Adapting Cross-Domain Kill-Webs (ACK)

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A Framework for Decentralized Control of Multi-Domain Mosaic Warfare

Proposers Day

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Mosaic Warfare: Combined arms warfare conducted in parallel, over wide areas, at machine speeds that cognitively overwhelms a linear adversary

From Monolithic Kill Chains...
- Risk centralized in monolithic platforms
- Vulnerable to evolving adversary kill-chains
- Difficult to upgrade

To Adaptive Kill Webs...
- Risk distributed across manned/unmanned platforms
- Adapts to evolving adversary kill-chains
- Rapidly upgradable
Services Recognize the Need for Multi-Domain Battle

…but today’s command and control organization and processes cannot support the new warfighting concepts

- Heterogeneous planning / control cells and manually-intensive processes limit multi-domain ops
  - Siloed hierarchical teams – coordination via liaisons
  - Statically allocated resources
  - Manual and slow
- E.g., air-land coordination in today’s Air Operations Centers:

Unsynchronized, but not sufficiently coordinated to realize the full potential of multi-domain battle

• Significant progress towards realizing the multi-domain “mosaic” is being made
  • DARPA CASCADE is developing composition tools to help identity useful webs of capabilities
    and effects

• DARPA SoSITE is developing technologies to make the “lightening bolts real”

• DARPA RSPACE, DBM, and CODE are demonstrating decision aids and autonomy to build
  and manage fixed system-of-system architectures in a single domain

…but a gap remains – real-time cross domain adaptation of the mosaic
• Proposed framework – *Virtual Liaisons* and the *Capability Marketplace*
  • *Capability Marketplace* - All nodes across all domains are potential “suppliers”
  • Command and control nodes (“consumers”) connect with suppliers via *virtual liaisons*
  • Virtual liaisons may be at the platform level, unit level, or higher – as appropriate
  • Negotiate the use of services to achieve effects in the context of on-going missions

Matching Effects Suppliers with Needs to Build Cross-Domain Kill Webs
All Nodes in the Mosaic are Service Suppliers – Regardless of Domain

Exposed Services:
- Sensor
- Comms

Exposed Services:
- Sensor
- Comms

Exposed Services:
- Weapon
- Comms

Exposed Services:
- C2
- Sensor
- Comms
- Weapon

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Exposed Services:
- Sensor
- Comms

Exposed Services:
- Weapon
Example: Target Tracking Radar Emits, Detected By Fighter Which Builds Kill Web Option #1

Sensor: Fix, ID, Track
Sense: Detect
BMC2
Comms
Weapon

Target Emits

Supplier:
• How can I support?
• What can I offer?

Consumer:
• What is available?
• What should I use?
Example: Target Tracking Radar Emits, Detected By Fighter Which Builds Kill Web Option #2

Sense: ID, Track, Localize
Sense: Detect
BMC2
Comms
Weapon
SEAD
Example: Target Acquisition Radar Detected By Space Kill Web Option #3 – Competes For Resource with Kill Web #1

UNCLASSIFIEDApproved for Public Release, Distribution Unlimited
Approach - Decentralized Construction of Kill Webs

**Context:** On-going missions, commander’s intent

1. New Event – E.g., Pop-up Target
2. Select Relevant “Plays”
3. Construct Bid Requests to Fill Out the Selected Plays
4. Return Service Offers In Response to Bids
5. Form the “Kill Web” – Select the Play and the Service Suppliers

Problem is further complicated when multiple consumers competing for the same suppliers
Technical Challenges

• Challenges
  • In real-time (and to a large extent at planning time), little or no insight into what capabilities are available and what capacity they may have
  • Multiple commanders and missions across domains - no mechanism for assessing “value” / “cost” of supporting a new mission versus your current mission
  • Given a set of cross-domain kill web options, no mechanism for building and comparing diverse options and selecting the “best”

• Suppliers - the **virtual liaisons**
  • Develop language for defining services, expressing effects, quality of service, etc.
  • Assessing dynamic impact and **cost** of fulfilling a bid with respect to baseline missions / guidance

