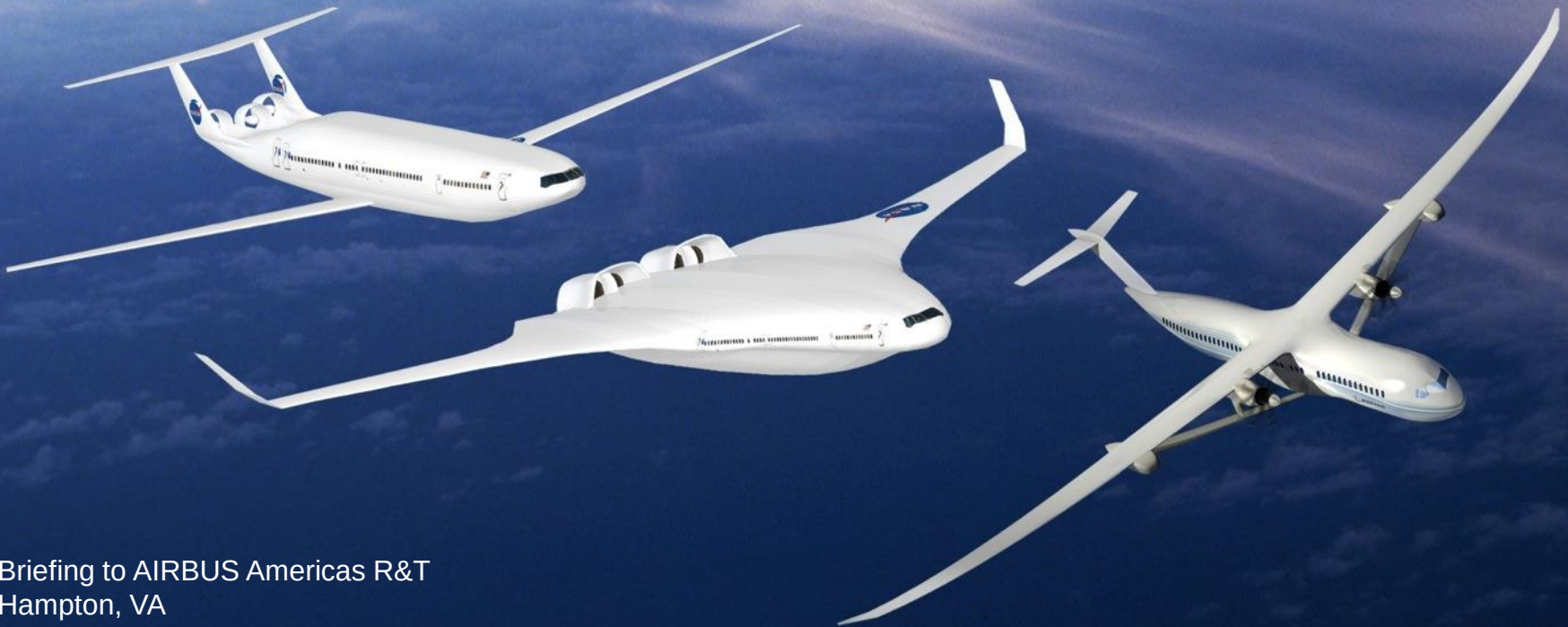




Advanced Concepts Design Tools and Capabilities at LaRC

Andrew Hahn, Mark Guynn, Craig Nickol, Lori Ozoroski

Aeronautics Systems Analysis Branch
NASA Langley Research Center



Briefing to AIRBUS Americas R&T
Hampton, VA
June 18, 2014



- Purpose Of NASA Aeronautics Advanced Concepts Systems Analysis
- NASA Goals For Future Vehicles
- Recent And On-going Study Efforts
 - NASA concept development
 - Contracted concept development
 - “Smart Buyer” and “Honest Broker” roles
- Tools And Methods Development
- Summary

Purpose of NASA Advanced Concepts SA



- Stimulate Thinking On Potential Aircraft Solutions To Significant Problems Of The Future
- Identify Advanced Airframe And Propulsion Concepts, As Well As Corresponding Enabling Technologies
- Identify Most Promising Technologies For Fundamental Research Investments
- Prime The Pipeline For Future, Revolutionary Aircraft Concepts And Technology Developments

