CFD 2030 Aerospace Grand Challenges for Revolutionary CFD Capabilities

AVIATION 2020 – Forum 360
Virtual Event
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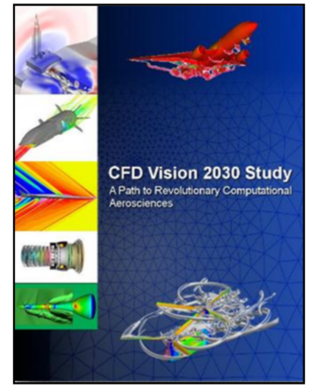
AVIATION FORUM

NASA CFD Vision 2030 Study

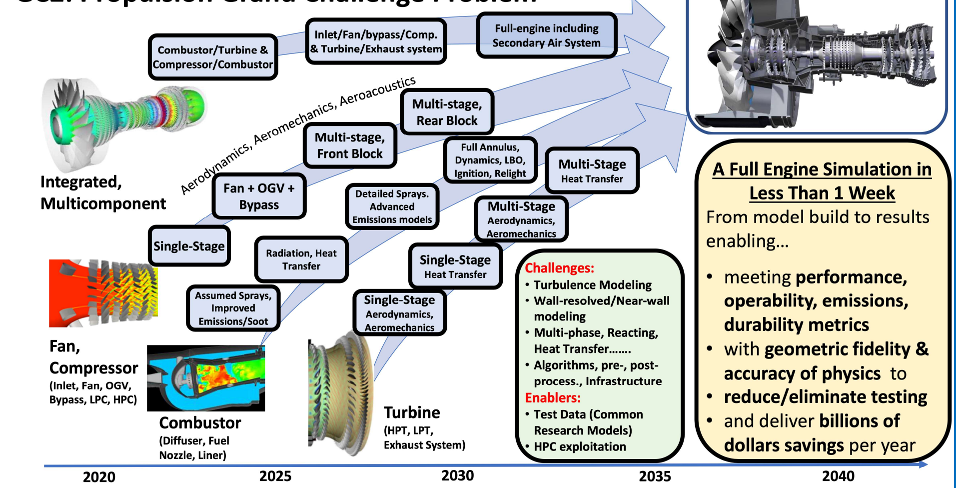
- **Emphasis on physics-based, predictive modeling**
  Transition, turbulence, separation, unsteady/time-accurate, chemically-reacting flows, radiation, heat transfer, acoustics and constitutive models
- **Management of errors and uncertainties**
  Quantification of errors and uncertainties arising from physical models, mesh and discretization, and natural variability
- **Automation in all steps of the analysis process**
  Geometry creation, meshing, large databases of simulation results, extraction and understanding of the vast amounts of information
- **Harness exascale HPC architectures**
  Multiple memory hierarchies, latencies, bandwidths, programming paradigms and runtime environments, etc.
- **Seamless integration with multi-disciplinary analyses and optimizations**
  High fidelity CFD tools, interfaces, coupling approaches, the science of integration, etc.

Slotnik, et al., "CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences," NASA/CR-2014-218178, 2014

