AIAA

High-Lift Prediction Workshop 6 Kickoff Presentation

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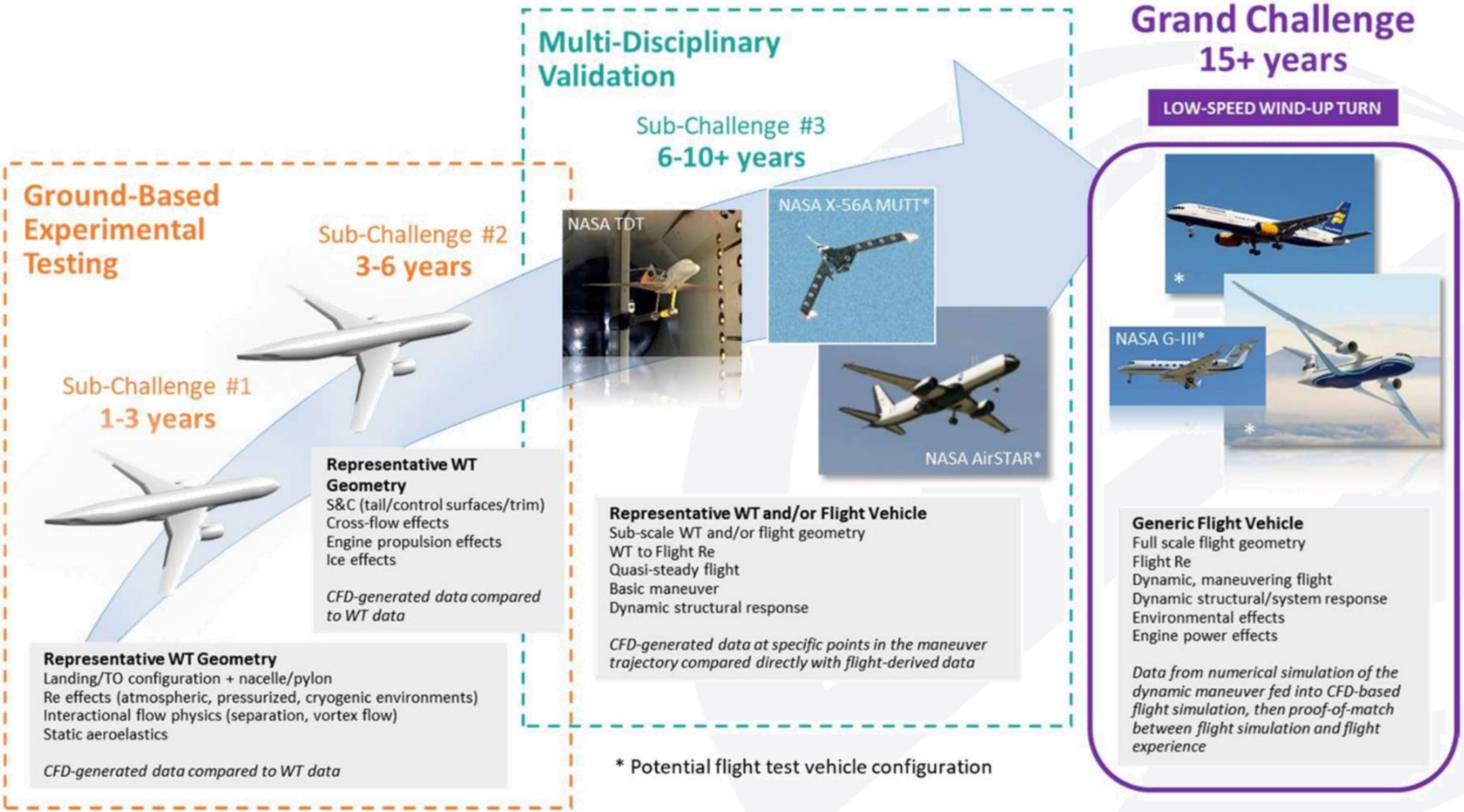
HLPW Leadership Committee

