Air Force Space Command Strategic S&T Challenges

August 23-24, 2016

Briefers from AFSPC/
ST, A2/3/6, A2/3/6SF, A2/3/6SR, A5C, A5XC, A5FE, A8XP, 24AF

Why We Must Invest in Science and Technology

"Victory smiles upon those who anticipate the changes in the character of war, not those who wait and adapt themselves after the changes occur." *

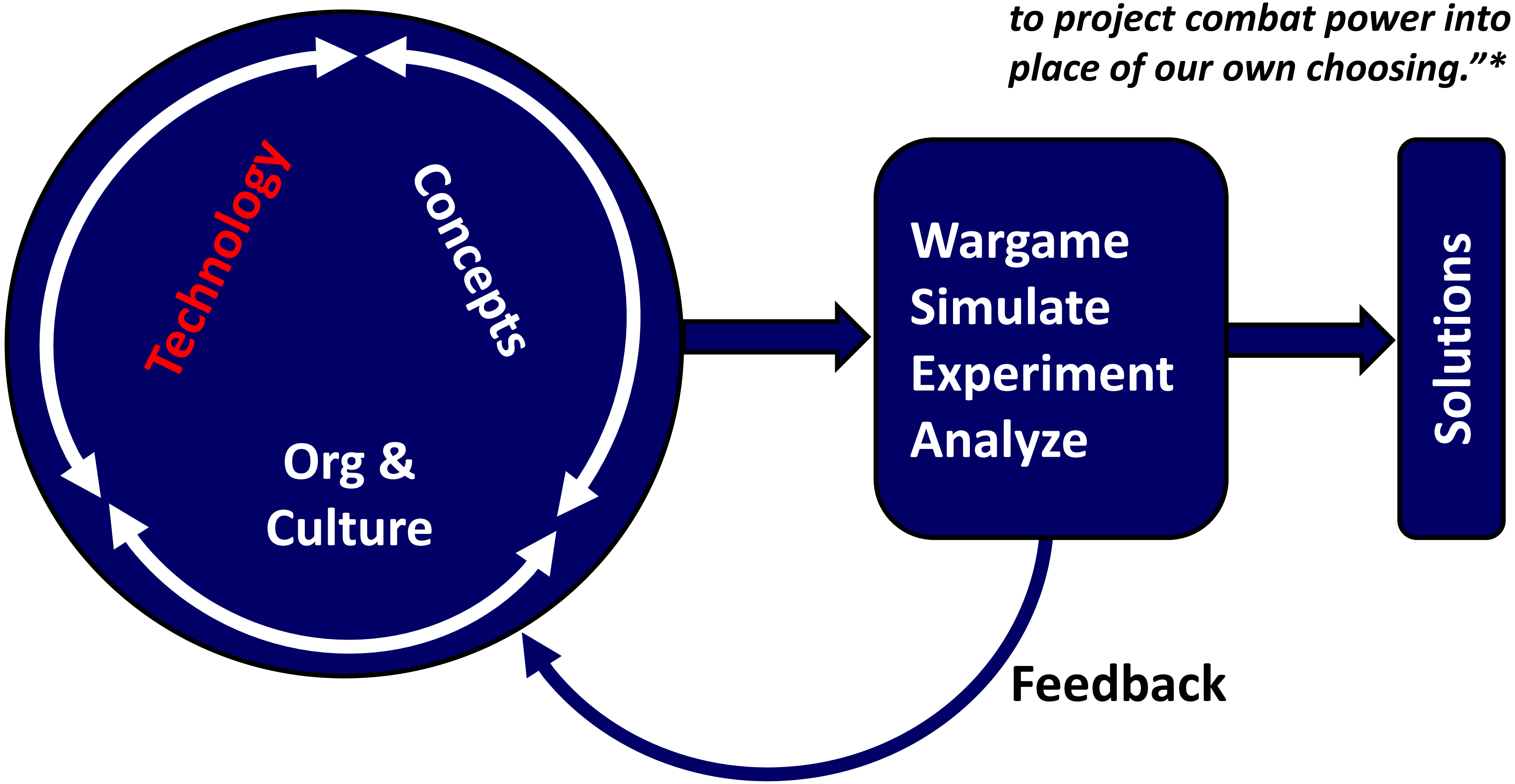
Giulio Dauhet

Italian Airpower Theorist, 1928

* Taken from the Forward of the Air Force Space Command Commander's Strategic Intent

Shaping the Future Force

*"A combination of technology, operational concepts, and organizational constructs to maintain our ability to project combat power into any area, at a time and place of our own choosing."**



*Speech by Defense Deputy Secretary Robert Work at the European Policy Center, 29 April 2016
http://www.defense.gov/News/Article/article/746336/work-us-nato-must-use-21st-century-approaches-for-deterrence-dominance

Why Operational Agility Matters

- **Air Force Future Operating Concept:**
  - **“In 2035 AF Forces will leverage operational agility as a way to adapt swiftly to any situation or enemy action. Operational agility is the ability to rapidly generate – and shift among – multiple solutions for a given challenge.” [pg. 2]**
  - **“The AF Future Operating Concept envisions a future in which information technologies permeate almost every object. Cyberspace will no longer be clearly separable from the physical domains, as actions in cyberspace will create effects in all other domains.” [pg. 6]**

http://www.af.mil/Portals/1/images/airpower/AFFOC.pdf

AFFOC Implications

- *Diverse portfolio of air/ space/cyber capabilities*
- *Multi-domain counters to A2/AD environments*
- Modern munitions, emitters, and platforms
- Tailored forward presence and streamlined logistics
- *Autonomous processing, exploitation, dissemination*
- Reduced classification barriers
- *Advanced decision aids for human/system teaming*
- *Advanced M&S for multi-domain operations*
- *Human/computer systems and networks for secure collabora*tion
- Improved trust relationships for enhanced teaming
- *Mix of manned, remotely operated, and autonomous systems*
- *Modular and configurable systems*
- Balanced pool of airmen expertise and experience
- Organic additive manufacturing
- Cognitively-ready airmen
- *LVC training for multi-domain operations*
- Optimized Human-Systems Integration
- *Human-System teaming for ISR/C*2
- Strong external partnerships

*_Air Force Future Operating Concept: A View of the Air Force in 2035_, September 2015

Long Term Space S&T Challenges

S1 - Enhanced multi-domain and multi-phenomenology Space Situational Awareness, Battlespace Awareness, and ISR

S2 - New technologies applicable to space based capabilities

S3 - Enhanced space access and logistics

S4 - New concepts in space ground operations

S5 - Dynamic new technologies applicable to all space systems

Long Term S&T Challenge:
Enhanced multi-domain and multi-phenomenology Space Situational Awareness, Battlespace Awareness and ISR - S1

Briefer: Dr Michele Gaudreault

Contributors: Kevin Hopkins
Bob Lopez

Why [S1] matters to AFSPC

- Current situation
  - Stovepipes – systems don’t talk to one another
  - Lack of real-time communication impacts situational awareness
  - Data reliability
  - Lots of disparate data, but lack ability to turn it into information
- Why this is not enough
  - Distractors impact operations
  - Can’t distinguish between natural space effects and intentional interference
- How should this look in the end?
  - Quick identification of emerging threats
  - Multi-level, multi-domain fusion of information to enable complete, real-time Battlespace Awareness

S1. Enhanced multi-domain and multi-phenomenology Space Situational Awareness, Battlespace Awareness and ISR – Effective use of advancing sensor technologies to provide information of activities in the terrestrial, air, and space domains, including exploitation of multiple spectral regimes (infrared, ultraviolet, radio, optical, etc.), and the integration and human interface of the sensor-derived information.

