Towards Certification by Analysis for Flight Characteristics

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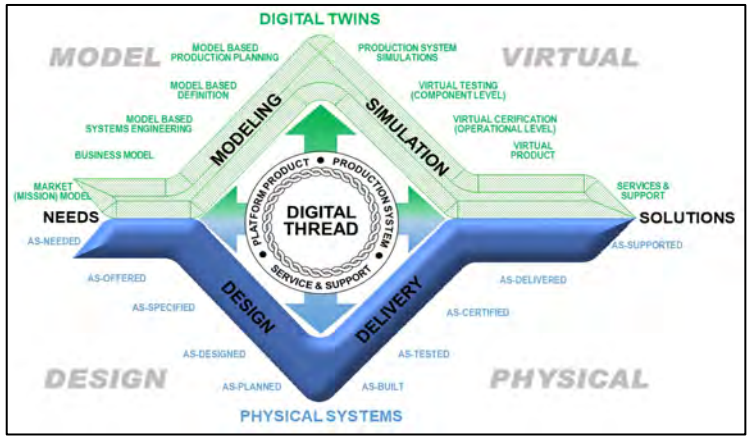
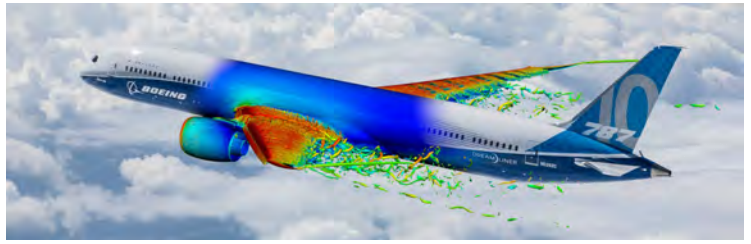
Current Trends

- Industry is taking advantage of **Model Based Engineering**
  - Requires **reliable** aerodynamic/flight characteristics predictions
- CFD - **Scale Resolving CFD** tools are showing progress towards physics based, edge-of-the-envelope predictions
- Computer Technology / HPC Capabilities
  - CFD Model complexity and fidelity is paced by HPC capabilities (compute speed and memory limitations)
  - GPU Technology is providing a path for meaningful engineering use of Advanced CFD tools
  - Computing capability continues to **increase by 3X every 18 months**

