U.S. AIR FORCE

Headquarters U.S. Air Force

Air Force Global Horizons

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Integrity - Service - Excellence

The Air Force is Critically Dependent on Science & Technology Advances

Powered flight

Supersonic flow

Communications

Global positioning

Stealth / LO

Long-endurance ISR

Gas turbine engine

Night attack

Aerial refueling

High-speed flight

ICBM

Space ISR

Precision strike

Space launch

Computer simulations

Directed energy

High-power lasers

Hypersonics

Rocket flight

Long-range radar

5th-gen fighters

Blended wing-body

Unmanned systems

Cyber operations

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Global Horizons Study Methodology

STRATEGY

REQUIREMENTS AND PLANS

Global Threats and
Opportunities

COCOM and MAJCOM
Requirements

CFMPs, STIPLs

CORE
FUNCTION

GLOBAL
SECTOR

Air

Trans

Space

Mfg

Cyber

Comm/IT

C2ISR

Energy

Enabling

Health

Support

Ed/Train

Global Horizons

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

AF/ST TR 13-01
1 August 2013

Independent
Senior
Expert
Review

RFI, EXPERT SUMMITS

GLOBAL PRIVATE SECTORS

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

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

the JOE
Joint Operations Environment

ALTERNATIVE
WORLDS

2011
US AIR FORCE
GLOBAL
PARTNERSHIP
STRATEGY

2011

Cyber Vision 2025

Energy Horizons

Report on
Technology Horizons
Technology Assessments and
Implications for the Air

AF/ST-TR-08-XX
31 December 2009

United States Air Force
Energy S&T Vision
2011-2020

United States Air Force
Science & Technology
Plan
13-01

Global R&D (2011)

Size of circle is relative amount of Annual R&D

Sources: Battelle R&D Magazine, International Monetary Fund, World Bank, CIA World Factbook, OECD

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Global Environment

Global Forces

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

Space:

Congested,
Competitive,
Contested

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

Global Sectors

- Manufacturing and Materials
- Transport and Logistics
- Energy and Utilities
- Health and Pharma
- Communications and IT
- Financial Services
- Education and Training

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 Domains and Globalized Industrial Sectors***

Air Challenges and Opportunities

Maturing affordable game changing S&T across the Air Domain allows us to remain ahead of near-peer threats, operate with efficiency and impunity in A2AD environments, and evolve Air Doctrine with new technologies.

Theme	Near (FY13-17)	Mid (FY18-22)	Far (FY23-27)
High Speed Systems/Directed Energy	Weapons (L) High Power Microwave missile (L) Target identification (pulsed lasers) (L)	High Speed Systems ISR platforms (L) Directed Energy Mounted a/c self protect (CW electric lasers) (L)	Reusable, responsive platforms (L) Integrated a/c self protect; speed-of-light strike (L)
Autonomy/Distributed Decision Making/Fractionated Systems	Distributed mission planning (L) Sense and avoid (L) Automat/Autonomous formation flight (L)	C2 and Communications Automated terminal area operations (F*) Platform and Operations Cooperative and autonomous control (L)	Human/machine cognitive communications (F*) Human/machine teaming (F*)
Advanced Aircraft Adaptive Architecture	Enhanced analysis for V&V (F*) Certification of composite structures (F*) Large composite structures (F*)	Processes System-of-system certification (F*) Products Modular aircraft architectures (F*) Plug-and-play avionic interface (L)	Automated assembly and quality assurance (F*) Universal weapon system interface (L)
Small Munitions/Long Range Missiles	Cooperative control & selectable effects (L) Self-realizing and adaptive guidance (L)	Small munitions Multi-purpose, multi-mode effects packages (L) Long Range Missiles Sensor/seekers, apertures, payload, guidance (L)	Optimized internal carry design (L) Real-time adaptive software (L)
Energy Efficient Aircraft and Propulsion Design	ADVENT/AETD/ESSP (L) Thermal management/adaptive cycles (F*) Laminar flow control (F*) Conformal antennae (F*)	Propulsion and Power HEETE (L) On-demand integrated subsystems (L) Airframe/Aerodynamics Lightweight, unitized structure (F*) Adaptive structure and active flow control (F*)	Adaptive HEETE (L) Hybrid systems/distributed propulsion (F*) Supersonic tailless designs (L) N+1 generation efficient aircraft configurations (F*)

* AF should follow industry, unless a specific AF application is identified.

