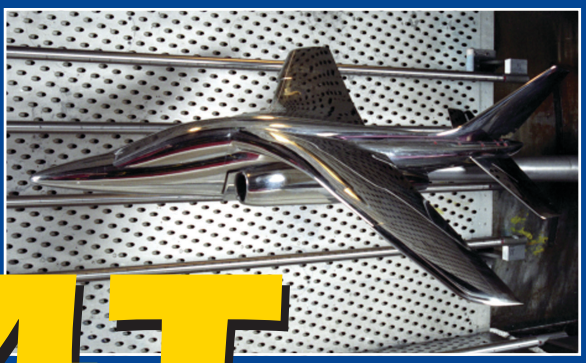
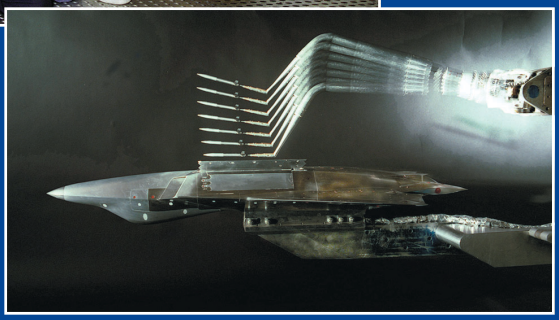


4T Aerodynamic Wind Tunnel



Arnold Engineering Development Center

An Air Force Materiel Command Test Center

AEDC

The U. S. Air Force's Arnold Engineering Development Center (AEDC), located in Middle Tennessee, is the home of some of the world's finest wind tunnels, large and small. The Aerodynamic Wind Tunnel 4T, situated in the Propulsion Wind Tunnel Facility (PWT), is a versatile mid-size test unit which has a 4-ft by 4-ft by 12.5-ft long test section. The "T for transonic" designation indicates its primary utility for testing at near-sonic airspeeds. However, its Mach number capability extends from less than 0.2 to 2.0, which is roughly equivalent to an airspeed range from 160 to 1,600 miles per hour.

Tunnel 4T is a continuous-flow wind tunnel that can simulate altitudes from below sea level to 96,000 feet above sea level. A distinguishing feature of the test unit is its variable-porosity walls which afford low wall interference at subsonic test conditions and better wave cancellation properties and superior air flow quality than can be attained with fixed-porosity walls for airspeeds near Mach 1.0. Tunnel 4T also offers good flow quality with flow angularities of less than 0.1 degree throughout most of its Mach number range. Moreover, because of its independent drive system, Tunnel 4T offers an economical testing capability at Mach numbers up to 1.3.

Tunnel 4T is employed in conducting a variety of testing types, many of which can be conducted simultaneously during a single test entry:

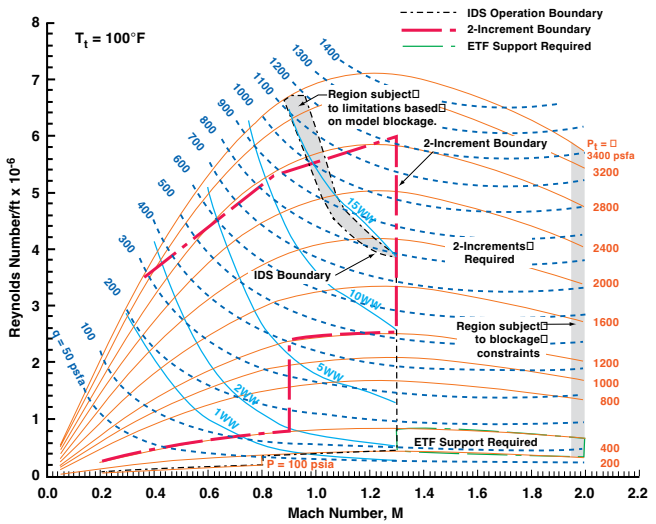
- Aerodynamic performance (lift and drag)
- Lateral and longitudinal static stability
- Control effectiveness
- Surface static pressure mapping
- Bomb bay acoustic
- Heat transfer (aerodynamic cooling)
- Aerodynamic loads:
  - Panel
  - Control surface
  - Internal store
  - External store
  - Segmented model
- Inlet performance
- Duct drag
- Spin damping
- Pitch/yaw damping
- Magnus force and moment
- Jet interaction/effects
- Flow visualization:
  - Fluorescent oil
  - Tufts
  - Liquid crystal
  - Sublimation
  - Shadow-graph
- External and internal store separation and jettison:
  - Captive trajectory
    - Ejector simulation
    - Autopilot simulation
  - Free drop
    - High-speed photography
    - Telemetry
  - Flow-field surveys:
    - Pressure
    - Loads

