

PAST PRESENTATION PACKET



PRESENTATION LIST:

-  **Advancing Challenging Aerothermodynamic and Propulsion System Phenomena Via Hypersonic Vehicle Simulation**
Dr. Russ Cummings Managing Director, DoD HPCMP Hypersonic Vehicle Simulation Institute United States Air Force Academy
-  **The Strategic Implications of Hypersonic Technology Development: Russia, China & Missiles and Nukes**
Dr. Peter Huessy, Director for Strategic Deterrent Studies Mitchell Institute for Aerospace Studies
-  **Traditional Heat Transfer And Fluid Mechanics Investigations For Hypersonic Flight**
Dr. Phil Ligrani on Physical Phenomena Associated With Hypersonic Weapon Vehicles
-  **Aggregating Hypersonic S&T Data To Rapidly Deliver Next-Gen Technology Development**
Dr. Joseph Bonivel, Jr., Subject Matter Expert Defense Technical Information Center



October 28-30, 2020 | Washington, D.C.

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Advancing Challenging Aerothermodynamic and Propulsion System Phenomena via Hypersonic Vehicle Simulation

Hypersonic Weapons Summit
Institute for Defense & Government Advancement
Arlington, VA



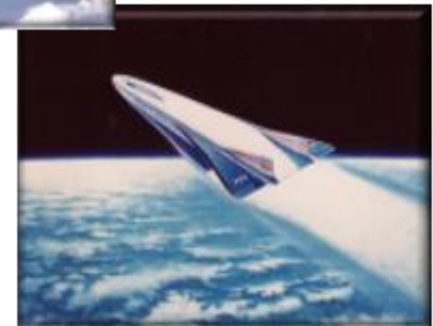
Russell M. Cummings, HVSI Managing Director

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Mar 31, 2020

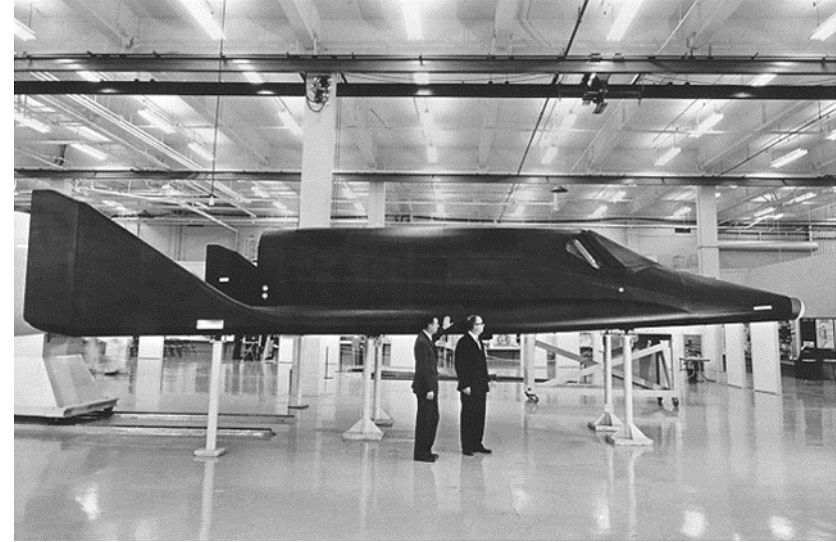
Introduction and Background

- **75 years of hypersonic flight progress hampered by:**
 - Cancellation of major programs
 - Significant “gotchas” leading to near misses and accidents
 - Cyclical nature of funding (10-12 year period)
- **These issues make consistent, long-term progress in hypersonics challenging (facilities, people, knowledge)**



Cancellation: X-20 Dyna-Soar

- Re-entry vehicle program from 1957 to 1963
- Designed to increase mission flexibility over capsules that were being used at the time
- Based on the concepts of Sänger in the 1930s
- Several known technical challenges (and other non-technical issues) led to cancellation in 1963
- Great potential was lost, especially for collecting data and increasing knowledge/experience
- One benefit: many of the workers moved to Apollo program after cancellation of X-20



Gotcha: X-15

- Hypersonic rocket-powered flight test program from 1955 (project start) through 1968 (final flights)
- X-15 launched from B-52 and then used rocket power
- 199 flights broke multiple speed/altitude records, including reaching altitude of 108 km and speed of 7,273 km/h
- Pilots included: Neil Armstrong, Scott Crossfield, Bill Dana, Joe Engle, Pete Knight, and Robert White



Gotcha: X-15A-2 Hypersonic Research Experiment

- The desire to design supersonic combustion systems led to hypersonic scramjet experiment on the X-15
- Initial tests done at lower Mach numbers with dummy ramjet mounted on lower ventral pylon
- During $M = 6.7$ flight severe damage took place to the experiment and pylon in spite of the use of ablative materials



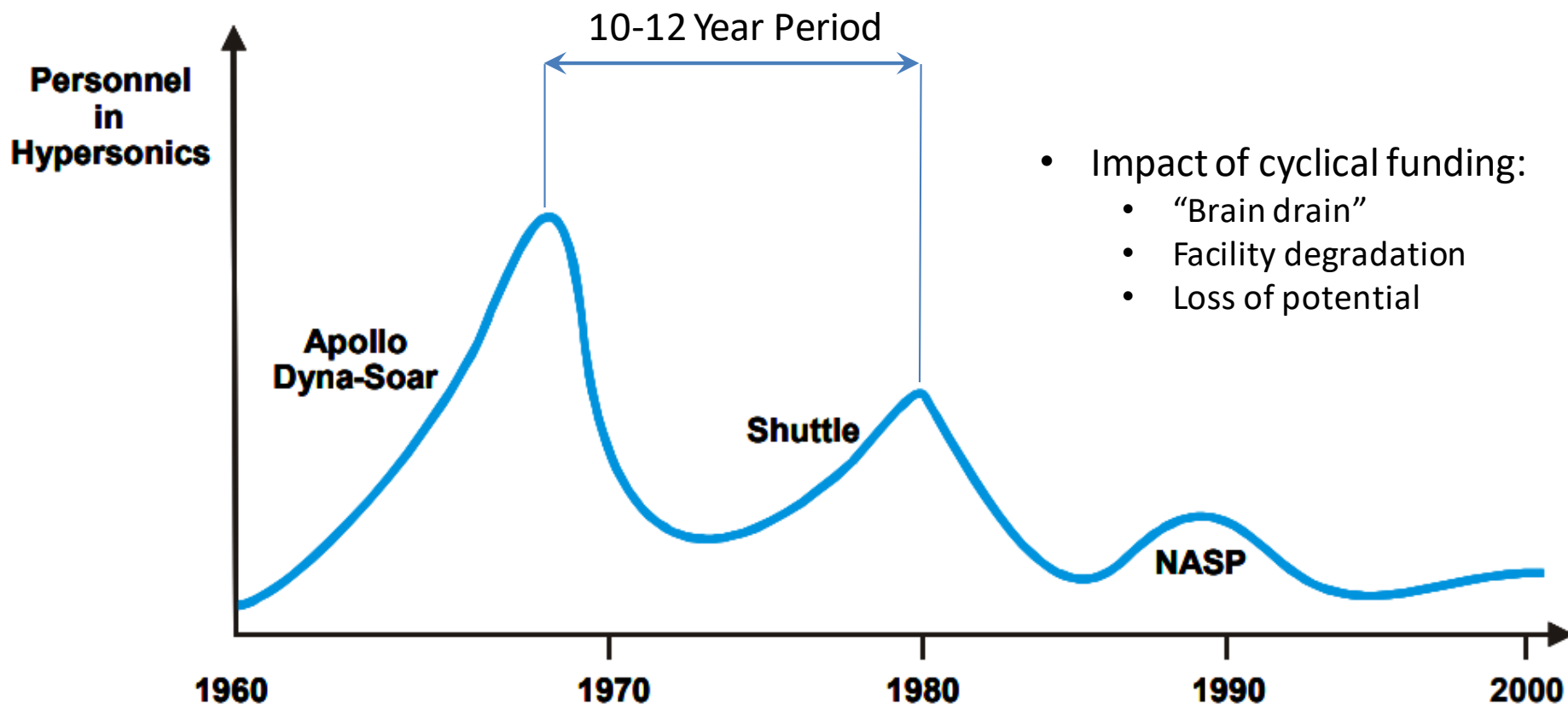
Gotcha: X-15A-2 Hypersonic Research Experiment

- Shock/shock interactions caused locally high heating rates that produced severe damage to ventral pylon structure (unknown unknown)
- “This project, the Hypersonic Research Experiment (HRE), cost \$50 million, and generated only one noteworthy accomplishment: ‘the illumination of critical unknowns.’” Houchin (1987)

Ventral pylon made of Inconel X alloy with melting temperature of 2600°F



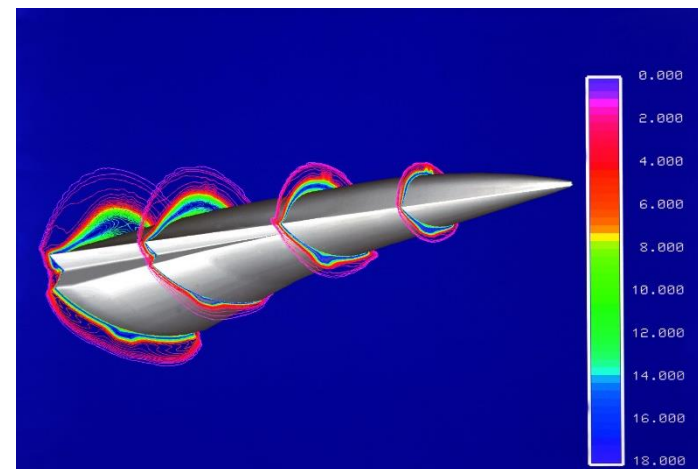
Cyclical Funding



“Why and Whither Hypersonics Research in the US Air Force,”
USAF Scientific Advisory Board, SAB-TR-00-03, Dec 2000

