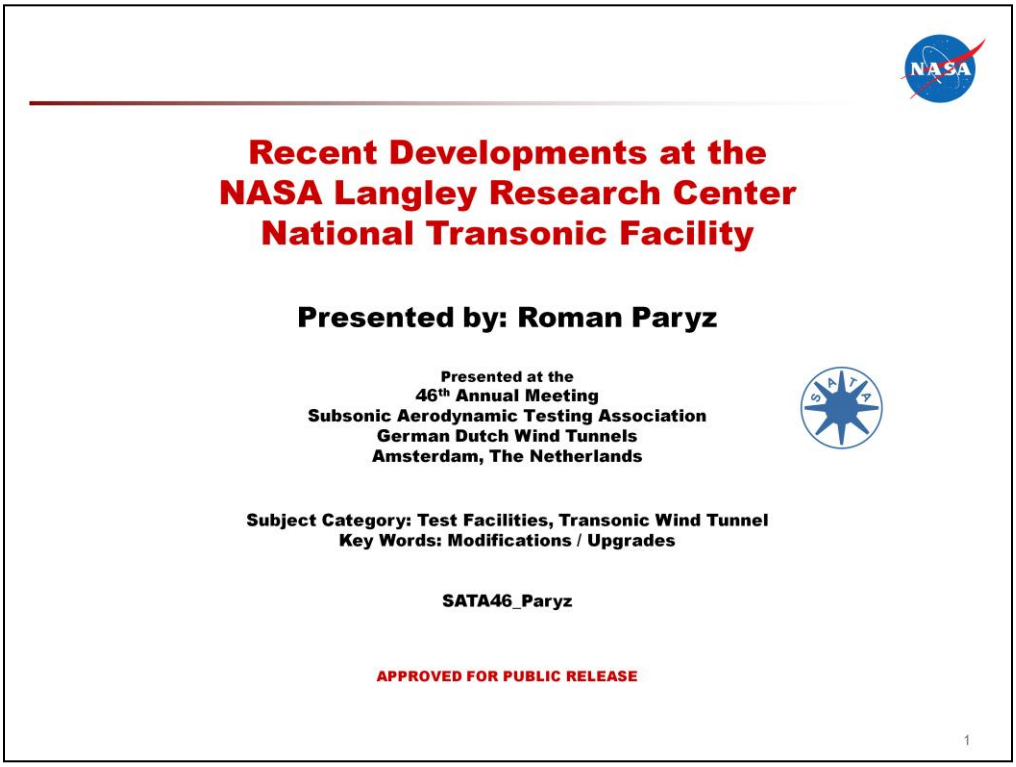


Recent Developments at the NASA Langley Research Center National Transonic Facility

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Subject Category: Test Facilities, Transonic Wind Tunnel
Key Words: Modifications / Upgrades

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Abstract:

Several upgrade projects have been completed or are just getting started at the NASA Langley Research Center National Transonic Facility. These projects include a new high capacity semi-span balance, model dynamics damping system, semi-span model check load stand, data acquisition system upgrade, facility automation system upgrade and a facility reliability assessment. This presentation will give a brief synopsis of each of these efforts.

Outline



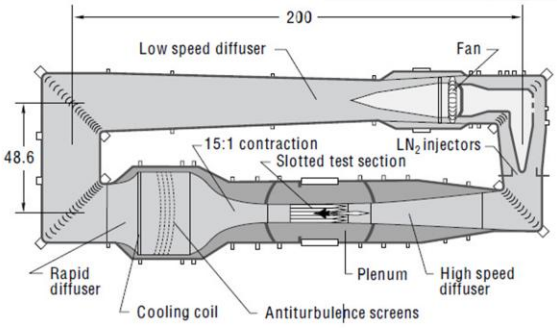
- **NTF Overview**
- **Completed Projects (Recent)**
  - Liquid Nitrogen Plant
  - New Semi-span Balance
- **Projects Just Finishing**
  - Model Dynamics Damping System
- **Projects Just Getting Underway**
  - Semi-span Model Check Load Stand
  - Data Acquisition System Upgrade
  - Facility Automation System Upgrade
  - Facility Reliability Assessment

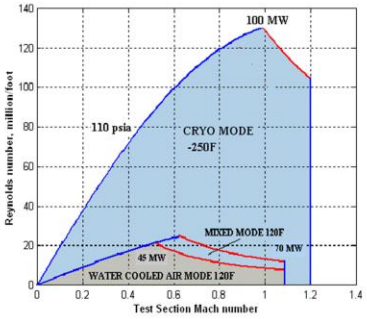
National Transonic Facility – NTF USA

25 Years of High Reynolds Number RDT&E



Test Section	8.2 x 8.2 x 25 Feet (2.5 x 2.5 x 7.6 meters)	
Pressure	14.7 to 125 psia; 1 to 8.5 atm.; 1.01 to 8.6 bar	
	Air Operations	**N_2 Operations**
Mach No.	0.1 to 1.05	0.1 to 1.20
Reynolds No. Max	$20x10^6$ / ft ($65x10^6$ / m)	$145x10^6$ / ft ($475x10^6$ / m)
Temperature	90° to 150°F (32° to 65°C)	-50° to -250°F (-45° to -157°C)





