



Arnold Engineering Development Complex



AFMC



U.S. AIR FORCE

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U.S. Air Force Investments in Hypersonic Test Technologies & Infrastructure

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Hypersonic Weapons



Offering Disruptive Advantages, Presenting T&E Challenges

Enhanced ability to overcome challenges of time, distance, and enemy defenses

• Hypersonic T&E Challenges

- Far more extreme flight conditions than other DoD weapons
- Timely enhancement of T&E capabilities to acquisition program caliber
 - Improved flight simulation in ground test facilities
 - Lower cost/more data per flight test
 - Lower data uncertainty

Anti-Access / Area Denial Zone

Effective T&E is key to successful development and fielding of hypersonic systems:

- Provides knowledge to lessen probability of in-flight failures and performance shortfalls
- Delivers cost and schedule risk reductions for acquisition programs
- Validates promised capability to effectively penetrate and control contested battlespace



Strategic Partnership w/ TRMC

Closing Gaps in Hypersonic T&E Capability



Closing hypersonic test & evaluation gaps by developing and investing in improved test technologies, tools, techniques, facilities, and technical workforce for flight test, ground test and modeling and simulation; enabling effective acquisition-caliber T&E of high speed systems

Goals

DoD T&E capability to effectively develop and field high speed systems

Needs

Improved tools, techniques, capabilities and technical workforce for:

Solutions

Air Force Test Center

Test Resource Mgmt. Center



HSST
Advanced Tech

HyTIP
Investments

Flight Test

Ground Test

Modeling and Simulation



HSST – High Speed Systems Test
(\$200M T&E S&T Tech Development)

HyTIP – Hypersonic T&E Investment Program
(\$350M Test Infrastructure Enhancement)

Focused Investments in DoD Test Ranges and Centers

Mach No.

Time





AFMGC

HSST & HyTIP

T&E Capability Enhancement Areas

Aeropropulsion



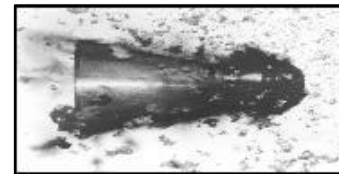
Improving Propulsion Ground Test Methods, Expanding Test Envelopes, Improving Accuracy & Fidelity

Aerodynamic & Aerothermal



Improved Aeroheating & Ablation Test Capabilities, Improved Flow Quality, Aero-Thermal Structural, Aero-Optics, High-Speed Munitions Dispensing Testing

Weather Effects



Developing Capability to Simulate Thermo-mechanical Responses of High Speed Thermal Protection Systems and Control Surfaces in Natural Environments

GN&C, Seekers, Lethality



Developing Integrated End-to-End Hardware in the Loop Mission Simulation; GN&C and Seeker/Sensor; Ordnance Evaluation

Flight Test



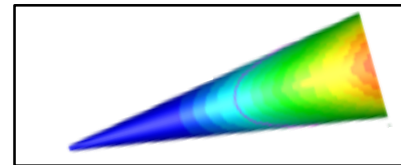
Evaluating Range Corridor and Infrastructure Needs, Improving Mission Assurance and Launch Flexibility, Developing In-Flight Measurements, Increasing Data Capture per Flight

Instrumentation & Test Techniques



Innovative New Sensors, Improving Accuracy, Increasing Measurement Ranges, Test Techniques for Improved Correlations

Modeling & Simulation



Improved Flight Performance Prediction Capabilities. Validating Codes, Developing Complex Physics-Based Tools

Workforce Development



Develop Advanced Workforce Skills, Techniques, and Expertise for Current and Future Hypersonic T&E Workforce

M&S, Instrumentation & Test Techniques, and Workforce Development Embedded in Multiple Capability Enhancement Areas