NASA Goals For Future Vehicles



- NASA Has Goals For Future Aircraft Focused On:

- Fuel Efficiency
- NO_x Emissions
- Noise

- Goals Set At Three Future Time Horizons

- TRL 4-6
- N+1 (2015), N+2 (2020), N+3 (2025)

- Stretch Goal Targets Informed By Systems Analysis

	N+1 Supersonic Business Class Aircraft (2015)	N+2 Small Supersonic Airliner (2020)	N+3 Efficient Multi- Mach Aircraft (Beyond 2030)		
Environmental Goals					
Sonic Boom	65-70 PLdB	65-70 PldB	65-70 PLdB Low Boom flight 75-80 PldB		
Aircraft (cumulative) Cruise (Cruise NO _x) Performance Cruise Range Payload Fuel Burn (pass-miles)	TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)			
		N+1 (2015)	N+2 (2020**)	N+3 (2025)	
		Noise (cumulative margin rel. to Stage 4)	-32 dB	-42 dB	-71 dB
		LTO NO _x Emissions (rel. to CAEP 6)	-60%	-75%	-80%
		Cruise NO _x Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
		Aircraft Fuel/Energy Consumption [†] (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

† CO₂ emission benefits dependent on life-cycle CO_{2e} per MJ for fuel and/or energy source used

NASA Concept Development



- In-house Development Of Advanced Vehicle Concepts Undertaken To Complement And Supplement Contracted Efforts
- Work Funded Both Within Defined NASA Projects And Through Center and HQ “Innovation” Funds



Truss Braced Wing Example



- TBW Promises Ultra High Wing Spans And Low Weight
- Center Innovation Funds First Applied In 2007 With An Emphasis On High-fidelity, Physics-based Tool Development
- Consistent Internal Funding And Systems Analysis Branch Involvement
- Boeing Proposed TBW In SFW N+3 NRA Phase I & II
- Boeing Tested Flutter Model In Phase II Using The Tools Developed Under The NASA Effort As Well As Their Tools And Expertise To Design It



N+2 Subsonic Advanced Vehicle Concepts



- Advanced Concept Studies Of Commercial Subsonic Transport Aircraft Capable Of **Simultaneously** Meeting NASA's "N+2" Goals With TRL 4-6 In 2020
- Phase I Conceptual Design Studies Awarded To Three Contractors
- Phase II Subscale Test Vehicle (STV) Design Study Awarded To Boeing For The BWB



LOCKHEED MARTIN

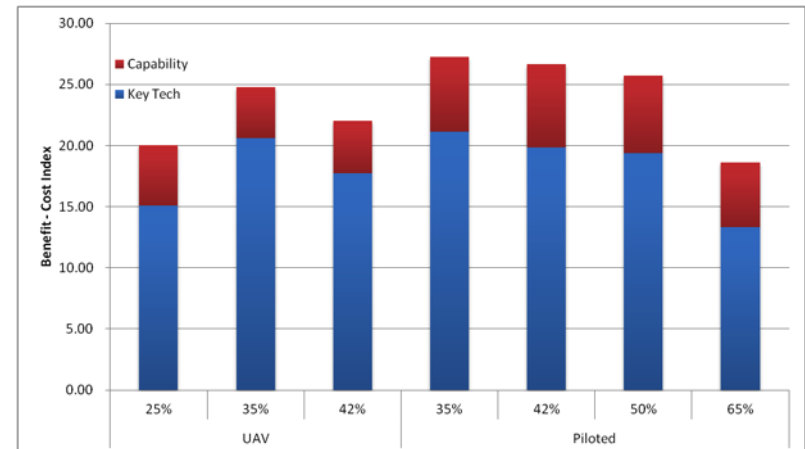
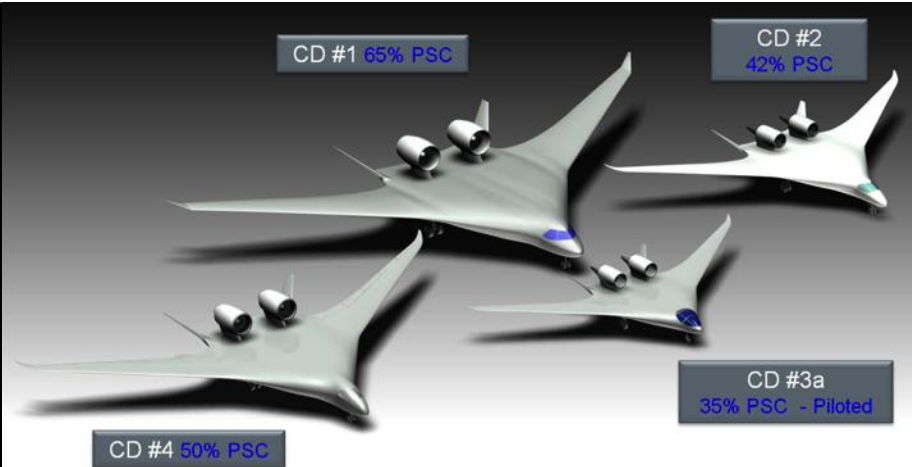


