Leveraging Information Technology to Enable Network Centric Engineer Reconnaissance Operations

by

Keith W. Barton, P. E.

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Submitted to the Department of Civil and Environmental Engineering
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Abstract

The Naval Construction Force has traditionally depended on outside sources to obtain and analyze engineering data in contingency situations. The Navy has embarked on an initiative to develop Seabee Engineer Reconnaissance Teams to perform this function, both as a basis for projects slated for in-house construction and as a product to deliver to other organizations. Exercises and operations have thus far shown that the concept is viable, but Seabee Engineer Reconnaissance Teams have encountered problems with data gathering and reporting, and transmission of data and images.

Concurrently, the Department of Defense is pursuing a transformation toward network-centric warfare. Network Centric Warfare represents a powerful set of warfighting concepts and associated military capabilities that allow warfighters to take full advantage of all available information in order to bring all available assets to bear in a rapid and flexible manner.

This research explores the state of the practice of military engineer reconnaissance as described by established Army doctrine and as enacted by Navy Seabee Engineer Reconnaissance Teams. Commercial information technology applications are reviewed in the areas of geographic information systems, collaborative design, and wireless communications. Solutions are proposed for their potential to enable network centric engineer reconnaissance operations.

Network Centric Warfare concepts provide a framework for analyzing the state of the practice in military engineer reconnaissance versus the state of the art in information technology. Current status is assessed and a methodology is proposed to move the Navy quickly forward on the continuum of the Network Centric Operations Maturity Model that enables shared situational awareness, with a brief discussion on the implications for decentralized decision-making.

Thesis Supervisor: John B. Miller
Title: Associate Professor of Civil and Environmental Engineering

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And lastly to my parents, who instilled in me the sense of responsibility, integrity, and work ethic that have enabled me to progress this far.

Biographic Note

Keith W. Barton is a Lieutenant in the United States Navy Civil Engineer Corps. A native of Queensbury, New York, he received his Bachelor of Science Degree in Civil Engineering from Cornell University. He received his commission through the Naval Reserve Officers Training Corps in 1994.

His first duty station was at the Naval Postgraduate School in Monterey, CA as the Facility Support Officer and Seabee Division Officer. Following six months of study at the Defense Language Institute in Monterey, he transferred to Engineering Field Activity Mediterranean in Naples, Italy, as the Assistant Operations Officer. While in Naples, he also served as the Deputy Resident Officer in Charge of Construction for the Southern Italy office. He then reported to Naval Mobile Construction Battalion SEVEN in Gulfport, Mississippi, where he completed deployments to Puerto Rico as the Assistant Operations Officer and to Sigonella, Sicily as the Detail Officer-in-Charge.

Lieutenant Barton's next assignment will be as the Aide to the Deputy Chief of Naval Operations (Fleet Readiness and Logistics) in Washington, DC.

Lieutenant Barton is a registered Professional Engineer in the state of North Carolina and is qualified in Seabee Combat Warfare. His decorations include the Navy and Marine Corps Commendation Medal, the Navy and Marine Corps Achievement Medal, Navy Meritorious Unit Commendation, Kosovo Campaign Medal, and NATO Medal.

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1.1.1 History of the Seabees

Prior to World War II, the United States Navy used civilian personnel for any required construction tasks. However, after the Japanese bombing of Pearl Harbor on December 7, 1941 and the subsequent U. S. entry into the war, this use of civilians in war zones was not practical. International law did not permit civilians to engage the enemy if attacked; the penalty could be as severe as classification as guerillas and potential execution.

Logistics dictated that advance bases in the Pacific would be required to successfully carry out the war effort, and there were none. Leaders of the Navy, specifically Rear Admiral Ben Moreell, recognized this problem and decided the best course of action would be to establish Navy construction units. On December 28, 1941, he requested authority from the Bureau of Navigation to recruit men with construction experience and enlist them in the Navy; on January 5, 1942 he was granted this authority.

The first Seabees were not typical sailors. They were drawn directly from the civilian construction trades with extensive experience on projects including the Boulder Dam, national highways, and New York skyscrapers. In this case, with experience came age; the allowable range for enlistment was 18-50, but numerous men older than 60 snuck through, and the average age of Seabees early in the war was 37.[1]

On March 5, 1942, the first Construction Battalion was formed (the term Seabees is derived from the initials of these groups). Rear Admiral Moreell, generally regarded as the "Father of the Seabees", also provided the official motto for the Seabees, *construimus batuimus*, "We Build, We Fight." As the motto indicates, while the primary mission of the Seabees is to build, they are also trained to defend themselves and their projects.

Throughout World War II, the Seabees distinguished themselves. From Guadalcanal to Okinawa, they went ashore with U.S. Marines and built airstrips and bases; in Europe they took part in amphibious invasions from Sicily to Normandy. Throughout their history the Seabees have excelled during both wartime and peacetime operations.

1.1.2 History of the Civil Engineer Corps

In the early history of the Navy, there were not uniformed civil engineers in the Navy; the Secretary of the Navy appointed civilians to perform this function. These engineers supported the Navy's shore establishment as members of organizations known as the Board of Navy Commissioners, the Bureau of Navy Yards and Docks, the Bureau of Yards and Docks, and ultimately the Naval Facilities Engineering Command.

On 2 March 1867, Congress passed an act that provided that the Navy's civil engineers should be commissioned by the President, by and with the consent of the Senate. This legislation signaled the birth of the Navy Civil Engineer Corps. When the Construction Battalions were established in 1942, the Navy was confronted with the problem of who should command them. Regulations restricted the command of enlisted troops to line officers, and the Civil Engineer Corps (CEC) was a staff officer community. Nevertheless, the officers in the CEC possessed the requisite qualifications and experience to lead the construction forces in accomplishing their mission. Rear Admiral Moreell presented his case to the Secretary of the Navy, and despite resistance from line officers, the Secretary gave authority on March 19, 1942 for Civil Engineer Corps officers to command personnel assigned to construction units.

This was a very important event in the history of both the Civil Engineer Corps and the Seabees. It guaranteed qualified and experienced leadership for the Seabees in construction units, and established a very important mission area for CEC officers, the opportunity to command troops in military operations. This synergistic relationship has greatly contributed to the success of both groups, and they are now inextricably linked.

1.2 Focus Areas

This paper focuses on three main areas: network centric warfare, engineer reconnaissance, and information technology applications. Network centric warfare and network centric operations are a new paradigm that could lead to a transformation of the Department of Defense. These concepts provide a framework for analyzing the state of the practice in military engineer reconnaissance versus the state of the art in information technology, including geographic information systems, collaborative design, and wireless communications. Recommendations will be made to leverage applications from the state of the art to improve the state of the practice.

1.3 Hypothesis

The Naval Construction Force has traditionally depended on outside sources to obtain and analyze engineering data in contingency situations. They have embarked on an initiative to develop Seabee Engineer Reconnaissance Teams to perform this function, both as a basis for projects slated for in-house construction and as a product to deliver to other organizations. Exercises thus far have shown that the concept is viable, but they have encountered problems with data gathering and reporting and transmission of data and images. This paper will suggest a methodology to enable shared situational awareness, with a brief discussion on the implications for decentralized decision-making. The hypothesis of this research is:

Concurrent with the development of their Seabee Engineer Reconnaissance Team initiative, the Naval Construction Force must adopt a new information-sharing paradigm and leverage information technology to enable network centric engineer reconnaissance operations.

1.4 Research Approach

A thorough literature review in combination with case study methodology was used to identify and examine the feasibility of transferring commercial information technology applications to improve the practice of military engineer reconnaissance. Established Army doctrine was reviewed along with draft tactics, techniques and procedures for Navy SERT units to obtain a baseline understanding of their processes. Observations, lessons learned, and after action reports from exercises and operations were examined to identify successes and areas for improvement. Commercial information technology applications were reviewed and solutions in the areas of geographic information systems, collaborative design, and wireless communications were selected for their potential to enable network centric engineer reconnaissance operations.

Chapter 2 Network Centric Warfare

The term Network Centric Warfare was first introduced to a wide audience in 1998 in the *Proceedings of the Naval Institute.* The article, "Network Centric Warfare: Its Origins and Future," described a new way of thinking about military operations in the Information Age and highlighted the relationship between information advantage and competitive advantage.[2]

Network Centric Warfare is a concise way to describe a broad class of military operations that are enhanced by networking the force. Networking the force must go beyond providing physical connectivity among components; it must also extend to the development of doctrine and associated tactics, techniques, and procedures that enable forces to leverage an information advantage into a competitive advantage.

The terms Network Centric Operations and Network Centric Warfare are the military's parallel to the terms "e-business" and "e-commerce".[3] Similar to the wide range of business activities that have either been enabled or enhanced by the Internet, the Department of Defense intends to exploit advances in information technology to transform the force and gain competitive advantage in future operations.

2.1 Joint Vision 2020

As the name implies, Joint Vision 2020 is a planning document for the Department of Defense that proposes as an overall goal "the creation of a force that is dominant across the full spectrum of military operations---persuasive in peace, decisive in war, preeminent in any form of conflict."[4] Network Centric Warfare is a warfighting concept that allows the *Joint Vision 2020* operational capabilities to be achieved. It is a maturing approach to warfare that is specifically designed to achieve the multi-dimensional integration and synergies necessary to realize DoD transformation goals.

2.2 Congressional Direction

Section 934 of the Defense Authorization Act for Fiscal Year 2001 (Public Law 106-398) required the Secretary of Defense to report to Congress on the progress of the implementation of Network Centric Warfare (NCW). Specifically:

SEC 934. NETWORK CENTRIC WARFARE

1. Findings. Congress makes the following findings:
   (a) Joint Vision 2020 set the goal for the DoD to pursue information superiority in order that joint forces may possess superior knowledge and attain

decision superiority during operations across the spectrum of conflict.

(b) One concept being pursued to attain information superiority is known as NCW. The concept of NCW links sensors, communication systems, and weapons systems in an interconnected grid that allows for a seamless information flow to warfighters, policy makers, and support personnel.

(c) The Joint Staff, the Defense Agencies, and the military departments are all pursuing various concepts related to NCW.

2. Goal. It shall be the goal of DoD to fully coordinate various efforts being pursued by the Joint Staff, the Defense Agencies, and the military departments as they develop the concept of NCW.

3. Report on NCW. The Secretary of Defense shall submit to the congressional defense committees a report on the development and implementation of NCW concepts within the DoD. The report shall be prepared in consultation with the Chairman of the Joint Chiefs of Staff.

The Department of Defense responded by submitting the required report to Congress on July 27, 2001, wherein, "The Department recognized that this direction by the Congress provided an opportunity not only to assemble a comprehensive report on its thinking and activities related to NCW, but also to stimulate a continuing dialogue both within DoD and between DoD and the Congress on this subject."[5]

2.3 Network Centric Warfare Value Chain

All network-centric concepts share the same simple, yet powerful idea: information sharing is a source of potential value. Michael Porter, noted author and professor at the Harvard Business School, states that the information revolution is affecting competition in three vital ways:[6]

- It changes industry structure and, in so doing, alters the rules of competition.
- It creates competitive advantage by giving companies new ways to outperform their rivals.
- It spawns whole new businesses, often from within a company's existing operations.

In his book *Competitive Advantage*, Porter also suggests a methodology to evaluate a company's activities that he calls the "value chain." The value a company creates is based on the "value activities" it performs and the linkages between these activities. Figure 2-1 is a graphical representation of the Network Centric Warfare value chain.[7] This figure places the NCW value chain in the context of the domains of warfare and relates Information Superiority, Decision Superiority, and Full Spectrum Dominance.

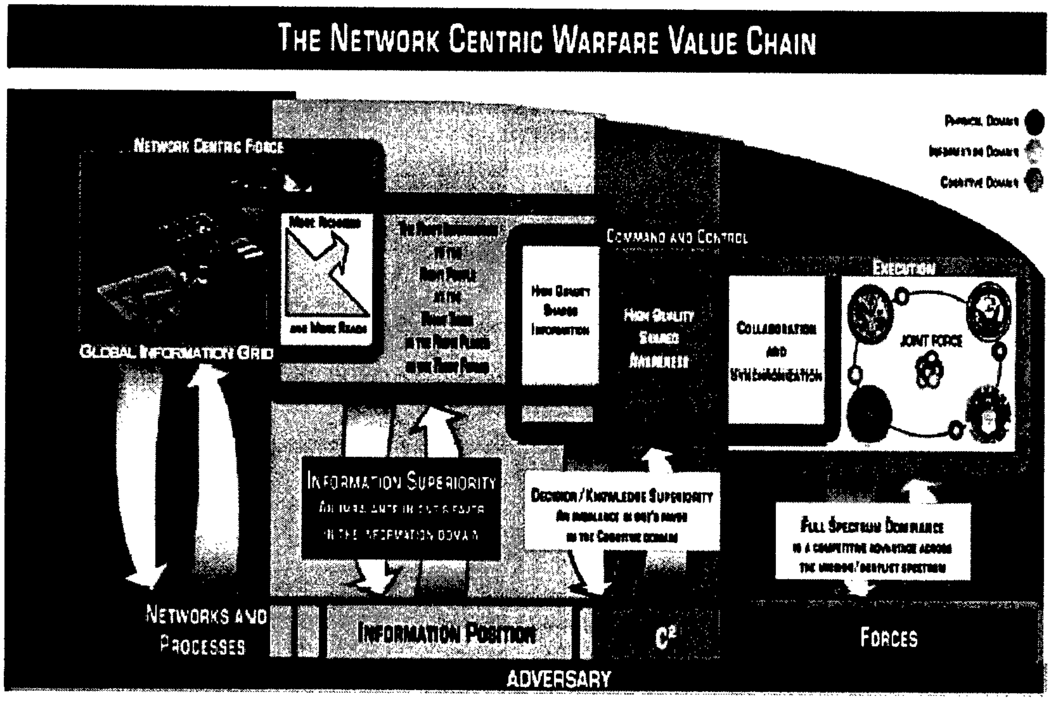


Figure 2-1 Network Centric Warfare Value Chain

2.4 Networking and the Information Domain

The information domain can be characterized in terms of the broad attributes of information richness and information reach.[8] Broadly speaking, information richness is a measure of the quality of information, and information reach is a measure of the degree to which information can be shared.

Network Centric Warfare allows the force to achieve an asymmetric information advantage. This information advantage is achieved, to a large extent, by allowing the force access to a previously unreachable region of the information domain, the network-centric region, which is broadly characterized by both increased information richness and increased information reach, as portrayed in Figure 2-2.[9]

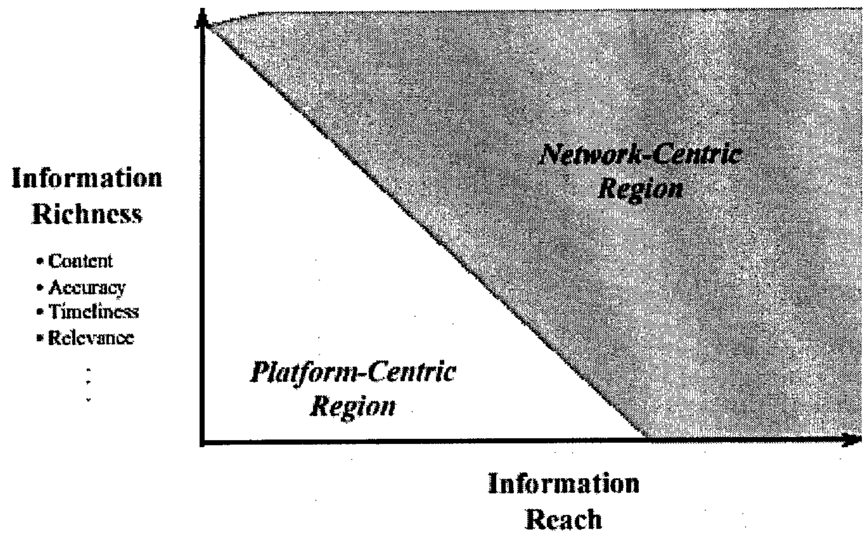


Figure 2-2 Network-Centric Region of the Information Domain

Operating in this network-centric region of the information domain allows warfighters to achieve information positions not previously feasible and, as a result, to develop a *new type of information advantage* previously unattainable. This new "network-centric information advantage" is portrayed in Figure 2-3 in comparison to both the "adversary information position" and the "platform-centric information advantage" currently achieved.[10]

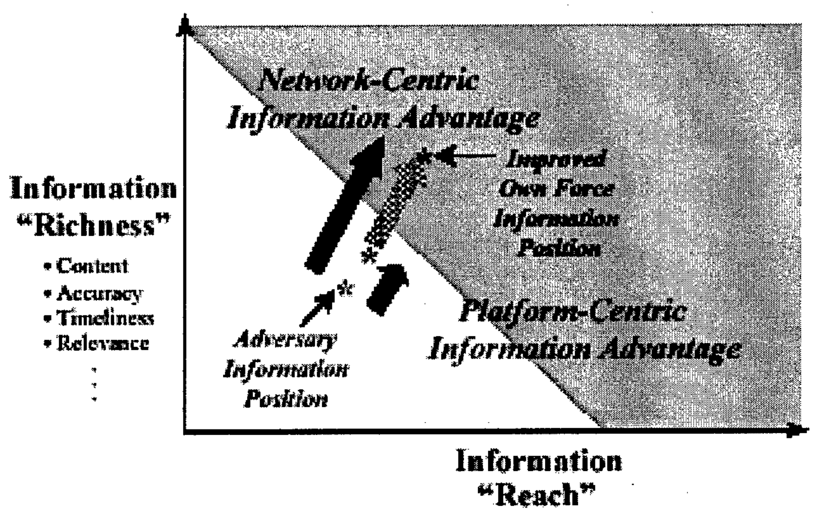


Figure 2-3 Network-Centric Information Advantage

NCW is predicated upon dramatically improved capabilities for information sharing. When paired with enhanced capabilities for sensing, information sharing can enable a force to realize the full potential of dominant maneuver, precision engagement, full dimensional protection, and focused logistics.

2.4.1 *Information Superiority*

Joint Vision 2020 states that information superiority is fundamental to the transformation of the operational capabilities of the Joint force. It acknowledges that there is an ongoing "information revolution" that is forever changing the information environment, thereby necessitating profound changes in the conduct of military operations. *Joint Vision 2020* characterizes information superiority as having the following attributes:[11]

- A state of imbalance in one's favor in the information domain
- State of imbalance is potentially transitory in nature
- State of imbalance is enabled, in part, by information operations
- Information contributing to this state is not perfect; the "fog of war" is reduced, but not eliminated

2.4.2 *Decision Superiority*

Joint Vision 2020 recognizes that an information advantage can be effectively translated into a competitive advantage when it enables commanders and their forces to arrive at better decisions and implement them faster than an opponent can react. In a noncombat situation, this capability to make decisions at an increased tempo allows the force to shape the situation or react to changes and accomplish its mission. These collective capabilities are referred to as "decision superiority."[12]

Decision superiority does not automatically result from information superiority; organizational and doctrinal adaptation, relevant training and experience, and the proper command and control mechanisms and tools are equally necessary. Decision superiority does result from superior information filtered through experience, knowledge, training, and judgment. It is also important to highlight that decision superiority does not stop at the commanders' level; it encompasses the entire force and their ability to make better decisions.

2.4.3 *The Global Information Grid*

The framework for achieving this capability to operate in the network-centric region of the information domain is known as the Global Information Grid, "...the globally interconnected, end to end set of information capabilities, associated processes, and people to manage and provide information on demand to warfighters, policy makers, and support personnel."[13]

The Global Information Grid (GIG) will help enable Network Centric Warfare and Network Centric Operations by improving information sharing among all elements of a Joint force, and with Allied and coalition partners. This improved information sharing provides the basis for shared situational awareness and enhanced command and control of forces. The success of the GIG will depend in large part on how well it helps achieve fully interoperable forces by connecting today's islands of interoperability to allow force-wide information sharing.

The GIG will also help facilitate information exchange with diplomatic and law enforcement communities as well as with non-governmental and private organizations. DoD needs to be able to work with these organizations across the spectrum of conflict: during planning, execution, and post-execution phases in support of a variety of missions.

The role of the GIG in enabling NCW, Information Superiority, Decision Superiority, and ultimately the full spectrum dominance proposed in *Joint Vision 2020* is portrayed in Figure 2-4.[14]

Figure 2-4 The GIG as an Enabler

2.5 Prerequisites for Network Centric Warfare

A broad overview of network-centric concepts has thus far been presented. However, many details will need to come together to see the concept implemented, as network-centric capabilities:

- Involve new ways of thinking about how task and missions can be accomplished
- Change organizational roles and responsibilities
- Require that information be shared outside of existing communities
- Depend, in part, upon the development of new technologies
- Require a better understanding of how to create, share, and exploit awareness
- Create combat and operational value in new ways

It will not necessarily be easy to implement these changes in a bureaucracy as large as the Department of Defense. Therefore, to make NCW a reality, a number of conditions must exist, including a climate that fosters disruptive innovation, an infostructure that is robustly networked to support information sharing and collaboration, an appropriate technology base, an improved understanding of related issues, and a way of analyzing and assessing network-centric capabilities.[15]

2.6 Department of Defense Transformation

It was no mistake that the authors of the DoD's report chose to use the term "disruptive innovation" when discussing the conditions necessary to implement NCW. In numerous publications including *The Innovator's Dilemma*, Clayton Christensen has introduced two types of innovation in business: sustaining innovation and disruptive innovation.

Sustaining innovation gives customers something more or better in product attributes they already value. Most successful companies, at one time or another, become very good at sustaining innovation, because they must continuously innovate to develop new products to remain viable. In the process of becoming successful, companies develop processes and rules for allocating resources and for deciding how big a market needs to be to be worth pursuing. Consequently, only products or services that are perceived able to contribute directly to achieving this level of sales or to provide required profit margins are viewed as worth pursuing.

As a result of this decision logic, technology innovations that don't meet these criteria are not pursued or developed by large companies.[16]

Disruptive innovation, on the other hand, introduces a different group of attributes from those that mainstream customers value. Disruptive technologies generally underperform established products when measured with traditional value metrics, but have other features valued by small market segments. A key feature of disruptive technologies is that initially there is a great deal of uncertainty regarding the size and attributes of the potential market. As a result, in the judgment of mainstream market decision-making, the initial market opportunity is either viewed as inadequate to meet the growth needs of large companies or perhaps even non-existent. This phenomenon generates a key insight into how one can begin to cope with the management struggle required as an organization searches for ways to sustain market leadership in a changing market environment. The inability to recognize and deal effectively with disruptive innovation can have significant consequences. In a number of industries, many companies have floundered and gone out of business, are currently in the process of floundering, or have floundered and been acquired because they were unable to deal effectively with challenges posed by disruptive innovation.[17]

One of Christensen's key findings is that the competencies that organizations develop in becoming successful at sustaining innovation create impediments to disruptive innovation. The Department of Defense has very good platforms and weapons, and works to continuously perfect them, as evidenced by the development of stealth planes and precision weapons. Senior leaders who have progressed through the military's structured chain of command and are comfortable with the organization's values are those in charge of acquisition of major systems. These personnel logically make budgeting and resource allocation decisions based on their experience, thus promoting sustaining innovation.

If the current DoD transformation were about sustaining innovation, no major policy, process, strategy, or organizational changes would be required; platform-centric warfare could continue. However, the principal component of this transformation is information, and advances in information technologies are enabling operations in a new part of the information domain that create opportunities to do things differently. While many in the DoD agree that a transformation is necessary, the term does not mean the same thing to everyone. In the Quadrennial Defense Review, the Secretary of Defense defined the terms transformation and modernization:

- *Transformation*: the evolution and deployment of combat capabilities that provide revolutionary or asymmetric advantages to our forces.
- *Modernization*: the replacement of equipment, weapons systems, and facilities in order to maintain or improve combat capability, upgrade facilities, or reduce operating costs.

The DoD report to Congress suggests "the appropriate application of IT, in conjunction with other technologies (such as stealth and precision weaponry), can both modernize the force ***and*** enable changes in the way the armed forces operate. With this premise, it is clear that a DoD transformation that leverages IT, by necessity, must involve not only adapting to new systems capabilities but also developing new paradigms for their use."[18]

2.7 Infostructure

Just as the commercial sector required a critical mass of connectivity, computers, and customers to successfully innovate with e-business solutions, DoD requires a similar critical mass of integrated communications and computing capability. The ability to conceive of, experiment with, and implement new network-centric ways of doing business that leverage the power of Information Age concepts and technologies depends upon what information can be collected, how it can be processed, and the extent to which it can be distributed throughout the organization. The ability to bring this capability to war will depend upon how well it can be secured and upon its reliability. The DoD requires an infostructure that is secure, robustly networked, seamless, and coherent; that has access to required radio frequency spectrum; that has built-in security; that supports Joint and coalition operations; that is able to generate synergy between the Revolution in Business Affairs (RBA) and the Revolution in Military Affairs (RMA); that leverages commercial technology and accommodates evolution, and that can exploit space-based capabilities.[19]

2.7.1 Security Built In

The ability to protect information, systems, programs, people, and facilities in a risk management environment directly impacts the ability to successfully prosecute the military mission. Security, like interoperability, must be engineered into systems from the beginning to be effective and affordable. The forging of a coherent infostructure out of many legacy systems poses a significant challenge in this regard. The ability to maintain security as information transits system interfaces is the key. DoD's continuing migration from analog to digital systems will facilitate these efforts. However, there will always be legacy systems and systems that coalition partners bring to the table that do not have adequate security. DoD is exploring ways to deal with these exceptions; however, these will most likely limit the functionality and utility of these non-conforming systems.