Cyclical Funding

- **Take the National Aero-Space Plane (NASP) as an example:**
 - when NASP started very little hypersonic design work had taken place for nearly 15 years
 - most of the challenges that faced NASP CFD are similar today:
 - validation of higher-order turbulence models
 - improvement in modeling compressible turbulence
 - predicting location and length of boundary layer transition zone
 - improvement in numerical methods
 - treatment of boundary conditions
 - more efficient cooperation between government and industry in CFD code development and validation
 - explicitly evaluating and publishing the uncertainty in CFD simulation results as a function of vehicle speed and location on the vehicle



NASA NASP-Computer Aided Design Computational Fluid Dynamics
NASA Langley Research Center 6/6/1988 Image # EL-1996-00191

S.K. Liu, "Numerical Simulation of Hypersonic Aerodynamics and the Computational Needs for the Design of an Aerospace Plane," RAND Note N-3253-AF, 1992

Hypersonic X-Plane Program Duration and Cost

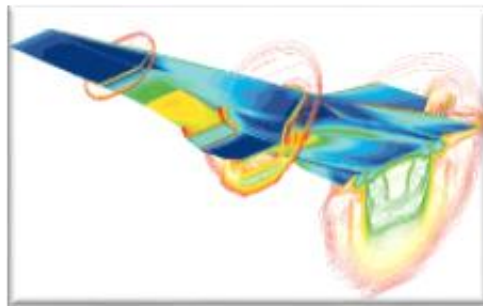
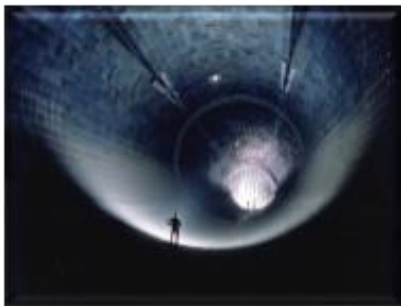


Program	Years	Flights	Failures	2017 \$
X-15	1955-1968	199	1	\$2.00B
X-20	1957-1963	0	0	\$5.30B
X-24A/X-24B	1969-1975	64	0	?
X-30 (NASP)	1986-1993	0	0	\$3.24B
X-33	1996-2001	0	0	\$1.75B
X-34	1996-2001	0	0	\$0.49B
X-37	1999-present	5	0	\$0.49B for X-37A
X-38	1995-2002	8 drop tests	0	\$0.50B
X-43	2001-2004	3	1	\$0.26B
X-51	2005-2013	4	2	\$0.34B

“Our rate of flight testing is appalling—Ops Tempo is important!” Michael Griffin

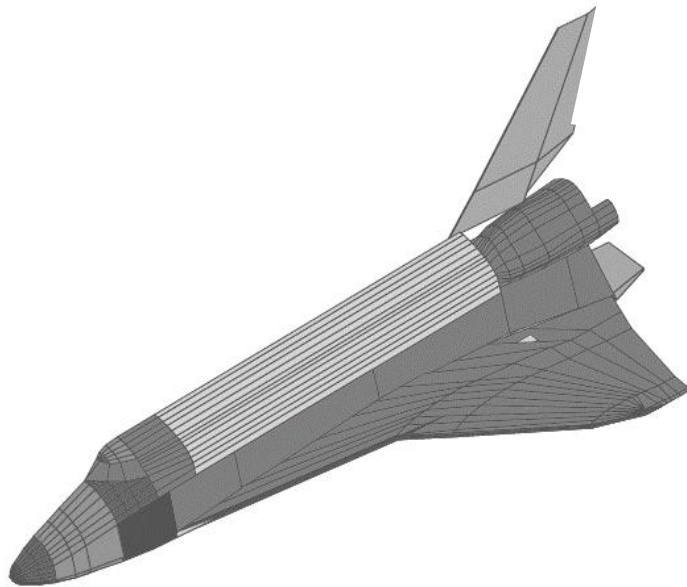
Implications and Tool Set

- **An engineer's response to technical uncertainty: conservative vehicle design approaches**
- **Hypersonic vehicles cannot be designed well without good predictions of forces, moments, and heat flux**
- **Available tool set for hypersonic vehicle design:**
 - semi-empirical/theoretical predictions (low fidelity methods)
 - high fidelity CFD methods
 - ground test
 - flight test



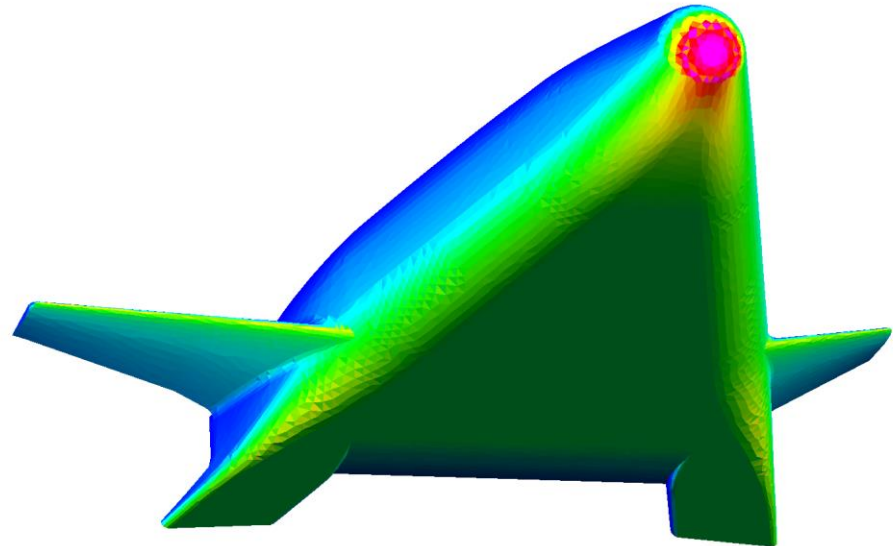
Low-Fidelity Methods . . .

In the 1960s



Supersonic/Hypersonic
Arbitrary Body Program

In the 2010s



CBAERO, AIAA Paper 2004-0031

Only limited change!

High-Fidelity Methods . . .

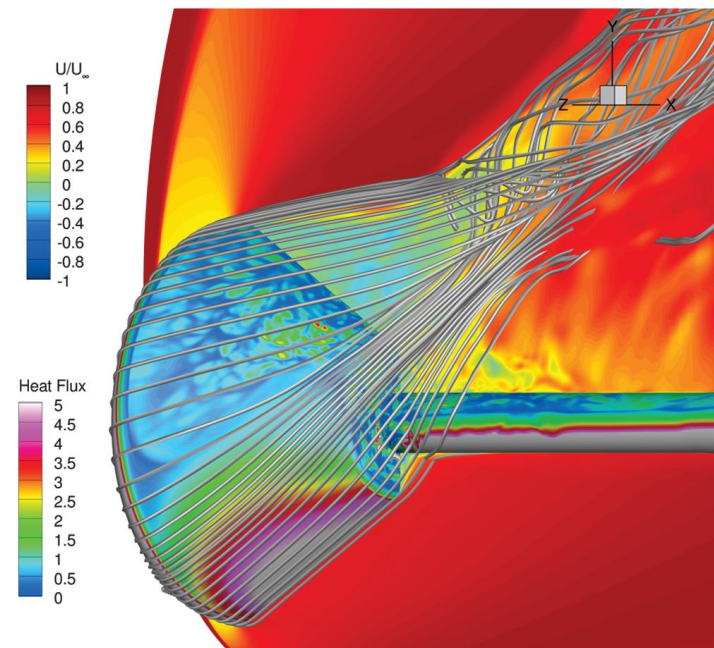
In the 1960s

$$u_i^{n+1} = \frac{1}{2} \left\{ u_i^n + \overline{u_i^{n+1}} - \frac{c\Delta t}{\Delta x} (\overline{u_i^{n+1}} - \overline{u_{i-1}^{n+1}}) \right\}$$

No flow visualization!

MacCormack's Explicit Method,
AIAA Paper 69-0354

In the 2010s



US3D Prediction of Capsule Wake,
J. Spacecr. Rockets, 52(1), 2015, 17-28

Significant change!

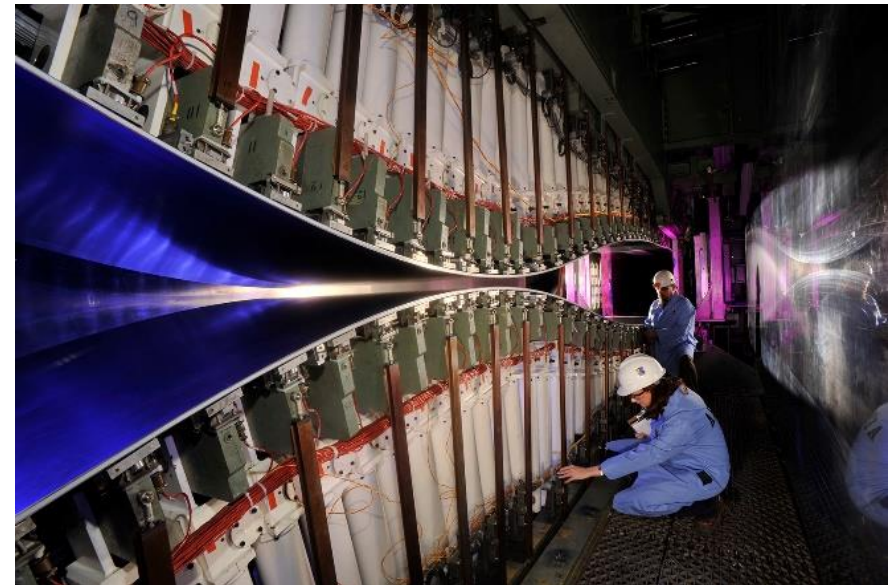
Ground Test Facilities . . .

In the 1960s



JPL 21-inch Hypersonic Wind Tunnel

In the 2010s



AEDC von Karman Gas Dynamics Facility

Only limited change in tunnels!
(although data acquisition has changed significantly
and the advent of quiet tunnels is important)

Ground Test Facilities . . .

