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The Evolution of C2

Composable Capability on Demand (CCOD®): A New Paradigm for the Design, Acquisition and Employment of IT-Based C2

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Abstract

This paper presents a new paradigm for meeting IT-based needs of Command and Control: Composable Capability on Demand (CCOD®). This transformational concept represents a deliberate shift away from traditional C2 systems acquisition and development strategies toward developing and fielding infrastructure and components that can be rapidly integrated to create new and enhanced capabilities when necessary. In so doing, this concept enhances the users' ability to innovate and define a more responsive, flexible, interoperable and robust C2 capability.

The underlying tenets of CCOD are consistent with state-of-the-art theory and practice for IT developments. This new approach (as compared with current DoD acquisition practice for IT-intensive C2 systems) capitalizes on many of these same architectural tenets to expose data and services to users such that they are readily leveraged and integrated to create "new" C2 capabilities - *on demand*.

CCOD is driven by operational need and enabled by technology advances. Moreover, for the acquisition community, CCOD promotes more rapid evolution of capability than what is feasible with today's acquisition processes. This paper examines each of these factors and presents our MITRE-developed CCOD research agenda and strategy to develop a CCOD reference implementation, build and test against operationally relevant use cases, and formulate viable acquisition and governance processes.

1. Introduction

This paper presents a new paradigm for meeting IT-based needs of Command and Control: Composable Capability on Demand (CCOD®). This transformational concept represents a deliberate shift away from traditional C2 systems acquisition and development strategies toward developing and fielding a flexible infrastructure and separate components that can be rapidly integrated to create a new and enhanced capability that a situation demands. With this approach, users will be able to respond to situations—whether it's setting up a command center on the battlefield or during a hurricane—with an adaptable, interoperable capability.

The underlying tenets of CCOD are consistent with state-of-the-art theory and practice for IT developments. This new approach (as compared with current DoD acquisition practice for IT-intensive C2 systems) capitalizes on many of these same architectural tenets to expose data and services to users such that they are readily leveraged and integrated to create "new" C2 capabilities - *on demand*.

CCOD is not a system, and it is more than an architecture approach; it is a concept that promotes a new approach to how we design and develop IT-based C2 capability and how the users employ it. CCOD is driven by operational need and enabled by technology advances. Moreover, for the acquisition community, CCOD promotes more rapid evolution of capability than what is feasible with today's acquisition processes.

The first portion of this paper presents the motivation for CCOD in terms of the three above-mentioned factors – operational need, technology enablers, and acquisition reform. The second portion of this paper presents the MITRE-developed CCOD research agenda and strategy to develop a CCOD reference implementation, build and test against operationally relevant use cases, and formulate viable acquisition and governance processes.

2. Operational Need for the 21st Century: Dynamic and Responsive C2 Capability

"What is dubbed the war on terror is, in grim reality, a prolonged, worldwide irregular campaign -- a struggle between the forces of violent extremism and those of moderation. Direct military force will continue to play a role in the long-term effort against terrorists and other extremists. But over the long term, the United States cannot kill or capture its way to victory."

Secretary of Defense Robert Gates, January 2010

Secretary Gates' sobering characterization of the Global War on Terror is a harbinger of our nation's military challenges for the twenty-first century. Our strategic environment has fundamentally changed; it is no longer sufficient to rely on military doctrine and C2 systems designed for conventional warfare and phased operations. Instead, we must consider the nature of current and evolving threats to US security and our strategic interests, explore lessons learned from recent and on-going conflicts, and respond by developing command and control capabilities that will be effective across the widest possible spectrum of conflicts that we are likely to face in the future.

In his February 2009 *Annual Threat Assessment of the Intelligence Community*, Mr. Blair, Director of National Intelligence, provides a comprehensive assessment of threats to US national security. Central to this assessment is the complex set of factors that contribute to instability in many regions across the globe, notably: the far-reaching effects of the global economic crisis, violent extremism and terrorism, and the proliferation of weapons of mass destruction. From a geographical perspective, the "Arc of Instability", i.e. the region from the Middle East to South Asia, is considered the epicenter for challenges the US military will face in the 21st century.

In fact, we have witnessed each of these factors and the instability and challenges they create in today's conflicts in Afghanistan and Iraq. We have also witnessed the shortcomings of military doctrine and systems that were conceived of and designed for a very different war. In *Winning the Peace: The Requirement for Full Spectrum Operations*, Maj Gen Chiarelli and Maj Michaelis make a compelling case for the need for adaptive and responsive C2 capabilities based on their experience in Bagdad, where the objective is "not to win the war but to win the peace". Specifically: "Even our own

C2 systems and process, oriented on providing clarity above, had to be turned upside down to focus on providing the tip of the spear with the information and actionable knowledge needed to determine the best course of action within the commander's intent, guidance, rules of engagement, and law of land warfare."

Adaptive, responsive command and control is equally critical for effective response to emergencies such as natural disasters and acts of aggression toward or within our homeland or our allies and partners. Events in our homeland present added complexity because they require swift decision-making and action and involve coordination and collaboration across organizational and jurisdictional boundaries, e.g. military and civilian organizations at the National, State and Local levels. Additional needs include seamless integration of traditional and non-traditional data sources, concurrent consequence and crisis management, and often, an extended period of recovery and reconstitution. Consider Hurricane Katrina as an example of both the challenges surrounding a catastrophic event and the shortfalls in our ability to respond effectively with today's capabilities.

