National Aeronautics and Space Administration

SFW's Second-Generation MDAO Capability (GEN2) Integration Process and Validation Plans

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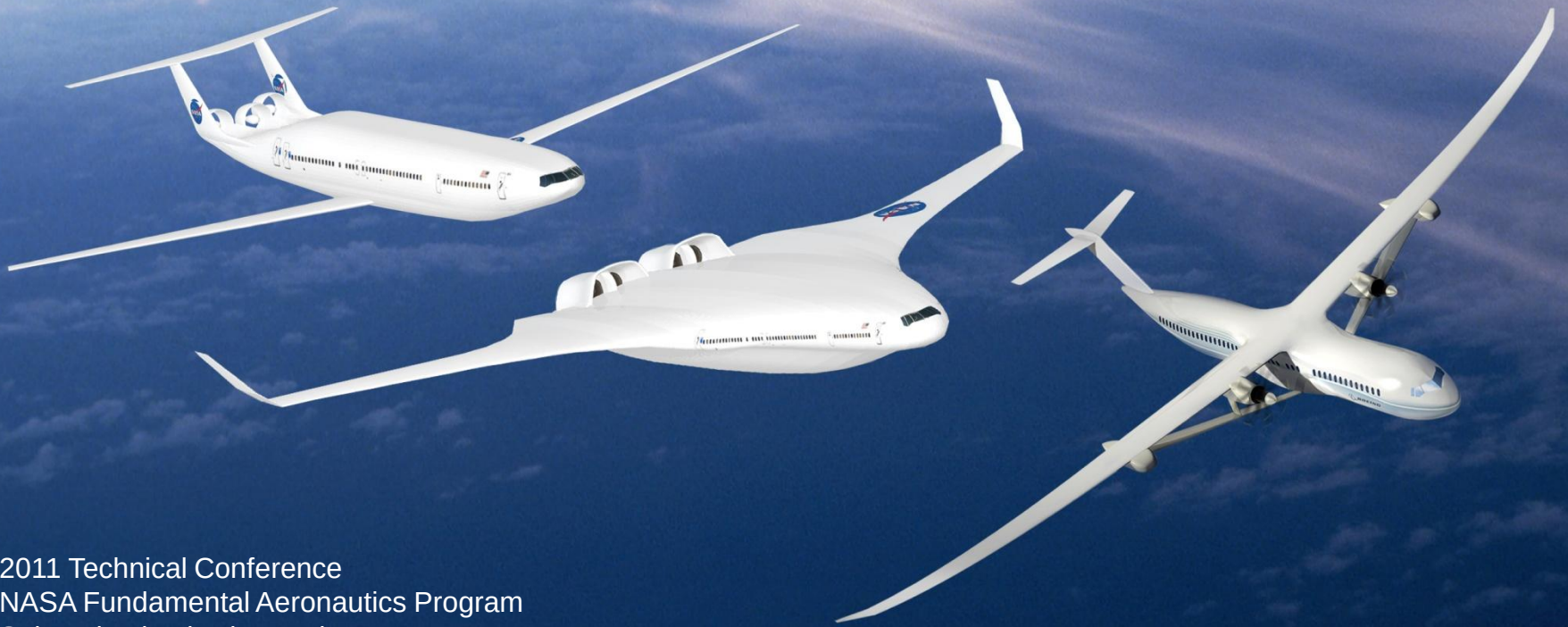


2011 Technical Conference
NASA Fundamental Aeronautics Program
Subsonic Fixed Wing Project
Cleveland, OH, March 15 - 17, 2011

NASA Subsonic Transport System Level Metrics

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

CORNERS OF THE TRADE SPACE	N+1 (2015)*** Technology Benefits Relative to a Single Aisle Reference Configuration	N+2 (2020)*** Technology Benefits Relative to a Large Twin Aisle Reference Configuration	N+3 (2025)*** Technology Benefits
Noise (cum below Stage 4)	- 32 dB	- 42 dB	- 71 dB
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance Aircraft Fuel Burn	-33%**	-50%**	better than -70%
Performance Field Length	-33%	-50%	exploit metroplex* 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 areas

SFW Approach

- Conduct Discipline-based Foundational Research
- Investigate Advanced Multi-Discipline Based Concepts and Technologies
- Reduce Uncertainty in Multi-Disciplinary Design and Analysis Tools and Processes
- Enable Major Changes in Engine Cycle/Airframe Configurations

Outline

- Background
- GEN2 methods toolbox
- Reference aircraft
- Analysis process flows
- Validation plans and progress

GEN2 Milestones FY10-11

- FY10: Complete new suite of integrated multidisciplinary analysis tools to predict noise, NO_x, takeoff/landing performance, cruise performance, and take-off gross weight (TOGW)
  - Valid for conventional ("tube and wing") aircraft and unconventional aircraft (e.g. hybrid wing-body).
  - Verify successful integration of multiple low/intermediate/high fidelity modules within an MDAO framework.
- FY11: GEN 2 Validation of integrated tool set with experimental data
  - Validate NO_x, takeoff/landing, cruise performance, takeoff gross weight, noise for conventional and unconventional systems.

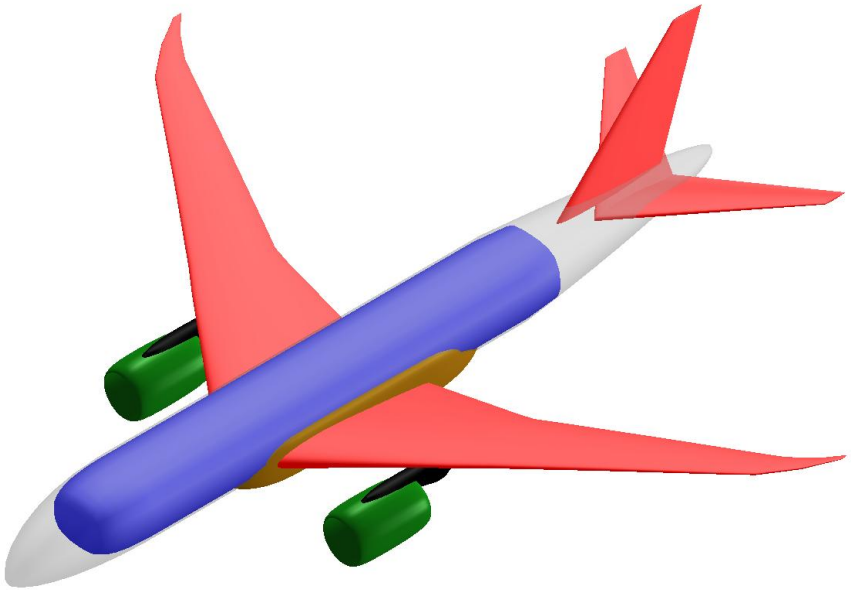
GEN2 Methods Toolbox (1 of 2)

