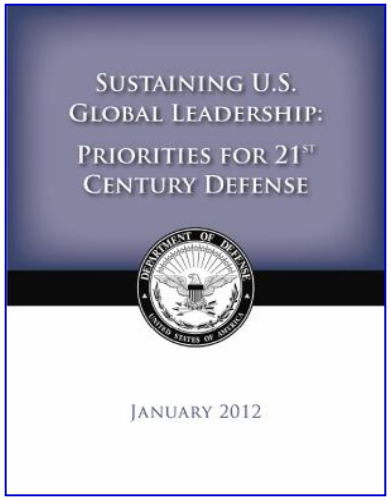
Technology Surprise—Need for Rebalance of R&E Investments

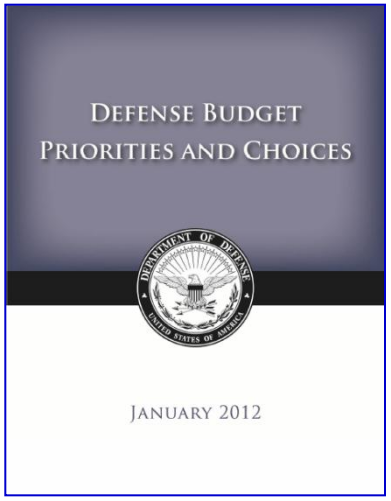
18 March 2014

Al Shaffer

Acting Assistant Secretary of Defense for Research and Engineering

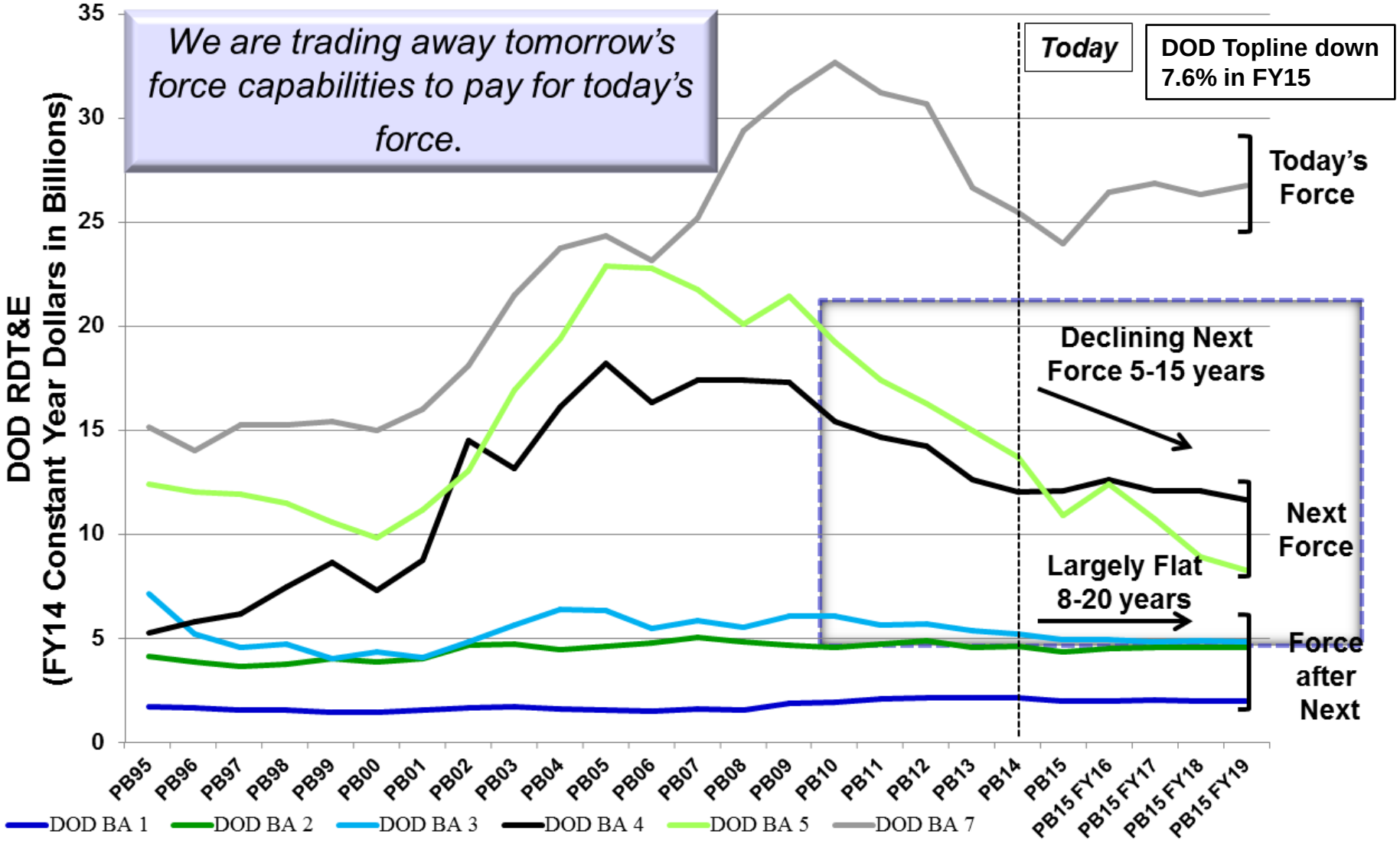
Key Elements of Defense Strategic Guidance



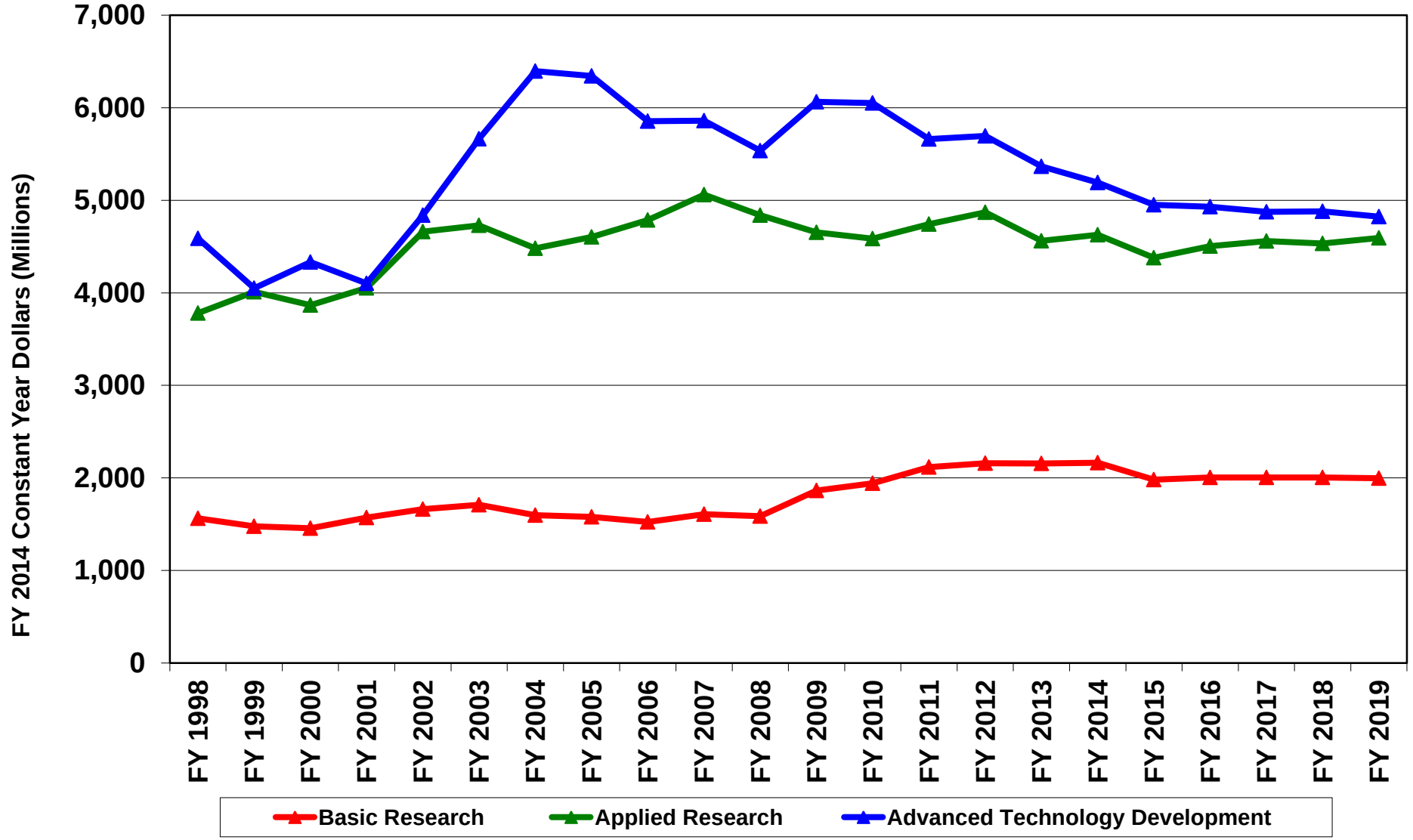


- **The military will be smaller and leaner, but it will be agile, flexible, ready and technologically advanced.**
- **Rebalance our global posture and presence to emphasize Asia-Pacific regions.**
- **Build innovative partnerships and strengthen key alliances and partnerships elsewhere in the world.**
- **Ensure that we can quickly confront and defeat aggression from any adversary anytime, anywhere.**
- **Protect and prioritize key investments in technology and new capabilities, as well as our capacity to grow, adapt and mobilize as needed.**

DOD RDT&E – PBR1995-PBR2015



DoD S&T Funding by Budget Activity
FY 1998-2019
(President's Budget Request)



Defense R&E Strategy

"Protect and prioritize key investments in technology and new capabilities, as well as our capacity to grow, adapt and mobilize as needed."

