The CREATE Element of the U.S. DoD HPC Modernization Program

"Past, Present, and Future"

Computational Research & Engineering Acquisition Tools and Environments (CREATE)

Robert L. Meakin, Associate Director for CREATE

October 22-25, 2018

CREATE Mission

- **We are in this to change a paradigm.**
  Paradigm used by the Department of Defense for acquisition, deployment, and maintenance of weapon systems.

- **We are in this to provide and maintain a significant strategic advantage for the United States over all present and future adversaries.**

> "I did not take this job to reach parity with adversaries, I want to make them worry about catching up with us again. Any American, any ally or partner that we have who doesn't see it that way, I don't have time for you. "
>
> – Dr. Michael Griffin
> new Under Secretary of Defense for Research and Engineering

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.

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

Mother Nature always gets the deciding vote. When we are surprised by how she votes, the consequences are usually very expensive – schedule, money, sub-optimal systems.

It is crucial to understand that ***we get to decide*** when she votes and how often. HPC and physics-informed analysis is the way for us to avoid, or at least to minimize, surprises.

Use physical test to validate the design.

A Word on Digital Engineering

Capabilities being deployed through HPCMP CREATE™ products are driven by prioritized requirements of the Services and correspond to a number of important workflows across the Defense Acquisition spectrum.

System definition, geometry, materials, and operational conditions needed to apply physics-based virtual tests are important elements of the “Digital Thread” associated with targeted platforms.

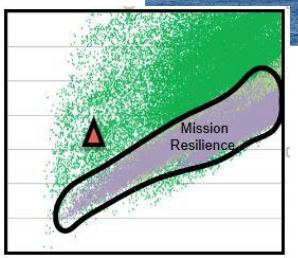
Physics-Informed Analysis and Virtual Test Enable…

Contributions to the design of **next gen military weapon systems**

Examples…

LX(R) and SSR Analysis of Alternatives

HPCMP CREATE™ – SH RSDE has been used by the Navy, with ERS facilitating efforts, to inform system requirements via analysis of alternative studies.



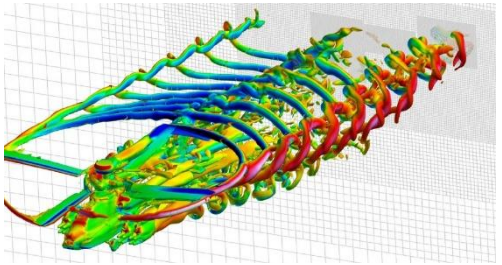
HPCMP CREATE™ – SH RSDE

Future Vertical Lift (FVL)

Mr. Pat Mason (SES), Army Aviation PEO
Dr. Bill Lewis (SES), AMRDEC

HPCMP CREATE™ – AV Helios is being used in support of JMR-TD. The Army expects at least one Single Main Rotor winged Compound Helicopter (SMR-CH) concept will be proposed against the Future Vertical Lift RFP. The Army is taking actions now to be in a position to use Helios to perform analysis of alternatives and proposal evaluations for FVL.

HPCMP CREATE™ – AV Helios



Physics-Informed Analysis and Virtual Test Enable…

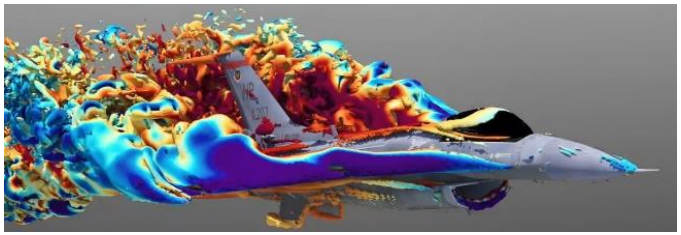
Design verification prior to key decision points (and prior to fabrication of test articles or full-scale prototypes)

Insertion of physics-based virtual test technology early into the Defense acquisition cycle enables large impacts (programmatic cost & improved design and system performance).

