2006 Command and Control Research and Technology (CCRT) Symposium

TITLE: A Framework for Architecture-Based Planning and Assessment to Support Modeling and Simulation of Network-Centric Command and Control

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BACKGROUND:

In 2003 the Department of Defense (DoD) began transforming the methodology for modernizing military forces. For many years, the DoD had used a top-to-bottom force structure planning process based on a set of planning scenarios developed from National Military Strategy, Unified Command War Plans, and expected future threats provided by the Intelligence Community. This part of modernization planning accounted for doctrine, organization, training, leadership, and, in part, for facilities. Modernization planning had previously been a stovepipe process whereby each functional area was responsible for modernization planning for the material means and supporting facilities, using different evaluations of the expected future threats. The acquisition process was more narrowly focused on developing specific systems, which were based on bottom-up specified requirements. These requirements were based on scenario-specific threats and included system-unique specifications derived to counter these threats. But the international security environment has changed --- and it will continue to change.

This new environment led the DoD to transform the planning and modernization processes. Additionally, the force planning, functional area planning and acquisition processes (described above) were found to have some downsides. First, manpower requirements were driven at least as much by system manning requirements as by requirements derived from the force structure planning process. Second, modernization planning in one functional area often impacted modernization planning in other functional areas, without providing any indication of those interdependencies. The effect was to provide no insight as to the total cost of ownership for new-development initiatives. Additionally, the stovepiped functional area planning process provided no opportunity for combat support functional areas to show their value, or lack of value, to combat capability. Finally, each modernization process (force structure planning, functional area planning, and acquisition) had its own vocabulary, thus making it difficult to integrate the goals and outcomes of these processes.

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In response to the changes in the world environment, the DoD has adopted an integrated top-down capabilities-based planning and assessment methodology in response to the shortcomings in the previous modernization process. This new methodology includes a concept development process, a capabilities-based assessment process for developmental capabilities, a Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities (DOTMLPF) requirements process for non-developmental capability changes, and a new capabilities-based acquisition process.

Capabilities-based planning begins with the concept development process (Joint Concept Development and Revision Plan) including development of effects-based Joint Operations Concepts (JOC) and Joint Functional Concepts (JFC) which describe planned future capabilities. The Joint Concept Development and Revision Plan defines a capability as, "the ability to achieve an effect to a standard under specified conditions through multiple combinations of means and ways to perform a set of tasks." Finally, the process includes Joint Integrating Concepts (JIC) which couple one or more JOCs to one or more JFCs. The JICs identify the capability tasks with the associated performance standards needed to achieve one or more specific effects. The capabilities, associated tasks and performance standards serve as the input to the processes that establish new capabilities.

The first step in establishing new capabilities is to evaluate potential non-developmental changes in DOTMLPF (CJCSI 3180.01). If non-developmental changes in DOTMLPF do not satisfy (or only partially satisfy) new capability needs, then a Capabilities-Based Assessment (CBA) is begun.

The Capabilities-Based Assessment process is defined by the Joint Capabilities Integration and Development System (JCIDS) in the CJCS 3170 series documents. This process is now being used to determine the system requirements for the DoD Net-Centric Operating Environment (NCOE). A principal feature of the planned NCOE CBA is the maximum possible use of modeling and simulation (M&S) in support of analysis.

In general, a CBA encompasses three major phases:

- The Functional Area Analysis (FAA): The FAA characterizes a particular military arena in terms of the operations that are required to be performed. The FAA identifies the operational tasks, conditions and standards needed to achieve military objectives.
- The Functional Needs Assessment (FNA): The FNA assesses the ability of the current and programmed warfighting systems to deliver the capabilities identified in the FAA. The FNA considers the full range of operating conditions against specific measures of effectiveness.
- The Functional Solutions Analysis (FSA): The FSA is an operationally-based assessment of all potential DOTMLPF and policy approaches to solving (or mitigating) one or more of the capability gaps identified in the FNA.

Finally, the outcome of the FSA becomes the input to the acquisition process. The new acquisition process (DoDI 5000.2) is designed to align with the top-down capabilities-based planning and assessment methodology.

OBJECTIVE:

The objective of this project, conducted under the sponsorship of the Net Centric Capabilities Division (J6A) of the Joint Chiefs of Staff, is to define an architecture-based process as a rigorous and repeatable tool that can support the capabilities-based planning, assessment and acquisition processes described above.

The process will be tested by direct application to the real-world problem of the NCOE CBA. Using this architecture-based process, MITRE will identify the architectural data objects needed to provide a complete audit trail from a selected military command and control example down to the underlying net-centric capabilities needed to support it. This explicit identification of data objects and their relationships should then facilitate modeling and simulation analyses to be conducted in support of the CBA.

DISCUSSION:

Though the guiding document for the conduct of CBAs, CJCSI 3170.01E, specifies for the use of “integrated architectures” as part of the process, the document provides no insight into what constitutes an “integrated architecture,” leaving the reader to turn to DoD Architecture Framework (DoDAF), Ver 1.0, for further guidance and direction. Unfortunately, DoDAF focuses on information technology and the means by which architecture should be “presented” – and not on how it should be developed or used.

Furthermore, since the JCIDS process is a relatively new development in the DoD, only a few CBAs have been conducted to date. These have been performed by different teams, each of which has had to make their own determination of what constitutes an “integrated architecture.” Consequently, each team developed architecture its own way, applying “unique” approaches to performing associated analyses. The resulting architectures vary considerably in terms of form and content, and the analytical techniques employed also differ; some are quite informal, while others reflect only the judgments of a particular team.