-SECDEF, January 2012 Strategic Guidance

1. Mitigate new and emerging threat capabilities

- Cyber
- Counter Space
- Electronic Warfare
- Counter-WMD

2. Affordably enable new or extended capabilities in existing military systems

- Systems Engineering
- Prototyping
- Interoperability
- Modeling and Simulation
- Developmental Test & Evaluation
- Power & Energy

3. Develop technology surprise through science and engineering

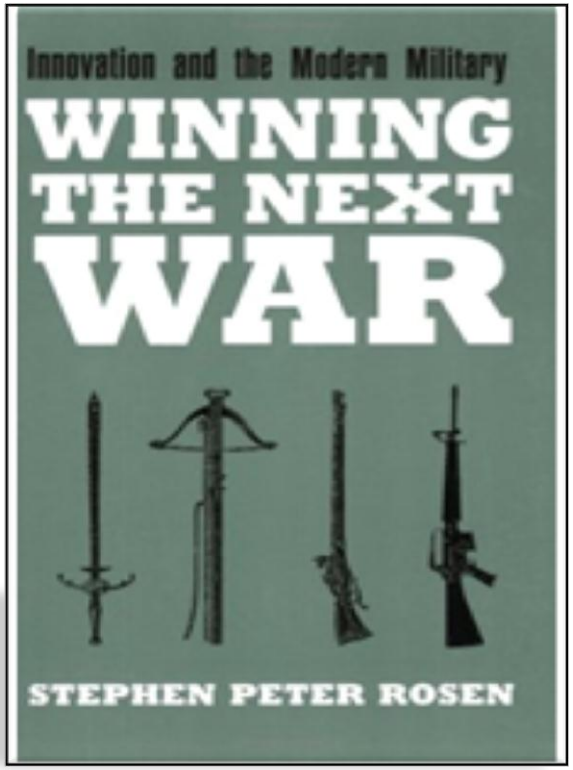
- Autonomy
- Human Systems
- Quantum
- Data-to-Decisions
- Hypersonic

Technology Needs

- Cyber / Electronic Warfare
- Engineering / M & S
- Capability Prototyping
- Protection & Sustainment
- Advanced Machine Intelligence
- Anti-Access/Area Denial (A2/AD)

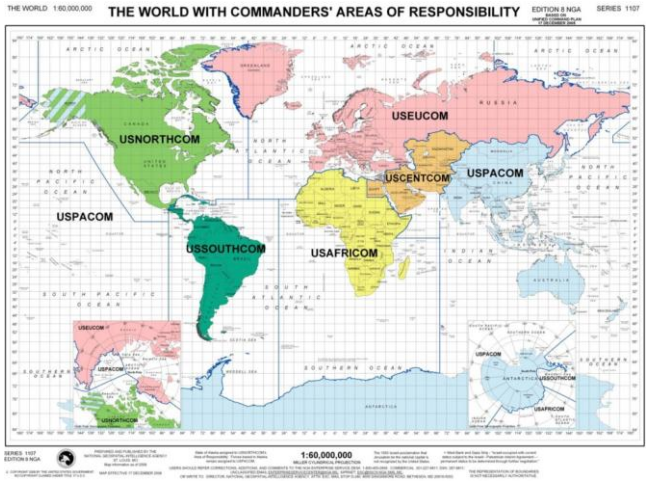
“Winning the Next War”
-Stephen P. Rosen

- Armies and navies are not forever doomed to "fight the last war." -- Rather, they are able to respond to shifts in the international strategic situation.
  - To not lose the war one needs to keep investing in new capabilities between the wars.

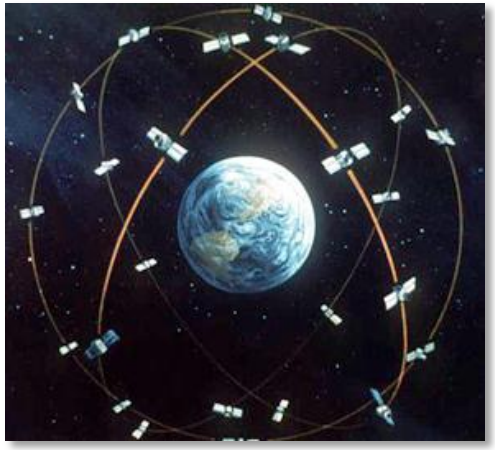


Rise of the Commons

Electronic Warfare

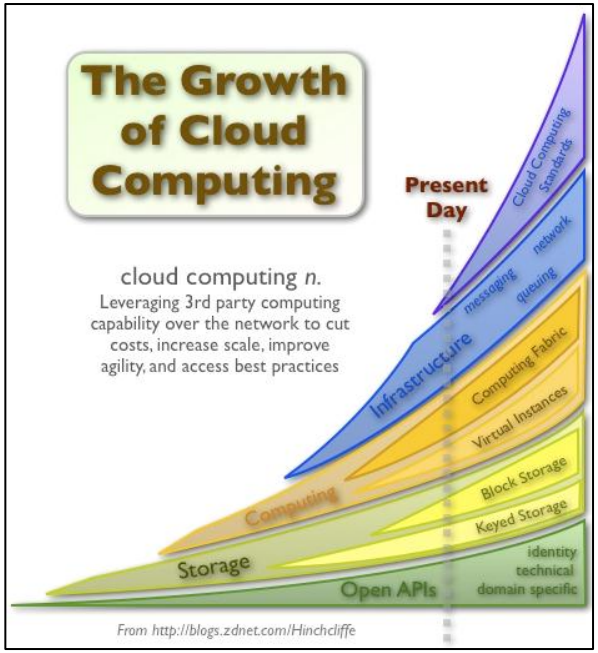


Oceans



Space

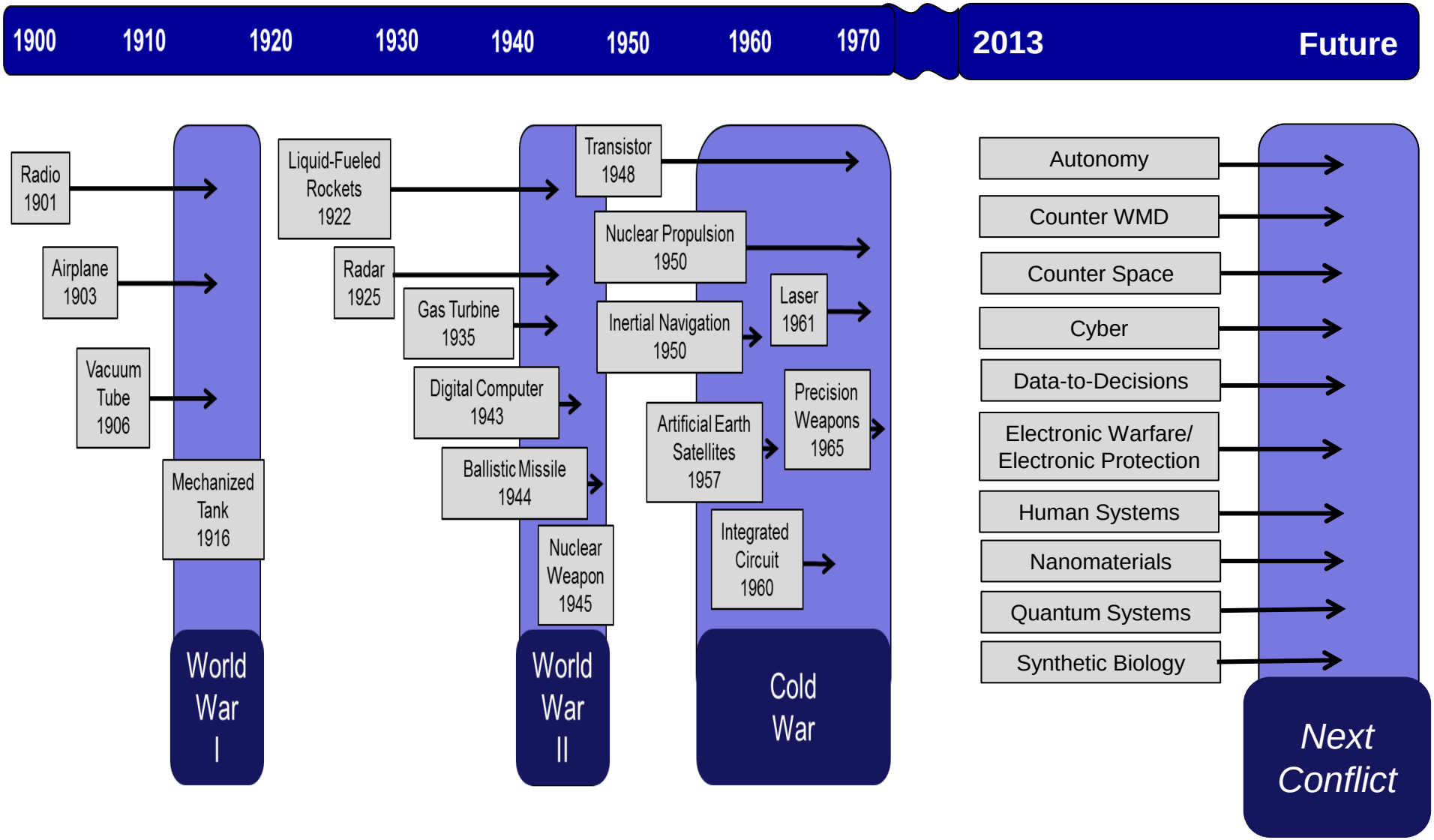
Cyber



Ubiquitous Data

Military Operations Increasingly Depend on Being Able to Operate in Places "No One Owns" – *The Enablers*

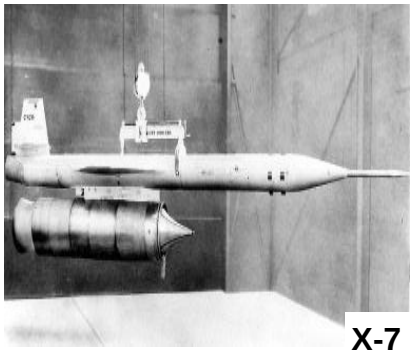
Lab Demo to Forcing Function:
Technology Investment Stocks Cupboard



Capability Prototyping
Proof of Concept: "X"- Plane Prototyping

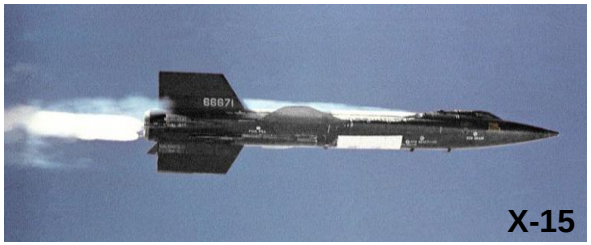
First flight: 1947
Speed: Mach 1.26

First flight: 1952
Speed: Mach 3.2



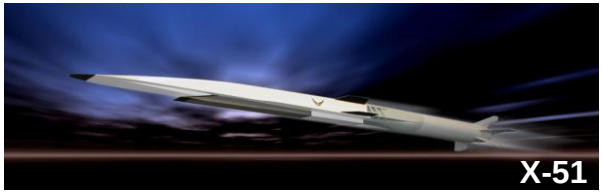
First Flight: 1951
Speed: Mach 4.31

First Flight: 1953
Speed: Mach 2



First Flight: 1959
Speed: Mach 6.7

First Flight: 2001
Speed: Mach 6.83



First Flight: 2010
Speed: Mach 5.1

The Department can cost-effectively drive innovation in aviation, space, maritime and ground combat systems through prototyping