2.7.2 Robustly Networked

The robustness of the infostructure is dependent on sufficient connectivity and bandwidth. The explosive growth of cell phones, the Internet, and personal digital devices (PDAs) has increased competition for bandwidth in general, and radio frequency spectrum in particular. Access to adequate radio frequency spectrum for data transport like satellite links, wireless networks, and mobile communications systems is essential for DoD to operate effectively on a global basis. Spectrum limitations will adversely impact the ability of DoD to carry out Network Centric Operations. To ensure access to adequate spectrum in the short term, DoD must articulate the spectrum requirements associated with current operations and work with national and international forums and individual nation states to secure the required spectrum. For the longer term, DoD must conduct research into better ways to utilize spectrum, identify spectrum requirements necessary to support mature Network Centric Operations, and work with others to ensure that spectrum is allocated in a way that does not adversely impact DoD ability to carry out its assigned missions.

2.7.3 Seamless and Coherent

To facilitate the end-to-end flow of information throughout the DoD necessary to support Network Centric Operations, information processes must be transparent to users. To accomplish this, DoD systems must transition from isolated stovepiped environments to a seamless and coherent infostructure. Creating this requires the establishment of a Department-wide mechanism for gaining visibility into the many separate planning, budgeting, acquisition, operations, and maintenance activities that contribute to DoD's information systems and processes. DoD's Global Information Grid is designed to achieve this by creating a DoD-wide network management solution, comprised of enterprise network policies, strategies, architectures, focused investments, and network management control centers that bring order out of the currently highly fragmented Service-centric DoD information infrastructure.

2.7.4 *Born Joint and Combined*

Future operations will be Joint and Combined. Their effectiveness will depend upon the ability of DoD to share information and to collaborate externally as well as internally. Therefore, interoperability is a key parameter in all DoD operational and systems architectures. Experience has shown that retrofitting interoperability is costly, does not satisfy mission requirements, and creates security problems. Born Joint and Combined systems, achieved by engineering in interoperability attributes from the start, will provide the needed capabilities more economically and without the vulnerabilities created by retrofitting.

2.7.5 *Revolution in Business Affairs (RBA) and Revolution in Military Affairs (RMA) Synergy*

The DoD is undergoing twin revolutions driven by the concepts and technologies of the Information Age. The RBA, modeled on the successes experienced in the commercial sector, is transforming the business side of DoD while the RMA, based upon adapting lessons from other domains to the domain of warfare, is transforming military operations. These are not independent revolutions. Transformations in the business side not only free up resources that can be more highly leveraged by combatant commands, but also provide improvements in combat support that enable more effective concepts of operation, organization, and doctrine.

2.7.6 *Leverages Commercial Technology*

The engine driving advances in IT is in the commercial sector. Commercial firms are adopting information technologies and finding new ways to create competitive advantages that leverage IT. The DoD benefits from the enormity of the commercial IT market because its scale drives down the costs of off-the-shelf capabilities and fuels an unprecedented rate of improvement in cost and performance. As a result, DoD now can reap the benefits of private sector investments, thus saving scarce Research and Development dollars to invest in militarily significant areas that the commercial sector is not addressing. Furthermore, adopting commercial standards and leveraging COTS capabilities makes it easier to achieve and maintain desired levels of interoperability. There are, of course, some drawbacks in this role reversal. In the past, government led the way in new information technologies and was able to control the most sensitive of them. Now the latest technology is available to potential foes and Allies alike. With rapidly changing commercial innovation now the source of the latest breakthroughs, DoD is no longer master of the course that technology takes. DoD therefore must learn to work closely with industry to ensure that the Department's requirements can be satisfied and can influence industry's future technology developments.

2.7.7 *Accommodates Evolution*

Change is the constant of the Information Age. DoD infostructure therefore must be designed to accommodate change as both requirements and as technology evolves. A comprehensive strategy that consists of appropriate architectures, standards, design principles, configuration management, and regression testing will be incorporated into DoD's infostructure processes.

Experience shows that advances in technology do not automatically translate into cost-effective applications. In fact, it takes a great deal of time and effort to understand operational implications of advances in information technologies, develop military Concepts of Operations and modify doctrine, organization, training, materiel, leadership, personnel, and facilities to exploit new capability. Thus, while investments in IT are necessary to achieve Information Superiority, these investments are not in and of themselves sufficient. Achieving Information Superiority requires a close partnership between technologists and warfighters, and a balanced set of investments that ensure that each of the elements of Information Superiority is adequately addressed.

2.8 Enabling Network Centric Warfare

The capability to conduct NCW depends upon the ability of a critical mass of the force being able to conduct Network Centric Operations. While it has been estimated that only a relatively small portion of the force needs to have this capability to produce a qualitative effect on the battlefield, the network-centric portion of the force must be comprised of the right functional elements. Getting the greatest benefit from a network-centric capability often requires that portions of the force that currently do not work closely together, or work together in an arms length, sequential fashion, need to be part of the network-centric team to enable a new way of doing business: one that is more dynamic and collaborative. First this requires recognition that there may be a better way. Often this recognition comes about only after individuals and organizations have hands-on experience in exchanging information with others. The existence or absence of the following set of enablers strongly influences the nature of the network-centric capabilities that are likely to be developed: connectivity, technical interoperability, sense making (semantic interoperability), integrated processes, integrated protection, and network-ready battlespace enablers.[20]

2.8.1 Connectivity

If you have access to the "net," then you can be a player. But connectivity takes on different forms and one's level of participation is limited by the nature of the connectivity that exists across the set of mission participants. Voice connectivity, for example, significantly restricts the richness of the exchange while data connectivity enhances the ability of distributed parties to exchange information and to collaborate with one another.

2.8.2 Technical Interoperability

Technical interoperability exists at a variety of levels that affect the nature of the "conversation" that can take place. There is a huge difference between the ability to send messages back and forth and the ability to directly update databases that feed Common Operational Pictures. In general, these differences affect the amount of time it takes and the number of people that need to get involved to affect an exchange of information. The more time and human resources involved, the less responsive the resulting process.

2.8.3 Sense Making (Semantic Interoperability)

Network Centric Warfare is based upon the ability of a force to develop shared situational awareness. Technical interoperability will enable the information to be correctly represented in distributed systems, but does not ensure that the individuals in different locations, in different organizations, at different echelons have a similar understanding even though they "see" the same thing. With the added complexity of coalition operations that involve different cultures, the problem is greatly compounded. Semantic interoperability is the capability to routinely translate the same information into the same understanding. This is, of course, necessary to develop the shared situational awareness upon which mature forms of Network Centric Warfare are based.

2.8.4 Integrated Processes

Sharing information and collaboration are two different things. One "shares" information in a sequential process that passes output from one stage to the next. This can be contrasted with a collaborative process in which the product is formed and developed as a result of continuous interactions among key participants. Collaborative planning is such an application. Integrated processes are essential ingredients for mature network-centric applications.

2.8.5 Integrated Protection

In a network-centric environment, security is only as good as the weakest link. Since security is essential to warfighting operations, a lack of integrated protection will constrain network-centric applications and/or organizations individually.

2.8.6 Network-Ready Battlespace Enablers

A "net" without its nodes has no potential value. Nodes that are not connected or have limited connectivity (even with all of the enablers previously discussed) have limited value. In a platform-centric environment, the potential value of adding or enhancing an entity that is not a node is additive. The potential value of a force is the sum of the potential value of its entities, which in turn is heavily dependent on the nature of the "net" that connects them. A robust, interoperable network adds value to each and every one of its nodes. Hence the potential value of improvements to the capabilities of the network (interoperability, robustness, services provided, etc.) is multiplicative. When nodes are "net-ready," that is, when they are capable of fully interacting with other nodes on the net, the potential value that they contribute is also multiplicative.[21]

2.9 Mission Capability Packages

The notion of a Mission Capability Package (MCP) is central to the development of NCW capabilities. A mission capability package consists of an operational concept and associated command concepts, doctrine, organizational arrangements, personnel, information flows, systems, materiel, education, training, and logistics; that is, everything needed to make the concept work in an operational setting. Network-centric MCPs always start as ideas for how things could be done, or MCP concepts. The process the DoD will use to take NCW concepts from ideas to fielded operational capability is depicted in Figure 2-5.[22]

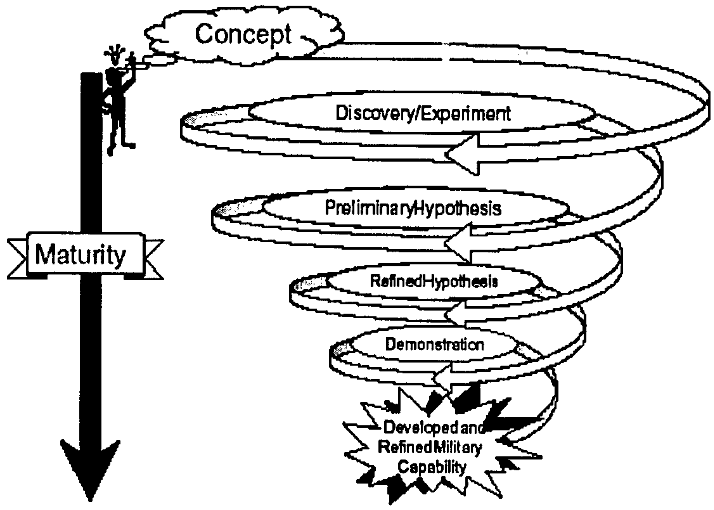


Figure 2-5 Mission Capability Package Development

Development of MCPs will be an iterative process, as represented in Figure 2-6.[23] Each iteration increases in the degree to which it corresponds to reality and, correspondingly, the cost of the iteration and the time needed to accomplish it. Ideas for MCPs can and will be rejected and/or refined at each stage of this process. The concept moves to three main phases on its way to a field capability: concept development, concept refinement, and MCP implementation, as analysis, modeling, and simulation give way to different types of experiments and eventually to exercises and demonstrations. Progress may not be linear. MCPs may need to return to previous stages when they are significantly modified or potential problems are identified.

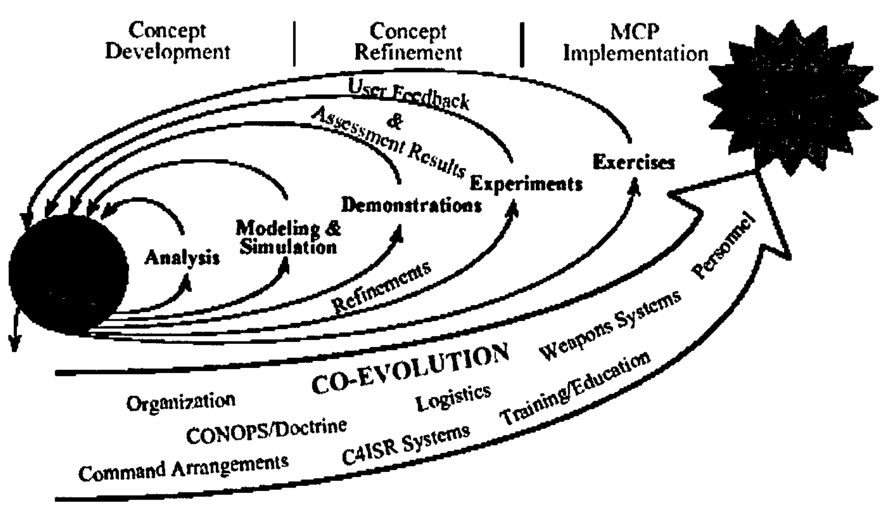


Figure 2-6 Iterations of Mission Capability Package Development

2.10 Co-Evolving the Infostructure

Co-evolution refers to a process through which simultaneous changes or modifications take place in an ecosystem or system. In a warfighting context, technology, organization, and process must co-evolve with each other to achieve dramatic changes in warfighting effectiveness. The strategy that the Department of Defense will use to co-evolve the infostructure capabilities to support emerging network-centric capability packages is based upon the following:[24]

- *Creating awareness.* The development of a widespread understanding of why the DoD is moving towards NCW and what this means in terms of the nature of the infostructure necessary to support these capabilities
- *Changing Priorities.* Increasing the importance of connectivity and interoperability as critical performance factors in the design and acquisition of command and control and weapons systems
- *Increased Visibility.* Creating an annual report on the status of the infostructure
- *Improved Oversight.* Moving from a system that is program-centric to one that examines portfolios of infostructure-related capabilities

2.11 Evolution of NCW Concepts and Applications

DoD's strategy for developing and implementing network-centric concepts recognizes that the network centric capabilities that are fielded not only need to continuously co-evolve over time, adapting to new threats and opportunities, but also will continue to become "mature." There can, and will be, many instantiations of NCW. As experience is gained with these applications of theory, both the theory and the practice will mature. At this point in time, the majority of work is being devoted to networking the force and to improving the quality of the information from which situational awareness is derived. Other efforts are trying to come to grips with how to adapt traditional command and control processes to take advantage of vastly improved shared situational awareness. Efforts are beginning to explore new ways of synchronizing actions that could replace traditional notions of command and control. As time goes by, it can be expected that the mix of these efforts will change to be more heavily weighted toward those that are exploring new ways of achieving synchronized effects, including efforts exploring ways that redefine existing missions.[25]

2.12 Department of Defense Network Centric Warfare Goals

In Section 934 of Public Law 106-398, Congress calls for, among other things, "the methodology being used to measure progress toward stated goals." DoD's NCW-related goals are articulated in the Department's initial response to Congress on March 7, 2001 as follows:[26]

> "The Department is fully committed to creating a 21st Century military by taking advantage of Information Age concepts and technologies, particularly new 'business models' and information technologies. IT provided the building blocks for the Internet, radically restructured the economics of information, and enabled new ways of doing business that have created a 'new economy.' These same dynamics can help the Department transform its primarily platform-centric force to a network-centric force: a force with the capability to create and leverage an information advantage and dramatically increase combat power."

2.12.1 Joint Vision 2020 and the Army Vision

In addition to goals for the entire Department of Defense, Services described their vision for the implementation of Network Centric Warfare. The Army indicates, "information superiority, knowledge, and decision superiority are absolutely critical for their transformation to the Objective Force and are key to maneuver- and execution-centric operations."[27] Some examples are:

- Collaborative and simultaneous planning and execution among widely dispersed commanders and staff saves planning and travel time, allowing commanders to focus on information collection, decision making, and execution.
- Enroute mission planning and rehearsal among dispersed force elements prior to deployment, enroute, and in theater.
- Split-based operations reduces the number of staff and support personnel required to be deployed to theater thus reducing the associated Tactical Operations Center footprint.
- Virtual support services assist deployed forces from centers of knowledge in the continental U.S.
- Integrated and layered Intelligence, Surveillance and Reconnaissance (ISR) allows commanders, staffs and analysts worldwide to collaborate in the development of real time combat information and near real time, predictive intelligence products for the warfighter.

2.13 Maturity Scales for Network Centric Operations

The ability to conduct Network Centric Operations can vary from barely being able to execute the basics to a very sophisticated, professional-level mastery of the concepts and techniques. Therefore, it is important to be able to distinguish among different levels of maturity of the application of Network Centric Warfare theory. Network-centric applications can vary greatly in size and complexity, from single service squads at the tactical level to theatre-level Joint forces to coalition operations. To accurately measure progress, two scales are needed: the first to measure the level of maturity of a particular NCW application, and the second to measure the scope and complexity of the application that achieves selected levels of maturity.

2.13.1 Network Centric Operations Maturity Model

Figure 2-7 depicts a five-level maturity model for Network Centric Operations.[28] This model is an initial formulation of a micro-level metric that compares the basic features of an application (state of the practice) against the theory (state of the art).

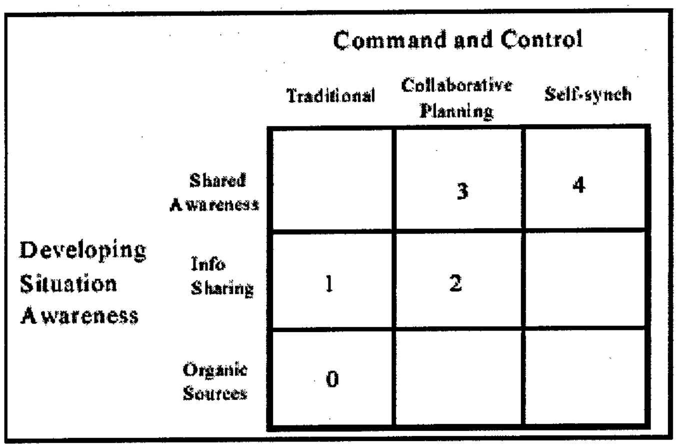


Figure 2-7 Network Centric Operations Maturity Model

Each of the values for the maturity of a network-centric warfighting capability is defined by considering these two aspects of network-centric behavior. The first, the process of developing shared situational awareness (SSA), is meant to be a reflection of the degree to which information and awareness are shared. The second, the nature of command and control, is meant as a surrogate for how SSA is leveraged.

Platform-centric operations anchor the Network Centric Warfare Value at Zero. At the other end of this scale (Value Four) are mature Network Centric Operations that involve widespread information sharing, the development of a fully integrated Common Operational Picture that promotes SSA, collaborative planning processes, and a self-synchronizing approach to command and control.

Moving from Value Zero (platform-centric operations) to NCW maturity Value One involves the ability to share information. Information sharing is assumed to be associated with improved awareness. Moving from Value One to Value Two involves the addition of some form of collaborative planning among the participants. Movement from Value Two to Value Three involves richer collaboration, involving more actors and integrating more aspects of the operation. In many cases, there is less communication among the participants because of the SSA achieved (though early in the process of learning to collaborate, there may be more, and cases have been reported where communication stays the same, but has richer content). Movement from Value Three to Value Four requires a Mission Capability Package that allows integration across doctrine, organization, training, material, and other aspects of the force and its supporting systems that permit self-synchronization.

The following chapters will explore, compare, and contrast the state of the practice and the state of the art in the area of engineer reconnaissance.

Chapter 3 State of the Practice: Military Engineer Reconnaissance

Reconnaissance is a crucial component of any well-executed military strategy. Engineer reconnaissance is but one piece of an overall reconnaissance and surveillance plan.

3.1 Army Engineer Reconnaissance

Established on June 14, 1775, the United States Army has a long and proud heritage. Throughout its existence, the U. S. Army has established doctrine, tactics, techniques, and procedures for all aspects of their operations that are described in great detail in documents known as Army Field Manuals (FM). The Field Manuals that pertain to engineer reconnaissance include FM5-170, Engineer Reconnaissance, FM5-34, Engineer Field Data, and FM 5-36, Route Recon and Classification. The following excerpts from FM5-170 highlight the need for reconnaissance and the mission of an engineer reconnaissance unit. [29]

> "The key to using combat power effectively is gathering information about the enemy and the area of operations (AO) through recon. A recon provides current battlefield information that helps a commander plan and conduct tactical operations. A recon greatly enhances maneuver, firepower, and force protection when properly executed.
>
> An engineer recon team's primary mission is collecting tactical and technical information for the supported or parent unit. The team must be able to perform this mission mounted or dismounted, during the day or at night, and in various terrain conditions."

The Engineer Reconnaissance Field Manual further expands on the subject by defining the capabilities of an engineer recon team:[30]

- Increases the supporting unit's recon capability concerning complex mine and wire obstacle systems, enemy engineer activities, and details of mobility along a route.
- Provides detailed technical information on any encountered obstacle.
- Conducts an analysis of what assets will be needed to reduce any encountered obstacle.
- Marks bypasses of obstacles based on guidance from the supported commander. This guidance includes whether to mark bypasses and in which direction the force should maneuver when bypassing an obstacle.
- Assists in gathering basic enemy information.
- Provides detailed technical information on routes (including classification) and specific information on any bridges, tunnels, fords, and ferries along the route.
- Assists in acquiring enemy engineer equipment on the battlefield.

- Assists in guiding the breach force to the obstacle to be reduced.

3.2 Navy Engineer Reconnaissance

Since its inception in World War II, the Naval Construction Force (NCF) has been dependent on other units and services to provide engineer and construction intelligence in order to plan operations during times of military conflict. However, the reconnaissance units providing the intelligence from the area of operations generally did not contain trained engineers or experienced construction personnel. Accordingly, the information received by the Seabee units did not always contain sufficient data to adequately plan for construction operations.

The NCF will address this problem through the formation of Seabee Engineer Reconnaissance Teams (SERT). A Seabee Engineer Reconnaissance Team's primary mission is "to collect engineering-oriented technical information for the supported or parent unit for tasking and design of construction projects. The team must be able to perform this mission mounted or dismounted, during day or night, and in various terrains and environments, and with a long-range communications capability."[31]

Rather than starting from scratch in describing the tactics, techniques, and procedures for these units, the Navy has decided to adopt the doctrine of the Army as described in their Field Manuals. While the principles are the same, the Navy will apply them more selectively as the range of missions will be more limited for the SERT units.

3.2.1 SERT Purpose and Fundamentals

Reconnaissance is an essential, continuous function conducted to collect information about the enemy and the battle space. Engineer reconnaissance of the battle space provides important information to the planners and decision makers of the Naval Construction Regiment (NCR), Naval Mobile Construction Battalion (NMCB), Marine Air Ground Task Force (MAGTF), and its elements. The role of engineers in reconnaissance and intelligence preparation of the battle space supports the commander's decision process in determining a course of action. Per the Commander's Intent, SERT will:[32]

- Provide the NCF with increased engineering capability to support MAGTF by capitalizing on Naval Facilities Engineering Command capabilities to provide real time engineering solutions to the battlefield.
- Provide NCF eyes forward to get "ground truth" construction & repair data early for

critical construction tasks, allowing for faster design solutions and sourcing of manpower, tools, equipment, and materials.

- Provide NCF greater maneuver capability to keep up with today's faster maneuver warfare. Provide data using reach back capabilities to solve complex engineering problems that can't be worked in the field, but require data from the field.

The senior engineer assigned to the engineer reconnaissance mission must clearly understand the mission and commander's guidance and know what is expected of his engineers during the reconnaissance. Also, he must be given the areas or points of concern to be reconnoitered and know what information he is expected to gather. Data collected through engineer reconnaissance should be treated the same as information collected by all other types of reconnaissance. This information must be conveyed to the supported unit commander along with the other data collected. It could be critical for the intelligence estimates being formed by the supported unit's staff.

3.2.2 Three Types of Engineer Reconnaissance Missions

Reconnaissance techniques achieve a balance between the acceptable level of risk and the security necessary to ensure mission accomplishment. This balance is often a tradeoff between speed and security. The faster the reconnaissance, the more risk a reconnaissance team accepts and the less detailed reconnaissance it conducts. Technical reconnaissance involves gathering detailed data that requires close, on-site observations and measurements. Examples of technical reconnaissance include precise measurements of metal girders on a bridge, the measurements for a tunnel, soil conditions, etc. Technical reconnaissance normally takes place during any of the three types of engineer reconnaissance missions: route, zone, and area.[33]

3.2.2.1 Route Reconnaissance

Route Reconnaissance is focused along a specific line of communications, such as a road, railway, or waterway, to provide new or updated information on route conditions and activities along the route. This ensures the commander has the latest information about the route's current condition, the existence of obstacles, and observed and potential problems (e.g., low areas subject to flooding, etc.). It also is intended to confirm the route's suitability for the types and numbers of vehicles to traverse it.

3.2.2.2 Zone Reconnaissance

Zone Reconnaissance is a direct effort to obtain detailed information concerning all routes, obstacles (to include chemical or radiological contamination), and terrain within a zone defined by boundaries. A zone reconnaissance normally is assigned when the enemy situation is vague or when information concerning cross-country trafficability is desired. The zone is a smaller, defined area within the area of operations (AO). Commanders normally assign a zone reconnaissance mission when they need information prior to traversing the zone with maneuver units or equipment. Engineers produce information about routes, cross-country trafficability, terrain, and obstacles. A zone reconnaissance is often most suited for gaining information about an AO where long term operations are anticipated or when information for possible future uses are required. Depending upon how much technical reconnaissance activity will be performed in the zone, commanders should anticipate that the engineer reconnaissance would be more time consuming than a typical non-engineering reconnaissance of the same size zone.

3.2.2.3 Area Reconnaissance

Area Reconnaissance is a directed effort to obtain detailed information concerning the terrain or AO, such as a town, ridgeline, woods, or other feature critical to operations. An area reconnaissance could be made of a single point, such as a bridge or installation. A SERT unit normally conducts an area reconnaissance to support operational plans with specific information about point or localized sites, or objectives.

3.2.3 <u>SERT Critical Tasks</u>

In carrying out their mission, the tasks most likely to be assigned to SERT units include:

- Route survey/trafficability
- Inspecting and classifying all bridges
- Inspecting and classifying all overpasses, underpasses, and culverts
- Locating bypasses around built-up areas, obstacles, and contaminated areas
- Battle Damage Repair

There are prescribed means and methods for gathering and reporting data for routes, bridges, overpasses, underpasses, culverts, and other items in the Army Field Manuals. Forms designed to help organize reconnaissance data (DA Forms 1248, 1249, 1250, and 1711) are included in Appendix A. The Navy has chosen to adopt these means and methods. Following are some descriptions of how this is accomplished.

3.2.3.1 Route Classification

Route classification is a tool that helps determine what loads of vehicles can travel along a route and how fast they may travel. After a route is reconnoitered the results are transferred to an overlay for display on a map. During war or military operations other than war, only the necessary and essential facts about a route are gathered as quickly and safely as possible. This information is placed on a route classification overlay and supplemented by additional reports. During area reconnaissance, detailed route classification missions are performed to obtain information for future use.

