FORCEnet Science and Technology Needs-*Draft*

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Paper for the OASD-NII Command and Control Research and Technology Symposium, 20-22 June, 2006

TD-06-008

Non Technical Data

Raytheon Company

NCS, Marlborough

ABSTRACT

The US Navy has developed a concept, FORCEnet, to take advantage of Net Centric Operations. This paper addresses issues associated with C2 Concepts and Organization, Network-Centric Metrics and C2 Analysis.

The US Navy tasked the Naval Studies Board of the National Research Council (NRC) to provide advice on the adequacy of the definition and the actions required to implement FORCEnet. The NRC published the final report in December, 2006 to the general public. The report contains eight chapters and one chapter was dedicated to science and technology issues associated with FORCEnet. This paper was derived from

that chapter. The paper presents a recommended process to identify technology gaps in operational capabilities. The FORCEnet operational capabilities that are addressed in this paper are:

- Reliable wideband mobile communications
- Information management, including common operational picture
- Situational awareness and understanding
- Information assurance
- Modeling and Simulation
- Dynamic composability and collaboration
- Support of disadvantaged user-personnel, platform, or sensor
- Persistent intelligence, surveillance and reconnaissance

Each of these capabilities is examined and broken into component operational functional parts. The paper addresses specific challenges for each of the eight FORCEnet capabilities, listed above. Technology gaps for each capability are identified and recommendations are made for continued or new Science and Technology (S&T) programs. The paper presents the S&T findings for each operational capability and then recommends specific S&T recommendations.

Introduction

The US Navy has developed a concept, FORCEnet, to take advantage of Net Centric Operations. The Chief of Naval Operations has defined FORCEnet as:

"The Operational construct and architectural framework for naval warfare in the information age that integrates warriors, sensors, networks, command and control,

platforms, and weapons into a networked, distributed, combat force that is scalable across all levels of conflict from seabed to space and sea to land".

This paper addresses issues associated with C2 Concepts and Organization, Network-Centric Metrics and C2 Analysis.

The US Navy tasked the Naval Studies Board of the National Research Council (NRC) to provide advice on the adequacy of the definition and the actions required to implement FORCEnet. The NRC published the final report to the general public in December, 2006. The report contains eight chapters and one chapter was dedicated to science and technology issues associated with FORCEnet. This paper was derived from that chapter[1]. It represents the results of over 20 meetings with government, industry and academia. It used numerous documents and referenced 11 publications. The paper presents a recommended process to identify technology gaps in FORCEnet operational capabilities. The FORCEnet operational capabilities that are addressed in this paper are:

- Reliable wideband mobile communications
- Information management, including common operational picture
- Situational awareness and understanding
- Information assurance
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Each of these capabilities is examined and broken into component operational functional parts. The paper addresses specific challenges for each of the above FORCEnet capabilities. Technology gaps for each capability are identified and recommendations are made for continued or new Science and Technology (S&T) programs. The members of the Science and Technology sub-panel were:

- Chip Elliott, BBN

[1] The figures and tables in this paper are taken from Chapter 6 of the National Research Council FORCEnet Implementation Strategy Study

- Joel Engel, Consultant, IBM Fellow
- Jude Franklin, Raytheon
- Ken Jordan, SAIC
- Otto Kessler, MITRE
- Jerry Krill, JHU APL
- Dan Siewiorek, CMU
- Mike Zyda, NPS, now USC

The Office of Naval Research formed a Network Centric Warfare Working Group and published a Net Centric Operations technology taxonomy that was used as an initial input to the present study. The ONR Network Centric Working Group technical taxonomy was addressed in earlier papers at the CCRTS (2004) and the ICCRTS (2004). The technical taxonomy can be found at the following URL http://www.onr.navy.mil/02/baa/expired/2003/03_007/default.asp

The first recommendation of the S&T study group was that the Navy must have a consistent process to determine Net Centric Operactions, NCO, Capabilities, S&T needs and associated S&T shortfalls. The process shown in Figure 1 needed to be adapted to the one shown in Figure 2. This allows for a broad vision of S&T needs with the addition of a feedback analysis that provides for NCO analysis that includes S&T improvemnets as well as evolving threat capabilities and improved US Naval tactics.

