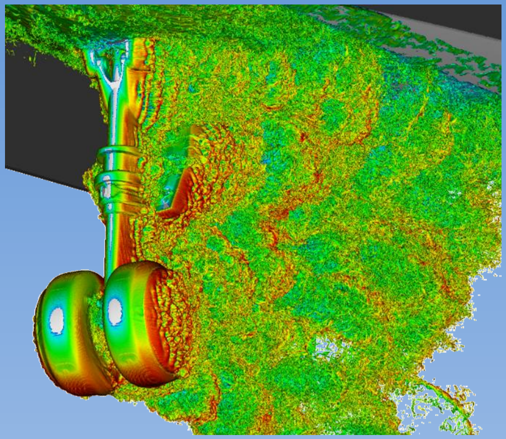
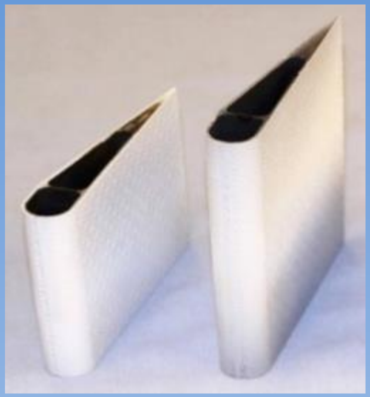
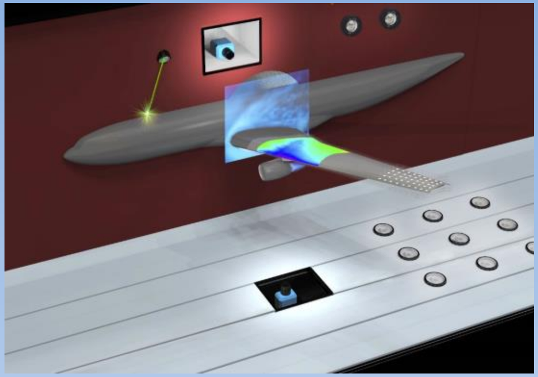
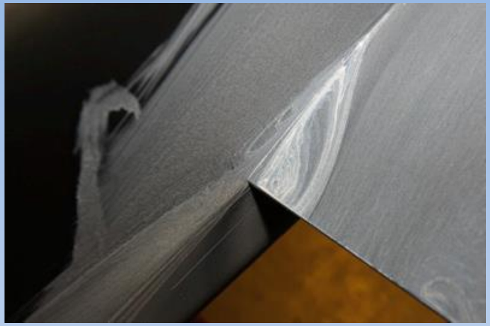
Transformational Tools and Technologies (T^3) Project

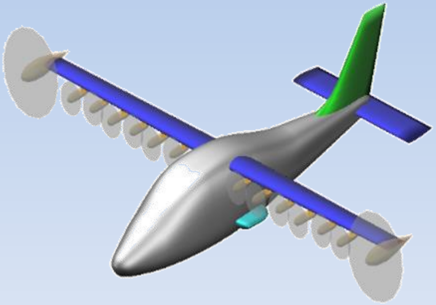








Future CFD Technologies Workshop
January 7, 2018



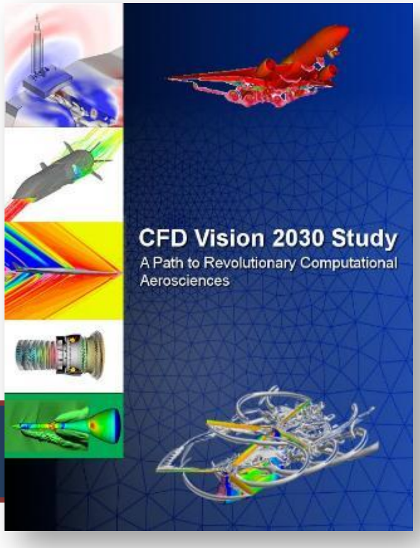
Michael M. Rogers, Project Manager
Dale Hopkins, Deputy Project Manager
Joe Morrison, Associate Project Manager

