Test & Evaluation/Science &Technology Program

High Speed Systems Test Technology Program

AFOSR Aerothermodynamics, Turbulence and Transition Portfolio Reviews

15 July, 2015

High Speed Systems Test Technology Area

Develop, validate and support transition of T&E technologies that will permit effective and timely T&E of advanced propulsion and high speed systems with the same accuracy and robustness as legacy subsonic and supersonic systems

- OSD TRMC T&E/S&T funded
- HSST headquartered at AEDC, Arnold AFB, TN
- Current portfolio: 15 Projects
- Total budget across FYDP: $82M

Executing Agent
Ed Tucker
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Arnold Engineering Development Center
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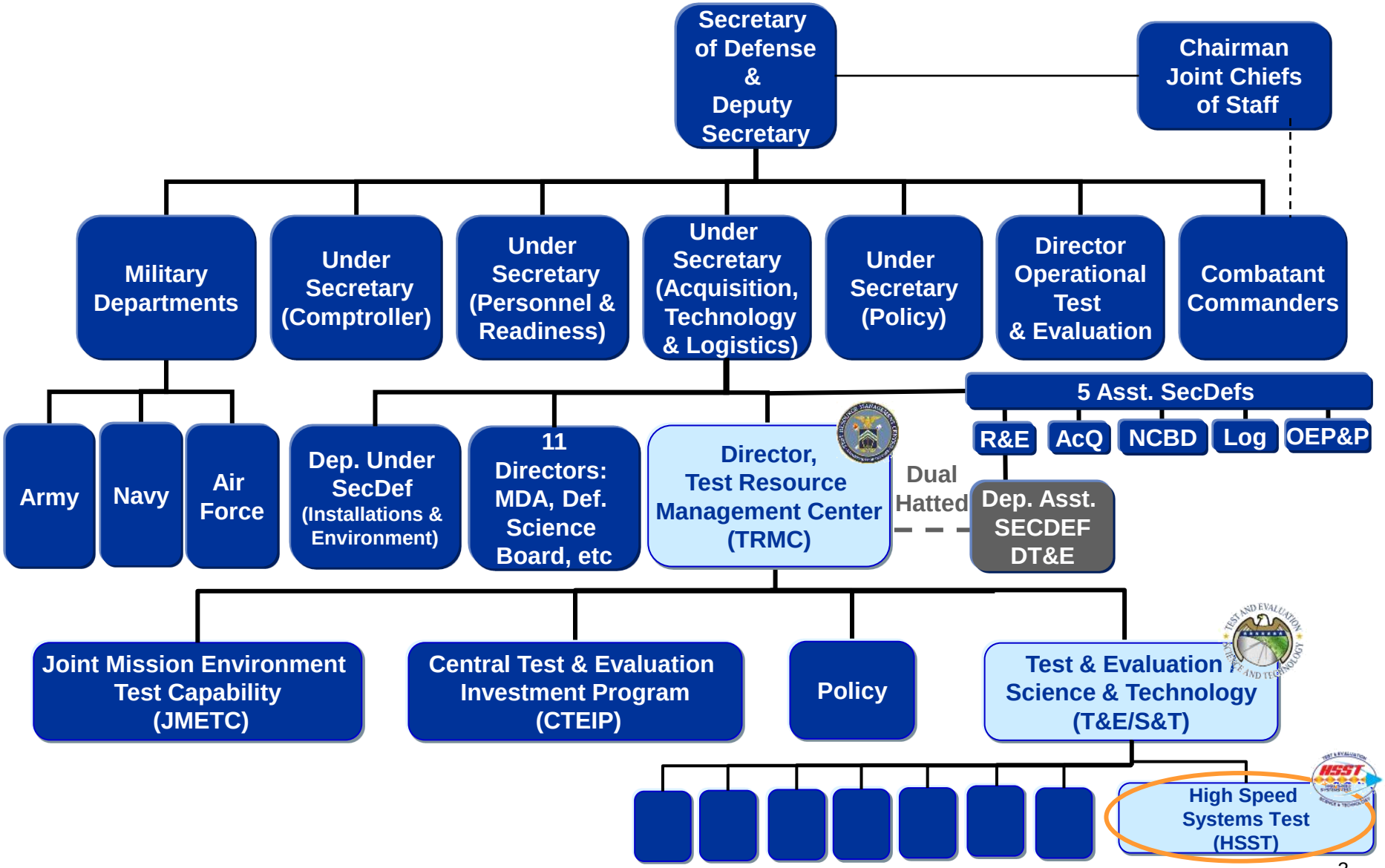
Collaboration

- Industry
- Universities

Test Resource Management Center
Direct Report to USD(AT&L)



