Air Force Global Horizons

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19 March 2014
The Air Force is Critically Dependent on Science & Technology Advances

- Powered flight
- Gas turbine engine
- Aerial refueling
- Rocket flight
- Supersonic flow
- Night attack
- High-speed flight
- Long-range radar
- Rocket flight
- Communications
- Global positioning
- ICBMs
- Space ISR
- 5th-gen fighters
- Precision strike
- Space launch
- Blended wing-body
- Unmanned systems
- Directed energy
- High-power lasers
- Stealth / LO
- Computer simulations
- Long-endurance ISR
- Hypersonics
- 5th-gen fighters
- Global positioning
- Communications
- Night attack
Global Horizons
Study Methodology

STRATEGY

Requirements and Plans

COCOM and MAJCOM

Requirements

Independent
Senior
Expert
Review

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

AF/ST TR 13-01
1 August 2013

RFI, EXPERT SUMMITS

GLOBAL PRIVATE SECTORS

GLOBAL THREATS AND OPPORTUNITIES

Air
Space
Cyber
C2ISR

CORE FUNCTION

GLOBAL SECTOR

Air
Space
Cyber
C2ISR

Mfg
Comm/IT
Energy
Health
Support
Ed/Train

Global Vigilance, Reach and Power dependent upon contested Global Domains and Globalized Industrial Sectors
Global Horizons
1999-2025+

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)

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

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

Global R&D (% foreign)

Climate Change
+1.25°F, +5% Humidity

Global Horizons
1999-2025+

CMOS
– Complimentary Metal–Oxide Semiconductor; IC
– Integrated Circuit
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
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

Global Environment

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

Space: Congested, Competitive, Contested

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.

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

* * AF should follow industry, unless a specific AF application

**Contested world vs Rest of world vs US**

- Boeing Market Outlook (2012)

**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.**
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 m
- 1-3 m

Ballistic missile flight
- 500 m
- 0.1 m
- 1-3 m

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

Direct Digital & Additive Mfg: Small lot production

Auto/Digital Inspection: 20% less time

Automated Assembly: 30% less time

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

Flex Weapons

Open Architecture ISR Pod

Destined for Society

Model-Based/ Virtual Mfg: 50% 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

Under-utilized existing capability

Open technical challenges needing investment

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

Data Transformed
Into Higher Levels
Of Situation Awareness

Trusted
Resilient
Software &
Cyberspace

Effective
Human &
Automation
Teams

Built on a platform for rapid innovation, prototyping and testing

Distribution A. Approved for public release; distribution is unlimited.
Air Force Global Horizons

- Sets Air Force Science and Technology Vision 2013-2027

<table>
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<tr>
<th>CORE FUNCTION</th>
<th>GLOBAL SECTOR</th>
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<tbody>
<tr>
<td>Air</td>
<td>Transportation</td>
</tr>
<tr>
<td>Space</td>
<td>Matl &amp; Manf</td>
</tr>
<tr>
<td>Cyber</td>
<td>Comm/IT/Finance</td>
</tr>
<tr>
<td>C2&amp;ISR</td>
<td>Energy</td>
</tr>
<tr>
<td>Support Tech</td>
<td>Pharma &amp; Health</td>
</tr>
<tr>
<td>Enabling S&amp;T</td>
<td>Education &amp;Train</td>
</tr>
</tbody>
</table>

Global Horizons
United States Air Force Global S&T Vision 2013-2027
AF/ST TR 13-01
1 June 2013
Research Opportunities

- All opportunities published at [www.grants.gov](http://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