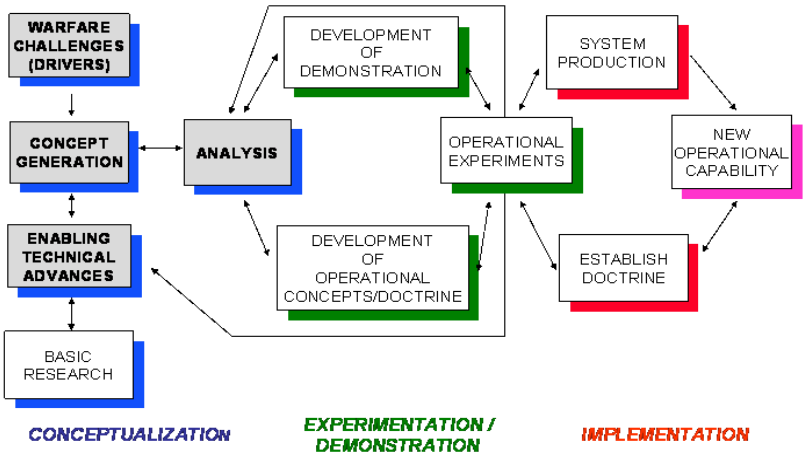

Figure 1, Notional Innovation Process. SOURCE: ADM R. J. Natter, "Sea Trial, Innovation Enabler for a Transformed Fleet" NIP, Nov 2003.

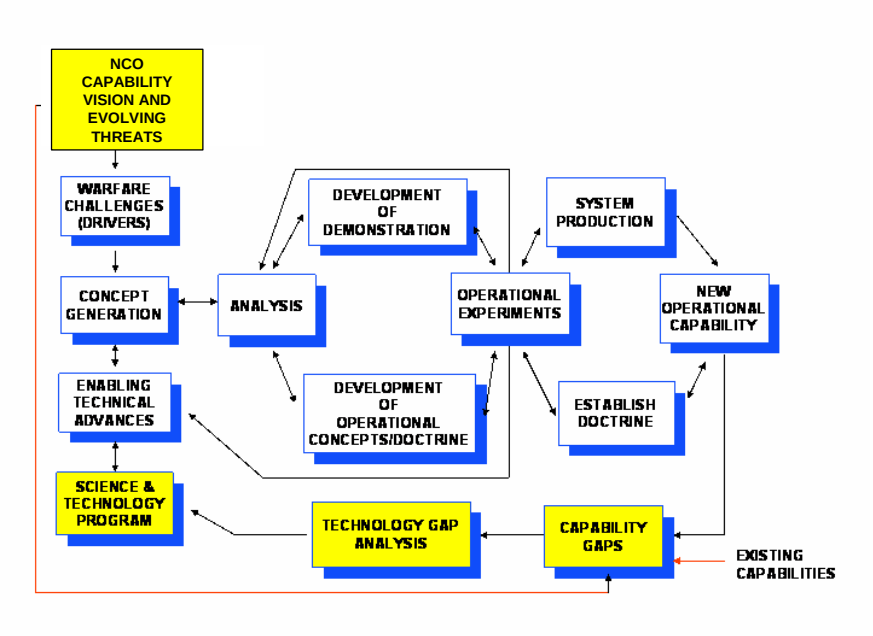

Figure 2, Recommended Augmented Process for Identifying Technology Gaps –. Adapted from: ADM R. J. Natter, "Sea Trial, Innovation Enabler for a Transformed Fleet" NIP, Nov 2003. From NRC FORCEnet Implementation Strategy, National Academies Press, Washington, DC, 2005

1) RELIABLE WIDEBAND MOBILE COMMUNICATIONS

The Navy has severe operational limitations for high bandwidth, mobile, continuous communications. An example is shown in Figure 3

