Army Science & Technology

Army Science and Technology (S&T) Future Needs and Capabilities

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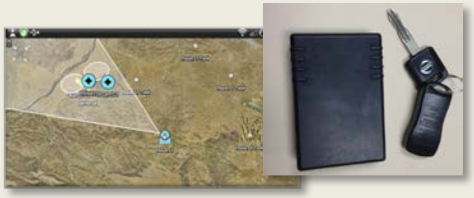
Army S&T Principles

***MISSION:* Identify, develop and demonstrate technology options that inform and enable effective and affordable capabilities for the Soldier**

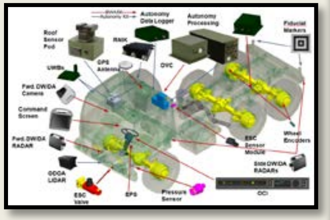
***VISION:* Providing Soldiers with the technology to Win**

Current Force

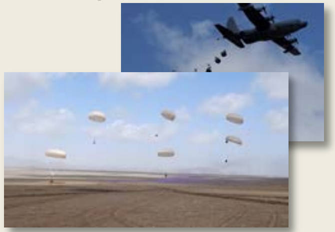


Deployable Force Protection Adaptive Red Team

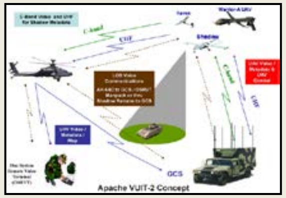
Advanced Rotary Wing Aerial Delivery Sling Load Net



Autonomous Mobility Appliqué System



High Speed Container Delivery System

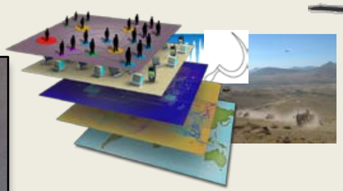


Video from Unmanned Aerial Systems

Enabling the Future Force

Enhancing the Current Force

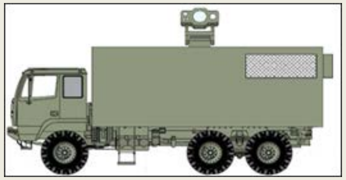
Future Force



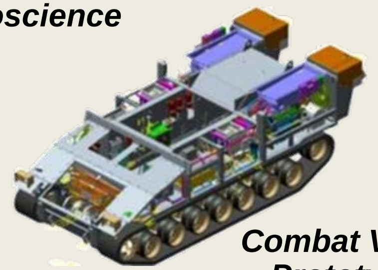
Cyber tools

Next Generation Rotorcraft

Neuroscience



High Energy Lasers



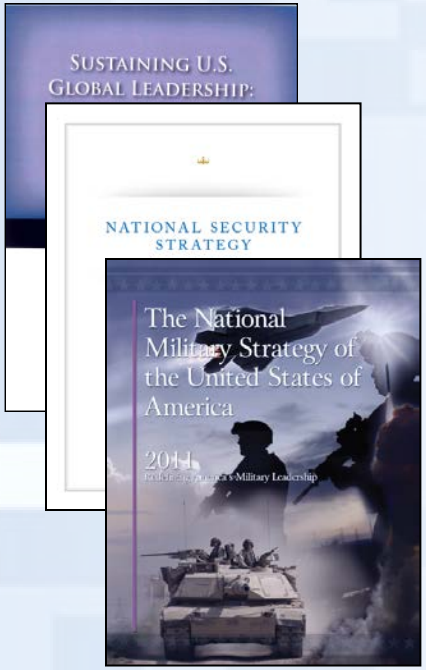
Combat Vehicle Prototyping

Army Enduring Challenges

- Greater ***force protection (Soldier, vehicle, base)*** to ensure survivability across all operations
- Ease ***overburdened*** Soldiers in Small Units
- Timely ***mission command & tactical intelligence*** to provide situation awareness and communications in all environments
- Reduce logistic burden of ***storing, transporting, distributing*** and ***retrograde*** of materials
- Create ***operational overmatch*** (enhanced lethality and accuracy)
- Achieve operational ***maneuverability*** in all environments and at ***high operational tempo***
- Enable ***early detection*** *and* ***improved outcomes for Traumatic Brain Injury (TBI)*** *and* ***Post Traumatic Stress Disorder (PTSD)***
- Improve ***operational energy***
- Improve ***individual & team training***
- ***Reduce lifecycle cost*** of future Army capabilities

Sources Informing Capability Investment

National/DoD Priorities

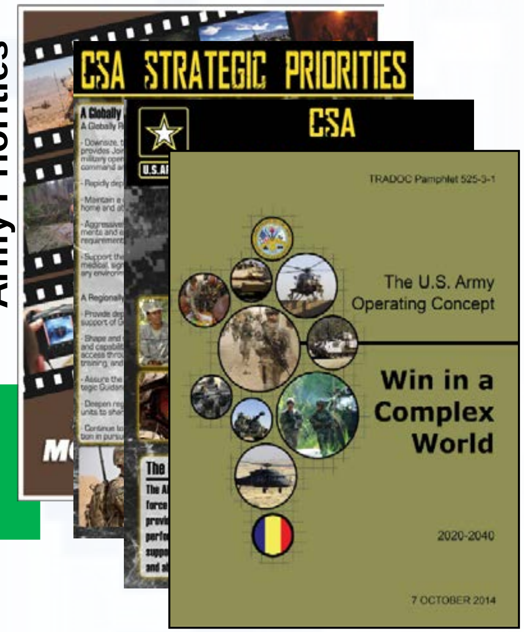


International/ Industry/ Academia

The S&T Portfolio strategy takes into account:

- ***Army Missions/Capability Gaps***
- ***Emerging and Potential Threats***
- ***Technology Opportunities***
- ***Army Core Technical Competencies***
- ***Leveraging other sources of technology wherever possible***

Army Priorities



- **Defense Planning Guidance**
- **DoD Service/Agency Investments**
- **Joint Capabilities Integration and Development System (JCIDS)**
- **Communities of Interest**

Threat

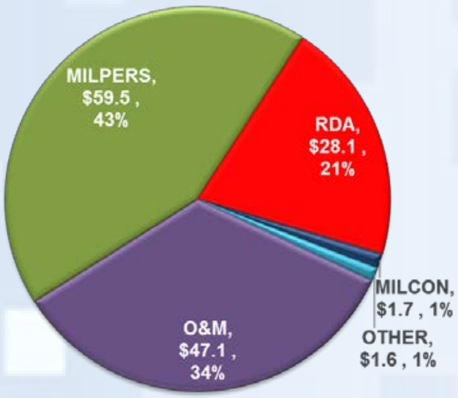
NGIC/Intel Community

- **Army Operating Concept**
- **TRADOC: Army Warfighting Challenges, Capability Needs Analysis, Wargaming/ Exercises**
- **Long-range Investment Requirements Analysis (LIRA)**

Army S&T Investments focus on Army-specific areas that address capability shortfalls which cannot otherwise be met

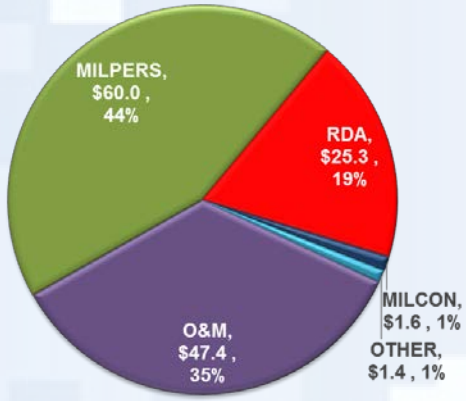
FY17 Declining
Army Top Obligation Authority (TOA) ($B)

FY17 in PB13



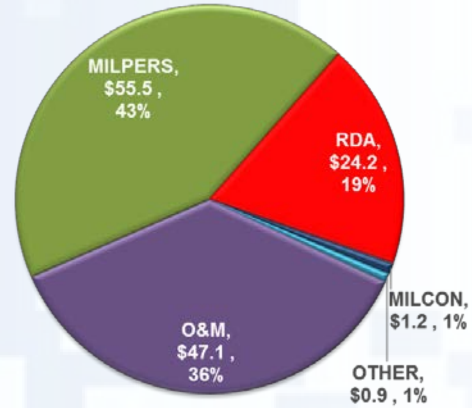
ARMY TOA: $138.0 (B)

FY17 in PB14



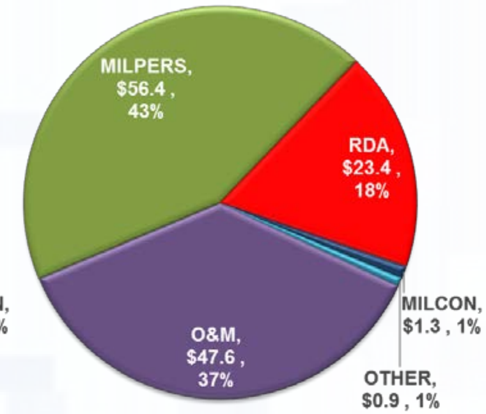
ARMY TOA: $135.7 (B)

FY17 in PB15



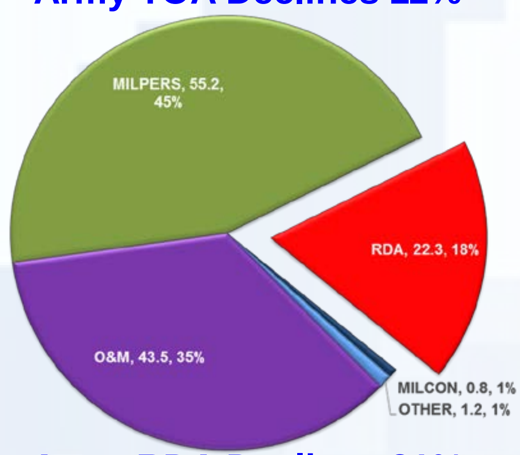
ARMY TOA: $128.9 (B)

FY17 in PB16



ARMY TOA: $129.7 (B)

Army TOA Declines 11%



Army RDA Declines 21%

FY17 in PB17-21

ARMY TOA: $123.1 (B)*

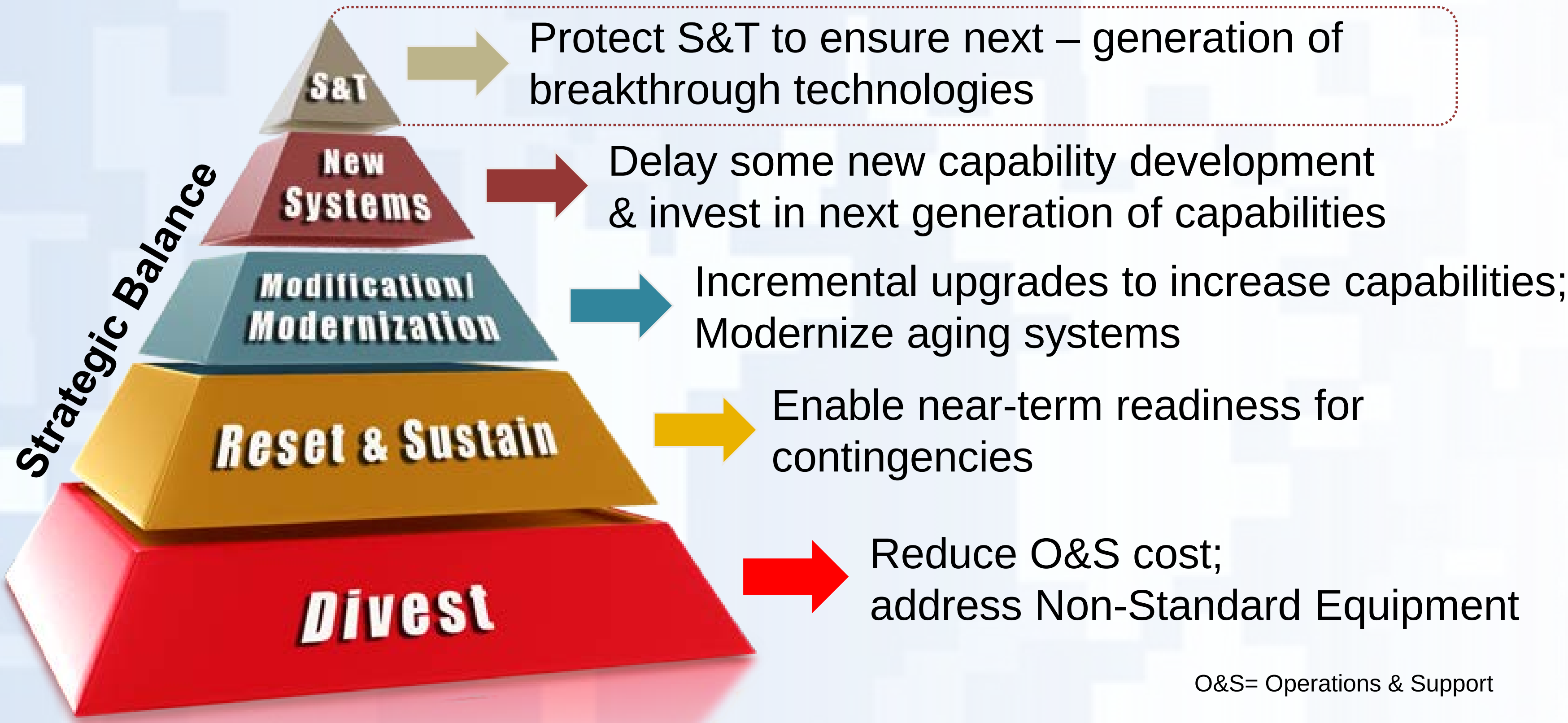
*Requested TOA

Over the Last 50 yrs, RDA Averages 21.9% of TOA

FY17 RDA 18% of TOA

Modernization Strategy in a Fiscally Challenged Environment

- **Reduce procurement quantities to match force structure reductions**
- **Gained efficiencies**
  - **Leveraging multi-year procurement (e.g. Black Hawk, Chinook)**
  - **Incorporate Better Buying Power initiatives (contracting, should-cost, competition)**