- Propulsion
  - Numerical Propulsion System Simulation (NPSS) / WATE++
- Geometry
  - HWB Cabin Layout
  - Vehicle Sketch Pad (VSP)
- Aerodynamics
  - Flight Optimization System (FLOPS)
  - Vorview
  - PMARC
  - CPPAero
  - CART3D (in progress)
- Structures / Weights
  - FLOPS
  - Structures Unified (HWB only)
  - Boeing Centerbody Weights (HWB only)
  - VSP to NASTRAN (in progress)

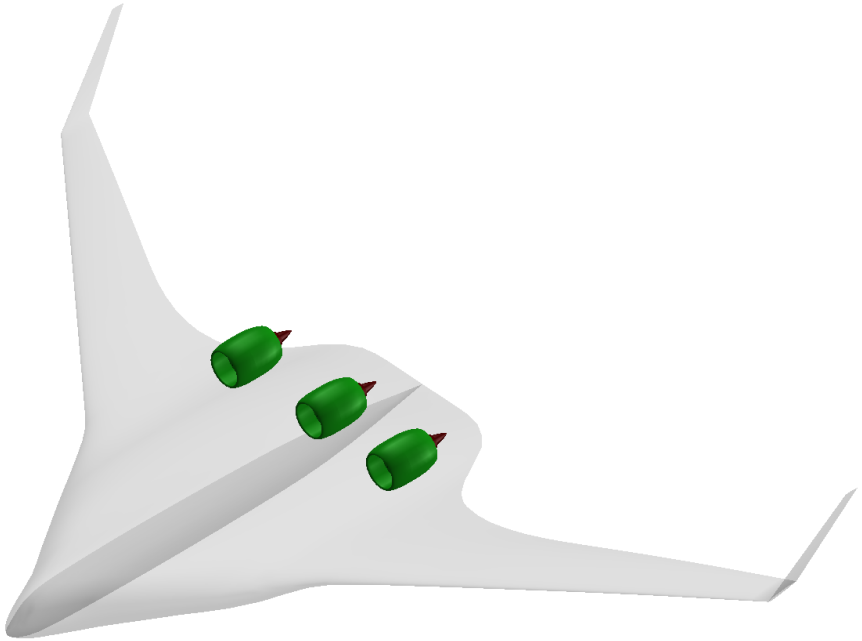
GEN2 Methods Toolbox (2 of 2)

- Mission Analysis
  - FLOPS
- Stability & Control
  - Matlab Stability & Control Toolbox (MaSCoT)
- Acoustics
  - Aircraft Noise Prediction Program (ANOPP)
  - ANOPP WING
  - Fast Scattering Code (in progress)

