NRAC
NAVAL RESEARCH ADVISORY COMMITTEE

Naval Research Advisory Committee Report

Lightening the Information Load

Leveraging Information Technology to Enhance the Marine

"Critical Information in Context"

October 2012

This report is a product of the Naval Research Advisory Committee (NRAC) Panel on *Lightening the Information Load* for the U.S. Marine Corps. The opinions, recommendations, and/or conclusions contained in this report are those of the NRAC Panel and do not necessarily represent the official position of the Department of the Navy, or the Department of Defense.

Table of Contents

Executive Summary

The Naval Research Advisory Committee was asked to study the apparent increasing demand on Marine Corps operating forces from a multiplicity of sensors and communication systems, and to assess whether this "information load" might be reduced. The results might be subtitled "leveraging technology to enhance human cognition," or "leveraging the human brain to make best use of technology." There are a number of major themes from the Panels fact-finding and analysis done that should help to guide the Marine Corps as they view their future Information Technology needs:

- Exponential IT and sensor growth can enable greater Marine effectiveness,
- Humans are better than computers at pattern recognition and decisions in high ambiguity environments,
- Computers are better than humans at filtering "big data" and tracking details,
- Future end-user devices can provide real-time critical information in context to the individual Marine,
- IT systems can supply critical information in context, even with rapid situation changes and intelligent adversaries,
- User-centered design is difficult, but essential,
- Horizontal IT – cloud-architectures – and powerful end-user devices are key to supplying information in context, and,
- Designing for information in context requires an information architecture and agile application (i.e., apps) acquisition, which DoD 5000 policy can support.

The Panel developed a number of recommendations across specific areas.

- An "information architecture" should be developed to guide investments which build on the existing Marine Air Ground Task

Force Command and Control (MAGTF C2) Information Exchange Requirements (IERs). It should include an iterative process that establishes requirements for critical information in context – accounting for new sensors, communications links, as well new tactical, and organizational constructs.

- The Marine Corps should embrace concept-based experimentation when developing an information architecture through the integration of modeling and simulation, technology war-gaming, intelligence analysis, and field experimentation with a tight user-centered design process.
- A small group of Marines should be tasked to keep abreast of commercially available IT platforms – especially those featuring user-centered design – whose attributes can optimize human cognition. Also, the Office of Naval Research (ONR) disciplines of Information Technology and Human Cognition should be more closely integrated for Marine IT developments.
- Marine Corps procurement personnel should take advantage of DoD 5000 agile acquisition options when buying low cost, fungible IT assets and should write contracts that support rapid, continuous capability improvements.
- The Marine Corps should consider establishing a cadre of trained Information Management Officers at multiple levels of command – to ensure future IT developments and expeditionary operations are optimized for MAGTF information management.

Panel Membership

Dr. Mark Bregman
Chair
CTO, Neustar

RADM John Tozzi, USCG (Ret)
Co-Chair
Independent Consultant

MajGen R. D. "Tex" Alles, USMC (Ret)
Deputy Assistant Commissioner
US Customs & Border Protection

Dr. Michael Bruno
Dean of Engineering and Science
Stevens Institute of Technology

Dr. Mary "Missy" Cummings
MIT Associate Professor
Department of Aeronautics & Astronautics
Director, Humans and Automation Lab

Dr. Marv Langston
Former DoD Deputy CIO

RADM William Miller, USN (Ret)
Academic Dean and Provost, Emeritus
U.S. Naval Academy

Mr. William Schmitt
Retired SES, Naval Reactors/SEA 08

Dr. Frank Shoup
Retired Navy SES

Dr. Joseph Walsh
Professor and VP for Research
Northwestern University

Executive Secretary

Capt John Pico, USMC
Capabilities Officer, Tactical Radios
MCCDC/CD&I, C2ID

The NRAC Panel was composed of individuals with wide-ranging knowledge and experience in the military, government, industry, and academic domains, which helped frame the questions and issues that were addressed on behalf of the Marine Corps. In many cases, individual Panel member experience was spread across multiple experience domains.

Captain John Pico, USMC of the Marine Corps Combat Development Command (MCCDC) served as the Executive Secretary.

Panel biographies are in Appendix A.

Terms of Reference (TOR)

- **Objective:**

  Assess the *information requirements at all echelons* in modern-day battlespace, evaluate the current level of effectiveness and efficiency being attained, and *recommend technological directions* for optimizing the delivery and assimilation of available *information to/from the warfighter*. While emphasis will be placed squarely on the Marine in the battlespace, the essential connection of Marine Corps fighting elements to supporting Naval forces afloat and in the air will be addressed as well.

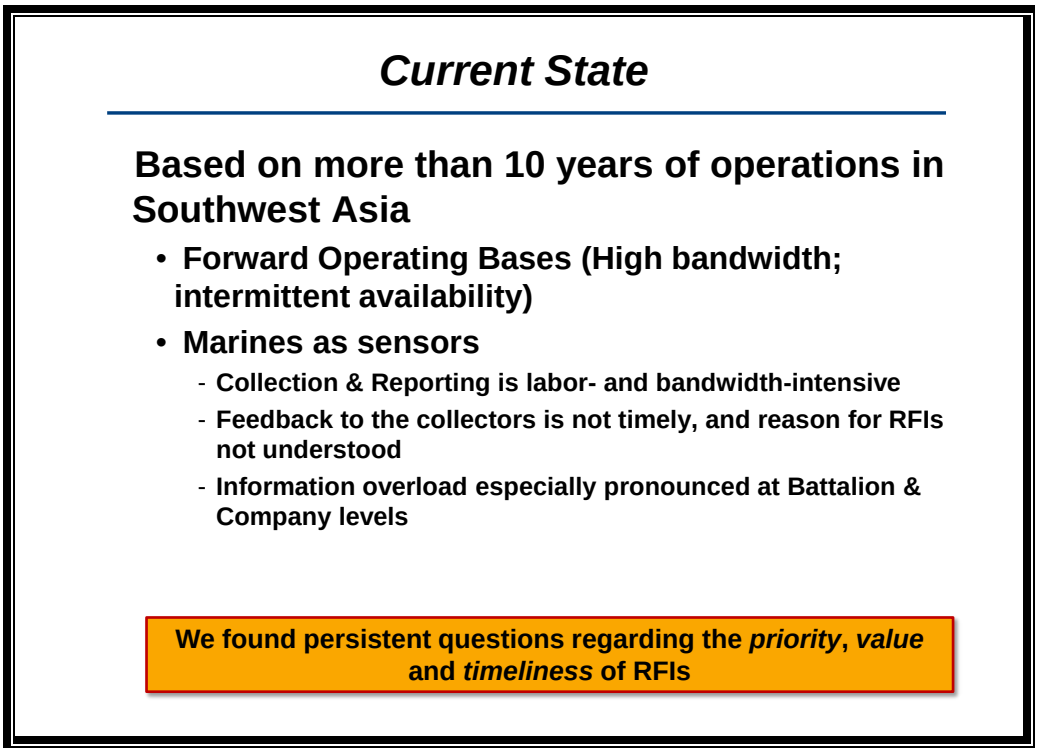
- **Specific Taskings:**
  - ***Frame the information requirements of each echelon* in the battlespace, and establish the shortfalls in availability, access, and presentation of essential information at all levels.**
  - **Review any relevant human factors studies related to the ease of assimilation (by the human intellect) of information provided through technology available today and projected into the future.**
  - ***Identify and evaluate Naval S&T initiatives* as well as the direction *of commercial development* in guided information search/discovery/filtering that are being or could be pursued to optimize the information form and flow to the warfighter. Consideration must be given to speed of delivery and ease of assimilation, including the flexibility and adaptability of information presentation to suit a variety of individual recipients.**
  - **Finally, *recommend the direction of S&T* to support the needs of *future warfighters* as they engage more diverse forces than ever before imagined in the air, on the ground, at sea, and in cyberspace.**

The Terms of Reference (TOR) for the study were derived from discussions with LtGen Richard Mills (Commander, MCCDC) and his staff. He expressed concern that Marines in the field might be experiencing "information overload", especially with the explosion of new sensors and communication links that have characterized the last ten years of conflict in Southwest Asia. The NRAC panel was asked to look at the information requirements at all echelons of the Marine Corps, with particular emphasis on the squad and below. He was especially concerned that the Marine rifleman might become distracted by the potential flood of information coming to him, to the detriment of his primary responsibility within his squad. The Panel was also asked to look at the state of knowledge in human factors research that might provide some insights into how information could be more effectively presented at the various command echelons to enhance information assimilation. Also, the Panel was encouraged to view both Naval and commercial technology developments that might support current and future warfighter information needs.

The complete study Terms of Reference are in Appendix B.

The Panel met with individuals from various Marine Corps staff elements, other Department of Defense entities, for-profit companies, and academic institutions. Especially valuable to the Panel were meetings held at the Marine Corps Base Camp Pendleton with Marines who had recently returned from combat duty in Afghanistan. At Camp Pendleton, the Panel spoke with all levels of command – from the division commander down to individual rifle squad leaders. As will be elaborated later in this report, the insights provided from commercial companies were especially helpful in illuminating current trends and future possibilities for providing clear, useful, and timely information to the warfighter.

A complete listing of the individuals who briefed or met with the Panel is in Appendix C.

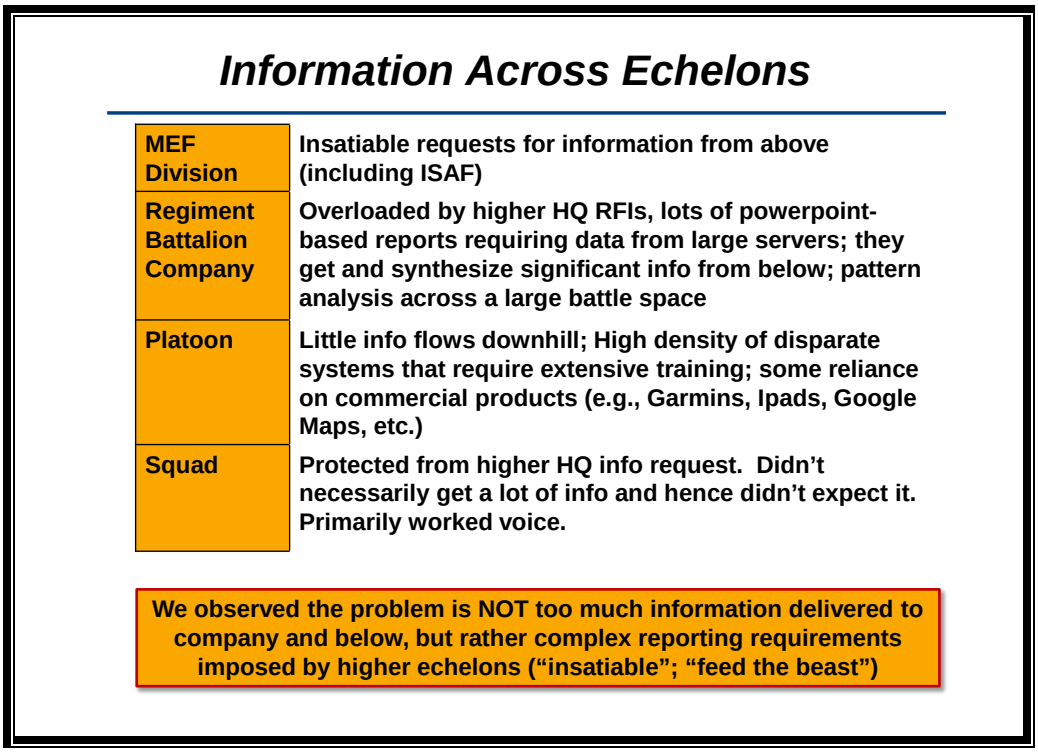


As an expeditionary force, the U.S. Marine Corps has traditionally capitalized on speed and maneuverability from the sea to gain access. As a key component of Single Naval Battle, "the Marine Corps provides the ability to extend naval operations into the landward portion of the littorals, engaging forward to build relationships, while remaining capable of responding to crisis, projecting power, and creating access." (*Ship-to-Objective Maneuver*, Marine Corps Combat Development Command, 2011).

