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.
We are trading away tomorrow’s force capabilities to pay for today’s force.

Today’s Force

Today DOD Topline down 7.6% in FY15

Declining Next Force 5-15 years

Largely Flat 8-20 years

Force after Next
DoD S&T Funding by Budget Activity
FY 1998-2019
(\textit{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)
• 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

1900 1910 1920 1930 1940 1950 1960 1970

Radio 1901
Airplane 1903
Vacuum Tube 1908
Mechanized Tank 1916

Liquid-Fueled Rockets 1922
Radar 1925
Gas Turbine 1935
Digital Computer 1943
Ballistic Missile 1944

Nuclear Weapon 1945
Transistor 1948
Nuclear Propulsion 1950
Inertial Navigation 1950
Artificial Earth Satellites 1957
Integrated Circuit 1960

Laser 1961
Precision Weapons 1965

Cold War

Next Conflict

Counter WMD
Counter Space
Cyber
Data-to- Decisions
Electronic Warfare/Electronic Protection
Human Systems
Nanomaterials
Quantum Systems
Synthetic Biology

Autonomy

PSAR 2014
Distribution Statement A: Approved for public release; distribution is unlimited
Capability Prototyping
Proof of Concept: “X”- Plane Prototyping

X-1
First flight: 1947
Speed: Mach 1.26

X-2
First flight: 1952
Speed: Mach 3.2

X-7
First Flight: 1951
Speed: Mach 4.31

X-10
First Flight: 1953
Speed: Mach 2

X-15
First Flight: 1959
Speed: Mach 6.7

X-43
First Flight: 2001
Speed: Mach 6.83

X-51
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
“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, Uncertainty, 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

Globally Accelerating Technology

OPPORTUNITIES FOR NEW APPROACHES
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
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

![Diagram](image-url)
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.

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

Schedule

<table>
<thead>
<tr>
<th>Government-only Study Kickoff</th>
<th>Technology Baseline Defined</th>
<th>Brief OSD</th>
<th>Industry Contracts Awarded</th>
<th>TIM</th>
<th>TIM</th>
<th>Update to OSD</th>
<th>TIM</th>
<th>Study Completion, Prototyping Programs Defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threat Picture Defined</td>
<td>2020-2050 Opportunities Identified</td>
<td>RFPs, Concept Studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
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)

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

**Candidate Measures of Success**
- **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

HDBT Numbers, Hardness, Cost, Value Comparisons

Increasing Number of Facilities

Above Ground Bunkers
Basement Bunkers
Underground Bunkers
Simple Tunnels
Complex/Strategic Tunnels

Increasing Construction Cost*

Increasing Hardness to Penetration/Ground Shock (Depth)

*Equal mission area used for bunker and tunnel cost comparison

PSAR 2014
Distribution Statement A: Approved for public release; distribution is unlimited
Example CWMD Technology (DTRA)

Multipurpose weapon with enhanced AD capability

Optimize HE/Agent

Sub-Scale Agent Defeat Phenomenology
Architectures – Technology Trade Space

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
Prepare for an Uncertain Future
Concern of Losing Technological Edge

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

“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.”

• “I’m very concerned about eroding technological superiority”
• DoD’s R&D spending declined 14% since 2009
  • We have to preserve the future capability
Human Systems

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

Data-to-Decision

- 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
“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

- 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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Budget</strong></td>
<td>575.53</td>
<td>579.97</td>
<td>573.59</td>
<td>534.27</td>
<td>526.60</td>
<td>486.84</td>
</tr>
<tr>
<td><strong>Change from Previous Year (S)</strong></td>
<td>6.02</td>
<td>4.44</td>
<td>-6.38</td>
<td>-39.32</td>
<td>-7.67</td>
<td>-39.76</td>
</tr>
<tr>
<td><strong>Change from Previous Year (%)</strong></td>
<td>1.1%</td>
<td>0.8%</td>
<td>-1.1%</td>
<td>-6.9%</td>
<td>-1.4%</td>
<td>-7.6%</td>
</tr>
</tbody>
</table>