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The National Transonic Facility (NTF) is a fan-driven, closed-circuit, continuous-flow cryogenic pressurized wind tunnel that became operational in 1984. The facility has the capability to adjust test conditions to match model size and has independent control of total temperature, pressure, and fan speed allow isolation and study of pure compressibility (Mach) effects, viscous (Reynolds number) effects, and aeroelastic (dynamic pressure) effects. Combinations of these test parameters can yield Reynolds numbers from 2 to145 million per foot (6.6 to 475.7 million per meter). The test section is approximately 8.2 feet (2.5 meter) by 8.2 feet (2.5 meter) and 25 feet (7.6 meter) long with a cross sectional area of 66.8 ft^2 (6.2 m^2). The test section has six slots in the ceiling, six slots in the floor, 14 re-entry flaps in the top and bottom walls to prevent the flow from choking the tunnel at near-sonic conditions, and a 6% openness ratio based on the wall surface area (wall divergence set at zero). NTF can be operated using either air or nitrogen as the test medium. During air operations temperature is controlled by a water-fed heat exchanger located in the settling chamber. During nitrogen operations the temperature is controlled by evaporating liquid nitrogen which is dispersed into the tunnel circuit just upstream of the fan through 296 nozzles in 12 bundles at a maximum rate 1,100 lbs/sec (9,680 gal/sec; 36K liters/sec). 430 tons of LN_2 is produced on site per day and stored in two tanks with a total capacity of 3,800 tons (1,150M gallons; 4.4M liters) These two modes provide the ability to operate the tunnel between -250°F (-157°C) and +150°F (+65°C). Thermal insulation that resides inside the pressure shell minimizes energy consumption. Pressure is controlled by two large vent valves connected to the tunnel circuit between turns #3 and #4. The facility can operate from 14.7 psia (101.4KPa) to 125 psia (861.8 Kpa) (1 to 8.5 atmospheres; 1.01 to 8.6 bar) in either medium. The tunnel drive system is powered by a variable speed motor that has variable maximum torque or power output up to 360 RPM. At 360 RPM the maximum power is 135,000 Hp (101 MW) and that maximum power level is maintained up to 600 RPM. The compressor consists of a fixed pitch, single stage 25 bladed fan with variable inlet guide vanes. For fine Mach number control, the inlet guide vanes are varied to achieve the required compression ratio to maintain the desired Mach number. Temperature can be maintained within ± 0.3°F (0.17°C) for N_2 operations or ± 1°F (0.56°C) for air operations; Pressure ± 0.07 psi (482 Pa); Mach no ± 0.001 or better.

The NTF provides testing in support of stability and control, cruise performance, stall buffet onset, and configuration aerodynamics validation for both full-span and half-span models. The model support system is a circular arc sector that provides an angle-of-attack range of -11.5° to 19.0° at a rate of up to 4° per sec. The strut incorporates a roll drive with a range of -90° to 180° which, in conjunction with the pitch of the strut, is able to provide pitch and yaw data. The normal force load capacity of the strut is 27,000 lbs. Several sting and strut combinations are available for testing of aerodynamic models. The NTF can accommodate various types of internal 6-component strain gage balances. Onboard angle-of-attack accelerometers are available that include thermal conditioning systems for cryogenic operation.

LN2 Plant

- Directly adjacent to NTF
  - Built in 2007 by Air Products
  - Eliminates the need to truck in LN2 or direct Praxair line
  - Supplies 1.5x more than previous method
- Produces ~430 tons per day
  - 143K gallons (541K liters) per day
  - Supplies Two Tanks
    - 800 ton Main Tank (250K gallons / 946K liters)
    - 3,000 ton Storage tank (900K gallons / 3.4M liters)
- Lower Cost



