NASA AETC Test Technology Subproject

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Test Technology in the AETC Project Structure

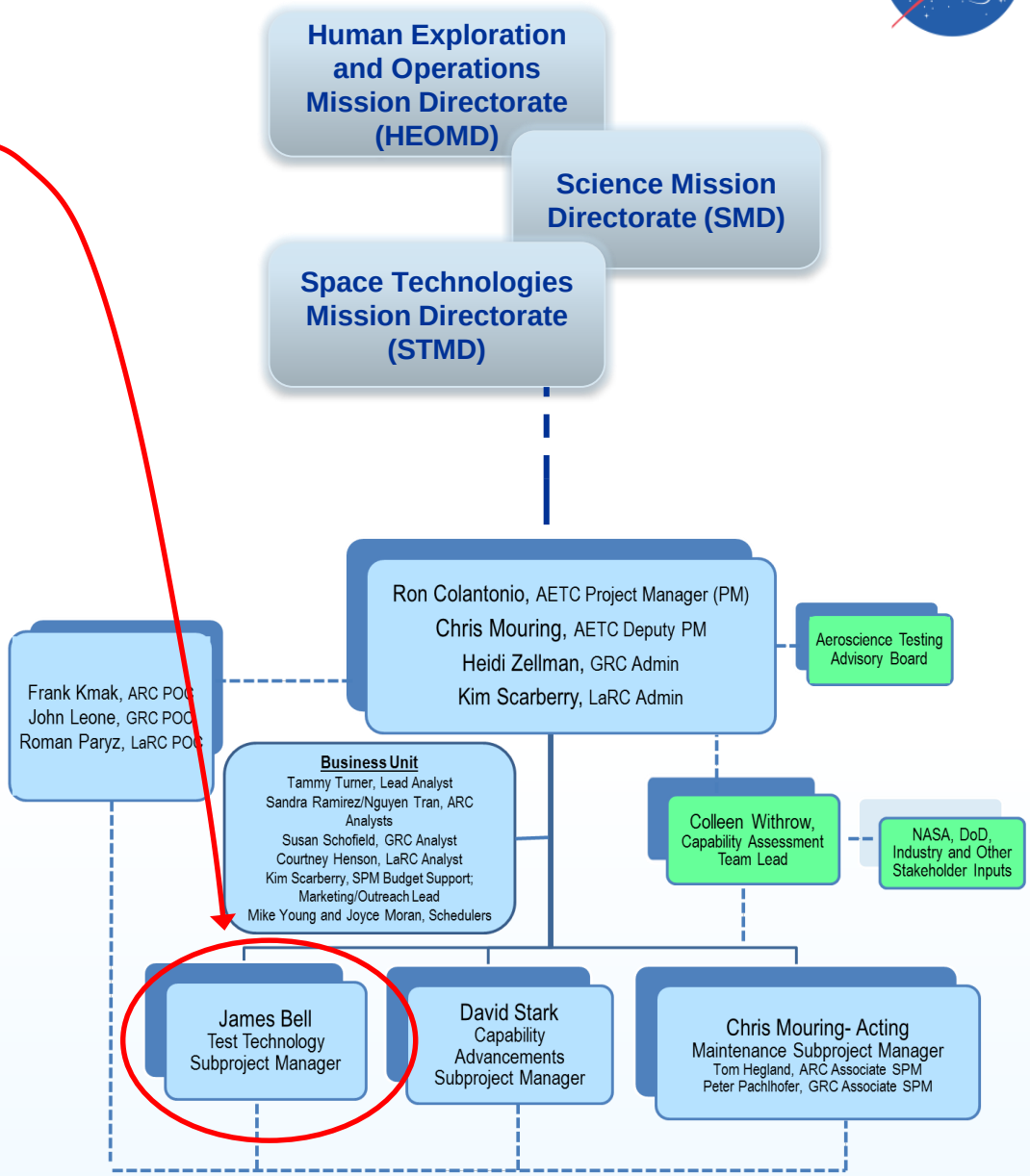
TEST TECHNOLOGY

Funds directed to improve measurement capabilities (pressure, force, flow, and temperature), test techniques and processes, and develop technologies critical to meeting NASA research needs and applicable to a multitude of facilities.