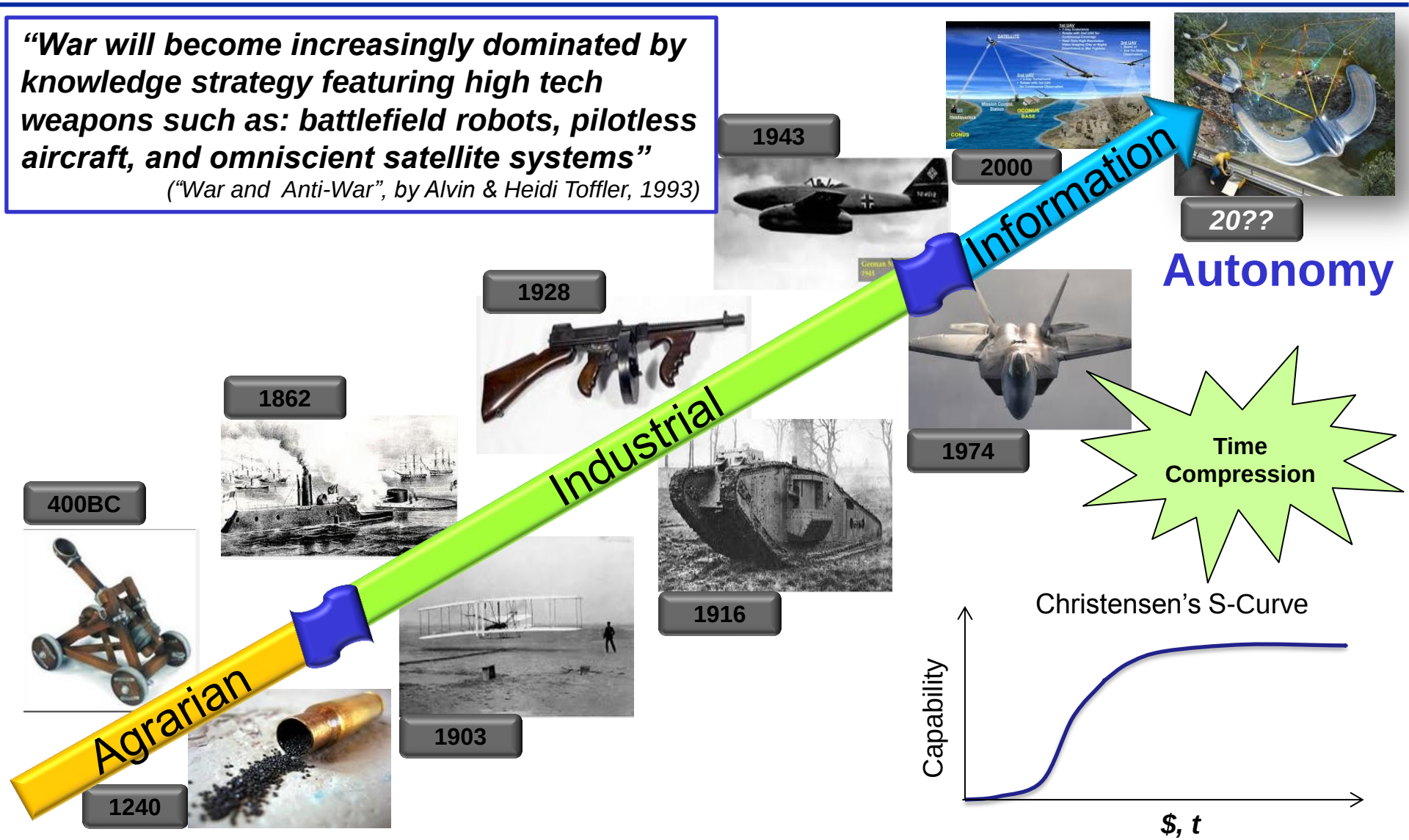
Autonomy

- Three Revolutions
  - Autonomy
  - Speed
  - EM

Revolutionary Military Capability

"War will become increasingly dominated by knowledge strategy featuring high tech weapons such as: battlefield robots, pilotless aircraft, and omniscient satellite systems"

("War and Anti-War", by Alvin & Heidi Toffler, 1993)



Autonomy

- *Autonomy* enables a particular action of a system to be "automatic" – The machine will make decisions
- *Autonomy* won't replace the human
- *Autonomy* is a data problem

Autonomy allows Warfighters to focus on their primary mission, not on operating their tools

Autonomous systems promise to allow DoD to address *Manpower* and *Force Safety*

Key Operational Challenges Addressed by Autonomy

Decentralization, Uncertainly, Complexity…Military Power in the 21st Century may be defined by our ability to adapt – adaptation is THE underlying foundation of autonomous technology

- Manpower efficiencies
- Harsh environments
- Rapid response and 24/7 presence
- New mission capabilities
- Advanced medical applications
- Capabilities beyond human limits

Autonomy is not about making widgets…

It is to allow existing/future systems to be more self-governing

High Speed Weapons

Hypersonic Air Vehicle and Propulsion Technologies Enable Long Range at High Speed with Effective Payload

Precision Strike

Variable Warhead Effects

Aircraft Systems

Internal bombers
External fighters

Net Enabled

In-Flight Targetable

Long Range

High Speed

Rapid, Responsive Strike in Anti-Access/Access Denied (A2/AD) Environments

Hypersonics
Building on Recent Success

- **X-51A**
  - M4.7-6+; fixed geometry; B-52 launch; JP7 fuel
  - 1st flight in May 2010 partially successful
  - 2nd flight in June 2011 unsuccessful (fuel system)
  - 3rd flight in August 2012 unsuccessful (flight controls)
  - 4th flight full success (300+ second flight)

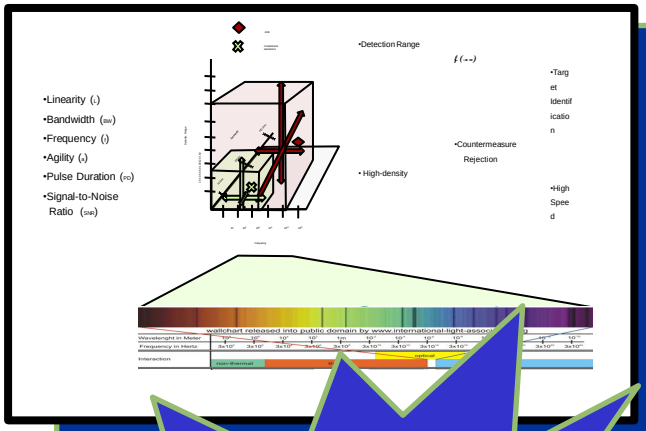
- **Conventional Prompt Global Strike (PGS)**
  - High M boost glide; advanced materials and thermal protection
  - Hypersonic Test Vehicle (HTV-2): two flight tests did not meet objectives; substantial data obtained
  - Advance Hypersonic Weapon (AHW): first flight test met objectives

- **HIFiRE**
  - Foundational flight test experiments; collaborative with Australia
  - 4 (of 5) flight tests successful
  - Engineering systems and avionics, aerodynamics and aero heating, hydrocarbon scramjet operability to Mach 8, hydrogen scramjet at Mach 8

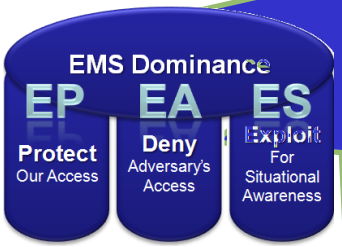
Electronic Warfare

U.S. EW Superiority is Being Broadly Challenged

- Digital signal processing expanding
- Threat systems more lethal, longer range, mobile
- Sensors are networked and active – passive combinations are appearing
- Radar and radio systems are trending to software-driven waveform generators
- Weapon seekers are more sophisticated with spectral diversity and ECCM processing
- Advanced jamming techniques and technologies are now available to adversaries



OPPORTUNITIES FOR NEW APPROACHES



Globally Accelerating Technology

Electronic Warfare Summary

- **Threats are in development that will push legacy EA system capability beyond the horizon**

- **New methods, platforms, and architectures are needed and the underlying technology solutions are being defined**
  - Technology adaptation strategies to facilitate rapidly reconfigurable, lower cost systems
  - Advanced mechanisms for delivery of EW attacks in high threat domains
  - Normalized frameworks for combat value analysis
  - Advanced methods for modeling non-kinetic effects on combat outcomes
  - Cost containment & reduction strategies and technologies
  - Affordable, expendable, agile
  - Streamlined manufacturing, integration, and fielding options

Global Change

Radio Frequency Systems

- **Extended-range detection and engagement systems**
  - Passive Sensing , Multi-aperture tracking
  - Tailored weapons
    (UAVs, Specialized Jammers , ASCMs, TBMs)

- **Emergence of complex, adaptive waveforms and advanced digital processing**
  - Agile LPI/LPD
  - Accelerated by commercial designs/algorithms

- **Active Jamming, Decoys, High Power Defensive Systems**
  - Counter-Targeting, Counter-HARM
  - COMMS Jamming
  - Counter- Space/PNT

Electro – Optical Systems

- **Multi Function Seekers**
  - Combined optical and RF tracking
- **Damage Class Lasers**

LONG RANGE SENSORS & STANDOFF WEAPONS OF HIGH LETHALITY

EXPANDED PRESENCE OF DIGITAL PROCESSING AND NETWORKING

Resilience and Operate Thru

In order to deter attacks on U.S. or allied space systems, DoD will mitigate the benefits to an adversary of attacking U.S. space systems by enhancing the resilience of our space enterprise and by ensuring that U.S. forces can operate effectively even when our space-derived capabilities have been degraded.

- Space Policy DoD Directive 3100.10

Technology & Idea Needs:

- **Small commoditized launchers with rapid launch capability**
- **Large dispersed affordable constellations**
- **Alternate, affordable non-space means for A2/AD environment**
- **Electromagnetic domain awareness and spectrum management tools**
- **Multi-path communications networking – space, air, maritime**

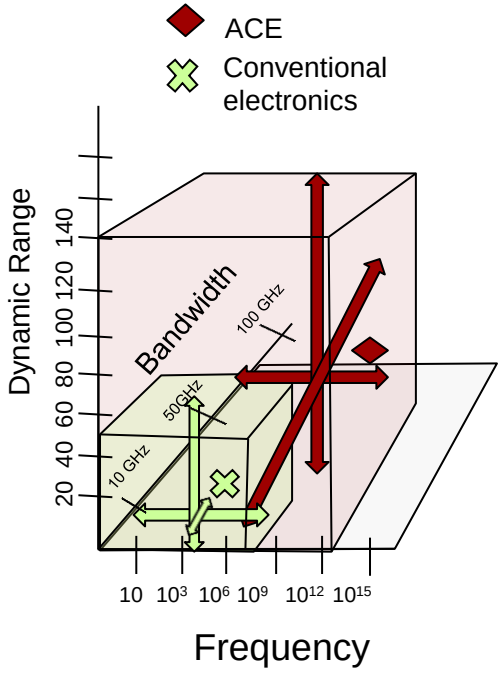
Summary

- DoD S&T aligned to meet priorities for a 21st Century security environment
- DoD Strategic Framework….. lays the foundation for S&T commitments – 7 Priority S&T Areas
- Federal Deficit Reduction will impact; S&T remains steady priority
- Asia-Pacific rebalance is the foundation of our R&E strategy
- DoD R&E is committed to a healthy Defense Industrial Base
- EW is at the forefront of DoD technological superiority efforts

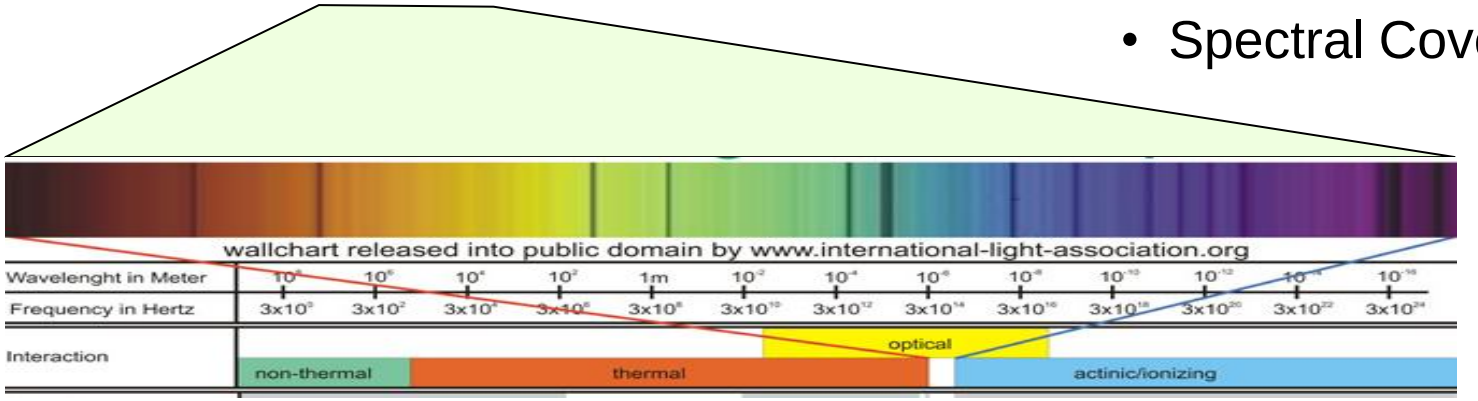
BACK-UP

Electronic Warfare Battlespace

- Linearity (L)
- Bandwidth (BW)
- Frequency (f)
- Agility (a)
- Pulse Duration (PD)
- Signal-to-Noise Ratio (SNR)

