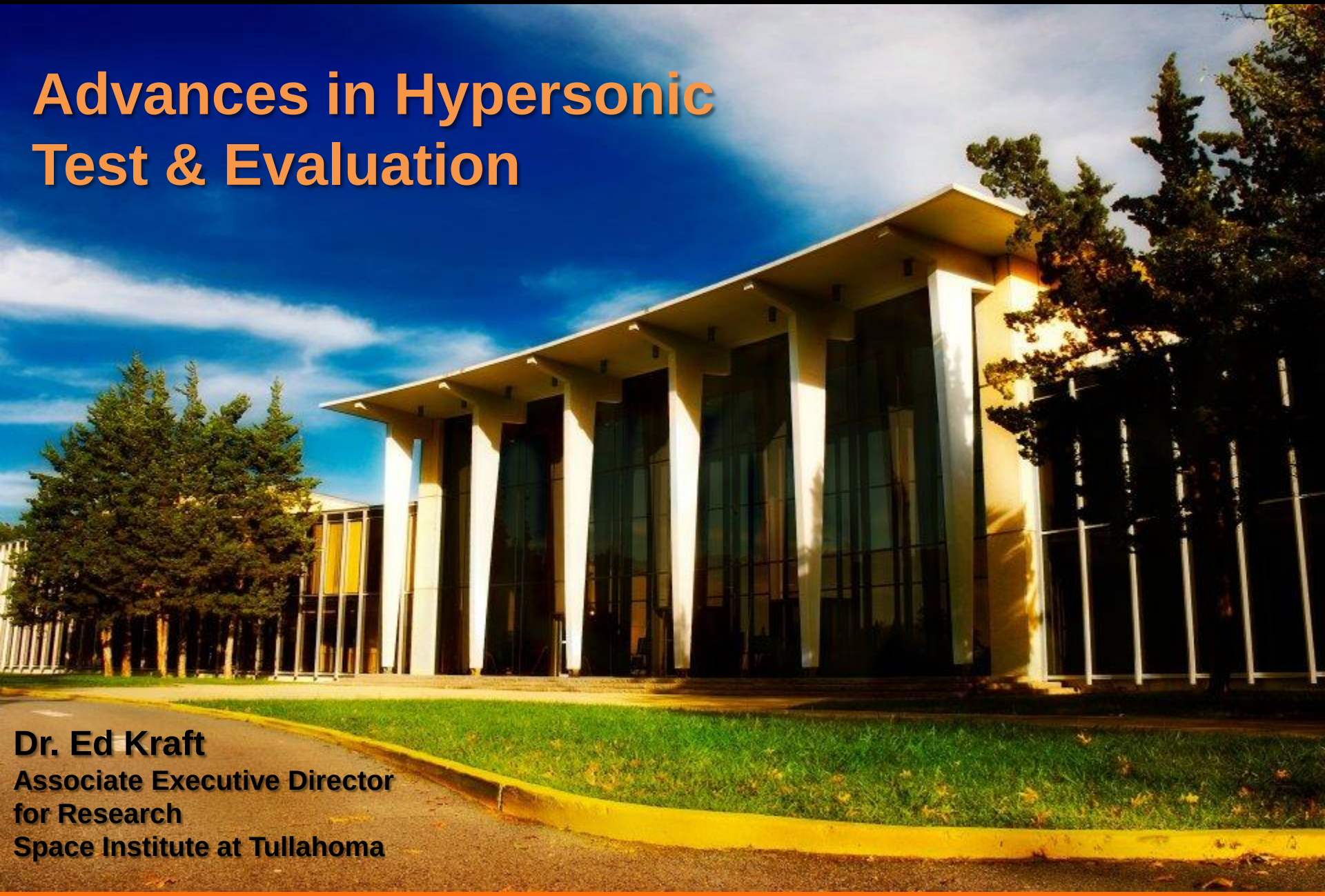
Advances in Hypersonic Test & Evaluation



Dr. Ed Kraft
Associate Executive Director for Research
Space Institute at Tullahoma

