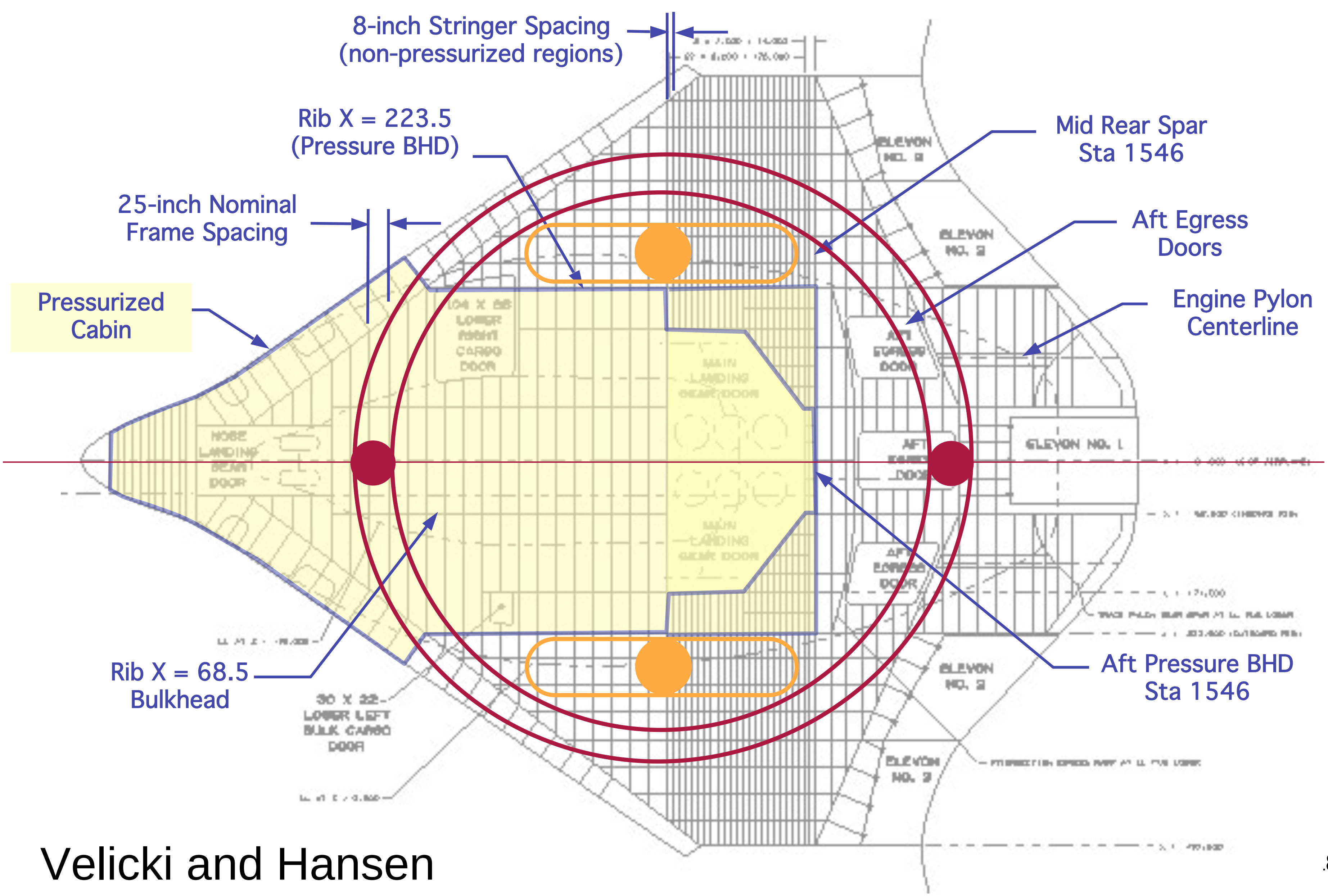
Wing-tip mounted superconducting turbogenerators

