Next Generation Combat Systems - An Overview of Key Development Concepts

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Note these slides are extensively annotated. Full text is available by printing in PowerPoint "notes pages".

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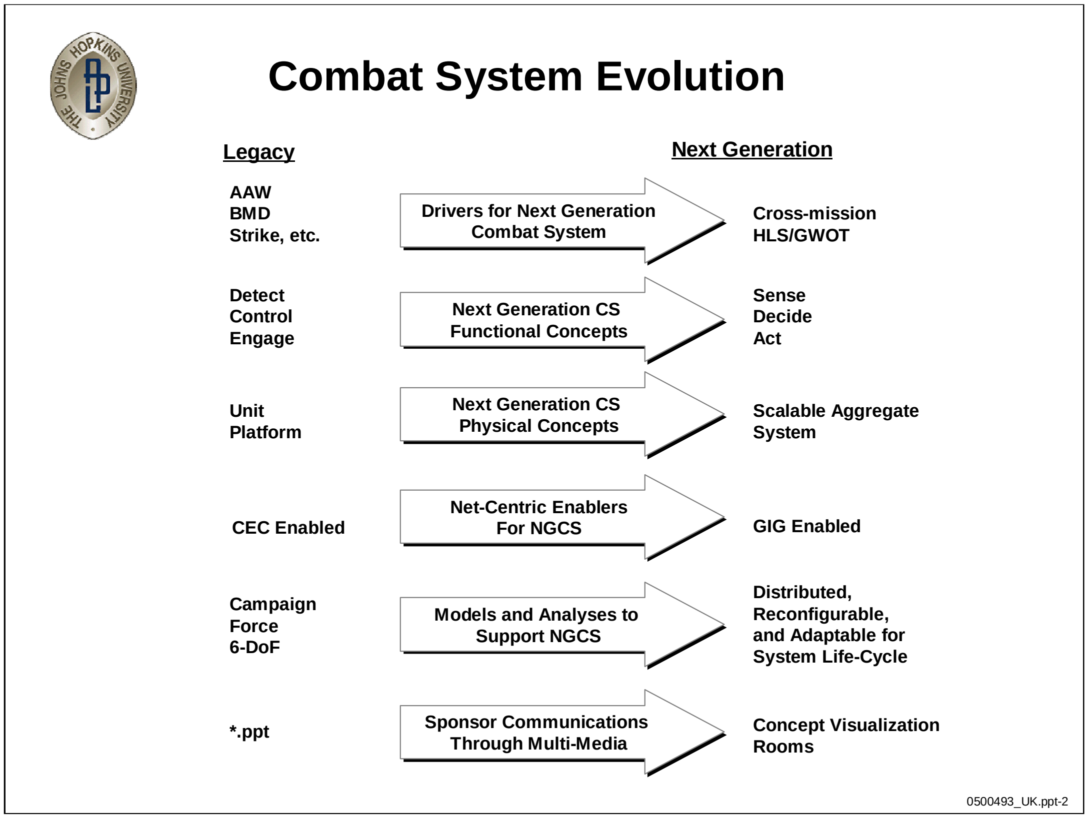
Abstract

Threats to ground, air, space, and sea are increasingly diverse, and the large set of operating environments for our Armed Forces now includes non-traditional roles of law enforcement, humanitarian aid, and homeland defense – all markedly different missions that must be performed against a backdrop of terrorism. At the same time, long-time threats, such as cruise and ballistic missiles, are becoming increasingly sophisticated, more difficult to counter, and more widely distributed. These factors pose critical challenges to the collective defensive posture and the ability to achieve fiscally acceptable solutions with next generation systems. After reviewing the threats and problems anticipated, a set of generic key concepts for next generation combat systems (NGCS) is proposed: aggregation, automation, and adaptation, along with three derivative areas: operational control, human understanding, and communications. The authors propose that such concepts be developed and built into systems in a general and consistent manner.

To help verify these key concepts, the authors illustrate their use through notional application to the Ballistic Missile Defense System (BMDS).[1] Finally, the relationship between these key concepts and the emerging Global Information Grid (GIG) is examined.

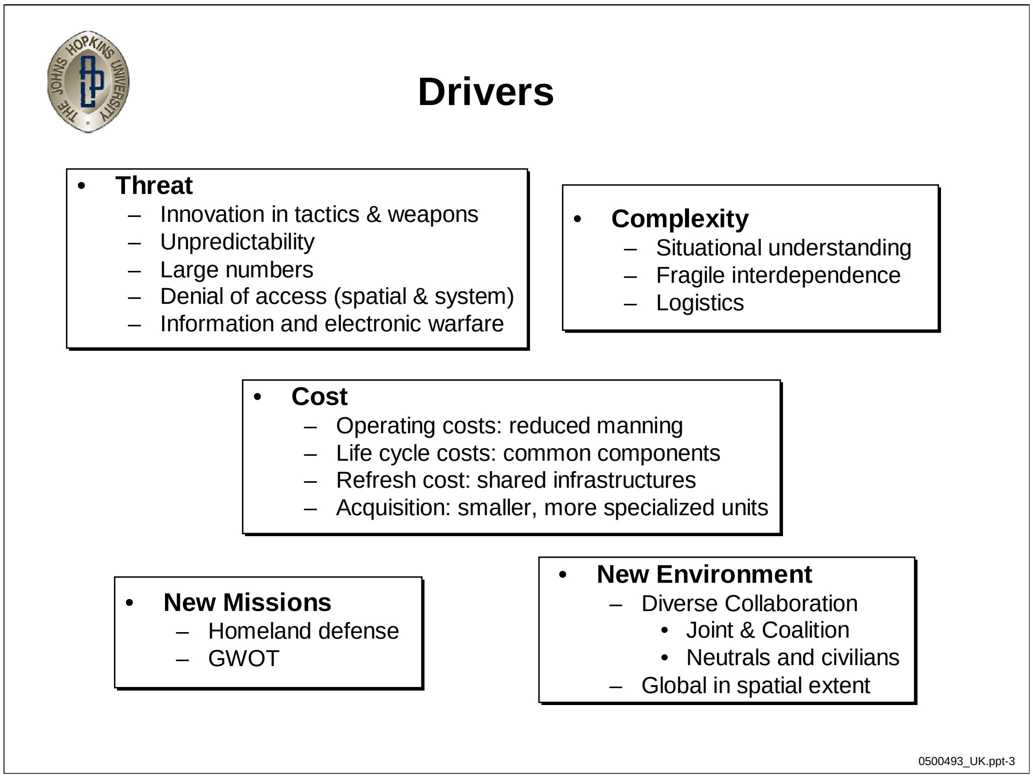
[1] Acronyms are also expanded on the last page of text.



Combat systems have evolved considerably over time to reach their current level of capability and integration among component systems. In early systems, "integration" was performed by people using skills and processes developed through training and experience to achieve objectives only possible through the synergy of multiple systems. Key in the evolution of the Navy's current generation of combatants was the development of the Aegis Combat System. In Aegis, the Navy achieved an integrated fighting ship that "represented a major transformation, in which the ship, the combat systems and the training systems were designed as a single unit."[1] Integration among systems within the ship became the realm of automation and tailored, managed responses governed by "doctrine".

