[Airbus Amber]

Certification by Analysis

Some thoughts

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Agenda

- **Why Certification by analysis**
- **The pyramide of CbA**
- **Find the right balance**
- **The challenge of CbA**

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Why Certification by Analysis ?

- **Avoidance of late surprises** (typically discovered during Flight Test)
- More efficient and **optimized certification process**
- Usage of **simulation capabilities**, which are needed also for aircraft development and for Digital Twins
- **Acceleration of product development plan** and time-to-market

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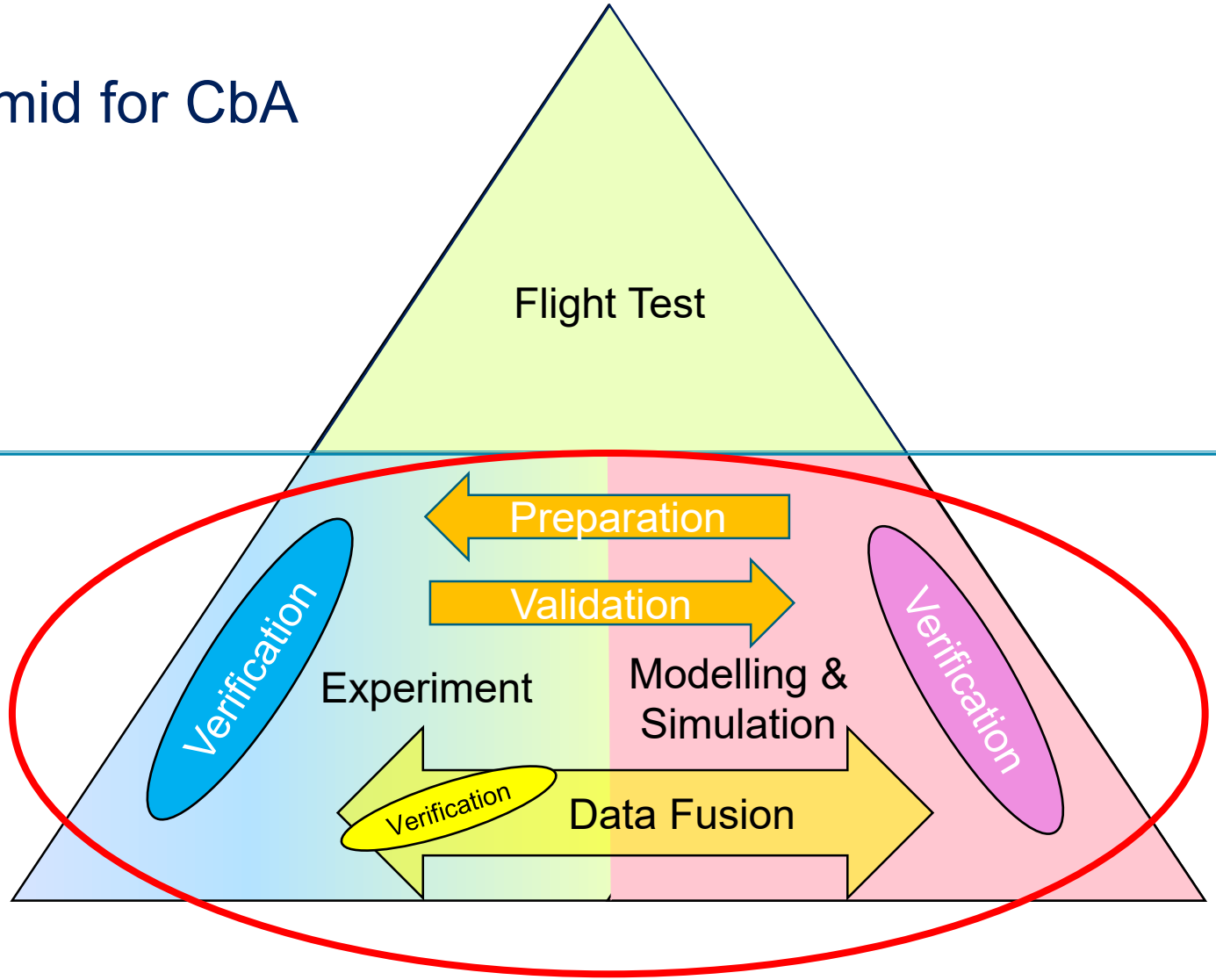
The pyramid for CbA



