Aeronautics Evaluation and Test Capabilities (AETC) – Boundary Value Wind Tunnel Introduction

Test Technology (TT) Subproject

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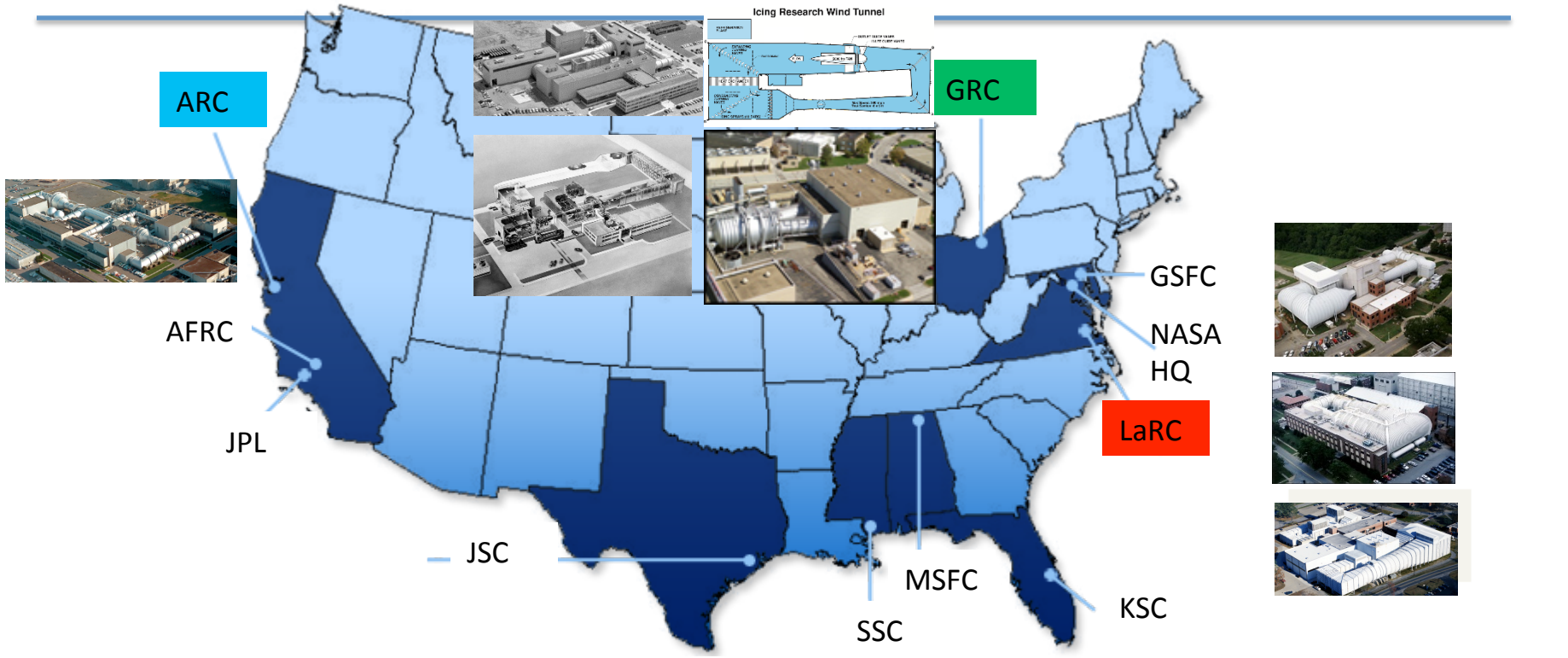


Outline



- Orientation
  - Introduction to AETC and TT subproject
  - Introduction to Capability Challenges
  - Funding model changes in FY17 and beyond
- Premises
  - Doing CFD for tests is important
  - CFD needs boundary conditions
  - We can measure boundary conditions
- Basic Questions
  - What boundary conditions can we measure
  - How accurately
  - In which facility
- Three possible feasibility studies
- A complementary approach: Simulation of entire wind tunnel circuit
- Summary
  - Are premises correct?
  - What boundary condition measurements are most valuable?
  - What is the best way to move forward?