The bottom line is that a more rigorous and repeatable process would facilitate the application of architectures in support of the NCOE CBA and to support the concurrent use of modeling and simulation techniques.

An effective CBA requires three things:

- identification of the various components of military operations and their supporting capabilities,

- understanding of the relationships among those components, and
- the use of modeling and simulation (M&S) tools to incorporate that understanding while assessing and comparing alternative solutions to meet operational needs.

To provide them, the authors propose a rigorous approach to conducting CBAs that explicitly identifies:

- the individual components of an integrated architecture and their relationships, and
- a logical analytical flow from the military operations that need to be conducted down to the supporting capabilities needed to enable the military operations.

The detailing of each component and the relationships among components provides a sound basis for the logical construction of models that represent the integrated architecture and helps to highlight factors and relationships that need to be simulated as part of the CBA process.

The current DoDAF does not adapt well to the capability-based planning process, in large part, due to object class limitations and the inability to render the architectural data in a way that is useful to many of the governance process leaders. The Concept Development and JCIDS processes describe the following key entities (or object classes): effect, capability, task, attribute, condition, measure and criterion. With the exception of tasks (activities in DoDAF), these entities are not described in the DoDAF. This limitation and other shortfalls in DoDAF led the MITRE Corporation to begin development of the Architecture Specification Model (ASM).[1] As depicted in **Figure 1**, the ASM is aimed at relating architecture objects to the six basic interrogatives that can be used to address all the dimensions of an architecture: who, what, when, where, how, and why. As such the ASM describes a much broader set of architectural objects and attempts to explicitly show the relationships among them. These objects may then be rendered into any view that best suits the type of analysis and preferences of the intended user.

[1] The Architecture Specification Model has been the result of the collaborative efforts of Mr. David Nicholson, Mr. Bradford Mercer, and Ms. Huei-Wan Ang of the MITRE Corporation..

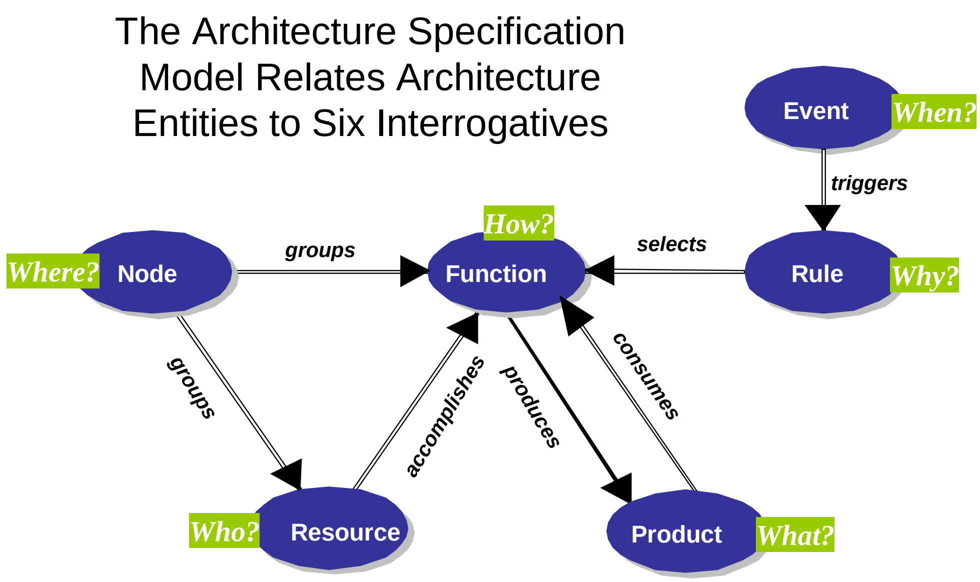

Figure 1. High Level Structure of Basic Components of the ASM

To address the specific needs of the NCOE CBA and using the basic logic of the ASM model as a basis and information and information sharing as the context for analysis, the authors postulated a high level relationship model to describe the components of the DoD's net-centric Global Information Grid (GIG). As shown in **Figure 2**, the architecture objects "above" the dotted line represent the operations or business artifacts within the GIG that are directly related to accomplishment of military missions, while the objects "below" the line represent infrastructural services that enable the operations to be performed. Information Assurance (IA), consisting of both operational and infrastructure components, has direct linkages to every other component, so it has been shown as a backdrop to the other objects.

