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TECHNICAL
REPORT

CANES Contracting Strategies for Full Deployment

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Prepared for the United States Navy

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

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Preface

The Consolidated Afloat Networks and Enterprise Services (CANES) is the U.S. Navy's next generation of networks and computing infrastructure, primarily for use on ships. The system consists of hardware, operating systems, virtualization software, system management software, and numerous applications.

This report discusses contracting strategies for the main hardware component and integration capabilities, referred to as the Common Computing Environment (CCE), which will be used with CANES. CANES is not complete without the applications and services it provides, but the development and production of these applications are not part of the CANES program. We propose five potential alternatives and identify a preferred solution. A series of case studies and interviews, detailed in the appendixes of this work, served as the basis for our recommendations. We conducted this research from April 2010 to October 2010.

This research was sponsored by the CANES Program Office in the U.S. Navy's Program Executive Office (PEO) Command, Control, Communications, Computers, and Intelligence (C4I). It was conducted within the Acquisition Technology and Policy Center of the National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.
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Summary

The Consolidated Afloat Networks and Enterprise Services (CANES) program seeks to consolidate disparate computing networks. The program has a rigorous fielding and upgrade schedule to replace the legacy systems of the fleet. If successful, the program will give the Navy a common set of key command, control, communications, computers, and intelligence (C4I) networks across the fleet, reducing costs and minimizing obsolescence issues. Successful implementation of CANES will also represent a major step toward creating a Program Executive Office (PEO) organization that is "horizontal," data-centric, and able to rely on a service-oriented architecture for success.

While developing the software required for CANES, the Navy let two contracts for developing the Common Computing Environment (CCE) to be used with CANES. Under these contracts, contractors will design CANES, identifying specific hardware and developing the integration software necessary to consolidate existing C4I functions. At the time this research was conducted, the Navy expected that a down-select would occur in late spring 2011. After this point, a single contractor would become responsible for producing the CANES design, refining integration software, and assembling and testing the system in 2012 in the limited deployment (LD) phrase. The program office anticipated that a full deployment (FD) contract would be awarded in spring 2012. The successful contractor would be responsible for executing the purchased design and assembling the systems, ensuring that the integration software is functioning. An important assumption being made by the program office is that the designs produced during system development will be build-to-print designs based on the system configuration developed during system design and development (SDD) and tested and refined during LD.[1] The expectation is that the CANES program will then be able to leverage a much broader production base for contracting during the FD phase of the program. The Navy must also determine acquisition and supporting contracting strategies for the FD phase. The objective of this research is to identify which contracting option for the FD phase of the CANES program will best support the Navy's program priorities and objectives.

This report identifies and assesses five potential contract strategies for the FD phase of the CANES program. We focus primarily on initial fielding, which is expected to take approximately six years. (Our examination of other programs reveals that the acquisition and contracting strategy can evolve to fit the needs of the program as it matures.) The potential strategies we identified are based on our understanding of the program goals and risks that we derived from

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1 The term *build-to-print* refers to materials received by the government from the contractor that include the design of the system, identification of hardware components, information on how to assemble the hardware, data rights to the software code, and instructions on how to load and run required integration software.

interviews with program staff and from our review of all of the available program documentation. The strategies were also informed by lessons learned from similar programs we studied.

Potential Strategies

We developed five procurement approaches for the CANES program. Our governing principles for developing the approaches were that they had to (1) be flexible enough to accommodate the known and unknown risks, (2) provide a broad range of strategies, and (3) provide best value in terms of price and quality.

The first option we developed would maximize work to be done by a single prime contractor. We also considered the opposite option, maximizing work to be done by the government. The other three options allocate specific functions to varying contractors under multiple award contracts (MACs) using an indefinite delivery, indefinite quantity (IDIQ) format for production and installation. Table S.1 shows the five options and the primary functions that need to be performed during the FD phase of the program.

Single Prime Contractor

Our first option, maximizing work for a single prime contractor, is the most commonly used acquisition model in the Department of Defense for large acquisition programs. In this model, the Navy employs a single contractor (in Table S.1, the “prime”) to be responsible for program performance. This minimizes the need for multiple contractor coordination and the need for

Table S.1
Procurement Options for the Full Deployment Phase

	Option				
Function	**Single Prime Contractor**	**Multiple Contract Model A**	**Multiple Contract Model B**	**Multiple Contract Model C**	**Government**
Design and integration Technical advice Systems engineering Configuration management In-service support	Prime	Contractor A	Contractor A	Contractor A	Government
Production	Prime	Winners of production MAC IDIQ (not Contractor A)	Winners of production MAC IDIQ (not Contractor A)	Winners of production MAC IDIQ (not Contractor A)	Government plus winners of existing service center MACs
Installation	Prime	IMO	Winners of installation MAC IDIQ (not Contractor A or the winners of the production MAC IDIQ)	Winners of production MAC IDIQ (not Contractor A)	IMO

NOTES: IDIQ = indefinite delivery, indefinite quantity. IMO = Installation Management Office. MAC = multiple-award contract.

government-furnished equipment (GFE) as well as technical risks by using consistent standards and communication protocols.

There are, however, disadvantages to this approach. Once the contract is awarded, the government can do little to address subsequent cost and performance problems.[2] This model also requires new processes and agreements with installation activities. Much of the dollar value of such contracts is negotiated on a sole-source basis with the prime contractor after contract award, when the government has minimum leverage to obtain best value. Finally, this model requires extensive Navy effort to negotiate many task orders, delivery orders, and contract changes in a sole-source environment.

Multiple Contract Model A

Model A uses one contractor (in Table S.1, "Contractor A") to conduct the necessary technical and engineering effort, including design and integration. The contract can be competitively awarded but needs to cover a number of fiscal years to ensure continuity and avoid disruptive and costly contractor turnover. Assuming acceptable contractor performance, it is a good idea to maintain this contractor for the duration of the program. Production is carried out by other contractors that receive periodic awards of delivery orders under MACs using an IDIQ format. The installation is handled by Space and Naval Warfare Systems Command's (SPAWAR's) existing Installation Management Office (IMO) process. This option allows Contractor A to perform all engineering functions and to maintain continuous experience for a long period, thereby minimizing cost and risk. Contractor A would, of course, be able to subcontract various functions. This model also allows periodic competition for production of ship sets, thereby securing the best and most current hardware pricing and eliminating the risks associated with using new organizations, processes, and contractors for installation. This alternative also, however, requires multicontractor coordination and the provision of GFE and government-furnished information (GFI). This may make it more difficult to negotiate contract changes and to hold contractors responsible for their performance.

Multiple Contract Model B

This approach has many of the same characteristics and advantages as Model A. It adds periodic competitions for installation, which has the advantage of keeping the pressure on installation contractors to improve cost. This approach has the same disadvantages as Model A and additional disadvantages in its requirements for (1) extra government effort to set up and administer two sets of MAC contracts and (2) new processes and agreements for coordinating the installations. This model may also require modifications to Navy and SPAWAR policy.[3]

Multiple Contract Model C

Model C uses one set of MAC IDIQ contracts to combine CANES production and installation. This approach has all of the advantages of Model B, as well as the advantage of holding one contractor responsible for each ship. It also has all of the disadvantages of Model B plus a

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2 Changing the prime contractor once it has been selected is expensive. Furthermore, penalizing the prime contractor for poor performance is an ineffective means to improve performance.

3 See SPAWAR, 2006. Current policy states that all installations must be managed through the Installation Management Office.

greater likelihood that the IDIQ awards will exceed $10 million, thereby permitting MAC bid protests under the Federal Acquisition Regulation (FAR).

Government Option

Under this approach, the technical and engineering functions are assigned to SPAWAR's Systems Centers (SSCs). The government would procure information technology hardware using existing MACs and assemble and wire them into racks at the SSCs. The IMO would handle the installation using the existing ship installation process. This option has the advantage of minimizing contract actions, using existing installation processes, and giving the program office excellent oversight of performance. There are disadvantages, however. This is an unconventional acquisition model for such a large program. There is a perception that, because the program office has so few tools to ensure good performance, the government would not be the most effective performer. Only a very small amount of the program's dollar value would be awarded through competitive contract, and the program office would have little leverage over the workload priorities of other government organizations.

The Preferred Approach: Multiple Contract Model A

In any of the above five strategies, the government could choose to let a contract to an entirely new contractor in the FD phase of the program for any of the design/redesign, production/manufacture, and installation activities. There is inherent risk in shifting from one contractor to another when moving from the development to the production phase of the program. The Navy is planning to mitigate such risk by acquiring the data and information that a new contractor will need to produce the system. The Navy intends to own the design of the system and all technical instructions and manuals related to production and installation of the system.

A review of programs whose characteristics are similar to those of CANES reveals that a number of contracting strategies can yield a successful product. There is no single "right" construct. Some programs we examined adopted a single prime contractor model; others assigned different program tasks to various contractor and government entities. Although any one of the alternatives can be made to work, there were some common themes among successful programs.

First, the government played a leading role in the successful programs. Government representatives participated in specific technical and managerial activities; importantly, the government retained management and decisionmaking responsibilities for the program. Second, although contractors identified what was technically possible and carried out the lion's share of the actual software and hardware development, the government maintained responsibility for specifying the requirements and, critically, for testing. The government also maintained responsibility for the development of the architecture specification. Third, the government guided the integration effort by clearly specifying the roles and responsibilities of the various parties through an integration plan and integration strategy. This guidance included government participation in and management of standards and protocols required to aid the integration effort. Although standards were proposed by contractors in some cases, the government approved or disapproved those recommendations. This required maintaining technical expertise within the government program offices, even though most of the actual programming work was done by contractors. Fourth, successful programs assigned functions to the organizations that could provide the best value (quality and cost). Successful programs provided incentives for schedule performance but also permitted the flexibility required to carry out constant technical updates and to cope with uncertainties, such as integration challenges and changing operational schedules.

Multiple Contract Model A assigns the technical, production, and installation functions to the organizations that can provide the best value. It keeps competitive pressure on costs of ship-set production and minimizes the risk of installation failure by using the existing IMO process for installation.[4] Model A is superior to the single prime contractor option in several important respects:

- It requires active and continuous government involvement, which, as noted earlier, is a common theme among the successful military information technology (IT) programs we reviewed.
- It obtains frequent competitive prices for IT hardware in an environment where hardware capabilities and prices are constantly improving.
- It uses proven SPAWAR IMO processes to install CANES on board warships and does not require the development of new processes and the negotiation of numerous contract changes to reflect constantly changing ship schedules and shipyard service costs.

Because it uses the IMO for CANES installation, Model A is superior to Models B and C, which, like the single prime contractor option, require the development of new processes and the negotiation of numerous contract changes. Model A is also preferable to the government option because it obtains competitive prices for IT hardware.

Considerations for Any Contracting Strategy

All the risks and lessons learned point to the need for a flexible and agile contracting strategy. The amount of risk in the FD phase will depend on the quality of the design that emerges from the design phase of the program. PEO C4I should consider a strategy that will help mitigate the risk of receiving an incomplete or inadequate design. In addition, there should be flexibility to meet changing system requirements through periodic upgrades and to eliminate unwanted or infeasible requirements. We recommend that the PEO adopt a "crawl, walk, run" approach that targets the most important requirements first and then develops the capability over time. In a program as technically complex as CANES, evolving a capability is less risky than attempting to develop all the desired capabilities in a single step.

In addition, the program office should be aware of both some common network integration pitfalls and some potential mitigation strategies.[5] For example, two common problems have been (1) a lack of sharing of proprietary source code between the government and industry and (2) a lack of technical manuals. The FD contract should ensure that such items are

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4 Interviews with CANES program office staff provided examples of cases where the IMO was not used. In one case, the installation was significantly delayed and ultimately scheduled through the IMO because the selected contractors did not have the necessary qualifications and certifications to enter the shipyard.

5 Programs are discussed in Chapter Four.

addressed. Mitigation strategies for the common network implementation pitfalls observed in our case studies include

- creating an integrated requirements document (for all ship networks) that contains individual functional-area requirements
- requiring the design team to work with the operational users of the system to identify system functional and end-user requirements *before* system concept design
- writing a well-defined concept of operations that encompasses the entire system and user functional interactions of individual networks, ship systems, and other interfaces
- reducing the amount of manually inputted data by allowing data to be passed from system to system whenever possible
- conducting a risk analysis and implementing a management process with full-scale testing for each ship or ship type under dynamic shipboard conditions for all new technology, equipment, and architectures or configurations that have never before been used on a ship
- conducting a land-based test of the system prior to shipboard installation, or, if that is too costly, developing a virtual integration concept that involves all system sites
- ensuring that contractor-furnished equipment (CFE) is not designed and procured years before installation so as to avoid hardware obsolescence
- developing a life-cycle software and maintenance-control plan
- establishing a dedicated organizational entity to serve as life-cycle manager in an in-house Navy organization with staffing components from headquarters, naval organizations, and private companies
- establishing a distinct program and system integration office that is responsible for interface control, management of all CFE and GFE system hardware, software maintenance and control, systems integration, system-level functional requirements, control for services and resources, budget formulation, future technical changes, interface control, and plan execution
- conducting several meetings one year before the first system delivery to determine whether requirements are feasible or need to be modified
- putting C4I personnel and systems on board earlier in the shipbuilding process so that the users are properly acclimated to the network
- providing more shipboard training or establishing a reliable remote management capability to effectively monitor the health of the network
- ensuring that networks are not "ship-unique," thereby allowing for cost-effectiveness in schoolhouse training
- synchronizing multiple upgrades when upgrading systems so as to identify adverse effects earlier.

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Abbreviations

ACAT	Acquisition Category
Acct Dir	Account Directory
ACS	Afloat Core Services
ADMACS	Aviation Data and Management Control System
ADNS	Automated Digital Network System
AI	application integration
AIT	Alteration Installation Team
Ao	operational availability
APB	Advanced Processing Build
ARCI	Acoustic Rapid COTS Insertion
ASTO	Advanced Systems Technology Office
AT&L	Acquisition, Technology and Logistics
ATM	Asynchronous Transfer Mode
BNIDS	Bayesian Network Intrusion Detection System
C4I	command, control, communications, computers, and intelligence
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAAS	Central Amplifier Announcing System
CANES	Consolidated Afloat Networks and Enterprise Services
CC	common capabilities
CCE	Common Computing Environment
CDD	Capability Development Document
CDR	Critical Design Review
CENTRIX-M	Combined Enterprise Regional Information Exchange System–Maritime
CFE	contractor-furnished equipment
CLIN	contract line items number
CMFP	Combined Maritime Forces Pacific
CNFC	Combined Naval Forces CENTCOM

CONOPS	concept of operations
COTS	commercial off-the-shelf
CP	cost plus
CPD	Capability Production Document
CPU	Central Processing Unit
CSRR	Common Submarine Radio Room
DCGS-N	Distributed Common Ground System–Navy
DHCP	Dynamic Host Configuration Protocol
DNS	Domestic Name Service
DO	delivery order
DoD	Department of Defense
DSR	Digital System Resources Inc.
EA	early adopters
EB	Electric Boat
EOL	end-of-life
FAR	Federal Acquisition Regulation
FCS	Future Combat System
FD	full deployment
FFP	firm-fixed-price
FP	fixed price
FPI	fixed price incentive
GCCS-M	Global Command and Control System–Maritime
GCTF	Global Counter-Terrorism Force
GFE	government-furnished equipment
GFI	government-furnished information
GigE	Gigabit Ethernet
HVAC	heating, ventilation, air conditioning
IC	internal communications
ICAN	Navy Integrated Communications and Advanced Networks
IDIQ	indefinite duration, indefinite quantity
IETM	interactive electronic technical manual
IMO	Installation Management Office
INE	inline network encryptor
IOC	initial operating capability
IP	Internet protocol
IPT	Integrated Project Team

ISEA	In-Service Engineering Agent
ISNS	Integrated Shipboard Networks Systems
IT	information technology
IVCS	Integrated Voice Communication System
IWS	Integrated Warfare Systems
JCIDS	Joint Capability Integration Development
JLENS	Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor System
KSA	key system attribute
LAN	local area network
LD	limited deployment
LM	Lockheed Martin
LOE	level of effort
LRIP	low-rate initial production
LSI	Lead System Integrator
MAC	multiple award contract
MARMC	Mid-Atlantic Regional Maintenance Center
MCFI	Multi-Coalition Forces Iraq
MOC	Maritime Operations Center
MOSA	Modular Open System Architecture
MPS	Mission Planning System
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NCES	Net-Centric Enterprise Services
NCOW RM	Net-Centric Operations and Warfare Reference Model
NGNN	Northrop Grumman Newport News
NIC	Network Interface Card
NPES	Non-Propulsion Electronic System
NUWC	Naval Undersea Warfare Center
O&M	operations and maintenance
ONR	Office of Naval Research
PEO	Program Executive Office
PDR	Preliminary Design Review
PM	project manager
PMAG	Program Manager Advisory Group
PMW	Program Manager, Warfare
PMW 160	Program Manager, Warfare Tactical Networks

PPSM	Procurement Planning and Strategy Meeting
QoS	quality of service
R&D	research and development
RDT&E	research, development, test, and evaluation
RFP	Request for Proposal
RMC	Regional Maintenance Center
RF	radio frequency
SBIR	Small Business Innovative Research
SCD	Ship Change Document
SCI	Sensitive Compartmented Information
SD	system development
SDD	system design and development
SEIC	Systems Integration Contractor
SEP	System Engineering Plan
SID	Ship Installation Document
SHIPSUP	Ship Supervisor
SOA	service-oriented architecture
SPAWAR	Space and Naval Warfare Systems Command
SSC	SPAWAR Systems Center
SubLAN	Submarine Local Area Network
SWAN	Shipboard Wide Area Network
SVDS	Shipboard Video Distribution System
TAC	Tactical Advanced Computer
TEMP	Testing and Evaluation Master Plan
TO	task order
TRR	Test Readiness Review
TSCE	Total Ship Computing Environment
UPC	Unique Planning Component
V&V	validation and verification
VIXS	Video Information Exchange System
VoIP	Voice over Internet Protocol
VTC	video teleconferencing
WAN	wide area network
WPICS	Wirefree Portable Interior Communication System

CHAPTER ONE

Introduction

The Navy faces the challenge of having a large number of networks on board ships that are often not well integrated with other systems and are increasingly costly and difficult to maintain and operate. Some Navy ships have as many as 50 separate networks—and as many sets of training and support issues. Meanwhile, commercial-sector information technology has been moving toward service-oriented architectures that are cheaper and easier to change and that provide much greater long-term flexibility for users.