NDIA 32nd Annual National Test & Evaluation Conference
March 7, 2017

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Introduction

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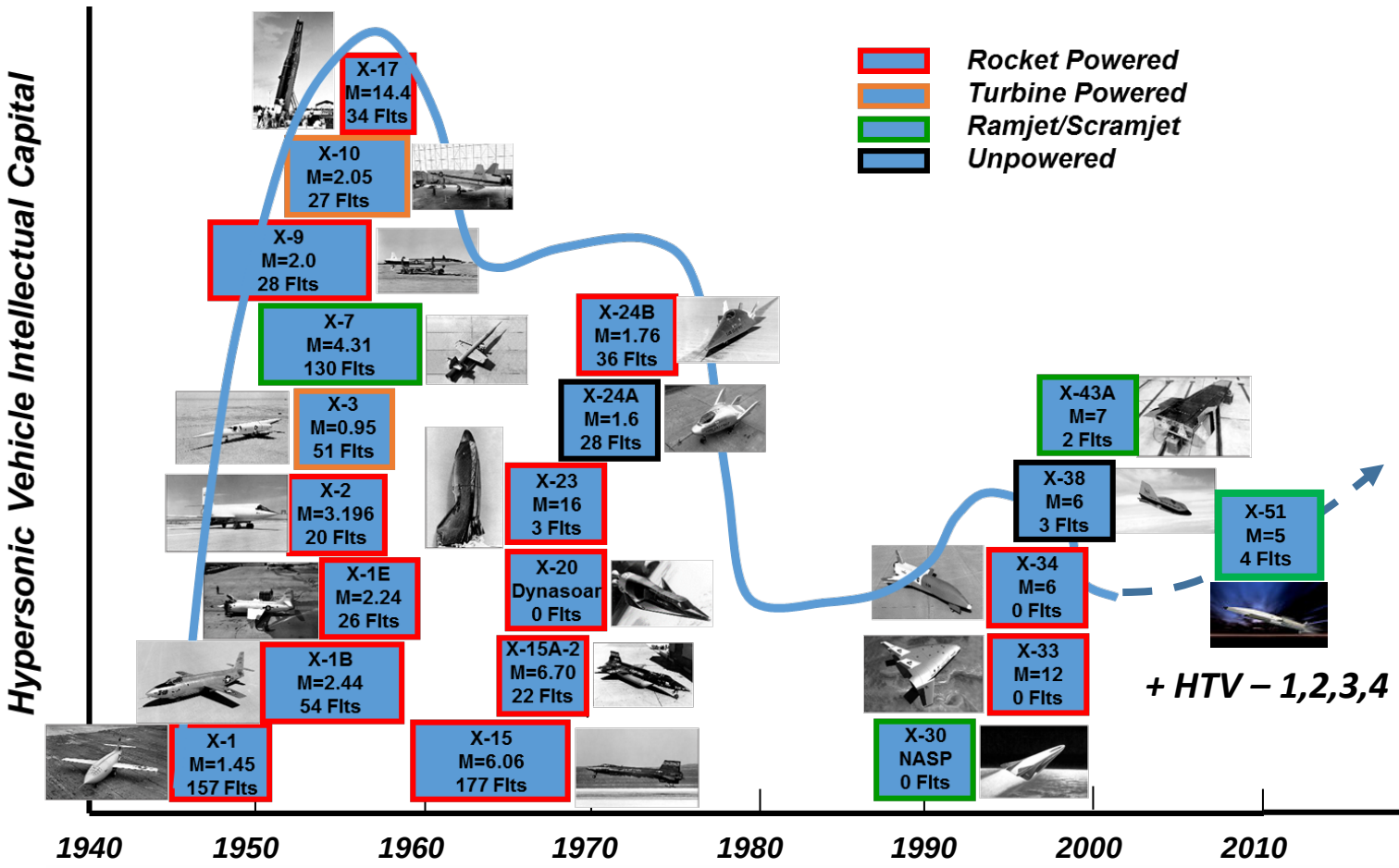

Continuing Hypersonic T&E Advances

- *Test infrastructure investments*
- *T&E S&T*
- *Physics-Based Modeling*
- *Education and Training*
- *New paradigms in lifecycle management*

Advancements in Test Infrastructure, Test Technologies, Modeling, Education, and Development Processes Will Be Required for Success

