Defense Advanced Research Projects Agency

Dick Urban

Special Assistant to the Director

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DARPA

Director
Arati Prabhakar

Deputy Director
Steven Walker

Geoff Ling | Alicia Jackson
BIOLOGICAL TECHNOLOGIES

Stefanie Tompkins
DEFENSE SCIENCES
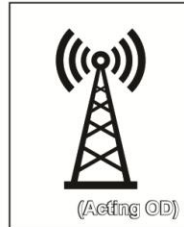
Dale Waters | Chuck Wolf
ADAPTIVE EXECUTION

Bill Lehr | Ann Morgan
COMPTROLLER

Dan Kaufman
INFORMATION INNOVATION

Bill Chappell
MICROSYSTEMS TECHNOLOGY

Joe Mazur
CONTRACTS MANAGEMENT

Crane Lopes
GENERAL COUNSEL

Nils Sandell | Khine Latt
STRATEGIC TECHNOLOGY

Brad Tousley | Pam Melroy
TACTICAL TECHNOLOGY

Mary Vander Linden
HUMAN RESOURCES

Brian Eshenbrenner
SUPPORT SERVICES

Budget Activities ($ in Millions)

(FY2015 PBR Actual Dollars)

FY15 Pres Bud	FY 2013	FY 2014	FY 2015	% change FY14-FY15
Basic Research (6.1)	310.9	364.5	362.0	-1%
Applied Research (6.2)	1,049.4	1,173.6	1,136.5	-3%
Adv Tech Dev (6.3)	1,083.3	1,168.9	1,344.9	+15%
DARPA S&T Total	2,443.6	2,707.0	2,843.4	+5%
R&D Mgmt Support (6.5)	137.0	71.7	71.4	-0.4%
DARPA Total Budget	2,580.6	2,778.7	2,914.8	+5%

Major Investment Areas – FY14 to FY 15
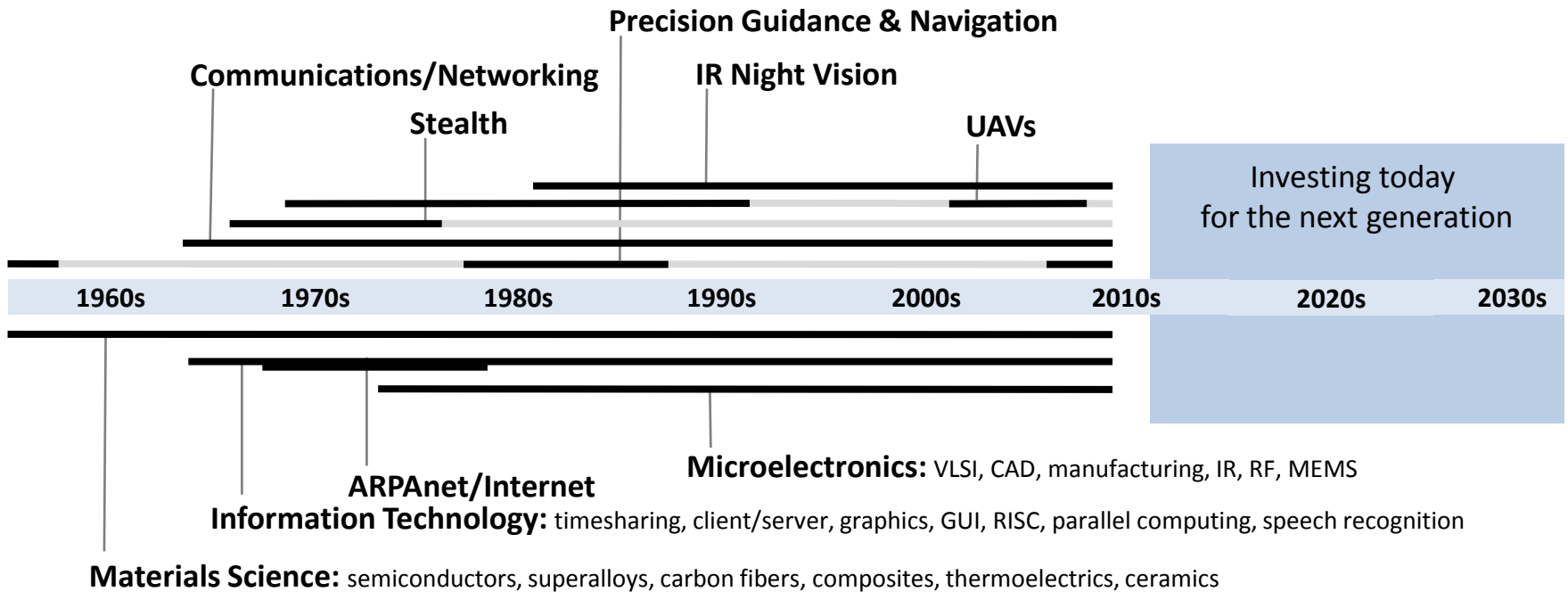
- Growth Areas   (FY2015 PBR in actual dollars)

$ in Millions	FY 2014	FY 2015
Cyber and Big Data	522	581
Space	143	180
Brain Research	60	83
Prototyping	254	304
Engineering Biology	29	53

- Declining/Ending Areas

$ in Millions	FY 2014	FY 2015
Cognitive Computing	16	0
MEMS	32	12

Breakthrough Technologies for National Security

Precision Guidance & Navigation

Communications/Networking

IR Night Vision

Stealth

UAVs

Investing today
for the next generation

| 1960s | 1970s | 1980s | 1990s | 2000s | 2010s | 2020s | 2030s |

Microelectronics: VLSI, CAD, manufacturing, IR, RF, MEMS

ARPAnet/Internet

Information Technology: timesharing, client/server, graphics, GUI, RISC, parallel computing, speech recognition

Materials Science: semiconductors, superalloys, carbon fibers, composites, thermoelectrics, ceramics

These new capabilities require a healthy ecosystem across Service S&T, universities, and industry