To address these operability issues and to adopt the best evolving commercial practices, the Navy has developed the Consolidated Afloat Networks and Enterprise Services (CANES). CANES represents the Navy's approach to the next generation of networks and computing infrastructure, primarily for shipboard use.

CANES components include hardware and software for an operating system, systems management, virtualization, and numerous applications. The combination of hardware and virtualization software, which will allow for integration of disparate systems, is referred to as the Common Computing Environment (CCE). The program (minus the cost of applications) is estimated to cost more than $1.5 billion (Department of the Navy, 2010) to outfit a large portion of the fleet and Maritime Operations Centers ashore.

Not only is the program sizeable, it also has an ambitious schedule. The Navy intends for CANES to reach initial operational capability (IOC) in fiscal year (FY) 2012. The Navy is developing a set of core services (software), but may desire to contract this function in the future. The Navy has let two contracts for developing the CCE. At the time this research was conducted, the Navy was scheduled to conduct a down-select in spring 2011[1] for the limited deployment (LD) phase of the program, with a full deployment (FD) contract being let in 2012 (Figure 1.1).

The Navy must determine acquisition and supporting contracting strategies for the FD phase of the CANES program. The objective of this research is to identify and assess which contracting options for full deployment of the CANES program will best support the Navy's program priorities and objectives. This determination requires answering questions such as the following

- What are the technical and program objectives of the CANES program?
- What work needs to be accomplished for full deployment?
- What are the potential issues and challenges to the program?
- What should the program office's role be in key tasks?

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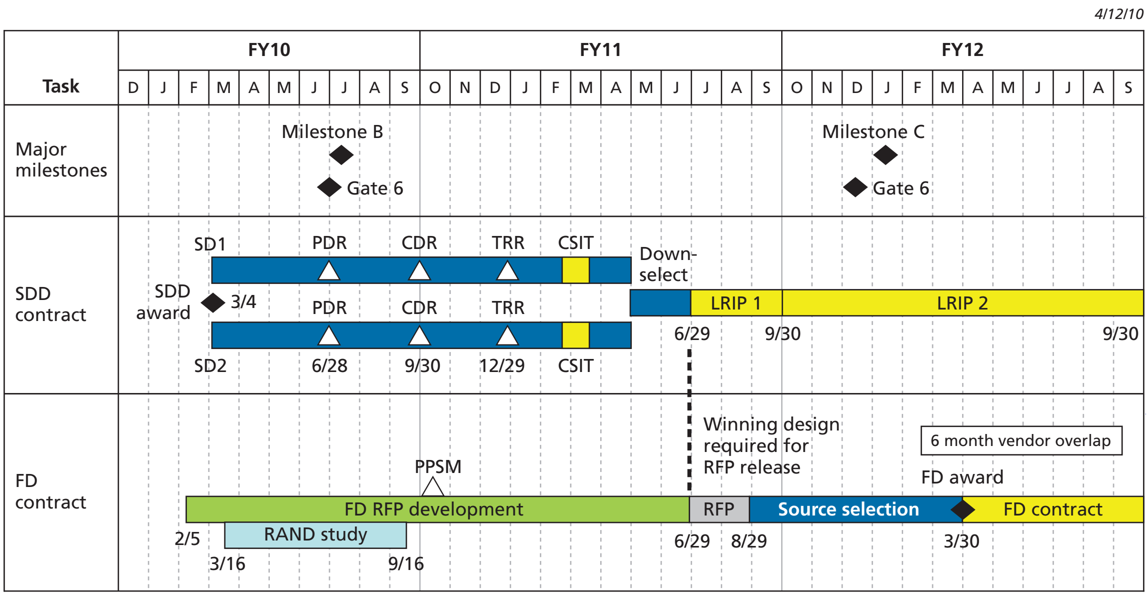
1 As of December 12, 2011, a down-select had not taken place.

Figure 1.1
High-Level CANES Schedule



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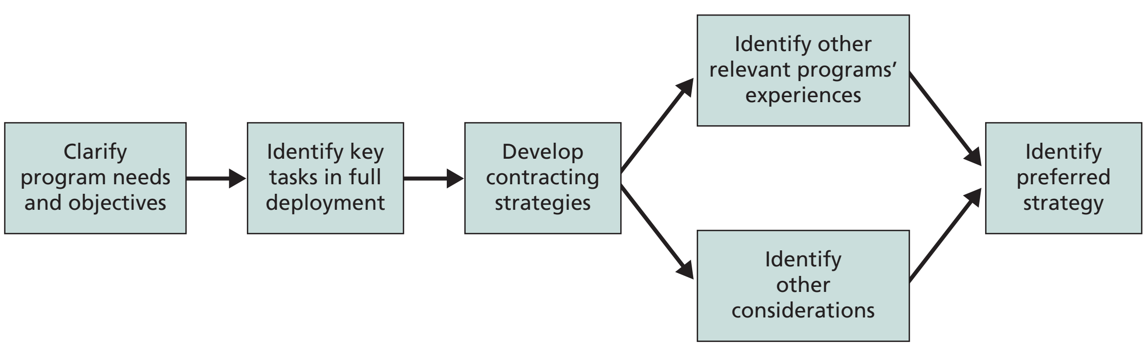
- What program elements should be acquired through competitive contracts and what are the most appropriate contracting strategies and incentives?

Research Approach

To determine the best contracting strategies for CANES full deployment, we completed five tasks (Figure 1.2). First, we clarified program needs and objectives as pertaining to this research. Second, we identified key tasks for full deployment, including technical and programmatic challenges. Third, we developed contracting strategies. Fourth, we assessed these contracting

Figure 1.2
Tasks Completed to Determine Contracting Strategies



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strategies in light of experiences of other programs and other relevant considerations. Fifth, we identified a preferred strategy.

To accomplish these tasks, we interviewed several people within the program office, including all Integrated Project Team (IPT) leaders as well as the Tactical Networks Program Manager and deputy program manager. At the direction of the Navy, and so as not to inadvertently reveal any preferential information, we did not interview any potential contractors. We reviewed all available CANES program documents, such as the Architectural Specification, the Functional Specification, the System Engineering Plan (SEP), Testing and Evaluation Master Plan (TEMP), the Acquisition Strategy, and Application Integration concept of operations (CONOPS) documents. We conducted case studies of other programs (detailed in Appendixes A through G), including programs both in the Navy and in other Services, reviewing available program documentation and interviewing staff.

Research Assumptions

The Department of Defense (DoD) is currently pursuing many efficiency initiatives (Under Secretary of Defense, 2010). The Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L) has called for greater use of firm-fixed-price (FFP) contracting, more competition, and adjustments to progress payments. Accordingly, we assume that the Navy will wish to pursue FFP contracting and competition within the CANES program.

Other assumptions guiding our exploration of contracting strategies include the following:

- For the CANES program, schedule and cost are the primary considerations.
- Desired capability will be gained through multiple increments, allowing schedule adherence.
- Contract strategy should maximize competition.
- The government will be in a position to have an open competition for the CCE in FD. This means it will have obtained all data rights, designs, and knowledge required for future winners of competitive contracts to develop system increments.

Organization of the Report

Chapter Two of this report provides an overview of the CANES program and describes key program tasks. Chapter Three provides an overview of five potential contracting strategies and summarizes the benefits and drawbacks of each. Chapter Four presents additional "lessons learned" from programs analogous to CANES. Chapter Five reviews other lessons that we consider useful to the program office, independent of the contract strategy chosen. Chapter Six describes the preferred alternative and summarizes our conclusions.

CHAPTER TWO

The CANES Program

The goal of the CANES program is to better consolidate and control key command, control, communications, computers, and intelligence (C4I) networks. Historically, it has been difficult to integrate these "bolt-on, stove-piped" designs because very few were designed to be integrated.[1] CANES is a major step toward a Program Executive Office (PEO) C4I organization that is "horizontal," data-centric, and able to rely on a service-oriented architecture. The goal of the program is to field a single, consolidated enterprise information environment on board ships and shore-command nodes.

When implemented, CANES will provide a common computing and storage infrastructure and core services for hosted applications. It will provide platform-network connectivity for all levels of security. CANES will also attempt to incrementally collapse Unclassified, Secret, Secret Releasable, and Sensitive Compartmented Information (SCI) enclaves while preserving the confidentiality of all data within all security classifications. The primary functions of CANES are to provide intraship communications, ship-to-ship and ship-to-shore communications, and an infrastructure to support communications for tactical and administrative applications that rely on an information technology (IT) local area network (LAN). IT LAN–based communications are primarily for data but also include video and voice.

CANES Is More than Just the CCE Hardware

In addition to hardware, PEO C4I is buying a software-intensive system capable of integrating numerous other applications and services. Such software must have nine key system attributes, or KSAs (Table 2.1).

Many of the key attributes of CANES may "ride on," or utilize, the CCE (listed in KSA 5). Their requirements and goals, however, extend beyond the hardware in the commercial-off-the-shelf (COTS)–based CCE. The CANES program manager's initial focus on the CCE likely stems from the plans to integrate many of the KSAs on the CCE, which in turn could lead to substantial cost savings. This is true for Core Infrastructure Services, much of Information Management, and parts of Network Support, Voice, Video, and Network Access. Some of these KSAs, such as Voice, Video, and Systems Management, will also have designed capability that exists outside the CCE.

[1] The *PEO C4I Master Plan* discusses this in more detail. The document discusses a vision of "shaping and aligning programs to achieve a cost-effective, fully integrated PEO C4I" (Navy Program Executive Office, 2009).

Table 2.1
Key System Attributes (KSAs) in the CANES Specification

Key System Attribute	Comment
1: Network Access	Information transport both wired and wireless
2: Voice	Through voice over internet protocol (VoIP) (not replacing existing voice communications)
3: Video	Video teleconferencing (VTC) capability
4: Network Support	Information assurance, authentication, and certification
5: Information Management	Application hosting (CCE) User data storage Printed media Peripheral devices (Blackberries) Email and calendar applications Office productivity Messaging tools Collaboration (data/audio conference) Knowledge management
6: Core Infrastructure Services	Data mediation Discovery Portal access User profiling and customization Machine-to-machine messaging Service orchestration
7: Systems Management	Performance, availability, and service-level management Fault, problem, incident, and service desk management Configuration, change, and release management Security management (security policy violations) Capacity management
8: Materiel Reliability	Mean time between failure
9: Ownership Costs	Operating and support costs considered in decisionmaking

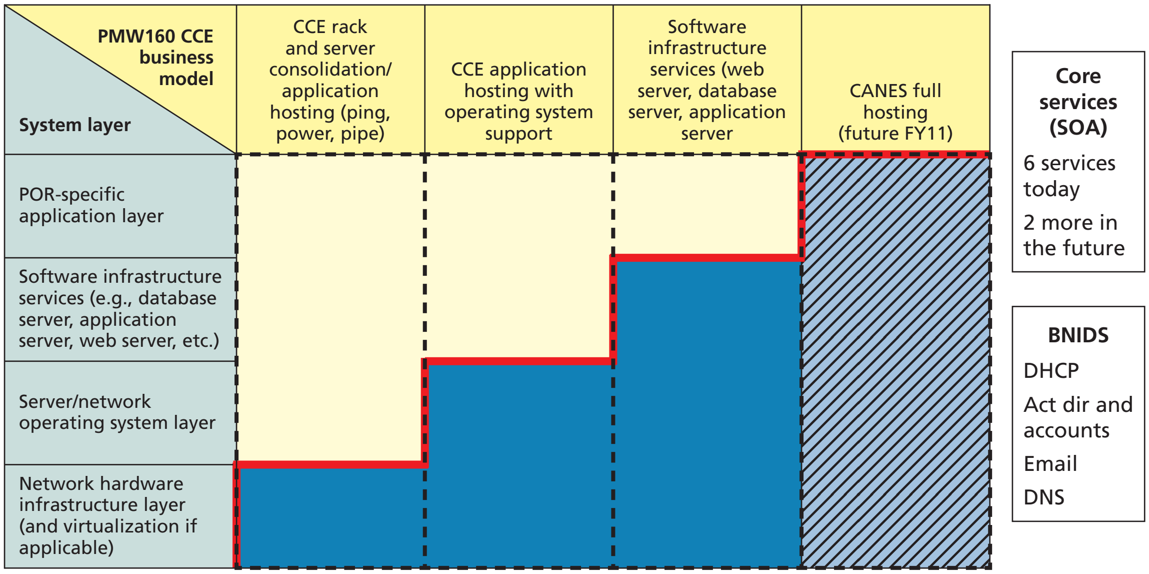
SOURCE: CANES Program Office, 2009a.

Much of the technical risk for CANES is in the software. Figure 2.1, taken from the *PEO C4I Master Plan*, highlights that "CANES Full Hosting" will include a very robust network hardware infrastructure layer with software and infrastructure services evolving in the iterative growth of CANES. The Network Hardware Infrastructure Layer will host subsequent increments of software to realize the desired CANES capability.

CANES Elements

CANES is based on the consolidation of C4I surveillance and reconnaissance (C4ISR) networks for afloat platforms and Maritime Operations Centers ashore. It will consolidate several existing networks into a single system meeting the requirements of many legacy systems. These include Integrated Shipboard Networks Systems (ISNS), SCI networks, Submarine Local Area

Figure 2.1
Application Hosting Model



SOURCE: Navy Program Executive Office, *PEO C4I Master Plan*, 2009.
NOTES: EA candidates start at lower left—disparate hardware. Any application or system can consume core services or BNIDS at right. Ping, power, and pipe refer to provision of network, processing time, and network connections.
RAND *TR993-2.1*

Network (SubLAN), Combined Enterprise Regional Information Exchange System–Maritime (CENTRIX-M), Video Information Exchange System (VIXS), Global Command and Control System–Maritime (GCCS-M), Distributed Common Ground System–Navy (DCGS-N), and Shipboard Video Distribution System (SVDS).[2] In addition, the office responsible for CANES will assume hardware-procurement activities currently carried out by offices responsible for application programs soon to be hosted within CANES. In its initial deployment configuration, CANES will not support applications for weapon systems, ship-engineering functions, or navigation.

CANES is a software-intensive system. Its many levels of software include operating software, system management, virtualization,[3] and applications or services such as email. Initially, the CANES program had two main developmental activities: (1) the CCE, which covered hardware and all the software, except that for applications and services, and (2) software to support core services, referred to as Afloat Core Services. The government, however, determined it would be less risky to provide a set of core services to the developers as government-furnished equipment (GFE), meaning that only the CCE will be developed at this time. The government could later contract for future CANES services and applications.

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[2] We describe these systems in Appendix H.

[3] Virtualization software allows multiple disparate applications to run on a single server.

The Common Computing Environment

The Navy has let two contracts for developing the CCE. The CCE is expected to be a COTS systems integration effort. The Navy seeks a system developer that will use state-of-the-industry networking hardware in its design. The government will own the design and the components required to assemble the system. The contractor will also have to develop the software capabilities necessary for consolidation. The government intends to own the data rights for future integration implementation.