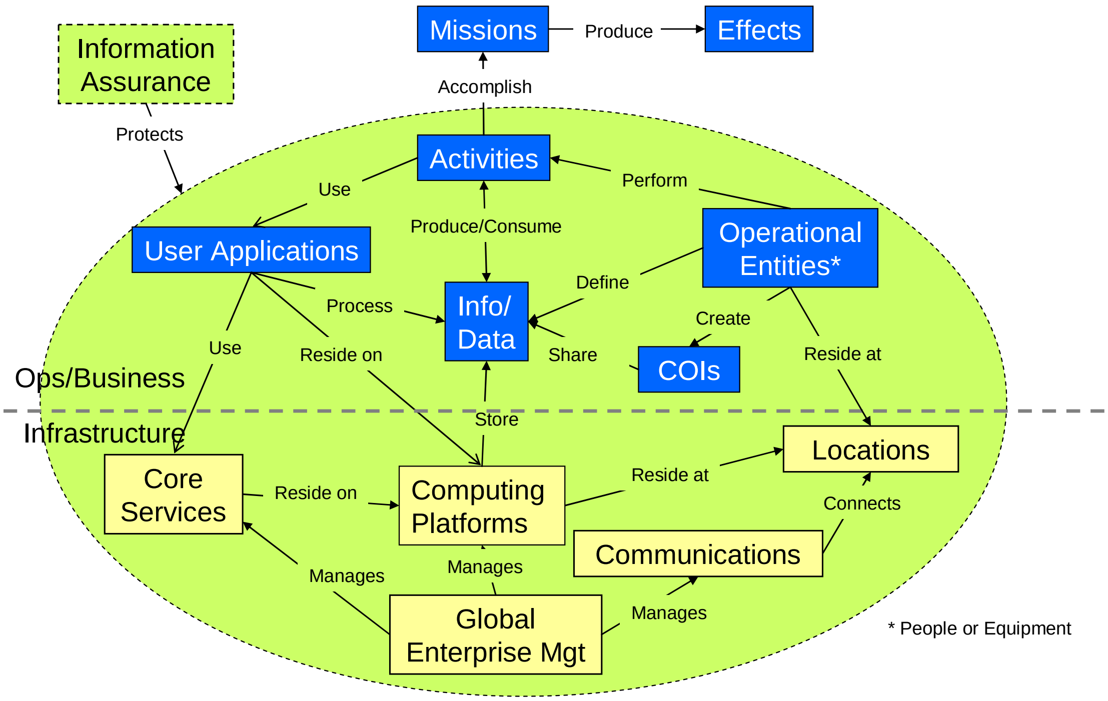

Figure 2. A Global Information Grid Conceptual Model

Using the GIG model as a basis for analysis, the authors selected one of the illustrative examples of the use of the Net-Centric Operations Environment (NCOE) presented in the NCOE Joint Integrating Concept (JIC), as a sample problem set to which the analytical process is applied. The selected, illustrative example represents operational support for dynamic targeting.

The first challenge faced by the team was the lack of detail specified in the NCOE JIC, upon which analyses could be conducted. To fill this gap, the team turned to other documents, such as the Joint Battle Management Command and Control (JBMC2) Roadmap, and other source materials for additional details. These documents identify , six generic activities related to the targeting process: Find, Fix, Track, Target, Engage, and Assess (F2T2EA). These F2T2EA activities can be summarized as follows:

- ***Find*** – look for and detect a potential target
- ***Fix*** – locate, identify, and characterize the potential target
- ***Track*** – maintain continuous cognizance of the status and location of the target
- ***Target*** – determine options to pursue and select the best method of attacking the target

- ***Engage*** – direct forces to attack the target and follow through on the direction
- **Assess –** determine what impact the attack had on the target

Furthermore, these activities may be performed in a combination of sequential and parallel activities, thereby reflecting both the traditional and net-centric approaches.

To this end, the team developed two "animated" high level activity models (OV-1s) to contrast a sequential approach to accomplishing F2T2EA (where information flows in turn from one operational entity to another) with a more net-centric approach, wherein information is shared via common information pools, which provide operational entities with speedier access to information.

Recognizing that the DoDAF's use of operational node connectivity diagrams (OV-2s) and information exchange matrices (OV-3s) may lead readers to think only in terms of "point-to-point" information exchanges, the team devised a set of diagrams that more readily depict information flows in a net-centric environment. This combined "OV-2/3" concept is depicted in **Figure 3**.