AETC Facility Locations and Summary

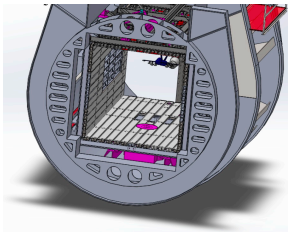


ARC	11x11	General purpose transonic	GRC	IRT	Subsonic icing
ARC	9x7	General purpose supersonic	GRC	PSL	High altitude engine test cell with icing
GRC	10x10	Supersonic propulsion/aerodynamic	LaRC	NTF	Transonic full-scale Reynolds number
GRC	8x6	Supersonic propulsion/aerodynamic	LaRC	TDT	Transonic aeroelastic
GRC	9x15	Subsonic propulsion & acoustics	LaRC	14x22	Subsonic general purpose

AETC Overview



Operations and Maintenance Support for Tunnels Such as the LaRC 14x22 Wind Tunnel



Capability Advancement Support Such as the "Optical Test Section of Tomorrow" at the Ames Unitary Plan Wind Tunnel

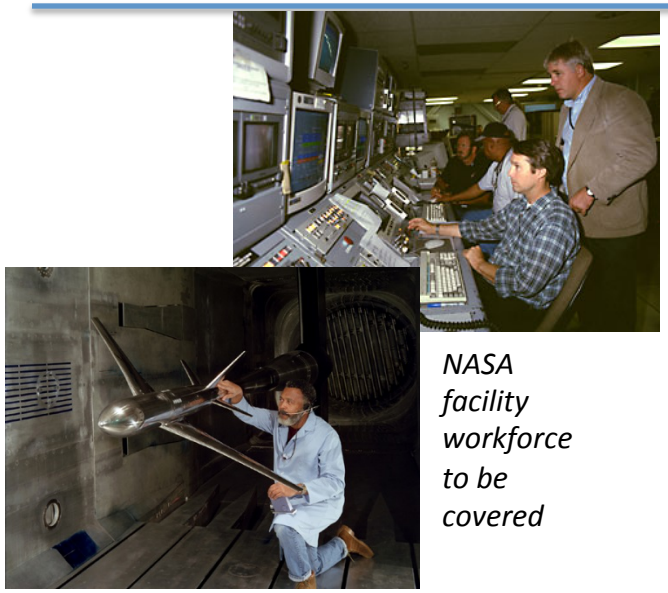


Test Technology Support Such as Force and Moment Test Techniques

AETC will invest in workforce and assets (facilities and related systems and support tools) necessary to meet technical needs within ARMD. The investments are broken down into four elements:

- ✓ **Operations:** Funds directed to key facilities to support labor and procurement needs and close resource gaps on full cost operations while maintaining stable and competitive operating rates.
- ✓ **Maintenance:** Funds directed for the maintenance of key facilities to ensure current and future operations while minimizing risk to ARMD testing.
- ✓ **Capability Advancement:** Funds directed to create new capabilities needed by ARMD in specific facilities. They include larger-scale investments in areas such as data systems, tunnel and model controls, new test environments, and facility systems.
- ✓ **Test Technology:** Funds directed to improve measurement capabilities (pressure, force, flow, and temperature), test techniques and processes, and develop technologies critical to meeting ARMD research needs and applicable to a multitude of facilities.

