



C4I Community of Interest C2 Roadmap

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John Willison (SES), C4I COI Lead



Agenda



- **Purpose**
- **C2 Roadmap Approach**
- **C2 Roadmap Conclusion**
- **Current C4I COI Focus Areas**
- **Conclusion**



C4I COI Overview



- Purpose: The C4I CoI provides the DoD S&T EXCOM recommendations on matters related to planning and managing research and development programs in the fields of Command, Control, Communications, Computers, & Intelligence
- Initial task is to develop a C2 Roadmap



C4I COI Approach



- As chartered, initial focus of C4I COI is on C2
- C2 capability advancements over time result from the application of combinations of advancements made in different technology areas applied to C2 domain
- Task is relatively complex given:
 - Inter-dependency between C4I and all other COIs
 - Many-to-many relationship of technology advancements to capability area advancements (C2 and other)
 - Similar technology advancements often enable different C2 advancements in order to address unique, Service-specific needs

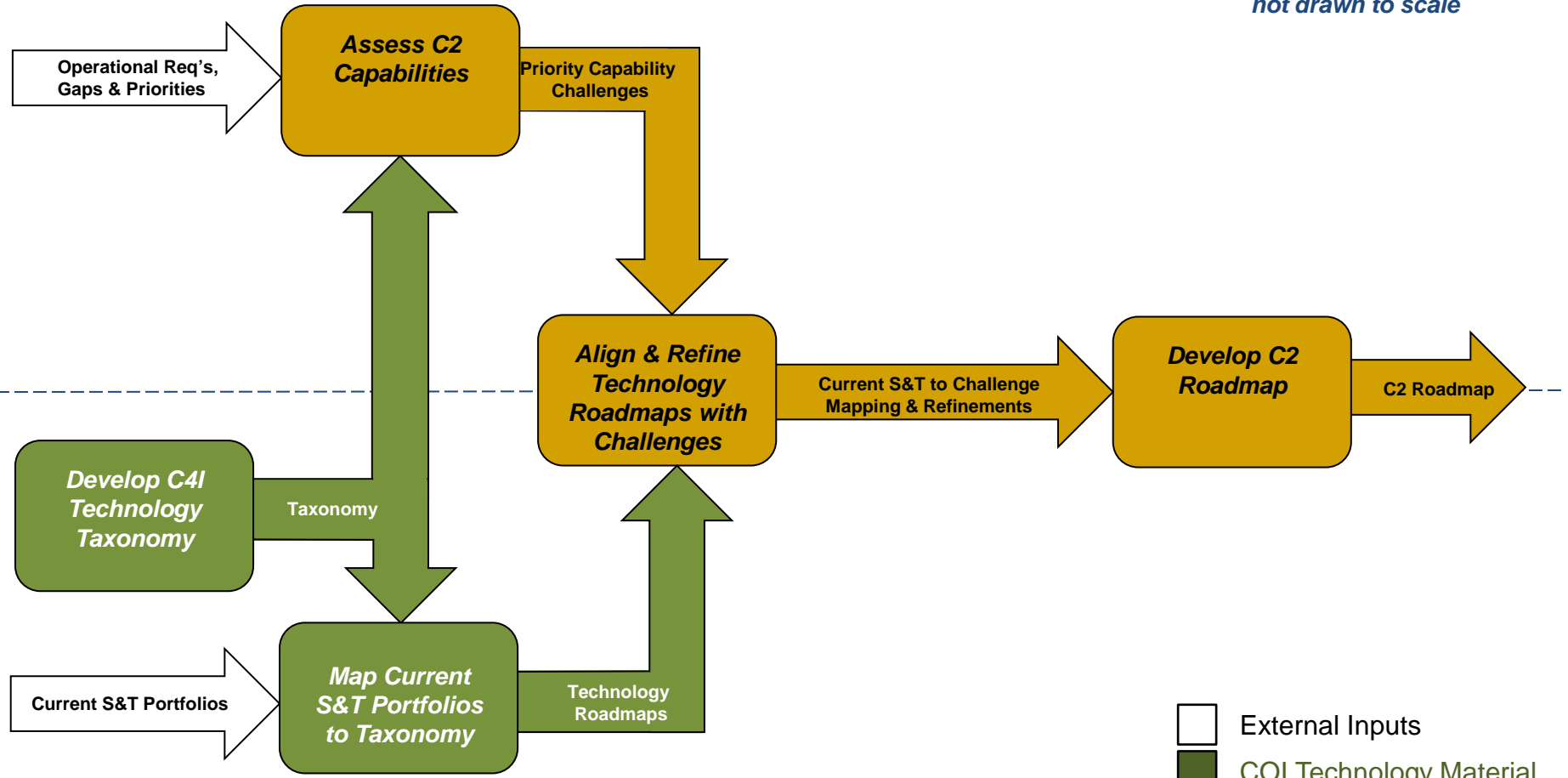


C2 Roadmap Approach - Revised -



Capabilities... What do we need?