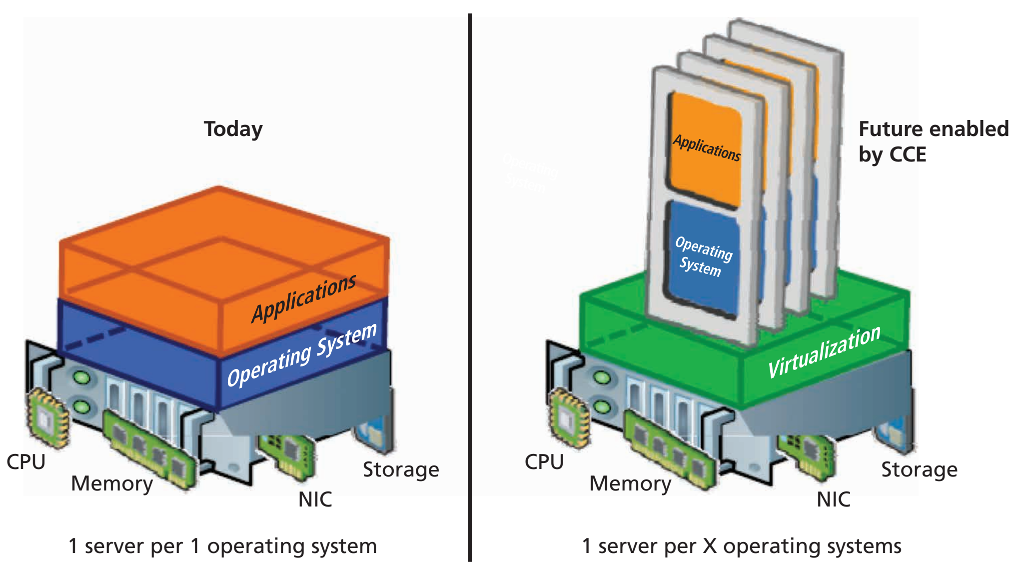
Figure 2.2 shows the vision for CANES as enabled by the CCE. Currently, each operating system has its own server. In the future, a virtual server will enable multiple operating systems to run on a single server. This process of "virtualization" using service-oriented architectures will consolidate many computing functions on a common network and set of servers. The Navy expects that this will allow for less expensive and easier upgrades in the future and commonality across the fleet.

Software and Services

Multiple levels of software are required for CANES. The virtualization software discussed above allows seemingly incompatible systems to run on a single server. Different operating systems (e.g., Linux, Solaris, Windows) will be able to run on the same hardware and server. All of the applications that are supported by each operating system will also be available on a single server. The challenge will be to develop the virtual environment in a way that allows all these disparate systems and programs to run on a single server in an efficient way.

The services or applications (e.g., email, voicemail, videoconferencing) used by the fleet will be hosted on the CANES CCE hardware infrastructure. Many different services and applications are owned by numerous stakeholders, not all of them in PEO C4I. Coordination of the development of the CCE with existing and future customers, some of whom are currently unknown, is a real challenge. The CANES program office has identified an initial core

Figure 2.2
Common Computing Environment



RAND *TR993-2.2*

set of 37 applications but indicates that considerably more applications are currently being used in the fleet. The GFE software furnished to the development contractors is based on three of the 37 core applications identified by the program office. The integration of current and future services within the CCE is a key challenge and will be critical to the success of CANES.

Program Objectives

In January 2009, the CANES program Acquisition Strategy stated four main objectives (Program Manager, Tactical Networks, 2009a). They were (1) consolidate and reduce the number of afloat networks through the use of mature cross-domain technologies and CCE infrastructure; (2) reduce the infrastructure footprint and associated costs for hardware afloat; (3) provide increased reliability, application hosting, and other capabilities to meet current and projected Warfighter requirements; and (4) federate Net-Centric Enterprise Services (NCES) service-oriented architecture (SOA) core services to support migration of DoD C4ISR applications to a SOA environment. An October 2009 revision of the Acquisition Strategy added a fifth objective, "provide a secure afloat network required for Naval and Joint Operations" (Program Manager, Tactical Networks, 2009b).

While the Acquisition Strategy could be revised in the future, technology limitations could place the current objectives at odds with one another. Consolidation of networks (Goal 1) could be at odds with the security goal (Goal 5) and the reliability goal (Goal 3). We discuss these issues in Chapter Three.

The October 2009 Acquisition Strategy and a briefing developed by the Navy's Program Manager, Warfare Tactical Networks (PMW 160) (Beel, 2009) also identified several program goals and objectives, including

- competition
- use of small businesses
- use of COTS technology
- quick delivery
- cost reduction.

While some programs have been successful in meeting the challenge of improved capability at reduced cost delivered quickly, others have found a need to sacrifice one or another of these goals. For the CANES program, schedule and cost are the primary considerations. The acquisition strategy calls for the delivery of an acceptable increment of capability meeting defined cost and schedule objectives, consistent with the principles of evolutionary acquisition. The cost goals are expected to be met through system consolidation, continuous competition, and use of COTS technology.

Acquisition Strategy

The CANES program also embodies a business strategy. It is adopting an acquisition approach in which new capabilities are introduced incrementally throughout the life of the program consistent with the DoD 5000 principles of incremental acquisition. The program decouples hardware and software, giving the government and application developers greater agility. Program documentation that describes the risks of the program indicates that the success of the program will be determined, to a large degree, by the ability to integrate the hardware and software upgrades. Program success will also depend on the ability to manage the technology-insertion upgrades and configuration baselines;[4] many application owners will need to house their applications on CANES. CANES not only consolidates the technical or physical aspects of existing programs, it also consolidates the programmatics and infrastructure of existing programs, streamlining the acquisition process by reducing the documentation, integration, and testing requirements. The use of interface-control documents will be very important.

The CANES acquisition strategy depends on an update cycle of four years for hardware and two years for software. These scheduled baselines are intended to assist developers by providing known and predictable technology and software insertion points while also offering an architecture that mitigates end-of-life (EOL) and supportability issues. As mentioned above, the CANES program office is currently planning for 37 C4ISR-related applications to be included in the initial FD version that will be fielded to the fleet. In the time it will take to refit existing ships with CANES, several two-year software updates will have taken place.

The CANES program office plans to work closely with other stakeholders in PEO C4ISR to field an initial software and hardware baseline that can support all CANES applications. Once the initial version of CANES is deployed, the program office will continue to work with other stakeholders to ensure that software and hardware upgrades take place on schedule and to a standard that will meet the needs of the fleet. Backward compatibility considerations will be very important.[5]

The two contracts the CANES program has let to Northrop Grumman and Lockheed Martin for the system design and development (SDD) of the CCE were Cost Plus Incentive Fee contracts for $15 million each. The Navy held preliminary design reviews in summer 2010 and scheduled critical design review for October 2010. At the time of this research, the Navy expected that a down-select would occur in late spring 2011.[6] After the down-select, a single designer was to take the program through the LD phase. At the time this research was conducted, the Navy anticipated seeking bids for an FD contract in spring 2012. The Navy expected that the designs produced during system development will be build-to-print, based on the system configuration developed in SDD and tested and refined during low-rate initial production (LRIP). The Navy expects that the CANES program will then be able to leverage a much broader production base in seeking contract proposals for full deployment.

CANES Program Functions in Full Deployment

Development of the first increment of CANES will be finished prior to the start of FD. The first increment will be the largest; subsequent increments are expected to be smaller in scope. As a result, once FD begins, production, installation, and software integration will be the

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4 A baseline is an established architecture for software and hardware interdependencies. The number of baselines has not yet been determined.

5 Growth in the program is expected to be managed by a board of stakeholders that reviews new requirements and must approve them for CANES.

6 As of December 12, 2011, a down-select had not taken place.

major activities of the CANES program. The initial fielding of CANES will be a significant undertaking. In some cases, the ship's cabling will have to be replaced, requiring significant industrial work. The current plan is to have the initial ship-sets outfitted with CANES within six years. Once a ship is outfitted, a technology update cycle will begin. Hardware will be replaced every four years, and software will be updated at least every two years. We briefly describe below the major program functions in FD that the acquisition and contract strategy must accommodate.

The CANES program office identified some of the required functions. The Program Office developed an SDD statement of work with an option for one year of FD performance. This option describes three main functions for the FD phase of work: production, engineering support, and engineering design. The program office intends to construct a new statement of work for the FD phase of the program. As a result, current descriptions include only a portion of the work that will actually need to be performed in FD. RAND researchers, through review of program documentation, discussion with program staff, and analysis of other programs, identified additional program functions, as discussed below.

Production

After the first increment is complete, the Navy expects that one or more organizations will fabricate, integrate, test, and deliver the CANES system. The organization(s) will be expected to provide workstations and peripherals to support the delivered system. Other possible responsibilities might include loading government-furnished software.

System Testing

A number of testing activities will occur throughout the life of the program as hardware and software are updated. There will need to be testing of the CCE and its applications, of CCE and application integration, and then operational testing for each new update. In the SDD phase of the CANES program, the contractors are responsible for testing the CCE equipment against government specifications. The application providers are responsible for ensuring that their applications can run on the CCE. The government is responsible for the integration testing.

Once the CCE is delivered, but prior to installation, verification and validation of the equipment will occur at the vendor site and be performed by the In-Service Engineering Agent (ISEA). This agent is part of the Space and Naval Warfare Systems Command (SPAWAR) and is independent from the contractor and the program office. The CANES program office is establishing a lab to perform the integration testing of independently developed hardware and software. The contractor will be responsible for providing equipment to the lab. During FD, the lab could continue developing software applications and testing their integration.

System Installation

The program offices within PEO C4I procure the equipment to be installed on the ship. The modernization process is complex, involving many organizations outside the PEO. The planning for modernizations begins two years prior to the start of the work, when a Ship Change Document (SCD) is submitted with a limited description of the system to be installed. The corresponding platform Program Manager Warfare (PMW) will then review and submit the work order to a database (Navy Data Environment) so that it can be reviewed in a process used to prioritize and execute modernizations (referred to as SHIPMAIN). There are three main phases of approvals as the installation date nears, and the level of detail regarding the installation increases at each phase. The system may require several certifications involving outside organizations. SPAWAR System Centers (SSCs) or contractors must engage with the Naval Surface Warfare Center, Carderock Division, to receive necessary shock and vibration certifications. SPAWAR determines whether certain cyber security–related certifications are required. An In-Service Logistics Support certification must be submitted by the Naval Sea Systems Command (NAVSEA). NAVSEA will ultimately approve the installation and provide a letter of authorization for installation.

Every ship has a shipyard, referred to as its *planning yard*, responsible for planning its maintenance. Approximately 15 months prior to installation, the planning yard is notified of the plan to install equipment. When funding and the ship are available, the planning yard will inspect the ship and produce a Ship Installation Document (SID) that has drawings of the ship with details required for the installation team. It may be several months before the documents are delivered to the Installation Management Office (IMO), the SPAWAR organization responsible for coordinating the installation with the shipyard, and the actual contractors who perform the installation, or the Alteration Installation Team (AIT). Because many activities are typically being performed during a ship's maintenance availability, all are managed by the fleet's Regional Maintenance Center (RMC). IMO's Ship Supervisor (SHIPSUP) manages the overall SPAWAR effort during the availability. Daily production meetings are held with the RMC, AITs, IMO, SHIPSUP, and the ship's force and shipyard personnel to discuss work priorities and assignment of resources.

Personnel involved with installation activities are invited to examine equipment when it arrives at the staging area. The ship's force is expected to help transfer data. The application owners will determine who will install the applications during the staging. The application owners also have an ISEA.

Design Services

As technology evolves, further design may be required. This could include developing integration work or new baselines and drawings for platforms that were not in the initial design pool. The designer may need to provide technical support for other functions, such as system and application integration, installation, and testing.

The organization providing design services may also support the development of technical reports and studies on new and emerging technologies, noncritical problems, and other CANES-specific technology areas needing further analysis, such as how to facilitate and realize the integration of the CCE and applications. Given intimate knowledge of the system and its workings, the designer may also need to participate in logistics and support activities, such as the development of technical and support manuals.

Systems Engineering and Integration

Systems engineering and integration is a key CANES activity. Other program personnel have described system engineering and integration as an extremely challenging task, the focus of which is the design, management, and execution of the integration. Essentially, the integrator is responsible for getting the system to "work." The integrator may need to develop interfaces, including "glue"—the virtualization that is required to integrate the CCE and the various applications. The integrator may need to work with the developers and production to resolve integration challenges. The integrator should have a long-term relationship with the government because the accumulated knowledge and expertise required to perform integration activities is difficult to replace. There will also be a continuous need for hardware and software integration as the system is updated. The integrator might design and update standards and protocols for the integration of applications.

Configuration Management

As various ships receive hardware and software updates, there will be many configurations in the fleet. Ensuring that all ships have the correct hardware and software baselines could be a very challenging task. It entails developing a detailed recording and updating of information that describes the hardware and software, including the recording of versions and updates that have been installed. It also requires tracking and managing hardware and software updates by ship.

In-Service Support

Once the system is installed, there will likely be a need for system support. While the update rate is designed to address obsolescence issues and minimize the amount of support required, hardware or software failures should be expected. When these failures occur, the designer, integrator, or production organization might need to assist the government. The technical data and documentation required to support the system will have been provided to the government so that the government might address the problem. There are many options for providing this support. A facility, staffed by government or contractor personnel, may be set up to provide such support. Alternatively, existing facilities may provide support.

The Navy has included incentives to use COTS, Government Off-The-Shelf, or other open standards in system development so as to facilitate updates and reduce life-cycle costs. The Navy is expecting a system design that will maximize its ability to accommodate the fast pace of change experienced in the commercial sector. Upgrading the hardware on a four-year cycle and the software on a two-year cycle is expected to minimize technical obsolescence issues, which can lead to significant life-cycle costs.

Governance

Numerous organizations require network services afloat and are able to procure supporting hardware and software. Some of these organizations, such as the Intelligence Agencies, are outside the Navy. In order to consolidate networks and obtain C4I commonality across the fleet, the Navy will require some form of governance for the CANES system. Top Navy leadership will need to ensure that CANES is used to the maximum extent possible to meet the needs of varying organizations. In December 2009, the Chief of Naval Operations sent a message to all potential stakeholders establishing a CANES Oversight Review Board, whose responsibilities are to integrate "appropriate existing Navy . . . processes for the Consolidation of afloat networks and migration of applications and systems into the CANES [and to] approve any networks, applications, and/or systems" that would operate on CANES following installation (CNO, 2009). Systems that will not use the CANES/CCE infrastructure do not need to be approved by the board. This concerned some of our interviewees, who said that without a higher level of governance, additional systems will be put on the ship, thereby minimizing the desired effects of CANES.

CHAPTER THREE

Contracting Strategies

Grouping CANES functions can help in developing contracting options. There are many potential ways to group CANES functions. Each function requires a specific set of skills. Production requires procurement, assembly, testing, and shipping skills. Installation requires ship-engineering, logistic, and ship-alteration skills. Design services require IT and logistics skills.

For purposes of this analysis, we aggregated the functions to be performed during the FD phase of the CANES program, based on the similarity of the skills and the time frame that exercise of these skills may require for providing best value to the government. For example, some functions may be better performed if a long-term relationship exists between the government and contractor, so we grouped those activities accordingly. The result was three functional categories.

- **Technical:** advice, design, systems engineering and integration, configuration management, in-service support, and other efforts requiring engineering, technical, or IT support for the hardware and software systems. These skills are best employed in a long-term relationship with the program office to maintain continuity and consistency and to maximize benefit of feedback from the field.
- **Production:** acquisition, assembly, and wiring of hardware racks; installation of software and kitting necessary to prepare ships for installation. With well-defined specifications, these skills can be periodically employed through competitive contracts for up to one year's worth of hardware and services.
- **Installation:** all effort necessary to plan, document, accomplish, test, and accept the installation of CANES systems on warships. These skills require a long-term relationship with the program office in order to perform the two years of planning necessary for the SHIPMAIN process prior to installation.

Criteria for Developing Procurement Approaches

For the full deployment of CANES, we sought governing principles that would be flexible enough to accommodate changes in the following:

- **Technology:** Moore's Law will mean constant changes in commercially available hardware over the life of the CANES program.
- **Requirements:** CANES software applications will also change continually.

- **Schedule:** The schedule for installing CANES systems on every warship in the fleet will change as ship availabilities change due to myriad operational, maintenance, and funding issues.

Moreover, the options need to provide the best technical, production, and installation value for the government. While price is always an important consideration, best value is critical for the CANES. If the hardware, software, or installation process does not work properly, a warship may not be operational, negating any procurement savings. Even a delay in installation could keep a ship in a shipyard longer than necessary, with associated additional costs. The program must achieve a balance between price and quality.

Governance Options

An acquisition strategy should first determine the role the government will perform in executing the program. If the government could write a complete, detailed specification ensuring that it will receive what it needs, it could turn all governance over to industry and inspect and accept the CANES installation at the end of the process. Alternatively, the government could control all aspects of the acquisition and hire support contractors to provide resources used under government direction while maintaining performance of inherently governmental functions.[1] A middle role for government involvement appears ideal for the CANES program. This option provides government oversight while assigning tasks to organizations most qualified to perform them. In developing procurement options, we assume the government will take such a role. Specifically, we assume that the government will

- make major program decisions for CANES
- maintain responsibility for development and ownership of requirements, program management, and testing
- maintain technical authority
- create an integration strategy that assigns roles and responsibilities to various parties
- support and determine the future direction of the program.