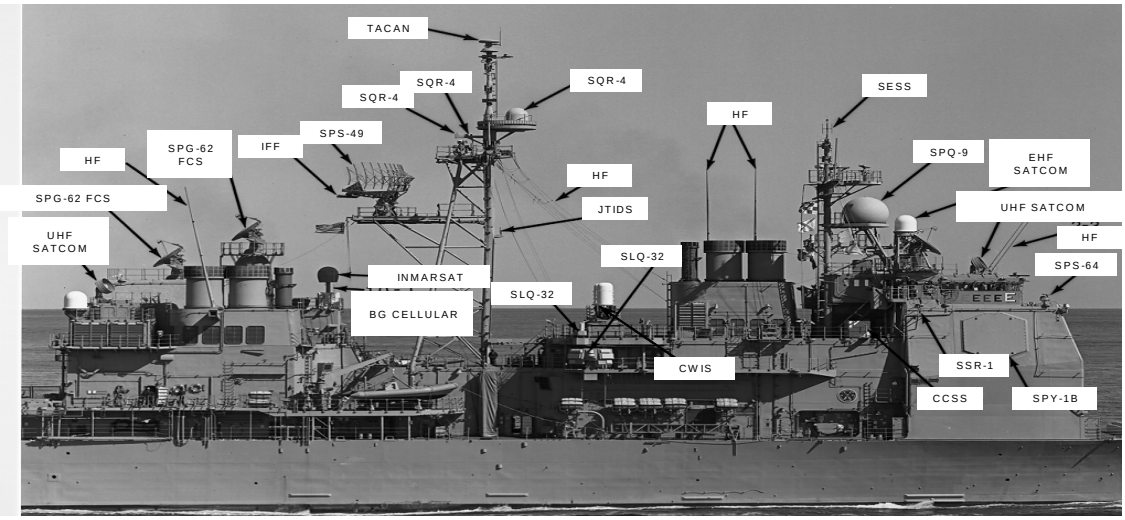

Figure 3, Antennas resident on a U.S. Navy cruiser, circa 1996. SOURCE: TCA Overview Briefing.

Findings for Reliable Wideband Mobile Communications[2]

Currently available technology is not sufficient to support the robust communications infrastructure needed for the long term Net Centric Operations (NCO) vision**.**

a. More capability is needed in the link and antenna area to provide increased data rates and beam agility.

[2] All of these and subsequent findings and recommendations are taken from the National Academies NRC FORCEnet Implementation Strategy, December, 2005

b. The present capability for QoS and network monitoring, control, and reconfiguration is not adequate for needed availability and reduced latency
c. Present protocols, in use today, are inadequate for FORCEnet mobility, disruption, and IA.

Recommendations for Reliable Wideband Mobile Communications

The following actions should be addressed:

(1) Conduct S&T investigating the applicability of optical frequencies for high data rate communications from satellite or airborne platforms to surface ships.

(2) Conduct S&T with the objective of providing automated monitoring and control for FORCEnet links and networks

(3) Conduct an effort to explore the solution space for network approaches for FORCEnet mobility, disruption, and security using M&S and experimental approaches. Consider applications, such as the Littoral Combat Ship, as points of departure for this effort.

2 Information Management

Information Management, IM involves the distribution, processing and priority for information as driven by the criticality of the operational situation**.** The contributing technology applications include:

Sensor processing / Data fusion
Information

Data / Information dissemination

User defined needs

Sensor management

IM FORCEnet Implications- Findings and Recommendationsmooo

Findings -Key Challenges- Information Management

- Ontology consistency across Communities of Interest
- Information services to enable management of information content/quality
- Automated sensor resource management, coupled to dynamic tactical needs and military operational needs
- Distributed, multi-source real time level 1 data fusion
- User defined visualization
- Appropriate degree of automation
- Enterprise monitoring

Recommendations- Information Management

- Conduct S&T to support distributed real time processing, heterogeneous fusion and automated resource allocation driven by current operational situation understanding. To enable a FORCEnet capability within the GIG paradigm, this S&T must support the development of an ontology framework and information services that assure consistent processes across the enterprise.