Host Center: Glenn **Partner Centers: Ames, Armstrong, Langley**

Transformational Tools & Technologies Sub-Projects

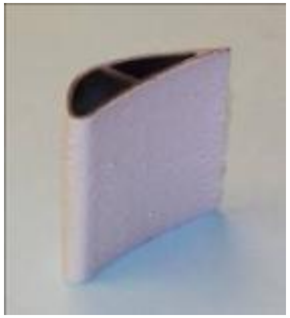
Revolutionary Tools and Methods

- Physics-based Predictive Methods for Improved Analysis and Design
- Improved CFD Models and Algorithms
- MDAO/System Analysis Tools
- Materials and Structures Modeling and Simulation **Vision 2040**
- Combustion Modeling
- Validation Experiments



Critical Aeronautics Technologies

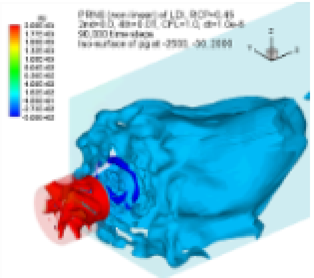
- High-temperature Engine Materials
- Multifunctional Materials and Structures
- Combustion Technologies
- Propulsion Controls
- Advanced Flight Controls
- Innovative Measurements

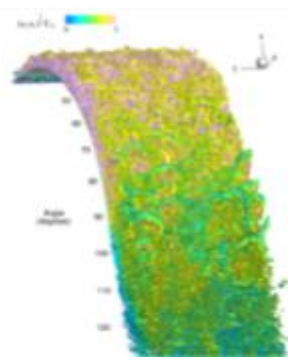


EBC-Coated CMC Vane

NiTiHf Shape Memory Alloy torque tube actuators for UAV flight demo

RCA Technical Challenge – Completes May 2018





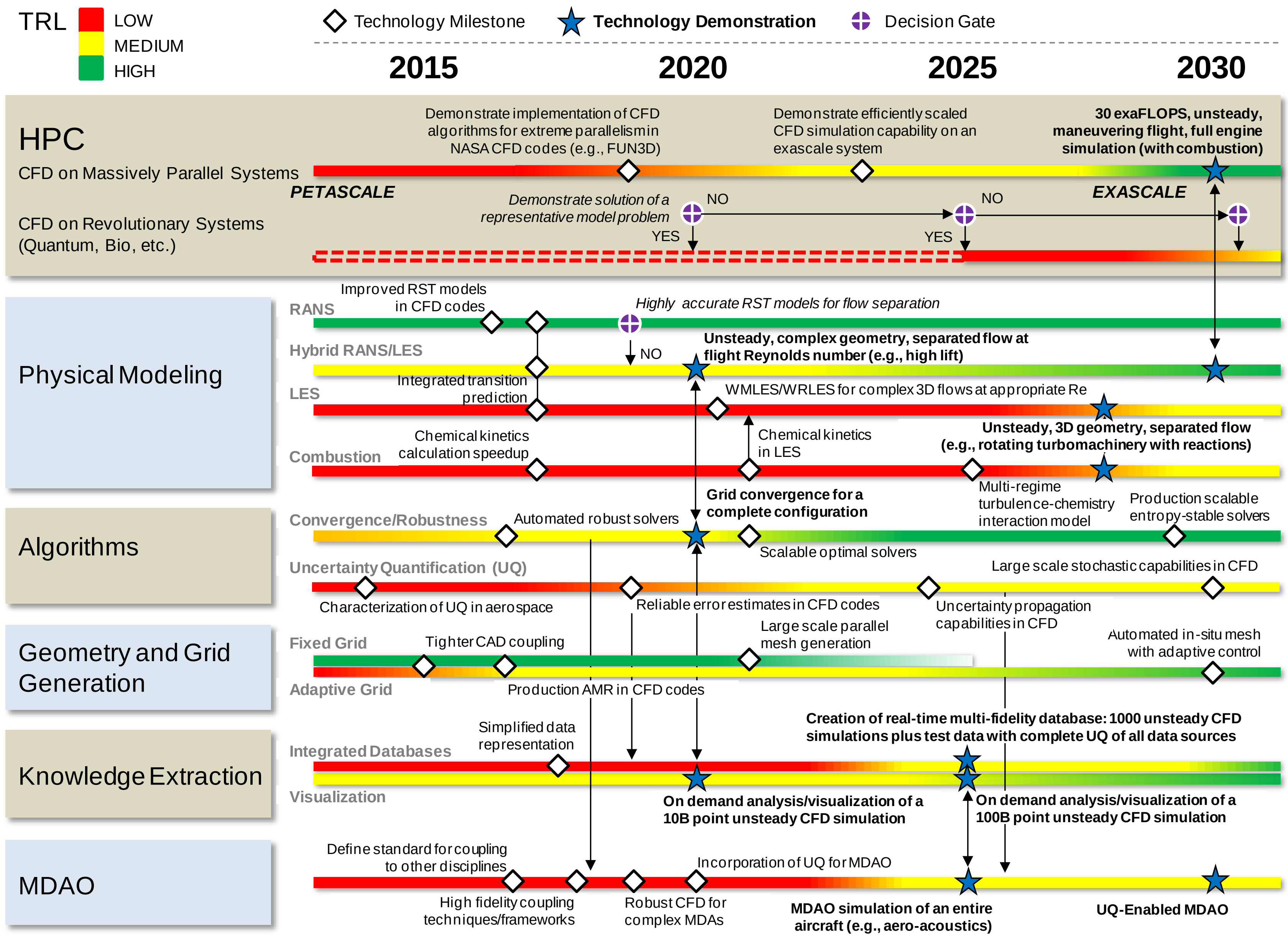
Technical Challenge	Milestones
Physics-Based Turbulence Models & Simulations: **Identify and downselect critical turbulence, transition, and numerical method technologies for 40% reduction in predictive error against standard test cases for turbulent separated flows, evolution of free shear flows, and shock-boundary layer interactions on state-of-the-art high performance computing hardware.