- **In 1960s there were 78 hypersonic wind tunnels in US***
 - University & non-profit research tunnels (not counting small shock tubes): 18
 - Industry tunnels: 27
 - Government lab wind tunnels: 33
- **Today there are $\approx$ 40 hypersonic wind tunnels**
 - University research tunnels are currently expanding in number
 - Most industry tunnels demolished during 1970s
 - Half of all government tunnels demolished since 1970



AEDC Tunnel 9

*Vicente and Foy, "Hypersonic Wind
Tunnel Facilities in the United States,"
March 1963

Ground Test Facilities . . .

- **Impact: recent US upturn in hypersonic vehicle development has already saturated many of the key hypersonic wind tunnel facilities**
- **Often 5-10 year lead time for designing, building, and making new tunnels operational**
- **China has been building an entire suite of new, large hypersonic wind tunnels at a rapid pace**



China Aerodynamics Research and Development Center

Flight Test Facilities . . .

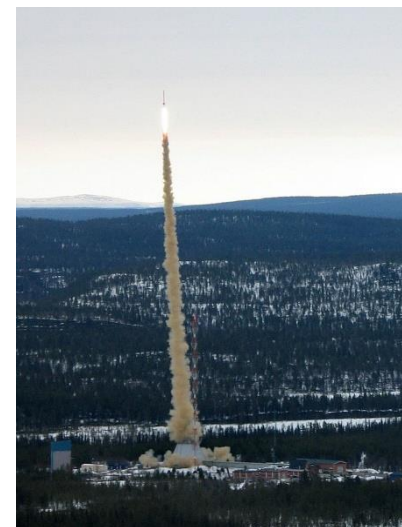
- US has limited number of flight test facilities with constrained test ranges; very high cost per flight test
- Impact: limited flight test data and increased use of flight test ranges in Australia, Norway, and Sweden



**RAAF Woomera Range Complex
Australia**



**Andøya Rocket Range
Norway**



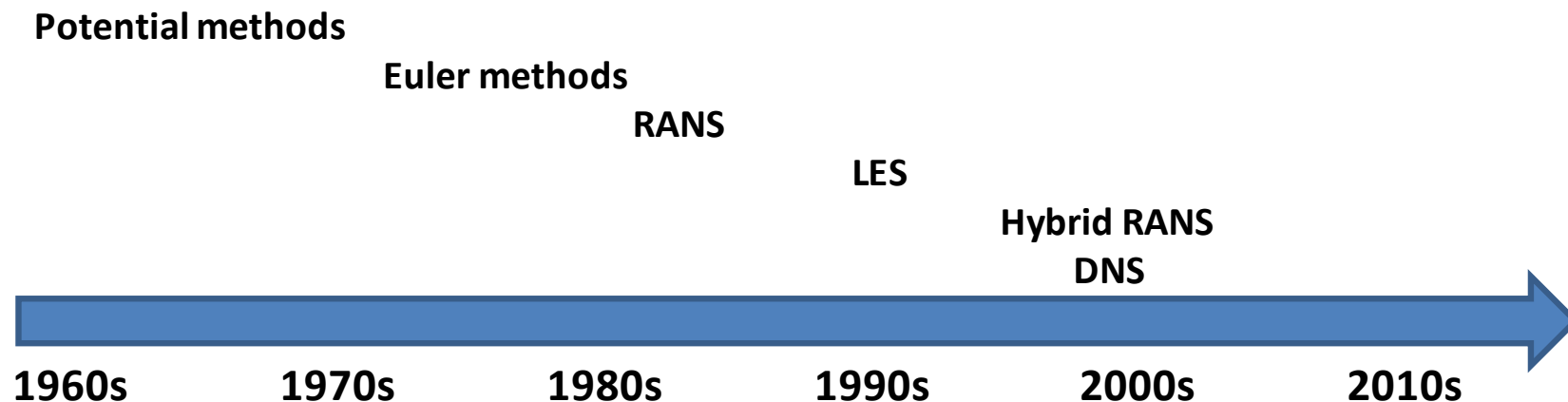
**Esrange Space Center
Sweden**

Where Are We Now?

- **Computational simulation has the ability to significantly impact the acquisition process**
 - With increased ground and flight test used for verification and validation (V&V) and vehicle development
- **How can we improve our capabilities for hypersonic vehicle simulation?**
- **S&T Gaps: Hypersonic CFD codes need to include simulation capabilities or modeling for:**
 - High temperature effects, turbulence, boundary layer transition, ablation, rarefaction effects, shock/shock and shock/boundary layer interactions, fluid/thermal/structural interactions, combustion, etc.
- **These gaps must be filled in order to have significant impact on acquisition cycle for hypersonic vehicles**

Background of CFD Development

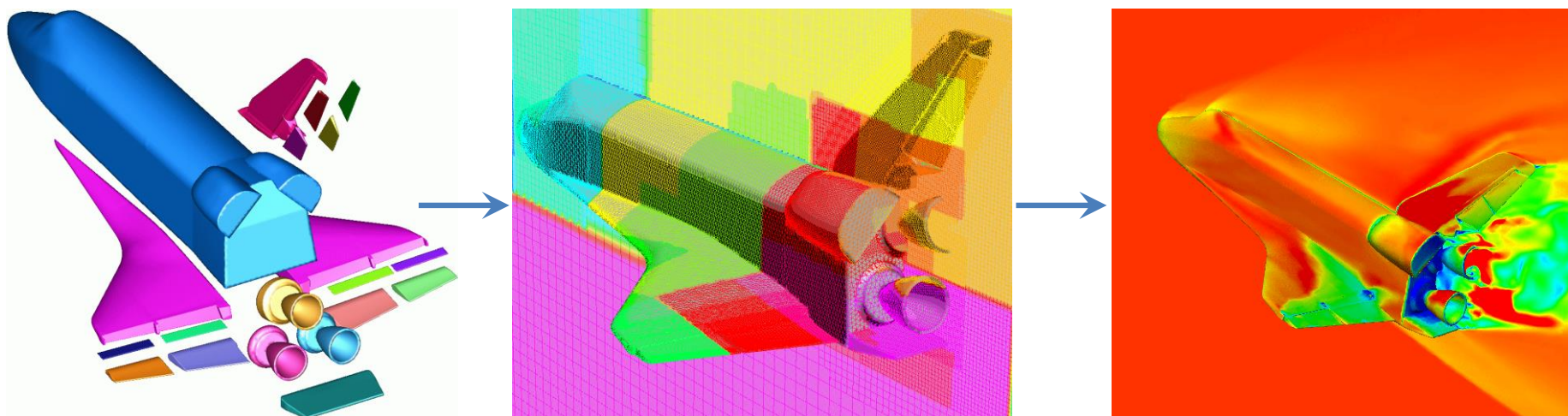
- CFD research has taken place in a mostly linear fashion for the past 50 years
- Once a new capability is possible (usually due to computer improvements) the next higher fidelity capability is introduced
- Little or no improvement continues for lower fidelity capabilities (except in a few rare circumstances)



Exception to the Rule

• CART3D

- Euler code for conceptual/preliminary design from NASA Ames
- Automated CFD analysis on complex geometries:
 - automated/robust Cartesian mesh generation
 - adjoint-driven mesh adaptation
 - utilities for geometry import, surface modeling and intersection, and post-processing of results
- Code created years after Euler methods were “out of fashion”
- Used a great deal by industry for hypersonic design!



https://www.nas.nasa.gov/publications/software/docs/cart3d/pages/cart3d_images.html

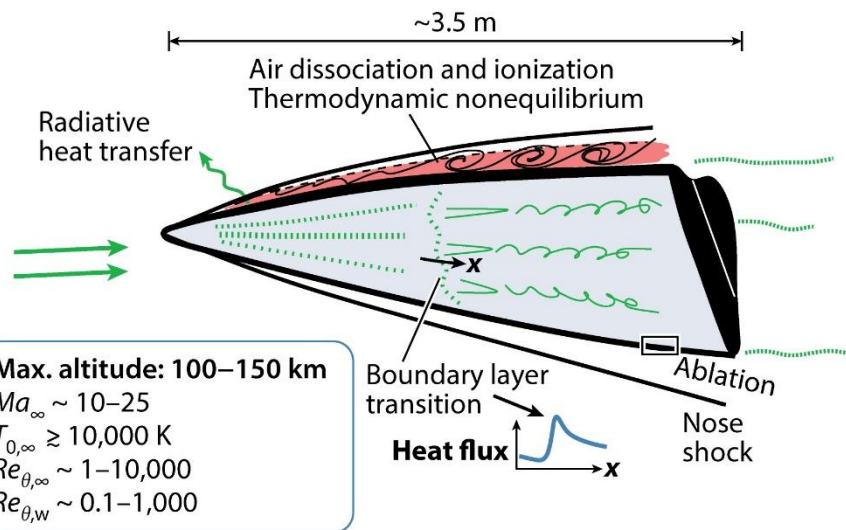
We Need More “Exceptions to the Rule”

- **Improvements to RANS codes largely slowed once researchers moved from RANS to LES/DNS**
 - little/no funding for improved turbulence models, parametric geometry definition, automatic mesh generation, post processing
 - some of these features are now developed at companies or government labs
- **Impact?**
 - 1983: “A major challenge is the user interface, with spatial and surface grid generation being the major component” from AIAA Paper 83-2060
 - 1999: “Generation of computational meshes around a 3-D configuration is another bottle-neck in the application of CFD to complex configurations” from *Applied Mathematical Modelling* 23 (1999) 705-735
 - 2014: “Mesh generation and adaptivity continue to be significant bottlenecks in the CFD workflow” from NASA CFD Vision 2030 Study
- **We need a “CART3D-Like” RANS Code for hypersonics!**