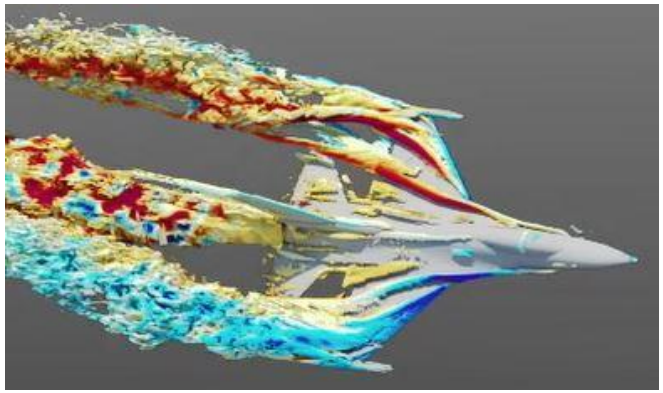
Example…

Airframe and Propulsion System Integration

Component mating and integration testing does not take place until late in development (i.e., full-scale flight test) which may not occur for 15-20 years after concept development.



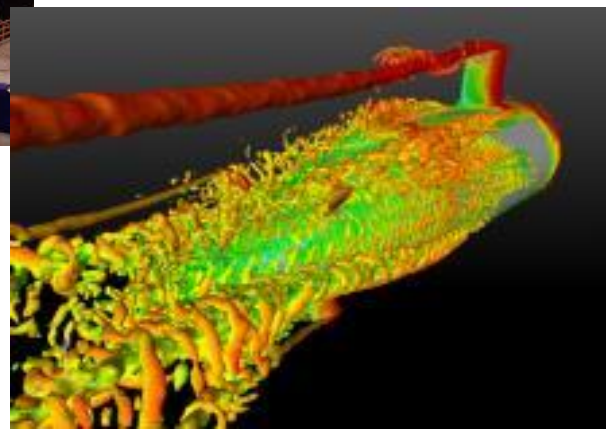
HPCMP CREATE™ – AV Kestrel

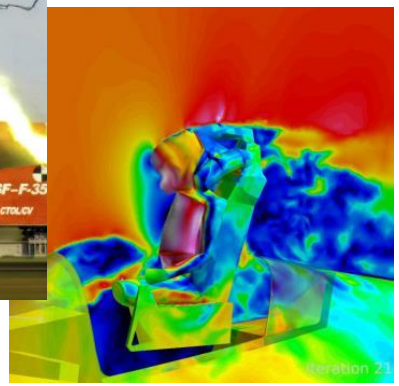


Physics-Informed Analysis and Virtual Test Enable…

Planning/rehearsal of scale-model and full-scale physical test campaigns (more bang per test dollar)

Examples… Anything you can test physically can be virtually tested. Why not take advantage of this fact and use it to determine regimes/conditions of highest uncertainty and focus your physical test resources there?





HPCMP CREATE™ – AV Kestrel

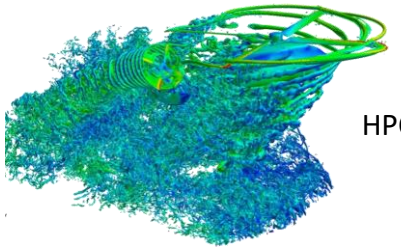
HPCMP CREATE™ – SH NavyFOAM

Evaluation of planned (or potential) **operational use** scenarios

Example…

Launch and Recovery Envelope Generation Process

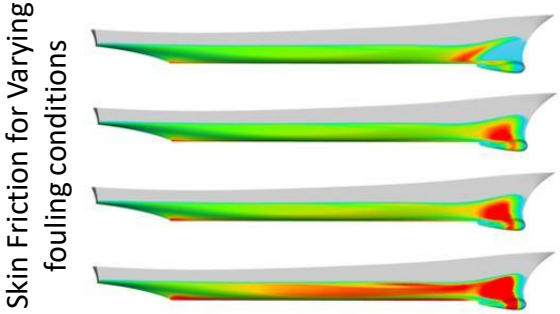
Currently, the process is measured in weeks to months, depending on ship and aircraft availability, as well as weather conditions and sea-states. Virtual (physics-based) test capability reduces schedule, dependency on environmental conditions, and reduces risk (crew and platforms).



HPCMP CREATE™ – AV Helios

Bio-Fouling on Ship Resistance

An ability to anticipate system performance subject to operational conditions is essential to sound acquisition and sustainment decisions.