AIAA SciTech: 14 January 2026

Virtual: January 20, 2026

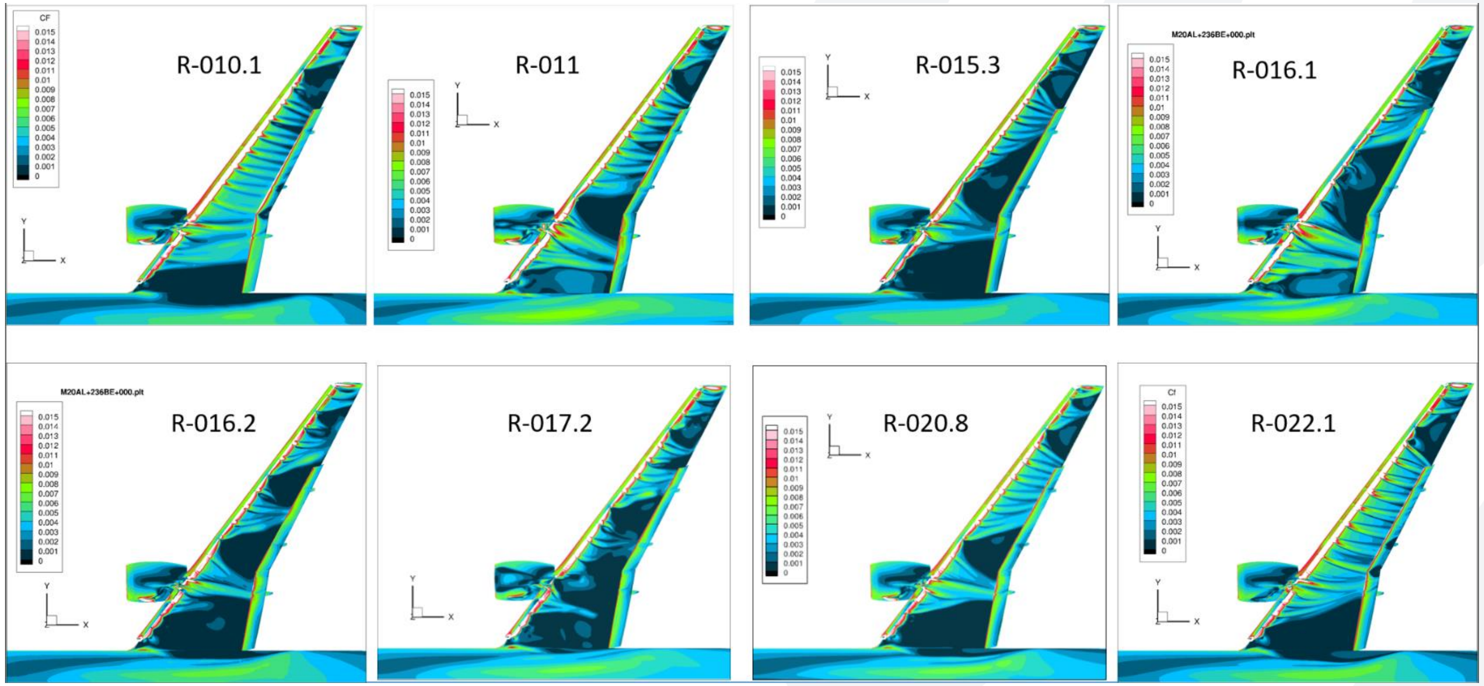
Why do we do workshops?



HLPW-5 Recap

HLPW-5 Key Takeaways

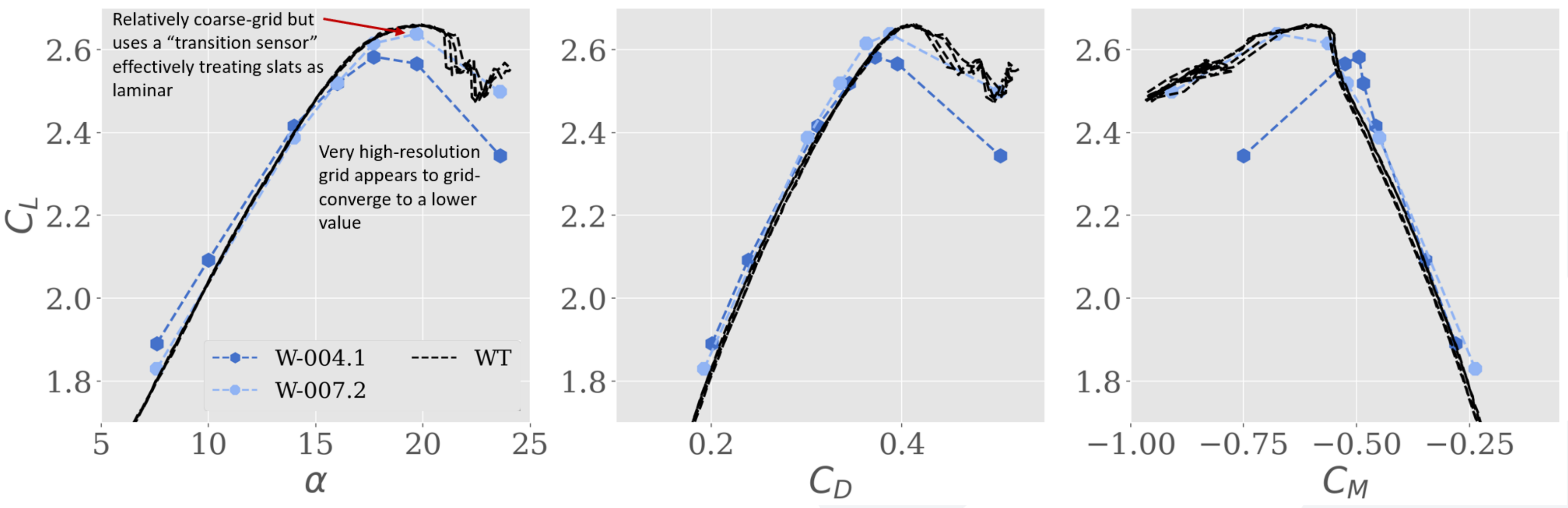
- Lots of great progress across all TFGs
- Poll at end of workshop indicated participants were eager to continue addressing unresolved problems related to high-lift prediction
- RANS: Continues to see pizza-slice separation at high angle of attack using both fixed and adaptive meshes