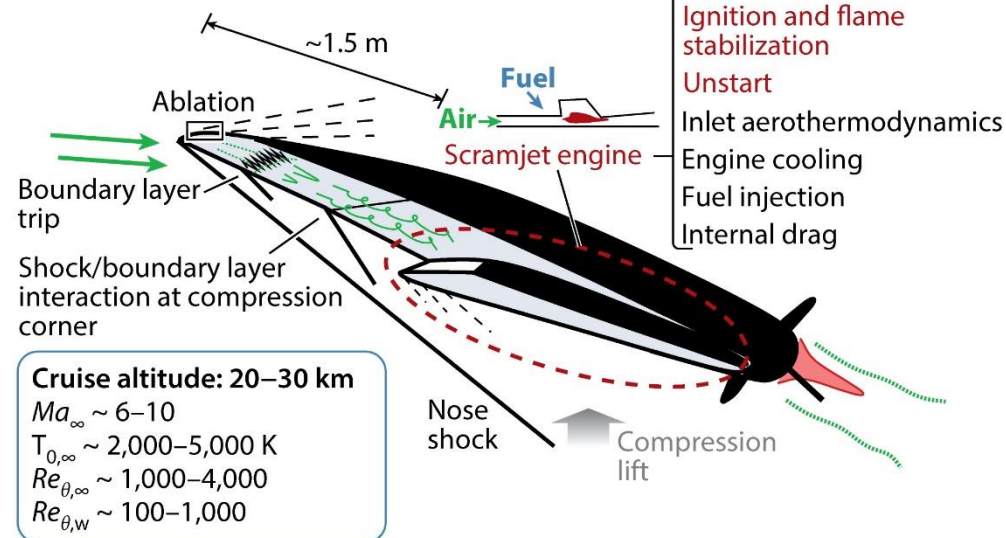
https://www.nas.nasa.gov/publications/software/docs/cart3d/pages/cart3d_images.html

S&T Gaps for Hypersonic Vehicles

Boost-glide weapon



Hypersonic air-breathing cruise missile



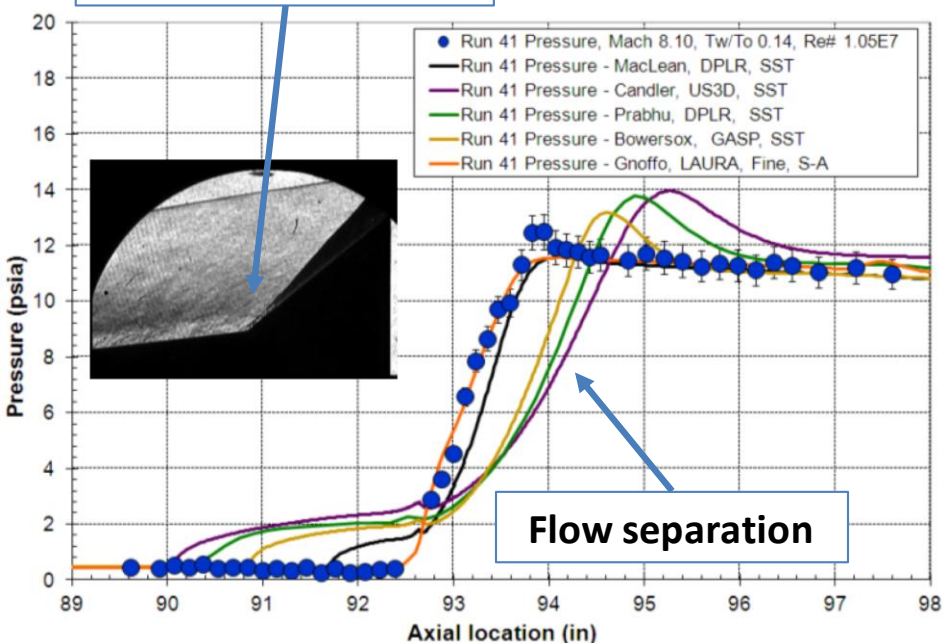
AR Urzay J. 2018.
 Annu. Rev. Fluid Mech. 50:593–627

Example Gap: Turbulence Models

Typical results for the AIAA/CUBRC blind code-validation study on large cone-flare
 $M = 8.1$, $Re = 1.05 \times 10^7$, and $T_w/T_o = 0.14$

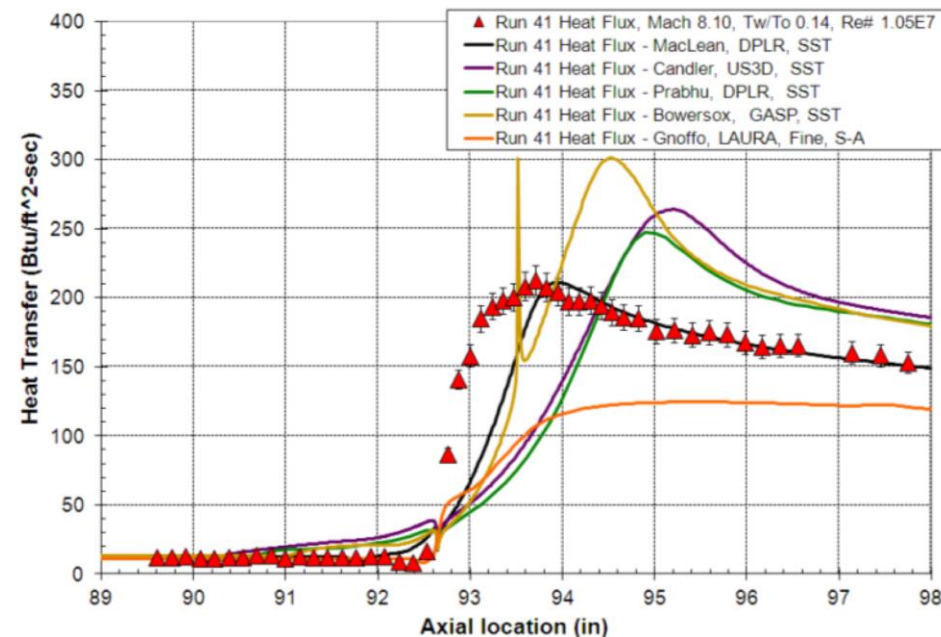


No flow separation



Surface pressure

Flow separation

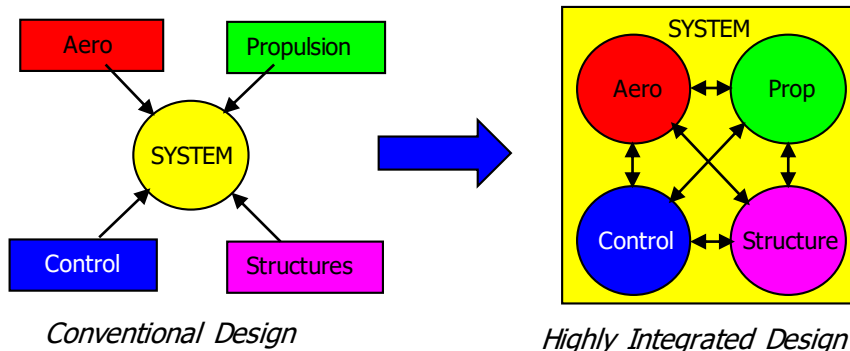
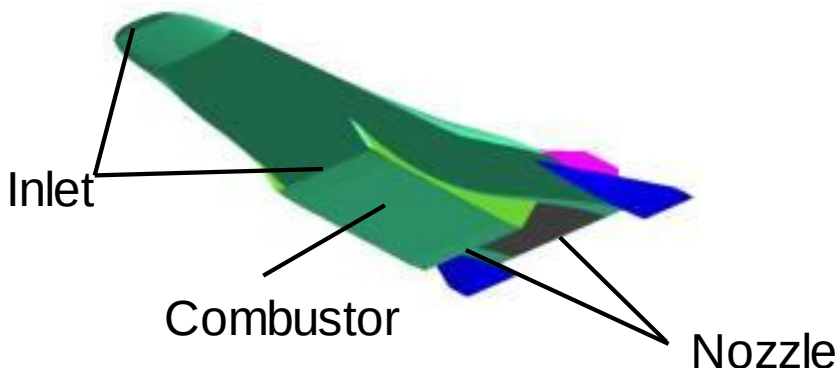


Heat flux

Highly Integrated Nature of Hypersonic Vehicles Makes Their Design Challenging

All vehicle components and functions strongly interact

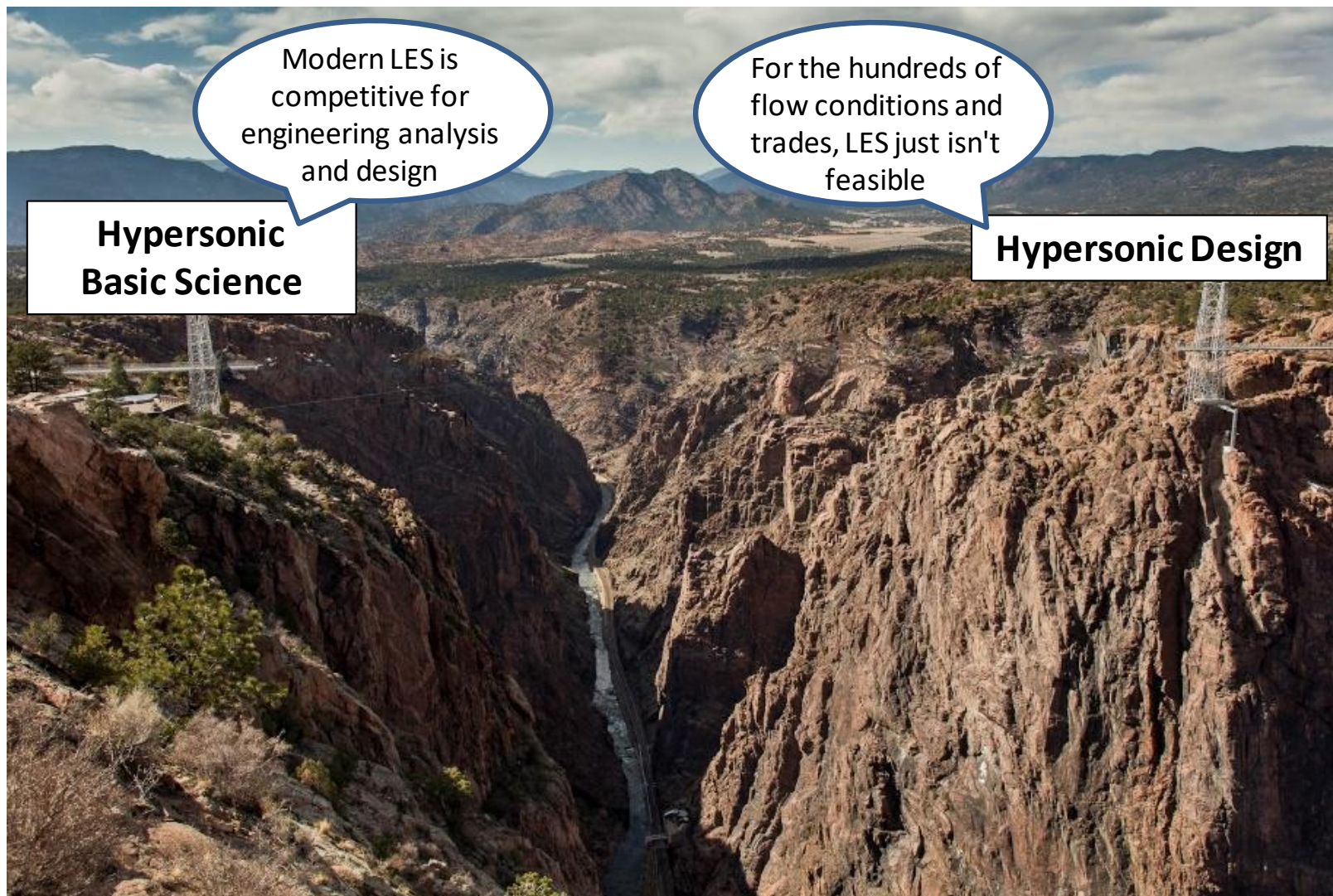
- Good hypersonic aircraft designs blend the body, wings and engine to achieve high performance through shared functionality and synergy