Note - Process (over)simplified and not drawn to scale

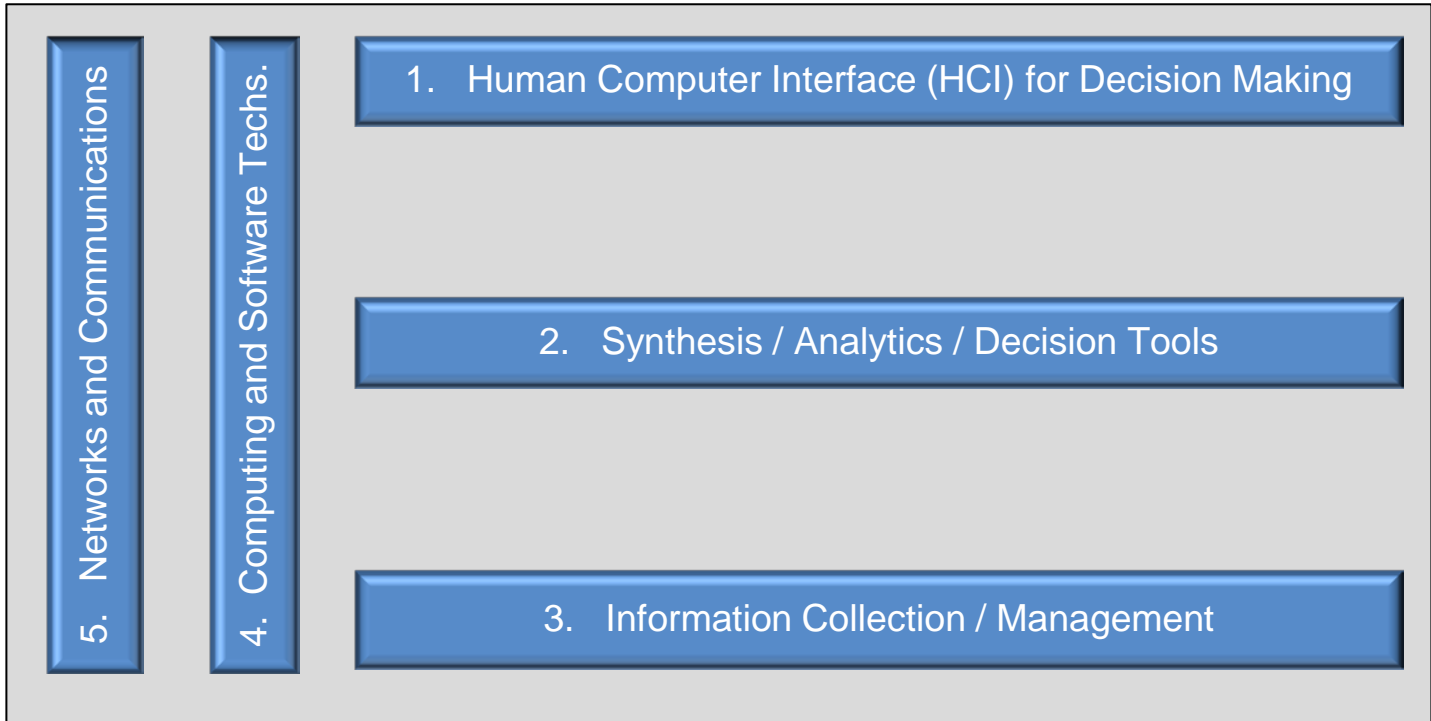
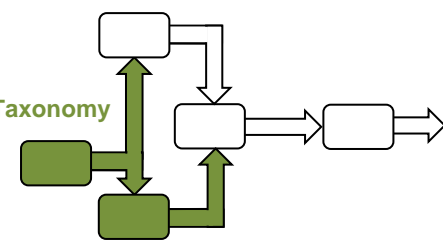


- External Inputs
- COI Technology Material
- COI Capability Material

Technologies... What can we get?



Technology Taxonomy Tier 1





Technology Taxonomy: Tier 2



HCI for Decision Making

- User Interaction
- Collaboration
- Information Presentation
- Display Management

Synthesis / Analysis / Decision Tools

- Sensor Understanding
- Data Fusion and Analysis
- Human Language Technology (HLT)
- Mixed Initiative Planning and Execution
- Autonomous Reasoning and Decision Making
- Continuous Assessment

Information Collection / Management

- Acquire
- Transform
- Access
- Architectures

Computing and Software Technologies

- Computing Hardware
- Algorithms and Software
- Systems and Processes

Networks and Communications

- Radios and Apertures
- Networks
- Information



Technology Taxonomy: Tier 2&3



HCI for Decision Making

- User Interaction
 - Understanding Nonverbal Behavior
 - Natural Task & Content Interaction
 - Bio-Psychometrics
- Collaboration
 - Facilitated Shared Awareness
 - Virtual Human Behavior Modeling
 - Collaboration with autonomous systems (Advanced Supervisory Control)
- Information Presentation
 - Innovative Display Technologies
 - Presentation Aware Information Derivatives
 - Task/Decision based Information Abstraction
- Display Management
 - Task & Display-Aware Information Routing
 - Task & Display Sensitive Adaptive Information Displays
 - Progressive Information Disclosure
 - Spatial Localization Cueing
 - Adaptive Aesthetics

Synthesis / Analysis / Decision Tools

- Sensor Understanding
 - Object/Anomaly Detection
 - Object Tracking
 - Object/Attribute Recognition Mission assurance
 - Scene Reconstruction / Understanding
- Data Fusion and Analysis
 - Data Conditioning
 - Object / Entity Assessment
 - Situation Assessment
 - Impact Assessment:
 - Process Refinement/Resource Management
- Human Language Technology (HLT)
 - Textual Data Analysis
 - Speech Analysis
- Mixed Initiative Planning and Execution
 - Cognitive Work Analysis
 - Course of Action Development and Analysis
 - Synchronization of cross domain (air, space, cyber,

- land and maritime) effects
 - Dynamic re-allocation and tasking
 - Distributed collaboration
- Autonomous Reasoning and Decision Making
 - Machine Learning
 - Cooperative Teaming
 - Automated Planning and Plan Recognition
 - Closed loop Resource Management
 - Trust
- Continuous Assessment
 - Presentation of forces
 - Operational assessment
 - Mission Assurance
 - Managing Uncertainty

Information Collection / Management

- Acquire
 - Adaptive Collection
 - Aggregation & Inference
- Transform
 - Unstructured-to-structured (rep & process)
 - Ontologies
 - Provenance
- Access
 - Search & Retrieval
 - Info Discovery
 - Trust & Access Control
- Architectures
 - Tactical Realization of Enterprise Architectures
 - Policy-based Information Exchange
 - Heterogeneous Interoperability
 - Semantic Stores and Warehouses

Computing and Software Technologies

- Computing Hardware
 - High Performance Computing
 - Distributed Tactical Computing
 - Advanced Computing Architectures
 - Advanced memory and Storage Technologies
- Algorithms and Software
 - Programming Languages

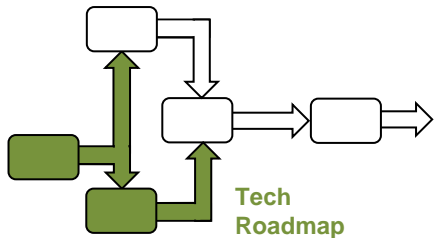
- Formal Methods
- Parallel OS / scalable algorithms
- Predictive science
- Uncertainty Quantification
- Optimization / Intelligent Algorithms
- Data Intensive Science algorithms
- Systems and Processes
 - Co-design and user composition
 - Software Engineering
 - Software architectures
 - Energy-efficient (systems/processors)
 - Intelligent/Adaptive computing platform
 - Simulation and Emulation processes