Hypersonic T&E Roadmap

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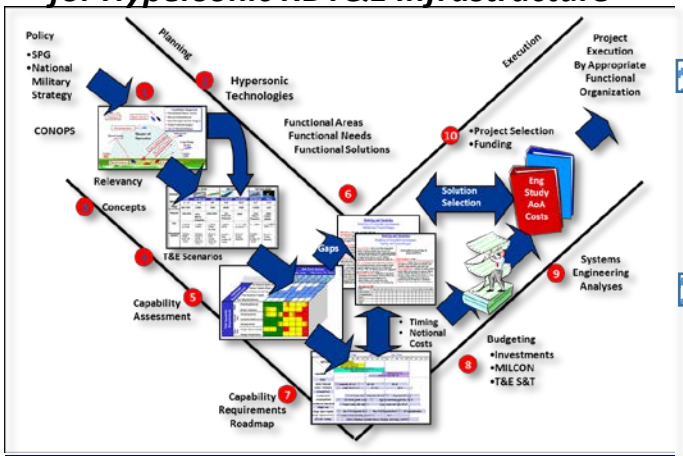
2005
Capability-Based Planning Process
for Hypersonic RDT&E Infrastructure*



What we need to do rather than what equipment we are replacing

Facility Status

AF Improvement & Modernization of Test Facilities

Congressionally Directed, OSTP Led Hypersonic T&E Study

TRMC Funded Hypersonic Facility Upgrades

TRMC CTEIP

TRMC T&E S&T Program

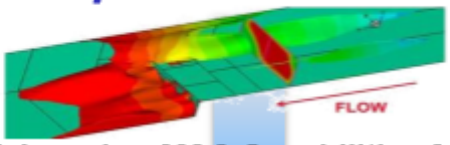
Coordinated Investment Strategies Producing Needed Hypersonic Test Capabilities

*Fetterhoff, Thomas, Kraft, Edward M., Laster, Marion L., and Cookson, William "High-Speed/Hypersonic Test and Evaluation Infrastructure Capabilities Study," AIAA-2006-8043, 14th AIAA/AHI Space Planes and Hypersonic Systems and Technologies Conference, Canberra, Australia, Nov. 6-9, 2006

Approved for public release, AEDC 2013-122

HSST
Domains and Applications

Computational Tools

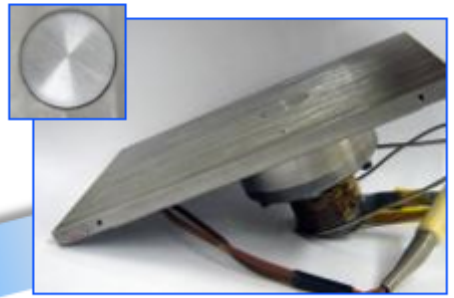


Advancing M&S Capabilities for Hypersonic T&E

Advanced Propulsion

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

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

Capability Improvement Activities

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Range G Weather Erosion Capability

CTEIP Mid Pressure Arc Heater

- *Clean Air Heater*
- *Extended Run Time*
- *Variable Mach Number*
- *Direct Connect Technologies*