Procurement Options

The five procurement options we developed cover two opposite strategies and three variants that fall in between. The two opposing strategies are (1) maximizing as much of the effort as possible under one prime contract or (2) performing as much effort as possible using existing government resources.

The three intermediate options involve different mixes of multiple contractor and government resources. The five options developed for analysis are presented in Table 3.1.

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1 The Federal Activities Inventory Reform Act (P.L. 105-270) defines an inherently governmental function as "a function that is so intimately related to the public interest as to require performance by Federal Government employees." Such an approach would likely violate the Federal Acquisition Regulation (FAR) (37.104[b]) prohibition on personal service contracts and blur responsibility for performance, but is noted here to help delineate the range of options the government might consider.

Table 3.1
Procurement Options

	Option				
Function	**Single Prime Contractor**	**Multiple Contract Model A**	**Multiple Contract Model B**	**Multiple Contract Model C**	**Government**
Design and integration Technical advice Systems engineering Configuration management In-service support	Prime	Contractor A	Contractor A	Contractor A	Government
Production	Prime	Winners of production MAC IDIQ (not Contractor A)	Winners of production MAC IDIQ (not Contractor A)	Winners of production MAC IDIQ (not Contractor A)	Government plus winners of existing service center MACs
Installation	Prime	IMO	Winners of installation MAC IDIQ (not Contractor A or the winners of the production MAC IDIQ)	Winners of production MAC IDIQ (not Contractor A)	IMO

NOTES: IDIQ = indefinite delivery, indefinite quantity. IMO = Installation Management Office. MAC = multiple-award contract.

A Single Prime Contractor

A single prime contractor is the acquisition model most commonly used in the Department of Defense. Under this acquisition model, a single organization is responsible for the design, production, and sometimes the in-service support of the system. While the prime contractor may subcontract or partner with others, the government deals directly with the single prime as the responsible party.

When using a single prime contractor, the government may use one prime contract, requiring multiple contract line items numbers (CLINs) to accomplish all FD functions over several years. The CLINs would require different contract types and work scopes (e.g., cost-plus-fixed-fee or firm-fixed-price [FFP], some with completion work scopes and others with level-of-effort [LOE],work scopes[2]) to operate effectively. Some CLINs will likely have to allow delivery and task orders[3] to be negotiated and awarded subsequent to prime contract award, given that hardware-production baselines and installation schedules for ships receiving CANES in future

[2] A completion work scope describes, in detail, everything necessary to perform the job. A LOE work scope loosely describes what needs to be done in a specified number of hours. An LOE work scope can be used in either a cost or fixed-price contract. If used in a fixed-price contract, the hourly rates are locked, but more hours must be added if the work is not completed.

[3] In federal procurement terminology, delivery orders buy supplies and task orders buy services under previously awarded contracts.

years cannot be specified today.[4] A notional CLIN schedule for a single prime contract might include the following:

- **CLIN 001 Provide technical advice to PMW 160**
  - This would be a cost-plus (CP) LOE with task orders (TOs) having a CP or fixed-price (FP) basis for studies and analyses.
- **CLIN 002 System Engineering and Integration**
  - CP LOE with TOs (CP or FP) for studies and analyses
- **CLIN 003 Configuration Management**
  - CP LOE or completion scope of work
- **CLIN 004 Production**
  - Firm FP delivery orders (DOs)
- **CLIN 005 Installation**
  - CP TOs or FFP TOs with many changes
- **CLIN 006 In-service support**
  - CP LOE or time and material work scope

These recommendations are derived from basic contract principles. Where the level of required effort is unknown or risks are high, a CP contract is suggested. If the price and amount of work is known, then a FP contract is suggested.

Although this single prime contract could be competitively awarded based on best value, such a competition would not be meaningful. This is because some CLINs would have LOE work scope for which the government must pay whatever it takes to complete the work, whereas other CLINs would also require subsequent sole-source negotiation of numerous changes or TOs and delivery orders (DOs) with the prime contractor.

A prime contractor model would, however, have the following advantages:

- Only one contractor would be responsible for program performance.
- Contractor-coordination efforts would be minimized.
- There would minimal need for government-furnished information (GFI) or GFE, reducing the government's liability for contract changes or disputes.
- Using one contractor, and hence consistent standards and communication protocols, can reduce technical risk.

The one prime contractor model has several disadvantages.

- Much of the dollar value of the prime contract would be negotiated with the prime contractor after contract award on a sole-source basis, [5] when the government has no competitive leverage.

[4] According to Department of the Navy, 2010, less than one-fifth of the money needed to procure and install CANES hardware will be funded in FY 2012, when a full deployment contract is assumed to be awarded. With constantly changing production baselines and installation schedules, future-year production and installation requirements will require sole-source negotiation of (a) changes, if out-year production and installation are prepriced, or (b) new delivery and task orders as production baselines and schedules are updated.

[5] According to Program Manager, Tactical Networks, 2010, more than 82 percent of the program's total funding is procurement funding, with the rest being research, development, test, and evaluation (RDT&E) and Operations and Main-

- The one prime contractor model will require intense Navy effort to negotiate many TOs, DOs, and contract changes in a sole-source environment.
- Once the prime contract is awarded, the government will have fewer tools to manage performance or costs.
- The one prime contractor model would require new processes and agreements with installation activities (e.g., planning yards, RMCs, private shipyards) that currently deal with the SPAWAR IMO to install ship alterations.

Multiple Contract Model A

Model A uses different contracts for different functions. It uses one contract to provide the necessary technical and engineering effort, including design and integration. This contract can be competitively awarded but must cover multiple years to ensure continuity and avoid disruptive and costly contractor turnover. The CLINs would be mostly cost-plus, LOE scopes with some TO provisions for the contractor to address technical requirements and schedule changes that cannot be managed through FP contracts. The FD production effort in this model would be carried out by contractors receiving periodic MAC IDIQ awards as prescribed in FAR Subpart 16.5.[6] The MAC contracts would be competitively awarded to several contractors that would compete periodically to deliver one or more ship-sets of CANES equipment ready for shipment to the warship installation site. The installation would be handled by the SPAWAR IMO, which would use AIT contractors, experienced in shipyard work, to install the systems.

Model A offers several advantages:

- One contractor performing all engineering functions and maintaining continuous experience over long terms. This minimizes the cost associated with changing contractors as well as the risk to integration of engineering products.
- Periodic FFP competitions for production ship-set delivery orders. This would
  - help obtain current best prices for hardware to facilitate production baseline updates without negotiating changes due to late or defective GFI or GFE
  - allow past performance to be competition for future delivery orders, thereby providing incentives for current performers to provide quality and timely performance
- Use of existing organization, contractors, and processes for the complex installation process.

The disadvantages of the Model A option are that it requires multicontractor competitions, awards, and coordination by the program office as well as program manager assumption of responsibility for meeting system requirements and provision of GFE and GFI.[7] This may require negotiating contract changes, thus making it harder to hold contractors responsible for

tenance, Navy (O&M,N). As previously noted, only 18.5 percent of the program's procurement funds are budgeted for FY 2012. The vast majority of the program's procurement and installation funding occurs in subsequent years when production baselines and installation schedules are continuously changing.

[6] We cannot comment on how successful IDIQ contracts have been in other, similar programs.

[7] For example, the hardware delivered by the production contractor will become GFE to IMO's alteration installation contractor.

their performance. Moreover, there is some concern that the IMO process may not obtain the lowest cost for installation.[8]

Multiple Contract Model B

Model B is similar to Model A in that it uses one competitively awarded, long-term contract for the engineering effort and competitive MAC IDIQ delivery orders for production of ready-to-install CANES ship-sets. It differs from Model A in that it would use a separate set of MAC IDIQ contracts for ship installations.

This approach has the same advantages as Model A and the additional advantage of periodic competitions for installation task orders, giving the government some leverage for improving cost, schedule, and quality.

The Model B option also has the same disadvantages as Model A. It has the additional disadvantage of requiring extra government effort to set up and administer two sets of MAC contracts. Like the one-prime-contract model, it would require new processes and agreements to coordinate with planning yards, type commanders, RMCs, shipyard contractors, and others. Navy and SPAWAR policy may also need to be modified to allow such transactions.[9]

Multiple Contract Model C

The Model C multiple contract option uses the same competitively awarded, long-term contract approach as Models A and B. It differs in its use of one set of MAC IDIQ contracts to combine CANES production and installation. It would hold periodic competitions between the MAC contractors for combined DOs and TOs to produce and install CANES. The DO CLIN would be FFP and the corresponding installation TO CLIN would initially be cost plus incentive fee. As installation experience was gained, installation task orders could shift to a fixed price incentive (FPI) CLIN.

This approach has all the advantages of Model B. It has the additional advantage of holding one contractor responsible for each ship. It also has all the disadvantages of Model B. It has the additional disadvantage that the IDIQ awards would likely exceed $10 million, thereby permitting MAC bid protests under the FAR.

Maximum Government Performance

The last option is in many ways the opposite of the first mentioned, that of maximum government performance. Under this approach, the technical and engineering functions would be assigned to the SSCs, the IT hardware would be procured using existing government MACs, and the IMO would handle the installation using existing processes and AIT MACs.

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8 Numerous interviewees complained about the cost of installing hardware on warships during private-shipyard availabilities. Not all of this cost is attributable to the IMO's alteration-installation contractor. Each ship class has a planning yard that maintains the drawings for the ships. The IMO must pay the planning yard to verify the ship configuration and modify the drawings to accomplish the installation. Moreover, the shipyard performing the availability charges to provide direct support services (e.g., rigging, welding) to the IMO's alteration installation contractor. The RMC also prorates the cost of indirect services (e.g., security, temporary power, ventilation) provided by the availability shipyard to all work performed during the availability. All these costs can be quite large and variable and must be paid regardless of whether the installation is handled by the IMO or a PMW 160 contractor.

9 SPAWAR (2006), p. 4 states that "planning and execution of installations shall be centralized in the established SPAWARSYSCEN Atlantic and SPAWARSYSCEN Pacific Installation Management Offices. . . ."

The advantages of this model are that it minimizes contract actions, uses existing installation processes, and provides the program office with excellent oversight.

There are three principal disadvantages to this approach. First, the program office would have to compete for priority of SSC resources. Second, this approach would subject only 62 percent of its program spending to competition.[10] Third, the program office would have little incentive to manage the performance of other government organizations.[11]

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[10] The previously cited FY 2011 CANES procurement budget (Department of the Navy, 2010) shows that, of the $1,455.9 million to be spent on CANES procurement from FY 2010 to FY 2015, $353.9 million would be for installation and $1,102.0 million would be for production equipment. In this model, only production equipment would be procured through competitive contracts. The $1,102.0 million for production equipment is 62.4 percent of the total program cost of $1,766.7 million previously cited.

[11] One potential tool is to allow the CANES program manager to provide input to the performance and promotion reviews of the performing activity.

CHAPTER FOUR

Insights from Other Programs

CANES is an ambitious program that, if successful, will significantly consolidate the amount of C4I hardware and software on board Navy ships. Given the number of legacy systems that are on board today's ships, the process of consolidating older C4I applications will be challenging. Of perhaps equal importance will be the one- to two-year software updates and four-year hardware updates that the CANES program is planning. As the CCE is updated, the Navy will need to ensure that all the applications running on the system are compatible with the new hardware. Integrating the inputs from multiple stakeholders will be a challenging task.

Other programs within the Department of Defense can offer some important lessons for the CANES program. This chapter examines seven such programs. The sources available to us on these programs had differing amounts of information, resulting in a different presentation of information for each program.

We examined four programs in detail: the Air Force Mission Planning System (MPS), the Navy Acoustic Rapid COTS Insertion (ARCI), the Navy *Virginia*-class Non-Propulsion Electronic System (NPES), and the Navy Common Submarine Radio Room (CSRR). We selected these programs because they are all IT integration efforts that were not part of the host vehicle design and were produced independently of the host vehicle. These programs also required the coordination of many producers, each responsible for a different piece of the program. They were also considered by the literature to be "successful" programs in that they delivered a desired capability at an acceptable cost and schedule.

We also reviewed the Army Future Combat System (FCS), the Coast Guard Deepwater program, and the Navy Integrated Communications and Advanced Networks (ICAN). We reviewed these programs because they had a complex integration requirement or were employing an open-architecture approach, two key characteristics of the CANES program.[1]

Some of the programs reviewed have been considered "successful," meaning that the desired capability was delivered on time and within budget. Others have not been considered successful. While none of these programs is identical to CANES, all offer useful insights.

MPS, ICAN, ARCI, NPES, and CSRR are similar to CANES in their goals and challenges. These programs can provide lessons on the magnitude of the integration challenge.

[1] We also based our selection on the availability of information regarding the program. For those programs where we were able to gain greater insights, we provide additional program information in Appendix A on the Mission Planning System, Appendix B on the Integrated Communications and Advanced Networks, and Appendix C on Acoustic Rapid COTS Insertion. In some cases, we were able to interview individuals, such as current or past program managers, who have intimate knowledge of the program. In other cases, we only had publicly available documentation or unpublished RAND research available to us.

The contracting options developed for these programs can also offer lessons for the Navy CANES effort. These programs can help inform the CANES program office concerning

- assignment of roles and responsibilities for various functions
- the most appropriate contracting strategies
- top technical issues.

Contracting

The NPES program consists of many electronic systems outside the propulsion plant. NPES has "sonar displays and processors; Navigation and Combat Control Architecture; Data Distribution and Display, Electronic Support Measures, Onboard Team Trainer; Total Ship Monitoring; and Submarine Regional Warfare systems . . . all electronically integrated on a rafted system and inserted into the Virginia hull" (Global Security, 2008). The design was developed separately from the hull design.

For NPES, a single prime contractor was selected: Electric Boat (EB), which designed and built the *Virginia* class. Successful delivery of NPES was the responsibility of the shipbuilder. To gain sufficient IT expertise for this work, EB subcontracted to Lockheed Martin and the Naval Undersea Warfare Center (NUWC). Lockheed Martin and the NUWC assisted with system design, engineering, and integration, while Electric Boat managed production and installation.

MPS and ARCI did not have a prime contractor. Instead, these programs had multiple contracts for different functions.

MPS is a ground-based pre–mission planning system for most types of aircraft in the Air Force. It is a ground system executed on laptops. There is no platform installation on board aircraft; mission planning data are transferred to the aircraft computers. MPS has three main components:

- the system framework, which performs basic mission planning
- the common capabilities (intelligence, imagery, refueling) hardware (personal computers and servers obtained through GSA contracts)
- the platform-unique planning components.

MPS has two main contracts:

- a long-term contract with a system integrator responsible for having all pieces work together
- an IDIQ MAC for the design and production of the software associated with the common capabilities and unique planning components.

The first contract, with the system engineering and integration contractor (SE&IC), assigns the responsibility of providing a fully functioning system to the Air Force. Much of the material passed to the SE&IC is furnished by the government. Under the MAC, five companies competed for different work under task orders. To maintain and refine the system framework, the MPS program office has a long-term (12-year) contract with a single contractor.

A major challenge for the MPS program is integrating multiple software applications from offices for different aircraft throughout the Air Force. Other program offices that develop weather or threat-related software also have to integrate their applications into MPS. This is very similar to the challenge that CANES will face as it receives applications from various Navy C4ISR stakeholders.

ARCI was a Navy initiative to improve, with a decreasing budget, acoustic abilities of the submarine fleet. The program has evolved since its inception in the early 1990's. There has never been a single prime contractor for ARCI. Rather, as the Air Force has had for MPS, for ARCI the Navy has had one long-term relationship with a system integrator, Lockheed Martin, and other contracts for development and production. The system integrator is responsible for delivery of the desired capability, but the government is ultimately responsible for it. Initially, there were two main contracts, one to Digital System Resources Inc. (DSR) to develop the initial system and one to Lockheed Martin to integrate the system with the existing platform. There are currently four contracts: two contracts for engineering services and hardware, one for integration, and one for software. None of these contracts are multiple award contracts. The program used a combination of incentive-fee and award-fee contracts in an effort to get the greatest cooperation among all contractors.

CSRR is a Navy program to consolidate and update the radio room on board submarines. Initially, the system design, engineering and integration functions were performed by a prime contractor, EB. EB subcontracted with Lockheed Martin for design support, engineering, and integration. Following initial installations, the government performed all system design, engineering and integration, and support and installation tasks. The NUWC and the SSC–Charleston have since provided all in-service support for CSRR, except where Lockheed Martin has a contract to provide support for the software. The System Centers did not participate greatly in the design or production of the systems. Rather, they had to develop knowledge and expertise of the systems necessary to repair and upgrade equipment.

