Air Force Global Horizons

Dr. Mark T. Maybury
Chief Scientist

24 April 2013

Global Horizons
Terms of Reference

- **Background:**
  - **Global demographic, economic, technological, and military trends forecast an increasingly complex, competitive, and contested future.**
  - **Need an Air Force wide, collaboratively derived, near-, medium- and far-term S&T vision that articulates revolutionary capabilities that anticipate future threats, mitigate vulnerabilities, and shape and take maximal advantage of impending and unexpected opportunities to sustain our strategic advantage and assure Global Vigilance, Global Reach and Global Power across air, space, and cyberspace.**

- **Key Stakeholders: Air Staff, MAJCOMS, AFRL, Agencies, International**

- **Approach**
  - **Identify and forecast global trends (e.g., economic, demographic, S&T, military) and S&T revolutions that may radically transform threat vectors and/or opportunity spaces**
  - **Identify and prioritize the most promising S&T areas for dramatic change (economic, operational) in core AF missions**
  - **Articulate AF near (present-17), mid (FY18-22) and far (FY23-27) term S&T to fill gaps, indicating where AF should lead, follow, or watch**
  - **Prioritize the most strategic AF problems and identify best practices (e.g., partnerships, competitions, prizes) for motivating solutions that help overcome obstacles and achieve more rapid and economical S&T advancement**
  - **Engage and partner (industry, academia, national labs, FFRDC, government)**

- **Product: Global HorizonsS&T Vision to top 4 by ~~8/15/13~~ 5/7/13 (Report ~~10/1/13~~ 6/1/13)**

Global Horizons
Study Methodology

STRATEGY

REQUIREMENTS AND PLANS

Global Threats and Opportunities

COCOM and MAJCOM Requirements

CFMPs, STIPLs

NATIONAL SECURITY STRATEGY

May 2010

SUSTAINING U.S. GLOBAL LEADERSHIP: PRIORITIES FOR 21ST CENTURY DEFENSE

JANUARY 2012

Air Force Basic Doctrine, Organization, and Command

Air Force Doctrine Document 1
14 October 2011

Global Horizons

United States Air Force Global S&T Vision 2013-2027

**AF/ST TR 13-01
1 August 2013**

Independent Senior Expert Review

MISSION FOCUS	GLOBAL SECTOR
Air	Transp
Space	Manuf
Cyber	Comm/IT
C2	Energy
ISR	Health
Support	Ed/Train

Enabling S&T

RFI, EXPERT SUMMITS   **GLOBAL PRIVATE SECTORS**
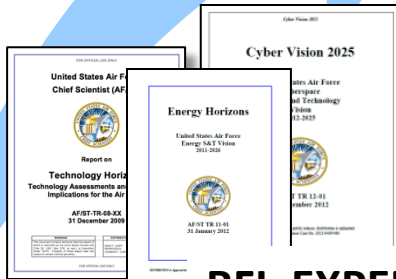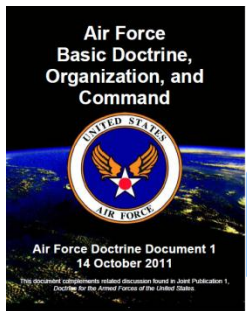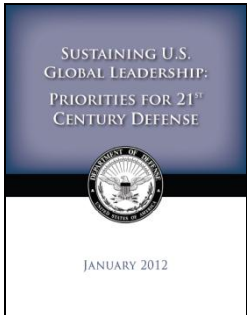
Global Horizons Stakeholders

- ## Senior Governance Team (3*) and Key Senior Stakeholders

Air Staff

AF/CVA: Lt Gen Frank Gorenc
AF/A1: Lt Gen Darrell Jones
AF/A2: Lt Gen Larry James
AF/A3/5: Lt Gen Burton Field
AF/A4/7: Lt Gen Judith Fedder
AF/A8: Lt Gen Michael Moeller
AF/A9: Dr. Jacqueline Henningsen
AF/RE: Lt Gen James Jackson
AF/SG: Lt Gen Thomas Travis
AF/ST: Dr. Mark Maybury (chair)

Secretariat

SAF/GC: Mr. Charles Blanchard
SAF/FM: Ms. Marilyn Thomas
SAF/IE: Mr. Terry Yonkers & Ms. Kathleen Ferguson
SAF/CIO A6: Lt Gen Michael Basla
SAF/AQ: Lt Gen Charles Davis
SAF/IA: Ms. Heidi Grant
SAF/US(M): Mr. David Tillotson
SAF/PA: Brig Gen Les Kodlick

MAJCOM Representatives

ACC/CV: Lt Gen William Rew
AMC/CV: Lt Gen Robert Allardice
AFMC/CV: Lt Gen Andrew Busch
AETC/CV: Lt Gen Douglas Owens
USAFE/CV: Lt Gen Noel Jones
AFSPC/CV: Lt Gen John Hyten
PACAF/CV: Lt Gen Stanley Kresge
AFRC/CV: Maj Gen Craig Gourley
AFSOC/CV: Brig Gen Michael Kingsley
NGB/CF: Brig Gen James Witham
AFGSC/CV: Maj Gen Everett Thomas

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Global Horizons Leads

- **Core Function Teams**
  - **Threat:** <u>Mr. Gary O'Connell (NASIC),</u> Maj Gen Jim Keffer (A2), Col Matthew Hurley (AF/A2DD)
  - **Air:** <u>Dr. Don Erbschloe (AMC),</u> Dr. Dave Robie (ACC), Doug Bowers (AFRL/RQ), Bill Harrison (AFRL/RQ), Dr. Bob Peterkin (AFRL/RD), Dr. Mikel Miller (AFRL/RW), Dr. Kamal Jabbour (AFRL/RI), Dr. Brian Kent (AFRL/RY)
  - **Space:** <u>Dr. Doug Beason (AFSPC),</u> Dr. Jim Riker (AFRL/RV), Col Scott Beidleman (SMC/XR), Dr. Roberta Ewart (SMC/XR), Dr Alan Weston (NASA)
  - **Cyber:** <u>George Duchak/Dr. Rich Linderman (AFRL/RI),</u> Dr. Doug Beason (AFSPC), Mr. Arthur Wachdorf (24AF), Frank Konieczny (SAF/A6 CTO), Mr. Mike Kretzer (688th), Steve Schneider (AFRL/RY), Dr. Rusty Baldwin (AFIT/ENGE)
  - **C2 and ISR:** <u>Dr. Steven K. Rogers (AFRL/RY/RI),</u> Dr. Terry Wilson (RY), Mr. Stan Newberry (AFC2IC), Dr. Chris Yeaw (AFGSC/ST), Jeff Eggers (AF/A2), Keith Hoffman (NASIC), Mr. Bill Marion (ACC)
  - **Mission Support (Acquisition, T&E, Workforce):** <u>Dr. David Walker (AQR),</u> Susan Thornton (AFMC/EN), Col Derek Abeyta (AF/TE), Maj Mike Dunlavy (SAF/AQR), Lt Col Dan Ward (LCMC), Ed Kraft (AEDC/CZ), Dr. Alok Das (RY)
  - **Enabling Technology:** <u>Dr. Jennifer Ricklin (AFRL),</u> <u>Dr. Chuck Matson (AFRL/AFOSR/CL),</u> Dr. Pat Carrick (AFRL/AFOSR/RT)
- **Global Sector Teams**
  - **Manufacturing and Materials** – <u>Dr. Barry Farmer (AFRL/RX),</u> <u>Doug Bowers (AFRL/RQ),</u> Dr. Mikel Miller (AFRL/RW), Col Keith Bearden (AFLCMC/XZ), Rollie Dutton (AFRL/RXM)
  - **Transportation and Logistics** – <u>Don Erbschloe (AMC),</u> Steven Hofmann (A3O, Next Gen)
  - **Energy, Utilities & Mining** – <u>Dr. Kevin Geiss (SAF/IE),</u> Bill Harrison (AFRL/RZ), Bob Peterkin (AFRL/RD)
  - **Health Care & Pharma** – <u>Dr. Morley Stone (AFRL/RH),</u> Deb Niemeyer (59 MDW/ST), Lt Gen Tom Travis (AF/SG); Col Randy Ashmore (AFMSA/SG5)
  - **Communications, Information Technology, Financial Services** - <u>George Duchak/Dr. Rich Linderman (AFRL/RI),</u> Dr. Doug Beason (AFSPC), Dr. Kamal Jabbour (AFRL/RI), Dr. Paul Antonik (AFRL/RI), Dr. Rob Gold (ASD R&E)
  - **Education and Training** – <u>Dr. Bruce Murphy (AU/VP Academic Affairs),</u> Dr. Todd Stewart (AFIT), Dr. Nathaniel Davis (AFIT), Jack Blackhurst/Dr. Morley Stone (AFRL/RH), John Geis (AU/AFRI), Dr. Steven Hansen (AU), BGen Scott Vander Hamm/Craig Seeber (AETC/A5/8/9A), Lt Col Chris Bohn (AETC/Spaatz Center), Dr. Aaron Byerley, (USAFA)

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Senior Independent Expert Review Group (SIERG)

Air	Space	Cyber	C2ISR	Msn Support	S&T, Threat, …
Trans	**Man/Mat**	**Comm/IT/FInancial**	**Energy**	**Ed & Train**	**Health**
Dr. Mark Lewis, IDA	*Dr. Mike Yarymovych, Sarasota Space*	Prof Ed Feigenbaum, Stanford Gil Vega, DoE Andrew Makridis, CIA Glenn Gafney, CIA	Prof. Alex Levis, GMU Dr. Donna Rhodes, MIT SEAri Dr. Mica Endsley, SATech	Dr. Steve Walker, DARPA Norm Augustine Heidi Shyu, ASA ALT Mr. John Gilligan	Gen (Ret) Mike Carns Prof. Werner Dahm, ASU Lee Jameson, NSF Charles Bouldin, NSF Lauren M. Van Wazer, OSTP Tomas Vagoun, NITRD
Natalie Crawford, RAND	*Dr. Rami Razouk, Aerospace*	Dr. Paul Nielsen, CMU/SEI Dr. Steve Burssolari, MIT LL Alan Bernard, MIT LL	Al Grasso, MITRE Ralph Semmel, JHU-APL	Jim Gosler, Sandia Giorgio Bertoli, Army	Konrad Vesey, IARPA Stan Chincheck, NRL Dr. Walter Jones, ONR
Lt Gen (Ret) George Muellner	*Dr. Eli Neiwood, MIT LL* *Dr. David Miller, MIT* Don Kerr Keith Hall	Gen Mike Hayden (Ret), USAF Lt Gen Ken Minihan (Ret) USAF Paul Laugesen, NSA/TAO Dr. Yul Williams, NSA/CSS TOC Dr. Mike Wertheimer, DoD Dr. Boyd Livingston, DoD Lt Col Marion Grant, USCYBERCOM/J9	VADM (Ret) Mike McConnell Lt Gen (Ret) David Deptula Dr. Jim Hendler, RPI Ray Haller, MITRE Dr. Steve Cross, GTRI Landon Derentz, DoE	Al Shaffer, OSD (R&E) Greg Smith, NGA Ben Steinberg, DoE Gen (Ret) Duncan McNabb	Gen (Ret) Jim McCarthy, USAFA Dr. Peter Friedland Prof Pat Winston, MIT Terry Jaggers, NAS Richard Matlock, MDA
Robert Osborne, NNSA Dr. Tom Hussey, AFOSR	Dr. Mason Peck, NASA CTO BGen (Ret) Pete Worden, NASA Matt Linton, NASA ARC-IS	Dr Starnes Walker, Navy Larry Schuette, ONR Tim Grance, NIST Dr. Steven King, OSD(R&E) PSC	Lt Gen (Ret) Ted Bowlds Lt Gen (Ret) Robert Elder MGen (Ret) Ken Israel	Dr. Tim Persons, GAO Brian Hughes, AT&L Tom Ehrhard, OSD(P)	David Honey, DNI Dr. Kathryn Sullivan, NOAH Paul Kaminski, DSB Chair