GEN2 Reference Models

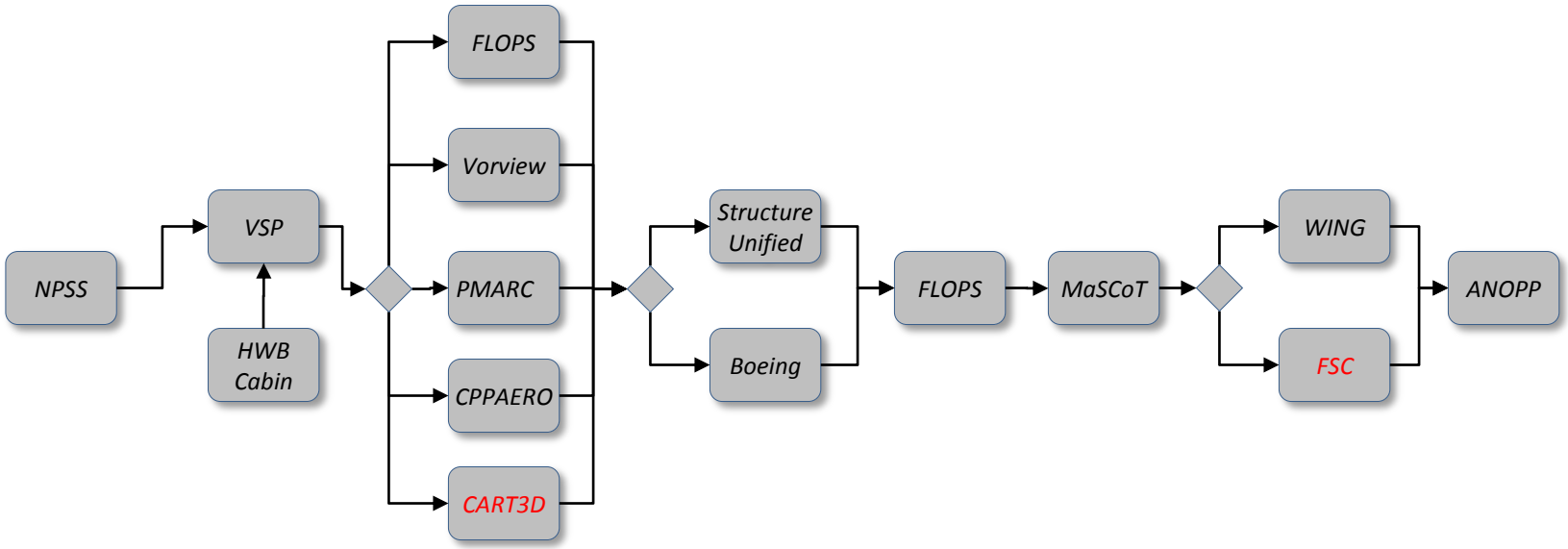


Conventional
B787-8 / Genx-2B67
242 pax in 3 classes



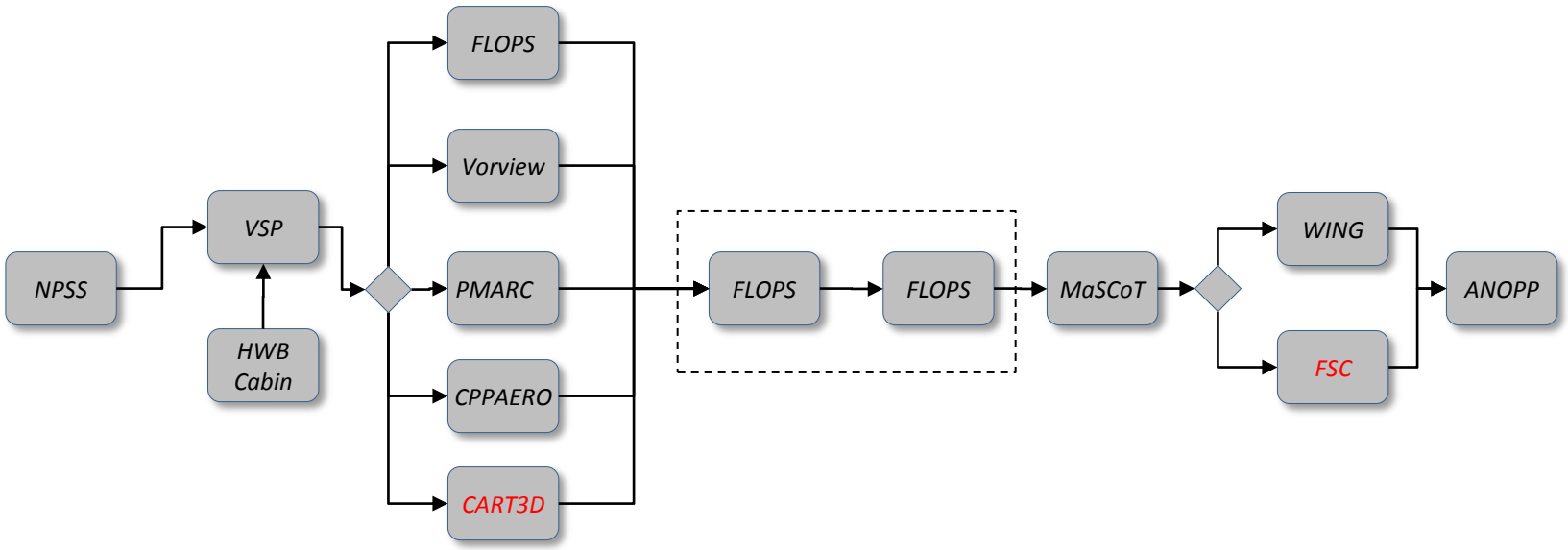
Unconventional
Boeing BWB-710 dual-use freighter
Rolls-Royce direct-drive turbofans
20 commercial containers