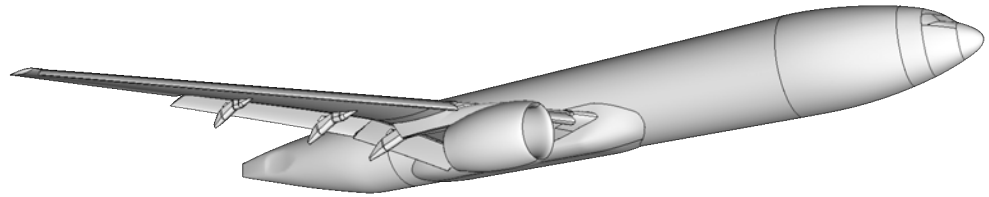


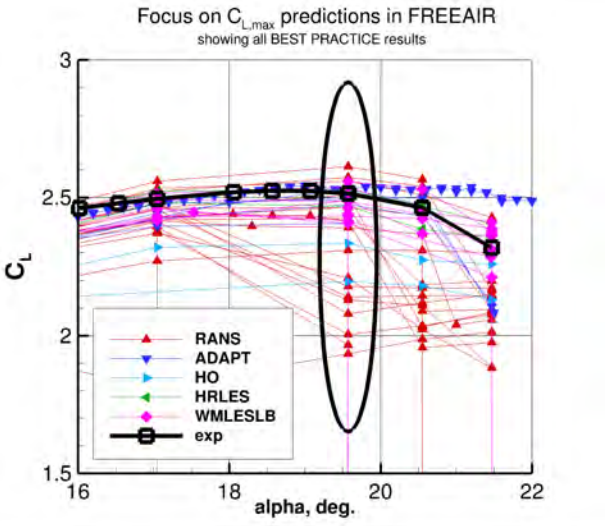


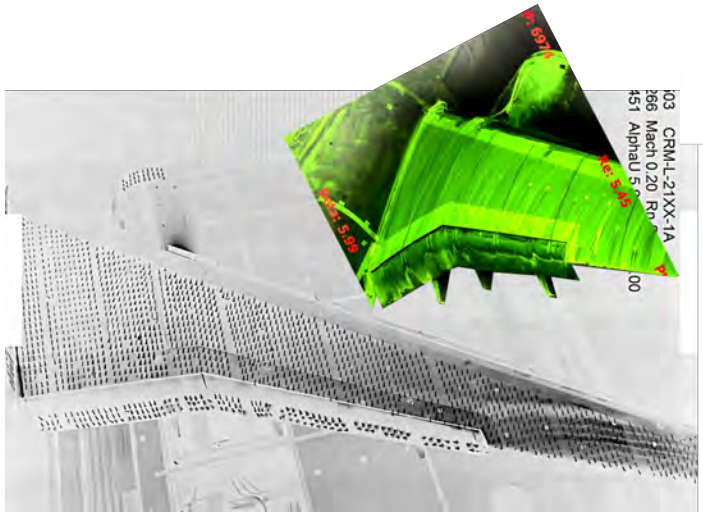
Oak Ridge Exascale Project

Current Status of CFD Prediction for High Lift Aerodynamics

- **Very limited improvement** in RANS-based CFD predictive modeling demonstrated over four High Lift Prediction Workshops (HLPW) held during the past 12 years
  - Methods cannot adequately predict flow separation, and effect of separation on flow breakdown at stall
  - Better agreement when using verified turbulence models
  - Mesh adaptation greatly improves consistency, but fails to improve prediction of flow physics
- Results from **scale-resolving simulation (SRS) methods, like hybrid RANS/LES and Wall-Modelled LES (WMLES)** are showing consistently better prediction of maximum lift (CLmax)
  - Multiple results from multiple codes
  - Getting the right answer for the right reasons
  - Developing best practices is an ongoing focus
- Still need for more **high-quality data**
  - Model deformation (aeroelastics)
  - Skin friction, surface properties (flow transition)
  - Off body velocity, pressure (interactional flow physics)







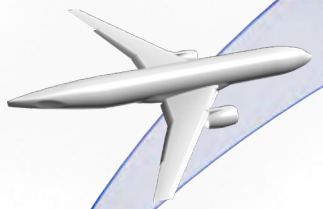
Advancing High Lift Aerodynamic Prediction
Series of Technical Challenges

Focus on key technical obstacles over specific time periods to make progress towards solving the grand challenge

Ground-Based Experimental Testing

Sub-Challenge #2
3-6 years

Sub-Challenge #1
1-3 years



Representative WT Geometry
S&C (tail/control surfaces/trim)
Cross-flow effects
Engine propulsion effects
Ice effects

CFD-generated data compared to WT data

Representative WT Geometry
Landing/TO configuration + nacelle/pylon
Re effects (atmospheric, pressurized, cryogenic environments)
Interactional flow physics (separation, vortex flow)
Static aeroelastics

CFD-generated data compared to WT data

Multi-Disciplinary Validation

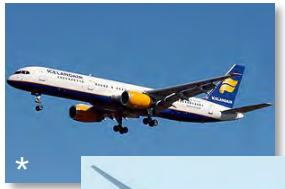
Sub-Challenge #3
6-10+ years

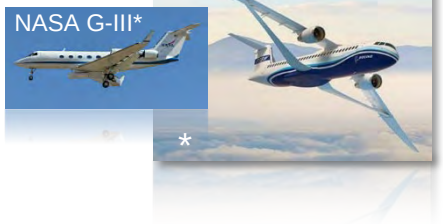
Representative WT and/or Flight Vehicle
Sub-scale WT and/or flight geometry
WT to Flight Re
Quasi-steady flight
Basic maneuver
Dynamic structural response

CFD-generated data at specific points in the maneuver trajectory compared directly with flight-derived data

Grand Challenge
15+ years

LOW-SPEED WIND-UP TURN





Generic Flight Vehicle
Full scale flight geometry
Flight Re
Dynamic, maneuvering flight
Dynamic structural/system response
Environmental effects
Engine power effects

Data from numerical simulation of the dynamic maneuver fed into CFD-based flight simulation, then proof-of-match between flight simulation and flight experience

* Potential flight test vehicle configuration

17 June 2022

CRM-HL Ecosystem Development Plan

NASA 10% SS (14x22/Q, 1atm / 3atm)
- Confirm CRM-HL design features
- Data for reference configurations
- NASA research (AFC, noise)
- Tie in to NTF-derived Re # trend data

NASA 5.2% SS cryo (NTF/ETW/others)
- Primary model for Re # trends
- SS/FS model issues deemed Re # dependent
- Wall effects
- NASA research (Flow measurements, AM, others)

NASA 2.7% SS/FS cryo (NTF/ETW/others)
- SS/FS model issues deemed Re # dependent
- NASA research (Flow measurements, AM, others)