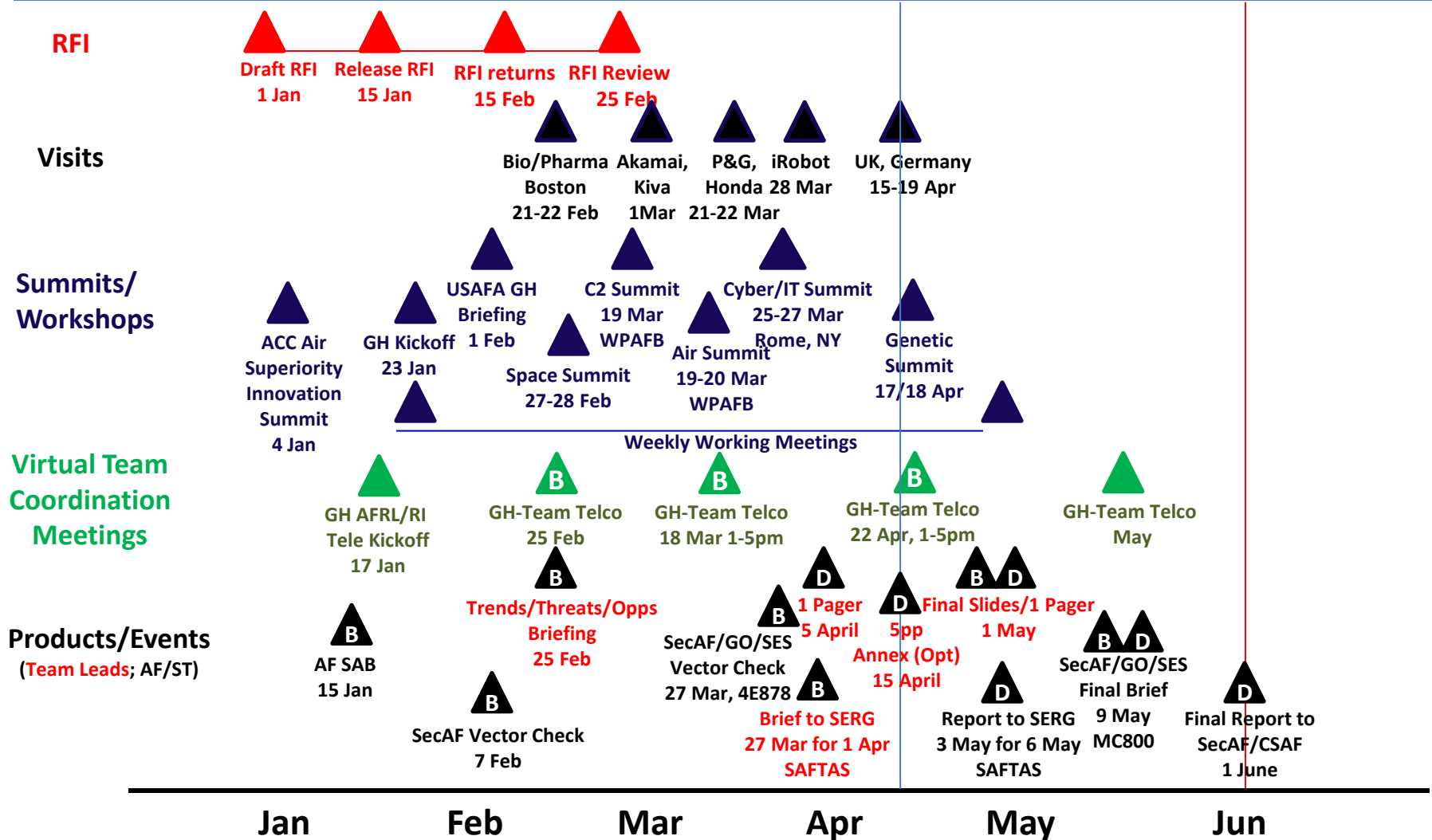| Former USAF Chief Scientist	Former NRO Director	Former Director NSA, DIA	Former DNI	Former CSAF or VCSAF	*AF SAB EXCOM*

Coalition

AVM Brecht & Mr. Philip Rayfield, MoD UK   Dr. Anthony Shellhase. DSTO, Australia   Mr. Christopher McMillan, DRDC Canada

Global Horizons (GH) Schedule

RFI
- Draft RFI 1 Jan
- Release RFI 15 Jan
- RFI returns 15 Feb
- RFI Review 25 Feb

Visits
- Bio/Pharma Boston 21-22 Feb
- Akamai, Kiva 1 Mar
- P&G, Honda 21-22 Mar
- iRobot 28 Mar
- UK, Germany 15-19 Apr

Summits/Workshops
- ACC Air Superiority Innovation Summit 4 Jan
- GH Kickoff 23 Jan
- USAFA GH Briefing 1 Feb
- Space Summit 27-28 Feb
- C2 Summit 19 Mar WPAFB
- Air Summit 19-20 Mar WPAFB
- Cyber/IT Summit 25-27 Mar Rome, NY
- Genetic Summit 17/18 Apr
- Weekly Working Meetings

Virtual Team Coordination Meetings
- GH AFRL/RI Tele Kickoff 17 Jan
- GH-Team Telco 25 Feb
- GH-Team Telco 18 Mar 1-5pm
- GH-Team Telco 22 Apr, 1-5pm
- GH-Team Telco May

Products/Events (Team Leads; AF/ST)
- AF SAB 15 Jan
- SecAF Vector Check 7 Feb
- Trends/Threats/Opps Briefing 25 Feb
- SecAF/GO/SES Vector Check 27 Mar, 4E878
- Brief to SERG 27 Mar for 1 Apr SAFTAS
- 1 Pager 5 April
- 5pp Annex (Opt) 15 April
- Final Slides/1 Pager 1 May
- Report to SERG 3 May for 6 May SAFTAS
- SecAF/GO/SES Final Brief 9 May MC800
- Final Report to SecAF/CSAF 1 June

Jan | Feb | Mar | Apr | May | Jun

today

B = Briefing
D = Document
SERG = Senior External Review Group

*Final Briefing (7 May 2013)*
Final Report (1 June 2013)

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Global Environment

Global Forces
- Demographics
- Climate
- Resources (Natural, Talent, Treasure, Time)
- Globalization/Proliferation
- Conflict

Global Sectors
- Manufacturing and Materials
- Transport and Logistics
- Energy and Utilities
- Health and Pharma
- Communications and IT
- Financial Services
- Education and Training
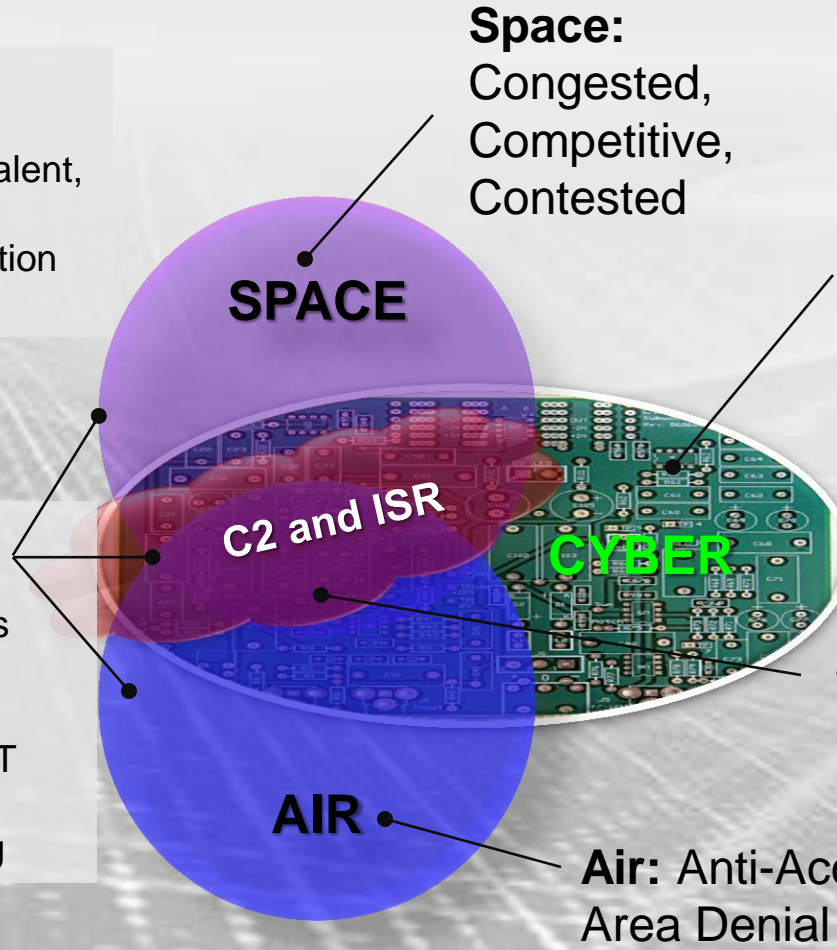
Space: Congested, Competitive, Contested

Cyberspace: threatened by malicious insiders, supply chain attacks, and advanced persistent threats to deceive, degrade, disrupt, destroy

SPACE

C2 and ISR

CYBER

AIR

Command and Control (C2) & Intelligence Surveillance and Reconnaissance (ISR) targeted as a center of gravity threatening integrated and resilient global operations
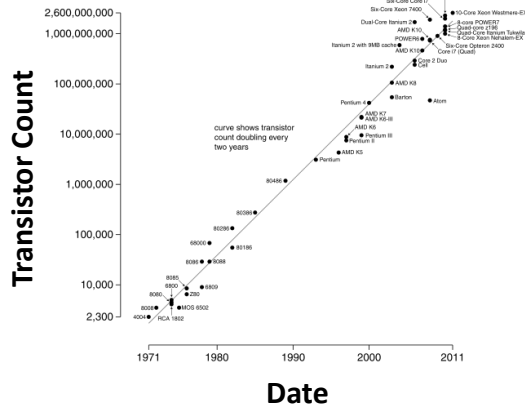
Air: Anti-Access, Area Denial (A2/AD)

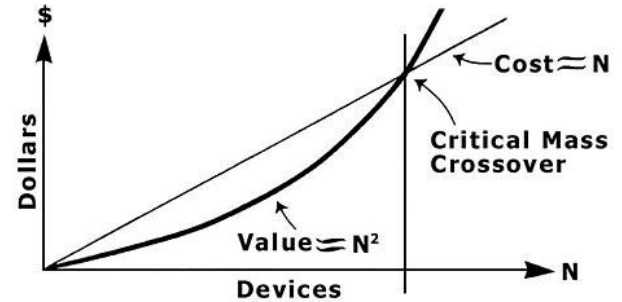*Global Vigilance, Reach and Power dependent upon contested Global Commons and Globalized Industrial Sectors*

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Laws Help Forecast Future

Microprocessor Transistor Counts 1971-2011 & Moore's Law

Moore's Law

The Systemic Value of Compatibly Communicating Devices Grows as the Square of Their Number:

Cost $\cong$ N

Critical Mass Crossover

Value $\cong$ N^2

Metcalf's Law

overtrust

undertrust

TRUST

Productivity

Confidence — f(threat, vulnerability, resilience, consequence)

| Low "in" | Med "on" | High "out" | ← Autonomy |
| ← Human Control |

Autonomy

Maybury's Law

Phone, Radio, Television, PC, Mobile Phone, Internet, Facebook, ?