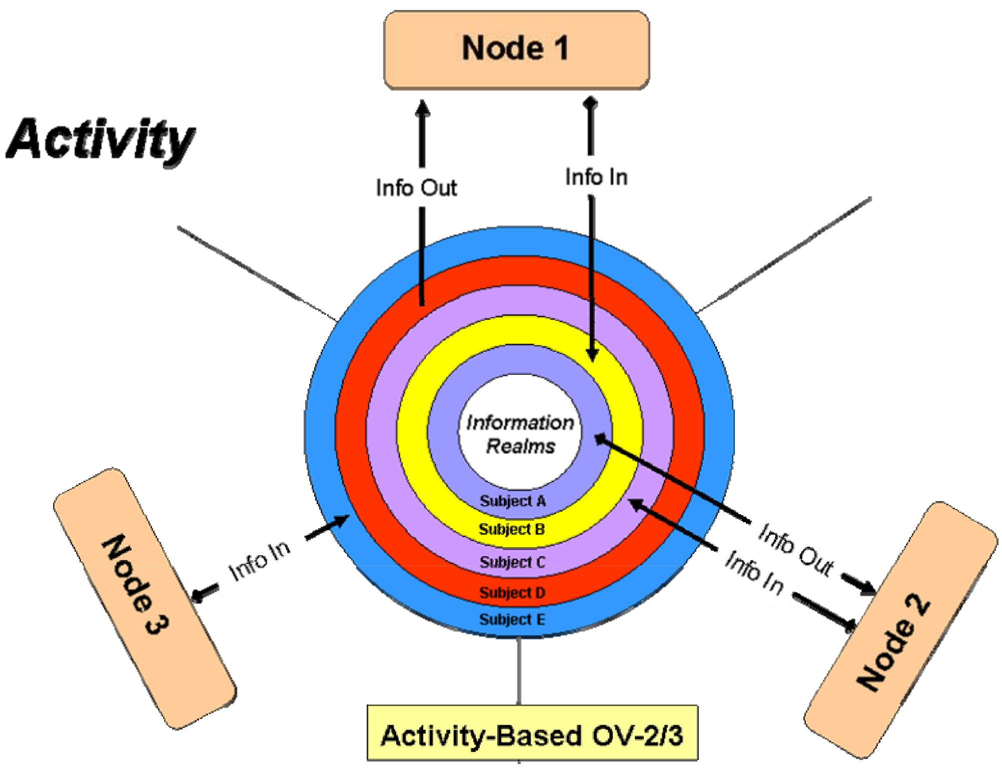

Figure 3. Notional Activity-Based Net-Centric OV-2/3 Diagram

Using this diagram as a model, the team proceeded to identify major categories of information (e.g., situation, friendly force, enemy force, environment, etc.) to be provided by each of the relevant types of operational entities (i.e., sensors, deciders, shooters) involved in the TST process. The team also identified candidate communications capabilities and enterprise services associated with TST. As a validation of the overall GIG model concept as a framework for the analysis, these entities were overlaid on the GIG model, as depicted in **Figure 4**, wherein the boxes in bold outlines represent those elements of the GIG model that were considered as part of the NCOE Baseline/Investment Plan effort, and the elements in red text represent those that could be included as part of the thin thread analysis.

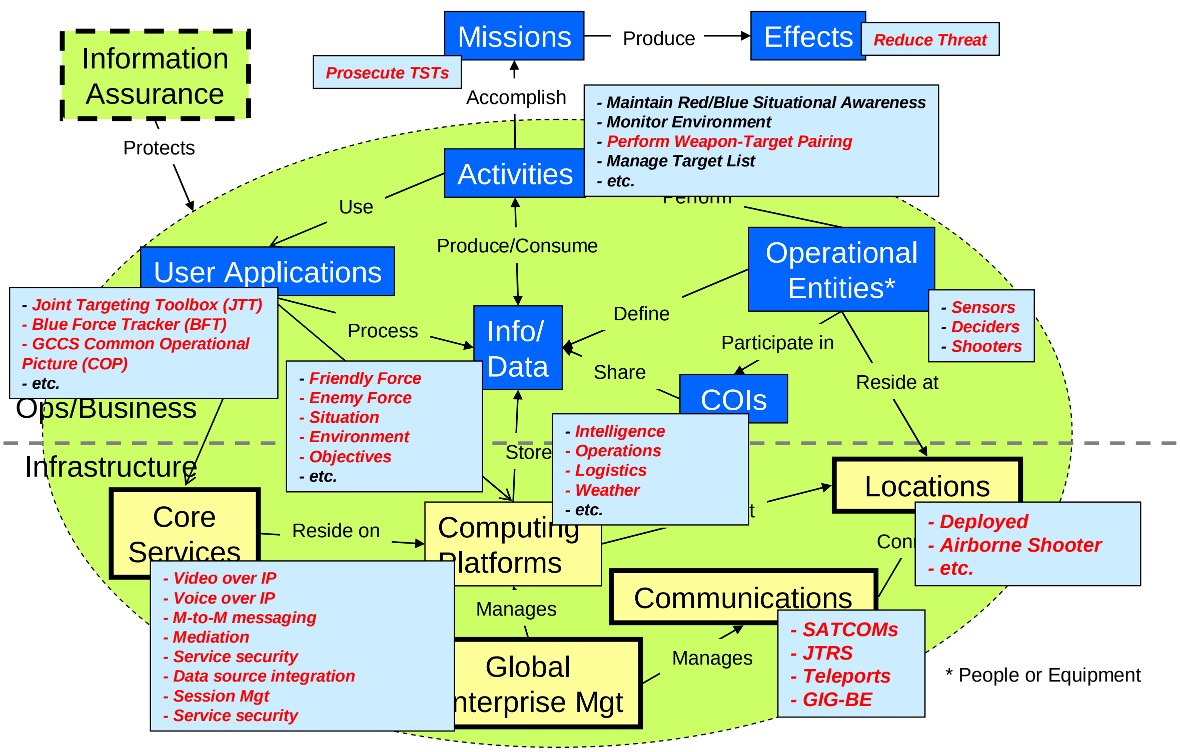

Figure 4. GIG Model with NCOE-Relevant Elements Considered for Thin Thread

INITIAL ANALYSIS

An initial set of analyses was conducted by focusing on the Targeting phase of the F2T2EA process described above and by focusing on only selected elements of the GIG infrastructure that would support that phase. In support of the analyses, a more formal Entity-Relationship (E-R) diagram was developed to describe a selected subset of the elements in the GIG model presented above. This diagram is displayed in **Figure 5**.