3) Situation Awareness and Understanding

Technologies, that are critical include, inference engines, knowledge management (knowledge bases, sources, acquisition, authoring, and validation tools), probabilistic and uncertainty representation, large scale relational and control frameworks, human-machine, human-human, and machine to machine collaboration, interactive hypothesis management) and cognitive modeling. Situation awareness and understanding must address automated consistent understanding of situations, automated consistent

understanding of adversary intent and threats, adversary intent analysis, anticipation of possible battlespace futures, data mining, information discovery, automatic (or aided) target recognition, activity pattern recognition and dynamic "what if" analysis

Findings for Situation Awareness and Understanding –

Major challenges remain in the technologies needed to achieve the following:

- Contextual reasoning that deal with scale and uncertainty of battlespace problems
- Knowledge bases and tools for diverse battlespace expertise
- Visualization and cognitive interfaces
- Interactive human-machine hypothesis management

Recommendations for Situation Awareness and Understanding

Conduct R&D in the following areas to support automated situation awareness

- Improved inferencing techniques for relating objects and events to their environment and to units, activities, and behaviors
- Development of a relational and control framework to handle a broad range of knowledge representations, hypotheses, assertions, etc.
- Development of automated techniques for information capture, representation , authoring and validation
- Integration of human and machine capability to accommodate hypothesis management to deal with numerical scale problems and human intuition

4) Information Assurance, IA

Overview

Information Assurance involves the availability, reliability, security, and trustworthiness information. Communications/Network Core. Metrics for security and trustworthiness have to be developed

Findings for Information Assurance

- Metrics and automated network analysis/monitoring are not capable of scaling to net centric operations

- Collaboration exacerbates Information Assurance with regard to multiple independent levels of security, coalition operations and trusted information exchange
- Trustworthiness of software systems and associated information is inadequate
- Intrusion detection and insider threats are major limitations

Recommendations for Information Assurance

- Conduct research and development to identify improved metrics and to develop automated real time net centric systems analysis to identify and predict information systems failures
- Develop approaches to deal with real time IA
- Conduct S&T to develop improved techniques to achieve multiple levels of information security

5) Modeling and Simulation, M&S

M&S is a critical area to support Net Centric Operations. It affects the architecture, systems engineering, and technology evolution. The M&S capability must be able to scale to realistic Net Centric Operations.

Findings for M&S

No means to checkout large scale systems prior to deployment
No robust" what If " Analysis
Trustworthiness of results of M&S for NCO systems is inadequate

Recommendations for M&S

- Coordinate R&D for M&S to support large scale systems engineering with the appropriate parts of the Defense Department, Industry, Academia and the Commercial Sector

- Conduct S&T for adversarial analysis M&S. ONR also must coordinate this work with the other relevant research and development, such as the Air Force Predictive Battlespace Awareness Program.

6) Composability/Collaboration

A major component for FORCEnet operational success is the ability to "compose" capabilities from components of the enterprise, to provide robust warfighting capability in response to the changing operational conditions. See Figures 4 and 5.