Networks and Communications

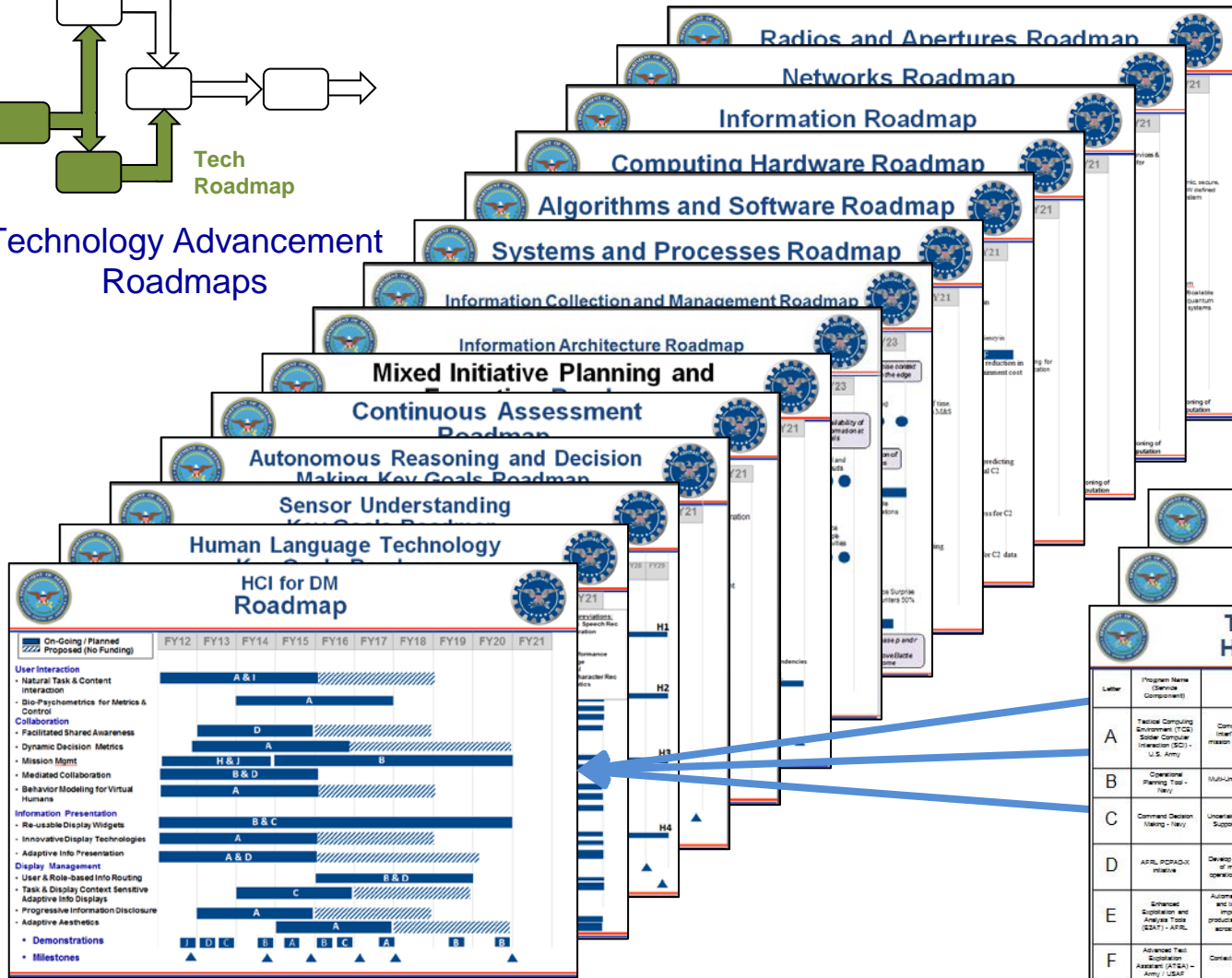
- Radios and Apertures
 - Spectrum sensing/sharing/management
 - Unicast/Multi-cast protocols
 - Software defined interfaces
 - Dynamic Forward Error Correction (FEC)
 - Spatial multiplexing
 - Quantum, optical, THz communications
 - Physical layer security
 - Components
 - Compatible or common gateways/interfaces
- Networks
 - Software-defined/cognitive networking
 - Network coding
 - Routing protocols
 - Transport protocols (e.g. IP)
 - Disruption tolerant networking
 - Directional networking
 - Network assurance
 - Dynamic collaboration
- Battlespace Networked C2
 - Transport protocols/services/applications
 - Data/message standards
 - On-demand QoS-based services
 - Digital policy-based prioritization
 - Dynamic bandwidth allocation
 - Automated network management