In comparison to the Ship-to-Objective Maneuver (STOM) doctrine, the Marine Corps experience in the wars in Southwest Asia has been unique. Most notably, Marine forces have operated primarily out of stationary Forward Operating Bases. This situation has afforded opportunities to create a large supporting infrastructure – including high bandwidth communications and data fusion and analysis centers – that significantly enhance Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capabilities. The downside of this situation is the enormous volume of data that can be collected. Much of this information gathering is coordinated by the Company-level Intelligence Cells (CLICs) that work with Platoon leaders to

ensure that Squads gather the required information, and to share information as required. The CLICSs then aggregate the information and send it up to the Battalion staff, where additional information aggregation and analysis is performed.

This process of data-to-information-to-situational awareness is clearly a critical component of success in the field. But it carries with it several, perhaps unforeseen, “penalties”. Chief among these penalties is the burden placed on the collectors – the Marines in the field – and the aggregators – at the Company and Battalion levels. The collectors, in fact, rarely if ever are provided the reasons for Requests for Information (RFIs), and they do not see a significant “return on investment” in the form of information flow back to them from the analysts. The aggregators at the Company and Battalion levels, on the other hand, are apparently overwhelmed with both the volume of incoming data, and the volume of RFIs from the upper echelons.



"…90% of the information requested was already in the system, but the person asking didn't know where to look or how to extract it." (As quoted by a Marine officer who had recently returned from duty in Afghanistan.)

The current "information overload" exists not at the Platoon or Squad levels (although these are the levels where information gathering can sometimes be a burden), but primarily at the Company and Battalion levels where RFIs are directed from higher headquarters. It is the Panel's perception that these "insatiable" RFIs originate not only from U.S. headquarters, but also from the NATO International Security Assistance Force (ISAF) headquarters. The Panel was not able to determine the exact source or reason for this situation. What is certain, however, is that large streams of data come into the aggregation and analysis centers at the Company, Battalion, and Regiment levels, and this information requires significant effort before it is synthesized into the requisite format (typically Powerpoint) for delivery to higher authority.

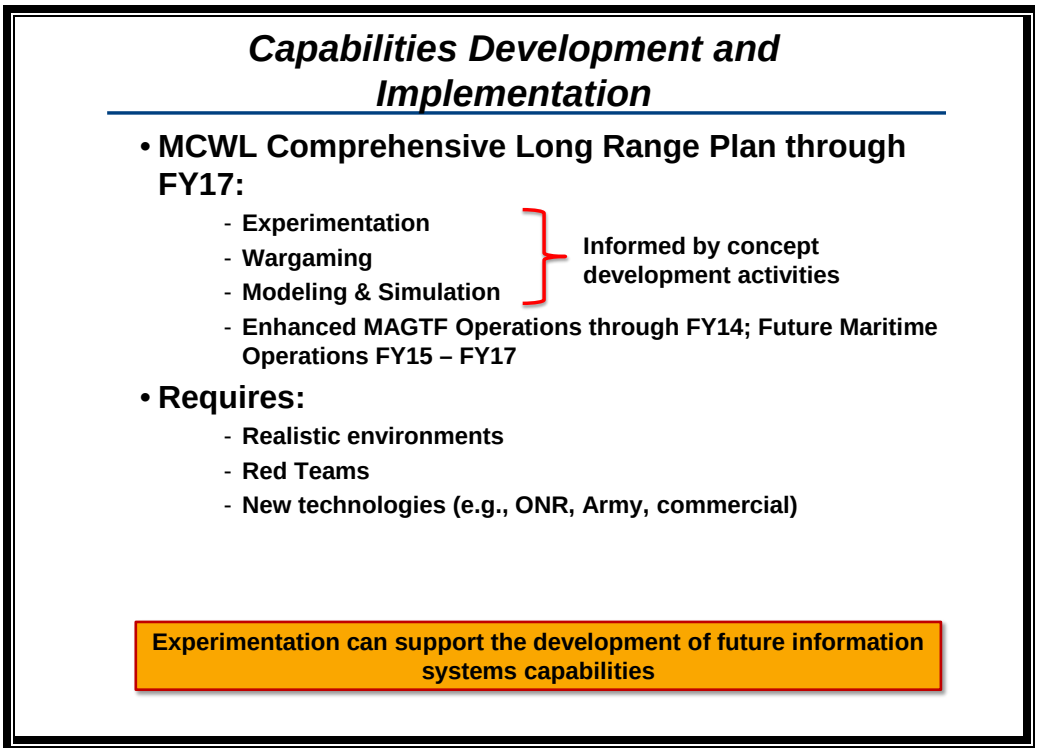
In discussions with the Marines who recently returned from Afghanistan, the Panel perceived that Company-level leadership does its best to “shield” the Marines in the field from an excessive level of RFIs. At the same time, the Marines in the field did not receive an excessive amount of information from analysts at the Company level and above. Although the absence of “information overload” at the Squad level was deemed a positive finding, the Panel is concerned that there is also no evidence that suggests that the Marines in the field are benefiting greatly from high value information from the analysts at the Company level and above. We did see evidence of slow delivery (i.e., a high amount of latency) for such information when it is requested from the Marines in the field.

Current State Observations

- **Specific issues with reporting requirements:**
  - **Unstructured data formats (PowerPoint, email, …)**
  - **Reporting system requirements & procedures were developed with little input from tactical units**
  - **Inconsistent network architectures (SIPRNET, CENTRIX, email)**
  - **Equipment is NOT a system, and is expensive to support**
- **Other observations**
  - **Information Management Officers (IMOs) not well prepared**
  - **Information Exchange Requirements (IER) good but not sufficient**
  - **Little significant involvement of lower echelon Marines in the development cycle**
  - ***Information Systems Architecture* has been focus but not *Information Architecture***

The Panel heard numerous complaints regarding not only excessive RFIs, but also the required format for the information. At the Company and Battalion levels in particular, great effort is expended in preparing PowerPoint files for delivery to higher headquarters. There is little evidence that Marines at the Platoon or Squad level have ever been involved in the determination of the type and quantity of data collected in the field, and in the information that is developed as a result of this data collection. From the perspective of personnel, the Panel found that Marine Corps Information Management Officers (IMOs) are not provided with a structured training course prior to deployment. It is an assigned collateral duty that is "learned on the job". From the perspective of equipment, the Panel found that the existing communications and information processing equipment is not designed and delivered to operating Marines as a coherent, comprehensive system. Rather, it is a collection of sometimes disparate and disconnected components, often augmented with personal (or donated) commercial products such as iPhones, Garmin GPS navigation devices, and iPads.

A reliable and robust information gathering and decision-support system cannot exist without the capacity to access, verify (i.e., quality assurance/quality control), and combine data and data products across multiple information types and sources. Users must be able to search for and retrieve the data they need, ingest these data into their analysis or visualization software and decision-support tools, and understand the source, quality, applicability and limitations of the data. In practice, this generally translates into a set of recommended or required standards and protocols. It is imperative that Information Architecture developmental efforts include the users of the system, in this case, the Marines in the field. The term information architecture will be discussed later in the report.



The Marine Corps Warfighting Laboratory (MCWL) currently has a comprehensive long-range plan for a parallel series of experiments, wargames, and modeling and simulation that support Enhanced MAGTF Operations through FY14, and Future Maritime Operations through FY17. These activities are informed by ongoing concept development activities such as those conducted by the Ellis Group (formerly the Amphibious Capabilities Working Group). The activities also allow for the inclusion of new technologies developed, e.g., by ONR and other services, as well as the commercial sector.

It is the Panel's view that MCWL should capitalize on these activities to support the development of future information systems capabilities. In order to be effective in this regard, the activities must include Red Teaming and should be conducted in realistic environments.

S&T Investment

- **ONR IT investment strategy generally well conceived to leverage much larger commercial and Army IT initiatives**
- **ONR funding excellent work in human-machine integration**
- **ONR IT investments and human factors investments insufficiently coordinated to achieve the appropriate user-centered design**

The ONR S&T investment strategy for information systems technology development is well constructed to emphasize long-range development of future capabilities. The plan includes capturing and adapting commercial advances as well as leveraging the work of the Army NETT Warrior (formerly known as the Ground Soldier System) initiative.

But, Marine Corps strategy and operating concepts (e.g., littoral maneuver warfare) must involve special considerations and constraints for information delivery to the "Marine on the move", which are unlikely to evolve from commercial or Army doctrine concepts. Adaptation will have to consider these "Marine-unique" mandates. Marines are in the best position to inform the S&T associated with these specialized information system attributes. Their input becomes critical to information architecture development, and applications (i.e., "apps") formulation and deployment.

While ONR S&T investment within Code 34 is actively pursuing broad efforts in human cognition and human-centered interface development, there does

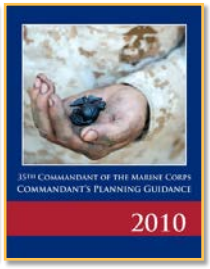
not appear to be sufficient coordination between that investment and ONR Code 31 S&T efforts in the development and optimization of Information Technology systems – particularly for Marine-unique considerations.

The Future Environment

Force Implications for 2025

"To remain the Nation's force in readiness, the Marine Corps must continuously innovate. This requires that we look across the entire institution and identify areas that need improvement and effect positive change."

-Marine Corps Vision and Strategy 2025
-Commandant's Planning Guidance 2010



The Panel drew upon two Marine Corps documents to develop insight into the way Marines view their future environment: *Marine Corps Vision and Strategy 2025* and the *Commandant's Planning Guidance 2010*. Two points were clear:

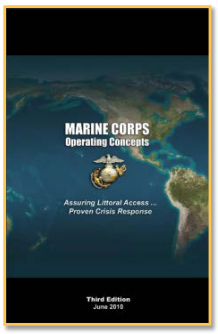
- We need to focus on the future … out to 2025, and
- The Marine Corps must continuously innovate.

It is very clear that Marine Corps lessons learned in Iraq and Afghanistan do not address the complete spectrum of missions or capabilities necessary to enable the entire range of future Marine Corps operations. It is also clear that the application of new technologies and new concept development – paced by future Information Systems requirements – will require continuous innovation.

21st Century Marine Corps

Marine Corps Operating Concepts: Third Edition

- **USMC Core Missions**
  - **Military Engagement**
  - **Crisis Response**
  - **Power Projection**
  - **Small wars**
- **USMC Operating Concepts**
  - **Mission Command and Enhanced MAGTF Ops**
  - **USMC flexibility and effectiveness across the ROMO**



The following appears in the forward of *Marine Corps Operating Concepts: Third Edition* (2010) "Military excellence is defined by the excellence of our Marines; their thinking, ability to *innovate, adapt*, and to overcome the challenges presented by complex environments, threats, and conditions."

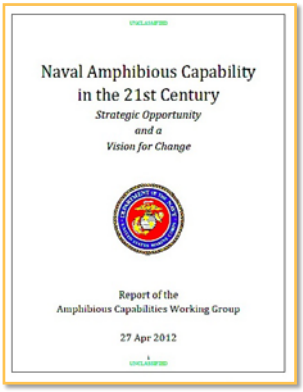
New threats and missions, that cannot be known today, will require the agile adoption of technologies – making the culture of <u>continuous innovation</u> in the Marine Corps more than a goal – but a requirement. The Panel's contribution will be to suggest ways in which the integration of emerging information technologies with operational concepts can be a part of this culture of innovation.