Primarily works by funding small ($40K - $400K) tasks which result in a demonstration or initial capability of a new technology in an AETC facility.

TT research and development tasks are generally TRL 3-6; they should be things which work in small scale or lab environments but need further development for use in production facilities.

TT differs from CA in its focus on smaller-scale tasks and on instrumentation. Technologies developed by TT may become CA projects in order be fully realized within a facility.



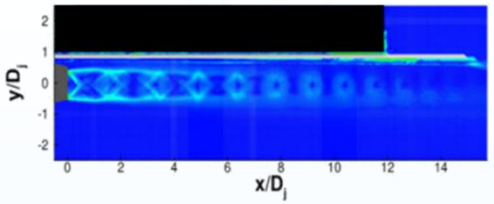
Capability Challenges for Test Technology

AETC develops and completes Capability Challenges in the same manner that other ARMD projects take on and complete Technical Challenges.

Capability Challenges provide a means to organize the wide variety of Test Technology tasks into a set of deliverables which can be clearly articulated. The Capability Challenges are intended to support the goals of our NASA test customers, as articulated through the ARMD Strategic Implementation Plan.

When AETC was stood up in 2015, three Capability Challenges were identified through an initial review of ARMD plans. Further Capability Challenges can be added as resources are freed up by the completion of old CCs.

1. CC-TT-01 Optical Instrumentation for Advanced Flowfield Measurements Needed for Next Generation Computational Simulation Development and Validation [FY15-19]

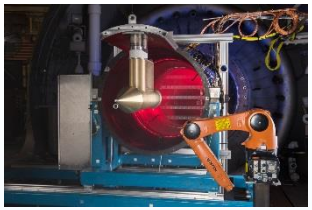


Optical Instrumentation

2. CC-TT-02 Force Balance Repeatability and Accuracy to Accommodate Needs of Advanced Aircraft Design Wind Tunnel Models [FY15-19]

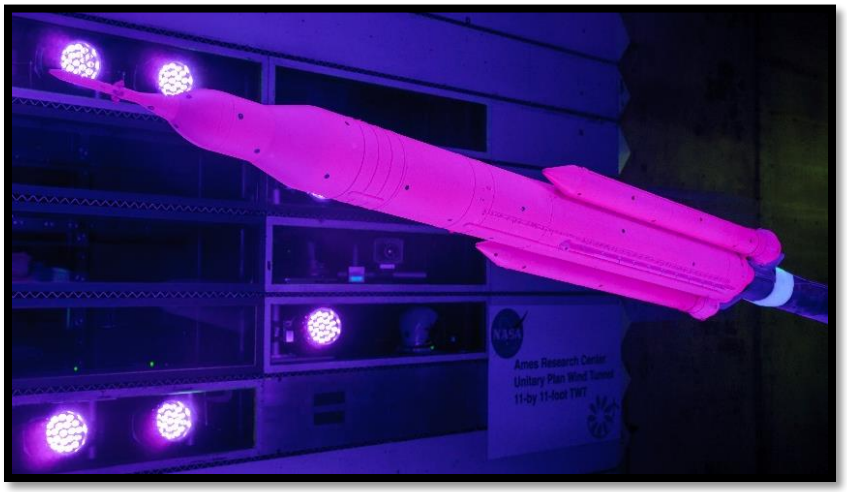
Force Balance

3. CC-TT-03 Integrated, NIST-Traceable Calibration and Characterization of Wind Tunnel Facilities [FY15-19]

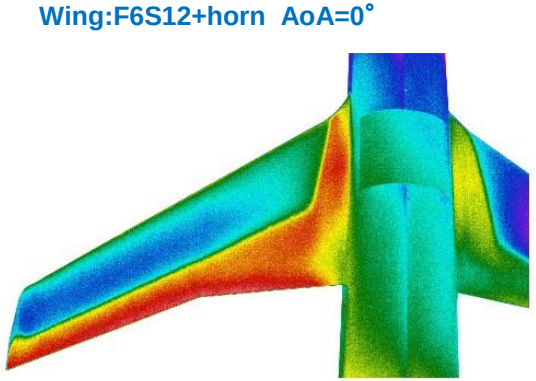


Calibration and Characterization

CC-TT-01 Optical Instrumentation



SLS model with PSP applied in ARC 11x11



IR Thermography showing transition on Juncture Flow Model in LaRC 14x22

Optical Instrumentation for Advanced Flowfield Measurements Needed for Next Generation Computational Simulation Development and Validation

