



POINT ONE PERCENT

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(APA-28/GT-09, Shared Opportunities in Uncertainty Quantification in Support of CFD Validation)

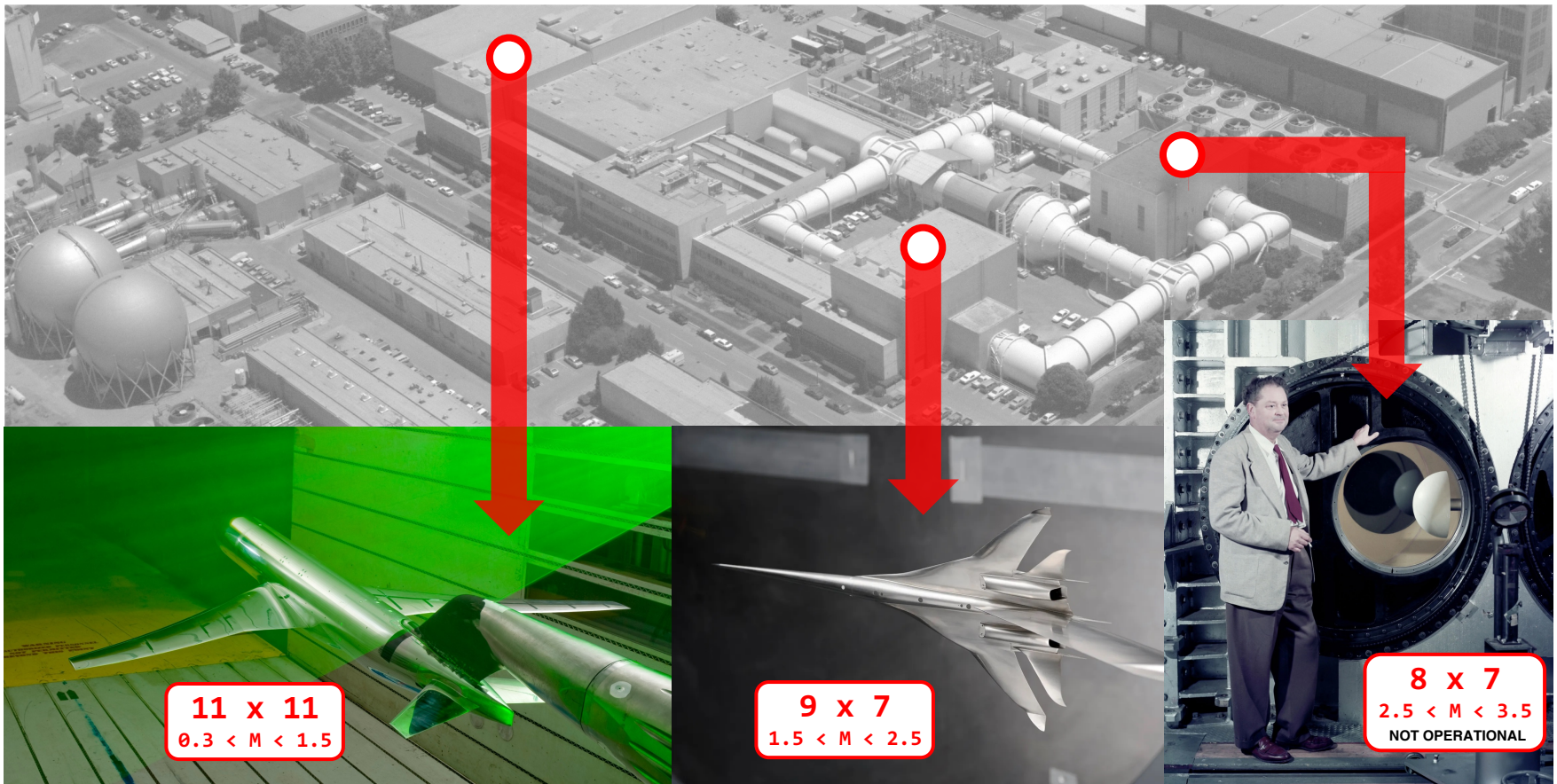
January 7, 2025

OVERVIEW

- PRODUCTION WIND TUNNEL
- INCREMENTAL TESTING
- ONE DRAG COUNT GOAL
- POINT ONE PERCENT
- UNCERTAINTY CHAIN ELEMENTS

PRODUCTION WIND TUNNEL

- NASA AMES UNITARY PLAN WIND TUNNEL ...
... NASA's MOST FREQUENTLY USED PRODUCTION WIND TUNNEL.