Many factors are pressing the evolution of combat systems beyond our current legacy capability. Achieving the "next generation" envisioned on the right-hand side of the slide will require us to address a large set of driving functions and develop technology enablers.

[1] "History of Aegis," http://www.nps.navy.mil/meyerinstitute/history.htm.



Drivers for Change

While the current state of combat system capability is unparalleled in naval history, complacency is not acceptable. The environment in which naval forces operate is constantly changing, and a corresponding evolution of our capabilities is required. Drivers for this evolution include the following:

Threat – The weapons employed by our adversaries continue to evolve. Some threats are evolving in technical sophistication, making it increasingly difficult to develop single combatant solutions that provide the desired sureness of defense. These weapons are also seeing greater proliferation.

> A new generation of cruise missiles … could lead to weapons that are effective to ranges of approximately 600-800 km. While primarily pursued as naval weapons, conversion to land-attack variants would be a relatively straightforward process. The Iranian anti-ship cruise missile case points to a larger problem of attempting to control the spread of cruise missiles: an increasing number of suppli-ers, low cost, ready availability of dual-use technologies, and weak international controls. In acquiring production capabilities, Iran is also poised not only to further develop, but also to export a range of cruise missiles[1]

Enemy states and organizations are also evolving unorthodox approaches that stress our ability to adapt systems and methods to counter them. The lessons of 9/11 and current operations in Iraq are clear evidence of a trend that enables smaller and smaller groups to have significant impact.

> Not only is it likely that many of the conflicts facing the West will be of an asymmetrical nature, it is also likely that these threats will come from diverse and simultaneous sources. For example, the possibility that conventional terrorism and LIC [low intensity conflict] will be accompanied or compounded by cyber/infrastructure attacks, damaging vital commercial, military and government information and communications systems, is of great concern. In this sense, a major Western country could suffer greatly at the hands of an educated, equipped and committed group of fewer than 50 people. Such an attack could have an effect vastly disproportionate to the resources expended to undertake it[2]

Under other potential conflict scenarios, threats may appear in large numbers, stressing our ability to manage a complete response, and challenging our ability to create cost-compatible solutions.

[1] “Ra'ad cruise missile boosts Iran's military capability,” Scott Jones, ***Jane’s Intelligence Review***, 1 April, 2004.

[2] “Intelligence Gathering on Asymmetric Threats – Part One,” Kevin O’Brien and Joseph Nusbaum ***Jane’s Intelligence Review***, 1 October, 2000.

New Missions – The mission set for Navy combat systems is constantly expanding. Humanitarian aid, low intensity conflict, law enforcement, and terrorist attacks were not primary concerns (or even envisioned in some cases) when constructing many of today's combat systems. New mission needs are pushing the Navy out of its traditional operating format. GWOT requires the ability to respond rapidly and simultaneously in many areas of the world. As described in a draft Navy strategy[1], four national security challenges stem from the GWOT: irregular (uncon-ventional methods), catastrophic (rogue employment of weapons of mass destruction [WMD]), traditional, and disruptive (application of breakthrough technologies).

> "The agility of operational deployed naval forces supporting a Joint Force Commander provide the United States with extraordinary overseas reach…The increasingly urgent task for the Navy, and the larger Joint Force, is to determine what forces and concepts are required to meet the four challenges outlined by the Secretary of Defense"[1].

The difficult part is that these will be sustained mission obligations with three of the four demanding an innovation cycle much shorter than for traditional combat equipment. Combat system responses must vary dramatically depending on these missions, and future combat systems must be able to configure themselves rapidly and easily to the future changing mission environment.

New Operating Environment – Joint operation is expected to predominate, and coalition operation will become even more common. "The joint force, because of its flexibility and responsiveness, will remain the key to operational success in the future."[2] While this is not a new trend, the extent to which military planners are incorporating it as standard procedure is of note. There is still much to do in aligning our individual combatant capabilities to the notion of a coherently operated joint force. In an address to the 17th International Seapower Symposium, Admiral Mike Mullen, Chief of Naval Operations, extended this principle to encompass the international Navy community in commenting on the difficulty of addressing "irregular and unrestricted warfare"[3]: "Perhaps the most profound effect of today's challenges is the increased value of cooperation between friends, allies, coalition partners, and like-minded nations. Despite differences in size or structure of our navies, cooperation today is more necessary than ever before".

Complexity Management – As combat systems have evolved, they have become more complex, making the task of effective employment increasingly difficult. These complexities must be explicitly recognized and addressed in future combat systems. A key example is the difficulty we have in understanding the tactical situation: what are we in a position to do, what will our automation do without our intervention, and what new courses of action should be formulated. Increasing the interdependency among components of a system-of-systems introduces additional complexity. Widespread joint operations and their associated component interdependencies pose that risk. Efforts to address robustness and integrity must keep pace with the growth toward more interconnected capabilities to stem the tendency toward fragility. While often viewed as mundane, the ability to support operations must also be considered. As stated recently, "Absent a concomitant revolution in the support activities of defense, the Revolution in Military Affairs will quickly outrun the ability of logistics, personnel, medical and other systems to support it."[4]

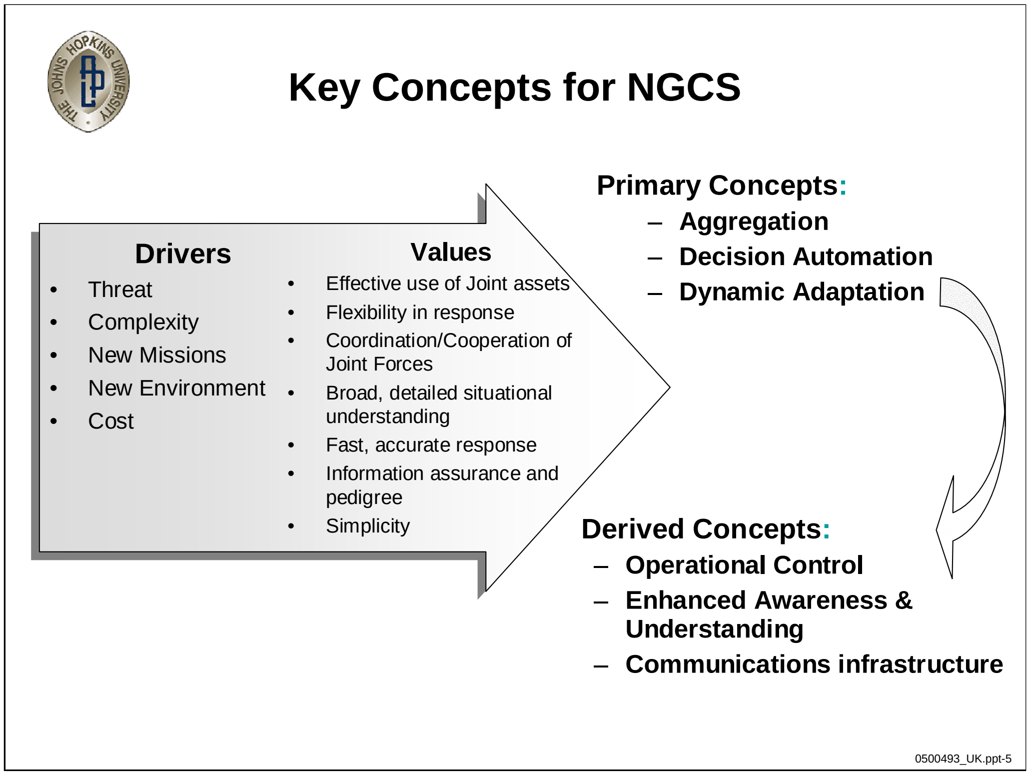
Cost – Pressure to control cost is present in all aspects of new and existing systems: development, production, operation, and maintenance. Achieving standardization of function and interfaces is an approach to more efficiently developing elements of the combat system. It allows them to be used across many systems which will share the development and maintenance burden. The Navy is exploring the concept of smaller, more mission-focused combatants (e.g. littoral combat ship). While the smaller, more focused unit provides a lower unit production cost, it will need to work closely together and with other joint assets in order to fulfill all missions. Reduced manning on the Navy's major combatants has been a cost reduction objective for quite some time. Progress in the operator/decision maker area has improved the ability to accomplish more, but it is unclear whether the current pace of progress is keeping up with the growing complexity of the systems, number of options, and collection of roles that face the modern-day warfighter.