A route classification overlay depicts a route's entire network of roads, bridge sites, and other major features or points of concern. These items are reconnoitered and the data recorded as supporting documentation for the route overlay. A route classification gives details on what obstructions will impact the movement of personnel, equipment, and supplies along the route. A sample route classification overlay is shown in Figure 3-1.

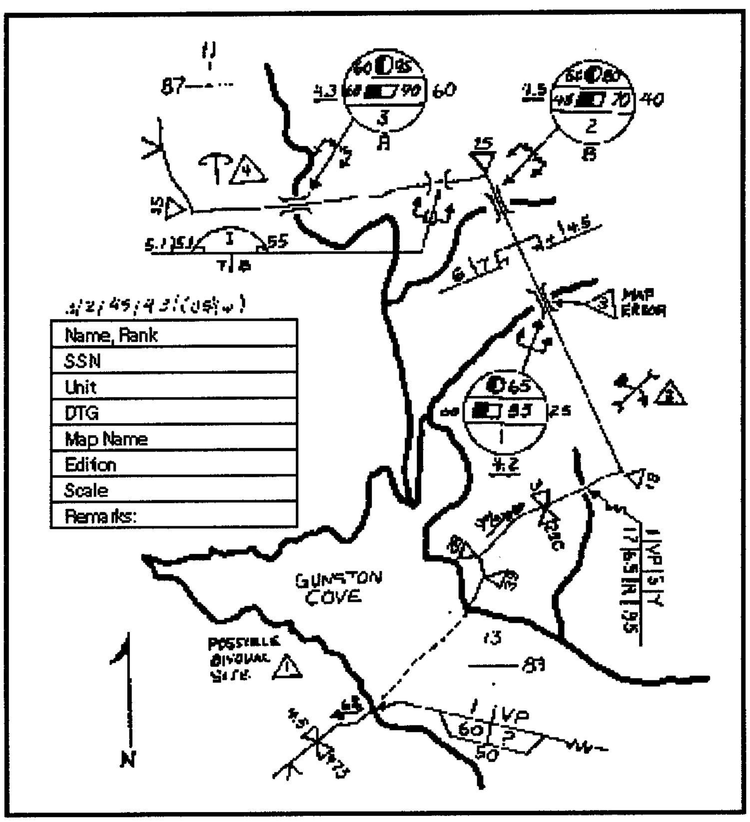


Figure 3-1 Route Classification Overlay

A route classification must include every alternate road on which movement can be made along the route, all lateral roads intersecting the route out to direct fire weapons range, the types of vehicles that can utilize the route, and the traffic load specific portions of the route can handle. Routes are classified by obtaining all pertinent information concerning trafficability and applying it to the route classification formula. The formula is recorded on the route classification overlay and consists of the following:

1. Route width
2. Route type (based on ability to withstand weather)
3. Lowest military load classification (MLC)
4. Lowest overhead clearance
5. Obstructions to traffic flow (OB), if applicable
6. Special conditions, such as snow blockage (T) or flooding (W)

Example:	5.5/	Y/	30/	4.6	(OB)	(T or W)
	(1)	(2)	(3)	(4)	(5)	(6)

Usually, the lowest bridge MLC (regardless of the vehicle type or conditions of traffic flow) determines the route's MLC. If there is not a bridge on the route, the worst section of road will determine the route's overall classification. Engineers perform road reconnaissance to collect technical data to determine the traffic capabilities of a road within a route. The load bearing capacity of a road for wheeled vehicles is determined by measuring the thickness of the surface and base course and determining the type of subgrade material (using the California Bearing Ratio), and comparing these figures with tables and charts provided in the Field Manuals.

3.2.3.2 Bridge Classification

Bridges are very valuable pieces of infrastructure in times of conflict. A bridge is evaluated in terms of two possible uses: to determine its load carrying capacity for use by friendly forces or to determine the best way to destroy it to deny use by the enemy. Bridges are normally the controlling factor in determining the viability of a given route segment, and their evaluation is critical. Because of the complexity of analyzing bridges, all bridge reconnaissance should be performed by engineers.

A systematic bridge reconnaissance obtains valuable data. DA Form 1249 (Figures A-5 and A-6) is the basic form used for the evaluation. It provides a structured framework that when used in conjunction with tables provided elsewhere in the Field Manuals yields a load capacity to assign to a bridge. Worksheets for classifying the six most commonly encountered types of bridges are included in Appendix B: Timber or Steel Trestle Bridge with Timber Deck, Steel-stringer Bridge with Concrete Deck (Noncomposite Construction), Concrete Steel-Stringer Bridge (Composite Construction), Concrete T-beam Bridge with Asphalt Wearing Surface, Concrete Slab Bridge with Asphalt Wearing Surface, and Masonry-Arch Bridge. Bridge information is recorded on a map or overlay by using the full NATO bridge symbol (see Figure 3-2).

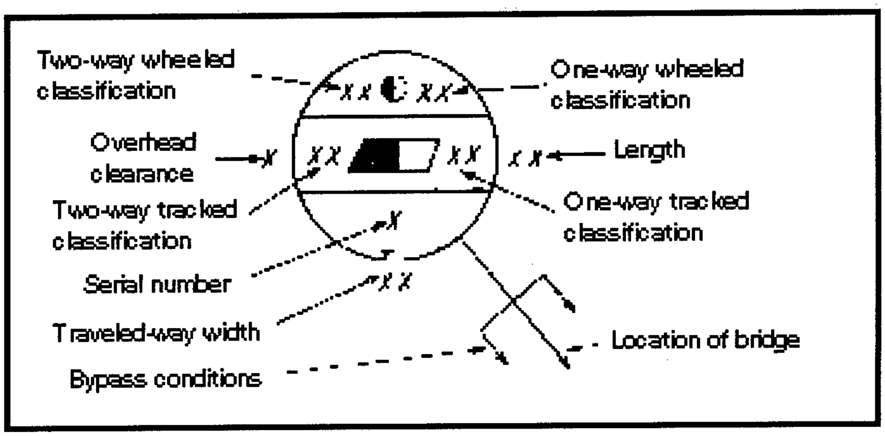


Figure 3-2 Full NATO Bridge Symbol

The NATO symbol is intended to convey all necessary information in a concise, standardized method. The bridge symbol contains the following:

- Bridge Serial Number: A bridge serial number is assigned for future reference and is recorded in the symbol's lower portion. The number is either assigned according to the unit's Standard Operating Procedures or taken directly from the bridge's data plate.
- Geographic location: The bridge's geographic location is shown by an arrow extending from the symbol to the exact map location.
- Military Load Classification (MLC): This number indicates the bridge's load carrying capacity; classifications for both single and double flow traffic are included. In those instances where dual classifications for wheeled and tracked vehicles exist, both classifications are shown.
- Overall length: The bridge's overall length is the distance between abutments, measured

along the bridge's centerline.

- Minimum lane width: The minimum lane width is the clear distance between curbs. Bridges may be an obstruction to traffic flow because the traveled-way width of the overall route may be reduced by the width of the bridge.
- Overhead clearance: Overhead clearance is the minimum distance between the bridge's surface and any obstruction above it. Any overhead clearance less than 4.3 meters is shown as an obstruction in the route-classification formula.
- Available Bypasses: Any detours available to avoid the bridge are shown here. Bypasses are covered in more detail later in this section.

3.2.3.3 Underpass and Tunnel Classification

Underpasses and tunnels are also critical to the route classification process, as they can be constrictions that require bypasses.

An underpass is depicted on a map or overlay by a symbol that shows the structure's ceiling. It is drawn over the route at the map location. The width is written to the left of the underpass symbol, and the overhead clearance is written to the right of the symbol (see Figure 3-3).

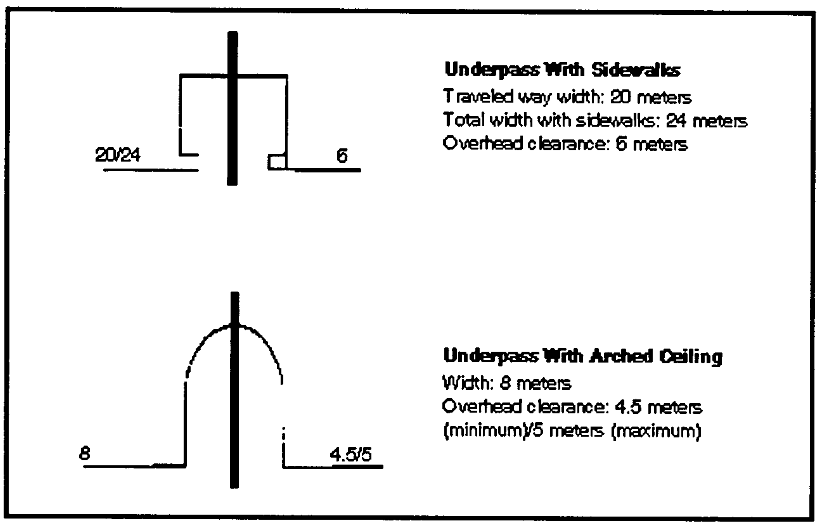


Figure 3-3 Underpass Symbols

A tunnel is an artificially covered or underground section of road along a route. A tunnel reconnaissance determines essential information, such as the serial number, location, type, length, width (including sidewalks), bypasses, alignment, gradient, and cross section. Basic tunnel information is recorded on maps or overlays using symbols (see Figure 3-4).

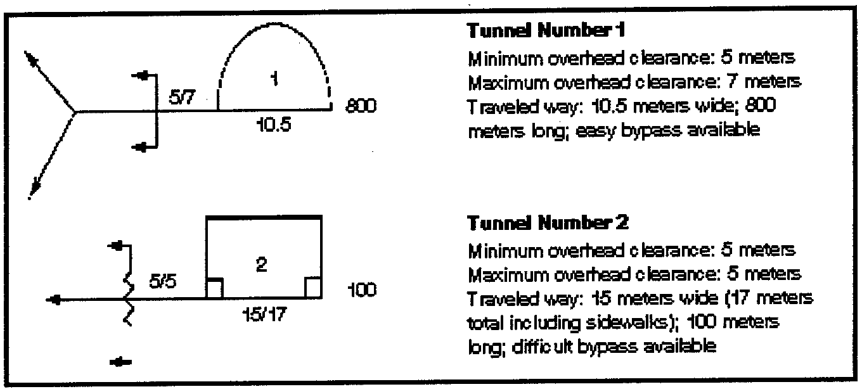


Figure 3-4 Tunnel Symbols

The location of the tunnel entrance is shown on a map or overlay by an arrow from the symbol to the location of the entrance. For long tunnels (greater than 30.5 meters), both tunnel entrance locations are indicated. Similar to bridges, a serial number is assigned to each tunnel, and the number is recorded inside the symbol. The traveled way width is shown in meters and is placed below the symbol. Overhead clearance measurements are crucial when evaluating tunnels. Additional measurements as shown in Figure 3-5 are necessary to accurately classify the tunnel.

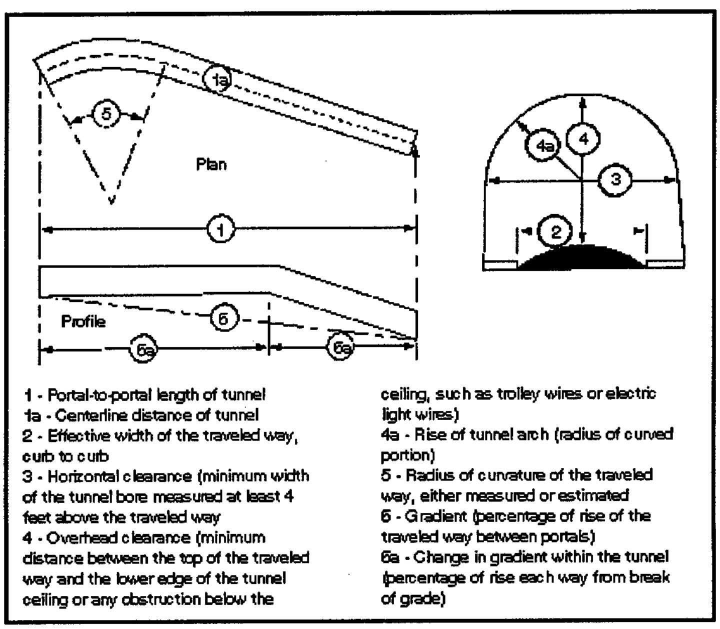


Figure 3-5 Dimensions Required for Tunnels

3.2.3.4 ***Bypass Classification***

Bypasses are detours along a route allowing traffic to avoid an obstruction. Bypasses are classified as easy, difficult, or impossible. Each type of bypass is represented symbolically on the arrow extending from the tunnel, ford, bridge, or overpass symbol to the map location (see Table 3-1).

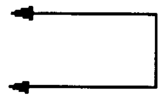
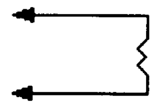
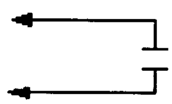
	Bypass easy. Use when the obstacle can be crossed in the immediate vicinity by a US 5-ton truck without work to improve the bypass.
	Bypass difficult. Use when the obstacle can be crossed in the immediate vicinity, but some work to improve the bypass is necessary.
	Bypass impossible. Use when the obstacle can be crossed only by repairing or constructing a feature or by detouring around the obstacle.

Table 3-1 Bypass Symbols

3.2.4 *<u>SERT Concept of Operations</u>*

SERT units would consist of a total of 10 personnel, organized into two elements: a 3-person Liaison element (LNO), and a 7-person Recon and Security element. The Liaison element would be located in or near the Tactical Operations Center of the supported unit, and act as the "construction agent" for the supported unit, providing responsive engineering solutions. While supervised by the LNO, the Recon and Security element would operate independently to accomplish their mission. Communications would be maintained at all times between the two elements as shown below in Figure 3-6.

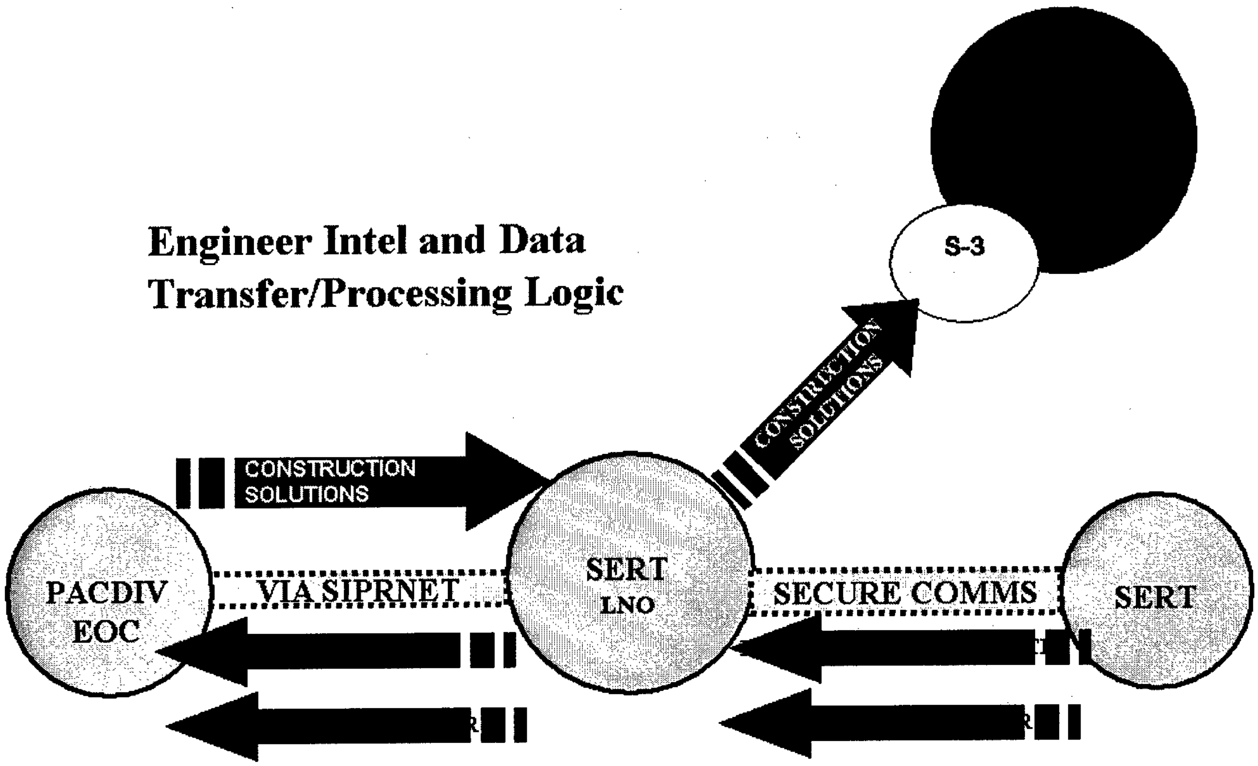


Figure 3-6 Communications and Data Transfer for SERT Units

A simplified fictional scenario will be presented to further clarify the concept of operations for a SERT team. A Naval Construction Force unit has deployed with a Marine Air Ground Task Force to country A in support of contingency operations. The Marines need to know the conditions of a possible route into country B; the route is approximately 40 kilometers long and includes 2 bridges.

The Liaison element would establish a presence in the Tactical Operations Center of the Marines. The Recon and Security element would proceed to recon the route, maintaining radio contact with the Liaison element. Utilizing the forms from the FM5-170, the Recon element would gather the necessary data to evaluate and classify the bridges and the overall route. The Liaison element would also establish communications with an Engineer Operations Center (EOC) located most likely in the United States, staffed by military and civilian engineers.

Everything progresses smoothly for most of the route and classification of the first bridge. However, they run into problems at the second bridge; it has been severely damaged by a bomb or missile attack. The recon element gathers the necessary data, completes the bridge evaluation form and scans it into electronic format. They also take digital pictures of the site and potential bypass routes. Because of the time-sensitive nature of their mission and the need to recon the remainder of the route, they elect to transmit the documents and images to the LNO via high-frequency radio rather than hand-carrying them. The LNO receives the data and forwards it via secure Internet (SIPRNET) connection to the Engineer Operations Center. While waiting for the response from the EOC, the LNO begins to prepare the route classification overlay. Within a few hours, the EOC responds with two options: a design to repair the existing bridge, and a recommended location to erect a temporary, field-expedient bridge. Meanwhile, the recon element has completed the route recon and transmitted the remaining data to the LNO.

The LNO compiles all the information and completes the route classification overlay for presentation to the Marines. The recon and security element returns safely to the base camp, and the SERT team stands down to await further orders.

3.3 Operations, Exercises, and Lessons Learned

The following sections describe operations and exercises in engineer reconnaissance by the Navy and the Army along with observations and lessons learned for future activities.

3.3.1 Operation Allied Force---Albania

As part of Operation Noble Anvil, the U.S. component of the NATO Operation Allied Force, Alpha Company of the U.S. Army's 40th Engineer Battalion deployed to Albania on April 8, 1999. Their original tasking included high-intensity conflict and force-protection tasks. This was quickly amended to include the construction of a forward operating base, more than 150 kilometers from their established base in Tirana, Albania.

Route reconnaissance and classification became critical as they sought to locate the best methods of transit. However, this proved difficult, as the route recon mission was much different from engineer obstacle recon missions they had trained on. Nevertheless, they adapted to the situation at hand and depended on the Army Field Manuals, FM 5-170, Engineer Reconnaissance, and 5-34, Engineer Field Data, in concert with locally developed checklists to accomplish the mission.

In order to better prepare their troops, they created training plans and opportunities on the fly. A critical component of their success was that they continually incorporated lessons learned in the development of future recon missions. They began to categorize the engineer recons as initial, intermediate, or deliberate, depending on the time allowed and the enemy situation. Initial recons were very rudimentary, where an engineer rode along with others taking digital photos for later review. The next step was an intermediate recon where teams of four to six engineers would be formed, tailored to the task at hand, and proceed independently to evaluate the route. The final step, a deliberate recon, would be performed only if necessary, and would involve outside personnel and subject matter experts to accurately evaluate the situation.

The Commander felt that this mission validated the long-standing doctrine, tactics, techniques, and procedures for engineer reconnaissance. He also observed that, "because many of today's military missions initially occur in countries with underdeveloped lines of communication, engineers must be well-trained in the vital mission of route recon."[34]

3.3.2 Operation Enduring Freedom—Afghanistan

In November 2001, approximately 25 Seabees from NMCB 133 deployed with a group of Marines to an airfield in Afghanistan that came to be known as Forward Operating Base (FOB) Rhino. The Marines would be using the airfield for C-130 and C-17 operations. The Seabees were tasked with making the dirt runway operational and maintaining it. They prepared for the mission through the review and analysis of engineer intelligence provided by forces that had viewed and visited the site before them.

Military planners originally noticed the site in satellite images provided by the National Imagery and Mapping Agency (NIMA). Convinced that this airstrip with adjoining operational facilities was a valuable target, they planned a raid of the facility. While Army Rangers were securing the buildings, specialists from the Air Force surveyed the runway with instruments such as penetrometers, and obtained valuable data regarding the load bearing capacity of the runway.

Armed with this information, Seabees were able to determine the equipment and materials that would ultimately allow them to support more than 800 landings on the unimproved airstrip. One of their first tasks was to find a water supply to use in controlling the dust generated by the numerous airplane and helicopter take-offs and landings. They dug a 6-foot deep pit and provided soil classifications and digital images of the conditions to engineers located in Hawaii and Bahrain. Reviewing the electronic data from the field in concert with images from NIMA, the engineers determined that there was water in the area, but it would require drilling to a depth of over 600 feet. Another solution would be to fly in bulkwater on a continual basis to meet the requirement. After consultations and discussions via radio and e-mail, it was determined that flying in the bulkwater was the preferred course of action.

Nevertheless, the remote engineers continued researching ways to solve the problem. They discovered a manufacturer that made a liquid compound that would help stabilize the soil and control the dust. After completing an emergency acquisition of the material, it was delivered to the Seabees. However, when it arrived, it became clear that the Seabees' intended application was not covered by the manufacturer's included instructions. After a couple satellite phone calls to the engineers and manufacturer's representative they had the necessary information and they were in business.

The officer in charge of the operation declared it a success, dependent on the ingenuity of the Seabees and the reach-back capability employed to tap the resources and expertise of remote engineers.[35]

3.3.3 Exercise Desert Knight / Steel Knight 02

Naval Mobile Construction Battalion Four (NMCB 4) sent a SERT team to participate in the 1st Marine Division's Exercise DESERT KNIGHT/STEEL KNIGHT 02, held in December 2001. Exercise DESERT KNIGHT is a Regimental Ground Combat Element Maneuver and Live-Fire exercise conducted annually at the Marine Corps Air Ground Combat Center 29 Palms, CA, testing 7th Marine Regiment units in Mission Essential Tasks. Naval Construction Force participation in DESERT KNIGHT 02 (DK 02) was aimed primarily at further refinement of SERT Concept of Operations and Tactics, Techniques, and Procedures.

During the internal training phase, the SERT unit completed the following missions: (1) conducted engineer recon of a possible site for permanent bridge construction; (2) conducted engineer recon of roads and culverts; (3) conducted engineer recon to expand an Expeditionary Air Field (EAF) from current capacity to C-5 heavy lift capability. Data from the culverts and EAF was sent to the Engineer Operations Center (EOC) at the Third Naval Construction Brigade and Pacific Division in Hawaii for analysis. The Liaison Officer (LNO) Cell utilized all available means including NIPRNET (non-secure Internet), SIPRNET (secure Internet), and STU (secure telephone unit) phones to communicate, and exchange designs/feedback with the EOC.

After attaching to the 7th Marines Regiment, three recon team members were inserted via helicopter onto the top of an observation post site to conduct an engineer recon to gather information to produce a design for an access road. The recon element concluded the route provided by the EOC to be non-passable, requiring extensive large rock crushing and cross cutting into the mountains to make it accessible.

The recon element communicated with the LNO via high frequency (HF) radio, and the LNO relayed engineering field data packages to the EOC via SIPRNET. Minimal problems were faced during HF radio data transfer. Sporadic problems with the USMC SIPRNET communication beyond internal camp limited communications with the EOC via SIPRNET; therefore, the majority of the data sent to the EOC was via NIPRNET.

3.3.3.1 Observations and Lessons Learned

Exercise Desert Knight/Steel Knight 02 was deemed a success, as it provided outstanding interaction between the Naval Construction Force and the United States Marine Corps. The Marines were in support of another SERT mission to the observation post site in hopes of finding a successful route.

Nevertheless, NMCB 4 found the SERT mission to be extremely communication-dependent. They felt that the dependence on solely HF to transmit data was a significant drawback, as the low data rate of HF makes transmitting large data files very time-consuming and the electronic signature of the radio is a tactical liability. They recommended the use of the very-high frequency (VHF) and ultra-high frequency (UHF) spectrums to take advantage of higher bandwidth and smaller signature of higher frequency communications.

3.3.4 8th Engineer Support Battalion Deliberate River Crossing Exercise

Naval Mobile Construction Battalion 133 (NMCB 133) Seabee Engineer Reconnaissance Team (SERT) was tasked to participate in the 2nd Marine Division, 2nd Force Service Support Group, 8th Engineer Support Battalion's Deliberate River Crossing Exercise, held in December 2002 at Camp Lejeune, North Carolina. The Deliberate River Crossing Exercise provided a tactical environment to refine the ability to plan and execute river crossing operations. Command and control was exercised over two crossing sites; one crossing utilized a standard Medium Girder Bridge (MGB) and the other crossing utilized an Improved Ribbon Bridge (IRB). NCF participation in the exercise allowed further refinement of SERT Concept of Operations and Tactics, Techniques, and Procedures. The SERT supported two different evolutions during the exercise: a river crossing reconnaissance of Duck Creek, and a battle-damaged bridge reconnaissance over Wallace Creek.