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- **WHAT IS A PRODUCTION WIND TUNNEL ?**
 - TEST FACILITY THAT IS USED FOR THE DEVELOPMENT OF COMMERCIAL PRODUCTS.
- **WHAT DRIVES DATA UNCERTAINTY IN A PRODUCTION WIND TUNNEL ?**
 - REQUIREMENTS OF THE MOST DEMANDING CUSTOMERS (ALL OTHERS BENEFIT).
- **WHAT TYPE OF TESTING IS OFTEN DONE IN A PRODUCTION WIND TUNNEL ?**
 - INCREMENTAL TESTING.

INCREMENTAL TESTING

- **HOW DOES INCREMENTAL TESTING WORK ?**
 - LARGE NUMBER OF TUNNEL CONDITION & MODEL CHANGES ARE MADE.
 - OBSERVED COEFFICIENT CHANGES BECOME BASIS FOR DESIGN DECISIONS.
 - EXAMPLE ... POSITION & ORIENTATION OF THE WINGLET OF AN AIRPLANE ARE VARIED TO FIND COMBINATION THAT MINIMIZES THE DRAG COEFFICIENT IN CRUISE.
- **WHAT UNCERTAINTY CHALLENGES ARE ASSOCIATED WITH INCREMENTAL TESTING ?**
 - SIGNAL NOISE AND PRECISION ERROR ... MUST BE CONTROLLED TO ALLOW FOR RELIABLE DETECTION OF SMALL AERODYNAMIC COEFFICIENT DIFFERENCES.
 - TEST-TO-TEST REPEATABILITY OF BASELINE CONFIGURATION ... MUST MEET EXPECTATIONS SO THAT RESULTS FROM INDEPENDENT TESTS CAN BE COMPARED.

ONE DRAG COUNT GOAL

- TESTS OF COMMERCIAL TRANSPORT AIRCRAFT DESIGNS HAVE SOME OF THE HIGHEST ACCURACY REQUIREMENTS IN PRODUCTION WIND TUNNEL TESTING.
- A REDUCTION OF THE DRAG COEFFICIENT OF A COMMERCIAL TRANSPORT AIRCRAFT IN CRUISE CONDITION BY ONE COUNT (0.0001 OR 1/10000) TRANSLATES INTO A PAYLOAD INCREASE OF ABOUT 1 PERCENT (SEE FOOTNOTE).
- THEREFORE, OVERALL UNCERTAINTY REQUIREMENTS OF A PRODUCTION WIND TUNNEL ARE OFTEN DESIGNED AROUND THE GOAL OF BEING ABLE TO DETECT A ONE DRAG COUNT CHANGE (OR BETTER) IN DATA OF A COMMERCIAL TRANSPORT AIRCRAFT.

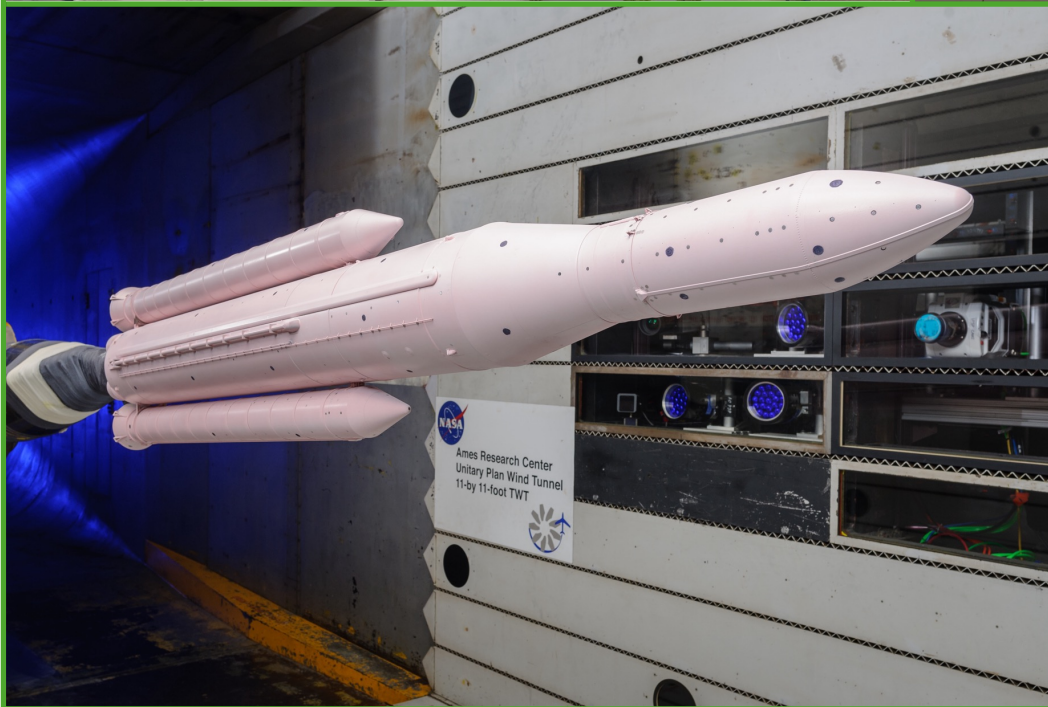
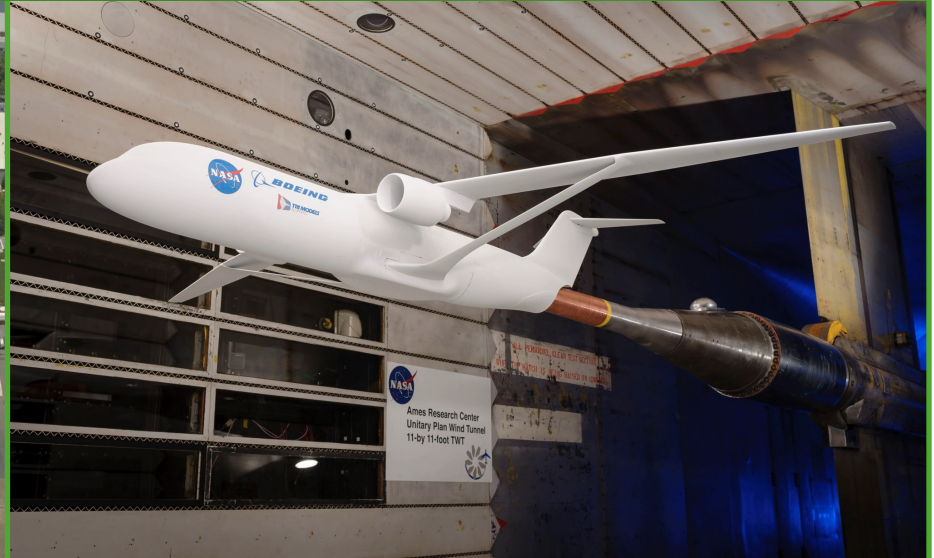
FOOTNOTE: INFORMATION WAS TAKEN FROM AIAA 2017-0484, P.25.