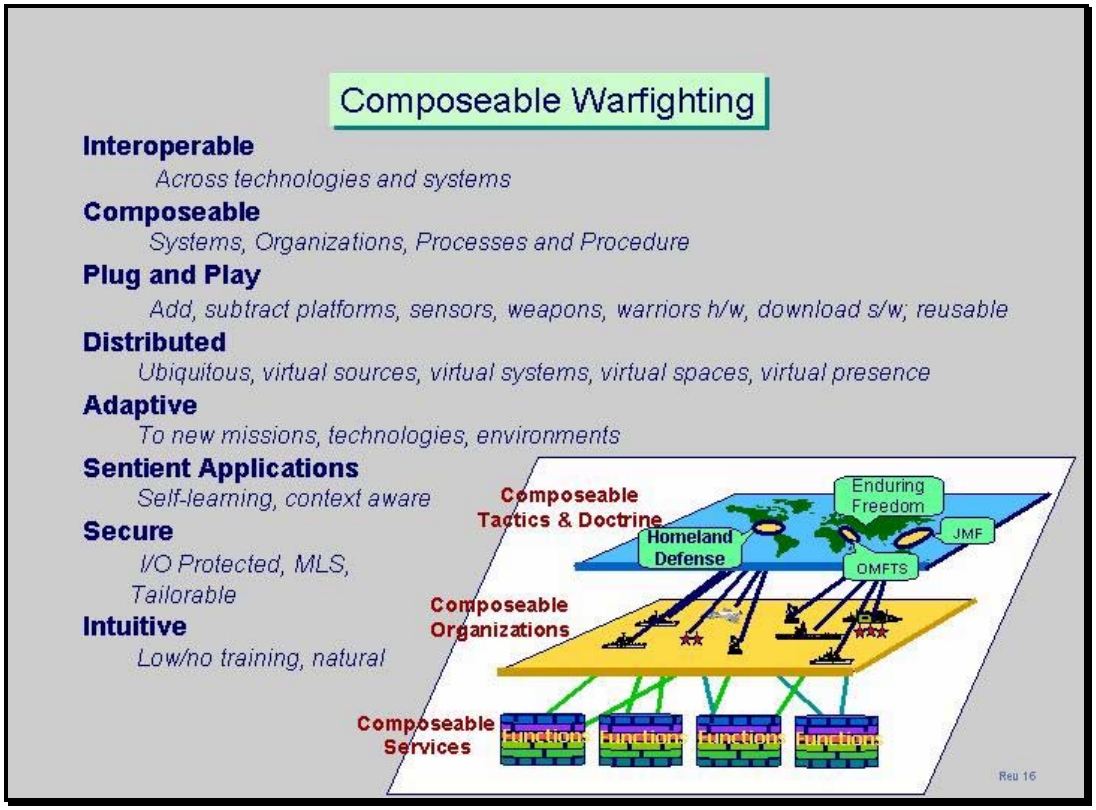

Figure 4, FORCEnet Support of Dynamic Force Composition. SOURCE: GRA, 4/03.