The SERT Recon Element observed 8th ESB Engineers stage components, prepare the bridge site, and construct two bridges: a Medium Girder Bridge and an improved ribbon bridge. The team was able to assess the difficulties encountered in maneuvering equipment and personnel in a confined site at waters edge as well as the impacts inclement weather and darkness have on assault bridging construction efforts. The SERT Liaison Element established a link with the 8th ESB Crossing Area Engineer (CAE). The CAE is the primary planner and advisor on matters pertaining to the selection of crossing sites, release lines, assembly areas, call-forward areas, bridge assets to be used, and the re-composition of bridge assets. It is normally located with the supported Regiment's forward command post where it can best advise the supported unit commander on matters associated with gap crossing operations.

The 8th ESB's primary interest in engineering solutions provided by SERT was to predict the timing for onward movement of assault bridging assets. SERT conducted two reconnaissance efforts and developed two engineering reports (both from the first recon effort) for 8th ESB. SERT performed the first recon mission at Duck Creek as the 8th ESB bridge company was constructing the MGB. Investigation revealed a 30-meter crossing with heavy brush and trees along the creek and near/far access roads. The SERT developed a hasty solution recommending constructing a culvert system that would take 5 days to complete. After analyzing the data provided by the SERT, the EOC proposed construction of a Mabey-Johnson bridge due to the water depth and poor bottom composition; construction duration was not estimated.

The ability of the recon element to communicate their observations to the EOC was hampered by the slow speed of the HF data transmissions. EOC engineers were eager to relay to the recon element their desire for more descriptive photos or more detailed soil characteristics and profile data, but encrypted voice capability was not available for real time communication due to the monopolization of the HF radio for data transmissions.

SERT performed a second recon at night at Wallace Creek evaluating a damaged bridge. An improved ribbon bridge was constructed alongside the damaged bridge to continue movement while the SERT gathered information for a repair solution. SERT conducted a detailed survey of existing conditions, taking measurements and describing bridge components and battle damage. Recon revealed a 230-meter long, 17-meter wide, timber bridge with asphalt wearing surface. SERT assumed the scenario to be two impassable 30-foot craters separated by

50 feet of passable bridge way. The SERT recommended solution was to repair the damage using similar materials. Estimated time was 14 days. File size prevented rapid transmission of data back to NMCB 133. No solution was provided by the EOC for this mission.

3.3.4.1 Observations and Lessons Learned

In general, the team found its greatest limitation to exercise the SERT concept was in data throughput via high frequency transmission. Some messages with few attachments took at least one hour to transmit and often timed out prior to successful completion. Also, in some cases it was determined only after lengthy transmissions that some attachments were not required by contingency engineers to develop a solution. It was difficult to transmit information with only one HF link at the LNO. At times both parties needed to send information, but could not because the link was tied up for an hour sending a message. In addition, communications between the recon element and the LNO were challenging; procedures called for transmitting the data via HF radio, but the participants felt it actually would have been faster to hand carry them.

They also experienced difficulties in entering the recon data into their laptop computers. The process of filling out the forms by hand while performing the recon and then entering the data afterward proved very time-consuming and inefficient. They also experienced problems recording and entering the data at night and in inclement weather. They recommended as a solution to both issues to equip the units with personal digital assistants capable of operating the necessary software to allow direct data entry and improve performance.

The development of expeditionary engineering solutions also proved difficult. The various parties had different opinions and expectations of the level of design necessary. The supported commander wanted an "expeditionary" solution that could be communicated to the maneuver commander and planners so that adjustments in the scheme of maneuver could be made. The speed of advance of the assault forces did not allow time for a normal design effort and the SERT team was unable to collect all of the requested data. The SERT team used abbreviated standard forms from military field manuals; however, they were unable to collect all of the data requested by the designers with the equipment that was used on the exercise.

The officer in charge recommended increased involvement of the civilian engineering personnel in these exercises to better define what information is required in order to develop solutions. The SERT teams also need to continue training in gathering the required information and developing estimates of the construction effort. He felt that the overall goal should be to "train to provide the '85%' solution and allow the personnel on the ground to make adjustments based on experience and existing conditions."[36]

Chapter 4 State of the Art: Engineer Reconnaissance

When one considers the term reconnaissance, the connotation is generally that of military operations. This is confirmed by Webster's Dictionary, which defines reconnaissance as "a preliminary survey to gain information; *especially*: an exploratory military survey of enemy territory." Thus, while it is especially a military term, there is also the more generic meaning as it applies to gathering any information.

In the preceding chapter, I discussed the value the Naval Construction Force hopes to gain by forming SERT units to perform military engineer reconnaissance. I also reviewed the processes they will use to perform the reconnaissance and share the gathered data, the "state of the practice." It is now important to explore the information technology applications in use to perform engineer reconnaissance, or that could be employed to do so, the "state of the art." Two categories of information technology applications hold particular promise for improving engineer reconnaissance: geographic information systems and collaborative design.

4.1 Geographic Information Systems

Geographic Information System (GIS) technology is computer software that links geographic information with descriptive information. Unlike a flat paper map, a GIS can present many layers of different information. Each layer represents a particular theme or feature of the map; examples of themes include all of the roads, lakes, or cities in a given area. These themes can be laid on top of one another, creating a stack of information about the same geographic area. Each layer can be turned off and on, as if you were peeling a layer off the stack or placing it back on. You control the amount of information about an area that you want to see, at any time, on any specific map.

Information that was once limited to spreadsheets and databases is being tapped in a new, more powerful way, all by using geography. Geography, or location of information, is helping people gain new insights and make better decisions in many disciplines. Geographic data can be gathered and organized to support the generation of information products that are integrated in the business strategy of any organization. A geographic information system is not an end in itself; it is used to create useful information products that help organizations run better. GIS software applications from two providers, ESRI and Syncline, will be reviewed for possible applications to military engineer reconnaissance.

4.1.1 ESRI

The Environmental Systems Research Institute (ESRI) is the world leader of GIS solutions, according to analysts at Daratech in Cambridge, Massachusetts. With a global market of more than two million organizations using GIS software, ESRI has over 300,000 client sites. Their comprehensive suite of software products, known as ArcGIS™, forms a complete GIS built on industry standards. The various components, including ArcReader™, ArcView®, ArcEditor™, and ArcInfo™, share the same core applications and user interface, and can be scaled to meet the needs of individuals and organizations. Figure 4-1[37] displays the ArcGIS™ Family of Software along with some GIS applications enabled by wireless communications.

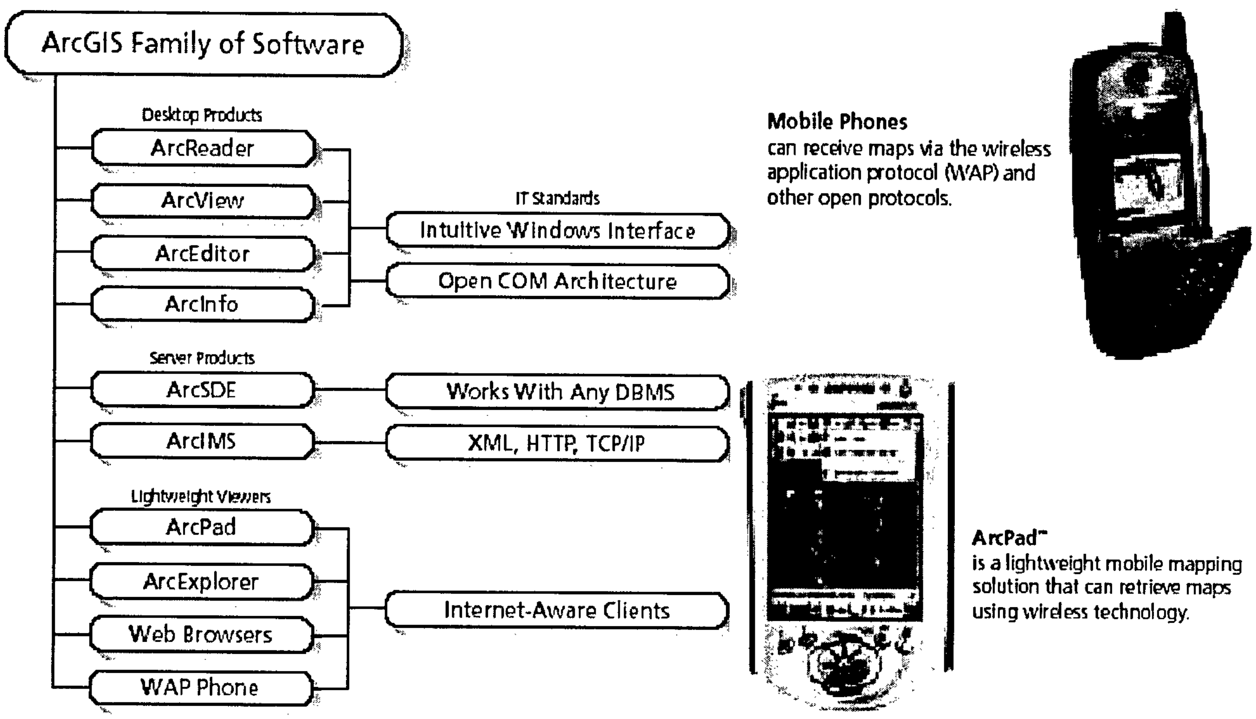


Figure 4-1 ArcGIS™ Family of Software and Wireless Applications

4.1.1.1 ArcGIS™ Military Analyst

ESRI also offers a plug-in for the ArcGIS™ family called the ArcGIS™ Military Analyst. This extension incorporates a number of tools that enhance the effectiveness of the software for military planners and intelligence analysts. It simplifies access and facilitates direct use of the entire suite of National Imagery and Mapping Agency (NIMA) data products, allowing users to focus on data analysis rather than file management.

4.1.2 Syncline®, Inc.

Syncline®, Inc. is a "leading provider of enterprise e-government solutions whose software uses the power of Geographic Information Systems (GIS) to streamline common business processes and workflow management fundamentals at all levels of an organization."[38] Targeting public users, Syncline helps governments at the city, county, state and federal level conduct business using applications created, managed, and shared via the Internet. Examples range from simple street and parcel maps for public use to sophisticated applications for economic development, asset management and permit administration.

Syncline was recently named ESRI's 2002 Partner of the Year based on their dedication to delivering cost-effective solutions that are easy to use and implement. They have also capitalized on their expertise in web-based geographic applications to assume a leadership role in developing and testing software standards for Geographic Web Services with the Open GIS Consortium (OGC), the standard-setting body for the spatial community.

Syncline's technology platform, MapAccess™, is the foundation for MapCiti™ Hosted Solutions and MapCiti™ Software, their suite of products built to address a variety of e-government service needs. MapCiti™ Hosted Solutions enable a wide range of e-government services from property searches to permitting while limiting the burden on IT departments, as the data is hosted by Syncline.

4.1.2.1 MapCiti™ Viewers

MapCiti™ Viewers put interactive, information rich maps on-line with a simple, hands-off approach. While government officials provide the data and control the presentation, citizens, businesses, and other users can easily access up-to-date geographic information wherever they have access to a computer. Each viewer is issue-specific, and comes with high quality data from GDT and TeleAtlas. Following is a survey of applications provided by Syncline on the MapCiti™ system.[39]

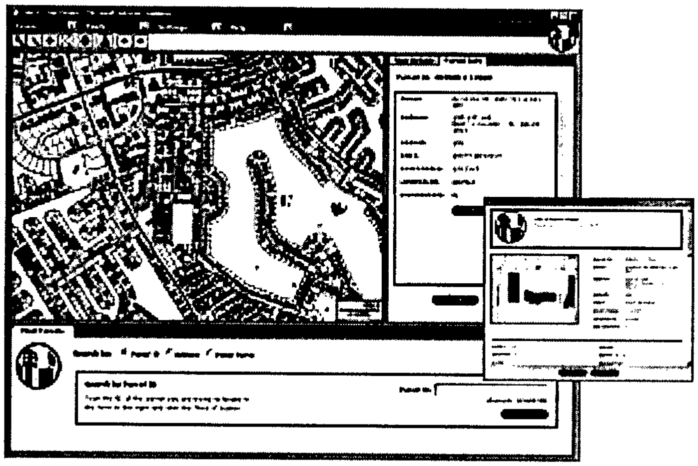


Figure 4-2 Parcel Viewer

4.1.2.1.1 Parcel Viewer

The Parcel Viewer is an effective solution for making property information and other parcel data widely available to community officials, citizens, and local businesses. The Parcel Viewer allows tax professionals, developers, homeowners, utilities, and realtors to locate and print parcel maps and information remotely from home or the office using a simple web browser.

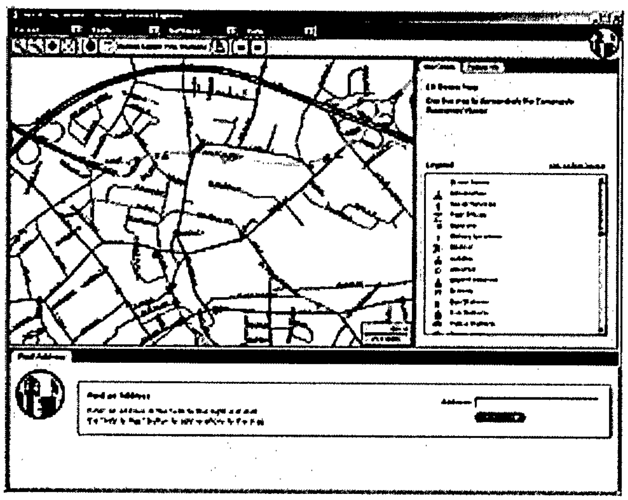


Figure 4-3 Community Resources Viewer

4.1.2.1.2 Community Resources Viewer

The Community Resources Viewer highlights the multitude of resources available to the public, such as: police stations, fire stations, schools, hospitals, libraries, parks, stadiums, golf-courses, skating rinks, tennis courts, swimming pools, recreation centers, parking garages, museums, landfills, recycling centers, cemeteries, and more. Users can click on any point-of-interest (POI) to view its relevant data, such as address, business hours, and contact information. Each POI can easily be linked to a web site or digital photography.

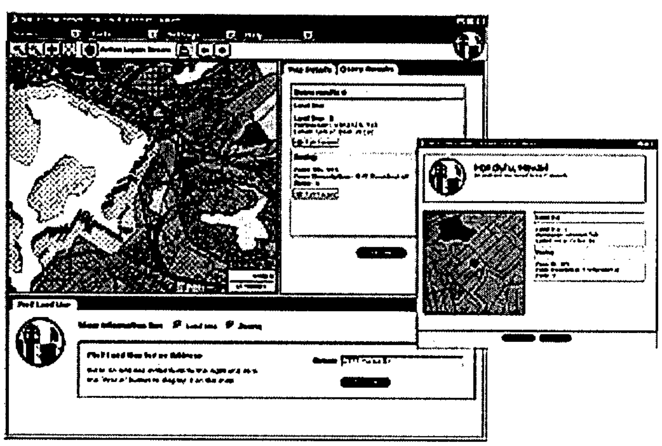


Figure 4-4 Zoning & Land Use Viewer

4.1.2.1.3 Zoning & Land Use Viewer

The Zoning & Land Use Viewer addresses the common need for sharing zoning and land use information with local businesses, citizens, elected officials, and government employees across all departments. The viewer can be used to examine proposed zoning and land use changes and development trends with existing zones and master plans. Users can print detailed, high-resolution zoning maps.

4.1.2.2 MapCiti™ Modules

MapCiti™ Modules are end-to-end solutions that automate business processes and streamline workflow in communities of all sizes. Each module increases efficiency, bolsters revenue, and improves access to key processes across departments and with local businesses.

4.1.2.2.1 Permitting Module

The Permitting Module automates the issuance, management and tracking of permits (street cuts, building, right-of-way, etc.), thus eliminating the problems and delays associated with traditional front counter, paper-based permitting systems. Proven to reduce the time it takes to issue a permit by over 70%, this module is available for either Internet or Intranet deployment, at all levels of government. An e-commerce add-on is available for collection of fees online.

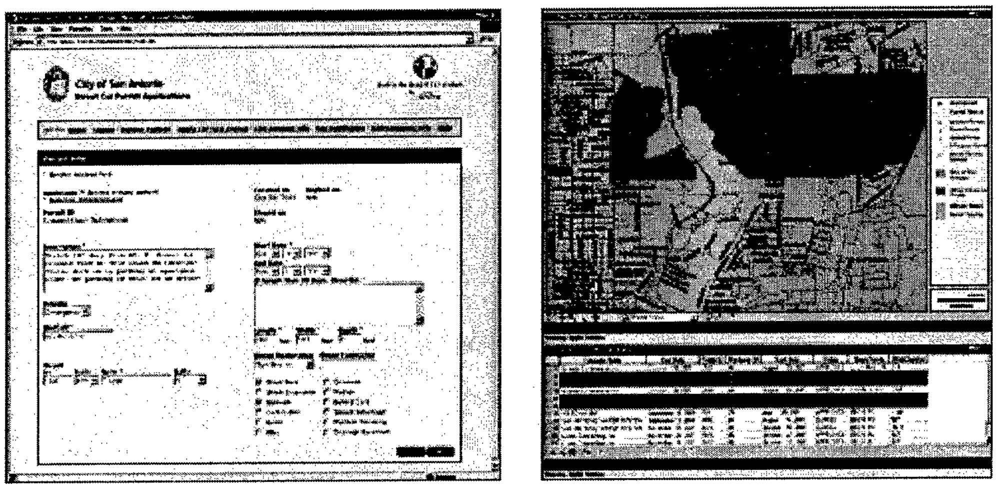


Figure 4-5 Permitting Module

4.1.2.2.2 Economic Development Module

The Economic Development Module is a tool communities can use to attract new businesses and industries to their area, enabling users to perform simple site selection analyses on available city/county-owned property. Users can search by size, assessed value, and proximity to features (transportation, water, etc.).

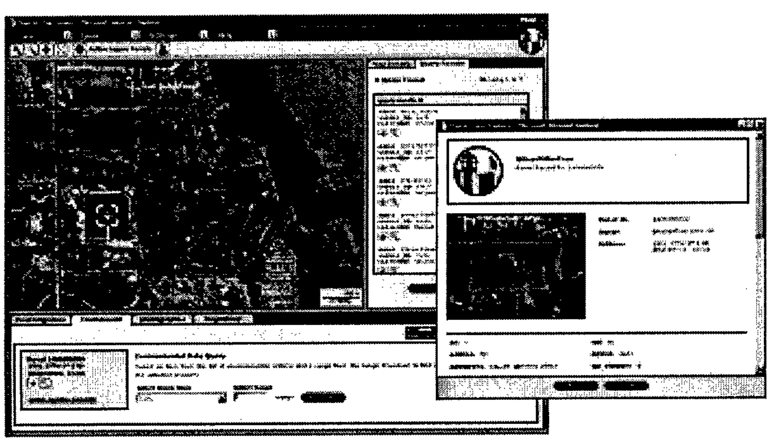
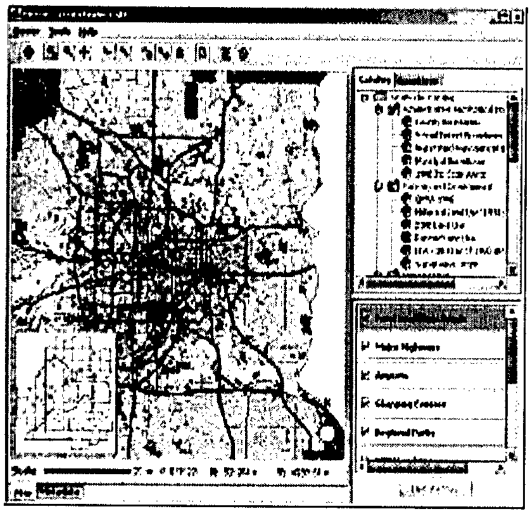


Figure 4-6 Economic Development Module



4.1.2.2.3 Data Extraction Module

The Data Extraction Module is an innovative, web-based data distribution tool that allows organizations to securely provision their data online. This e-government solution eliminates the need to provide large data sets to end users via CD-ROM and puts an end to bandwidth hungry downloads.

Figure 4-7 Data Extraction Module

4.1.2.3 MapCiti™ Enterprise Manager

The MapCiti™ Enterprise Manager ties everything together; it is "the only comprehensive hosted GIS solution on the market today; the first to offer live data uploads, dynamic map publishing and a security framework for controlling access to maps and content on-line. This robust solution enables users to create, manage and view spatial content and maps from anywhere, at any time without purchasing additional hardware, software, or the need to know anything about programming."[40] Users of Enterprise Manager can manage the full range of MapCiti™ Viewers and Modules, all from a common web-browser. The Enterprise Manager acts as the behind the scenes interface to the suite of solutions available from MapCiti™.

4.1.3 Barchan

Barchan is a remote-hosted, web-based capital asset management tool developed by Syncline® to assist public works officials and town and city managers in meeting the requirements of the Government Accounting Standards Board Statement 34, which requires local governments to report the value of their infrastructure assets. Barchan accesses local Geographic Information System (GIS) mapping networks to display the most current infrastructure system layout available within the client's specific planning area. Using the GIS network, metasegments of infrastructure assets such as road, water, wastewater, storm water, and other networks are constructed.

The program is currently undergoing Beta testing before formal release. The roadway module is the most advanced, so the system explanation will focus on that area. Individual roadway segments can be grouped into metasegments based on a number of criteria, including traffic flow/type, maintenance schedules, etc. After metasegments are built, administrative classifications, functional groupings, and geometric cross-sections are assigned. Currently, more than 58,000 different cross-sections of roadways and streets are included in the roadway module; later releases of the program will allow users to build their own cross-sections. Infrastructure quality assessments are then assigned to each metasegment, reflecting the initial date the roadway was put in service, the current condition of the roadway, and any repair/maintenance issues observed.

With geometry and other attributes known, Barchan utilizes its link to the RSMeans Construction Costs database to assign an initial asset value relative to the in-service date and a present value based on current roadway conditions, in accordance with the accounting requirements of Statement 34. The software also includes a robust scenario development tool to enable local governments to allocate limited funds across maintenance, preservation, and/or addition activities, test the effectiveness of changing budgets on the overall condition of infrastructure assets, and quickly conduct simple explorations of numerous alternative strategies for allocating limited resources across recommended activities.

4.2 Design Collaboration

Designers have always collaborated, but the way that they go about it is changing. What started with paper and blueprints can now be performed digitally using Computer-Aided Design (CAD). CAD files can be shared any number of ways, ranging from disks to CDs to office networks to file transfers over the Internet. File Transfer Protocol (FTP) is the standard for file transfers on the Internet, and allows high-speed data transfer to project participants throughout the world. E-mail messages with attachments are also a common method of sharing files, but the exchange can become confusing and potentially lead to inaccurate or incomplete designs if conventions are not established to control the process and participants.

4.2.1 DrChecks Design Review system

The Design Review and Checking System (DrChecks) was created by the U.S. Army Corps of Engineers out of an in-house effort to improve the design review process. It links designers, reviewers, project managers, and other interested parties via the Internet to track the review of construction plans and specifications. While bearing similarities to commercial Web-collaboration tools developed for the architecture, engineering and construction market, DrChecks provides additional security, since the software and data are hosted on a federal computer system.

DrChecks also employs a structured, database-driven approach specifically geared toward managing design reviews. Using a standard Web browser, users can log on to check a project's review status, submit comments and responses and sort comments by date, discipline, reviewer and other categories. Typically, a project manager creates review phases for each project and reviewers submit comments during each phase. Designers then evaluate and respond to comments. Communication is logged to a database. Drawings and other files can be attached to postings.

Another attractive feature of the system is the comment clearinghouse and central repository of information. Project participants throughout the world can access the system at any time of day and virtually work around the clock. The U.S. State Department has incorporated the system into a six-step "Integrated Design Review Process", reducing the number of design comments by at least 20% by eliminating redundant comments. On smaller projects, DrChecks has decreased the review period from weeks to as little as 48 hours.

In addition to the Corps of Engineers and the State Department, the U.S. Naval Facilities Engineering Command and the General Services Administration also are using the system, and the National Aeronautics and Space Administration is preparing to launch a trial. The Overseas Building Office of the State Department has used the latest version of DrChecks on 23 reviews and logged over 4,000 comments. Robert Clark, an architect for the State Department, estimates that DrChecks can save up to $500,000 on a $100-million project through efficient reviews and improved design, which decreases change orders and delays.[41]

4.2.2 Bentley Systems, Incorporated

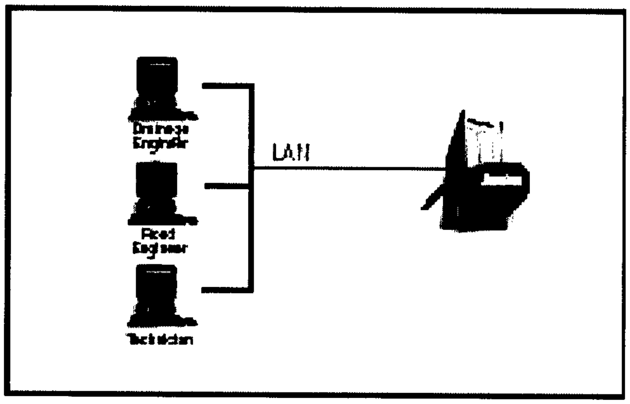
Bentley Systems, Incorporated is a global provider of collaborative software solutions to create, manage, and publish architectural, engineering, and construction (AEC) content. Its software solutions are used to design, engineer, build, and operate large constructed assets such as roadways, bridges, buildings, industrial plants, power plants, and utility networks. The company focuses on five vertical industries: transportation, manufacturing plants, building, utilities, and government.