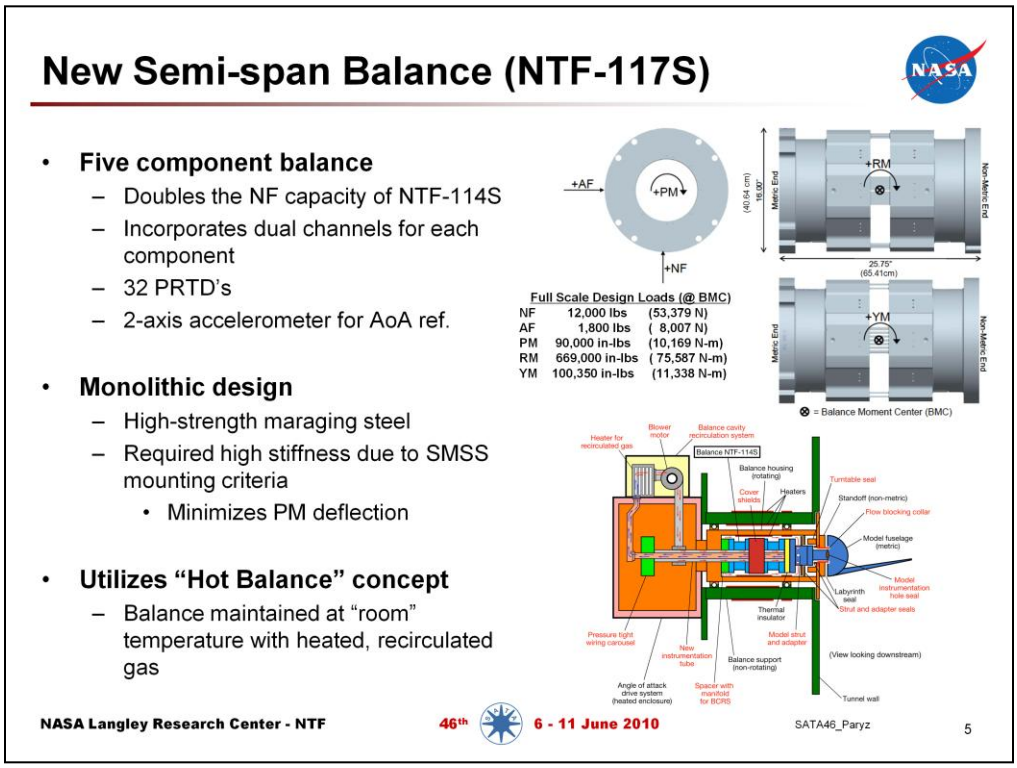
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NASA-Langley has constructed a liquid nitrogen plant immediately adjacent to the NTF. Cost was minimized by utilizing the existing infrastructure including a closed building and interfacing with the truck delivery station piping. Noise from the main air compressor (MAC) was abated by locating the MAC in the existing building. Locating the plant close to the truck fill station simplified the interface to the NTF liquid nitrogen transfer system. Risks of handling other liquefied gases have been reduced by venting the gases back to the atmosphere. This plant produces only liquid nitrogen for the NTF. NTF contract personnel operate and maintain this plant; which became operational in 2008. The plant has a production capacity of 430 tons of liquid nitrogen (LN2) per day. The off-site commercial plant produced about 300 tons/day. With this facility improvement NASA has full control of the production of LN2 to operate the NTF. In addition, NASA implemented the ability to fill a 6,000 gallon LN2 tanks that previously required truck delivery. This tank, which is connected to a vaporizer, provides gaseous nitrogen (GN2) purges to a myriad of systems including cryogenic pumps, tank annulus, main air compressor and cold boxes. The capability to fill this tank eliminated the need for truck delivery of nitrogen to maintain the GN2 purges. To reduce the time required for starting the plant NASA implemented the capability to pump liquid nitrogen from the storage tanks back to the plant. This feature is used to establish the necessary liquid levels in the plant before production and storage can begin. The highly automated LN2 plant runs independently of the NTF; therefore, production and storage of LN2 can occur concurrently with normal cryogenic wind tunnel operations. With the increased LN2 production capacity NASA-Langley can now fill the NTF LN2 tanks in less than nine days. Before installation of the new plant 13 days were required to fill the tanks. The new LN2 plant reduced the time required to complete a typical cryogenic test cycle, and decreased the cost of LN2 due to the elimination of commercial profit. This capability provides for more efficient testing at the NTF.

Reference AIAA 2009-419 - Selected Major Modifications To The National Transonic Facility

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The semi-span model test technique at the NTF has traditionally focused on high-Reynolds number testing of low-speed high-lift configurations. The NTF-114S balance used for this testing is not well suited for transonic testing due to the elevated model loads generated. A larger load capacity balance, the NTF-117S was fabricated to obtain this high load data.

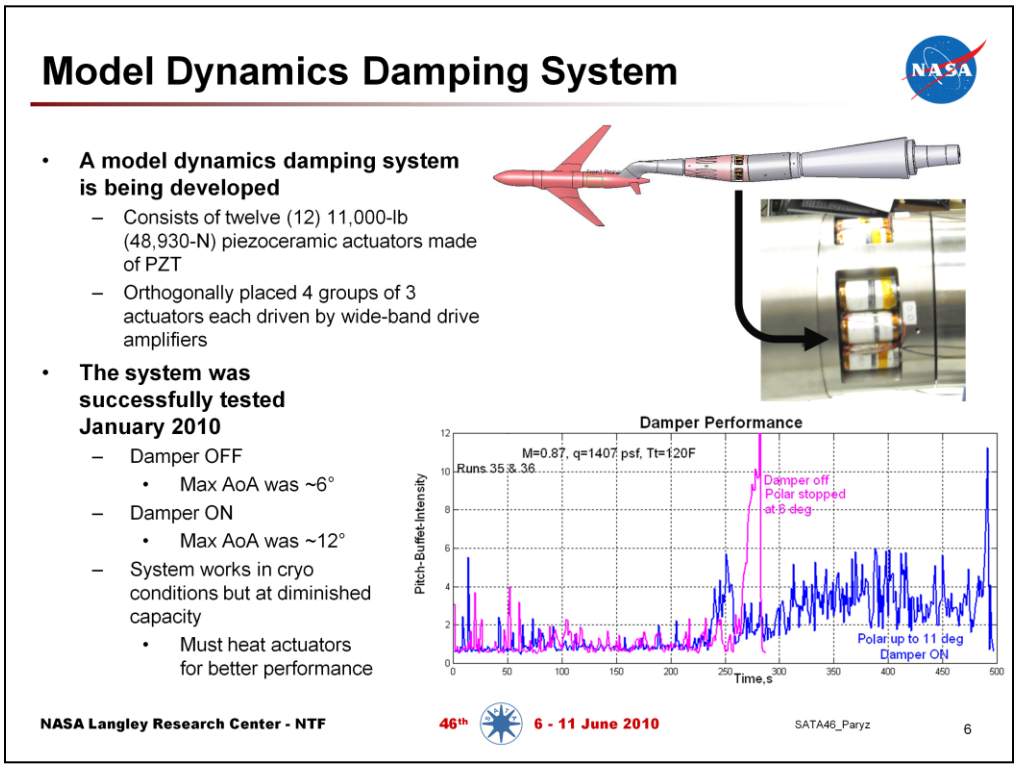
The NTF-117S is a monolithic balance made from a single piece of high strength maraging steel. Its overall dimensions are approximately 16 inches (40.64 cm) in diameter by 25.75 inches (65.41 cm) long and it weighs approximately 900 pounds. It is a five-component balance, measuring normal force, axial force, pitching moment, rolling moment, and yawing moment. The balance instrumentation consists of a primary and secondary sets of strain gage bridges. Thirty-two platinum resistance temperature detectors (PRTDs) monitor the balance temperature profile. These temperature sensors are strategically located to provide a global temperature profile as well as localized measurements near the strain gages. The balance design also contains a two-axis on-board accelerometer that provides an absolute reference of the balance attitude. The on-board accelerometers also provide a direct transfer of the balance calibration coordinate system to the wind tunnel model coordinate system. This is especially important since a flow angularity technique has not been developed for semi-span testing, and therefore the offset between the balance axes and the model axes must be mechanically determined.