O&S= Operations & Support

Long-range Investment Requirements Analysis (LIRA) Task and Objectives

Task

Examine annually the life cycle affordability of estimated future materiel requirements, for 30 years, as measured against the estimated Total Obligation Authority (TOA).
(30 Year Period is FY18-FY47)

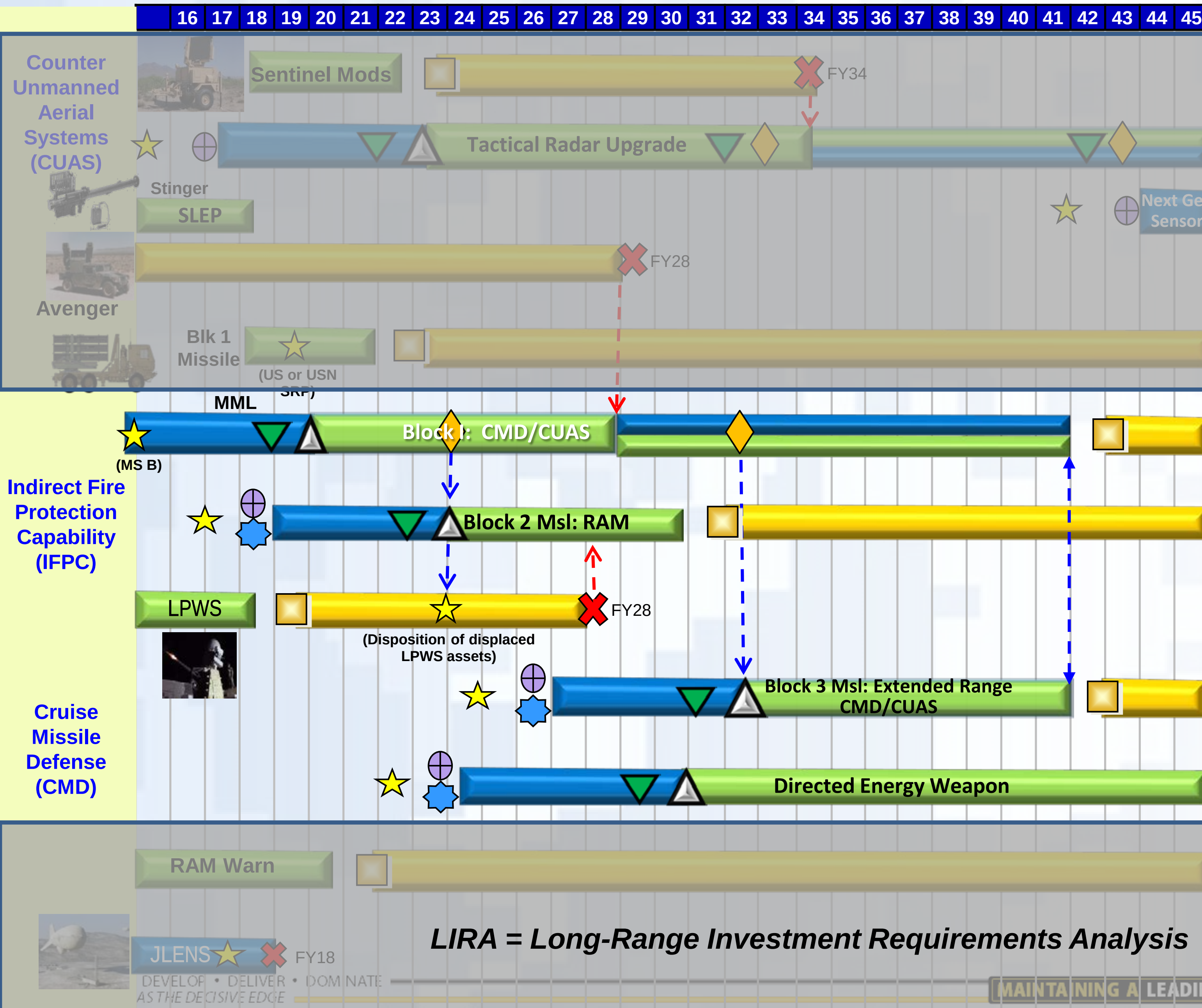
Objectives

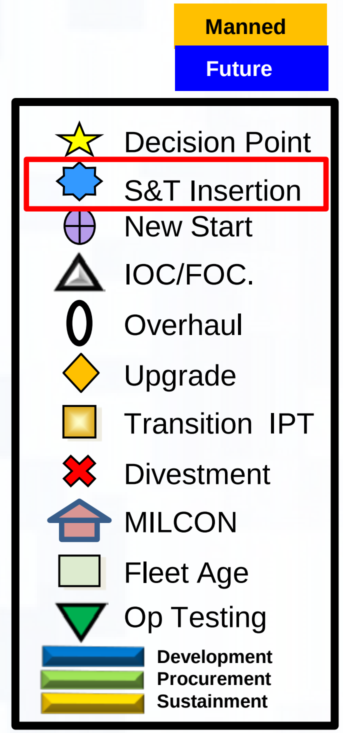
- Demonstrate lifecycle affordability
- Provide vital information for decision making forums and shaping/defending Program Objective Memorandum (POM)
- Develop Cross-Program Evaluation Group (PEG) synchronization strategies
- Informs materiel enterprise of future Army needs/capabilities
- Look at process improvement

Cross-PEG Coordination Ensuring the Best Solution for the Army

LIRA17 Example

Fires – Air & Missile Defense Modernization Strategy



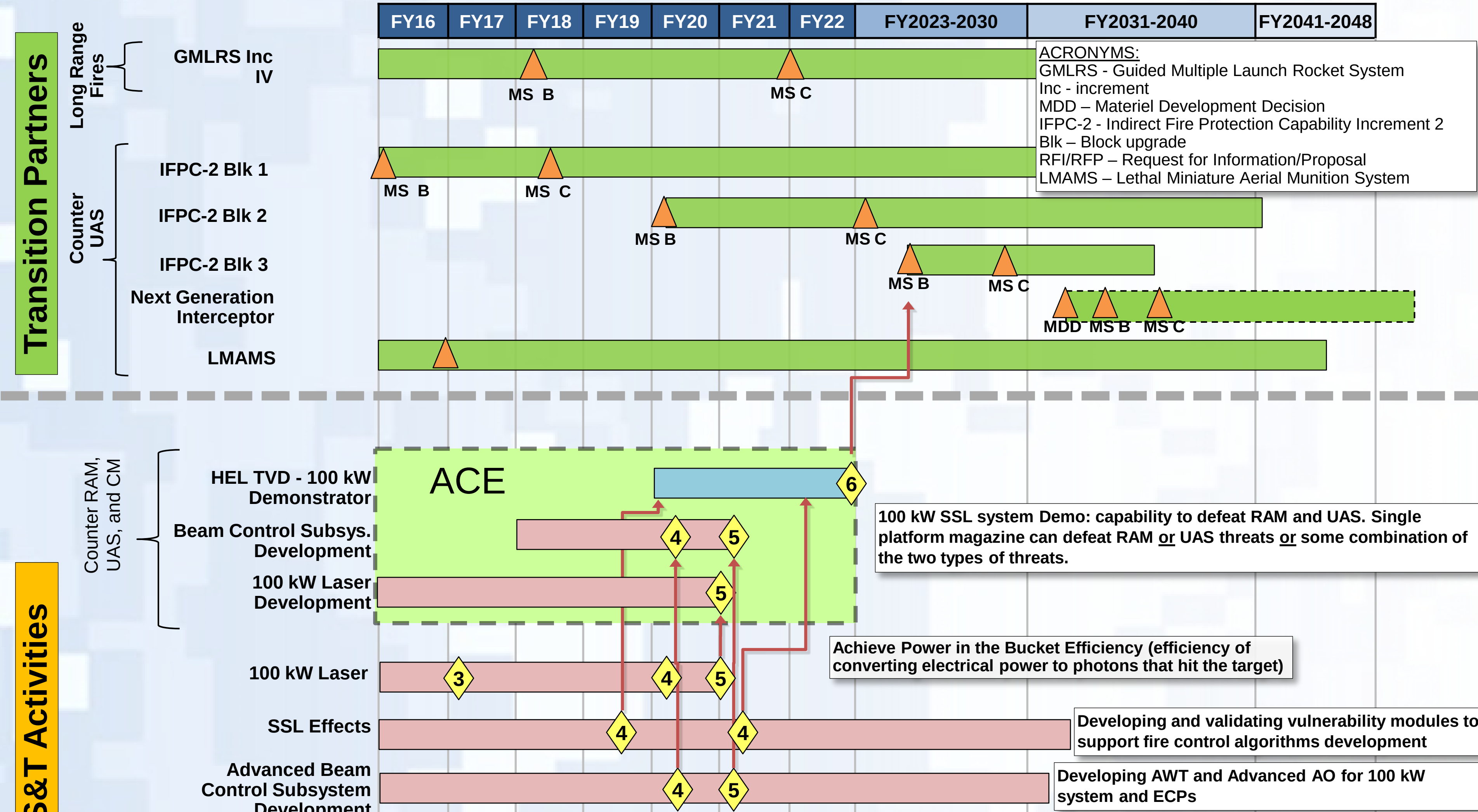


Legend

CMD: Cruise Missile Defense
CUAS: Counter Unmanned Aerial Systems
IFPC2-I: Indirect Fire Protection Capability 2 - Intercept
JLENS: Joint Land Attack Cruise Missile Defense Elevated Netted Sensor
LPWS: Land-based Phalanx Weapon System
MML: Multi-Mission Launcher
RAM: Rockets, Artillery and Mortars
SLEP: Service Life Extension Program

Supporting S&T Timeline for LIRA

High Energy Laser (HEL) – Tactical Vehicle Demonstrator (TVD) Roadmap



ACRONYMS:
AWT – All Weather Tracker
CDD – Capabilities Development Doc.
CM – Cruise Missile
C-RAM – Counter Rockets, Artillery and Mortars
CUAS – Counter Unmanned Aerial Systems
ECP – Engineering Change Proposal
FMTV – Family of Military Tactical Vehicles
HEL – High Energy Laser
RELI – Robust Electric Laser Initiative
SSL – Solid State Laser
TVD – Tactical Vehicle Demonstrator

Legend: 6.1 | 6.2 | 6.3 | 6.7 | Future Activities | Decision/Milestone | # TRL

As of PB17

S&T Resources
Funding Categories, Work Focus, Timeframes

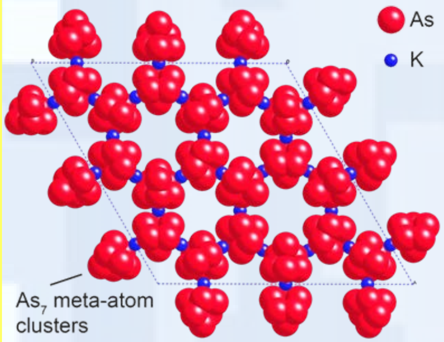
S&T (RDT&E BA 1-3) **$2.3B** (1.8% TOA, 10.2% RDA)

Development* $5.2B (4.3% TOA, 23.5% RDA)

Acquisition (Procurement Appropriation) $14.8B (12.0% TOA, 66.3% RDA)

6.1: Basic Research $429M (19% of S&T)

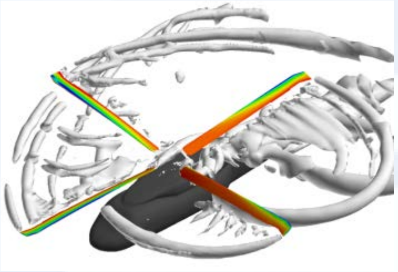
Material Science



- Understanding to solve Army-unique problems
- Knowledge for an uncertain future

6.2: Applied Research $908M (40% of S&T)

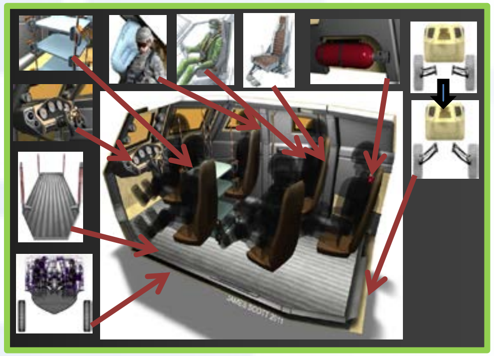
Aeromechanics and Computational Methods



- Applications research for specific military problems
- Components, subsystems, models, new concepts

6.3: Advanced Technology Development $930M (41% of S&T)

Occupant Centric Protection



- Demonstrate technical feasibility at system and subsystem level
- Path for technology spirals to acquisition—rapid insertion of new technology

6.4: Technology Maturation Initiatives $70M

- Funds technology maturation efforts, including competitive prototyping and experimentation in support of selected pre-Milestone B Programs of Record.