Years
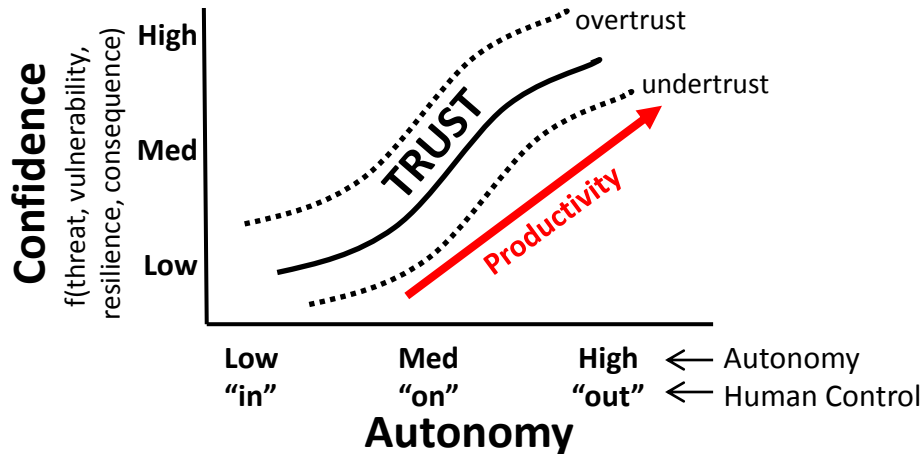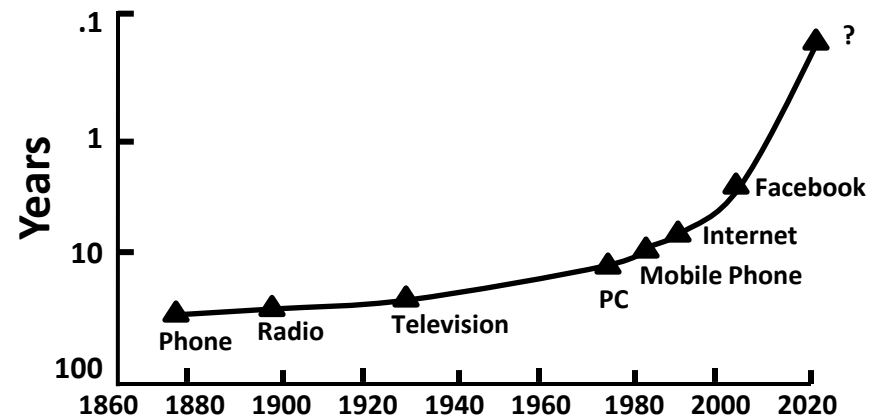
Adoption Acceleration

Source: KurweilAI.net

Global Horizons
1999-2025+

Shocks
(Health, Env, Econ, Soc, Pol)

Global Population (% urban, avg age, % middle class)
US Off-shoring (% Change)
CMOS Integrated Circuit Feature Size
Info Tech – Hosts, Users (% Pop), Mobile, Bandwidth (log), Speed
US Computing PhD Degrees
Chinese Computing PhD Degrees
Malware Signatures
Climate Change (Temp, Humidity)
Reserves/Production (Energy, Minerals)
Global R&D (% foreign)

Malware

200 M

IT

Population
9.2 B (70% U, 41yrs, *65%*)

8 B (58%U, 35yrs, 60%)

-10%

-5%

Oil (42), Pb (22) Ni (21) Indium (8)

Reserves

10^{13} bps, 10 Exaflops

Off-shoring

+40%

Climate Change
+1.25°F, +5% Humidity

3B, 5.5 B (68.8%), +.75°F, +2.5% Humidity

Global R&D (% foreign)
~$4.3T, *70%*

$1.4T, 60%

$2 T, 65%, China=US

IC Size

6 B (46%U, 27 yrs)

180 nm

43M, 147 M (2.5%)
10^5 bps, 1 Tflop

+0.3°F, +1%H

8-10nm

818M, 2.03 B (30.2%), 49 B

8500 **Chinese CS PhDs**

7 B (50% U, 31 yrs, 50% MC)

2500

1600

3.9 M

35 K

US CS PhDs
3800

57.9°F

$641B, 66%

2025
- **Econ: China #2, India #3**
- **Pop: +2B, ~60% Urban, 13% older**
- **7T IP enabled devices**
- **50 zetabytes (10^{21}) data**
- **IT/nano/bio converge, Quantum**
- **Climate Extremes, Scarecity**
- **World Bank, WTO, IMF**

1999

2012

2025

2050

CMOS – Complimentary Metal-Oxide Semiconductor; IC – Integrated Circuit
World Trade Organization (WTO), International Monetary Fund (IMF)
PhD Degrees in Computer Science/Computer Engineering/Computational Mathematics

Threat Development

- **S&T talent drive air/space/cyber research and development**

  - **By 2015, Brazil, China, and India will graduate 88% of worldwide graduates in STEM programs accelerating solutions to militarily significant technology problems ***

- **"Big Data" enables accurate and innovative analysis**

  - **40 Zetabytes by 2020 (1.8 ZB in 2011)**

- **Increased pace of technology development**
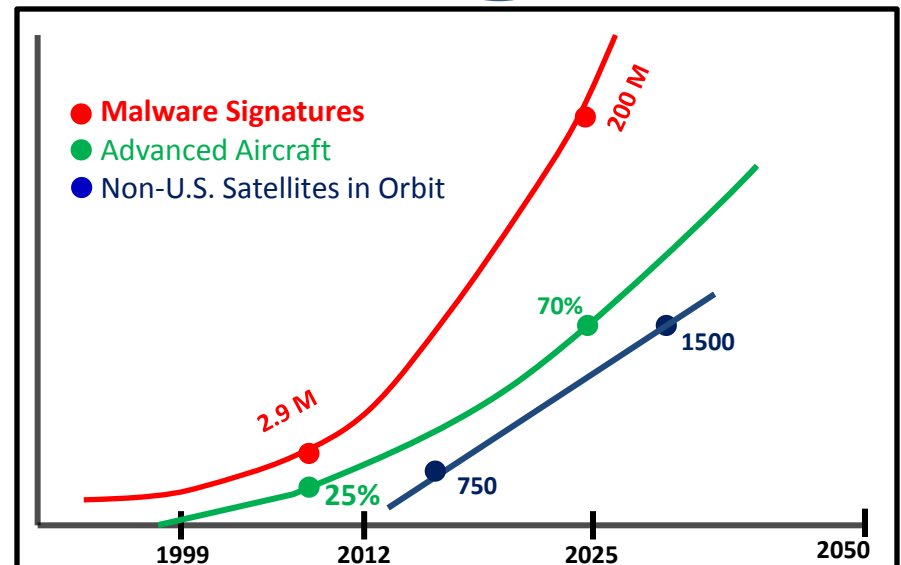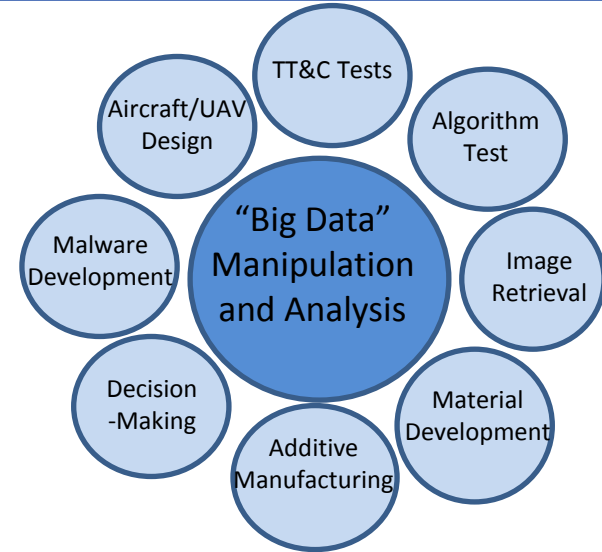
* No Shortage of Talent. September 2011
Accenture Institute for High Performance Analysis,

TT&C = Telemetry, Tracking & Command

Diagram circles: Aircraft/UAV Design, TT&C Tests, Algorithm Test, Malware Development, "Big Data" Manipulation and Analysis, Image Retrieval, Decision-Making, Additive Manufacturing, Material Development

Chart legend:
- **Malware Signatures**
- Advanced Aircraft
- Non-U.S. Satellites in Orbit