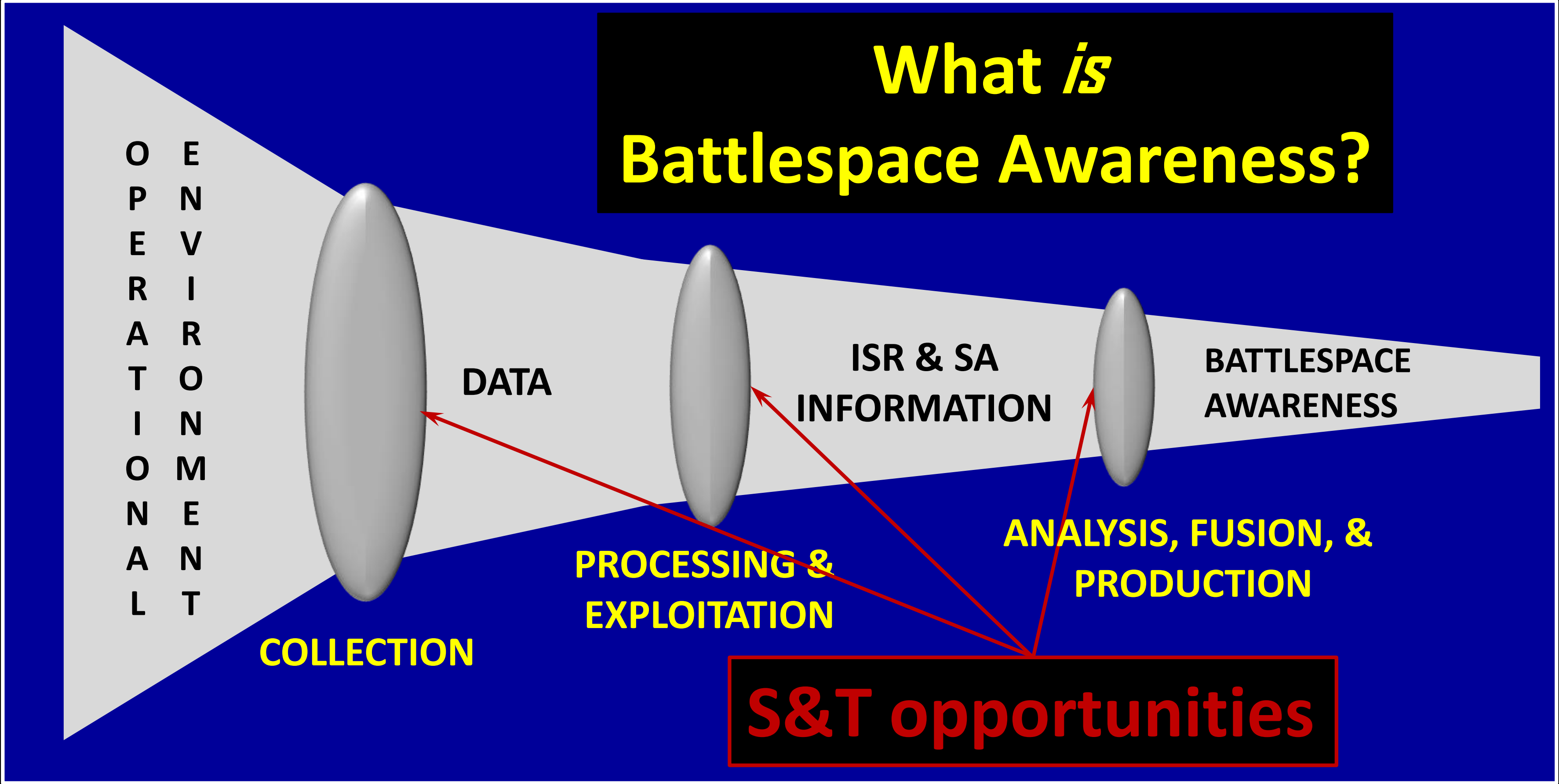
S1.a. Technologies that will provide commanders with pre-decisional understanding of the space situation, adversary actions, environmental variables, attribution (natural versus man-made), and present courses of action. Predictive technologies underpinned by trusted data sources and resilient communication systems.

S1.b. New technologies/techniques to improve visualization and understanding.

S1.c. Technologies could include improved sensors which will provide detection and characterization of all events of interest in a format which will be ingestible by the Command and Control (C2) systems.

S1.d. Revolutionize space and cyberspace Battle Management Command and Control (BMC2) and integrate these capabilities tightly with other multi-domain military operations.

SA + ISR = BATTLESPACE AWARENESS



SSA & Predictive technologies - S1.a

- Technologies that will provide commanders with pre-decisional understanding of the space situation, adversary actions, environmental variables, attribution (natural versus man-made), and present courses of action.
- Predictive technologies underpinned by trusted data sources and resilient communication systems.

- We need *reliable data*, *advanced processing and analysis techniques*, and *robust methods to convey* the decision space to the commander.

New visualization technologies/techniques - S1.b

- New technologies and techniques to improve visualization and understanding.

- We need better ways to enable space operators to quickly comprehend and integrate the diverse space environment technical collects and understand the implications of activities occurring in space.

Improved sensors for detection & characterization - S1.c

- Technologies could include improved sensors which will provide detection and characterization of all events of interest in a format which will be ingestible by the Command and Control (C2) systems.

- Better characterization of the space environment – and the ability to convey ingest that information into our C2 systems – is critical to attaining space superiority

Integrated, Revolutionary BMC2 across all domains - S1.d

- Revolutionize space and cyberspace Battle Management Command and Control (BMC2) and integrate these capabilities tightly with other multi-domain military operations.

- To regain the upper hand in space and cyberspace, we need to transform our C2 systems and fully integrate them with air, land, and sea military operations.

Final Thoughts – S1

- **Quick identification of emerging threats**
- **We need technology to enable the intelligent fusion of ISR and SSA to provide decision quality information to commanders**
  - **Multi-level, multi-domain, timely**
- **Fully integrated C2 systems with our joint and allied partners**

- **Questions:**
  - Can sensors be developed which operate in new or broader portion of the spectrum?
  - How can sensor information be processed (including integration of various types of sensors and mission-tailored processing) and presented to personnel to enable improved, trusted, and time-sensitive decision-making?

Q&A

Long Term S&T Challenge: New technologies applicable to space based systems – S2

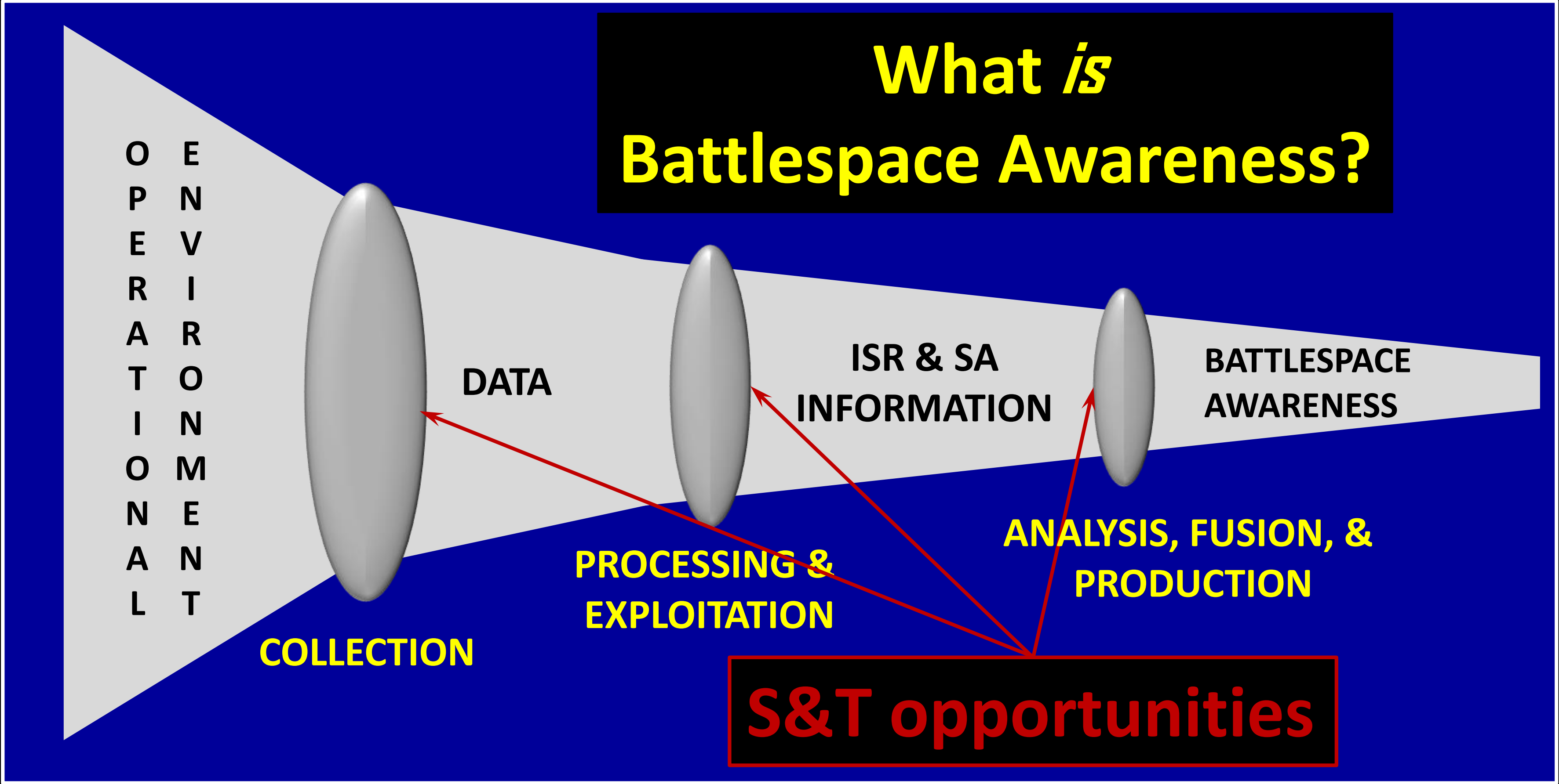
Mr. Richard “Rags” Boller

HQ AFSPC/A8XP - Aerospace

Why [S2] matters to AFSPC

- Current situation
  - Large stovepipe satellites with single missions
  - Sitting ducks
  - One-of-a-kind satellites
- Why this is not enough
  - Changing adversaries
  - Changing technologies
  - Everything is moving
- How should this look in the end?
  - Completely networked
  - Cross-functional and resilient constellations
  - Paradigm shift from today