Single Naval Battle

- **Marines at the edge**
  - **High value complex tasks**
  - **Decision making with high ambiguity**
- **Integration with the Navy will be key**
- **Applications on mobile devices will be the primary interface between the information and the Marine**

Designed :

- **To support critical information in context**
- **To support expeditionary operations with intermittent connectivity**
- **To minimize information/bits transported**
- **For human cognition**

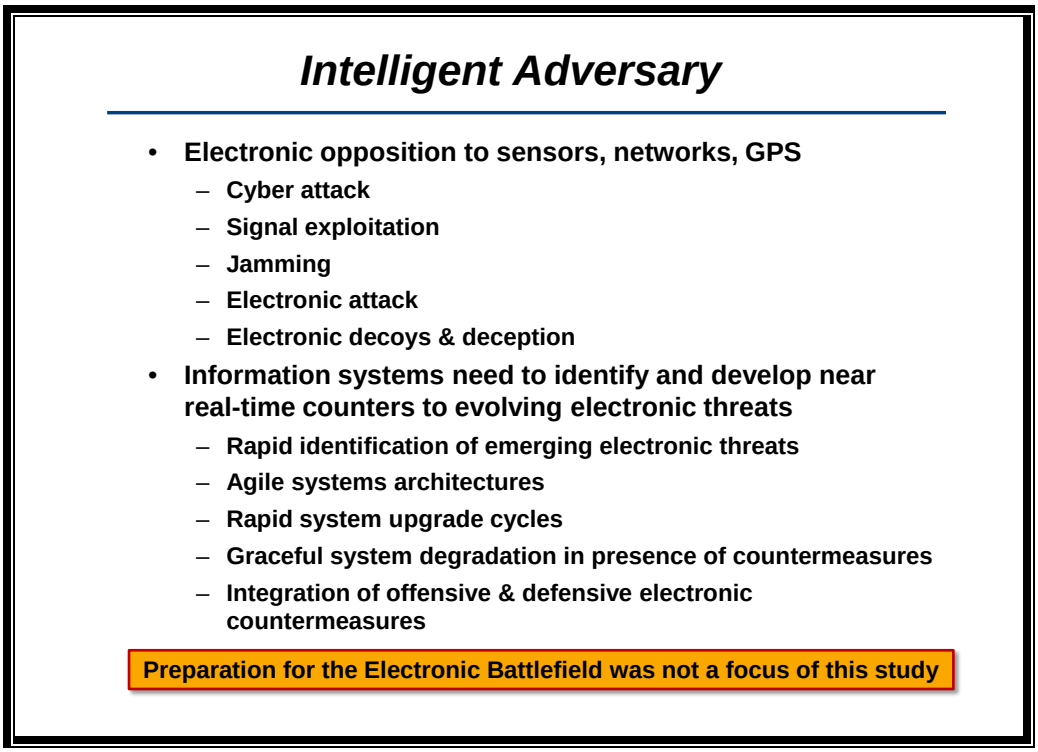


Design information systems to support the forward Marine

The "Single Naval Battle" concept discussed in the 2012 report from the Amphibious Capabilities Working Group (renamed the Ellis Group) provides an important framework for the Panel's analysis. The implication for Marine information systems is to provide Marines ashore with mission-tailored information supporting complex operations in sometimes-ambiguous situations. An essential component of this concept is the "Naval cloud" – the Naval version of the cloud (or so-called "horizontal") architecture, an emerging technology with significant commercial applications today.

The flexibility and scalability offered by cloud technology, mobile devices, and their associated applications are significant. The design will need to support critical information in context to Marines "on the edge". This will enable implementation of the Single Naval Battle concept and support MAGTF Command Elements on the move with limited or intermittent connectivity. This will require the capability to minimize the information that needs to be transported – while optimizing human cognition. Marines must be able to receive

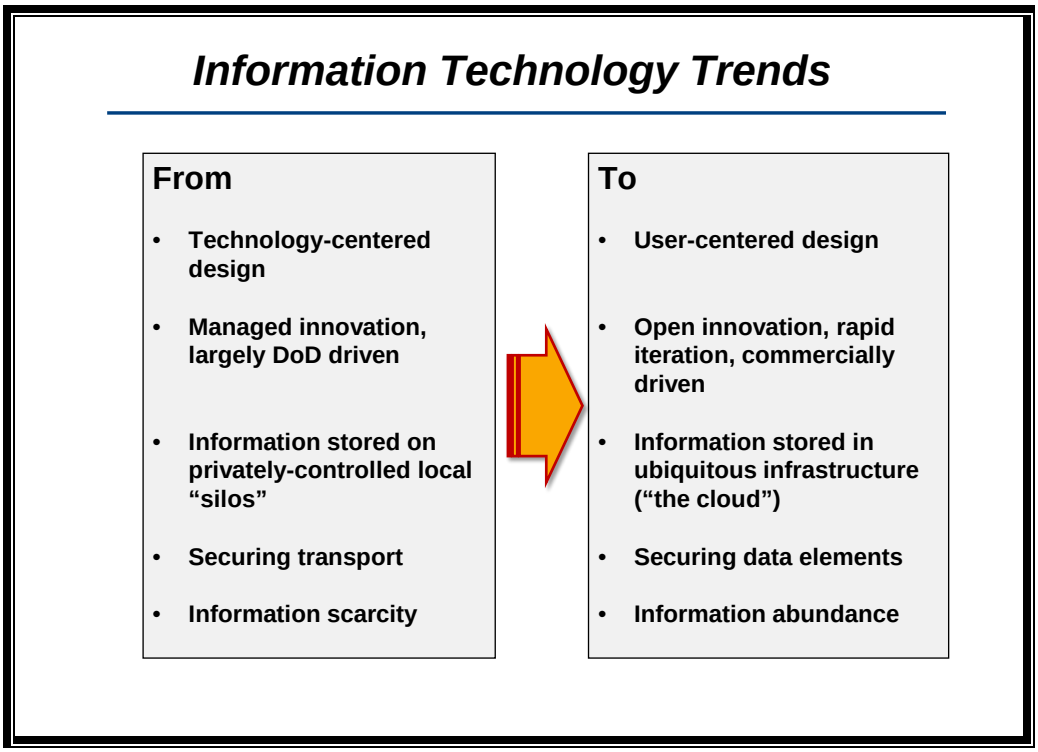
the required information in a timely fashion, in context, in order to take meaningful action in stressful, complex combat situations.



As we consider the role of advanced technology information systems in future military operations, it is important to remember that electronic opposition will be a feature of combat operations. So it is important to consider the impacts that future countermeasures may present to the use of blue force information systems.

CYBERWAR is the electronic threat that has received the most recent attention: it emphasizes that new systems may introduce new vulnerabilities besides the mere disruption of blue force communications. As one considers the wider use of networks, it is signal exploitation – i.e., the location of emitters on a battlefield – that is a significant consideration for the employment of networked information systems. Also, traditional electronic jamming, spoofing, and decoys – and more advanced threats such as electronic attack – will pose significant threats

to advanced information systems. Accordingly, electronic opposition needs to be factored into the design of future information systems. (Preparation for the electronic battlefield, however, was not a focus on this study.)



Even to the casual observer, information technology is changing at an extraordinary rate. The current state of the technology is such that managed innovation has been overtaken by open innovation coupled with rapid iteration. Future capability is defined in the imaginations of the myriad of users. Smartphone users have effectively joined the developer community in helping to define and deliver new capabilities and applications. Consequently, design that heretofore has been focused on accommodating the state of the technology is now focused on the needs and wants of the user; the commercial arena now leads technological innovation that was driven largely by military applications in the past.

Cloud architecture is permitting information sharing as it has never been done before, but with commensurate challenges to traditional information assurance schemes. In turn, cloud developments are driving the evolution of information assurance away from securing data/information "transport" toward securing the data elements themselves. Metaphorically, the "fortress" model of information assurance is giving way to schemes that are more akin to "hiding in

plain sight." Finally, our insatiable appetite for information is being overwhelmed by the abundance of information. The world culture is evolving at a very rapid pace toward the expectation of unlimited information available at an instant's notice. The challenge is finding the *relevant* information, not just finding information.

Designing for Humans is Complex

- **Most information systems are poorly designed for humans**
- **There is huge leverage in good user-centered design: Apple has excelled by addressing the challenge of designing for users**
- **Challenges**
  - **Large variations in how humans understand information**
  - **Mental capability varies by stress, competing activities**
  - **Information addiction – desire for unnecessary information**
  - **Propensity to trust and/or not-trust automated information systems**
  - **Erosion of skills and "common sense"**
- **Large body of untapped research addressing designs for human effectiveness**
- **Combat operations are more complex than most human activity**

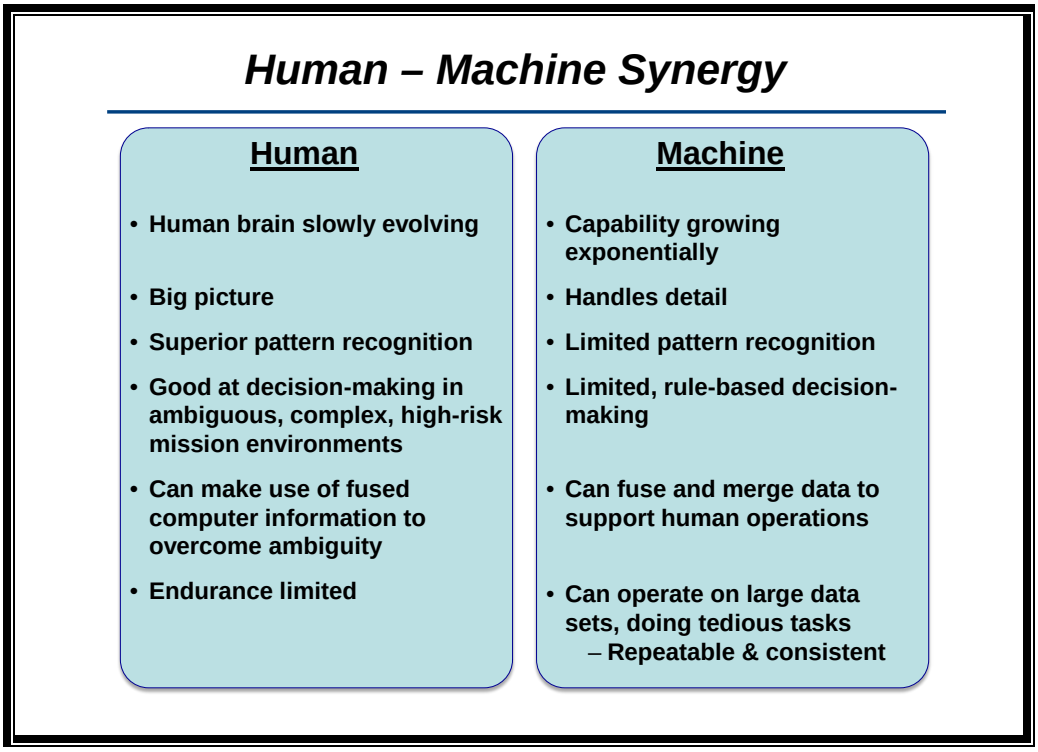
User-centered design facilitates accurately and timely decisions

Designing for humans is, in fact, so difficult that it is often not done very well.

Application development has moved more and more to "crowd sourcing," enabled largely by the success of companies such as Apple in seeding the field with end-user products that are intuitive to the majority of the user base. User-centric design is the new emphasis in the commercial world. However, there remain several challenges before the technology can deliver a truly individually-tailored product to each user. There are large variations in the way individual users assimilate information. Some may be visual assimilators while others have an innate preference for hearing or touch. There are different ways of interfacing the human brain with the technology. While the technology is relatively insensitive to the physical situation at the time, a human's ability and means of ingesting information will vary with the pace of activity and his/her level of stress. The individual's appetite for information in a particular situation and his/her propensity to trust the information offered – which varies widely among individuals – must also be incorporated into the design. Perhaps most importantly

is the propensity for some individuals to lose sight of the situation due to an overdependence on technology, which can lead to an erosion of skills and common sense. For example, a young person growing up in the fully digital world may have difficulty with basic arithmetic operations from the over-reliance on a calculator or a checkout clerk trusting cash register “change owed” totals when input data must be wrong, or one who lacks the skill and patience to adequately research a topic without total reliance on Google search.

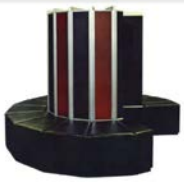
There is a large body of research addressing designs for human effectiveness that may be incorporated into future commercial products. However, because of the complexity of combat operations, the Marine Corps must look for critical omissions in commercial technology applications when adopting them for their own use.



The key in the optimal human-machine design is to have the human do what humans do best while focusing machines on tasks to which they are most suited. In effect, the machine becomes an adjunct to the human; not a driver of human thought or action but rather a facilitator in those areas where the human brain is not as effective or efficient. On the current time scale of technology advancement, the human brain is a relatively fixed asset – while computing capability is growing exponentially. As humans have evolved, they generally process the "big picture" well – on the other hand, computers will always excel at keeping track of quantities of data to the smallest bit. The human brain is wired to recognize patterns, a capability that is very difficult to translate into rule-based computer algorithms. And most obviously, machines are not as endurance-limited as humans, not requiring rest or sustenance to perform at full capacity.

Era of The End-User App

- **End-user-device capability will continue to grow exponentially**
- **Recruits will enter with info-tech knowledge and a smart phone**
- **Default interoperability and "there is an app for that" enabled by horizontal cloud architectures (platform as a service)**



CRAY-1 Supercomputer; 1979

- **100MFLOPS**
- **$29M (2012 equivalent)**
- **11,000 pounds w Freon Cooling**
- **8 MB RAM**
- **32 GB storage**
- **230 KW of Power**
- **Fastest in the world then**

Common smartphone; 2012

- **100 MFLOPS**
- **$600**
- **0.25 pounds**
- **1000 MB RAM**
- **64GB storage**
- **21 hr talk time on one battery charge**
- **GPS, 8 M camera, HD video, 3 radios**

- By 2016, projections show there will be a smartphone for nearly every adult in the US – echoing a worldwide trend.