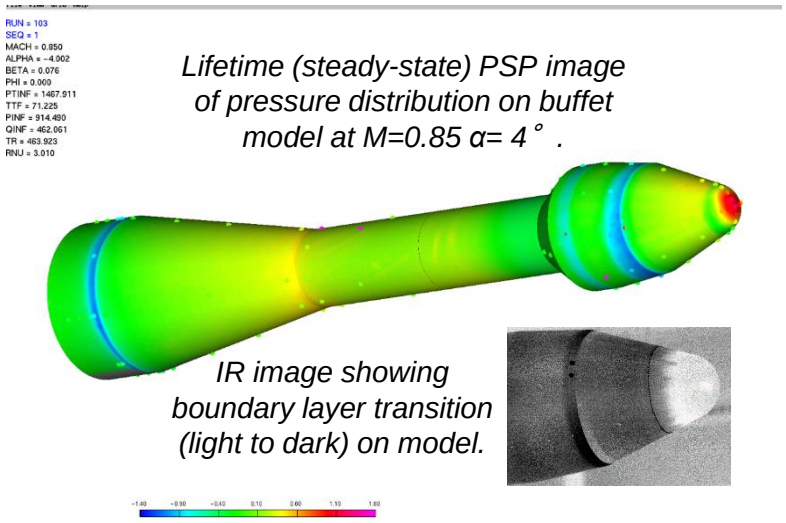
Description: Provide initial deployment of advanced optical instrumentation in AETC facilities to support CFD validation, wind tunnel characterization, flow diagnostics, and assessment of wind tunnel model performance.

Objective: Enable acquisition of next generation aerodynamic test data required by researchers and modelers to further develop CFD tools.Funds directed to improve measurement capabilities (pressure, force, flow, and temperature), test techniques and processes, and develop technologies critical to meeting NASA research needs and applicable to a multitude of facilities.

Optical Techniques

Pressure-Sensitive Paint

Developing production-level systems for routine use of time-averaged PSP for flow diagnostics and loads measurements, and developing initial capability with unsteady PSP. The unsteady PSP activity is initially focused on transonic buffet, but extending to flows in turbomachinery. The work primarily involves integration of cameras, lamps, and data reduction software, but also includes the development of new higher-brightness paints.



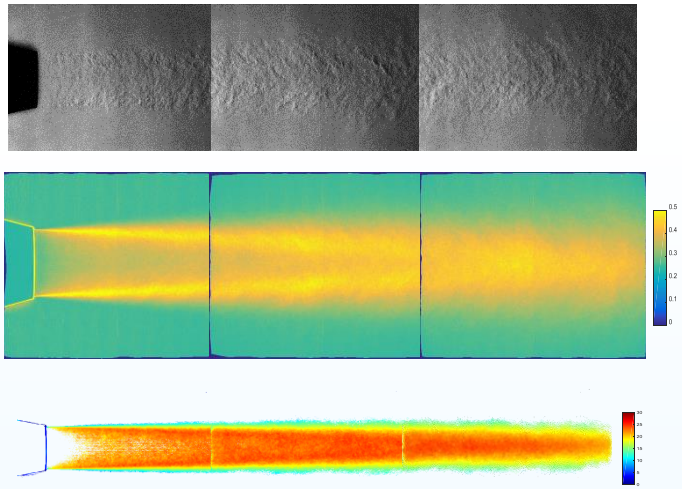
Lifetime (steady-state) PSP image of pressure distribution on buffet model at M=0.85 α= 4° .

IR image showing boundary layer transition (light to dark) on model.