NORTHROP GRUMMAN

Boeing Phase II Subscale Test Vehicle Study



- Boeing Did An Excellent Job
- Examined The STV Options In Significant Detail, Including Innovative Costing Analysis
 - Created A Cost Tool Sensitive To Program Phasing And Was Able To Optimize The Schedule To Minimize Program Cost Subject To Constraints Such A Program Duration And Peak Year Outlay
 - Looked At Cost/Benefit Ratio Of Piloted Vs Uninhabited



N+3 Subsonic Advanced Vehicle Concepts



Boeing, GE, GaTech



154Pax
3500nm
M.70

Advanced concept studies for commercial subsonic transport aircraft for TRL 4-6 in 2025

NG, RR, Tufts, Sensis,
Spirit



120Pax
1600nm
M.75

Intended to stimulate far-term thinking towards future aircraft needs and identify key technologies needed.

GE, Cessna, GaTech



20Pax
800nm
M.55

MIT, Aurora, P&W, Aerodyne



354Pax
7600nm
M.83



180Pax
3000nm
M.74



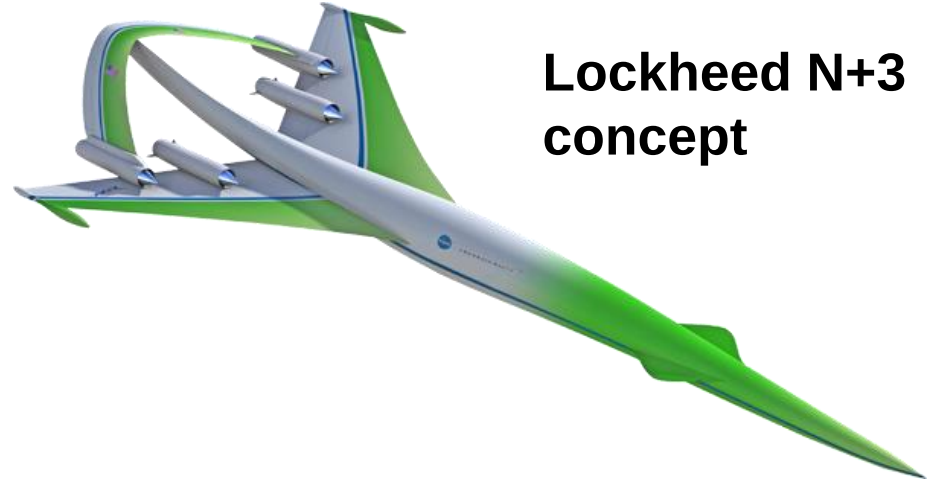
Aviation Week cover picture and story (May 17, 2010)

Copyright, The McGraw-Hill Companies. Used with permission.