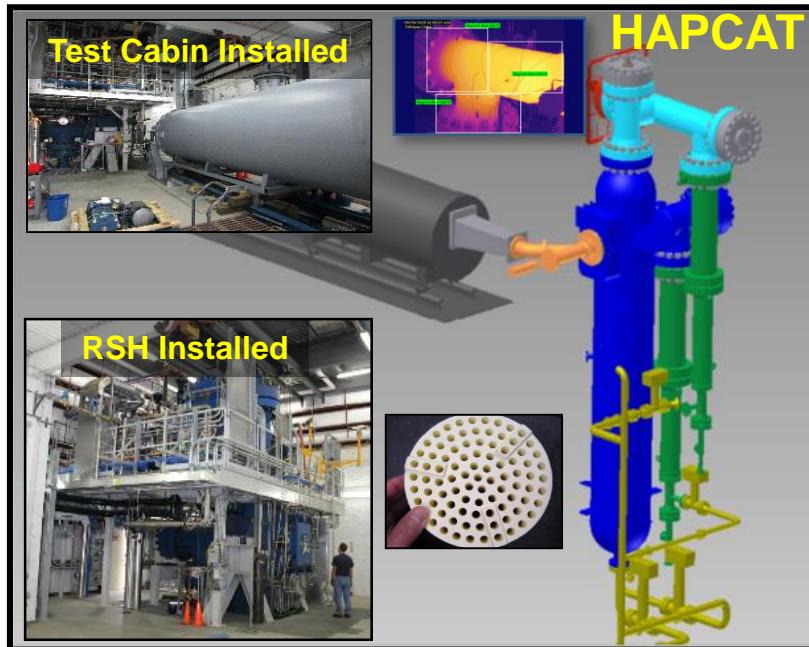


AFMC

Current Efforts

Aerothermal Structural and Advanced Propulsion

Hypersonic Aerothermal and Propulsion Clean Air Test Capabilities
Improving Ground Test Methods, Expanding Test Envelopes, Improving Accuracy and Fidelity



Clean air heat addition up to Mach 7.5

- Current facilities use combustion heated test air
- Clean air is representative of true flight air chemistry
- Reduces uncertainty for system design margin, performance, operability, and durability

Variable Mach number nozzle (4.5-7.5)

- Current facilities use single point Mach nozzles
- Variable Mach nozzle permits much more accurate simulation of transient operation along flight trajectory



- *Accurate determination engine performance and operability*
- *Representative environments for aero-thermal structural and aero-optic testing*
- *Validated technologies reduce risk to build full scale test facility*

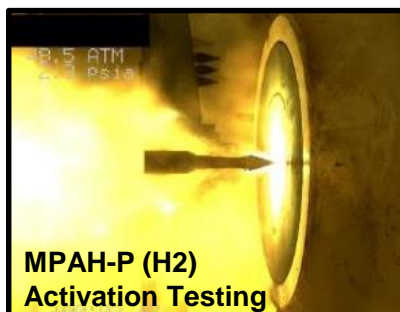
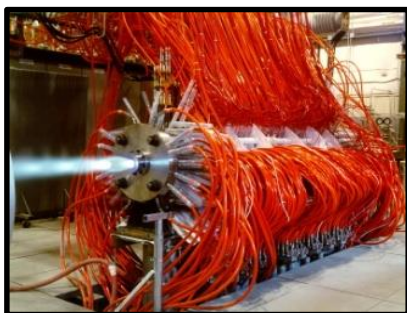


Current Efforts

Aerodynamics & Aerothermal

Improved Arc Heater Design Enables Key Test Capability for Boost-Glide Systems

- High enthalpy flow with longer test times
- Expanded test envelope representative of typical boost glide trajectories
- Improved electrode design and arc control provides more consistent conditions and longer component life



State of the Art Prediction Tools for Boundary Layer Transition



- Correlate BLT results between different test facilities using various vehicle shapes
- Facility flow noise characterization
- Defines optimal methods & instrumentation
- Validates prediction tools and measurements of transition mechanisms