**	**FY17**: 1. Evaluate advanced RANS and scale-resolving simulations capability for prediction of shock-boundary layer interactions. 2. Juncture Flow Experiment to obtain CFD validation data (complete first test entry of the 8% scale juncture flow model - slipped).
	FY18: 1. Evaluate large-eddy simulation codes for high Reynolds number flow separation prediction. 2. CFD Prediction Assessment Workshop. 3. Complete juncture flow experiment to obtain CFD validation data (second entry).

Technical Areas and Approaches

- Development of more accurate physics-based methods (e.g. higher-moment closure, LES, hybrid approaches)
- Advanced numerical methods
- Transition prediction and modeling
- Validation experiments (Juncture Flow, THX, HL-CRM, Aeroelasticity,…)
- Multidisciplinary analysis and design (high fidelity)

What's Next?

Technology Development Roadmap



Some thoughts captured from workshop talks

CFD Vision 2030

- Strong community support – consensus helps advocacy
- AIAA CFD2030 Integration Committee
- CFD Vision 2030 roadmap updates? Machine Learning, Big Data, New Computing Technology (e.g., Quantum Computing, Neuromorphic)

Future Drivers

- Certification by Analysis, Prediction of full flight envelope
- Changing HPC architectures – Significant impact to CFD in the near future; Are we looking far enough ahead?
- System focus (or even System of Systems Focus?)