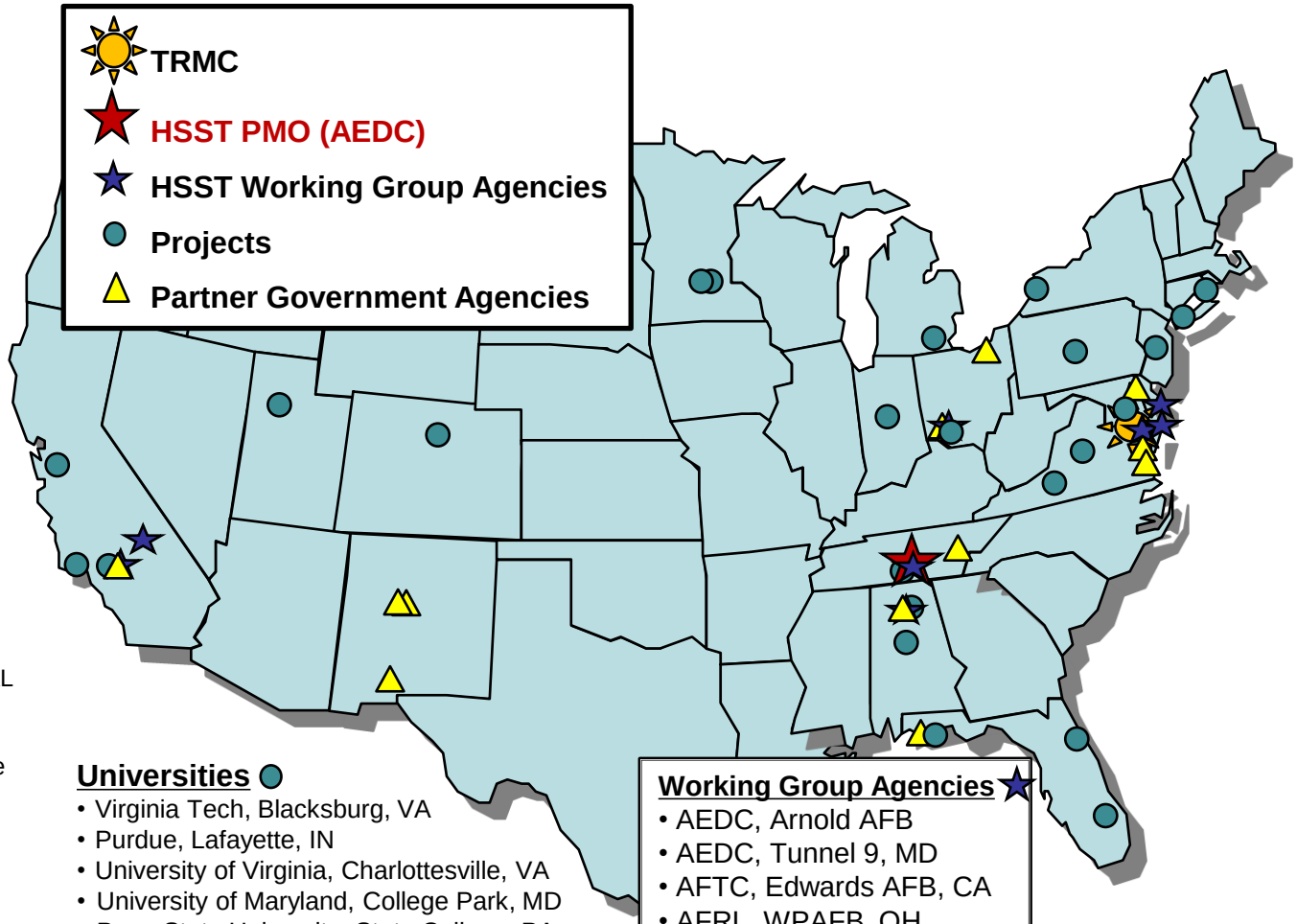
HSST Partners

Partner Gov. Agencies

- NASA Glenn, Cleveland, OH
- NASA Langley, VA
- NASA Armstrong, CA
- NASA Wallops, VA
- AMRDEC, Redstone Arsenal, AL
- DOE, Oak Ridge, TN
- ONR, Washington, DC
- AEDC, Arnold AFB, TN
- AFRL, Wright Patterson AFB, OH
- AFRL, Eglin AFB, FL
- AFOSR, Washington, DC
- AFTC, Edwards AFB, CA
- WSMR, NM
- Sandia National Lab, Albuquerque, NM
- ORS, Kirtland AFB, NM
- Range Commander's Council

Project Companies

- Aero Systems Engineering, St. Paul, MN
- Teledyne Scientific, Thousand Oaks, CA
- Pratt & Whitney Rocketdyne, West Palm Beach, FL
- Southern Research Institute, Birmingham, AL
- Michigan Aerospace Corporation, Ann Arbor, MI
- ATK GASL, Ronkonkoma, NY and Salt Lake City, UT
- Luna Innovations, Inc., Blacksburg, VA
- ATA, Arnold AFB, TN
- UTRC, East Hartford, CT
- CUBRC, Buffalo, NY
- Lockheed Martin, Palmdale, CA
- GoHypersonic, Dayton, OH
- Los Gatos Research, Mtn. View, CA
- Zolo, Boulder, CO
- Kratos/Digital Fusion Solutions, Huntsville, AL
- Opto-Knowledge Systems, Inc, Torrance ,CA
- Controlled Dynamics Inc. Huntington Beach, CA



Universities

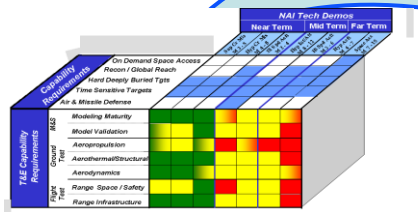
- Virginia Tech, Blacksburg, VA
- Purdue, Lafayette, IN
- University of Virginia, Charlottesville, VA
- University of Maryland, College Park, MD
- Penn State University, State College, PA
- Stanford University, Stanford, CA
- University of Minnesota, Minneapolis, MN
- Johns Hopkins University, Laurel, MD
- Embry Riddle University, Daytona Beach, FL
- Princeton University, Princeton, NJ
- University of Tennessee, TN

Working Group Agencies

- AEDC, Arnold AFB
- AEDC, Tunnel 9, MD
- AFTC, Edwards AFB, CA
- AFRL, WPAFB, OH
- NAVAIR, China Lake, CA
- NAVAIR, Pax River, MD
- ATEC, Aberdeen, MD
- AMRDEC, Redstone, AL