- *Fills requirement for mid pressure arc heater capability*
- *Provided dsstantial tool in advanced materials characterization & Thermal Protection System design*

- *Provides acquisition roadmap for system development*
- *Develops computational link between ground and flight test BLT predictions*



Current Efforts

Flight Test and Evaluation



UAV BASED RANGE

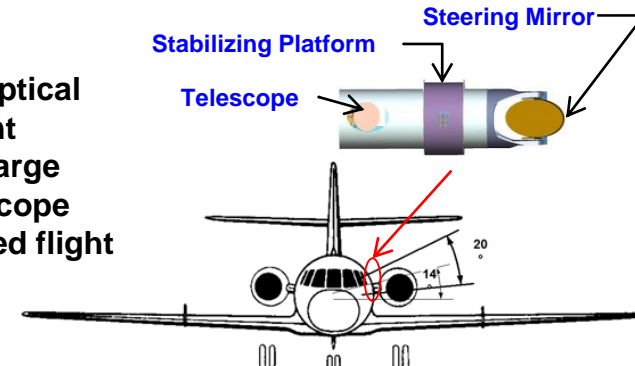


- Determine the technical performance, capital & operational costs, & CONOPS for a High Altitude, Long Endurance Uncrewed Aerial System
- Analyze telemetry, flight safety, optical remote sensing, LIDAR atmospheric measurements capabilities

Lower cost flight test range support while providing greater data quantity & quality

AIRBORNE HIGH-RESOLUTION MULTI-SPECTRAL TELESCOPE

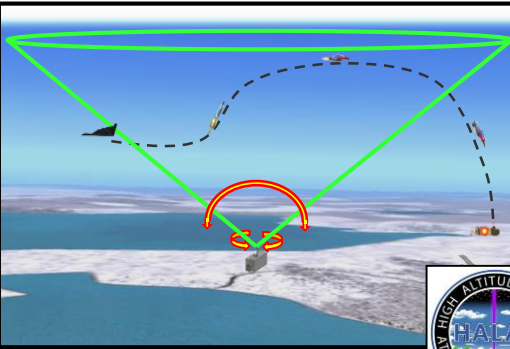
- High fidelity optical tracking mount
- Lightweight, large aperture telescope
- Sensor directed flight



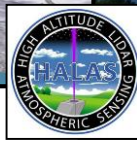
Remote in-flight readings of the environment surrounding hypersonic vehicles

- Improving mission assurance and launch flexibility
- Developing in-flight measurements
- Increasing data capture per flight
- Reducing overall flight test cost

HIGH ALTITUDE LIDAR ATMOSPHERIC SENSING (HALAS)

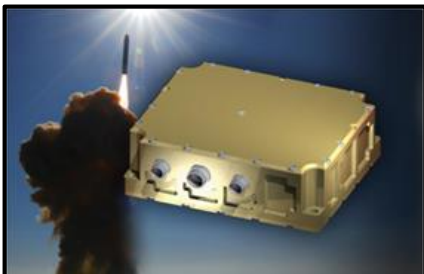


Measures Temperature, Wind Speed/Direction, Density, O₂ Mass Fraction



Measurement of atmospheric flight conditions for flight tests. Significantly more accurate test data analysis and vehicle performance estimates with low uncertainties and better spatial and temporal resolution

AUTONOMOUS FLIGHT SAFETY SYSTEMS (AFSS)



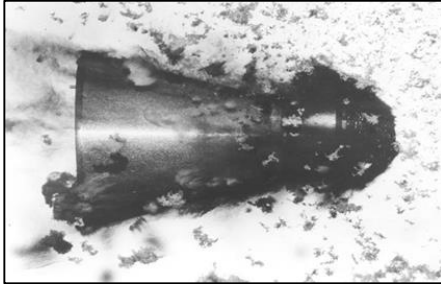
First range safety compliant Autonomous Flight Safety Systems to support over-the-horizon flight and remote launch where no range infrastructure exists