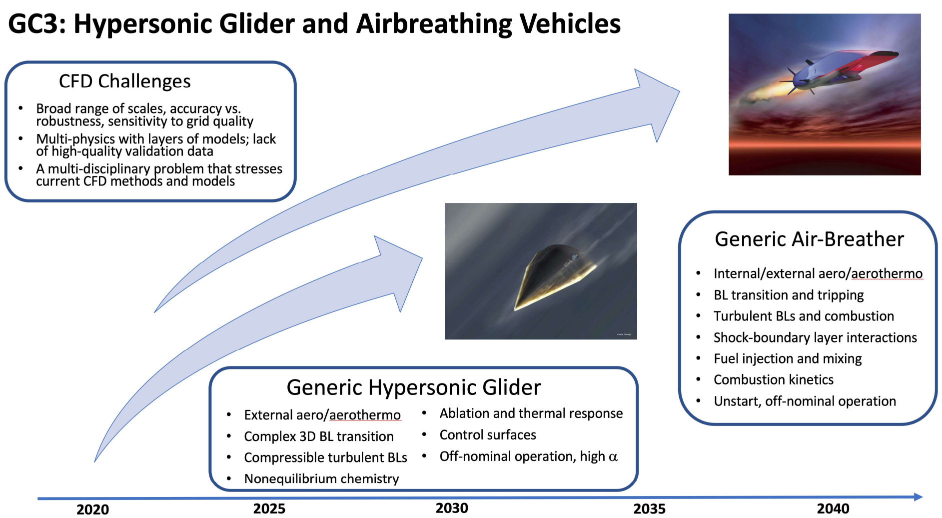


GC1: Advancing High-Lift Aerodynamic Prediction

GC2: Propulsion Grand Challenge Problem



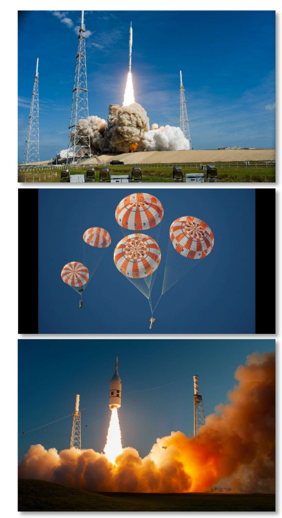
GC3: Hypersonic Glider and Airbreathing Vehicles



GC4: Space Access

CFD-in-the-Loop Monte-Carlo Flight Simulation for Space Vehicle Design

- **Space vehicle flight testing is extremely sparse leading designers to rely on statistical processes to predict and certify design performance.**
- **Monte Carlo Flight Simulation is broadly used to perform the statistical analysis.**
- **Flight simulators require extensive aerodynamic databases with quantified uncertainty to drive 1000's of required Monte Carlo simulations.**
- **Development of aerodynamic databases can take years involving wind tunnel test, CFD, empirical data, and engineering judgment.**
  - Orion and SLS aerodynamic databases have been in development for well over a decade.
- **Efficient flight simulation using direct coupling of CFD to the flight simulator for Monte Carlo analysis would be a game-changer for space vehicle design and development.**



GC1: Advancing High-Lift Aerodynamic Prediction

Series of Technical Challenges

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

Ground-Based Experimental Testing

FLOW PHYSICS PREDICTION

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
Acoustics (landing gear)
Engine propulsion effects
Ice effects

CFD-generated data compared to WT data

Sub-Challenge #3
6-10+ years

LOW-SPEED STALL SPEED DETERMINATION

Generic Flight Vehicle
Sub- or full-scale flight geometry
Flight Re
Steady flight
Basic maneuver
Dynamic structural response