MicroStation is a single, comprehensive platform for design and engineering projects and is the foundation for the latest generation of software from Bentley. MicroStation is used to create and publish intelligent two-dimensional drawings, maps, and three-dimensional models. The latest release, MicroStation V8, features key advances in three areas: data exchange, reuse, and interoperability; workflow and user-level improvements; and application platform enhancements. In the area of data exchange, the DGN file format (the native vocabulary of MicroStation) has been expanded and is now able to digest information from other formats. It can now read and write AutoCAD DWG files directly, without time-consuming, error-prone translation. Another enhancement is based on the inclusion of Bentley's ProjectBank server technology; V8 now has a Design History feature, which allows the history of a design to be automatically maintained within a DGN file. This capability is enabled by a history journal that tracks changes in a design, the date and time the changes were made, who made them, and comments about why the changes were made. Discipline-specific applications are available to extend MicroStation's capabilities to enable automated, directed, and intelligent design tailored to distinct industries. Users include Bechtel Group, Fluor, 46 state departments of transportation, the U.S. Army Corps of Engineers, and many others. User comments indicate that MicroStation is relatively easy to use compared to other CAD systems and easy to implement and configure in networked environments.[42]

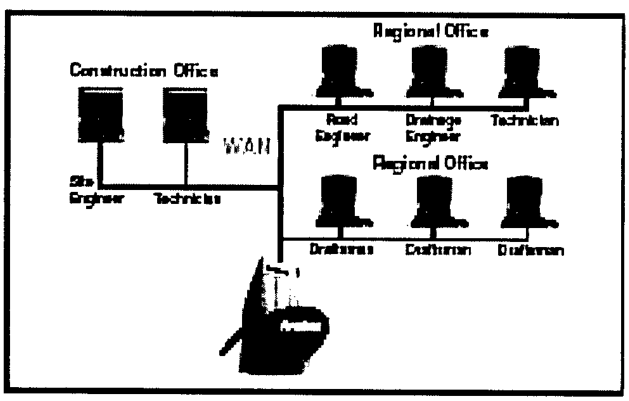
Bentley also has collaboration servers that allow project participants from different organizations to collaborate and share AEC content and expertise. These solutions allow users to query and annotate designs, track change history, and interface with accounting, procurement, and other enterprise divisions. They fall into two main categories: *Content Management*, products that deliver engineering information to colleagues and enterprise systems in both graphic and intelligent forms, and *Content Publishing*, solutions that provide integrated network plotting and Web publishing capabilities.

4.2.3 Infrasoft Corporation

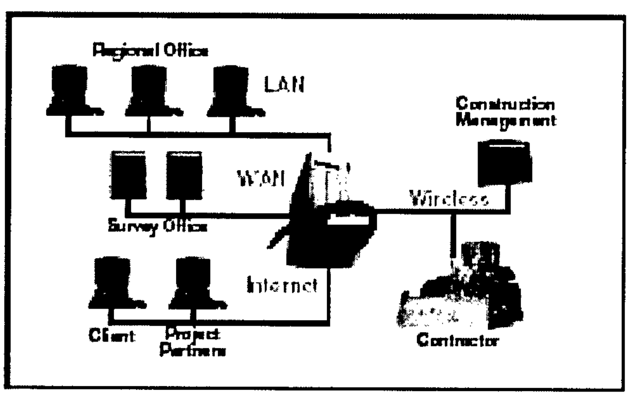
Bentley has expanded their capabilities by acquiring Infrasoft Corporation and their civil engineering collaboration and design management software, Arenium. Arenium provides seamless interaction with MX (Infrasoft's three-dimensional model-based design software), AutoCAD, and MicroStation. It lets engineers and others work together on a 3D model from the inception of a project over a local- or wide-area network or the Internet. Arenium runs efficiently over all of these media because it tracks each change made to data and sends only the changed data. This allows users to maintain the most current data quickly and easily, even over low-bandwidth connections. Various alternative network configurations are displayed below in Figure 4-8 to illustrate the capabilities of Arenium to enable collaborative design.



Arenium makes any two users of MX more productive by enabling the sharing of design data. However, Arenium can scale to meet the needs of any project structure, small or large.



At the project level, the entire project team can collaborate using Arenium.



Arenium users can create and complete projects no matter where they are located - in the same room, in another city or another country.

Figure 4-8 Arenium Network Configurations

4.2.4 *Bentley/ESRI Interoperability*

ESRI, as a GIS provider, and Bentley, with its solutions for architecture, engineering, and construction (AEC) professionals, both provide graphically oriented applications that use a spatial context. These applications are often used within organizations served by both Bentley and ESRI, including municipalities, transportation departments, national government agencies, utilities, and others.

While Bentley and ESRI applications may create and maintain data in a common coordinate space, they are designed for unique purposes and therefore used by individuals with distinct organizational functions. ESRI users typically perform enterprise data management, decision support, cartography, planning, and analysis functions. Bentley users design, engineer, build, and operate roadways, buildings, plants, communication networks, and other large constructed assets. For example, a planner requires a broad view of spatial information, the ability to work with large areas, and a powerful toolbox of analytical functions; these needs are best met by a continuous database, a GIS. Engineers create and work from sets of detailed drawings and models, with spatial information, and require a rich set of 2D and 3D geometry-based engineering and design functions; these requirements continue to be best met by a model and drawing paradigm. Nevertheless, planners and engineers very much depend upon each other to conduct their work; planners need accurate information on as-built conditions and engineers and architects need the context of plans to create their designs.

Despite an obvious need to share information, it is very difficult to share digital content between planners and AEC professionals. Very little true functional integration exists between AEC and GIS solutions. Today, most users attempt to practice interoperability by exchanging files in an ad hoc manner; files are then imported and reformatted for use in the target system. Or, for those uncomfortable with electronic files, printed materials are still exchanged. Under a file exchange process, considerable information is lost in the translation. There is no record of information dependencies, and significant editing of the translated information is required to clean up the data. File translation communicates only the lowest level of information content, and there is no central information index that details who has what information.

Bentley and ESRI are therefore embarking on a high level approach to integrate the AEC content created and managed with the Bentley solution and the GIS information created and managed by the ESRI solution. This integration will: [43]

1. Enable MicroStation to read ArcGIS maps / data and enable ArcGIS clients to read DGN & DWG files.
2. Provide support for ArcGIS files (SHP, MXD, coverage, etc.) within Bentley's Content Management & Publishing environment.
3. Result in an "Enterprise Connector" with ArcGIS that synchronizes relevant AEC content with the ArcGIS Geodatabase and retrieves relevant GIS information from the ArcGIS Geodatabase.

The Bentley/ESRI Interoperability paradigm leverages the best of both worlds and does not ask users to work with lowest common denominator tools or data to accomplish their tasks. This work began in 2002 and will be realized with commercial delivery staged throughout 2003.

Chapter 5 Communications

Wireless communications offer organizations and users many benefits such as portability and flexibility, increased productivity, and lower installation costs. Wireless technologies cover a broad range of differing capabilities oriented toward different uses and needs; two of the most prevalent are wireless local area networks (WLAN) and Bluetooth. WLAN devices allow users to move their laptops from place to place within their offices without the need for wires and without losing network connectivity. Less wiring means greater flexibility, increased efficiency, and reduced wiring costs. Bluetooth enables ad hoc networks that allow data synchronization with network systems and application sharing between devices, and eliminate cables for printer and other peripheral device connections. Handheld devices such as personal digital assistants (PDA) and cell phones allow remote users to synchronize personal databases and provide access to network services such as wireless e-mail, Web browsing, and Internet access.

However, risks are inherent in any wireless technology. Some of these risks are similar to those of wired networks, some are exacerbated by wireless connectivity, and some are new. Perhaps the most significant source of risks in wireless networks is that the technology's underlying communications medium, the airwave, is open to intruders.[44] Unauthorized users may gain access to systems and information, corrupt data, consume network bandwidth, degrade network performance, launch attacks that prevent authorized users from accessing the network, or use network resources to launch attacks on other networks.

5.1 Wireless Networks

Wireless networks serve as the transport mechanism between devices and among devices and the traditional wired networks (enterprise networks and the Internet). Wireless networks are many and diverse but are frequently categorized into three groups based on their coverage range: Wireless Wide Area Networks (WWAN), Wireless Local Area Networks (WLAN), and Wireless Personal Area Networks (WPAN). All of these technologies are "tetherless"—they receive and transmit information using electromagnetic (EM) waves. Wireless technologies use wavelengths ranging from the radio frequency (RF) band up to and above the infrared (IR) band. The frequencies in the RF band cover a significant portion of the EM radiation spectrum, extending from 9 kilohertz (kHz), the lowest allocated wireless communications frequency, to thousands of gigahertz (GHz). See Table 5-1[45] for a list of common wireless frequencies and applications.

EM Band Designation	Frequency Range	Wireless Device/Application
VLF: Very Low Frequency	9 kHz–30 kHz	
LF: Low Frequency	30 kHz–300 kHz	
MF: Medium Frequency	300 kHz–3 MHz	AM radio stations (535 kHz–1 MHz)
HF: High Frequency	3 MHz – 30 MHz	
VHF: Very High Frequency	30 MHz–300 MHz	FM radio stations VHF television stations 7–13, NTSC Standard (174 MHz–220 MHz) Garage door openers (~40 MHz) Standard cordless telephones (40 MHz–50 MHz) Alarm Systems (~40 MHz) Paging Systems (50 MHz–300 MHz)
UHF: Ultra High Frequency	300 MHz–3 GHz	Paging systems (300 MHz–500 MHz) 1G mobile telephones (824 MHz–829 MHz) 2G mobile telephone (800 MHz–900 MHz) Global System for Mobile Communication (GSM) Enhanced Data Rates for Global Evolution (EDGE) (800/900/1800/1900 MHz bands) 3G Mobile telephones (international standard) (1,755 MHz–2200 MHz) Bluetooth devices (2.4-2.4835 GHz) Home RF (2.4 GHz ISM Band) WLAN (2.4, 5 GHz)
SHF: Super High Frequency	3 GHz–30 GHz	Applications in the short range, point-to-point communications including remote control systems, PDAs, etc. WLAN (5.8 GHz). Local Multipoint Distribution Services (LMDS), a fixed wireless technology that operates in the 28 GHz band and offers line-of-sight coverage over distances up to 3 to 5 kilometers.
EHF: Extremely High Frequency	30 GHz–300 GHz	Satellite communications
IR: Infrared	300 GHz	Remote controls for home audio-visual components IR links for peripheral devices PDA and cellular telephone IR links

Table 5-1 Common Wireless Frequencies and Applications

5.1.1 <u>*Wireless Local Area Networks*</u>

WLANs allow greater flexibility and portability than do traditional wired local area networks (LAN). Unlike a traditional LAN, which requires a wire to connect a user's computer to the network, a WLAN connects computers and other components to the network using an access point device. An access point communicates with devices equipped with wireless network adaptors and connects to a wired Ethernet LAN. Access point devices typically have coverage areas of up to 100 meters. This coverage area is called a cell or range. Users move freely within the cell with their laptop or other network device. Access point cells can be linked together to allow users to "roam" within a building or between buildings. By deploying multiple access points with overlapping coverage areas, organizations can achieve broad network coverage. WLAN technology can be used to replace wired LANs totally and to extend LAN infrastructure.

The reliable coverage range for WLANs depends on several factors, including data rate required and capacity, sources of RF interference, physical area and characteristics, power, connectivity, and antenna usage. Theoretical ranges are from 29 meters (for 11 Mbps) in a closed office area to 485 meters (for 1 Mbps) in an open area. However, the practical range for connectivity of WLAN equipment is approximately 50 meters indoors, and about 400 meters outdoors. Special high-gain antennas can increase the range to several miles.

5.1.1.1 Benefits

WLANs offer four primary benefits:[46]

- *User Mobility.* Users can access files, network resources, and the Internet without having to physically connect to the network with wires. Users can be mobile yet retain high-speed, real-time access to the enterprise LAN.
- *Rapid Installation.* The time required for installation is reduced because network connections can be made without moving or adding wires, or pulling them through walls or ceilings, or making modifications to the infrastructure cable plant.
- *Flexibility.* Enterprises can also enjoy the flexibility of installing and taking down WLANs in locations as necessary. Users can quickly install a small WLAN for temporary needs such as a conference, trade show, or standards meeting.
- *Scalability.* WLAN network topologies can easily be configured to meet specific application and installation needs and to scale from small peer-to-peer networks to very large enterprise networks that enable roaming over a broad area.

Because of these fundamental benefits, the WLAN market has been increasing steadily over the past several years, and WLANs are still gaining in popularity. WLANs are now becoming a viable alternative to traditional wired solutions; for example, hospitals, universities, airports, hotels, and retail shops are already using wireless technologies to conduct their daily business operations.

5.1.2 Ad Hoc Networks

Ad hoc networks such as Bluetooth are networks designed to dynamically connect remote devices such as cell phones, laptops, and PDAs. Ad hoc networks are a relatively new paradigm of wireless communications in which no fixed infrastructure exists such as base stations or access points. In ad hoc networks, devices maintain random network configurations formed "on the fly," relying on a system of mobile routers connected by wireless links that enable devices to communicate with each other. Devices within an ad hoc network control the network configuration, and they maintain and share resources. Ad hoc networks are similar to peer-to-peer (P2P) networking in that they both use decentralized networking, in which the information is maintained at the end user location rather than in a centralized database. However, ad hoc and P2P networks differ in that P2P networks rely on a routing mechanism to direct information queries, whereas ad hoc networks rely on the device hardware to request and share the information.

Ad hoc networks allow devices to access wireless applications, such as address book synchronization and file sharing applications, within a wireless personal area network (PAN). When combined with other technologies, these networks can be expanded to include network and Internet access. Bluetooth devices that typically do not have access to network resources but that are connected in a Bluetooth network with a WLAN capable device can achieve connection within the corporate network as well as reach out to the Internet.

Bluetooth can be used to connect almost any device to any other device. An example is the connection between a PDA and a mobile phone. The goal of Bluetooth is to connect disparate devices (PDAs, cell phones, printers, faxes, etc.) together wirelessly in a small environment such as an office or home. According to the leading proponents of the technology, Bluetooth is a standard that will ultimately:[47]

- Eliminate wires and cables between both stationary and mobile devices
- Facilitate both data and voice communications
- Offer the possibility of ad hoc networks and deliver synchronicity between personal devices.

Bluetooth is designed to operate in the unlicensed ISM (industrial, scientific, medical applications) band that is available in most parts of the world, with variation in some locations. The three ranges for Bluetooth are depicted in Figure 5-1. As shown, the shortest range may be good for applications such as cable replacement (e.g., mouse or keyboard), file synchronization, or business card exchange. The high-powered range can currently reach distances of 100 meters.

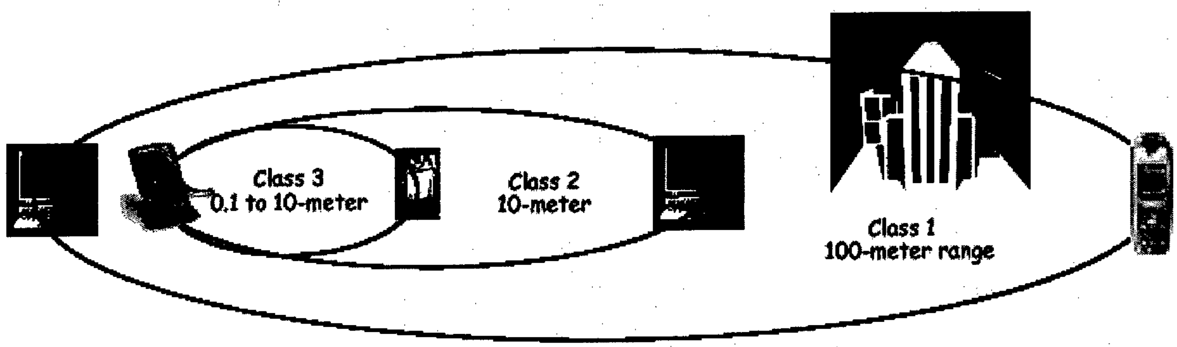


Figure 5-1 Bluetooth Operating Range

5.1.2.1 Benefits

Bluetooth offers five primary benefits to users. This ad hoc method of untethered communication makes Bluetooth very attractive today and can result in increased efficiency and reduced costs. The efficiencies and cost savings are attractive for the home user and the enterprise business user. Benefits of Bluetooth include:[48]

- *Cable replacement.* Bluetooth technology replaces cables for a variety of interconnections. These include those of peripheral devices (i.e., mouse and keyboard computer connections), printers and modems, and wireless headsets and microphones that interface with PCs or mobile phones.
- *Ease of file sharing.* Bluetooth enables file sharing between Bluetooth-enabled devices. For example, participants of a meeting with Bluetooth-compatible laptops can share files with each other.
- *Wireless synchronization.* Bluetooth provides automatic wireless synchronization with other Bluetooth-enabled devices. For example, personal information contained in address books and date books can be synchronized between PDAs, laptops, mobile phones, and other devices.
- *Automated wireless applications.* Bluetooth supports automatic wireless application functions. Unlike synchronization, which typically occurs locally, automatic wireless applications interface with the LAN and Internet. For example, an individual working

offline on e-mails might be outside of their regular service area. To e-mail the files queued in the inbox of the laptop, the individual, once back in a service area, would activate a mobile phone or any other device capable of connecting to a network. The laptop would then automatically initiate a network join by using the phone as a modem and automatically send the e-mails after the individual logs on.

- *Internet connectivity.* Bluetooth is supported by a variety of devices and applications. Some of these devices include mobile phones, PDAs, laptops, desktops, and fixed telephones. Internet connectivity is possible when these devices and technologies join together to use each other's capabilities. For example, a laptop, using a Bluetooth connection, can request a mobile phone to establish a dial-up connection; the laptop can then access the Internet through that connection.

5.1.3 *Emerging Wireless Technologies*

Originally, handheld devices had limited functionality because of size and power requirements. However, the technology is improving, and handheld devices are becoming more feature-rich and portable. More significantly, the various wireless devices and their respective technologies are merging. The mobile phone, for instance, has increased functionality that now allows it to serve as a PDA as well as a phone. Smart phones are merging mobile phone and PDA technologies to provide normal voice service and email, text messaging, paging, Web access, and voice recognition. Next-generation mobile phones, already on the market, are quickly incorporating PDA, IR, wireless Internet, e-mail, and global positioning system (GPS) capabilities.

Manufacturers are combining standards as well, with the goal to provide a device capable of delivering multiple services. Bluetooth is being built into office appliances (e.g., PCs, faxes, printers, and laptops), communication appliances (e.g., cell phones, handsets, pagers, and headsets), and home appliances (e.g., DVD players, cameras, refrigerators, and microwave ovens). Applications for Bluetooth also include vending machines, banking, and other electronic payment systems; wireless office and conference rooms; smart homes; and in-vehicle communications and parking. However, each new development will present its own security risks, and agencies must address these risks to ensure that critical assets remain protected.

5.1.4 *Wireless Security Threats and Risk Mitigation*

The risks related to the use of wireless technologies are considerable. Although these technologies offer significant benefits, they also provide unique security challenges over and above those of their wired counterparts. The coupling of relative immaturity of the technology with poor security standards, flawed implementations, limited user awareness, and lax security and administrative practices forms an especially challenging combination.[49] In a wireless environment, data is broadcast through the air and organizations do not have physical controls over the boundaries of transmissions or the ability to use the controls typically available with wired connections. As a result, data may be captured when it is broadcast.

Some of the more immediate concerns for wireless communications are device theft, theft and/or denial of service, and industrial and foreign espionage. Theft of wireless devices is likely to occur because of their portability. Authorized and unauthorized users of the system may commit fraud and theft; however, authorized users are more likely to carry out such acts since users of a system may know what resources a system has and the system's security flaws. Theft of service occurs when an unauthorized user gains access to the network and consumes network resources; denial of service is similar, but in this case the unauthorized user prevents others from using the network. Industrial and foreign espionage involves gathering proprietary data from corporations or intelligence information from governments through eavesdropping. In wireless networks, the espionage threat stems from the relative ease with which eavesdropping can occur on radio transmissions.

5.2 SERT Communications

The Department of Defense has significant experience with wireless communications and the associated security risks. Encrypted radio transmissions are the norm for voice communication on the battlefield, and many of the same radios are now being used to transmit encrypted data. Communications security is paramount in contingency operations, as interceptions may allow the enemy to determine the location of and ambush friendly forces.

This focus on security may slow the military's adoption of commercial technologies. While companies or institutions may make the risk decision to use WLANs and Bluetooth networks with less-than-perfect security in place, the Department of Defense does not have this luxury. This decision process contributes to some of the problems experienced by SERT teams in operations and exercises thus far. The existing technologies employed by the Seabees are in most cases effective, but far from efficient or innovative.

5.2.1 Current Methods

Figures 5-2[50] and 5-3[51] reflect the current methods of communication for SERT teams. Voice communications via encrypted radio take place over established nets, including the SERT Command and Tactical nets and the Marine Command net. Data transfer takes place between the Security element and the Liaison element; however, the Recon element must hand carry the data they gather to the Security element for transfer. The Liaison element receives the data, downloads it to a disk and transfers it to a secure computer connected to the SIPRNET. As indicated in Section 3.3, observations from operations and exercises have shown that SERT is a very communication-dependent mission and exclusive use of high frequency data transfer is not sufficient.

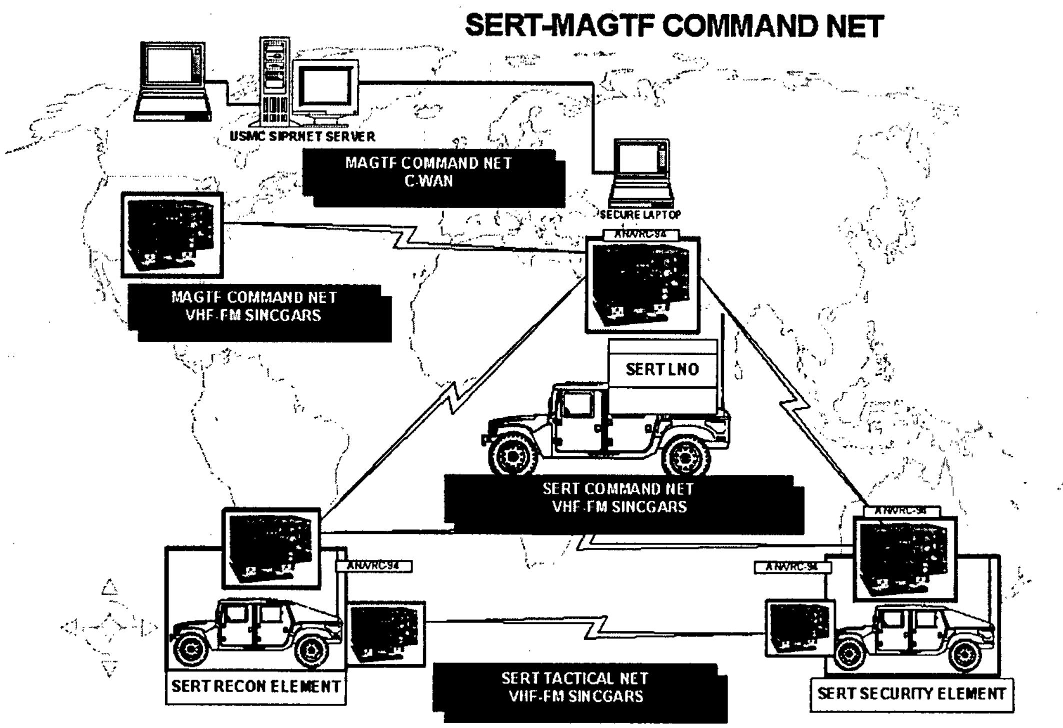


Figure 5-2 SERT Voice Communications

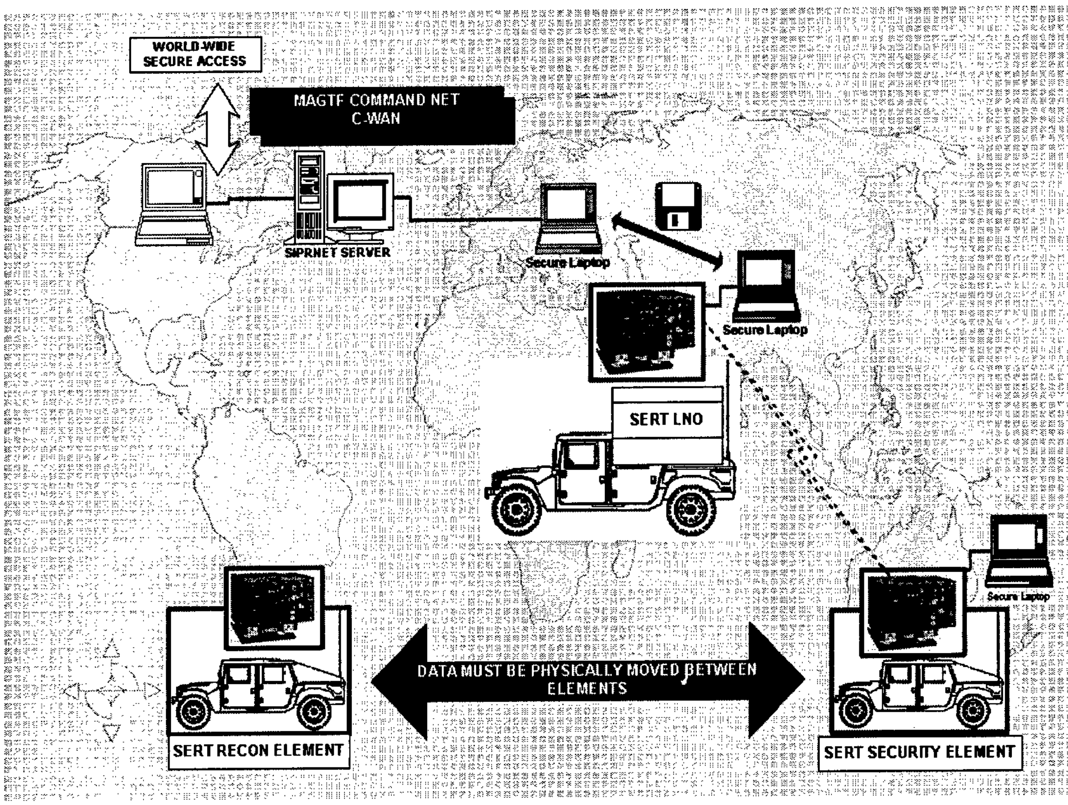


Figure 5-3 SERT Data Transfer-Current

5.2.2 Interim Step 1

The leaders of the Naval Construction Force have recognized these deficiencies and have formulated a plan to improve communications. The first step is to begin using a different system of data transfer applying the concepts of wireless communications previously discussed, but in a secure environment. This will take place through the employment of a new product from Harris Corporation, the RF-6710W Wireless Message Terminal. The RF-6710 enables e-mail communication over a variety of radio frequencies, automatically relaying messages over predetermined alternate paths. Equipping all elements of the SERT team with these terminals will allow simultaneous data exchange. This interim step also improves communications in the field by eliminating the dependency on HF communications, but does not change the data transfer via disk to the SIPRNET. This new process is shown conceptually in Figure 5-4[52].