Chart values: 200 M, 2.9 M, 70%, 25%, 1500, 750

X-axis: 1999, 2012, 2025, 2050

Trend-Threat-Capability

DRAFT

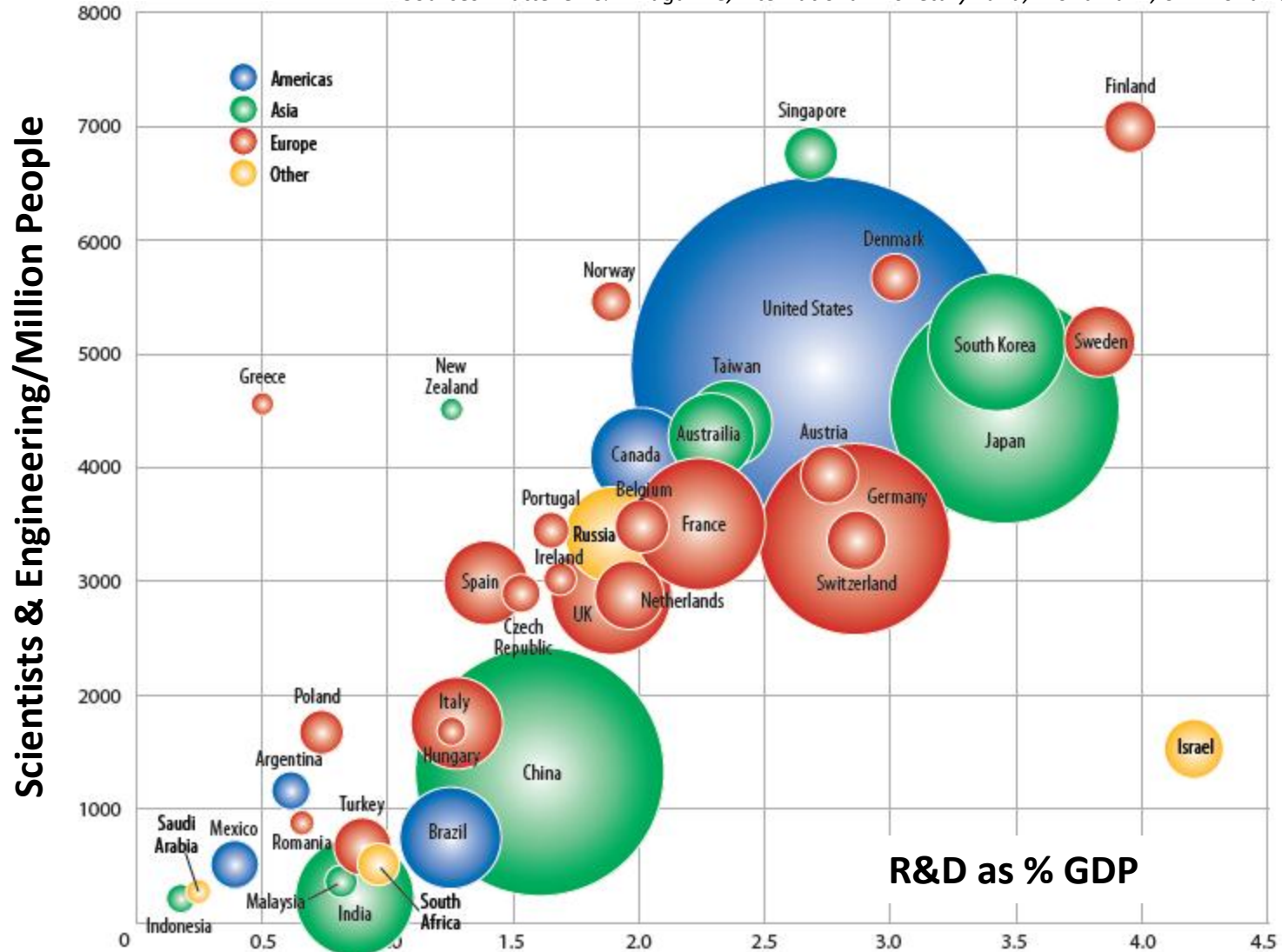| Global Trend	Military Threat/Requirement	Required Capability
Proliferation - Missile - Jam/Spoof	Medium and Long range Missiles, Counter EW, Counter DE	-BMD (all domains), Hypersonics -Assured Comms -PNT
Youth Growth (Middle East/Africa)	Growth of Islamic Fundamentalism	COIN, Ubiquitous ISR, Human terrain
Urbanization	Insurgent Operations	Persistent ISR, Precision Strike for Zero Collateral Damage, Urban Operations, Agile Mobility
Global Climate Change	Sea Level Rise, Desertification, Change in geographic focus, challenges to allies' sovereign territories	Expeditionary operations, Mobile basing, Global mobility, Humanitarian Operations
Resource Depletion	Natural Resource Conflict	Alternative/Sustainable Energy, New Materials, Recycling of Rare Materials
Growing Deficits	RDT&E Restrictions	Low Cost, Innovation, Sustainable Weapon Systems
Declining STEM	Technology gaps with peer/near-peer	Virtualized education & training

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Function to Sector Mapping

FUNCTION/ SECTOR	Threat	Air	Space	Cyber	C2	ISR	Support
Threat		Missiles, DE	Direct Ascent	Supply Chain, Insider, APT	D4, Integrity	D4, Integrity	Supply, Life Cycle
Manuf & Materials	Global S&T Intelligence, Nano sensors	Autonomy, Robots, Add Manufact., Composites, Nanotech, Design	Autonomy, Robots, Add Manufact., Nanotech, Design, Manuf in Space	Autonomy, Robots, Nanotech, Design, Rev Engineering	Autonomy, Robots, Nanotech, Design	Autonomy, Robots, Add Manufact., Composites, Nanotech, Design	Add Manufacturing
Transport & Logistics	Smuggling, Trafficking	Autonomy, scheduling, tracking, energy	Autonomy, tracking, launch, space transport	Global Supply/ Logistics	Global Supply/ Logistics	Global Supply/ Logistics	Global Supply/ Logistics
Health & Pharma	Illegal drug trade, unregulated manufacture	Perform enhance, bio, force protect	Perform enhance, bio, force protect	Perform enhance, bio, force protect	Perform enhance, bio, force protect	Perform enhance, bio, force protect	Trauma, supply chain protection
Energy, Util, Mining	HPM and Lasers, Rare materials	Bio Fuels, Directed Energy	Directed Energy, Space Mining	SmartGrid	SmartGrid	Bio Fuels, SmartGrid	Gas/Oil, (Small Modular) Nuclear, Sunshine to Petrol
Comm, IT	Hacking, Decryption	Artificial cortex, quantum, intelligent spectrum, wireless ubiquity, laser com, PNT					
Financial	Global Debt, Terrorist Financing	Automation, InfoSec (Key Management, Insider Threat), Privilege Management, Offshoring					
Ed & Train	Terrorist training	Virtual gaming, Intelligent Tutoring, Augmented Cognition					

DRAFT

Global R&D (2011)
Size of circle is relative amount of Annual R&D

Scientists & Engineering/Million People (y-axis, 0 to 8000)

R&D as % GDP (x-axis, 0 to 4.5)

Legend:
- Americas (blue)
- Asia (green)
- Europe (red)
- Other (yellow)

Countries plotted include: Finland, Singapore, Denmark, United States, South Korea, Sweden, Norway, Taiwan, Australia, Austria, Japan, New Zealand, Canada, Belgium, Germany, Greece, Portugal, Russia, France, Ireland, Spain, Switzerland, Netherlands, UK, Czech Republic, Poland, Italy, Hungary, China, Israel, Argentina, Turkey, Saudi Arabia, Mexico, Romania, Brazil, Malaysia, India, South Africa, Indonesia

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Industrial R&D (2010)
Size of circle is relative amount of Annual R&D

R&D Spending as Percent of Net Sales (vertical axis)

Legend:
- Automotive
- Telecomunications
- Pharmaceuticals
- ICT
- Other

Companies plotted (upper chart): Lilly, Takeda, Boehringer, Merck US, Roche, Bristol-Myers Squibb, Amgen, Alcatel, Novartis, Intel, Ericsson, Sanofi, AstraZeneca, Pfizer, Oracle, GlaxoSmithKline, Cisco, Microsoft, Google, Nokia, J&J, Abbott

The horizontal scale for the companies shown to the right has been expanded from the horizontal scale for the companies shown above to reveal differences between the tight clustering of the mostly automotive, ICT, and other companies. The size of the circles in the chart to the right is at the same scale as the circles shown above.

Companies plotted (lower right chart): Canon, Denso, Bayer, Bosch, NEC, Panasonic, Nissan, EADS, Siemens, Boeing, Sony, Samsung, IBM, Fujitsu, Toshiba, Daimler, Honda, BMW, Hitachi, Ford, GM, HP, GE, NTT, Toyota, LG, Peugeot, Volkswagen

R&D Spending / Number of Employees, Thousands of U.S. Dollars

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Concept Quad
for Global Horizons RFI
(examples FICTITOUS)

FUNCTION: (air, space, cyber, C2, ISR, msn support)
SECTOR: (eg., man., log., fin.)
TRL: 1-9
MRL: 1-10
CLASSIFICATION

Objective (relate to Global Horizons Needs)

- **Clearly state the problem and why it is hard**
- **State qualitative & quantitative objectives, e.g.,**
  - **Revolutionary new technology to decrease maintenance cost by five fold**
  - **50% increase in mean time between failure, 100% increase in part failure prediction accuracy, 25% increase in reuse**
- **Relate objectives to AF function (air, space, cyber, C2, ISR, mission support), global threat, and global opportunity (e.g., robustness, resiliency, stealth, efficiency)**

Revolutionary Concept/Capability

- **What specific new material, operational, and/or cultural change will result from activity and when?**
- **How does what you propose differ from today?**
- **What is revolutionary/game changing about your idea?**

- Include graphic as appropriate
- Attach any existing studies/analyses/papers

Technical Approach

- **Detail of how you are going to achieve revolutionary technological breakthrough. (What are the mid term and final exams?)**
- **What kind of exploration, experimentation, and/or demonstration is required? How long?**
- **Why will it be successful? Provide explicit evidence (past/current experiments, pilots, preliminary results) that illustrate feasibility**
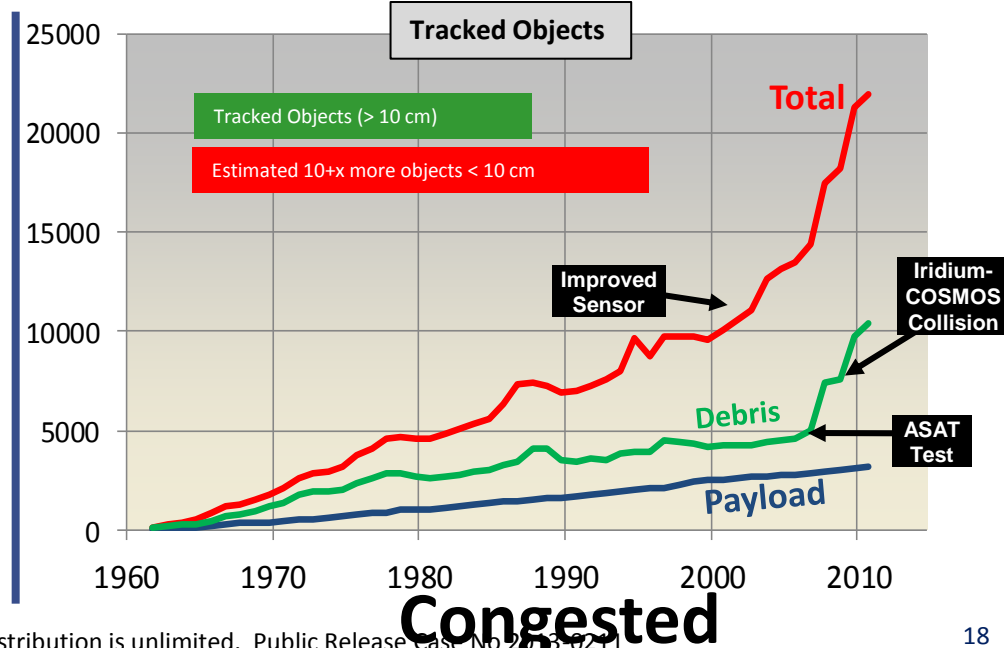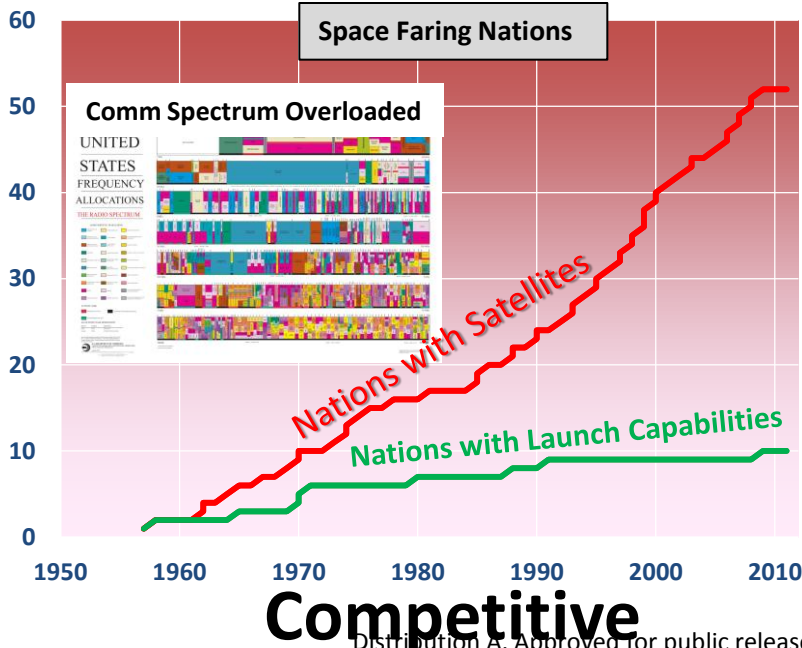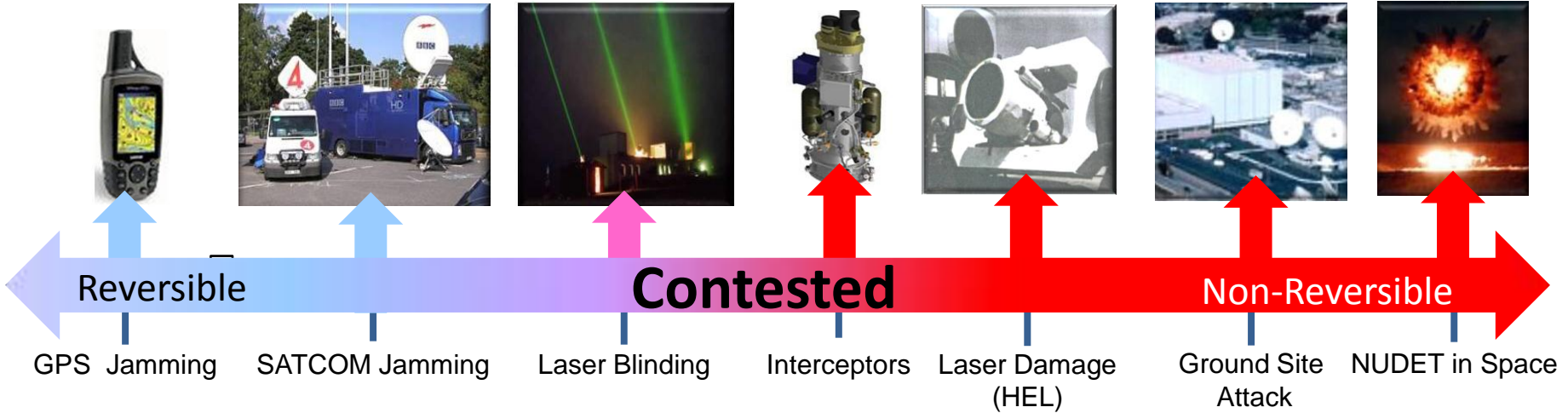
Risk and Impact/Payoff