[1] "Navy 3/1 Strategy: The Maritime Contribution to the Joint Force in a changed Strategic Landscape," N3/N5, April, 2005.

[2] "Joint Vision 2020," Chairman of the Joint Chiefs of Staff, May 2000.

[3] From "Remarsk as Delivered for the 17th International Seapower Symposium," ADM Mike Mullen, Naval War College, 21 September, 2005, as recorded in http://www.chinfo.navy.mil/navpalib/cno/speeches/mullen050921.txt.

[4] From leading change in a new era http://www.defenselink.mil/pubs/dodreform/fullreport.pdf



Concepts

There are many viewpoints painting a vision of the operational future, the needs of the various services in the coming era, and the transformational efforts that will be required to reach these goals. Some of these visions are documented in references cited throughout this paper. The fusion of these many thoughts into a small number of key concepts was a difficult exercise in synthesis that applied loosely structured events and exercises. Ideas on potential concepts and their relationships to drivers and values were collected and merged where possible. We made significant use of "mindmaps" [1] to organize ideas from reference sources, and later, to consolidate them. Governing this effort was a theme: What fundamental concepts could be developed or extended to enhance the capabilities of the combat system no matter what the mission, no matter what new weapon technology might bring, and no matter what tactics an adversary might apply? The notion is that key advances in integration of capabilities (at the combat system level) if established in a common form, can amplify the steady march of progress in sensors, and weapons – independent of specific technology.

The concepts that emerged from this effort appear in the slide above: aggregation, automation, and adaptation are three primary concepts[2], with operational control, enhanced awareness and understanding, and communications infrastructure as "derived" concepts. (The derived concepts support the primary concepts.) Each of these is defined below, with the primary concepts addressed in more detail in subsequent sections. (Amplification of the derivative concepts will be reserved for a later paper.)

Instances of these concepts have emerged with some of our more advanced capabilities. However, they have emerged in specialized form for particular domains. It is felt that these concepts are (or should become) fundamental tools in modern combat systems. They should be built into the system at the most fundamental levels and in a generic way. This will allow the concepts to permeate the combat systems of a force and bring about a dramatic magnification of capabilities.

[1] "Definition of Mindmaps," Tony Buzan, http://www.mind-map.com/EN/mindmaps/definition.html

[2] It is important to note that we still consider this a work in progress. We have a strong feeling that there may be more "primary" concepts that we have not yet labeled.

Aggregation is the pooling of resources from independent units to collaboratively perform mission tasks. In aggregation, resources (or portions of them) from independent systems are nominated to be constituents of a resource pool. Those resources are then applied to broad mission objectives that might be unachievable by any individual unit. How such resources are identified, partitioned, tasked, and controlled is critical to a robust operational capability. These form the primary areas of interest for aggregation concept development.

(Decision) Automation is the ability of a "system" to autonomously initiate actions or develop alternatives for human decision. This is not a new concept; it is quite analogous to the "automated doctrine" used in Aegis. The difference is in the breadth of generality and capability that we are striving for. The goal is to significantly increase the set of information on which decisions are based (including expanding that information set beyond the confines of the individual unit) and to grow the collection of "actions" that can be taken. The term "actions" is intended to be very encompassing, e.g., it includes the capability to prompt the human decisionmaker to action, issue alerts, provide recommendations, alter/highlight displays, or even modify the internal processing (parameters or rules) of a system component. Decisions are automated through a rich set of rules linking the initiation of each action to specific observable events.

Adaptation is the ability of the combat system to respond rapidly to changes in asset participation, environment, mission, or threat. Our forces operate in an environment in which change is constant. Threat tactics change, the environment changes, systems arrive and depart as participants in a force, and the capabilities of those systems change with upgrades and new installations. This requires us to establish a mature approach to managing responses to the various types of change. Change cannot be considered an anomaly.

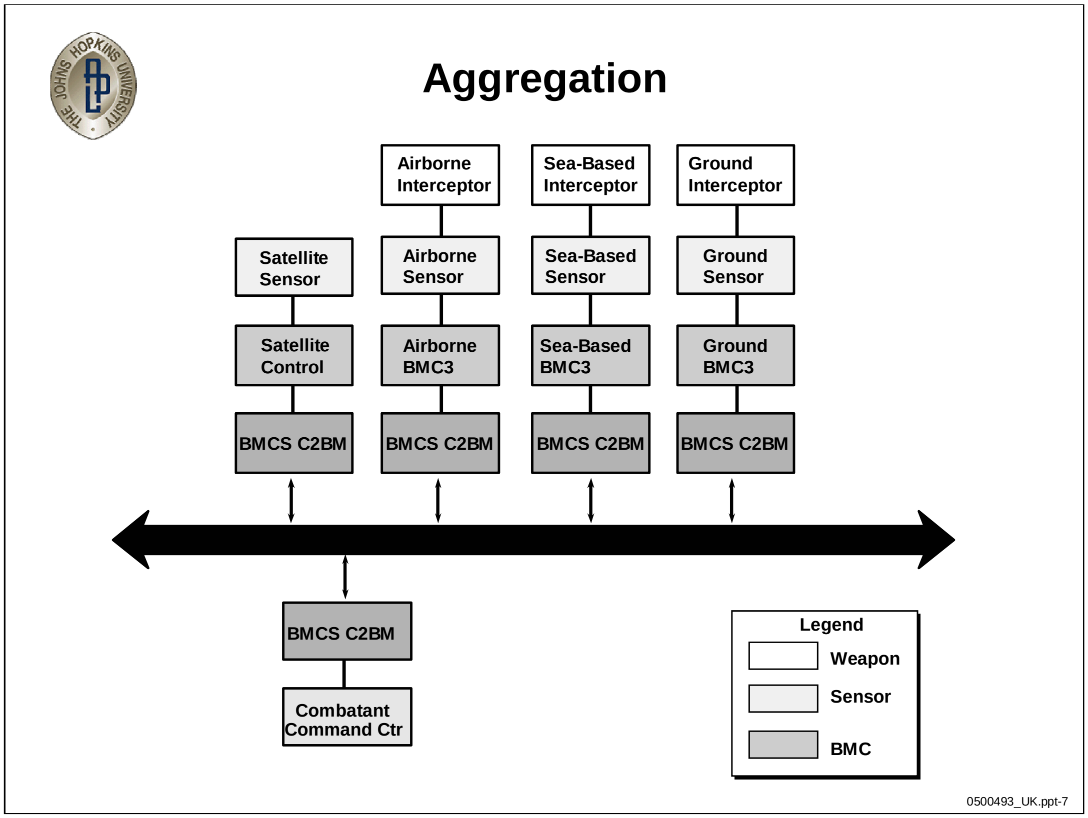
Operational Control is the ability to monitor and manage the dynamic automated aggregate operations. There are two very different aspects to this concept. First, the appropriate interactions among decision makers at all levels of command must be established and supported. Passing of "control" (or even lesser responsibility) of a resource from the unit that owns it to another unit that may be making more global decisions, is a significant change that must be considered by the operational community. Establishing the principles by which that may occur (in a general sense) will be a significant undertaking but is critical to advancing the aggregation concept. Secondly, there must be reliable and predictable control of the aggregate system (including its automation and adaptation functions) in order for these concepts to be operationally acceptable. More rigorous approaches to ensuring that components will behave as desired, and only as desired, must be established.