Felder, Kim, Brown

Cryogenic Cooling Options

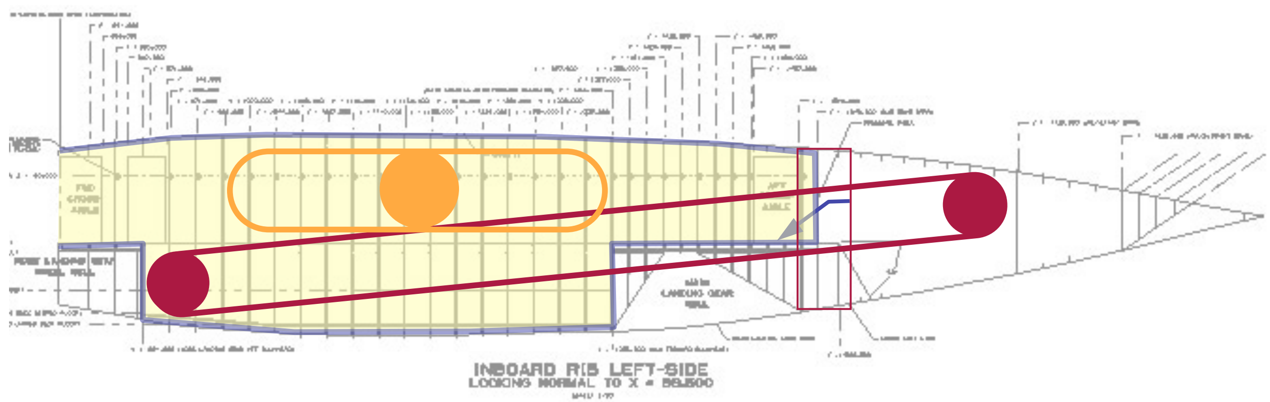
- Jet fuel with Refrigeration
  - Jet-A fuel weight is baseline for comparison
- Liquid Hydrogen cooled and fueled
  - No refrigeration required
  - 4 times the volume & 1/3 the weight of the jet fuel baseline
- Liquid Methane cooled and fueled
  - 5% of the baseline refrigeration
  - 64% larger volume & 14% less weight the jet fuel baseline
- Liquid Hydrogen cooled and Hydrogen/Jet-A fueled
  - No refrigeration required
  - 32% larger volume & 6% less weight than the jet fuel baseline
- Liquid Methane/Refrigeration cooled and Methane/Jet-A fueled
  - 5% of the baseline refrigeration
  - 17% larger volume & 2% less weight than the jet fuel baseline

Structural Concepts for Storing the LH2

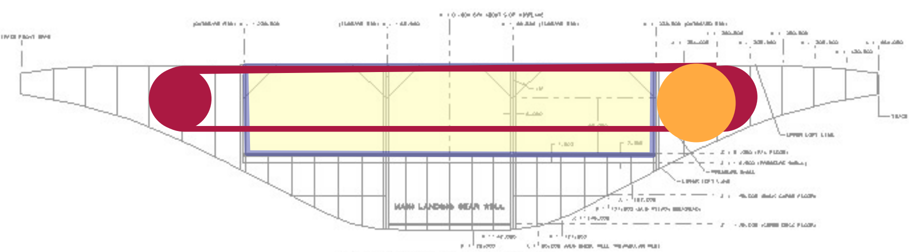


Velicki and Hansen

Structural Concepts for Storing the LH2



View Looking Inboard at Rib X = 68.5 (Cabin Divider)



Landing Gear Bulkhead

Velicki and Hansen

Possible Turboelectric - HWB advantages

The turboelectric/hybrid wing body approach may meet 3 of the 'N+3' goals as well as reduce runway length.

Fuel Burn/NOX:
- BLI drag reduction
- 14 fans allows clean integration of large fan area from low fan pressure ratio
- Large turbomachinery core with many embedded, distributed propulsors = very high bypass ratio
- Fan/turbine at any desired speed
- Clean air to turbogenerators
- Asymmetric thrust reduces aero surface drag for control and trim
- <0.5% transmission loss

Noise:
- Low pressure fans for low fan nozzle velocity
- Fan nozzle at surface back from trailing edge
- Low turbogenerator exhaust velocity
- Asymmetric thrust reduces control deflection
- Low cabin noise due to remote location of fans and turbogenerators.

Field Length:
- Blowing at low speed/high power delays separation and increasing lift coefficient
- "Blown" pitch effector
- Higher static thrust

Felder, Kim, Brown

Exotic fuel trades

For same aircraft configuration

- Liquid hydrogen
  - Lower takeoff gross weight, possibly higher empty weight (tankage)
  - Many operational and engineering challenges to solve
  - Method of H_2 production (present method very pollutive), and infrastructure issues
- Liquid Methane
  - Positive benefits lie in-between kerosene and Hydrogen
  - Modest reduction in CO_2 and NOx
- Nuclear-powered
  - Weight of reactor dependent on shielding requirements
  - CO_2 depends on fuel (but greatly reduced). NOx production probably substantially less or about equal to base (based on study assumptions)
  - Safety and acceptance difficult
- Fuel cell powered
  - True zero-emissions (depending on source of H2)
  - Fuel cell technology has a long way to go for transport application (20-25 years)

Questions or Comments