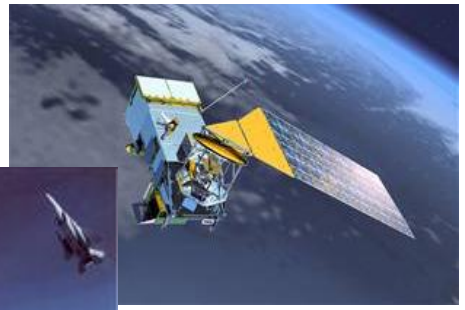


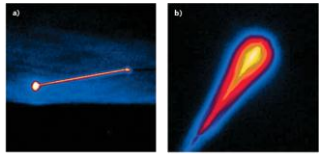
- Detection Range
  f (**L, BW, SNR)**
  - Target Identification
- Countermeasure Rejection
- High-density
  - High Speed
  - Spectral Coverage

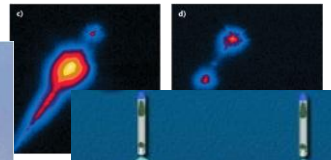


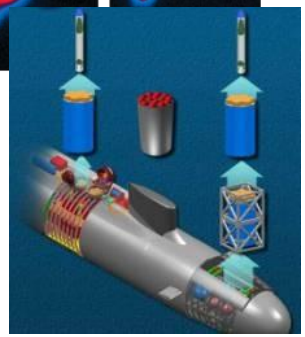
Anti-Access/ Area Denial Current A2/AD Priorities

- **Electronic Attack / Electronic Protection**
- **Cyber Operations**
- **Space / Counter Space**
- **Counter Missile / Missile Defense**
- **Counter Integrated Air Defense Systems**
- **Undersea Operations**







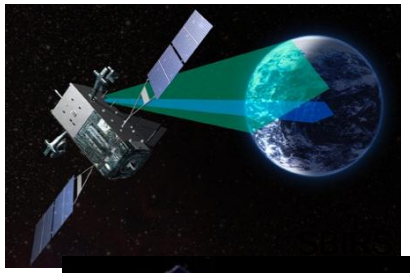


Space and Cyberspace

From 2012 Chairman's Joint Operational Access Concept

- Space and cyberspace are increasingly important and contested domains with critical importance for the projection of military force.
- Future enemies will seek to contest space control and cyberspace superiority as means to denying operational access to U.S. joint forces.
- Gaining and maintaining space and cyberspace superiority will be a constant challenge

SATCOM



Missile Warning

PNT

ISR

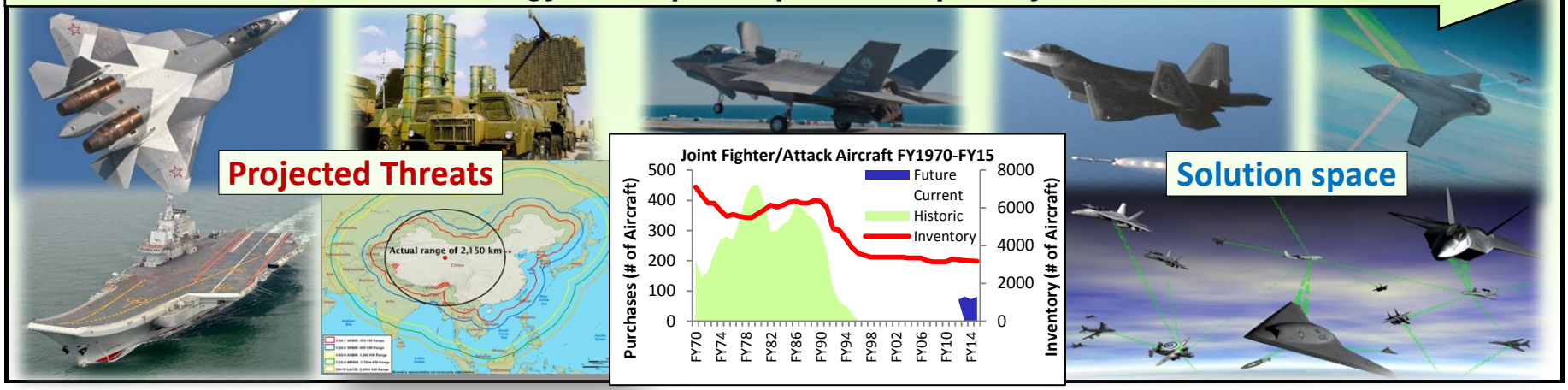
GPS III

ORS-1

The current and future strategic environment is driven by three trends – space is becoming increasingly congested, contested, and competitive.
- 2011 National Security Space Strategy

System of Systems & Prototyping: Air Dominance Initiative (ADI)

What is our technology development plan for capability in 2020 – 2050 ?



Purpose

- OSD directed DARPA /USAF/USN technology game-plan to ensure Air Dominance through 2050
- Baseline our currently funded acquisition projects to ensure maximum integrated development; security umbrella put in place
- Identify high-payoff technology concepts
- Prototype those high risk technologies and determine which ones merit an acquisition program

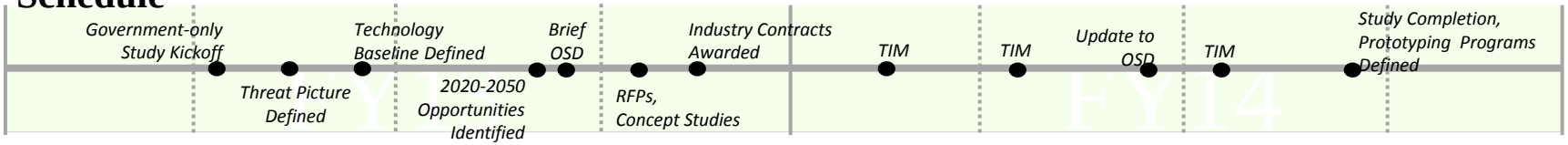
Key Technologies

- No single silver bullet program
- Systems approach to Air Dominance
- Next generation platforms
- Advanced networking capabilities
- Ensured, reliable navigation
- Passive and active system defense
- Electronic attack technologies
- Area denial capabilities
- Situational awareness technologies
- Cyber effects considerations
- Surveillance capabilities

Metrics

- Study completed in 18 months
- Maximum use of existing systems
- Cost of proposed concepts must be within available budgets
- Close integration coordination with focus on combined effects
- Prototype demonstrations completed within 5 years

Schedule



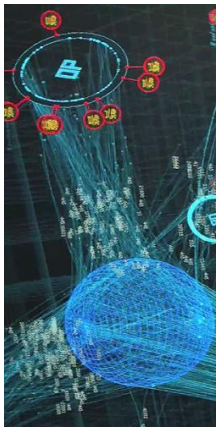
Modern Integrated Air Defense Systems

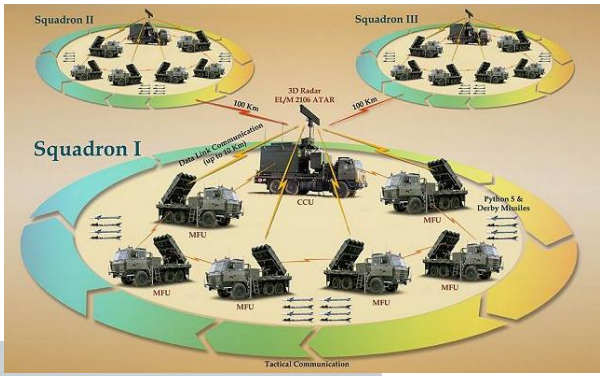
The Challenge

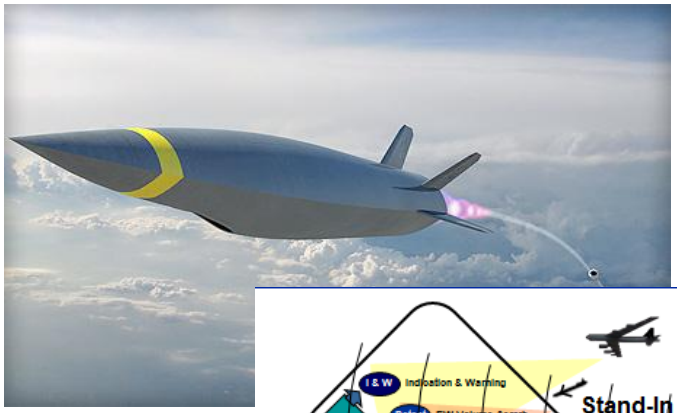
- Networked
- Mobile
- Redundant

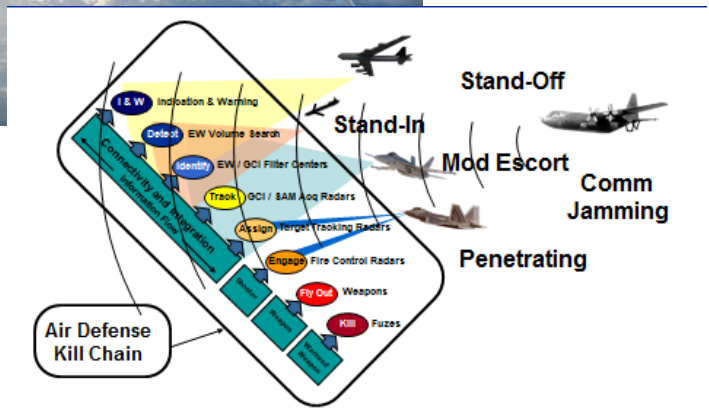
Solutions

- Electronic Attack
- Cyber Attack
- High Speed Strike









Counter-electronics High-powered microwave Advanced Missile Project (CHAMP)

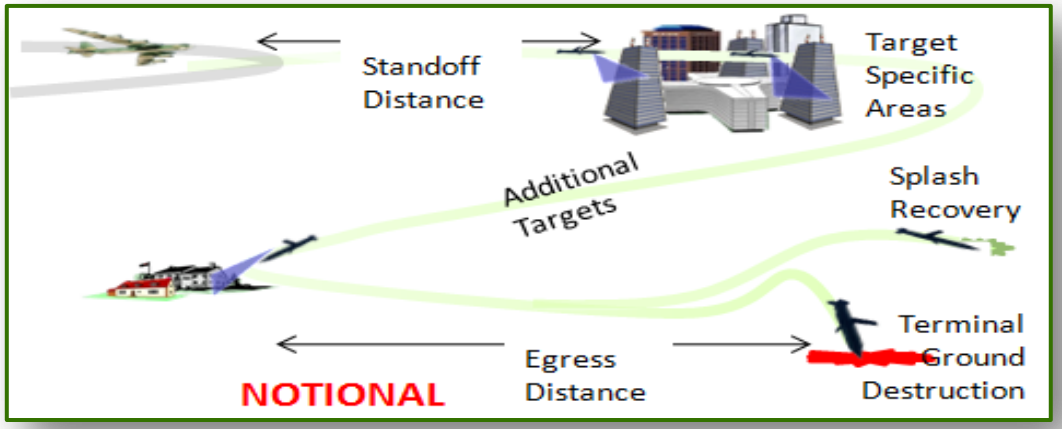
FY09

Technical Issues

- HPM device
- Missile package, fuzing/firing
- Predictive Modeling & Simulation tool

Candidate Measures of Success

EW



- Year 1: HPM payload and modifications to the aerial platforms
- Year 2: System integration, HPM effects tests, pointing demo with inert system, and static demo
- Year 3: All Up Round flight test, result verification static test and Operational Utility Assessment. Results incorporated into Non-Kinetic Counter Electronics Analysis of Alternatives. Final Military Utility Assessment pending.