Enhanced Awareness and Understanding is the ability to develop comprehensive situational understanding. This is a long pursued objective, and progress has been made in many existing and emerging systems. But it is also clear from observations of the Human Machine Interface aboard the USS Ronald Reagan that there is yet work to do [1]. The growth of aggregate functionality and increased automation will also increase the complexity of understanding how systems will respond and what controls need to be manually asserted. Simply understanding "what will the system do if I leave it alone" is not a trivial exercise.

Communications infrastructure comprises the services that enable collaboration among aggregate components and warfighters. None of this will happen without communications and, more importantly, without communications that is much more capable, predictable, and robust than currently available. The establishment of the GIG recognizes this need[2]. The key is for the GIG development to fully recognize the communication requirements of combat systems.

[1] "Sail-Around Evaluation: The Battle Management Organization and Human Machine Interface as part of the USS Ronald Reagan Combat System," Draft Report, Technology Management Group, Inc., February 2005.

[2] Global Information Grid Capstone Requirements Document, JROCM 134-01, 30 August, 2001

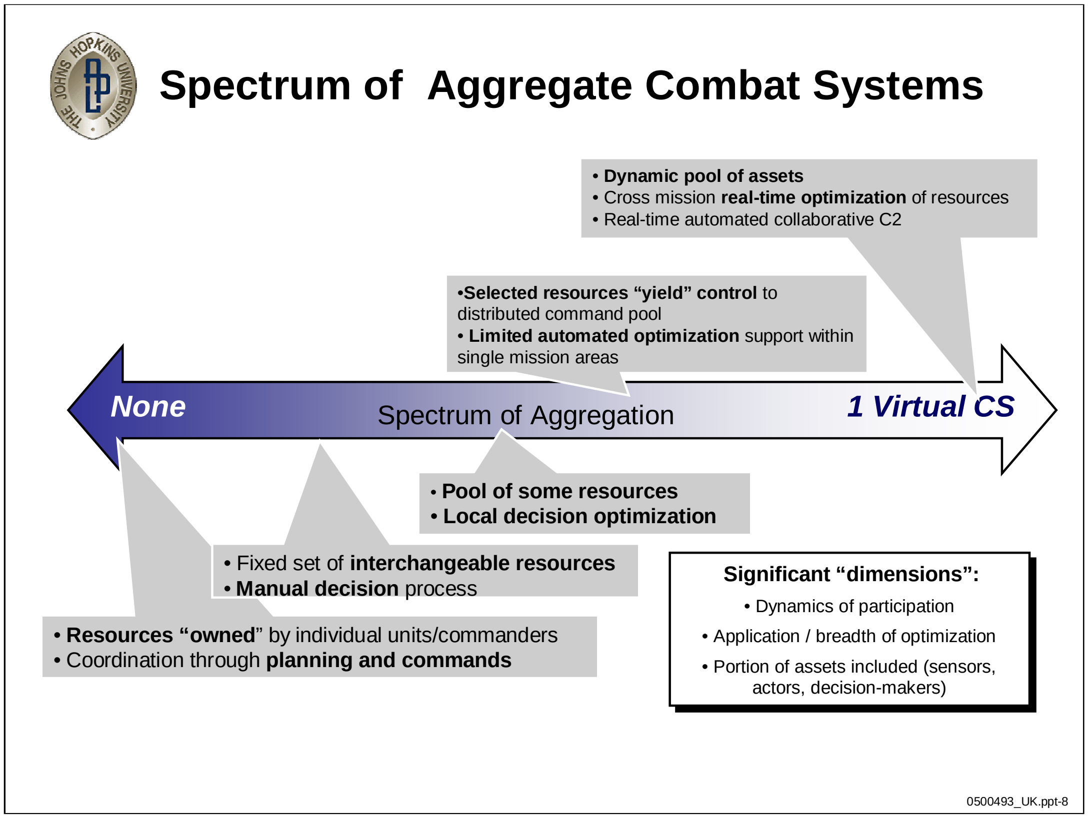


Aggregation

Aggregation is simply the application of all available and appropriate resources to a mission, independent of which unit hosts them. Examples of aggregation are emerging in current systems. The Ballistic Missile Defense System's (BMDS) overall concept is clearly one in which a diverse collection of assets is applied to multi-mission objectives of national missile defense and regional defense against short and long range ballistic missiles. No single system or unit can "solve" the problem. It is only through the synergy of multiple sensor and weapon systems (and their associated combat systems) that operationally viable solutions are achieved. The slide above depicts a notional interconnect of different components in the BMD system. The Command and Control Battle Management (C2BM) component of that enterprise is tasked with providing the required coordination among components to support the complex objectives. A second example of emerging aggregation is the Navy's Cooperative Engagement Capability (CEC). This provides a sensor information sharing and integration system that creates improved tactical awareness and also enables multi-unit supported guidance for engagements[1]. It seems that we are on the front edge of a technologically supported ability to reap the benefits of much more closely coordinated behavior among our individual systems. As suggested by the Undersecretary of Defense for Acquisition, Technology, and Logistics at an Armed Forces Communication and Electronics Association (AFCEA) conference, "I can think of no more critical need than the development and fielding of a joint battle management capability. … A key objective is to provide robust capabilities and innovative approaches for the full spectrum of potential missions using a system of systems approach."[2]