Spurious separation in submitted RANS solutions (skin friction) for Case 2.4

HLPW-5 Key Takeaways

- Scale Resolving Simulations:
    - Over-prediction of flap health at low angles of attack in some WMLES solvers but not others
    - Strong solution sensitivities to laminar flow, particularly on LE Slat
    - Modified shielding function in DDES better protects attached BL
    - When should we use WMLES vs DDES?



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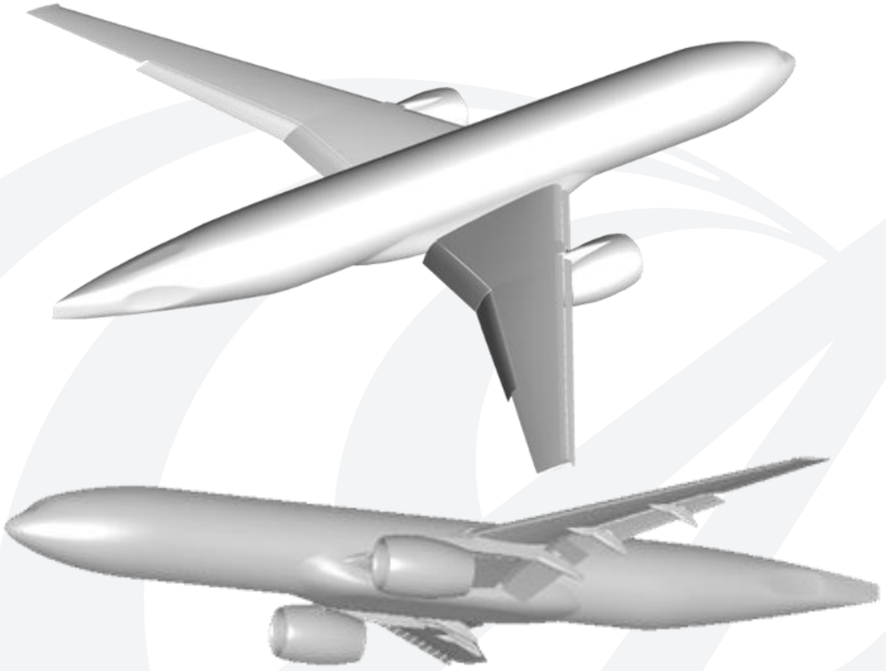
CRM-HL Ecosystem

High Lift Common Research Model (CRM-HL) Ecosystem

Boeing developed the high lift variant of the **NASA Common Research Model (CRM-HL)** in 2016

Informal group of international partners ("Ecosystem") formed to acquire high-quality test data using CRM-HL

Partners fund their own activities (e.g., build and/or test wind tunnel models) and **agree to share a minimum set of results** (e.g., experimental data) either among partners and/or publicly through CFD validation workshops



(6) Wind tunnel models and (16) tests have been used to obtain high-quality data as of Dec 2025

Ref: Slotnick, J., *ICAS 2024-1210 A CFD Validation Ecosystem to Advance the Prediction of Low-Speed Aerodynamics*, Florence, Italy: ICAS, 2024.

CRM-HL Ecosystem Progress

Six unique models have been tested across (8) facilities → (16) separate test campaigns since 2018

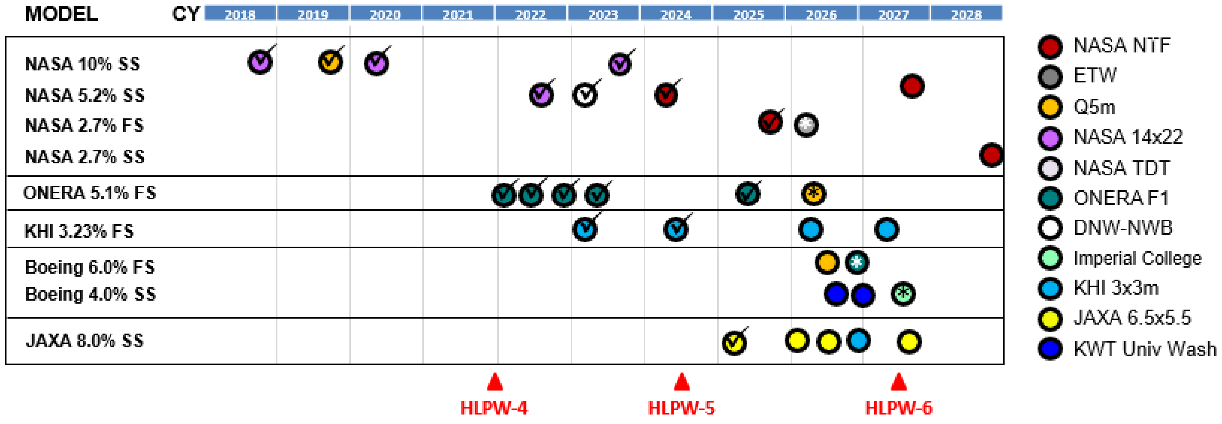
- Un-iced and with artificial ice shapes