Aerosciences Ground Test Capabilities New Funding Model



NASA facility workforce to be covered



Consumables for testing

- A stable, sustainable funding model has been approved for NASA's Aeroscience Ground Test Capabilities
  - The NFM starts in FY17
  - Operations costs for a planned capacity will be *covered* by ARMD, HEOMD, SMD, and STMD. This is analogous to the High End Computing Program.
  - For FY17 and FY18, Operations costs for the planned capacity, except capability consumables, will be *covered* for NASA testers. All customers will still have to fund:
    - Capability consumables (e.g., electricity, LN2, R-134a)
    - Models, models consumables, and special instrumentation and test techniques
    - Non-facility workforce (e.g., acoustics researchers)
    - Over-capacity hours
  - For FY19-21, all internal Operations costs, including capability consumables, will be *covered* for NASA testers
  - External customers will continue to pay hourly utilization rates plus consumables plus test-specific costs
- NASA collaborations, partnerships, and agreements with external entities are encouraged, and the expectation is testing under these partnerships could be *internal/covered*. Any issue(s) will be resolved by the Aerosciences Test Advisory Board (ATAB).
- In March 2016, there will be a call by the ARMD Aeronautics Evaluation and Test Capabilities (AETC) Project to NASA Mission Directorate programs, projects, and supporting technical leaders to collect facility testing requests for 2017 and out

Investment Areas- Capability Challenges (CC)

AETC has Capability Challenges (CC) that define

- Specific near-term goals that address new facility capabilities and test technologies needed to successfully enable the future testing requirements of ARMD technical challenges.
- The CC provides the optimal emphasis for the AETC investment portfolio based on the needs of ARMD research projects.

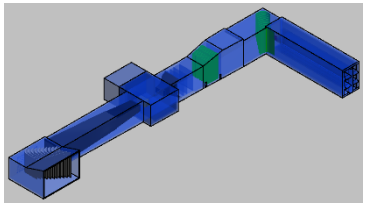
Capability Challenges are analogous to the aeronautics research efforts addressing "Technical Challenges"

- 4 CCs defined for Capability Advancements
- 3 CCs defined for Test Technologies
- No CCs for Operations and Maintenance

Current AETC Project FY15 CCs defined based on previous ATP focus and later assessed and validated through AETC Capability Assessment process



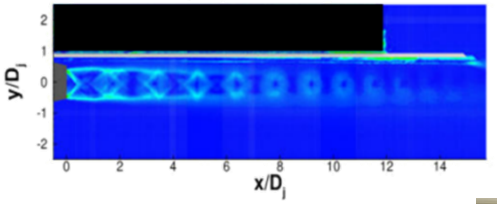
Optical Test Section of Tomorrow



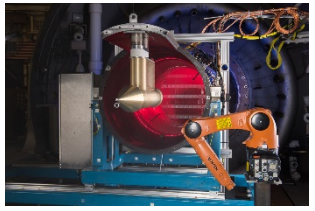
Reduce Background Noise



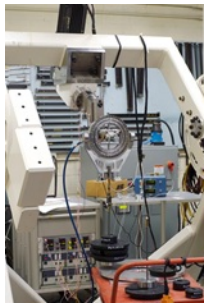
New Icing Capabilities



Optical Instrumentation



Calibration and Characterization



Force Balance

Possible New Capability Challenges

- Technologies for advanced powered testing.
  - Develop technologies to perform testing with powered models with no loss of productivity or accuracy relative to unpowered models.
  - Rationale: Next generation of aircraft will require much closer airframe/powerplant integration, which will require powered testing.
- Mapping boundary conditions for CFD/experiment integration.
  - Develop the capability to measure test section boundary conditions routinely during testing for input to CFD.
  - Rationale: Current large tests are all combined with CFD, but accurate CFD requires knowledge of inflow conditions which tunnels do not regularly provide.

Premises (Things I Claim Are True)

- All large wind tunnel tests are done as part of design or research projects which have a strong CFD component. Getting accurate CFD of the model in the wind tunnel is important.
- CFD of the model would be significantly improved if test section boundary conditions were better known – and getting better boundary conditions is the best thing the wind tunnels can do now to improve CFD.
- With reasonable investment the wind tunnels can provide boundary condition measurements useful to CFD.
  - Overall cost range $300-500K over 2-4 yrs.
  - Can start with just one or two AETC facilities

Pathway for Defining a New CC Around Measurement of Boundary Conditions

- Are the premises true – or at least not obviously false?
- Get preliminary answers to some basic questions.
  - What flow quantities should be measured?
  - In which facilities?
  - With which instruments?
- Come up with some small-scale projects which will help prove feasibility of the idea.
  - Could be funded out of (sub)project reserve or any hypothetical augmentation.
  - Executable in FY16.