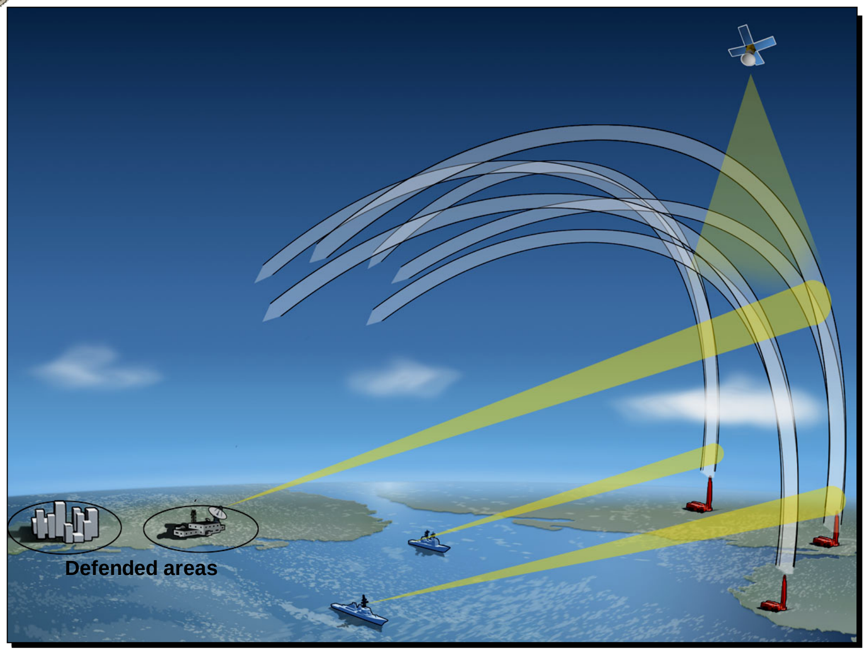
[1] "CEC: Sensor Netting with Integrated Fire Control," C. J. Grant, Johns Hopkins APL Technical Digest Vol 23, Nos. 2 and 3, 2002.

[2] As reported in "CHIPS – The Department of the Navy Information Technology Magazine," Summer 2004, http://www.chips.navy.mil/archives/04_summer/Web_pages/Michael_Wynne.htm.



We can look at aggregation as a spectrum of behavior (depicted above) ranging from simple single-objective human coordinated efforts to fully automated, real-time optimization of resource use across multiple missions. While drawn as a single-dimension continuum, the spectrum has somewhat independent dimensions of breadth (the number of resources addressed), scope (the set of objectives simultaneously addressed), and dynamism (the ease/speed with which the management adapts to new conditions). The appropriate working point within this spectrum depends on the state of technology to support it. The technology task ahead is to push the operating point forward; the systems engineering job is to select the appropriate operating point for any given time.

Notional Detection/Surveillance Aggregation



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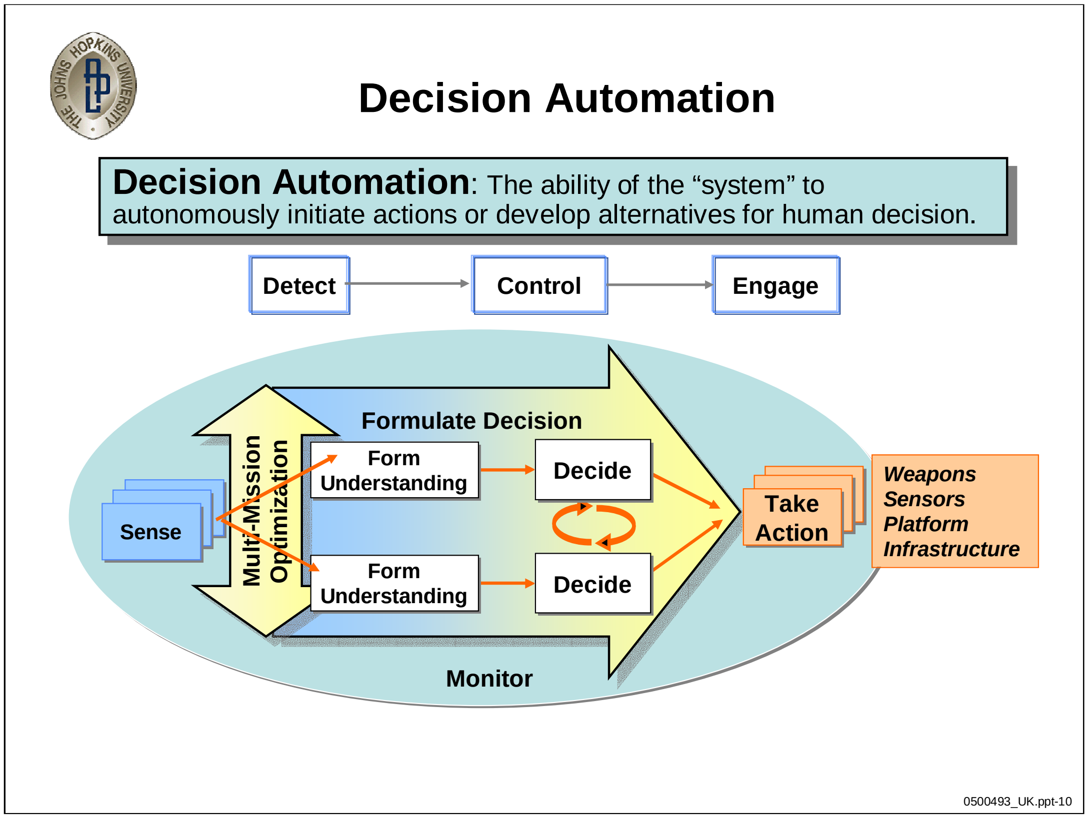
Throughout the paper, we examine the application of these concepts to the BMD domain. In this extremely challenging technical problem, we find multiple sensors of varying types that can be applied to the detection and tracking problem, multiple weapons that have varying ranges, and hosts that vary in mobility and command structure. The slide above depicts a notional case in which a land-based sensor, two ship sensors, and a satellite are available to support detection and tracking of ballistic missile launches in the region. To help raise the likelihood of detection, the land- and sea-based sensors focus their detection energy on areas determined by combinations of launch and impact points. The satellite has a broader field of view for detection, but lacks precision for tracking and may suffer from time-varying characteristics: It may not always be in place and does not always have a clear view (due to atmospheric interference). The problem, very simply, is to use these assets to the best of their abilities, in combination, to provide the most reliable and accurate detection and tracking of ballistic missiles possible (with those assets). The changing nature of the environment, intelligence (anticipated launch points), the resources themselves (satellite and ship locations), etc., establish a dynamic environment in which this optimization is performed.

To support the aggregation concept in a general way, capabilities must be established that allow resources from independent units to be grouped for optimized application to a mission. Mechanisms must be established to do the following:

- Create a pool of resources (in this case, the sensors).
- Nominate resources to the pool, i.e., give approval for the nominated resource to be used (as determined by the resource manager). It also seems likely that a mechanism for (optional) final approval be established to allow the resource owner final say on how a resource might be used.
- Express a mission objective in a way that allows a resource manager to discover a “good” (ideally optimal) resource allocation to fulfill it. Mechanisms for feedback to human decisionmakers and thresholds for acceptability are needed to provide the resource manager the needed guidance on when “best effort” is suitable and when decisionmakers must enter the picture to consider the problem (with additional options not available to the resource manager).
- Provide a mechanism for managing the resources in a pool, allocating them to specific responsibilities that collectively fulfill a mission objective. (This includes the “optimization” function that here must provide best-effort solutions to prioritized objectives under any collection of resources and objectives.)