Needs and Solutions Process

T&E Gap Assessment

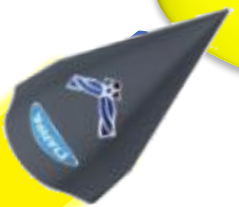


High Speed Systems Requirements

Attributes	Near Term (2010)			Mid Term (2015)		Far Term (2020)	
	SCM	HCM	HS Aircraft	Interceptor	HS Aircraft	HS Aircraft	Space Access
Mach No	3-5	4-8	2-4	8-12	3-6	4-7	7-15
Range (Nautical Miles)	400-700	1000	2300	1500	5000	12000	LEO
Payload	250-500	250-1000	10% Mass Fraction	2000	3% Payload Fraction	10% Mass Fraction	3000 25000 40000
Size	L 168 in. D<24 in	L 168 to 250 in. D<24 in	L 100 to 150 ft.	? < L ~ 100 to 120 ft.> ?	L 100 to 150 ft.	L ~150 ft.	? < L 150 to 200 ft.
Propulsion System	Turbine + (Ram) Fuel: JP-7/8/10	Boost to Ram / Scram, Fuel: JP-7/8/10	Turbine, Large D. (48 in.) Fuel: JP-7/8/10	Boost to Scram, Slush H2	Turbine + Ram / Scram, JP-7/8/10	Turbine + Ram / Scram, JP-7/8/10	AB: M 0 to Scram, or Boost to Scram, Slush H2

T&E Technology Topics

Future Hypersonics T&E Capability

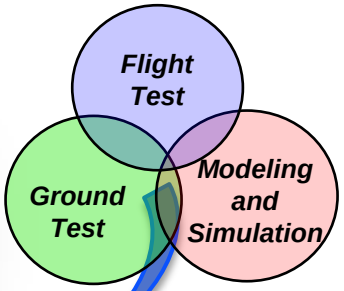


T&E Needs

HSST Roadmap

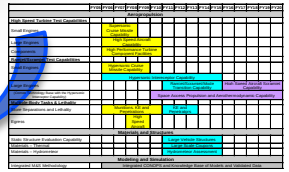
HSST S&T Solutions

Enabling T&E Technologies



HSST Projects

Current Hypersonics T&E Capability



T&E Infrastructure Capabilities Roadmap

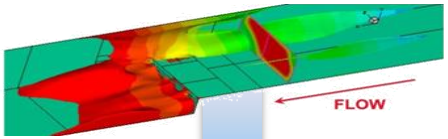
HSST
Domains and Applications

MISSION: ***Develop, validate and transition of technologies, tools and techniques that will permit effective and timely T&E of high speed systems***

Advanced Propulsion

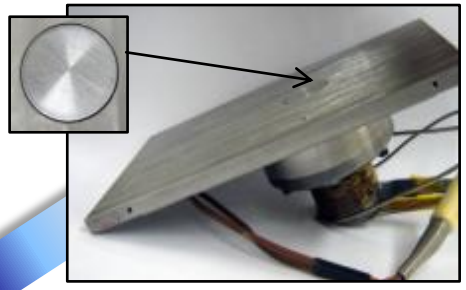
Improving Propulsion Ground Test Methods, Expanding Test Envelopes, Improving Accuracy & Fidelity

Computational Tools



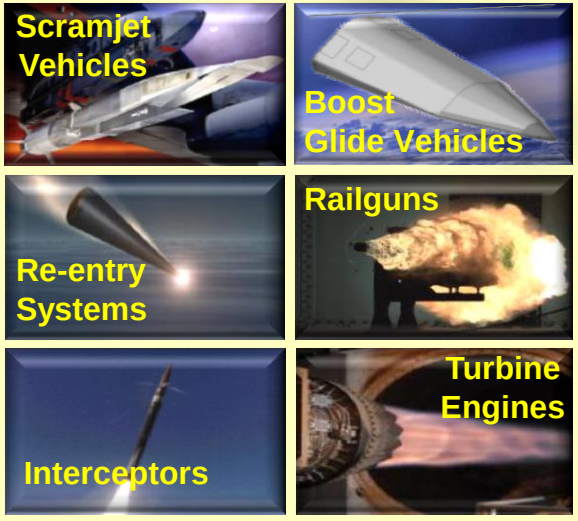
Advancing M&S Capabilities for Hypersonic T&E