### DOD RDT&E Budget

<table>
<thead>
<tr>
<th></th>
<th>FY 2010</th>
<th>FY 2011</th>
<th>FY 2012</th>
<th>FY 2013</th>
<th>FY 2014</th>
<th>FY 2015</th>
<th>% Decline from Recent High Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S&amp;T</strong></td>
<td>12.58</td>
<td>12.52</td>
<td>12.73</td>
<td>12.09</td>
<td>11.98</td>
<td>11.31</td>
<td>-11% (2012)</td>
</tr>
<tr>
<td><strong>Engineering 6.4</strong></td>
<td>15.44</td>
<td>14.70</td>
<td>14.26</td>
<td>12.64</td>
<td>12.06</td>
<td>12.12</td>
<td>-22% (2010)</td>
</tr>
<tr>
<td><strong>Systems Development &amp; Demonstration 6.5</strong></td>
<td>19.27</td>
<td>17.43</td>
<td>16.28</td>
<td>14.97</td>
<td>13.70</td>
<td>10.89</td>
<td>-43% (2010)</td>
</tr>
<tr>
<td><strong>Management Support 6.6</strong></td>
<td>4.71</td>
<td>4.75</td>
<td>4.34</td>
<td>4.34</td>
<td>4.32</td>
<td>4.14</td>
<td>-13% (2011)</td>
</tr>
<tr>
<td><strong>RDT&amp;E</strong></td>
<td>84.69</td>
<td>80.65</td>
<td>78.27</td>
<td>70.72</td>
<td>67.52</td>
<td>62.41</td>
<td>-26% (2010)</td>
</tr>
<tr>
<td><strong>RDT&amp;E Change from Previous Year (S)</strong></td>
<td>-2.60</td>
<td>-4.04</td>
<td>-2.38</td>
<td>-7.55</td>
<td>-3.20</td>
<td>-5.10</td>
<td></td>
</tr>
<tr>
<td><strong>RDT&amp;E Change from Previous Year (%)</strong></td>
<td>-3.0%</td>
<td>-4.8%</td>
<td>-3.0%</td>
<td>-9.6%</td>
<td>-4.5%</td>
<td>-7.6%</td>
<td></td>
</tr>
<tr>
<td><strong>S&amp;T as Percent of RDT&amp;E</strong></td>
<td>14.9%</td>
<td>15.5%</td>
<td>16.3%</td>
<td>17.1%</td>
<td>17.7%</td>
<td>18.1%</td>
<td></td>
</tr>
</tbody>
</table>
Defense Innovation Marketplace
Resources For Industry And DoD

Improving Industry Understanding of DoD Needs

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


PSAR 2014
Distribution Statement A: Approved for public release; distribution is unlimited
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:** Microsystems 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

**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

**DoD S&T Priorities**

- Complex Threats
  - Electronic Warfare / Electronic Protection
  - Cyber Science and Technology
  - Counter Weapons of Mass Destruction
- Force Multipliers
  - Engineered Resilient Systems
  - Data-to-Decisions
  - Human Systems
  - Autonomy

- 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
Engineered Resilient Systems

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

Data-to-Decisions

- Data Management
- Analytics
- User Interface

Multi-Layer Approach

1 - Affordable

2 - Effective

3 - Adaptable

Human Systems

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

Autonomy

Environment – Capability - Technology

- Data-driven analytics
- Sensor/data driven decision models
- Robust cognitive models

“Full” Autonomy

Integration of artificial intelligence with human cognitive models—agents must understand human intent, not just words/commands

Remote Operation

Empirical studies

Supervised Autonomy

Optimized interfaces for maximized human perception

Increasing degree of autonomy
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
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

- Data-driven analytics
- Robust cognitive models
- "Full" Autonomy
- Empirical studies
- Supervised Autonomy
- Optimized interfaces for maximized human perception

Technical difficulty

Integration of artificial intelligence with human cognitive models—agents must understand human intent, not just words/commands

Advanced feedback interfaces for maximized machine perception

Increasing degree of autonomy
S&T Gaps
- Resilient Infrastructure
- Agile Operations
- Assuring Effective Missions
- Trust
- Cyber Experimentation and Measurement

Lack of resiliency: Inability to stop attack spread
Lack of agility: Inability to maneuver and avoid attack
Lack of assured effective missions: Missions impaired by cyber attacks
Lack of trustworthiness: Can't trust global supply chain for mission-critical components
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