- **Identify the top risks (technical, transition, operations, economic, etc.) and TRL, MRL**
- **Project cost/benefits as appropriate, e.g.**
  - **Cost: e.g., system or operational improvement, total life cycle or FDIP savings, and/or staff/fleet/facility impact**
  - **Benefits: e.g., $XM in savings, Y% reduced errors, Z% increased speed, etc.**

Additional detail, references etc. can be added as text in the notes section of this slide in no less than 10 pt font that describes/amplifies concept & addresses Heilmeier questions
(see www.design.caltech.edu/erik/Misc/Heilmeier_Questions.html).
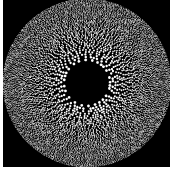
External Experience

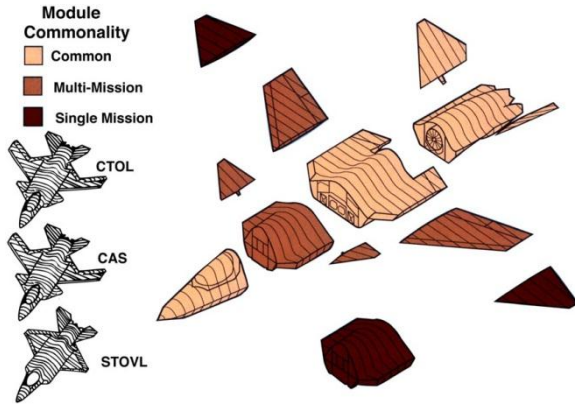40
33 33
28
25
20
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17
0

Cyber C2ISR Air Space Msn Spt S&T

30
27
20
11
10
10
9
7
5
0

Energy Comm/IT Transp Manuf Health Ed/Train

Palantir
GE
ROCKET·LAB·LTD — Innovative access to space
verizon
IBM
TERADATA
mc10 reshaping electronics
UNIVERSAL SPACE NETWORK — SSC
ITT EXELIS
SSLC
PUMPKIN SPACE SYSTEMS
HONDA
McAfee — An Intel Company
Sandia National Laboratories
BROOKHAVEN NATIONAL LABORATORY — home
Pacific Northwest NATIONAL LABORATORY
Los Alamos NATIONAL LABORATORY — EST.1943
INL — Idaho National Laboratory
Lawrence Livermore National Laboratory
citibank
SPACE SYSTEMS LORAL
LOCKHEED MARTIN
NORTHROP GRUMMAN
Raytheon
UNION PACIFIC
Aurora FLIGHT SCIENCES
ATK
Booz | Allen | Hamilton
United Technologies Research Center
HARRIS
BOEING
MASSACHUSETTS GENERAL HOSPITAL
MGH 1811
THE NEUROSCIENCES INSTITUTE
Innoflight
ALLEN INSTITUTE for BRAIN SCIENCE — Fueling Discovery
Virgin Galactic
Space Dynamics LABORATORY — Utah State University Research Foundation
AEROSPACE CONCEPTS
DEEP SPRINGS TECHNOLOGY
PRATT & WHITNEY DEPENDABLE ENGINES
TR:DENT
Microcosm Inc
prime
goldbot consulting
iRobot
Stottler Henke — Smarter Software Solutions
ECLIPSE AEROSPACE
DESIGNinteractive
voice lever
synerscope — connecting the dots
MIT Lincoln Laboratory
RAND CORPORATION
VFA
mc10 reshaping electronics
DIGITALGLOBE
ORBITEC
CRITICAL technologies
GTRI RELENTLESS COMMITMENT
MITRE
UNIVERSITY OF Cincinnati
AEROJET
University of Colorado Boulder
STANFORD AERONAUTICS & ASTRONAUTICS
MILLENNIUM SPACE SYSTEMS
Tamarin
UNIVERSITY of VIRGINIA
ARIZONA
JOHNS HOPKINS UNIVERSITY
IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY — SCIENCE WITH PRACTICE
JMG technology
STILMAN advanced strategies
MOOG
Washington WASHINGTON · UNIVERSITY · IN · ST. LOUIS
Aerospace Engineering Sciences UNIVERSITY OF COLORADO BOULDER
ILLINOIS
PENNSTATE
MIT
Stony Brook University
Utah State Univ
NASA
DEPARTMENT OF ENERGY UNITED STATES OF AMERICA
COLLEGE OF NANOSCALE SCIENCE & ENGINEERING UNIVERSITY AT ALBANY State University of New York
USC
UNIVERSITY OF Cincinnati
THE UNIVERSITY of TENNESSEE KNOXVILLE
UNM
AIR FORCE SPACE COMMAND
DARPA

Space Trends/Challenges

Reversible **Contested** Non-Reversible

GPS Jamming   SATCOM Jamming   Laser Blinding   Interceptors   Laser Damage (HEL)   Ground Site Attack   NUDET in Space

Space Faring Nations

Comm Spectrum Overloaded

Nations with Satellites

Nations with Launch Capabilities

Competitive

Tracked Objects

Tracked Objects (> 10 cm)

Estimated 10+x more objects < 10 cm

Total

Improved Sensor

Iridium-COSMOS Collision

Debris

ASAT Test

Payload

Congested

Space S&T
Game Changers/Roadmap

Technology	Near-term (FY13-17)	Mid-term (FY18-22)	Far-term (>FY22)
Disaggregation	F6 program (W)	NavSat (L)	Microsatellites (F)
Responsive Launch	100-kg to LEO for $1-3M (W)	GEO and LEO commodity launch (L)	Launch raw materials (L?), Launch deployables (L)
Space Cyber	Testbeds (L)	Space-HAIPE (F)	Agile and Resilient by Design (W)
Architectures	Deployable antennas (L), Open Standards (L)	Synthetic apertures (F) Open Arch (L)	Composable constellations (L)
Communications	AEHF (L) V/W band (L)	Laser Communications (F)	QKD free space, multiple site (F)
Manufacturing	Radiation-hard (L)	Additive Manufacturing (F)	Build in space (L?)

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Air Game Changers

Modularity: "Plug and Play" armaments, avionics, airframe, mission

Autonomy: Bioinspired and Swarming

Operational Analysis points to high speed as key to survivability
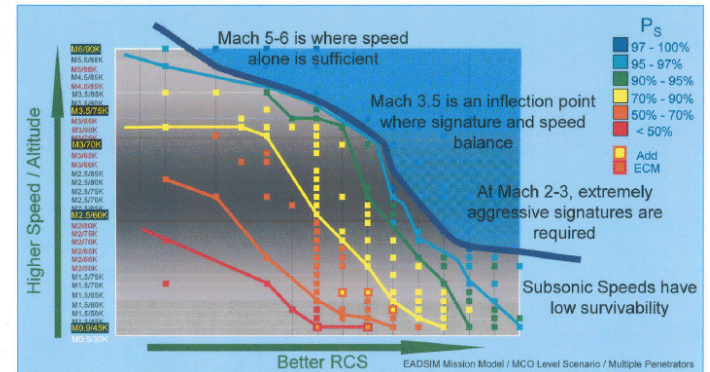
Speed: Gamechanger that requires synthesis of several technologies
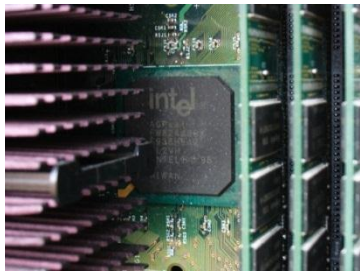
Distributed Decision Making: Requires gains in computing power, connectivity, and trust in systems & components

www.youtube.com/watch?v=Cu6E4mtO85I
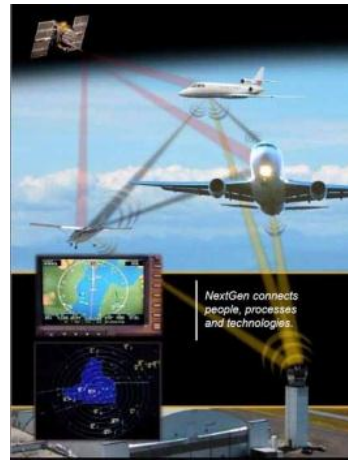
Turning mandates into capability: Fuel efficiency to range, payload, endurance; avionics equipage to better SA; etc.