Supersonic Advanced Vehicle Concepts



Boeing N+2 Baseline concept



**Lockheed N+3
concept**



**Lockheed
N+2 concept
Aviation
Week cover
picture and
story, July
2011**

Boeing N+3 concept





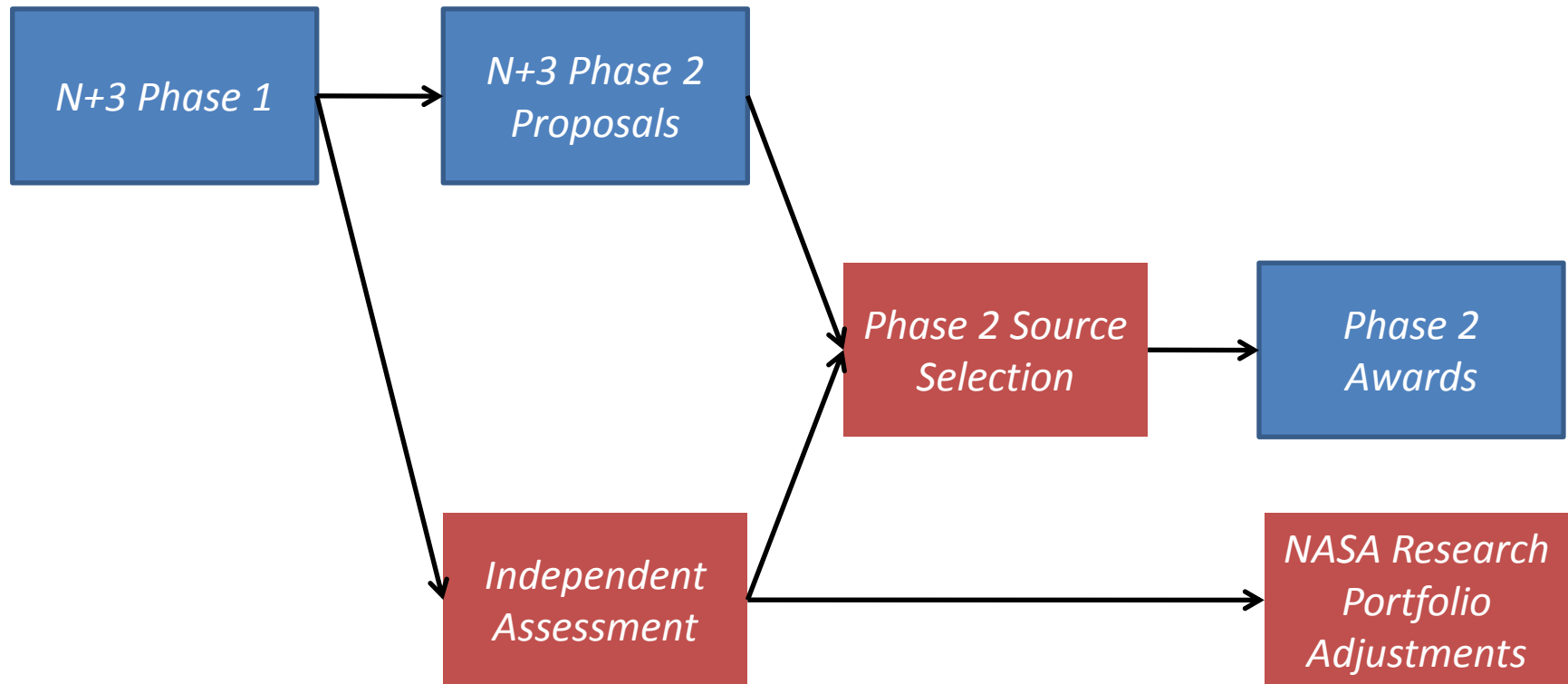
Objectives

- Assess The Level Of Confidence We Have In The Concept Data Provided By The Study Contractors
- Identify Areas Of High Payoff In Contractors' Designs
- Identify Areas Of High Risk In Contractors' Designs

Approach

- Systems Analysis Team Assigned To Follow Contractor's Work
- Collect Detailed Information From Contractors
- Concepts Evaluated At A System Level

“Smart Buyer”: Subsonic N+3 Example



- = Contractor Involvement
- = Systems Analysis Involvement

NASA Langley system analysis of Phase 1 concepts influenced selection of Phase 2 efforts as well as NASA in-house research portfolio