Compliance Demonstration by Flight Test (MoC 6)

Compliance Demonstration by Simulation – Certification by analysis (MoC 2)

… needs to be accompanied by proper Uncertainty Quantification & Management

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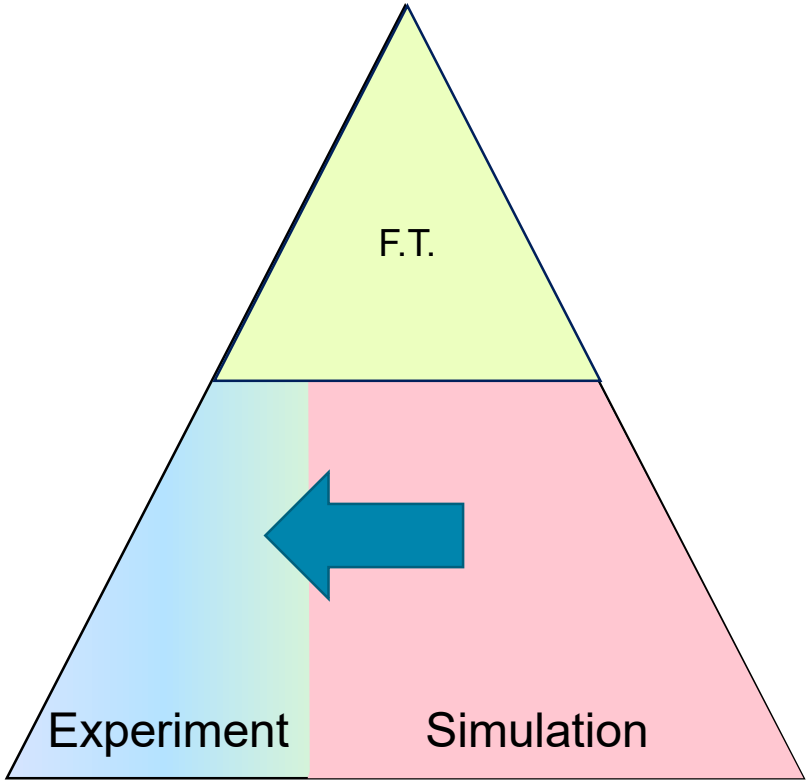
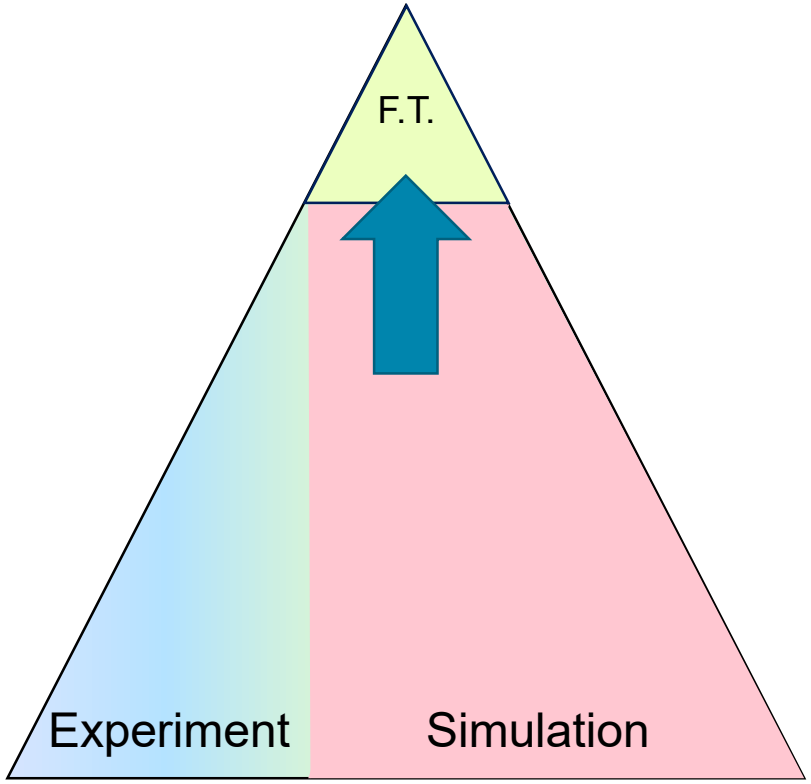
Find the right balance