CO_2

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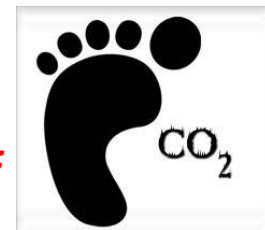
Cyber, Communications, IT, Finance Game Changers and Roadmap

Increasing Complexity

Air

% Capability in Software

Source: SEI, LM

Space

Millions ESLOC

DSP   SBIRS   AEHF   GPS III

Source: SEI

Increasing Performance

Computing Density & Computing Cost Trends

120X   400X

- 2D Computing Density
- 3D Computing Density
- Cost of Computing
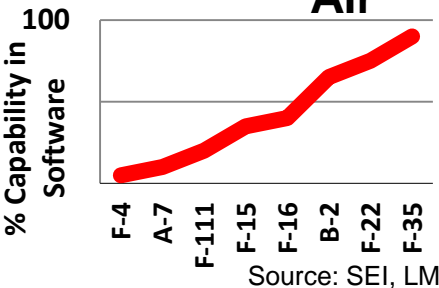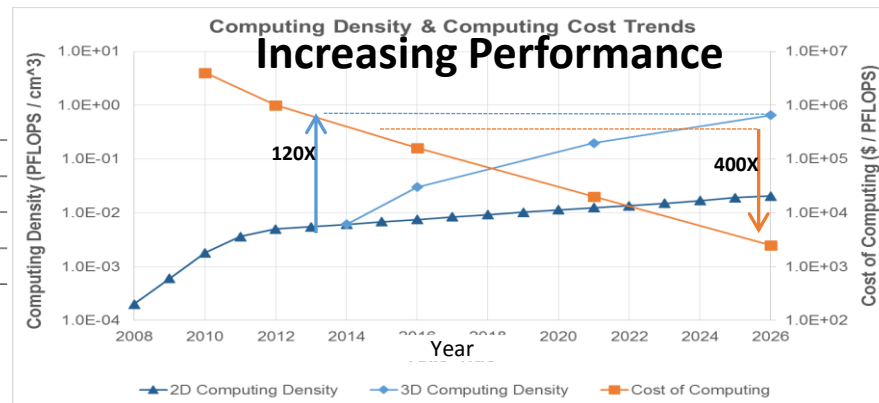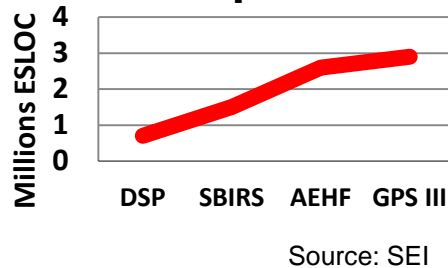
Area	Near (2013-2017)	Mid (2018-2022)	Far (2023-2027)
Cyber	Mission aware information objects (L)	Mission Aware Cyber C2 (L)	Autonomous Cyber Collectives (L)
	Quantum Encryption (W)	Real-time Cyber SA (L)	Dynamic S/W (F)
	Root of trust H/W & S/W (F)	Trusted embedded systems (L) Wireless Power (W)	Trusted Automation (F)
Communications	Cognitive Comms (L) Near-Field Communication (W)	Distributed & De-centralized Connectivity (L) Merged Communications, EW, SIGINT (L)	Quantum Communications (F)
Information Technology	Computational Intelligence (F) Deep Belief Networks (L)	Artificial General Intelligence (F) Large-Scale Inference (L)	Human-Level Autonomous Systems (F) Neuromorphic architecture (L, F)
	3-D integrated circuits (F)	Memristive devices and circuits (F) Spin Torque Transfer Technology (F)	Graphene-based circuits (F)
	Widespread Robotics (W) Big data analytics(L, F)	Quantum Computing (F)	Augmented Reality (F) Nano tailored circuits (F)
Finance	Advantage from maneuverability & big data analytics (W)	Personal Identity Authentication & Management (W) Assured Operations(W)	

DRAM = Dynamic Random-Access Memory
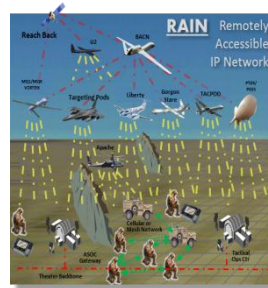
C2 and ISR
Game-Changers and Roadmap

"Collect"
Integration across Missions and Domains
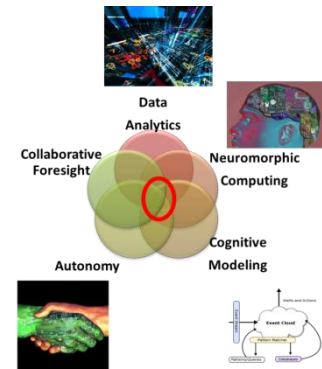
"Communicate"
Battlespace Networking for C4ISR Collaboration

"Process"
Innovative Exploitation

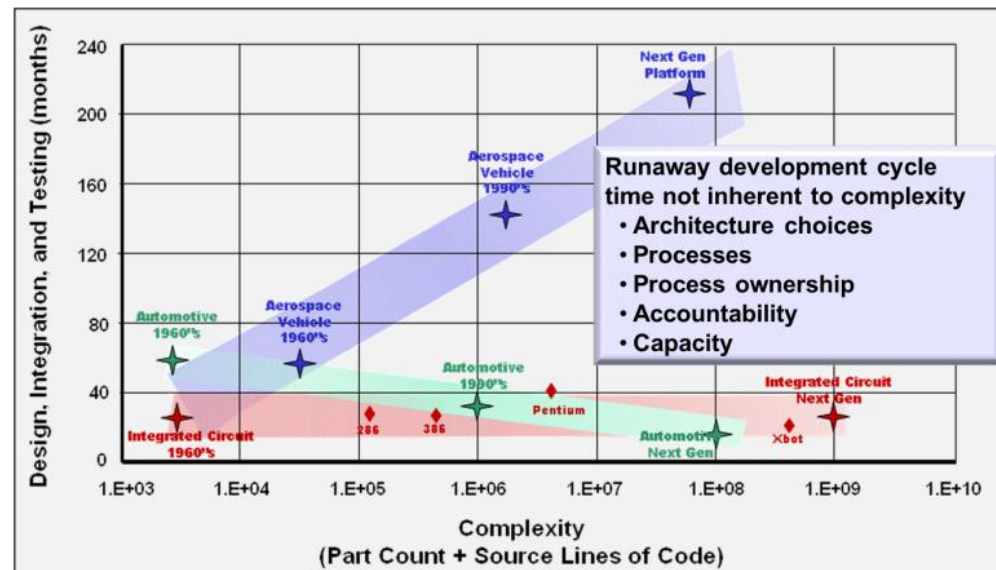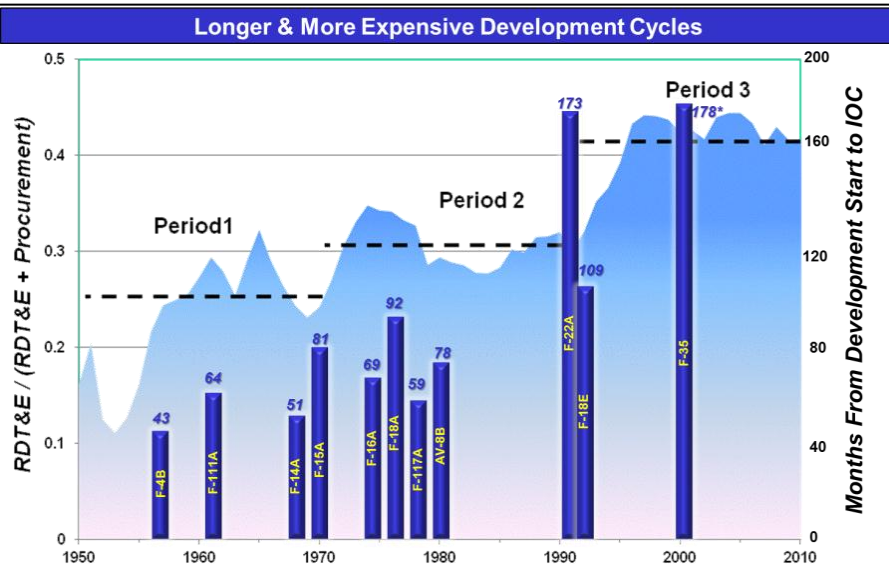| Game-Changer	Near (F13-FY17)	Mid (FY18-22)	Far (>FY23)
Integration across Missions and Domains	• ISR Enterprise Support for 5th Gen Air (F) • Distributed Team Collaboration for Integrated A/S/C Plans (W)	• Dynamic Reallocation of Resources (F) • Full spectrum targeting kinetic/non-kinetic (L)	• Automated Sensor Tasking (F) • Pervasive/Persistent C2ISR Enterprise (W)
Battlespace Networking for C4ISR Collaboration	▪ BLOS Integrated C2 to tactical edge (F) ▪ IFDL/MADL/Link16 gateway (L)	▪ Weapons Data Link (L) ▪ Rapidly Reconfigurable Systems (F)	▪ Fractionated/Distributed A/S/C intra-networks (L) ▪ Mission-aware routing and on-demand information prioritization & dissemination (F)
Innovative Exploitation	• Operational/adaptive machine learning with low power hardware (L) • Big data analytics (F)	• Integration of human sensing with machine intelligence for effective, trustable teaming (F) • Predictive cognitive modeling for system design and training Analysis of Alternatives (L)	• Cognitively enhanced complex event processing for novel autonomous system functionalities (W)

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Mission Support
Trends (Acquisitions, T&E, Workforce)

- **Rapid innovation and emergence of new technologies**
  - **Agile SW, HW, manufacturing – rapid prototyping, scalable systems, & smaller lot sizes**
  - **Low-cost innovation – autonomous transatlantic robot (5-7 undergrads, $25K, 10 weeks)**
- **Increasing complexity, cost, and time-to-field of Defense systems**
  - **Highly interoperable and interdependent systems – 24M LOC in F-35**
  - **RDT&E is 40% of acquisition budget; avg time to IOC for next-gen F-XX to exceed 200mos (260% increase)**
- **Increasing global competition for highly skilled and technical workforce**
  - **80% jobs will require tech skills next decade; over 1 million US job openings in STEM-fields by 2018 (BLS)**
  - **US ranks 27th in % of undergrad STEM degrees; foreign born US PhD engineering grads>US born (NRC)**

small rocket nozzle

Longer & More Expensive Development Cycles

Runaway development cycle time not inherent to complexity
- Architecture choices
- Processes
- Process ownership
- Accountability
- Capacity

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Source: Dr. Kirstie L. Bellman, Making DARPA META Goals Come True: How do we Revolutionize Verification and Validation for Complex Systems? S5 2010, WPAFB, June 17, 2010

23

Mission Support Opportunities
(Acquisitions, T&E, Workforce)

- **Revolutionize acq system w/agile approach – quickly field simpler, scalable, small production lot systems**
  - **Digital modeling to accelerate cycle time – concept trades, design, test, manufacture**
  - **Loosely coupled systems w/ designed-in trust & flexibility: scalability & rapid tech refresh**
  - **Reduce oversight, regs, reqs – empower decision makers & create culture NOT risk averse**

- **Generate buzz & excitement w/ revolutionary S&T – increase demos & better communicate capabilities**
  - **Create rapid design / prototype environ – fast build-test-break iterative cycle to demo/trans S&T**
  - **Open Innovations / Challenges for S&T info, concept demos, urgent needs – fast & broad solution set**
  - **Harvest small business innovation – require primes to team w/small business– tie to award fee**