The design requirements of the NTF-117S were also unique in the area of stiffness. In this case, model dynamics were not the driving factor for the stiffness requirement. The stiffness requirement was due to the unique assembly of the semi-span model system. This assembly requires a minimization of the pitching moment deflection of the metric portion of the model relative to the non-metric standoff. In this system there is a non-contacting seal between the model standoff (non-metric) and the model fuselage (metric). A high torsional (pitching moment) stiffness of the balance was requested to maintain this gap under aerodynamic loading.

During tunnel operations, the balance is heated and maintained at room temperature or above. Since this "hot-balance" concept has been adopted; the calibration of the semi-span balances includes a complete room temperature calibration and primary calibration at 150 degrees Fahrenheit. The elevated temperature calibration is used to determine coefficients that compensate for the change in sensitivity as a function of temperature.

The design and fabrication of this second generation NTF semi-span balance has been completed. This balance will provide enhanced force measurement capability for continued investigations of high-lift systems of aircraft at near flight Reynolds numbers.

	NTF-114S		NTF-117S	
Normal Force - NF lbs (N):	6,100	(27,134)	12,000	(53,379)
Axial Force – AF lbs (N):	1,000	(4,448)	1,800	(8,007)
Pitching Moment – PM in-lbs (N-m):	70,000	(7,909)	90,000	(10,169)
Rolling Moment - RM in-lbs (N-m):	350,000	(39,545)	669,000	(7,558)
Yawing Moment - YM in-lbs (N-m):	76,000	(8,587)	100,350	(11,338)



Common Research Model (CRM) with active Model Dynamics Damping System

The front, upswept, sting for this configuration is fabricated from Vascomax 200/250, the damper body is INVAR36, and the stub-sting at the rear is made of A286. The INVAR36 and A286 have vastly different coefficients of thermal expansion. The damper consists of twelve (12) 11,000-lb (48,930-N) piezoceramic actuators made of PZT orthogonally placed around the adapter in 4 groups of three actuators each. The actuators are driven by wide-band drive amplifiers capable of driving 30-microfarad actuators for the damper.

The basic principle and function of a damper is to generate a dissipating energy based on the stored energy in the sting. For the CRM sting system, 12 joules are released in 25 milliseconds (1/4th of first mode frequency of 10 Hz-100ms) equating to a power of 600 watts. Piezo devices can absorb this energy as current of appropriate polarity as determined by balance feedback, using an appropriate control laws driven by balance moments. The piezo cluster thus has to dissipate 12 joules in 25 milliseconds. (At 10Hz sting mode, quarter wave occurs in 25 ms). At a voltage rate of 24,000 V/s, (600 volts in 25 ms) the flow of current into the 15 microfarad cluster is 0.36 amps, and this amounts to 2.7 watts or 5.4 watts for pitch axis for max energy of 12 joules. As shown below, there is enough dissipation in the piezo devices to quickly damp the oscillations.

During January 2010, the damper system was installed at NTF and tested in air mode. The Mach number range was from M=0.70 to M=0.92. Dynamic Pressure varied between 1,200 and 1,400 psf (57.5 and 67.0 KPa). Angle of attack range varied from -3° to +12°. Three model configurations, wing & fuselage, wing-fuselage with nacelle, and wing-fuselage with tail were tested. The model encountered severe buffet at angles above 6°.