Advanced Schlieren

Developing schlieren and shadowgraph systems which can produce quantitative data on different aspects of the flow. These include:

- Tracking of shock and vortex positions with photogrammetric and/or plenoptic schlieren.
- Seedless velocimetry by tracking flow disturbances.
- Measuring frequency spectra of flow disturbances with high-speed shadowgraph.



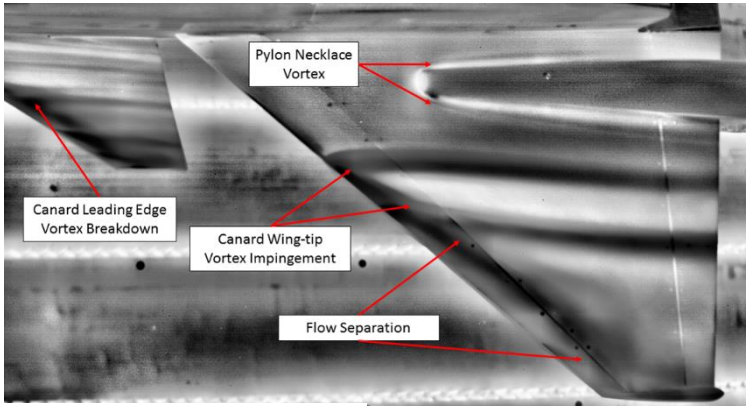
Focusing Schlieren Velocimetry image of jet flow AAPL. Raw data plus streamwise velocity.

Optical Techniques (cont'd)

Infra-Red Thermography

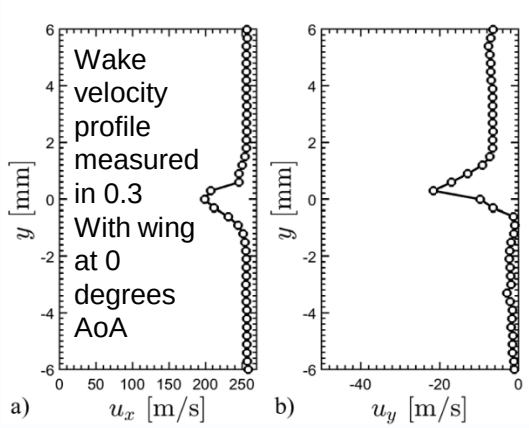
We have developed an automated multi-view IR thermography system for the ARC 11x11, and prototype systems for the LaRC 14x22 and 8' HTT. Highly sensitive modern IR cameras can detect transition without having to ramp tunnel temperature. Data system automatically scales images and records data over the entire test.

IR image of HATOL model in ARC 11x11.



Femtosecond Laser Electronic Excitation and Tagging

This technique can obtain off-body flow velocity, temperature, and density without seeding the flow. It is suitable for cryogenic nitrogen environments and thus will give us an off-body velocimetry technique usable in the LaRC National Transonic Facility.

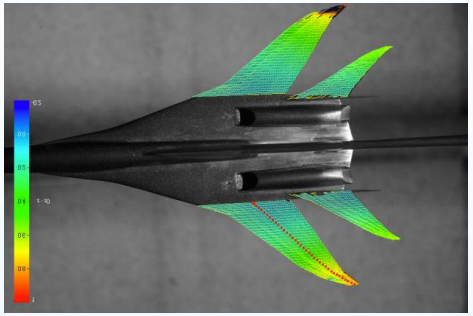


Used a wing model in Langley's 0.3 m Transonic Cryogenic Wind Tunnel; profile location shown

Photogrammetry

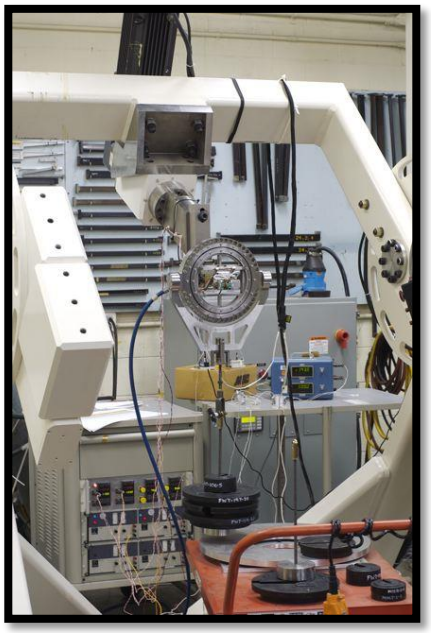
Used to obtain wind tunnel model deformation data at several AETC facilities. Test Technology is addressing the challenge of providing rapid, reliable data reduction to allow model deformation and angle of attack to be determined in real time.