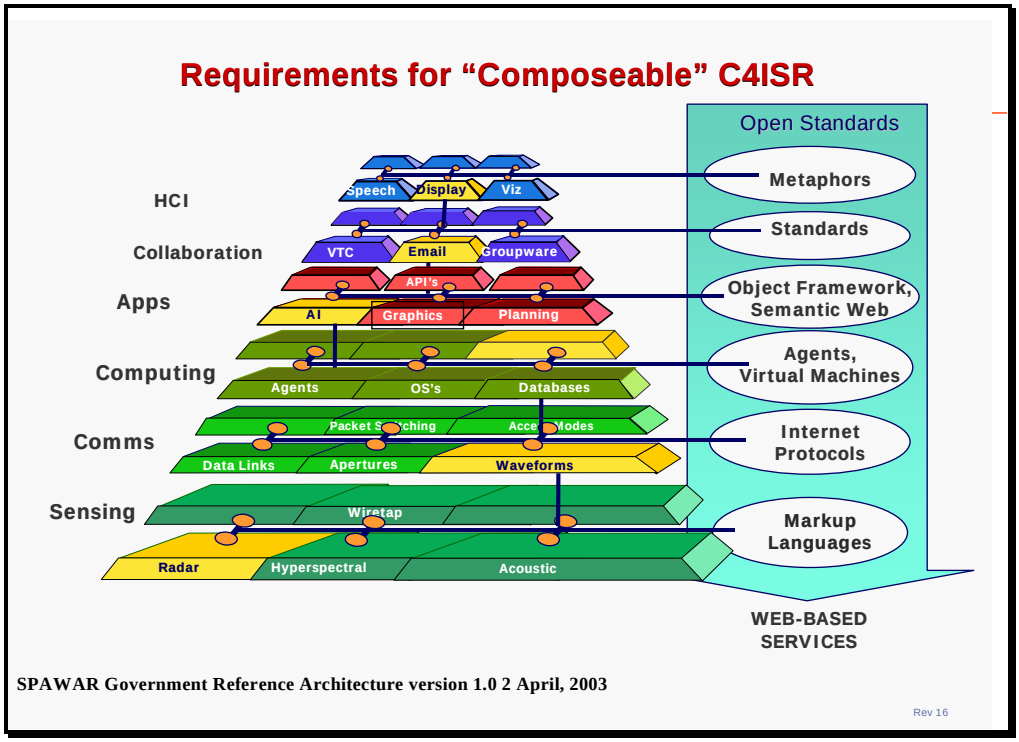

Figure 5 FORCEnet Dynamic Composition of Mission Capability. SOURCE: from GRA, 4/03.

Findings – Composability/ Collaboration

Achieving FORCEnet capability for mission composability while properly understanding the implications for campaign level control, will be a difficult challenge.

- Very little work has been done to address the complexity of managing mission composability in a way that assures integrated, dynamic mission goals will achieve desired campaign outcomes.
- Real-time feedback to decision makers about the state of enterprise readiness will be needed. A 'readiness' monitor that confirms the state of the enterprise (core plus COIs, across all enterprise layers) in any given configuration, for all users, will be needed.
- Manpower and training issues relevant to composed functionality have not been addressed.
- Present tools do not support automated means to facilitate collaboration between people and/or machines

Recommendations – Composability/Collaboration

- Conduct S&T investment to solve complex resource management (allocation and coordination) issues
- Implement a long term co-evolutionary process, that involves laboratory and field experiments and real time resource management, to evolve the required technical composition with naval tactics, procedures and personnel.
- Conduct S&T to develop automated collaboration tools to facilitate interactions and problem solving between humans, between machines and between humans and machines. The S&T must also address issues associated with the variable reliability of the Naval communications.

7)Disadvantaged User

This area includes dismounted troops, small platforms and distributed sensors. Key issues involve limited communications, processing power, power sources and associated weight/space problems

Findings for Disadvantaged Users

- The Human Machine Interface (HMI) is a crucial area for further research. Today's hand held displays are difficult to read and are distracting, head gear is bulky and inefficient. Information must be custom tuned to the user.
- There are issues with the size and weight of apertures for the disadvantaged users.
- Power sources are too heavy and bulky

Recommendations for Disadvantaged Users

- Conduct S&T Research to provide the minimum essential situation awareness for dismounted troops in a way that is least distracting
- Coordinate S&T with DARPA and the Army to provide light weight, high density power sources and improvements in power consumption

8) Persistent ISR

Persistent ISR is an extension of situation awareness and understanding. It includes dynamic composeability, sensor management, information management, resource allocation, adaptive control, distributed autonomous sensors, automated and persistent coverage in changing environmental conditions, automated C2, dynamic planning, and automated processing

Findings – Persistent ISR

- The role of ISR in net-centric operations will require new automation for adaptive sensor control, coordinated usage of multiple sensors, and more robust sensing modalities.
- With the likely proliferation of small sensors for wide area coverage of difficult areas, automation will be needed to drastically reduce manpower requirements.
- Need for small networked sensors to accommodate wide area surveillance in dangerous and remote sites

Recommendations – Persistent ISR

Initiate R&D investment in the following areas:

- Netted sensor technology for wide area alerting of asymmetric targets/activity;
- Automated sensor management to adjudicate sensing needs across mission goals, and for sensing responsiveness to dynamic battlespace needs;
- Machine to machine collaboration for remote operations

FINDINGS AND RECOMMENDATIONS

Science and Technology Findings

1) Currently available technology is not sufficient to support robust communications infrastructure needed for the long term Net Centric Operations (NCO) vision

- There are lots of problems with communications to underwater vehicles.
- There is a need for shared, robust, reliable, multi-beam apertures satellite relay alternatives, communications on the move and adaptive networks
- Reliable high speed communications, including optical, in the marine layer are needed
- Disadvantaged user and platforms/sensors have issues with antenna apertures

2) Insufficient effort is directed at understanding the information management issues (accessing, processing, dissemination, presentation) in Net Centric Operations.