- Conventional airplane design approach does not work well for highly integrated vehicles
- Multidisciplinary design optimization (MDO) approach crucial!

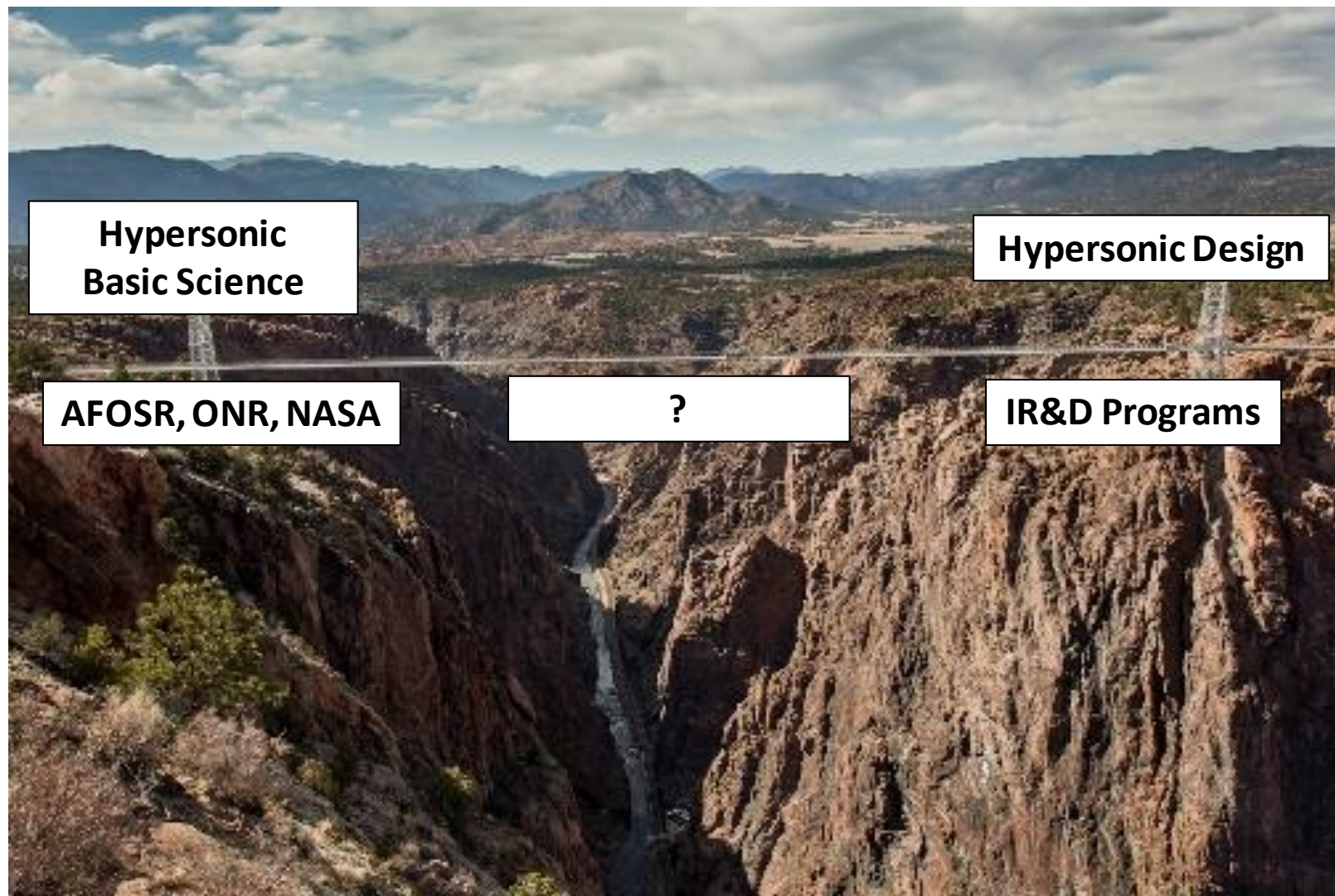
Slide courtesy of Kevin Bowcutt, Boeing Research & Technology

Bridging the M&S Chasm



Royal Gorge, CO

Bridging the M&S Chasm



**Hypersonic
Basic Science**

Hypersonic Design

AFOSR, ONR, NASA

?

IR&D Programs

Royal Gorge Bridge, CO

DoD High Performance Computing Modernization Program (HPCMP)

A DoD-wide program and national asset providing high performance computing capabilities and expertise to solve DoD's most critical mission challenges

DoD Services & Agencies

Army
Navy
Air Force
DTRA
MDA
DARPA

Major Functions

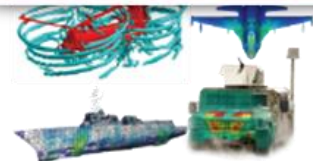
Science and Technology



Test and Evaluation



Acquisition Engineering



Hardware

DoD Supercomputing Resource Centers (DSRCs)



U.S. Air Force
Research
Laboratory DSRC



U.S. Army
Research
Laboratory DSRC



U.S. Army Engineer
Research and
Development
Center DSRC

Maui High
Performance
Computing
Center DSRC



U.S. Navy DSRC

+

Network

Networking and Security

Defense Research & Engineering Network
(DREN)



Computer Network Defense,
Security R&D, and Security Integration



+

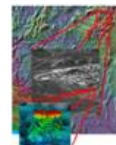
Software

Software Applications



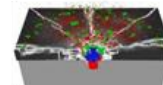
CREATE:
Software
Engineering

Institutes
Cross-service
software capabilities
teams



PETTT: Training
and
Computational
Expert Support

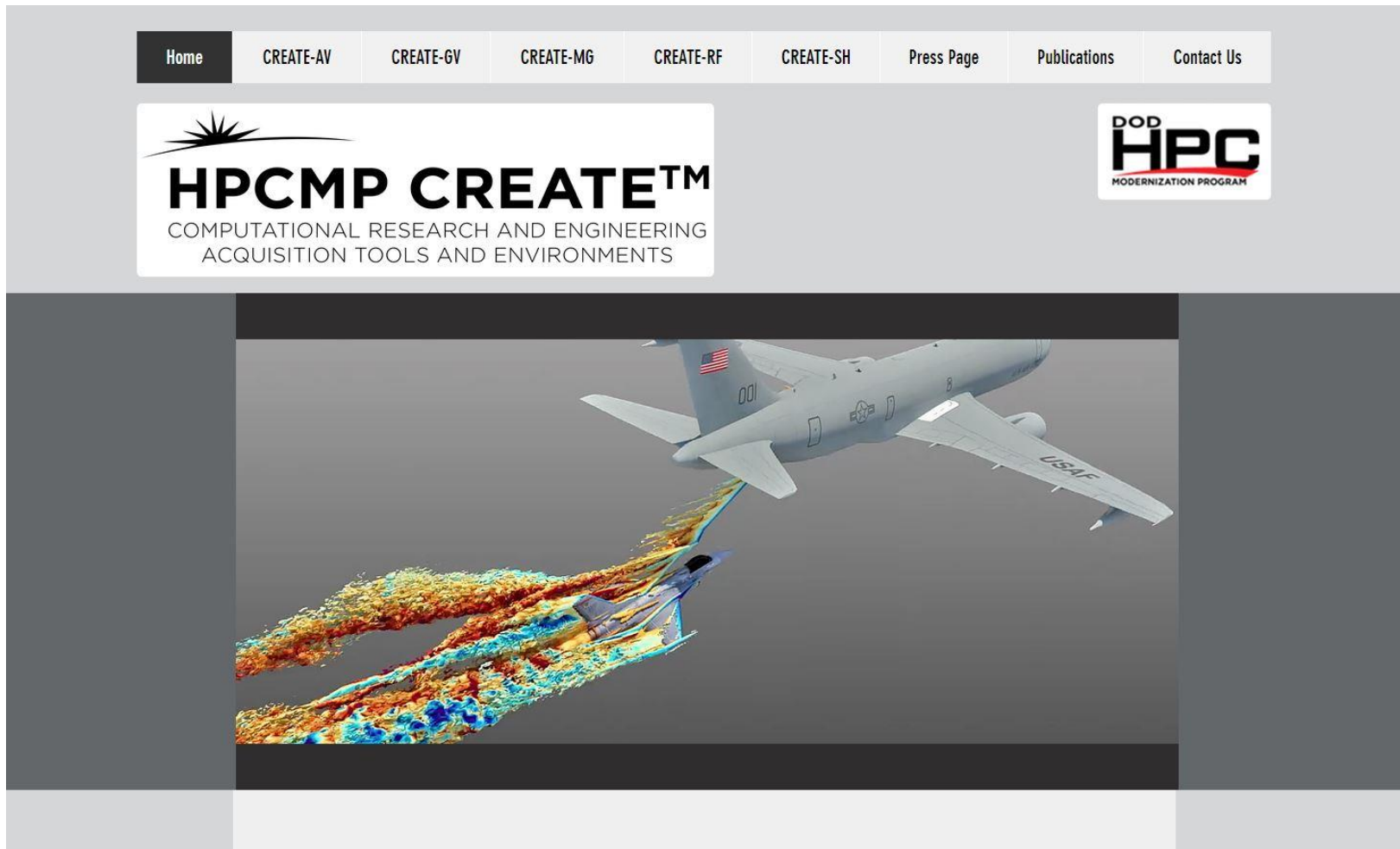
Frontier:
Computationally
Intensive
Projects