The balance might be different for different use-cases

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The challenge of Certification by Analysis (CbA)

- Robust configuration, **process and data management**
- **Holistic model integration** at all development levels, e.g.
  - Models and data covering e.g. the entire flight envelope
  - Combine single effects to complex physical interactions
  - Multidisciplinary aspects - Systems, structure, engine, fluids
- **Smart exchange of models and data** at all development levels - surrogates to quickly assess overall aircraft performance against changes
- **Uncertainty management** / Guidance on systematic handling of uncertainties / extrapolation
- System of **verification and validation** means matching with model integration levels
- Find the **right balance** between experimental and numerical simulation means

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Thank you

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National Aeronautics and Space Administration

Transformational Tools and Technologies (T^3) Project

Next Steps Towards Certification by Analysis

Dr. Michael M. Rogers

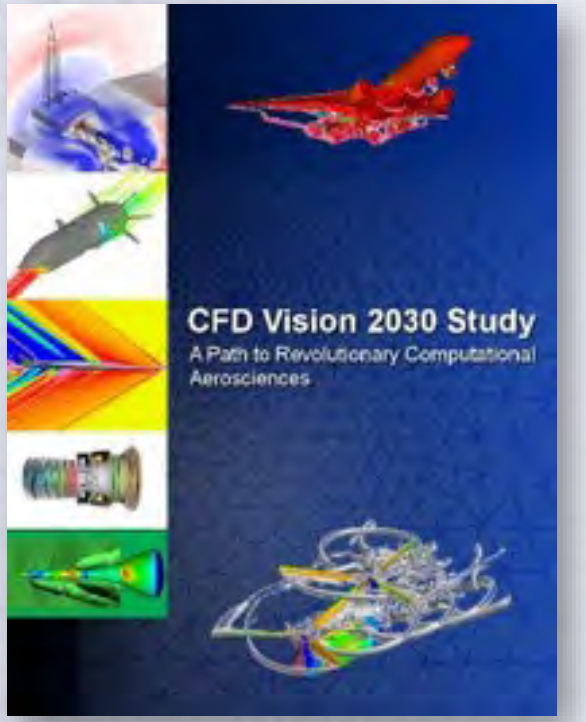
Innovative solutions through foundational research and cross-cutting tools