Benefit

- Provide the Warfighter with an ability to destroy/disrupt their electronic systems, or any installations with electrical components, without having to use a kinetic (hard kill) system.
- Relatively inexpensive compared to dropping 2 missiles per aimpoint into a target kinetically.
- Capable of degradation, disrupting, or damaging systems

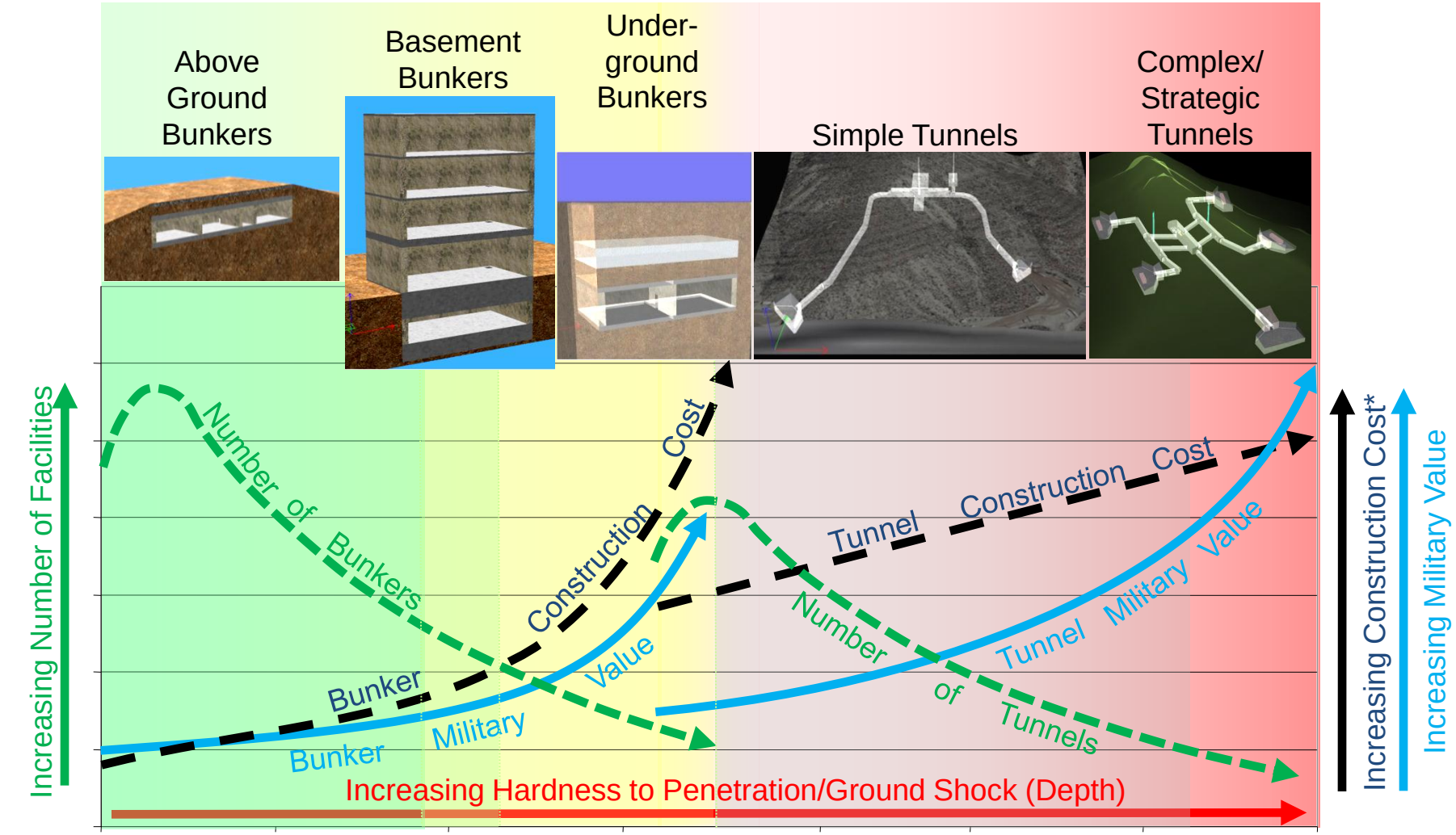
Critical Enablers for the Regional Missile Defense Mission*

- **Fast Missiles**
- **Long-range radars with precision tracking**
- **Reliable defense discrimination of threat objects**
- **Effective networking of defense assets across wide areas**

Defense Science Board Report on Science and Technology Issues of Early Intercept Ballistic Missile Defense Feasibility

http://www.acq.osd.mil/dsb/reports/ADA552472.pdf

HDBT Numbers, Hardness, Cost, Value Comparisons



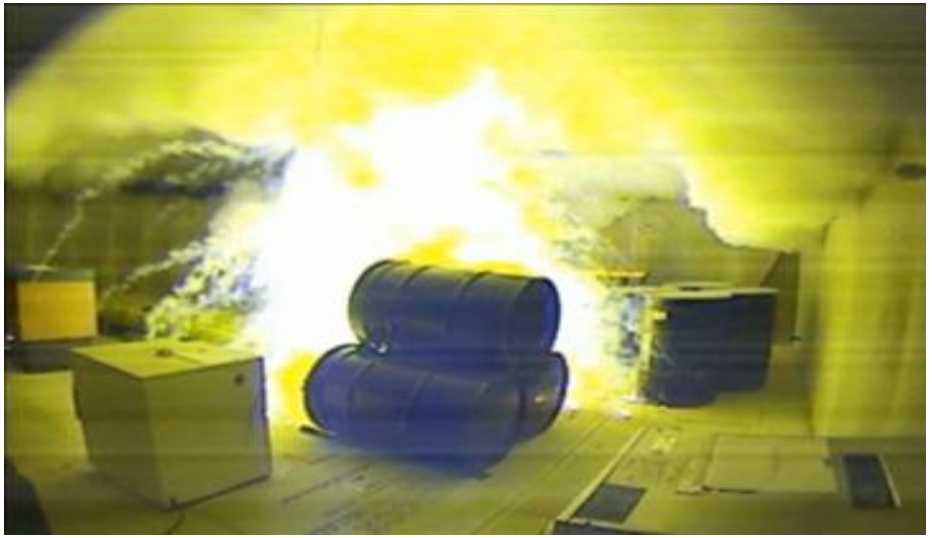
*Equal mission area used for bunker and tunnel cost comparison

Example CWMD Technology (DTRA)

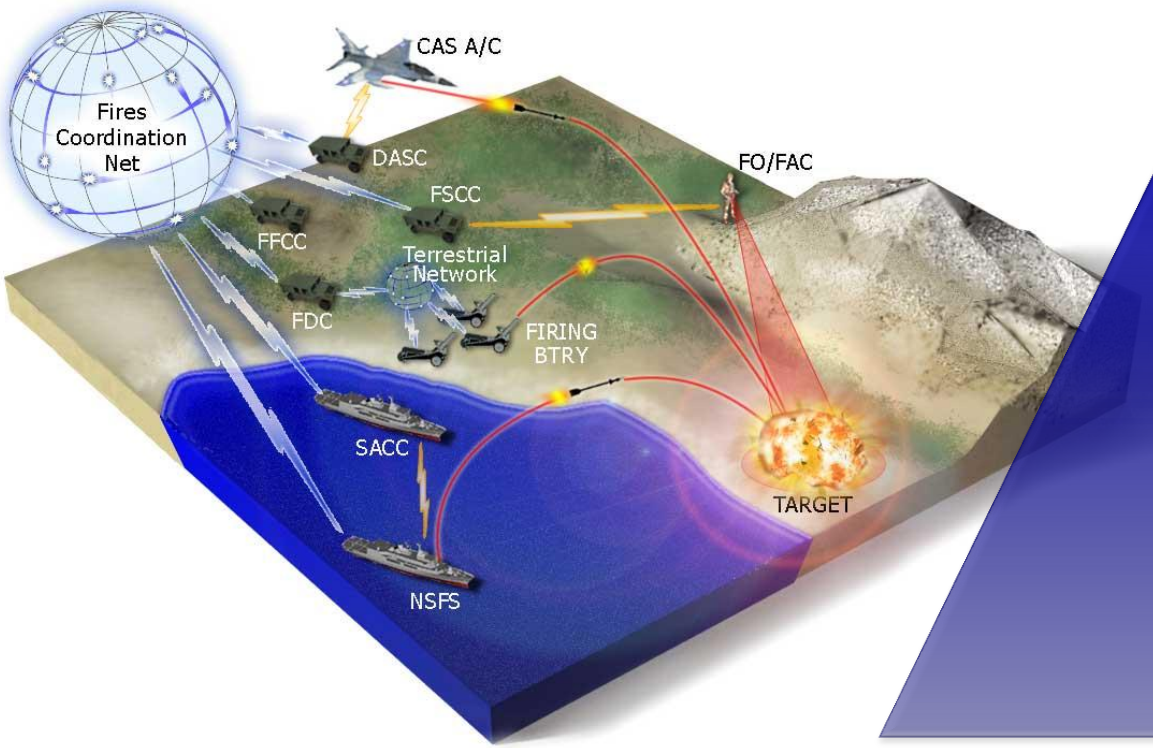
Multipurpose weapon with enhanced AD capability

Optimize HE/Agent

Sub-Scale Agent Defeat Phenomenology



Architecture – Technology Trade Space



Architectures

Capabilities

Technologies

Architectures Drive Technologies
Technologies Inform Architectures

Past MDD in MDAP Acquisition

- **AIM-9X Block II**
- **Long Range Stand-Off (LRSO)**
- **Offensive Anti-Surface Warfare (OASuW)**
- **Integrated Force Protection Capability – Increment 2 Intercept (IFPC-I2 I)**
- **Small Diameter Bomb (SDB) II**
- **Joint Air-Ground Missile (JAGM)**
- **Guided Multiple Launch Rocket System Alternative Warhead (GMLRS-AW)**

MDD: Materiel Development Decision

MDAP: Major Defense Acquisition Program

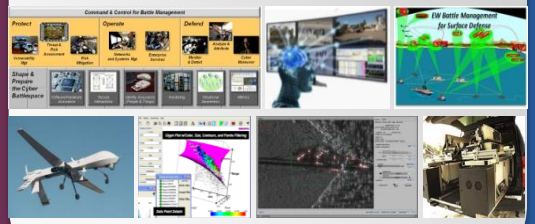
Technology Intelligence Interaction

Near Term

Specific potential adversary system performance parameters

Mid Term

Strategic force development plans



Far Term

Understanding investment in research coupled with assessment of potential adversary capabilities