Partners

DoD/Federal Agencies + PEO's/PM's + Academia + Industry

Current CREATE Software



AV-Air Vehicles, GV-Ground Vehicles, MG-Meshing & Geometry, RF-RF Antennas, SH-Ships
<https://www.hpcmpcreate.org>

The Paradigm to Change

- **From:**

- Reliance on physical test as the driver for design iteration and primary source for “actionable engineering data”, e.g. support warrant holder requirements, system certifications, etc.

- **To:**

- Use physics-informed analysis and **virtual test to drive design iterations**, and as a source of actionable engineering data.

Use virtual test
to drive design
iterations



Use physical test to validate the design

Hypersonic Vehicle Simulation Institute (HVSI)

- **HPCMP CREATETM-AV Board of Directors saw the need for production hypersonic software tools**
- **Most hypersonic physics are not modeled by current production aerodynamic codes**
 - gaps exist between current codes and required capability
- **HVSI has been established by HPCMP for the purposes of filling those gaps**
- **HVSI began in Summer 2018**
- **HVSI is being hosted at the US Air Force Academy**

Hypersonic Vehicle Simulation Institute

CREATE Goal: Accelerate the successful development of hypersonic systems through the use of HPC software and hardware.

HVSI Mission: To measurably improve the simulation of hypersonic vehicles

HVSI Objectives:

- (1) Facilitate the development and documentation of a **national vision for hypersonic vehicle simulation** by pulling together the DoD, DOE, NASA, and Industry hypersonic RDT&E community
- (2) **Co-Fund projects** in the gaps of current DoD, DOE, NASA, and Industry research efforts critical to improving DoD hypersonic vehicle simulation
- (3) Facilitate transition of hypersonic research into **production quality simulation software** available to government, academic, and industry acquisition partners
- (4) Create a national repository for hypersonic simulation **verification and validation data**
- (5) Fund **Shadow Projects** to validate results on real world hypersonic vehicles

HVSI Immediate Tasks

- **Conducting 2030 Vision Study Report for hypersonic simulation: “where should we be in hypersonic simulation by the year 2030?”**
 - “Gap” survey, Tech Advisory Board, and workshops currently underway
- **Creating V&V library accessible through HPC systems**
 - Currently identifying candidate experiments
 - Also identifying what experiments are required for future V&V
- **Identify and fund R&D projects to fill S&T gaps**
 - First research projects currently underway on Hypersonic Turbulence
 - Second research projects on Transition Prediction just starting
 - Investigating various lower-order methods that can be used now
- **Leverage funding by coordinating with AFRL, ONR, DARPA, etc.**

Summary

- **The DoD HPCMP has established a Hypersonic Vehicle Simulation Institute at the US Air Force Academy**
- **HVSI is bringing together stakeholders to formulate a plan for improving hypersonic simulation**
- **Goal is to accelerate the acquisition process by improving low- and high-fidelity simulation tools**
- **HVSI will fund projects that help to fill gaps between basic science and model development**
- **Developing a V&V data base for hypersonic vehicle simulation including experimental and numerical results**

Peter Huessy
President of GeoStrategic Analysis

**The Strategic Implications of Hypersonic Technology Development:
Russia, China & Missiles and Nukes**

April 1, 2020

**Institute for Defense and Government Advancement, Hypersonic Virtual
Summit, Washington, D.C.**

Strategic Implications of Hypersonic Missile Technology

- **Key Conclusions and Findings**
- **Threat: Russian and Chinese Developments/Strategy**
- **Response: USAF Technology Development**
- **Implications: Change to Strategic Landscape**
- **Critics Misconceptions**
- **Sign-Posts**
- **Conclusion**

Conclusions and Major Findings

- ❖ What:

- ❖ Hypersonic missile technology exceeds Mach 5 (+3600 mph) & is highly maneuverable and accurate & difficult to detect and track & significant and serious technological development

- ❖ Why Care:

- ❖ Russia and China have more options to target more time-sensitive and mobile targets, with much reduced USA decision-making response time, can use conventional or nuclear warheads, dramatically increasing threats to the US and allies including nuclear coercion

- ❖ US Should Do:

- ❖ Develop both USA and allied defense and offensive hypersonic technology, especially significantly improved space-based sensors & regional and CONUS based missile defenses, and offensive hypersonic missiles
- ❖ Highly recommend the IFA National Security Update of November 2019 on Hypersonic Missiles and US Security and the Mitchell Institute's Hypersonic Weapons and US National Security: A 21st Century Breakthrough of January 2016.

Russian/Chinese/Iran/DPRK Hypersonic Technology Developments

- I. Technology is to provide more capable access denial (A2/AD) networks, to make it increasingly difficult and challenging for the US to defend her allies in Europe, the Middle East and the Pacific from Chinese, Russia, Iran or DPRK aggression
- II. General Paul Selva former Vice Chairman/JCS and Mike Griffin, the Undersecretary of Defense for R&E both note China is developing the technology, to spend multiple billions to bring the Df-17 hypersonic glide vehicle into the force, and hold at risk US bases, US land forces and US carrier battle groups, to seek hegemonic control of the Pacific to allow unfettered aggression. Mike Griffin notes Chinese threat undergirded by over 24 successful hypersonic technology tests....
- III. Russia has deployed the first such hypersonic capable missile—the Avangard—and President Putin explains such technology along with its advanced nuclear modernization gives Russia superiority over the US and is thus able to better threaten the NATO alliance—we won't know the target says one NATO official until there is “boom on the ground”.
- IV. China: DF-ZF; DF-26 HGV; and Xing Kong-2
- V. Russia: Avangard HGV; KinzhalALHM; Tsirkon, SLHCM; BrahMos-II, HCM

US Hypersonic Developments

- I. US seeks to deploy such technology with conventional warheads giving a capability to strike a target anywhere on earth within one hour, particularly to counter Chinese and Russian anti-denial strategies
- II. US is developing space-based sensors to see and track such missile threats
- III. US must also develop intercept capability best achieved through boost-phase/space-based interceptors, upgrades to current regional and CONUS based defense systems and the enhanced ability to “strike left of launch”
- IV. The DOD considers developing such hypersonic capable weapons one of the nation’s highest technical research and engineering priorities. On March 19, the US Army tested the C-HGB hypersonic glide body from the Pacific Missile Range in Hawaii;
- V. The USAF has picked the AGM-183 Air-Launched Rapid Response Weapon, which can be carried in large quantities by the B-52 and the F-15, and passed a critical design review in late February. USAF acquisition chief Roper said a key will be the ability to spiral development advances in the technology after initial deployment.....
- VI. The Hypersonic Conventional Strike Weapon was not chosen by the USAF; however both programs were progressing well and the Army and Navy will continue to work the surface launched versions.

Strategic Implications I

- I. Putin: “We have a unique situation now. For the first time, we have created such offensive strike systems the world has never seen...Now they are chasing us, trying to catch up.”
- II. “It is critical that US defense makers grasp and understand the hypersonic threat and the role [hypersonic missiles] plays in the plans of China and Russia...[which] see [hypersonic missiles] as an effective....means to deliver nuclear weapons...[including] provide to US adversaries such as North Korea and Iran...”
- III. Such adversary technology “will severely limit response times available to targeted nations and create a dangerous degree of uncertainty....[which] could lead to the rapid escalation of military conflicts” ...South China Morning Post

Strategic Implications II

- I. Russia has turned into an antagonist as it seeks global power, says NATO's Supreme Allied Commander, March 2017, General Curtis Scaparrotti
- II. Russia has updated its nuclear doctrine to intimidate NATO nations as well as former Soviet states says Scaparrotti....
- III. In a new strategy adopted and first described as “escalate to de-escalate” but actually “escalate to win”, Russia is seeking to use or threaten to use limited numbers of nuclear weapons early in a crisis to get the US to stand down, and lose the perceived capability to protect its NATO allies....to “freeze a conflict in place” ...

Strategic Implications III

- I. It is one of the most challenging military questions you have said General John Hyten, then Commander of US Strategic Command and now Vice Chairman of the Joint Chiefs of Staff said in March 2017 to the SASC. “And for us to win, we have two choices. One to prevent the escalation. Or two, respond in such a way after that escalation that would want to stop any aggression.”
- II. While the United States sought to de-emphasize the role of nuclear weapons in our deterrent strategy said Hyten, our adversaries have done exactly the opposite.
- III. The USAF Chief of Staff, General Dan Goldfein said it best, It’s a new world, It is a grave new world in HASC testimony , April 2017.
- IV. “At the very edge of Hudson Bay, you have enough velocity to hit all 48 of the continental United States....you can choose to make a right or left turn and hit Maine or Alaska...” General Paul Selva, Vice Chairman of the JCS, 2019

Critics Get It Wrong—As Usual

- I. Arms control critics of the USA pursuing defenses against hypersonic capable missiles and an offensive deterrent force make three arguments:
- II. The technology is not revolutionary....
- III. Conventional ballistic missiles work perfectly well...
- IV. There is no missile defense against range ballistic missiles now so any defense against hypersonic speed & maneuverable is not going to work either....
- V. Technical challenges to developing hypersonic speed systems are a long way from being resolved, so there should be no rush to deploy....
- VI. US goal is to unfairly intimidate China and Russia with such systems as part of a US hegemonic strategy of seeking what Bill Keller of the NY Times has described as an “unfettered” US security strategy.....