Air Domain Highlights

- **Key Challenge will be Contested Environment (A2/AD)**
 - **Future adversaries will have 5th Aircraft, UAVs & systems to undermine our ability to operate with impunity**
 - **Drives our focus to new capabilities to regain our critical edge**
 - **Long range precision strike**
 - **Hypersonics**
 - **Directed energy Weapons**
 - **Precise targeting, disrupt/destroy electronics, sensing, blind/destroy sensors**
 - **Precision effects, fast response, low collateral damage, deep magazine, low costs**
 - **High power microwave – non-lethal effects to disperse crowds and disrupt electronics**
 - **Anti-GPS denial, cold atom navigation, robust secure comms**

Cold-Atom Inertial Navigation Systems For GPS-Denied Environments

Position Uncertainty for 3 Scenarios

36 h loiter

20,000 m

20 m

1-3 m

Flight half-way around world

1000 m

1-3 m

1 m

Ballistic missile flight

500 m

1-3 m

0.1 m

GPS

Cold Atom INS

Laser-based INS

Cold atom INS: potentially provide orders of magnitude better performance than laser-based INS, and accuracy comparable to GPS for GPS-denied environments

Air Domain Highlights

- **RPAs will be called upon to do a larger set of missions and work as a part of mixed aircraft team**
 - **Requires systems to better support integrated operations**
 - **Trust in autonomy, distributed decision making**
 - **Need improved remote cockpits to support pilot SA**
 - **Need to be able to defend against enemy RPAs**
 - **Global market to double by 2022, largest sales in Asia**
- **More efficient engines**
 - **ADVENT – versatile components to provide extra thrust when needed, improved efficiency when needed**
 - **25% energy savings**
 - **HEETE – improved engine core to provide up to 35% energy savings**
 - **Cost savings, or increased payload, range, endurance, combat capability**

Space Highlights

- **Modern operations are highly dependent on space assets to provide comms, precision navigation and superior battlefield SA.**
- **Space will be congested, contested and competitive**
- **Need to be able to defend space assets to maintain our advantages, be agile to attacks and changing operational needs, and rapidly insert new capabilities**
 - **Highly distributed and disaggregated space assets**
 - **More agile, reliable, and defensible posture**
 - **Low-cost, small satellites**
 - **Flexible, quick, easy, inexpensive launch**
 - **Improved space situation awareness**
 - **Tracking 10's of thousands of objects**
 - **Understanding their impact on our operations**
 - **Additive manufacturing**
 - **Long term promise for rapid response and parts in space**

Cyberspace Highlights

■ **Mission assurance and empowerment**

- **Enhanced cyber situational awareness for air, space, and cyber commanders enabled by automated network and mission mapping**
- **Early vulnerability detection and enemy behavior forecasting enabled by advanced cyber ranges, including high fidelity, real-time modeling and simulation**
- **Develop offensive cyber capabilities to augment kinetic operations during wartime scenarios to affect strategic, operational and tactical missions**

■ **Agility and Resilience**

- **Effective mix of redundancy, diversity, and fractionation for survivability**
- **Reduction of attack surface, critical mission segregation, and attack containment**
- **Autonomous compromise detection and repair (self healing) and real-time response to threats**
- **Transition from signature based cyber sensors to behavior understanding to enhance high performance attack detection**
- **Active defense requires rapid maneuver enabled by dynamic, reconfigurable architectures (e.g., IP hoping, multilevel polymorphism)**