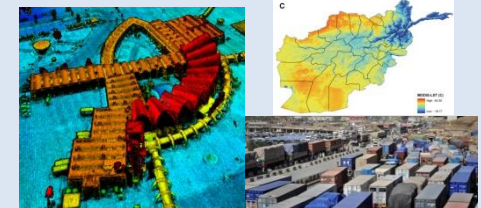## DARPA's role: pivotal early investments that change what's possible

DARPA Forward Cell Afghanistan 2010-13
Technology Trials Supporting Different Echelons of the Force

ISAF and IJC

- Large data analysis: **Nexus 7**
- Wide area high resolution LiDAR: **HALOE**
- Clandestine tracking of logistics: **ITV**
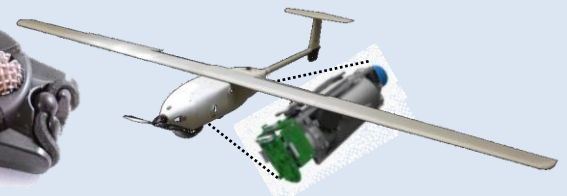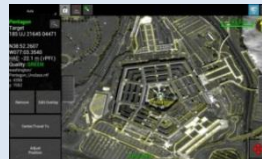
Regional Commands and FOBs

- Networked video and precision fires for FOB protection: **WRAITH**
- Radio interoperability and video feeds for force protection: **MAINGATE**

Tactical Users

- Handheld Tactical Apps Suite : **TransApps**
- Android-based precision fires tools: **PFIV-A**
- Blast event data and soldier triage: **Blast Gauge**
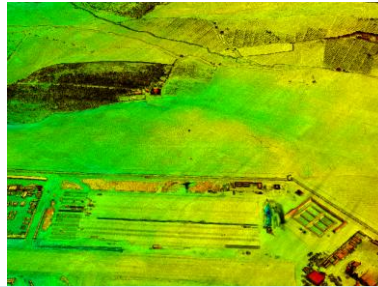- Long endurance fuel cell powered UAV: **Stalker XE**

Blast Gauge
- Low-cost, disposable, wearable sensor that records conditions during IED event to immediately quantify exposure and indicate TBI
- Developed <1 year, $1 million – helping warfighters and brain-related research
- 15,000+ Soldiers, Marines, and Special Operators wearing Blast Gauges today

High-Altitude LIDAR Operations Experiment (HALOE)
- Provided forces in Afghanistan ability to rapidly collect wide-area, long-range, high-resolution 3D datasets
- Deployed into AFRICOM and CENTCOM

Language Programs (BOLT, RATS, MADCAT)
- Recognize, classify, and help digest written and spoken foreign languages
- SOCOM in Tampa implementing BOLT; AF assisting with RATS testing; multiple organizations using, developing, or testing MADCAT

(1.5 x 2.7 x 0.8 cm)

Network Enabled by Wavelength (NEW-HIP)
- Replacing current aircraft wiring with a single-mode fiber-optic network
- Reduced weight, better resistance to environmental conditions, can interconnect dozens of connections
- NAVAIR continuing development for EA-6B Prowler, other aircraft

Long Range Anti-Ship Missile (LRASM)
- Stealthy, survivable, precise subsonic cruise missile to provide a leap ahead in U.S. surface warfare capability
- DARPA-Navy rapid development process underway
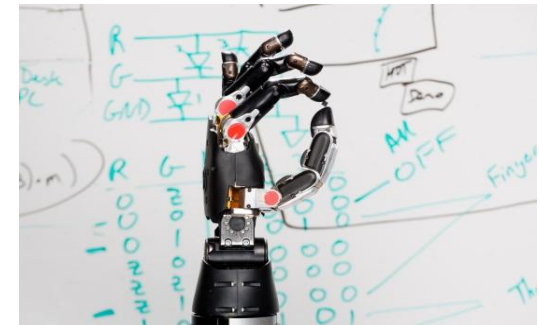
Revolutionizing Prosthetics
- State-of-the-art advances in prosthetic technology to increase range of motion, dexterity, and control options; in FDA review for transition to VA and commercial industry
- Demonstrated direct brain control by tetraplegic of an advanced arm system; research continuing

7

National Security Landscape	DARPA Approaches
Wide range of national security challenges:	Game-changing new systems
from nation states	Layered, multi-technology systems
to diffuse, shifting terror networks	Catalyzing new national technology capabilities
Globally available technologies	Exploiting commercially available technologies
Cost as a major factor in choices about operational capabilities	Adaptable solutions
	Inverting the cost equation

A New Generation of
Breakthrough Technologies for National Security

Breakthrough Military Capabilities

Cyber Capability	Wield cyber as a military capability with confidence in our own cybersecurity
Electromagnetic Spectrum Dominance	Fully & dynamically control the EM spectrum for communications, sensing, imaging
Position, Navigation, and Timing Beyond GPS	Deliver accuracy without dangerous reliance on GPS + enable new coherent effects
Robust Space	Restore confidence in all aspects of space operations despite new threats
Hypersonics Capability	Prevent peer adversary sanctuary or strategic surprise

New Enabling Technologies

|	
Big Data Analytics	Understand behavior patterns at scale
Engineering Biology	Create new classes of materials that are unattainable through today's chemistry
Brain Function Research	Create fundamental advances in how warfighters work with complex systems & manage extreme stress

Next-Generation Mission Capabilities

Air Dominance	Architect sustainable, cost-effective air superiority over a peer adversary in 2030+
Overmatch Squad	Expand reach, situational awareness, and maneuver to create strategic overmatch for a dismounted squad
Defense Against Mass Terror Attacks	Establish defense against biological, chemical, and radiological mass terror threats