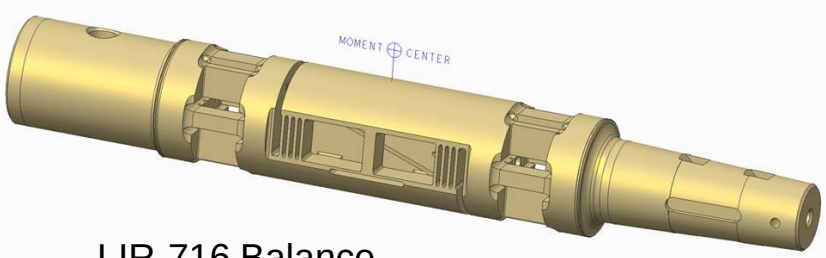
Sonic boom model in ARC 9x7. Image is colored according to model deformation.



CC-TT-02 Force Balance

Single Vector System balance calibration apparatus





LIR-716 Balance Design

CC-TT-02 Force Balance Repeatability and Accuracy to Accommodate Needs of Advanced Aircraft Design Wind Tunnel Models

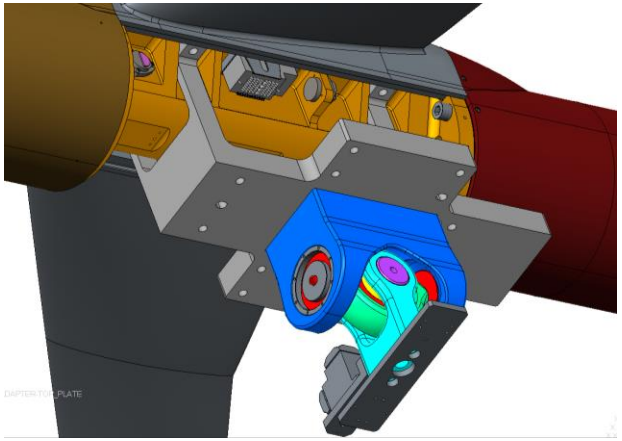
Description: Develop new balance technology which will enable more accurate force and moment measurements on models to meet the needs of a new generation of higher L/D aircraft designs.

Objective: Double the force balance accuracies as applied to advanced aircraft having 50% higher L/D ratios.

Force Balance Improvement

In-Situ Load System

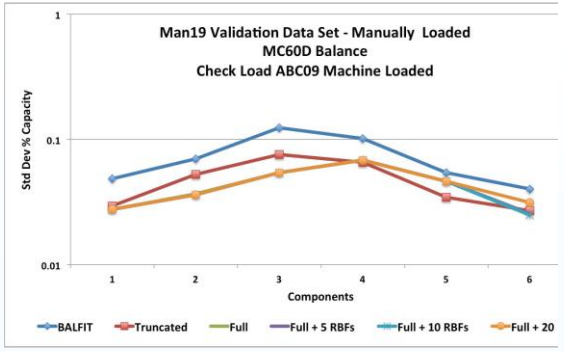
The ILS will allow high precision, repeatable loads to be applied to balances built up in a wind tunnel model in the model prep area or test section. This will allow balance calibrations to be verified under actual use conditions and help understand whether calibrated balance accuracies can be achieved under real-world conditions. It may also help estimate bias errors due to installation (e.g. wiring bridging the balance).



ILS bearing block (blue/green) attached to balance block of wind tunnel model using adapter plate (grey). Configured to supply positive normal loads using gravity.