Current Efforts

Weather Effects

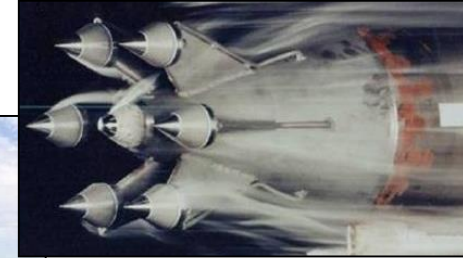
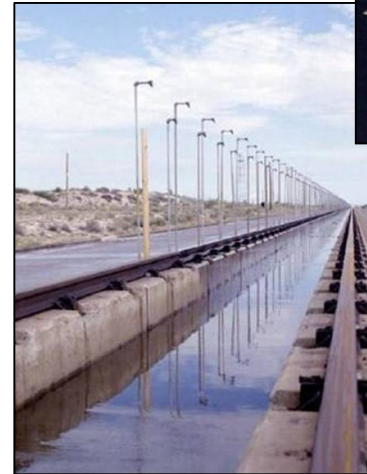
Improving Mission Assurance Through Accurate Weather Impact Material Response Assessment



Provide a rain, snow, and ice erosion capability in ballistic range. Develop modern suite of instrumentation for high resolution data capture

- New Material Response Models & Integrated Operational Tools
- Modern technology for defining and modeling global weather

M&S methods for all relevant events must be developed/validated in order to extrapolate ground test data to the flight environment



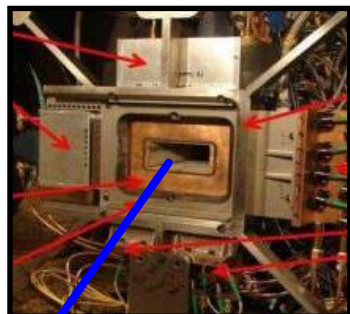
Upgrade the Holloman High Speed Test Track to provide realistic rain environments for testing future hypersonic weapons systems.



Current Efforts

Computational Tools for High Speed Flow Fields

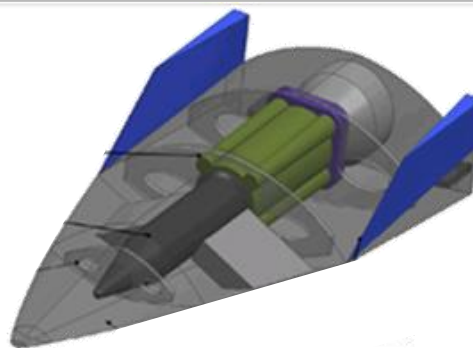
Advancing Modeling and Simulation Capabilities for Hypersonic Test and Evaluation



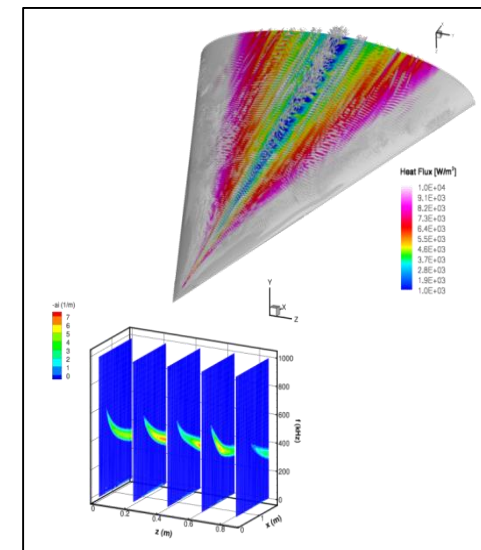
TDLAS Flange

- 2D spatial maps of exhaust gas properties from laser absorption measurements
- Improved understanding of combustion processes

Enables pre/post-flight assessment of hypersonic flight systems' TPS, aero-optical and aero-structural responses



- Full vehicle simulation capability for transient aero-heating analyses of high-altitude, long duration flight vehicles
- Tightly integrated, efficient engineering tool
- Faster processing times



- Predict 2nd mode BLT
- Models crossflow mode BLT
- Enables physics based 3-D boundary layer transition and stability prediction
- For use on hypersonic vehicles at angles of attack and yaw

Verification of CFD code predictions, evaluation of turbine and scramjet engine combustion efficiency, performance and operability.