ICAS 2022, Stockholm, Sweden
6 Sept 2022

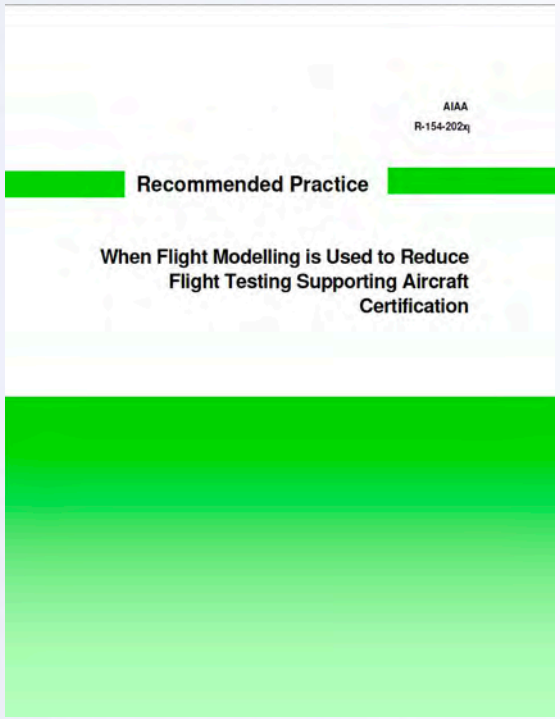
www.nasa.gov

Transformational Tools & Technologies (T^3) Project

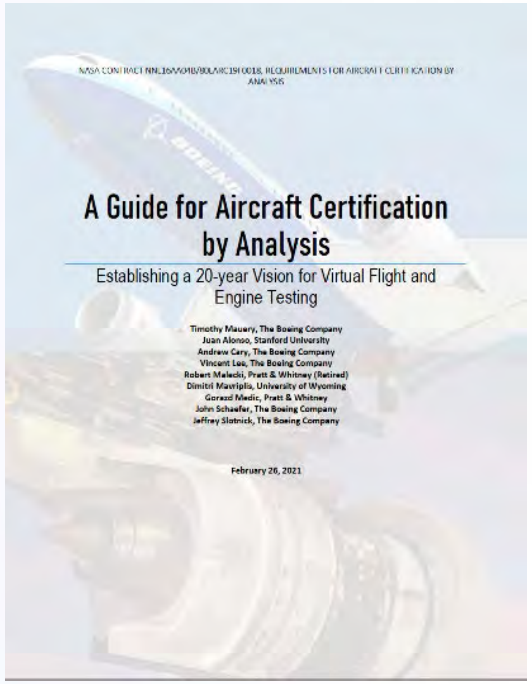
Enables fast, efficient design and analysis of advanced aviation systems from first principles by developing physics-based tools, methods, and cross-cutting technologies.