New Math Models for Balance Calibration

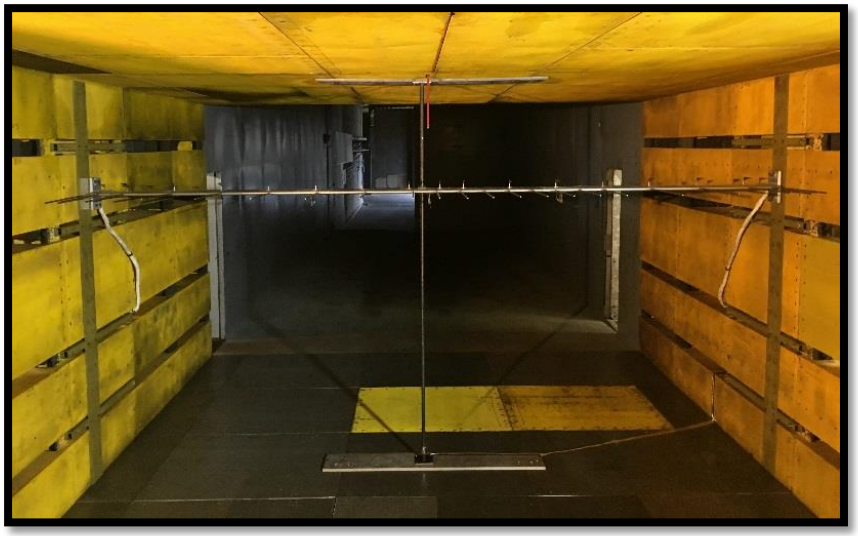
Develop new hybrid non-iterative and non-parametric balance load calibration methods using Gaussian radial basis functions. New methods show promise for being able to more closely fit balance calibration data than traditional math models currently used with balances.



Comparison of Balance Math Model Residuals

CC-TT-03 Wind Tunnel Calibration

New Check Standard Model for ARC 11x11



Old flow characterization rake (to be replaced) in GRC 9x15

Integrated, NIST-Traceable Calibration and Characterization

Description: Develop the capability to routinely and efficiently characterize all AETC wind tunnels using documented NIST-traceable procedures and equipment, and provide training to allow these tasks to be performed consistently and repeatedly for enhanced data quality.

Objective: Harmonize test calibration and characterization best practices across the AETC supported facilities.

Wind Tunnel Characterization

Check Standard Models

Check standard testing is a vital component of statistical process control for AETC facilities. Replace existing inventory of worn-out and obsolete check standard models with modern designs appropriate to each tunnel's range of test conditions. Investigate areas where a common model or model design might serve multiple facilities

New check standard model for ARC 11x11 assembled in machine shop.

Assessment of Flow Characterization Hardware

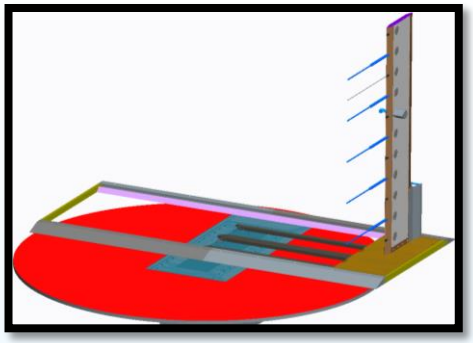
Examine NASA's inventory of flow characterization hardware to assess it's condition, identify what portion is useable for modern flow characterization hardware, and identify what pieces of hardware can be loaned between facilities. US Air Force facilities at AEDC and WPAFB also participated.

Hardware Assessment Task Force Chair, Ross Flach (ARC) inspects one of the GRC cone cylinder models during the team's field trip to Plum Brook Station.

Flow Characterization Rakes

Design and build new flow characterization rakes where needed due to poor condition of old hardware or changes to the facility. Ongoing projects include new traversing total pressure rakes for the GRC IRT and a new multi-purpose traversing rake for the GRC 9x15 to be used after acoustic modifications to that facility are completed.

CAD model of new traversing rake for GRC Icing Research Tunnel.