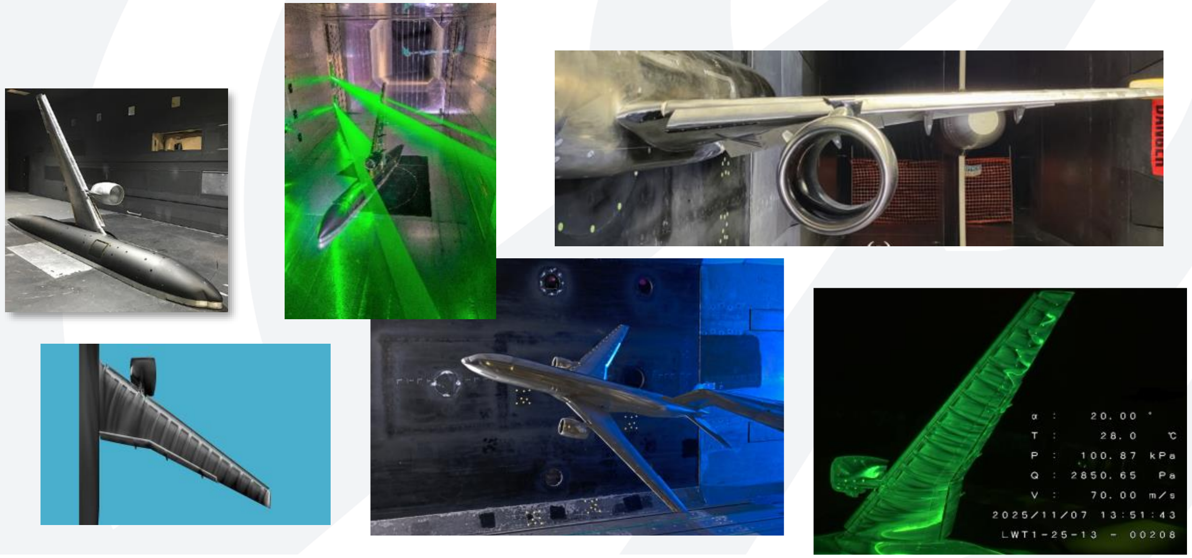
Integrated testing facilitates unique learning opportunities and collaboration

- Ecosystem partners collaborate with each other and external entities

Large volume of data supports community workshops and CFD validation

- Current focus is un-iced, build-up configurations





Large volume of data being obtained through integrated testing—with much more to come

HLPW-6

Logistics

- Workshop level communications happening via email distribution – if you’re not on the DL, send a note to:
  - hiliftpw@gmail.com
- New website! https://aiaa-hlpw.org/
- Workshop launch:
  - January 20th 7am Pacific / 10am Eastern
  - Send an email to hiliftpw@gmail.com if you have not obtained a meeting invite
- Continuing with Technical Focus Groups, similar to HLPW-5
- Conducting mini workshops to evaluate TFG progress, and share cross TFG learnings
- HLPW-6 is currently scheduled to conclude during AIAA Aviation 2027

Technical Focus Groups & Test Cases

- Previous workshops featured Technical Focus Groups working collaboratively towards common goals on workshop test cases
- This workshop will be similar, but with a bit more autonomy in TFGs
- Some overlap where appropriate, but Scale Resolving and RANS fundamentally should be focusing on different challenge areas
  - At the same time, there's overlap where TFGs need to learn from each other collaboratively
- Communal 'Test Cases' defined, TFGs can spend as much or as little time on them as deemed appropriate, trying to answer key questions