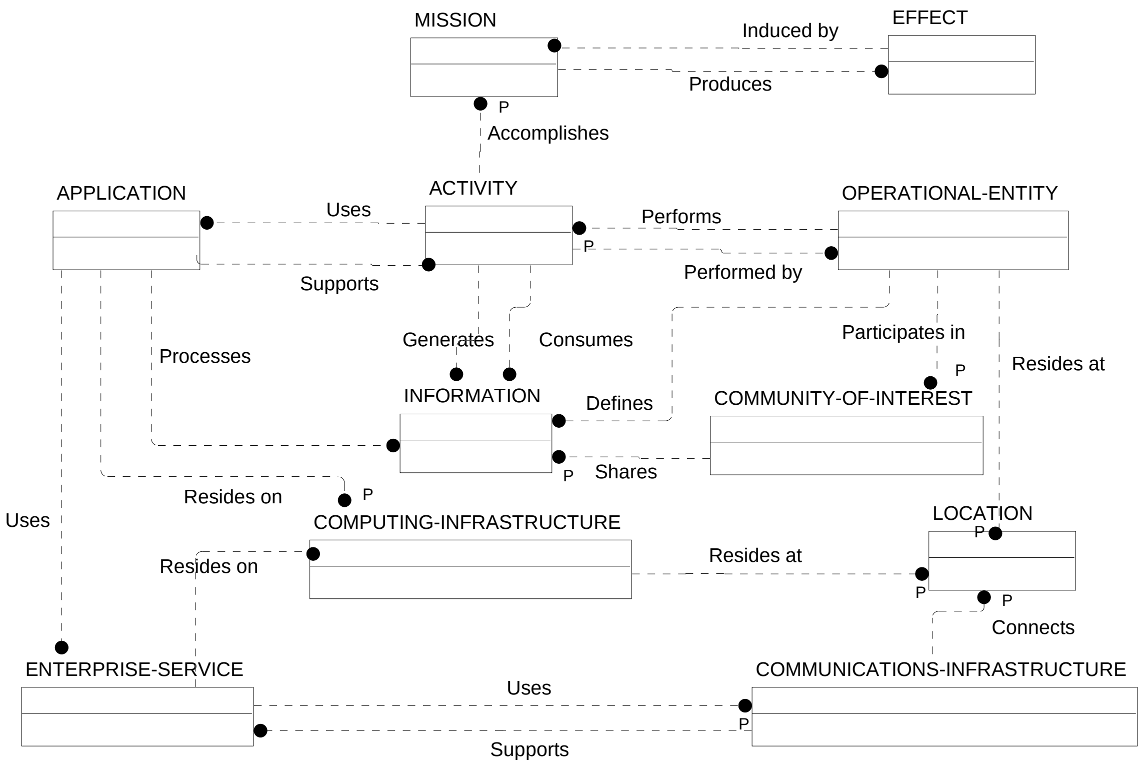

Figure 5. Entity Relationship Model of Selected GIG Elements

The relationships defined in this E-R model were then translated into a set of pair-wise relationships among each of the entities that could be implemented in a series of spreadsheet tables. The layout of these pair-wise relationships is depicted in **Figure 6**.

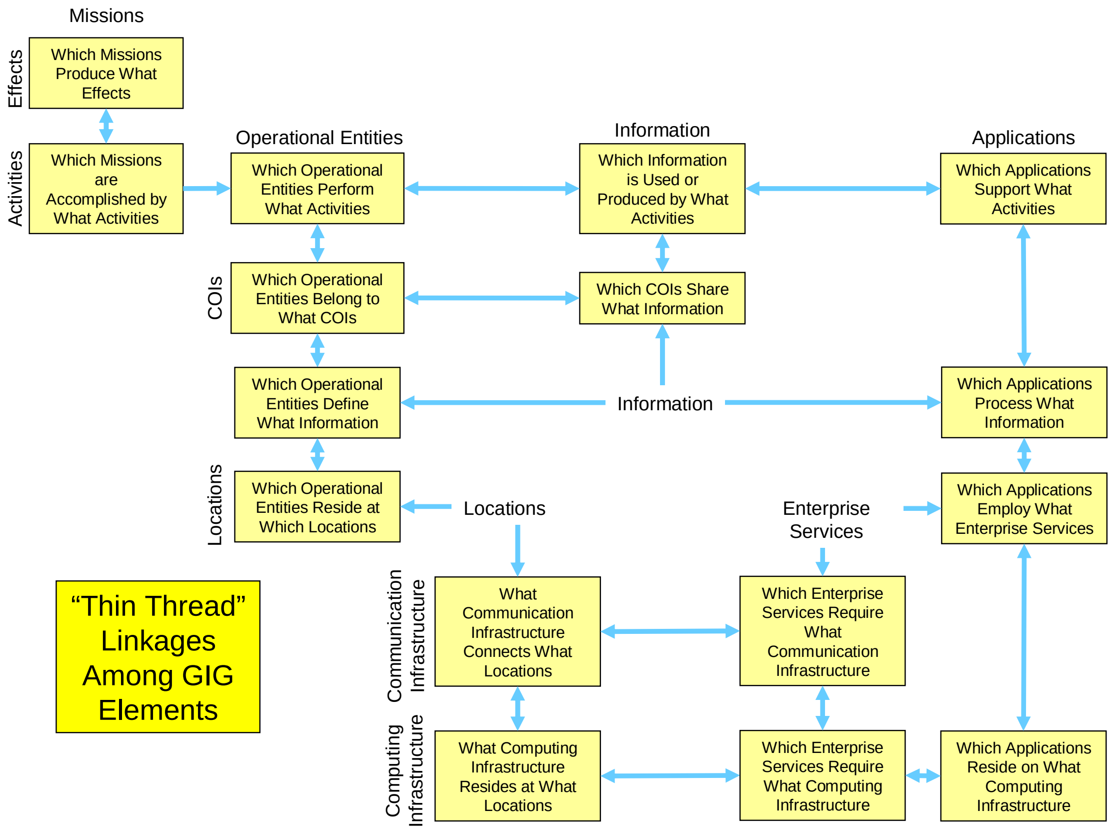

Figure 6. Pair-Wise Thin-Thread Linkages Among GIG Entities

For the initial thin thread analyses, an MS Excel spreadsheet was developed to identify and enable tracing of the relationships from a specific desired operational effect (reduce the threat posed by time-sensitive targets) through the GIG model to the enterprise services required and the communications infrastructure needed to support delivery of the desired effect. The actual spreadsheet is presented in **Appendix A**. The instantiation of the relationships was conducted only at a very high level on detail to permit manual and visual tracing of the relationships through the link tables.