Prepare for an Uncertain Future

USD(AT&L) Priorities
Concern of Losing Technological Edge

Frank Kendall
USD (AT&L)
Mr. Kendall, Engineering Week, February 2014

- "*I'm very concerned about eroding technological superiority*"
- DoD's R&D spending declined 14% since 2009
  - We have to preserve the future capability

"The United States has enjoyed ***tech superiority* for decades not by happenstance. Rather, because of engineers and design teams who are confident enough to push the envelope, take the chance, and bring the next level capability into a reality."**

Technology Surprise
Human Systems, Data-to-Decisions, Autonomy

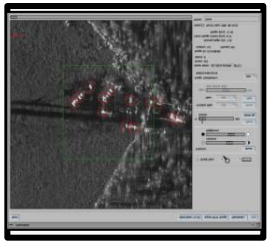
Human Systems

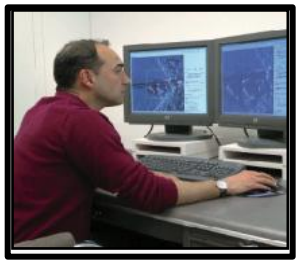
- System Interfaces
- Personnel & Training
- Protection & Sustainment
- Social & Cultural Understanding

Data-to-Decisions

- Data Management
- Analytics
- User Interface

Multi-Layer Approach

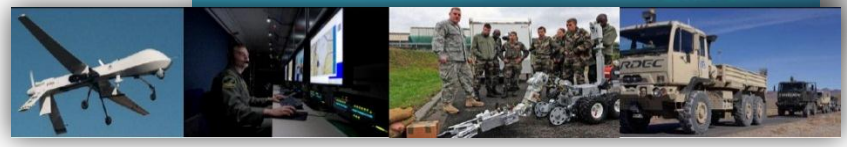




Autonomy

Advanced Machine Intelligence for Missions in Complex and Dynamic Environments

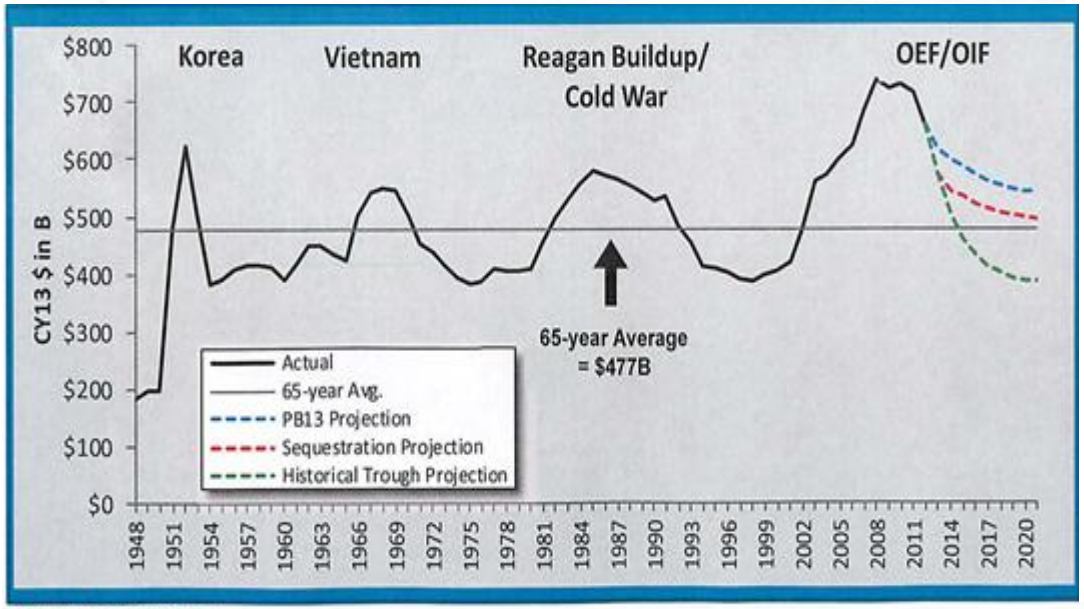
- Human/Autonomous Systems Interaction and Collaboration
- Scalable Teaming of Multiple Autonomous Systems
- Machine Reasoning, Perception and Intelligence
- Optimized teaming between operators and their machine "partners"
- Scalable operations across air, land, sea, cyber, and space domains
- Predictable system safety and mission effectiveness



Budget Challenge Hitting Hard

"Our current security challenges are more formidable and complex than those we faced in downturns following Korea, Vietnam, and the Cold War. There is no foreseeable "peace dividend" on our horizon."

GEN DEMPSEY, CJCS
Testimony to SASC, 12 Feb 2013



UNCLASSIFIED

- Sequestration hit 2013- 9% reductions to all accounts
- Dec 2013- Bipartisan Budget not affirmed sequestration but added funds in FY14 - FY15
  - 4% reduction in FY14 ($-27B)
  - 8% reduction in FY15 ($-41B)
  - 10% reduction FY16 - FY19

DOD Budget Top Line

DOD Budget (Fiscal Year 2014 Constant Year Dollars in Billions)						
	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Base Budget	575.53	579.97	573.59	534.27	526.60	486.84
Change from Previous Year ($)	6.02	4.44	-6.38	-39.32	-7.67	-39.76
Change from Previous Year (%)	1.1%	0.8%	-1.1%	-6.9%	-1.4%	-7.6%

DOD RDT&E Budget (Fiscal Year 2014 Constant Year Dollars in Billions)							
	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	% Decline from Recent High Year
S&T	12.58	12.52	12.73	12.09	11.98	11.31	-11% (2012)
Engineering 6.4	15.44	14.70	14.26	12.64	12.06	12.12	-22% (2010)
Systems Development & Demonstration 6.5	19.27	17.43	16.28	14.97	13.70	10.89	-43% (2010)
Management Support 6.6	4.71	4.75	4.34	4.34	4.32	4.14	-13% (2011)
Operational Systems Development 6.7	32.69	31.25	30.66	26.68	25.46	23.95	-27% (2010)
RDT&E	84.69	80.65	78.27	70.72	67.52	62.41	-26% (2010)
RDT&E Change from Previous Year ($)	-2.60	-4.04	-2.38	-7.55	-3.20	-5.10	
RDT&E Change from Previous Year (%)	-3.0%	-4.8%	-3.0%	-9.6%	-4.5%	-7.6%	
S&T as Percent of RDT&E	14.9%	15.5%	16.3%	17.1%	17.7%	18.1%	

Defense Innovation Marketplace

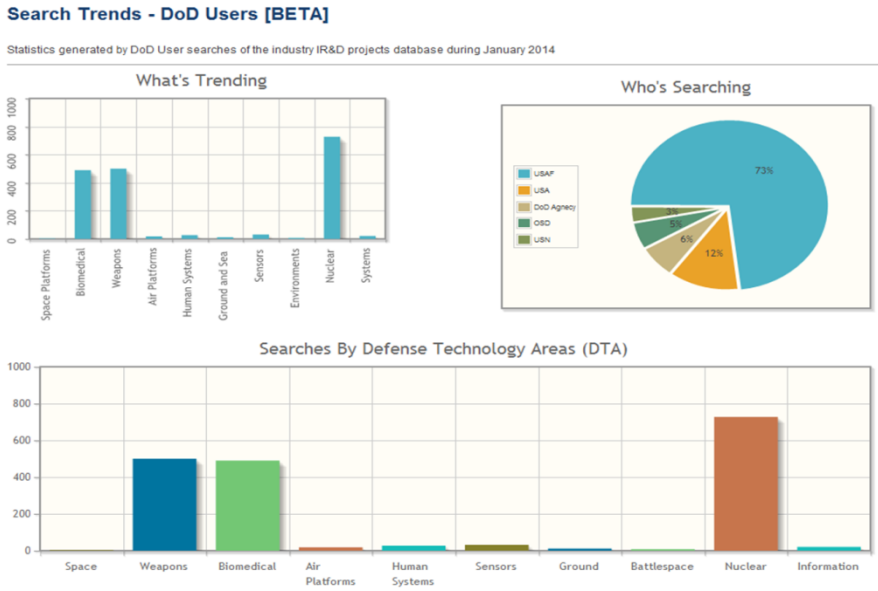
Resources For Industry And DoD

Improving Industry Understanding of DoD Needs

www.DefenseInnovationMarketplace.mil

Marketplace: Resources for Industry

- DoD R&D Roadmaps; Investment Strategy
- Business Opportunities with the DoD
- Virtual Interchanges & Events
- Secure Portal for IR&D Project Summaries
- Top Downloads/Pages visited
- DoD IR&D SEARCH Trends



Marketplace: Resources for DoD

- Secure portal with more than 10K IR&D Project Summaries
- Access for DoD R&D and Acquisition Professionals
- DoD Searchers encouraged to contact the Industry POC listed on project summaries of interest

Autonomy Progress – Some Examples

- **ARMY: Collaborative Technology Alliance (CTA): a cooperative agreement between a Consortium of academic/industrial partners and the Government**
  - **Micro-Autonomous Systems Technology (MAST) CTA:** Microsystem Mechanics, Microelectronics, Processing for Autonomous Operation and Integration.
  - **Robotics CTA:** Perception, Human/robot interaction, Dexterous Manipulation, and Unique Mobility.
- **NAVY: Multi-disciplinary University Research (MURI) Programs**
  - **Adaptive Networks for Threat and Intrusion Detection Or Termination (ANTIDOTE):** Create decentralized robust algorithms.
- **Office of the Secretary of Defense (OSD)**

  Autonomy Research Pilot Initiative (ARPI): In-house research to build Autonomy capacity within the DoD.
- **DARPA:**
  - **Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE):** program to build a new kind of computer with similar form and function to the mammalian brain.
  - **Robotics Challenge:** project to develop ground robots capable of executing complex tasks in dangerous, degraded, human-engineered environments.

