Physics and Model-Based Aerodynamic Design and Analysis

Presented:

NDIA Systems Engineering 2017

October 26, 2017

GENERAL ATOMICS AERONAUTICAL

General Atomics Aeronautical Systems

Predator A Piston (In Production)

Predator B/C Turboprop/fan (Production/Dev)

Small/Large UAVs (In Dev)

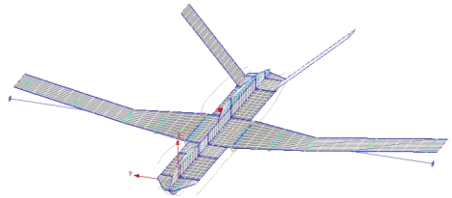
Product Aerodynamic Lifecycle

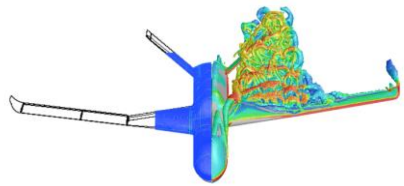
- Requirements
- Conceptual Design
- Prelim/Detailed Design
- Test
- Sustainment / Growth

- **Aerodynamic design and analysis relevant to all stages of the product life cycle**
- **Ideally need a set of "multi" tools**
  - Multi-fidelity (low → high fidelity)
  - Multi-physics (aero → aero+)
  - Multi-cost (sec/min → days/weeks)
  - Multi-user/org (aero vs. struct SME)
  - Multi-product (Aircraft A vs. Aircraft B)