HPCMP CREATE™ – SH NavyFOAM

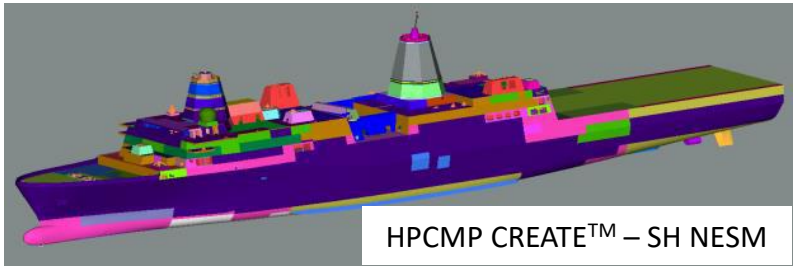
Physics-Informed Analysis and Virtual Test Enable…

Generation of engineering data required by warrant holders for associated system certifications

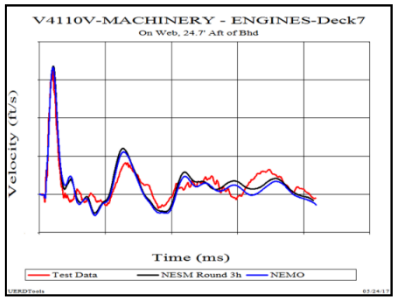
Example…

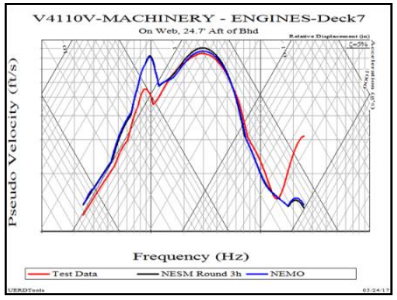
Full Ship Shock Trials

The Navy requires validation of ship shock hardening to expected threats. DOT&E LFT&E requires assessment of ship survivability to expected threats. Physics-based virtual test has clear roles relative to FSST, but also for earlier phase decision points and design verification.



HPCMP CREATE™ – SH NESM





Ms. Robin White, Director
Surface Ship Design & Systems Engineering (NAVSEA 05D)

CREATE Software Engineering Credentials

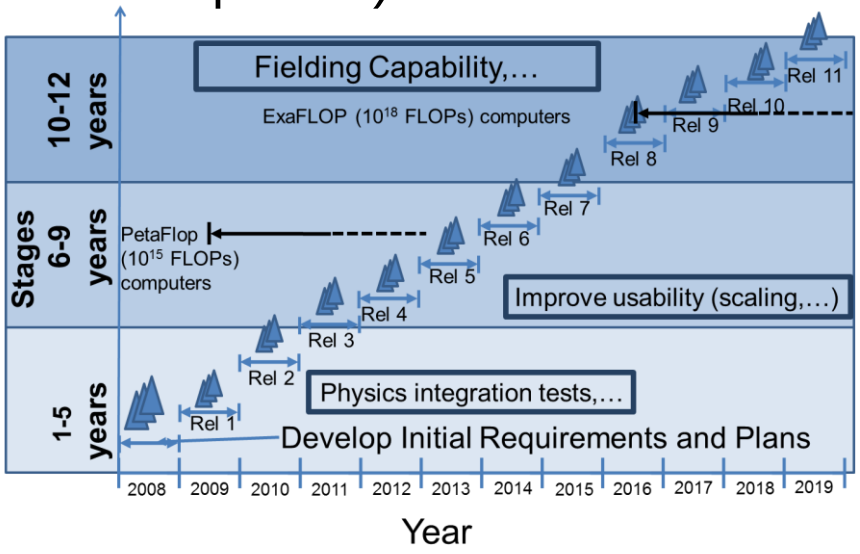
Production quality software, designed for a service life measured in decades.

A technology bridge – transitioning maturing research into production technology.

Annual Release Cadence (with intermediate updates)

- Agile software development practices
- Rigorous unit, system, and integration testing
- Automated verification and validation testing

12 Physics-based Simulation Software Products



AIAA *American Institute of Aeronautics and Astronautics*

2019 Aerospace Software Engineering Award

HPCMP CREATE™ – AV PM, Dr. Scott Morton, selected for significant research and innovations in the software engineering of multi-disciplinary, physics-based simulation tools for the design analysis and virtual test of aeronautical systems.