Technology Roadmap Summary

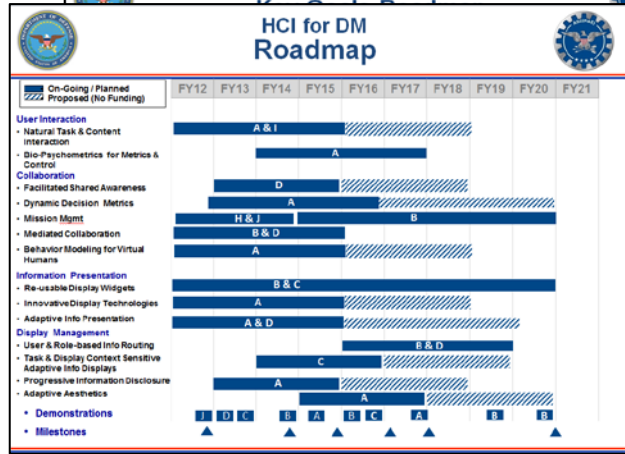


Technology Advancement Roadmaps



Over 350 pages of material

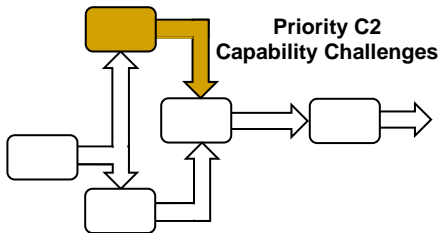
Programs and metrics



Letter	Program Name (Service Component)	Technical Contribution	Metrics		
			New (F1)	Mid (F2-F3)	Far (F4-F5)
A	Tactical Computing Environment (TCE) / Social Computer Interaction (SCI) - U.S. Army	Command-centric Human Computer Interface (HCI) to reduce manual tasks in any weapon.	Baseline: Time to complete task & cognitive workload (subjective manual measures)	Automatic, unobtrusive and continuous task & cognitive workload measurement and workload reduction; improvement of 25% over baseline.	Real-time, dynamic and unobtrusive workload measurement; auto-remediation; improvement of 50% over baseline.
B	Operational Planning Tool - Navy	Sub-Unit Mission Management / Navigation Decision Support Tools	Demomstrate on-demand taskgroup re-planning in < 2 min.	Transitioned across Fleet & Multi-echelon	
C	Command Decision Making - Navy	Uncertainty Management; Proactive Decision Support; Context-Driven Decision Making	Uncertainty Management validated in operations setting. Operational time accommodated < 10 min.	POS tools demonstrated with CS2, via JFCC. 2L reduced in 1/3 time. Operational Context Modes demonstrated.	POS ubiquitous across echelons. Scheduled in Autonomous systems.
D	APRL PODARC Initiative	Developed HCI tools to enable workflow analysis of multi-IT data for OCSG tactical operations in support of situation awareness	Decrease timeline by 1 hour	Support demonstration of OCSG information with tracking for fast search and discovery.	
E	Scheduled Disposition and Analysis Tools (SDAT) - AFRL	Automated assessment; target recognition and tracking for overwatch and follow-up; improve ability to search data, build products, and improve OCSG team workflow across multi-IT data feeds, information context, and enterprise.	Analytic Values for OCSG	Deployed in OCSG PODARC	
F	Advanced Test Support Assistant (ATSA) - Army / USAF	Context-based Test selection for MUNIT analysis	Analytic Values for OCSG	Deployed in OCSG PODARC	



C2 Definition, Vision, & Gaps



Joint C2 Vision

- Commanders and staff require Joint C2 capabilities that provide timely, relevant and accurate data to **improve their situational awareness and assist decision-making.**

Joint C2 Definition

- Command and Control**
 - "The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. Mission command is the preferred method of exercising C2."
- Mission Command**
 - "The conduct of military operations through decentralized execution based upon mission-type orders. Empowers individuals to exercise judgment in how they carry out their assigned tasks... Successful mission command demands that subordinate leaders at all echelons exercise disciplined initiative and act aggressively and independently to accomplish the mission. Essential to mission command is the thorough understanding of the commander's intent... and a command climate of mutual trust and understanding."

Joint Publication 1 - Doctrine for the Armed Forces of the United States, 28 March 2013

FOUO: Pre-decisional

AF C2 Capability Gaps 2

AF C2 Capability Gaps 1

CFLI: ACC

Navy C2 Gaps

Army Mission Command Gaps

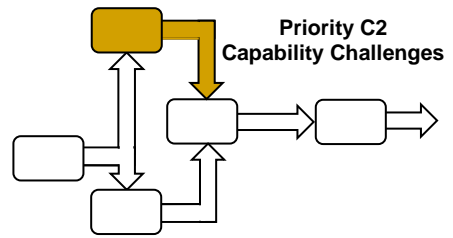
Objective	Taxonomy	Sources
<h3>Joint C2 Capability Gaps</h3> <ul style="list-style-type: none"> Gap 1: Inability to collaboratively construct and actively manage operations plans and orders Gap 2: Inability to manage creation and updating of SA Gap 3: Inability to collaboratively plan and synchronize employment of forces Gap 4: Inability to make releasable COP track information available and accessible to mission partners of separate network domains. Gap 5: Inability to quickly and securely pass non-COP operations and planning information to mission partners on separate networks Gap 6: Inability to provide integrated, interoperable, Joint C2 information environment Gap 7: Inability to integrate ISR assets across national, Service and Component boundaries 		
<small>Joint Command and Control (C2) Capability Development Document (CDD) Version 1.4 9 April 2013</small>		
<small>FOUO: Pre-decisional</small>		

References:

- Joint Pub. 1: Doctrine for the Armed Forces of the United States
- Joint Command and Control (C2) Capability Development Document (CDD) Version 1.4

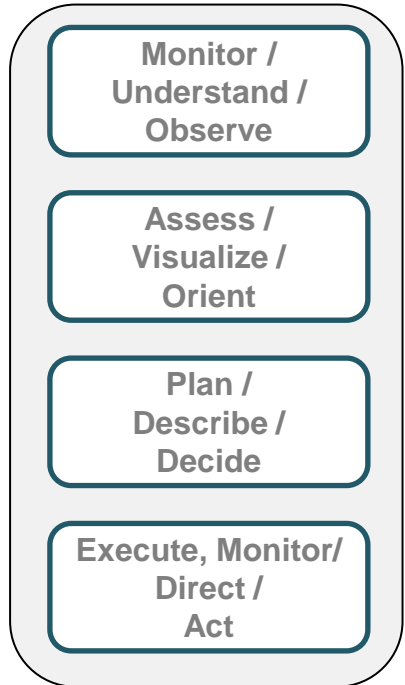


Priority C2 Capability Challenges



Priority C2 Capability Challenges

C2 Capabilities (MAPE / MC / OODA)



Collaboration

Enable human interaction and collaborative decision making to achieve unity of effort

Automation /
Autonomy

Enhance force capability through Automation/Autonomy

Uninterrupted
Command

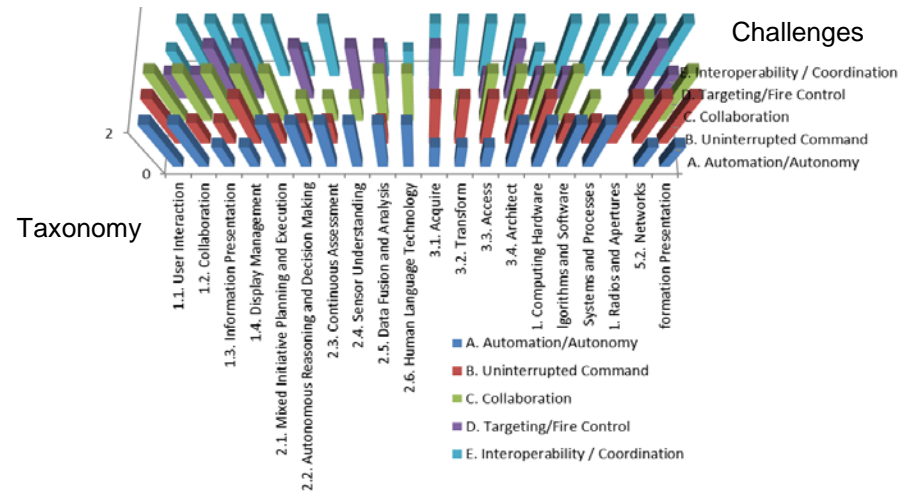
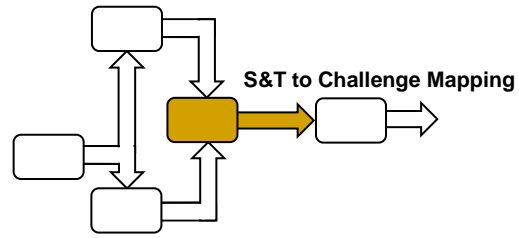
Enable mission execution at all echelons anywhere, at anytime, regardless of network/system status