6.6: Technical Information Activities $37M

- Advisory Bodies
- Reporting and Info Dissemination
- Studies and Tech Assessment

6.7: Manufacturing Technology $62M

- Address manufacturing issues and facilitate affordable production of weapon systems and materials

Far Term	Mid Term	Near Term
12-20+ yrs	6-12 yrs	0-6 yrs

Note: Figures may not add due to rounding

Army Investments by Portfolio

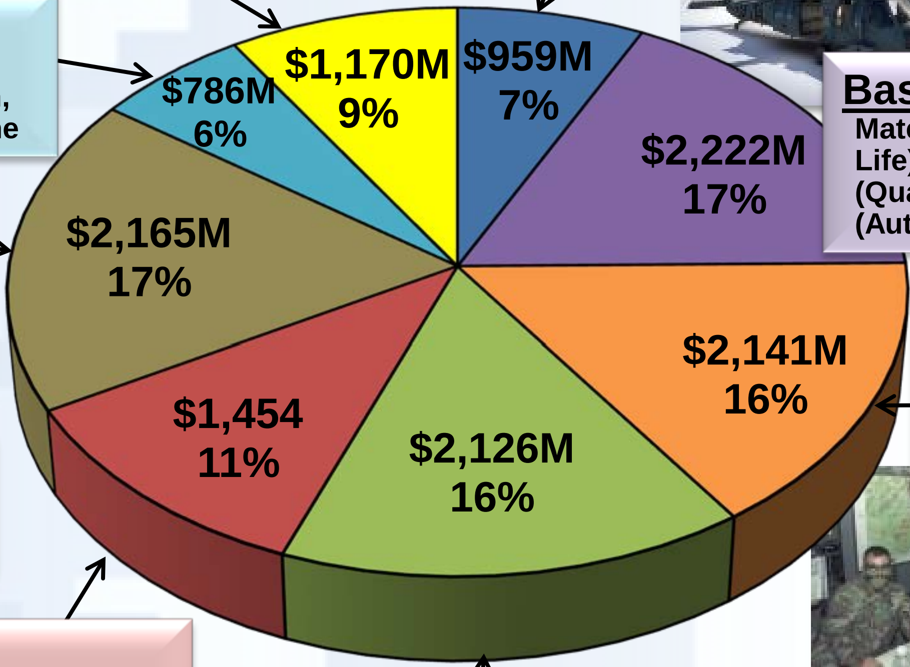
PB17 - $13.0B (FY17-21)

As of PB17

Soldier/Squad
Personnel, Training, Human System Integration, Dismounted mission equipment and power & energy

Air
Advanced Air Vehicles; Survivability; Unmanned Aerial Systems; Manned/Unmanned Teaming

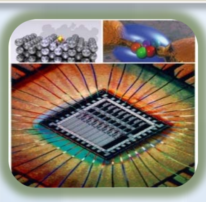
Medical
Combat Casualty Care, Infectious Disease mitigation, clinical/rehabilitative medicine

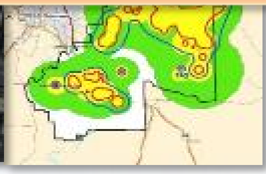


Basic Research
Materials Science; Human (Medical, Life) Sciences; Info Sciences (Quantum, Cyber); Platforms (Autonomy, HPC)

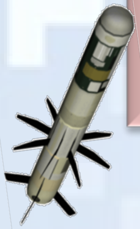
Innovation Enablers
High Performance Computing; Environmental Protection; Base Protection; Studies; Technical Maturation Initiatives; Procurement

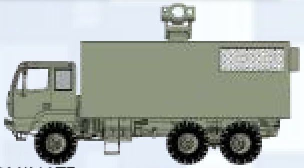
C3I
Assured Communications; Cyber/EW; Sensor Protection; Aircraft Survivability Equipment (ASE); Geospatial Research; Assured PNT





Lethality
Offensive/Defensive kinetic (guns, missiles), Soldier Weapons, Directed Energy (HEL) weapons





Ground Maneuver
Combat/tactical ground platforms survivability; unmanned ground systems; austere entry; power & energy; assured mobility/countermobility

Army Investments	FY17-21
BA1	$2,222M
BA2	$4,660M
BA3	$4,977M
BA4	$340M
BA7	$309M

BA6 $186M, Procurement $330M

Chief of Staff of the Army
Future Army Priority

"We will do what it takes to build an agile, adaptive Army of the future. We need to listen and learn – first from the Army itself, from other Services, from our interagency partners, but also from the private sector, and even from our critics. Developing a lethal, professional and technically competent force requires an openness to new ideas and new ways of doing things in an increasingly complex world. We will change and adapt."

MARK A. MILLEY
General, United States Army
39th Chief of Staff of the Army

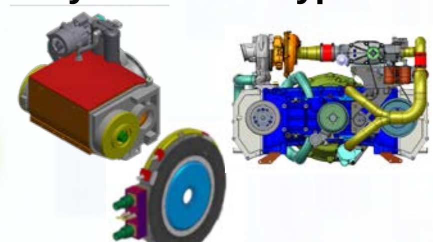
Technology Development for Combat Vehicle Prototyping

Purpose: Enable the next generation combat platforms delivering leap-ahead mobility, survivability and lethality capabilities, and light-weighting approaches. Ensure future acquisition program requirements are informed with what is technically feasible and affordable while driving down future acquisition program technical risk.

Survivability Technology Demonstrator

Multi-Material Joining

Automotive Sub-system Prototypes



Turret & Weapon Sub-system Prototype

50mm Main Armament

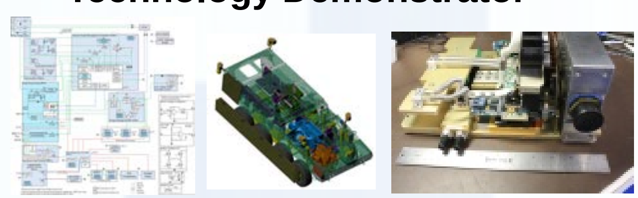
50mm Ammo

50mm Ammo Handling & Fire Control

Active Protection System (APS) Prototype

Modular APS Framework
Modular APS Controller

Vehicle Power & Data Architecture Technology Demonstrator

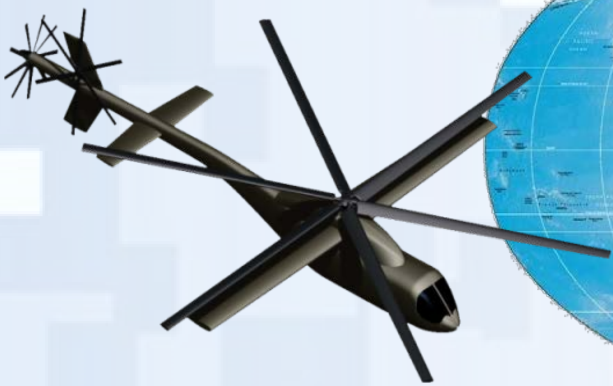


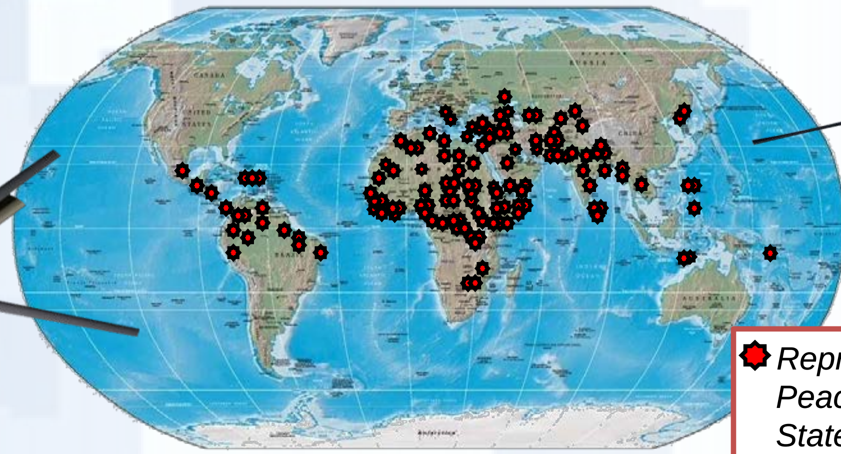
Products: Major efforts include: Advanced System Concepting; Automotive Subsystem Prototypes (Powertrain, Track & Suspension); Survivability Technology Demonstrators (Armor, Structure, Blast Protection, Modular Active Protection System) ; 50mm Medium Caliber Weapon System Prototype & Ammunition; Vehicle Power & Data Architecture Technology Demonstrator; and Hostile Fire Detection (HFD) Systems

Joint Multi-Role Technology Demonstrator (JMR TD)

<u>Purpose:</u> Demonstrate transformational vertical lift capabilities to prepare the DoD for decisions regarding the replacement of the current vertical lift fleet

Capability to Perform Worldwide Operations





Represents armed conflicts, UN Peace Keeping mission, Dept of State Travel Advisories & failing states

For the entire year, considering 24-hour cycles:

4K/95 °F – CANNOT conduct 24-hour ops for 66 days per year due to environmental limitations

6K/95 °F – only limited by environment 5 days per year

<u>Product:</u> Two (2) demonstrator aircraft showcasing affordable capabilities that enable higher speed, better lift efficiency, lower drag (L/De), and improved Hover Out of Ground Effect (HOGE) at high/hot conditions (6K/95). Flight and mission systems architecture demonstrations occur from FY17 through FY19

Army S&T Red Teaming

New theaters present new challenges – future operations with technically savvy opponents requires "red teaming" of technologies and systems to maintain military superiority

Live Field Experiments

$26M in FY17

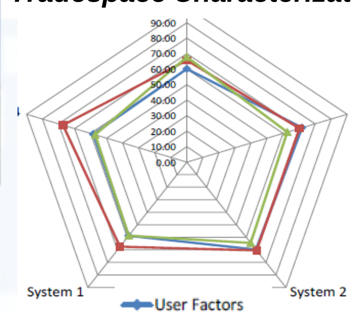
FY16 Topics

- ***Directional Networking/Contested Tactical Communications***
- ***Assured Positioning, Navigation and Timing***
- ***Advanced Precision Munitions***
- ***Platform Sensor Protection from Lasers***
- ***Electro-Magnetic Armor***
- ***Future Rotorcraft Blade Control***
- ***Denial and Deception Technologies***
- ***Airborne Intelligence, Surveillance and Reconnaissance (ISR)/Precision Geolocation***
- ***Next Generation Area Denial***
- ***Unmanned Aerial System (UAS) Threat and Counter-UAS Technologies***
- ***Autonomous/Semi-Autonomous Ground Vehicle Systems***

- **Identify and understand potential vulnerabilities *early* in the materiel development lifecycle:**
  - **Emerging technologies**
  - **Emerging systems/sub-systems**
- **Conducts lab, virtual, and live field experiments to stress and assess technology components and integrated systems**
- **State-of-the-art tools and methodologies to address potential vulnerabilities across a spectrum of threats and environments**
- **Challenge the conventional approaches to technology insertion – identify risks, reduce vulnerabilities and optimize performance in operations**