Basic Questions

- What are the measurement parameters?
  - Prioritized list of most important conditions/flow properties to be measured.
    - Inflow properties (velocity, pressure, temperature, density, turbulence level).
    - Outflow properties (same as above)
    - Sidewall boundary layers
    - Sidewall pressures (often already available)
  - How accurately must boundary conditions be measured?
  - Are measurements required during the test (biases work toward non-intrusive measurement techniques) or can they be done with empty test section (periodic surveys ok)?

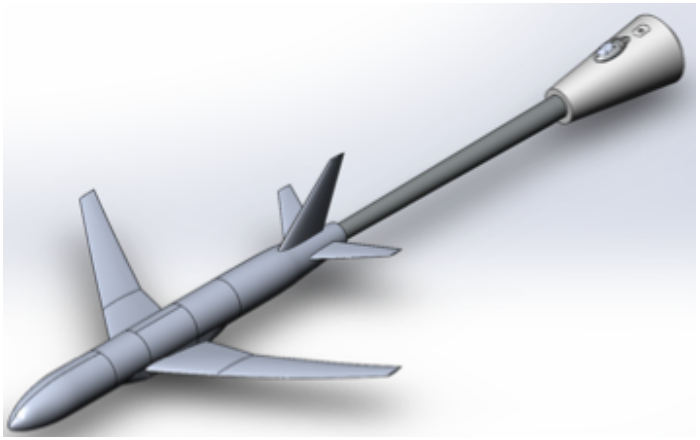
Basic Questions Continued…

- Which facilities should be prioritized
  - Which facilities are the easiest to work in
    - 14x22 has low speed, removable sidewalls.
    - 11x11 has new Optical test Section of Tomorrow.
    - 10x10 and NTF would probably be hard.
  - Which facilities would give the biggest payoff
    - 11x11: Many tests per year.
    - NTF: High impact tests.
    - 14x22: Useful for Juncture Flow Model tests.
- Which measurement techniques
  - PIV: Non-intrusive flow velocity but complex.
  - QWSS: Fast 5-hole survey probe but not NASA-owned.
  - Boundary layer rakes?
  - Other techniques?

Possible Assessment Project #1

- It may be possible to do a quick set of CFD studies to assess how sensitive OVERFLOW is to changes in boundary conditions.
- Tim Barth has some sensitivity software that is tailored to OVERFLOW.
  - Can specify uncertainty probability laws for inflow parameters.
  - Can specify correlated random fields for inflow data.
  - Outputs uncertainty statistics and error bounds on uncertainty statistics including CFD realization error.
- Could be used two ways
  - Estimate CFD uncertainty based on our current understanding of how well we know the boundary conditions.
  - Estimate CFD uncertainty resulting from expected uncertainty of different measurement techniques.

Possible Assessment Project #2



ARC 11x11 Check Standard Model (M. Amaya)



