About This Publication
The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

Copyright Notice
© 2015 Institute for Defense Analyses
4850 Mark Center Drive, Alexandria, Virginia 22311-1882 • (703) 845-2000.

This material may be reproduced by or for the U.S. Government pursuant to the copyright license under the clause at DFARS 252.227-7013 (a)(16) [Sep 2011].
Presentation Overview

• Review the evolution of command and control concepts and approaches in response to
  – Desire to take advantage of the power of information age technologies
  – Need to respond to the complexities of 21st mission challenges

• Suggest that recent developments in C2 theory and concepts provide an appropriate conceptual framework for thinking about how to design autonomous systems and integrate them into operations
Do we need to change our approach to C2?

Yes—We Need New C2 Approaches

- Legacy approaches to C2 are insufficient because:
  - They cannot satisfy critical mission requirements
  - They can not fully leverage increasingly automated / autonomous capabilities
- We have an opportunity to do C2 differently because:
  - The economics of C2-related technologies have changed significantly
  - They continue to change at a rapid pace
- We now understand how to deliberately manipulate C2
  - But, new approaches to C2 will not arise naturally
  - Long-held assumptions impede the design, development, and adoption of new approaches
C2 Approach Space

- There are a great many possible approaches to accomplishing the functions that we associate with Command and Control.
- Developing the “option space” for Command and Control requires that major differences between possible approaches are identified.
  - Centralized v. Decentralized
  - Fixed Vertical Stovepipes v. Dynamic Task Organized
  - Limited information dissemination (need to know) v. broad dissemination (need to share)
- These differences are reflected in the dimensions of the C2 Approach Space (options available)
  - Allocation of Decision Rights (within an entity or to the collective)
  - Patterns of Interaction
  - Distribution of Information

The C2 Approach Space
NATO C2 Conceptual Reference Model*

An approach to C2 determines the nature of the endeavor, the way individuals and organizations relate to one another, and determines the information positions of all participants.

* NATO SAS-050

Network Enabled C2 Approaches

Source: SAS-065 NATO NEC C2 Maturity Model
Network Enabled C2 Approaches

Harmonizing a Mix of C2 Approaches within an enterprise or a collective
Harmonizing a Mix of C2 Approaches within an enterprise or a collective

How does the approach to C2 practiced by one entity (unit or system) affect the ability of the Enterprise to function?
- How does it affect the distribution of information?
- How does it change the patterns of interactions?
- What happens when an entity does not cede any decision rights to the enterprise?

C2 Shapes and Employs

C2 both **shapes** the force and **employs** it

<table>
<thead>
<tr>
<th>Shaping is C2 at the Enterprise level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creates the “Force”</td>
</tr>
<tr>
<td>Determines Capabilities over time</td>
</tr>
</tbody>
</table>

**Shaping Determines What is Possible**

<table>
<thead>
<tr>
<th>Employing Determinates the What and How of an Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employing is C2 at the Mission level</td>
</tr>
<tr>
<td>Establishes Intent</td>
</tr>
<tr>
<td>Creates/Instantiates a Mission Capability</td>
</tr>
<tr>
<td>Package at time ( t ) for purpose ( p )</td>
</tr>
</tbody>
</table>

**Employing Determines the What and How of an Operation**

C2 creates the initial conditions for an operation and dynamically adjusts.
Complex Endeavors and Enterprises

- Complex Endeavors are characterized by multidimensional, interdependent effects spaces and profound levels of uncertainty.
- Complex Endeavors involve Complex Enterprises, a heterogeneous collection of networked military and civilian partners and systems that each can function with varying degrees of autonomy (a multi-genre, composite network).
- There will, of necessity, need to be multiple approaches to C2 and the processes that support C2.
- Operations, to be effective, will require developing synergies between and among the actions taken by individual entities and collections of entities (human and ‘machine’).
- Complexity, with inherent lack of predictability greatly increases the need for and value of Agility.

Agility

- Agility is the capability to successfully effect, cope with, and/or exploit changes in missions and circumstances.
- Its enablers include:
  - Responsiveness
  - Versatility
  - Flexibility
  - Resilience
  - Adaptability
  - Innovativeness
- Agility is a necessary response to growing mission complexity and uncertainty and have expressed a desire for more agile forces.
- Agility is applicable to individuals, organizations, material, systems, and collections of these.
- Agility is much too important to be left to chance.
This is a most appropriate C2 Approach for this particular mission and set of circumstances.