SA + ISR = BATTLESPACE AWARENESS



S2. New technologies applicable to space based systems

a. Smaller, networked and functionally resilient satellites and/or satellite constellations for communications, position navigation and timing (PNT) , space situational awareness (SSA), and launch detection/missile warning operations in contested/degraded environments

b. Cognitive systems for secure, agile, and self-healing.

c. Spacecraft resilience to, and reconstitution from, natural and manmade events.

d. Electromagnetic spectrum and exo-electromagnetic spectrum technologies for transmitting communications and satellite commands unimpeded and undetected.

e. Alternatives for ground and communications systems that increase capacity and connectivity with new approaches and phenomenology, frequency, reuse, routing and node concepts (e.g. waveforms, proliferated relay architectures, packetizing at spacecraft/relay level, data management of variety of priority, data type, data sensitivity and latency requirements).

The Way Forward – S2

- **2.a. Smaller, networked and functionally resilient satellites and/or satellite constellations for communications, position navigation and timing (PNT) , space situational awareness (SSA), and launch detection/missile warning operations in contested/degraded environments**
- **Keys:**
  - **Smaller**
  - **Networked**
  - **Functionally Resilient**
- **Focus:**
  - **Comm**
  - **PNT**
  - **SSA**
  - **LD/MW**
  - **Contested/degraded environments**

The Way Forward – S2

2. b. Cognitive systems for secure, agile, and self-healing.

- Keys:
  - Thinking systems
  - Rapidly moveable systems
  - Systems that when damaged can fix themselves

The Way Ahead – S2

2.c. Spacecraft resilience to, and reconstitution from, natural and manmade events.

- **Keys:**
  - **Resilience is a recurring theme**
  - **If resilience fails – What is our reconstitution architecture and timeline**
  - **Space is not a refuge or benign environment**

The Way Ahead – S2

2.d. Electromagnetic spectrum and exo-electromagnetic spectrum technologies for transmitting communications and satellite commands unimpeded and undetected.

- **Keys:**
  - **Electromagnetic spectrum is exhausted and sold off**
    - **V & W band are inhospitable base of other bands**
    - **Is there new technology outside the electromagnetic spectrum?**
- **Desires:**
  - **New sanctuaries for communications and satellite TT&C**

The Way Ahead – S2

2. e. Alternatives for ground and communications systems that increase capacity and connectivity with new approaches and phenomenology, frequency, reuse, routing and node concepts (e.g. waveforms, proliferated relay architectures, packetizing at spacecraft/relay level, data management of variety of priority, data type, data sensitivity and latency requirements).

- **Keys:**
  - **If we cannot exploit NEW technologies how do we BETTER exploit that which we have?**
    - **Waveforms**
    - **Proliferated relay architectures**
    - **Frequencies**
    - **Reuse (Cognitive, Multiplexing)**
    - **Packetizing**
    - **Data management**
    - **Data Type**
    - **Data Sensitivity & Latency**

Final Thoughts – S2

- **Existing technologies are approaching exhaustion**
  - **Spectrum is full and sold off**
- **New Technologies are very applicable**
- **Bring forward new concepts so there is time to develop them**
- **We need to assess:**
  - **Benefits**
  - **Risks**
  - **Limitations**
  - **Timelines**
  - **Defined work and commercial development??**

- **Questions (same as S1):**
  - Can sensors be developed which operate in new or broader portion of the spectrum?
  - How can sensor information be processed (including integration of various types of sensors and mission-tailored processing) and presented to personnel to enable improved, trusted, and time-sensitive decision-making?

Q&A

10 min Break

Long Term S&T Challenges: Enhanced Space Access - S3

Introduction of Briefer: A2/3/6SR

AFSPC Long-Term S&T Challenges – S3

S3. **Enhanced Space Access and Logistics.** Use of evolved techniques to deploy space-based capabilities, such as multiple-payload boosters, space-plane deployment, and on-orbit construction (3-d, robotic, mini-factory, space station)

a. Advanced innovations for space transport and servicing; new transport capabilities to and through space, logistics support capabilities for space vehicles
b. Companion microsatellites attached on larger payloads, designed to separate and potentially connect with other microsats to enable increased mission synergy
c. Development of lunar-based or orbiting manufacturing station with 3-D printing, construction capability, fueling, and potential data relay or diagnostics capabilities
d. Robotic/remote-controlled harvesters of defunct satellite components and materials to develop or regenerate satellites
e. Trans-atmospheric vehicle to near-space with subsequent boost of a hosted space access vehicle
f. Rail-launched delivery system using magnetic rail-gun or other technology to initiate scramjet or super impulse propulsion
g. Rapid Launch Capability to enable rapid reconstitution of space-based capabilities

- Other AFSPC/CC "must haves":
  - Robust, responsive, and resilient space transportation capabilities that are available to enable and advance civil and national security missions." (NSTP, 21 Nov 13)
  - (1) the availability of at least two space launch vehicles… and (2) a robust space launch infrastructure and industrial base." (USC Title 10, Subtitle A, Part IV, Chap 135, Section 2273)
  - Other goals in space access: Mission Assurance, Public Safety, Return to Flight following errant events

ASSURED SPACE ACCESS VISION

23 August 2016

These charts were removed for public release.

HQ AFSPC/A236SR

Questions – S3

- How can new technologies in launch/access be introduced effectively and efficiently by the Air Force with acceptable mission risk?
- Can on-orbit production capabilities be used and made cost-effective (3-d, robotic, mini-factory, space station)?