Aerodynamic Pre-Flight Tool belt

Physics Based | **Test Based**

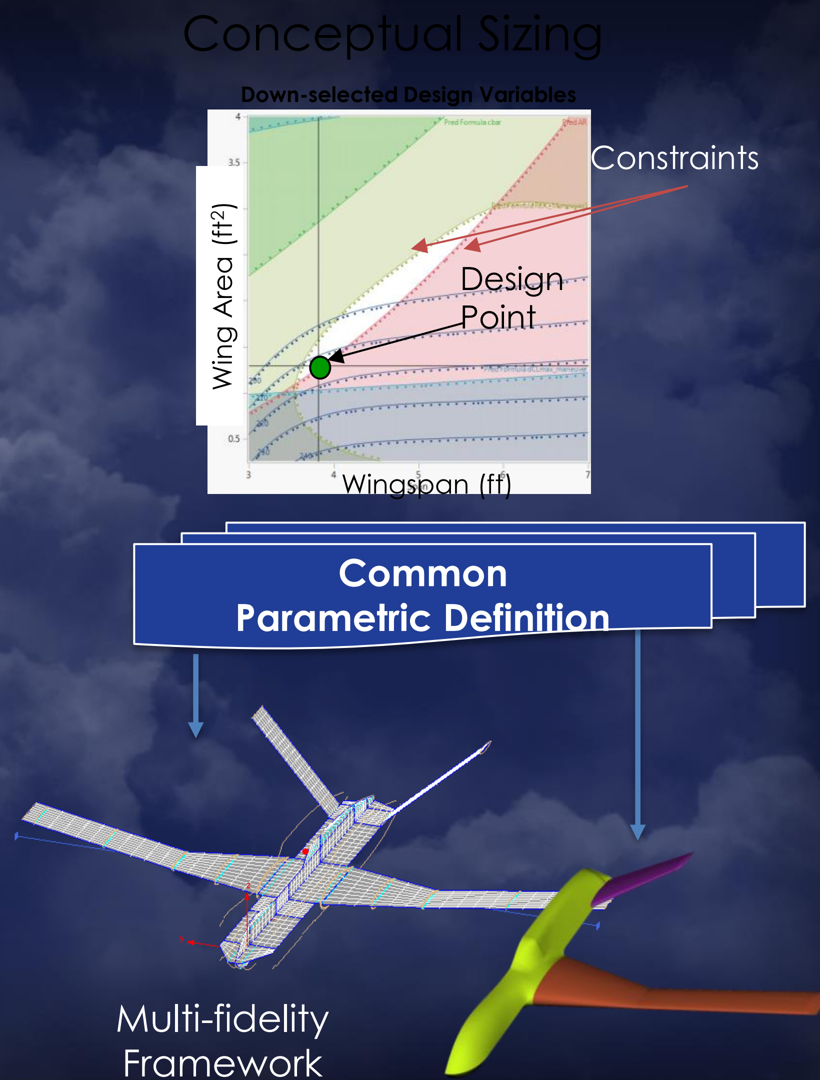




Physics	Vortex Lattice / Panel	CFD	Wind Tunnel
Inputs	Conceptualize → Run	CAD → Mesh → Run → Post	Plan → CAD/Build → Test → Post
Outputs	**Steady/Unsteady** Linear aero **Quick** prelim results	Steady/Unsteady **Non-linear aero** **Validation required**	Typically steady aero **Non-linear aero** **Established data source**
Scale (Reynolds #)	Full-scale (Inviscid i.e. Re→∞)	**Full-Scale** (Flight Re)	Sub-scale or partial model (Variable Re adds **cost**)
Compressibility	Incompressible or compressibility corrected	Compressible (Flight Mach)	Compressible. Separate tests depending on Ma
Viscous Effects	Inviscid or viscous corrected	Typically fully turbulent Recent RANS transition models	Typically tripped or natural transition at test Re
Geometry	Panel representation and **simple shapes**	Geometric complexity increases meshing cost; smooth	Smooth; gaps/slots sizes may need to be Re scaled
Propulsion	Faired; no or limited prop effects	Faired or flow-through; can model propulsion effects	Faired or flow-through; separate tests for prop effects
Environment	Modeled in farfield	Modeled in farfield	Corrected for tunnel effects

Requirements / Conceptual Design

- **Semi-empirical methods drive requirements and sizing**
  - High level
  - Grounded in actuals
  - Good for derivative designs
  - Good for high level trades
- **Opportunities**
  - Multi-fidelity framework at GA-ASI
  - Others successfully options exist e.g. MIT TASOPT



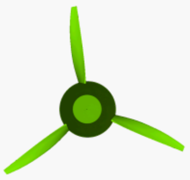
GENERAL ATOMICS AERONAUTICAL

Preliminary / Detailed Design

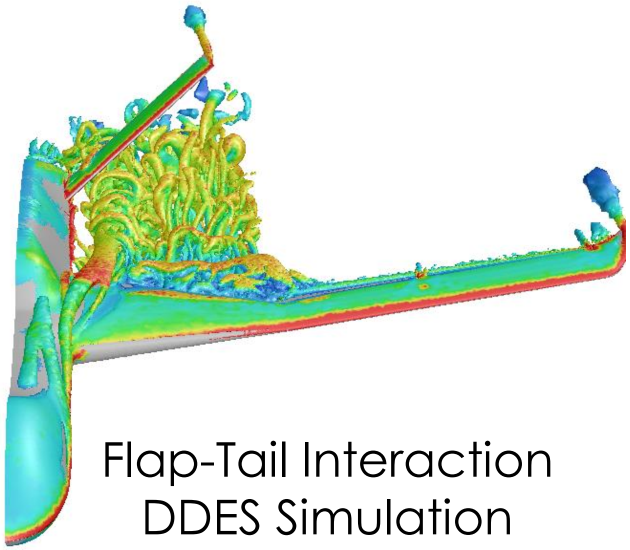
- **CFD and wind tunnel test drive design**
  - Analysis for design trades
  - Test for database generation
  - Test for perf verification
- **Challenges**
  - Managing multiple models… CREATE-AV enabling multi-disciplinary analysis
  - Physics!.. the RANS plateau LES/DDES still costly