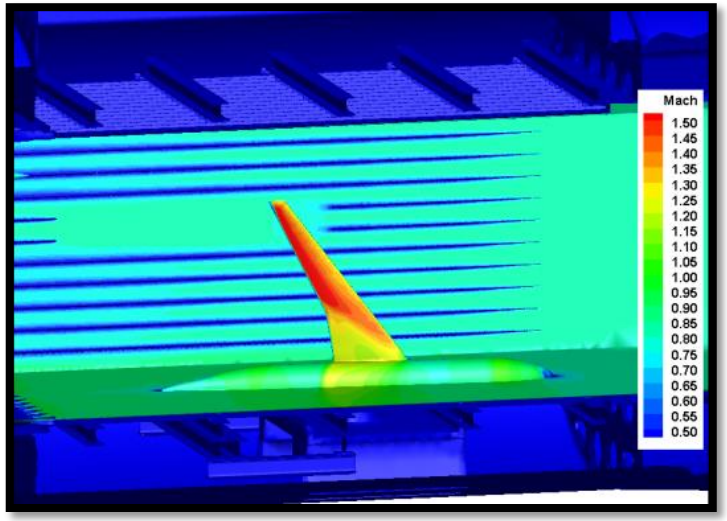


CC-TT-?? Developing New Capability Challenges

- As original Capability Challenges are completed, funding becomes available to pursue newly-developing ARMD needs.
- Working Groups are composed of personnel from the various NASA centers who have an interest and expertise in the group's particular subject.
- Working Groups do the following
  - Maintain NASA's base of expertise in technologies which are critical to the operation of AETC facilities.
  - Develop new technologies and techniques associated with their area of expertise and infuse these into the AETC facilities.
  - Provide redundancy by ensuring support exists across multiple centers.
- Working Groups can range from very formal organizations with explicit goals and funding provided by AETC, to informal groups which simply allow members to exchange information.
- Not everything the Working Groups do is Test Technology.

CC-TT-?? Boundary Value Wind Tunnel

Boeing Quantitative Wake Survey System (QWSS) used to survey inflow conditions ahead of Juncture Flow Model in LaRC 14x22



Simulation of flow around a generic semi-span model in ARC 11x11, with partial blockage of slot baffles due to new schlieren windows.

As facility capabilities and customer needs evolve, new Capability Challenges become apparent. The 'Boundary Value Wind Tunnel' is an example of one such emerging CC.

Current aerodynamic R&D tasks typically involve both a CFD and experimental component. To combine the two requires the ability to properly compute flows around models in wind tunnels. This requires knowledge of the computational boundary conditions. But current wind tunnels rarely provide boundary condition data such as inflow profiles, outflow pressures, or wall boundary layer data.

The new CC would combine research to determine what boundary conditions need to be specified, and how accurately, with work to develop wind tunnel instrumentation needed to provide boundary condition data.

Non-CC Tasks

Some Test Technology tasks do not fit within any Capability Challenges but are needed to address facility or customer needs. Two examples are given below:

Next-Generation Miniature Pressure Sensors

Work with vendors developing new Electronic Pressure Sensor modules. New modules offer higher accuracy and are smaller or have other advanced features such as built-in networking capability for output via Ethernet. Task funds acquisition of 'beta-test' units from vendors and developmental testing with new units to reduce risk prior to deployment.

High Temperature Position Sensors

Models with moving parts in high temperature tunnels such as the GRC 10x10 require accurate position sensing at temperatures beyond the capability of current suppliers. Funds a search for new COTS suppliers for sensors.