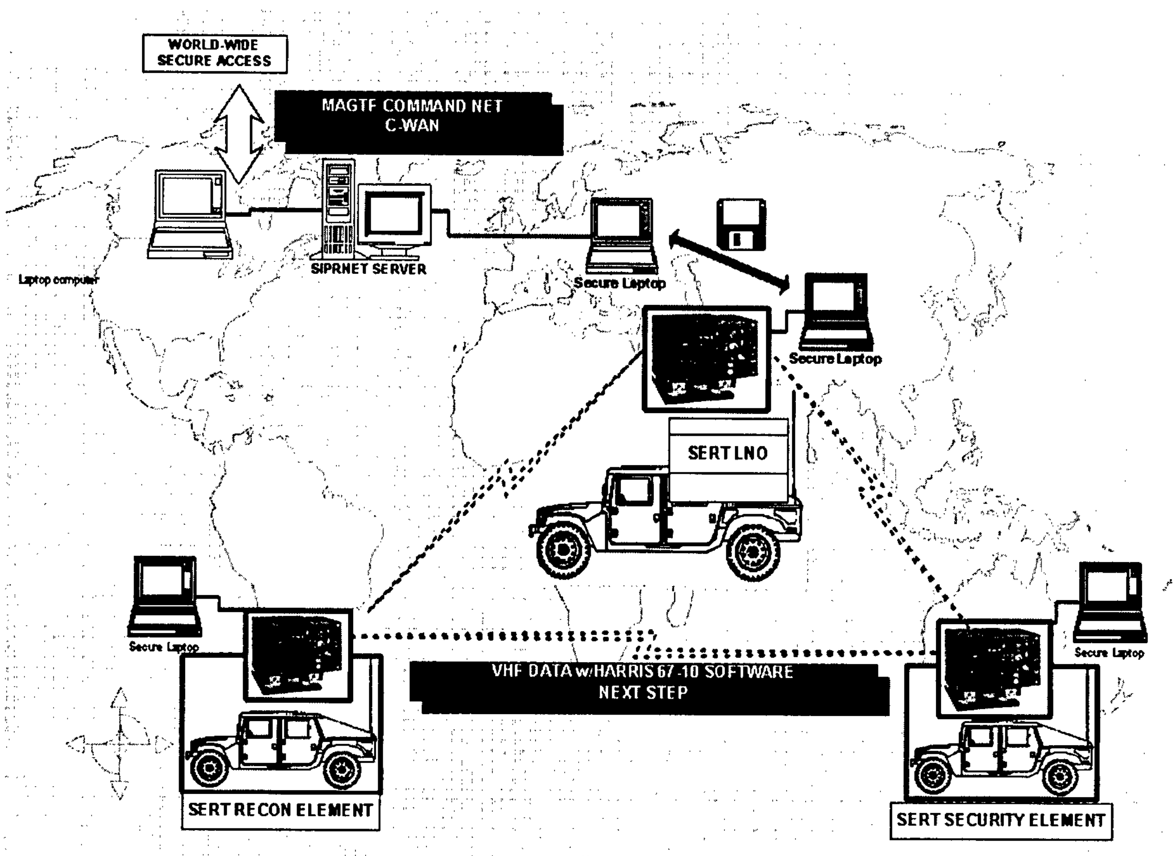


Figure 5-4 SERT Data Transfer---Interim Step 1

5.2.3 *Interim Step 2*

The next step adds satellite communications to the available options. It also incorporates another product from Harris, the RF-6750W Wireless Gateway, which serves as the access point to connect the wireless net with the SIPRNET or Local Area Network.

The Security element can now receive the data from the Recon element and transmit the data via a military satellite directly to the Engineer Operations Cell. At the same time, they can transmit the data to the Liaison element, who in turn sends the data via commercial satellite or follows the established path to send the data over the SIPRNET. The Engineer Operations Cell will employ the RF-6750 to receive the data from the military satellite and transfer it directly to a network to allow others to view and use it. This process is shown in Figure 5-5[53].

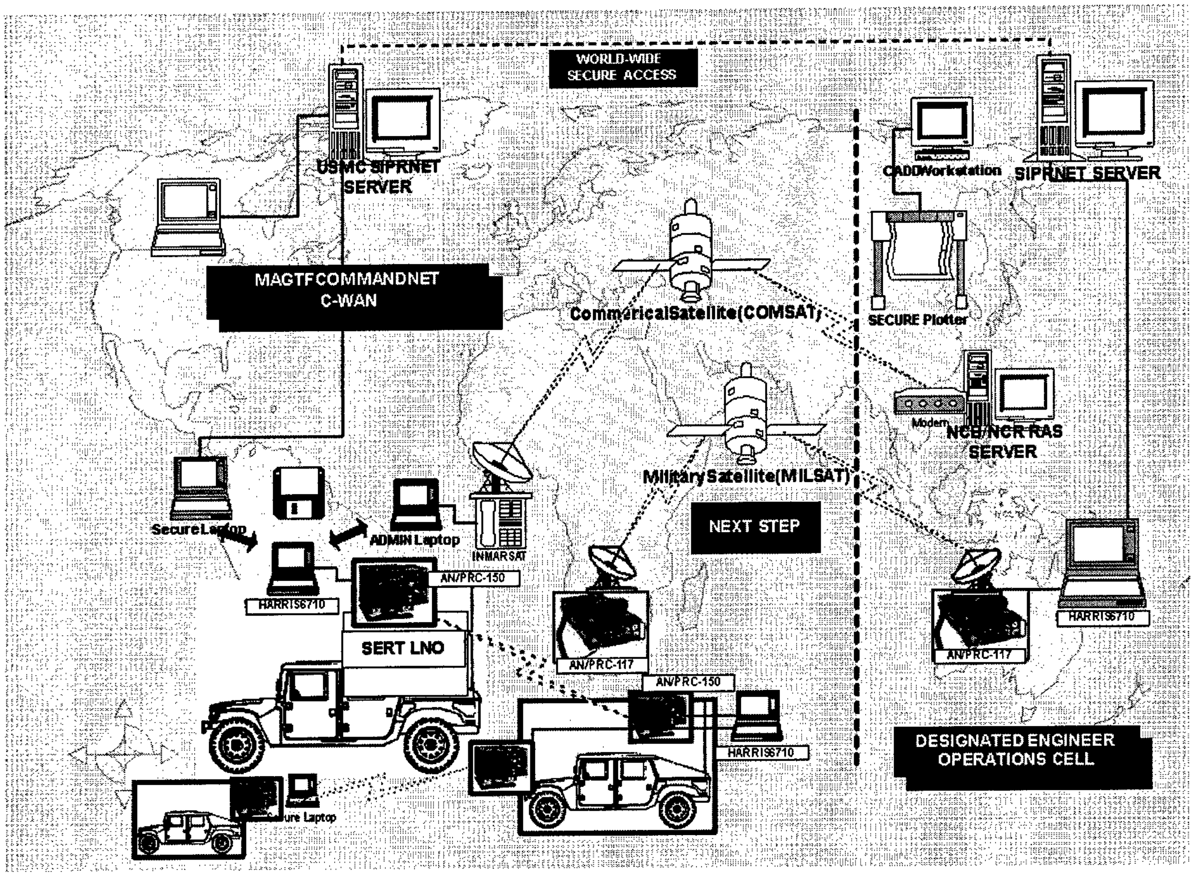


Figure 5-5 SERT Data Transfer---Interim Step 2

5.2.4 <u>End State</u>

The final step eliminates many of the intermediate steps and connects all of the players via military satellite communications. The SERT team in the field will utilize the RF-6710W to transfer data and images over military satellites to RF-6750W terminals at the Liaison element and the Engineer Operations Center. Other paths will remain to facilitate communications if problems arise with the military satellites. This end state is displayed in Figure 5-6[54].

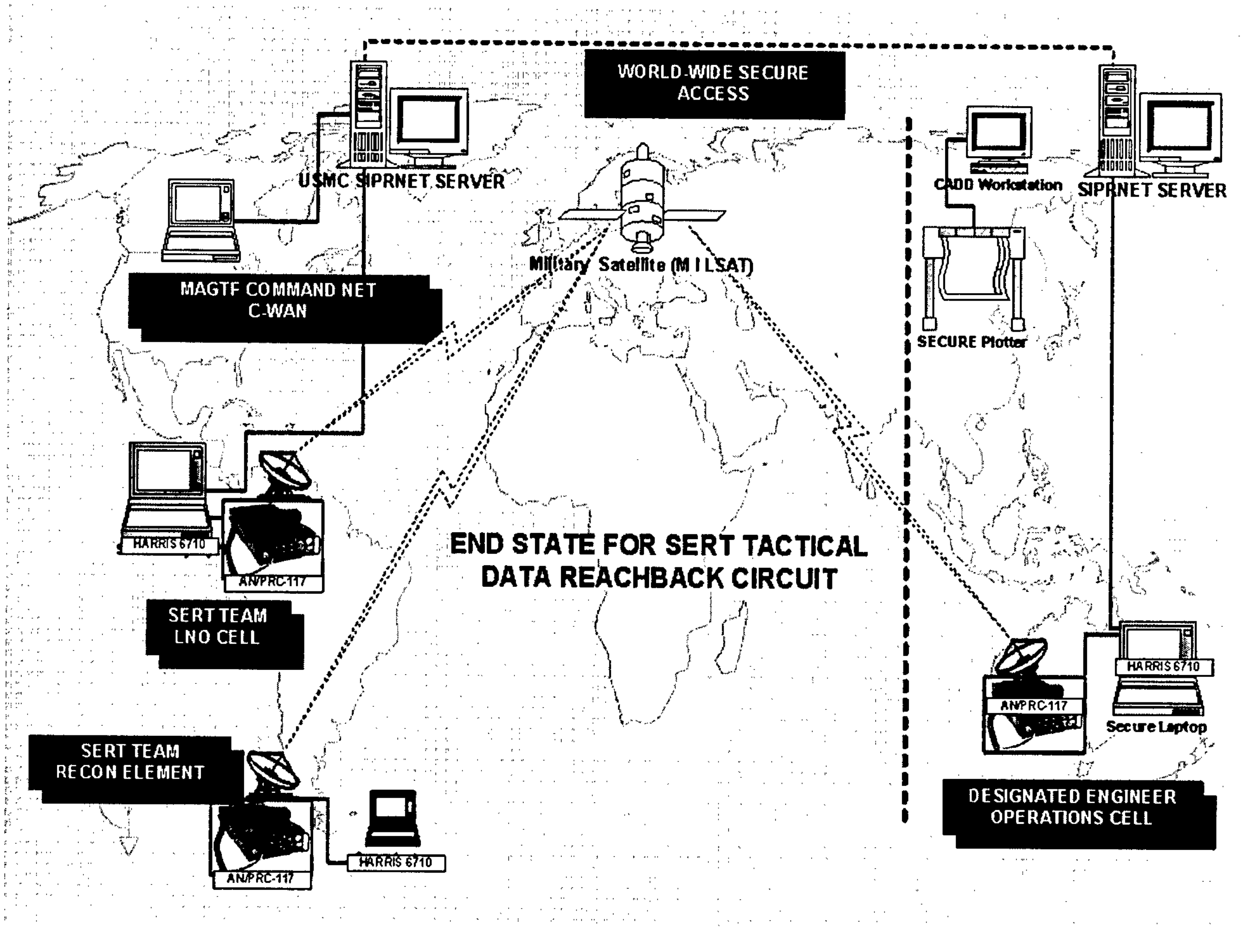


Figure 5-6 SERT Data Transfer---End State

These applications of technology should greatly improve the communications for SERT teams with other units in the area of operations and reachback with the Engineer Operations Center. Nevertheless, this solution does not incorporate the principles of Network Centric Warfare including shared situational awareness. The next chapter will explore the application of other information technology advances to exploit these improved communications.

Chapter 6 Enabling Network Centric Engineer Reconnaissance Operations

I have thus far presented the state of the practice in military engineer reconnaissance (Chapter 3), the state of the art in engineer reconnaissance (Chapter 4), and communications methods in both arenas (Chapter 5). It is now important to assess the state of the practice versus the state of the art under the framework of network centric operations.

6.1 Extent of Network-Centric Research

Section 2.11 introduced the idea that there will be many instantiations of NCW; as experience is gained with these applications of network-centric theory, both the theory and the practice will mature. There is much about the very nature of network-centric concepts and the application of these concepts to the domain of warfare that is not understood or where understanding is very limited. Most of the efforts to date by the Department of Defense have focused on getting better information in the first place. To progress further, they have identified three main concentration areas:[55]

- *Shared Situational Awareness.* The DoD recognizes that they know relatively little about how to turn the information they collect and display into shared situational awareness. Now that they have been able to greatly improve what they can collect, it is time to pay more attention to how they can move this data up the knowledge chain so that it will result in improved awareness.
- *Decentralized Decision Making.* To date, most work in decision theory and tools has focused upon a single decision maker. They need to move beyond this to shed light upon how distributed teams behave and how these teams can collaborate to make synergistic or synchronized decisions.
- *How Bad Information Affects Decisions.* The DoD has heretofore focused upon how good information helps decision-making. They now need to expand upon decision making related research to deal with how bad information affects decision making and how decision makers can best deal with a large variety of disparate sources of information with unknown pedigree and veracity.

6.2 Hypothesis

The hypothesis of this thesis predominantly addresses the issue of shared situational awareness, with a brief discussion on the implications for decentralized decision-making.

Concurrent with the development of their Seabee Engineer Reconnaissance Team initiative, the Naval Construction Force must adopt a new information-sharing paradigm and leverage information technology to enable network centric engineer reconnaissance operations.

6.3 Maturity of Engineer Reconnaissance Operations

As originally presented in Section 2.13, Figure 6-1 depicts a five-level maturity model for Network Centric Operations. This model is an initial formulation of a micro-level metric that compares the basic features of an application (state of the practice) against the theory (state of the art).

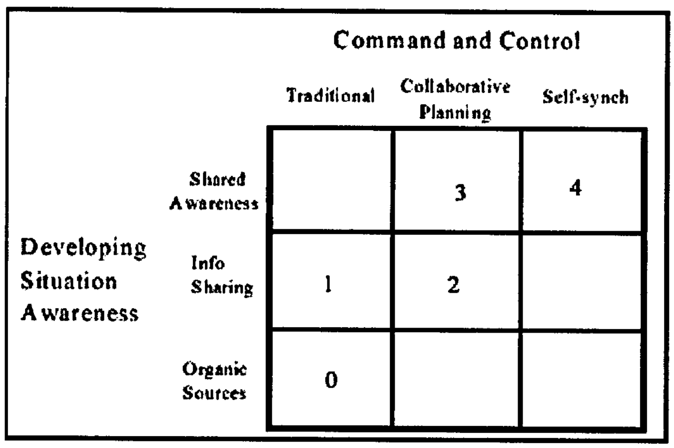


Figure 6-1 Network Centric Operations Maturity Model

Each of the values for the maturity of a network-centric warfighting capability is defined by considering two aspects of network-centric behavior. The first, the process of developing shared situational awareness (SSA), is meant to be a reflection of the degree to which information and awareness are shared. The second, the nature of command and control, is meant as a surrogate for how SSA is leveraged.

6.3.1 Current Status

Currently the Naval Construction Force is at Value 1 on the Network Centric Operations Maturity Model. SERT teams are sharing information, but are using very rudimentary techniques to do so. They also use very traditional command and control methods. I discussed their communications methods, shortfalls, and proposals to correct these problems in Chapter 5. However, even with these deficiencies addressed, the proposed methods to share information need to be addressed and improved.

I discussed in Chapter 3 the methods and procedures to prepare route classification overlays, one of the critical tasks for SERT teams. It is beneficial at this point to note what is involved in developing the overlay. Preparing an overlay is a time-intensive process that includes affixing a transparent sheet to a military map, establishing reference points so the overlay can be used effectively in the future, and noting the required information on the overlay. The overlay could then be reproduced for distribution; however, in many contingency situations, copiers are not readily available, so this must be done by hand. Another drawback to this approach is that the overlay can only be used on the same map on which it was created; it cannot be used on maps of different scales.

The method for gathering and sharing the data for bridges, tunnels, and other features is also antiquated. As described in Chapter 3, the reconnaissance forms are currently filled out by hand in the field and the forms must be scanned or the data must be entered into a laptop so it can be transmitted to the Liaison element.

6.3.2 Moving from Value 1 to Value 2

To progress to Value 2 on the maturity model, there must be some sort of collaborative planning among the participants. To accomplish this in the realm of military engineer reconnaissance, SERT teams must engage in collaborative design. While the concept of engineer reachback is valuable, it has also been shown that solutions are not provided quickly enough to meet the timelines imposed by contingency situations. In the "push versus pull" paradigm of information sharing, the current method of sending data and images to an Engineer Operations Center via e-mail messages and attachments is a "push" effort; the data is constantly being pushed through the pipes to those who need it. It is necessary to move to a "pull" situation where project participants can access web-collaboration sites and pull the necessary information to make their contributions.

Initial efforts on this front could involve the use of the DrChecks Design Review System. This is not a system that allows designers to work on a set of drawings simultaneously. However, it does provide a secure, structured setting to share documents, review designs, and provide comments. SERT team members could post their reconnaissance data to a project site on the DrChecks system and engineers worldwide could access the site and recommend possible solutions.

Designs will in almost all cases be completed using CAD software, whether that be AutoCAD or MicroStation. I have presented MicroStation V8 as a recommended platform due to Bentley's reputation for collaboration, the ability to work with either DGN or DWG files, their recent acquisition of Infrasoft and Arenium, and their interoperability efforts with ESRI. As described in Chapter 4, designs can be shared and modified online, design histories maintained in a history journal, and all of it can be done over a LAN, WAN, Internet, or using wireless communications. Security issues remain a source of concern, but partnerships could be formed to solve these problems. It is critical that the design timeframes be shortened in these contingency situations, and this can be achieved by sharing the engineering data gathered from the field as soon as possible with the subject matter experts in a collaborative environment.

6.3.3 Moving from Value 2 to Value 3

To further progress to Value 3 on the maturity model, there must be richer collaboration, involving more actors and integrating more aspects of the operation. This will entail the use of geographic information system (GIS) technology to rapidly share the information gained by SERT teams during route classification missions. I therefore suggest parallel uses for the Syncline® applications presented in Chapter 4.

- *Route Classification Viewer.* Based on the Parcel Viewer and Community Resources Viewer, it would display the various routes in the area of operations using color-coding and symbols. Points of Interest (POIs) would include bridges, tunnels, underpasses, bypasses, etc. and users could click on any POI to view its relevant data, such as a NATO Bridge Symbol (Figure 3-2), Tunnel symbol (Figure 3-4), and others.
- *Convoy Module.* Based on the Permitting Module, it would greatly simplify the convoy request, approval, and tracking process. Any convoy transiting in the area of operations must first obtain approval to do so. In my experience, convoy requests are difficult and tedious to prepare, with lots of time wasted filling out paperwork, communicating the details, etc. By automating the convoy request process, users could access current data on available convoy routes, fill out and submit convoy requests online, and obtain

approval online. The module would also allow tracking of active convoys as they passed checkpoints to more efficiently manage traffic flow.

- *Forward Operating Base Module.* Based on the Zoning and Land Use Viewer and Economic Development Modules, it would improve the planning for establishing forward operating bases. As demonstrated during Operation Iraqi Freedom, location of operating bases and supply and logistics are critical aspects of successful military operations. It is no longer feasible to expect that forward operating bases will be constructed in greenfield areas according to generic plans and layouts; contingency operations are more likely to occur in and among urban, or brownfield, areas. In such cases, it is almost an operational necessity to gather data on the existing facilities to determine their structural integrity, available floor space, and operational utility. Engineer reconnaissance units could gather this information and populate the forward operating base module so planners within and outside the area of operations could determine the optimum location and configuration of forward operating bases.

Another possibility is the adoption of the Barchan software. While Barchan was developed to enable local governments to keep better track of their infrastructure assets, its functionality has potential applications in the field of engineer reconnaissance. With the underlying GIS roads layer for the area in question, reconnaissance personnel could quickly assess and catalog the cross-section, condition, and other appropriate characteristics of road segments. With minimal additional programming or plug-ins, the application could calculate the load-bearing capacity and trafficability of the metasegments and display viable routes. For those segments in need of repair or upgrade, engineers could tap not only the cost data, but also use the time and labor figures in RS Means to determine a reasonably accurate estimate of cost and time required. The scenario tool could then be modified to recommend strategies to optimize the network based not only on cost, but also time, labor, and material constraints.

These tools do more than enhance shared situational awareness; they enable decentralized decision-making. By sharing the information contained in GIS applications such as the proposed *Route Classification Viewer, Convoy Module,* and *Forward Operating Base Module* in real time, geographically dispersed users, whether they are in the area of operations or spread throughout the globe, could make informed decisions at the lowest possible level.

6.3.4 *Moving from Value 3 to Value 4*

To progress to Value 4, a Mission Capability Package is required that allows integration across doctrine, organization, training, material, and other aspects of the force and its supporting systems that permit self-synchronization. Section 2.9 introduced the concept of Mission Capability Packages and the numerous iterations required to take a concept from idea to fielded operational capability. Various exercises and operations have taken place that demonstrate the viability of SERT teams using the established Army doctrine; however, there is still enough time to move beyond the antiquated methods of information sharing and adopt collaborative design and GIS technologies. These network-centric concepts could then be refined through further exercises and operations before being adopted as a Mission Capability Package.

6.4 Obstacles to Implementation

Military history is full of examples demonstrating that even when the technology was widely available, disruptive innovations made possible by this technology did not occur concurrently with the availability of the technology. Innovation only occurred when a number of conditions were met: a combination of the right people, a set of organizations that could learn, the proper institutional relationships among those organizations, and an established industrial base to supply the technology, products, and services necessary for disruptive innovation to occur.[56] For ease of presentation, the following obstacles are categorized as political, cultural, business, technical, or security obstacles, when in reality all blur the lines and involve some combination thereof.

6.4.1 *Political and Cultural Obstacle*

In the late 1800s, a British Naval Officer was concerned about the lack of accuracy of the gunfire aboard ship. The recognized technique required the gunners to set the elevation of the gun based on an estimated range, and then time their firing between the rolls of the ship on the sea. This approach resulted in gunnery being more art than science. While observing target practice one day, Admiral Sir Percy Scott noticed that one of his men was constantly turning the elevating gear of the gun to compensate for the rolls of the ship.

Scott quickly realized that with some gear ratio changes, the elevating gear could be modified to allow the gun crews to constantly adjust the gun's elevation, thereby keeping the target vessel in the sights and allow continuous aim and fire. He also fitted the guns with a new sleeve to make the telescopic sight more effective and added a training target to each gun to allow his sailors to practice. Within one year, his ship the Scylla established unprecedented records for accuracy.

In 1900, Scott was transferred to the H.M.S. Terrible in China Station, where he introduced his revolutionary techniques to the new crew. The methods were again proven successful, and drew the notice of an American junior officer, William S. Sims. Sims transferred the continuous-aim firing approach to his ship and the Americans capitalized with remarkable success of their own. Sims then ensued on a campaign to notify and educate the Navy leadership. Over the course of two years, he sent numerous communications the Bureau of Ordnance and the Bureau of Navigation explaining the technology and citing the exceptional performance of his crew. Nevertheless, no one believed his reports and they were filed away to collect dust.

Frustrated by the lack of response, Sims continued to submit the reports, but also sent copies to other officers in the fleet. With others now aware of his outrageous claims, the Bureaus were forced to act. They discredited the claims, citing experiments of their own that claimed to prove that continuous-aim firing was impossible. The leadership of the two Bureaus had a vested interest in preserving the existing technology; after all, they were responsible for developing and implementing it in the first place and hadn't lost a war yet.