However, even this gross level instantiation of the relationships for the TST Thin Thread example required defining activities to a lower level than found in any available documentation. Consequently, the specific activities defined for the example reflect only the opinion of the authors and have not been vetted by any military organization. For example, since multiple operational entities are involved in the activity "Weapon-Target Pairing" and more than one application supports this activity, "Weapon-Target Pairing" was hypothetically decomposed further into the following subactivities:

- Determine Desired Effects
- Determine Constraints
- Determine Target Vulnerability

- Select Weapon
- Determine Shooter Availability
- Select Shooter

Using this further level of decomposition, one could associate the operational entity "Sensors" with the subactivity "Determine Target Vulnerability" and the operational entity "Decider" with "Select Shooter." Similarly, the application "Blue Force Tracker" could be associated with the subactivity "Determine Shooter Availability" and the application "Joint Targeting Toolkit (JTT)" could be more easily associated with "Select Weapon."

In reality, the operational entities also need to be decomposed into more granular components (e.g., shooter in F-15 aircraft) and the applications need to be subdivided into more granular modules to really permit any significant analysis to be conducted. Similarly, the other entities in the link tables (e.g., communications connectivities, enterprise services, etc.) also need to be further decomposed.

As all of the entities are further decomposed, the ability to manually and visually trace through the linkages becomes increasingly more difficult. Hence there is a need to capture the decompositions and the relationships in an automated repository that provides sufficient functionality to trace through the linkages to answer such questions as:

- What communications capabilities are needed between a particular set of locations?
- Which operational entities will have access to which enterprise services?
- What effects would be adversely affected by the loss of a particular computing capability?

The list of questions can be infinite, but this sample reflects those that must be addressed to conduct capabilities based assessments.

In parallel to development of linkage tables, the team also started to postulate the characteristics of the various elements of the model that may need to be considered to support capabilities-based analyses. Candidate characteristics associated with particular entities are presented below with respect to each entity.

- "Activity" characteristics to consider:
    - Operational Role – what activities are performed?
    - Criticality – how important are the activities?
    - Precision – how accurate do the result of the activity need to be?
    - Knowledge – what information is needed to accomplish the activity?
    - Tempo - how often is the activity performed?
    - Timeliness – how fast is the activity performed?
    - Operational Security – how much does it need to be protected?

- "Operational Entity" characteristics to consider:

- Organizational affiliation – who are they?
- Physical location – where are they located?
- Environment – what kind of conditions prevail or are possible?
- Degree of mobility – how much do they move?

- **“**Community of Interest” characteristics to consider:
  - Community affiliations – what COIs are involved?
  - Vocabulary – what “language” do they speak?

- Information” characteristics of to consider:
  - Content – what is the substance of the info (intel, ops, weather, logistics, etc.)?
  - Currency – when was it created or last updated?
  - Perishability – what is the “shelf life” of the information?
  - Availability – can it be physically obtained?
  - Format – what form is it in (text, audio, video, imagery, etc.)
  - Discoverability – is it tagged and indexed so it can be readily found?
  - Accessibility – is interaction with it possible and allowed?

RESEARCH STATUS:

The research being conducted under this project is still underway. In parallel with the definition of the thin thread for NCOE described above, the authors have been working closely with the developers of ASM to further refine the model and ensure its practical applicability to a specific problem as that of the NCOE CBA. Towards that end, specific submodels of ASM are being defined as described below.

For example, a capability model based on a sub-set of the ASM object classes is shown in **Figure 7**. This model describes the effect, tasks (functions), conditions and performance objects, with their relationships, as the architectural framework for capability-based planning. A complicating factor is that most effects and capabilities are currently being described in traditional operational terms. For example, an effect might be “establish air superiority” and an associated capability might be “the ability to neutralize ground-based time sensitive targets”. The problem is to describe the relationship between an enabling capability, such as some IT capability, and one or more of the traditional operational capabilities.

The assertion of the authors is that association between capabilities, particularly when the capabilities cross functional boundaries, is best established at the task level. The first step is to identify the dependencies between the tasks in the primary capability and enabling, or supporting, tasks that have been defined for a supporting capability. Next, a well defined set of operational conditions and task performance criteria should be established for the primary capability which can in turn be used to establish a set of enabling tasks with associated performance criteria for external supporting tasks. In general, a minimum set of operational tasks and performance criteria are included in the supporting capability architectural model to show relational dependency and establish performance rules for enabling task performance.