These focus areas are part of a broad and diverse portfolio of DARPA investments
Focus areas change over time as some succeed and graduate, others fail, and DARPA identifies new challenges and opportunities
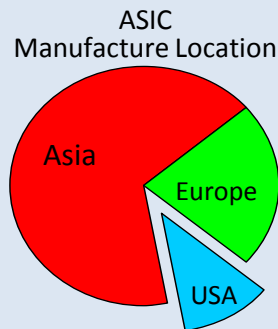
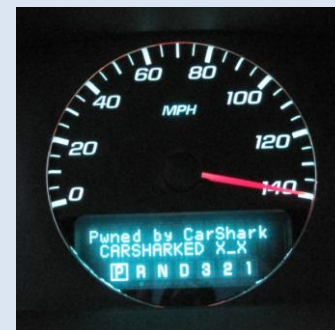## Attackers penetrate the architecture easily

Source: 123rf.com

Users are a weak link

The supply chain can be compromised

ASIC
Manufacture Location
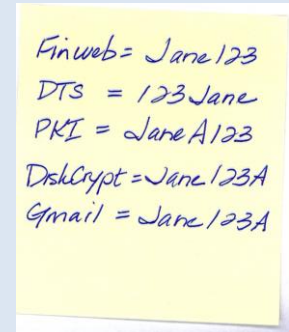
Physical systems are vulnerable

Building a Foundation for Cybersecurity

Attackers penetrate the architecture easily

Heterogeneity and computing on encrypted data

Users are a weak link

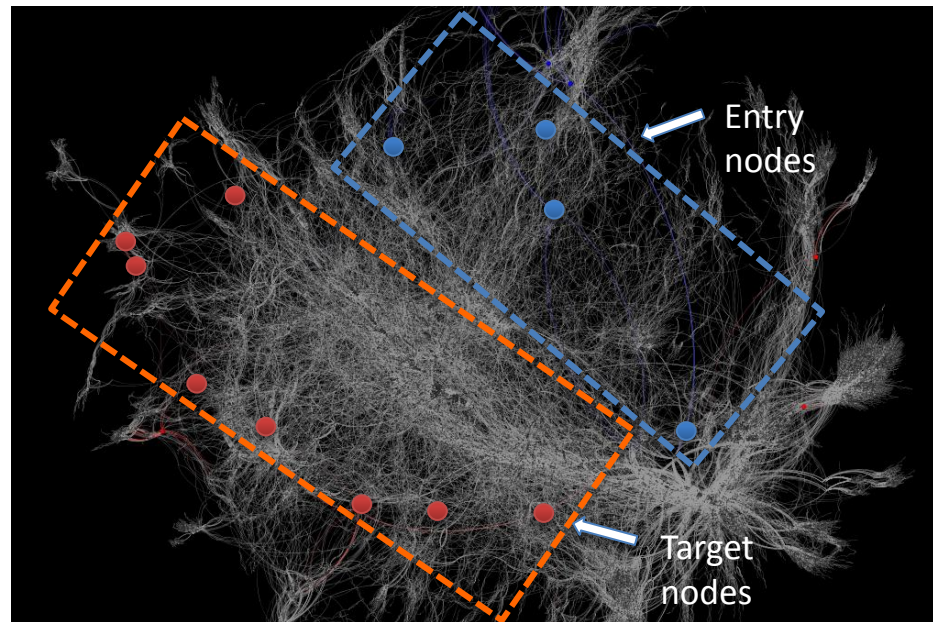*Software-based biometrics*

The supply chain can be compromised

Fully automated analysis tools
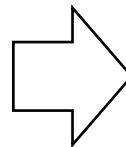
Physical systems are vulnerable

Correct by construction

Cyber Warfare: Military Capability

Today's cyber tools

- Artisan approach
- One-off without reliable or measurable effects
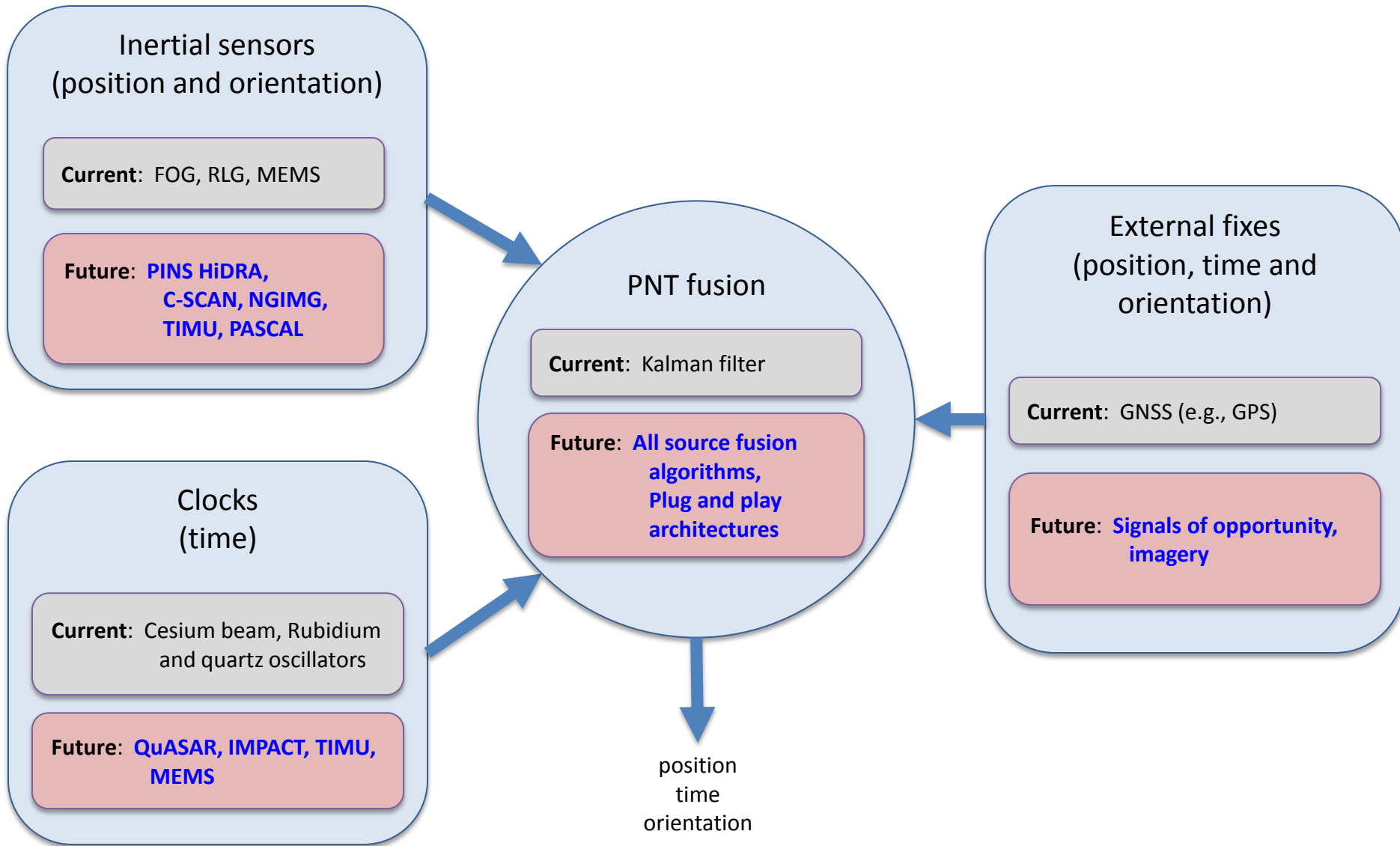- Extraordinary authority required for use