What followed was a period of letter writing and name-calling; however, rather than dissuade Sims from pursuing his case further, it convinced him that one final step was needed. He sent a letter directly to President Theodore Roosevelt explaining the phenomenal success of this new approach and of the refusal of the Navy leadership to take action. Roosevelt responded by recalling him from China Station and appointing Sims as the Inspector of Target Practice. Upon his departure from the post six years later, he was regarded by many American sailors as "the man who taught us how to shoot."[57]

While the application of information technology to engineer reconnaissance is not nearly as innovative as changing the way naval gunfire is delivered, similar obstacles may exist in the politics and established culture of the military.

6.4.2 <u>Security Obstacle</u>

Collaborative design and geographic information systems require good communications, in this case wireless communications, to be effective. Chapter 5 described the great potential and great liabilities associated with wireless communications. The Naval Construction Force has a plan to guard against these risks through the use of encrypted communications, but none of the proposed interim steps are guaranteed.

Network Centric Warfare offers the potential for dramatic advantages, but carries the risk of a major loss of capability if networks are penetrated or significantly disrupted. As NCW capabilities increase in maturity and warfighters effectively exploit enhanced shared situational awareness enabled by information sharing, the ability to defend networks that enable this information sharing becomes increasingly important. Consequently, progress in implementing Network Centric Warfare is closely linked to improvements in information operations and information assurance capabilities.[58]

6.4.3 Technical Obstacle

Network Centric Warfare is a different approach to warfighting that will require disruptive innovation and a transformation of the Department of Defense. It will not happen overnight, as reflected by the thoughts of Admiral Vern Clark, the Chief of Naval Operations, as he discussed ForceNet, an information technology vision for the Navy, "we have been talking about network-centric warfare for a decade, and ForceNet will be the Navy's plan to make it an operational reality."[59] Nor will everyone agree with the need for transformation or the effectiveness of network centric operations. Some will argue that we have already done enough. "Much of the attack against the current naval structure is based on a claim that the Navy is resisting transformation as it always has, and that it is not at all net-centric. The unstated irony is that not only is the Navy network-centric right now, but it is so to a much greater extent than the other services."[60]

6.4.4 Business Obstacle

The Naval Construction Force is not at the top of the "food chain" in the Department of Defense. While they provide a valuable service in times of peace and conflict, they are in the simplest sense an arm of the logistics organization in the military, and do not always receive adequate funding to maintain their existing equipment, much less purchase innovative information technology applications.

An illustration of a parallel case occurred during Operation Iraqi Freedom when members of the Army's 507th Maintenance Company were attacked and taken prisoner outside Nasiriya on

March 23, 2003. Accounts of the incident vary, but it appears that these vehicles were part of a supply convoy and became separated from the rest of the convoy. Having neither global positioning system devices to verify their location nor adequate communications capability (stories indicate that drivers communicated by pulling alongside other vehicles and screaming through open windows), these vehicles made a wrong turn and drove directly into an Iraqi ambush.

Despite their motto "we build, we fight", the Seabees are a defensive force and will not receive the latest weapons, communication gear, nor equipment in a military where resources are constrained. Nevertheless, the SERT initiative coupled with the Congressionally mandated implementation of Network Centric Warfare provide an exciting opportunity. The Naval Construction Force is a relatively small organization with a viable method to inexpensively test the application of information technology to improve engineer reconnaissance; their lessons learned could be incorporated into doctrine, tactics, techniques, and procedures and implemented throughout the military, with applications and extensions to allies, law enforcement, and diplomatic agencies via the Global Information Grid.

None of these obstacles are insurmountable. In the business world, successful entrepreneurs look for opportunities in imperfect markets, and the more imperfect the market, the greater the opportunities. Opportunities are created by changing circumstances, inconsistencies, information gaps, chaos, and other discontinuities.[61] Leaders of the Naval Construction Force have seized on an opportunity by implementing Seabee Engineer Reconnaissance Teams; they now need to take advantage of the information revolution and adopt a new paradigm for gathering and sharing information. The technologies surveyed are currently available and could quickly be adapted to the practice of military engineer reconnaissance.

Chapter 7 Conclusions

7.1 Conclusions

Conclusions of this research are:

- Seabee Engineer Reconnaissance Teams are a viable concept. Exercises and operations show this is a valuable expansion of the Seabees' traditional mission.
- SERT is a communications-dependent mission and the Naval Construction Force has a strategy to improve the inefficient system currently in use. Nevertheless, the information-sharing paradigm is outdated and must be changed to take advantage of the improved communications.
- Network Centric Warfare provides a structured framework to gauge the maturity of operations, and SERT is at Value 1 on this scale. They are sharing information, but are using very rudimentary techniques to do so, and they use very traditional command and control methods.
- To progress to Value 2 on the Network Centric Operations Maturity Model, there must be some sort of collaborative planning among the participants. To accomplish this in the realm of military engineer reconnaissance, SERT teams must engage in collaborative design using applications such as the DrChecks Design Review System, Bentley's MicroStation V8, and Infrasoft's Arenium.
- To further progress to Value 3 on the Maturity Model, there must be richer collaboration, involving more actors and integrating more aspects of the operation. This will entail the use of geographic information system (GIS) technology to rapidly share the information gained by SERT teams during reconnaissance missions. Commercial solutions from ESRI, Syncline, and Barchan can be adopted with minimal customization to enable shared situational awareness.
- Collaborative design and geographic information systems must be employed and tested in exercises and operations to fully develop a Mission Capability Package and progress to Value 4, the final step on the Network Centric Operations Maturity Model. Successful implementation of these technologies will provide more than shared situational awareness; it will enable decentralized decision-making.

- There are various obstacles to implementing these technologies, but none of them are insurmountable, and obstacles and other discontinuities lead to opportunities. Leaders of the Naval Construction Force have seized on an opportunity by implementing Seabee Engineer Reconnaissance Teams; they now need to take advantage of the information revolution and adopt a new paradigm for gathering and sharing information.

7.2 Future Research

This research generated opportunities to go farther in the following areas.

7.2.1 Applications to AEC Industry

In general terms, engineer reconnaissance can be used to describe a process of gathering information in difficult circumstances to provide engineering solutions. These difficult circumstances could include: contingency situation (military), time constraints, economic constraints, personnel constraints, environmental conditions, political conditions, or a natural disaster. When faced with any of these circumstances, or a combination thereof, a possible solution is to select a small group of professionals skilled in engineering and construction to insert in the area. This small group could then survey the area in question, gather the required data and images, and make this information available electronically to a remote team of experts for review, analysis, recommendations, and solutions.

This approach has applications throughout the Architect, Engineer, and Construction (AEC) industry. In these challenging times with economies in recession, wars being fought, increased threats of terrorism, and increasing overseas development, prudent professionals need to find ways to obtain competitive advantage. The concepts explored in this research could easily be exported to the practice of engineer reconnaissance in the AEC industry.

7.2.2 Information Technology Applications

The technologies presented here are by no means an all-inclusive list. These were selected based on their potential to provide the greatest "bang for the buck" in the area of military engineer reconnaissance. Other technologies may be available now or may soon be developed that will further enhance the state of the practice.

7.2.3 Alternative Methods

There is nothing more valuable to the military than its people. This is evidenced by the increasing investment in technologies that reduce the risk to soldiers in the battlespace or remove them all together through the use of unmanned aerial vehicles and robots. Advances in areas such as remote sensing and nanotechnologies may reduce the risk of putting people in harm's way to gather engineer reconnaissance data.

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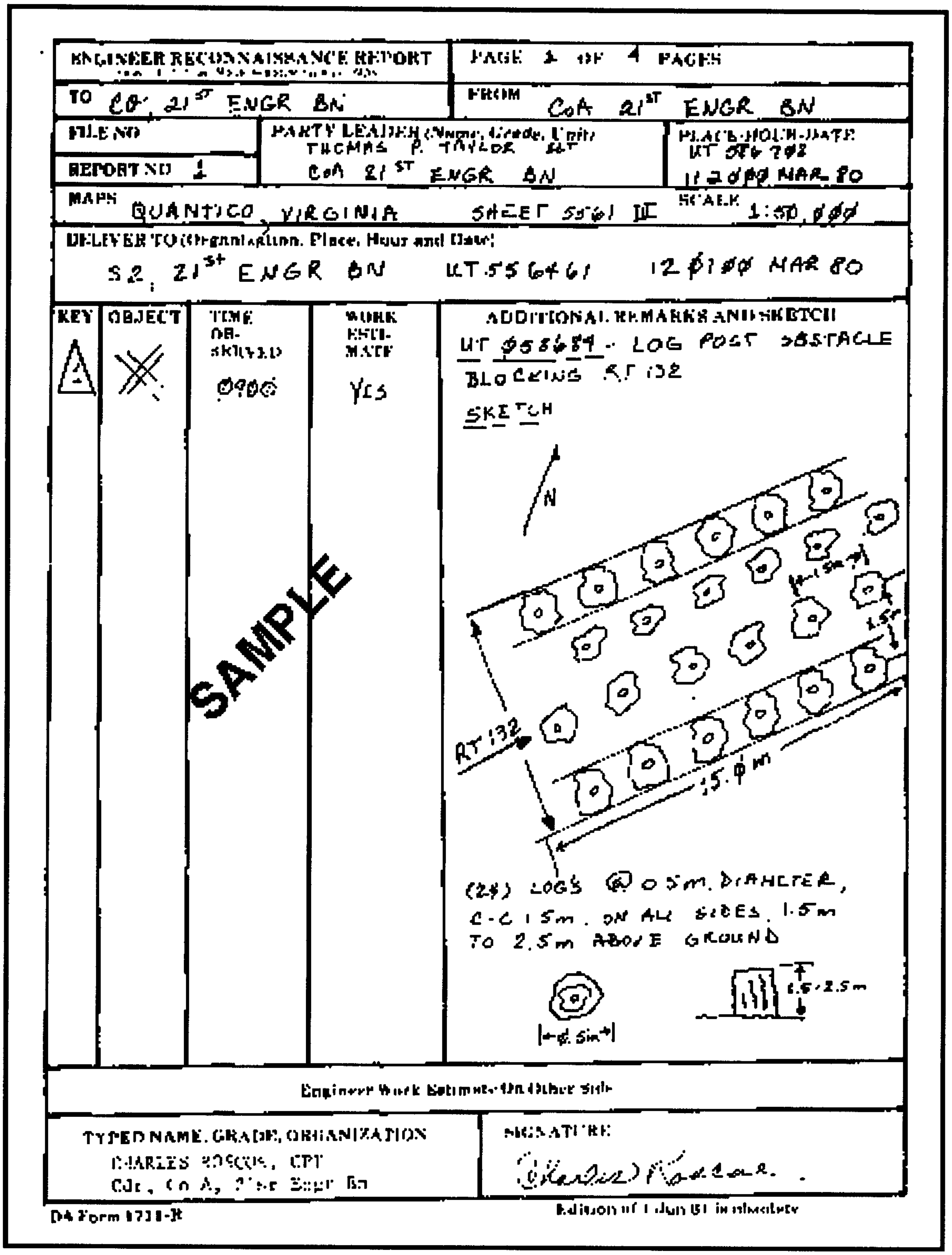
APPENDIX A Department of the Army Engineer Reconnaissance Forms



ENGINEER RECONNAISSANCE REPORT | PAGE 1 OF 4 PAGES

TO CO, 21ST ENGR BN | FROM CoA 21ST ENGR BN

FILE NO | PARTY LEADER (Name, Grade, Unit) THOMAS P. TAYLOR SGT CoA 21ST ENGR BN | PLACE-HOUR-DATE

REPORT NO 1

MAPS QUANTICO, VIRGINIA SHEET 5561 III | SCALE 1:50,000

DELIVER TO (Organization, Place, Hour and Date) S2, 21ST ENGR BN UT 556461 120100 MAR 80

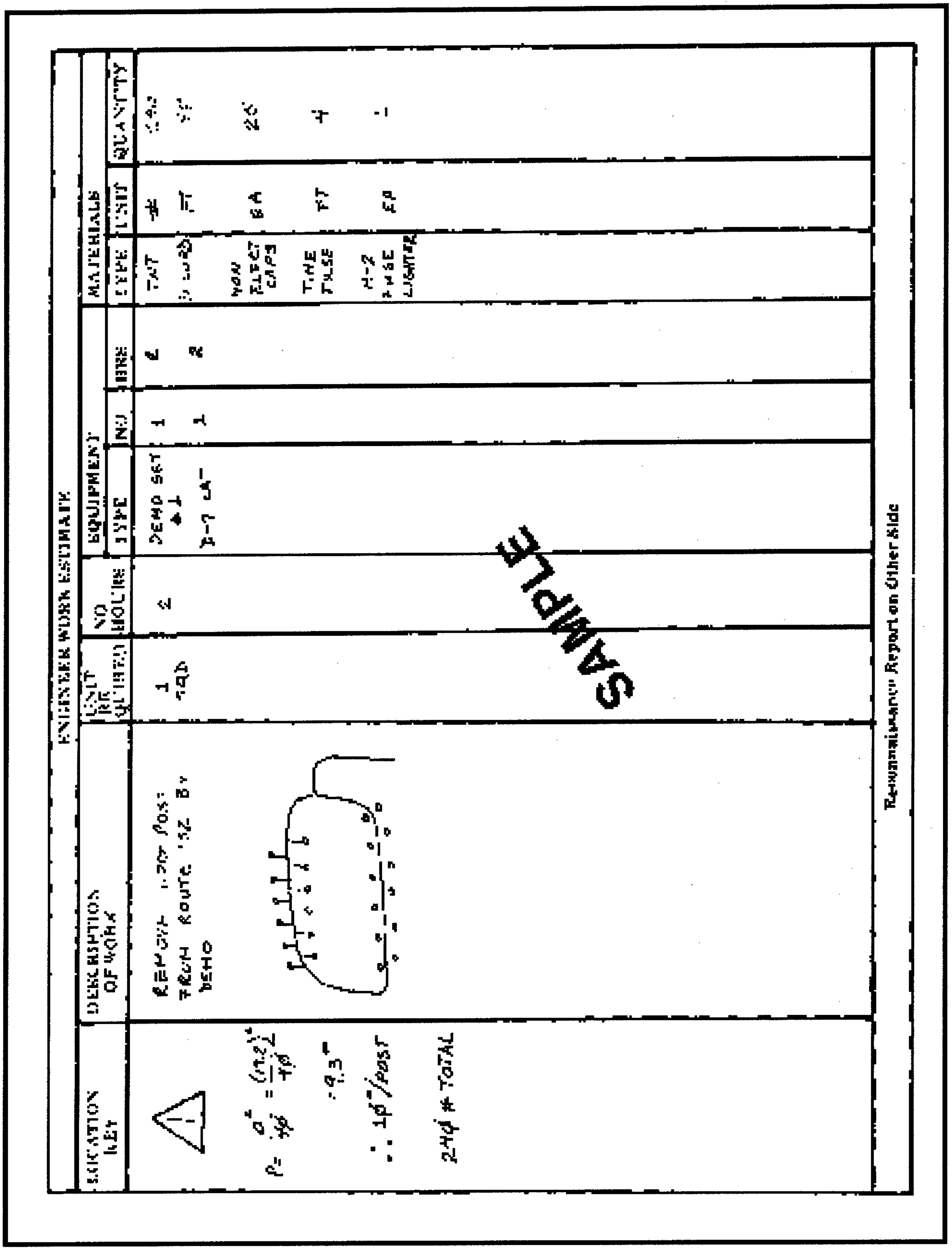
KEY	OBJECT	TIME OBSERVED	WORK ESTIMATE	ADDITIONAL REMARKS AND SKETCH
		0900	YES	UT 058689 - LOG POST OBSTACLE BLOCKING RT 132 SKETCH

Engineer Work Estimate On Other Side

TYPED NAME, GRADE, ORGANIZATION | SIGNATURE

DA Form 1711-R | Edition of 1 Jun 61 is obsolete

Figure A-1 Sample Engineer Reconnaissance Report DA Form 1711 (front)



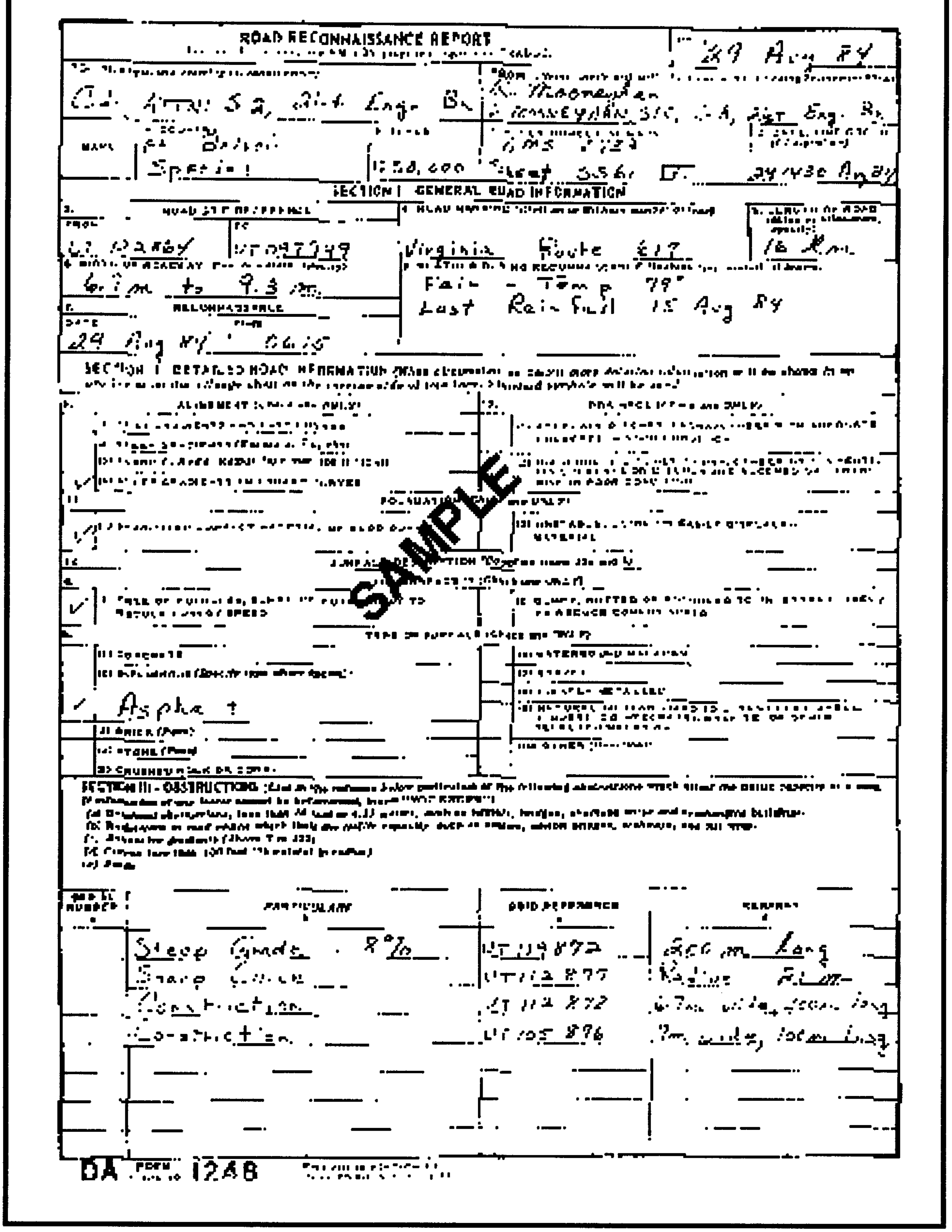
ENGINEER WORK ESTIMATE

LOCATION KEY	DESCRIPTION OF WORK	UNIT REQUIRED	NO HOURS	EQUIPMENT TYPE	EQUIPMENT NO	EQUIPMENT HRS	MATERIALS TYPE	MATERIALS UNIT	MATERIALS QUANTITY
1 (triangle); P = $\frac{a^2}{40} = \frac{(19.2)^2}{40}$ = 9.3 ∴ 10#/POST; 240# TOTAL	REMOVE [illegible] POST FROM ROUTE 152 BY DEMO	1 SQD	2	DEMO SET #1	1	2	TNT	#	[illegible]
				D-7 CAT	1	2	DET CORD	FT	[illegible]
							NON ELECT CAPS	EA	25
							TIME FUSE	FT	4
							M-2 FUSE LIGHTER	EA	1

SAMPLE

Reconnaissance Report on Other Side

Figure A-2 Sample Engineer Reconnaissance Report DA Form 1711 (back)



ROAD RECONNAISSANCE REPORT

29 Aug 84

SECTION I - GENERAL ROAD INFORMATION

Virginia Route 617

16 Km

6.1 m to 9.3 m

Fair - Temp 79°

Last Rainfall 15 Aug 84

SECTION II - DETAILED ROAD INFORMATION

SAMPLE

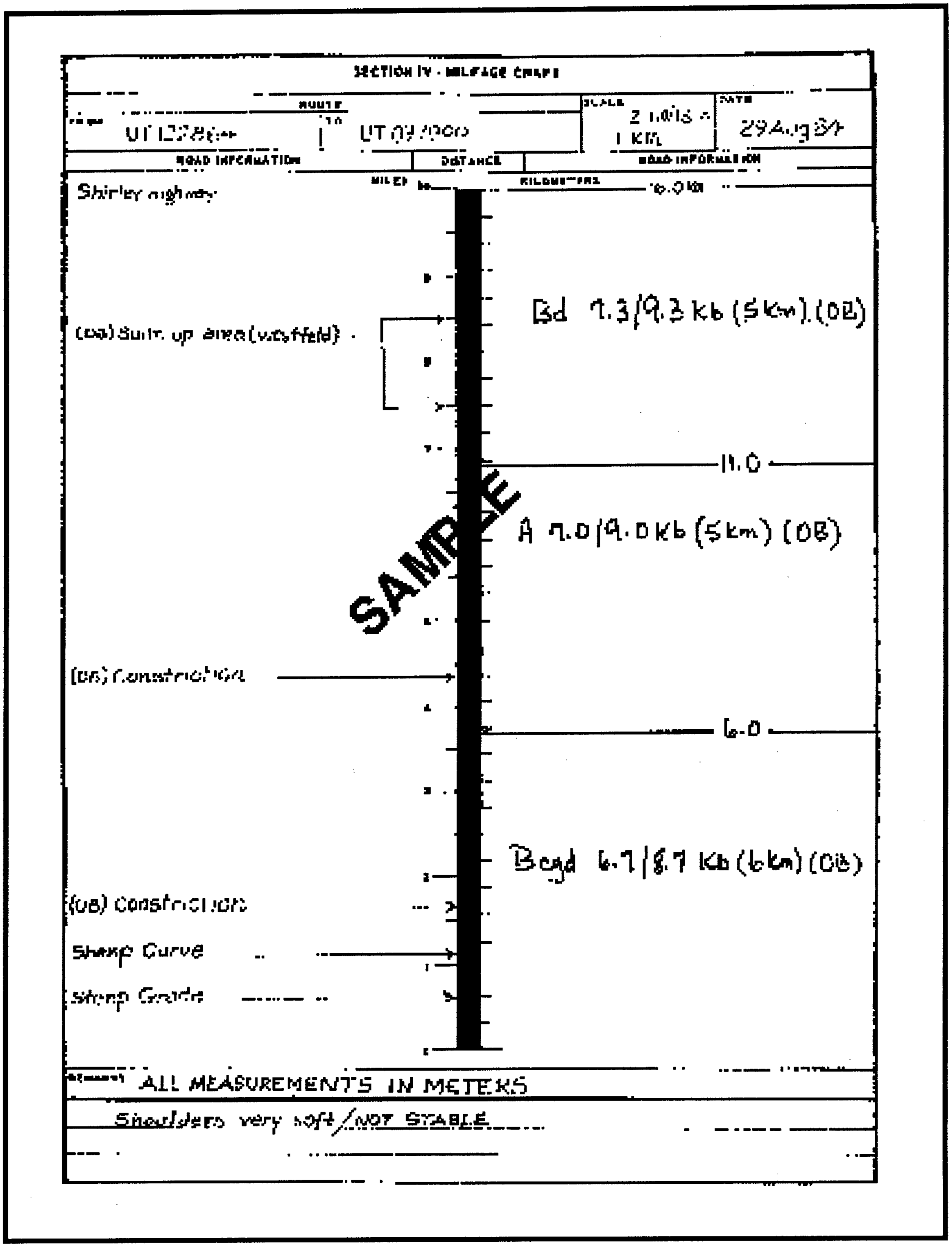
Asphalt

SECTION III - OBSTRUCTIONS

PARTICULARS	GRID REFERENCE	REMARKS
Steep Grade 8%	UT 114872	300 m long
Sharp Curve	UT 112877	Radius 21 m
Construction	UT 114872	6.7m wide, 100m long
Constriction	UT 105876	7m wide, 10m long

DA FORM 1248

Figure A-3 Sample Road Reconnaissance Report DA Form 1248 (front)



SECTION IV - MILEAGE CHART

ROUTE FROM UT 123456 TO UT 034000

SCALE 2 units = 1 KM

DATE 29 Aug 84

ROAD INFORMATION | DISTANCE | ROAD INFORMATION

MILES | KILOMETERS

Shirley Highway

16.0 KM

(09) Built up area (Westfield)

Bd 7.3/9.3 Kb (5 km) (OB)

11.0

A 7.0/9.0 Kb (5 km) (OB)

SAMPLE

(05) Construction

6.0

Bcgd 6.7/8.7 Kb (6 km) (OB)

(08) Construction

Sharp Curve

Steep Grade

REMARKS ALL MEASUREMENTS IN METERS

Shoulders very soft / NOT STABLE

Figure A-4 Sample Road Reconnaissance Report DA Form 1248 (back)