Propulsion Wind Tunnel Facility
Arnold Engineering Development Center

Operations

Tunnel operations are automated to a great degree:

- Computer control of test conditions minimizes off-condition times
- Variable-frequency starter system reduces power consumption during model changes
- Automatic model weight tare acquisition and application
- Automatic check loading technique applies end-to-end check of all systems at any model attitude



Model Positioning Mechanism

Model attitudes are established using a two-degree-of-freedom (pitch-roll) system. Angle ranges are:

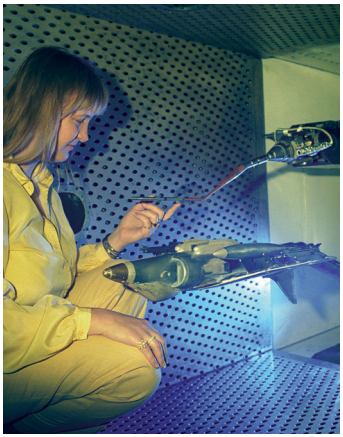
- -7.5 to 27.5 deg. in pitch
- -180 to +180 deg. in roll

Fully-automated model positioning offers stability-, missile-, and aeroballistic-axis system reference angle options for close-tolerance position control such as:

- Pitch sweeps at constant yaw angle
- Yaw sweeps at constant angle of attack
- Roll sweeps at constant pitch angle

The system is able to set requested attitudes to the following tolerances:

- Pitch and yaw angle errors: less than 0.1 deg.
- Roll angle error: less than 0.4 deg.



Store Separation Testing

Captive Trajectory Support System

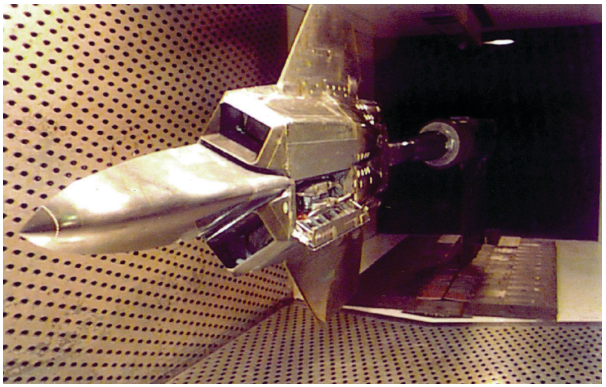
A six-degree-of-freedom captive trajectory support system permits precise linear and angular positioning of a store model in close proximity to an aircraft model. Types of data acquisition include:

- Captive trajectory/store separation
- Flow-field store loads survey
- Flow-field Mach number/flow-angularity survey

Data Acquisition

Tunnel 4T data systems are designed to provide high rates of data acquisition and to accommodate a large number of channels of each data type without modification:

- Electronically Scanned Pressure (ESP) data–2048 data channel maximum from 32 multiplex channels
- Dynamic pressure (acoustic/fluctuating load) data–64 channel maximum
- Total number of channels excluding Pressure data–256
- Force and moment–50 channel maximum
- Analog data–120 channel maximum
- Temperature data–96 channel maximum
- Data acquisition rate range (move-pause mode)–3 to 10 sec/point
- Data acquisition rate range (sweep mode)–variable, 1.2 sec/point current minimum

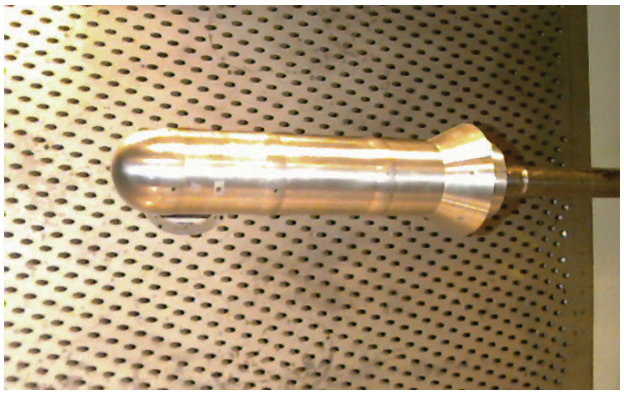


Acoustic Testing

Data Reduction

Standard data reduction codes provide a high degree of flexibility. Total and forebody coefficients can be calculated in the following axis systems:

- Body-axis system
- Missile-axis system
- Stability-axis system
- Missile-stability-axis system
- Wind-axis system
- Aeroballistic-axis system
- Modified aeroballistic- or aero-axis system

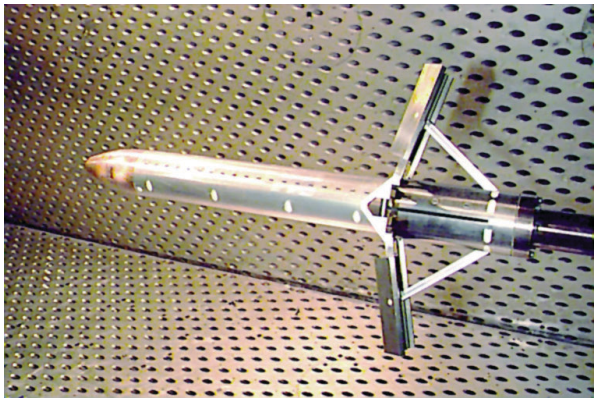


Static Stability, Spin-Damping and Magnus Testing

Data Package

Data packages are tailored to customer requirements. Customarily, they include the data in requested media form and a Test Summary Report documenting all aspects of the test including run logs, data nomenclature and model installation photographs. Digital data are supplied on CD-ROM. Tabulated data are also available.

Test data can be electronically transmitted from AEDC to a customer's home facility on a near-real-time basis for rapid analysis and evaluation. Thus, customer representatives can monitor the test from a remote site and make decisions that influence the direction of the wind tunnel test.



Heat Transfer Testing

Data Uncertainties

Computation of data uncertainties is performed using recently-developed state-of-the-art methodologies as presented in AGARD report AR-304 and AIAA standard S-071-1995.

Test Support

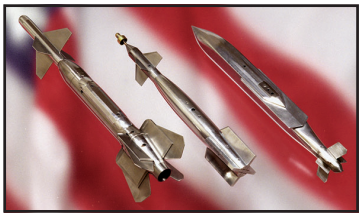
Wind tunnel testing support is available for the duration of each wind tunnel test program. AEDC personnel are skilled in test design and planning, model and balance design and fabrication, instrumentation system selection and assembly, data acquisition, test conduct, data analysis, data checking and data certification.

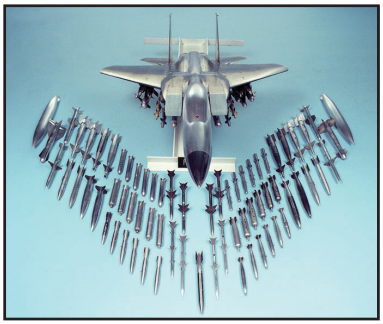
CFD support is available in the form of:

- Concept Definition Support
  - Early Trade Studies
  - Performance and Weapon Separation Assessment
  - Aerodynamic Loads and Flight Simulation Predictions (Empirical, Analytical &Viscous CFD)
- Test and Post-Test Support
  - Test Matrix Planning and Optimization
  - Tunnel Effects Corrections
  - Data Validation
  - Analysis Simulations
  - Data Anomaly Resolution
  - Performance Assessment
  - Datamining and Data Visualization
  - Databasing and Aerodynamic Math Modeling
  - Weapon Separation Analysis
  - Missile Staging Analysis
  - Ballistic Trajectory Analysis

AEDC encourages customer participation as an active member of the test team. Dedicated displays, work stations and personal computers in a private customer room as well as in the control room facilitate customer involvement.

For model design and fabrication, a complement of skilled design engineers, draftsmen and machinists is employed at AEDC. Available on site is a model shop equipped with conventional mills and lathes as well as 15 numerically-controlled (NC) or computer numerically-controlled (CNC) machine tools, five of which are Electrode Discharge Machines (EDM).





Machining Capabilities Pictured Include: Store Models, One-Piece Force-and-Moment Balance and F-15 and External Store Models

Benefits of wind tunnel testing include:

- Reduced air vehicle development time
- Reduced air vehicle development risk
- Reduced air vehicle development cost
- Increased flight test safety
- Extensive diagnostic capability for solving aerodynamic problems

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