Technical Focus Groups

HLPW-5

- Fixed-Grid RANS
- Adaptive RANS
- HRLES
- WMLES
- High-Order

→

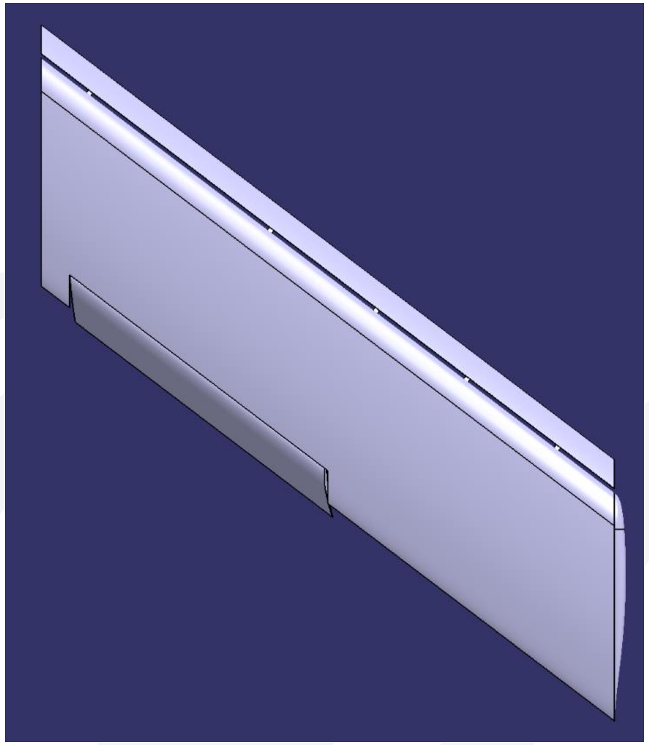
HLPW-6

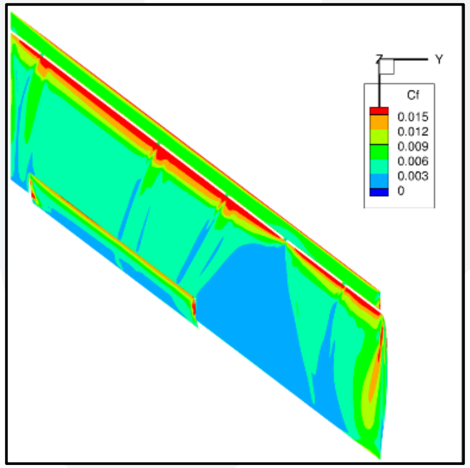
- **RANS**
  - Boris Diskin (NASA)
  - Mike Park (FlexCompute)
- **Scale-Resolving**
  - Konrad Goc (Boeing)
- **High Order**
  - Marshall Galbraith (MIT)
- **Artificial Intelligence / Machine Learning**
  - Neil Ashton (NVIDIA)

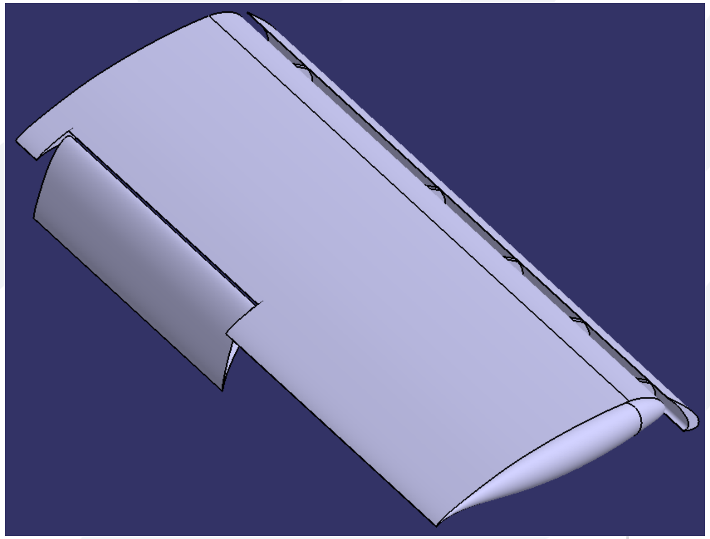
HLPW-6: Test Cases

Test Case 1: CRM-HLS

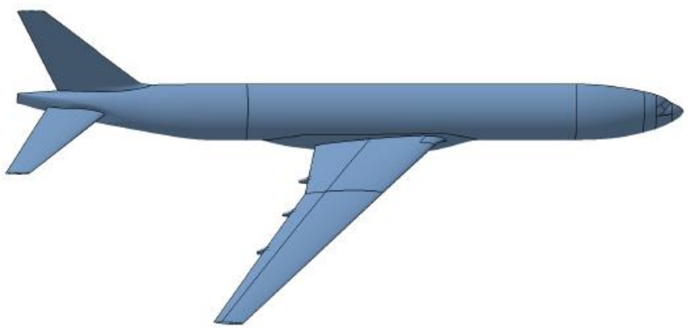
- Simplified High-Lift configuration, developed with Boeing / University of Washington Collaboration
- Features finite span wing, full span slat, partial span flap
- No experimental data yet, but maybe mid-workshop
- Free air with Y=0 Symmetry, 3.55m ReC
- Built to target slat bracket wake separation on 2nd from outboard bracket
- Many geometric variations possible
  - slat bracket width / depth
  - removable flap
  - removable slat
  - deflection changes, etc.