In summary, the military conflicts and national crises we face now and in the future are inherently dynamic, complex, and unpredictable – and can only be met effectively with a command and control capability that is flexible, adaptive and agile. Responding to this need will require fundamental changes in the technologies we exploit and our acquisition processes for IT-based command and control capability; we explore these topics in the following sections.

3. Technology Enablers: Web 2.0 and Beyond

What technologies will enable a flexible, adaptive C2 capability in the future? Clearly, Web 2.0 technologies will play a central role. Web 2.0 technologies are generally defined as web development and design that facilitates interactive information sharing, interoperability, user-centered design and collaboration. In short, Web 2.0 technologies provide web users with the ability to create content and custom products while capitalizing on the power of the web to leverage collective intelligence.

Web 2.0 is more than a technology trend - it is a reality. Today's internet users routinely experience Web 2.0 tools and processes; artifacts include web-based communities, hosted services, web applications, social networking, blogs, wikis, and mash-ups. It is important to recognize that Web 2.0 is an evolution that resulted from the cumulative changes in the way software developers and end users use the web - not by building to a set of pre-conceived requirements or by managing the configuration of a tightly controlled baseline. I will revisit this important point in the next section of this paper in my discussion of acquisition processes.

In *Everything Elastic: Accenture Technology Vision for 2009,* Swaminathan envisions a new flexibility that he dubs "elasticity", in which business capabilities can flex to adjust to ever-changing (dynamic) needs and opportunities. He describes four technology trends that underpin this new concept: Internet Computing, Data and Decisions, m is the new e, and convergence of the 4 C's, communication, collaboration, communities and content. Both the "elasticity" concept and the technology trends that enable it are directly relevant to our vision and need for flexible, adaptive command and control capability; a brief description of these technology trends follows.

The first and most fundamental technology trend toward "elasticity" is "Internet Computing", a new paradigm that enables hardware, software and storage to be dynamically sourced through the internet. Internet computing is enabled by cloud computing, infrastructure virtualization, emerging standards for web services (e.g. Representational State Transfer, or REST) that allow software components to interact, rich internet applications, and development environments that enable "software as a service". The implications of internet computing are striking; entities are no longer limited by their internal (fixed) hardware, software or business processes.

The second technology trend toward "elasticity" is "Data and Decisions", i.e. advances that ultimately enable better use of data in decision-making. The supporting technologies include: improved data access by adoption of standards such as REST; tighter integration between data and the knowledge processes needed to analyze it; new technologies such as mash-ups that enable users to access and manipulate live data from multiple sources to support their needs; increasingly capable data visualization tools that also enable collaboration; and dynamic business process management, i.e. automated adaptation of business processes in response to patterns detected in data.

The third technology trend toward "elasticity" is "m is the new e", i.e. mobile devices are the new e-business platform and communication medium. This trend is largely based on the astonishing rate of innovation and proliferation of increasingly capable mobile devices. Finally, the fourth "elasticity" trend is the "Convergence of the 4C's – Communication, Collaboration, Communities and Content" that leverages technology advances in each of these areas (particularly social networking) toward seamless yet substantive communication and collaboration across communities.

Several of the above-mentioned trends and the technologies also appear in Gartner's *Top 10 Strategic Technologies for 2010*, presented at their latest IT Expo in October 2009. Among those cited are: cloud computing, advanced analytics, reshaping the data center, social computing, virtualization for availability and mobile applications.

Clearly, technologies that enable a flexible, adaptive command and control capability are known and evolving rapidly; moreover, we see their far-reaching impact today, ranging from the way the average internet user interacts with the web to the transformation of business processes world-wide. Why then are we not capitalizing on these information technology advances as we conceive of, design and develop command and control capability? The answer lies with our requirements-driven, multi-year acquisition process. In the following section we examine recent developments aimed to improve DOD acquisition of IT-based capability as well as the challenges that remain.

4. Acquisition of Information Technologies: The Case for Change

"Information technology offers immense capability in terms of agility, flexibility, responsiveness and effectiveness. It enables nearly all of our military combat capability and has become a necessary element of our most critical warfare systems. However, there is growing concern within Congress and among Department of Defense (DOD) leadership that the nation's military advantage may be eroding. The deliberate process through which weapons systems and information technology are acquired by DOD cannot keep pace with the speed at which new capabilities are being introduced in today's information age – and the speed with which potential adversaries can procure, adapt, and employ those same capabilities against the United States."

Report of the Defense Science Board Task Force on Department of Defense Policies and Procedures for the Acquisition of Information Technology (March 2009).

During the past two years we have seen deliberate focus and steps toward improving DOD processes for acquiring IT-based capability. Specifically, a Defense Science Board Task Force was assembled at the request of Congress, triggered by language in the National Defense Authorization Act for Fiscal Year 2008. The motivation for this study is given by the above quote from the DSB Task Force final report.