GEN2 HWB Process Flow

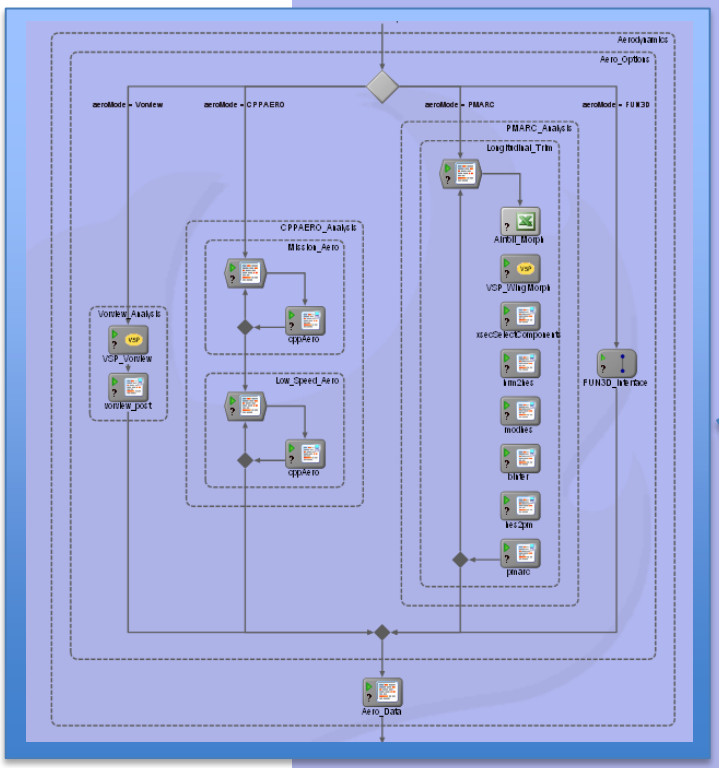


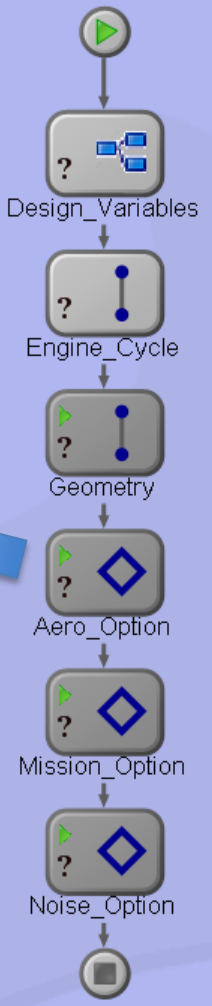
Status:
Completed
In progress

GEN2 Conventional Process Flow



Conventional Process in ModelCenter





Design Variables

Engine Cycle

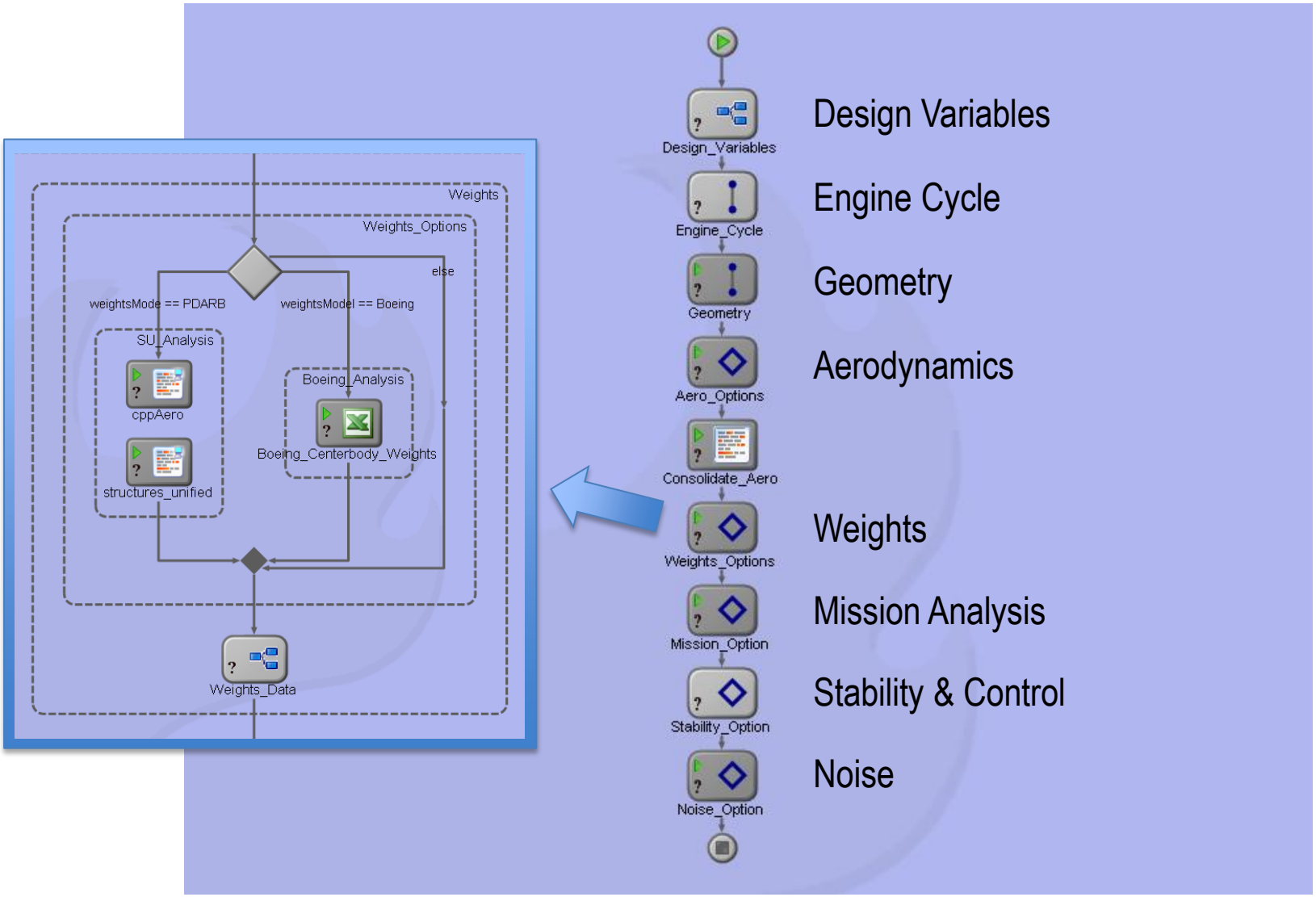
Geometry

Aerodynamics

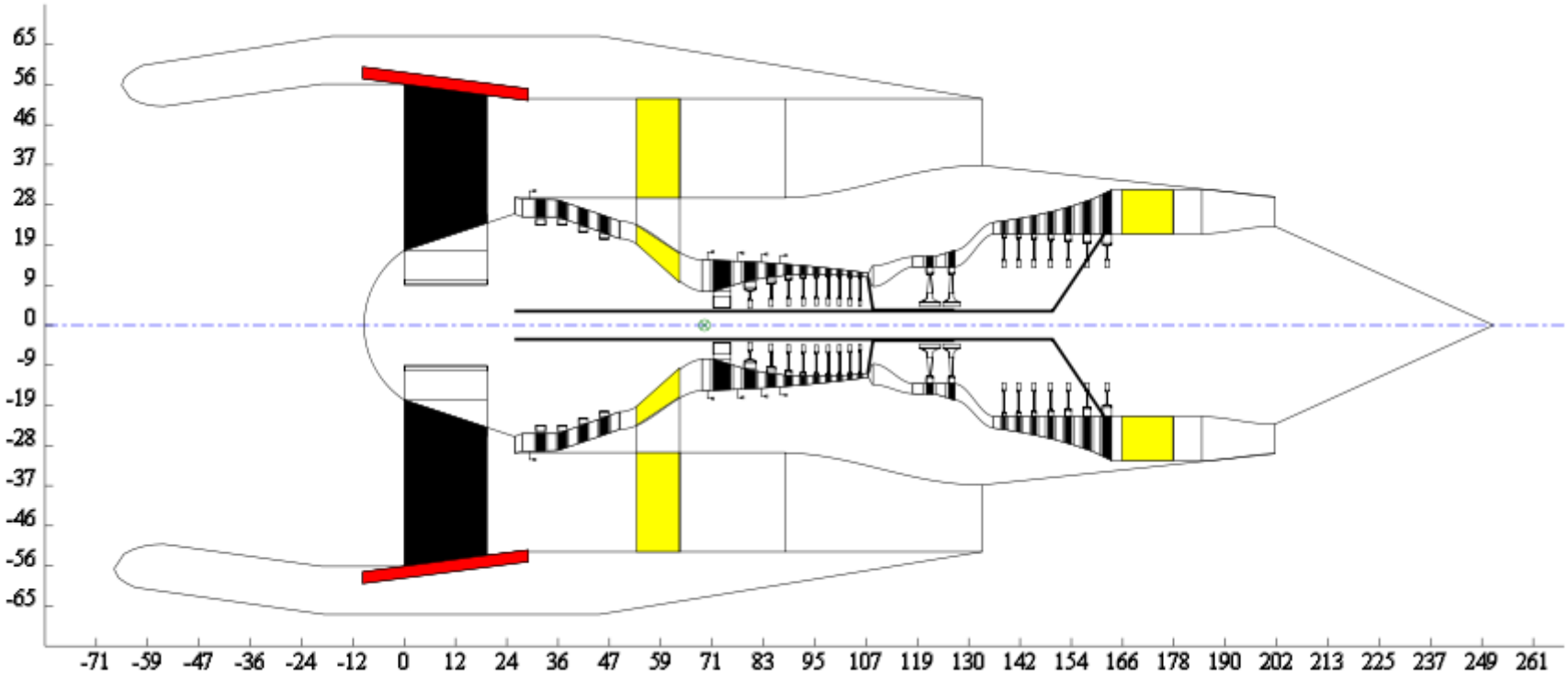