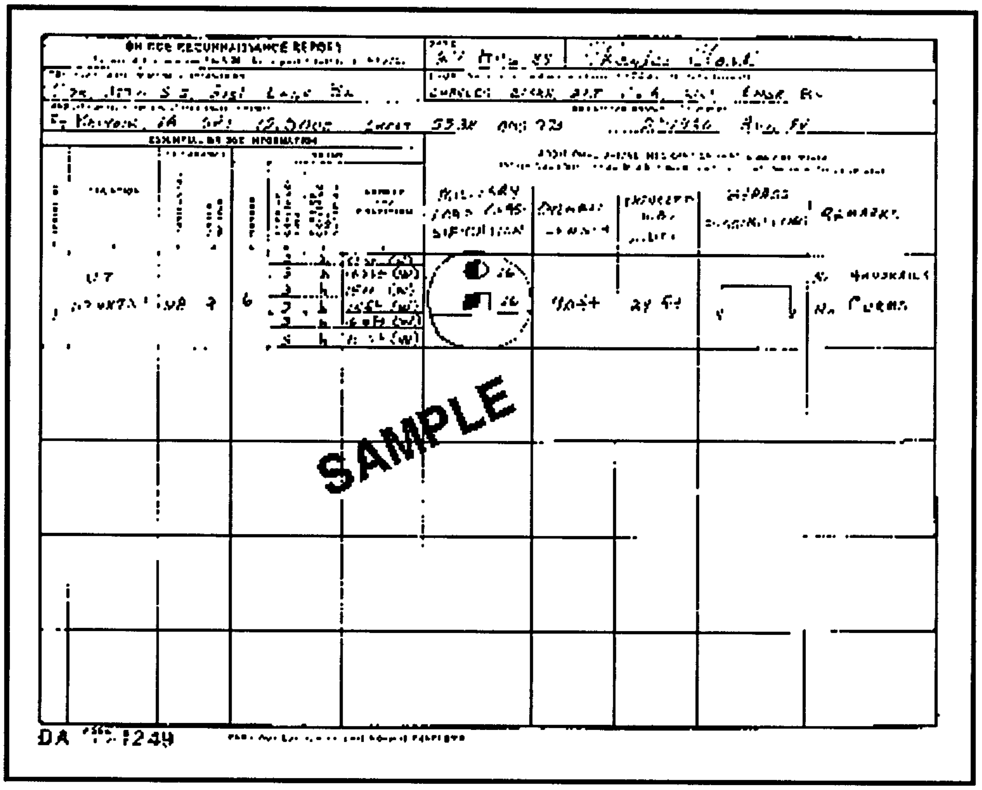


Figure A-5 Sample Bridge Reconnaissance Report with Full NATO Symbol DA Form 1249

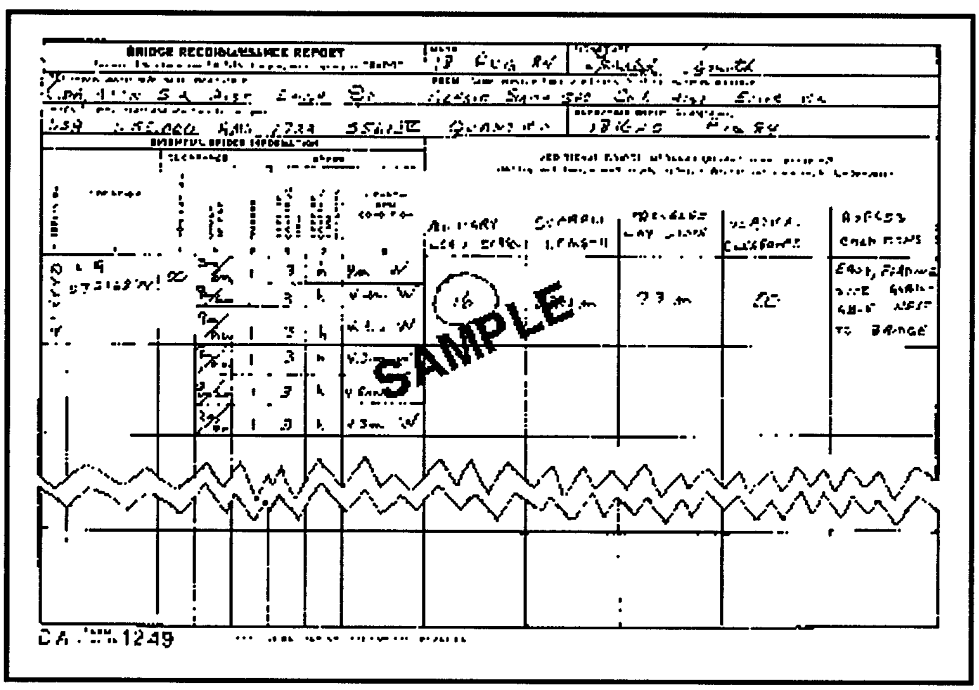
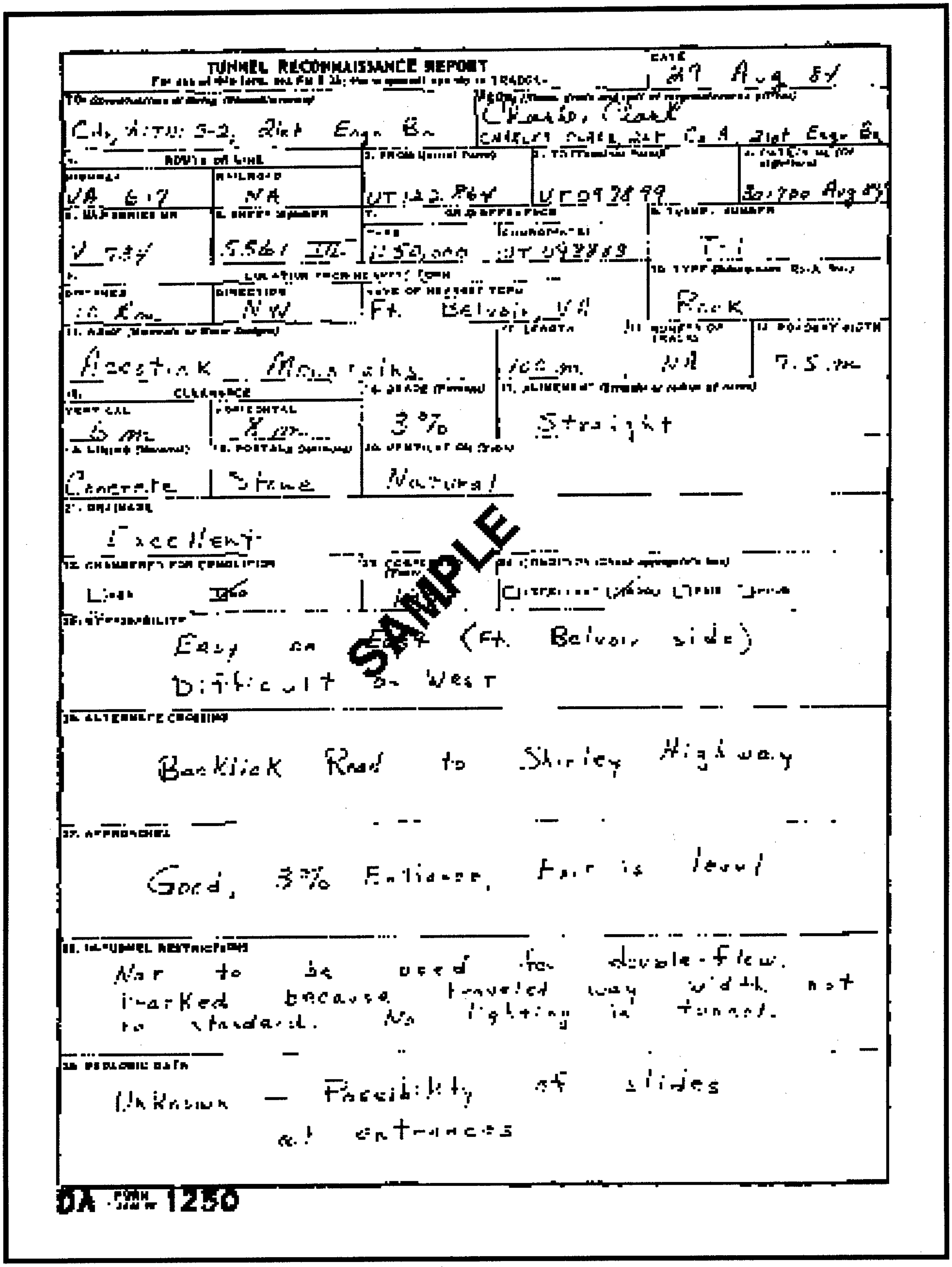


Figure A-6 Sample Bridge Reconnaissance Report with Abbreviated Bridge Symbol DA Form 1249



TUNNEL RECONNAISSANCE REPORT

DATE: 29 Aug 84

TO: Cdr, ATTN: S-2, 21st Engr Bn

FROM: Charles Clark, SGT, Co A, 21st Engr Bn

ROUTE OR LINE: Highway VA 617; Railroad NA

FROM: UT 142 764

TO: UT 094 799

DATE/TIME: 30 1700 Aug 84

MAP SERIES NR: V 734

SHEET NUMBER: 5561 III

SCALE: 1:50,000

COORDINATES: UT 092783

TYPE: T-1

TYPE: Rock

LOCATION FROM NEAREST TOWN: Distance 10 Km; Direction NW; Name of nearest town: Ft. Belvoir, VA

NAME: Accotink Mountains

LENGTH: 100 m.

NUMBER OF TRACKS: NA

ROADWAY WIDTH: 7.5 m.

CLEARANCE: Vertical 6 m.; Horizontal 8 m.

GRADE: 3%

ALIGNMENT: Straight

LINING: Concrete

PORTALS: Stone

VENTILATION: Natural

DRAINAGE: Excellent

CHAMBERS FOR DEMOLITION: Lined [illegible]

CONDITION: Excellent / Good / Fair / Poor

ACCESSIBILITY: Easy on East (Ft. Belvoir side) Difficult on West

ALTERNATE CROSSING: Backlick Road to Shirley Highway

APPROACHES: Good, 3% Entrance, Exit is level

IN-TUNNEL RESTRICTIONS: Not to be used for double-flow, marked because traveled way width not to standard. No lighting in tunnel.

GEOLOGIC DATA: Unknown — Possibility of slides at entrances

DA FORM 1250

SAMPLE

Figure A-7 Sample Tunnel Reconnaissance Report DA Form 1250 (front)

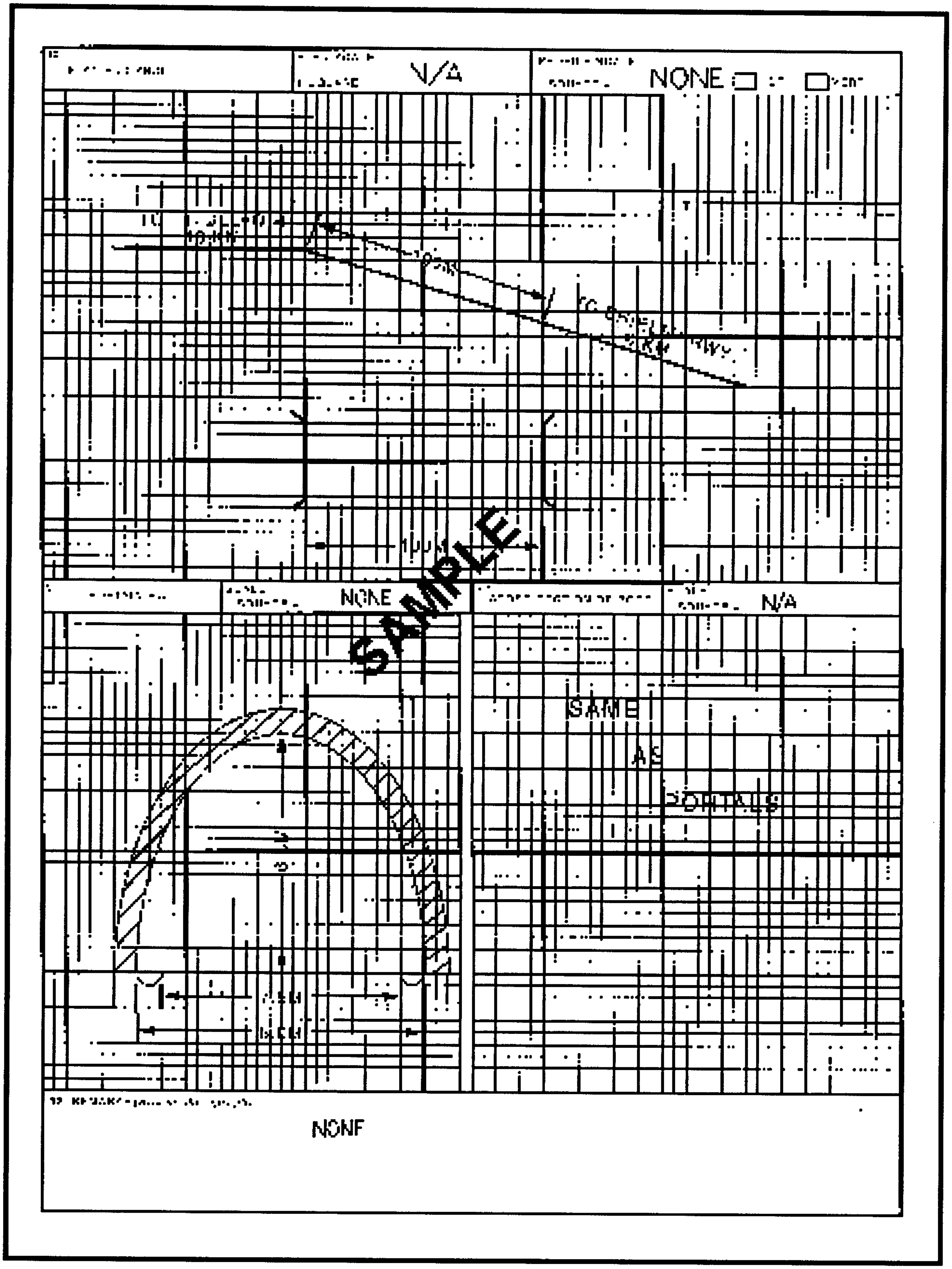


Figure A-8 Tunnel Reconnaissance Report DA Form 1250 (back)

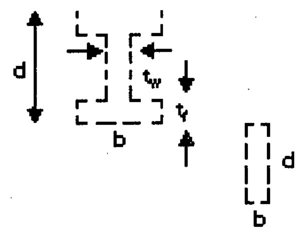
APPENDIX B Bridge Classification Worksheets

The following worksheets cover the six most common bridge construction types likely to be encountered in Seabee Engineer Reconnaissance Team missions.

Map Sheet Grid
Recon Officer/NCO Unit Date

BRIDGE DIMENSIONS

L ____ ft
b_R ____ ft
N_L ____ (2 if $b_R \geq 18$ ft)
N_S ____
S_S ____ ft
N_b ____
S_b ____ ft
Deck: Single-layer, multilayer, or laminated
t_d ____ in
% lam ____



STRINGER DIMENSIONS

Timber: b ____ in
d ____ in
Steel: Type ________
(Table B-4)
d ____ in
b ____ in
t_w ____ in
t_f ____ in

PROCEDURE

1. m ____ (Table B-3 or B-4)
2. M_{DL} ____ (Table B-5)
3. m_{DL} ____ (M_{DL} / N_s)
4. m_{LL} ____
   a. Timber: m - m_{DL}
   b. Steel: (m - m_{DL}) / 1.15
5. L_m ____ (Table B-3 or B-4)
6. Adjust m_{LL} if L > L_m: m_{LL} (L_m / L)
7. N_1 ____ (5 / S_s) + 1
8. N_2 ____ 0.375N_s; calculate only if $b_R \geq 18$ ft
9. M_{LL1} ____ (N_1) m_{LL}
10. M_{LL2} ____ (smaller of N_1 or N_2) m_{LL}
11. Moment classification (Figures B-13 and B-14)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
12. v ____ (Table B-3 or B-4)
13. V_{DL} ____ (Table B-5)
14. v_{DL} ____ (V_{DL} / N_s)
15. v_{LL} ____ (v - v_{DL})
16. V_{LL} ____
    a. Timber:
    (16/3) (v_{LL}) [N_1 or N_2] / [N_1 or N_2] + 1)
    b. Steel: (2v_{LL} / 1.15)
17. Shear classification (Figures B-15 and B-16)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
18. Width classification (Table B-2)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
19. Deck classification (Figure B-8)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
    a. Single-layer: $t_{eff} = t_d$
    b. Multilayer: $t_{eff} = t_d$ - 2 in
    c. Laminated: $t_{eff} = t_d$ (% lam)
20. $N_{b(reqd)}$ ____
    a. Timber: 3 required if $d \geq 2_b$
    b. Steel: (L / L_o) + 1 (L_o in Table B-4)
    Add braces if $N_b < N_{b(reqd)}$
21. Final classification

	T_1	T_2	W_1	W_2
Moment (Step 11)				
Shear (Step 17)				
Width (Step 18)				
Deck (Step 19)				
Final (lowest number)				

Figure B-1 Timber or Steel Trestle Bridge With Timber Deck

Map Sheet Grid

Recon Officer/NCO Unit Date

BRIDGE DIMENSIONS

L ____ ft

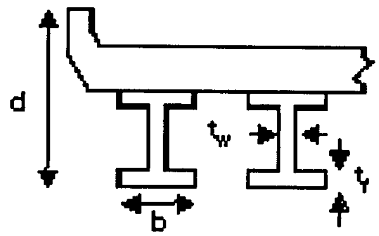
b_R ____ ft

N_L ____ (2 if $b_R \geq 18$ ft)

N_S ____

S_S ____ ft

t_d ____ in (do not include wearing surface)



STRINGER DIMENSIONS

Type ____ (Table B-4)

b ____ in

d ____ in

t_w ____ in

PROCEDURE

1. m ____ (Table B-4)
2. W_s ____ (Table B-4)
3. m_{DL} ____ $0.00013L^2 (W_s + (t_d) S_s)$
4. m_{LL} ____ $(m - m_{DL}) / 1.15$
5. L_m ____ (Table B-4)
6. Adjust m_{LL} if $L > L_m$: $m_{LL} (L_m / L)$
7. N_1 ____ $(5 / S_s) + 1$
8. N_2 ____ $0.375N_s$; calculate only if $b_R \geq 18$ ft
9. M_{LL1} ____ $(N_1)\ m_{LL}$
10. M_{LL2} ____ (smaller of N_1 or N_2) m_{LL}
11. Moment classification (Figures B-13 and B-14)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
12. Width classification (Table B-2)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
13. Deck classification (Figure B-8)
    T_1 ____ T_2 ____ W_1 ____ W_2 ____
    a. $t_d < 5$ in: Class 40
    b. $t_d \geq 5$ in: Class 150

14. Final classification

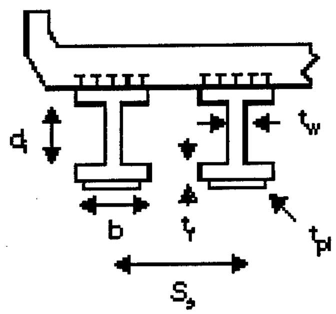
	T_1	T_2	W_1	W_2
Moment (Step 11)				
Width (Step 12)				
Deck (Step 13)				
Final (lowest number)				

Figure B-2 Steel-stringer Bridge With Concrete Deck (Noncomposite Construction)

Map Sheet   Grid
Recon Officer/NCO   Unit   Date

BRIDGE DIMENSIONS

L _____ ft
b_R _____ ft
N_L _____ (2 if $b_R \geq 18$ ft)
N_S _____
S_S _____ ft
t_d _____ in (do not include wearing surface)
S_c _____ (Table B-8)



STRINGER DIMENSIONS

Type ______ (Table B-4)
b _____ in
d _____ in ($d = d_i + 2t_f$)
t_w _____ in
t_f _____ in
S _____ in^3
t_{pl} _____ in
W_s _____ (steel type)

PROCEDURE

1. m_{DL} _____ $0.00013L^2 (W_s + (t_d) S_s)$
2. f_{bDL} _____ $12m_{DL} / [(S)(x_{PL})]$
   a. No plate: $x_{PL} = 1.00$
   b. $t_{pl} = 0.5t_f$: $x_{PL} = 1.25$
   c. $t_{pl} = t_f$: $x_{PL} = 1.50$
3. m_{LL} _____ $[(29 - f_{bDL})(S_c)(x_{PL})(t_x)] / 13.8$ (t_x from Table B-9)
4. N_1 _____ $(5 / S_s) + 1$
5. N_2 _____ $0.375N_s$; calculate only if $b_R \geq 18$ ft
6. M_{LL1} _____ $(N_1)\, m_{LL}$
7. M_{LL2} _____ (smaller of N_1 or N_2) m_{LL}
8. Moment classification (Figures B-13 and B-14)
   T_1 _____ T_2 _____ W_1 _____ W_2 _____
9. Width classification (Table B-2)
   T_1 _____ T_2 _____ W_1 _____ W_2 _____
10. Deck classification (Figure B-8)
    T_1 _____ T_2 _____ W_1 _____ W_2 _____
    a. $t_d < 5$ in: Class 40
    b. $t_d \geq 5$ in: Class 150
11. Final classification

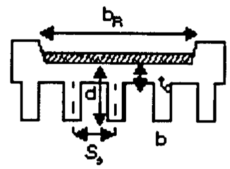
	T_1	T_2	W_1	W_2
Moment (Step 8)				
Width (Step 9)				
Deck (Step 10)				
Final (lowest number)				

Figure B-3 Concrete Steel-Stringer Bridge (Composite Construction)

Map Sheet | Grid
Recon Officer/NCO | Unit | Date

BRIDGE DIMENSIONS

- L ____ ft
- b_R ____ ft
- t_d ____ in
- S_S ____ ft
- N_S ____



STRINGER DIMENSIONS

- d ____ in
- b ____ in

PROCEDURE

1. m ____ $0.0116\ (S_s)\ (d^2)$
2. m_{DL} ____ $0.00013L^2\ (b_d + (t_d)\ S_s)$
3. m_{LL} ____ $(m - m_{DL}) / 1.15$
4. N_1 ____ $(5 / S_s) + 1$
5. N_2 ____ $0.375N_1$; calculate only if $b_R \geq 18$ ft
6. M_{LL1} ____ $(N_1)\ m_{LL}$
7. M_{LL2} ____ (smaller of N_1 or N_2) m_{LL}
8. Moment classification (Figures B-13 and B-14)
   T_1 ____ T_2 ____ W_1 ____ W_2 ____
9. Width classification (Table B-2)
   T_1 ____ T_2 ____ W_1 ____ W_2 ____

10. Final classification

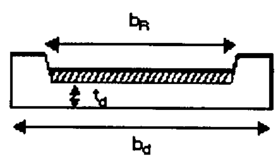
	T_1	T_2	W_1	W_2
Moment (Step 8)				
Width (Step 9)				
Final (lowest number)				

Figure B-4 Concrete T-beam Bridge With asphalt Wearing Surface

Map Sheet | Grid
Recon Officer/NCO | Unit | Date

BRIDGE DIMENSIONS

- L ____ ft
- b_d ____ ft
- b_R ____ ft
- t_d ____ in (do not include wearing surface)



PROCEDURE

1. m_{LL} ____ (Figure B-10)
2. b_e ____
   a. One-lane:
   $b_{e1} = L / [0.75 + (L / b_d)]$
   b. Two-lane:
   $b_{e2} = L / [0.25 + (2L / b_d)]$
   (Calculate b_{e2} only if $b_R \geq 18$ ft)
3. M_{LL1} ____ $(b_{e1})\ m_{LL}$
4. M_{LL2} ____ $(b_{e2})\ m_{LL}$
5. Moment classification (Figures B-13 and B-14)
   T_1 ____ T_2 ____ W_1 ____ W_2 ____
6. Width classification (Table B-2)
   T_1 ____ T_2 ____ W_1 ____ W_2 ____

7. Final classification

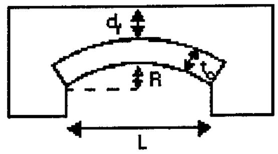
	T_1	T_2	W_1	W_2
Moment (Step 5)				
Width (Step 6)				
Final (lowest number)				

Figure B-5 Concrete Slab Bridge With Asphalt Wearing Surface

Map Sheet	Grid
Recon Officer/NCO	Unit	Date

BRIDGE DIMENSIONS

L ____ ft
t_c ____ ft
d_f ____ ft
b_R ____ ft
R ____ ft



PROCEDURE

1. PLC ____ (Figure B-11)
2. Arch factors:
   a. Span-to-rise ratio (SR = L / R) ____
   b. Profile factors (Table B-6) ____
   c. Material factors (Table B-7) ____
   d. Joint factors (Table B-7) ____
   e. Deformations (Table B-7) ____
   f. Crack factors (Table B-7) ____
   g. Abutment size factors (Table B-7) ____
   h. Abutment fault factors (Table B-7) ____
3. Classification of arch factors:
   T_1 ____ (PLC x product of factors 2b through 2h)
   T_2 ____ (0.9T_1)
   W_1 ____ (Figure B-12)
   W_2 ____ (Figure B-12)
4. Width classification (Table B-2)
   T_1 ____ T_2 ____ W_1 ____ W_2 ____

5. Final classification

	T_1	T_2	W_1	W_2
Factors (Step 3)				
Width (Step 4)				
Final (lowest number)				

Figure B-6 Masonry-Arch Bridge