The DSB Task Force's primary conclusion is that "the conventional DOD acquisition process is too long and too cumbersome to fit the needs of many IT systems that require continuous changes and upgrades." The Task Force offered several recommendations, most notably, a new acquisition process for IT, "modeled on successful commercial practices, for rapid acquisition and continuous upgrade and improvement." Further, "the process should be agile and geared to delivering meaningful increments of capability in 18 months or less – increments that are prioritized based on need and technical readiness."

As a direct result of the DSB Task Force's recommendations, Section 804 of the National Defense Authorization Act (NDAA) for Fiscal Year 2010 legislates the implementation of a new acquisition process for information technology systems. Specifically, this new process shall be based on the recommendations in Chapter 6 of the March 2009 DSB report and include: early and continual involvement of the user; multiple, rapidly executed increments or releases of capability; early, successive prototyping to support an evolutionary approach; and a modular, open systems approach. Work is underway to flesh out the new acquisition process (including implementation schedule and other details) and due to report back to Congress within 270 days after enactment of the NDAA for Fiscal Year 2010.

These new developments are encouraging, particularly the call for early and continual user involvement. However, many of the fundamental tenets of traditional weapon system acquisition remain, such as pre-defined requirements, a "system" focus that implies a tightly controlled baseline, and incremental releases that may take up to 18 months. These pose significant limitations for the desired end state.

In the previous sections of this paper we have established (1) the need for flexible, adaptive command and control capability, and (2) Web 2.0 and related technology advances that enable user-based innovation, evolve over time, and are trending toward "elasticity" – the ability to flex in various dimensions according to need. But how will we specify a requirement for a dynamic, responsive capability that capitalizes on technologies that are evolving at breakneck speed? Why do we continue to think in terms of "systems" with rigid boundaries that inherently limit flexibility and agility? Most importantly, why should we constrain innovation and adaptability with tightly controlled baselines and incremental releases? The following section proposes a fundamentally new way of addressing command and control that capitalizes on technology and puts the ability to innovate squarely in the hands of the user.

5. Composable Capability on Demand: A Strategic Advantage

At MITRE, we are working to develop a transformational concept for IT-based command and control that we call Composable Capability on Demand (CCOD®). There are two key facets of our CCOD® vision. The first is to empower the warfighter to leverage information as an effective weapon by providing the ability to rapidly combine, adapt and extend C2 capabilities in response to evolving threats and mission needs. The second is to introduce a new acquisition paradigm for IT-based capability in which we rapidly develop and field infrastructure, components and a method to employ them. Together, these elements offer a strategic advantage by enabling the user to innovate and define a more responsive, flexible, interoperable and robust C2 capability.

The desire for increased flexibility to modify C2 systems over time is not new; technologies such as Service Oriented Architectures that are widely employed in IT-system design and development today represent a step in that direction. Today however, we see Web 2.0 and other technologies such as internet computing that offer a new level of flexibility – with impacts ranging from dynamic access and use of computing and network resources to the ability to *compose capability* – without artificially imposed system boundaries, a tightly controlled baseline, or incremental builds. These are the advantages we wish to introduce and leverage to meet the dynamic needs of command and control in the 21st century.

As with any new concept, there is much work to be done to develop and evaluate enabling technologies and operational concepts. To this end, MITRE has established an Internal Research and Development (also known as MITRE Innovation Program) investment portfolio for CCOD®. We have three primary goals for this investment, as given in Figure 1.