NASA CR 2014-218178
March 2014

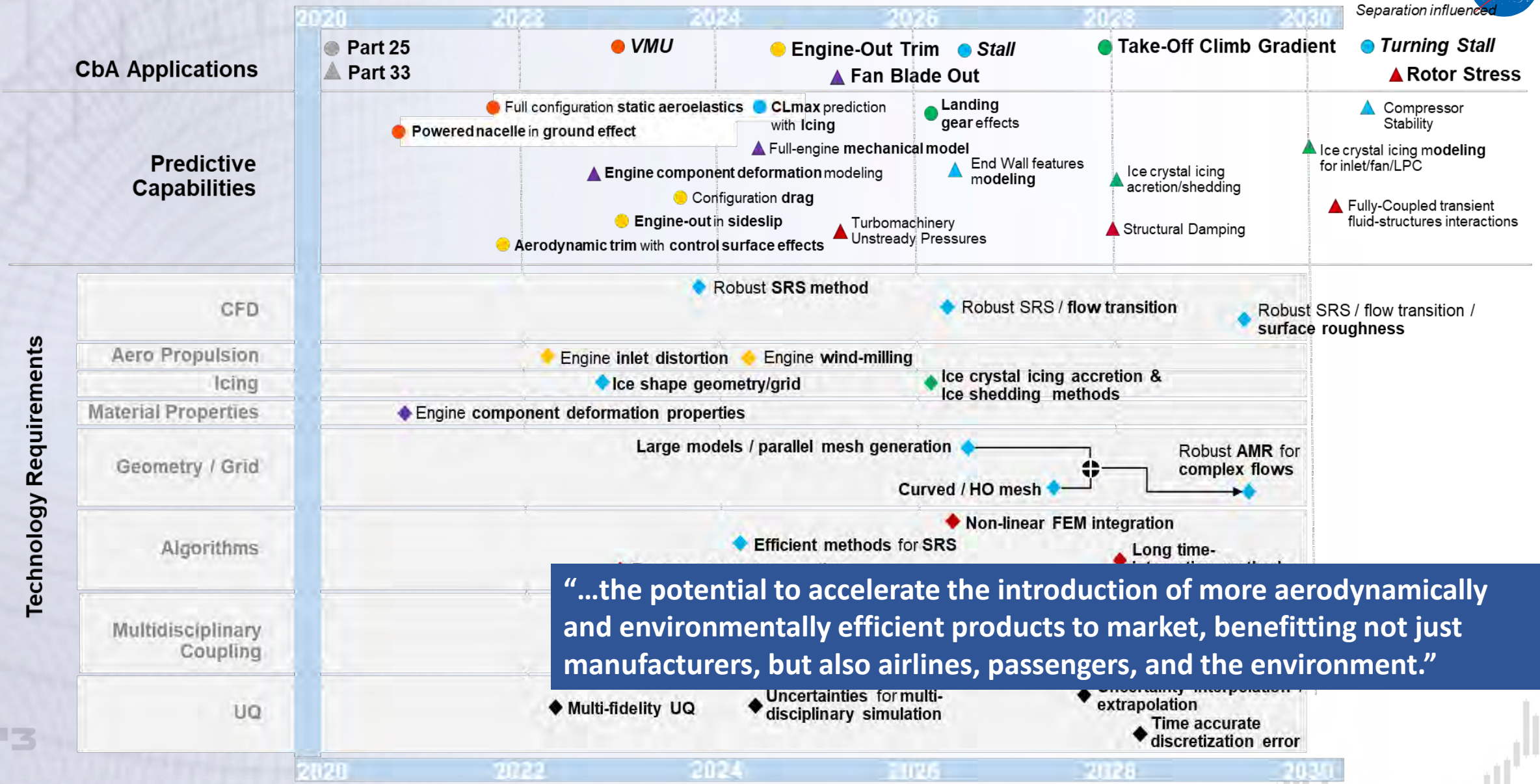


AIAA R-154-2021
April 2021



NASA CR 20210015404
May 2021

Certification by Analysis – Near-term Roadmap



"…the potential to accelerate the introduction of more aerodynamically and environmentally efficient products to market, benefitting not just manufacturers, but also airlines, passengers, and the environment."