Critics: A Reply

- I. Technology being pursued by our adversaries is in service of a hostile strategy—ignoring our adversaries activities led to Pearl Harbor and 9-11.....
- II. Maj Gen Curtis Bedke USAF (Ret.) explains the hypersonic technology follows stealth and turbojet engines both of which revolutionized military affairs
- III. China has done more than 24 successful tests of the technology and Russia has deployed the technology---whether the technology is revolutionary or not...
- IV. New US developed defense technology works.....
- V. Decision Speed is needed because the US was way behind adversaries.....
- VI. Missile defense of CONUS worked in 6/7 previous tests; we have also not deployed missile defenses that are more effective due largely to political opposition to such systems not because of technology roadblocks.....
- VII. Whether defense or offense technology, the US is seeking to DETER bad behavior by rogue nations including invasions and terror attacks—stopping such behavior is not unfair.....the US and its allies are the “good guys”..
 - **Always blaming America first is not a sound security policy**

SIGN-POSTS

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Peter Huessy
President of GeoStrategic Analysis

**The Strategic Implications of Hypersonic Technology Development:
Russia, China & Missiles and Nukes**

April 1, 2020

**Institute for Defense and Government Advancement, Hypersonic Virtual
Summit, Washington, D.C.**

Strategic Implications of Hypersonic Missile Technology

- **Key Conclusions and Findings**
- **Threat: Russian and Chinese Developments/Strategy**
 - **Response: USAF Technology Development**
 - **Implications: Change to Strategic Landscape**
 - **Critics Misconceptions**
 - **Sign-Posts**
 - **Conclusion**

Conclusions and Major Findings

- ❖ What:

- ❖ Hypersonic missile technology exceeds Mach 5 (+3600 mph) & is highly maneuverable and accurate & difficult to detect and track & significant and serious technological development

- ❖ Why Care:

- ❖ Russia and China have more options to target more time-sensitive and mobile targets, with much reduced USA decision-making response time, can use conventional or nuclear warheads, dramatically increasing threats to the US and allies including nuclear coercion

- ❖ US Should Do:

- ❖ Develop both USA and allied defense and offensive hypersonic technology, especially significantly improved space-based sensors & regional and CONUS based missile defenses, and offensive hypersonic missiles
- ❖ Highly recommend the IFA National Security Update of November 2019 on Hypersonic Missiles and US Security and the Mitchell Institute's Hypersonic Weapons and US National Security: A 21st Century Breakthrough of January 2016.

Russian/Chinese/Iran/DPRK Hypersonic Technology Developments

- I. Technology is to provide more capable access denial (A2/AD) networks, to make it increasingly difficult and challenging for the US to defend her allies in Europe, the Middle East and the Pacific from Chinese, Russia, Iran or DPRK aggression
- II. General Paul Selva former Vice Chairman/JCS and Mike Griffin, the Undersecretary of Defense for R&E both note China is developing the technology, to spend multiple billions to bring the Df-17 hypersonic glide vehicle into the force, and hold at risk US bases, US land forces and US carrier battle groups, to seek hegemonic control of the Pacific to allow unfettered aggression. Mike Griffin notes Chinese threat undergirded by over 24 successful hypersonic technology tests....
- III. Russia has deployed the first such hypersonic capable missile—the Avangard—and President Putin explains such technology along with its advanced nuclear modernization gives Russia superiority over the US and is thus able to better threaten the NATO alliance—we won't know the target says one NATO official until there is “boom on the ground”.
- IV. China: DF-ZF; DF-26 HGV; and Xing Kong-2
- V. Russia: Avangard HGV; KinzhalALHM; Tsirkon, SLHCM; BrahMos-II, HCM

US Hypersonic Developments

- I. US seeks to deploy such technology with conventional warheads giving a capability to strike a target anywhere on earth within one hour, particularly to counter Chinese and Russian anti-denial strategies
- II. US is developing space-based sensors to see and track such missile threats
- III. US must also develop intercept capability best achieved through boost-phase/space-based interceptors, upgrades to current regional and CONUS based defense systems and the enhanced ability to “strike left of launch”
- IV. The DOD considers developing such hypersonic capable weapons one of the nation’s highest technical research and engineering priorities. On March 19, the US Army tested the C-HGB hypersonic glide body from the Pacific Missile Range in Hawaii;
- V. The USAF has picked the AGM-183 Air-Launched Rapid Response Weapon, which can be carried in large quantities by the B-52 and the F-15, and passed a critical design review in late February. USAF acquisition chief Roper said a key will be the ability to spiral development advances in the technology after initial deployment.....
- VI. The Hypersonic Conventional Strike Weapon was not chosen by the USAF; however both programs were progressing well and the Army and Navy will continue to work the surface launched versions.

Strategic Implications I

- I. Putin: “We have a unique situation now. For the first time, we have created such offensive strike systems the world has never seen...Now they are chasing us, trying to catch up.”
- II. “It is critical that US defense makers grasp and understand the hypersonic threat and the role [hypersonic missiles] plays in the plans of China and Russia...[which] see [hypersonic missiles] as an effective....means to deliver nuclear weapons...[including] provide to US adversaries such as North Korea and Iran...”
- III. Such adversary technology “will severely limit response times available to targeted nations and create a dangerous degree of uncertainty....[which] could lead to the rapid escalation of military conflicts” ...South China Morning Post

Strategic Implications II

- I. Russia has turned into an antagonist as it seeks global power, says NATO's Supreme Allied Commander, March 2017, General Curtis Scaparrotti
- II. Russia has updated its nuclear doctrine to intimidate NATO nations as well as former Soviet states says Scaparrotti....
- III. In a new strategy adopted and first described as “escalate to de-escalate” but actually “escalate to win”, Russia is seeking to use or threaten to use limited numbers of nuclear weapons early in a crisis to get the US to stand down, and lose the perceived capability to protect its NATO allies....to “freeze a conflict in place” ...

Strategic Implications III

- I. It is one of the most challenging military questions you have said General John Hyten, then Commander of US Strategic Command and now Vice Chairman of the Joint Chiefs of Staff said in March 2017 to the SASC. “And for us to win, we have two choices. One to prevent the escalation. Or two, respond in such a way after that escalation that would want to stop any aggression.”
- II. While the United States sought to de-emphasize the role of nuclear weapons in our deterrent strategy said Hyten, our adversaries have done exactly the opposite.
- III. The USAF Chief of Staff, General Dan Goldfein said it best, It’s a new world, It is a grave new world in HASC testimony , April 2017.
- IV. “At the very edge of Hudson Bay, you have enough velocity to hit all 48 of the continental United States....you can choose to make a right or left turn and hit Maine or Alaska...” General Paul Selva, Vice Chairman of the JCS, 2019

Critics Get It Wrong—As Usual

- I. Arms control critics of the USA pursuing defenses against hypersonic capable missiles and an offensive deterrent force make three arguments:
- II. The technology is not revolutionary....
- III. Conventional ballistic missiles work perfectly well...
- IV. There is no missile defense against range ballistic missiles now so any defense against hypersonic speed & maneuverable is not going to work either....
- V. Technical challenges to developing hypersonic speed systems are a long way from being resolved, so there should be no rush to deploy....
- VI. US goal is to unfairly intimidate China and Russia with such systems as part of a US hegemonic strategy of seeking what Bill Keller of the NY Times has described as an “unfettered” US security strategy.....

Critics: A Reply

- I. Technology being pursued by our adversaries is in service of a hostile strategy—ignoring our adversaries activities led to Pearl Harbor and 9-11.....
- II. Maj Gen Curtis Bedke USAF (Ret.) explains the hypersonic technology follows stealth and turbojet engines both of which revolutionized military affairs
- III. China has done more than 24 successful tests of the technology and Russia has deployed the technology---whether the technology is revolutionary or not...
- IV. New US developed defense technology works.....
- V. Decision Speed is needed because the US was way behind adversaries.....
- VI. Missile defense of CONUS worked in 6/7 previous tests; we have also not deployed missile defenses that are more effective due largely to political opposition to such systems not because of technology roadblocks.....
- VII. Whether defense or offense technology, the US is seeking to DETER bad behavior by rogue nations including invasions and terror attacks—stopping such behavior is not unfair.....the US and its allies are the “good guys”..
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 - Submission to journal
 - Volunteer as a JDR&E peer reviewer
 - JDR&E publication process
- Q&A