POINT ONE PERCENT

- LIST OF UNCERTAINTY REQUIREMENTS RESULTING FROM THE ONE DRAG COUNT GOAL ...
 - MACH NUMBER UNCERTAINTY < 0.001 0.1 % OF MACH NUMBER RANGE OF 1.0
 - DYN. PRESSURE UNCERTAINTY / DYN. PRESSURE < 0.001 ... 0.1 % OF DYNAMIC PRESSURE
 - ANGLE OF ATTACK UNCERTAINTY < 0.020 [DEG] 0.1 % OF ANGLE RANGE OF 20 [DEG]
 - LOAD UNCERTAINTY / LOAD CAPACITY < 0.001 0.1 % OF BALANCE LOAD CAPACITY
- WIND TUNNEL DATA CAN MEET THE 0.1 % REQUIREMENT AS LONG AS THE UNCERTAINTY OF EVERY SINGLE ELEMENT OF THE MEASUREMENT CHAIN IS CONTROLLED.
- NASA AMES UNITARY PLAN WIND TUNNEL MAINTAINS ITS HIGH LEVEL OF ACCURACY BY REGULARLY ASSESSING DATA FROM A CHECK STANDARD MODEL TEST WITH METHODS FROM STATISTICAL PROCESS CONTROL.

UNCERTAINTY CHAIN ELEMENTS

	TEST ARTICLE DESCRIPTION	FLOW FIELD DESCRIPTION	INTEGRATED LOADS
WIND TUNNEL TEST	➤ <i>MODEL FABRICATION</i> - MACHINING TOLERANCES - MODEL SCALE - GAPS BETWEEN MODEL PARTS	➤ <i>FLOW FIELD MEASUREMENTS</i> - MACH NUMBER - DYNAMIC PRESSURE - ANGLE OF ATTACK ➤ <i>REYNOLDS NUMBER EFFECTS</i> - LAMINAR-TO-TURBULENT TRANSITION (TRIP DOT SIZE & PLACEMENT) - VORTEX STRUCTURE - ONSET OF FLOW SEPARATION ➤ <i>INTERFERENCE EFFECTS</i> - SUPPORT SYSTEM - WIND TUNNEL BOUNDARIES (WALLS)	➤ <i>BALANCE LOAD PREDICTION</i> ➤ <i>CAVITY PRESSURE CORRECTION</i>
CFD	➤ <i>NUMERICAL DESCRIPTION OF TEST ARTICLE GEOMETRY</i>	➤ <i>NAVIER-STOKES EQUATIONS</i> ➤ <i>MESH SHAPE & DENSITY</i> ➤ <i>TURBULENCE MODEL</i> ➤ <i>SOLUTION CONVERGENCE CRITERIA</i>	➤ <i>SURFACE PRESSURE INTEGRATION</i>



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