Figure 7. Near-Term Certification by Analysis Roadmap

High Lift Grand Challenge

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

Ground-Based Experimental Testing

Sub-Challenge #1
1-3 years

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

Sub-Challenge #2
3-6 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

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

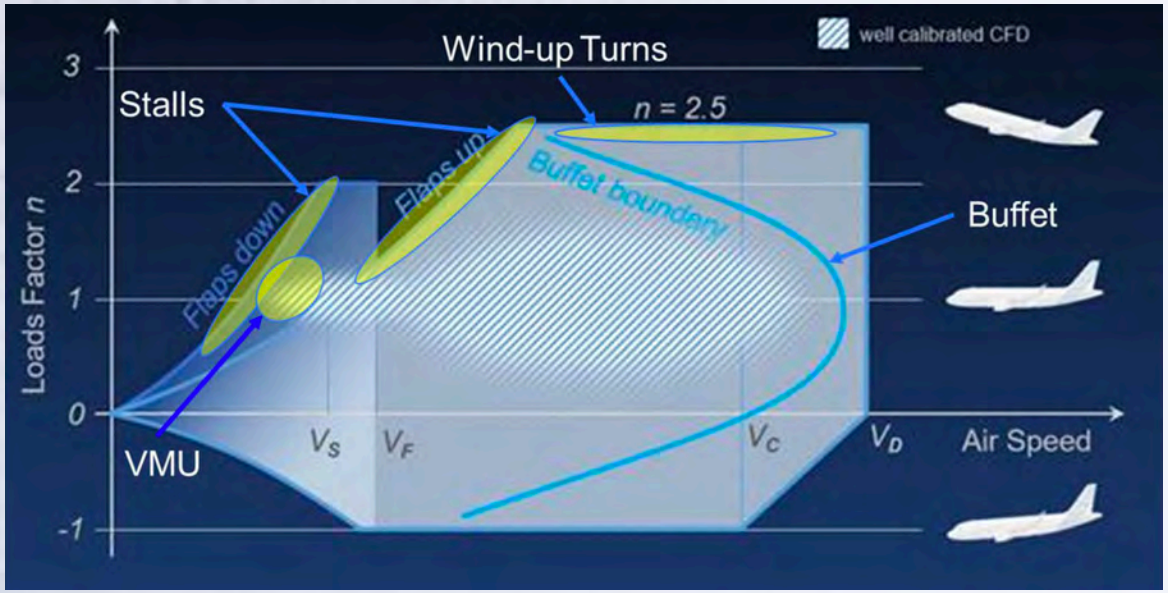
LOW-SPEED WIND-UP TURN

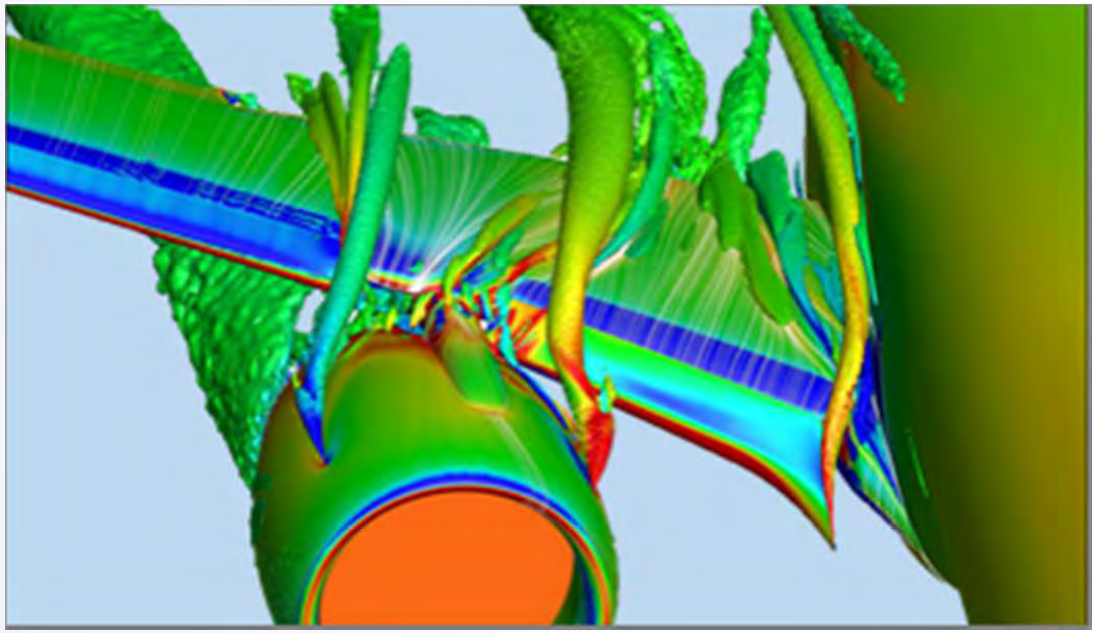
Generic Flight Vehicle
Full scale flight geometry
Flight Re
Dynamic, maneuvering flight
Dynamic structural/system response
Environmental effects
Engine power effects

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

Challenges predicting complex flow fields associated with high-lift configurations