While each program pursued a unique contracting strategy, there are some common themes regarding task responsibility. Production has typically been a contractor activity. System design, engineering, and integration have been predominantly contractor activities with some government participation in modernization. In-service support and installation has been predominantly a government activity with support from contractors. All these programs faced challenges integrating multiple software applications from other organizations.

Roles and Responsibilities

Government Activities

For inherently governmental reasons, the government needs to participate in specific technical and managerial activities. The government must maintain management and decisionmaking responsibilities and staff programs with personnel capable of undertaking these tasks. While contractors may identify what is technically possible, the government should maintain responsibility for specifying requirements and, importantly, testing. The government should maintain responsibility for developing architecture specifications. It should also guide the integration effort by clearly specifying roles and responsibilities for various parties, developing an integration plan or strategy. The government should participate in the development of and manage standards and protocols required for the integration effort. While contractors may propose standards, the government should have final approval of them. This requires maintaining technical expertise within the government program offices, even if most programming work is done by contractors. For Navy programs, this technical expertise came from the Warfare Centers and SPAWAR.

In successful programs, the government maintained responsibility in the sustainment phase for maintaining and modernizing materiel and equipment. At the same time, contractors also played some critical roles in program maintenance and modernization. In the ARCI and CSRR programs, for example, the government in-service support and modernization is largely performed by contractors.

Our review of these select programs indicates that major program decisions for CANES need to be made by the appropriate government activity, not by industry. For inherently governmental functions, the government should maintain responsibility for requirements, program management, and operational testing. It should maintain technical authority, even though system engineering, software engineering or hardware development may be done by contractors. The government needs to have the information and expertise required to offer integration guidance and to create an integration strategy that assigns roles and responsibilities to various parties. It also needs information and expertise to support, install, and determine the future direction of the program.

When the government contracts for services and products, it can still maintain responsibility for key program activities. A technically competent government representative can participate in Integrated Product Teams to represent government interests and to keep the government aware of the technical risks and challenges that the program faces. Carefully constructed contracts can also ensure that the government maintains responsibility for key program decisions.

Industry Activities and Contracting Strategies

While the government has maintained oversight and management responsibilities for successful programs, contractors have performed the bulk of design, development, and production work. Table 4.1 shows contractor activities in successful programs, including primary systems-engineering and integration execution.

Each program pursued a different acquisition and contracting strategy. Two of the four programs had a single prime contractor; the other two programs had a prime system integrator with multiple contracts for different functions. Each program had strategies that evolved as the program matured**.** CSRR transferred system-engineering and program-integration responsibilities from industry to government when the program moved from system design and development to in-service support and modernization. The *Virginia*-class NPES program was developed for new ships only; the other three programs focused on retrofitting existing forces.

Assignment of Roles and Responsibilities for CANES

It is clear that the government needs to play a significant role in the CANES program, including developing requirements, program management, technical direction, and technical authority. Major program decisions must be made by the government. The government must have the information and expertise needed for integration guidance and strategy, assigning roles and responsibilities. The government also needs to have the information and expertise required to support, install, and determine the future direction of the program.

Table 4.1
Industry Activities for MPS, ARCI, *Virginia*-Class NPES, and CSRR

Activity	MPS	ARCI	VA NPES	CSRR
System engineering and integration	Prime system integrator	Prime system integrator (LM)	EB prime with subcontract to LM and NUWC CNPT	Development—EB prime with subcontract to LM Modernization—NUWC/SSC
System design	Multiple contractors	Multiple primes with input from user	Prime with subcontractors	Prime with subcontractor
In-service support	Multiple contractors	Government/LM	UNK	NUWC/SSC (supported by LM)
Production	Multiple contractors	Multiple contractors	Prime (EB)	Prime (EB)
Installation	N/A	Shipyard	Prime (EB)	Modernization—SSC-SD
Assessing future direction	Government	Collaborative	UNK	UNK
Configuration management	Prime system integrator	UNK	UNK	SSC

NOTES: *Configuration* is defined as tracking and managing which units have which version of the baseline and which will receive an update. N/A = not applicable. UNK = unknown.

The CANES program could adopt any number of assignments of responsibilities for program tasks and be successful. Our assessment of program goals and other program experiences shows no reason why the CANES program could not adopt a typical assignment of responsibilities, with design, systems engineering and integration, and production activities performed by contractors and overseen by government, at least initially. Collaboration between the program office, SPAWAR, and industry could improve the ability of each to perform its function. It could also help the government, should it wish to do so, to develop the expertise required to take on system design, engineering, and integration roles in the future. To be in the best position, government organizations, such as SSC, should be active in system design, engineering, and integration activities from the start of the program.

Other Lessons Learned

Several past network implementations—ICAN, the Shipboard Wide Area Network (SWAN), Total Ship Computing Environment (TSCE), Aviation Data and Management Control System (ADMACS), and Integrated Voice Communication System (IVCS)—also offer a number of lessons in requirements, documentation, acquisition and contracting, technical design, test and evaluation, supportability, and training. Some of the lessons we draw from them here were consolidated from earlier studies sponsored by PEO C4I that were conducted by RAND (Schank et al., 2009). All are relevant to future network implementations.[2]

2 We provide additional information on the LPD-17 SWAN in Appendix D, on the ADMACS in Appendix E, on the TSCE in Appendix F, and on the IVCS in Appendix G.

Tables 4.2 and 4.3 summarize two groups of lessons: common pitfalls and recommended actions. Many of these pitfalls are well understood; indeed, the CANES program was designed to address some of them. Table 4.3 references mitigation strategy by problem number listed in Table 4.2. Problems and solutions are discussed in much greater detail in the appendixes.

Table 4.2
Network Implementation Pitfalls

No.	Potential Pitfall	Area
P1	No independent (third-party) cost estimate for expenditures	Acquisition and contracting
P2	Lack of sharing of proprietary source code between the government and private industry	Acquisition and contracting
P3	Lack of off-the-shelf replacements when companies go out of business	Acquisition and contracting, supportability, and technical design
P4	Lack of shipbuilder network designs available to the users	Documentation
P5	Lack of technical manuals	Documentation
P6	Insufficient level of understanding between the government and the shipbuilder on requirements	Requirements
P7	Lack of subject-matter expert input (for each functional area) to the shipbuilder; requirements made at the ship specification level, not the department (navigation, engineering, combat systems, air) level	Requirements
P8	Lack of configuration accounting or source code for software life-cycle management upon ship delivery, making it difficult for the Navy to fix problems	Supportability, acquisition, and contracting
P9	Quality of service not considered when voice and controls data depend on the same backbone	Technical design
P10	Poorly tested software and hardware modifications; upgraded systems not tested for adverse effects on other shipboard systems	Testing and evaluation
P11	No systemwide land-based testing of a system prior to onboard installation	Testing and evaluation
P12	Lack of shipboard personnel with training and technical expertise	Training
P13	Lack of formal training	Training
P14	Frequent human errors	Training and technical design
P15	Networks and applications that are not up-to-date	Technical design, acquisition, and contracting
P16	Excessive life-cycle costs due to operations and maintenance (O&M) costs	Acquisition and contracting

Table 4.3
Network Implementation Mitigations

Mitigation	Area (pitfalls addressed)
Create an integrated requirements document (for all ship networks) that contains individual functional-area requirements	Requirements (P6, P7)
Require the design team to work with the operational users of the system to identify system functional and end-user requirements prior to design	Requirements (P6)
Write a well-defined concept of operations encompassing the entire system and user functional interactions of individual networks, ship systems, and other interfaces	Requirements (P6)
Reduce manual inputs by allowing data to be passed from system to system whenever possible	Technical design (P14)
Conduct a risk analysis and implement a management process with full-scale testing under dynamic shipboard conditions for all new technology, equipment, architecture, or configurations that have never before been used on a ship	Testing and evaluation (P10)
Conduct a land-based test of the system prior to shipboard installation or, if that is too costly, develop a virtual integration concept that involves all system sites	Testing and evaluation (P10, P16)
Ensure that CFE is not designed and procured years before installation to avoid hardware obsolescence	Contracting and acquisition (P15)
Develop a life-cycle software and maintenance-control plan	Supportability (P16)
Establish a dedicated organizational entity to serve as life-cycle manager in a Navy organization with staffing components from headquarters, naval organizations, and private companies	Supportability (P3, P8, P16)
Establish a distinct program and system integration office that is responsible for management of all CFE and GFE system hardware, software maintenance and control, systems integration, system-level functional requirements, control for services and resources, budget formulation, future technical changes, and plan executions	Acquisition and contracting (P3, P8, P16)
Conduct several meetings one year before system delivery to determine whether requirements are feasible or need to be modified	Requirements (P6)
Put C4I personnel and systems on board earlier in the shipbuilding process so that the users are properly acclimated to the network	Training and requirements (P7, P12)
Provide more shipboard training or establish a reliable remote management capability to effectively monitor the health of the network	Training (P8, P14)
Ensure that networks are not “ship-unique” to allow for cost-effectiveness in schoolhouse training	Technical design, contracting, and acquisition (P16)
When upgrading systems, synchronize multiple upgrades so that adverse effects on other shipboard systems are realized earlier	Supportability (P8)

CHAPTER FIVE

Important Issues for Any Contracting Strategy

Understanding the technical risks and their effects is fundamental to determining the appropriate contract strategy, including specific language that will help establish responsibilities of the government and contractor(s).[1] This study focuses on acquisition and contracting, but this chapter considers how technical issues of CANES affect contracting decisions and choices. In particular, it identifies risks that can affect the FD contract. We explore risks (1) in the current vision of CANES, (2) related to how the system development (SD) and LRIP directly affect FD, and (3) identified in previous attempts to implement similar systems.

In this chapter, we first observe the importance of software when assessing the procurement of hardware. Second, we highlight issues and challenges associated with requirements, metrics, configuration and control, and system integration. Third, we list a number of other technical risks. Finally, we summarize general conclusions.

Requirements and Specifications

Importance of Getting the Initial Requirements Right

Success or failure in a project can often be traced to initial development of requirements. Specifying appropriate detail in requirements is challenging. There is risk in both overspecification and underspecification. There is also risk in allowing too many changes and in being too inflexible to change.

The Traditional Approach and the CANES Approach

Traditional DoD approaches to large-system design usually begin with the enumeration of all requirements of a system before proceeding to design and development. This appears to be the approach that PEO has taken with CANES. PEO C4I is also providing a functional architecture that will allow the SD contractors maximum flexibility in design. The SD contractors will develop a functional realization of the architecture, refined where needed, to meet PEO requirements. Ideally, the system will evolve through frequent updates to its design.

Flexible Requirements are a Key Lesson Learned

The long-troubled Joint Tactical Radio System (JTRS) program and ARCI offer many lessons for setting requirements. One of these lessons has to do with the ultimate adverse impacts of

[1] Previous attempts at network consolidation in the Navy (see ICAN program for CVNs) were hurt by poor risk mitigation early in the program. This adversely affected development, testing, installation and, ultimately, system performance.

inflexible and unnecessarily challenging requirements. Initial requirements made the system technically very challenging, which led to a failure to meet initial requirements, increasing cost and creating delay.[2]

One reason that the ARCI program has succeeded is because it specifies and then meets small increments of capability. Although the CANES program will be much broader than ARCI, it, too, would benefit from specifying and then meeting minimum increments to satisfy the most fundamental requirements. The program would also benefit from giving system and application developers the greatest flexibility possible.

Observations and Examples from Existing CANES Specifications

CANES architectural (and subsequent) specifications have very good traceability, but they lack references for specific performance metrics. Some reference to operational conditions or the Initial Capability Document can help achieve verification and acceptance from users. Table 5.1 provides examples of two requirements and the issues they raise.

For the second example in Table 5.1, it would seem more prudent to separate performance requirements such as "less than 1 second" from the specification. The requirement is that CANES shall federate all near-real-time services. A more precise performance requirement can be defined during system acceptance testing.

Prioritize Vital over Desirable Requirements

System specification should prioritize vital over desirable but possibly costly requirements. If it is not possible to do this until after the contract award, the Navy should be prepared to change requirements as necessary over the course of the contract.[3]

Table 5.1
Examples of Requirements

Requirement	Reference	Comment
"Large Screen Display resolution shall support, at a minimum, 1080p."	UID03163 in CANES Program Office, *Architecture Specification*, 2009.	This specific example will likely not cause much consternation for developers, but it shows a requirement written to the best commercially available standard, rather than the minimum capability required.
"The CANES System shall provide limited federation with NCES discovery of people and services (Threshold). The CANES system shall provide federation of all near-real-time services (Objective). Near-real-time = less than 1 second with a relative variance of 0.5 seconds squared."	UID00581 in CANES Program Office, *Architecture Specification*, 2009.	This requirement depends on systems outside CANES, and yet the requirement seems fairly stringent for any potential developer to meet. It lets the developer define "limited," making this an example where a minimum amount of capability could be delivered and anything beyond that could be costly for the Navy.

2 The need for flexible requirements is also espoused in National Research Council (2010).

3 National Research Council (2010) describes a process of identifying "Big R" and "Small R" requirements, where "Big R" requirements are the higher-priority, expected outcomes and "Small R" requirements are more detailed requirements that are expected to evolve.

Too many noncritical requirements will strain system developers. It is important to identify the most important requirements so that those of lesser importance can be relaxed or delayed in order to meet more important requirements and program schedule.

Programs can manage a large number of requirements if the requirements are prioritized adequately. The current architecture and functional specifications do not make clear what should be the minimum level of specification for CANES functionality. Although an absolute prioritization may not be immediately apparent, it is vital to analyze requirements and determine which are truly required and which are desirable but not required.

The requirements for CANES were developed and consolidated from the requirements documents of legacy programs, which were designed to operate independently of one another. The PEO should reconsider requirements for operation with an open architecture.

Measures and Metrics

Operational Availability

Requirements and specifications are only as good as the measures and metrics used to make them. Porche et al. (2010), in a 2009 study sponsored by 2009 PEO C4I, identified certain measures used for specifying network performance in requirements documents that were outdated and too general. For example, operational availability (Ao) was originally conceived as an accounting measure for machines and other hardware. The concept of being "up or down" is clear for a mechanical device. For networks, this metric is insufficient, because networks can be both.[4]

User Perception of Availability

A network can be operating in a degraded mode that may be satisfactory but prevent some users from performing a specific task. In such cases, the network may be technically "up," but, as perceived by select users in the fleet, it is down. Both PEO C4I staff and trouble tickets from the Navy's Remedy database indicate this has been a problem in the past.[5]

Configuration Control

Software configuration control will take on a new meaning for the PEO. Instead of allowing a large number of heterogeneous configurations, the PEO will try to consolidate and manage a reduced number based on a consistent architecture.

The ongoing need for multiple software configurations is due to the nature of naval operations, the array of platform types, and ship availability. Despite a consistent architecture, the CANES program still must manage many different baselines because each ship class may have

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[4] The CANES Architecture specification states that "a service is considered down when it is unavailable or inaccessible by user access devices within a given platform and enclave" (CANES Program Office, Architecture Specification 1.4.2, 2010). This statement does not translate well to software in general, nor to a service-oriented approach to software specifically. This type of software service availability is not captured by the availability Key Performance Parameter.

[5] Remedy is a software application produced by BMC Software, Inc. It is one of the most widely distributed tracking systems for business processes. In the case of the Navy (and also at RAND), Remedy is used to track IT-related problems or issues reported by users in the field. Trouble ticket refers to an instance of such a report.

a different implementation of the architecture. As we will discuss later, representatives from other programs (such as the Air Force's Mission Planning Enterprise) frequently cited software-configuration management as a major challenge.

As it stands today, software configuration control is a part of the application integration (AI) process. Its role should perhaps be elevated to a higher level of governance. Using configuration control to manage baselines can help reduce AI complexity. This will be critically important to the success of CANES. The ability of applications to manage many baselines is likely proportional to how well the applications' architecture design or data flows can be modified.[6]

System Integration

An ongoing future challenge, and perhaps the most important technical risk for CANES, is how to continuously integrate new applications quickly and successfully.

Like ICAN, SWAN, and TSCE,[7] the CANES program seeks a consolidation and integration of a certain number of onboard networks. Specifically, it consolidates ISNS, CENTRIXS-M, IC, SCI, SVDS, and SubLAN, to include Total Ship and VIXS (CANES Program Office, 2008b). It differs from some previous efforts (like ICAN) in not having to integrate ship control and weapons-system networks.

A large element of system integration is the test-and-evaluation period of software and hardware products. The validation and verification (V&V) of applications will determine their readiness to be a part of a future CANES baseline. The AI team must consider the specific needs of an open architecture. Application developers and CANES developers need to collaborate through the AI team to evaluate how well their software will work together. This is complicated by the need of the CANES program to consider many other applications. Application developers, CANES developers, and the AI team may affect each other in ways not foreseen, requiring them to find ways to mitigate undesirable effects.