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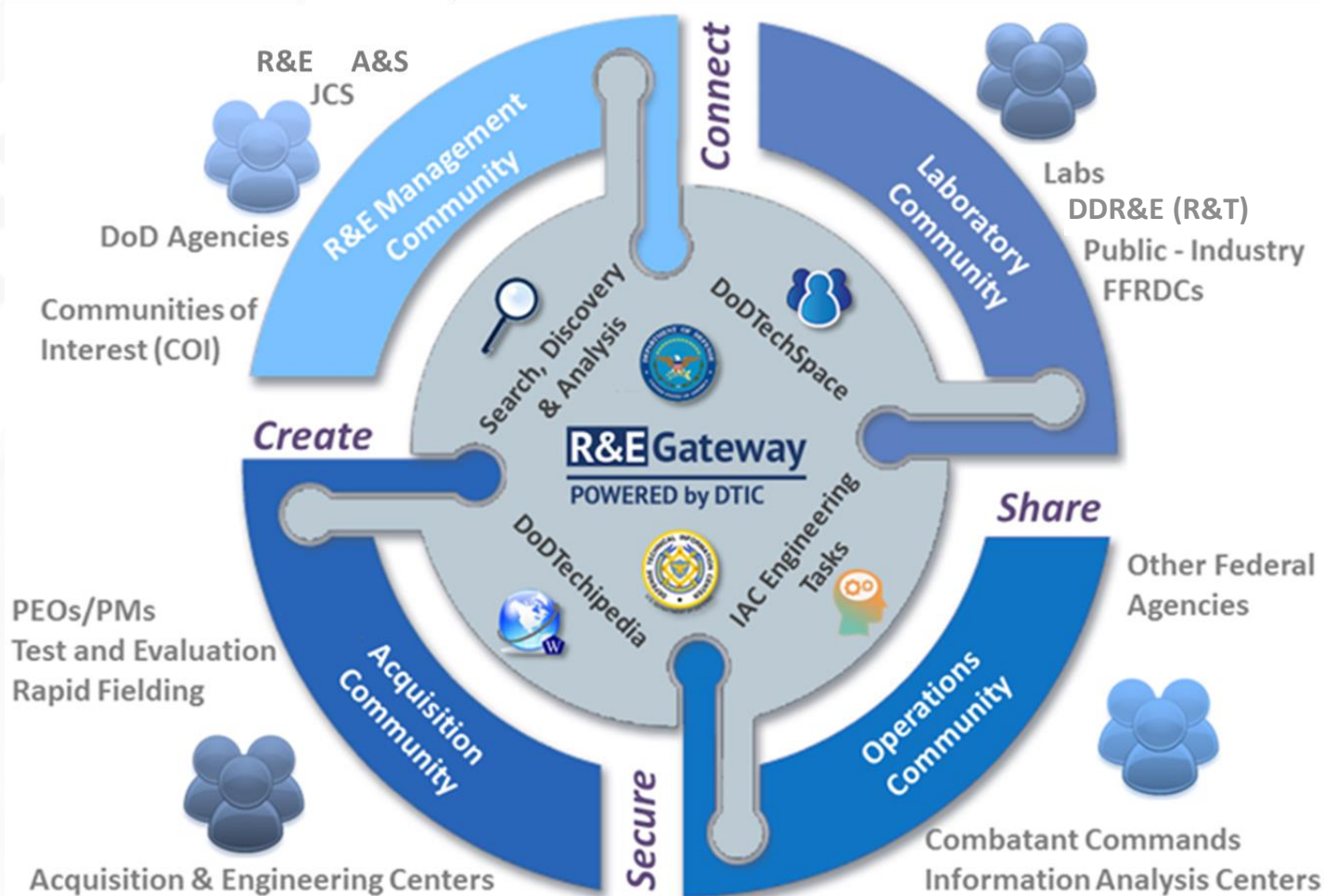
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HON Dr. Michael Griffin

Under Secretary of Defense for Research and Engineering



In February 2018, the Journal of DoD Research and Engineering (JDR&E) was established to encourage collaboration among the best minds in the DoD. **The purpose of this addition to our collection of peer-reviewed publications is to foster synergistic efforts across the entire S&T community, allowing researchers to publish their classified and controlled unclassified works without fear of exfiltration**

We find ourselves at a unique point in the history of our Nation: a return to an era of great power competition that we have not seen since the early days of the Reagan era.

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Dr. JihFen Lei

Acting Director of Defense Research and Engineering for Research and Technology in the Office of the Under Secretary of Defense for Research and Engineering



Cognizant of our increasingly capable competitors and near-peer adversaries, the DoD S&T community is engaged in a race to develop cutting-edge technologies and to modernize existing capabilities. As Acting Director of Defense Research and Engineering for Research and Technology, **I recognize the strategic importance of knowledge sharing and collaboration among DoD's S&T professionals to drive scientific breakthroughs. I strongly believe that by highlighting and celebrating these breakthroughs, we help open up the pathways to deliver actual Warfighting capabilities.** This is the role that JDR&E plays: recognizing the accomplishments of our technical workforce and ensuring that we can build upon its scientific advances.



Ms. Mary Miller

Principal Deputy, Director of Defense Research and Engineering for Research and Technology



The need to work together to advance technologies creates a dilemma—sharing information exposes us to the problem of exfiltration, but not sharing creates stagnation. We face the competing necessities of protecting our sensitive research and sharing that research with industry partners. **The DoD's concern over exfiltration, a valid and ever-present danger, has prevented our researchers, scientists, and engineers from collaborating and gaining peer-reviewed status for limited or classified projects** curbing our ability to share information and further leverage discoveries.

In an effort to create an alternative to these less-than-ideal scenarios, **in June 2017 I asked the Defense Technical Information Center (DTIC) to develop an internal journal to recognize the science and technology community's best works at the classified or controlled unclassified level**. To that end, they have established the Journal of DoD Research and Engineering (JDR&E). The JDR&E will provide a peer-reviewed, protected forum for our highly skilled personnel to share their work on limited and classified projects and distribute their findings with the broader S&T Communities of Interest.



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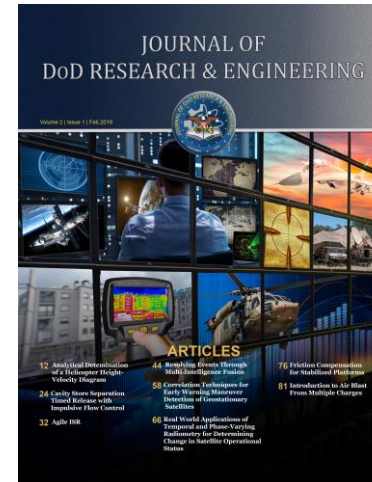
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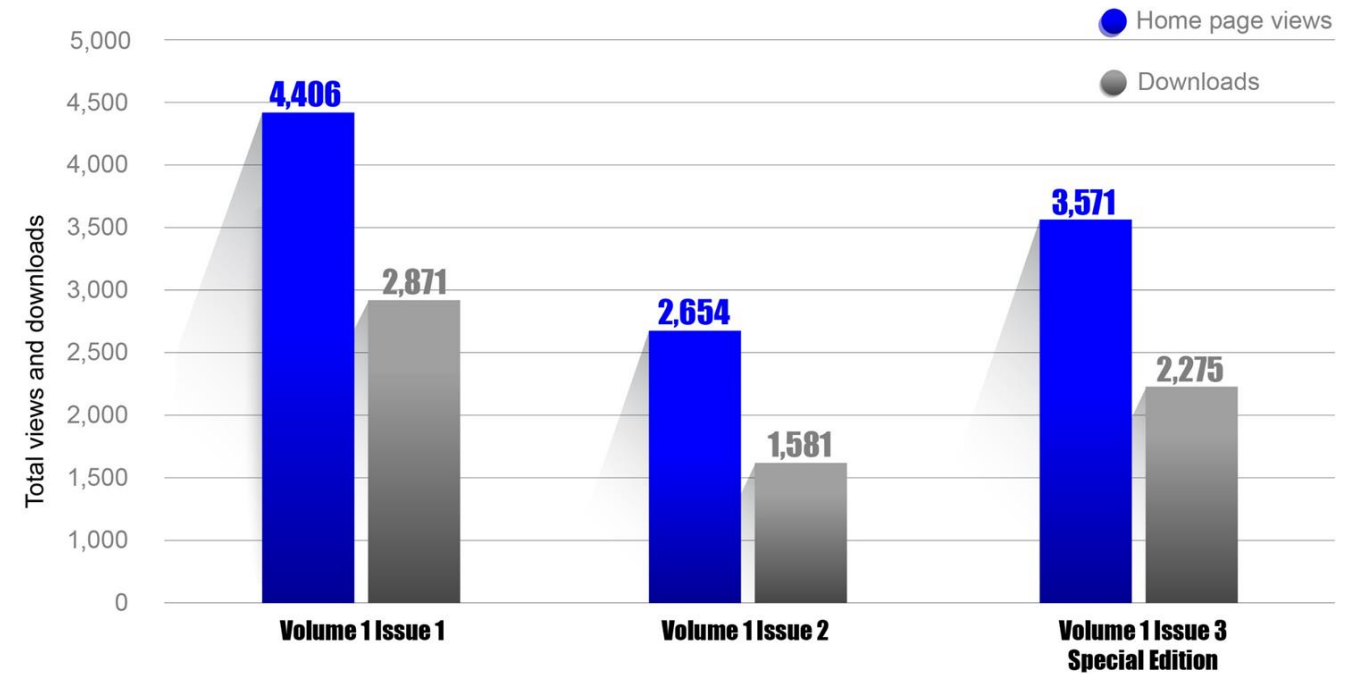
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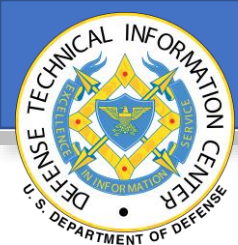
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p_t = qubit to be teleported

$v = \dots$

1. (U) Introduction

(U) Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam nibh. Nunc varius facilisis eros. Sed erat. In in velit quis arcu ornare laoreet...

(U) Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nam nibh. Nunc varius facilisis eros. Sed erat. In in velit quis arcu ornare laoreet.

(U) Previous work on factoring integers and discrete logarithms [1]

2. (U) Method

2.1 (U) Subtitle

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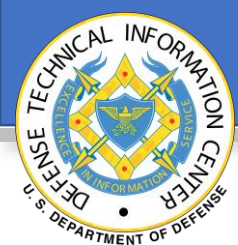
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Ryan Makinson received his B.S. in Neuroscience and Behavioral Biology from Emory University in 2011, and a Ph.D. in neuroscience from the University of Cincinnati (UC) in 2017. Ryan's research has primarily focused on interactions between stress and the immune system on brain functioning. This work has resulted in numerous first author publications and grant funding.

Currently, Ryan is a 2018-2019 AAAS Science and Technology Policy Fellow, where he works at the DoD Defense Technical Information Center (DTIC). At DTIC, Ryan serves as a subject matter expert, as well as helps coordinate outreach and management of the Journal of DoD Research and Engineering.

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