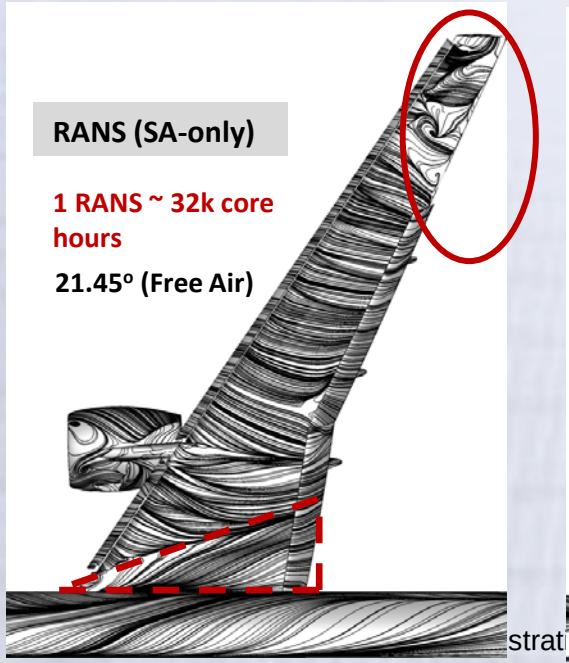


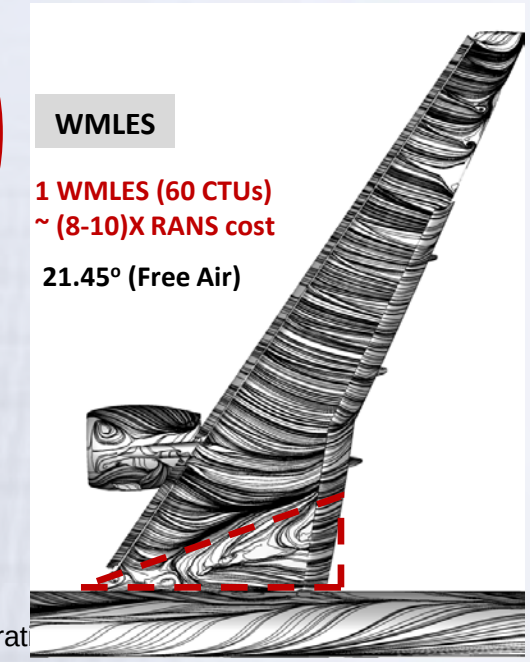


Technical Challenge: Develop and demonstrate computationally efficient, eddy-resolving modeling tools that predict maximum lift coefficient (CL*max*) for transport aircraft with the same accuracy as certification flight tests.

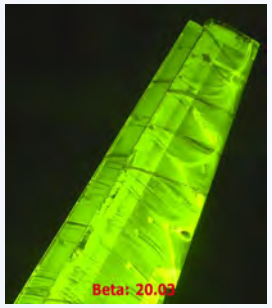
Eddy Resolving Simulations

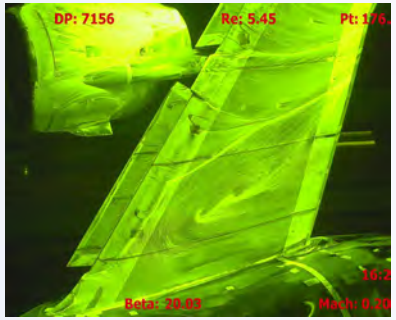
- Eddy Resolving Simulations are showing promise
  - Hybrid Reynolds Averaged Navier Stokes/Large Eddy Simulations (HRANS/LES) and Wall Modeled Large Eddy Simulations (WMLES) predict the smooth body separation better than the legacy Reynolds Averaged Navier Stokes (RANS) simulations