- **Attract, energize & retain best global talent: fund high value talent & ideas … not programs**
  - **Advocate for policy to grant Visas to world's best for DoD employment only**
  - **Place new S&E workforce in rapid prototype environment – create multi-disciplinary skills**
  - **Long-term view of S&E workforce – fund w/ 1 color of $, expand lab demo, & "ring fence" key talent**
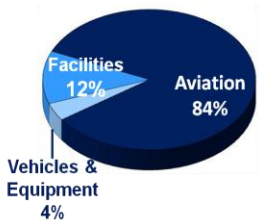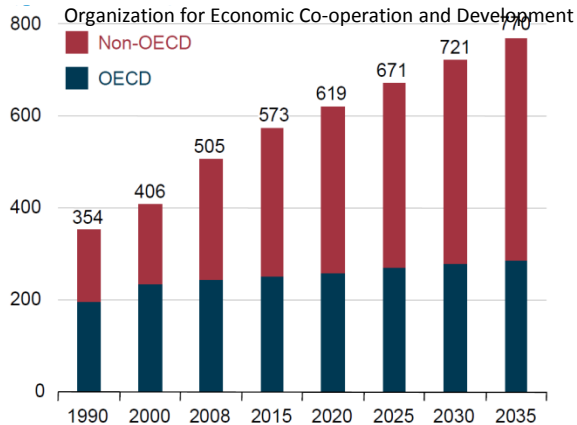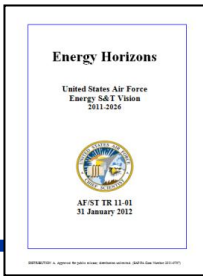
Education & Training
Virtualized Learning (Example: PME Teambuilding Exercise)
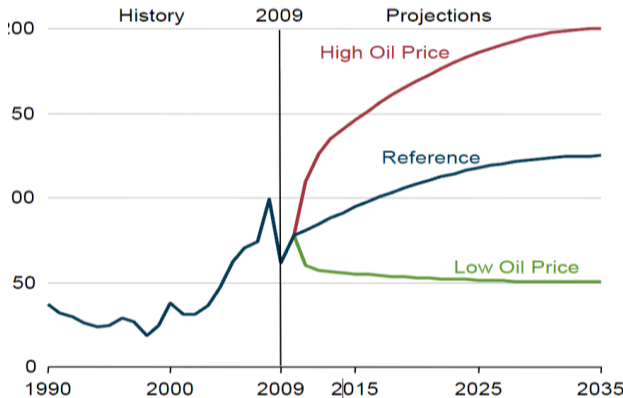

- **Increases exposure**
  - **Experiential activities available to wider audiences**
- **Increases precision**
  - **Simulations focus-able on specific needs and objectives**
- **Reduces cost**
  - **Eliminate need for travel**
- **Reduces physical risk/injury**
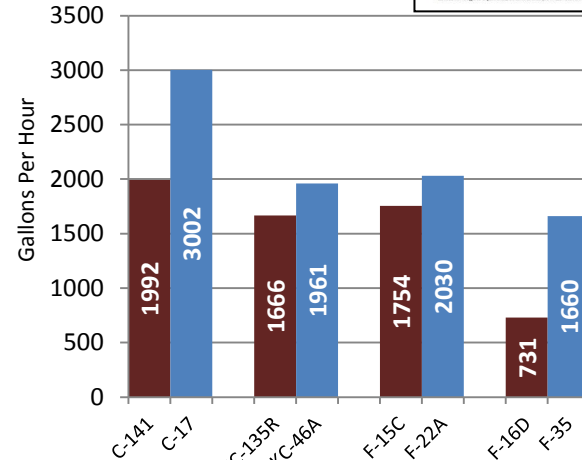- **Improves participation**
- **Replayable scenarios**

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Energy Game Changers for Assured Energy Advantage

FY10 Cost Breakdown

- Facilities 12%
- Aviation 84%
- Vehicles & Equipment 4%

Energy Horizons
United States Air Force
Energy S&T Vision
2011-2026

AF/ST TR 11-01
31 January 2012

World Energy Consumption (quadrillion Btu)

Organization for Economic Co-operation and Development
- Non-OECD
- OECD

1990	2000	2008	2015	2020	2025	2030	2035
354	406	505	573	619	671	721	770

World Oil Price ($ per barrel)

History — 2009 — Projections
- High Oil Price
- Reference
- Low Oil Price

More Capability, More Fuel

Gallons Per Hour

C-141	C-17	KC-135R	KC-46A	F-15C	F-22A	F-16D	F-35
1992	3002	1666	1961	1754	2030	731	1660

Area	Near (2013-2017)	Mid (2018-2022)	Far (2023-2027)
Propulsion & Aerodynamics	ADVENT (L)	HEETE (L)	
Energy Storage		Nano Materials (L) Carbon-Carbon Nanotubes, Memristers	
	Adaptable Storage/Emerging Battery Technologies (F) Metal Hydrides, Sodium-Air, Electrochemical Flow Capacitor		
	Superconducting Magnetic Energy Storage (W)		
Directed Energy		Directed Energy Power Beaming (L)	
		Directed Energy Kinetic Weapon Alternative (L)	
Energy Harvesting		Energy Harvesting for Small RPAs (L)	
		Inverted Meta-Morphic Space Photovoltaic Arrays (L)	
	Thermoelectric/Pyroelectric Material (F)		
Modeling & Simulation	Systems of Systems M&S (L)		

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Greatly Reduced Mass Flow via Lean Logistics

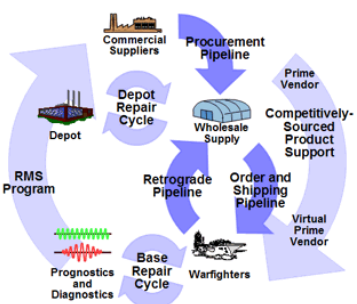## Assets Needed to Close the TPFDD to put JSTARS Package in Theater

- 1 JSTARS; 12 hour mission per day – 1 day
  - 227 support personnel and 4 C-17's of cargo
- When operational:
  - Hotel load of support personnel ~ 20 gal/day/person
  - Typical fuel burn per day JSTARS ~900 gal/hr
- 227 personnel x 20 gal/day = 4540 gallons
- 12 hour mission x 900 gal/hr = 10,800 gallons
- Total gallons = 15, 340 gallons x $4/gal = $61,340/day/JSTARS
- **$1.84M/month for 1 JSTARS (fuel cost only)**

DISTRIBUTION STATEMENT D: Distribution authorized to the Department of Defense and U.S. DoD contractors only – Critical Technology; 24JUL2012. Other requests shall be referred to AFRL/RQ

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Automation:

www.youtube.com/watch?v=6KRjuuEVEZs

www.youtube.com/watch?v=qxD9Uyz4e9o

On-site manufacture & production:

http://www.youtube.com/watch?v=VhWugjxpueg

Energy from Waste

Acquisition:

DoD Logistic Cycles

Efficiency:
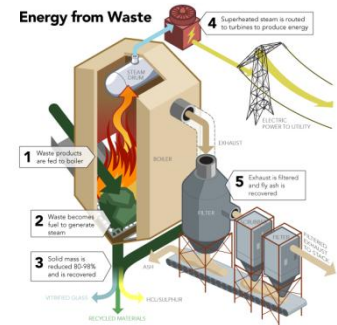
www.youtube.com/watch?v=l4G-9uwuKnc&playnext=1&list=PLFAA64E5743637008&feature=results_main

Transportation Autonomy
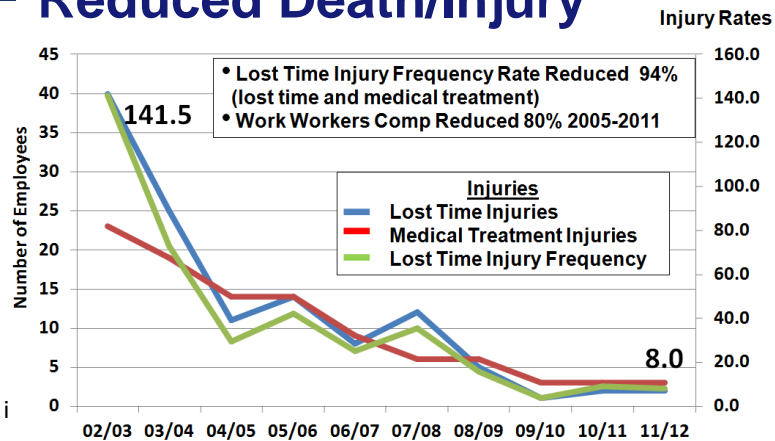## Global Shipping at Brisbane Terminal, AU

- **-27% Labor, -40% Fuel**
  - **'98: 120k lifts,122 perms, 3 cranes, 500K TEU**
  - **'12: 320k lifts, 83 perms, 5 cranes, 800K TEU**
- **Increased Precision** (MM radar, 2cm)
- **+66% Speed; -70% Maintenance**
- **Improved Cost, Use of Capital**
  - **Labor to revenue down 50% to 21%**
  - **+10% to automate, 1.5 -2yr payback**
- **Reduced Death/Injury**

PATRICK

AUSTRALIA'S LEADING SHIPPING, TRANSPORT, TRADE AND LOGISTICS NEWSPAPER

Lloyd's List DCN Special report

A TERMINAL FOR THE 21ST CENTURY

SUPPLEMENT TO THURSDAY, DECEMBER 1, 2005 /$5

March of the machines

Patrick Corp puts its revolutionary free-ranging robotic technology into full operation at its Fisherman Islands terminal – and creates global interest, reports DAVID WORWOOD

Injury Rates

- Lost Time Injury Frequency Rate Reduced 94% (lost time and medical treatment)
- Work Workers Comp Reduced 80% 2005-2011

141.5

8.0

Injuries
- Lost Time Injuries
- Medical Treatment Injuries
- Lost Time Injury Frequency

Number of Employees

02/03 03/04 04/05 05/06 06/07 07/08 08/09 09/10 10/11 11/12

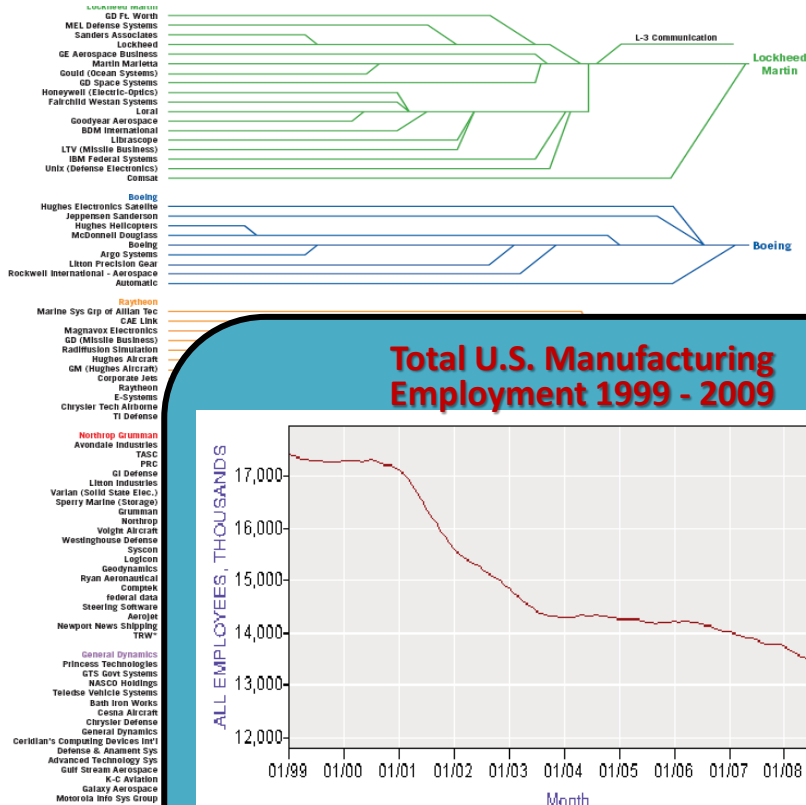See video at: tinyurl.com/brisbane-port-autonomy