Future tactical cyber warfare

- Integral to warfare - an alternative and augmentation to kinetics
- Automated, real time, scalable
- Predictable effects and BDA
- Rules of engagement with graduated authorities: 19-year-old to POTUS

Position, Navigation, and Timing Beyond GPS

Inertial sensors (position and orientation)

Current: FOG, RLG, MEMS

Future: **PINS HiDRA, C-SCAN, NGIMG, TIMU, PASCAL**

Clocks (time)

Current: Cesium beam, Rubidium and quartz oscillators

Future: **QuASAR, IMPACT, TIMU, MEMS**

PNT fusion

Current: Kalman filter

Future: **All source fusion algorithms, Plug and play architectures**

External fixes (position, time and orientation)

Current: GNSS (e.g., GPS)

Future: **Signals of opportunity, imagery**

position
time
orientation

Launch

- Large and small payloads are expensive to launch
- Long call-up times, typically >2 years
- Launch from a few fixed points around the world

Satellites

- Cost of national security satellites is increasing
    - We launch fewer satellites that are bigger and more complex
    - Our satellites must last longer

Space Domain Awareness (SDA)

- SDA: detecting, tracking, and monitoring of all space objects and the environment
- Detect and track (D&T) is the traditional mission, but is now being recognized by senior space leadership as not enough – *need indication and warning (I&W)*

Launch: ALASA and XS-1

Airborne Launch Assist Space Assist (ALASA)

Developing a less expensive approach for routinely launching small satellites, **A**irborne **L**aunch **A**ssist **S**pace **A**ccess (ALASA) has a goal of at least threefold reduction in costs compared to current military and U.S. commercial launch costs.
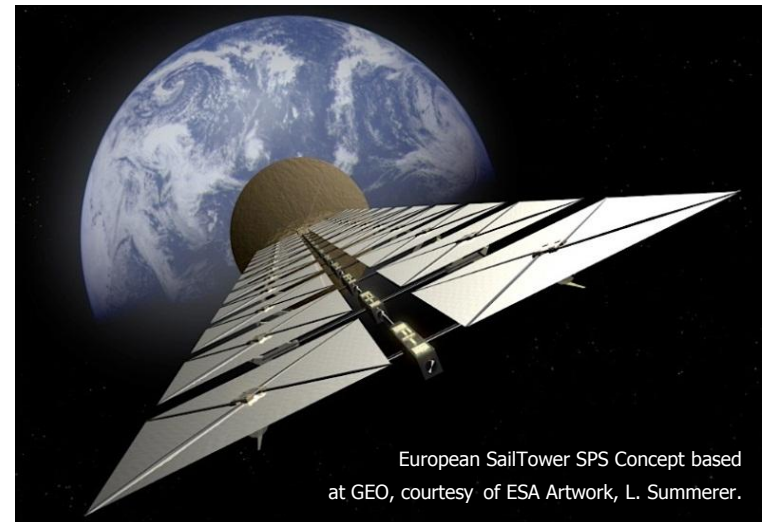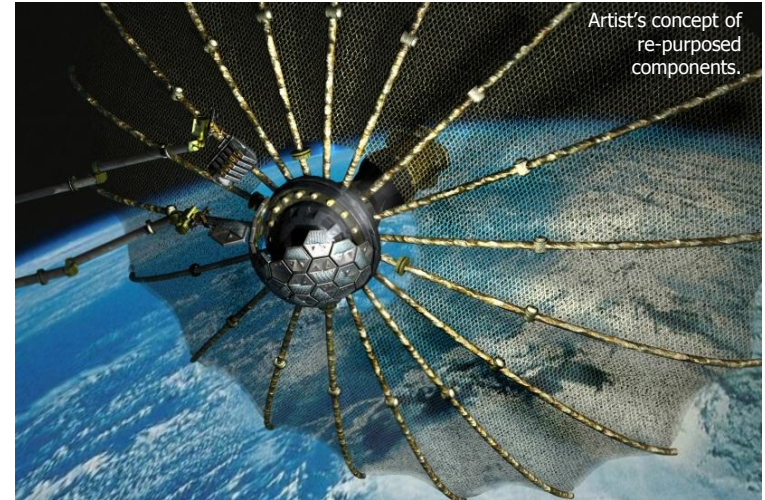
All images are artist's concepts

Experimental Spaceplane (XS-1)

Enabling routine-access space/hypersonic vehicles, E**x**perimental **S**paceplane (XS-1) seeks to integrate, test, and mature technologies and lean operations

- Change how satellites are built, shifting to on-orbit assembly and servicing

- Enable faster satellite upgrades to accommodate new electronics/technologies

- Enable increased effectiveness to DoD/US Government Return on Investment by re-using highest value components on orbit

- Using high volume, low cost manufacturing for modular satellite elements

Artist's concept of re-purposed components.