Threat Emulation

Tradespace Characterization



Adaptive Red Teaming – Activity Snapshot

Technology Setup and Emplacement

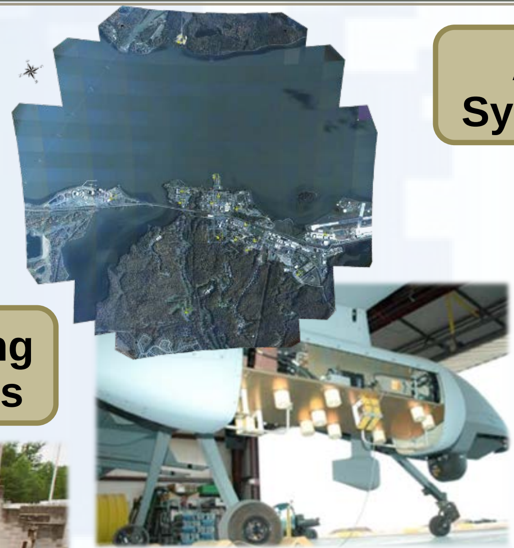
Scenario Execution

Adaptive Red Teaming Field Demonstrations

Technical Support and Operational Analysis 15-3
Marine Corps Base Quantico, VA

GPS and Mobile Communications Jammers and Advanced Drones

Adaptive Red Teaming Systems Intensive Analysis

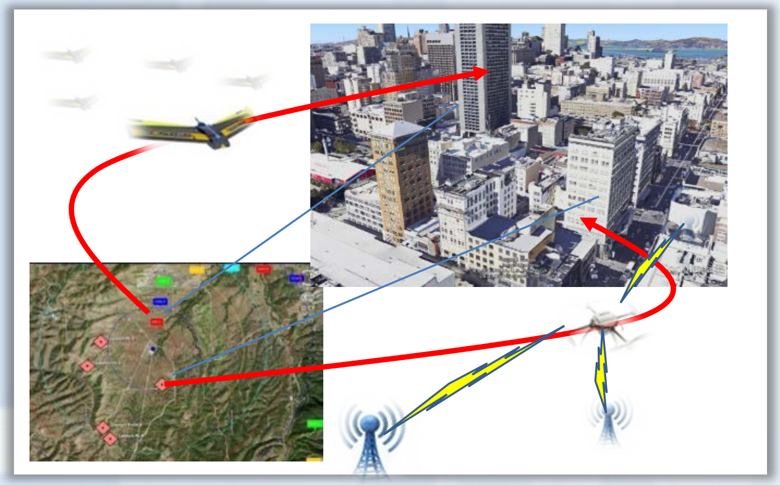


Airborne Precision Geolocation and Imagery Integration

Multi-Tiered Segmented Structures and Urban Atmospherics

Unmanned Aerial Systems as Threats

Success Story: Systems Adaptive Red Team Unmanned Aerial System as a Threat

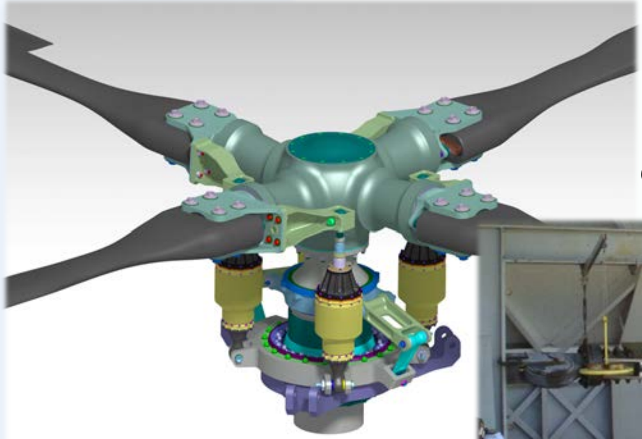


The Army S&T Adaptive Red Team UAS Intensive: Informs Army S&T Counter-UAS development by identifying and assessing effective Group 1 and 2 UAS Threat (UAS-T) tactics, techniques, and procedures (TTPs) and emerging technologies that could create capability gaps in Counter-UAS systems operating in contested, congested, peer/near-peer environments

- **The ART UAS-T field experiment at Camp Roberts, CA in August 2015 included 120 participants from more than 50 Joint, Interagency, Intergovernmental and Multi-national organizations**
- **Organizations represented included Army, Navy, Air Force, Marine Corps, SOCOM, DoS, DHS, DoE, CIA, UK MoD, and NATO to name a few**
- **Baselined threat UAS TTP for Group 1 platforms against 10 Counter-UAS radars and purpose-built defeat devices in open, rolling terrain**
- **Gained insights into capabilities of a set of Group 1 UAS Threat TTPs that were capable of overcoming current U.S. C-UAS capabilities**
- **Future field experiments are planned, including urban environments**

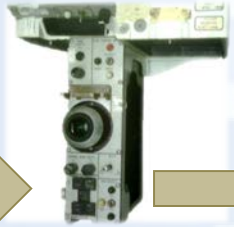
Technology Red Teaming – Activity Snapshot

Autonomous Ground Resupply Architecture Red Teaming

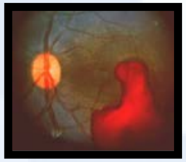


Ballistic Vulnerability of Individual Blade Control Technologies

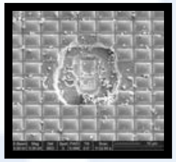
Vulnerability Assessment and Analysis of Technologies



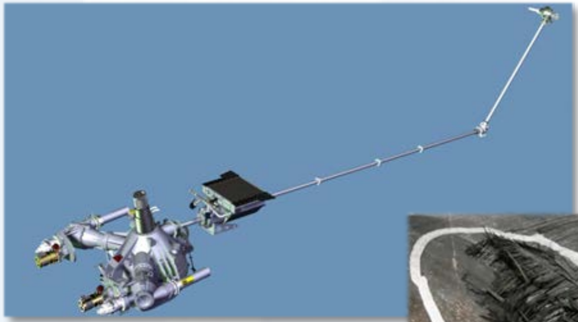
Sensor Protection Technology against Future Threat



Eye Damage



Sensor Damage



Failure Mechanisms of Flexible-Matrix-Composite Drive Shaft Technology

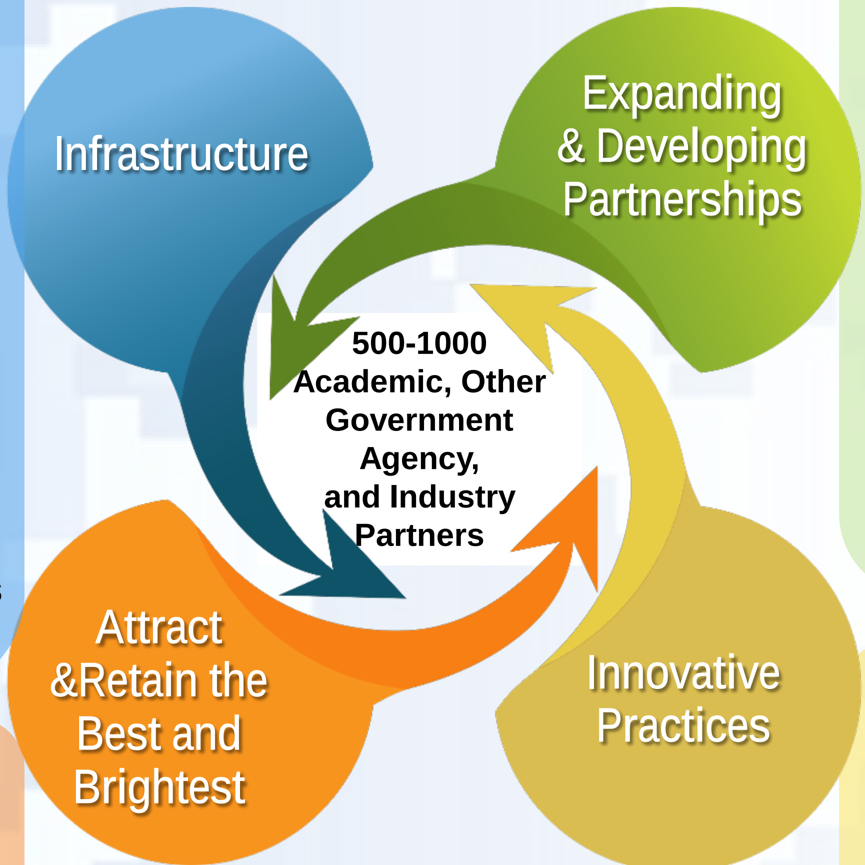
ARL Open Campus

Adelphi Laboratory Center

- Construct collaborative space for network and modeling research
- Expand ALC Open Campus to 3rd & 4th floors & open quantum research wing
- Enhance autonomous systems facility
- Construct Research Park (EUL)
- Integrate ALC into White Oak Science Gateway

Aberdeen Proving Grounds

- Open admin spaces in B4600 & implement layered security measures
- Acquire buildings in close proximity to B4600
- Leverage available existing EUL facilities
- New construction of S&T Collaboration Center



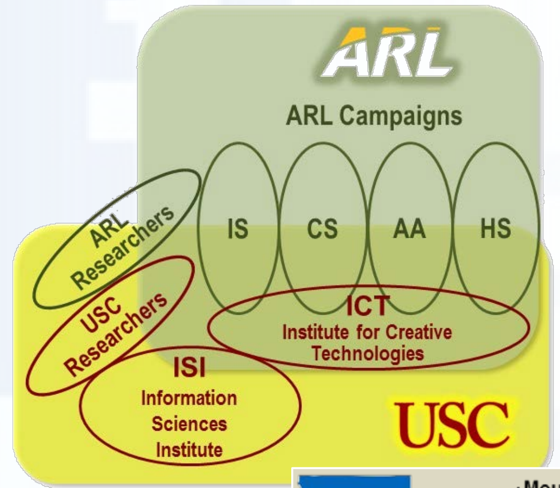
- Develop umbrella agreements with new partners
  - U of CA System, Princeton, Northeastern MD Tech Council, Chesapeake Science Community Corridor, and more
- Continue to leverage existing agreements
  - U of MD, MIT, CalTech, 3M, UDEL
- Establish international research centers in Tokyo, London, and Santiago to advance outreach to foreign universities
- Explore feasibility of establishing consortium wide agreements such as with DoD Ordnance Technology Consortium

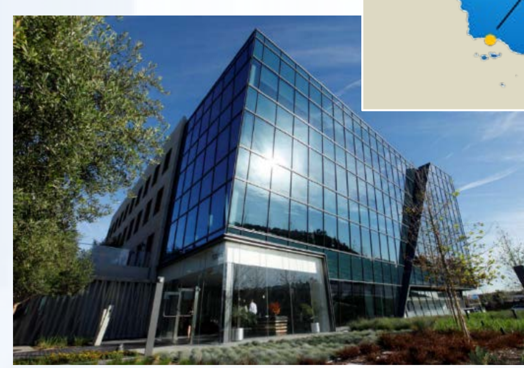
- Active personnel "flow" between government, academia, small-business and industry
- New relationships producing employees, collaborators, and infusion of new ideas

- Expand participation with competitive entrepreneur programs
- Increase incubator opportunities
- Increase transition to small businesses

ARL West

- **ARL-distinct facilities are available at the Army's University of Southern California Institute for Creative Technology (ICT)**
  - Employees & contractors work for ARL
  - Research driven by ARL mission, Army needs & requirements
  - Force protection for ARL staff easily addressed
- **Excellent potential for increased innovation through closer collaboration with USC & ICT research staff**
  - Exploit strengths of USC staff & facilities
  - Leverage ongoing research at ICT & USC Information Sciences Institute
- **Establishes "beachhead" for ARL west coast S&T campaign activities**
  - Local hub for west coast university interactions & recruitment





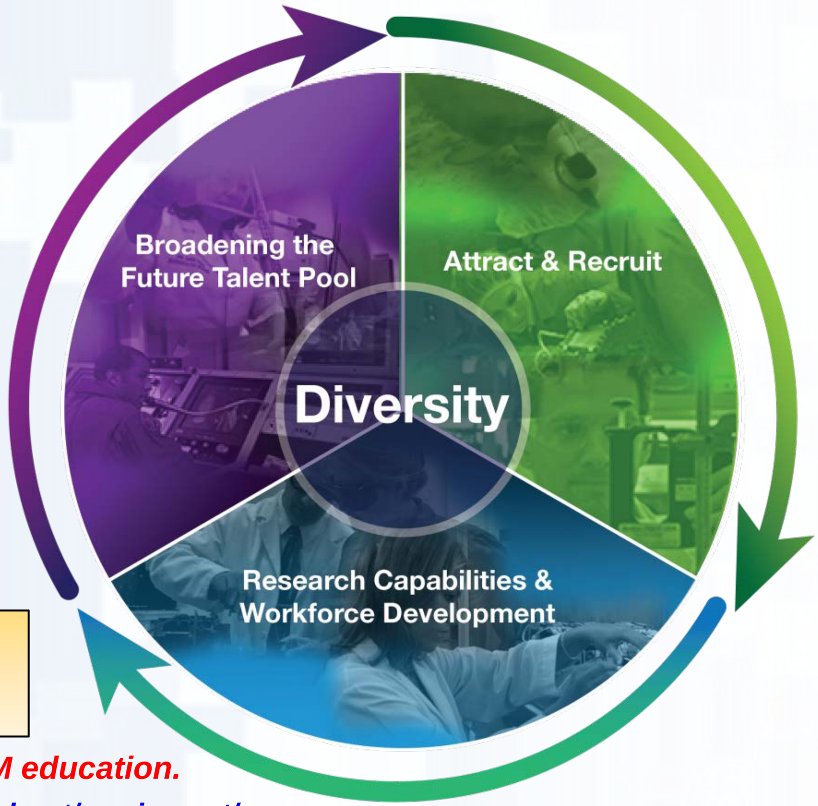
Army Educational Outreach Program (AEOP)

Vision: A diverse, agile, highly competent STEM talent pool, representative of our nation's demographics to supply Army workforce initiatives

Mission: Offer students and teachers a collaborative, cohesive, portfolio of Army-sponsored STEM programs that effectively engage, inspire, and attract the next generation of STEM talent through K-through college programs and expose them to DoD STEM careers

Priorities:

- STEM Literate Citizenry: broaden, deepen, and diversify the pool of STEM talent in support of our Defense Industrial Base
- STEM Savvy Educators: support and empower educators with unique Army Research and Technology resources
- Develop and implement a cohesive, coordinated, and sustainable STEM education outreach infrastructure across the Army



The Army has a holistic approach to STEM capabilities

AEOP serves to broaden the future talent pool

AEOP aligns to a BBP 3.0 initiative to increase DoD support for STEM education.