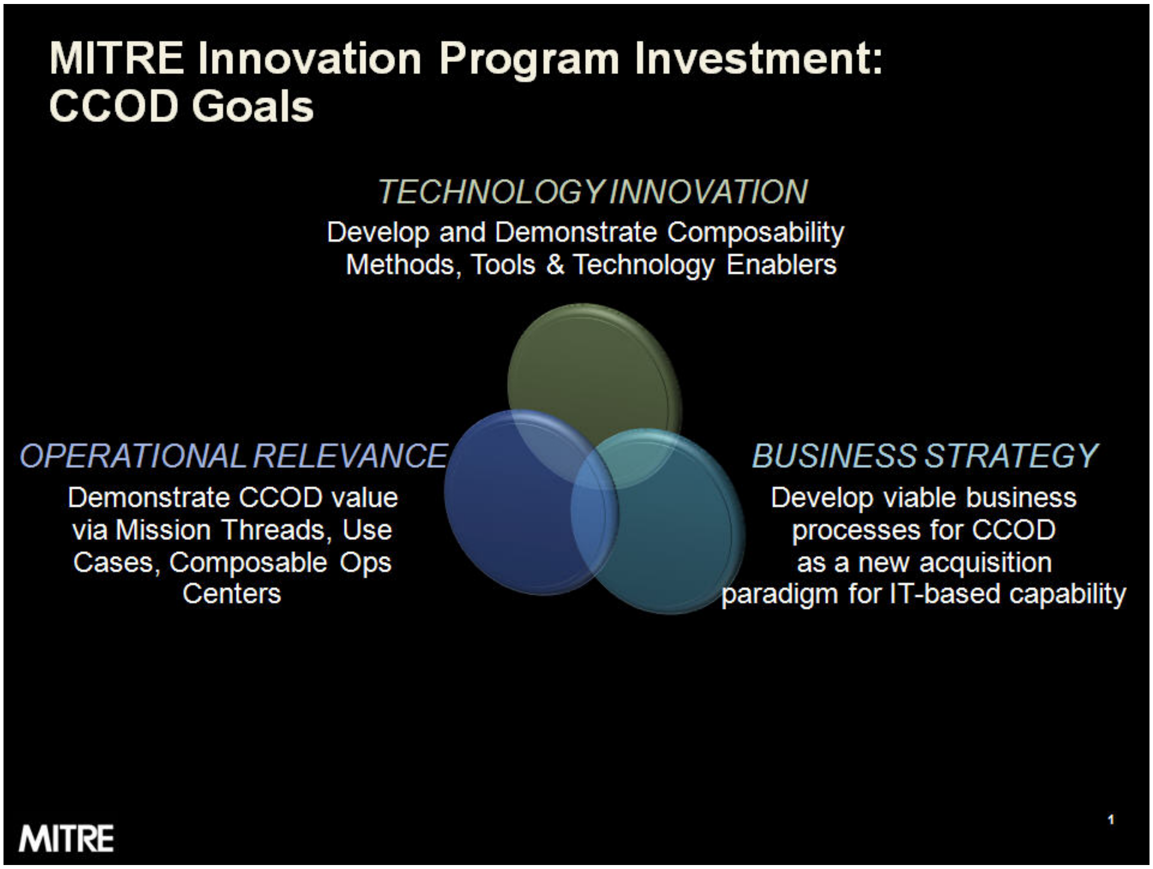

Figure 1. MITRE Innovation Program Goals for CCOD®

To meet these goals we have developed a research agenda comprised of eight elements, listed below. The first six of these address the functional capabilities that must be established for CCOD®; the seventh element addresses the new approaches and methods to system engineering for composability; the eighth element addresses the business processes of acquisition and governance that will be needed support this novel concept.

1. Establish that users can effectively access, adapt and dynamically employ distributed resources to support mission objectives
2. Establish resources are represented in a way that facilitates their effective discovery and effective use by users and applications
3. Establish (distributed) resources can be determined to be trustworthy and secure
4. Establish that users can dynamically plan, monitor, adapt and control provisioning of resources in support of mission objectives
5. Establish dynamic network access & linking capability responsive to computational distribution needs
6. Establish a distributed hybrid (fixed/mobile) processing environment to demonstrate a working model of a dynamic adaptive resource pool
7. Establish system engineering principles and methods of composable resources and architectures
8. Establish enterprise acquisition and governance models

More detail on each of these elements is provided by the Figures in Appendix A. Specifically, for each element we have developed a set of research questions that must be answered (with technical solutions) to achieve CCOD® functionality consistent with our vision. In MITRE's FY10 CCOD® portfolio we have invested in each of the above-mentioned eight elements, however we have given added priority (and IR&D dollars) to those we believe are fundamental for CCOD – specifically, elements 1, 2, 5 and 6.

The product of our FY10 efforts will be a CCOD reference implementation (version 0.1). This purpose of the reference implementation is three-fold: (1) to serve as CCOD proof-of-principle, (2) to provide a construct to capture and employ technology enablers as they are developed, and (3) to guide future research and development investments. Future investments in CCoD will be largely driven by the issues and challenges that surface and/or remain after FY10, and will contribute to an increasingly robust reference implementation.

During FY10 we are executing a series of integrated build/test events to assess technical solutions and demonstrate operational relevance and utility. Figure 2 presents the evaluation criteria driving our hypotheses, and Figure 3 presents three Use Cases we are using to assess and demonstrate operational relevance and utility.