Weights & Mission Analysis

Noise

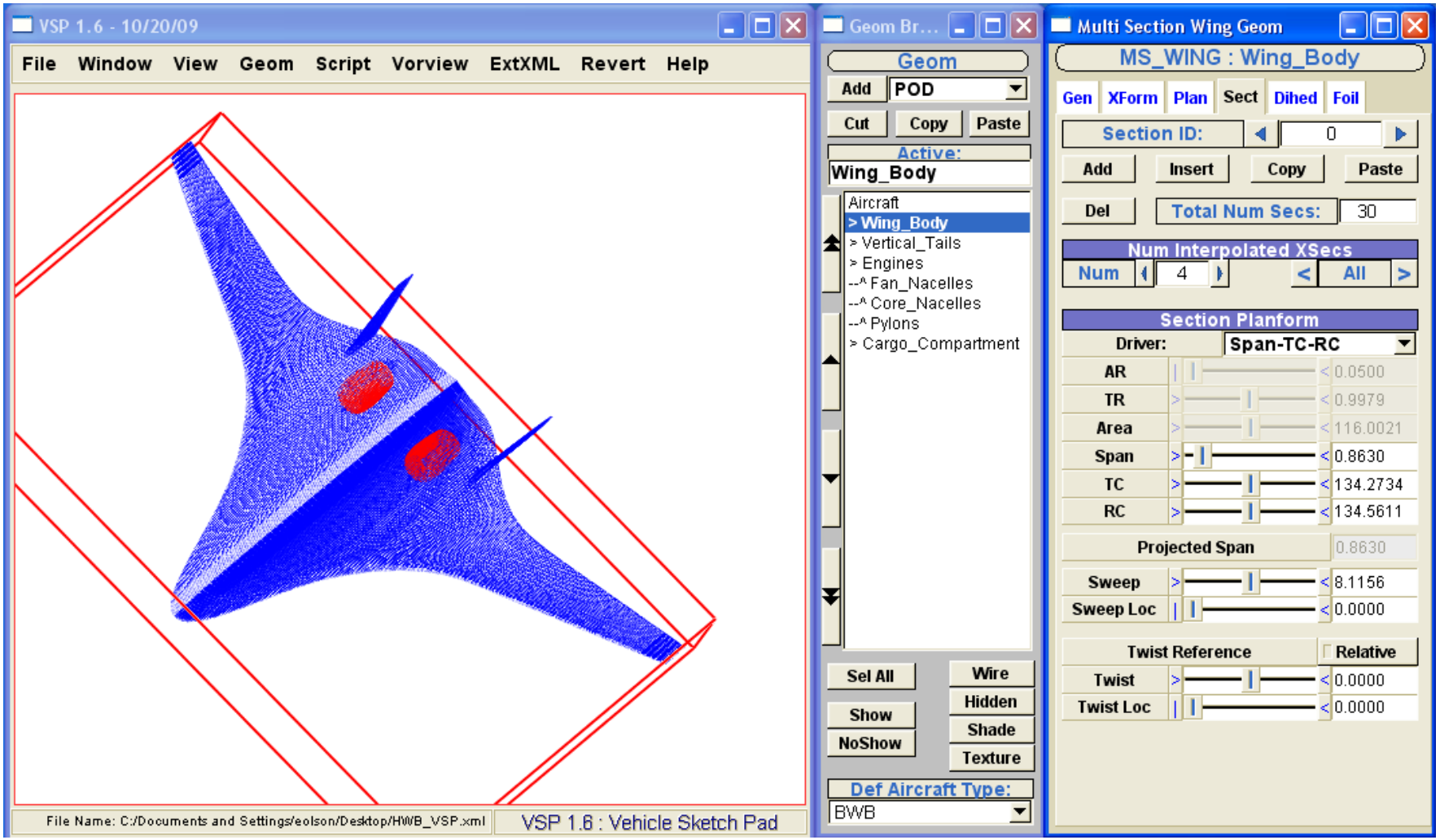
HWB Process in ModelCenter



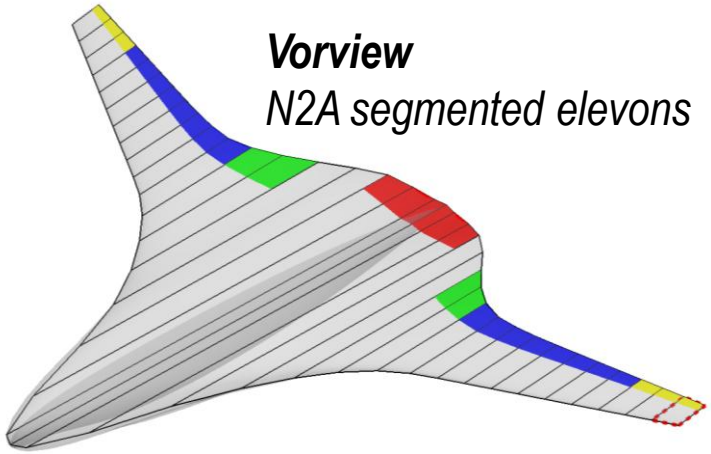
GEnx Engine in WATE++



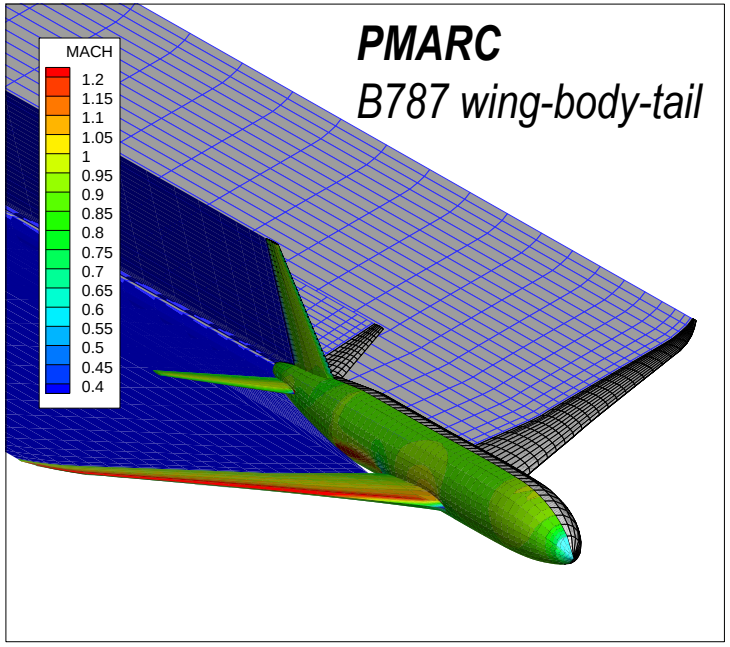
Vehicle Sketch Pad



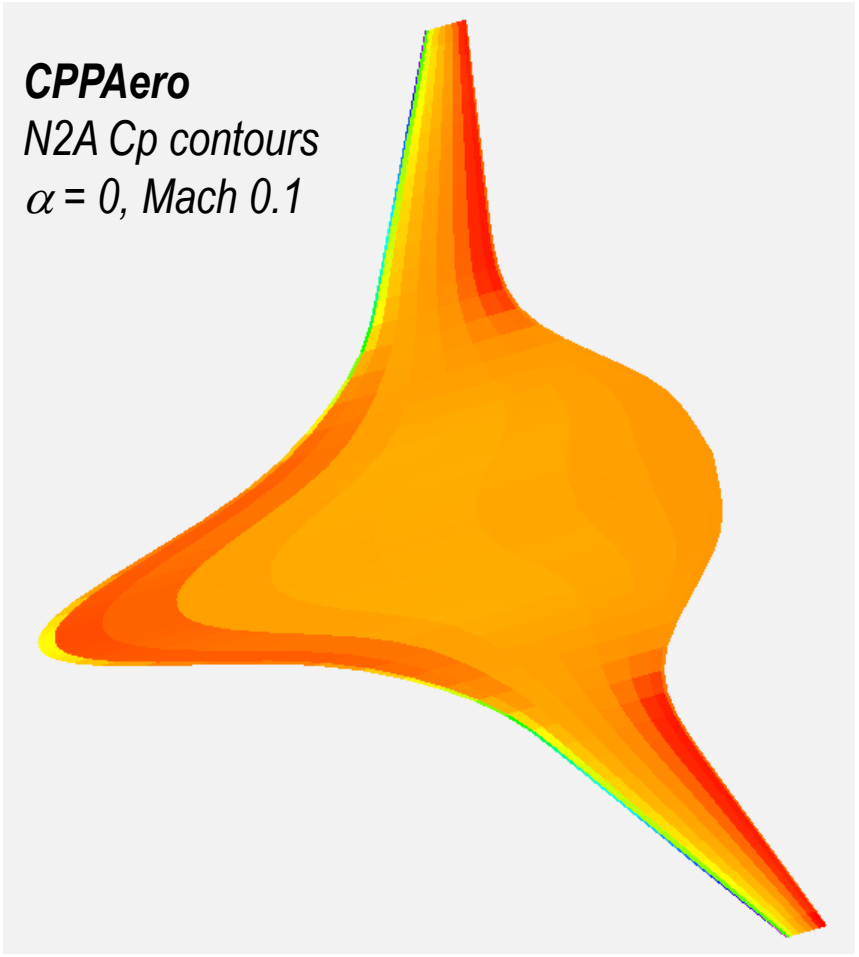
GEN2 Multi-Fidelity Aerodynamic Analysis