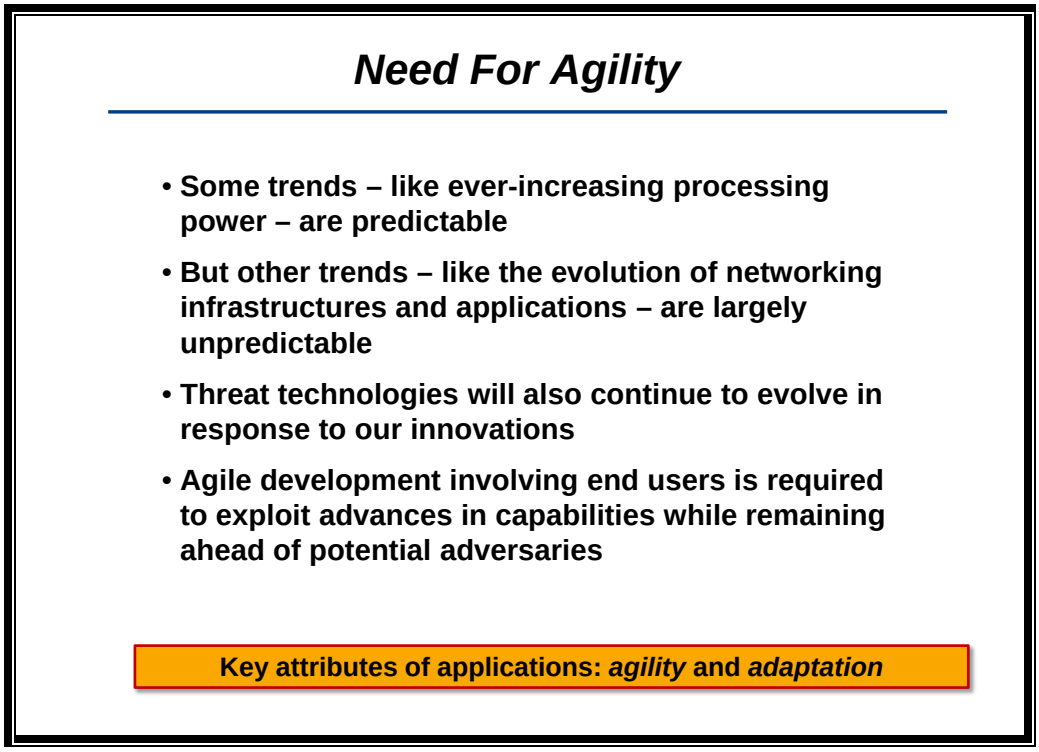
(*The Global Information Technology Report 2012*)

- There are currently over 500,000 apps available from the Apple iStore.

(*Apple website*)

From the standpoint of the technology, the era of the end-user application has arrived. Current and future network architectures will drive the technology even more in that direction. An indicator of where we are today, consider the current iPhone. This single device has more than 75 times the processing power of the Cray-1 Supercomputer which cost about $8M in 1979. It is doubtful that anyone at the time could have predicted computer processing gains of this magnitude in our lifetime. It is projected that by 2016, there will be roughly 260 million smart phones in the U.S alone. This leads to an assumption that most every military recruit will arrive at boot camp with his or her own smart phone – so training in using this type of device will be minimal.

As noted, much of the future innovation will be focused in the application layer. The particular IT platform that will enable the apps, known as "platform as a service," can be a fungible asset – easily exchangeable with other IT platforms – and can be procured and refreshed on a time scale totally disconnected from app development. The security and assurance of the infrastructure will be separate from the individual apps. This will allow each app to be certified in a way that will support rapid innovation. In addition, this type of network architecture will provide a common computing environment that will provide cross-device interoperability. Consequently, end-user devices can be viewed as consumables with the apps providing interoperability and standardization. Physical hardening for field use will become less important. In fact, the durability designed into the devices for commercial purposes may fulfill, in most cases, the requirements of the battlefield. Concerns about information assurance and bandwidth management will remain. These are areas that will require monitoring by the Marine Corps and should benefit from Naval S&T investment.



With mankind firmly astride the information age, evidence of technology's "creative destruction" is obvious. Entire industries have been created while others have withered away in very short order – always rewarding fast-paced entrepreneurial effort. Key to continued success in the IT world is the rapid adaption of the latest hardware and software developments. Hardware improvements still adhere to Moore's Law – espoused by Intel co-founder Gordon E. Moore in the 1960's – which stated that the number of transistors on a semiconductor doubles approximately every 2 years, affecting such attributes as processing speed, memory, communications though-put, etc. While the demise of Moore's Law has long been predicted, innovation in hardware has thus far not abated. Unfortunately, there is no "law" for the progression of software development – it is significantly less predictable.

We should expect that the US, our allies, *and our adversaries* will continue to rapidly leverage information technology improvements at an ever increasing rate in the future.

Much can be learned by military requirements and procurement officials regarding the best methods to evolve IT solutions – rapidly and agilely. The key is user-centered design. User-centered design comes in a number of forms but generally involves a first focus on the needs of the user, not the technologies available. The identification of these needs is, however, no easy feat. Often an expert in a field has developed a method of achieving a particular goal via a series of work-arounds that are not obvious to other users or a novice observer of those users. Nonetheless, a good user-centered design process can lead to vast improvements to the task at hand. While examples in many fields are well known, a good example of the challenges of user-centered design was presented to the Panel during a brief by the Palo Alto Research Center, a Xerox company. PARC was contracted to develop an IT interface to support a hospital medical staff. The task involved entering and retrieving critical patient data during their busy work shifts throughout the hospital. Initially, despite PARC's experience with using user-centered design criteria, the IT interface failed in the view of the user population. But a significant component of a good user-centered design process is iteration and experimentation. By carefully listening to clinician feedback and digging deeper into the actual requirements – not just the initial needs expressed by the staff – a true user-centered system was developed and was very successfully demonstrated. The analogy to the military situation, with its persistent data streams, need to enter and retrieve data in context, and high stakes (i.e., life and death) were readily apparent.

The user-centered design process is not unique to any particular field. Just as the Marines Corps can adapt this approach in the IT field, it is just as likely that our adversaries will do the same. To gain advantage in the past, our military was able to rely on technologies that had long development cycles and high cost in order to differentiate the U.S. from its adversaries. In the IT world, an adversary will have access to low-cost end-user devices and available apps (e.g., Google maps). The differentiator then, must be based in a design process that takes advantage of U.S. entrepreneurial supremacy to rapidly innovate, and adapt across the information technology spectrum.

Information & Technology Imperatives

Deliver critical information in context

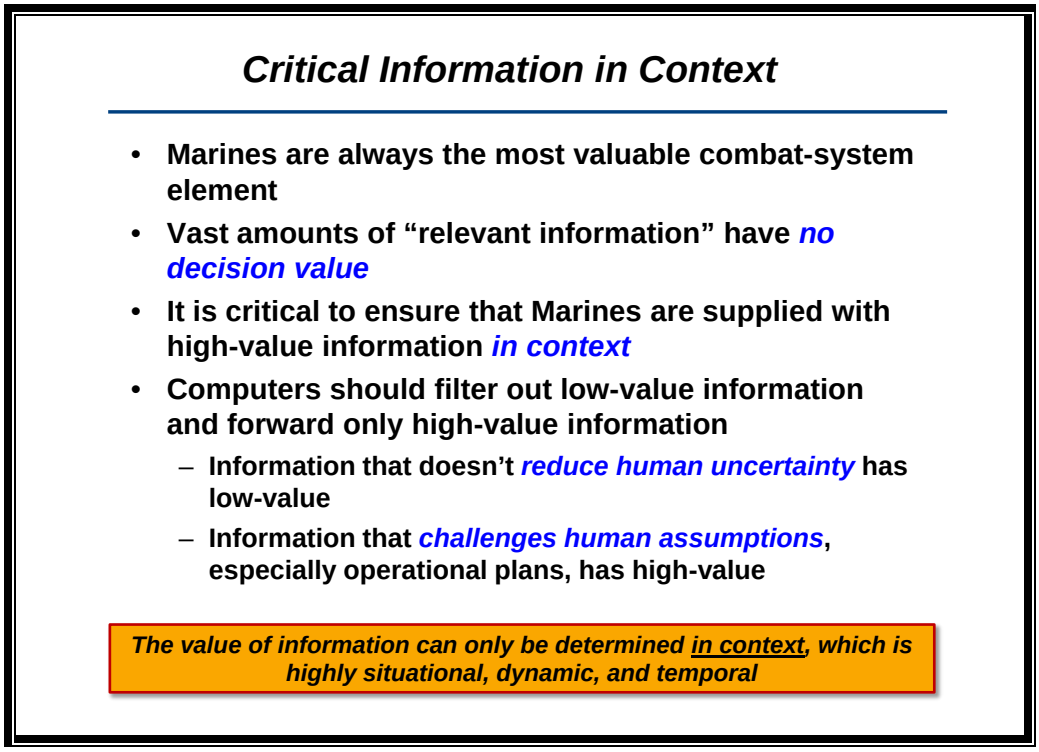
- **Environment that tolerates Reduced Bandwidth & Intermittent Connectivity**
- **Technology permitting staff to focus on analysis to support the forward Marine**
- **Applications tailored to support the forward Marine**

It was clear to the Panel, that Marines can achieve remarkable improvements in data delivery and display when systems are designed with the user (i.e., warfighter) clearly in mind. The goal is to deliver to the user, the most critical information at the right time, in the right context. For instance, the Marine staff – charged with analysis, should be able to totally focus on that task – and forward Marines, in close proximity to the enemy – should have available only critical, context-dependant information delivered at the relevant time. The ultimate information system challenge is to provide Marines with only the relevant information at the time and in the correct situational context.

But, there will always be challenges within the IT environment that are particular to the warfighter. The preferred bandwidth for communications connectivity may not be available. To solve this, some required information might need to be downloaded to the Marine's mobile device at the Company Level

Intelligence Center (CLIC) before going “outside the wire”. Later, thin connectivity may permit only the most critical updates to the pre-loaded data.

One might envision a system that adapts and recognizes the most vital data and prioritizes the use of the limited bandwidth. It will take experimentation and significant user participation to develop a capability that best delivers critical information in context. As in the previous PARC example, medical care specialists could not initially define their own information needs, so too, Marines will require a comprehensive, iterative user-centered design process to solve their future information management challenge. A user-design process is much more than experimentation and demonstration. It involves a range of tools to elicit critical feedback during development – feedback that is more extensive than just questions about the system – but higher level questions about the information and the context. Unlike systems with long development cycles, good IT development requires a tight feedback loop to ensure a state-of-the-art capability.