When circumstances change, a different C2 Approach may be more appropriate.
C2 Agility

- C2 Agility = f(C2 Approach Agility, C2 Maneuver Agility)

**C2 Approach Agility** is the area of the region in the Endeavor Space where an entity can operate successfully by employing a given approach to C2.

**C2 Maneuver Agility** is the ability to recognize the C2 approach appropriate for the circumstances and transition to this approach in a timely manner. It is a function of the set of C2 Approaches available to the entity.

---

### Traditional v Agile C2

<table>
<thead>
<tr>
<th></th>
<th>Traditional C2</th>
<th>Agile C2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approach</strong></td>
<td>one way</td>
<td>set of options</td>
</tr>
<tr>
<td><strong>Decision Rights</strong></td>
<td>limited delegation of decision</td>
<td>as appropriate</td>
</tr>
<tr>
<td></td>
<td>rights</td>
<td></td>
</tr>
<tr>
<td><strong>Interactions</strong></td>
<td>prescribed interactions</td>
<td>tailored</td>
</tr>
<tr>
<td><strong>Information Dissemination</strong></td>
<td>limited - need to know</td>
<td>access as appropriate - need to share</td>
</tr>
<tr>
<td><strong>System Requirements</strong></td>
<td>point to point support established processes</td>
<td>network support emergent processes</td>
</tr>
</tbody>
</table>
Traditional v Agile C2

Which approach is more appropriate for autonomous forces?

<table>
<thead>
<tr>
<th></th>
<th>Traditional C2</th>
<th>Agile C2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approach</strong></td>
<td>one way</td>
<td>set of options</td>
</tr>
<tr>
<td><strong>Decision Rights</strong></td>
<td>limited delegation of decision rights</td>
<td>as appropriate</td>
</tr>
<tr>
<td><strong>Interactions</strong></td>
<td>prescribed interactions</td>
<td>tailored</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>limited - need to know</td>
<td>access as appropriate - need to share</td>
</tr>
<tr>
<td><strong>Dissemination</strong></td>
<td>point to point support established</td>
<td>network support emergent processes</td>
</tr>
<tr>
<td><strong>System Requirements</strong></td>
<td>support established processes</td>
<td></td>
</tr>
</tbody>
</table>

C2 Research and Analysis Findings

- No single approach to accomplishing the functions associated with C2 fits all missions or situations whether for a single entity or a collection of interdependent entities
- Thus, the most network enabled approach is not always the most appropriate
- Rather, the most appropriate approach will be a function of the endeavor and the prevailing condition and circumstances
- The manifested C2 Approach can be significantly different from the intended C2 Approach due to conditions and circumstances
- Therefore,
  - Entities will need to be able to appropriately employ more than one C2 approach and monitor it
  - Collections of interdependent entities will need to harmonize their approaches to C2
Comparative Agility Map
for Organization-Approach options

Endeavor Space

with varying conditions of signal to noise
and with varying requirements
for shared situation awareness and response time

Source: Alberts, D.S. The Agility Imperative, 2010 Part V: Agility Experiments

Simulation Results–Base C2 Approach

Start-point - currently:
Target Folders are distributed for
development through e-mail (fixed allocation) and the decision boards follow
specific timetable (no targets getting vetted/validated outside this process)
New, Co-Evolved C2 Approach

Allow for priority targets to be vetted/validated outside standard operating procedure (as ready v. specific time) and resources to be assigned based on utilization (shared folder v. email)

Overall JTL & Priority Target Development Time Decreases and Resource Utilization Levels out

C2, Automation and Autonomy

- Automation involves the delegation of selected decision rights to ‘agents’ that operate within specified rules of engagement (doctrine)
- Autonomy is the delegation of decision rights within the context of command intent
  - Applies to humans, robots, and software agents
  - Can command intent be dynamic?
- Both can be thought of in terms of the C2 Approach Space
  - Their accesses to information
  - How they interact with other automated entities and/or human (human in the loop v. human on the loop )
- Both automated and autonomous entities can possess varying degrees of Agility
C2 Questions Relevant to Autonomy

Operational Approach
- Purpose
- End State
- Relevant Actors

C2 Approach
- Decision Rights
- Interactions
- Access to Information

Authorities clear?
Decision rights allocated appropriately?
Right relationships established?
Adequate collaboration?
Information flowing appropriately?


Thanks for your attention.