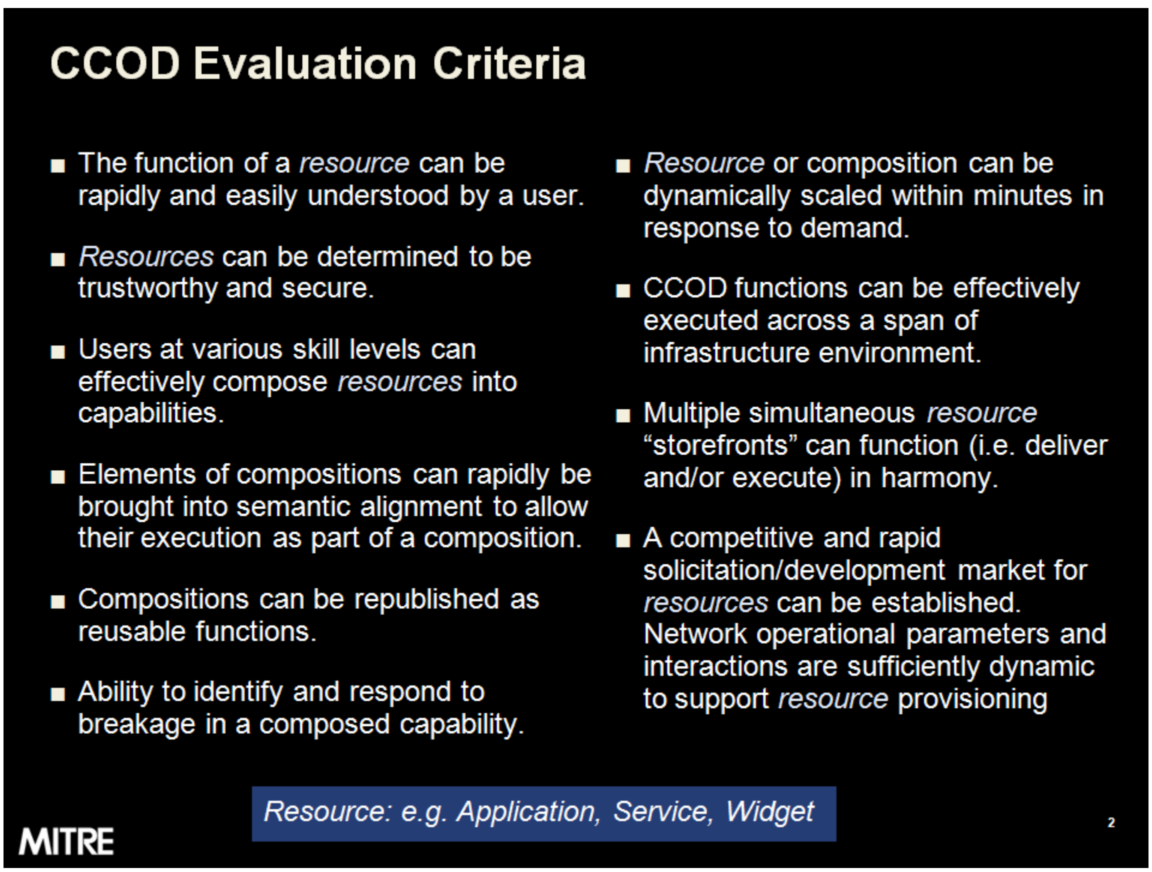

Figure 2. CCOD Evaluation Criteria

Figure 3. FY10 CCOD® Use Cases

These use cases were selected to address a cross-section of mission needs and operational challenges; a common denominator among them is the need for robust, dynamic, and responsive IT-based C2. Located at HQ SOUTHCOM, The Partnership for Americas Collaboration Center (PFACC) is a standing Joint Intelligence Operations Center (JIOC) with a wide range of mission areas and mission partners. The Joint Air-Ground Integration Cell for Irregular Warfare (JAGIC-IW) is a new development, envisioned to be a modular, scalable, tailorable cell to integrate and coordinate joint fires and air operations - supporting full spectrum ops for conventional and irregular warfare. The Incident Command Center entails responding to catastrophic events that require rapid constitution of incident command among disparate stakeholders.

We have developed a real-world disaster relief scenario that spans the challenges in the three above-mentioned use cases and against which we will exercise CCOD solutions and measure value in terms of improved operational effectiveness, e.g. situation assessment, decision-making, response timelines.

6. Summary and Conclusion

Flexible, adaptive command and control capability is imperative for military conflicts and effective response to national emergencies. Today, operational users are severely limited in their ability to respond and adapt to unanticipated events due to the rigid nature of and lengthy acquisition process for IT-based command and control systems. The CCOD® concept introduced in this paper leverages Web 2.0 and other evolving technologies to provide to users infrastructure, components and the means to employ them, thereby enabling user-based innovation and rapid, responsive configuration of C2 functions to meet immediate needs.

As evidenced by recent legislation and special studies, our DOD senior leaders have clearly recognized the need for significant change in the acquisition process for IT-based capability - to keep pace with technology advances and to out-pace our adversaries. Although change is underway, it appears that many of the fundamental tenets of traditional weapon systems acquisition remain, such as pre-defined requirements and a "system" approach with tightly controlled baselines and incremental releases.

We contend that a more radical change is needed to regain our strategic advantage; specifically, we must enables the warfighter to leverage information as an effective weapon by enabling user-based innovation and removing the boundaries and constraints of traditional C2 systems.

At MITRE, we have devised a research agenda and investment strategy geared toward producing a CCOD® reference implementation to both serve as proof of principle for this transformational concept and guide future research investments. During FY10 we are exploring and developing technology solutions in key areas, and testing them in the context of use cases to ensure operational relevance and robustness - of both the technology enablers and the CCOD® concept in the large.

Acknowledgements

I wish to acknowledge the following individuals who have each contributed greatly to the Composable Capability on Demand (CCOD®) concept and research agenda: Bruce Hendrickson, Mark Heller, Bob McKee, John McNamara, Bruce Noll, and William Sax and Tom Gannon. Their innovative thinking, technology expertise, domain knowledge and dedication to putting enhanced capability in the hands of the warfighter is nothing short of extraordinary.

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APPENDIX A
CCOD Research Agenda Detail

This appendix presents additional detail on the eight elements of MITRE's CCOD® research agenda. Specifically, for each element we have developed a set of research questions that must be answered (with technical solutions) to achieve CCOD functionality consistent with our vision; the set of research questions, by element, are given in Figures A-1 though A-8.