CFD-generated data compared with flight-derived data

* Potential flight test vehicle configuration

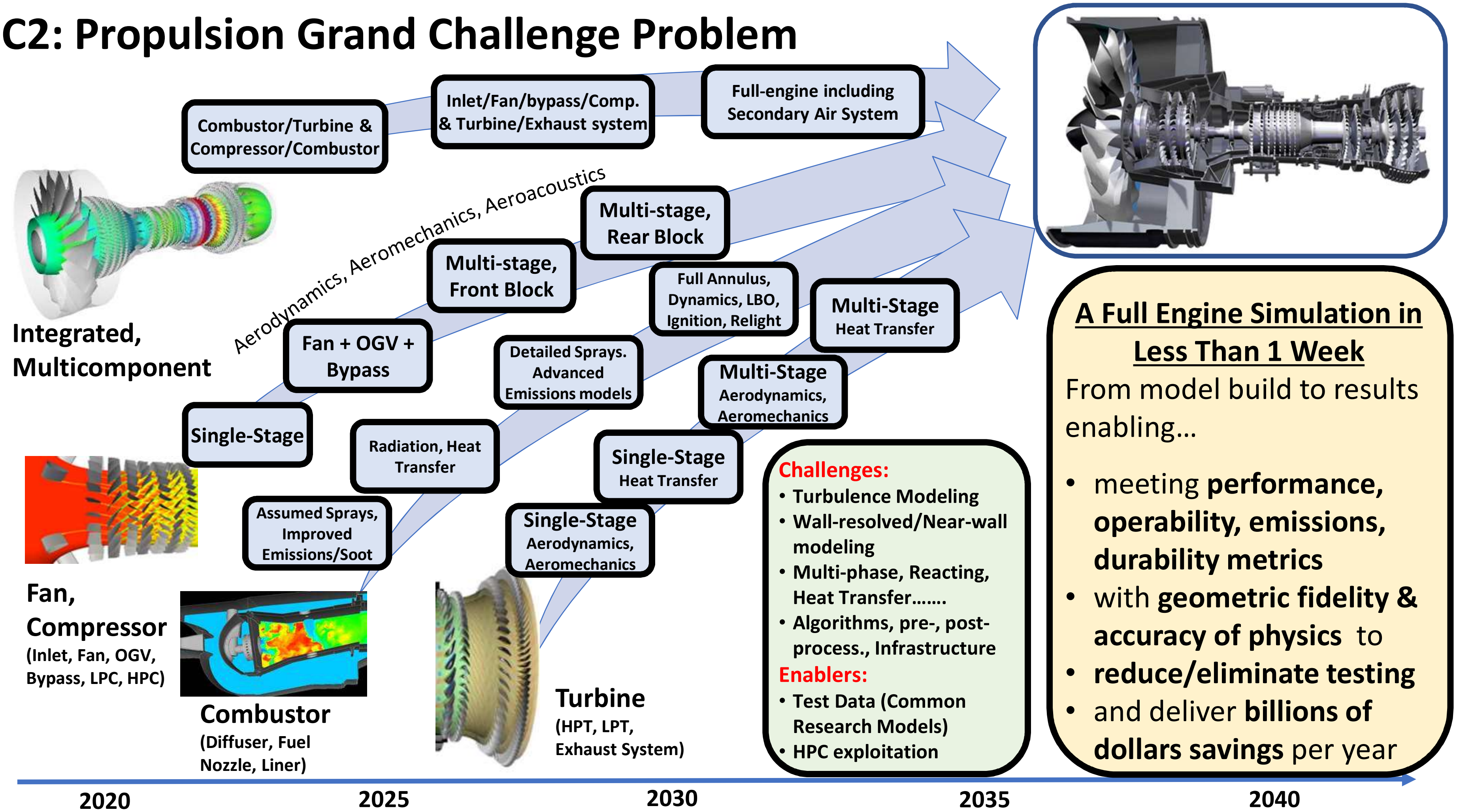
Grand Challenge
15+ years

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

CFD-based flight simulation (flight test used to verify flight simulation)

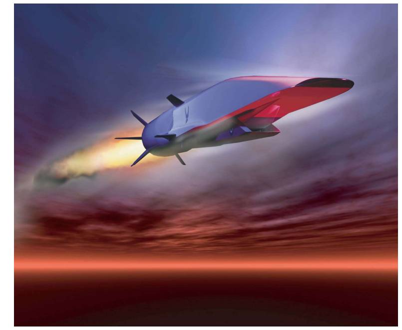
GC2: Propulsion Grand Challenge Problem



GC3: Hypersonic Glider and Airbreathing Vehicles

CFD Challenges

- Broad range of scales, accuracy vs. robustness, sensitivity to grid quality
- Multi-physics with layers of models; lack of high-quality validation data
- A multi-disciplinary problem that stresses current CFD methods and models



Generic Air-Breather

- Internal/external aero/aerothermo
- BL transition and tripping
- Turbulent BLs and combustion
- Shock-boundary layer interactions
- Fuel injection and mixing
- Combustion kinetics
- Unstart, off-nominal operation

Generic Hypersonic Glider

- External aero/aerothermo
- Complex 3D BL transition
- Compressible turbulent BLs
- Nonequilibrium chemistry
- Ablation and thermal response
- Control surfaces
- Off-nominal operation, high α

2020 **2025** **2030** **2035** **2040**

GC4: Space Access

CFD-in-the-Loop Monte-Carlo Flight Simulation for Space Vehicle Design

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