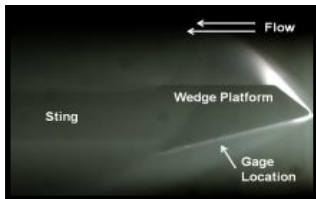
Accurately determine the associated effects of heat transfer, drag and ablation on a hypersonic vehicle



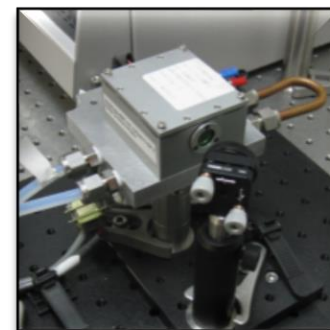
Current Efforts

Instrumentation & Diagnostics

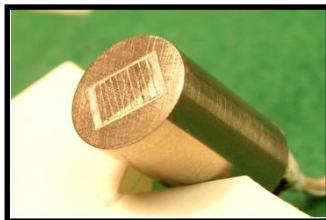
Innovative New Sensors, Improving Accuracy, Increasing Measurement Ranges



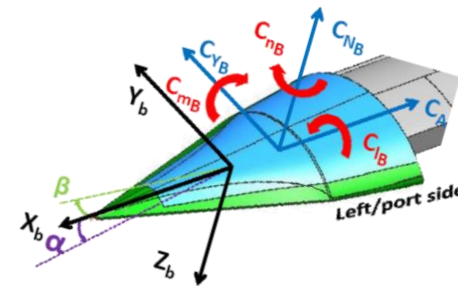
High enthalpy skin friction sensor to accurately measure surface shear forces for high speed system development



Developing Mid- IR Tunable Laser Absorption Spectroscopy Technology that will significantly increase the precision and accuracy over current methods leading to improved hypersonic facility and engine system diagnostics



Heat flux sensor capable of surviving extremely high temperatures associated with hypersonic ground test conditions



Develop a force balance system with high stiffness and frequency response to make measurements in hypervelocity flows with test durations of 1-2 msec



Hypersonic Combined Test Force (HFTT)

Arnold AFB TN & Edwards AFB CA



Ground Test, Aircraft Integration and Flight Test Expertise for Hypersonic System and Aerospace Vehicle Development

FLIGHT TEST

- Range Safety Planning (FTS design)
- Landing and Recovery Operations
- Flight Test Planning and Range Operations
- Flight Test Safety Planning
- TM and Optical Tracking

MODELING & SIMULATION

- Aerodynamic Heating and Heat Transfer
- Thermal Protection Systems
- Trajectory Development/Optimization
- Parameter Identification/Estimation
- Quantitative Risk Analysis

AIRCRAFT INTEGRATION

- Launch platforms/MDS expertise/Test Aircrew
- Integrated Maintenance Facility (Bldg 710)
- Test Load Crews/Test Load Procedures
- Rocket Vehicle Integration and Test Site (RVITS)



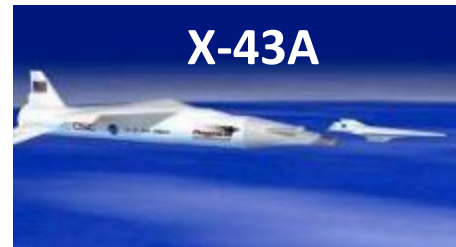
X-15

1960s



Space Shuttle

1970-80s



X-43A

1990s



X-51A

2000s

Questions?