Instrumentation



Innovative New Sensors, Improving Accuracy, Increasing Measurement Ranges

Applications



Aerodynamic & Aerothermal

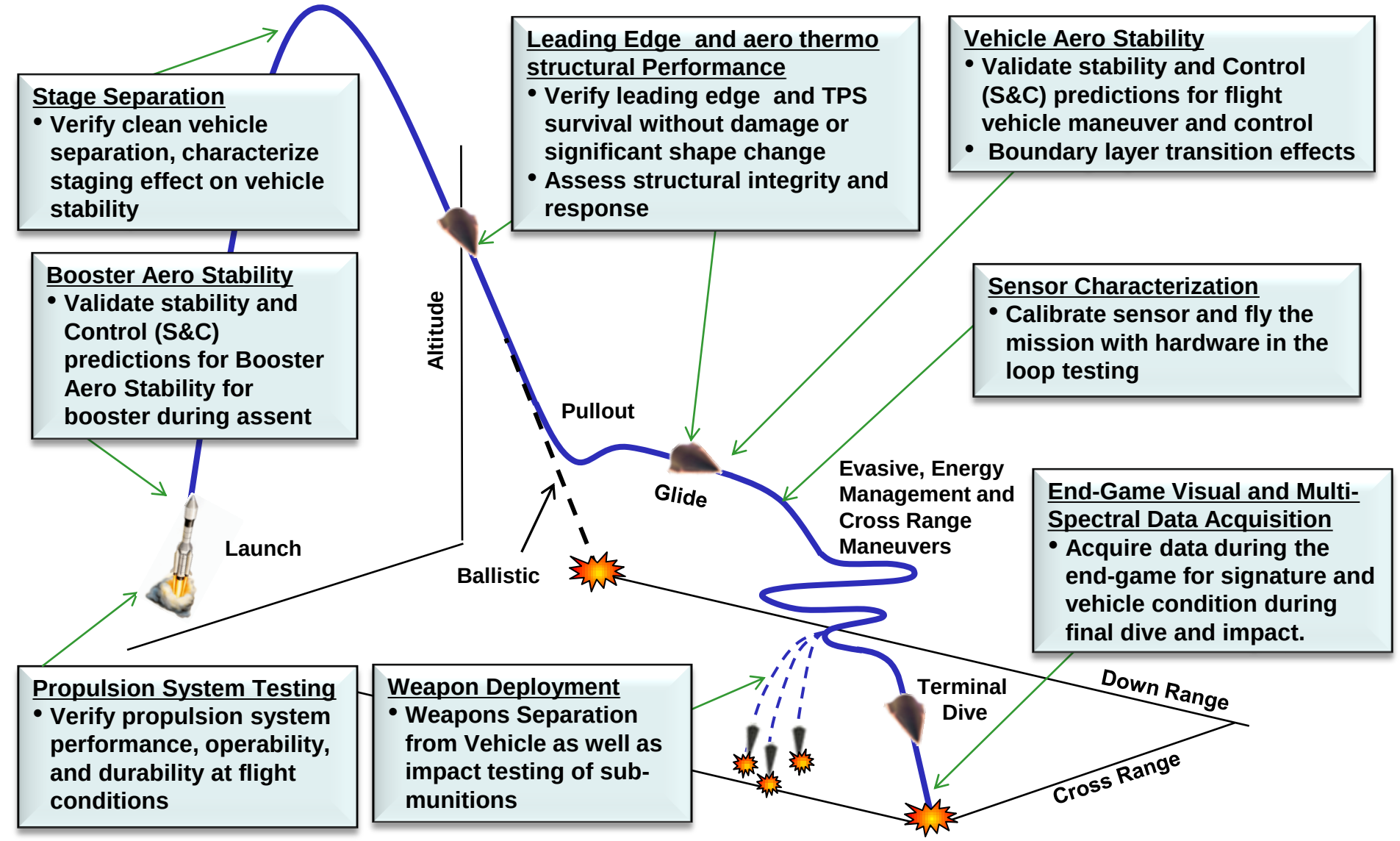
Improved Aeroheating & Ablation Test Capabilities, Improved Flow Quality, H/S Munitions Dispensing Testing

Flight Test

Improving Mission Assurance and Launch Flexibility, Developing In-Flight Measurements, Increasing Data Capture per Flight