Interoperability
/ Coordination

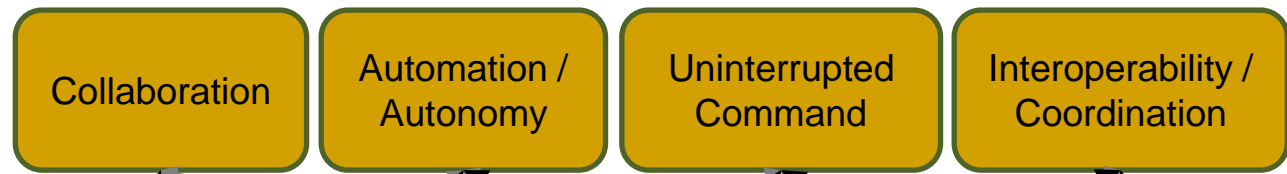
Seamless and secure movement and integration of mixed format data/information between service, joint and coalition networks/systems



Technology to Capability Mapping



Priority C2 Capability Challenges



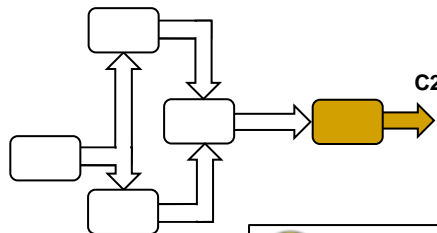
Technologies



Significant Dependency



C2 Capability Roadmaps



C2 Roadmaps

Collaboration Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Context Driven Planning and Decision Making		

Collaboration Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Human-Machine Collaboration		

Autonomy/Automation Roadmap - Example (Continued) -		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
C2 of Autonomous Systems		

Autonomy/Automation Roadmap - Example -		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Automated Planning, Analysis and Decision Tools		

<ul style="list-style-type: none"> Reduce cognitive burden on signal staff by providing automated network analysis Optimized planning of air, space and cyber assets maximum effect for limited scale/complexity event Sense changes in environment and autonomously propose planning updates Automated, planning/decision tools can maximize the performance of a sensor field Automated COA creation Common network picture for improved joint SA, automated network risk status & analysis tool, tactical network resource decision support, network traffic & health monitor Synchronization of air, space, cyber forces - Deliberate planning, limited scale and complexity Warfighters give assistance with cognitively overwhelming tasks via Artificial Intelligence (Associate Systems) Assess effects of full-spectrum force options at all levels (Strategy - T&E) Lower echelon tools for situational awareness and decision support 	<ul style="list-style-type: none"> Extend game theory to enable decentralized and dynamically-centralized problem solving for dynamic learning Sense changes in environment and autonomously propose planning updates Planning and synchronization, increased scale - common plan understanding across all domains, seamlessly integrate non-linear associations (C2/COA/COE/COI) Quantify impact of network status on mission assurance Autonomous, self-reconfiguring network resource allocation schemes responsive to current conditions, situations and priorities as each mission is executed Reduce Cognitive Burden by unloading tasks (could support force reduction) Increase targeting capabilities to include full range of options, increase depth & breadth of analysis, reduce time to perform analyses & generate target listers Smart/intelligent sensor management/integration of sensor management and operational planning tools Software and algorithms to support interoperability and real-time (MUSG, low latency) data processing for planning and decision support tools Techniques for handling uncertainty representation throughout the planning process Agile virtual staff assisting with both mundane and wicked problems to compensate for personnel and training shortfalls 	<ul style="list-style-type: none"> Automated mission assurance C2 systems assess, identify, present options in near real time within & across air, space, cyber domains Automated extraction of info from level 2 speech reduce data overload, enables the use of automated analysis tools, and results in faster, more effective assessment Ability to perform Cross-Domain Solutions (CDS) remote monitoring at the Enterprise level that provides full SA of the operations of multiple security domains Agile operations, dynamic option/generation across air, space, cyber domains Better utilization of expensive/critical/scarc assets; faster, better, more accurate decisions. Ability to manage and control large, complex distributed systems Demonstrate a robust, unified autonomy capability for complexity Comprehensive in-depth understanding of causal relationships - Linked effects, actions, and desired end-states
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FOUO: Pre-decisional

Interoperability/Coordination Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Data Interoperability		

Interoperability/Coordination Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Hardware Interoperability		

Uninterrupted Command Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
Maintain Cores		

Uninterrupted Command Roadmap		
Near (1-5 years)	Mid (6-10 years)	Far (11-15 years)
<ul style="list-style-type: none"> Real-time, on-board processing enabling autonomous sensing and prioritized IR in A2AD environments Optimized routing to increase network efficiency. Reduce network operating and assessment costs C2 messages easily transmitted over low bandwidth to maneuver / cap platforms beyond detected threats Understand behavioral behaviors to proactively manage delivery of high value information to counter threats Robust cognitive communications for mobile, situation aware force operating in dynamic, contested, & connected IR environment 	<ul style="list-style-type: none"> Transforming C2 data sets into common format, based on common C2 ontology, for exploitation via analytics that output low bandwidth information for decision making, then output to C2 Develop mission aware techniques to prioritize information requirements during times of intermittent connectivity Techniques to re-prioritize tactical assets during intermittent connectivity in accordance to commander's intent Live, virtual, and constructive (LVC) simulation of disconnected, interrupted, and low-bandwidth environment 	<ul style="list-style-type: none"> Resource aware IR management services responsive to dynamic user needs and limited resources Investigate techniques to prioritize nodes, assets and resources critical to execution of the campaign to ensure they remain functionally responsive to commander's intent in any operating environment or condition Investigate adaptive tactics/system based systems to understand CIL Development of adaptive collaboration tools techniques & procedures, Proactive Decision-Support tools, & research on dynamic context modeling
<ul style="list-style-type: none"> Operate With Low Bandwidth 	<ul style="list-style-type: none"> Operate Without Cores 	<ul style="list-style-type: none"> Operate Without Cores
<ul style="list-style-type: none"> Demonstrate Autonomous Systems ability to thrive in contested environments through dynamic reconfiguration and acting within a pre-planned policy Real-time, on-board processing enabling autonomous sensing and prioritized IR in A2AD environments Reduced off-load cores via on-board sensor processing to reduce IR bandwidth pressure 	<ul style="list-style-type: none"> Increase effectiveness of unmanned systems in A2AD environments Develop mission aware techniques to prioritize information requirements during times of intermittent connectivity Information presentation in augmented reality (AR) contexts providing opportunities for tactical Warfighters who are disconnected from track-based capabilities for tactical support Live, virtual, and constructive (LVC) simulation of disconnected, interrupted, and low-bandwidth environment 	<ul style="list-style-type: none"> C2 of C2 in A2AD environments Investigate techniques to prioritize nodes, assets and resources critical to execution of the campaign to ensure they remain functionally responsive to commander's intent in any operating environment or condition Investigate adaptive tactics/system based systems to understand CIL