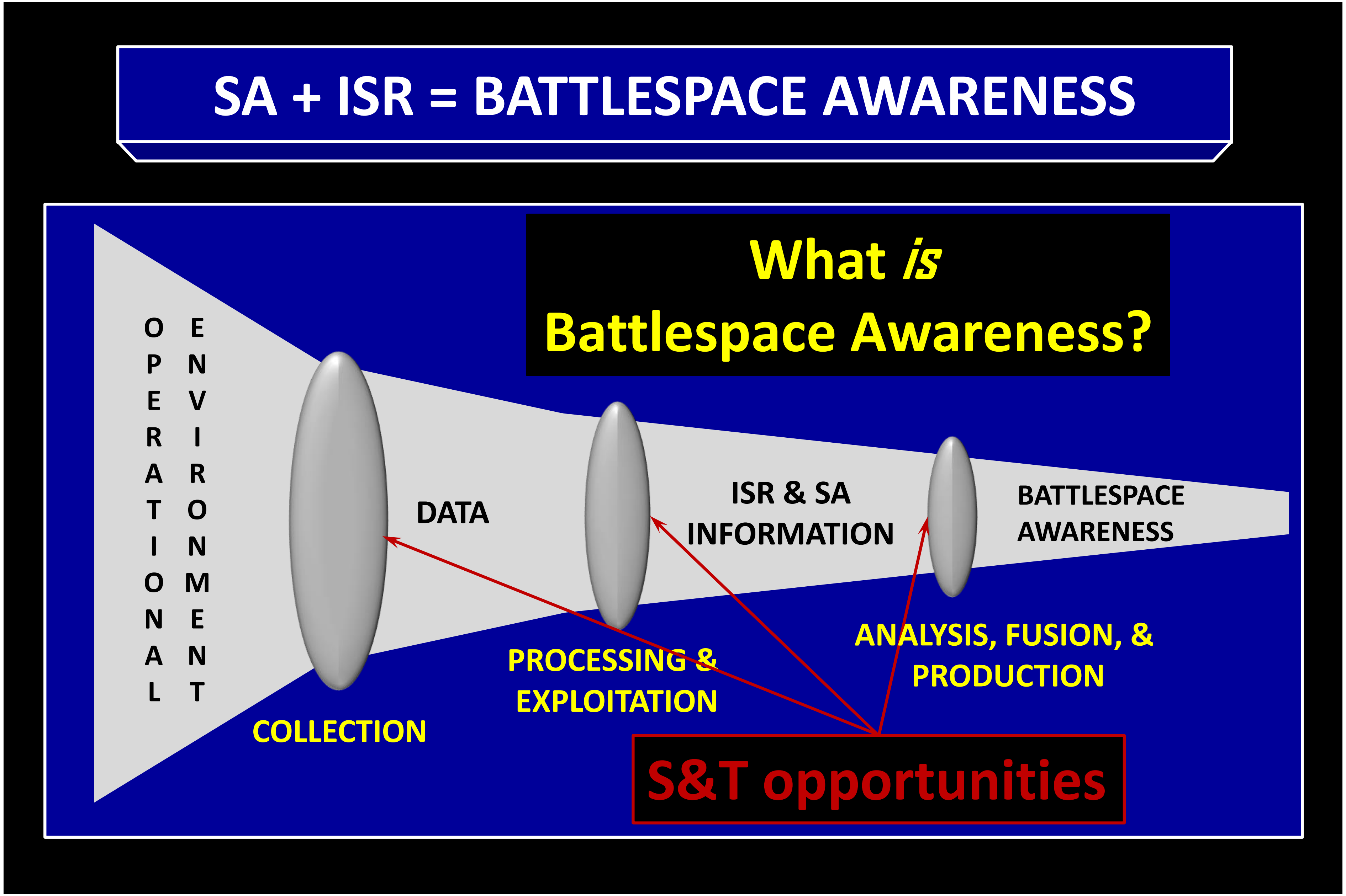
Q&A

Long Term S&T Challenges: New Concepts for Ground Operations - S4

Briefer: Mr. John Kress

Why space evolution matters to AFSPC – S4

- Current situation
  - Communications and ground control follows stovepiped, mission-unique systems
  - Volumes of data can be produced by sensors on satellites (mission or mission-supporting)
- Why this is not enough
  - Costs are increasing to keep up with technological demands required to meet threats and related mission needs
  - Data which is produced by systems is not fully exploitable and leaves potential loss of decision-facilitating information
  - Lack of ground system flexibility, responsiveness, and robustness is likely to produce large segments of vulnerabilities in each mission area architecture
- How should this look in the end?
  - Satellites or systems can be extended in their life, built more quickly, quickly tailored, or call upon residual assets to expand capabilities to meet dynamic mission needs
  - Ground system interface with space systems can be flexibly used to enhance command and control
  - Proliferated and agile mobile ground systems can enhance overall mission resliency
  - Data collection through ground and in-space interface is more possible with a flexible ground architecture; smart data analytics can yield information useful to warfighter in rapid manner


SA + ISR = BATTLESPACE AWARENESS
What *is* Battlespace Awareness?
OPERATIONAL
ENVIRONMENT
DATA
ISR & SA
INFORMATION
BATTLESPACE
AWARENESS
COLLECTION
PROCESSING &
EXPLOITATION
ANALYSIS, FUSION, &
PRODUCTION
S&T opportunities

AFSPC Long-Term S&T Challenges – S4

S4. **New concepts in space ground operations.** Enterprise Ground Services, small-light-mobile emplaceable terminals, networking of high data rates, added resiliency, and defense of ground systems.

a. Technologies to simplify ground operation of space systems and increase protection and mobility.
b. Enhanced predictive technologies, autonomy and manufacturability.
c. Space systems with a high level of trust capable of rapid extensibility to accomplish unforeseen space missions.
d. Dynamic encryption and signal beaming based on mission needs, threats, and automated processes.
e. Service capability focused for responsive and agile options for execution of all missions through advanced ground processing systems.

Enterprise Ground Services

These charts were removed for public release.

Maj Mark Ciesel
AFSPC/A5FE

Questions – S4

- How can advanced technology permit smaller yet more resilient systems, to include mobile or relocatable systems which are protected from the spectrum of physical, electromagnetic, and cyber attack?
- How can future ground systems exploit technology to be rapidly agile to meet varying mission needs, permitting surge and dwell while maintaining readiness and crew proficiency?

Final Thoughts – S4

Science and technology will permit a vast number of possibilities for satellite on-board capability, delivery to orbit, maintenance on orbit, and operational use. How will the AF choose and develop technology in a way that is cost-efficient yet will meet the threats of the future?

Similarly, there will not be an endless amount of funds to pursue all available technologies in the future, so what is the optimum means to get capability o orbit and utilize it in national defense operations?

- **Questions:**
  - How can advanced technology permit smaller yet more resilient systems, to include mobile or relocatable systems which are protected from the spectrum of physical, electromagnetic, and cyber attack?
  - How can future ground systems exploit technology to be rapidly agile to meet varying mission needs, permitting surge and dwell while maintaining readiness and crew proficiency?

Q&A

Long Term S&T Challenge: Dynamic new technologies applicable to all space systems – S5

Mr. Richard "Rags" Boller

HQ AFSPC/A8XP - Aerospace

S5. Dynamic new technologies applicable to all space systems

a. Improved ultra-high efficiency power system components, such as solar cells, thermal generators, alternate power generation and storage technology, batteries and adaptive point-of-load converters

b. Maximize satellite dry mass reduction through game-changing technologies

c. Develop technologies and architectures that facilitates integrating US systems with international and commercial partner systems and technologies including but not limited to worldwide PNT capabilities (e.g. Multi-Global Navigation Satellite Systems)

d. Provide autonomous spacecraft protection through on-board sensing and warning technologies while implementing revolutionary spacecraft technologies that will provide capabilities to reduce space transportation cost

e. Innovate mini, micro and nanosatellite technologies that will provide capabilities to reduce space transportation cost

f. Implement space logistics and manufacturing technologies to expand the service life of conventional satellites

g. On-orbit Range and Test infrastructure technologies to develop on-orbit missions from current tot S&T capabilities (e.g. Nellis or Edwards AFBs in space for satellite and man-made spaceflight)

Current Foundational and Pervasive Areas Today – S5

- Space (Radiation Hardened) Electronics
- Spacecraft Propulsion
- Spacecraft Size, Weight and Power
- Space System Resiliency

The Way Forward – S5

- **Space (Radiation Hardened) Electronics – S 5.a.**
  - **Ultra-high efficiency power systems**
    - **Solar Cells**
    - **Thermal Generators**
    - **Alternative Power Generation**
    - **New Storage Technologies**
    - **Adaptive Point-of-load Converters**

The Way Forward – S5

- **Spacecraft Propulsion – S 5.b.**
  - **New propulsion systems**
    - **High Power Solar electric Power (HP-SEP)**
  - **Newer & greener fuels**
  - **Mini-, Micro-, and Nanosatellite Technologies**
    - **Focus Reduce Space Transportation Costs**

The Way Ahead – S5

- **Spacecraft Size, Weight and Power – S 5.b.**
  - **Satellite Dry Mass Reduction**
    - **Game changing Technologies**
      - **Carbon fiber structures**
      - **Carbon nanotube connectivity**

The Way Ahead – S5

- Space System Resiliency – S5.c., S5.d., S5.f.,
  - Technologies and Architectures
    - Integrating US Systems with International and Commercial Partners
  - Improved PNT Capabilities
    - Multi-Global Navigation Satellite System
  - Autonomous Spacecraft Protection
    - On-board Sensing and Warning Technologies
    - New Technologies for Threat Avoidance
  - Space Logistics and Manufacturing Technologies
    - Assemble on Orbit
    - 3D Printing
    - Space Maneuver Capabilities

Final Thoughts – S5

- **Our Long Term S&T Challenges are outside our existing programs, requirements and capability gaps**
  - **Don't try to tie them together**
- **Technology is dashing forward at an unprecedented rate**
- **Technologies identified today will be the systems of tomorrow**
- **All areas have high potential**
  - **Resiliency is the most diverse area**
- **Help us identify our unknown unknowns and develop the systems of the future**

- **Questions:**
  - How can advanced technology be used to make satellites more defended against threats, specifically sensors and protective systems on board which are automated along with inherent robustness?
  - How does the AF maximize mission capability and survivability in the arena in which the system is intended for use by "smart" aggregation and disaggregation?