Road Blocks

- False prophets (but still working LES, HO DG, etc. – and LB)
- End of Moore's Law

Needs/Challenges

- MDAO, physics-based integrated-system simulation
- Integration of new advanced work from different fields into advanced computational frameworks
- Some familiar challenges (separation, transition, aeroelasticity, hypersonics)
- Time concurrency – O(N log N)

Vision 2040 for Integrated, Multiscale Materials and Structures Modeling/Simulation NRA

Key Element Domains

1. Models and Methodologies
2. Multiscale Measurement & Characterization Tools and Methods
3. Optimization & Optimization Methodologies
4. Decision Making and UQ
5. Verification & Validation
6. Data, Informatics, & Visualization
7. Workflows & Collaboration Frameworks
8. Education & Training
9. Computational Infrastructure

2040 Vision State

*A cyber-physical-social ecosystem that impacts the supply chain to **accelerate** model-based concurrent design, development, and deployment of materials and systems throughout the product lifecycle for **affordable**, **producible** aerospace applications*

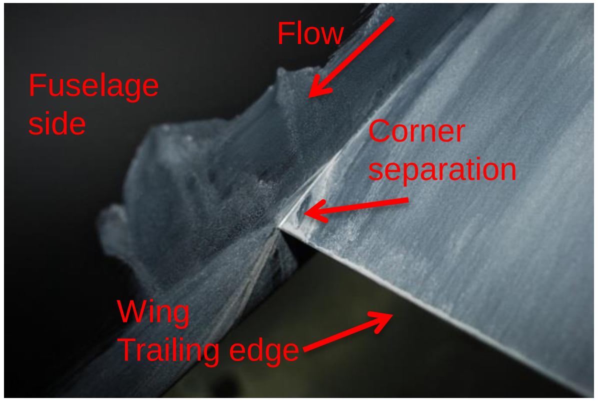
Needed to overcome various gaps and challenges to achieve the fully integrated 2040 Vision end state

Pratt & Whitney (A United Technologies Company) | NEXIGHT GROUP | esi get it right® | BlueQuartz Software — Phase II

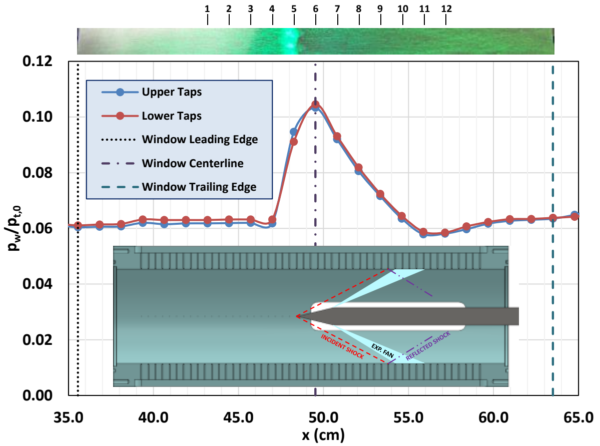
BOEING | Rolls-Royce | UCSB University of California Santa Barbara | United Technologies Research Center — Phase I

CFD Validation Experiments

- **Juncture Flow Experiment**
  - Prediction of trailing edge corner separation a challenge
  - First 14’x22’ WT entry in November 2017
  - Second entry in March 2018
- **Turbulent Heat Flux Experiment**
  - Need experimental data for CFD of turbulent heat transfer
- **Shock Wave/Boundary Layer Interaction**
  - Mach 2.5 Axisymmetric SWBLI (attached and separated)
  - Mean and turbulent stress data
- **2D Flow Separation**
  - NRA to Notre Dame (Flint and Corke)
  - Data for attached and separated (incipient, small, large) flow
- **2D Compressible Mixing Layer**
  - NRA to U-Illinois (Dutton and Elliott)
  - Full documentation of BC and mean/turbulence data
- **CRM in Fluid Dynamics Lab**
  - Characterize on-body (e.g., skin-friction) and off-body (wake) flow field



Experimental surface flow visualization



Axisymmetric SWBLI – 13.5° Cone Angle

Each set of fringes is a C_f data point.