- Additional S&T is needed to assure integrity of information and associated processes across the enterprise
- New methods are required for reliable, accurate distributed fusion and visualization of heterogeneous sensors and sources.
- There is a need for S&T directed at design of an 'enterprise monitor and control' to give the user feedback concerning performance, expected information latency, flow and quality

3) Automated situation awareness and threat understanding are not available

- Issues include robust inference methods, knowledge basses, and cognitive interfaces

4)) Composability and Collaboration

- The state of technology to support disadvantaged users (small boats, dismounted marines, etc.) is deficient
- Today's technology does not support dynamic composability on the fly
- There is a need to address automated resource allocation, plug and play, autonomous teams, automated collaboration, as well as planning and replanning Contributing technologies such as collaboration, autonomous agent technologies, and intelligent resource management are not understood in terms of performance or scaling, for Net Centric Operations

5) Information assurance S&T is inadequate to support the FORCEnet vision

- No accurate means to assess the reliability and security of the network and its information

- No means for addressing the balance between information protection and information sharing

6) The present state of modeling and simulation does not scale to FORCEnet

- Major issues with scaling to large numbers of sensors, platforms and users
- Systems engineering for Net Centric Operations demands modeling and simulations to support life cycle design, test and validations
- Need What If? Analysis

7) Disadvantaged User

- Human Machine Interface require custom information tuned by the current operational needs
- Displays, power sources and antenna apertures are too bulky and weigh too much

8) Persistent ISR

- NCO demands will require automated adaptive sensor control, coordinated usage of multiple sensors and more robust sensing modalities
- The increased number of sensors to achieve NCO will mandate automated sensor management

S&T Recommendations

1)Reliable Wideband Moile Communications

- Shared multi-beam apertures
- Satellite relay alternatives
- Automated monitoring and control for FORCEnet links and networks
- Optical communications in the marine layer

2) Information management

- Distributed real time information processing, heterogeneous fusion and automated resource allocation for automated representation of operational activities and events.
- Automated collaboration across sensors, platforms and users

3) Situation awareness and understanding/persistent ISR

- Improved inferencing techniques to relate objects and events to their environment, and to units, activities and behaviors
- Development of a relational and control framework for managing a broad range of knowledge bases, representations, hypotheses and assertions
- Automated techniques for information capture, representation, authoring and validation
- Integration of human and machine capability for hypothesis management

4) Composability and Collaboration

- Automated means to facilitate teams of sensors, weapons, autonomous intelligent systems, and personnel to work togethre to solve complex NCO problems
- Automated systems to support dynamic composability on the fly as the operational scenario unfolds

5) M&S capability to support:

- NCO operations research analysis and M&S to support large scale life cycle systems engineering
- Adversarial planning and what if analysis
- Automated M&S to support performance assessment and monitoring of large scale net centric systems operations and status

6) Disadvantaged User

- Attention should be given to technologies applicable to the disadvantaged userb to include HMI, intelligent automation and power consumption/generation
- Minimal essential situation awareness in a manner that is the least distracting

7) Information Assurance

- Improved metrics and automated real time net centric systems analysis to identify and predict information systems failures
- Improved techniques to achieve multiple levels of information security for joint and coalition environments

Summary

This paper has discussed the S&T implications of achieving FORCEnet. A process was descired that will facilitate the identification of FORCEnet S&T gaps and critical FORCEnet operational capabilities were discussed. Findings were identified for each FORCEnet operational capability and subsequent S&T recommendations were made.

References

Franklin, Jude E, “Science and Technology Implications for Net Centric Operations”, CCRTS, June, 2004

Franklin, Jude E, “Science and Technology Implications for Net Centric Operations”, ICCRTS, September, 2004

National Research Council, “FORCEnet Implementation Strategy” National Academies Press, Washington, DC, December, 2005