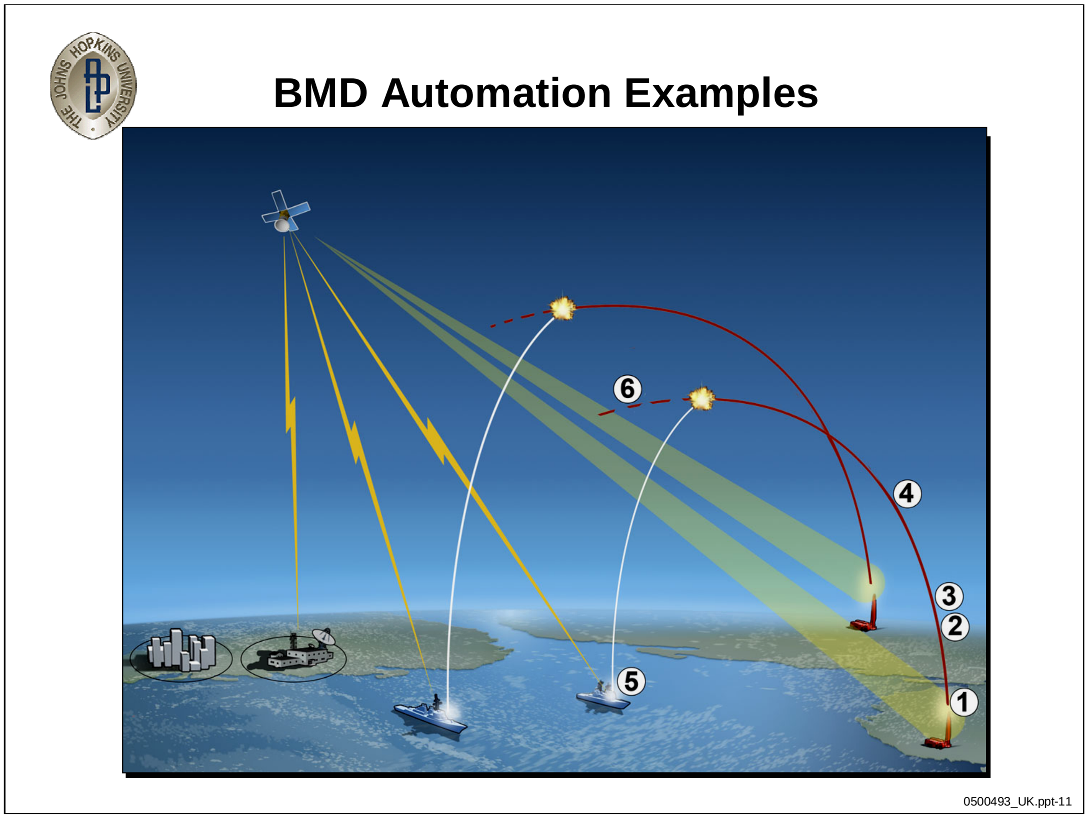
Automation

Automation is a broad term. In Aegis as well as in many other combat systems, a set of automated capabilities already exists, including automated detection and tracking, automated status reporting, and readiness assessments. The focus here is decision automation, which also has an existing set of capabilities supporting automated and human-supported decisions involved in object identification, threat engagement, and radar control. Automation joins our list of key concepts due to its continuing importance.

The current operational context includes large collections of sensors, weapons, systems, rules for use, preferred application techniques, etc. While these provide capability (and options), they substantially complicate decisions about what to do and when. The intended extension of automation we seek is the significant broadening of all aspects of the capability: the input set that is applied to the decision process, the richness of the language that is used to express desired automated actions, and the set of actions that may be taken as a result of automation. Moreover, it is desired that these extensions take a form that can be applied in a regular fashion to all the component systems (and their associated controls) that comprise the combat system "system of systems."

In the development of Aegis, the simple model "detect, control, engage" was used to provide a high level characterization of its overall architecture and automation approach. In considering the growth of automation for the future combat system context, a more apropos model is "sense, decide, act," where the growth in domain of all three steps is generalized to the broader mission context. In this model, automation and human decision must collaborate effectively and efficiently to address the staggering number of options that are afforded by increasingly capable and flexible systems. In its simplest form, sensed data and information are used to decide when and under what conditions various system capable actions are initiated.

An important principle in these systems, however, must continue to be the ability of the human decisionmakers to exercise supervisory control. This really requires two things": first, that appropriate control mechanisms exist, and second, that the behavior of the system be comprehensible to the decisionmaker. As more automation is established, both of these become more difficult to achieve and new techniques may well be required.



Automation in a ballistic missile defense scenario should assist in many of the operational decisions that may occur. The slide above depicts a complex situation involving multiple ballistic missiles, multiple sensors, multiple defensive firing units, and multiple defended areas. It is annotated with some of the decision points listed below, where we would expect that broad automation capabilities would play a major role in collecting relevant information and either making decisions outright or providing recommendations or option summaries for human decision.

1. For any initial detection (especially one that is the "first" in an actual military exchange), there are significant decisions that must be made on whether the observation is indeed a real object and whether it is one of interest, e.g., a ballistic missile of some sort.
2. Given that a real missile has been detected, the next set of questions pertains to whether it is something that warrants engagement. Is it perhaps just a test? If it is indeed a hostile action, is it of sufficient concern that we should attempt engagement? (An answer to this question varies considerably depending on prior events and weapon stores.)
3. On the event of a verified first hostile launch, there may be many actions (changes to automation settings, for example) that might need to be altered to establish a more active, faster response to further hostilities.
4. A ballistic missile in flight may be trackable by multiple assets. Which ones should be used? Are there sensor resource loading issues to address if there are multiple missiles in flight? Are different sensors better equipped to address different phases of tracking and discrimination? (Clearly, this ties into the aggregation concept quite directly.)
5. For a missile that is to be engaged, selection of the engaging unit and weapon must be made. What strategy should be applied to the engagement: salvo, shoot-look-shoot, single-shot?
6. For an engaged target complex, an assessment must be done to determine whether the warhead has been neutralized. This may also lead to a decision on whether to reengage, with criteria for reengagement changing as a result of the tactical situation and number of remaining defensive missiles. Again, a choice of engaging unit and weapon must be made (when more than one option remains).

Adaptation

Adaptation: The ability of the combat system to respond rapidly to changes in asset participation, environment, mission, or threat.

Aspect

- Focuses on the infrastructure required to adapt to or to institute change at various levels of the aggregated combat systems.
  - **Asset participation**: protocol for adjusting to the entry/exit of a unit or its resources from participation in one or more aggregate resource pools
  - **Operational doctrine modification**: ability for unit personnel to adjust or select automation rules in response to an operational situation
  - **Engineering doctrine modification**: ability to adjust combat system parameters and automation rules and forward them for ship use

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Adaptation

A century ago, German strategist Field Marshal Helmuth von Molke warned, “No plan survives the first engagement with the enemy’s main force.”[1] The creativity and innovation shown by current enemies seem to bear this out as a continuing principle. The risk in creating more complex collaborative and automated approaches to warfare and defense is that we may create capabilities that are overly rigid and vulnerable to unanticipated innovation.