FOUO: Pre-decisional



C2 Capability Roadmaps

- Top Level -



C2 Priority Challenges

Barriers/Impacts

Enabling S&T Investments

Uninterrupted C2

- Operate in A2/AD Environment
 - Maintain Connectivity
 - Operate Disconnected
- C2 in Austere Environments
- C2 On The Move

- Network vulnerabilities
- Overdependence, no fallback

Near: Mobile computing platforms, Discovery algorithms, Study alternative transmission platforms
Mid: Mission aware prioritization, cognitive reconfiguration
Far: Non-contiguous spectrum, Hardened/advanced transmission media (quantum, optical)

Autonomy/Automation

- Machine "Comprehension" of CDR's Intent
- Lighten the staff's load
- Improve Decision Making

- Overwhelming data abundance
- Human resources

Near: Planning/COA Analysis, *autonomous interpretation of intent, better understanding of trust*
Mid: Real-time planning updates, *Certainty metrics in support of recommendations/actions, V&V in support of trust*
Far: *Staff support in absence of staff, near real-time planning updates, comprehend orders documents*

Collaboration

- Capture CDR's Intent
- Intuitive
 - Product Sharing
 - Interaction

- Communicate but can't share ideas
- Unintuitive interface

Near: *Touch, gesture, voice interaction, improve understanding of distributed decision making, tailorable visualization*
Mid: *Automated/user-sensing display management, Human Machine Experimentation Environment,*
Far: *decomposed representation of commander's intent, transparent facilitated collaboration, context/user aware information display*

Interoperability/Coordination

- Cross Domain Solutions
- Cognitive Systems

- Partners left in dark
- Dependence on Field Support Reps.

Near: *push/pull info mechanisms, scalable waveforms, language translation, exploration of data/info sources*
Mid: *unified, cross domain platform solutions, reduce unstructured data exchange, unstructured data transformation*
Far: *real-time spectrum management, information sharing across waveforms and message standards, automatic info guard functions*

Blue text indicates tie with human-machine initiative



HCI for Decision Making Challenges



Challenge: Speed of Command requires timely delivery of useful information, to the right people at the right time, presented so as to support mission critical decisions. Too much data - not enough information.

Opportunities:

- Valuing & sharing information based on task needs ^{HCI-1}
- Uncertainty Management ^{HCI-3}
- Proactive Planning Decision Support, Learn User's habits / needs ^{HCI-5}
- Information Provenance Pedigree ^{HCI-6}
- Machine Facilitated Collaboration for managing Autonomous & Complex Systems ^{HCI-8}
- Information Management for limited connectivity ^{HCI-11}
- User Behavioral Anomaly Detection ^{HCI-13}



Synthesis/Analytics/Decision Tools Challenges



Challenge: Current C2 planning processes exhibit horizontal and vertical information gaps, and human planners lack cognitive bandwidth to effectively coordinate and synchronize operations across the unique complexities of the air, space, cyber, land and maritime domains.

Opportunities:

- Develop tools for tracking, positive ID, observing behaviors and activities of objects in all domains to determine adversary threats ^{SADT-1}
- Determine the nature and impact of conditions and events on force capabilities and commander's intent ^{SADT-2}
- Develop tools for developing, evaluating, and selecting courses of action ^{SADT-3}
- Develop technologies for synchronization of forces, and real-time planning updates ^{SADT-4}



Information Collection/ Management Challenges



Challenge: Recent conflicts indicate we must consistently prepare for operations in contested environments that are communications constrained and demand increased op tempo and exploitation of heterogeneous sources, all in an era of decreasing manpower

Opportunities:

- Scalable semantic interoperability ICM-1
- Tactically distributed collection & processing ICM-2
- Task-centric, federated, extensible data models ICM-3
- Context enhanced information fusion and integration ICM-5
- Dynamic context (mission/user) aware information retrieval ICM-6



Computing and Software Challenges



Challenges:

Rapid obsolescence hinders maintenance of overmatch, consumer systems enable opportunities to challenge our overmatch. Disruptive technologies such as quantum, bio-mimicking, and other new architectures present opportunities and threats.

Opportunities:

- Cost of Tech Refresh: Improve Reconfigurability, Modularity, Interoperability, Extensibility
- Robust real-time situational awareness for C2 by exploiting computing research and software technologies
- Future and exotic computing architectures and associated algorithms and software
- Distributed Computing
- Reduce Size, Weight, Power, Cost



Networks and Comms Challenges



Challenge: An increasingly crowded spectrum and contested environments threaten our ability to assure connectivity for C2

Opportunities:

- Spectral Efficiency ^{NC-1}
- Spectral Diversity ^{NC-1}
- Electronic Protection (Anti-Jam Comms & Co-Site Mitigation) ^{NC-3}
- LPD/LPI Comms ^{NC-4}
- Increased Range ^{NC-7}
- Increased Loss Tolerance & Recovery ^{NC-7}
- Mobile Ad Hoc Networking ^{NC-8}
- Autonomous Network Management & Control ^{NC-10}



Collaboration Opportunities



Warfighter Capability:

- Ability for CDR, staff and peers to seamlessly interact and collaborate using digital data across mission areas in real time in distributed environments

Opportunities:

- Develop standards and employment protocols for User Defined Operational Picture widgets & services across multiple missions and warfare domains
- Develop agent-based simulations of military C2 units for evaluation of alternative HCI design concepts
- Develop Context Driven Decision Making capabilities
- Research languages and techniques for developing executable policies that can be potentially be applied to multi-security-domain exchange
- Develop enterprise network collaboration tools and collaboration apps for application to military needs