Program evaluations are all available online at http://www.usaeop.com/about/our-impact/

Army Educational Outreach Program Cooperative Agreement (COA)

The Army strategically manages our annual ~$10M STEM education investment under a 10 Year Cooperative Agreement

ARMY EDUCATIONAL OUTREACH PROGRAM

U.S. ARMY RDECOM

Junior Solar Sprint & Unite

Junior Science & Humanities & Apprenticeship Management

Medical Research & Materiel Command

US Army Corps of Engineers

COA Management

International Mathematics Olympiad (IMO)

Strategic Partnerships with underserved & underrepresented organizations

Air Force STEM

AEOP Evaluation & Assessment

eCYBERMISSION, Gains in the Education of Math & Science (GEMS) & Camp Invention

Research Experience for STEM Educators and Teachers (RESET)

Navy STEM

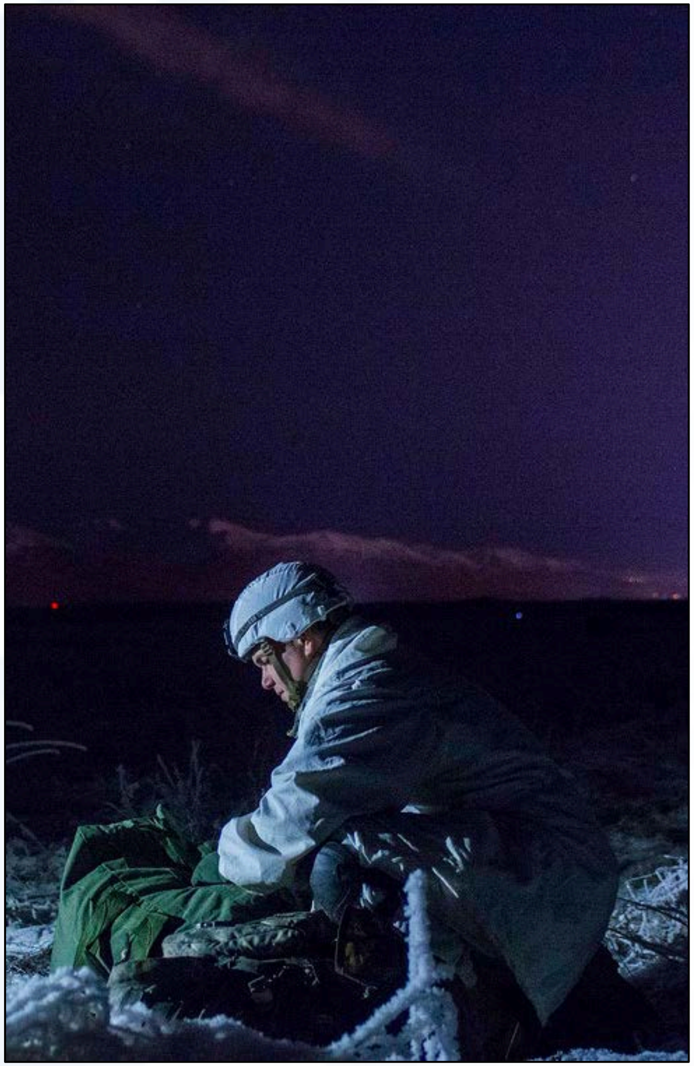
Marketing & Communications

AEOP Alumni Management

The Army's STEM education program success is critically dependent on a strong partnership with academia and industry – just as the Army's research program is critically dependent on a strong relationship with the Defense Industrial Base

A Question…

Based on knowledge of current and emerging systems and technology, what are the most radical changes that the Army will need to deal with in the future to prevent, to shape, and to win?



- ***Technology Parity***
- ***Interconnected, global environment***
- ***An unpredictable enemy – from individual actors to nation-states***
- ***…***

Technology Parity

- Increasingly technically capable and economically strong adversaries are likely to develop countermeasures to technologies that the U.S. has become reliant upon
- Global access to technology impacts our capability advantage
  - Must assess the impacts/opportunities of adopting commercial and open standards
- In this environment, training and leadership will make the critical difference – it becomes imperative to adapt quickly and respond to surprise
- We must seek low cost ways to change the enemy's cost paradigm – quantity over quality – less capable, but overwhelming in numbers

"High Tech" loses its advantage if everyone has it

Interconnected, Global Environment

- Enemies and adversaries will challenge U.S. competitive advantages in the land, air, maritime, space, and cyberspace domains. Advanced technologies will transfer readily to state and non-state actors.
- Both friendly and hostile systems are more interconnected, but more threatened by cyber, Electronic Warfare, and disruptive technologies / capabilities; our current advantage in a capability area may be degraded, defeated, or rendered irrelevant
- Social Media will play into warfare of the future… we need to look at this differently – how can we use this to our advantage?

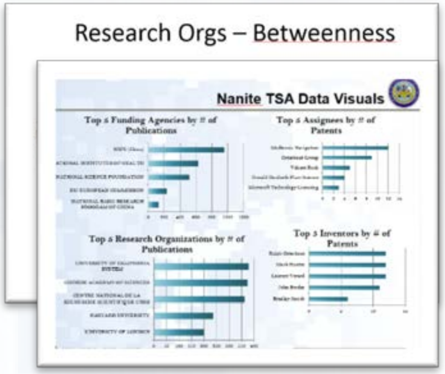
Technology Wargaming Overview

- Crowdsource future capabilities from the Army S&T enterprise, academia, and non-traditional DoD thinkers
  - Mitigates risk of cognitive bias's within the Department of the Army by leveraging the creativity and insight of non-traditional DoD individuals and organizations
  - Executed through in-person and online ideation exercises
- Analyze potential technologies using bibliographic-based data analytics (universities, personnel, countries performing the research)
- Through SME review create a functional decomposition of a potential capability
- Assign probabilities and perform Monte Carlo Simulation to create a here-to-there narrative for how basic science advances will produce an Army capability through a Technology Sequence Analysis (TSA)
- Provide broad future S&T context in Annual Trends Report

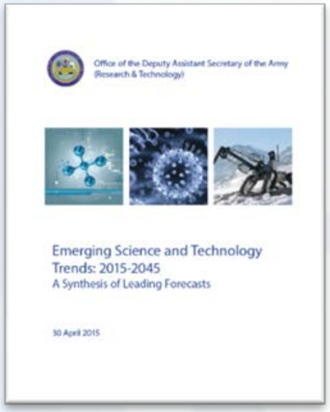
"…The elite amateurs were on average about 30% more accurate than the experts with access to classified information...the full pool of amateurs also outperformed the experts. The most careful, curious, open-minded, persistent and self-critical…did the best."[1]

Crowdsourcing

SME-Informed Bibliometric Search

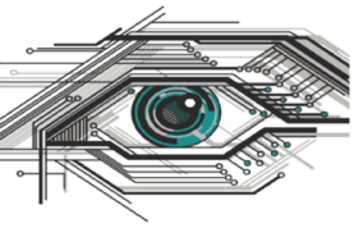


S&T Trends Report



Deep Dive Analysis

[1] Zweig, J. (2015, September 25). The Trick to Making Better Forecasts. Retrieved November 20, 2015, from http://www.wsj.com/articles/the-trick-to-making-better-forecasts-1443235983



Autonomous Systems

By 2045, autonomous systems will likely be a ubiquitous part of everyday life. Autonomous vehicles will reduce traffic congestion and all but eliminate accidents. Robots will perform surgery, deliver goods, harvest our crops, and provide many daily services. Intelligent software agents will automate critical infrastructure such as power plants and perform knowledge work, including routine administrative and research tasks. The use of robots in military operations will expand as robots gain mobility, dexterity, and autonomy. At the same time, the rise of autonomous systems could displace hundreds of millions of labor and service workers, creating economic instability and the risk of social unrest. Networked autonomous systems will also become an attractive target for adversaries and a new priority for cyberdefense.

86% Concurrence
13% Share

ENABLING S&T

Machine Learning
Learning is critical for autonomous systems to adapt to novel, complex environments. Impressive strides are being made in deep learning, inspired by a growing understanding of how learning occurs in biological nervous systems.

Sensors and Control Systems
To interact safely and effectively with humans in real-world environments, robots and other autonomous systems will need to incorporate sensors and control systems that provide increased dexterity and mobility.

Human-Agent Interaction
We are just beginning to understand how to design autonomous systems that can partner with humans to perform complex, real-world tasks.

Agent-Agent Interaction
As autonomous systems become more prevalent, it will also become important for robots and other autonomous agents to be capable of communicating with each other.

SIGNALS

Facebook's DeepFace project is developing software that can determine whether or not the same person appears in two different photographs. People are about 97.53% accurate at this kind of task. In its latest test, DeepFace got it right 97.25% of the time.

Engineers at HRL Laboratories demonstrated a small drone controlled by neuromorphic chip technology. Unlike traditional semiconductor-based processors, neuromorphic chips use silicon "neurons" that communicate via electrical spikes.

Google has completed its first complete prototype of a consumer-grade driverless automobile and plans to begin testing the cars on public roads early in 2015.

DARPA's Fast Lightweight Autonomy (FLA) program is developing a small drone that can fly up to 45 miles per hour through the interior of an unfamiliar building without GPS or any intervention from a human operator.

IMPACT

Social
As autonomy and machine intelligence grow we will face difficult questions about the role of personal responsibility and "machine rights".

Political
As robots become integrated into society, political systems will face challenging legal and regulatory issues around how much autonomy robots should be granted.

Economic
Autonomous systems will transform work, transportation, and the consumer experience. However, automation will displace human workers and could increase unemployment.

Environmental
Robots will be able to clean up pollution in areas too hazardous for humans to enter. Disasters like the Fukushima nuclear incident will be mitigated by robot relief crews.

Defense
Robots will redefine the role of the Soldier in combat. Our adversaries will also use autonomous systems, and might be willing to go further than us in giving combat robots complete autonomy.

...robotics could eliminate the need for human labor entirely in some manufacturing environments, with total automation may becoming more cost effective than using large levels of labor or outsourcing to developing countries.

National Intelligence Council (GT2030)

We estimate that by 2025 advanced robotics could have a worldwide economic impact of $1.7 trillion to $4.5 trillion annually across the applications we have sized

McKinsey Global Institute (MGI)

The United States lost its monopoly on drones years ago. Autonomous systems are now being developed by dozens of other state and non-state actors.

Center for a New American Security (CNAS)

3D & 4D Printing

3D printing "prints" physical objects layer-by-layer in an additive fashion, unlike molding, machining, or other traditional techniques. Today, additive processes can create objects from a variety of materials, including plastic, metal, ceramics, glass, paper, and even living cells. By 2045, 3D printers will be able to print objects made from multiple materials that incorporate electronics, batteries, and other components. Personal 3D printers will transform commerce, allowing individuals to create goods directly at the point of use based on models purchased or shared over the Internet. 4D printing will extend additive manufacturing by creating objects that can self-assemble or change shape on their own. Objects will become information, and digital piracy will replace shoplifting. Terrorists and criminal organizations will print advanced weapons using raw materials that will be almost impossible to track.

79% Concurrence
8% Share

ENABLING S&T

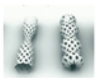
Improving Speed, Size, and Quality
Outside of high-end industrial systems, today's 3D printers are slow, can produce only small parts, and cannot match the precision of traditional molding or machining technology.

Materials
Newer polymers that can work in 3D printers offer flexibility, electrical conductivity, and even biocompatibility (e.g., for implants).

Bioprinting
We are beginning to use 3D printing techniques to create complex biological structures out of cells, using dissolving lattices to provide structure. This opens to the door to printing organs and providing us with "replacement parts" that our bodies won't reject.

4D Printing
4D printing extends additive manufacturing by giving 3D-printed objects the ability to self-assemble and adapt in response to local conditions.

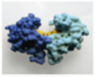
SIGNALS



The U.S. Army is funding 4D printing research at Harvard University. University of Pittsburgh and University of Illinois that is exploring how self-assembling objects could be used to create tactical bridges, shelters, and other equipment on the fly.

Scientists at the U.S. Army Natick Solder Center are experimenting with 3D printing food. This technique could create new possibilities for designing functional foods tailored to individual nutritional needs.

The Chinese construction firm WinSun has used four giant 3D printers to build 10 one-story houses in a single day. The printers, which were 33 feet wide and 22 feet high, printed the homes using a combination of cement and construction waste. The result is a construction method that is faster, cheaper, and safer than traditional construction.



Scientists are using 3D printing to study protein folding and to develop entirely new protein structures based on more rugged synthetic amino acids. In addition to advancing understanding of protein function, this work could lead to novel protein structures that could be used to detect biological or chemical contamination.

IMPACT

Social
3D printing and social media could move "maker" culture into the mainstream. People will be able to collaborate, customize, and share design files in ways that will be difficult to predict or control.

Political
3D printing presents challenges for intellectual property. When matter is reduced to information, design files for 3D printing will become the target of online piracy and cyberespionage.

Economic
Additive manufacturing will make low-rate production and customization cost-effective. This could create an economic impact of over $500 billion per year across multiple industries.