Our focus on adaptation concepts is pointedly aimed at avoiding that problem. We envision three types of adaptation (as shown above):

• Changes in resources/participation – previously discussed as an element of aggregation (and indeed it is) in which the overall force must adapt in real time to the presence of different resource sets under a continuing fixed set of mission objectives. A broad interpretation of this also encompasses the evolution of systems: one may see an airborne warning and control system (AWACS) aircraft depart and a new one arrive on station with significantly different capabilities.

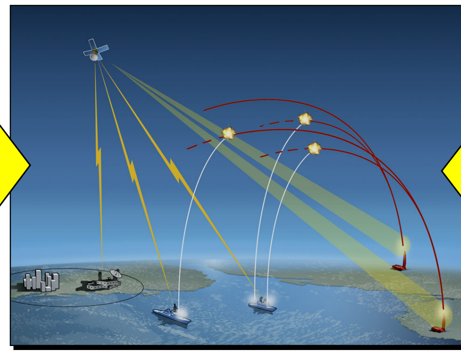
• Field modification of automation – With suitable support for entering and validating new automation rules, we wish to enable the warfighter community to tailor automated responses to the demands of their particular environment and operational guidelines. Achieving this requires a balance between flexibility and complexity, hopefully elevated by effective human interface design.

• Engineering station modification of automation – There are elements of automation control that may be beyond the expected proficiency of the warfighter. These areas can still be addressed as adaptable functions but with the support of an engineering community at a base or command installation. In addition to personnel with additional training, such a site might also have considerably greater assets for the determination of optimal automation settings and for the validation of what might be a large set of interrelated adjustments.

[1] cited in “Transforming military improvisation into strategy,” The Lawton Constitution.com, Richard Hart Sinnreich, http://www.lawton-constitution.com/sinnreich/archives/Transforming%20military%20improvisation%20into%20a%20strategy.htm.

Adaptation in BMD Scenario

Warfighter | **Engineering Center**



Adaptation capitalizes on the assets of the deployed fleet and its engineering support centers to rapidly react to changes in the threat and enemy tactics.

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Adaptation in a ballistic missile defense scenario might follow many paths. First, as discussed initially under aggregation, the set of resources to be applied to the detection and tracking problem should be seen as a set under the constant potential of change due to environment, system availability, and even pressing needs in another mission area. Second, on the event of the first confirmed tactical ballistic missile (TBM) launch, it is very likely that many identification (ID), tracking, and engagement controls might be altered to operate more aggressively (and with less command level confirmation) to allow weapons and systems to be used to their greatest effectiveness. Third, the experience of engaging the enemy might, for example, reveal an unexpected decoy approach. With the support of remote engineering analysis fueled by detailed field sensor data, the algorithm for identifying the ballistic missile warhead might be adapted to yield a lower susceptibility to deception. A network-based delivery of the new parameters for identification automation would be provided and installed with as quick a turn around as possible.

GIG Definition and Objectives

- Definition:

  Global Information Grid: "The globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policy makers, and support personnel."

- Needs
  - "The GIG shall support all DoD missions with information technology…"
  - "The GIG assets shall be interoperable …"
  - "The GIG shall be based on a common, or enterprise level, communications and computing architecture to provide a full range of information services at all major security classifications…"
- Vision

  "U.S. forces must leverage information technology and innovative network-centric concepts of operations to develop increasingly capable joint forces. Our ability to leverage the power of information and networks will be key to our success in the 21st century. We must make information available on a network that people will be willing to depend on and trust. We must populate that network with new types of information needed to defeat future enemies and make existing information more readily available. And we must deny enemies' information advantages against us."

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Key Concepts and the GIG

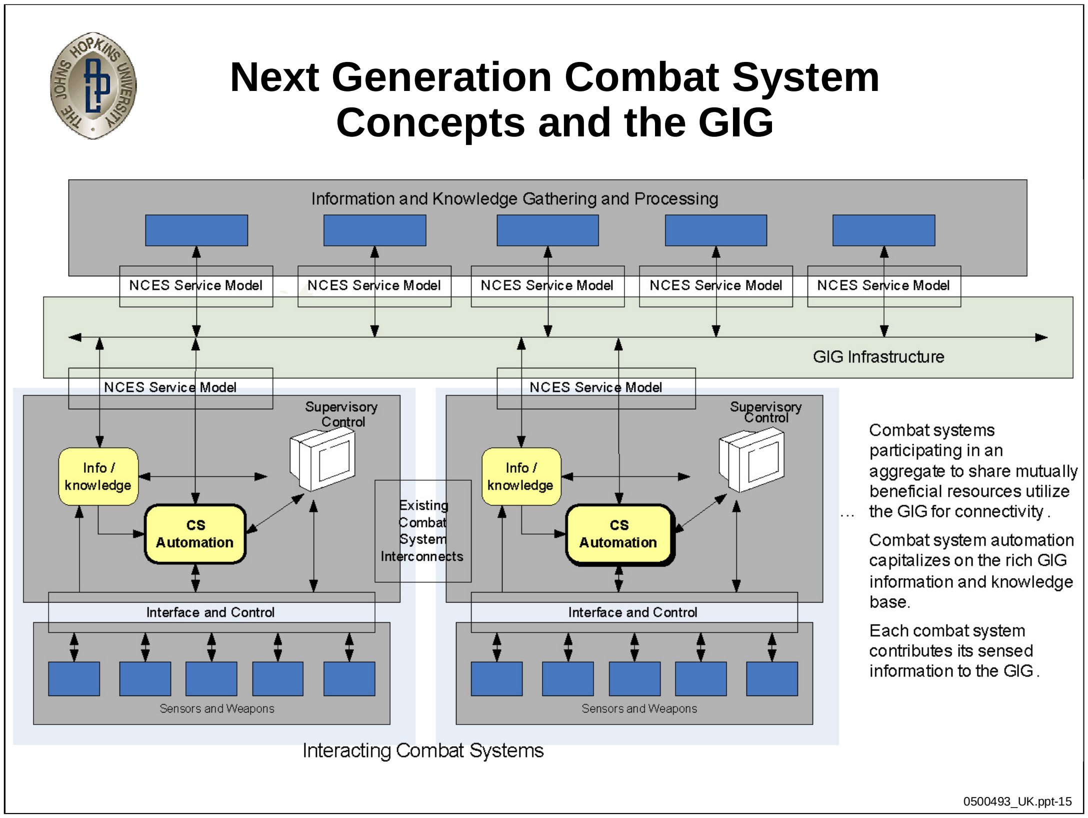
Policy for the GIG[1] aims for a future in which virtually all information systems (and those that employ or provide information to them) are crafted to operate in a common information exchange environment. With standards guiding interoperability, enterprise-level services providing common and efficient base capability, and a greatly extended communications infrastructure, the GIG promises to be "transformational" in the truest sense of the word. It is critical then to consider how this much-elevated capability for delivering and processing information may influence the combat systems of the future.