Cyberspace Highlights

- **Optimized human-machine systems**
 - Measurement of physiological, perceptual, and cognitive states to enable personnel selection, customized training, and (user, mission, and environment) tailored augmented cognition.
 - High performance visualization and analytic tools to enhance situational awareness, accelerate threat discovery, and empower task performance.
 - Autonomy appropriately distributed between operators and machines, enabled by increased transparency of autonomy and increased human “on the loop” or supervisory control.
- **Software and hardware foundations of trust**
 - Operator trust in systems (e.g., sensors, communications, navigation, C2) enabled by trusted foundries, anti-tamper technologies, and supply chain assurance, as well as effective mixes of government, commercial off the shelf, and open source software
 - Formal verification and validation of complex, large scale interdependent systems
 - Advanced vulnerability analysis, automated reverse engineering, real-time forensics tools
 - High speed encryption, quantum communication, and quantum encryption for confidentiality and integrity

System Design, Material, & Manufacturing Highlights

- **Open system architectures**
 - Plug-n-play, modular, standardized components
 - Standardized interfaces
 - Critical for technological agility
 - Threats change, technology changes
 - Need to be able to rapidly modernize
- **More efficient systems**
 - Design for maintainability
 - Design for operability (human-system integration)
 - Energy efficiency
- **Seamless thread from design to manufacturing to maintainability**
 - Rapid prototyping test environments
 - Significant build up of modeling and simulation tools
 - Digital thread
 - connectivity of test data/models to provide integrated information on a system
 - Digital twin
 - life time model of system to make maintenance & logistics customized
- **Additive manufacturing**

Agile Manufacturing for Rapid & Affordable Fielding

Affordable Capability..... New Systems /sub-systems

Networked Collaborative Design: 60% less time

Seeker Mission Computer / Guidance Payload / Effect Aerodynamics Propulsion

Flex Weapons

EO Sensor

IR Sensor

HSI Sensor

LIDAR Sensor

Open Architecture ISR Pod

**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**

C2ISR Highlights

- **Data transformed into higher levels of SA**
 - **Swimming in sensors, drowning in data**
 - **Integrate data and provide rapid “at a glance understanding of information” using cognitive engineering tools**
- **Integrated networked operations (connect 4th gen and 5th gen aircraft), sensors, command centers across air,space, cyber, sea, ground**
 - **Secure, resilient, agile, and high capacity air-space-and-surface network to enable joint and multinational global C2 and ISR.**
 - **Fully integrate weapon systems and PCPAD across air, space, and cyberspace to achieve synchronized effects**
 - **Provide processing to provide the right information to each user based on goals/decision needs**
 - **Cognitive modeling to provide better funneling of information under limited bandwidths**
- **Effective human/automation teams**
 - **Develop flexible autonomy and all-source fusion technologies for enhanced analysis and planning capabilities for C2 and ISR.**

Missed Opportunities, Needed Technology Developments

*Defense Science Board , Task Force on the
Role of Autonomy in the DoD Systems, 2012*

Need Effective Synergy of the Human/Automation Team

- **Synergistic human & automated agent team is critical to success**
 - **Overseeing what system is doing**
 - **Intervening when needed**
 - **Coordination and collaboration on functions**
- **Main benefits of autonomous capabilities are to extend and complement human performance, not provide a direct replacement of humans**
 - **Extend human reach: perception, action, speed, persistence, size, scale, fatigue**
 - **Permit delegation and reduction of cognitive load – if explicitly designed to do so**
 - **Expand the adaptive capacity of the warfighter (e.g., more options, more flexibility)**
 - **Synchronize activities of UxS, software, and warfighter over wider scopes and ranges**

Trust in Autonomy: Verification & Validation of Software

- Systems and software V&V a major cost and schedule driver
- High level of autonomy will require new V&V methods
- IVHM for mission survivability
- Complex adaptive systems with autonomous reconfigurability
- Approach infinite-state system even for moderate autonomy
- Data/communication loss link and latencies exacerbate
- Traditional methods based on requirements traceability fail
- Extremely challenging problem; must overcome for “trust”
- Requires entirely new approach
- Graceful degradation, “safeing”

Future C2 & ISR

**Integrated
Networked
Operations**

**Trusted
Resilient
Software &
Cyberspace**

**Effective
Human &
Automation
Teams**

**Data Transformed
Into Higher Levels
Of Situation Awareness**

Built on a platform for rapid innovation, prototyping and testing

Air Force Global Horizons

- **Sets Air Force Science and Technology Vision 2013-2027**

<http://www.af.mil/Portals/1/documents/news/GlobalHorizons.pdf>

CORE FUNCTION	GLOBAL SECTOR
Air	Transportation
Space	Matl & Manf
Cyber	Comm/IT/Finance
C2&ISR	Energy
Support Tech	Pharma & Health
Enabling S&T	Education & Train