• Consumers – building the kill web
  • Selecting appropriate plays / plan templates
  • Constructing the “bid requests” in terms of desired effects (as flexible as possible), timelines, quality of service desired, …
  • Selection amongst the received options based on QoS / success probability estimates, costs, …

• Architecture and CONOPS
  • Distributed implementation – software infrastructure, multi-level security, …
  • Mechanisms for managing authority and service exposure based on conditions and rules of engagement
ACK Program Structure
Program goal: demonstrate proof of concept solution(s) that
   • Show technical viability of the vision
   • Focus on highest risk research
   • Paves the way for future development focused on transition

Potential military benefits
   • Improved multi-domain kill web recommendations (vs. human planners)
     • Increased efficacy, reduced errors
     • More options recommended
   • Better capability/resource utilization
   • Faster recommendations (via automation)
   • Protection of sensitive capability details

Existence Proof: Baseline Approach - Program Will Explore Improvements
• Use expressive commerce framework

Suppliers
(a) Pre-defined fixed supported / supporting relationships
(b) Universal mission priority scheme
(c) Offer based on feasibility and fixed rules from (a) and (b)

Consumers
(a) Bid requests based on plays
(b) Decisions based on quality of service and constraints
(c) Do not consider cost from the supplier side
**Program Plan**

**Phase 1 (18 Months)**
- Static Evaluations
- Build Testbed

**Phase 2 (18 Months)**
- Dynamic Evaluation in Testbed

**Phase 3 (12 Months)**
- Capstone demonstration with services

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**Task 1 – Technology Developers**
- Architecture / CONOPS
- C2 Decision Aid – “Consumer”
- Virtual Liaisons – “Supplier”

**Multiple Performers Developing End-to-End Prototypes**
- Design Review
- Design Review
- Design Review
- Design Review

**Task 2 – Evaluator**
- Build Testbed
- Scenario Development
- Test Plan
- Conduct Evaluations

**Testbed Development**

**Scenario, Test Plan, and Evaluation Support**
- Evaluation 1
- Evaluation 2
- Evaluation 3
- Evaluation 4
- Integration Test
- Capstone
• Develop end-to-end solutions addressing the ACK technical challenges
• Develop capability (sensors, weapons, etc.) representations
  • Ability to represent capabilities in sufficient detail to allow the C2 node to reason over alternatives
  • Ability for users to construct a library of kill-chain “plays” (and the software for managing and interacting with them) Develop bid request and offer message sets
• Develop bid request and offer language and message sets
  • C2 node / virtual liaison coordination across domains fill out all of the roles for a chosen kill-chain “play”
  • Allow users to describe rapidly the requirements, constraints, limitations, etc. of particular techniques so that the virtual liaisons can assign a cost
• Develop supplier-side virtual liaison offer generation algorithms
  • Adjudicate bid requests (which includes the decision whether or not to make an offer)
  • Algorithms to accept a commitment and shuffle the current commitments for a specific resource
• Develop consumer-side C2 node algorithms
  • Adjudicate amongst the offered capabilities in order to select the “best” kill-chain composed of the offered resources
  • Includes technical analysis capability that can score the offers and resulting plays against the original mission objective
• Develop user interface
  • Enables an operator the ability to visualize options and recommendations and select a final plan
Task 1 – Technology Development (2 of 2)

- Task 1 performers will deliver software agents (C2 nodes and virtual liaisons)
  - Run independently for each "node" in a simulation infrastructure developed by the Task 2 performer
  - For ACK purposes, proposers can assume the existence of a channel whose capacity is consistent with today’s tactical data links (e.g., Link-16) for passing bid and offer messages.