Vorview
N2A segmented elevons



PMARC
B787 wing-body-tail



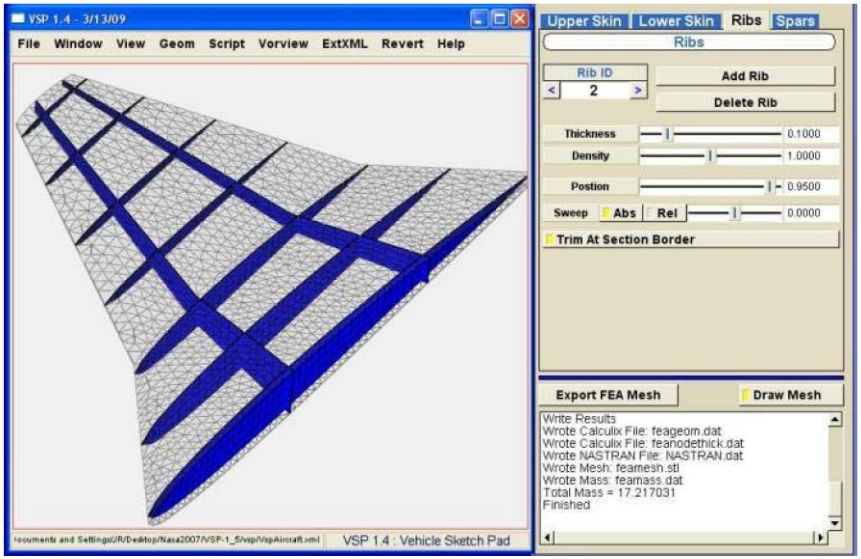
CPPAero
N2A Cp contours
α = 0, Mach 0.1

Verification Process

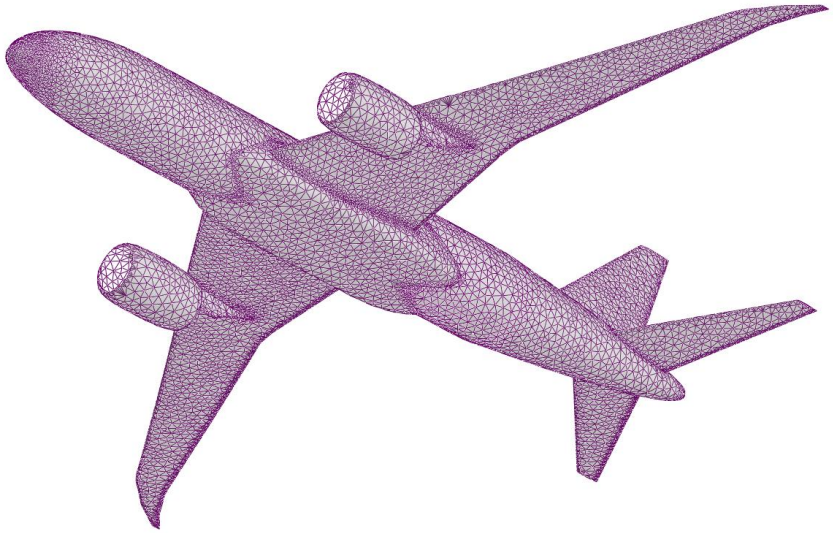
- Results from individual integrated components within ModelCenter are compared to results from stand-alone execution with manual data transfer
- Method integration passes verification test if the differences in output values are solely the result of the precision of input values
- Verification process completed Sept. 2010