Questions? Comments?
Assessing the C2 Approach

Macro Assessment

- What is the intended C2 approach?
- What has changed or could change in the operational environment that will impact the C2 approach?

Macro Red Teaming

- How will the most important changes impact the C2 approach?
- What indicators would illuminate change in the operational environment and how can they be monitored?

Are we doing the right things?
- Consider risk and urgency?
- What adjustment would be required?
- Communications security compromises

Are we doing things right?
- LOE (progress or lack of progress)
- Changes in the enemy situation (positive or negative) or in factors beyond the commander’s control that work for against mission accomplishment (such as weather and terrain)


C2 Questions Relevant to Autonomy

Operational Approach?
- Overarching purpose
- End state
- Who are the relevant actors?

What are we doing relative to C2?
- Are the right relationships (links) established?
- Are the right information flowing?
- Is there adequate collaboration among the links?
- Are authorities clear and decisions distributed appropriately?
- Is the Sub-System C2 approach working?
- Are C2 activities supportive of the overarching purpose and end-state?
- Are the right actors involved?

Are we doing the right things?
- How can this be implemented? What are the commander’s C2 information requirements

Can be derived from the Strategic End State

14 CCRP, "C2 by Design," pg 27.
Tenets of NCW

NCW provides opportunities to employ new C2 approaches and warfighting concepts

A robustly networked force* improves Information Sharing

Information Sharing and Collaboration enhances Quality of Information and Shared Situational Awareness

Shared situational awareness enables Collaboration and Self-synchronization

These, in turn, dramatically increase mission effectiveness.

**“Networking the Force” entails much more than providing connectivity among force components. It involves the development of distributed collaboration processes designed to ensure that all pertinent available information is shared and that all appropriate assets can be brought to bear ... Network Centric Warfare Report to the Congress March 2001**

C2 and NCW

• “NCW, in its most mature form, involves profound changes in the role of a commander and the relationships between a commander, a commander’s staff, subordinates, and superiors.”
C2 and NCW

Automation / Autonomy

"NCW, in its most mature form, involves profound changes in the role of a commander and the relationships between a commander, a commander’s staff, subordinates, and superiors."

Evidence Continues to Accumulate

a few examples

- NCW book provided examples of how leveraging shared awareness results in increased combat power [http://www.dodcrp.org/files/Alberts_NCW.pdf]
- NATO SAS-065 reports on cases studies and experiments that address the link between various C2 approaches and mission success [http://www.dodcrp.org/files/N2C2M2_web_optimized.pdf]
- NATO SAS-085 provides results from case studies and from an analysis of data from a variety of experiments that support the need for more network enabled and agile C2 [http://www.dodcrp.org/html/sas-085.html]
- NATO SAS-104 is currently working to help member nations and NATO organizations create awareness of C2 Agility and is gathering evidence of its mission impacts [http://www.dodcrp-test.org/sas-104]
Challenges

- Make the leap from thinking about the ‘network’ as ICT to thinking in terms of a multi-genre composite network that needs to be designed and operated in an integrated fashion
- Move beyond optimizing C2 for a given mission or scenario to developing more agile C2 Approaches and learning to maneuver in the C2 Approach Space
- Forge the partnerships necessary to create a transformation ecosystem linking research, analysis, experimentation, concept development and doctrine, education and training, acquisition, force development, and lessons learned
- Undertake real experimentation and exercises that are not ‘scripted’ but that are properly instrumented, create unfamiliar situations, and stress people, processes and systems

Challenges: The Science of C2

- Recognize that the performance and behaviors of communications, information, and C2 networks and their embedded automated processes are inter-dependent and cannot be studied in isolation
- Recognize that these networks are subject to damage and a variety of stresses that can cascade within individual networks and across network boundaries
- Appreciate that C2 is not an end unto itself but needs to be considered in mission and enterprise terms
- Recognize that automated processes constitute a delegation of decision rights and the need to find an appropriate balance
- The tenets of NCW apply to the research community every bit as much as they do to the operational community
Autonomy is, in fact, an approach to command and control (C2) as it involves a delegation of decision rights to the autonomous entity and with it, either implicitly or explicitly, access to information. Agility has been shown to be a function of the approach to C2. Thus, these three concepts are intimately related. As a result of the inter-relationships that exist, the conceptual framework developed by the DoD Command and Control Research Program with its international partners over the years provides a systematic way to think about and assess autonomy options.