European SailTower SPS Concept based at GEO, courtesy of ESA Artwork, L. Summerer.

All images are artist's concepts

SSA: SST and OrbitOutlook

Space Surveillance Telescope (SST)

Transitioning advanced **S**pace **S**urveillance **T**elescope (SST) capabilities enable space situational awareness of on-orbit operations via broad-area search, detection and tracking of small objects in deep space.
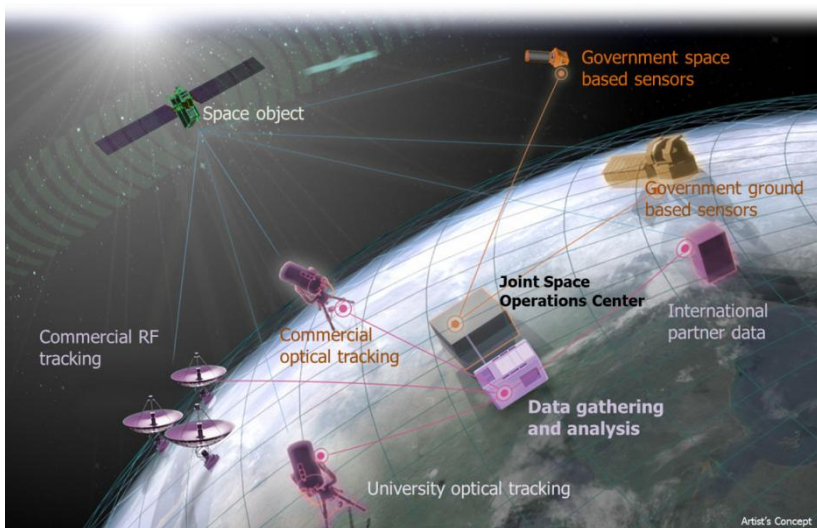
OrbitOutlook

Improving the Space Surveillance Network (SSN), **OrbitOutlook** adds more data more often from more diverse sources to increase SSA to determine when satellites are at risk.

Hypersonic Air-breathing Weapon Concept (HAWC)

•HAWC Program Goals (artist concept)

- Enable transformational changes in responsive, long-range strike against time-critical or heavily defended targets:

  - Advance air vehicle configurations capable of efficient hypersonic flight

  - Enhance hydrocarbon scramjet-powered propulsion to enable sustained hypersonic cruise

  - Design thermal management for high-temperature cruise

  - Develop affordable system designs and manufacturing approaches

- Extend technologies to reusable hypersonic air platforms for applications such as global presence and space lift
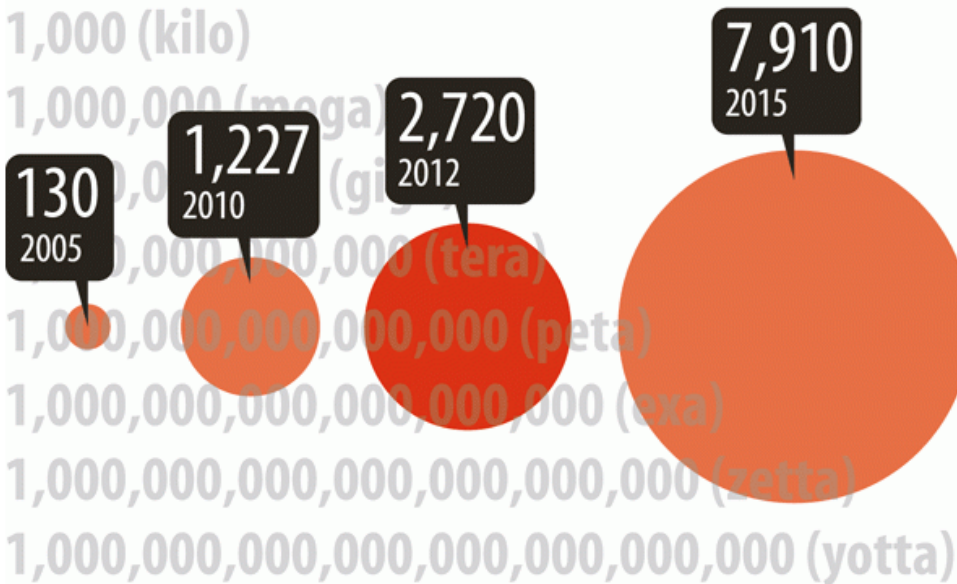
Tactical Boost Glide (TBG)

TBG Program Goals

- DARPA / Air Force effort that will develop and demonstrate technologies to enable air-launched tactical range hypersonic boost glide systems, including a flight demonstration.

- The program will also consider traceability to, and ideally compatibility with, sea-launch platforms.

- The program will address the system and technology issues required to enable development of a hypersonic boost glide system considering

  - (1) vehicle concepts possessing the required aerodynamic and aerothermal performance, controllability and robustness for a wide operational envelope,

  - (2) the system attributes and subsystems required to be effective in relevant operational environments, and

  - (3) approaches to reducing cost and improving affordability for both the demonstration system and future operational systems

Exaponential
Quantity of global digital data, exabytes

1,000 (kilo)
1,000,000 (mega)
1,000,000,000 (giga)
1,000,000,000,000 (tera)
1,000,000,000,000,000 (peta)
1,000,000,000,000,000,000 (exa)
1,000,000,000,000,000,000,000 (zetta)
1,000,000,000,000,000,000,000,000 (yotta)

130
2005

1,227
2010

2,720
2012

7,910
2015

Source: EMC/IDC Digital Universe Study, 2011

- 571 web sites created every minute of every day [1]