Autonomy Opportunities



Warfighter Capabilities:

- Ability to automate work that contributes to increasing speed and effectiveness of C2.
- Supervisory control of multiple autonomous systems

Opportunities:

- Research human trust in agent-presented information and analysis and in autonomous systems
- Develop a testbed and evaluate various advanced Human Computer Interface (HCI) technologies that allow Commanders to task and evaluate autonomous C2 systems
- Develop scenario based experiments to measure military effectiveness and highlight that autonomous operations can be trusted to perform missions as defined.
- Develop realistic C2 of autonomous systems challenge problems that are motivated by operational experience and evolving mission needs



Automation Opportunities



Warfighter Capabilities:

- Human-machine teaming for faster, informed decision making.
- Development and analysis operational plans and courses of action Maximized operator efficiency, give the machine jobs the machine does better

Opportunities:

- Translation of commanders intent and OPORDS to machine readable format
- Identify the biggest payoff C2 capabilities to leverage autonomy and automation to focus investments, [which manual processes could be done faster and better]*
- Develop capabilities for diverse genre networks (social, information, communication) information fusion.
- Adapted COTs and GOTs to move from traditional computing architectures to emerging and innovative computing architectures specifically for C2 applications



Uninterrupted Command Opportunities



Warfighter Capability:

- Enable mission execution at all echelons anywhere, at anytime, regardless of network/system status

Opportunities:

- Model and demonstrate technology alternatives for provisioning and operating assured communications in DIL and A2/AD joint space, aerial layer, surface and undersea environments.
- Develop cross-service, mission-adaptive collection and processing algorithms that can be employed at the sensor level to insure mission critical data collections have highest priority and distribution requirements are minimized.
- Research multi-layer distributed C3 capabilities to enable centralized planning, distributed control, and decentralized execution.
- Develop resource-aware information distribution algorithms that can be employed to decrease data throughput requirements when connectivity is intermittent.
- Mature neuromorphic, cognitive and quantum computing similar to traditional computing field



Interoperability/Coordination Opportunities



Warfighter Capabilities:

- Ability to seamlessly and securely move and integrate mixed format data/information between service, joint and coalition networks/systems in DIL Environments
- Ability for forces to enter/exit any operational environment and maintain secure connectivity to the grid, communicating at will with their mission partners, and having continuous access to relevant data under any threat conditions

Opportunities:

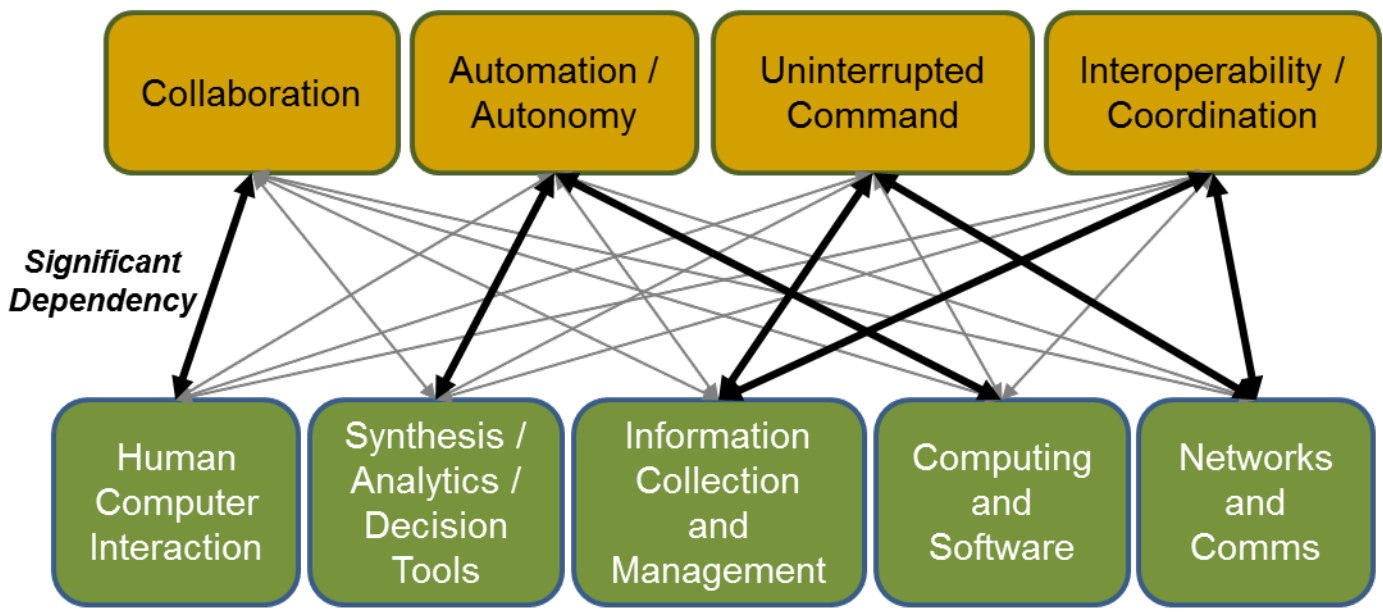
- Develop and utilize standards and protocols for interoperability of data, standardization approaches to SDK and apps across Services
- Investigate cognitive and software defined networking approaches as affordable means to interoperability, and to shape formative, pending standards developments.
- Extend Enterprise Cloud concepts to tactical environment for cross-service Situation Awareness applications
- Evaluate the impact of trust, quality and value mechanisms for addressing cross-service network overload and mission outcome.