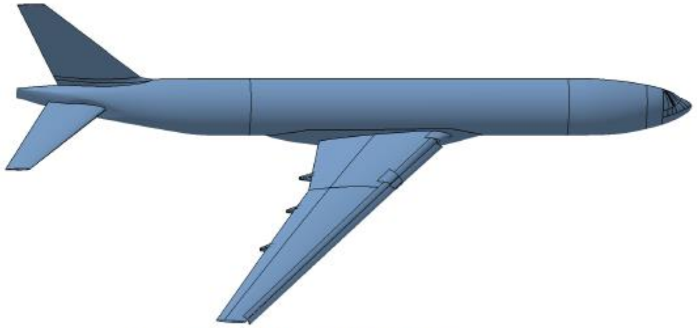




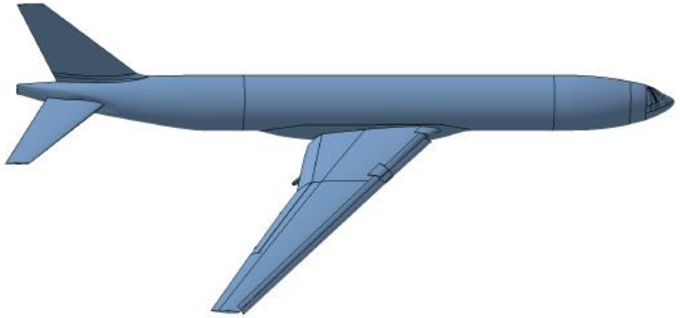
Test Case 2: ONERA LRM Configuration Buildup



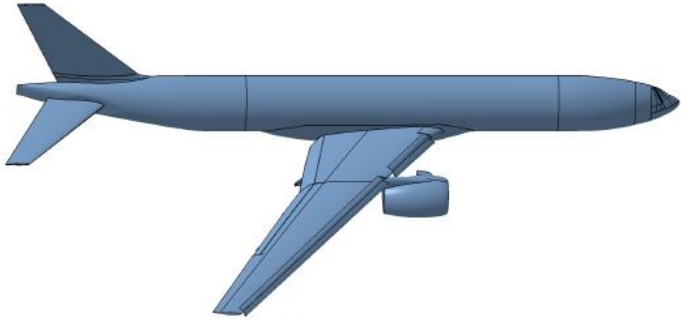
(a) TC2.1, CRM-HL-WBHV Configuration



(b) TC2.2, CRM-HL-WBSHV Configuration



(c) TC2.3, CRM-HL-WBSFHV Configuration



(d) TC2.4, CRM-LDG-HV Configuration

- Direct repeat of HLPW-5 Test Case 2
- Not as many required case as HLPW-5!
- TFGs can choose configurations and AoAs that make sense
- Tentative plan to repeat 2.4 at closeout of HLPW-6 across TFGs

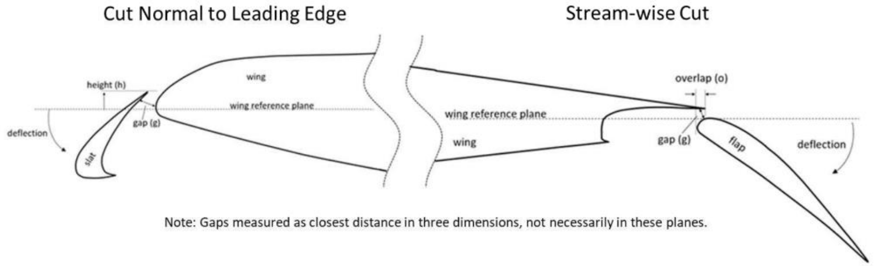
Test Case 3: CRM-HL Takeoff Configuration

- The CRM-HL Takeoff configuration features a shallower flap deflection, and a leading-edge slat that is deflected but sealed to the wing

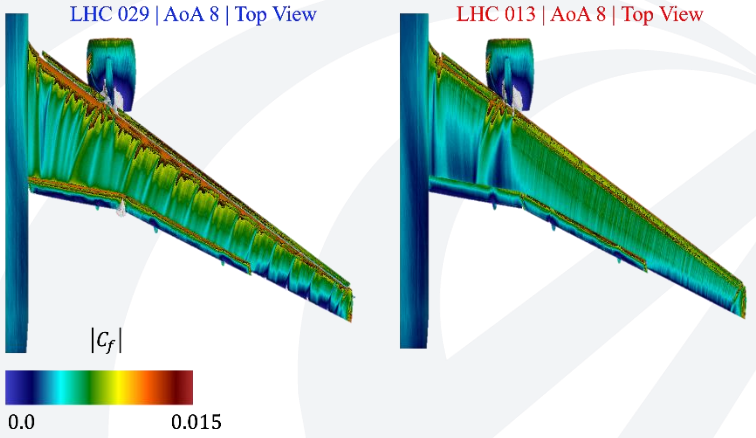
- Lift and Drag well before CL,max become the key parameters of interest.
    - *Expecting* less scatter here, along with higher expectations for accuracy. Wind tunnel has tighter bounds on repeatability here.