MDA Lethality Study Range G

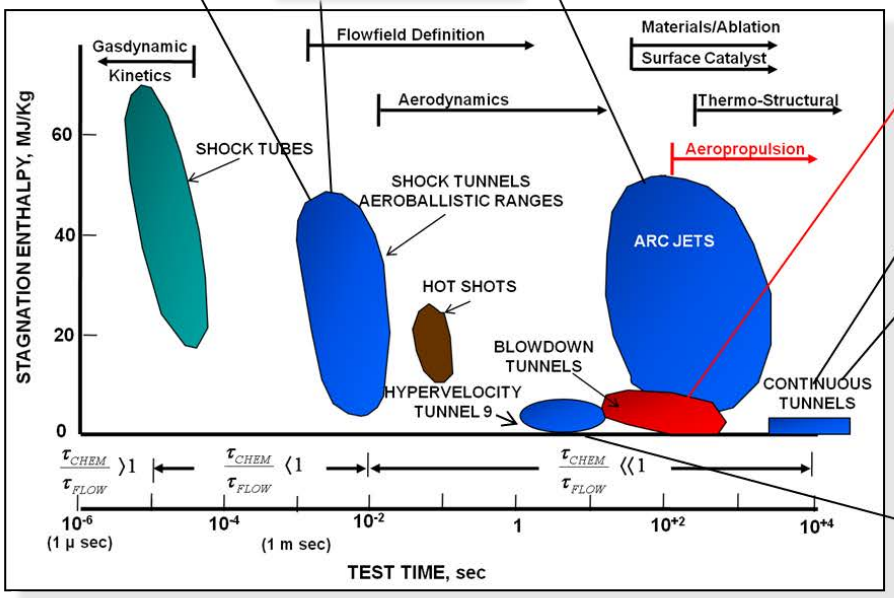
H-3 Arc Heater

CUBRC LENS Facility

ORION CEV Heat Shield H-2 Arc Heater

DARPA FACET Engine APTU

NASA HTT

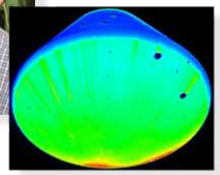


Return to Service

Direct Connect Engine AEDC T3 (M<4)