Ongoing VSP Enhancements

VSP Structural Meshing

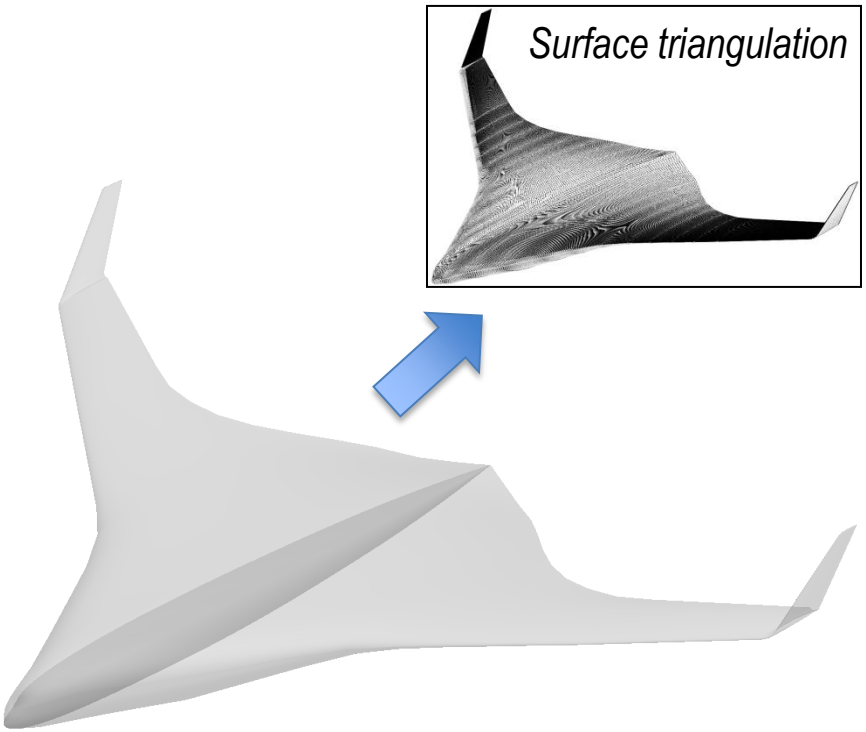


VSP High-Quality Surface Mesh

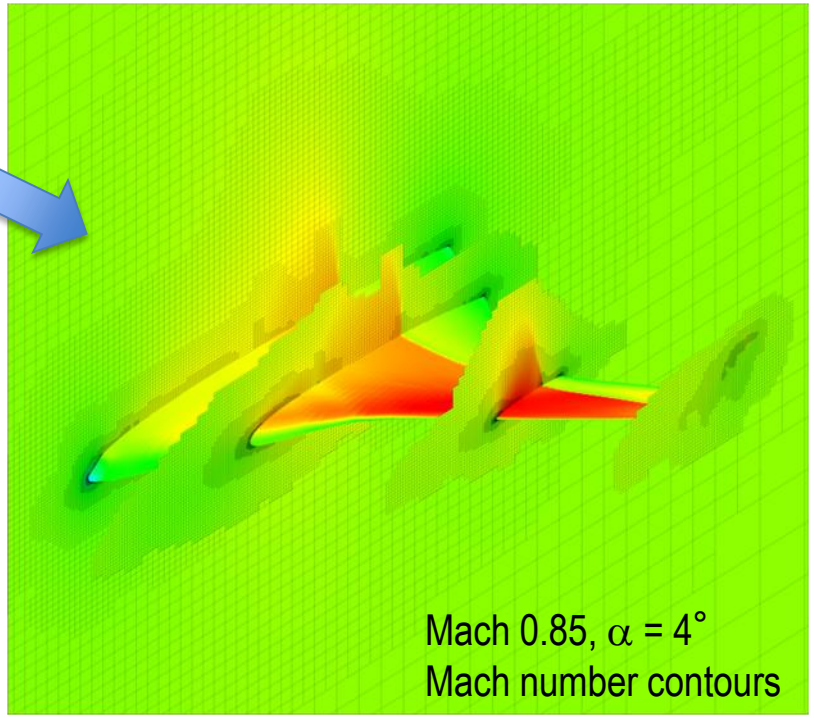


- Currently lacking automation and robustness
- Work underway and planned to improve VSP in these areas

VSP to CART3D Progress



VSP X-48B wing-body model
Adapted from unstructured grid



CART3D adjoint adapted solution

- Quality of solution appears to be independent of surface triangle quality
- Quality of flow visualization depends on a fine triangle density

GEN2 Validation Targets

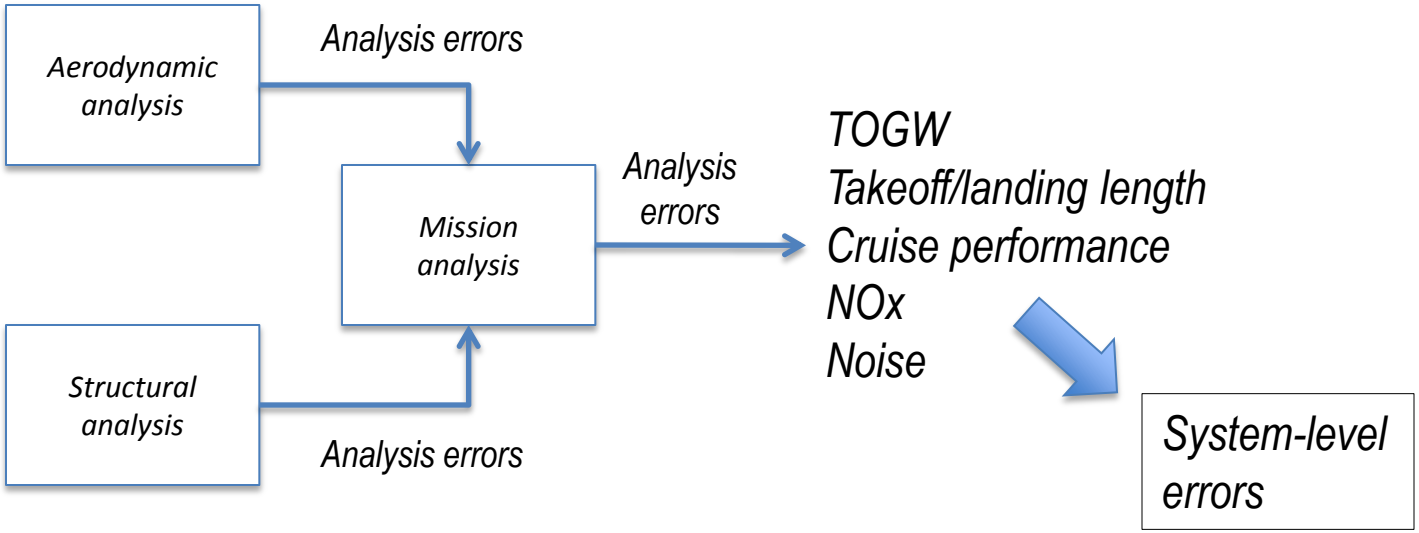
Metric	Conventional B787/GEnx-2B67	Unconventional Boeing BWB-710
NO_x	± 5%	± 15%
Takeoff/landing performance	± 5%	± 15%
Cruise performance	± 2.5%	± 10%
Takeoff gross weight	± 5%	± 15%
Noise	± 2.5 dB	± 7.5 dB *

** Limited benchmark data for HWB system noise*
Shielding analysis can be validated for BWB450, N2A

GEN2 Validation Plans

- Validation Datasets
  - 787-8 validation using flight test & certification results
  - HWB benchmarking using Boeing BWB-710 detailed analysis
  - HWB acoustic shielding for BWB-450, N2A (2012)
- Leverage ERA HWB validation efforts
  - Use validation of disciplinary analyses (aerodynamics, structures) to inform selection of appropriate methods and modeling techniques
  - Improve methods integration and incorporate additional methods
  - Use GEN2 integrated processes to compute system-level metrics for validation/benchmarking
  - Update GEN2 HWB models using lessons learned

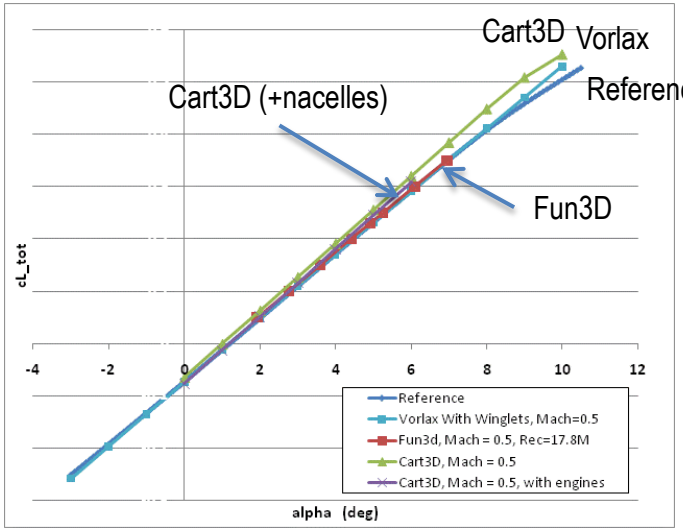
Discipline-Level Validation



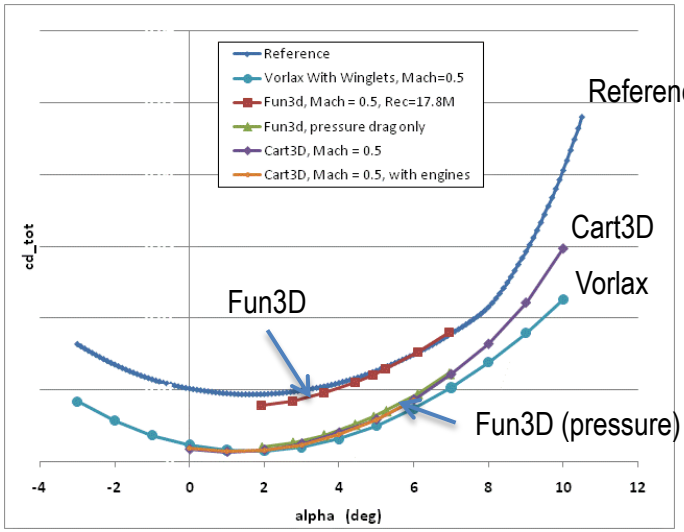
- Discipline-level errors propagate through to the system level
- Use validation at the discipline level to understand sources of errors
- Minimize discipline-level errors through improved modeling