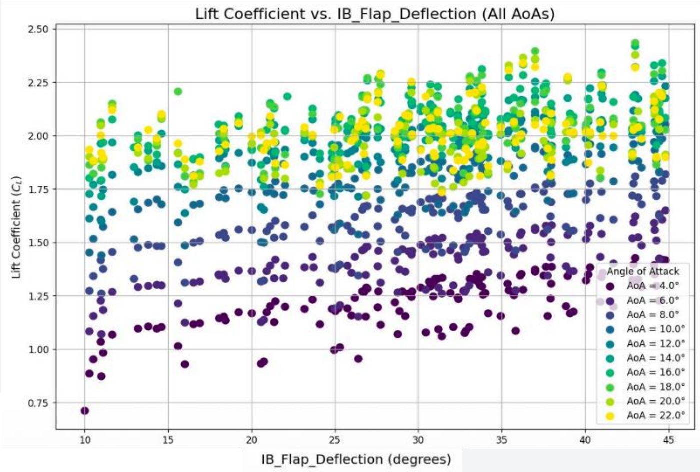
- Only notional at this point, likely not worked until early 2027

Test Case 4: AI / ML Dataset



- Joint open-source dataset (HiLiftAeroML) made developed through NVIDIA / Cadence / Boeing Collaboration
- High-Fidelity WMLES Simulation results (solution-adapted ~300-500M cells) made available across 180 geometry variations (*flap+slat angle changes*), 10 angles of attack each = 1800 simulations.
- Baseline geometry is essentially Case 2p4
- See AIAA-2026-0042 for initial details – more detailed preprint (data+ML benchmarks) will be available by end of January. Data available free of charge on HuggingFace (60TB)





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Call for Participants!

- If not already, join Workshop DL: Send email to **hiliftpw@gmail.com**
- TFGs will meet in different time slots. Participants are welcome to join one or multiple TFGs – can also just listen in, as desired
    - **RANS**: bi-weekly Wednesday 10-11am EST
    - **SRS**: bi-weekly, Tuesday 10-11am EST, starting 1/27
    - **High-Order**: <TBD>
    - **AI/ML**: <TBD>
- Email TFG leaders to indicate interest, and be added to DL

TFG Key Questions

RANS

HLPW-6 RANS TFG Key Questions with respect to Tast Case 1 (TC 1) configuration:

Can we compute iteratively and grid converged RANS solutions for this configuration?

Can we achieve agreement between converged RANS solutions computed by different solvers for this configuration at low, middle, and high angles of attack?

Is this geometry prone to spurious ‘pizza slice’ separation patterns similar to those observed in RANS solutions at high angles of attack for the HLPW-5 configurations 2.2-2.4?

Can spurious ‘pizza slice’ separation patterns be mitigated with better grid resolution and/or iterative convergence? If yes, what are requirements for grid resolution (both on surface and in volume) and levels of convergence to avoid spurious separation?

Do we observe multiple solutions of the Spalart-Allmaras (SA) turbulence model for this configuration and, if we do, what changes in the turbulence model should be made to ensure well-posedness (existence, uniqueness, and continuous dependence of the SA-model solution)?

What lessons learned from TC 1 can be applicable to more complex CRM-HL configurations such as TC 2.4?

Optional:

How do geometrical features (bracket shape / spacing between brackets, anything else) affect spurious separation in the RANS solutions?

RANS

Notional Schedule:

- January 2026 – August 2026 (tentative): CRM-HLS
  - Studies with SA model – Targeting ‘benchmark’ solutions for April mini-workshop
  - SST-Vm verification
  - Characterization of bracket wake flows
  - TC1 Mini-workshop in August / September

- September 2026 – December 2027 (tentative) – Pending outcome of TC1 findings
  - Geometric variations of TC 1?
  - Move on to TC 2?
  - Abbreviated look at TC 3?

- January 2027 – May 2027 (tentative): Apply learnings to Test Case 2.4
  - Single Reynolds number, limited number of cases

Scale Resolving Simulations

Overarching Key Questions:

1. Are there meaningful distinctions in the predictive accuracy among the various types of scale-resolving methods (e.g., WMLES, DES, LBM)? What are the relative strengths/weaknesses of the methods in predicting aircraft maximum lift and the flow features that drive it (e.g., wing root separation, slat bracket wakes, flap separation)?
2. What is the state of affordability of scale resolving methods for high-lift prediction? Are these methods feasible for routine industrial use on modern compute hardware?
3. Are there certain types of turbulence model choices/frameworks that are needed to systematically improve the accuracy of high-lift flow predictions?
4. What choices regarding grid distribution/topology/density are needed to achieve accurate predictions of high-lift flows? What are the implications for different SRS methods of near-wall grid size (e.g. WMLES/HRLES running at y+ in the log layer)?