Tunnels A/B/C
- *Upgraded*
- *Modern Data Systems*
- *Improved Flow Quality*

Navy Standard Missile Tunnel A



ORION CEV Tunnel 9

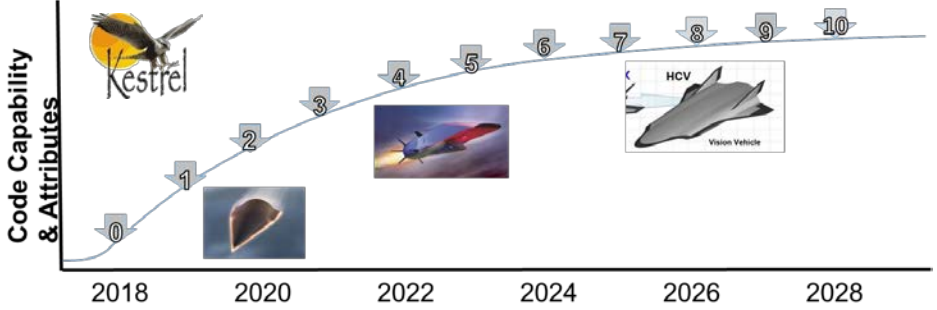
Mach 18 Nozzle

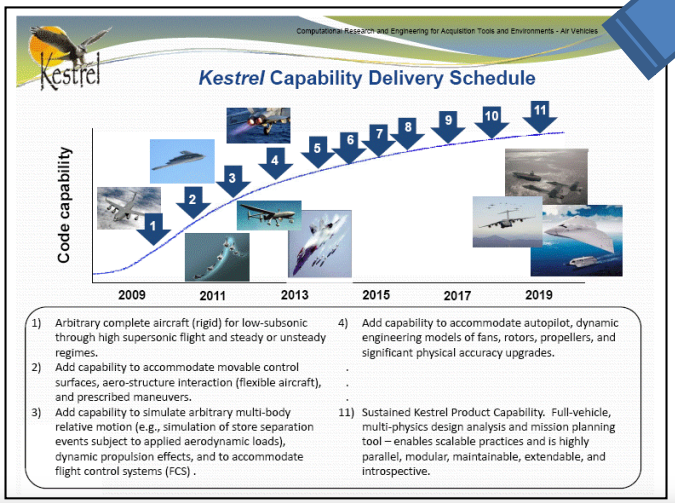
DoD High Performance Computing

Extending the CREATE-AV *Kestrel* Capabilities to Hypersonic Systems

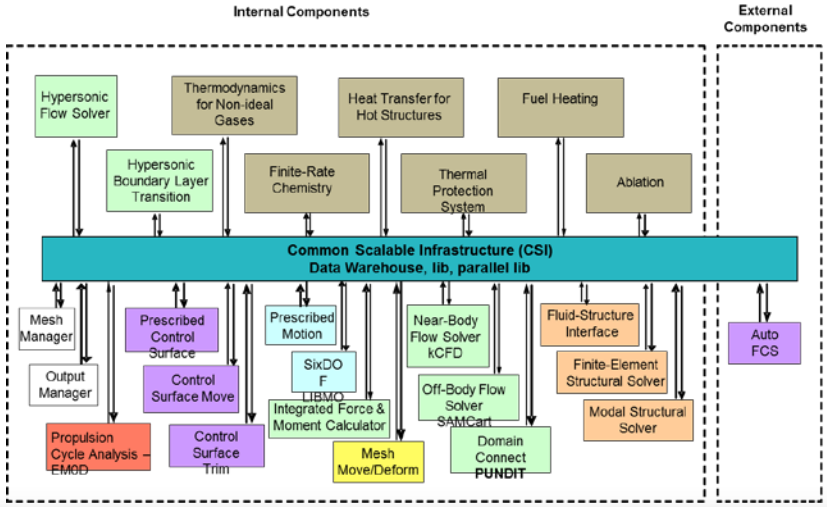
- **Computational Research Engineering Acquisition Tools Environment CREATE-AV, multi-level, multi-physics simulation of air vehicles**
- **2015 AFOSR/CREATE-AV workshop on hypersonic modeling identified requirements / approach**
- **Roadmap adopted as strategic initiative by HPCMP**
- **Initial activities underway**

Nominal Roadmap for Hypersonic Kestrel (Built off successful approach to Kestrel)





Notional Architecture for Hypersonic Kestrel



Development Team for Kestrel and Hypersonic Kestrel are located at AF Test Center Sites

Educational Initiatives

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Educational Initiatives
Hypersonic Center of Testing Excellence (CoTE)

- Cooperation between the University of Maryland (UMD), UTSI and AEDC to revitalize the aging hypersonic workforce
- Gives unique opportunities to American students to conduct mission focused research at Tunnel 9 under the mentorship of T&E experts at AEDC
- Sponsored by AFOSR and TRMC (HSST)
  - AFOSR provides support for graduate students and faculty at the University of Maryland (~4 PhD. students)
  - TRMC (HSST) provides funding for
    - Test articles
    - Sensors
    - Technology development
    - Tunnel 9 tests
  - Additional funding leveraged through collaborations

Integrity - Service - Excellence

Approved for public release; Distribution is unlimited

Enabling hands-on experience with real T&E capabilities

Center for Test Sciences

Accelerated Technology Transition

Targeted research specifically chosen to address critical challenges identified by *programs*

Ex: AFOSR- funded STAR team developed STABL code to improve aerothermodynamic heating analysis utilized in DARPA HTV-2 program

3-5 Generation Advancement, 30+ Tech Transitions beyond HTV-2

Workforce Development

Education of the *current* hypersonics workforce as well as potential future workforce

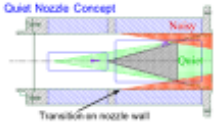
- Graduate degrees
- Specialty certificates
- Short Courses
- Online Seminars

~50% of the ME/AE students at UTSI are AEDC Employees

Methodology Development

New tools and methods critical to the advancement of hypersonic capabilities

Ex: CTS members are among the leading National Experts in Low Disturbance "Quiet" Tunnels



Restricted Access (Driven) Research

Research driven by needs from specific programs with specific access requirements.

- ITAR and classified
- Research can be unclassified/ITAR, but directed by sponsors to address challenges from restricted programs

Several CTS members have clearances

Center for Test Sciences — *Transforming Hypersonic RDT&E*

Focus on Test Sciences to go from laboratory scale to flight with confidence

Collaborative Education, Collaborative Research Initiatives

New Paradigms in Life Cycle Management Digital Engineering

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Digital Engineering Lifecycle Management

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Tenets of the AF Digital Thread/Digital Twin

- Access to and ability to exercise data to enable the government to understand performance and technical risk, i.e., "Own the Technical Baseline"
- End-to-end system model – ability to transfer knowledge upstream and downstream and from program to program
- Single, authoritative digital representation of the system over the life cycle
- Application of reduced order response surfaces and probabilistic analyses to quantify margins and uncertainties in cost and performance
- Preserve meta-data on decision processes and outcomes

Kraft, Edward M. "The US Air Force Digital Thread/Digital Twin – Life Cycle Integration and Use of Computational and Experimental Knowledge," AIAA Paper 2016-0897, SciTech 2016 Conference, San Diego, California January 4-8, 2016.