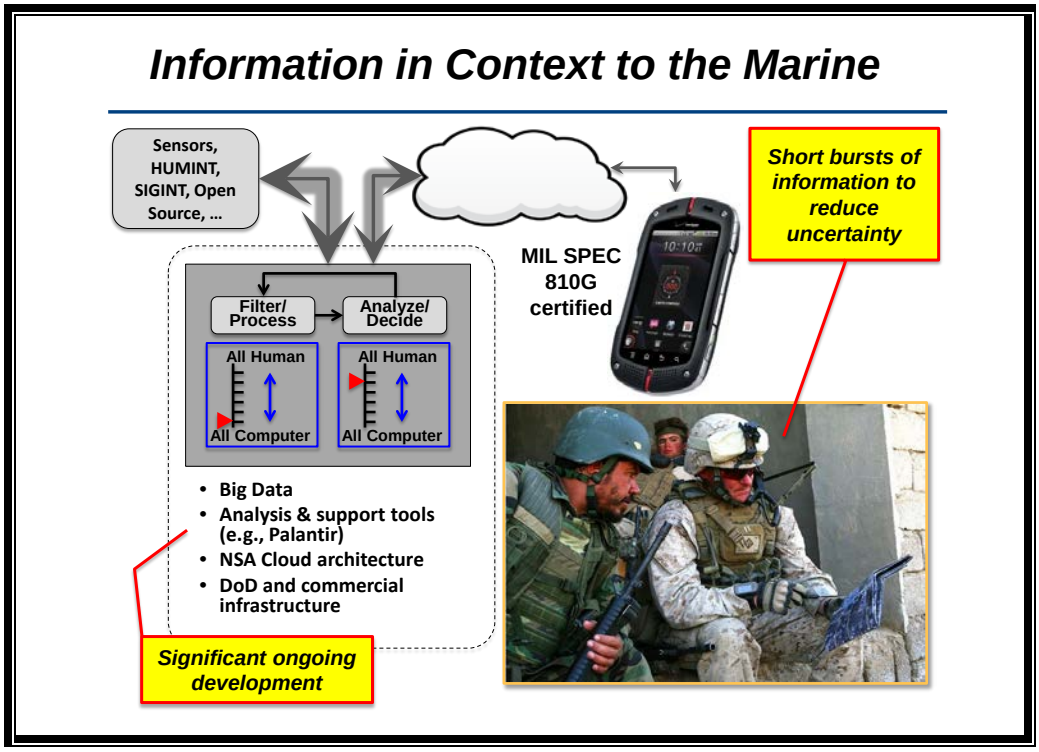


Critical information in context means that the information is valuable to the decision-maker at the correct time, place, and situation. One would envision that the cloud would have vast amounts of information, only some of which will be critical in any particular context. The purpose of the IT system (with the appropriate apps) would be to provide the Marine with the necessary high-value information. An interesting (albeit benign) example of this "information in context" is the Yelp application on smartphones, which draws on massive amounts of data that's out on the internet but organizes and makes it accessible to each user to suggest a local restaurant. This Yelp app knows the "context" of the user and the local area: time of day, geographic location, restaurant hours, and previous restaurant choices, to make an informed recommendation to the user at that moment.

Certainly, information that challenges current assumptions, in particular operational plans, would have particularly high value. In contrast, information that does not reduce situational uncertainty would be viewed as lower value. There are

vast amounts of information that may be deemed relevant but actually have no decision value when viewed from the narrow context of the decision being made.

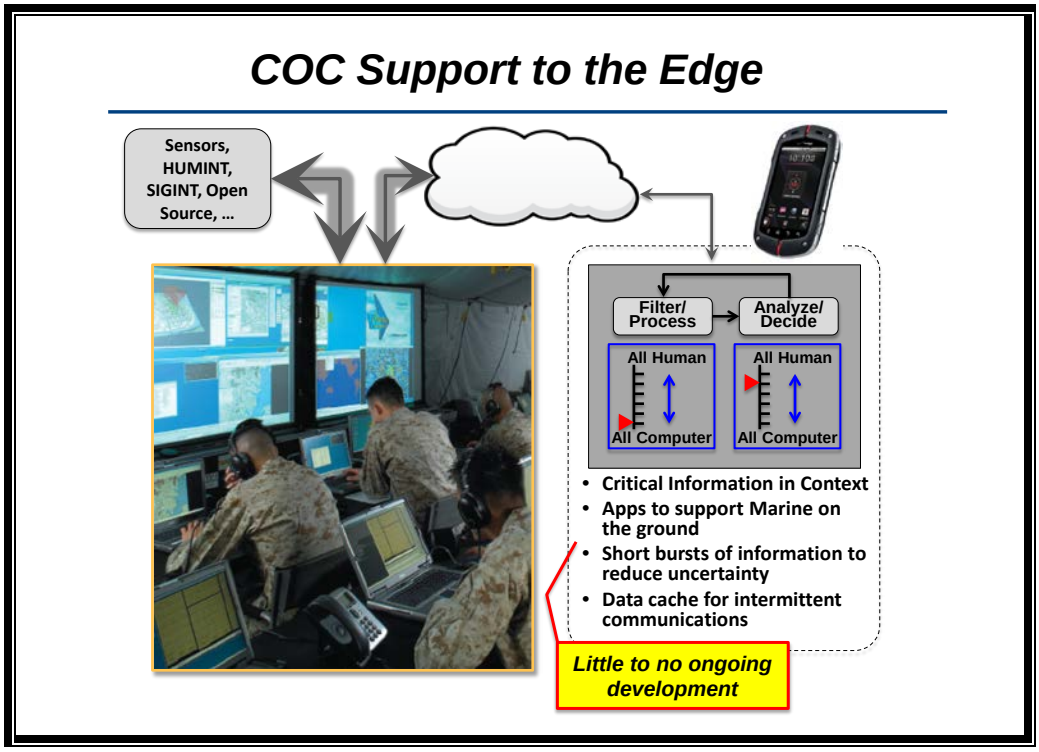
Ultimately, the value of the information will need to be determined in context. As the commercial world, a smart device used by the warfighter would help determine context and provide the up-to-date information given the available bandwidth. Or, if connectivity is limited, cache the information in the cloud for future update and user download when appropriate.



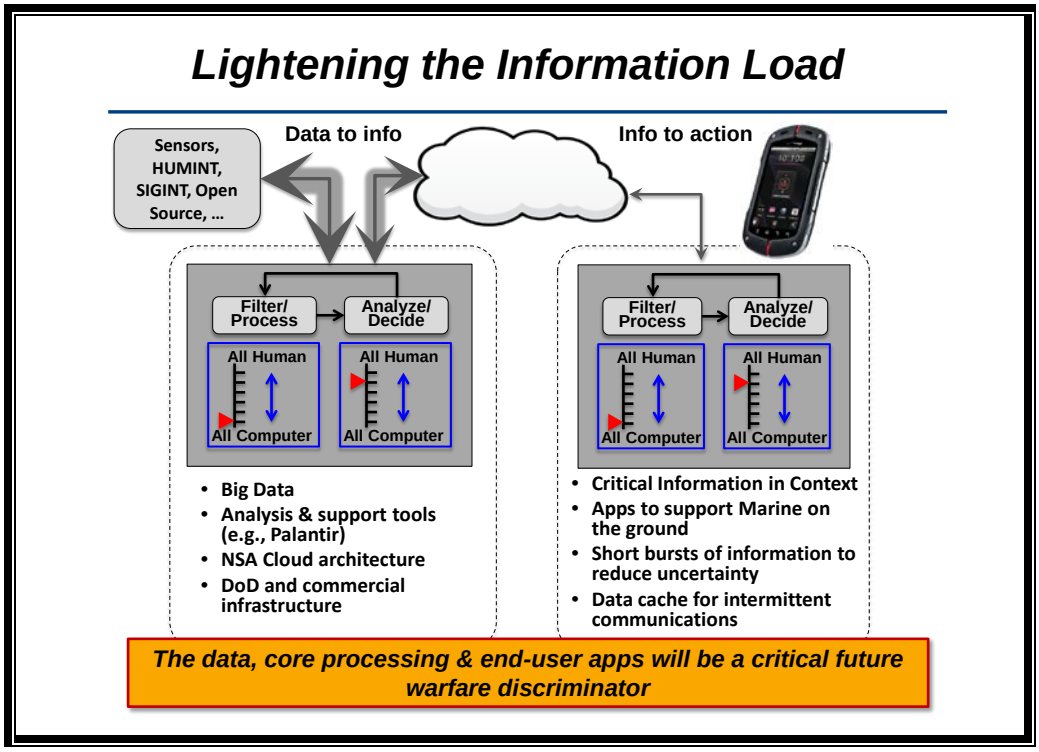
In order to provide information in context to the Marine, raw data from sensors, HUMINT, SIGINT, and other sources must first be collected, processed, filtered, and analyzed. Shown in the gray box on the left (above), large scale computer systems are well suited to processing and filtering this data so that human analysts can then make decisions and synthesize information which can be uploaded and stored in a cloud-based repository – a virtual storage capability that provides well-defined interfaces and is accessible to multiple applications. An important attribute of a cloud-based architecture is that it decouples the details of implementation from the use of the resources. In other words, an application can utilize the cloud without having to be concerned with changes to the underlying cloud systems. For example, Google is continuously changing and upgrading hardware and operating systems – but the changes are transparent to the user population.

The goal (as shown on the right side of the graphic) is for the Marine to have access to all the relevant information in his handheld device (illustrated here by a Mil Spec 810G compliant commercial smartphone) – and to have the capability to pull down new information in the particular context – using shorts bursts of information to reduce the uncertainty. A paper map may have relevant information but it's not up to date and doesn't have the full context. A mobile device accessing the cloud, would provide the most up to date information overlaid on a digital map that would facilitate the best course of action.

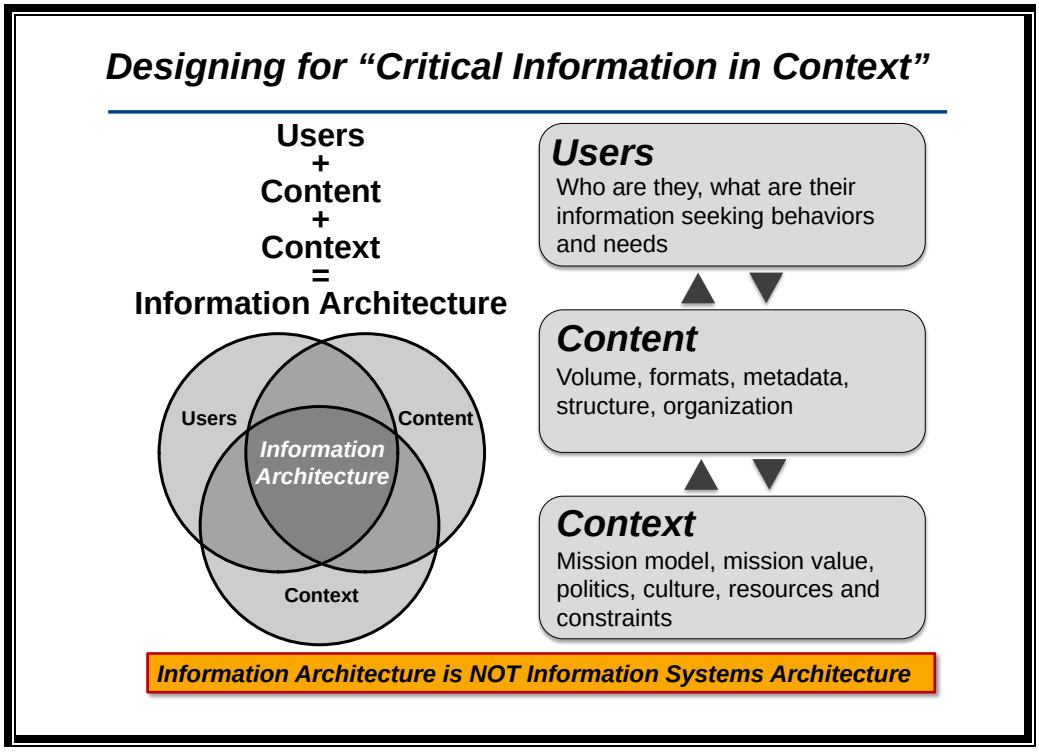
NSA and commercial providers such as Palantir Technologies, provide analysis support tools that help the analysts and operations personnel with converting massive amounts of raw data into actionable information. There is significant activity within DOD and the commercial sector that supports the infrastructure needs of the Marine Corps for the left side of the figure above. The portion, from the cloud to the Marine, has much less ongoing activity – as discussed on the next page.



Once information is processed and analyzed by the Combat Operations Center (COC) and higher echelons, it could be made available in a cloud-based system using purpose-built applications for wireless mobile devices. In a manner similar to the upstream situation, apps in the end-point device would utilize the local storage and computing power to pull information from the cloud in short bursts – filtering and processing it for the end-user. The large amount of memory available in mobile devices – currently up to 64GB – will allow caching of information to mitigate intermittent communications connectivity. Unfortunately, there is currently only limited S&T investment focused on applications needed to support the delivery of critical information in context to the Marine.



In summary, with the proper approach, the information load on the Marine has the potential of being reduced through technology: transforming data to information and then actionable knowledge for the battlefield using mobile devices and the appropriate apps. This leads to a discussion of Information Architecture.



In order to define critical information in context, it is necessary to start with an Information Architecture. Information Architecture represents the intersection of Users, Content, and Context. It provides a framework to understand what information is required by whom, in what context, and forms the foundation for developing the Information *Systems* Architecture that defines the *physical* systems that store, transport and process the information.

In the private sector, businesses have found that over time their business processes and information flows become governed by the information systems they have deployed and may no longer be relevant to their objectives. Companies find that they need to "re-engineer" their processes and information flows. This essentially is the process of refreshing their *Information Architecture*. With the new information architecture the company can then undertake a refresh of their information systems.