Environmental
Additive manufacturing generates far less waste than molding or machining. Point of use production will reduce pollution from transporting goods across countries and continents.

Defense
3D printers could transform military logistics by allowing units to print equipment and spare parts in the field. Adversaries will be able to print weapons from plans freely shared on the Internet.

3D printing technology will make physical things become information. Rapid innovation of the product will be possible through online manipulation of the digital design.

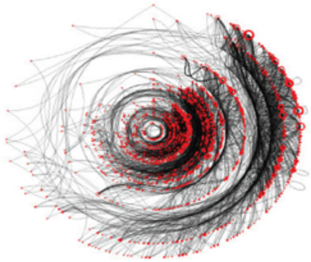
NATO

We estimate that 3D printing could generate economic impact of $230 billion to $550 billion per year by 2025 in the applications we have sized. The largest source of potential impact among sized applications would be from consumer uses, followed by direct manufacturing and the use of 3D printing to create tools and molds.

McKinsey Global Institute (MGI)

In the context of military operations, additive manufacturing could significantly alter logistics by allowing deployed units to print specific parts in situ from available materials.

Center for a New American Security (CNAS)



Analytics

Globally, over 2.5 exabytes of data are created every year. We are awash in data, but only just beginning to develop the tools to mine and visualize it to support complex decisions. While "Big Data" has become a buzzword, the real revolution lies in analytics. A major market for big data analytics has already emerged, and over the next 30 years our ability to make sense out of massive, dynamic data sets will improve. This will affect almost every sector of the economy, create new industries, and transform our capability to understand and influence the world. While the use of analytics at the enterprise level will continue, individuals will also have access to a growing volume of data about their own personal lives. A trend toward the "quantified self" will drive analytics solutions aimed at helping people optimize themselves through data.

64% Concurrence
9% Share

ENABLING S&T

Visualization
Better tools are needed for visualizing complex, multivariate data sets. Interactive visualizations, 3D displays, and virtual reality all offer new ways to explore data.

Machine Learning
Companies like Google are investing heavily in developments like deep learning – an approach that is based on the computational power of neural networks.

Natural Language Processing (NLP)
NLP uses computer algorithms to analyze patterns in unstructured text data. Current applications of NLP include sentiment analysis, which measures how people are reacting topics on social media.

Data Fusion
Research is under way to develop algorithms that can analyze and automatically correlate data from multiple sources, including text and images.

SIGNALS

Knack, a Silicon Valley startup, makes games for mobile devices that also measure personal qualities like creativity, persistence, and ability to prioritize. Royal Dutch Shell has used Knack's "people analytics" to identify people with the potential to generate disruptive new business models.

CancerRx is an app (available through iTunes) that provides doctors with a decision support tool that can recommend diagnostic tests and identify promising treatment options for a range of cancers.

IBM's Watson Analytics uses natural language processing and machine intelligence to allow people to explore large, complex data sets by asking questions through the Watson interface. Watson points to a future in which machines will shift from tools to active partners in data analytics.

HP's Zvr Virtual Reality Display blends a 3D monitor with precise head tracking and digital pen technology to create "virtual holographic 3D images" that can be manipulated to explore data in three dimensions.

IMPACT

Social
Analytics will have a profound impact on health care. For instance, epidemiologists will be able to better understand interactions among genetic and environmental factors in cancer and heart disease.

Political
There are difficult political issues around data ownership and privacy. As analytic capabilities mature the information value of data will increase, as will the pitfalls of data access.

Economic
Big data analytics will touch most economic sector by 2040. If current growth trends hold, the combined market impact of analytics will exceed half a trillion dollars by 2020.

Environmental
The ability to effectively draw insights from massive amounts of climate data will revolutionize climate modeling, enabling better predictions of climate change and weather.

Defense
Analytics will transform the ability to connect data to decisions. A commercial market for wearable sensors will drive innovations in monitoring individual Soldier performance. Adversaries could leverage analytics to identify weak points in interconnected global systems.

The ability to process, manipulate, and ultimately understand patterns in enormous amounts of data will allow decoding of previously mysterious processes in everything from biological to social systems.

Institute for the Future (IFTF2012-II)

Fear of the growth of an Orwellian surveillance state may lead citizens, particularly in the developed world, to pressure their governments to restrict or dismantle big data systems.

National Intelligence Council (GT2030)

Understanding the 'Big Data' – the knowledge that can be extracted from examination of the masses of data compiled every year – has been described as the next seismic shift.

NATO

Cyber

Cyberdefense is hardly a new trend - warnings about a "cyber Pearl Harbor" were made as early as 1991. However, over the next 30 years the rise of the Internet of Things and growing interdependence among connected aspects of everyday life will bring cybersecurity to the forefront. While the number and scope of cyberattacks is increasing, most have been targeted against individual consumers or corporations and the damage, while extensive, has been easily contained. As cars, home appliances, power plants, and millions of other objects become networked, the potential for a truly devastating cyberattack will grow. Nations, corporations, and individuals will be challenged to secure their data from ever more insidious attacks - many of which may go undetected for years. The worst-case scenario envisions a form of "cybergeddon", in which the immense economic and social power of the Internet collapses under the weight of relentless cyberattacks.

43% Concurrence
3% Share

ENABLING S&T

User authentication technologies
Future authentication techniques will use biometrics, personal cryptographic key generators, and other technologies that provide stronger and simpler access control than today's passwords.

Resilient networks
Research in underway to build networks that are self-configuring, self-healing, self-optimizing, and self-protecting.

Security-aware application design
Until recently, cybersecurity depended entirely on firewalls and "perimeter defense". Future applications will be security-aware and capable of dynamically protecting against attacks that get around firewalls and antivirus software.

Next generation encryption
Quantum cryptography is one example of future encryption technologies that will make it more difficult for cyberattackers to make use of stolen data.

SIGNALS

Cyber criminals are leveraging crowdsourcing. For example, "Flash Robs" are a recent form of cyber-coordinated crime in which social media is used to rally thieves to loot specific stores before police can arrive.

In November, 2014 Sony Pictures Entertainment became the target of one of the largest cyberintrusions in history. Hackers broke into the SPE network and stole emails, employee social security numbers, and even five soon-to-be-released films. Initial evidence pointed to North Korea, which had expressed outrage over an upcoming Sony film. The U.S. leveled new sanctions against North Korea in response – setting a new precedent for national response to cyberattacks against private companies.

China's military has been accused of cyberespionage against Lockheed Martin. Recent demonstrations of China's J-31 stealth fighter and a new long-range radar platform highlight striking similarities with the F-35 and radar products developed by Lockheed. Industry experts point to rumors of cyber penetration by Chinese hackers dating back to 2009.

IMPACT

Social
Ongoing security breakdowns and revelations about domestic monitoring of digital activity could further undermine people's trust in governments and corporations.

Political
Governments will be challenged to enact both domestic cyber policies and international protocols and standards governing cybercrime and cyberespionage.

Economic
An analysis by security firm McAffee estimates that cyberattacks cost the global economy $375-575 billion per year. This figure will continue to grow as more devices come online.

Environmental
Environmental hacktivism is an ongoing source of risk for businesses and governments. Future hacktivists might target energy infrastructure as well as financial and transportation networks.

Defense
Cyber creates new avenues for crippling adversaries without using lethal force. However, dependence on networks exposes U.S. forces to tremendous risk.

Cybercrime is accelerating at an exponential pace. In the not-so-distant future, everything from our watches to the EKG monitors in hospitals will be connected to the Internet and ready to be hacked.

Deloitte

The next generation could grow up with a cyberspace that is less open, less resilient and fundamentally less valuable than the one existing today. The most transformative technology since Gutenberg would regress, to the loss of societies, economies and humanity.

World Economic Forum (WEF)

Thus, the "Internet of things" provides significant opportunity to create asymmetric advantage for potential adversaries.

Center for a New American Security (CNAS)

Future of Medicine

Over the next 30 years medicine will be completely transformed. Genomics will enable doctors to tailor treatments for infections, cancer, and birth defects to an individual's genetic makeup. Artificial organs will be grown for transplantation using a patient's own DNA. Prosthetics will be wired directly into the nervous system and will incorporate biologically-based sensors that provide a near-normal sense of touch. Robotic first responders and tissue preservation techniques such as controlled hypothermia will revolutionize trauma care and greatly extend the "golden hour" for wounded Soldiers. As scientists unlock the keys to aging, people will live longer and stay healthy and active well into what today we consider "old age". At the same time, the cost of advanced medical care will trigger rising inequality in access to life-saving treatments, raising ethical issues and the prospect of social upheaval.

50% Concurrence
5% Share

ENABLING S&T

Genomics
Genomics is accelerating, and promises usher in an era of personalized medicine. Detailed understanding of human genetics will enable hyper-targeted treatments for many currently incurable illnesses.

Regenerative Medicine
Research is underway on growing organs, and potentially entire limbs, from a person's own genetic material. We will have access to personalized "replacement parts", turning many terminal diseases into manageable repairs.

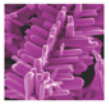
Biomedical Engineering
Advances in biomedical engineering will lead to breakthroughs such as injectable nanobots that target drug delivery and augment our natural healing capabilities.

Public Health
We are discovering that many diseases are the result of complex interactions among environmental factors, lifestyle, and genetics. More work is needed to translate these findings into interventions that can prevent disease.

SIGNALS

A Dutch engineering student has demonstrated an airborne defibrillator delivery drone that weights less than five pounds and can reach anyone within five square miles within minutes. Future versions of the drone could carry additional medical supplies and provide a communications link with medical personnel who can provide first aid guidance until EMTs arrive.

Scientists have demonstrated an ultrathin silicon nanoribbon that could one day be used to create artificial skin for prosthetics. The material incorporates sensors for detecting strain, pressure, temperature, and humidity.



Researchers at the University of Maryland are working on new technique to deliver drugs to tissues deep within the body using nano-scale rods driven by fast-pulsed magnetic fields.

A team of biomedical engineers at MIT has used 3D printing to create functional blood-vessel-like structures woven into biological material similar to an artificial organ.

IMPACT

Social
People will live longer and remain physically and cognitively vital. This could cause generational tensions, particularly in the workplace. The high cost of future medical care will raise ethical questions around access to life-extending care,

Political
Revolutionary medicine will come with a steep price tag, placing pressure on health care systems worldwide.

Economic
Workers will remain productive well into their 70s and even 80s. Genomics and biomedical engineering will grow into enormous industries that need millions of educated workers.

Environmental
Environmental impacts of future medicine are unclear, though rising populations will create more waste and create challenges for sustaining habitable cities.

Defense
Regenerative medicine will transform battlefield medicine, extending the golden hour. Genetic therapy will make it possible to "fix" congenital or developmental problems in new recruits.

Lab-on-chip (LOC) devices that integrate and scale down biomedical and other analytical laboratory functions will allow for very cheap and fast diagnoses of disease, medical conditions and other events...Incorporation of these devices within clothing will allow for the monitoring of body function information by medical or other operational forces.

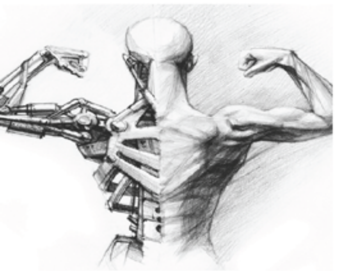
NATO

A more preventive, predictive and personalized medical model is emerging. From epigenetics which looks at the heredity role in gene expression for obesity, to fast gene analysis of our DNA, to the customized drugs we will be manufacturing on-demand, to telehealth, to nano-virus drugs to nano-devices; medical innovations are fast transforming health care.

Institute for Global Futures (GFF2013)

Today, a human genome can be sequenced in a few hours and for a few thousand dollars, a task that took 13 years and $2.7 billion to accomplish during the Human Genome Project. With rapid sequencing and advanced computing power, scientists can systematically test how genetic variations can bring about specific traits and diseases, rather than using trial and error.

McKinsey Global Institute (MGI)



Human Augmentation

Over the next 30 years technologies will emerge that allow us to transcend limits on human potential. Wearable computers will provide us with context-sensitive information to enhance memory and physical performance. Exoskeletons will provide superhuman strength and endurance. Sensors and computers embedded in contact lenses and permanent implants will let us hear whispers miles away, give us natural night vision, and allow us to immerse ourselves in augmented reality. The immense commercial potential of these technologies means they will be widely available to those who can afford them, including future adversaries.

64% Concurrence
8% Share

ENABLING S&T

Wearable Computing
Wearable computing will enable individuals to use data to understand and improve performance and maintain a seamless connection to the web.

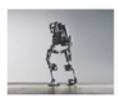
Exoskeletons
Exoskeletons are undergoing rapid development, with a focus on new control architectures, power for sustained operation, and optimizing the human-system interface.

Pharmacological Enhancement
Drugs like Modafinil and Adderall are common performance enhancers. Research is ongoing to find other drugs that improve mental and physical performance without negative side effects.

Advanced Prosthetics
Scientists and engineers are working on better techniques for encoding signals from nerves and training prosthetic controllers to enact complex actions based on a user's intentions.