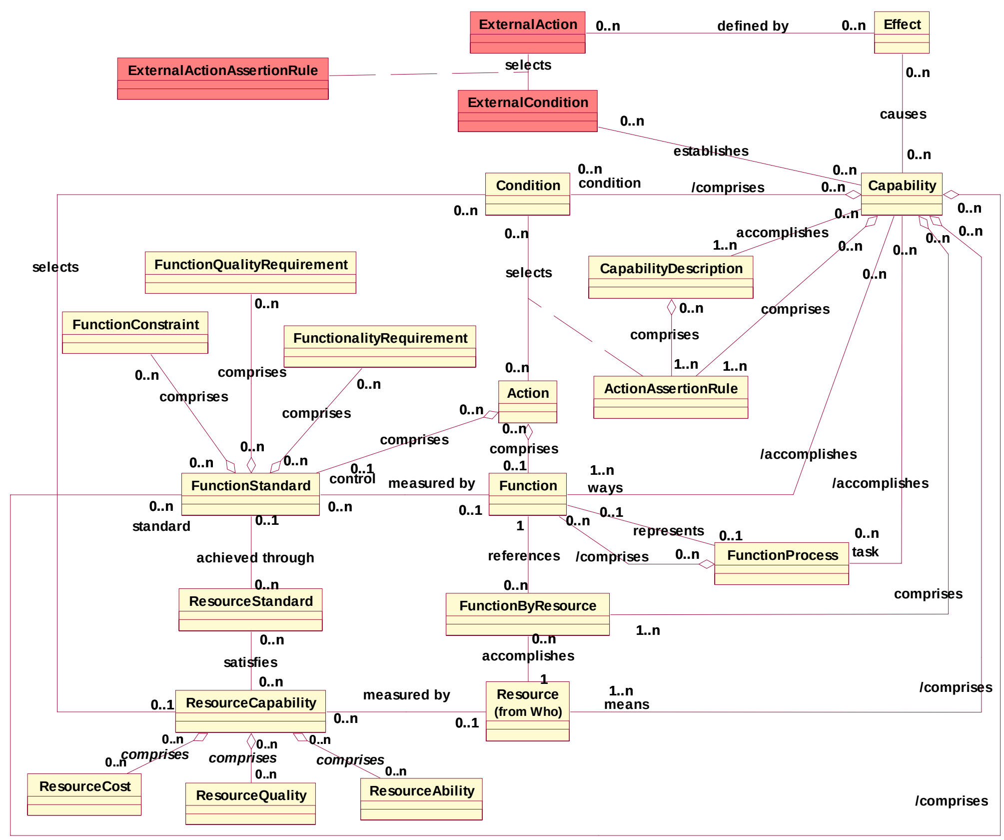

Figure 7. ASM Capability Model

The ASM model shown in **Figure 8** depicts *FunctionPrecedesFunction* and *Action AssertionRule* classes. In this figure, the external functions and rules come from the operational capability. The *FunctionPrecedesFunction* class may also be applied to external functions as “ExternalFunctionPreceeesFunction” to describe the relationship between external and external tasks. Similarly, the *Action AssertionRule class* may also be instantiated as “ExternalActionAssertionRule” to establish the relationship of external rules to task performance. The work accomplished to date under this project was focused on investigating the attributes required for the external class objects to establish the relationships between operational tasks and enabling tasks. Specifically, this was further scoped down to information and information sharing.

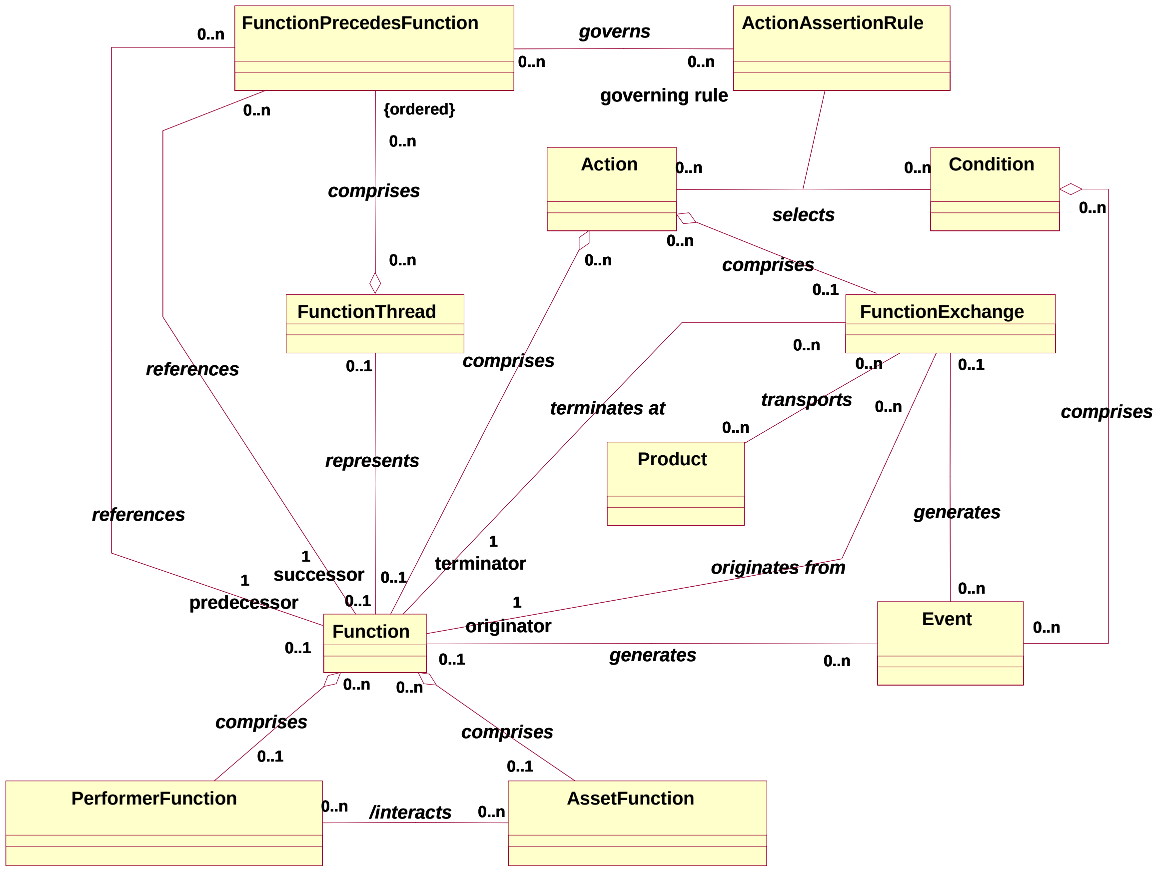

Figure 8. ASM Function Process Model

The team is now proceeding to research the implementation of the relationships in an automated tool with the intent of testing the use of the tool to answer selected questions as posed above. Two tools are being considered. The first is Vitech's CORE software. It is being closely examined for three reasons: first, it already contains pre-scripted queries that mirror some of the ones needed to answer some candidate questions, second, its internal tables can be easily modified to accommodate the specific entities defined for the GIG model, and third, it has a modeling and simulation capability. The other tool being considered is Troux's Metis software, principally because of its graphical interface that facilitates presentation of analytical results.