Boost-Glide Vehicles

T&E Objectives



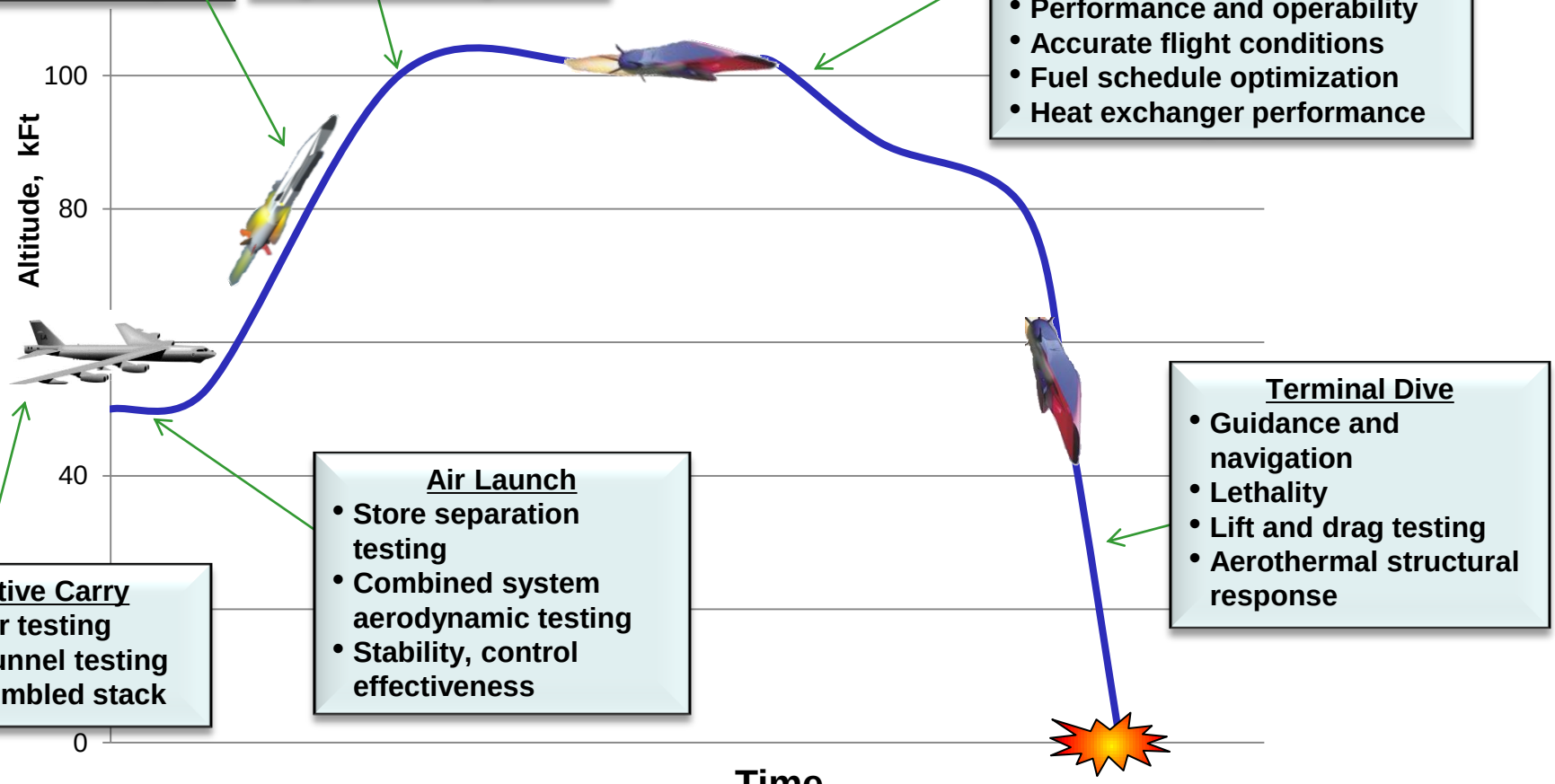
Hypersonic Cruise Missile

T&E Objectives

Boost Phase
- Ignition testing
- Transonic/Supersonic testing of system
- Booster separation wind tunnel testing

Booster Burnout & Scramjet Ignition
- Inlet performance and operability testing
- Propulsion system
- Ignition testing

Scramjet Powered Flight
- Isolator/Combustor development
- Isolator margin
- Propulsion system
- Combustion stability
- Performance and operability
- Accurate flight conditions
- Fuel schedule optimization
- Heat exchanger performance



Captive Carry
- Booster testing
- Wind tunnel testing of assembled stack

Air Launch
- Store separation testing
- Combined system aerodynamic testing
- Stability, control effectiveness

Terminal Dive
- Guidance and navigation
- Lethality
- Lift and drag testing
- Aerothermal structural response

T&E Needs

Advanced Propulsion

- Clean-air (non-vitiated) continuous flow at Mach 3-6 conditions
- Variable Mach number facility nozzles
- Innovative ground test methods
- Propulsion scaling techniques
- Test envelope expansion
- Advanced inlet characterization techniques
- Mach 8+ test concepts
- Engine/facility interaction assessment
- Advanced Thrust Measurements Techniques for Scramjet Performance

Aerodynamics & Aerothermal

- Mid pressure boost-glide and maneuvering reentry flight corridor simulation
- Arc-heater flow quality enhancement
- Flight and weather ablation measurement techniques
- Boundary Layer Transition techniques for assessing tunnel influences model development and validation
- Improved durability and test duration of facility components

Flight Test and Evaluation

- Autonomous flight safety systems to improve mission assurance and launch flexibility
- Tools and techniques to reduce flight test costs and increase data capture per flight
- Meteorological conditions measurement

Computational Tools for High Speed Flow Fields

- Improved Modeling & Simulation tools for T&E of High Speed / Hypersonic Systems
- Accurate modeling of high speed flow physics
- Code validation using flight & ground test data
- Effective transition to user community

Instrumentation & Diagnostics for High Speed Flow Fields

- Thermal protection system ablation characterization
- Flow characterization
- Gas turbine augmentor and high speed combustion diagnostic tools
- Improved Accuracy, Increased measurement ranges, reduced size/weight

Current HSST Projects & Studies

Advanced Propulsion

- *Hypersonic Aeropropulsion Clean Air Testbed (HAPCAT)*
- *Large-scale Scramjet Engine Testing Techniques (LSETT)*
- *Morphing Ceramic Components for Hypersonic Ground Test Facilities (MORPH)*
- *Improve High Speed Test Techniques (IHSTT) Study*

Computational Tools for High Speed Flow Fields

- *Modeling & Simulation Validation and Transition (M&S Val) Study*
  - *Characteristics-Based Grid Generator (CBGG)*
  - *STABL-3D Boundary Layer Transition Prediction Tool*
- *Computed Tomography Method (CTM) Study*
- *Transient Thermal Analysis Software Toolset (TTAS)*
- *Vitiation Effects Computational Fluid Dynamics (VECFD) Study*

Aerodynamics & Aerothermal

- *Arc Heater Flow Quality (AHFQ)*
- *Hypersonic Boundary Layer Transition Measurements (BLT) Study*

Flight Test and Evaluation

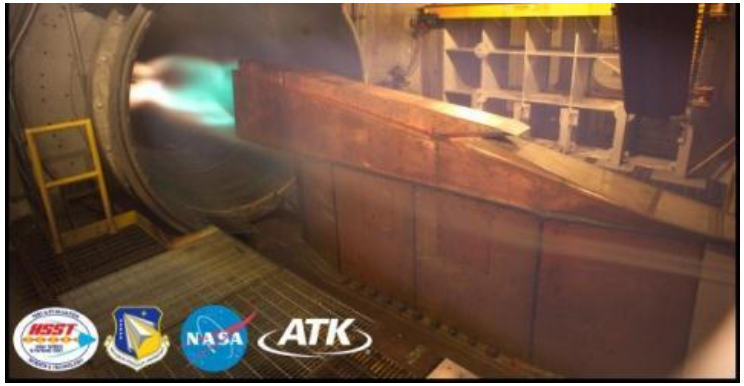
- *High Altitude LIDAR Atmospheric Sensing (HALAS)*
- *High-fidelity Automated Airborne Reconfigurable Tracking System (HAARTS)*