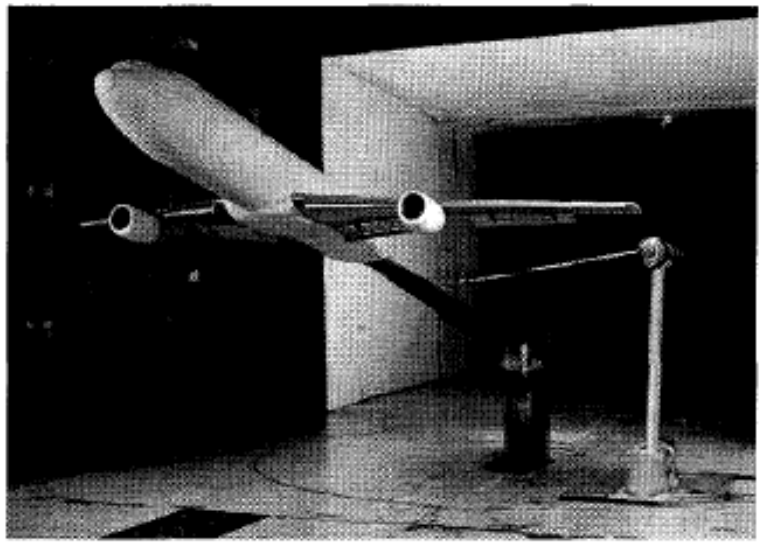
QWSS in BVWT (Yadlin et. al. AIAA 2010-324)

- New check standard model for 11x11 will be completed this March (CRM wing & fuselage with simplified tail). First test expected this summer.
- Boeing has developed QWSS (Quantitative Wake Survey System), a high accuracy, high reliability 5-hole probe wake survey instrument able to operate in transonic wind tunnels.
- Install QWSS in 11x11 and survey inflow with and without check standard model installed.
- Parallel CFD simulation to look for accuracy improvement when QWSS data are incorporated.

Possible Assessment Project #3



Juncture Flow Model in 14x22

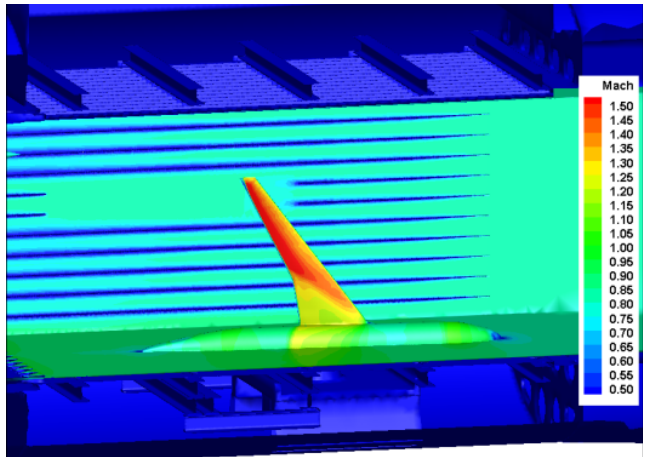


QWSS in 14x22 (Crowder et. al. AIAA 1997-5535)

- Juncture Flow Model developed for CFD validation testing in 14x22 and tested in Nov 2015. A second test is expected this summer.
- LaRC is proposing to offer PIV for non-intrusive surveys of flow around model during the summer test.
- Boeing has developed QWSS (Quantitative Wake Survey System), a high accuracy, high reliability 5-hole probe wake survey.
- Could install QWSS in 14x22 and survey inflow with and without Juncture Flow Model installed. QWSS has been used in 14x22 before.
- Parallel CFD simulation to look for accuracy improvement when QWSS data are incorporated.

Complete Wind Tunnel Simulation

- Most common current approach to CFD of wind tunnel models is to simulate only the test section, but it may be possible to get better results by simulating more of the circuit.
- Simulations of high speed leg:
  - Used at ARC by Melton & Hawke.
  - Used to model proposed facility improvements.



- Simulations of entire circuit:
  - 14x22: Simulations of high speed leg done by Nayani et. al. (AIAA 2015-2022) and gridding of entire circuit is in process.
  - NTF: Work underway to measure and grid entire circuit.
  - 9x15: Simulations being done for current project to improve tunnel acoustics.
- Should be considered as a complementary approach.

Points For Discussion

- Is this a good idea overall?
- If so ...
  - Best flow quantities to measure.
  - Required accuracy.
  - Best facilities.
  - Answers to these questions will be interdependent.
- Define feasibility studies
  - White paper?
  - CFD sensitivity study.
  - Piggyback wind tunnel test.
  - Other.





- Backup