Digital Thread Approach to Aerodynamic T&E – Providing the Performance Baseline Truth

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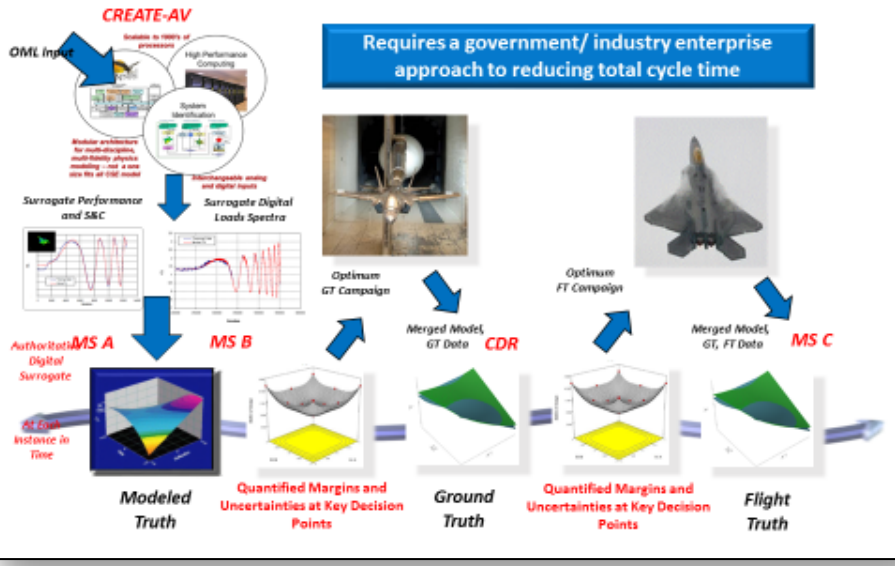


Kraft, Edward M. "HPCMP CREATE™-AV and the Air Force Digital Thread," AIAA Paper No. 2015-0042, SciTech 2015 Conference, Kissimmee, FL January 5-8, 2015.

Hypersonics T&E Will Require a Digital Thread Approach

Limited opportunities to fly at hypersonic speeds

- Cannot be fully duplicated in ground test
- *Seconds* of airbreathing flight data
- Requires *Intelligent Extrapolation* to flight conditions
- Integrated use of all knowledge to develop truth source

Efficient Access to Hypersonic Phenomena

Hypersonic Flight: $200M-$300M / flight

Intelligent Extrapolation

Sub-Scale Flight Research $5M-$10M / flight

Integrated Multi-Disciplinary / Multi-Domain Simulations

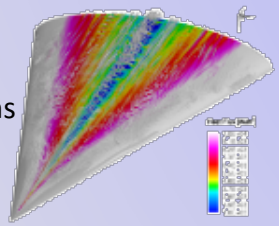
Scaling Guidelines

Uncertainty Quantification

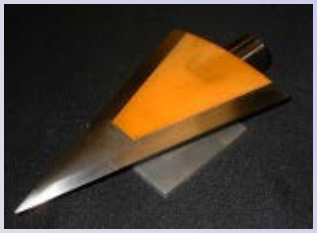
Improved Simulation & Measurement Methods

"Off Ramps" are Essential Tools for Digital Life Cycle Management

Simulations



T&E Scale



Academic Scale

Summary

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- **Hypersonic RDT&E is on a positive slope**
- **Strategic planning and investments in hypersonic T&E technologies and infrastructure are providing the best set of T&E capabilities in decades**
- **High performance computing and advances in scalable, multi-level, multi-physics modeling will be a key enabler in developing hypersonic systems**
- **Multi-university collaborative environment for education and foundational research is rebuilding hypersonic expertise**
- **Leveraging the Digital Engineering revolution underway across the Aerospace and Defense industry will transform hypersonic RDT&E and decrease the cycle time for weapon system development**

QUESTIONS?

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