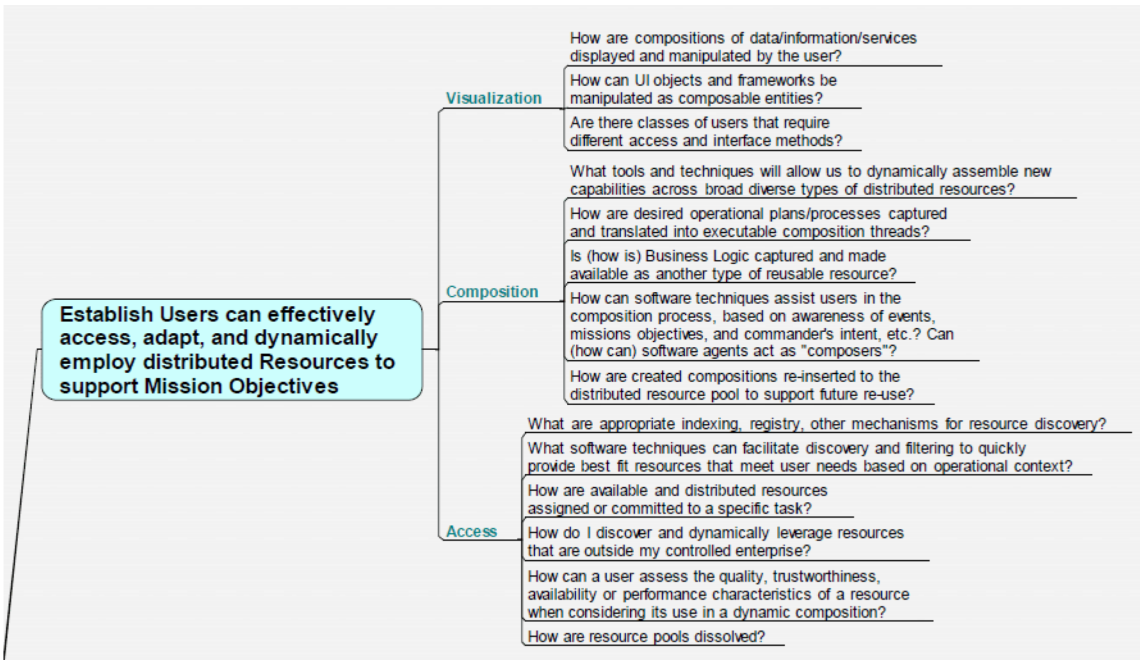

Figure A-1. Establish users can effectively access, adapt and dynamically employ distributed resources to support mission objectives

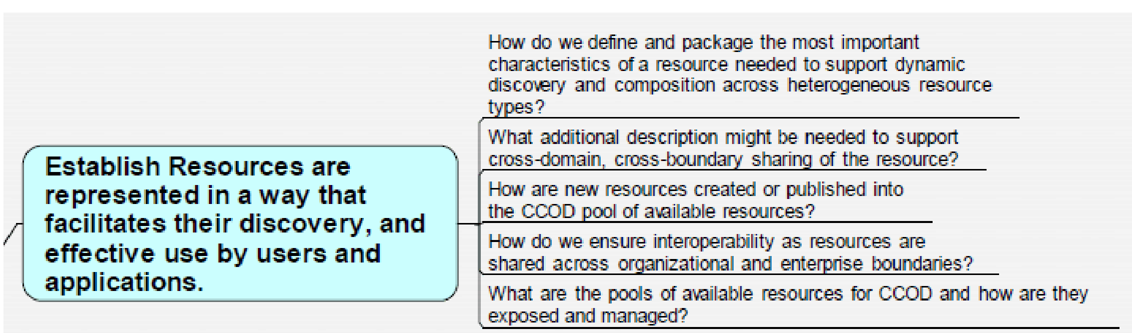

Figure A-2. Establish resources are represented in a way that facilitates their effective discovery and effective use by users and applications

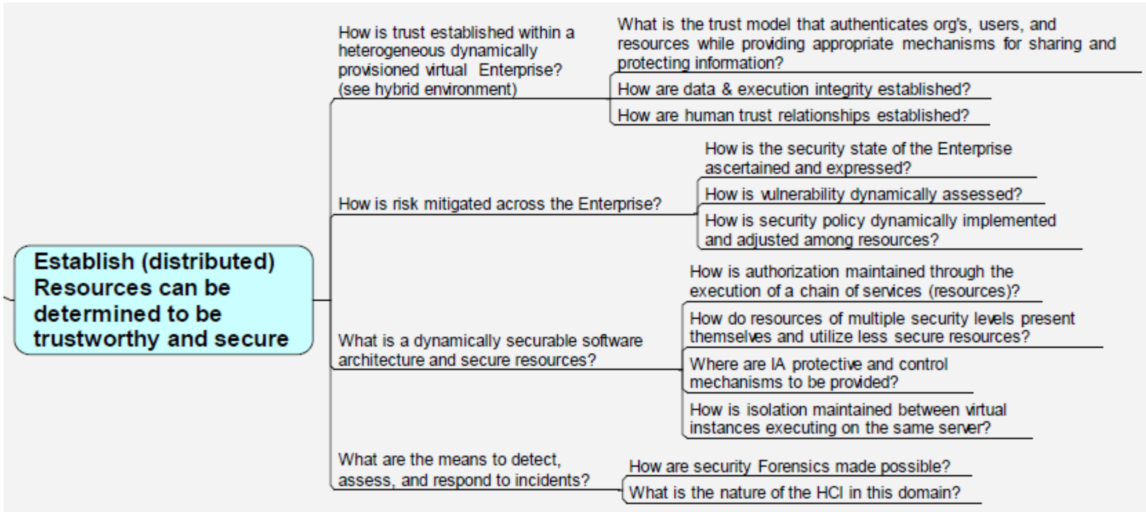

Figure A-3.Establish (distributed) resources can be determined to be trustworthy and secure