Instrumentation & Diagnostics for High Speed Flow Fields

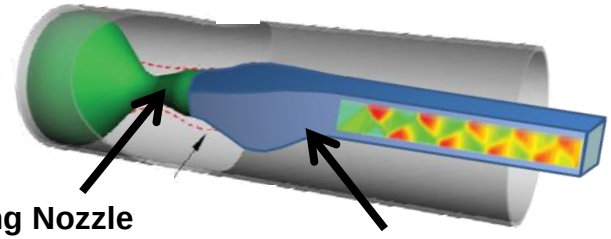
- *Hypersonic Instrumentation Development &Transition (HIDT) Study*
- *Real Gas Force Measurement (RGFM)*
- *Mid-Infrared Thermal Imaging Technique (MIRTI) Study*

Advanced Propulsion

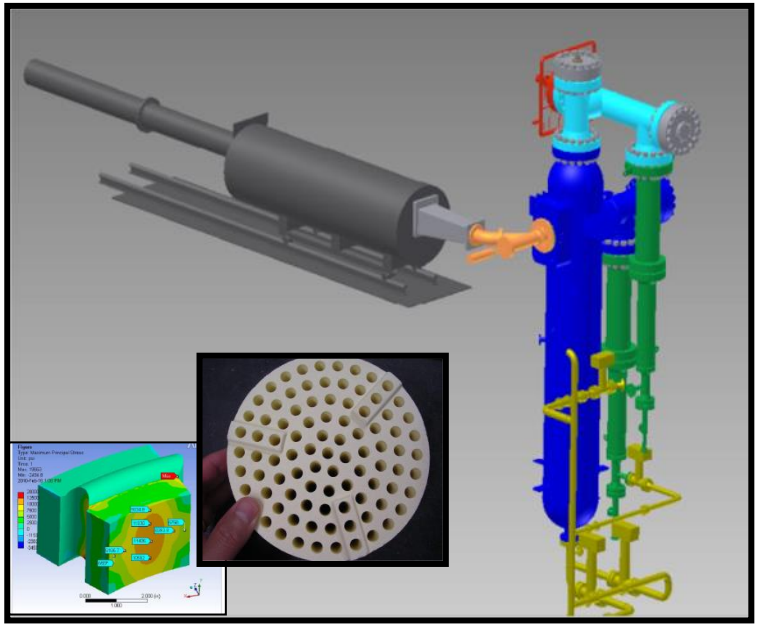
Improving Propulsion Ground Test Methods, Expanding Test Envelopes, Improving Accuracy & Fidelity



Testing scramjet engine in multiple test facility configurations to develop technique needed for developing large scale hypersonic propulsion systems in existing test facilities (LSETT)



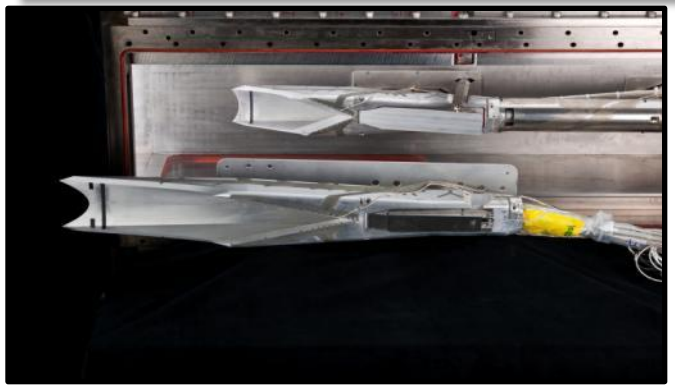
Designing and validating ceramic morphing components for hypersonic ground test facilities. Developing direct-connect variable Mach nozzle and distortion duct for scramjet T&E. (MORPH)



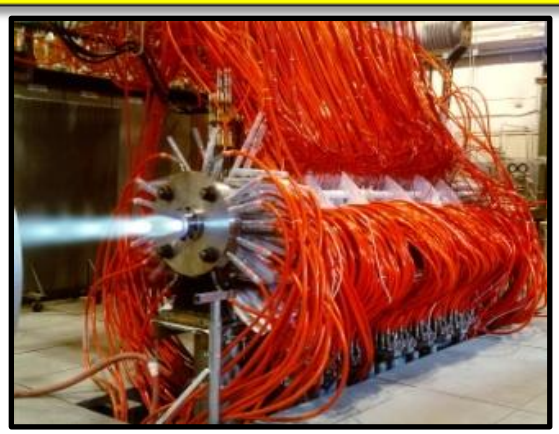
Provides the T&E community with the first clean air, true enthalpy hypersonic aero propulsion test facility capable varying simulated flight conditions from Mach 4.5 to 7.5 within a single test. (HAPCAT)

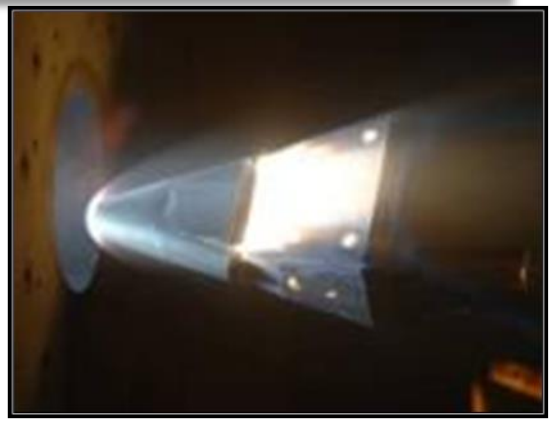
Aerodynamics and Aerothermal

Improved Aeroheating & Erosion Test Capabilities, Improved Flow Quality, H/S Munitions Dispensing Testing