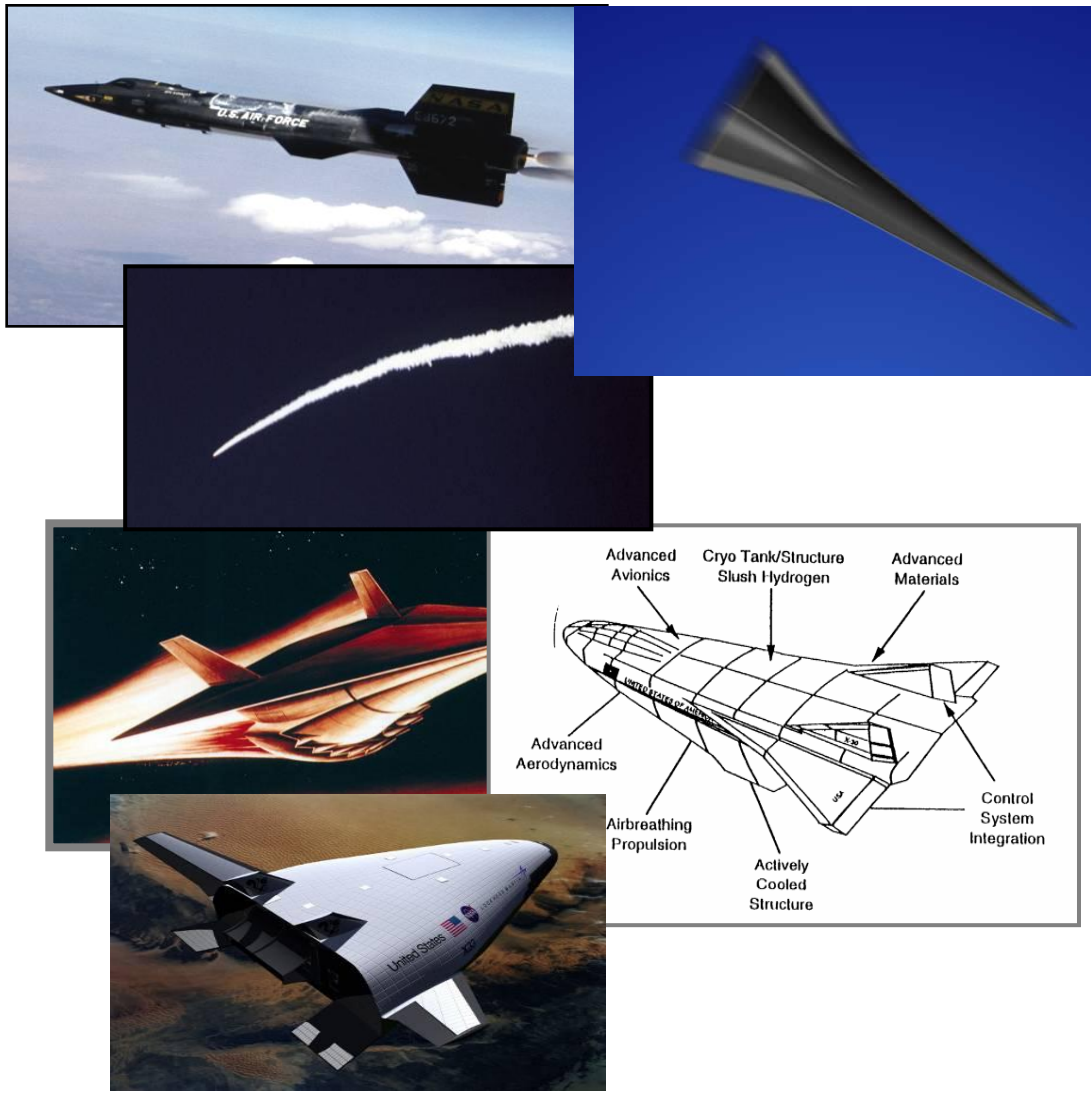
The Future of Autonomy S&T

- Improving data processing capabilities and efficiency of data collection across platforms
- Better understanding of autonomous system capabilities and facilitate transition to operational deployment
- Programs: Across the Services, ongoing efforts explore different and complementary approaches to creating effective autonomy
- MURI/SBIR/STTR: Multidisciplinary university research initiatives (MURI) and small business initiatives facilitate research in high priority Autonomy-related areas for defense & commercial purposes

Autonomy that allows Warfighters to focus on their primary mission, not on operating their tools

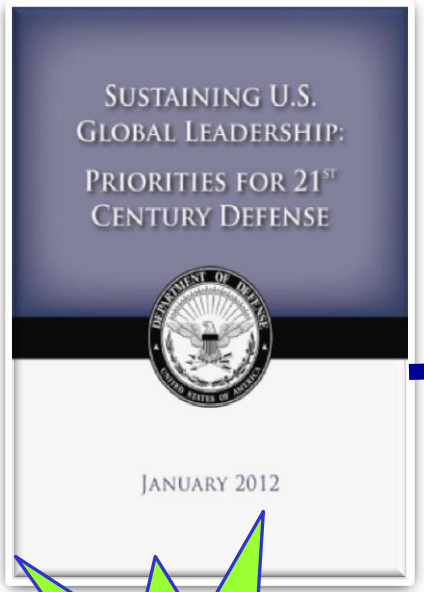
Hypersonic Research..... Turning the Corner

- **Successes**
  - X-15
  - Space Shuttle
  - X-43A
  - X-51A
  - Advanced Hypersonic Weapon (Nov 2011)
- **Did not meet goals**
  - Aerospace plane
  - NASP
  - X-33



Photos courtesy NASA, Richard Hallion

Priorities for 21st Century Defense

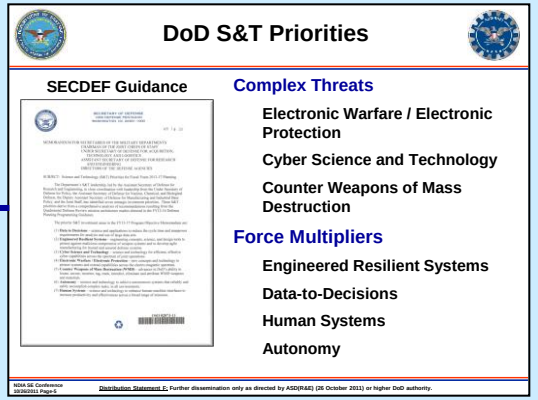


Missions in the Commons

Primary Missions of the U.S. Armed Forces

- Defend the Homeland and Provide Support to Civil Authorities
- Counter Terrorism and Irregular Warfare
- Conduct Stability and Counterinsurgency Operations
- Provide a Stabilizing Presence
- Deter and Defeat Aggression
- **Project Power Despite Anti-Access / Area Denial Challenges**
- Counter Weapons of Mass Destruction
- Operate Effectively in Cyberspace and Space
- Conduct Humanitarian, Disaster, Relief and Other Operations
- Maintain a Safe, Secure and Effective Nuclear Deterrent

S&T Focus Areas

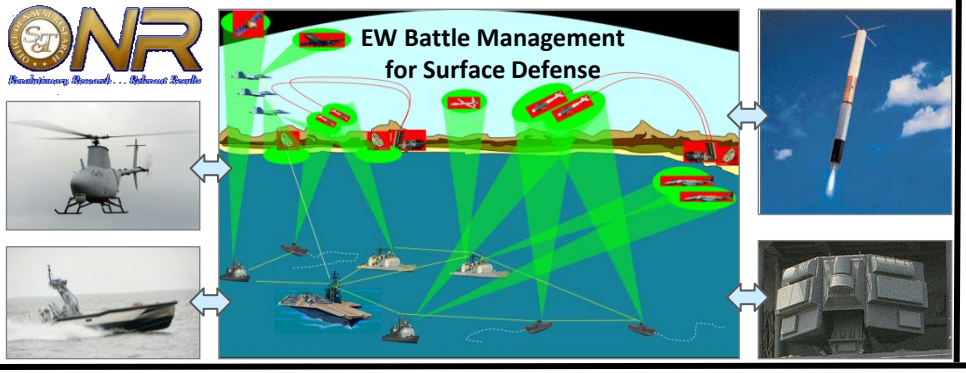


- Counter AA/AD capabilities
- Tailored and adaptive capabilities
- Low-cost, Small-footprint operations
- Developing and integrating partnership capabilities

DoD S&T Complex Threats

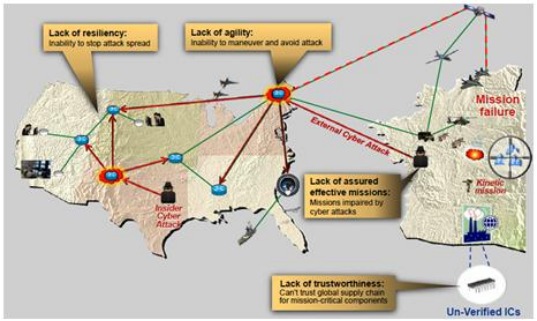
Electronic Warfare & Protection

- RF/Mixed Signal Component Technologies
- EO/IR Component Technologies
- Underlying technology enablers



Cyber Science and Technology

- Assuring Effective Missions
- Resilient Infrastructure Trust
- Cyber Experimentation & Measurement
- Agile Operations



Counter Weapons of Mass Destruction

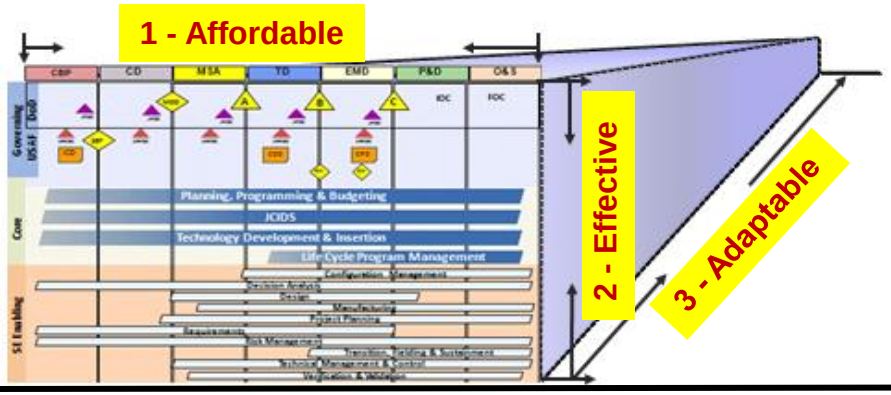
New concepts and technology for remote identification of nuclear, chemical, and biological material, and to assist in mitigation, containment, and attribution of the materials

- Broad Area Search
- Persistent Monitoring
- Tagging and Tracking

DoD S&T Force Multipliers

Engineered Resilient Systems

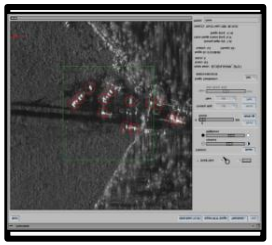
- Spans the Systems Lifecycle
- Uncertain futures & resultant mission volatility

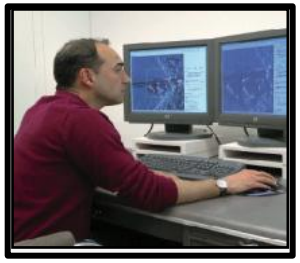


Data-to-Decisions

- Data Management
- Analytics
- User Interface

Multi-Layer Approach



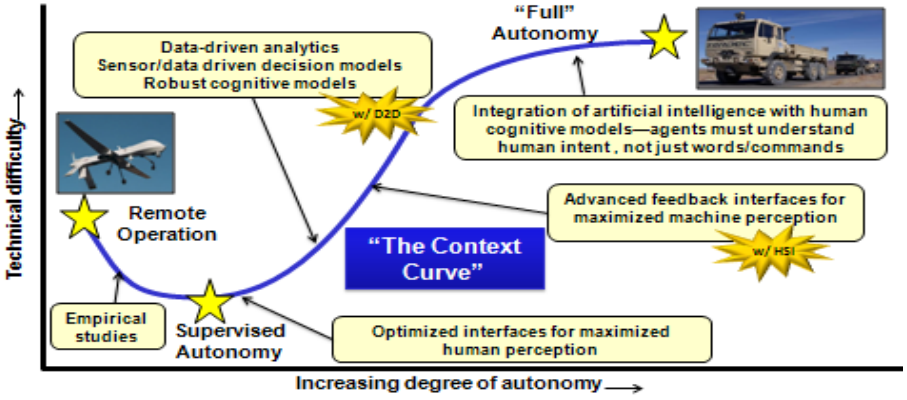


Human Systems

- System Interfaces
- Personnel & Training
- Protection & Sustainment
- Social & Cultural Understanding