American Society of Naval Engineers

2011 Gold Medal Award

HPCMP CREATE™ Associate Director (2008-2017), Dr. Douglass Post, selected for significant contributions to naval engineering and seminal role in high fidelity, physics-based design software development, for effective acquisition of military vehicles.

CREATE Quality Assurance

Protect the HPCMP CREATE™ brand!

- **Independent Quality Assurance Tests of ALL CREATE products (and materials) prior to EVERY release outside of CREATE.**
  - General and multiple update releases each year for every product.
  - Build and maintain automated validation tests for all capabilities released in all CREATE products.
  - Champion/stress-test ALL capabilities being released
- **Regional Training Events**
  - Helios, Kestrel
  - SENTRi
  - Mercury
  - RSDE, NESM, IHDE, NavyFOAM/Osprey
  - Genesis (Capstone, DESIGN, CFD, other)
- **Technical Support**
  - Field questions/issues from users
  - Interface w/ product development groups to resolve issues

CREATE Products are being Widely Adopted

- **Over 1,100 unique active software licenses as of Mar 2018**

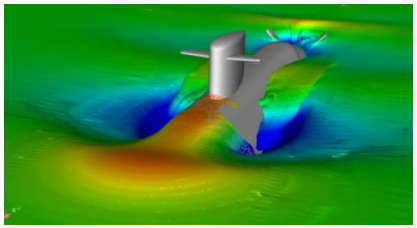
  We are seeing >10% growth annually per over last 3 or 4 years.

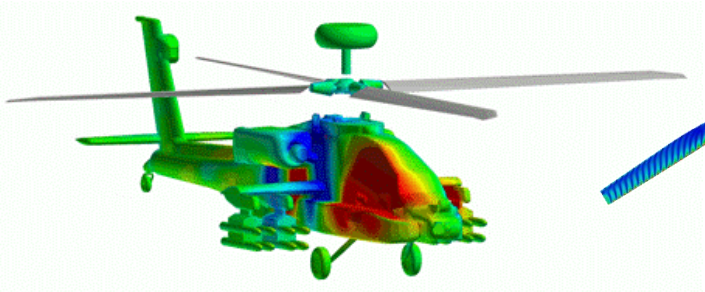
  Licenses must be renewed annually. Accordingly, renewed licenses is a good implicit measure of adoption.

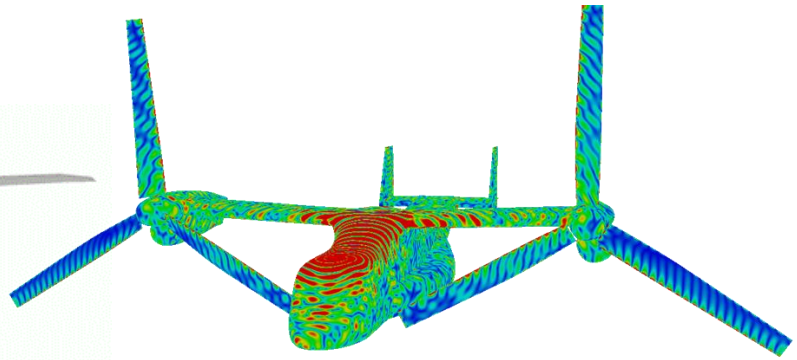
- **Over 160 DoD engineering organizations (government and industry) now using CREATE tools**