SIGNALS

Les Baugh lost both of his arms 40 years ago, and has been fitted with modular prosthetics developed by the Johns Hopkins Applied Physics Lab. The prosthetics are wired into Baugh's nervous system and are controlled by his thoughts. Within 10 days of receiving the arms Baugh was able to move cups between shelves of different heights and perform other complex actions.



Ekso Bionics is producing an exoskeleton that is being used by rehabilitation clinics to restore mobility to patients with lower body weakness. The U.S. Navy has purchased two FORTIS upper body exoskeletons from Lockheed Martin for testing in naval shipyards.

Wearables like the Fitbit and Samsung Galaxy Gear smartwatch are driving the trend towards the "quantified self", in which people use personal data analytics to improve their performance.

Microsoft has demonstrated a real-time speech translator that will be integrated into the Skype video chat application.

IMPACT

Social
The ability to transcend innate limits will be liberating, but will raise difficult questions about what it means to be human. Distinct subcultures could arise around particular enhancements.

Political
Through 2040 augmentation will be costly, leading to a two-tiered world of enhanced "haves" and "have nots". This will create political unrest and difficult regulatory issues.

Economic
The market for augmentation technology is massive and blurs lines between traditional markets. Entirely new industries will emerge to serve augmented humans.

Environmental
Environmental impacts from human augmentation should be limited, though resource conflicts could grow as enhanced humans become more active and longer-lived.

Defense
Augmentation (exoskeletons, nootropics) will revolutionize Soldier capabilities. We should expect to face augmented adversaries. Networked augmentations could be the target of cyberattacks.

Owing to the high cost of human augmentation, it probably will be available in 15-20 years only to those who are able to pay for it. Such a situation may lead to a two-tiered society of an enhanced and non- enhanced persons

National Intelligence Council (GT2030)

DOD must, however, be prepared for a future in which adversaries take advantage of human performance modification, and it must decide how to either deter development and adoption of these capabilities or establish how they will be countered.

Center for a New American Security (CNAS)

We've reached a turning point, a phase change in the nature of augmentation where physical enhancements that once served only to bring people with disabilities closer to the perceived norm can now push these same people - and others - past the norm.

Institute for the Future (IFTF2013)

Social Technologies

Over the next 30 years social networks will grow far beyond status updates and photo sharing. At the heart of social networking is the seed of a powerful idea - individuals can create new personas online and form virtual collectives that generate influence and action in the real world. Anonymous, the hacktivist collective, Kickstarter, a crowdfunding platform for startups, and Bitcoin, the world's first social currency, are all examples of this emerging trend. In the future, advances in telepresence software will further blur the lines between online and physical communities, and many people will identify themselves first and foremost as citizens of their social network. Traditional hometown and national loyalties could fade in importance.

36% Concurrence

3% Share

ENABLING S&T

Ubiquitous Telepresence
Future social networks will be strengthened through low-cost, high-fidelity telepresence technologies that allow people to be together, virtually.

Applied Social Science
Decades of research in anthropology, social psychology, and political science have yet to be applied to the design of social networks. Future networks will leverage social science to build more vibrant and empowering communities.

Identity Technology
Next generation peer-to-peer networking and other technologies will be developed that preserve anonymity by eliminating "digital trails" that allow individual social media use to be monitored.

Robust Networks
Social networks might grow to rival governments, who will seek to monitor and control participation in online communities. Peer-to-peer and other technologies will support robust networks that are difficult to suppress.

Software developments together with advancements in computer technology will allow more influence on opinion building and information sharing. The ability to be connected to anybody and to share thoughts and information reflects the original promise of social computing.

NATO

SIGNALS

Whisper, Secret, and Yik Yak are part of a new wave of anonymous social networking platforms. These applications allow users to register with fake names and make posts without linking to personally identifiable information like an email address.

Spayce, a new social networking startup founded by a recent Harvard graduate, will show users other people around them who also use Spayce. This hyper-local service uses the power of social networking technology to facilitate in-person connections.

Bitcoin, the world's first decentralized digital currency has no central bank or single authority. Instead, the money supply and transactions are underwritten by a peer-to-peer network. The value of one bitcoin is currently hovering around $311.

Massachusetts-based robotics company iRobot has begun selling its Ava 500 series of telepresence robots. Developed in partnership with Cisco, the Ava 500 is an autonomous robot that can navigate through offices and other indoor spaces. A large LCD screen and cameras provides a telepresence link, allowing remote workers to have a physical presence at meetings and other events.

...social stock exchanges are already disrupting both traditional corporations and philanthropies while bringing financial vigor to new kinds of enterprises that focus on social and environmental impact. But social stock exchanges will also take other forms including ways for people to monetize the value of their own social profiles in an ongoing public exchange.

Institute for the Future

IMPACT

Social
As web-mediated social communities become more immersive they will become woven into our lives. This will reshape how we value physical community. Those who are unwilling or unable to participate will try to preserve traditional social structures.

Political
Government crackdowns on social networks will increase as they become platforms for political activism and protest.

Economic
Hyper-local economies will spring up to service the specific needs of niche networks. These might be managed the way that farmers markets and barter economies operate today.

Environmental
The environmental impacts of social technology are unclear, but it is likely that many social networks will emerge with an environmental focus, organizing distributed and decentralized environmental action.

Defense
Terrorists and criminal organization already use social networks to share information and coordinate attacks. As networks become capable of virtual telepresence and self-contained economies the power of hostile networks will grow.

Social networks could also displace services that existing corporations and government agencies now provide, substituting instead new classes of services that are inherently resistant to centralized oversight and control.

National Intelligence Council (GT2030)

Quantum Computing

Quantum computing is poised to become one of the most potentially disruptive technologies of the next 30 years. Standard computers can only perform one calculation at a time, and are only as fast as the current generation of microprocessor. Quantum computers rely on properties like superposition and entanglement to perform millions of calculations simultaneously. Among other things, quantum computing would spell the end of modern cryptography. A quantum computer could crack all current methods for encrypting data. Researchers have begun to solve some of the technical problems that have limited the development of practical quantum computers. While real-world applications of quantum computing might not be seen for several more years, an influx of investment by governments and industry signals that quantum computing might be approaching a tipping point.

36% Concurrence
4% Share

ENABLING S&T

Quantum Error Correction
Qubits are hard to manipulate, since any disturbance causes them to fall out of their quantum state, or "decohere". The field of quantum error correction examines how to stave off decoherence and combat other errors.

Manufacturing Qubits
Current techniques for creating qubits - the quantum computing version of a transistor - work on a small scale but do not scale well enough for practical applications.

Quantum Programming
Quantum computers create output that is probabilistic, not concrete. This means a calculation must be repeated many times before a stable answer emerges. Programming this kind of system is an active area of research.

Verification
A basic idea behind quantum mechanics is that observing a quantum particle, or a qubit, changes its behavior. This makes it difficult to tell if a quantum computer is behaving in the way it's supposed to. Researchers are exploring how to verify the performance of a quantum computer.

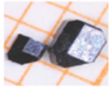
By harnessing the quantum state of electrons, computers will be able to handle multiple, simultaneous computations resulting in significant enhancement in computer speed, possibly reaching or exceeding the exaflop barrier. These properties will be particularly useful in cryptography, large scale modeling and working with large databases.

NATO

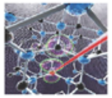
SIGNALS

Scientists at NASA's Jet Propulsion Laboratory have succeeded in teleporting information about the quantum state of a photon over 15 miles of optical fiber. This marks a major advance in quantum teleportation – a key component of quantum computing networks.

Scientists at Eindhoven University of Technology in the Netherlands have demonstrated a nanoscale device that can "sculpt" individual light photons on demand. The ability to precisely control the flow of photon is considered a key technology for developing a secure quantum Internet.



Physicists at the University of Michigan have discovered that the compound samarium hexaboride acts as a topological insulator – electrons flow freely over its surface, but are blocked from flowing through its interior. This compound could be used to reliably control the flow of electrons in a quantum computer.



Researchers have discovered a way to boost emission from nitrogen vacancy centers – atomic-scale defects in diamond crystals that can store quantum information and transmit it in the form of fluorescent light. This could provide a scalable source for qubits – a key step toward practical quantum computers.

...the secure distribution of encryption keys can be assured, as can the ability to safeguard the contents of encrypted messages In both cases the act of illicit 'listening-in' to the transmission changes its quantum properties, rendering it unreadable. The message is protected while its interception is flagged

UK Ministry of Defense (MoD)

IMPACT

Social
Quantum computers will make possible rapid calculations on massive data sets that are impossible today. This could affect Internet speed, diagnosis and treatment of disease, and lead to real-time digital entertainment that is indistinguishable from reality.

Political
The ability of quantum computers to crack commercial encryption will lead to significant political concerns over privacy and cyberprotection. Bank accounts, email, and all other "secure" data will be wide open to any agency with a quantum computer.

Economic
Economic impacts of quantum computing will be felt in financial modeling, logistics, engineering, health care, and telecommunications.

Environmental
The massive processing power of quantum computers would revolutionize climate modeling and lead to more accurate forecasts of weather and better models of climate change.

Defense
Quantum computers are capable of cracking any known encryption algorithm, making them powerful tools for both the U.S. and potential adversaries.

Quantum computing represents a potentially transformative alternative to digital computers, but the breadth of its applicability and impact remain unclear and the time frame for commercialization is uncertain.

McKinsey Global Institute (MGI)

Changing Nature of Work

Technology is underwriting a significant change in the relationship between individuals and their work. Freelancing is on the rise, fueled by access to web-enabled marketplaces and collaboration tools. Corporations are using freelance markets to rapidly change staffing in response to workload. Entrepreneurs are achieving rapid innovation using technologies like 3D printing and application program interfaces (APIs). Crowdfunding platforms like Kickstarter are changing the way new products are developed by directly connecting "makers" with consumers. Over the next 30 years, these trends will empower and challenge individuals to craft their own livelihoods. For some, declining barriers to entrepreneurship will create opportunities to rise out of poverty. For others, competition in the "gig economy" will mean lower wages, lack of benefits, fewer protections against exploitation, and economic insecurity.

43% Concurrence
9% Share

ENABLING S&T

APIs
APIs provide "hooks" for connecting pieces of software to build more capable applications. Many apps from major brands like Twitter are making APIs freely available, fueling innovation and empowering small teams to create major new products quickly.

Maker Technologies
Over the past 5-10 years a constellation of technologies like 3d printing, low-cost or free design software, and Internet-fueled global supply chains have given individuals and small teams of entrepreneurs access to capabilities previously available only to large enterprises.

Telework Technologies
Telepresence robotics and virtual/augmented reality are making remote work more effective. As these technologies evolve, geography will cease to be a meaningful barrier to collaboration.

Online Marketplaces
Web-based freelance markets, crowdsourcing platforms like Kaggle and Amazon Mechanical Turk, and online marketplaces are providing new channels for creating and delivering innovative products and services.

As the world of work is reorganized around micro-tasks and task-routing on the fly, companies may look more like cities: open, creative, dynamic networks that draw on all the human (and robot) resources around them.

IFTF 2013 10-year forecast

SIGNALS

There are approximately 53 million freelancers currently working in the U.S. – 34% of the total workforce.

quirky

Quirky is a crowd-based invention platform. Anyone can post ideas for a new product on Quirky's website and have community members vote on its appeal. The best ideas are then refined into marketable products that can be sold through Quirky's online storefront. Since 2009 over a million people have joined the network and over 400 new products have been created.

Pfizer

In 2008, the pharmaceutical company Pfizer realized that many of its most highly skilled workers were wasting 20-40% of their time on routine work such as data entry and building PowerPoint presentations. The company now contracts that work to a network of independent freelancers and small businesses.

MakeHartford, located in Hartford, Connecticut, is one of a growing number of open workshops supporting the maker movement. In addition to offering classes in both technical and artistic subjects, MakeHartford provides a fully equipped shared workspace with tools for designing and producing new products.

Ten-year-olds use CADCAM and 3D printers to make their own toys. They can navigate the web and participate in social networks and virtual worlds before they start kindergarten. Kid's programming sites like GameSalad teach them not only programming skills but also the template for open-source collaboration. By mid-century, this do-it-yourself workforce will be at the peak of their productive lives.

Institute for the Future (IFTF2012-SP)

IMPACT

Social
The changing nature of employment will democratize value creation and fuel bursts of innovation around niche communities. Workers who cannot thrive in this new world of work may become a burden on social safety nets.

Political
Freelancing and web-based markets will put pressure on outmoded regulations governing trade and worker's rights.

Economic
The changing nature of work has the potential to lift millions out of poverty. However, a decline in employment by large enterprises will create economic uncertainty for many future workers.

Environmental
Remote work has the potential to reduce pollution associated with commuting, as long as telework technologies can be powered with clean energy.

Defense
The defense community might benefit from engaging freelancers and entrepreneurs with niche skills who can innovate at lower cost. Adversaries might use freelance "dark markets" and maker technologies to source expertise and materiel that reduce our ability to maintain overmatch.

Enterprise adoption of the power of the crowd allows specialized skills to be dynamically sourced from anyone, anywhere, and only as needed. Companies can use the collective knowledge of the masses to help with tasks from data entry and coding to advanced analytics and product development.