- 48 hours of YouTube video is uploaded every minute of every day [1]

- 90% of world's data has been generated over last two years [2]

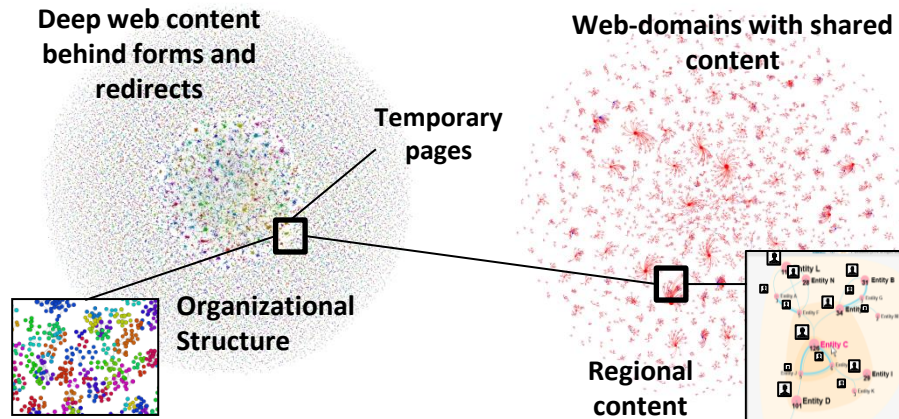- Organizations use less than 5% of available data because the rest is too expensive to deal with [3]

Big Data – MEMEX Program

Deep web content behind forms and redirects

Temporary pages

Organizational Structure

Web-domains with shared content

Regional content

Applications

Counter-terrorism, counter-drug, anti-money-laundering, and anti-human-trafficking, with transition partners from DoD and other USG activities.

- Develop the next generation of search technologies to revolutionize the discovery, organization, and presentation of domain-specific content

- Create a new domain specific search paradigm to discover relevant content and organize it in ways that are more immediately useful to specific missions and tasks

- Extend the reach of current search capabilities to the deep web and non-traditional content

- Enable the military, government, and commercial enterprises to find and organize mission-critical information on the Internet and in large DoD repositories

Create tools and processes to rapidly and predictably genetically engineer microorganisms for production of new specialty chemicals such as anti-fungals, lubricants, and energetic materials.
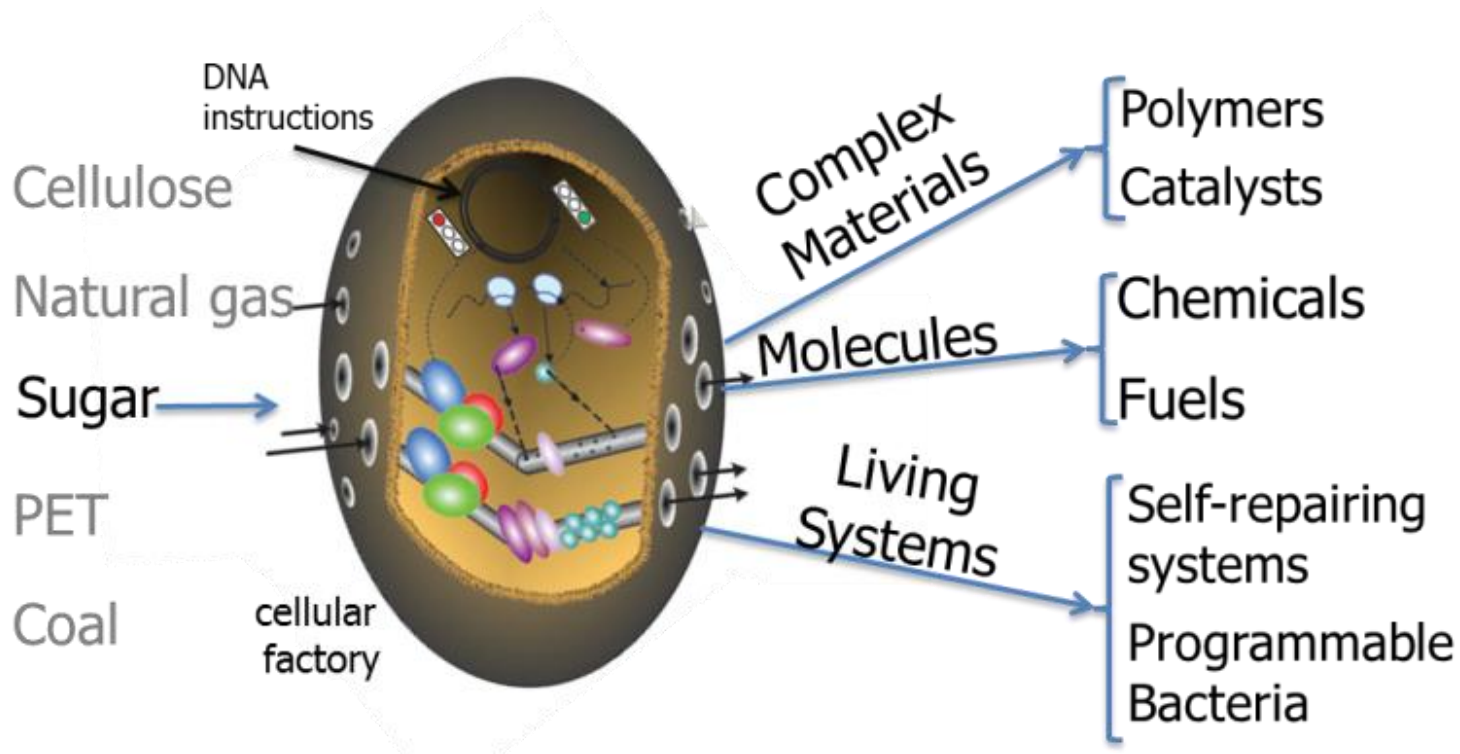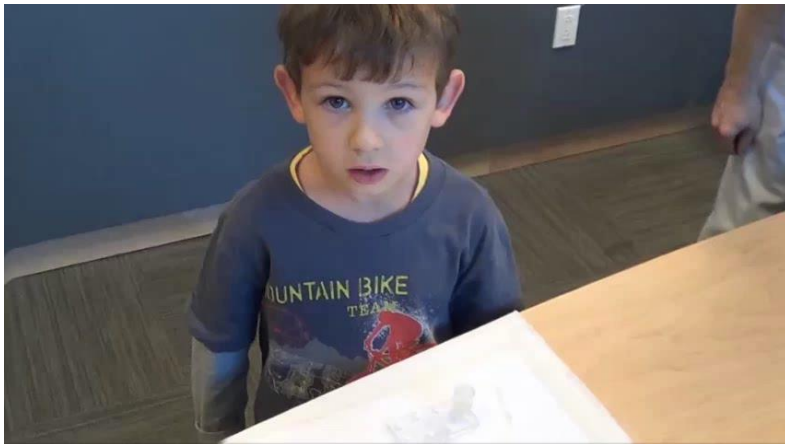