Integration-verification tests will come from the application developers. The CANES program is responsible for ensuring that CANES runs. The application providers are responsible for ensuring that their applications run on CANES. This presents some risk if key development specifications are not shared among AI, CANES, and application developers, ensuring that the integrated system functions robustly. One way to mitigate this risk is early adoption of frequent integration testing by a contractor or independent government agency. Stage 4 of the Application Integration Process and Service Framework addresses this (Program Executive Office, C4, 2009). Programs should also make clear who will write and conduct the tests. If the contractor writes the integration tests, then the FD contract needs to make clear that the

6 *Adaptive management* can help to improve configuration management. It is a process to deal with the uncertainty and other challenges posed by evolving designs.

7 *Total Ship Computing Environment* describes a Raytheon approach for networks and IT on the *Zumwalt* class. The term may have originally been coined by PEO C4I to describe the shipboard architecture, integration, and technical approach for implementing a consolidated, common network, processing and data-sharing solution for a ship. The terms TSCE-I or TSCE/I or TSCI refer to the installed fiber optics, copper cabling, hardware and software, and ship support systems interface (power, air conditioning, etc.) on a ship. A TSCE/I contract was awarded to Raytheon, and the term seems more synonymous with its particular implementation on the DDG-100. Raytheon defines TSCE-I as "an integrated suite of standardized OA [open-architecture] hardware, operating system, middleware and infrastructure services" which "forms the backbone" of the TSCE for all DDG-1000 software application programs (Raytheon, 2006).

integration testers can either accept or refuse a test as valid. Performance testing should be distinct from functional-verification testing and focus on meeting "minimum amount of service" (threshold). For example, a functional test might be determining whether the system turns on (yes or no), and the performance test would be a measure of how long it takes to turn the system on (a numerical assessment). While it is sometimes hard to separate performance testing from functional testing, it is worthwhile to do so where possible. It is better for the PEO to have a contractor first prove functionality, then to test performance. Current plans are for the Navy's SSC to handle integration testing.

COTS

One of the objectives of CANES is to use COTS software and hardware where available and applicable.[8] This is a valuable lesson learned from many programs, including ARCI and the Automatic Identification System. The CANES Program Office, 2008a, notes that "CANES relies heavily on COTS components." Specifically, the requirements (see UID00386) say "CANES shall use commercial off-the-shelf (COTS) products, wherever possible (Objective)." The statement "wherever possible" is a good example of a capability specified in the requirements language in a manner open to varying interpretation.[9]

Supportability

Supportability issues should concern the CANES program (or any program). Many ICAN problems stemmed from poor training, lack of technical manuals, and poor testing and evaluation for software and hardware (see Appendix B for a more detailed discussion). Supportability must be addressed in the design[10] and contracting considerations for a system. Intuitive interfaces, global management software (KSA 7), and online manuals managed by a third party can all help improve supportability.

Crew rotation will also greatly affect network maintenance (and hence will require reliance on a stable base of maintenance providers elsewhere).[11] CANES should help address some of these issues if it provides (as desired and once fully deployed) a consistent architecture across platforms, despite the many baselines to be managed.

Within CANES, there are vestiges of traditional engineering methods employed by DoD, mixed with more-modern approaches toward systems engineering. Classic approaches to development that involve well-defined specifications can be dangerous to systems that evolve quickly. They are also antithetical to modern evolutionary approaches to design. Less rigid evolutionary ecosystem methods—for example, those used by major companies such as Apple and Google—may be better for large systems because they provide the most flexibility (Denning, Gunderson, and Hayes-Roth, 2008). These methods expose the system to risk in such a way that subsequent failures can be used to make the system more robust. The design needs to be

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8 The challenges associated with the Department of Defense using COTS have been widely discussed. Burbank and Kasch (2004) provide an overview of several common issues, including robustness to interference (both intentional and unintentional), covertness, security, scalability, and support for end-to-end quality-of-service (QoS).

9 A suggestion for the FD contract is to either provides incentives for use of COTS equipment or require program approval for non-COTS equipment.

10 The effect of complexity on support can also affect development and design issues. The DDG-1000 network (e.g., TSCE) has at least 7 million lines of code. Supportability will be a challenge for such complexity.

11 This is particularly necessary when dealing with the encryption devices.

open to change for these methods to work; such openness to modification should be specified in the FD contract.

Other Technical Risk Areas

There are many technical risks, not all of which can be neatly characterized. We discuss these below.

Inherent Risks with Server Virtualization

Server virtualization is an increasingly common approach in industry. The CANES program is also undertaking it so as to make the most efficient use of hardware (servers). Server virtualization allows for multiple servers in one box (Miller, 2007). Virtualization allows multiple operating systems on an individual server. It allows multiple applications to share computing resources. Virtualization allows blade servers to further reduce space, weight, and power requirements, and for rapid reconfiguration and computing capacity (Miller, 2007). Virtualization is a fundamental characteristic of the CCE.

That does not mean it is risk-free. Among concerns about virtualization are those regarding information assurance. Gartner, Inc. (2006) says that "60 percent of virtualized servers will be less secure than the physical servers they replace through 2012."

Another concern is "over-virtualizing" a server. This may occur if a central processing unit is overtaxed or has insufficient storage.

Upgradability

C4I programs require annual upgrading.[12] Early planning considerations must consider flexibility for accommodating future needs. Approaches suggested by industry experts are to (1) use modular equipment, (2) rely on flexible infrastructure, and (3) pursue centralized management. In addition, a new platform should (4) forecast a design envelope for network and networked systems. (For further discussion, see Schank et al., 2009). This "envelope" should specify power; heating, ventilation, air conditioning (HVAC); and the physical space boundaries of the network.

Some needs, such as information assurance and cybersecurity, will be difficult to anticipate. These are particularly tough to plan because threats constantly change. It is difficult to anticipate future types of attacks. Furthermore, new threats will require quick and efficient installation of new security precautions. A flexible infrastructure is a requirement as well as a means to insert the updates through the fleet quickly.

Inherent Risk in Maintaining and Supporting CFE

Navy personnel have indicated that PEO C4I has had challenges with unique CFE. In particular, Raytheon's SWAN for the LPD-17 and Newport News' ICAN implementation for carriers

[12] Obsolescence was a major problem in previous network consolidation attempts. Schank et al. (2009) discuss the problem of continual technology upgrades (e.g., C4I). The CANES program is adopting an annual or biennial cycle for upgrading software and a quadrennial cycle for upgrading hardware. This approach has both benefits and drawbacks. One benefit is that it mitigates technical obsolescence. One drawback is the subsequent increased likelihood of requirements growth. This could be difficult to accommodate if growth margins were not planned.

were initially difficult to support and maintain (see Appendix B for a more detailed discussion). Network implementations for the two most recent littoral combat ship platforms have also drawn criticism for problems with CFE.

Many of these CFE systems have limited integration, usability, and transparency in the technical aspects required to maintain the systems. This causes PEO to spend funds addressing issues that should have been addressed by the developer. The upgradeability of the small-production, unique system can be difficult and costly for PEO C4I if there is a lack of transparency in the architecture and thus difficulty in future integration efforts.

Providing Adequate Technical Training

Training for users and network operators remains vital for reliable network operation. More training and IT personnel will decrease network trouble calls. Porche et al. (2010) found that human-related trouble tickets accounted for most trouble tickets generated for ISNS on ten aircraft carriers between 2006 and 2008 and that increasing each carrier's IT staff would reduce the total number of human errors.

Observations, Conclusions, and Recommendations

CANES is prompting rethinking of how the Navy procures software and hardware for its afloat platforms. Its success will depend on its flexibility for change, which will be bolstered by its software and hardware update cycles.

Quality in the SD Phase Will Drive FD Quality

A quality design coming out of the SD phase will define the constraints placed on the application programs in FD.

Plan Early to Mitigate Technology Risks

PEO C4I should consider a plan to mitigate the risk of an incomplete or inadequate design in the SD phase or difficulty proving CANES reliability in LRIP. A "crawl, walk, run" approach that targets the most important requirements first could keep the program on schedule in key areas. The program should start with core aspects and then let other aspects evolve as needed.

Prioritize Vital Requirements

Identifying the most vital requirements will ultimately promote success. This will give the program more flexibility to throw out less vital requirements that become problematic for or unwanted by users. This agile approach will require careful management as well as creative contracting options.

Ensure FD Contract Flexibility

To retain functional baselines through upgrade cycles, system requirements may have to change based on feedback from the fleet and changes in the "state-of-the-shelf" hardware and software. The FD contract(s) must be flexible enough to handle the baseline configurations of the configuration management team. The need to manage CANES and non-CANES baselines simultaneously further complicates configuration management, as do periodic software upgrades from multiple offices. This means that CANES managers will need contracting flexibility. The contract should address potential dependencies or constraints of maintaining multiple baselines.

CHAPTER SIX

Conclusions and Recommendations

Consolidating older C4I applications under the CANES umbrella will be challenging. It will require development of virtualization software that allows multiple applications to run on a single server. Once CANES is initially deployed to the fleet (itself a major task), the CANES program office will have to constantly work with other program offices within and outside of the PEO C4I structure to receive timely and workable upgrades to new applications. As the CCE is updated, program managers will need to ensure that all the applications running on the system are compatible. Integrating the inputs from multiple stakeholders will be challenging.

The CANES program acquisition strategy is unique. The CCE (which entails development of the computing architecture, including the selection of specific hardware and the development of virtualization software) will be acquired through a competitive contract. A downselect will occur for full-rate production. Although the selected design is expected to support current applications and services, application owners will be responsible for developing future applications that are consistent with the CANES architecture. When the program enters the FD phase, it will hold another competition. At this point, software upgrades will occur on a one- to two-year cycle, and hardware upgrades will occur on a four year-cycle. The SSC–Charleston will be responsible for loading the new applications onto the CCE.

Programs Analyzed

We reviewed several programs that share important characteristics with CANES, including complex integration challenges and an open architecture approach to system development. Other similarities between these programs and CANES include requiring the integration of hardware and software from different stakeholders (sometimes with competing objectives) and with disparate applications, operating software, and servers.

Although the programs represented a variety of life-cycle phases, Acquisition Categories (ACAT), and levels of funding, they offer useful insights for the CANES program. Each program pursued a unique contracting strategy, but we identified some common themes regarding program responsibilities. For example, production was typically a contractor activity. System design, engineering, and integration were also predominantly contractor activities but involved some government activity during modernization or in-service support. In-service support and installation were predominantly government activities, with support provided by contractors.

Another theme common to successful programs is strong government leadership. Government representatives have participated in specific technical and managerial activities of successful programs. Perhaps most important, the government has maintained program management and decisionmaking responsibilities. While contractors may have identified what is technically possible and done most of the actual software and hardware development, the government maintained responsibility for specifying the requirements and, importantly, testing. The government maintained responsibility for developing the architecture specification. It also guided the integration effort by clearly specifying, through an integration plan and strategy, roles and responsibilities for various parties. This included government participation and management of standards and protocols necessary for the integration effort. While contractors may have proposed standards, the government had ultimate approval over them. This required maintaining technical expertise within the government program offices. For Navy programs, this technical expertise came from the Warfare Centers and SPAWAR.

As successful programs moved into the sustainment phase, the government retained responsibility for maintaining and modernizing materiel and equipment. Contractors did have some critical roles in maintenance and modernization for these programs. In the ARCI and CSRR programs, for example, the government in-service support and modernization is largely performed by contractors.

Contract Strategy for CANES

There is no single "right" acquisition or contracting strategy for the CANES program in FD. Both the single prime contract model and allocation of tasks to different government and contractor organizations can be successful approaches for CANES, if properly managed and executed. Each alternative has unique pros and cons.

Nevertheless, our research indicates that a good approach for the CANES program would be to split it into three main functions and assign each function to the provider offering the best value as defined by quality and cost. The three main functions are (1) a technical function, consisting of technical advice and engineering services (including configuration management and system integration); (2) a production function to procure and assemble the systems; and (3) an installation function. Our analysis indicates that this approach would best enable the CANES program to achieve a competitive acquisition strategy. This strategy would minimize technical and programmatic risks by assigning performance of technical, production, and installation functions to organizations providing the best value. It would allow for the technical flexibility required and support an aggressive schedule. The preferred model would have schedule incentives as well as the flexibility required for constant technical updates, uncertainties associated with an ever-changing ship-availability schedule, and unexpected integration challenges.

Our contract Model A would, we submit, best enable the CANES program to achieve these outcomes. It would use different contracts for different functions. One contract would provide the necessary technical and engineering effort, including design and integration. This contract could be competitively awarded but should cover a number of fiscal years to ensure continuity and avoid costs and disruption associated with contractor turnover. The FD production effort in this model would be carried out by contractors receiving periodic and competitive MAC IDIQ awards. SPAWAR's IMO would manage installation and interactions with other activities, using Alteration Installation Team (AIT) multiple award contractors with experience in shipyard-work processes.

The preferred strategy, Model A, is superior to the Single Prime Contractor option in several ways.

- It requires active and continuous government involvement, which, as noted earlier, is common among successful military IT programs.
- It obtains frequent competitive prices for IT hardware in an environment where hardware capabilities and prices are constantly improving.
- It uses proven SPAWAR IMO processes to install the CANES systems onboard warships and does not require the development of new processes and the negotiation of numerous contract changes to reflect constantly changing ship schedules and shipyard-service costs.

Because it would use the IMO for CANES installation, Model A is superior to Models B and C, which, like the Single Prime Contractor option, would require the development of new processes and the negotiation of numerous contract changes. Model A is also preferable to the Government option because it obtains competitive prices for IT hardware.

Important Considerations for Any Contract Strategy

Assessments of the CANES program and other, similar programs indicate that there are three areas in FD on which the program office should focus. They are the integration of the initial system and future upgrades, the development and specification of requirements, and configuration management.

An ongoing future challenge, and perhaps the most important technical risk for CANES, is how to quickly and successfully integrate new applications. A significant component of system integration is the testing. The testing and evaluation requirements for CANES verification are derived from the PEO's requirements, and the integration verification tests are to come from the application developers. The sharing of responsibility among AI, CANES, and application developers for ensuring that the integrated system functions robustly has inherent risk. With shared responsibility, it is unclear how problems will be resolved. One way to mitigate this risk is to adopt early and frequent integration testing by an independent government agency or contractor. Whatever approach is adopted, it must be clear who will write and conduct tests.

Network-integration efforts also require careful specification of requirements in order to achieve successful, open, service-oriented systems. Finding the right level of detail to provide to contractors is challenging. The CANES program has provided an architecture that allows SD contractors to define how CANES system requirements are met. This gives the contractor a greater level of flexibility but could be constrained by requirements that are too specific or which may only be achieved singly. Having a requirements prioritization process in place that will allow for negotiation of requirements will not only help the program to achieve its goals but is also consistent with current Office of the Secretary of Defense guidance (OSD, 2008).

Instead of allowing a large number of heterogeneous configurations, the PEO will try to consolidate and manage a reduced number of configurations based on a consistent architecture. This will minimize risk to application developers.

Our research suggests that the following six activities can help the program office mitigate risks related to integration, requirements, and configuration management.

- Make software and hardware configuration control a priority.
- Adopt an "early and often" approach to integration and testing that will be performed by an independent government entity, contractor, or the CANES technical authority.
- Establish a development and integration process that allows for more-flexible requirements.
- Adopt a development process that tolerates problems and failures in select areas that can then be used to develop a more-robust system.
- Carefully select measures and metrics of system performance so that meaningful assessments of CANES can be made.
- Prioritize requirements and then adopt a "crawl, walk, run" approach in which capability is obtained incrementally.

APPENDIX A

Case Study: Mission Planning System

The Air Force's Mission Planning System (MPS) program started in 2002. It is intended to facilitate pre- and post-mission planning by most types of Air Force (and some other Service) aircraft. This is a large, ACAT-1 D program that affects the entire Air Force aircraft inventory. The MPS consists of a variety of software modules that run on COTS hardware (personal computers). Software modules include

- weather data
- aircraft route planning
- intelligence data
- refueling
- electronic warfare planning
- threat updates
- target area planning
- mission rehearsal
- air tasking order information.

The MPS moves legacy UNIX and PC-based systems and capabilities onto a single, modular, open-architecture system that can run on commercial laptops. Mission planning is done before aircraft start the mission. MPS data are then inputted to the aircraft and available to ground personnel who support, monitor, and analyze the air mission.

The MPS software architecture has three elements: (1) a framework used by all aircraft types, (2) functionality required by subsets of aircraft, such as fighters and bombers and provided through a common component, and (3) functionality unique to specific aircraft and provided through the Unique Planning Component (UPC). The software provided across the Air Force by the MPS Program Office (at Hanscom Air Force Base, Massachusetts) integrates these three components for different types of aircraft.