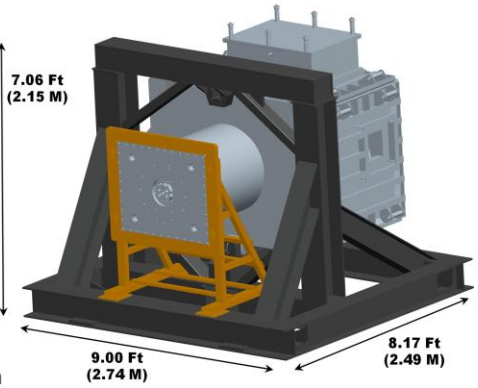
The figure above shows damper ON and Off runs. Pitch buffet Intensity is defined as an rms value of normal force fluctuations normalized by flow fluctuations without buffet at low angles of attack. With damper off, the pitch buffet intensity was roughly ten (10), while with damper on it dropped to about four (4), nearly a three-fold improvement. **Runs without the damper were forced to terminate at ~6° angle of attack. Runs with the damper active achieved ~12° angles.**

The system was also checked out at cryogenic temperatures. Even at -250° F (-157° C), the actuators work well except that the energy level dropped to 20% of the level at ambient conditions; hence they were not as effective. The loss of capacitance from 15 μF down to 3 μF at -250° F has resulted in a 80% loss of performance in energy capability; hence damper performance has been poor under cryogenic conditions. In future designs it will be necessary to find methods to keep the piezo actuators warm so that damping functions work at designed efficiency.

This system is being developed for NTF under a task order contract with ATK; Dr. S. Balakrishna.

Semi Span Model Check Load Stand

- **An enhanced calibration / check-loading load frame in development**
  - Matches full capacity of the Sidewall Mechanism Support Structure (SMSS)
    - NF = 27,000 lbs (120,102 N)
    - PM = 150,000 in-lb (16,948 N-m)
  - Allows for transporting the SMSS from the model build-up bay to the test section
  - Provides intermittent calibrations capability for semi-span balances
  - Load stand/cart retains the same basic volume / footprint as current cart design
  - Incorporates test section wall plate simulator for additional checkout
  - Weight of stand/cart will not exceed 5,000 lbs (2,268 Kg)



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A new load frame was required that is capable of supporting check-loading of semi-spans that are mounted internally to the Sidewall Mechanism Support Structure (SMSS). The motivation behind this project was to provide the NTF with a permanent in-house capability for check-loading semi-span balances (and semi-span models) up to full-scale design loads. It will also provide intermittent calibration capability for semi-span balances. The check-load stand is designed such that it allows for transporting the SMSS from the model build-up bay to the tunnel. The structure will be a weldment utilizing readily available materials.

To be compatible with existing facility structure and interfaces the following requirements were imposed:

• Load stand/cart must retain the same basic volume as current cart design
• Air casters must retain same nominal separation distance within ± 2 in (5 cm)
• Weight of stand/cart should not exceed 5,000 lbs (2,268 Kg)
• Maintain flatness of interface to 0.050 in (1.27 mm) across all 4 surfaces
• Design to allow for loading up to NF = 27,000 lb (120,102 N) & PM = 150,000 in-lb 16,948 N-m) loads at a distance of 43 in (1.09M) away from the SMSS mounting plane interface.
• Acceptable FOS > 2.0
• Load Frame to be permanently located in Bay #1
• Modify bay to accept secure mounting to floor during loading
• Allows for the routing / bridging of high pressure air lines

During the check loading process:

• A calibration interface will be mounted to the top-hat, and will be securely mounted to the bellows
• Calibration hardware will be designed/constructed, that will allow for applying loads to the balance, either via dead weights applied in the basement below Bay #1, or with hydraulic actuators
• Inner turntable inside the SMSS can be rotated such that both NF and AF components of the balance can be check-loaded via hanging a dead weight from the metric end of the balance.

ARRA Upgrades at NTF

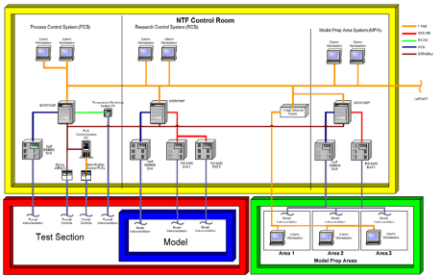


- **On Feb. 13, 2009, the US Congress passed the American Recovery and Reinvestment Act of 2009. The ARRA has three immediate goals:**
  - Create new jobs and save existing ones
  - Spur economic activity and invest in long-term growth
  - Foster unprecedented levels of accountability and transparency in government spending
- **NASA LaRC has received ~$14M in ARRA funds for facility upgrades**
  - NTF ~$9M for three projects
    - Data Acquisition System (DAS) Upgrade
    - Facility Automation System (FAS) Upgrade
    - Facility Reliability Assessment (and potential upgrades)
  - 14x22 LSWT ~$5M for three projects (not covered in this presentation)
    - Enhanced Rotor Test Cell Capacity
    - Phased Array Acoustic Traverse Mechanism
    - Jet Engine Simulator Fuel Supply and Purge Systems
- **All work must be completed no later than April 2011**

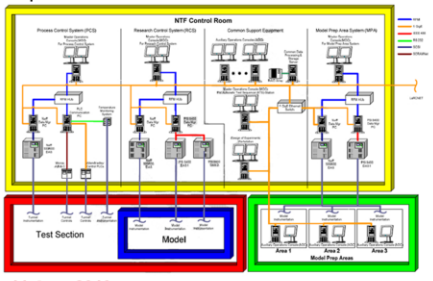
Data Acquisition System (DAS) Upgrade

- **Three system DAS is early 90's vintage**
  - Research Computer System (RCS)
  - Process Computer System (PCS)
  - Model Prep Area (MPA) DAS
  - All based on MODCOMP architecture
    - No longer supported / limited upgrade capability
- **New system will be PC (Windows) based**
  - Utilizes commercial-off-the-shelf data acquisition and supervisory control software
    - Test SLATE (Jacobs Engineering)
  - Provides 5x increase in throughput to 27 KBps
  - Provides 4x increase in scan rate to 200 Hz
  - Doubles A / D channels to 256 / 16
- **New features to be added**
  - Integrates the Dynamic DAS (DDAS) into the tunnel DAS systems operations
  - Automatic Test Sequencer (ATS)
  - Dedicated Design of Experiment (DOE) workstation
- **Five phase upgrade effort underway**
  - Design study, Preliminary design, Final (critical) design, Equipment / software bench-top integration, Facility installation