Q&A

Fitting Together the S&T Puzzle

Core Enabling Technologies

- Artificial Intelligence
- Advanced Data Analytics
- Trusted Networks, System, Applications
- Advanced Data Protection
- Human-Machine Interfaces
- Space New-Tech

Functional Technologies

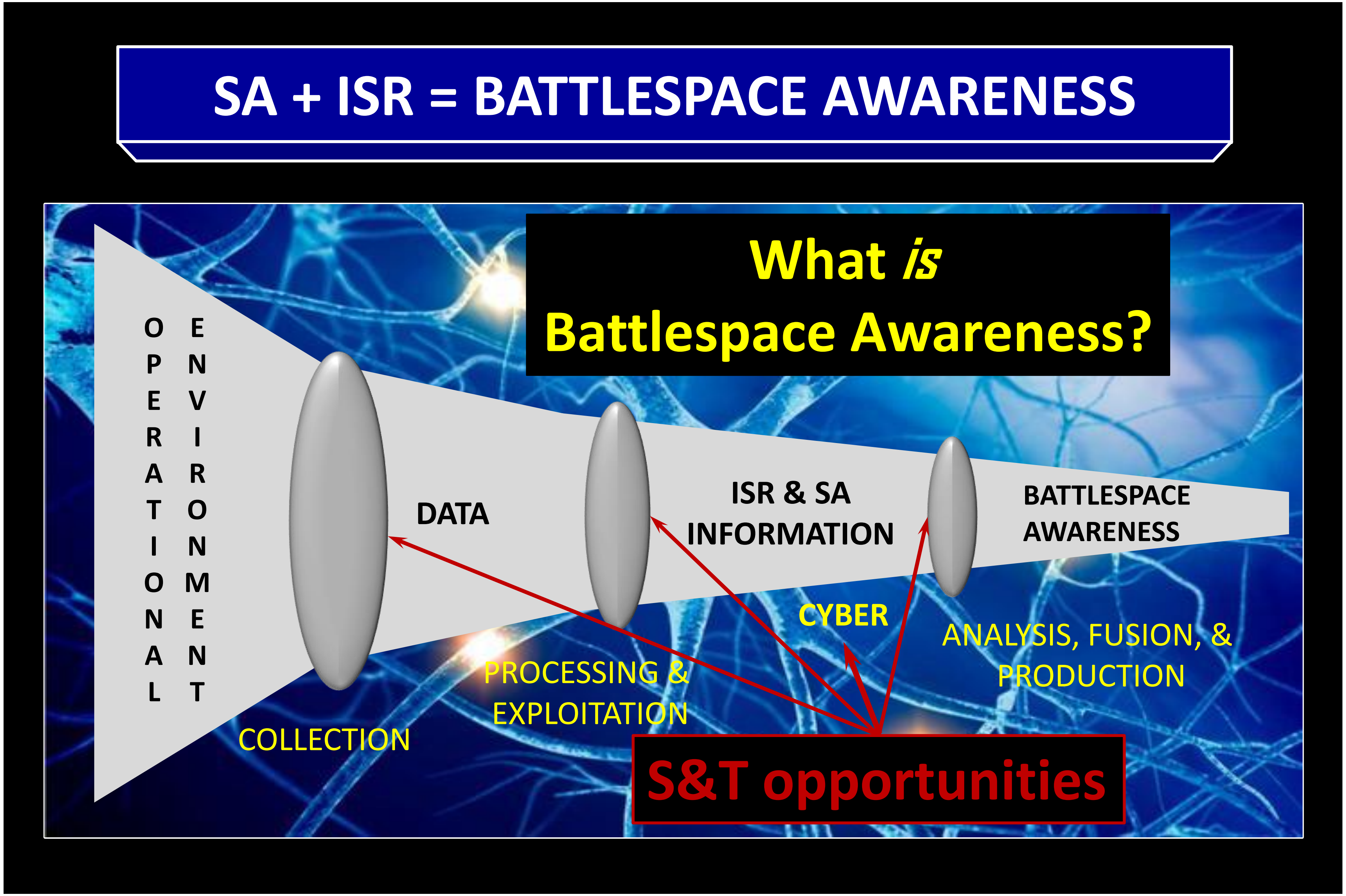
- Cognitive Electronic Warfare
- New Concepts for Space Ground Ops
- Extending Space-based Capabilities
- SSA/BA and ISR
- Enhanced Space Access

Long Term Cyberspace S&T Challenges

C1 - Trusted autonomous systems, networks, and applications

C2 - Human-machine interface design and biometrics

C3 - Advanced data protection technologies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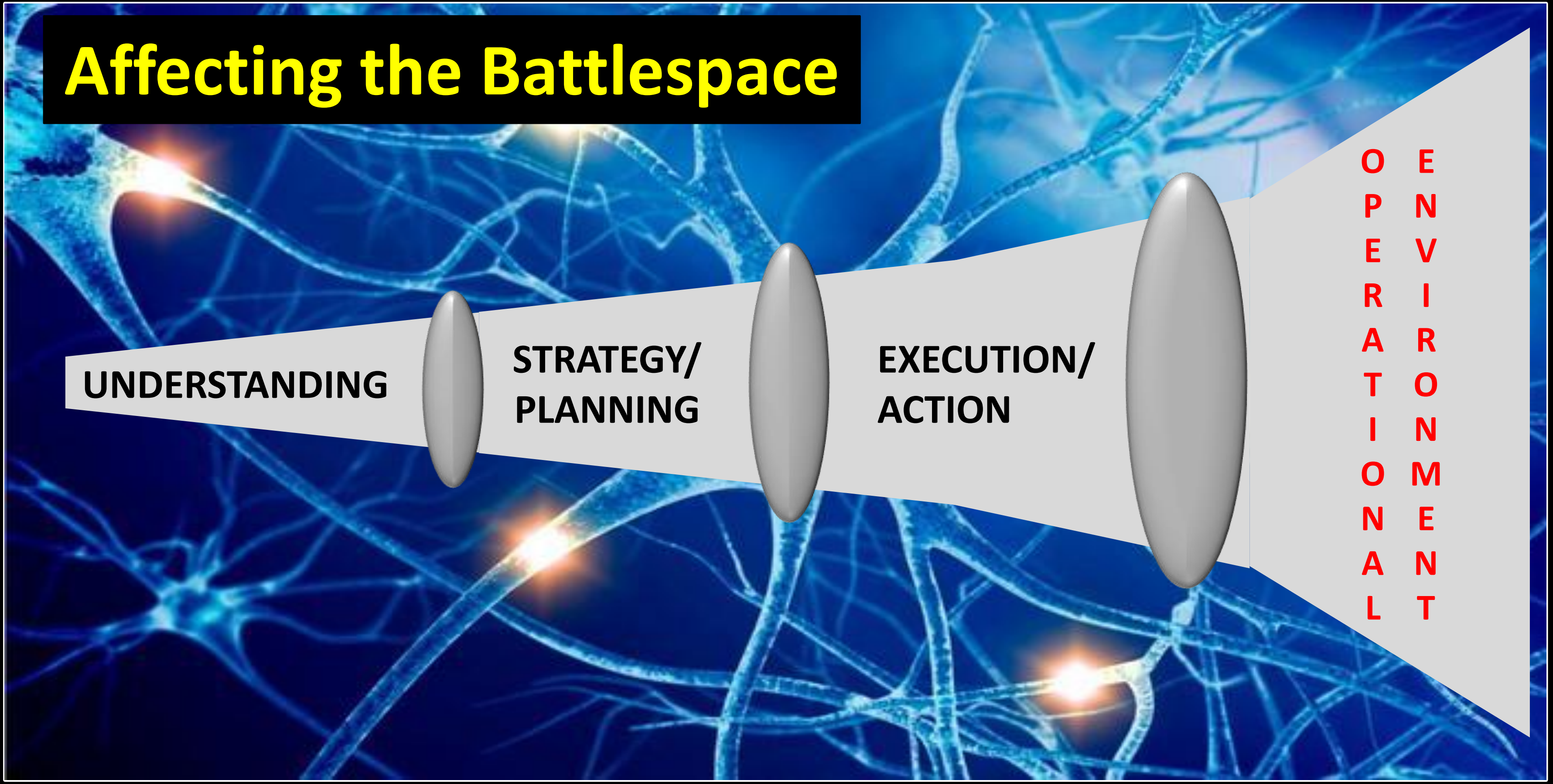
S&T opportunities

Battlespace Awareness Supports Action



Long Term S&T Challenge: Trusted Autonomous Systems, Networks & Applications – C1

Briefer: Mr. John Walsh

Contributor: Mr. Tom Harper

Why C1 matters to AFSPC

- **Current situation**
  - Space and cyber capabilities depend on trusted, available networks and applications
  - Mission assurance is increasingly difficult with proliferation of advanced technologies
  - There is almost no ability to leverage alternative infrastructures – blue, grey … red?
- **What's needed**
  - Self-aware, self-organizing, self-generating networks, applications and systems
  - Means to detect, understand, and dynamically respond to unanticipated network, application, and system behaviors
  - Ability to understand and operate in and through dynamic "global cyber terrain"
  - Adaptable, seamless networks that support multi-domain warfare – "internet of things"

Trusted Autonomous Systems, Networks, & Apps – C1

C1. Advanced technologies for autonomous, goal-seeking network capabilities that access and exploit any available communication medium to preserve connectivity.

C1.a Technologies to enable ***autonomous, goal-seeking, self-organizing, self-generating, and amorphous (ad hoc) network capabilities*** to include inherent abilities that enable enhanced access, and exploitation of ***owner agnostic communication*** mediums across the electromagnetic spectrum.

C1.b Technologies to enable ***unimpeded and undetected information transmission*** in innovative ways across electromagnetic and/or other spectrums.

C1.c Technologies to ***automate payload development*** and synchronize capability planning into singular action plans across the war-fighting domains through vulnerability analysis, discovery, reverse engineering, and adaptation.