Similarly, as the Marine Corps develops new systems to provide critical information in context to the forward Marine, it is important to start with an Information Architecture. This architecture must necessarily be a living concept to keep pace with rapidly changing technologies, data sources, operating concepts and user needs. An information architecture as shown in the graphic above will have key attributes, for example:

Context

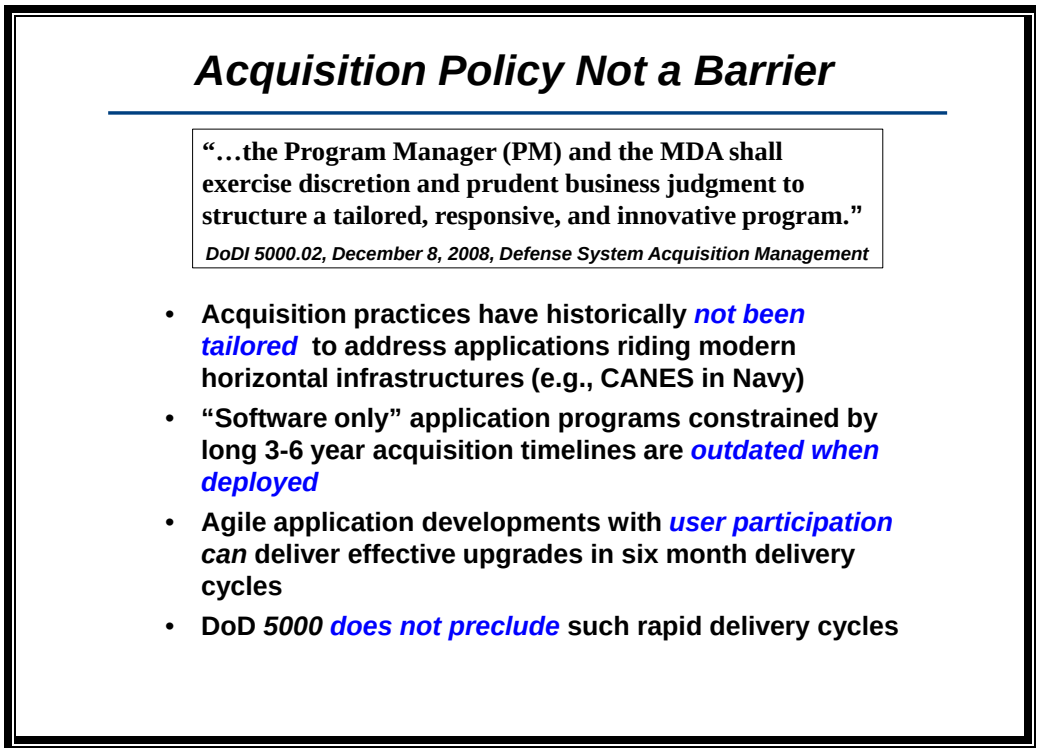
- Mission needs
- Mission dynamics
- Return on Investment (ROI) calculation
- Technical constraints
- Attention allocation

Content

- Indexing and cataloging
- Metadata
- Site architecture
- Navigation and labeling
- Content management
- Information filtering

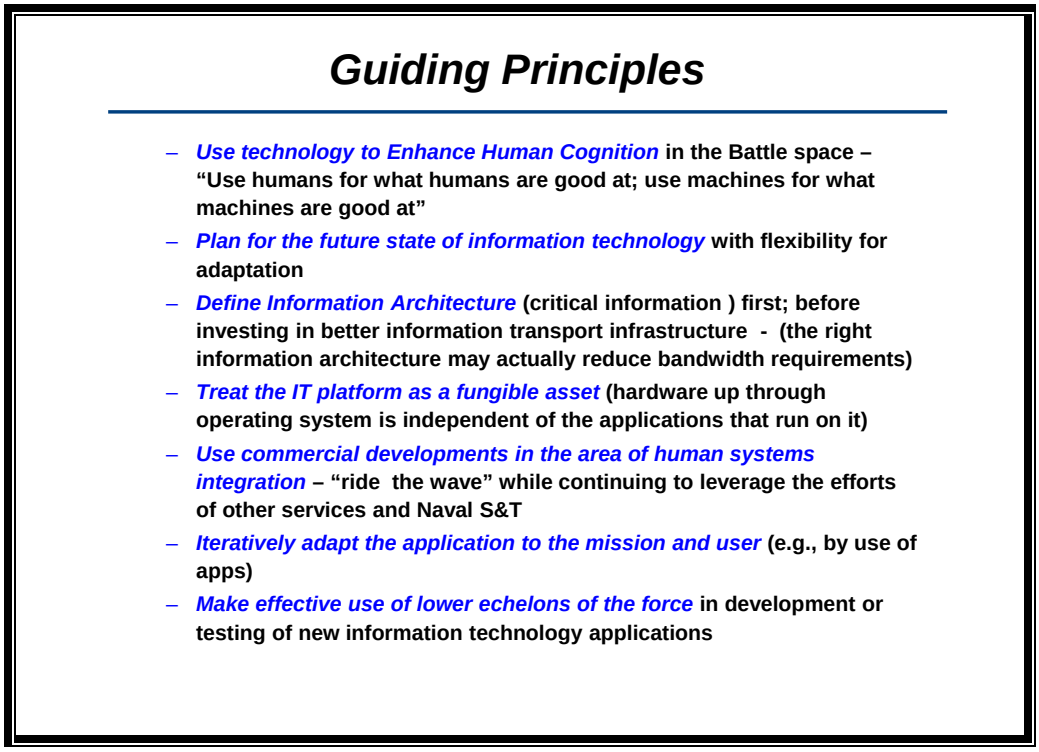
Users

- Task analysis
- Experience
- Individual vs. team
- Participatory development
- Assigned role



The Panel heard that current acquisition policy was a barrier, when in fact, the DoD 5000 allows for "prudent business judgment" to structure an innovative program. When purchasing vertically integrated, monolithic IT solutions that are large (and costly), the DoD acquisition process is naturally slow and complex – and the acquired system is frequently behind the state-of-the-art when delivered.

As new IT solutions utilizing cloud infrastructure and applications emerge, acquisition can be broken into smaller segments to speed up the acquisition timeline. Agile applications, with a tight user-centered design process, should allow for a six-month or less development cycle which occurs in the commercial world. To this end, DARPA launched the Transformative Apps program to facilitate a military apps marketplace to enable rapid innovation to meet user needs based on the collaboration of a competitive development community and military end-users.



Over the course of the study, the panel developed a set of "guiding principles" that must be considered by the Marine Corps when thinking about lightening the information load.

Finding 1: Information Architecture

Finding:

1. Marine Corps Information systems investments are not driven by an overarching Information Architecture

Recommendations:

1-A. USMC should build on existing MAGTF C2 Information Exchange Requirements to establish a baseline definition of critical information at each echelon within the MAGTF and use the result to drive future plans for information systems acquisitions

1-B. USMC should establish a process to iterate on critical information in context, one that evolves as new sensors, communications links, tactical concepts and organizational constructs are introduced

1-C. Operating Forces Marines should be primary participants in information architecture design. This should not be a contractor-led activity

Arguably the first finding (with supporting recommendations) is the most important of the five. There is no overarching Information Architecture laying the foundation for Marine Corps information systems procurements. The focus, therefore, has been on acquiring systems and equipment that transmit data most effectively, rather than on what information is required at each command echelon. For example, the Panel heard from Marines who had recently returned from operations in Southwest Asia that a large fraction of the information requested by higher headquarters staff was already available in the system, but those requesting apparently did not know where to look or how to access that information. With an effective Information Architecture in place, many of these requests for information would have been unnecessary and the demand for information would have been significantly reduced.

It is recommended that the Marine Corps build on the good work that has been done in identifying the command and control information exchange

requirements (IERs) with emphasis on establishing a baseline Information Architecture (i.e., a concept of operations for information availability) at each echelon within the MAGTF. This will only be a start – contributing to subsequent decisions regarding information systems procurements. This initial cut cannot be a static product. Each deployment of Marines anywhere in the world will generate unique information requirements – and the Information Architecture must be adaptable for each contingency.

The Panel recommends that the Marine Corps develop a process for regularly reviewing and re-thinking the dynamic MAGTF information requirements and architecture as new sensors, communications links, tactical concepts or organizational constructs are introduced. For this process to be truly user-centered, the Panel also strongly recommends that contractors NOT lead the effort – serving only in a support roll.

Finding 2: Concept Based Experimentation

Finding:

2. USMC has not been using concept-based experimentation in development of an Information Architecture

Recommendations:

2-A. USMC should integrate modeling and simulation, technology war gaming, intelligence analysis, and field experimentation to promote innovation in the development of a future MAGTF Information Architecture

2-B. USMC should develop a participatory design process built on iterative experimentation (e.g., using existing MCWL assets). Iterative interaction between the developer and operating forces is key

This finding, with its corresponding recommendations, supports the need for the future integration of Marine Corps doctrine and CONOPS into appropriate information architectures through iterative experimentation. The Marine Corps must utilize modeling, simulations, technology war-gaming – all the available tools in a collaborative participatory design process. This is important to all aspects of expeditionary operations, because it will impact IT infrastructure to support combat operations. The process must leverage the knowledge of experienced operators for concept definition, prototype testing, and evaluation with a systematic and iterative lessons-learned feedback loop that constantly informs the development process.

Finding 3: User-Centered Design

Finding:

3-a. Marine Corps IT infrastructure Investments do not currently make effective use of commercial user-centered design developments

3-b. ONR is supporting excellent work in Information Technology and Human Factors but these often are separate activities that are not well coordinated with each other

Recommendations:

3-A. USMC should designate a small group to experiment continually with current commercial IT offerings specific to user-centered design to see how force effectiveness can be improved quickly and incrementally

3-B. VCNR (CG MCWL) should facilitate improved coordination between ONR's Information Technology and Human Factors research with enhanced user-centered design and improved human cognition as the goals

User-centered design, especially for information access, dominates successful commercial products as noted in Apple products and Android smartphones. User-centered design appears to be the "special sauce" that differentiates these products from others. And, they offer a path to improving human information cognition, and decision-making. It does not appear that the Marine Corps is making optimal use of these rapidly unfolding commercial developments.

The ONR S&T investments in the disciplines of Information System Design and Improving Human Cognition are well structured and are on track to advance the state-of-the-art in both disciplines. But, an inherent "stove pipe" organizational divide within ONR – between these two disciplines – has hindered coordination is some cases, and ultimately may not serve the future IT needs of the Marine Corps.

To emulate and leverage commercial advances, the Panel recommends that a small group be tasked to continually experiment with the newest commercial IT offerings to determine if force effectiveness can be improved. It further recommends

that the Vice CNO/Commanding General MCWL facilitate improved coordination between the ONR Code 31 (Command, Control Communications, Computers, Intelligence, Surveillance, and Reconnaissance and Human Factors) and Code 34 (Warfighter Performance) departments when applicable to Marine Corps IT developments.

Finding 4: Agility within Acquisitions

Finding:

4-a. IT infrastructure is becoming a fungible commodity

4-b. Current DoD 5000 flexible acquisition regulations allow agile development and procurement of low cost applications

Recommendations:

4-A. USMC should structure IT acquisition contracts to specify that commodity products are current at time of delivery (i.e., not specified at contract award)

4-B. USMC should develop and manage their own information needs and thus their own apps

4-C. USMC should reduce time and cost for application acquisition by tailoring its use of the DoD 5000 process to support rapid and continuous capability development in IT (goal should be six month cycles or less)

The central message in this finding, with its corresponding recommendations, is that IT infrastructure and its complementary applications development are moving in a direction that will require a more literal use of the DoD 5000 acquisition directive. In fact, this wider use of DoD 5000, i.e., tailoring the process to the peculiarities of the particular acquisition, has been and is being done and is well within the guidance. However, the bureaucracy is often slow to adapt its processes to non-traditional acquisitions. Because the IT infrastructure for the individual Marine is becoming fungible and applications are evolving as consumables, there is no need to follow outdated, rigid procurement regulations that deliver a software product after a newer version is already available. Acquisitions must be structured to ensure the most up-to-date software is provided at the time of delivery, not at the time of contract award.