Tool Development: Integrated System Design



Current State-of-the-Art

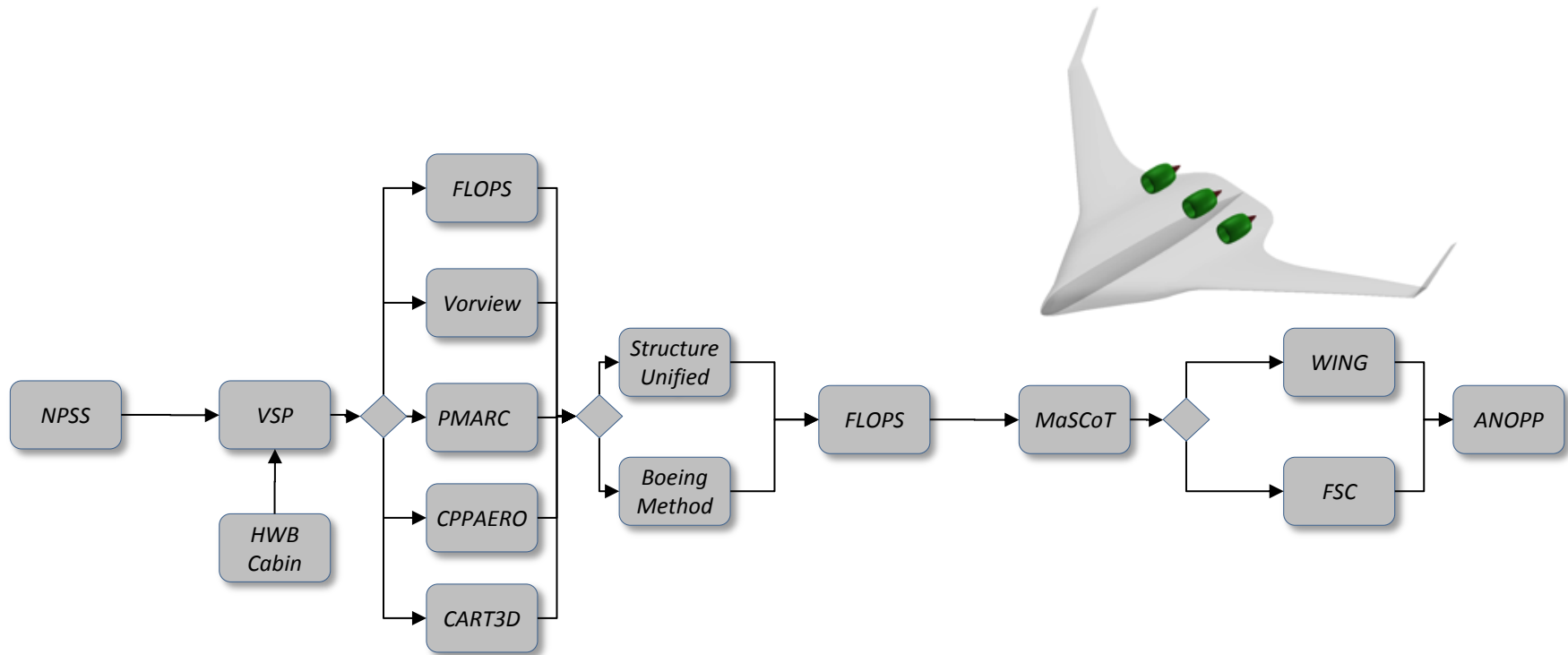
- High Order (Fidelity) Tools Rarely Included In System-level Analysis
- Geometry Limitations Between Fidelity Levels
- Tool Integration Often “Hard Wired,” Lacks Flexibility

Our Approach

- Integrate Discipline Level Tools Into Vehicle Analysis Capability
- Build A Physics-based Predictive Design Analysis And Optimization System
- Provide Flexible Integration, Select The Right Tool For The Job

Enable the ability to make informed decisions on the feasibility of advanced concepts and their required technologies

Integrated Analysis for “Hybrid Wing Body”