APPENDIX A
NCOE Thin Thread Analysis Link Table

The following pages present the initial linkages determined for the NCOE Thin Thread Analysis. The “Xs” in the cells indicate that a relationship of some sort exists between the elements identified in the particular row and column of the spreadsheet. The specific linkages presented are as follows:

Table A-1. Which Missions Produce What Effects
Table A-2. Which Missions are Accomplished by What Activities
Table A-3. Which Operational Entities Perform What Activities
Table A-4.. To Which COIs do What Operational Entities Belong
Table A-5. Which Information is Needed for What Activities
Table A-6. What COIs Share What Information
Table A-7. Which Applications Process What Information
Table A-8. Which Applications Use What Core Services
Table A-9. Which Cores Services Require What Communications
Table A-10. Which Communications Connects What Locations

The blue shading indicates specific relationships that have been identified for this analysis. As can be seen, the spreadsheet is still a work in progress and not all of the linkages have yet to be identified.

Missions

Effects

Which Missions Produce What Effects	Prosecute TST		
Reduce Threat	X		

Table A-1. Which Missions Produce What Effects

Missions

Activities

Which Missions are Accomplished by What Activities	Prosecute TST		
Find	x		
Fix	x		
Track	x		
Target	x		
Weapon-Target Pairing	x		
Determine Desired Effects	x		
Determine Constraints	x		
Determine Target Vulnerability	x		
Select Weapon	x		
Determine Shooter Availability	x		
Select Shooter			
Engage	x		
Assess	x		

Table A-2. Which Missions are Accomplished by What Activities

Operational Entities

Activities: Which Operational Entities Perform What Activities	Sensor	Decider	Shooter
Find			
Fix			
Track			
Target			
Weapon-Target Pairing			
Determine Desired Effects		x	
Determine Constraints		x	
Determine Target Vulnerability	x		
Select Weapon		x	
Determine Shooter Availability		x	x
Select Shooter		x	
Engage			
Assess			

Table A-3. Which Operational Entities Perform What Activities

Operational Entities

COIs: To Which COIs do What Operational Entities Belong	Sensor	Decider	Shooter
Intelligence	x		
Logistics	x	x	x
Medical			
Operations		x	x
TST	x	x	x
Weather	x	x	x

Table A-4. To Which COIs do What Operational Entities Belong

Information

Activities

Which Information is Needed for What Activities	Situation	Environment	Objectives	Enemy	Friendly
Find					
Fix					
Track					
Target					
Weapon-Target Pairing					
Determine Desired Effects	x		x		
Determine Constraints	x	x		x	x
Determine Target Vulnerability		x		x	
Select Weapon		x	x	x	x
Determine Shooter Availability	x				x
Select Shooter	x		x		x
Engage					
Assess					

Table A-5. Which Information is Needed for What Activities

Information

COIs

Which COIs Share What Information	Situation	Environment	Objectives	Enemy	Friendly
Intelligence				x	
Logistics					x
Medical					
Operations					x
TST	x		x		
Weather		x			

Table A-6. What COIs Share What Information

Applications

Information

Which Applications Process What Information	BFT	JTT	GCCS COP
Situation			x
Environment			x
Objectives		x	
Enemy		x	
Friendly	x		x

Table A-7. Which Applications Process What Information

Applications

Core Services

Which Applications Use What Core Services	BFT	JTT	GCCS COP
Video over IP			
Voice over IP			
M-to-M messaging			
Mediation			
Service security	x	x	x
Data source integration	x	x	x
Session Mgt	x	x	x
Service security	x	x	x

Table A-8. Which Applications Use What Core Services

Core Services

Comms	Which Core Services Require What Comms	*Video over IP*	*Voice over IP*	*M-to-M messaging*	*Mediation*	*Service security*	*Data source integration*	*Session Mgt*	*Service security*
Comms	Very High Capacity Terrestrial				x	x	x	x	x
	IP-Enabled LOS RF				x	x	x	x	x
	Satellite to Terrestrial Gateway				x	x	x	x	x
	Satellite				x	x	x	x	x

Table A-9. Which Cores Services Require What Communications

Locations

Comms	Which Communications Connects What Locations	CONUS-Large	OCONUS-GIG-BE	OCONUS-Other	Major Deployed	Airborne - C4ISR	Airborne - Shooter	Airborne - Mobility	Land Mobile -Vehicular	Land Mobile -Dismounted	Maritime -large	Maritime -Medium	Maritime - small
Comms	Very High Capacity Terrestrial	x	x										
	IP-Enabled LOS RF	x	x	x	x	x	x	x	x	x	x	x	x
	Satellite to Terrestrial Gateway	x	x										
	Satellite	x	x	x	x	x					x	x	x

Table A-10. Which Communications Connects What Locations