- **CREATE being applied to > 100 DoD weapon systems**

  ~ 70 unclassified and ~ 30 classified







CREATE Products are being Widely Adopted

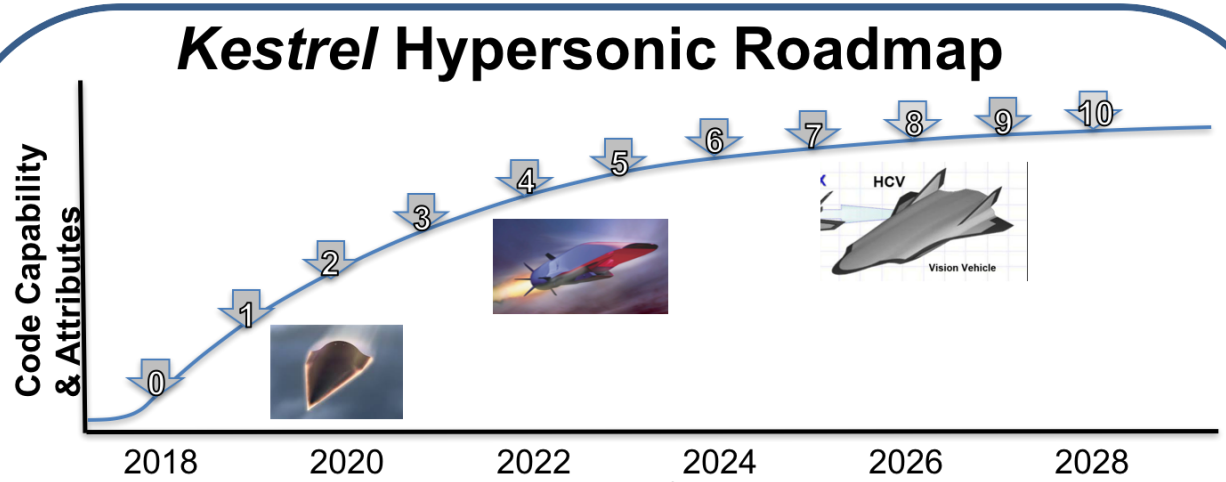
Breakdown of CURRENT License Holders (Feb 2018)

	AV	GV	MG	SH	RF	Genesis	Total
DoD	242	36	415	160	109	179	**1141**
Industry	282	7	227	39	152	14	**721**
Other Agency	38	0	14	0	1	29	**82**
Academia	143	0	42	12	8	148	**353**
Total	**705**	**43**	**698**	**211**	**270**	**370**	**2297**

NOTE: Numbers in the table above reflect active licenses by CREATE Project. Some users have active licenses in more than one project. Accordingly, the number of unique active licenses is something less than is shown here.

Projects maintain FWD looking development Profiles

e.g., working with a Community of Interest (COI*), now have a plan to build/transition technology necessary to deploy production quality virtual test capabilities for hypersonic systems at regular intervals.



0) Kv9 Baseline with Non-Ideal Gases

1) Improved Numerics for Hypersonics (Implicit Solvers, Time Integration Efficiency), Incorporation of chemistry, Initial capability to model Separating Tactical Boost Glide Vehicle (TBG), Non-combusting RAM/SCRAMJET Flow, Sensitivities for UQ, ID mesh needs for high Mach flows

2) Non-equilibrium chemistry using 2015 dissociation models, initial transition modeling, Continued improvements to numerics for hypersonics, Initial RAM/SCRAMJET combustion flowpath (RC22, Cross-flow Injection), Automated mesh generation for high Mach flows

3) Thermal-chemical non-equilibrium flows, surface chemistry, thermal-structural interactions, Improved transition modeling, Reduced order modeling for hypersonic structures and propulsion, Hypersonic Airbreathing Weapon Concept (HAWC)

4) Aero-thermal-structural interactions, equilibrium ablation, Full Trajectory with thermal soaking (HIFIRE6 hot structure), Combustion Flowpath with a hot structure, 3D Nose Tip Ablation

5) Coupled transition modeling for maneuvering vehicles, non-equilibrium ablation, Coupled radiation heat transfer, maneuvering TBG with store separation, Integrated UQ

6) Multi-phase injection flow for combustion, SCRAMJET flow with combustion, Initial capability of modeling Conventional Prompt Strike Vehicle (CPS)

7-8) Long duration simulation of the Conventional Prompt Strike Vehicle at hypersonic flight conditions