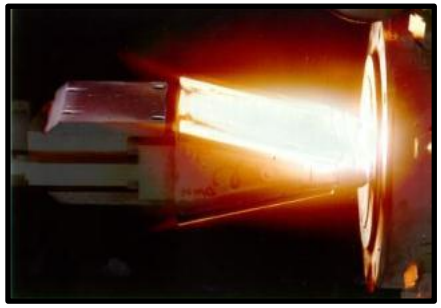


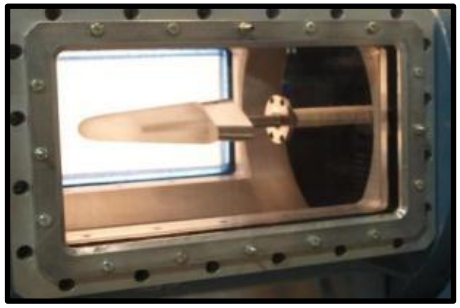
Inlet truncation methodology to enable semi-freejet testing of medium-scale scramjets in existing ground facilities (TRINT)



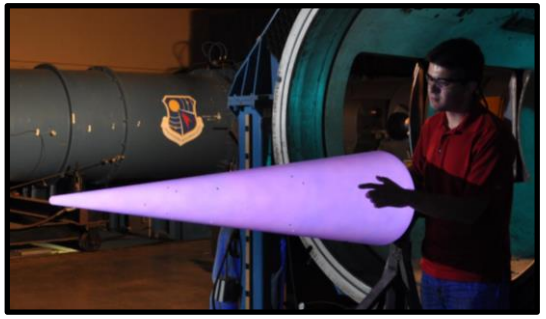


Improved arc heater design enabling critical mid-pressure test capability for CPGS systems (MPAH and AHFQ)





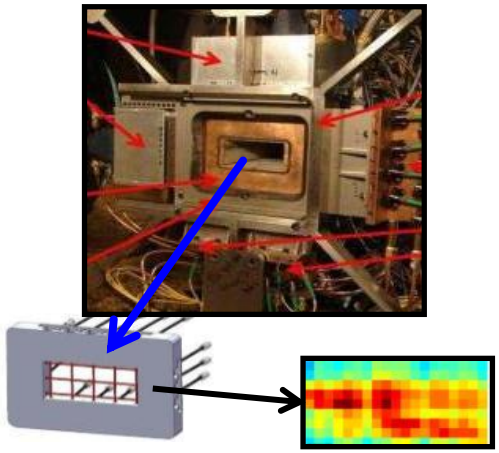
High enthalpy test capabilities, new instrumentation calibration methods and low temperature ablator test technique to improve Thermal Protection System T&E (AHA)



Develop understanding of the relationships between boundary layer transition data taken in diverse test facility environments for use in STABL-3D code validation (BLT)

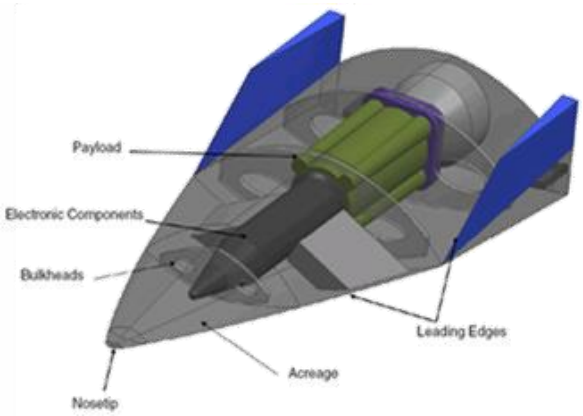
Computational Tools

Advancing M&S Capabilities for Hypersonic T&E

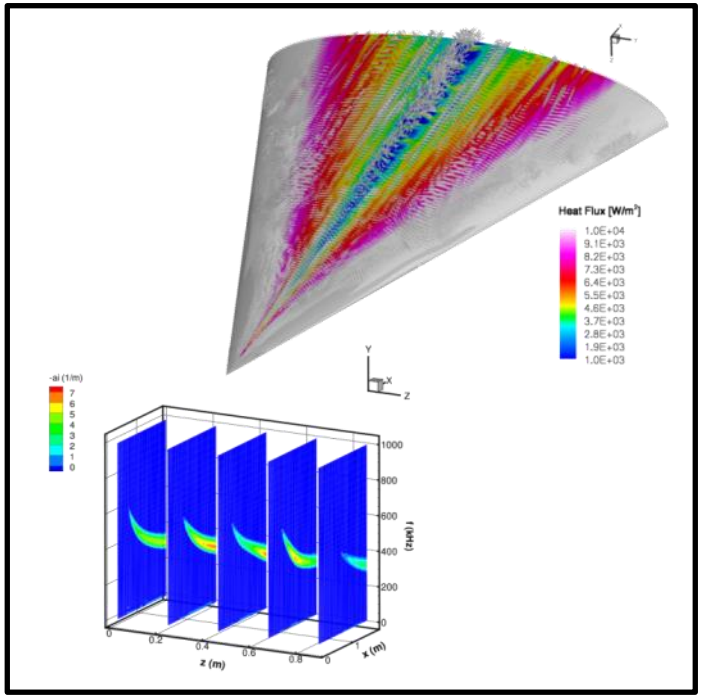


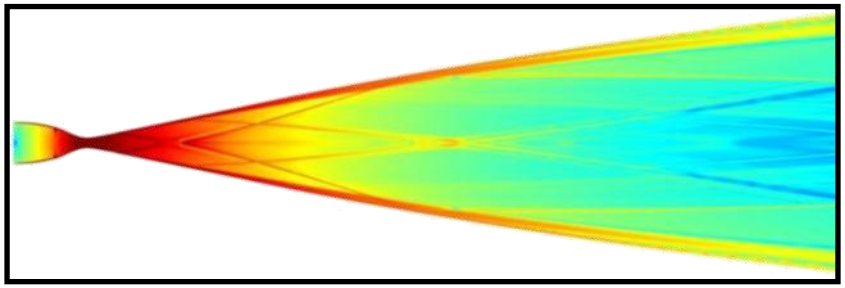
TDLAS Flange

2D spatial maps of exhaust gas properties from MLOS TDLAS measurements for verifying CFD code predictions & determining combustion efficiency (CTM)