The MPS project manager (PM) has the considerable challenge of integrating software provided by aircraft PMs throughout the Air Force. Aircraft-specific software is continually updated by individual aircraft PMs as new applications (such as new weapons or electronic countermeasures) and upgrades to existing programs are developed. Unlike the Navy's CANES, the MPS has no predetermined schedule for software integration. Rather, as aircraft PMs develop new software, they work with the MPS program office to ensure that integration will be successful. The MPS PM has a major challenge in ensuring compatibility of new and upgraded applications. From the beginning of the MPS project, there has been an evolving relationship between the PM (the government) and its contractors and vendors.

MPS Contract Strategy

Given the magnitude of the software development and integration challenge, the MPS PM has developed a multifaceted contract strategy.

Starting in late 2004, five multiple award IDIQ software development contracts were given to five different vendors. The five vendors compete for delivery orders to develop and maintain MPS software. Their tasks include (1) software development, (2) vertical product integration within the MPS three-tier architecture, (3) technology insertion, and (4) enterprise participation. The five vendors currently under contract for these functions are geographically dispersed and have five-year contracts with award-fee incentives. The program also features an overall SEIC. Due to the magnitude of the MPS integration task, the PM determined that a separate, long-term, integration contractor was required. It awarded a 12-year cost-plus contract to SAIC in April 2005. The SEIC's responsibilities include systems engineering and integration of components into the MPS architecture.

Lessons from the MPS Experience

MPS requires periodic integration of software provided by most aircraft program offices. The CANES program office will have a similar requirement as PMW 160 receives applications from other stakeholders within PEO C4I.

- Air Force managers from the MPS program office provided several helpful insights on their program and its contracting issues. Among their key insights: The requirement to integrate into the MPS architecture all the applications provided by the various aircraft program offices was much more difficult than originally anticipated. When the Air Force representatives whom we interviewed heard more about the CANES program, they predicted that integration problems would occur. Because of the likelihood they perceived for software problems, Air Force representatives we interviewed recommended early and frequent testing of software as one means to minimize overall integration problems.
- Stabilizing the MPS framework software (used by all aircraft) took longer than expected. While the framework had been stabilized by 2010, this was a very difficult task. The Air Force had to change the initial framework contractor due to inadequate performance.
- As the magnitude of the integration task grew, the government (i.e., the PM office) had to become more involved. Finding the right integration contractor was "a struggle."
- The Air Force discovered that, initially, none of the five software development contractors had a sufficient number of experienced engineers working on the project. Many of the junior and middle-grade software engineers lacked experience with Air Force aircraft operations. This lack of experience complicated project work. Getting the contractors to find and use software engineers with "domain experience" (i.e., USAF flight operations) was very important and had to be worked out over time.
- All the software used in MPS is GFI or GFE. This is because the various aircraft program offices send their applications to the MPS PM's office, which then has to integrate the software with the overall MPS system.
- Having a single prime contractor might have helped resolve problems in the first years of the project, but IDIQ guidelines for IDIQ restrict the use of a single prime.

- Government personnel from the MPS program office are responsible for official interaction with other PMs, including chairing periodic meetings where software update and integration issues are discussed. Contractors working for the MPS office frequently interact with software developers in the aircraft program offices in order to clarify software-related issues.
- The current system of five software development (IDIQ) contractors and one overall long-term integration contractor (cost plus) seems to be working well.

MPS Lessons of Possible Use by CANES

The Air Force's MPS program has existed for nearly a decade. It has many similarities to the Navy's still-evolving CANES program, most importantly the need to integrate a wide variety of software provided by other offices into a single, workable system. Today, MPS is a successful program that provides an important product to the entire Air Force.

In its first years, MPS experienced many challenges, most importantly in integrating aircraft-specific software received from fighter, bomber, and other aircraft program offices. Key lessons for CANES appear to be the following:

- Do not underestimate the magnitude of the integration challenge.
- Work closely with contractors to ensure that they have the right expertise for the project.
- Appropriately balance responsibilities between the government and the contractor(s).
- Be prepared for integration challenges and problems when CANES is first fielded to the fleet.
- Have contracts that allow maximum flexibility, as software problems are encountered, to change the specific tasks that contractors perform.

APPENDIX B

Case Study: Integrated Communications and Advanced Network

The ICAN program was an effort to integrate many networks needed on aircraft carriers into one. It was installed on CVN 68, 69, 76, and 77. The need to consolidate data, voice, and video infrastructure into a single common-network[1] architecture, long sought by the Navy,[2] motivated the ICAN effort.

ICAN did not meet its original performance expectations. Ultimately, it was separated into smaller, separate network programs.

Initial Goals

ICAN was developed by Northrop Grumman/Newport News (NGNN) (Obert, 1999). Matteo et al. (2004) described it as both a concept and as a strategy to acquire nondevelopmental items and COTS technology to integrate voice and data systems in the *Nimitz* class.

The original goals of ICAN were to (1) replace antiquated shipboard equipment with COTS technology, (2) integrate selected shipboard communication systems[3] over an "advanced core network," and (3) ideally, reduce life-cycle costs. Specifically, ICAN was to support voice, ship control (i.e., flat-panel displays), and navigation, as well as machinery control systems.[4]

[1] The concept of "one network" for each ship or even "one network" for the surface fleet is, generally speaking, ideal in many respects. The National Research Council (2006, pp. 63–64) notes:

> The U.S. Navy has historically had distinct development communities for ship combat systems, tactical air combat systems, and C4ISR. . . . The genesis of the division . . . dates back to days when ship combat systems were devoted to the completion of the fire-control loop, aircraft fought aircraft, and C4ISR systems were associated with the non-automated analysis of intelligence. . . . [A]dvances in computing and communications technology . . . have erased many of the reasons for which U.S. Navy combat systems and C4ISR systems were kept separate and distinct.

[2] Stated NAVSEA goals for interior communications are (1) "[r]eduction of the quantity and types of stand[-]alone voice and video systems and components through development of system interface and the introduction of new technology, including LAN technology" and (2) "[continuing] the effort to provide a single scalable voice communications system that supports all shipboard mission requirements" (see Bryant, 2008, slide 6).

[3] Initiatives to consolidate networks have persisted for some time: "A U.S. Navy initiative that seeks to standardize shipboard data networking may lead eventually to replacement of many of the dissimilar, stand-alone networks aboard Navy ships. At least that is what senior Navy engineering leaders are hoping. Navy engineering experts are keeping a close eye on the Navy Integrated Information Networking (NIIN) initiative, a joint-command integrated product team" (Walsh, 2000).

[4] Machinery control includes damage control, alarms, ventilation control, and the JP-5 fuel system.

ICAN's four components initially included the following:

- an integrated voice system to consolidate telephones, radios, shipboard announcing systems, sound-powered phones, and intercoms
- a machinery control system, integrating the aqueous film-forming foam control and monitoring system, the JP-5 fuel control and monitoring system, list-control indication system, and various alarm systems
- the ship control indication system, centralizing the monitoring of ship control and navigation functions
- the navigation-critical network, which distributes data to users needing time-critical navigation information.

ICAN was designed to

1. replace multiple stand-alone networks for voice, data, navigation, and mechanical control traffic
2. be a first step toward an all-electronic platform
3. remain within program cost and schedule constraints
4. meet or exceed current system functionality, survivability, and availability
5. use an open architecture that is transparent to vendor selection, expandable, and upgradeable
6. provide a physical infrastructure for emerging technology and future expansion
7. employ total ship engineering
8. address all logistical concerns
9. validate and test the integration of systems.

Some original program intentions follow.

- Shipboard maintenance and repair personnel were always to have libraries of digital information readily available for addressing any shipboard problems.
- Replacement parts were to be easy to retrieve because the parts would be from the commercial sector.
- Ship personnel trained on the ICAN system were to have marketable skills upon exit from the service.
- Validation would be established.

Installation

NGNN initially developed ICAN for the *Reagan* (CVN-76) and later for the *Eisenhower* (CVN-69), but it first installed a reduced system for the *Nimitz* (CVN-68). Problems were first discovered with functionality and reliability after delivery on CVN-68 in June 2001. By the time ICAN was to be installed on the *Vinson* (CVN-70), the program office for Aircraft Carriers (PMS 312) decided to replace ICAN with a government approach that used three separate federated systems for voice, navigation, and machinery control (Matteo et al., 2004). Other carriers that had ICAN installed went to a common functional baseline through a series of upgrades (ICAN Technical Assessment, NAVSEA).

Reported Performance

NAVSEA documented several high-risk ICAN problems, including problems that would "adversely impact the ship's ability to achieve operational readiness or significantly impact life-cycle supportability" (ICAN Technical Assessment). High-risk problems included

- erratic voice system operation and possible loss of tactical circuits directly affecting the ability of the ship to complete its mission
- ore network and fiber-optic cable plant design that was
  - overly complex and difficult to repair
  - had obsolete switches no longer supported by the manufacturer
  - in noncompliance with DoD security requirements
- a lack of overall configuration management in NGNN system design. Platforms are delivered with no configuration accounting and little or no source code for software life-cycle management. Source code is very expensive and proprietary and sometimes impossible to get, with commercial providers refusing to share it
- no formal system training
- ship staffing that did not support system maintenance
- a COTS life-cycle that was very short in comparison to that of GFE systems
- a lack of warranted technical authorities, making technical issues harder to resolve.

Other Supportability Problems

ICAN had many supportability problems, including

- inaccurate technical manuals
- obsolete COTS parts
- software and hardware variation by ship
- delivered software that was not identical to the software originally loaded
- a voice system comprising obsolete and unique proprietary equipment.

These problems ranged in importance for technical assessment and life-cycle support costs for the ICAN.

Details on Performance Problems

ICAN was initially installed with Asynchronous Transfer Mode (ATM) technology that did not perform as desired. These problems adversely affected operational readiness on the *Nimitz*; ICAN, in the view of a combat-systems officer, failed "to adequately support mission requirements" and representing "a significant step backward from legacy standards" (Jackson, 2001). The problems, which were eventually documented and addressed, related to voice system issues in particular and reliability issues in general (Schwartz, 2002).[5]

One specific problem was that voice and control data shared the same backbone. Bryant and Wolfe (2008) described the problem as the "unsuccessful integration of voice and data." This may have been because quality of service (QoS) did not meet expectations. As a result of

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[5] Voice and data networks were resegregated on some carriers. The problem, Schwartz (2002) noted, was that "[t]ime slips in the voice data between the telephone system and the Red Switch caused instability." Regarding the data network, Schwartz said, "Timing slips across the fiber network corrupted these data signals. Data flooding during sea trials was caused by a failed crypto unit, which was replaced."

this problem, the commanding officer of the *Reagan* could not launch aircraft. Because NGNN had created the design, the Navy did not have the required expertise to fix the problems.

The *Reagan* had to undergo many days of removal and replacement of systems installed by NGNN. Some systems were removed because they were poorly documented and the design was poorly understood.

A key lesson learned from the experience is "keep it simple" and segregate voice and data on separate systems. Perhaps complex network technology always requires a shake-out period. The Navy did later claim some improvements after the initial difficulties.

The *Eisenhower* received the same capabilities, and an expanded version of ICAN was included on the *Reagan*. Our interviews suggest similarly poor outcomes, as the PMAG corroborated (Matteo et al., 2004).

Criticism of ICAN tends to be harsh. Some interviewees describe the ICAN implementation as a disastrous attempt to "throw a lot of cool technology" onto the CVN-76 design. Critics say that the Navy pursued "science fair" projects without exercising oversight.

There were also more complex reasons for the difficulties. The program had incremental funding and no validated plan to consider available network technology and how best to integrate it. There were a greater focus and more personnel on mechanical-design issues at the expense of systems or networking technology issues and personnel. As a result, there was a complete lack of system engineering by NGNN and no good systems engineering practices in place. There was not good oversight. There was poor documentation, with the design documented only in drawing notes, and no system and subsystem design documentation. In short, ICAN failed because there were too many components to integrate and not all parties understood the technology.

Other specific issues with ICAN as detailed from Navy reports (the first four are from NAVSEA, the remaining are from Matteo et al., 2004) included the following:

- Installation of various portions of ICAN did not support operational requirements.
- System security and certification requirements were not followed.
- Test and training facilities did not accommodate the variety of CFE configurations.
- Proprietary software required higher-than-anticipated life-cycle support and costs to the government.
- Total ownership costs were not well understood. Neither dedicated personnel nor Navy project engineers with technical and program authority used independent analyses for CFE and GFE.
- There was a lack of technical authority within NAVSEA for shipboard internal communications (IC).
- Technical management oversight was diffuse and ineffective.
- ICAN lacked a viable life-cycle management plan and configuration control.
- ICAN was "oversold."
- There was no independent cost estimate for expenditures.
- There was no evidence that the Aircraft Carrier Change Control Board had thoroughly reviewed ICAN before approving it.
- The risk-management plan lagged behind actual events during the accelerated concurrent development and installation for the first ICAN installation.
- There was no systemwide land-based testing of the system prior to shipboard installation.
- There was minimal government oversight.

- No single designated individual was responsible for ICAN engineering and integration.
- There was a lack of an adequate integrated requirements package.
- There was no software baseline and little expertise in software testing at NGNN.
- ICAN COTS strategy was ill-defined.
- There were inadequate test and training facilities for shipboard personnel.

Design and Management Critique

The Navy managed the ICAN and its design differently from past network systems. There was no independent analysis regardless of whether new equipment would be GFE or CFE (Matteo et al., 2004). Instead, ICAN used integrated product teams whose role was program implementation, with NGNN serving as the systems integrator.

Difficulties in Designing for Multiple Stakeholders

Any substantial problem must deal with many different stakeholders, including, in the Navy, those concerned with combat systems; hull, mechanical, and electrical functions; navigation and control; and C4I. Each will have unique requirements and different interests as well as its own charter and warrants to execute within its area of responsibility. It is a significant challenge to get all to agree on system requirements. It can also be a challenge to write high-level requirements specifications that accommodate these stakeholders' detailed needs.

For ICAN, each stakeholder on an IPT had an agenda. Consequently, the ICAN management team established an IPT coordination-and-management staff to control team problems and help resolve conflict when necessary. Commercial subcontractors generally believed the proprietary agreements with the integrator were safer than those with the government, thereby preferring to work with a prime.

Security Clearance Issues

Security was also a key challenge. There are a high number of communication security devices on board in distant locations that require Top Secret clearances to access if the equipment needs to be destroyed. Also, shipboard personnel have little training for encryptor upgrades and (Schank et al., 2006).

Suggestions for Future Major Systemwide Installations

Suggestions for future major systemwide installations such as ICAN, derived from interviews, include the following (the first six from PMAG; the remainder from NAVSEA):[6]

- Create an integrated requirements document that contains individual functional area requirements. This allows network performance problems and system deficiencies to be corrected from an overall and subsystem point of view.
- Write a well-defined CONOPS document that encompasses the entire system and user functional interaction with individual networks, ship systems, and other interfaces. This minimizes operational and interface problems.

[6] This program was conducted at a time when acquisition policy reflected a confidence in industry to perform better than government, resulting in minimum requirements, rapid negotiation, and government insight, not oversight.

- Implement a complete land-based test of the system prior to shipboard installation. If that is too costly, implement a virtual or distributed integration concept between all system sites. This investment will reduce overall life-cycle costs.
- Develop a life-cycle software maintenance and control plan. This ensures that software maturity can be tested and that a true systems engineering approach will be followed.
- Establish a dedicated organization entity or executive steering committee to serve as life-cycle manager for major systems like ICAN in an in-house Navy organization. Staffing must include headquarters, naval organizations, and the private sector, given the number and expertise of personnel required.
- Establish a distinct program and system integration office responsible for management of all CFE and GFE system hardware, software maintenance and control, system integration, system-level functional requirements, control for services and resources, budget formulation, future technical changes, and plan execution.
- Establish test and training facilities to accommodate the variety of CFE configurations. (This may be hard if every system is "ship-unique.")

APPENDIX C

Case Study: Acoustic Rapid COTS Insertion

In the mid-1990s, the submarine community sought to improve its acoustic advantage but faced significant reductions to its budget. Those twin pressures led to the Acoustic Rapid COTS Insertion (ARCI) program, which pursued a new approach to gaining advanced capabilities quickly. The ARCI program adopted COTS technology to reduce costs and to take advantage of commercial-sector technological advances in computer-processing power.

The program updated hardware biennially and software annually to allow the Navy to maintain a capability advantage. Boats also get a new "baseline" every four to six years.

The Navy undertook a new approach to acquisition to allow such rapid upgrades. The program became a model for spiral development, evolutionary acquisition, and, specifically, Modular Open System Architecture (MOSA).[1] Full capability, which was not initially defined,[2] was developed incrementally over time. The first system developed under the ARCI program was the towed array sonar on 688-class submarines. Eventually, the program encompassed all sonar systems on attack submarines.

The hardware and software were developed and upgraded by two different contractors. Initially, the Navy accomplished this through rigorous management of key interfaces, use of open standards, and a modular design, all business practices of MOSA. Middleware was used to isolate the hardware and operating system from the applications (software).