Autonomy

Environment – Capability - Technology



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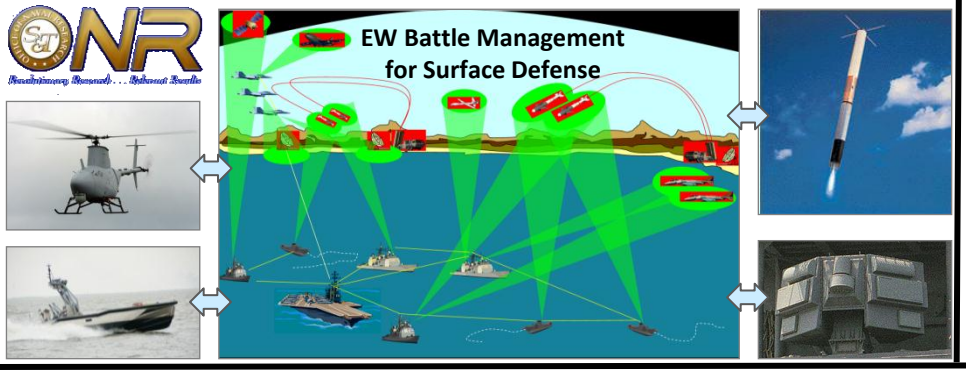

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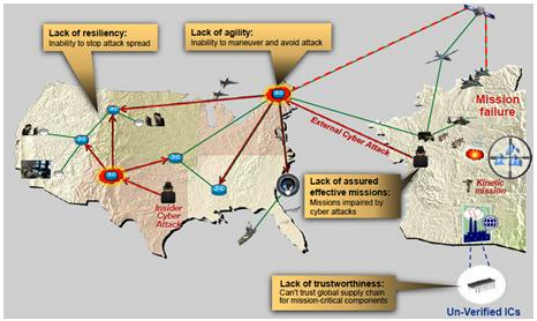

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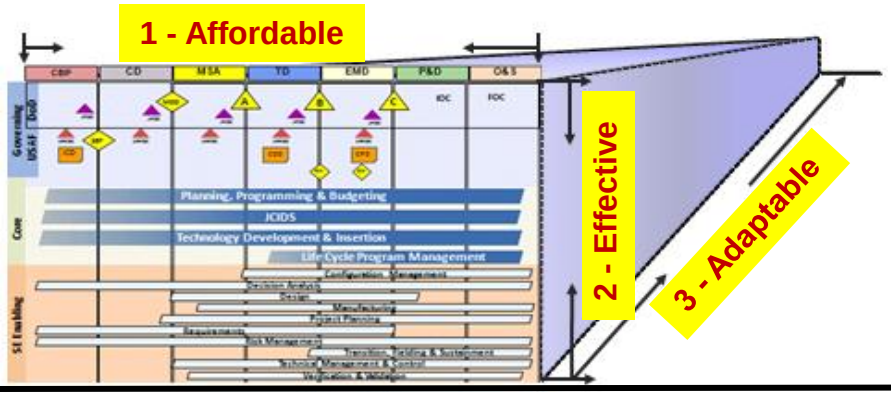

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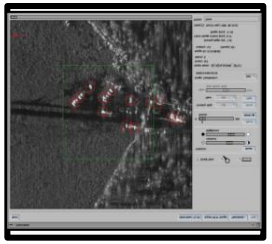

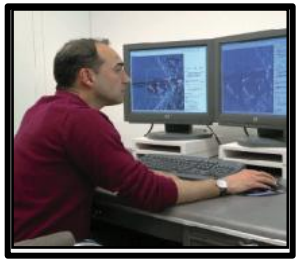

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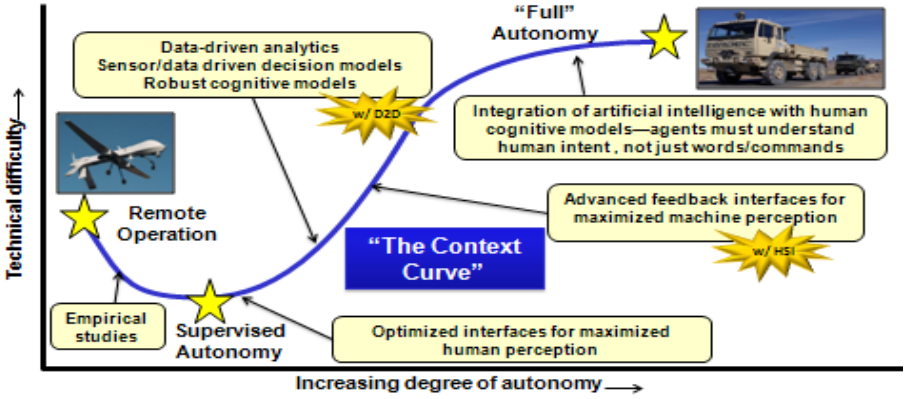
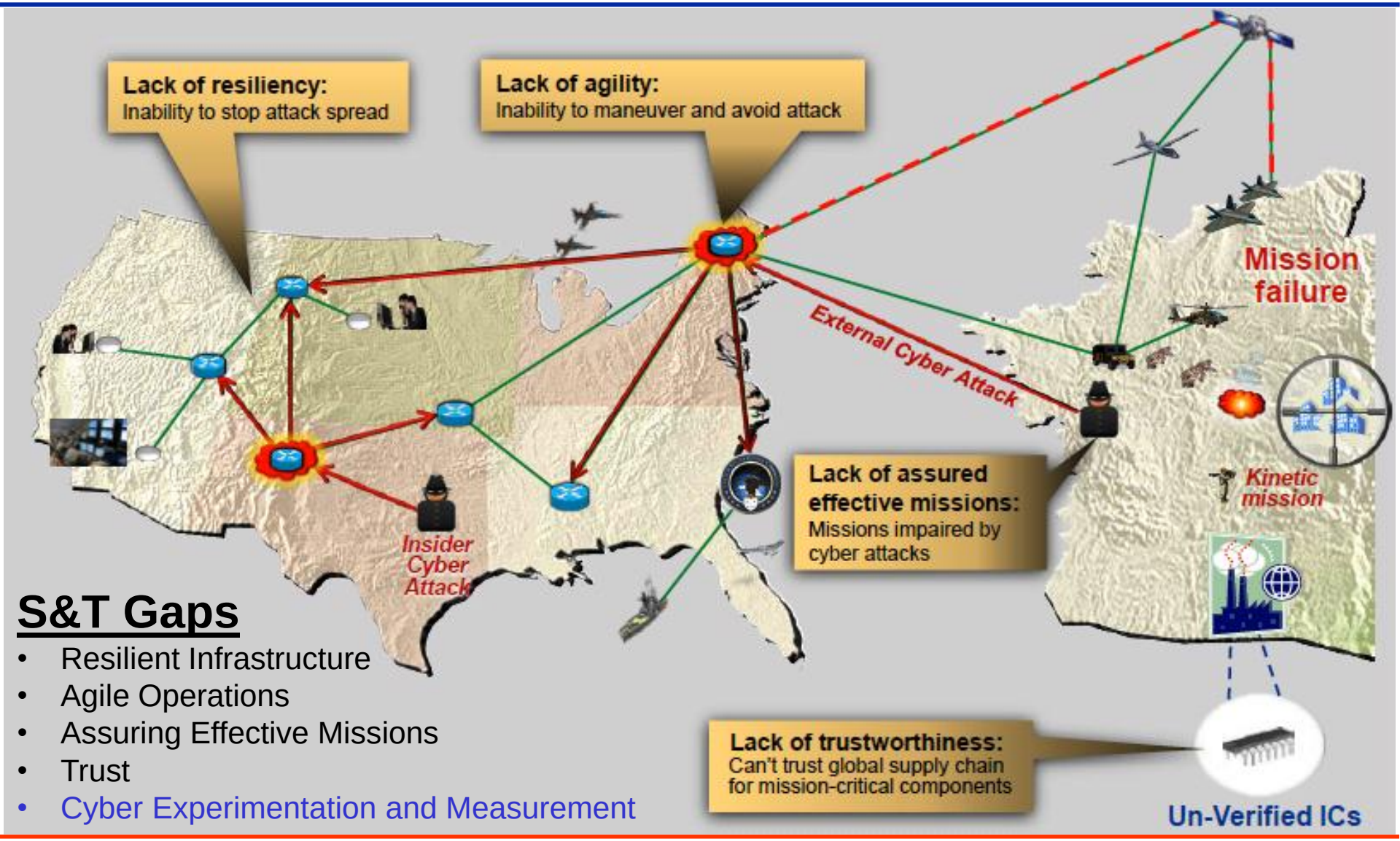


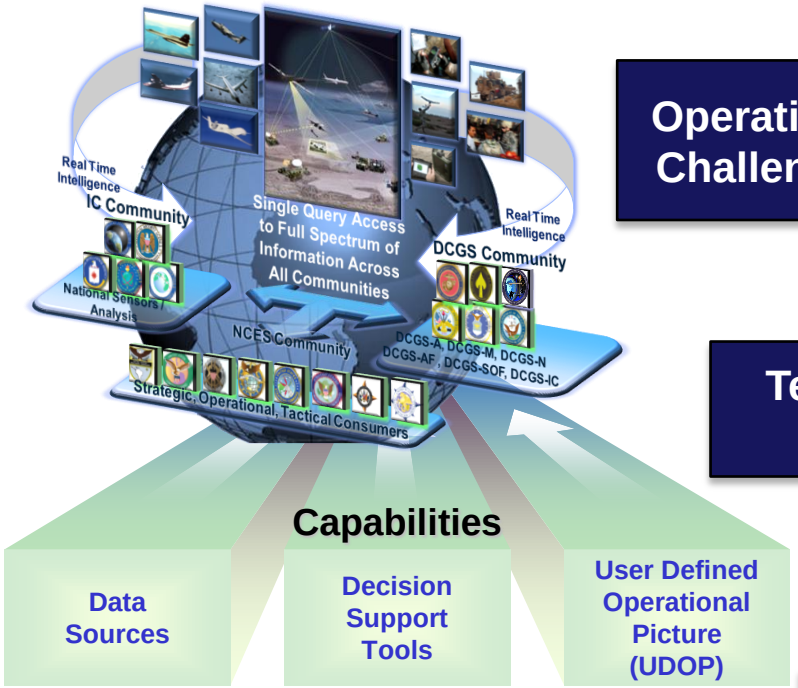
Cyber PSC – Problem Statement



S&T Gaps

- Resilient Infrastructure
- Agile Operations
- Assuring Effective Missions
- Trust
- Cyber Experimentation and Measurement

CLOUDBREAK



Operational Challenges

- **Multiple domains and distributed databases**
- **Single process of accreditation for cross-domain access**

Technical Issues

- **Analysis and production of Intel data**
- **Dynamic network mapping and unified cyber SA across networks**
- **Discoverable enterprise services across domains**
- **Dynamic / reconfigurable COP**

Benefit

- **A common C2 enterprise architecture across COCOMs**
  - Transition C2 tools and capabilities to Warfighter
  - “plug-and-play”

Candidate Measures of Success

- **Timely SA / assessment of Red and Blue**
- **Reduce percentage of time devoted to data mining versus analysis and production**
- **Successful execution of military and non-military missions in the presence of cyber attacks**