- Task 1 performers will integrate with the evaluation testbed using Task 2 performer-provided application programmers interfaces (APIs)
  - All performers will participate in the definition of the APIs through team-wide working groups run by the ACK government team (starting from an initial API definition proposed by the Task 2 team)

- Key Risk: Not able to develop sufficiently rich and general plan templates (or plays) for kill-chain construction and a language for requesting effects in a way that could be satisfied by a wide variety of capabilities across domains
  - If the plays and requests are too narrow, the set of feasible cross-domain kill-chains may be small and show little improvement over the baseline
  - Approaches should allow subject matter experts to quickly develop and edit plays on mission planning timelines
  - Request mechanisms should be framed in terms of desired effects and not overly prescriptive

- Multiple Task 1 performers are expected

- Proposers that propose to Task 1 may not submit a proposal to Task 2
• Tech developers deliver software agents to run independently for each “node” in the simulation
  • C2 nodes and virtual liaisons
  • Nodes are connected via simulated tactical data link representative of today’s and near future operational capabilities

• Evaluation team builds baseline scenario, missions, and mission plan – during runtime, injects events to trigger replan at C2 nodes, e.g.
  • New target
  • Loss of asset

• Performer software agents form / adapt kill webs via decentralized negotiation over simulated data links for a given inject

• State information provided by testbed to decision-making agents
  • Based on truth, with some uncertainty introduced

• Low-level autonomy (provided as part testbed) executes assigned tasks
  • Routing, scheduling of payloads, dynamic behaviors, …
Most existing mature DoD M&S capabilities are single domain focused
  - Developed by (single domain) program offices for experimentation, training, etc.
  - Other domains often represented at low fidelity and only where they intersect with primary domain

Multi-domain testbeds are now being developed and can be leveraged as a starting point
  - E.g., DARPA CDMAST, NGTS, AFSIM, AFMSTT (Air Force) family of simulations
  - **GOAL:** Build a capability sufficient for ACK experimentation, but no more!
  - Must build in sufficient time to adequately build up testbed for our purposes (Phase 1)
Evaluator is a critical role for ACK

- Quality of evaluations will only be as good as the quality of the scenarios and supporting models provided by the evaluator

Define multi-domain scenarios and the test plan for each evaluation event

- Scenarios need to be representative in the sense that they reflect the need to make time-critical decisions across a variety of military domains
- “Realism” in the sense of accurate representations of existing systems is not essential for assessing the ability of ACK technologies to support decision-making.
- Scenarios MUST be unclassified, and DARPA will review them prior to release to the larger ACK community.

Create multi-domain capability models as digital artifacts, along with supporting documentation

- Share them with the Task 1 performers
- Intention of this item is NOT to achieve high levels of realism and/or accurate details
- Task 1 technologies need to be model driven and the Task 2 provider will have to support this need, using unclassified models that DARPA will review prior to use.

Supply the evaluation test bed

Conduct the evaluations; analyze data, reports out on results.

Ensure fair comparison between competing Task 1 performer capabilities
• DARPA expects the Task 2 performer to leverage existing modeling and simulation (M&S) capabilities
  • Most currently existing mature M&S capabilities are single-domain focused, with other domains represented at low fidelity (only where the other domains intersect with the primary domain).
  • Task 2 performer will likely need to extend or integrate single-domain simulators to build a multi-domain testbed sufficient for ACK evaluations in Phase 2

• DARPA wants to ensure that Phase 1 does not limit evaluations to a single domain that is well-supported by M&S.
  • In order to support this goal, DARPA expects that during Phase 1, the Task 2 performer will conduct static model-based evaluations of kill-chain assignments as produced by Task 1 performer prototypes
  • DARPA expects Task 1 applications to take as inputs digital representations of the battlespace, including its current state.
  • Rather than being evaluated in simulation, Task 2 subject matter experts may evaluate the outputs of these applications by using appropriate tools

• Key risks
  • Construction of sufficiently rich scenarios to enable fair evaluation of the Task 1 performer solutions
  • Developing the M&S-based testbed with sufficient fidelity for meaningful evaluation
  • Success will require leveraging existing capability and careful management of scope
  • DARPA expects the Task 2 performer to integrate and extend existing simulations and represent cross-domain capabilities with just enough fidelity to accomplish the goals of the ACK program evaluations

• A single Task 2 performer is expected
• Proposers that propose to Task 2 may not submit a proposal for Task 1
• Task 2 performer will define a baseline approach inspired by today’s practice of defining fixed support relationships and mission priority schemes.