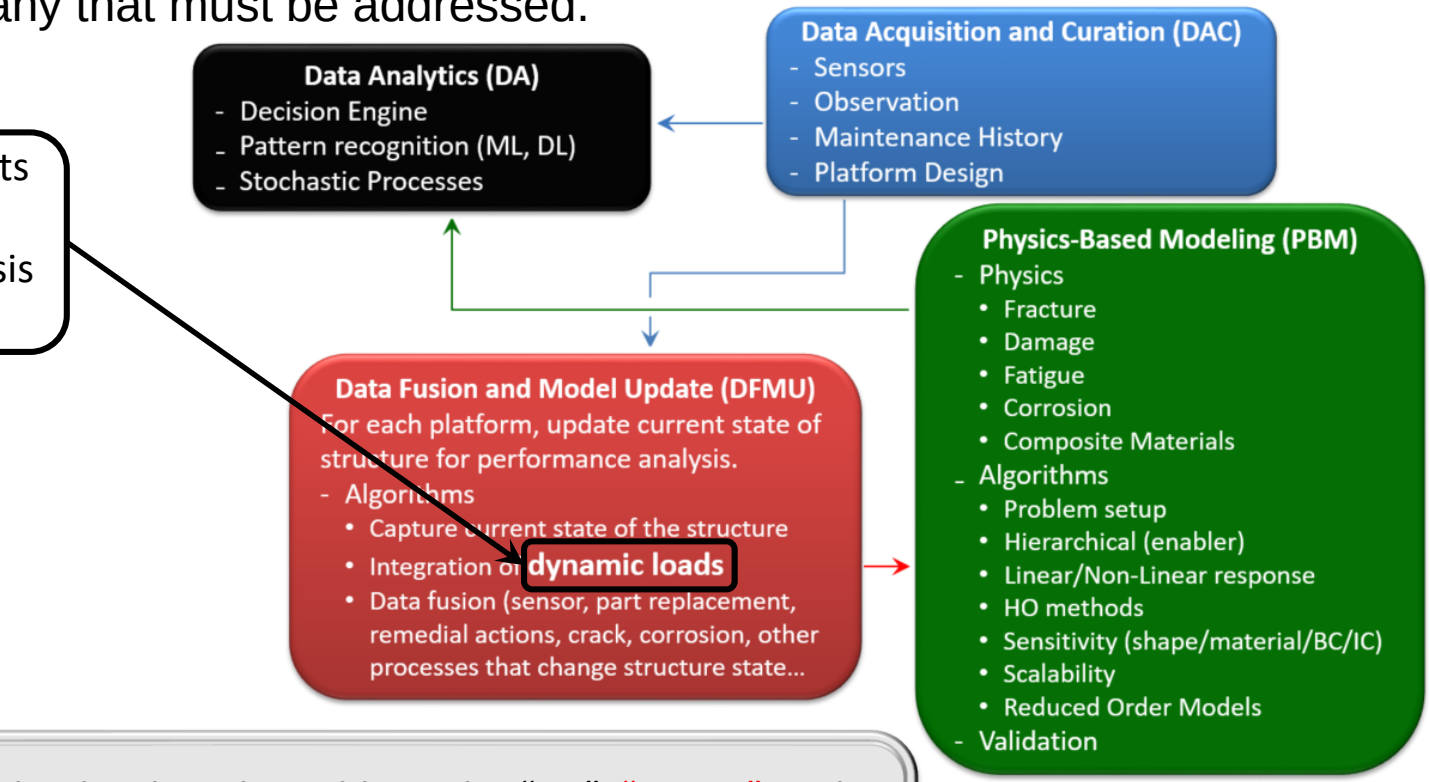
9-10) Full flight profiles of the TBG, HAWC, and CPS

COI AFOSR, AFRL, ONR, AMRDEC, DARPA, NASA, and key US Academic Institutions

Another Word on Digital Engineering

The **structural condition/health of military systems** (air/sea/land) and associated logistics represent a number of important facets of the grand Digital Engineering challenge before us. Physics-based modeling and simulation has a role to play, but it is only one of many that must be addressed.

Current CREATE products can inform structural system condition analysis tools and processes.



Software solutions can be developed to address the "DA", "DFMU", and "PBM" blocks. HOWEVER, the "DAC" block requires a POLICY solution motivated by IP, UNCLASS vs CLASS – and a TECHNICAL solution that insures the policy.

Concluding Remarks

- **Exponential growth in HPC capacity enables a paradigm in which physics-based virtual prototyping can significantly impact (revolutionize) vehicle development, deployment, and sustainment.**
- **Rapidly changing needs of the DoD to provide for our national defense (and evolving computer architectures) demand that the HPCMP execute continuous modernization actions for**
  - HPC Systems
  - Networks, and
  - Physics-based Virtual Test capabilities

  In response to prioritized requirements of the U.S. DoD.

QUESTIONS?