Kestrel CFD Model

Animated gif



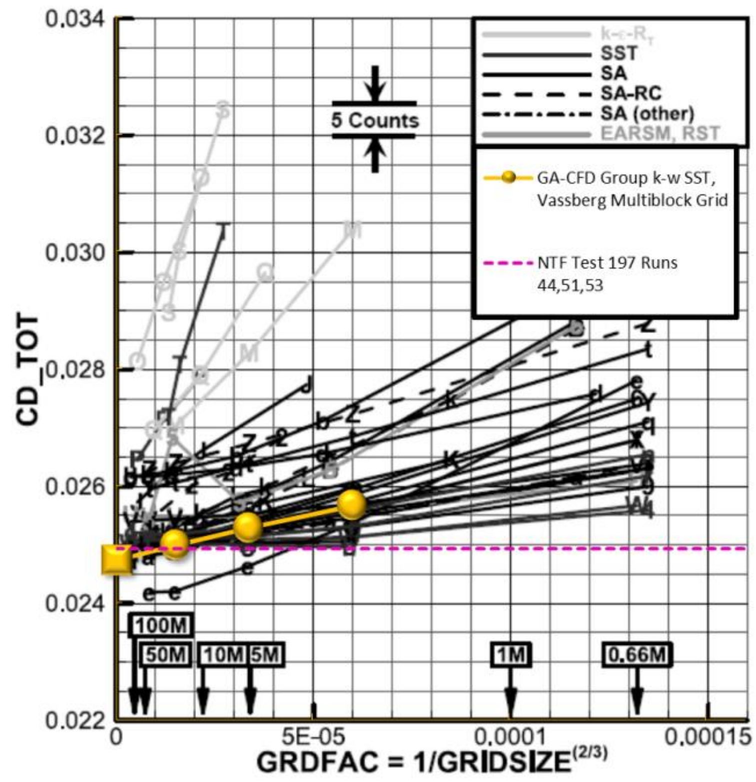
Overset allows moving control surfaces and props



Flap-Tail Interaction DDES Simulation

Prelim / Detailed Design (Cont.)

- **Challenges (Cont.)**
  - Scalability… Wind tunnel cheaper than CFD for large databases.
  - Trust… CFD meshing treated as an "art." Mesh convergence ≠ Solution accuracy. Test validation remains essential.
  - Expectations… CFD not fast enough to be in-exact.
  - Process… CFD treated as virtual wind-tunnel.

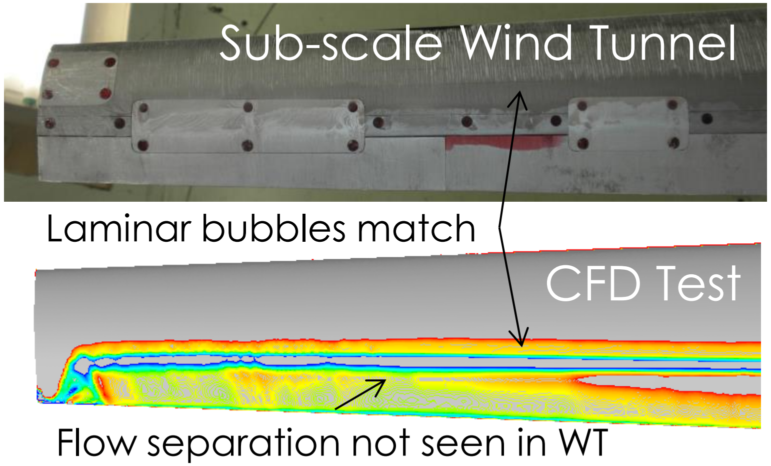


AIAA Drag Prediction Workshop (DPW5)