Deloitte

Mobile & Cloud Computing

Mobile and cloud computing are transforming the way people interact with data. Today's mobile devices feature ultra high-resolution screens, graphics power that rivals gaming consoles, and a growing variety of sensors that can pick up everything from environmental conditions to biometrics. Cloud-enabled applications allow mobile devices to "outsource" data storage and computation to powerful data centers much as terminals used to connect to mainframe computers. Over the next 30 years, cloud-based mobile computing could be transformative. For instance, cell phones could monitor vital signs and communicate directly with diagnostic applications. At the same time, mobile and cloud computing will put significant pressure on networks, and both consumers and enterprises will have to grow more comfortable with relinquishing their data to the cloud.

57% Concurrence
8% Share

ENABLING S&T

Robust wireless networking
With data traffic on mobile devices growing at 80-100% over the past several years, we will need tremendous innovation in spectrum management and network protocols to feed the demand for mobile computing.

Near-field & low-power networking
Low-power networks for networking wearable devices will also be important as smart watches, activity monitors, and other devices join the personal data ecosystem.

Power and energy
Power is emerging as a limiting factor in mobile device performance and a major research focus. Since 2000, battery capacity has only doubled, while processing speed has increased 12-fold.

Software-Defined Environments
Software defined networks, storage, and cluster computing are paving the way toward more agile, scalable computational infrastructure.

By 2025 most IT and Web applications and services could be cloud-delivered or -enabled, and most businesses could be using cloud facilities and services for their computing resources.

McKinsey Global Initiative (MGI)

SIGNALS

In a recent global survey of mobile Internet use, 24% of people in developing countries said they use mobile devices for educational purposes, and half wanted even more access to educational resources in the future.

In another recent survey, more than 50% of Europeans polled would rather give up fast food, chocolate, newspapers, and books than go without mobile Internet access.

Satya Nadella, the new CEO of Microsoft, has signaled a major shift towards a "cloud first, mobile first" strategy. This is a dramatic change for a company that grew out of the desktop computing paradigm of local software and data storage.

High-profile security breaches at Target, Home Depot, and Sony have highlighted the risks associated with cloud data storage.

Increasingly, it's the overall environment that will need to adapt to the requirements of the mobile user. This will continue to raise significant management challenges for IT organizations as they lose control of user endpoint devices. It will also require increased attention to user experience design.

Gartner

IMPACT

Social
Mobile computing will transform the way people access information, opening the doors to education and delivering advanced productivity tools to millions of people.

Political
As mobile dominates more aspects of everyday life governments will have to grapple with difficult issues around privacy, new regulations on cybersecurity, and demands for spectrum and wireless infrastructure.

Economic
The annual economic impact of mobile and cloud computing could reach $5-16 trillion by 2025, with significant growth in the developing world.

Environmental
Growth in mobile computing over the next 30 years will come with large increases in demand for power and raw materials. eWaste will be a growing environmental concern.

Defense
As mobile computing continues to grow, wireless networks and cloud-based data will become prime targets for terrorists and trans-national criminal organizations.

While networking data across millions of individual users and devices has many benefits, one major downside is increasing exposure to data security and privacy breaches.

Atlantic Council

Internet of Things

Over the next 30 years embedded sensors, actuators, and data communications technology will rewrite how we think about information networks. Everyday objects such as home appliances, cars, and infrastructure will be embedded with sensors and connected to the Internet. By 2020, up to 26 billion devices will be connected through the Internet of Things (IoT). Social and economic impacts will be felt through more efficient production, optimized logistics, flexible smart grids for utilities and transportation, and countless other applications. Sensors embedded in biological tissues and medical implants will put organisms "on the net", opening new opportunities for everything from medical monitoring to tracking biological threats, and creating disruptive capabilities for watching our every move.

36% Concurrence

5% Share

ENABLING S&T

MEMS
Micro-electromechanical systems (MEMS) make it possible to embed sensors and mechanical actuators in virtually any object. Researchers are creating MEMS with multiple microsensors and microactuators that integrate complex sensing and control functions in micron-scale packages.

Wireless Bandwidth
Mobile data traffic is forecast to exceed 11 exabytes (11 quintillion bytes) a month by 2017, with continued exponential growth. That volume of data requires pervasive wireless technology well beyond current standards.

High Volume, Micro-Scale Manufacturing
Demand for RFID, MEMS, and other miniaturized systems will require new manufacturing technologies that can reliably assemble at the scale of several microns.

Communication Standards
While not strictly a S&T issue, the lack of standard protocols for exchanging data among billions of different devices must be resolved before the Internet of Things becomes feasible at a global scale.

Merging the physical and digital world also has implications for privacy, security, and even how companies are organized. As with any data connection, the connections that allow remote machines to take action without a human operator are subject to hacking by criminals or terrorists.

McKinsey Global Institute (MGI)

SIGNALS

The city of Hamburg, Germany has developed what it refers to as a "smartPort", featuring sensors embedded in everything from container handling systems to streetlights. The smartPort will improve cargo handling efficiency and predict environmental impacts through sensors that respond to noise and air pollution.

Vancouver-based SemiosBIO is marketing a novel pest-management solution for orchards. The device uses sensors and cameras to allow farmers to monitor pest activity. Farmers can set the device to release scheduled doses of insect pheromones that confuse insect mating, cutting down on pests without chemical insecticides.

中国移动通信 CHINA MOBILE

China Mobile maintains a research facility that is developing a platform for the Internet of Things in China. As of 2014, China Mobile had implemented 32 million machine-to-machine connections, making them the world's largest machine-to-machine network operator.

White-hat hackers demonstrated an exploit targeting a leading brand of network-connected LED light bulbs. Networked LED lights give homeowners the ability to program their home lighting over a wireless network. The hack exposes WiFi passwords and demonstrates the potential security concerns inherent in the Internet of Things.

A desire not to be part of the "Internet of Things" may create new markets, for example a holiday resort advertising its facilities with a promise that you will be completely "off-grid". This could also lead to a drive to try to create spaces, both physical and virtual, which are unseen or ungoverned by state authorities around the world.

UK Ministry of Defense (MoD)

IMPACT

Social
The Internet of Things will radically transform societal views on privacy. Sensors will monitor our movements, transmit our vital signs, and listen to our every word. For this to work, trust must exist between individuals, corporations, and governments.

Political
The Internet of Things presents a host of challenges for privacy rights that will raise difficult domestic and international regulatory issues.

Economic
The McKinsey Global Initiative estimates that the IoT will have a direct economic impact of \$2.7 to \$6.2 trillion by 2025. Impact will be felt especially in health care, manufacturing , and infrastructure.

Environmental
The Internet of Things will enable smart grids for managing power and water distribution, increasing efficiency and reducing waste.

Defense
The ubiquity of networked sensors will open new vistas for intelligence gathering. However, cyberattacks will become an even greater threat as adversaries target billions of devices connected in mutually dependent networks.

More than nine billion devices around the world are currently connected to the Internet, including computers and smartphones. That number is expected to increase dramatically within the next decade, with estimates ranging from quintupling to 50 billion devices to reaching one trillion.

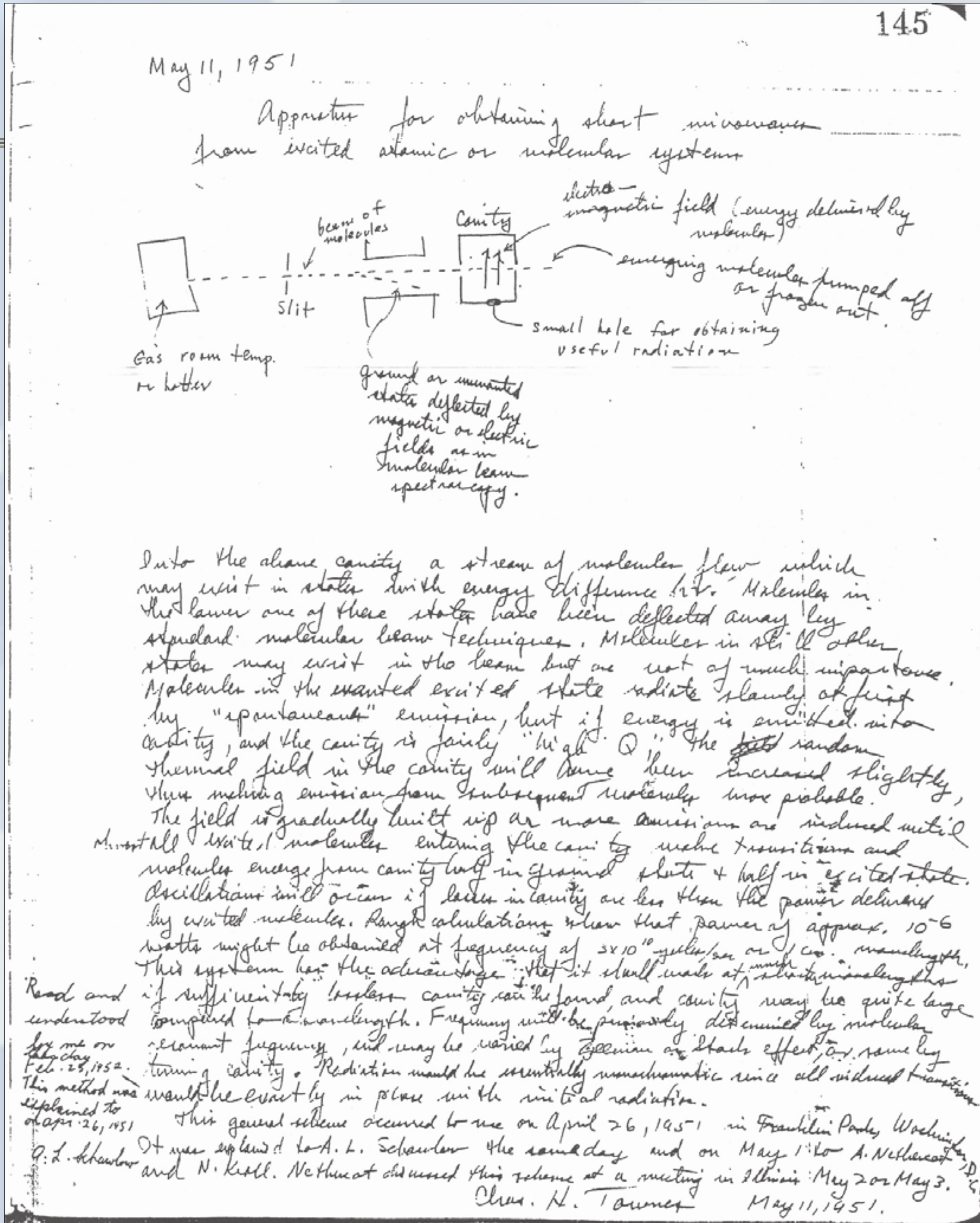
McKinsey Global Institute (MGI)

What the Army Needs

- **Alternate/Redundant and Affordable Capabilities**
- **Open Systems Architectures that lead to Ease of Upgrades**
- **Understanding of the Vulnerabilities in both Technology and Systems and Mitigation Strategies**
- **Lower Cost, Capable Systems**
- **Simplicity vs. Complexity**

We must leverage Industry R&D efforts to provide the best technology to our Soldiers

Inspiration to Innovation



145

May 11, 1951

Apparatus for obtaining short microwaves from excited atomic or molecular systems

Into the above cavity a stream of molecules flow which may exist in states with energy difference hν. Molecules in the lower one of these states have been deflected away by standard molecular beam techniques. Molecules in still other states may exist in the beam but are not of much importance. Molecules in the wanted excited state radiate slowly at first by "spontaneous" emission, but if energy is emitted into cavity, and the cavity is fairly "high Q", the ~~field~~ random thermal field in the cavity will have been increased slightly, thus making emission from subsequent molecules more probable. The field is gradually built up as more emissions are induced until almost all excited molecules entering the cavity make transitions and molecules emerge from cavity half in ground state + half in excited state. Oscillations will occur if losses in cavity are less than the power delivered by excited molecules. Rough calculations show that power of approx. 10^{-6} watts might be obtained at frequency of 3×10^{10} cycles/sec or 1 cm. wavelength. This system has the advantage that it should work at much shorter wavelengths if sufficiently lossless cavity can be found, and cavity may be quite large compared to a wavelength. Frequency will be precisely determined by molecular resonant frequency, and may be varied by Zeeman or Stark effect, or some by tuning cavity. Radiation would be essentially monochromatic since all induced transitions would be exactly in phase with the initial radiation.

This general scheme occurred to me on April 26, 1951 in Franklin Park, Washington D.C. It was explained to A. L. Schawlow the same day and on May 1 to A. Nethercot and N. Kroll. Nethercot discussed this scheme at a meeting in Illinois May 2 or May 3.

Chas. H. Townes May 11, 1951.

Read and understood by me on this day Feb. 25, 1952. This method was explained to me Apr. 26, 1951

A. L. Schawlow

Charles Townes, Leo Cooper, David Lee, Robert Curl, John Fenn

Questions?

Army Science & Technology

Providing Soldiers with the Technology to Win

ARMY S&T
SCIENCE & TECHNOLOGY