Current DAS



Proposed DAS



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The existing NTF Data Acquisition System (DAS) consists of three systems; a Research Computer System (RCS) DAS, a Process Computer System (PCS) DAS and a Model Preparation Area (MPA) DAS. These systems are based on the 1992 MODCOMP Real/Star systems (VME Bus architecture using a MODCOMP proprietary Operating System) platform that is no longer supported by industry, has limited expandability and does not have the capability to be simply upgraded to meet the increasing research needs for data quality that requires advanced data collection and analysis test techniques, data storage capability and system security requirements. Additionally, all three systems, hardware and software are obsolete and beyond their expected life with a limited number of spares/replacement parts and, therefore, must be replaced. The objective of this task is to improve the technical capability of the NTF in providing continued high-quality, high Reynolds number testing by upgrading the existing Data Acquisition Systems (DAS). This upgrade will improve the NTF's technical viability in the form of advanced data collection, analysis and signal processing techniques, while assuring future cost effective systems for maintainability, reliability and data and physical security in integrated commercially available systems. System definitions are as follows:

Process Computing System (PCS): The PCS DAS performs as the plant state monitor and logging historian.

Research Computer System (RCS): The RCS DAS performs the data acquisition and calculations for tunnel parameters, test article measurements and various research specific measurements.

Model Preparation Area (MPA): The MPA DAS performs data acquisition and calculations for signals generated in the Model Preparation Area.

New Dynamic Data Acquisition System (DDAS): The new DDAS will be an integral part of the facility research data collection process on RCS. The DDAS shall collect data simultaneously with RCS at higher sample rates (up to 5 KHz) on 128 analog channels at 24-bit resolution (allowing real-time spectral analysis up to 512 Hz) and concurrently collect data from RCS and PCS to time correlate RCS and PCS data to the DDAS data. (Current system has 64 channels of 16-bit resolution and up to 5 KHz sample rate.)

Implement a new Automatic Test Sequencer (ATS): A new ATS shall be developed to facilitate automating the "Run" test matrix, and support future testing techniques such as conditional data sampling methods, continuous sweep data collection and Design of Experiments (DOE).

Implement a dedicated Design of Experiments (DOE) Workstation: A new dedicated DOE workstation for dynamic (on the fly) test planning and runtime modification shall be provided. This system shall be compatible with the new Automatic Test Sequencer (ATS), and contain the toolset and algorithms supplied by NASA that are necessary to allow the generation of DOE test matrices, as well as the ability to monitor and analyze data as it is acquired in near real-time.

This DAS Project involves the design, purchase, construction, integration, installation and verification of a new DAS System at the NTF by replacing the Research Computer System (RCS) DAS, the Process Computer System (PCS) DAS, and the Model Preparation Area (MPA) DAS, and integrates the Dynamic DAS (DDAS) into the tunnel DAS systems operations. All new systems shall be compatible with all current facility ancillary systems interfaces which include, but are not limited to, the Controls Systems, NEFF Instrument Corporation Analog to Digital Interfaces, Pressure Systems Inc. (PSI) Flow Reference System, PSI-8400 Systems, Programmable Logic Controllers, and Video Data Systems. In addition, the replacement system shall be adaptable to current industry standards to allow for future upgrades.

The DAS upgrade approach, system development, and implementation shall be accomplished in five distinct phases.

Phase 1 - Design Study:

Perform a Design Study Report that includes the Project Requirements and Conceptual Design which clearly shows the project definition, scope and performance requirements, a requirements document for the new systems and an assessment of the new systems capabilities.

Phase 2 - Preliminary Design Review (PDR):

Using the approved Design Study Report and Work Plan for Phase 2 to develop a Preliminary Design Review package for the new DAS. The package shall include, at a minimum, a draft Systems Requirements Document and cost/schedule/resource status and project management, risk and configuration management plans.

Phase 3 - Critical Design Review (CDR):

Using the approved Preliminary Design Review package, Design Study Report to develop a complete Critical Design Review package, including final Systems Requirements Document, integrated system design documentation, updated cost/schedule/resource status, project management, risk, life cycle maintenance and configuration management plans.

Phase 4 - Equipment, Software, & Bench Top Integration:

Proceed with development and/or acquisition of appropriate components (equipment, hardware and software) for system development, component integration, system integration and testing. The successful execution of the Demonstration and Verification Test Plan with results documented against System Requirements will be performed.

Phase 5 - Facility Installation:

Facility operations shall execute the Installation and Acceptance Testing Plans for installing and checkout the new DAS at the NTF. The contractor shall deliver a new integrated DAS system that has been verified through an acceptance test process and all supporting documentation (e.g., drawings, manual, schematics, calibration records) that are field verified, archived and under configuration control, along with a completed Operational Readiness Review package for presentation, review, and approval by the Contracting Officer. Additionally, the contractor shall provide NTF operations staff with detailed training and training documentation on the operations and maintenance of the new DAS systems.