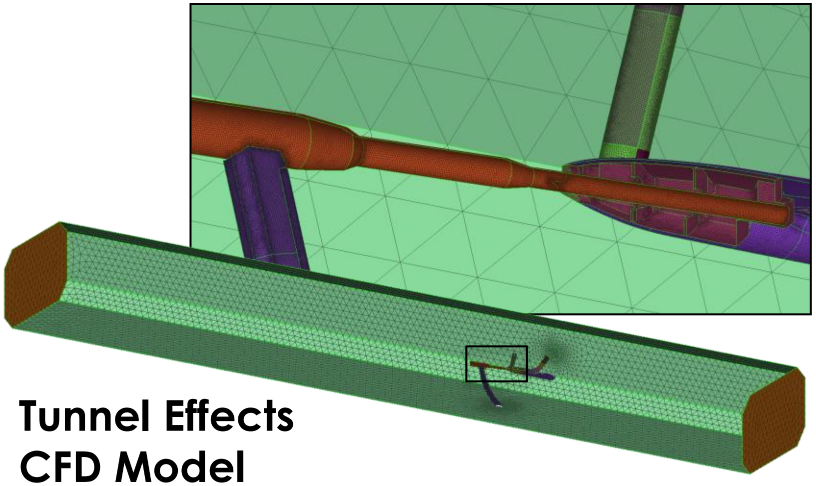
Graphic from: https://aiaa-dpw.larc.nasa.gov/Workshop5/presentations/DPW5_Presentation_Files/14_DPW5%20Summary-Draft_V7.pdf

Test

- **Pre-test predictions inform test focus areas**
- **Test helps CFD**
  - Separated flows
  - Interaction effects
  - Transition
- **CFD helps test**
  - Wind tunnel corrections
  - Propulsion effects
  - Aero-static effects



Tunnel Flow Viz Comparison



Tunnel Effects CFD Model

Graphic from: https://aiaa-dpw.larc.nasa.gov/Workshop5/presentations/DPW5_Presentation_Files/14_DPW5%20Summary-Draft_V7.pdf

Closing the Loop on Performance

Requirements

Conceptual Aero

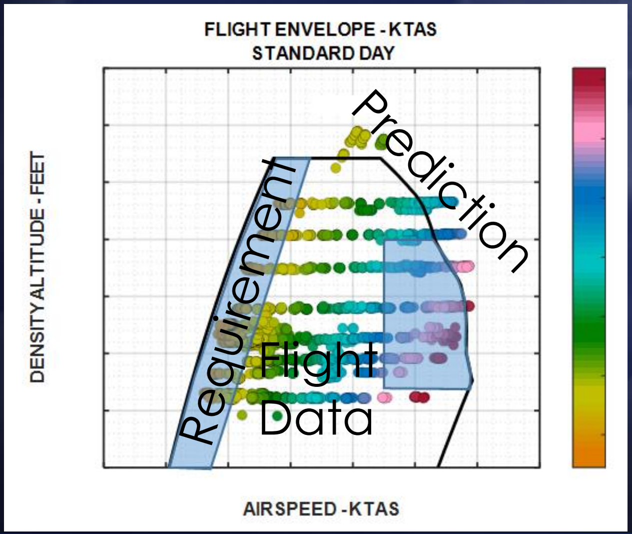
RANs Aero

Wind Tunnel Aero

Flight Test Aero

All aero models contribute to:

- Understanding of aircraft flow-field
- Support modeling for perf and S&C
- Air-data integration