Custom, distributed, on-demand production

Outpacing the spread of infectious disease

Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)
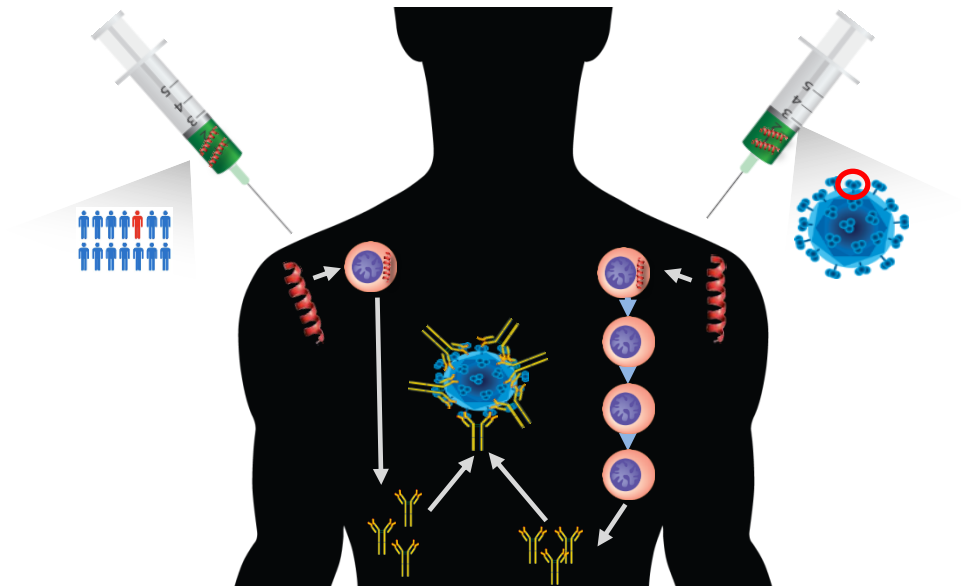
Rapid, specific diagnostics

Rapid development of prophylaxis

Courtesy of Rustem Ismagilov, Caltech

Diagnostics on Demand
Self-performed tests in limited resource settings and in point-of-care settings.

Controlling Cellular Machinery
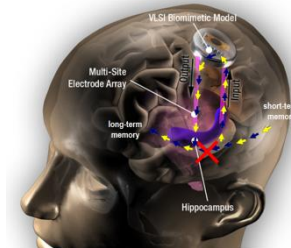- Diagnostics and therapeutics
- Vaccines

Brain Function Research Foundations and Applications

Revolutionizing Prosthetics (RP)

Restorative Encoding Memory Integration Neural Device (REMIND)

Restoring Active Memory (RAM)

Movement and Control
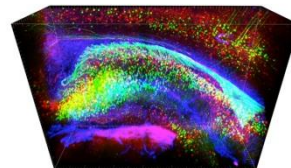
Memory Recovery

Behavior

Other…

Systems-Based Neurotechnology for Emerging Therapy (SUBNETS)

New Investments in Emerging and Supporting Areas

Understanding Plasticity and Adaptation Processing/Data Platforms

Reorganization and Plasticity to Accelerate Injury Recovery (REPAIR)
Neuro Function, Activity, Structure, and Technology (Neuro-FAST)

Societal Implications of New Technologies

- Leading edge of technology uncovers new societal questions
  - Ethical, legal, safety and security, policy
- Two responsibilities for DARPA
  - Explore new high-potential technology areas even in uncomfortable territory AND
  - Raise societal questions and engage others
- Our approach
  - Our work is rigorously done within the law and regulations
  - Engage experts with diverse viewpoints to open discourse on potential future uses
 - Technology solutions can sometimes be part of the answer

- Battlefield situational awareness with **ISR**
  - Space, AWACs, Hawkeye, Rivet Joint, JSTARs
- **Aerial refueling** providing global reach and persistence
  - Over 600 tankers refueling U.S. and coalition aircraft
- **Networked command and control**
  - Link 16, IP network connected ISR and command centers
- Negated their first shot with **stealth**
  - F-117, B-2, F-22
- **Lethal platforms:**
  - Integrated sensors with precision weapons
- Outranged our opponents with **long range weapons**
  - Tomahawk, AMRAAM, HARM, HARPOON
- Superior **weapons effectiveness**
  - Higher probability of kill (P_k) greater than 0.6