All work will be completed by April 2011.

Facility Automation System (FAS) Upgrade

- **Upgrade the early 90's vintage control systems and safety interlock systems**
  - Improve system performance
  - Enhance control algorithms
  - Improve maintainability & reliability
- **Five step upgrade process**
  - Replace control system (3) microprocessors
    - Will use Programmable Logic Controller (PLC), Industrial Personal Computer (PC), and Panel View® Human Machine Interfaces (HMI)
  - Replace Programmable Logic Controllers
    - Do 1 for 1 replacement using new Allen-Bradley Control Logix 5000 units, populated with the equivalent modules
  - Perform design study to replace PSI Flow Reference System (FRS)
    - Current FRS is obsolete (not supported)
  - Develop a software-based simulation model of NTF processes and control systems
    - To develop and evaluate new control algorithms
    - Design / evaluate new testing techniques
    - Allow exploration of enhancements to tunnel systems / control algorithms
  - Perform a verification / validation test using the facility's Check Standard Model before and after upgrade





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The objective of this project is to improve the technical viability of the NTF in providing continued high-quality, high Reynolds number testing by installing a new tunnel controls system, replacing the existing safety interlock systems, determining critical system replacements, developing a tunnel simulation tool and conducting a demonstration and validation test. This entire project will improve the nation's ability to deliver programmatic results by implementing high-performance productivity enhancements to the NTF that improves the data quality, enhance current testing techniques, support new testing techniques, better maintainability and reliability and provide the LaRC continued support of advanced testing requirements.

The scope of this Task Order is divided into five subtasks, as described below. The first four subtasks can be completed independently, but all are required to be completed prior to the final Demonstration and Verification test identified in Subtask 5. Consideration needs to be given during the final integration, checkout, and verification of each subtask to minimize facility downtime.

Subtask 1: Replace the existing NTF Controls System Microprocessors.

Replace the existing NTF Controls System Microprocessors (1992 vintage) consisting of Microprocessors A, B, and C, user interfaces, and all controls and interlock functions with an existing single Programmable Logic Controller (PLC), Industrial Personal Computer (PC), and Panel View® Human Machine Interfaces (HMI).

Subtask 2: Replace the existing NTF Programmable Logic Controllers.

Replace the existing PLC A, B, C, and D from the Allen-Bradley Series 5 to ControLogix 5000 (or equivalent system). Each existing PLC shall be replaced one-for-one with a ControLogix 5000 in order to maintain the current relationship on logic solving, allowing for parallel inputs and series outputs as in the existing operating PLCs.

Subtask 3: Replacement Design Study for PSI Flow Reference System.

The current NTF PSI Flow Reference System (FRS) is a critical data quality measurement device that provides precision absolute and differential pressure measurements that are used in determining the tunnel Mach number. Pressure Systems, Inc. has discontinued the FRS and no longer carries replacement or spare parts. Additionally, PSI has chosen not to offer a replacement or upgrade system for the FRS. As a critical component of this subtask, a viable replacement alternative that meets or exceeds the current performance of the current system will be recommended.

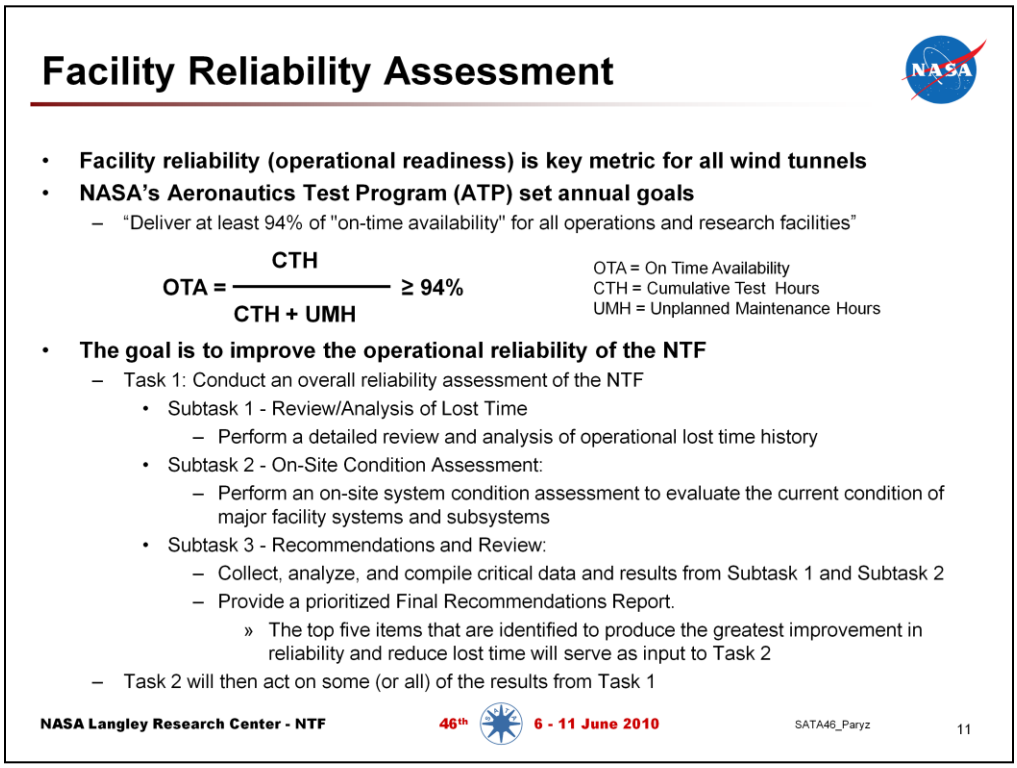
Subtask 4: Software-based Simulation Model of the NTF tunnel processes and control systems.