C1.d ***Autonomous "deep learning" machines*** and systems (AI) which can synthesize huge amounts of data/Situational Awareness/Intelligence Surveillance Reconnaissance and provide mission relevant information across all warfighting domains (a mission relevant shared consciousness) to support flat self-synchronizing C2 processes/systems (able to visualize relevant domains).

Trusted Autonomous Systems, Networks, & Apps – C1

C1.e Fully automated network and nodal analysis using AI.

C1.f ***Autonomous and intelligent agents*** scanning, analyzing, and providing relevant, actionable information.

C1.g Advanced algorithms, quantum technologies, and computational ***methods to understand behavior, pattern, context recognition, and heuristics***.

C1.h ***Predictive and automated threat analysis*** to inform operators and feed other automated cyber defense systems.

C1.i Cognitive Networks (Self-aware, self-healing networks)

- The network is its own record; you don't need a separate database/app to house network infrastructure information (maps, status of equipment, configuration); all hosts, servers, etc., know about their neighbors.
- ***Network self-heals or reconstitutes*** (reconfigures and fights thru an attack).
- Cognitive communications for agile, reconfigurable, and ***composable communications and sensors*** to enhance resilience and agility.
- Network is aware of key terrain and prioritizes based on impacts across the 5 core Air Force mission areas.
- Research and study methods to ***seamlessly adapt cyber operations capabilities to radio frequency*** through air, space, and terrestrial assets.

Trusted Autonomous Systems, Networks, & Apps – C1

C1.j Theories and methods to operate securely on distributed, cloud systems, and weapon systems, as well as, systems that may not be secure.

C1.k Autonomous "deep learning" machines and systems (AI) which can synthesize huge amounts of data/SA enabling self-healing/controlling networks and mission/weapon system.

C1.l Self-organizing networks.

C1.m Interwoven or integrated layer networks.

C1.n Create sophisticated, fully integrated, and seamless technologies, methods, and assets to provide ***cyber offensive and exploitation capabilities across air and space assets, electromagnetic spectrum***, and networks against any adversary cyber-capable systems.

C1.o Develop technologies to permit collective action of multiple EW platforms to deliver and ***create cyber effects from an ad hoc network of EW systems*** using swarm tactics that is cognitive and driven by advances in AI. Use advanced fusion algorithms that permit these *ad hoc,* networked, electronic attack-capable systems to autonomously prioritize targets based on risk and effects.

Major Themes – C1

- Technology for autonomous goal-seeking, self-aware and self-healing networks – communications that find a way
- Technology for networks that hide in the noise – operating in plain sight
- Technology for machine vs machine warfare – combat at the speed of cyber
- Technology for predicating operational environment – anticipating the next move or opportunity
- Technology for autonomous agents
- Technology for collaborative/automated discovery, vulnerability assessment, reverse engineering, and adaptation for payload engineering
- Technology for flexible compositions of hardware, software, processes, and people

Final Thoughts – C1

- What are some concepts for technologies that enable autonomous ability to fight through adversary efforts to deny critical networks, applications, and systems?
- What are some concepts for technologies that enable self-aware networks, systems, and applications?
- What are some concepts to incorporate advanced technologies into existing systems as we progress towards future systems?
- What are some concepts for technologies that enable machine vs. machine warfare?

Q&A

Long Term S&T Challenge: Human-Machine Interface Design and Biometrics – C2

Briefer: Mr. John Walsh

Contributor: Mr. Tom Harper

Why C2 Matters to AFSPC

- **Current situation**
  - Relationship between humans and machines is changing from operation to cooperation and collaboration
  - Machines lack the intuitive interfaces for natural cooperation/ collaboration between humans and machines
  - Cultural resistance to machines responsible for dynamic, life-death decisions

- **What's needed**
  - Ability for humans to interact with machines through natural language, expression, and direct cognitive relationships
  - Machines that anticipate and respond to human needs and the speed of warfare
  - Technologies to capitalize on potential advantages offered by application of biological materials and processes

Human-Machine Interface Design and Biometrics – C2

C2. Human-Machine Interface Design and Biometrics

C2.a. Technologies to ***enable biometric based access*** to multi-level security multi-domain Cyber Enterprise.

C2.b. Technologies to ***advance Human-Machine Interface for human performance*** augmentation via ***somatic and/or cerebral*** methods.

C2.c. Advanced ***human-machine teaming***, where a human is working with a cyberspace weapon system (shared consciousness – human provides goals).

C2.d. Research methods to develop ***stealthy, agnostic, and autonomous platforms, accesses, and payloads*** adapting capabilities across all networks, closed systems, electromagnetic spectrum, and space, air and terrestrial systems.

C2.e. Completely dynamic, always on, ***cyber modeling and simulation environment*** allowing all operators, across all mission areas to evaluate the full spectrum of effects and impacts as they would occur on actual blue, gray, and red spaces.

C2.f. ***Biological Computing*** (data storage, computing, augmentation)

Major Themes – C2

- Technology that capitalizes on nature's designs
- Technology that optimizes performance through human-machine collaboration – both physical and cognitive
- Technology that enables modeling and simulation of very complex and dynamic systems through virtualization
- Technology that enables us to hide

Final Thoughts – C2

- What are some concepts for technologies that enable reliable, intuitive interfaces between humans and machines?
- What are some concepts for technologies that magnify human somatic and cognitive performance?
- What are some concepts for technologies that incorporate biological elements for sensing, data storage, computing, networking, etc.?
- What are some concepts for human – machine interfaces we should consider for future systems?
- Are the concepts for biological technologies for storage, processing, sensing, etc., science fiction or tomorrow's breakthroughs?

Q&A

Long Term S&T Challenge: Advanced Data Protection Technologies – C3

Briefer: Mr. John Walsh

Contributor: Mr. Tom Harper

Why C3 matters to AFSPC

- **Current situation**
  - Crypto algorithms becoming insufficient to maintain edge
  - Network configurations typically static, bulky, and predictable
  - Credentialing methods inadequate to protect critical data
  - Present defenses focus on boundary and devices – not data elements
- **What's needed**
  - Quantum cryptography and networking
  - Polymorphic networks
  - Advanced user access to protect data and ensure attribution
  - Multi-domain solutions with advanced credentialing and crypto
  - Ability to obfuscate network metadata

Advanced Data Protection Technologies – C3

C3. Advanced Data Protection Technologies: Resilient, scalable and flexible low power data protection technologies that enable operators to seamlessly operate across classification domains with advanced user access methods.

C3.a. Technologies to ***advance Quantum capabilities*** in the areas of computing and cryptology.

C3.b. ***Flexible and scalable encryption*** (including reconfigurable sensors and fractionated platforms) for software, hardware, and networks allowing the operator to fight through adversarial conditions and ***seamlessly operate between multiple classification networks***.

C3.c. ***Advanced credentialing methods*** for accessing accounts, networks, data, and systems to prevent adversary exploitation and compromise and allow for complete auditing and attribution.

C3.d. ***Polymorphic defensive measures*** which automatically and seamlessly change network configurations and defensive surfaces to confuse and thwart adversary activity.

C3.e. ***Low Power Encryption*** which can also be used to ***protect routing protocols*** to entirely mask transmission addresses.

Major Themes – C3

- Technology that removes need for encryption
- Technology to directly associate data with authorized users
- Technology to enable polymorphic surfaces

Final Thoughts – C3

- What are some of the concepts for technologies related to quantum physics for network security and data protection we should be considering?
- What are other concepts for technologies related to network security and data protection?
- What are some of the concepts for technologies that will enable us to move past the current paradigm of multiple networks for each security levels?
- Are there concepts for technologies that might transform how we think about protecting data with through encryption?