National Force Measurement Technical Committee

- **Increase critical skilled knowledge, advance technology in existing and new balances, related systems and demonstrate integrated systems performance using these technologies**
- **Primary objectives of the NFMTC**
  1. Re-capitalize NASA strain gage balance inventory
  2. Develop a best practices for NASA strain-gage balance technology
  3. Improve balance calibration capabilities
  4. Establish and maintain staffing to sustain capability
  5. Reduce task/contract ‘turn-on’ time
  6. Increase research and development investments
  7. Collaborate with DoD
  8. Collaborate with industry and academic partners
  9. Be recognized as the force measurement consultants for NASA

- **Strategic investment of resources to maintain the capability <u>in addition to</u> satisfying the testing requirements of our customers**

Enhancing Balance Capability

Revitalizing NASA Balance Inventory

Design and fabricate a new series of balances to serve the emerging needs of NASA projects. This is to include:

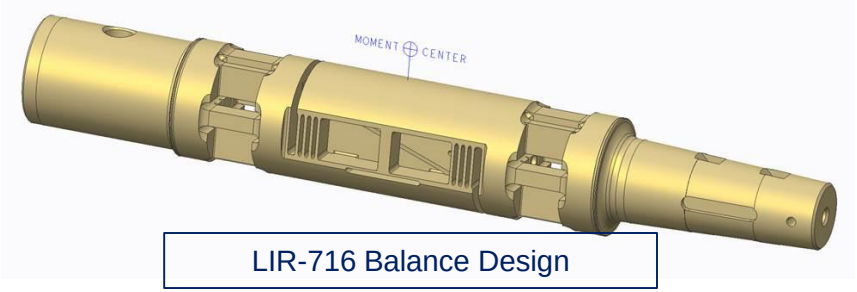
1. A new high accuracy single-piece balance for the ARC 11x11 check standard model.
2. A new rotating balance for fan testing at GRC.
3. New multi-purpose balances.
4. Other new balances as forecast by demand model.

Support Complex Balance Operations at NASA Facilities

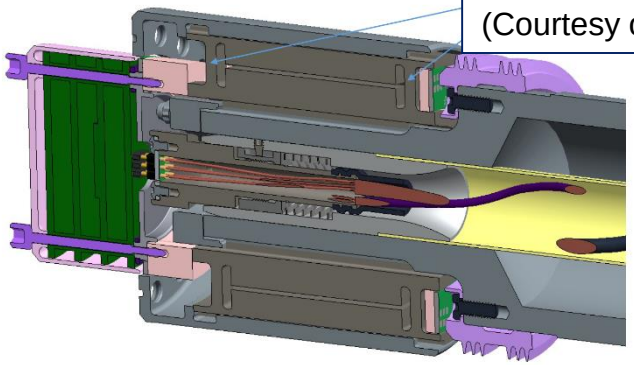
Maintain NASA's balance calibration facilities. Provide operational support when a facility needs balance expertise beyond the facility's capabilities (e.g to support investigations of balance problems, or tests which have a very complex or unusual balance setup.)

Advance Balance Understanding

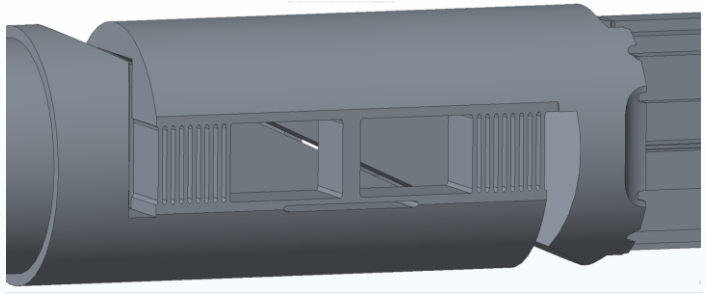
Develop a strategy for integrating finite element analysis into the balance operational readiness checkout process. Investigate new balance design and manufacturing techniques.



LIR-716 Balance Design



GRC 2-C concept (Courtesy of GRC)



Current design iteration of the LIR-1016 balance.

Working Groups

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Concluding Remarks

- Test Technology is something of a grab bag of activities.
  - "Research-oriented" activities such as supporting dynamic PSP, advanced Schlieren, and model deformation measurements.
  - Very basic "must-do" activities like maintaining the balance inventory and building calibration rakes.
- Test Technology was not set up this way intentionally – this is what evolved in response to facility needs.
- Common features of Test Technology activities.
  - Relatively small scale.
  - Can rapidly respond to changing circumstances – lots of different mechanism for approaching problems.
  - Connectivity to ARMD technical challenges.
  - Support current and emerging AETC facility needs.