… however, the days of being significantly better are in question.
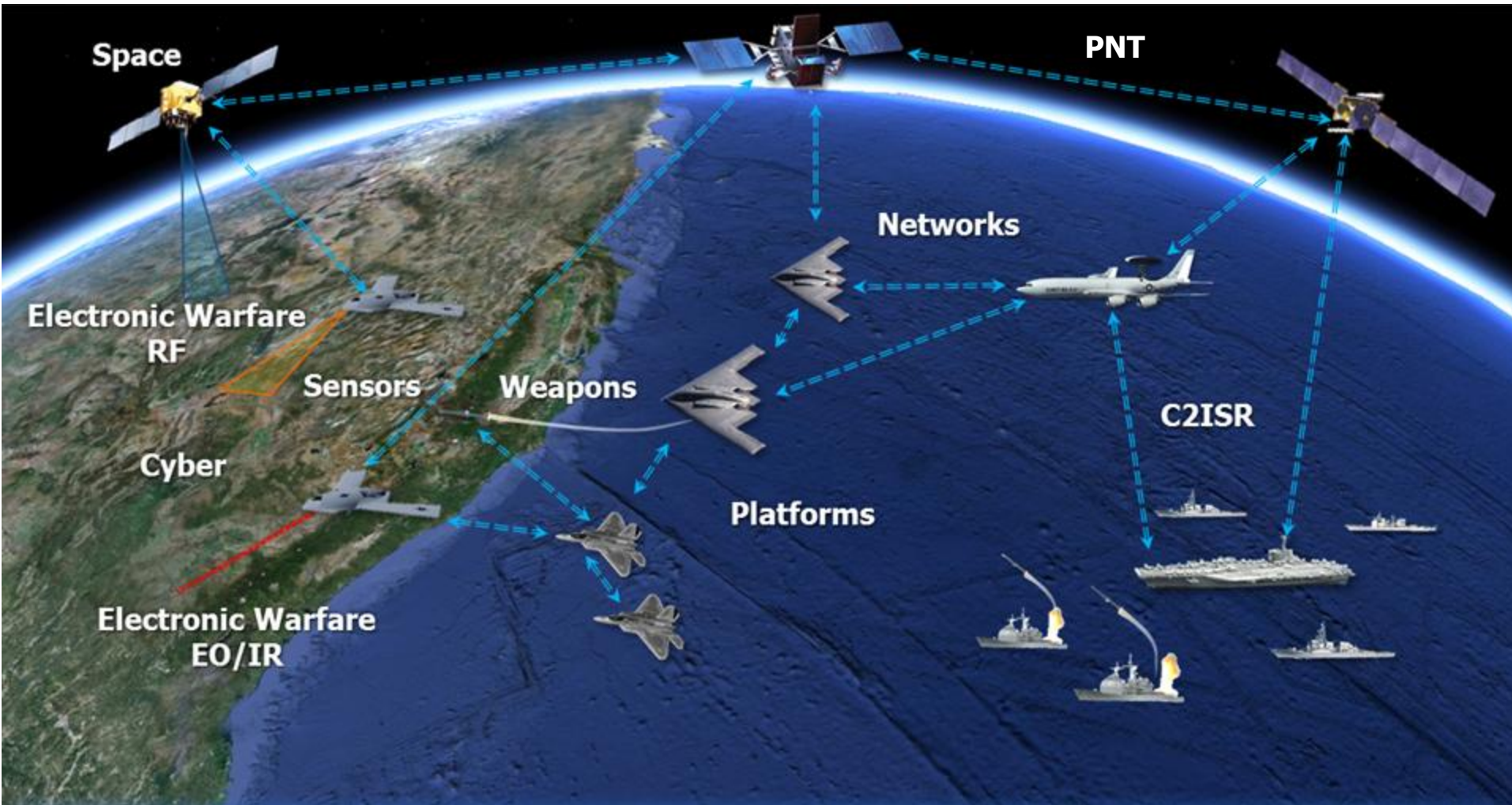
Long Range Anti-Ship Missile

Demonstrating an entirely new approach for penetrating sophisticated enemy air defense systems from long range -- with fewer missiles, striking from greater distances, at lower cost

DARPA-Navy Demonstration Program Benefits:

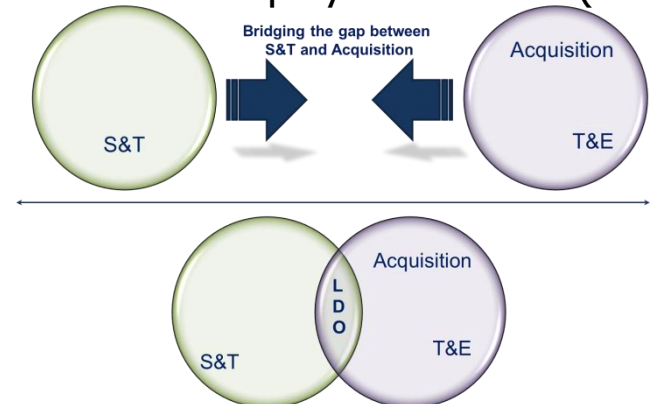| Current Anti-ship Missiles	LRASM
Large Salvos required for hit	Small Salvo achieves hit
Attack within enemy's kill zone	Significantly greater standoff
Less sophisticated target discrimination; Complex cueing	Self-correcting
Different air and ship systems	Common for air or ship launch; multi-service

2 Flight Tests - All Test Objectives Achieved

- Clean launch from B-1B
- Transition to sustained flight
- Receipt of IFTU
- Fly pre-planned waypoints to autonomous handoff point
- Fly to BAA range
- Predict max range IFD-1 could have flown

- Long range target acquisition and geolocation
- Target discrimination
- Transition to ARH homing
- Acquire / track MST with IR sensor
- Aimpoint selection
- Terminal guidance to MST impact
- BHI to ground stations

Free Flight Transition Test 27 Aug 2013

Integrated Flight Demonstration (IFD-1) 12 Nov 2013

LRASM Deployment Office (LDO) established to deliver early operational capability

- Accelerated Acquisition for Offensive Anti-Surface Warfare/Increment 1
- Acquisition Decision Memorandum signed by Mr. Frank Kendall, USD AT&L
- Co-located Air Force, Navy and DARPA Program Office

LRASM Deployment Office (LDO)

Bridging the gap between S&T and Acquisition

S&T — Acquisition / T&E

LDO — S&T / Acquisition / T&E

www.darpa.mil

Thank you