Finding 5: Information Management

Finding:

5. USMC lacks in-house professional military cadre with specific responsibility for information management across echelons (a collateral duty)

Recommendations:

5-A. USMC should establish a trained information management professional cadre – e.g., consider establishing a primary or secondary MOS as Information Management Officer with specified education/training to qualify

Panel discussions with Marines who recently returned from serving in Southwest Asia helped illuminate the fact that the Marine Corps does not currently have a professional cadre of personnel with specific knowledge and responsibility for information management across the force. Information Management Officers (IMOs) are now assigned at various command echelons – generally as a collateral duty – to individuals with no significant knowledge or experience in information management. Unfortunately the skill set of Communications Officers, who usually are assigned this collateral duty, do not match the requirements of the evolving IMO billet.

The Panel believes it will be necessary to designate a small cadre of Marines with specific training and expertise in the area of Information Management. This trend has already begun in industry with senior IT individuals now managing *information* rather than *hardware*. We recognize the challenges that a relatively small fighting force like the Marine Corps will have in creating and sustaining a cadre of

information management specialists. The Panel recommends that the Marine Corps investigate the feasibility of establishing a primary or secondary Military Occupational Specialty (MOS) in information management. Without specifying a particular solution, we could envision an individual with a primary MOS as a warfighter and a secondary MOS as an information management specialist.

Key Take-Aways

1. **Exponential IT and sensor growth *can enable* greater Marine effectiveness**
2. **Humans are *better than computers* at pattern recognition & decisions in high ambiguity environments**
3. **Computers are *better than humans* at filtering big data and tracking details**
4. **Future *end user devices can provide real-time* critical information in context to the individual Marine**
5. **IT systems can supply *critical information in context* even in the face of rapid situation changes and *intelligent adversaries***
6. **User-centered *design is difficult, but essential***
7. **Horizontal IT – *cloud-architectures* - and powerful *end-user devices* are key to supplying info in context**
8. **Designing for info in context requires *information architecture* and agile application acquisition (which DoD 5000 policy supports)**

It is always difficult to predict how rapidly evolving information technologies will be adopted on the modern battlefield. As is historically the case, new technologies both complicate and improve military operations. This study shows how greater Marine effectiveness can be enabled if the exponential growth of computers, networks, and sensors are systematically harnessed to support the Marine on the ground.

The foundation of this assertion is that humans and computers have complementary characteristics that can be designed to create significantly more synergy than is the case to date. Humans have always been better than computers at understanding the big picture, recognizing complex patterns, and making good decisions in high ambiguity environments such as the battlefield. Although science is struggling to understand how the human brain accomplishes these complex tasks, it is clear that our human experience and the resulting knowledge gained cannot be emulated by computers today.

While computers do not compete with human qualities, they clearly complement them. By being able to filter large amounts of data in minute detail, computers are capable of doing what humans do very poorly; namely keeping accurate track of tedious details without stopping for food and rest. The combination

or integration of humans and computers offers the potential for a radical change in warfare capability.

While we know information technology is changing exponentially, we often don't stop to appreciate the rate of change in end-user devices like the smartphone (which already represents over forty percent of the current mobile phone market). By taking better advantage of this phenomenon, it will be possible to change the way the Marine on the battlefield is enabled.

The key to better enabling the forward Marine is designing systems to discern critical information in context. This will require application (app) agility that is not possible today. Given that an intelligent adversary will have access to these same commercial technologies, we must rely on our agility in adapting to the dynamic information in context that will be the future warfare discriminator.

While it is easy to talk about critical information in context, the required user-centered design is not well understood and not a current Marine Corps development priority. However, limited research from the Naval Postgraduate School indicates that, in addition to improving warfare effectiveness, it can also reduce the burden on end-user information systems transport requirements by orders of magnitude.

There is significant ongoing work toward moving DoD and Naval information infrastructure toward cloud architectures. At the same time, the adoption of smart end-user devices is being investigated as an S&T priority. It will be the combination of both of these technologies that is essential to enabling the Marine on the battlefield.

Lastly, it is important to understand that information architecture is foundational to achieving information in context. Information architecture is not in any way the same as the information systems architecture that dominates our current acquisition processes. Information architecture is about understanding the needed information at all echelons and in all phases of a dynamic mission. Building and supporting this information architecture requires a continuous agile acquisition process with delivery cycles that should target months versus years for update cycles. Although agile delivery is not a standard acquisition practice today, the philosophy and intent of the DoD 5000 policy documents does support the agile application development recommended in this study.

Appendix A: Panel Biographies

(Panel Chair) Dr. Mark Bregman is Senior Vice President and Chief Technology Officer of Neustar. He is responsible for Neustar's product technology strategy and product development efforts. Prior to joining Neustar, Dr. Bregman was Executive Vice President and Chief Technology Officer of Symantec Corporation. Dr. Bregman's portfolio while CTO of Symantec included developing the company's technology strategy and overseeing its investments in advanced research and development, security and technology services. Prior to Symantec, Dr. Bregman served as Executive Vice President, Product Operations at Veritas Corporation, which merged with Symantec in 2005. Prior to Veritas, he was CEO of AirMedia, an early mobile content marketplace, and spent 16 years in a variety of roles at IBM. Dr. Bregman serves on the board of ShoreTel (SHOR), a VoIP Unified Communications company, chairman of the board of the Bay Area Science & Innovation Consortium and the Anita Borg Institute, which focuses on increasing the impact of women on all aspects of technology. He holds a bachelor's degree in physics from Harvard College and a master's degree and doctorate in physics from Columbia University.

(Co-Chair) RADM John T. Tozzi, (U.S. Coast Guard-Retired) is a former Vice President for Advanced Programs L-3 Communication Systems - East. He completed his Coast Guard career in 1999. When he retired, he was Assistant Commandant for Systems, a position he assumed in June 1997 after completing a tour as the Coast Guard's first Chief Information Officer. He is a 1968 graduate of the Coast Guard Academy. His operational assignments included tours in seven high endurance cutters, two of which he commanded. As a flag officer, he commanded Joint Interagency Task Force West, the U.S. Pacific Command's counter-drug joint task force. His postgraduate academic accomplishments include Master's Degrees in Naval Architecture & Marine Engineering and in Mechanical Engineering from the Massachusetts Institute of Technology as well as a Ph.D. (Fluid Mechanics) from the Catholic University of America. Upon his

retirement from active service, he took a position as Vice President for Information, Intelligence, and Advanced Technology with BMT Syntek Technologies, Inc., of Arlington, VA, and later with L-3 Communications. He is a past member of the Permanent Panel of Associates of the Naval Research Advisory Committee, a member of the Executive Committee of the Surface Navy Association, a National Vice President and National Director of the Navy League of the United States, and a past member of the Board of Directors of the Navy Mutual Aid Association. He received the Superior Public Service Award from the Secretary of the Navy in 2006 and a Distinguished Public Service Award from the Commandant of the Coast Guard in 2007.

Major General Randolph Alles, (U.S. Marine Corps-Retired) is the Deputy Assistant Commissioner, Office of Air & Marine, U.S. Customs and Border Protection. His most recent position while still on active duty was the Director for Strategic Planning and Policy, J-5, U.S. Pacific Command. Prior to that, General Alles was Commanding General, Third Marine Aircraft Wing (forward) headquartered at Al Asad Air Base, Iraq. A Marine aviator, he also served in numerous command and senior staff positions including Commanding General, Marine Corps Warfighting Laboratory/Vice Chief of Naval Research, Office of Naval Research; Deputy Director for Operations, Joint Staff, J-3; Chief, Aviation Weapons Systems Requirements Branch, Headquarters Marine Corps; and Commanding Officer, Marine Aircraft Group Eleven, Miramar, CA. He qualified in numerous combat aircraft including: F/A-18, A-4, F-4, F-16 and F-5 – and was flight instructor-rated in each. General Alles served two flying tours of duty aboard aircraft carriers and was a Top Gun instructor pilot. On active duty, he received the Legion of Merit with Combat "V", the Defense Superior Service Medal, and the Meritorious Service Medal, and the Air Medal with numeral 3. Major General Alles has a BA in accounting from Texas A&M University and a MA in National Security and Strategic Studies attained while attending the Naval War College, Newport, RI.

Dr. Michael S. Bruno is Dean of the School of Engineering and Science, and Professor of Ocean Engineering at Stevens Institute of Technology, Hoboken,

New Jersey. He is the Director of the Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR), a Department of Homeland Security National Center of Excellence. His research and teaching interests include ocean observation systems, maritime security, and coastal ocean dynamics. He is the author of more than 100 technical publications in various aspects of the field. Prior to assuming the duties of Dean, Dr. Bruno was the Director of the Center for Maritime Systems and Davidson Laboratory at Stevens from 1989 to 2007. During this period, he initiated the development of several ocean and weather observation and forecasting systems. Dr. Bruno is Chairman of the National Academy's Marine Board; Member of the Ocean Research Advisory Panel; and serves as the Editor-in-Chief of the Journal of Marine Environmental Engineering; Secretary-General of the Pan American Federation of Coastal and Ocean Engineers; and Visiting Professor at University College, London. A Fulbright Scholar (1996 appointment at the Aristotle University of Thessaloniki, Greece), Dr. Bruno is also a Fellow of the American Society of Civil Engineers. He received the Office of Naval Research Young Investigator Award in 1991, and the Outstanding Service Award from the American Society of Civil Engineers in 1988. Dr. Bruno holds a B.S. degree in Civil Engineering from the New Jersey Institute of Technology, a M.S. degree in Civil Engineering from the University of California at Berkeley, and a PhD degree in Civil and Ocean Engineering from the Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution.

Dr. Mary L. (Missy) Cummings is the Boeing Associate Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT). She is the director of the MIT Humans and Automation Laboratory, and holds additional appointments in the MIT Engineering Systems Division and the MIT Computer Science and Artificial Intelligence Laboratory. She is currently serving as a program manager in the Naval Air Warfare and Weapons Department of the Office of Naval Research in an Intergovernmental Personnel Act (IPA) position. Her previous teaching experience includes instructing for the U.S. Navy at Pennsylvania State University and as an assistant professor for the Virginia Tech Engineering Fundamentals Division. Professor Cummings received her Bachelor

of Science degree in Mathematics from the United States Naval Academy in 1988, her Master of Science in Space Systems Engineering from the Naval Postgraduate School in 1994, and her doctorate in Systems Engineering from the University of Virginia in 2004. A U.S. naval officer and military pilot from 1988-1999, she was one of the Navy's first female fighter pilots. Her research interests include human supervisory control, human-unmanned vehicle interaction, bounded collaborative human-computer decision making, simulation and evaluation of human interaction in automated systems, and the ethical and social impact of technology. Funding for her $10,000,000 laboratory comes from several Department of Defense agencies such as the Office of Naval Research, the Air Force Office of Scientific Research, and the Air Force Research Laboratory as well as other government agencies such as the National Science Foundation, the Federal Aviation Administration, and the Nuclear Regulatory Commission. She routinely partners with industry collaborators such as AAI, ABB, Alstom, Boeing, United Technologies, and several small companies across the United States. Professor Cummings has published over 100 peer-reviewed journal articles, conference papers, and book chapters and has served on several U.S. national committees such as the National Academy of Science Opportunities in Neuroscience for Future Army Applications Committee, the National Research Council Transportation Research Board En route Air traffic Control Complexity & Workload Model Review Committee, and as an advisor to the U.S. Air Force Scientific Advisory Board for UAVs in Irregular Warfare. She currently serves on the National Research Council Board on Human Systems Integration and NASA's Space Human Factors Engineering Standing Review Panel.

Dr. Marv Langston has 34 years of public service and six years of private sector service, bringing a broad background to his customers, where he provides consulting services for leadership, enterprise architecture & engineering, project management, and organizational strategy. Following his public service career, Marv served as the COO of a small high-tech start-up, CTO of a large business practice, led large corporation Information Technology transformation, initiated Account Management practices to unify customer trust relationships, and helped rebuild troubled system development programs. In government Marv served as

Department of Defense Deputy Chief Information Officer (CIO), where he helped initiate the Global Information Grid, Public Key Infrastructure - Common Access Cards, and led the Defense Department Year 2000 transformation. Prior to that he held positions as Deputy Assistant Secretary of Navy for C4I, Navy's first CIO, and Director of the Defense Advanced Research Projects Agency (DARPA) Information Systems Office. Marv began his Navy career as an enlisted nuclear submarine electronic technician and retired as a Combat Systems Engineering Duty Officer. Before rejoining government he worked at Johns Hopkins University Applied Physics Laboratory supporting U.S. Navy and Missile Defense Agency projects. His education includes: BSEE (Electronic Engineering) Purdue, 1973; MSEE (Electronic Engineering) Naval Post Graduate School, 1978; MPA (Public Administration) University of Southern California (USC), 1993; and DPA (Public Administration) USC, 1994. Government Computer Week magazine honored him with an Executive of the Year award in 1999.