The Navy has established a specific initiative for pursuit of GIG objectives, called FORCEnet, which specializes the requirements of the GIG to the Navy environment and provides a first-level view of a planned architecture[2]. Interestingly, the future combat system concepts we espouse most certainly fit under the GIG umbrella of a system that "transmits information to, receives information from, routes information among, or interchanges information among other equipment, software, and services."[1] However, historic differences in requirements and the ability of technology to meet them have fueled two independent development communities: the combat system and information system (sometimes known as command, control, communications, computers, and intelligence [C4I] communities).

The convergence of these two futures seems inevitable. The true "value" of the the GIG and its Navy FORCEnet manifestation is not so much its ever more powerful knowledge base but, rather, what can be done with the knowledge it creates. A favorite term in the intelligence community (which is a major player in the information system environment of the GIG) is "actionable intelligence." The future combat systems will be primary providers of that "action."

[1] "Global Information Grid (GIG) Overarching Policy," DoD Directive 8100.1, Deputy Secretary of Defense Paul Wolfowitz, 19 September, 2002.

[2] "FORCEnet Architecture Vision," Version 1.2, Office of the SPAWAR Chief Engineer SPAWAR 05, 18 July 2003.

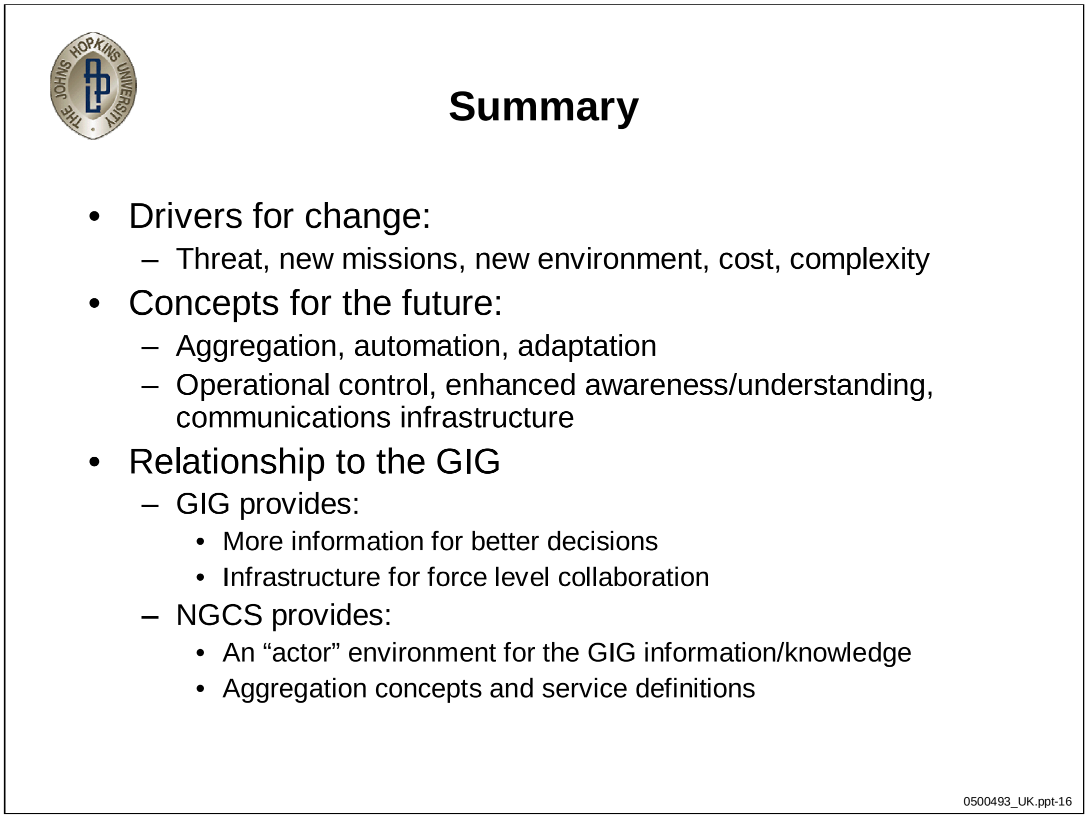


On the combat system side is a continuing quest for more and higher quality information that can be used to guide battle decisions. Our combat system concepts strive toward adaptable, automated capability, optimized across a collection of cooperating joint assets can only realize their potential with the type of adaptable, ubiquitous, and improved communications infrastructure promised by the GIG. Expanded automation capability appears to takes a central position in connecting these two objectives, as suggested above.

The richness of information made available ***(***and readily usable***)*** by the GIG will elevate the capabilities possible in a generalized automation scheme. No longer constrained to base decisions on own unit information, generalized decision automation will be free to identify and apply best sources, to incorporate information on other units' status and intent, and to utilize the real-time evolving experience base of its peers. But to achieve this integrated vision, the combat systems must be able to acquire information with the accuracy, reliability, and timeliness required for making real-time warfighting decisions. Bridging these two simultaneously evolving communities will take concerted effort, but with potentially high payoff.

The development of our NGCS key concepts may also contribute to the GIG's NCES. The development of components that support aggregation, automation, and adaptation might well be candidates for an extension of the current nine core enterprise services of the NCES[1]. In particular, the implementation of aggregation must employ a standard form across the participating systems to reap the desired advantages.

[1] "Global Information Grid (GIG) Enterprise Services (GIG ES) Capability Development Document," in ***Defense Acquisition Guidebook***, V1.0 Section 7.2.4.7, 17 October 2004.



Summary

The authors have assembled a summary of factors driving Navy combat systems to change. A synthesis of drivers and operational vision led to a collection of primary and secondary concepts that establish general system capabilities that can be applied across a wide variety of military systems and missions. The primary concepts of aggregation, automation, and adaptation are discussed in moderate detail and applied in "thought exercise" form to the BMD mission. While these concepts have emerged from a Navy context, they should be equally appropriate to the combat systems of the other services. Indeed, without adoption of compatible (if not identical) concepts by the developers of all joint future combat systems, the complex collaborative system behavior envisioned will not occur. Because a broad set of systems would be integrated and controlled through these combat systems, it seems highly beneficial to address these concepts with general implementations that can be universally applied.

The development of the GIG is a highly relevant effort to the evolution of combat systems and specifically, to the described concepts. While it will require time to align objectives, requirements, and communities, it would seem inevitable that the significant capabilities present in current combat systems must eventually benefit from the rich information environment that will be assembled in the GIG

Acronyms

6-DoF	Six-Degree of Freedom
AAW	Anti-Air Warfare
BMC3	Battle Management Command, Control and Communications
BMCS	Battle Management Control System
BMD	Ballistic Missile Defense
C2	Command and Control
C2BM	Command and Control/Battle Management
CS	Combat System
GBI	Ground-Based Interceptor
GIG	Global Information Grid
GWOT	Global War on Terrorism
HLS	Homeland Security
IR	Infrared
NCES	Net-Centric Enterprise Services
NGCS	Next Generation Combat System