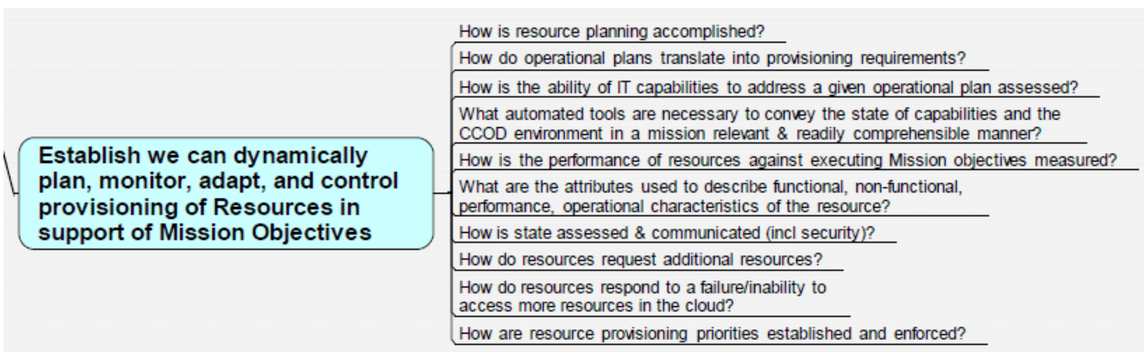

Figure A-4. Establish we can dynamically plan, monitor, adapt and control provisioning of resources in support of mission objectives

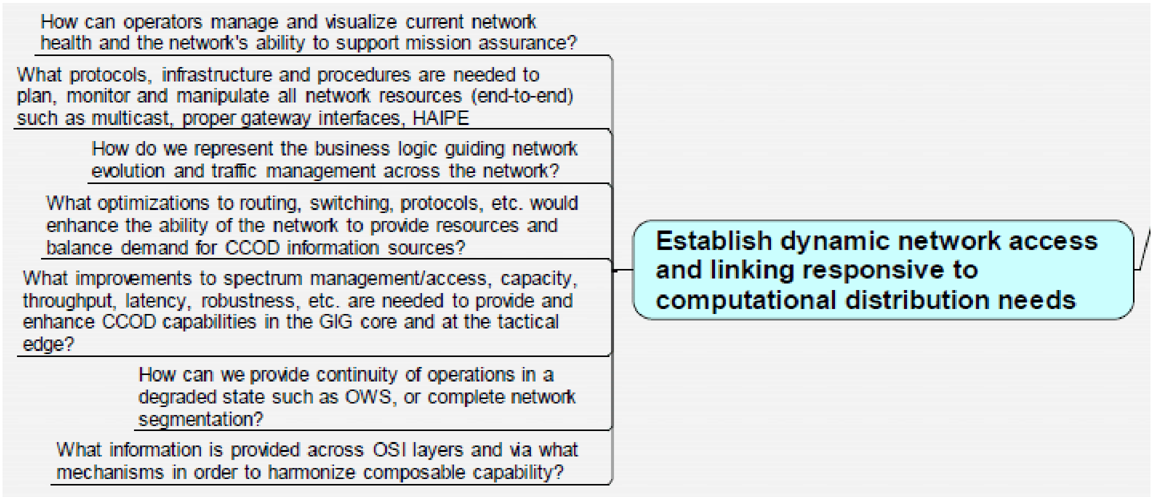

Figure A-5. Establish dynamic network access & linking responsive to computational distribution needs