Opportunities for Industry Engagement



- Innovation Marketplace:
<http://www.defenseinnovationmarketplace.mil/>
- C4I Page Under Development





C2 Roadmap Conclusions



COI activity provided for:

- **Common taxonomy and process for Joint S&T community collaboration on C2 and C4I**
- **Consensus on Priority C2 Capability Challenges that provided scope and focus for continued collaboration**
- **Refinement and completion of mid-term and long-term C2 Roadmaps**



C4I COI Current Focus



- **"Uninterrupted D2D"**
- **Human-Agent Planning Teaming and Execution (HAPTE)**
- **Exploring Other Cross-COI Opportunities**

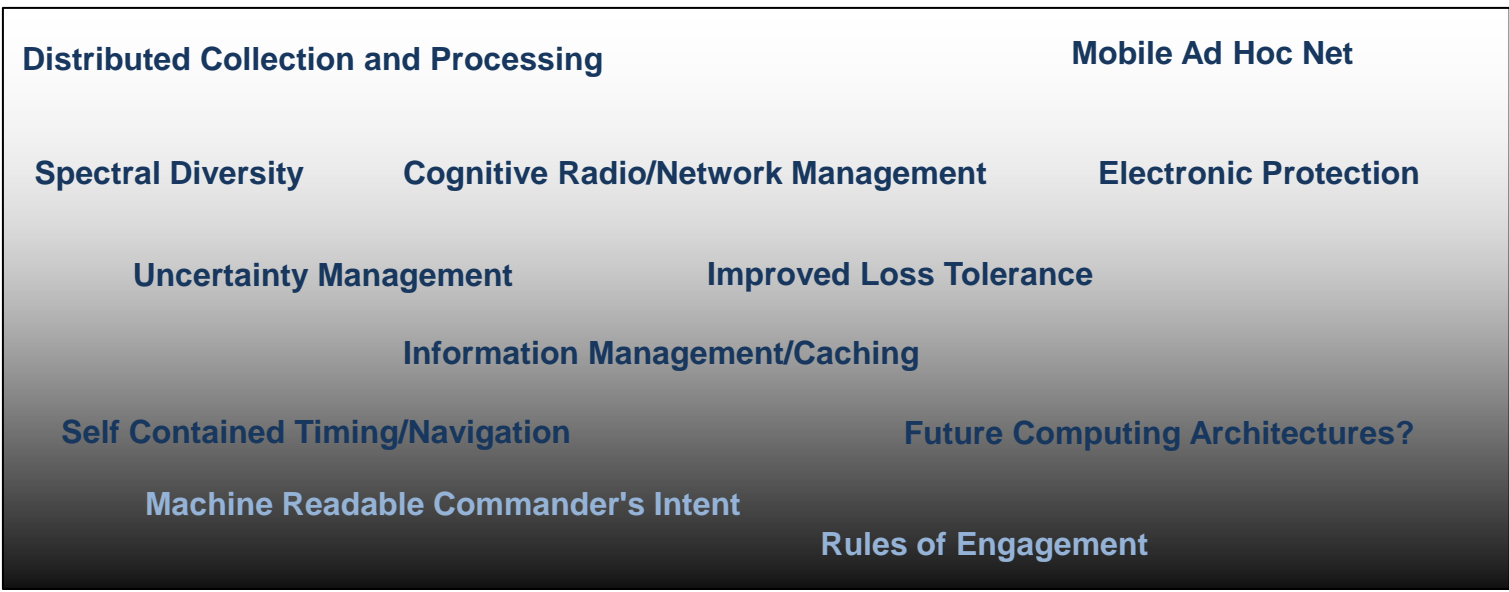


C4I COI Conclusions



- **‘Uninterrupted D2D’ being pursued as a follow-on COI activity**
 - Foundational to C2
 - Concluded independently from parallel ‘Hard Problems’ findings
 - Assured Position, Navigation, and Timing (PNT) and Comms included within scope of this activity; applying the same COI process to these areas

Stay
Connected



Operate
Disconnected



Cross-COI Conclusions



- **Human-Agent Planning, Teaming and Execution (HAPTE) Cross COI Initiative**

- Explicit touch points in taxonomies across C4I, Human Systems, Autonomy, and Sensors COIs
- Potential to expand collaboration beyond existing and established communities of practice
- Most significant advancement opportunity exists at the intersection of shared interests and investments

Propose this area as the basis for follow-on OSD focus and support



Human-Agent Planning, Teaming and Execution (HAPTE) Initiative



Objectives:

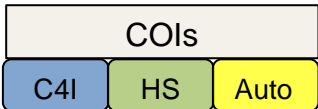
- *develop machine capability to capture and intelligently interpret Commander's Intent*
- *demonstrate improved Commander's mission analysis, Course of Action development / assessment*
- *demonstration of multi-agent development and execution of Joint ISR plans*

Operational Impact:

- *increase the speed and accuracy of Commander and staff decision making*
- *increase mission effectiveness*
- *reduce manpower requirements*

<ul style="list-style-type: none"> •System Interfaces •Personnel & Training •Social & cultural Understanding •Protection & Sustainment 	<p>Human Systems COI</p>
<ul style="list-style-type: none"> •HCI for Decision Making •Synthesis, Analytics for Decision Making •Information Collection & Management •Computing and SW •Networks and Communications 	<p>C4I COI</p>
<ul style="list-style-type: none"> •Human Autonomous Sys. Interaction & Collab. •Scalable Teaming of Autonomous Systems •Machine Perception, Reasoning & Intel •T&E, V&V 	<p>Autonomy COI</p>
<ul style="list-style-type: none"> •Electro-Optical and Infrared •Acoustic, Seismic and Magnetic •Radio Frequency (Radar) •(Processing) 	<p>Sensors COI</p>

HAPTE will be executed leveraging expertise from across the Services and the Communities of Interest. Partners include: ARL, ARI, RDECOM, NRL, ONR and AFRL.



HAPTE



5. Manned/unmanned agents execute ISR plan and feed information to commander

Information Presentation, Presentation Aware Information Derivatives, Task/Decision based Information Abstraction, Collection Management

Human-Machine Teaming, Intuitive Interaction

Robust Self-organization, Adaptation, & Collaboration, Calibrated Trust, Understanding the Situation/Environment

4. HAPTE systems task team of manned/unmanned agents to execute joint ISR plan

Intelligent Planning tools, Interoperability

Decentralized Mission-level Task Allocation/Assignment, Robust Self-organization Adaptation & Collaboration, Human-Agent Interaction

3. Based on intent & assets, intelligent systems assist in developing joint-ISR plan

Synthesis/Analytics/Decision Tools, COA development & Analysis, Collaboration with Autonomous Systems, Natural Task & Content Interaction, Situation Assessment

Intelligent, Adaptive Aiding

Understanding the Situation/Environment

2. HAPTE systems interprets intent

Collaboration with Autonomous Systems

Learning and Reasoning, Human-Agent Interaction, Common Understanding & Shared Perception

1. CDR issues mission intent in machine readable format

User Interaction, Natural Task & Content Interaction, Plan Recognition, Human Language Technology

Intuitive Interaction, Human-Machine Teaming



Conclusion



- **C2 Roadmap Baseline**
- **Follow-on Activities**
 - Continue to Refine C2 Roadmap
 - Work "Uninterrupted D2D"
 - Look for Cross-COI Opportunities