Q&A

10 min Break

Long Term Cross-cutting Space/Cyber S&T Challenges

X1 - Artificial Intelligence/Cognitive Electronic Warfare

X2 - Artificial Intelligence

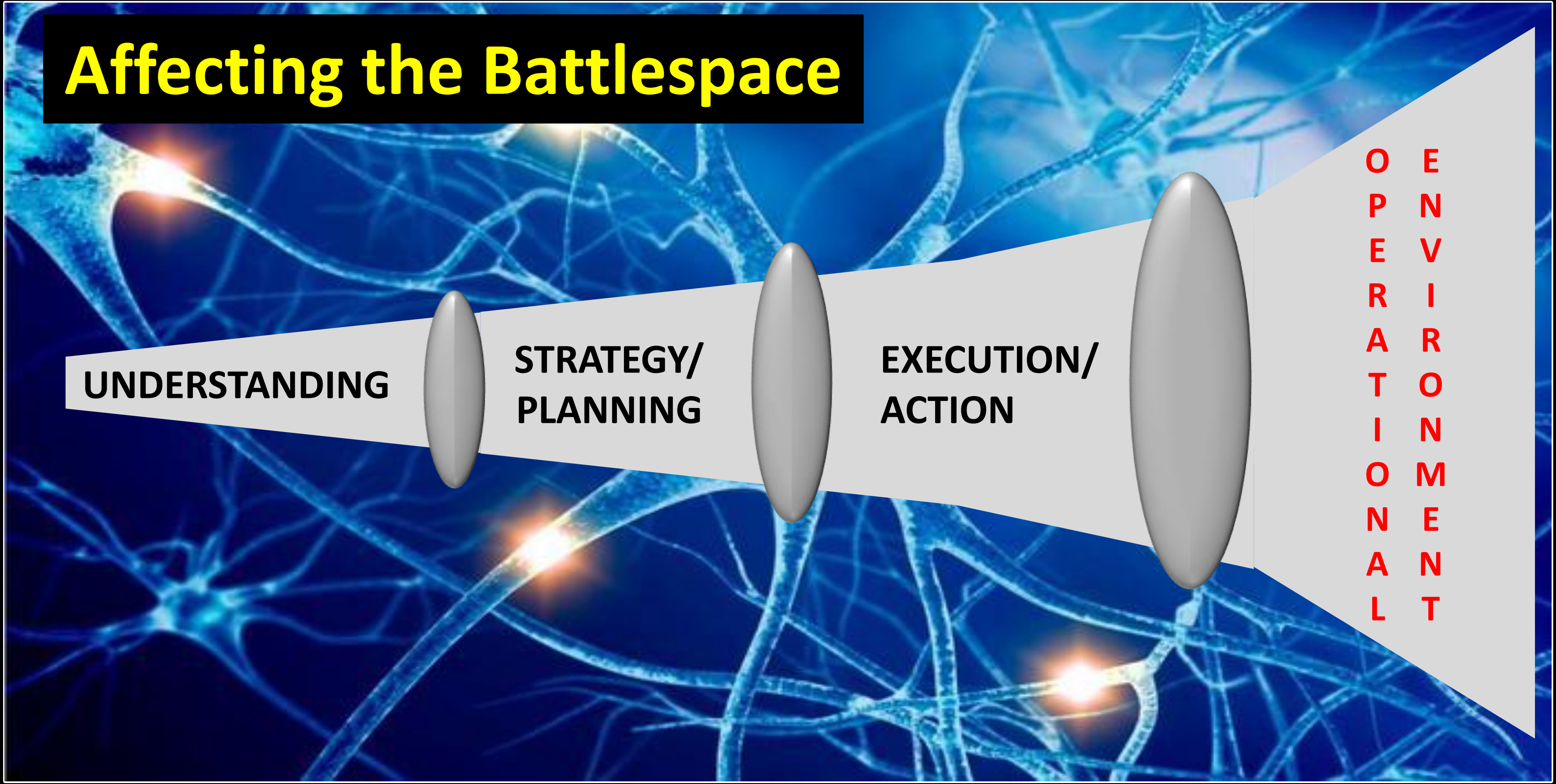
X3 - Advanced data analytics

Long Term S&T Challenge: Artificial Intelligence/Cognitive Electronic Warfare – X1

Briefer: Lt Col Andy Dills

Contributor: Mr. John Walsh,
Mr. Tom Harper

Battlespace Awareness Supports Action



Why [X1] Matters to AFSPC

- **Current situation**
  - AFSPC capabilities depend on freedom to operate in an increasingly crowded and contested Electromagnetic Spectrum (EMS)
  - Proliferation of advanced technology lowers the cost of entry for advanced Electronic Warfare capabilities able to interfere with and/or deny friendly use of EMS
- **What's needed**
  - Automated ability to sense, comprehend, and adaptively move within the EMS to preserve dependent capabilities – spectrum agility
  - Automated ability to sense, discover, comprehend, and effect adversary use of the EMS.
  - AFSPC must ensure AI/CEW technologies include ethical frameworks that account for the Nation's policies regarding use of military force.

Fight through Contested, Degraded, and Operationally-Limited Environments

Artificial Intelligence/Cognitive Electronic Warfare – X1

X1. Artificial Intelligence (AI)/Cognitive Electronic Warfare (CEW)

X1.a. AI/CEW involves the ***capability for systems to be controlled and defended by an inherent cognitive capability*** embedded in the system, reducing human involvement.

X1.b. Ensure control and desired ***recognition and reaction to threats***.

X1.c. Establish effective human-interaction and ***prevention of a friendly system from "turning"*** as a result of an infiltration or logic anomaly.

X1.d. Transition to a fall-back capability immune from an adversarial AI/CEW capability.

Example Foundational Tech: [C1.d] Adv. Data Analytics

"Develop technologies to …

- Permit collective action of multiple EW platforms to deliver and create cyber effects from an *ad hoc* network of EW systems using swarm tactics that is cognitive and driven by advances in AI.
- Use advanced fusion algorithms that permit these ad hoc networked, electronic attack-capable systems to autonomously prioritize targets based on risk and effects."

EXAMPLE: Ad Hoc, swarming EW Platforms

Foundational Tech: C1 – Trusted Autonomous Systems…

- Modular, open system/software configurable architecture for platforms from different vendors
- Swarming: systems would need to pass the following data to each other:

  - Position, vector, jamming frequency, power and techniques
  - Each would need to be capable of adapting on the fly to changes or countermeasures of the targeted system(s)

2nd Example of [C1] -- Advanced Fusion Algorithms

- **Enemy Emitters will outnumber friendly transmitters**
  - Requires autonomous EW platforms to prioritize emitters based on dynamic situation and reassign organic jammers.
  - Due to possible battle loss, each platform needs this capability.
  - Each EW platform should also be capable of assuming a lost platform’s jamming assignments and re-prioritizing.
    - Depends on “protected entity,” burn-through range, pop-up threats, & time on target.

Final Thoughts – X1

- **Can emerging space/cyber capabilities leverage legacy EW platforms?**
  - To what will those cyber capabilities transition to?
  - Are these cyber capabilities being considered in the JCIDS process for replacement platforms?
- **How will we ensure positive C2 of AI-based platforms in a congested and contested electromagnetic spectrum (EMS)?**
- **Where will the cognitive EW expertise come from?**
- **How will we ensure deconfliction, integration, synchronization of AI-based cognitive EW with EMS-dependent space systems? (e.g., TT&C of satellites)?**

**"Air Force systems will experience…
increasing levels of autonomy over the next several decades."**

Q&A

Long Term S&T Challenge: Artificial Intelligence – X2

Briefer: Mr. John Walsh
Contributor: Mr. Tom Harper

Why X2 Matters to AFSPC

- **Current situation**
  - Technological advantages are being eroded by proliferation of advanced technologies that threaten Joint Force capabilities
  - Artificial Intelligence technologies are increasingly augmenting or substituting for human cognition and decision-making enabling competitive advantage in speed and performance for a wide range of activities
- **What's needed**
  - We must develop and incorporate artificial intelligence technologies into future systems to preserve capability advantages in a fiercely competitive environment
  - We must ensure artificial intelligence technologies incorporate ethical frameworks that account for the Nation's values and policies regarding use of military force

Artificial Intelligence – X2

X2. Artificial Intelligence (AI): Technologies to advance AI enabled, human decision augmentation to enable decision superiority in the space and cyber domains.

X2.a. Develop advanced multi-domain technologies that provide ***real-time domain awareness and attribution, predictive battlespace awareness for man-made and natural phenomena***, and rapid development and assessment of mitigative course of action across all five operational domains – air, land, sea, space, and cyberspace.

X2.b. Create ***ethical based frameworks leveraging AI*** to mitigate insider threat, malicious activity, and support full spectrum cyber operations.

X2.c. Use ***AI augmentation for human decisions makers*** by developing recommendations based on threats, indications and warning, resources, and available tools.

Major Themes – X2

- Technology that incorporates ethical frameworks into AI
- Technology for AI frameworks that can satisfy multiple applications

Final Thoughts – X2

- What are some concepts for advanced artificial intelligence technologies that still preserve appropriate roles for Airmen?
- What are some of the concepts for AI technology in other sectors/industries (medical, transportation, materials) that might provide useful insights… especially regarding autonomy in critical applications?
- What are some of the concepts for applying AI technology toward understanding and predicting human behavior?
- Are there concerns AFSPC should have regarding application of AI in its future systems?

Q&A

Long Term S&T Challenge: Advanced Data Analytics – X3

Briefer: Mr. John Walsh
Contributor: Mr. Tom Harper

Why X3 matters to AFSPC

- **Current situation**
  - Limited visibility into cyber operations status, effectiveness, and more
  - Extensive manual intervention and coordination required
  - Extensive use of manually created presentations for making decisions
- **What’s needed**
  - Ability to synthesize data across multiple locations/security levels
  - Algorithms to heuristically identify and attribute anomalous behavior
  - Fully integrated operational decision making across all warfighting domains
  - Data to correlate units, tools, and assets to missions

Advanced Data Analytics – X3

X3. Advanced Data Analytics: Technologies to synthesize and display voluminous multi-source data to predict, detect, inform, and augment the spectrum of space and cyber operations to allow comprehensive C2 and SA.