End-to-end simulation capability to be used for the transient aero-heating analyses of high-altitude, long time duration flight vehicles (TTAS)

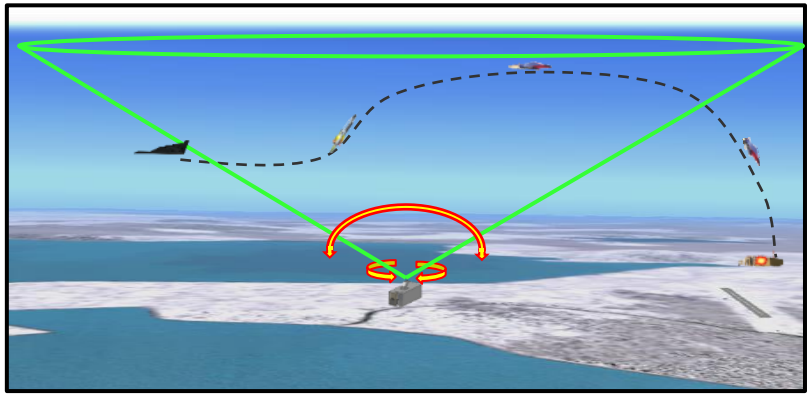




3-D boundary layer transition on hypersonic vehicles, flow quality assessment and improvement in hypersonic nozzles and engineering tools for real gas compressible flow properties and high temperature gas emission/absorption spectra (M&S Val)

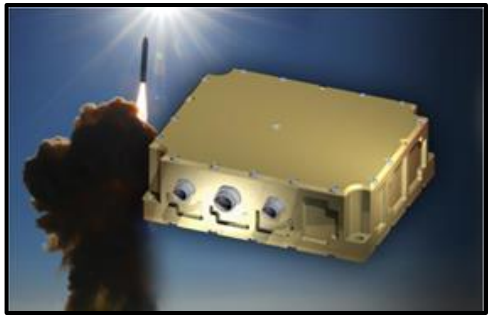
Flight Test

Improving Mission Assurance and Launch Flexibility, Developing In-Flight Measurements , Increasing Data Capture per Flight



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

Parameter Identification Maneuvers for improved flight test efficiency executed on X-51 flight 4 (PIDM)

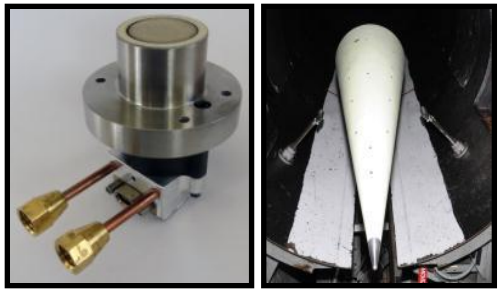


First range safety compliant Autonomous Flight Safety Systems to support over-the-horizon flight and remote launch where no range infrastructure exists (AFSS)

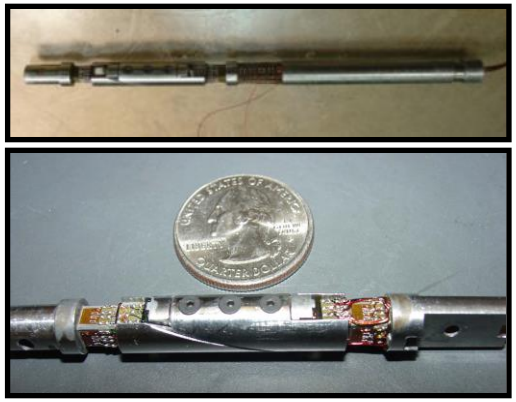
Flight weight/hardened TDLAS system provides non-intrusive, in-flight data on HIFiRE flights 1 and 2 (IFGCA)

Instrumentation and Diagnostics

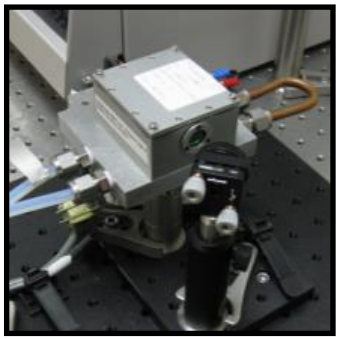
Innovative New Sensors, Improving Accuracy, Increasing Measurement Ranges



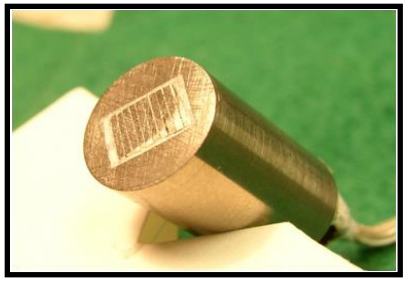
High enthalpy skin friction sensor to accurately measure surface shear forces critical for high speed system development (VT SSS)



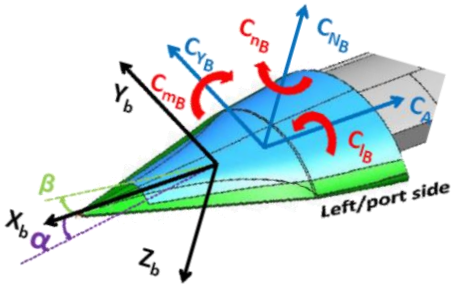
Enabling high speed store separation T&E with the development of a miniature, high temperature aerodynamic force and moment balance (CHIL)



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 (NFM)



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



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

Questions?


TEST & EVALUATION
HSST
HIGH SPEED
SYSTEMS TEST
SCIENCE & TECHNOLOGY