Scale Resolving Simulations

Case Specific Questions:

1. TC1 (CRM-HLS, Jan ‘26-May ‘26): Can scale-resolving methods be used to provide a high-fidelity reference solution set for the High-Lift CRM Simplified Wing (CRM-HLS) model, including solutions on highly resolved meshes (potentially WRLES/DNS)?
2. TC1/TC2.4: How should scale-resolving methods be handling laminar to turbulent transition, especially on the slat? How can the state of the leading-edge boundary layer predicted by scale-resolving methods be validated to build confidence in the predictions (e.g. using experimental or DNS/WRLES data)?
3. TC2.3: What can be done to improve the accuracy of scale resolving methods at low angles of attack, where inaccurate predictions of flap separation often lead to large mispredictions of aircraft lift?
4. TC3: Are scale-resolving methods able to reliably predict aircraft drag at low angle of attack? Does any particular SRS method (e.g., WMLES vs. DDES) show greater advantages in drag prediction for this configuration?

Scale Resolving Simulations

Notional Schedule

- Test Case 1 – CRM-HLS – January to April 2026
  - Plan to develop baseline solutions, but not comprehensively study sensitivities
  - Mini-workshop April
  - 2nd Mini workshop in 3Q26, with any updates

- Test Case 2 – ONERA LRM 2.3 or 2.4 – May 2026 to December 2026

- Test Case 3 – CRM-HL Take-off Configuration – January 2027 – June 2027 (should there be appetite!)

High-Order CFD

- This TFG has lost momentum in recent years.
- If participants want to do something here, we want to support you!

Key Questions:

- Can we generate high-quality meshes on high-lift configurations of interest?
- Can solvers produce high quality results on theses meshes?
- Do High-Order methods provide tangible value (Increased accuracy, decreased cost?) when compared to traditional 2^{nd} order solvers?

AI/ML

- KQ1: Prediction Accuracy Across Flow Regimes:
  - For a fixed training set (HiLiftAeroML), how does the predictive accuracy of AI surrogate models vary across distinct aerodynamic regimes:
  - **Linear/Attached Flow** (~AoA = 4): Can models accurately global forces/moment+surface/volume due to flap/slat geometry changes?
  - **Maximum Lift** (~AoA =18): Can models identify the subtle non-linearities and flow breakdown near Cl_max
  - **Deep Stall** (~AoA 22): Can models predict the massive separation and performance degradation characteristic of post-stall regimes?

- KQ2: Global Polar Prediction & Generalization
  - Can AI surrogates consistently predict the full aerodynamic polar (Lift, Drag, Moment vs. AoA) for unseen geometric configurations?
  - Do models enforce physical consistency (e.g., smooth polars) or do they exhibit non-physical noise when interpolating between sampled Angles of Attack?

- KQ3: Computational Efficiency & Trade-offs
  - What is the Pareto front between inference accuracy and computational cost (training vs. inference)?
  - Comparison of GPU-hours for training and wall-clock time for inference

AI/ML

- KQ4: Data Efficiency & Scaling Laws
  - What is the sensitivity of model accuracy to the size of the training dataset? If we reduce the training set from the full 1,800 samples to 10% or 50%, how rapidly does performance degrade? Crucial to determine ROI of generating expensive training databases.
- KQ5: Physics-Informed Constraints
  - To what extent does embedding physical constraints (e.g., mass conservation, boundary conditions) directly into the loss function or architecture improve generalization compared to purely data-driven approaches?
- KQ6: Data-Driven Turbulence Closure ***(in collaboration with RANS/SRS TFGs)***
  - Can data-driven turbulence models improve the predictive accuracy of lower-fidelity solvers (e.g., RANS or coarse LES) for RANS/SRS defined test-cases

AI/ML

- **January 2026 – April 2026 (tentative): logistics**
  - Gather core members of TFG
  - Find scope of interest from members (i.e surrogate versus AI-turb/solver enhancements)
  - Agree final key questions
  - Get logistical feedback on dataset (downloaded ok, no missing/corrupted files etc)

- **April – December 2026**
  - Focus on individual AoAs for initial training and testing (KQ1)
  - Progress from pre-stall, cl_max to post-stall i.e 4,18,22 (KQ1)
  - Focus on defining constant metrics and establishing best-practices for patch/slice/downsampling etc
  - Coordinate with other TFG to assess non-surrogate models i.e AI-developed RANS (KQ6)
  - Virtual Mini-workshop Q4 2026 to share initial results

- **December-July 2027**
  - Expand to include entire dataset across geometry/AoA changes. (KQ2/3/4)
  - Investigate physics-informed/inspired topic (KQ5)
  - Do final training ready for the workshop

Questions?

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https://aiaa-hlpw.org/