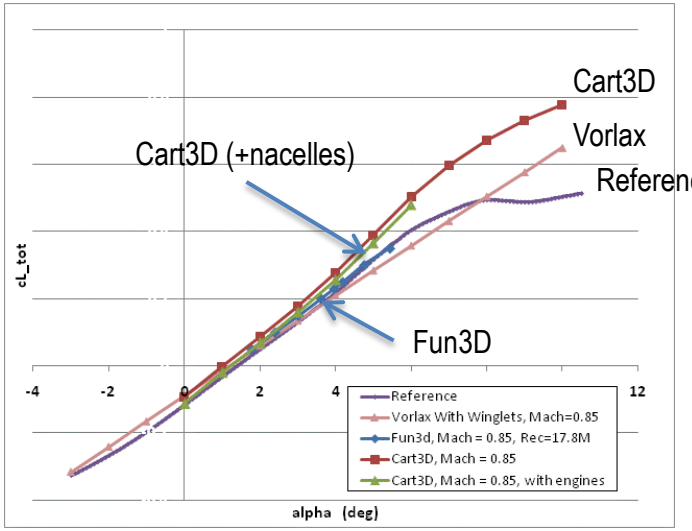
Sample Aero Validation Progress

X-48B, TF1038 wind-tunnel data

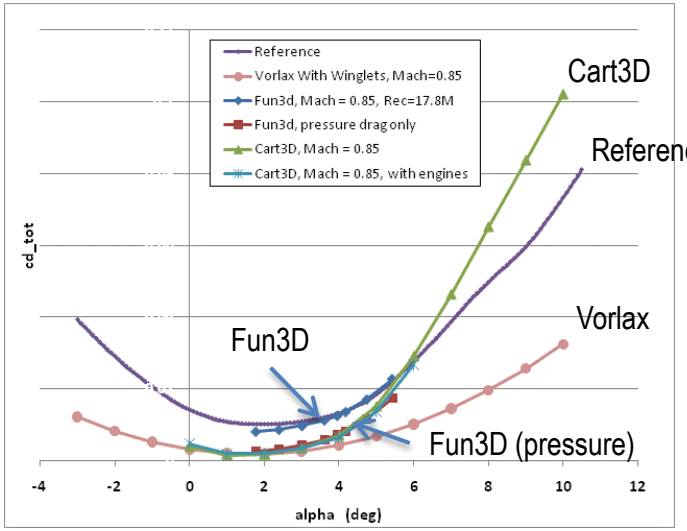


Mach 0.5

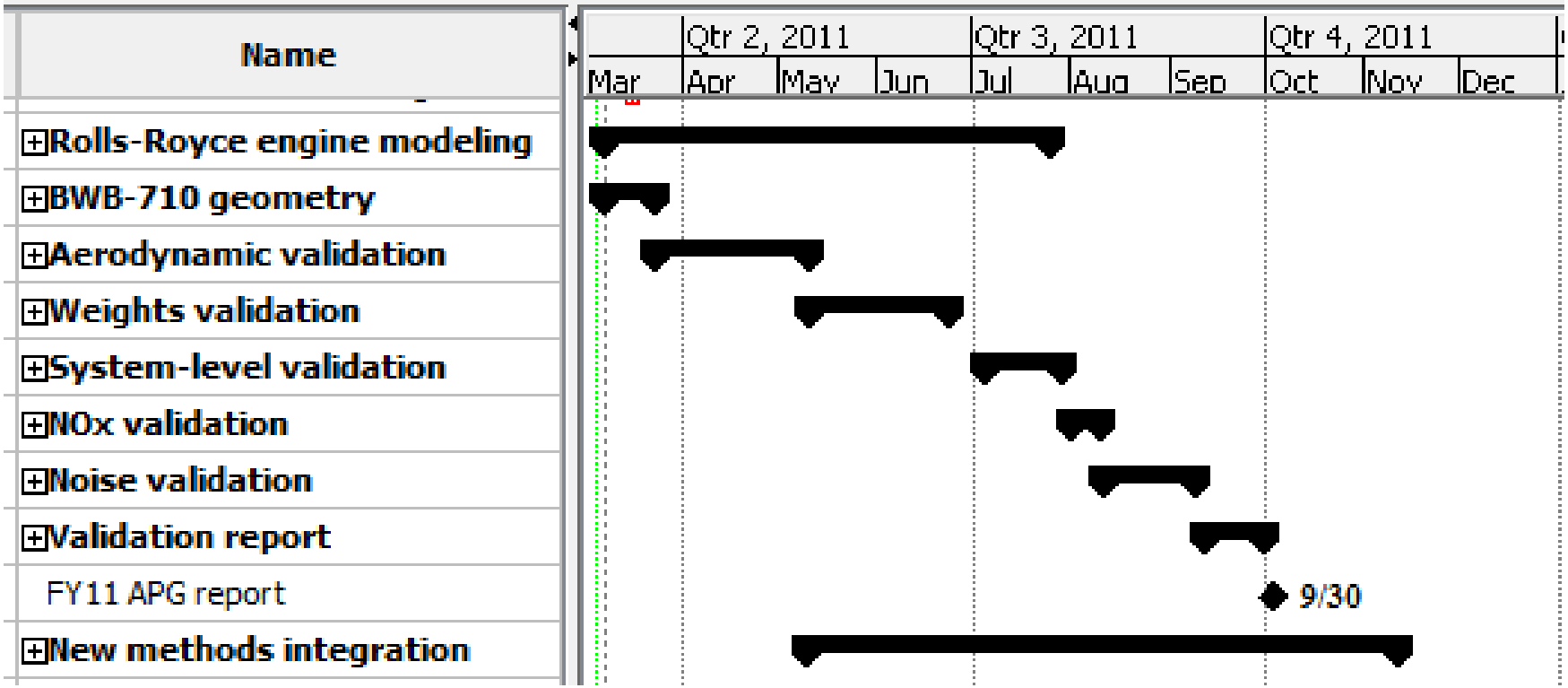


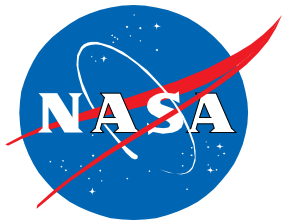


Mach 0.85



GEN2 Validation Schedule

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