The NTF has complex control systems with strong interactions and dependencies. For example, Mach number control is effected by tunnel pressure, temperature, fan pressure ratio, and whether the tunnel is operating with air or nitrogen as the test gas. Optimization of the current control systems has been limited by the complexity and wide range of facility operational conditions, high operational expenses, risks, and extensive commitments of tunnel operational time. As a result, little new optimization or algorithm development has taken place. A software-based simulation model will be developed and implemented that will allow for this necessary optimization development work without the need to operate the tunnel.

Subtask 5: Demonstration and Verification Tests:

This SOW contains three subtasks (Subtask 1 – Controls Upgrade, Subtask 2 – Programmable Logic Controller Replacement, and Subtask 3 – Simulation Model) that require a demonstration of the operations and verification of performance of the systems developed under each subtask. Two tests will be conducted at the facility, to meet all the demonstration and performance verification requirements of this SOW. These two tests shall repeat the "NTF Check Standard Test" and also include a limited number of additional Cryogenic Operations test conditions to cover the cryogenic operational capability of the facility. The first test was conducted in March 2010 to obtain a baseline of the facility operations (both Air and Cryogenic Operations). After the completion of the Controls Upgrade, PLC Replacement, and the Simulation Model, a second test, identical to the first, shall be conducted. The comparison of the results from the second test and first test, thereby providing a measurable metric of the improvements made by the ARRA NTF Projects.

All work will be completed by April 2011.



Facility reliability (operational readiness) is a key metric for all service providers. The annual goal of NASA's Aeronautics Test Program (ATP) is to "***Deliver at least 94% of "on-time availability" for all operations and research facilities. On-time availability" is defined as cumulative test hours divided by the sum of cumulative test hours plus unplanned maintenance and repair hours. The intent is to capture the effect of unplanned maintenance and repair events on scheduled tests. Unplanned maintenance and repair can happen before or during a scheduled test."***
The objective of this task is to improve the operational reliability of the NTF. To achieve this objective, an operational reliability assessment that provides detailed recommendations for implementation to improve the operational reliability will be performed. Areas (items) will be identified to improve the operational reliability of the NTF and to optimize facility investments over the long-term. Facility reliability is sustained through reliability based maintenance strategies including a cost effective blend of preventive (time-based), predictive (condition-based) reactive (breakdown based) and programmed (budget based) maintenance investments. This Project will be divided into two Tasks. Task 1 will conduct an overall reliability assessment of the NTF and provide a prioritized list of improvements that can be made. Task 2 will then act on some (or all) of the results from Task 1. Task 1 will be divided into three distinct subtasks.

Subtask 1 - Review/Analysis of Lost Time: A detailed review and analysis of operational lost time history of the NTF will be performed. This review and analysis shall identify the operational lost time and the associated cost impact per lost time per system over the last four fiscal years (2006, 2007, 2008, & 2009) and include data from all related Mishap Investigation Reports.
Subtask 2 - On-Site Condition Assessment: An on-site system condition assessment will be conducted and documented to evaluate the current condition of major facility systems and subsystems. The physical condition of each major system and associated subsystems will be assessed; the effectiveness of the current maintenance program will be evaluated, spare parts inventory and systems operations will be investigated; the systems will be assessed against the "industry standards" toward maintenance and reliability of similar equipment. This Condition Assessment Report shall also include an evaluation of the systems with regard to safety of equipment, safety of workforce, system reliability, an estimation of remaining useful life and likelihood and cost of a system or component failure.
Subtask 3 - Recommendations and Review: Critical data will be collected, analyzed, and compiled and results from the Review and Analysis of Lost Time (Subtask 1), the On-Site Condition Assessment (Subtask 2) and recommendations of the Mishap Investigation Reports to provide a Final Recommendations Report and presentation to improve the NTF's reliability through reduced operational downtime. The Final Recommendations Report shall include a summary of the project scope; description, approach, findings and detailed recommendations in priority order that are considered necessary to improve the NTF's reliability in priority order necessary to improve reliability and reduce lost time and costs. The five items that are identified to produce the greatest improvement in reliability and reduce lost time and costs shall include a detailed estimate of cost and schedule to implement the recommendation. The remaining items identified shall include a parametric estimate of cost for future implementation.

The results from Task 1 will then form the basis to initiate Task 2 which will implement the findings of Task 1.

All work will be completed by April 2011.

Most Unique Upgrade

- **Commercially available system was revitalized**
  - Older equipment (1956) is still functional
    - Hardware is in very good shape and still serviceable
      - Requires some refurbishment
        - » They don't build them like this anymore
    - Software requires significant re-programming
      - Must be adapted to different operating environment
  - Equipment had to relocated from a much older facility
    - Transportation of system was uneventful
      - Still being acclimated to temperature extremes
- **System is fully operational as of 21 Dec 2009**