Research Opportunities

- All opportunities published at www.grants.gov
- Search for AFRL
 - Research Interests of the Air Force Office of Scientific Research - BAA-AFOSR-2014-0001
 - Human-Centered Intelligence, Surveillance - BAA-HPW-RHX-2014-0001
 - Space Vehicles (RV) University Grants Program -FOA-RVKV-2013-0001
 - AFRL/RXC Structural Materials Open/Open BAA Program - BAA-RQKM-2014-0003
 - AFRL Research Collaboration Program -BAA-RQKM-2013-0005
 - Sensor Innovative Research -BAA-12-02-PKS
 - University Small Grants Broad Agency Announcement - BAA-RDK-2012-0001
 - Metamaterials for RF and Optical Applications- BAA-12-01-PKS
 - Air Force Medical Support Agency(AFMSA/SG9) Modernization Directorate Research/Development and Innovations -BAA-11-03-HPW

Logistics Highlights

- **Goal – to reduce logistics footprint of Air Force by 50% by 2025**
 - **Automated warehousing, shipping, support tasks**
 - **Additive manufacturing for on-site, on-demand parts**
 - **Improve logistics SA**
 - **Precision air drop/support of forward bases**

Healthcare Highlights

- **Increased use of personalized healthcare**
 - Apps/tools in the hands of individuals
 - Genomic based treatments
 - Electronic records and customization of treatments/jobs
- **Bio-Adaptable systems**
 - Physiologic monitoring tied to adaptive response systems
 - E.g. O2Sat, EEG, EKG
- **Medevac**
 - Care anywhere healthcare
 - Continuous quantification of health/readiness

Education and Training Recommendations

- **Pursue a Live, Virtual, and Constructive Training and Education Initiative**
 - Efficiently mix live and virtual with the increasingly realistic constructive players, software agents and job aids
 - Devise persistent metrics/assessments in achieving readiness goals
 - Expand scope: include strategic/operational level warfare, more players, international cooperation.

- **Outcomes:**
 - Stress warfighter in combat relevant contexts (current & future conflicts)
 - Generate greater efficiencies and effectiveness from focused E&T
 - Broadened participation and value from use in educational venues
 - Sets USAF priorities/creates conditions to enable all other S&T areas

Communications, IT, Finance Recommendations

- **Leverage innovative open source approaches to tap technical commonalities across the Comm/IT/Finance sectors**
 - Co-invest with international partners
- **Lead S&T for high performance embedded computing across air, space and cyber A2AD environments**
 - 3-D chip stacking, nano-technology, and quantum computing
 - Size, weight, and power constrained applications
- **Develop open architecture post-JTRS “cognitive” communications for agile, networked, cost effective communications in A2AD scenarios**
- **Leverage and adapt global sector expertise in “big data” analytics across multiple disparate sources**
 - Develop real-time analytics for ISR (Cyber/SIGINT/EW) akin to financial sector
 - Focus petascale computing on neuromorphic and symbolic approaches to computational intelligence
 - Adapt discovery/fusion ideas from IT/Finance to Multi-int ISR problems