Dr. William C. Miller retired from his alma mater, the United States Naval Academy, where he had been the Academic Dean since 1997. Before then he had served as Associate Provost for Research and Economic Development at West Virginia University. There he was responsible for providing institution-wide leadership for the university's research program, and for developing and guiding the university's contribution to economic development throughout the state. At the same time Dean Miller served as Executive Director and Vice Chairman of the Board for the West Virginia University Research Corporation, a private nonprofit corporation chartered to support and foster the research mission at the university. Before his arrival at West Virginia in 1993, Dr. Miller served in a variety of assignments in the U.S. Navy, the most prominent of which were in the areas of research and development. From 1990 to 1993, then Rear Admiral Miller served as the Chief of Naval Research in Washington DC, and chief executive of the Office of Naval Research. There he was responsible for the Department of the Navy's $1.5 billion annual investment in science and technology through universities, industry and government laboratories. Prior to that Dr. Miller served as chief executive of the Naval Research Laboratory; founding director of both the Navy's low observable (stealth) technology office and the DOD counter low

observable office. In addition to his undergraduate degree Dr. Miller earned his masters and doctor of philosophy degrees, both in Electrical Engineering, at Stanford University.

Dr. Frank Shoup has experience in both scientific and technical research and management, and in operational testing and analysis. His Naval technical management responsibilities in the Office of the Chief of Naval Operations have included Director, Science and Technology Division (OP-987); Associate Director, Expeditionary Warfare Division (N-75); Chief Scientist, Systems Analysis Division (OP-96); and Scientific Analyst, Electronic Warfare Division (OP-944). Other Naval assignments have included the Chair of Physical Sciences and Chair of Electronic Warfare at the Naval War College; Science Advisor to the Commander, U.S. Naval Forces, Europe; Science Advisor to the Commander, U.S. Sixth Fleet; CNA representative to Commander, U.S. Pacific Fleet and CNA representative to Commander, Task Force 77. His most recent position was as Director of the Wayne E. Meyer Institute of Systems Engineering at the Naval Postgraduate School. While on active duty with the Air Force, he served as project officer for nuclear weapons effects testing programs in five major nuclear weapons test operations in the Nevada Test Site and the Pacific Proving Grounds. Dr. Shoup did his graduate work in physics and his undergraduate work in chemical engineering.

Mr. William Schmitt (NRAC Consultant) is an independent consultant having retired from the Federal Senior Executive Service (SES-5) with over 32 years experience in the Naval Nuclear Propulsion Program. As a consultant, Mr. Schmitt is currently serving as a consultant to the Naval Research Advisory Committee. Previously he was appointed by the Secretary of the Navy to a panel of six experts charted to examine the Culture of Quality in Navy Shipbuilding and recommend changes in Navy practices to correct recurrent quality problems and unmet performance expectations in delivered naval vessels. In other consulting work, he was selected to provide support to the DOE's Sandia National Laboratories regarding program and project management, independent programmatic assessment and management improvement initiatives. He

developed new program and management plans for a corporate-wide initiative to improve product lifecycle management. Mr. Schmitt also consulted for Marinette Marine Corporation on U.S. Navy Littoral Combat Ship lead ship construction program. He advised senior management on corporate response to Navy initiatives for accelerated test program execution and management restructuring for improved test program execution. Mr. Schmitt spent over 20 years as Program Manager for Surface Ship Nuclear Propulsion at (NAVSEA) headquarters in Washington, DC, having reported directly to all five Naval Reactors Program Directors. As the Program Manager for Surface Ship Nuclear Propulsion, Mr. Schmitt reported to and advised Program Directors in all matters involving nuclear propulsion for nine U.S. Navy aircraft carriers and nine cruisers including; Congressional testimony; long range strategic program planning, policy formulation, implementation and enforcement; ship construction, and in-service ship operations management and regulation to ensure safe nuclear propulsion plant operation. He directed the Naval Reactors Headquarters Program for Surface Ships with an annual budget in excess of $300M involving over 5000 personnel at two U.S. DOE prime contractors, two U.S. Navy public shipyards and the largest nuclear-capable private ship builder in the U.S. (Northrop Grumman Newport News). He was responsible for all aspects of oversight of shipbuilder construction of the nuclear reactor plants of five of the U.S. Navy's NIMITZ Class aircraft carriers including construction certification, acceptance testing and delivery acceptance. Mr. Schmitt provided Naval Reactors Program-wide executive program direction and oversight of: long range planning and execution of shipboard reactor refueling; reactor and propulsion plant overhaul, repair, maintenance, and modernization; and post repair testing, including critical reactor plant testing, in nuclear powered aircraft carriers and cruisers. He also provided key leadership in Navy strategy and policy development of new aircraft carrier operational and maintenance plans to respond to the operational demands of the post - 9/11 era and the Global War on Terror. These plans achieved unprecedented increased ship operational availability and nuclear propulsion plant material readiness without sacrificing ship service life, propulsion plant readiness, or safety of nuclear propulsion plant operation.

Dr. John T. Walsh Jr. is the Vice President for Research at Northwestern University where he helps develop and implement the strategic plan for the university's research operations and where he oversees the research infrastructure on the campuses in both Evanston and Chicago, Illinois. Dr. Walsh also serves on the Board of Governors for Argonne National Laboratory, the Board of Directors for Fermi National Accelerator Laboratory, and on the Illinois Governor's Innovation Council. Dr. Walsh is also a Professor of Biomedical Engineering. His research area is the study of light tissue interactions. He has an approximately 25-year history of investigating the photo-physics and photobiology of laser-based ablation. He has most recently been investigating tissue birefringence feedback systems, the propagation of polarized light in tissue, optically induced stimulation of the auditory system, and nanostructured surfaces for biosensing applications. He has been the principle investigator on several NSF and NIH grants as well as industry sponsored translational research. Dr. Walsh has been a program chairman for 5 major conferences in his field. He is a past-president of the American Society for Laser Medicine and Surgery, the world's premier medical laser society. Dr. Walsh conducted his doctoral research on the medical applications of laser and other optical sources in the Wellman Laboratories at the Massachusetts General Hospital, received his Ph.D. from the Harvard-MIT Division of Health Science and Technology, and BS and MS degrees in Electrical Engineering from MIT.

Appendix B: Terms of Reference

Lightening the Information Load

Objective

This Naval Research Advisory Committee (NRAC) study will assess the information requirements at all echelons in modern-day battlespace, including air, land, sea, and cyberspace; evaluate the current level of effectiveness and efficiency being attained; and recommend technological directions for optimizing the delivery and assimilation of available information to/by the warfighter. While emphasis will be placed squarely on the Marine in the battlespace, the essential connection of Marine Corps fighting elements to supporting Naval forces afloat and in the air will be addressed as well.

Background

Modern open-source information technologies in the hands of ascending nations as well as militant groups from even the most underdeveloped regions have revolutionized today's battlespace. They have enabled forces that are clearly inferior in formal organization and kinetic power to equal, and sometimes surpass, the effectiveness of developed conventional forces principally through superior speed of action.

For developed conventional forces, this tips requirements heavily to the left side of the kill chain: acquiring relevant data, deriving actionable information, and making this actionable information available to the warfighter quickly and in a form that is intuitive to each individual. While our collection, analysis, and dissemination capabilities are well established, our ability to provide customizable information quickly and efficiently to the elements in contact with the enemy is rudimentary at best. This gap is manifested in an

unmanageable quantity of information that is effectively not accessible to those who need it the most.

Various concepts including "supply push," which emulates the established military intelligence processes of the day, and "demand pull," which is the direction of today's commercial development, have been proposed for military operations for some time. Yet, the information content and flow to the warfighter is still truly optimized for only the most rudimentary operations. If our forces are to remain preeminent in the battlespace in the face of the identified and yet unimagined future threats, a clear direction for improving this situation must be established and executed vigorously now.

Scope

This study will be conducted at a classification level consistent with the information considered and the sensitivity of the findings.

Specific tasking includes:

- Frame the information requirements of each echelon in the battlespace, and establish the shortfalls in availability, access, and presentation of essential information at all levels.
- Review any relevant human factors studies related to the ease of assimilation (by the human intellect) of information provided through technology available today and projected into the future.
- Identify and evaluate naval S&T initiatives as well as the direction of commercial development in guided information search/discovery/filtering that are being or could be pursued to optimize the information form and flow to the warfighter. Consideration must be given to speed of delivery and ease of assimilation, including the flexibility and adaptability of information presentation to suit a variety of individual recipients.
- Finally, recommend the direction of S&T to support the needs of future warfighters as they engage more diverse forces than ever before imagined in the air, on the ground, at sea, and in cyberspace.

Appendix C: Fact-Finding Contributors

Contributor	Organization
Capt Dixon, USMC	Marine Corps Systems Command
Mr. Jay Shivers	Marine Corps Systems Command- C2ID TTF
Mr. Dave Moore	Headquarters, US Marine Corps-C4
LtCol Woodburn	Marine Corps Systems Command- FMID MERS
Colonel Kirby	ONR Code 30
Mr. John Moniz	ONR Code 30
Mr. Martin Kruger	ONR Code 30
Mr. Dan Salyan	ONR Code 31 Contractor
Col Castellvi, USMC	I MEF Chief of Staff
LtCol Wolf, USMC	I MEF IMO
Colonel Miller, USMC	I MEF G-6
Maj Robinson, USMC	I MEF G-6
Maj Curran, USMC	1st Marine Division, Deputy Current Ops Officer
Lt Tadken, USMC	Company Staff, S-3A
Capt Hoover, USMC	Company Staff, S-2
Sgt Gordon, USMC	Company Staff, Data Chief
Sgt Bronsky, USMC	Company Staff, Tactical Radio Chief
Capt Schramel, USMC	Company Commander

Capt Forrer, USMC	Company Commander
1st Lt Hyatt, USMC	Company Executive Officer
1st Lt Ihenacho, USMC	Platoon Commander
1st Lt Alvarado, USMC	Company Executive Officer
1st Lt Green, USMC	Platoon Commander
1st Lt Hoogland, USMC	Platoon Commander
1st Lt Rehberg, USMC	Platoon Commander
Cpl Garcia, USMC	Training NCO, Assistant Patrol Leader
Sgt Bennet, USMC	Section leader
Sgt Hulett, USMC	Squad Leader
MGen Spiese, USMC	I MEF Deputy CG
LtCol Ford, USMC	1st Mar Div G-6
Prof. Rick Hayes-Roth, PhD	Naval Postgraduate School
Colonel Tony Wood, USMC-ret	Consultant
Mr. Michael Jones	Technology Advocate, Google
Mr. Eliot Hodges and Mr. Charles Smith	Palantir Technologies
Prof. Nancy Cook, PhD	Arizona State University
Dr. Mark Stefic	Palo Alto Research Center (PARC)
Mr. Mark Johnson	CEO, Zite
Mr. Vince Goulding	MCWL
Mr. Rob Anderson	HQMC C4
Mr. Jeff Castro	C2ID

Dr. Bobby Junker	ONR Code 31
MGySgt Millner/Capt Rodney	Intel Integration Division (IID)
Dr. Greg Tafton	NRL
CDR Joseph Cohn	ONR Code 34
Ms. Mary Brady	MCIA

Appendix D: Acronyms

C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance
CLIC	Company-level Intelligence Cell
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
COC	Combat Operations Center
CONOPS	Concept of Operations
DoD	U. S. Department of Defense
DON	Department of the Navy
EW	Electronic Warfare
FYDP	Future Years Defense Program
GPS	Global Positioning System
IER	Information Exchange Requirement
IMO	Information Management Officer
ISAF	(NATO) International Security Assistance Force
ISR	Intelligence, Surveillance, Reconnaissance
IT	Information Technology
MAGTF	Marine Air-Ground Task Force
MCCDC	Marine Corps Combat Development Command
MCWL	Marine Corps Warfighting Laboratory
NRAC	Naval Research Advisory Committee
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
RFIs	Requests for Information
S&T	Science and Technology
STOM	Ship to Objective Maneuver
TOR	Terms of Reference