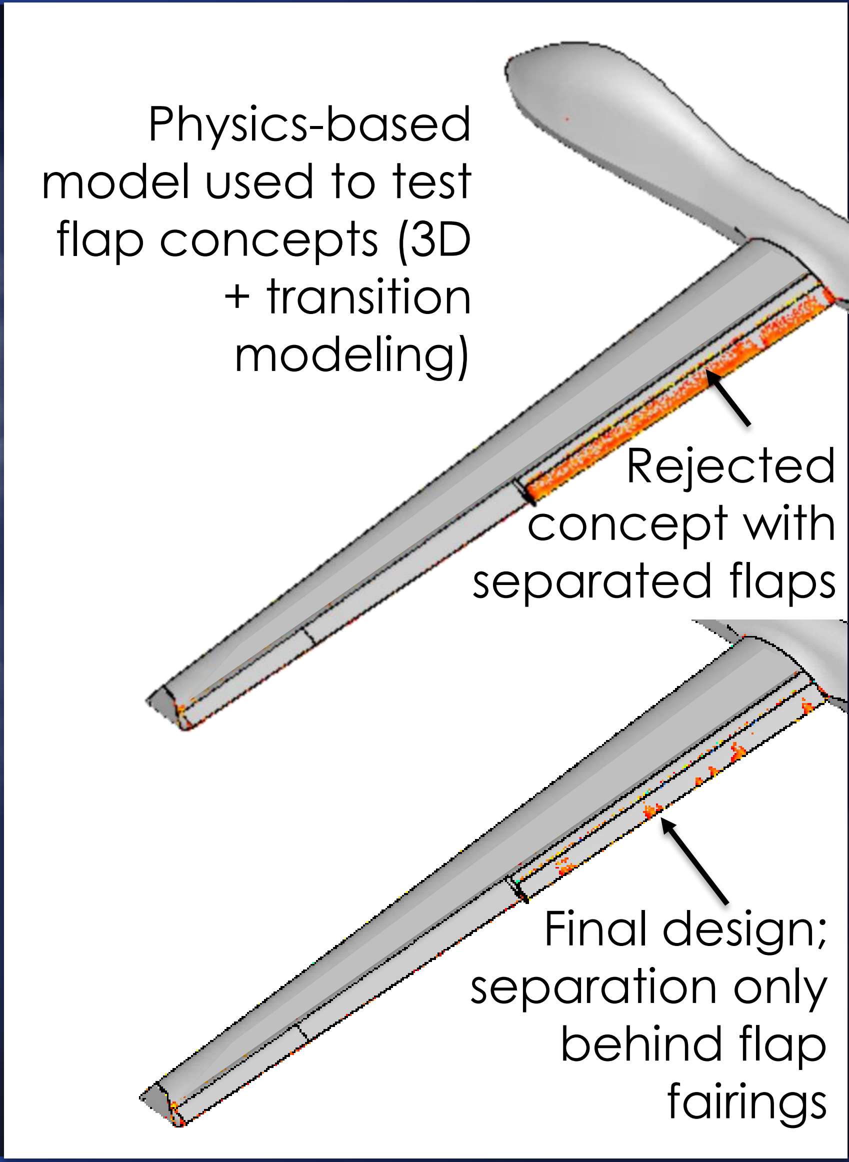


Aero + Weights + Propulsion = Performance

GENERAL ATOMICS AERONAUTICAL

Sustainment / Growth

- **New tools provide opportunities to improve existing systems and match evolving customer needs**
- **GE → GE-ER Case Study**
  - GE double slotted flap designed with 2D CFD
  - GE-ER reconfigured existing hardware to a single slotted flap with 3D CFD
  - Wind tunnel and flight test in both cases
  - Meet current customer needs



GENERAL ATOMICS AERONAUTICAL

Future Needs

- **Medium fidelity needs**
  - Fast 3D methods (can include fuselages)
  - Non-linear unsteady options (damping deriv, loads spectra)
- **Promising Candidates**
  - Coarsely auto-meshed RANS/URANS with wall functions
  - Auto-meshed Euler+IBLT3
  - Probabilistic multi-fidelity methods like Kriging
- **High fidelity needs**
  - More efficient algorithms (e.g. multi-grid)
  - Less reliance on hardware solutions (costly)
  - Faster CAD clean-up (time consuming)
- **Transition modeling essential for GA-ASI**
  - RANS based models promising from computational cost perspective
  - Need models robust to Re 5e5-10e6 (current γ-Reθ not there)
  - Natural transition covering TS, CF, laminar bubbles, attachment line contamination
  - Forced transition covering trip, surface roughness/defects
  - Non-dissipative methods for high level for freestream turbulence in RANS