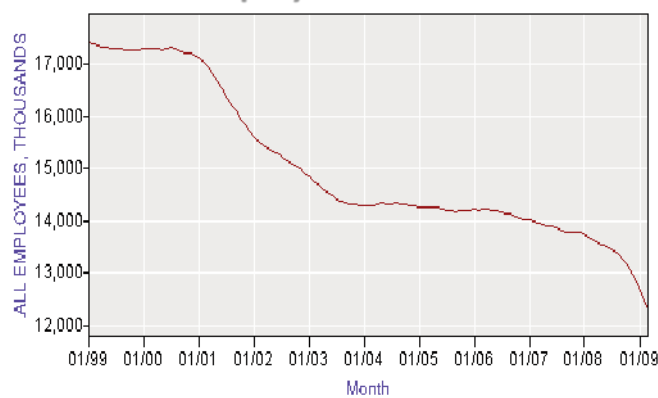blic release; distribution i

28

Manufacturing and Materials Trends

DoD Industry Consolidation

Total U.S. Manufacturing Employment 1999 - 2009

Source: MANUFACTURING&TECHNOLOGY NEWS, April 17, 2009

Declining

- **Domestic availability of critical raw materials**
- **US Intellectual dominance**
- **Manufacturing and industrial base**
- **Dominance of DoD M&P needs**
- **STEM resources**
- **Domestic engineering talent**
- **Development of major weapon systems**
- **Experience-base of aging workforce**
- **Capability/value of current technologies**

Increasing

- **Non-traditional battlespaces**
- **Rogue access to manufacturing capability**
- **Restrictions & Regulations (Environmental+)**

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Agile Manufacturing for Rapid & Affordable Fielding

Affordable Capability…… New Systems /sub-systems

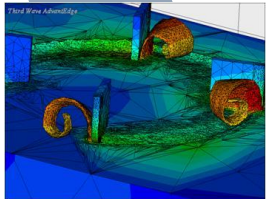**Networked Collaborative Design: 60% less time**

500 lb Multi INT Sensor Pod

EO Sensor

IR Sensor

HSI Sensor

LIDAR Sensor
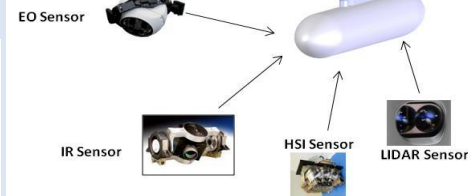
Open Architecture ISR Pod

Seeker | Mission Computer / Guidance | Payload / Effect | Aerodynamics | Propulsion
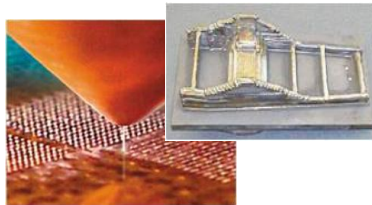
Flex Weapons

From S&T to the Field: Faster @ Less Cost

4. Add. Manuf

Detection

Model-Based/ Virtual Mfg: 50% less time

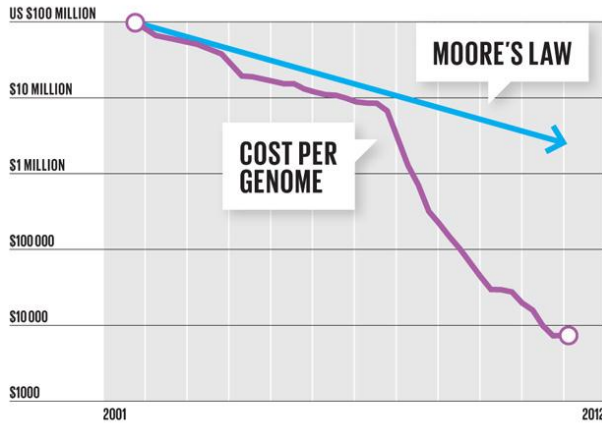**Direct Digital & Additive Mfg: Small lot production**

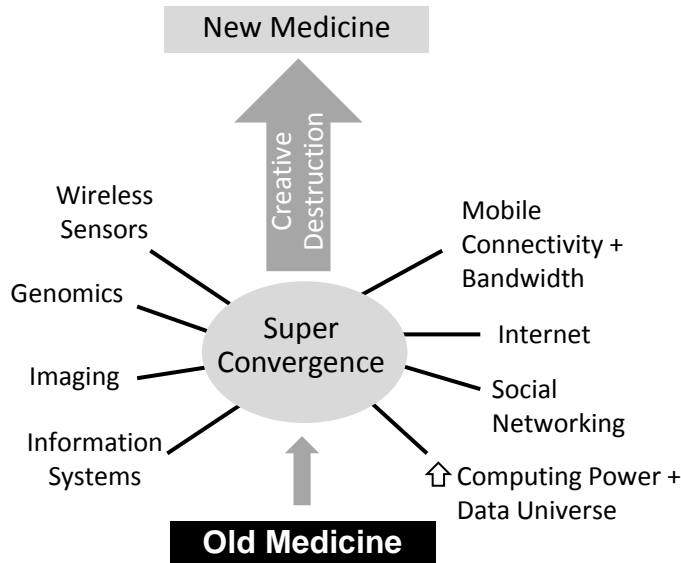**Auto/Digital Inspection: 20% less time**

Automated Assembly: 30% less time

Personalized Medicine/Performance

Source for Data: National Human Genome Research Institute. The big drop, beginning in 2008, is due to the proliferation of next-gen sequencing machines.[8]

Source: Eric Topol; The Creative Destruction of Medicine. Super convergence of global trends that is enabling Personalized Medicine.[4]

- **Increased Precision**

Diagnostic accuracy
- 1300 Genetic tests for ~2500 conditions, new tests emerging monthly

Patient-specific treatments
- '06: 13 vs '11: 72 (5.5x) prominent personalized products

Reduce trial-and-error prescribing
- Current: Yearly, 6.7% patients experience serious adverse drug reactions; Future: PM can decrease this

- **Increased Efficiency**

Rapid genomics: '01=13yrs, '12=24 hrs (Decade to day)

Growth of Electronic Medical Records -
for shared data & evidence-based medicine: US physicians w/EMRs '01=18.2%, '10=50.7%

Reaching patient crowds via Social Media -
@Novartis – 20K followers; @pfizer_news – 24K followers, @JNJComm – 13K followers

- **Decreased Cost**

Affordable genomics '01=$2.7B, '12=$5K

Success in prevention/successful treatment of chronic disease is TBD, but $ savings could be revolutionary

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Enabling Technologies

Area	Near (FY13-17)	Mid (FY18-22)	Far (FY23-27)
Materials sciences	Nanomat'ls and devices (F) Flexible electronics (F) Concept carbon devices (F) Metamaterial antennas etc (L/F) Photonic/plasmonic and quantum concept devices (L/F)	Molecular-engineered mat'ls and devices (F) New carbon electronics (F) Metamaterial devices (L/F) Photonic/plasmonic and quantum nanodevices (L/F)	Convergent nano-bio devices (F) Ubiquitous carbon electronics (F) Fully integrated metamaterial devices (L/F) Integrated photonic/plasmonic and quantum nanodevices (L/F)
Biotechnologies	Biomaterial prototypes (L/F) Bioelectronic studies (F) Human-machine interface designs and concepts (L/F)	Biomaterial components (L/F) Bioelectronic devices (F) Human-machine interfaces (L/F) Neuro-electronic devices (F)	Biomaterial systems (L/F) Bioelectronic systems(F) Human-machine interfaces (L/F) Neuro-based electronics (F)
Autonomous and robotic systems and platforms	Human-like communications (F) Trusted, robust systems and teams (L/F) Capable platforms (L)	Systems in adversarial environments (L/F) Real-time communications (L/F) Capable platforms (L)	Self-learning collective performance, with minimal human supervision, in adversarial environments (L)
Knowledge discovery and decision-making tools	Crowdsourcing (F/W) Data collection / transmission algorithms (L/F) Knowledge discovery tools (F)	Crowdsourcing (L) Integration with planning (L) Knowledge discovery from huge data sets (F)	Crowdsourcing (L) Real-time data-to -decisions tools under adversarial conditions (L) Even-more-complex data sets (F)
Forecasting and effects influence	Social datamining tools (F/W) Effects quantification studies (L) Cognitive-effects modeling (L)	Social sensors (W/F) Social movement prediction (F) Suite of influence tools (L)	Confident, probabilistic prediction methods (F) Influence tools integrated into planning (L)

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Global Horizons (GH) Next Steps

RFI
- Draft RFI 1 Jan
- Release RFI 15 Jan
- RFI returns 15 Feb
- RFI Review 25 Feb

Visits
- Bio/Pharma Boston 21-22 Feb
- Akamai, Kiva 1Mar
- P&G, Honda 21-22 Mar
- iRobot 28 Mar
- UK, Germany 15-19 Apr

Summits/ Workshops
- ACC Air Superiority Innovation Summit 4 Jan
- GH Kickoff 23 Jan
- USAFA GH Briefing 1 Feb
- Space Summit 27-28 Feb
- C2 Summit 19 Mar WPAFB
- Air Summit 19-20 Mar WPAFB
- Cyber/IT Summit 25-27 Mar Rome, NY
- Genetic Summit 17/18 Apr

Virtual Team Coordination Meetings

Weekly Working Meetings
- GH AFRL/RI Tele Kickoff 17 Jan
- GH-Team Telco 25 Feb
- GH-Team Telco 18 Mar 1-5pm
- GH-Team Telco 22 Apr, 1-5pm
- GH-Team Telco May

Products/Events (**Team Leads**; AF/ST)
- AF SAB 15 Jan
- SecAF Vector Check 7 Feb
- Trends/Threats/Opps Briefing 25 Feb
- SecAF/GO/SES Vector Check 27 Mar, 4E878
- Brief to SERG 27 Mar for 1 Apr SAFTAS
- 1 Pager 5 April
- 5pp Annex (Opt) 15 April
- Final Slides/1 Pager 1 May
- Report to SERG 3 May for 6 May SAFTAS
- SecAF/GO/SES Final Brief 9 May MC800
- Final Report to SecAF/CSAF 1 June

Jan | Feb | Mar | Apr | May | Jun

today

B = Briefing
D = Document
SERG = Senior External Review Group

Final Briefing (7 May 2013)
Final Report (1 June 2013)

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UNITED STATES AIR FORCE
CHIEF SCIENTIST