<table>
<thead>
<tr>
<th>Area</th>
<th>Near (FY13-17)</th>
<th>Mid (FY18-22)</th>
<th>Far (FY23-27)</th>
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<tbody>
<tr>
<td>Materials sciences</td>
<td>• Flexible electronics available for military use (F)</td>
<td>• Molecular-engineered materials and devices (F)</td>
<td>• Chip-based cold-atom navigation (L)</td>
</tr>
<tr>
<td></td>
<td>• Metamaterial-based antennas, detectors, coatings (F)</td>
<td>• Metamaterial-based optical detectors and filters (F)</td>
<td>• Tunable metamaterial devices (F)</td>
</tr>
<tr>
<td></td>
<td>• Molecular-engineered materials and devices (F)</td>
<td>• Large-airplane cold-atom navig. (L)</td>
<td>• Plasmonic-based high-speed/ low-power photonics (F)</td>
</tr>
<tr>
<td>Biotechnologies</td>
<td>• Biosensors (F)</td>
<td>• Bioelectronic devices (F)</td>
<td>• Synthetic bio for adaptable devices, mat'l's, fuels, electronics (F)</td>
</tr>
<tr>
<td></td>
<td>• Human-machine interface: control of biotic/abiotic(^1) interfaces (F)</td>
<td>• Computer-enhanced human sensing (F)</td>
<td>• Computer enhanced human cognition (F)</td>
</tr>
<tr>
<td></td>
<td>• Synthetic biology and Epigenetic control (F)</td>
<td>• Large-scale neuromorphic computer (W)</td>
<td>• General-purpose neuromorphic computer (W)</td>
</tr>
<tr>
<td>Autonomous and robotic systems and platforms</td>
<td>• Human-on-the-loop air vehicles (F)</td>
<td>• Trusted, robust human-machine teams (F)</td>
<td>• Self-learning collective performance, with minimal human supervision, in adversarial environments (F)</td>
</tr>
<tr>
<td></td>
<td>• Information visualization &amp; understanding tools (F)</td>
<td>• Collective performance in adversarial environments (F)</td>
<td>• Real-time data-to-decision tools under adversarial conditions (L)</td>
</tr>
<tr>
<td>Knowledge discovery and decision-making tools</td>
<td>• Crowdsourcing (W)</td>
<td>• Integration with planning (L)</td>
<td>• Influence tools integrated into mission planning (L)</td>
</tr>
<tr>
<td></td>
<td>• Prize competitions (W)</td>
<td>• Knowledge discovery from exabyte-sized data sets (F)</td>
<td>• Cyber tools for influence (L)</td>
</tr>
<tr>
<td></td>
<td>• Data collection / transmission algorithms (F)</td>
<td>• Actionable prediction of weapons effects on behavior (F)</td>
<td>• Trusted domestic-use autonomous systems (F)</td>
</tr>
<tr>
<td></td>
<td>• Knowledge discovery tools (F)</td>
<td>• Influence tool suite for AF effects (L)</td>
<td>• Trusted foreign-use autonomous systems (F)</td>
</tr>
<tr>
<td>Social forecasting and effects influence</td>
<td>• Actionable foreign culture insight and tools (L)</td>
<td>• Cognitive-effects modeling (F)</td>
<td>• (^1)The design of effective interfaces to facilitate seamless integration of human (biotic) and machine (abiotic).</td>
</tr>
<tr>
<td></td>
<td>• Actionable insight for trust in automation (F)</td>
<td>• Trusted foreign-use autonomous systems (F)</td>
<td></td>
</tr>
<tr>
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<td>• Cognitive-effects modeling (F)</td>
<td>• Influence tool suite for AF effects (L)</td>
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</table>
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

**World Energy Consumption (quadrillion Btu)**

<table>
<thead>
<tr>
<th>Year</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2035</th>
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<tr>
<td>Value</td>
<td>354</td>
<td>406</td>
<td>505</td>
<td>619</td>
<td>671</td>
<td>721</td>
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</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>1992</th>
<th>2002</th>
<th>2012</th>
<th>2022</th>
<th>2032</th>
<th>2042</th>
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</thead>
<tbody>
<tr>
<td>Value</td>
<td>731</td>
<td>1660</td>
<td>1754</td>
<td>3002</td>
<td>1500</td>
<td>1000</td>
</tr>
</tbody>
</table>

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**Theme**

**Near (FY13-17)**

- **Reduce Demand / Increase Efficiency**
  - Propulsion: ADVENT (L)
  - Aero: Blended Wing (F), Lifting Body, Laminar Flow Optimization
  - Thermal Management Cycles (F)
  - M&S: Systems of Systems (L)

- **Increase Supply / Storage**
  - Alternative Fuels (F)
  - Adaptable Storage/Emerging Battery Technologies (F)

- **Energy Resiliency**
  - Micro Grid (F)
  - Alternative Fuels (F)

- **Directed Energy**
  - DE Power Beaming (L)
  - DE Kinetic Weapon Alternative (L)

**Mid (FY18-22)**

- **Reduce Demand / Increase Efficiency**
  - Propulsion: HEETE (L)
  - Energy Harvesting for RPAs (L)
  - Energy Harvesting: Thermoelectric/pyroelectric Development (F)
  - Cyber Energy Efficiency (F)

- **Increase Supply / Storage**
  - Inverted Meta-Morphic Space Photovoltaic Array
  - Storage: Nano Materials (L)

- **Energy Resiliency**
  - Alternative Fuels (F)

- **Directed Energy**
  - DE Power Beaming (L)
  - DE Kinetic Weapon Alternative (L)

**Far (FY23-27)**

- **Reduce Demand / Increase Efficiency**
  - Propulsion: Adaptive HEETE (L)
  - Hybrid Sys/Distributed Propulsion (F)
  - N+1 Gen Efficient Aircraft Config (F)

- **Increase Supply / Storage**
  - Superconducting Magnetic Storage (W)

- **Energy Resiliency**
  - Compact Self Contained Nuclear Reactor (W)

- **Directed Energy**
  - DE Power Beaming (L)

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