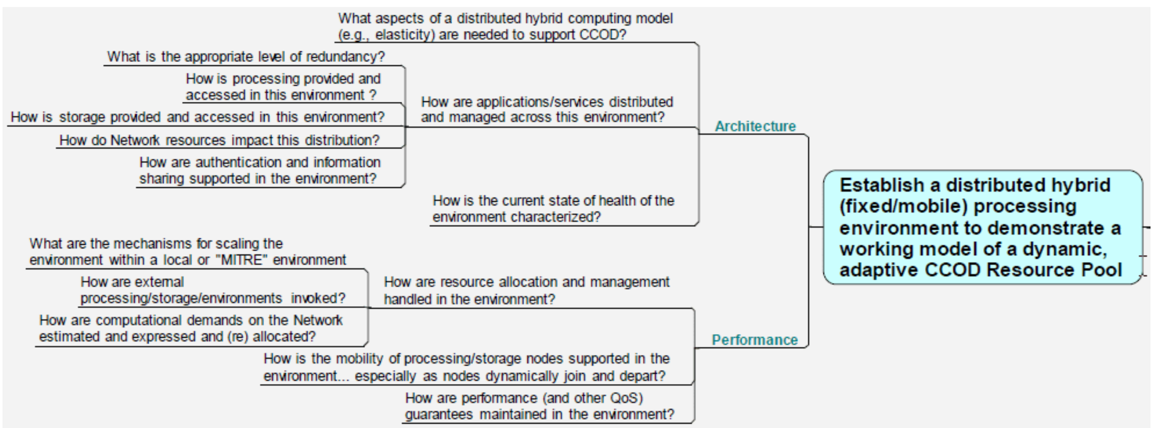

Figure A-6. Establish a distributed hybrid (fixed/mobile) processing environment to demonstrate a working model of a dynamic adaptive resource pool

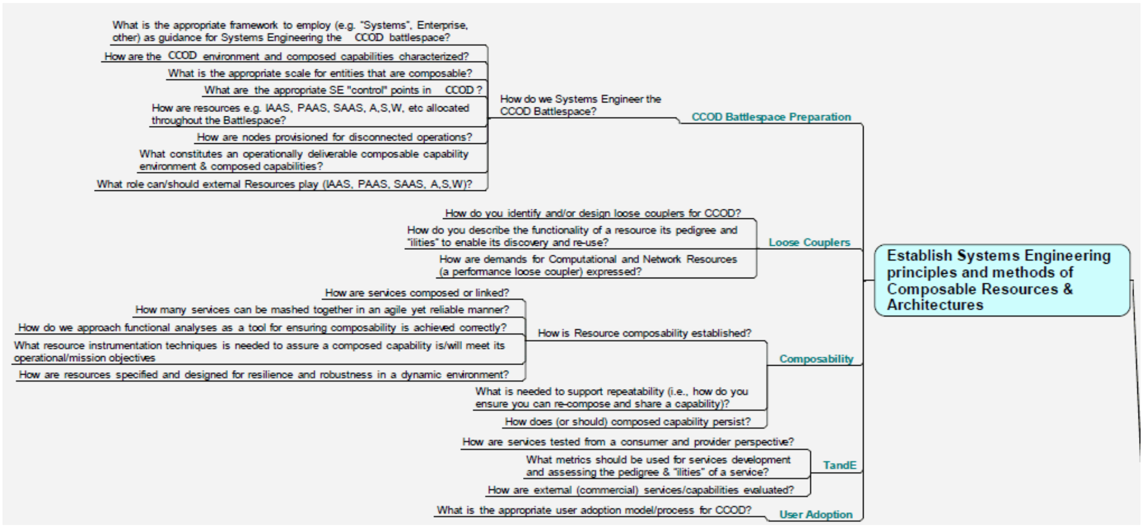

Figure A-7. Establish system engineering principles and methods of composable resources and architectures

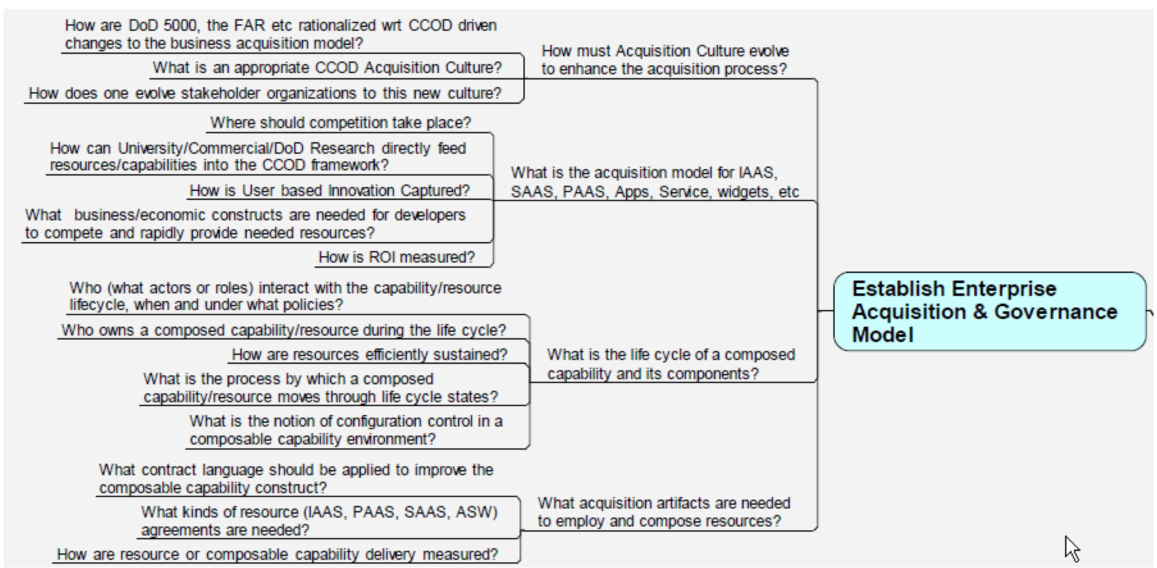

Figure A-8. Establish enterprise acquisition and governance models