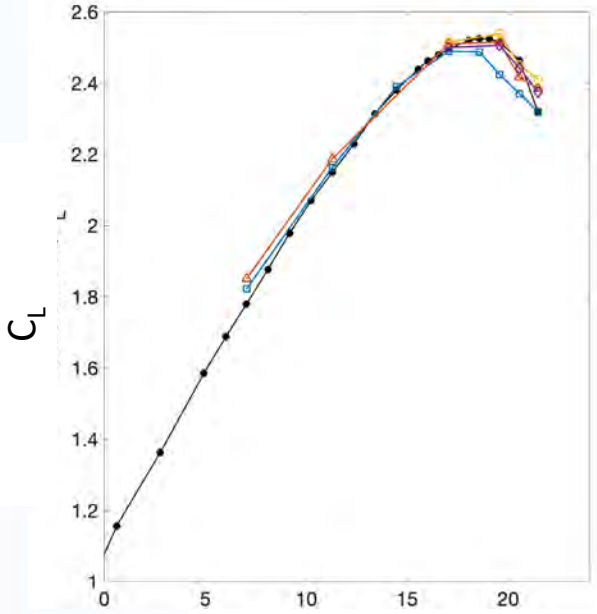


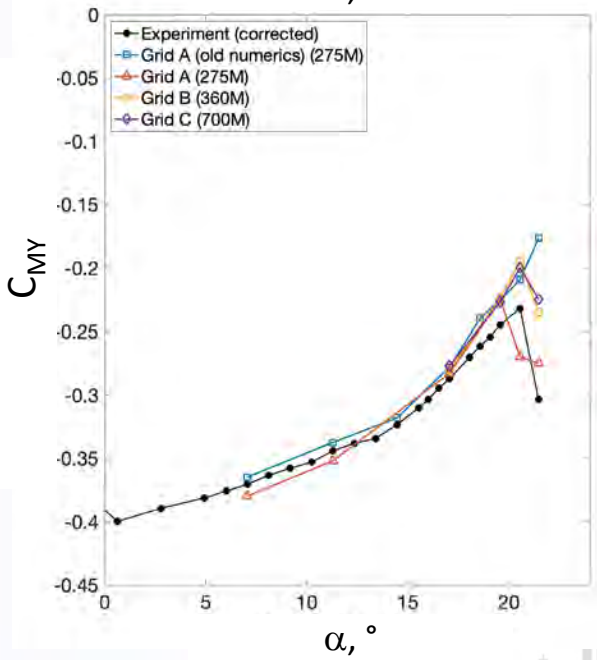


QinetiQ FY20 WT oil flow









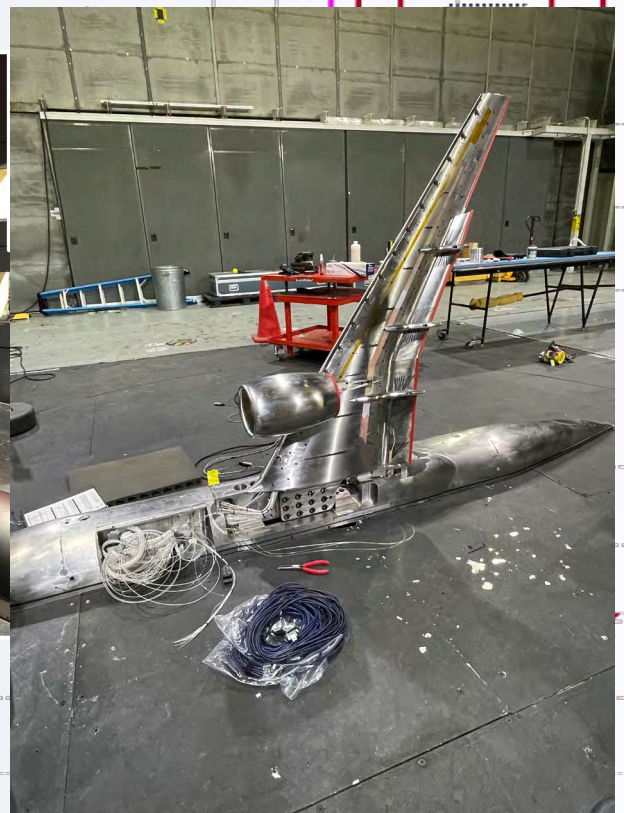
CRM-HL Ecosystem Development Plan

HLPW-4 ▲ HLPW-5 * ▲ HLPW-6 * ▲

MODEL	CY
NASA 10% SS	
NASA 5.2% SS cryo	
NASA 2.7% FS cryo	
NASA 2.7% SS cryo	
NASA 5.2% SS (LE treatment, HBR nacelle)	
Boeing 6.0% FS 3atm	
Boeing 4.0% SS	
ONERA 5.1% FS 3atm	
KHI 3.23% FS	
JAXA 8.0% SS	

2021 | 2022 | 2023 | 2024 | 2025

1 2 3 4 | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 | 1 2 3 4



1. Reference Configuration
2. Optimization/Sensitivity Data
3. Reynolds Number Effects
4. WT Mod
5. Flow Physics CFD Validation Data

Developing Innovative Measurement Techniques to acquire needed CFD validation data

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

A Look Ahead to FY23

- **High-Reynolds-Number test campaign begins, including two CRM-HL validation experiments in the NASA Langley National Transonic Facility**
- **Design a dynamically scaled aeroelastic CRM model for the NASA Transonic Dynamics Tunnel**
- **Focus on Uncertainty Quantification**
- **Application of Artificial Intelligence / Machine Learning to accelerate modeling**