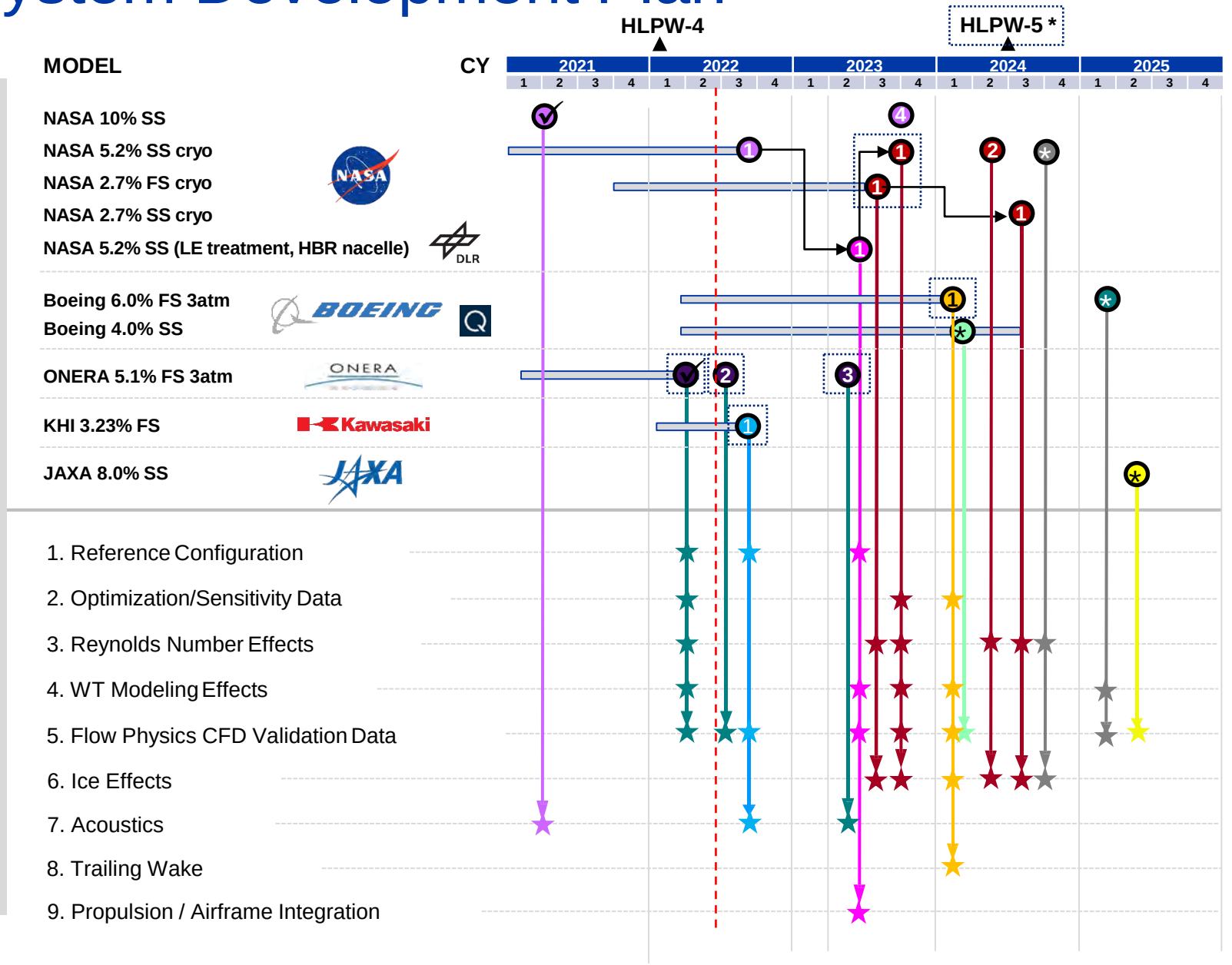
Boeing 6.0% SS/FS 3atm (Q/F1/others)
- Configuration variation data
- SS/FS model issues
- Tie in to NTF-derived Re # trend data
- Mounting system effects (T&I)
- Wall effects (collaboration with ONERA)
- Configuration-level PIV data

Boeing/UK 4.1% SS (Academic)
- Flow measurement technology development
- Platform for UK aerodynamic research

ONERA 5.1% FS 3.85atm (F1/Q)
- Wall effects (collaboration with QinetiQ)
- Exploit unique data collection opportunities
- Tunnel Standard Model

KHI 3.23% FS
- Aerodynamic and noise research
- Tunnel Standard Model

JAXA 8.0% SS
- CFD validation
- PIV flow field measurements
- Tunnel Standard Model



CRM = Common Research Model

HL = High Lift

SS = Semi-Span
FS = Full Span

atm = Atmosphere

- NASA NTF
- ETW
- Q5m
- NASA 14x22
- NASA TDT
- ONERA F1
- DNW-NWB
- Imperial College
- KHI 3.3m
- JAXA 6.5x5.5

Design/Fab

Test Objective

* Proposed

✓ Completed

Potential Data for Workshops

Challenges

- Continued validation of scale-resolving CFD methods on representative complex configurations
- Continue to work towards characterizing component and system level uncertainties
- Integration and validation of multi-disciplinary analysis (MDA) tools and processes
- Development of representative validation tests for MDA tools and processes
- Acquisition of appropriate flight test data to validate predictive flight characteristics for community benchmarks
- Continue to build Regulatory acceptance