Enabling Technologies

Area	Near (FY13-17)	Mid (FY18-22)	Far (FY23-27)
Materials sciences	<ul style="list-style-type: none"> Flexible electronics available for military use (F) Metamaterial-based antennas, detectors, coatings (F) 	<ul style="list-style-type: none"> Molecular-engineered materials and devices (F) Metamaterial-based optical detectors and filters (F) Large-airplane cold-atom navig. (L) 	<ul style="list-style-type: none"> Chip-based cold-atom navigation (L) Tunable metamaterial devices (F) Plasmonic-based high-speed/ low-power photonics (F)
Biotechnologies	<ul style="list-style-type: none"> Biosensors (F) Human-machine interface: control of biotic/abiotic¹ interfaces (F) Synthetic biology and Epigenetic control (F) 	<ul style="list-style-type: none"> Bioelectronic devices (F) Computer-enhanced human sensing (F) Large-scale neuromorphic computer (W) 	<ul style="list-style-type: none"> Synthetic bio for adaptable devices, mat'l's, fuels, electronics (F) Computer enhanced human cognition (F) General-purpose neuromorphic computer (W)
Autonomous and robotic systems and platforms	<ul style="list-style-type: none"> Human-on-the-loop air vehicles (F) Information visualization & understanding tools (F) 	<ul style="list-style-type: none"> Trusted, robust human-machine teams (F) Collective performance in adversarial environments (F) 	<ul style="list-style-type: none"> Self-learning collective performance, with minimal human supervision, in adversarial environments (F)
Knowledge discovery and decision-making tools	<ul style="list-style-type: none"> Crowdsourcing (W) Prize competitions (W) Data collection / transmission algorithms (F) Knowledge discovery tools (F) 	<ul style="list-style-type: none"> Integration with planning (L) Knowledge discovery from exabyte-sized data sets (F) 	<ul style="list-style-type: none"> Real-time data-to-decision tools under adversarial conditions (L)
Social forecasting and effects influence	<ul style="list-style-type: none"> Actionable foreign culture insight and tools (L) Actionable insight for trust in automation (F) Cognitive-effects modeling (F) 	<ul style="list-style-type: none"> Actionable prediction of weapons effects on behavior (F) Influence tool suite for AF effects (L) Trusted foreign-use autonomous sys (F) 	<ul style="list-style-type: none"> Influence tools integrated into mission planning (L) Cyber tools for influence (L) Trusted domestic-use autonomous systems (F)

¹The design of effective interfaces to facilitate seamless integration of human (biotic) and machine (abiotic).

Mission Support Recommendations

- **Experiment with new cross-domain Digital Design Tools**
 - Identify pilot programs to integrate System of System concept trades & digital design tools
 - Verify claims the new tools reduce development time by at least 25% and save program costs

- **Reinvigorate a technology demonstration prototype program**
 - Reallocate resources to increase the number of technology demonstrations
 - Explore feasibility and utility of creating small, independent rapid prototype teams comprised of Product Centers, Labs, Users, Academia, and Industry
 - Leverage external technical talent through Open Challenges and produce novel technologies and solutions at a fraction of the time and cost to conventional processes

Energy Challenges and Opportunities

Competition

World Energy Consumption
(quadrillion Btu)

World Oil Price (Uncertainty)
(\$ per barrel)

More Capability, More Fuel

Theme	Near (FY13-17)	Mid (FY18-22)	Far (FY23-27)
Reduce Demand / Increase Efficiency	<ul style="list-style-type: none"> Propulsion: ADVENT (L) Aero: Blended Wing (F), Lifting Body, Laminar Flow Optimization Thermal Management Cycles (F) M&S: Systems of Systems (L) 	<ul style="list-style-type: none"> Propulsion: HEETE (L) Energy Harvesting for RPAs (L) Energy Harvesting: Thermoelec/ pyroelectric Development (F) Cyber Energy Efficiency (F) 	<ul style="list-style-type: none"> Propulsion: Adaptive HEETE (L) Hybrid Sys/Distributed Propulsion (F) N+1 Gen Efficient Aircraft Config (F)
Increase Supply / Storage	<ul style="list-style-type: none"> Alternative Fuels (F) Adaptable Storage/Emerging Battery Technologies (F) 	<ul style="list-style-type: none"> Inverted Meta-Morphic Space Photovoltaic Array Storage: Nano Materials (L) 	<ul style="list-style-type: none"> Superconducting Magnetic Storage (W)
Energy Resiliency	<ul style="list-style-type: none"> Micro Grid (F) Alternative Fuels (F) 	<ul style="list-style-type: none"> Alternative Fuels (F) 	<ul style="list-style-type: none"> Compact Self Contained Nuclear Reactor (W)
Directed Energy		<ul style="list-style-type: none"> DE Power Beaming (L) DE Kinetic Weapon Alternative 	<ul style="list-style-type: none"> DE Power Beaming (L) DE Kinetic Weapon Alternative (L)