• Phase 3 capstone demonstration - Task 2 performer will work with potential transition partners to define acceptable performance criterion

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<thead>
<tr>
<th>Metric</th>
<th>Phase 1 Goal</th>
<th>Phase 2 Goal</th>
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</thead>
<tbody>
<tr>
<td>Number of domains</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Number of feasible recommendations</td>
<td>&gt; 1</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Relative effectiveness of recommendations (e.g., # pop-up targets successfully prosecuted relative to baseline)</td>
<td>50% improvement</td>
<td>100% improvement</td>
</tr>
<tr>
<td>Avg. ratio dropped missions / dropped missions in baseline</td>
<td>&lt; 1</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Max. processing time to generate recommendations</td>
<td>&lt; 3s</td>
<td>&lt; 3s</td>
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<tr>
<td>Scalability (# consumers / # suppliers)</td>
<td>3 / 50</td>
<td>5 / 100</td>
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Submission Highlights

• Teaming
  • Broad teams encouraged!
  • URL for teaming: http://events.sameetings.com/ACKProposersDay.

• Schedule
  • BAA released – July 20, 2018
  • Proposers Day – July 27, 2018
  • Teaming Profiles Due – August 3, 2018
  • Abstracts Due – August 17, 2018 at 4 pm EDT
  • Abstract Responses – August 29, 2018
  • Last date to request instructions to submit classified proposal material: August 31, 2018
  • FAQ/Questions Due Date – September 10, 2018, 4 pm EDT
  • Full Proposals Due – September 28, 2018 at 4 pm EDT
Evaluation Criteria

• Overall Scientific and Technical Merit
  • Standard DARPA BAA language
  • Task 1 proposals should clearly address the challenges of
    • Providing planners and operators sufficient information to identify available capabilities across multiple domains
    • Enabling rapid and meaningful assessments of the relative costs and benefits of supporting new missions
    • Providing mechanisms that facilitate the comparison and selection of alternative cross-domain kill-chain options.
  • Task 2 proposals should
    • Provide a credible plan to support evaluation within the scope of the proposed effort, identifying extant capabilities to be leveraged and clearly explaining the plan for extending those capabilities to meet the needs of the program.
    • Proposed scenarios are sufficiently rich to enable fair evaluation of the Task 1 performer solutions
    • The proposed M&S-based testbed has sufficient fidelity for meaningful evaluation
    • The baseline against which ACK Task 1 technological contributions will be assessed is clear, credible and achievable

• Potential Contribution and Relevance to the DARPA Mission
  • Standard DARPA BAA language

• Cost and Schedule Realism
  • Standard DARPA BAA language
Fundamental Research

- Government expects that program goals as described herein may be met by proposers intending to perform fundamental research and proposers not intending to perform fundamental research.

- Proposed research may present a high likelihood of disclosing performance characteristics of military systems that are unique and critical to defense.

- Government anticipates that some awards will include restrictions on the resultant research:
  - Based on the nature of the performer and the nature of the work.
  - Will require the awardee to seek DARPA permission before publishing any information or results relative to the program.

- Proposers should indicate in their proposal whether they believe the scope of the research included in their proposal is fundamental or not:
  - Government shall have sole discretion to select award instrument type and to negotiate all instrument terms and conditions with selectees.
  - Appropriate clauses will be included in resultant awards for non-fundamental research to prescribe publication requirements and other restrictions, as appropriate.

- For certain research projects, it may be possible that although the research being performed by the awardee is restricted research, a subawardee may be conducting fundamental research.
  - In those cases, it is the awardee’s responsibility to explain in their proposal why its subawardee’s effort is fundamental research.