Multi-Fidelity Low-Boom Design Process

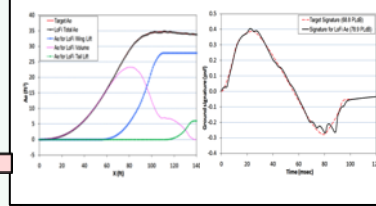


Low-Fidelity Ae Analysis



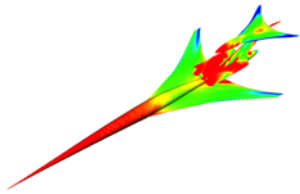
Iteration time: < 2 min

Low-Fidelity Ae Matching



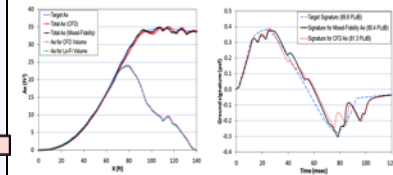
Design Objective: Modify the aircraft geometry to shape the high-fidelity ground signature for mitigation of sonic boom.

Medium-Fidelity CFD Ae Analysis

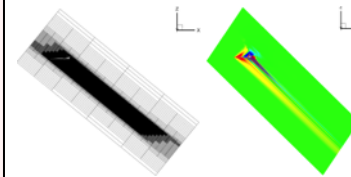


Iteration time: 20 min

Medium-Fidelity Ae Matching

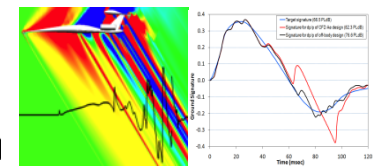


High-Fidelity Boom Analysis

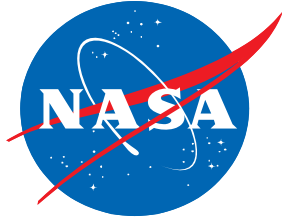


Iteration time: 2-3 hr

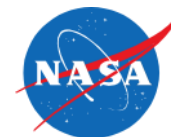
High-Fidelity Aft Shape Tailoring



- NASA Pursues Advanced Vehicle Concepts To Identify Key Technologies For Research Investment
- Large Overlap Between NASA and Aerospace Industry Focus On Reducing Fuel Consumption
- NASA Langley System Analysis And Concepts Directorate Provides:
 - Development of new concepts for incubation and projects
 - Independent evaluation of contractor developed concepts for project management
 - Development of new tools and methods for advanced concept design and analysis
- NASA Has Funded Several Industry Studies On Subsonic And Supersonic Concepts For Multiple Future Timeframes



NASA Subsonic Transport System Level Metrics



v2013.1

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption [‡] (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO2 emission benefits dependent on life-cycle CO2e per MJ for fuel and/or energy source used

NASA Supersonic Transport System Level Metrics



Balanced Goals for Practical Civil Supersonic Aircraft (Technology Available)	N+1 Supersonic Business Class Aircraft (2015)	N+2 Small Supersonic Airliner (2020)	N+3 Efficient Multi-Mach Aircraft (Beyond 2030)
Design Goals			
Cruise Speed	Mach 1.6-1.8	Mach 1.6 -1.8	Mach 1.3 - 2.0
Range (n.mi.)	4000	4000	4000 - 5500
Payload (passengers)	6-20	35-70	100 - 200
Environmental Goals			
Sonic Boom	65-70 PLdB	85 PldB (Revised)	65-70 PLdB Low Boom flight 75-80 PldB Overwater flight
Airport Noise (cum below stage 4)	Meet with Margin	10 EPNdB	10-20 EPNdB
Cruise Emissions (Cruise NOx g/kg of fuel)	Equivalent to current Subsonic	< 10	< 5 & particulate and water vapor mitigation
Efficiency Goals			
Fuel Efficiency (pass-miles per lb of fuel)	1.0	3.0	3.5 – 4.5

Subsonic N+3 Phase 2



- Five proposals submitted in 3 task areas
 - Experimental and higher-fidelity exploration of key technologies
 - N+3 advanced vehicle concept study
 - N+4 advanced vehicle concept study
- Four awards
 - Boeing
 - N+3 truss-braced wing concept refinement and experimental validation
 - N+3 hybrid electric concept refinement and tool development
 - N+4 concept study
 - Northrop Grumman
 - Advanced High-Lift Leading-Edge (AHLLE) system for laminar flow wings
 - MIT
 - Propulsion-airframe integration for “D8” aircraft
 - High efficiency small core engines
 - Cessna
 - STAR-C² protective skins - materials and requirements development