X3.a. Ability to ***detect and prevent insider threat through analytic means of intelligent human baselining*** and anomaly detection while integrating social factors

X3.b. ***Automated cyber forensic and analytics*** with evidence discover, dynamic sensing and real-time classification and correlation of network captures and host level events. Ability to ***synthesize multi-source, multi-time scale data analytics***. Needs to incorporate and inspect encrypted traffic.

X3.c. "Abstract away the uniqueness" by understanding the core capabilities/techniques and not being distracted by variants and signature adaptations

X3.d. Technologies to improve data storage and access

I. ***Reduce cost and size data storage***

II. Reduce latency for data access

Advanced Data Analytics – X3

X3.e. Technologies to ***reduce power/resource consumption***: Could root-in processing power with reduction in power consumption and increased heat resistance remove requirement for environmental controls.

X3.f. Integrated, advanced, and voluminous multi-source data across all networked, closed, embedded, electromagnetic spectrum, and unique business and weapons systems to predict, inform, and augment the spectrum of space and cyber operations while providing ***singular visualization platforms for situational awareness and command and control of weapon systems operations***, mission impacts, network activities, unit statuses, and more.

X3.g. Technologies to ***enable geolocation of adversary and friendly network systems*** which can be integrated into the full spectrum of operations across all warfighting domains, providing ***complete infusion and situation awareness of physical locations of key targets and assets***.

Major Themes – X3

- Technologies that will help us maximize value from all data and sources
- Technologies that make bad data useful
- Technology for data behavior analysis and pattern detection
- Technology for transforming virtual into the physical

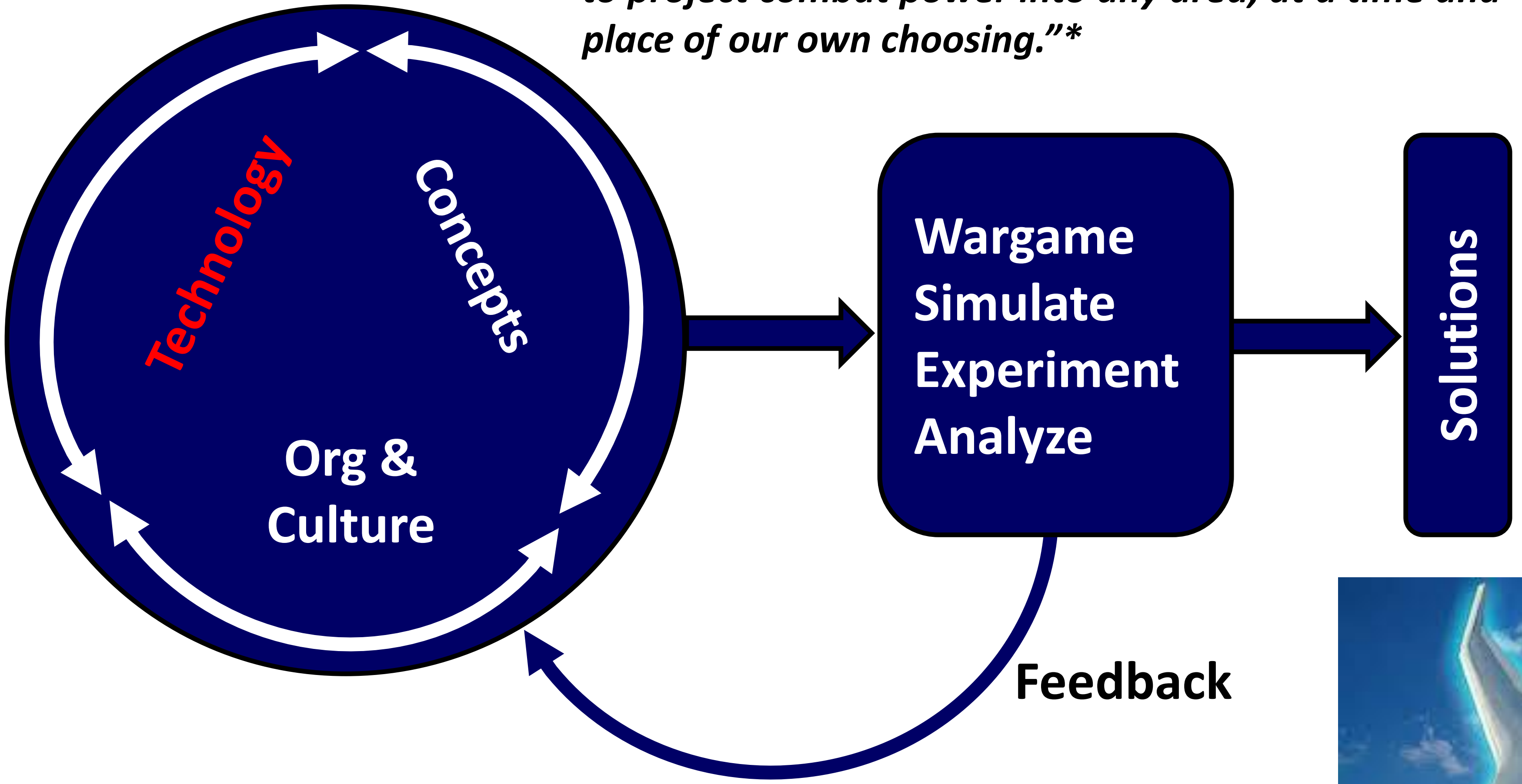
Final Thoughts – X3

- What are concepts for technologies within industry we should be considering for processing disparate data sources for actionable information?
- What are concepts for technologies that that will enable us to seamlessly process data across multiple security levels?
- What are concepts for technologies that will enable us to work across the continuum from advanced data analytics to AI ?

Q&A

Help Us Shape the Future Force

*"A combination of technology, operational concepts, and organizational constructs to maintain our ability to project combat power into any area, at a time and place of our own choosing."**



*Speech by Defense Deputy Secretary Robert Work at the European Policy Center, 29 April 2016
http://www.defense.gov/News/Article/article/746336/work-us-nato-must-use-21st-century-approaches-for-deterrence-dominance

Next Steps

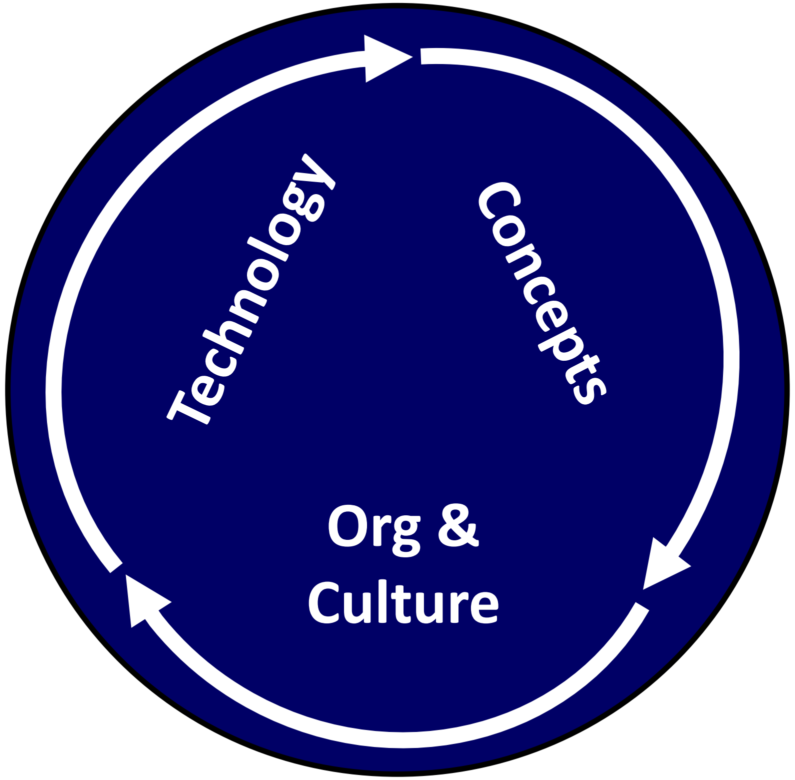
Lt Col Dills

Backup Charts

Air Force Strategy

Game-Changing Technologies
- Hypersonics
- Directed Energy
- Nanotech (Additive Manufacturing)
- Unmanned Systems
- Autonomous Systems

AF Future Operating Concept
- Integrated Multi-Domain Ops
- Superior Decision Speed
- Dynamic Command and Control
- Balanced Capabilities Mix
- Performance-Optimized Teams



Organization and Culture
- Autonomous Systems
- Strategic and Operational Agility
- Organizational and Cultural Inclusiveness
- Multi-domain Approach
- Bending the Cost Curve

Resilience Capacity

- Reduce time to respond to future threats
- Continue to deliver space combat effects to COCOM
- Applies to acquisition, sustainment, and operation