Developers and users worked closely together to define the next increment of capability in what was called the Advanced Processing Build (APB) process. This process was used to develop, select, test, and deploy new software. It had four steps: identification of potential algorithms, algorithm testing, testing on the current processor baseline, and at-sea testing.

Initially, the government managed this process among various participants, including program office staff, NUWC, academics, small businesses, Lockheed Martin, and DSR. This was in part because the program office wanted to maintain competition and implement solutions from a broader range of sources, moving away from a prime contractor model. The program office eventually selected a prime system integrator, Lockheed Martin, which was responsible for much of the systems engineering and integration of the hardware and software but was not responsible for the development of all hardware and software components. Lock-

1 For a description of these terms see Boudreau, 2006, p. 5–6.

2 Because the desired end state was not known, increments were undertaken to provide improvements available within the time and budget available for them.

heed Martin did not perform as a lead system integrator but was given COTS equipment and GFI.

The first installation for each boat required significant shipyard work. Shipyard personnel had to replace not only racks but also cabling and wiring in order to support the new processing hardware and software. As a result, the initial installations for each boat were more expensive than follow-on installations.

The ship alterations were managed by the Strategic and Attack Submarines Program Office (PMS 392) and were scheduled to occur during major availabilities. The goal is to have the installations performed during a 30-day pierside event. Each submarine's planning yard assessed the work to be performed and provided drawings to the applicable shipyard for the work. Participants in this process included Norfolk Naval Shipyard, Portsmouth, Puget, Pearl Harbor, Newport News, and Electric Boat. In addition to utilizing the shipyards, the Navy used the Mid-Atlantic Regional Maintenance Center (MARMC), NUWC, AITs, and even Tiger Teams[3] to assist with the installations.

Now that the program has had several technical installations, less shipyard work is necessary. For software upgrades, the type commander schedules the work for the MARMC, which will identify the appropriate installation to perform it, preferably at a time other than pierside availabilities in which more substantial work is performed. The prime system integrator has a minor role in the installation process. Lockheed Martin assists with loading the software, if needed, and provides logistics support, such as delivery of technical manuals, parts lists, and other interactive electronic technical manuals (IETMs), but its work in this function does not appear to have increased as the program has matured.

Later in the program, working through the Joint Capability Integration Development System (JCIDS) process and achieving an appropriate funding allocation from the right appropriation accounts were notable challenges. Initially, every required document had to be produced for each increment of capability. Currently, a Capability Development Document (CDD) and a Capability Production Document (CPD) cover a single technology of one hardware and two software upgrades. This requires level amounts of Procurement, research and development (R&D), Operation and Maintenance, Navy funding, and SCN funding for the systems going on board in new construction.

Today, the ARCI program manages 23 configurations across 71 submarines (Boudreau, 2006). The program experienced a sevenfold increase in processing capability within its first 18 months, and life-cycle costs have improved nearly fivefold. As a result, the program has been touted as a successful model for getting improved capability to the warfighter quickly and at a reduced cost.

Contract Strategy

Prior to ARCI, submarine sonar systems were provided by a prime contractor, Lockheed Martin. As noted, when the Navy decided to adopt a COTS-based system and more flexibility to upgrade technology quickly, it no longer desired a prime contractor acquisition model.[4] The

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[3] *Tiger Teams* are groups of individuals with specialized skills that are funded to perform a specific task.

[4] Modular Open Systems Architecture (MOSA) was the approach, even though MOSA had not yet been identified.

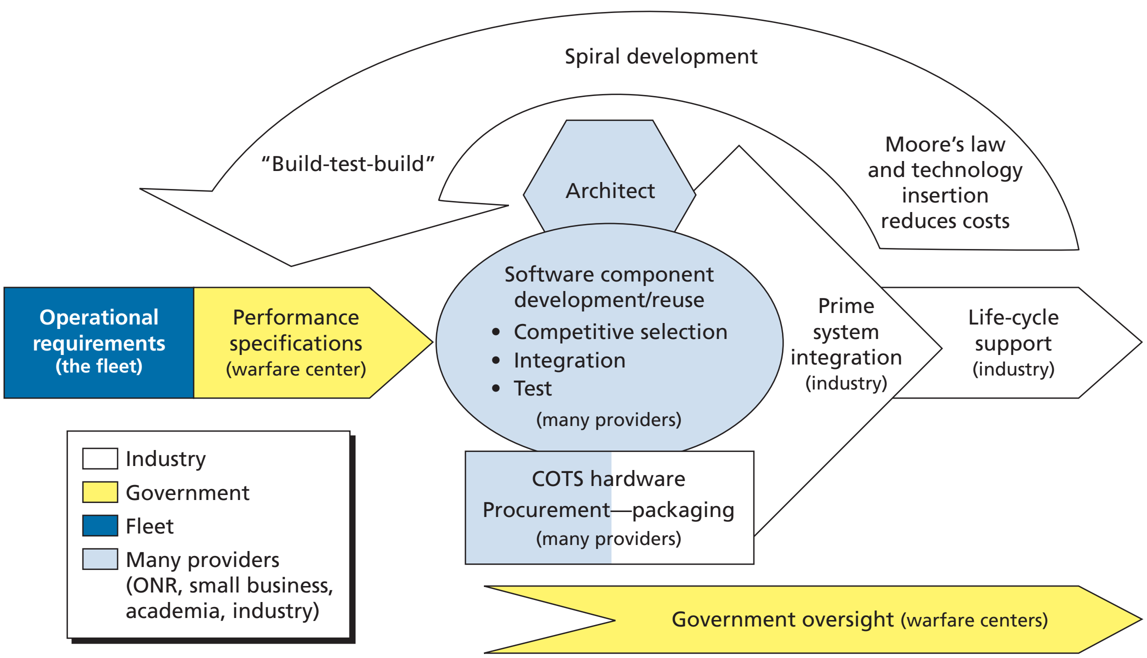
program manager sought a competitive-teaming approach including, as noted earlier, participation of academics, small businesses, and government labs.

Figure C.1 shows the unique development model used in the ARCI program.

Lockheed Martin Maritime Systems and Sensors was the initial Prime System Integrator for the tactical software development, a role it retains today. NAVSEA's Advanced Systems Technology Office (ASTO[5]) and the Submarine Combat System Program Office (PMS 425) spearheaded an APB for new signal processing algorithms to be used in combat system upgrades.

Lockheed Martin was also responsible for in-service support. A Small Business Innovative Research (SBIR) grant that was originally sponsored by the attack submarine (SSN) program office was used to buy COTS software for signal processing. The Navy used the competitive format of the SBIR program to select a company for developing a processing system using COTS hardware. A five-year contract was initially awarded to DSR, a small business selected for this program through the SBIR process, which had developed a Multipurpose Processor. The actual hardware was obtained from multiple vendors and, by 2006, had been upgraded

Figure C.1
System Development Model for ARCI



SOURCE: Boudreau, 2006.
RAND *TR993-C.1*

5 ASTO currently resides within PEO IWS 5.

five times. DSR also developed the middleware that allowed new and legacy software to run on the new processor and for software and hardware to be developed independently.

Lockheed and DSR had to work together to ensure the software would run on the new processors. As the prime system integrator, Lockheed had to ensure that the middleware and processor design produced by DSR could be integrated with the acoustic signal processing software. PMS 425 fostered a sense of shared responsibility for having all work together on integration. The program office used award and incentive fees to obtain cooperation, as well as contractor evaluation, which included interacting with other vendors.

The government maintained a great deal of responsibility for oversight and program success. A joint Navy/industry team was charged with researching and selecting the best path for technology insertion. NUWC provided the performance specifications required of the systems. At the beginning of the program, the NAVSEA ASTO had responsibility for system engineering. Early in the program, PMS 425, the program office responsible for ARCI, had to maintain this responsibility. Because Lockheed was competing to be the prime system integrator and NUWC was competing to provide software, neither could fulfill this role at first. Once a prime system integrator was established, system-engineering responsibilities transferred to the prime (Lockheed Martin).

Currently, the tech insertion team is the primary governing body for technical direction of the program. The team is responsible for providing guidance and specifications to Lockheed about what to buy. The tech insertion team, led by government employees, also works with Integrated Warfare Systems (IWS) to identify promising algorithms in the first step of the APB process. The tech team leverages the R&D efforts of IWS.

The program office structure has helped the program succeed by involving government personnel at all levels of decisionmaking. A complex arrangement of working groups, IPTs, and support and peer-review groups helped ensure product quality. The government oversaw all these groups and teams. There was also very strong leadership at multiple levels, and a unique assignment of shared responsibilities was adopted through a unique incentive structure. The software developers (including NUWC, academics, and persons from other government programs) were motivated by the potential for additional funding or future work.

Today, there are four main contractors. Lockheed Martin is responsible for building hardware, receiving hardware from other vendors, receiving software from other vendors, testing, and integration. Until 2010, the government had a sole-source contract with Lockheed. In 2010, the integration work was completed. Lockheed is also responsible for providing some in-service support and managing spare parts, including those retrieved from removal of old systems.

GDAIS (which subsequently bought DSR) and Progeny each has a contract for engineering services and hardware. Sedna has a contract for software only.

All material provided to Lockheed is GFI or GFE. Prior to a production decision, there is rigorous testing of the integrated system.

Having four main contractors and using award and incentive fees has fostered competition while providing incentives for cooperation. If performance is poor, work can be shifted to other contractors. The program office is currently assessing other strategies, because of current policy changes affecting use of an award fee.

Lessons Learned

The ARCI program has had much success, albeit accompanying challenges as well. As the program matured and established relationships, roles and responsibilities evolved. Key insights include the following:

- Initial equipment installations can require significant industrial activity. This work did not decrease until about the third or fourth update cycle, after all boats had received at least the first installation of ARCI. Significant work will be required again in the near future when the existing network can no longer support the required upgrades. This work should not be underestimated.
- Senior leadership and mid-level leadership empowered the cultural changes required for successful implementation and innovation. This helped the program launch successfully. Continued involvement by the government in key roles, such as requirements determination, program direction, and the selection of solutions, has been important to program success.
- Communication among the user, developers, and contractors was critical to program success. This was facilitated by contractual mechanisms, leadership, and the development of new processes.
  - User participation was important for getting feedback to the developer quickly enough for implementation of the next upgrade, as well as for operational testing and sailor acceptance.
  - Software applications were selected through a peer-review process. This ensured level competition and selection of the best solution.
  - The tech update IPT also considered a peer-review process for selecting hardware.
- The systems engineering function was difficult to assign at first. The government initially took on this role before giving it to the system integrator, Lockheed Martin.
- Managing intellectual property rights in an environment where sharing design information and data was critical to integration required contract language to ensure government acquisition of rights to data and intellectual property.
- New integrated testing processes are necessary when traditional end-to-end operational testing is too difficult and costly to implement for every spiral.
- Rapid upgrading of ARCI resulted in training challenges for operators and developers.
- Traditional JCIDS processes and funding allocations did not fit the program well.

ARCI Lessons for the CANES Program

While there are notable differences between the ARCI program and CANES, none larger than the ACAT designation, there are also some notable similarities. Most important, both programs seek competitive teaming in which different participants develop hardware and software and a third party integrates them. Both programs use an open-architecture framework to replace hardware and software at a much faster rate than has been accomplished by other programs. Some key lessons for CANES are the following:

- Start small and work toward full capability.
- Do not underestimate the amount of work required for the initial installations. Leveraging the existing industrial base to perform this function might be most efficient.

- The government must be involved as a technical authority and technical decisionmaker and must provide adequate oversight and direction to contractors at all levels of the program. The program office should be structured to best support success. This may require additional program staff.
- Planning for funding strategy and JCIDS produces challenges.
- Communication between user, contractor, and developer is key.
- Combining award and incentive fee strategies can help foster success in competitive-teaming among four separate prime contractors.

APPENDIX D

Case Study: LPD-17 SWAN

This appendix leverages past RAND studies sponsored by PEO C4I (including Schank et al., 2009, and Porche et al., 2010) to highlight relevant lessons for CANES.

Background on LPD-17 and SWAN

The LPD-17 (USS *San Antonio*) was delivered in 2005, eight years after the contract award. The LPD-17's SWAN was one of the first attempts to use CFE and a single LAN (by communities that might have traditionally had their own onboard subnets).[1] Ship control, weapon systems, and C4ISR are all on SWAN.

Initial Goals for SWAN

The LPD-17 SWAN was built by Raytheon.[2] It is a fiber-optic shipboard wide area computer network. It has classified and unclassified components, along with vital and near-vital applications, including ship control weapon systems and C4I. It was developed to be the backbone of the LPD-17 network, which supports thousands of physical and logical interfaces (Raytheon, 2003; IHS, 2006). Ideally, SWAN allows the crew to operate the ship from almost any terminal on board, a capability previously developed for commercial vessels but new to Navy amphibious ships. SWAN had two implementations: an ATM design and a later integrated processor gigabit ethernet (GigE) implementation to modify the unpopular ATM design. Eventually, SWAN will be replaced CANES.

Reported Performance

Several reports on general issues with the LPD-17 have included criticisms of SWAN. Hansen (2007) writes

> The highly touted nerve center of the new, $1.8 billion amphibious ship *San Antonio* is fraught with computer hardware crashes that could cripple operations. . . . Inspectors discovered hardware and software failures. The system sometimes crashes, hin-

[1] For the *Nimitz* class, the common ICAN core network is used by the machinery control systems, integrated voice systems, and the navigation systems.

[2] Raytheon is the ship systems integrator for the LPD-17 class and is under contract to Northrop Grumman Ship Systems to develop the SWAN.

> dering the crew's ability to command and control the ship and launch Marines on air, land and sea assaults. Replacement parts for the computer network were made by a company that has gone out of business. Often, repair parts are costly and need to be custom-made.

As noted by PEO C4I, SWAN is an "LPD-17 Class unique network" with CFE. It is pejoratively called a "boutique network." Because it was designed and procured years before installation, many of its hardware components are obsolete and unsupportable.[3]

Networking Performance Issues

SWAN's major performance flaw was its inability to guarantee a minimum amount of service for a diverse array of applications. The concept of QoS is supposed to allow for such guarantees. SWAN does have a formal QoS at its core: There is a core network and edge networks that connect to the applications. In other words, the core network is a high-speed backbone, and the edges connect to the ship from the core. However, there were no QoS specifications for the edge networks, which are not part of the core.

Thus, for the edge networks, it was first-come, first-served: There may be no problems on a lightly loaded network, but when the mission requires high bandwidth (such as for video and imaging), packets start to be dropped by the system. A key lesson is that QoS must extend to the "edge" applications.

In hindsight, the original specifications for the LPD-17 network, made at the ship-specification level, were made at too high a level. The industry partners were given the task of applying the requirements to lower levels, with few checks by the Navy.

Cabling Lessons Learned

LPD-17 took a phased approach to providing information about C4I equipment to the shipbuilder. First, contractors told the shipbuilder how much weight and power was required for unidentified equipment, and the shipbuilder would install the racks without knowing the equipment. Then, the contractor would provide all equipment and intraspace cabling while the shipbuilder bolted down the equipment and set up the interspace cabling. This approach allowed LPD-17 to have more up-to-date C4I equipment, but it created problems with cabling (see Schank et al., 2009, for a fuller discussion).

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[3] SWAN was originally an ATM network. According to PEO C4I, "SWAN network for LPD-17 is based on ATM switch technology, IBUS and Augmentix Servers, Windows NT operating system, and HP OpenView network management. For LPD-18–21, the SWAN network will be TAG-1 Servers with the standard Navy Common PC Operating System Environment (COMPOSE) operating system and INMPro network management. For LPD-22–25, the SWAN network will be TAG-2 servers and GigE technology" (Stull, 2007). Life-cycle support for SWAN is provided by Naval Sea Systems Command (PMS 317)/Naval Operations (OPNAV) N8.

APPENDIX E

Case Study: ADMACS and TACs on Carriers

Background on the Aviation Data and Management Control System (ADMACS)

ADMACS is "a real-time, redundant, configuration managed, tactical Local Area Network" (U.S. Navy, 2002). It provides air-operations network connectivity, allowing automated planning and reporting for launch and recovery activities, increasing safety and sortie rate and decreasing operator workload (NAVAIR Lakehurst, 2002).

The success of ADMACs is due in part to its being built to strict requirements carefully gleaned from fleet engineers responsible for air-operations networking needs.

The ADMACS design team worked with the operational users of the system to create Operational Requirement Documents with realistic requirements. In the 1990s, SPAWAR developed an initial block of ADMACS that was unsuccessful because the system was designed as a general network rather than as one accounting for the unique requirements of aviation and flight operations. The developers of the more successful follow-on block of ADMACS fostered a good relationship with system users, automated the system as much as possible to avoid human error, and worked with systems engineers who knew the software. One year before delivery of the system, the ADMACS team had several meetings to determine whether the requirements were feasible or needed to be modified. To reduce human error through automation, the team reduced the amount of manually input data by allowing data to be passed from system to system whenever possible. NAVAIR personnel also noted thatNAVAIR follows the systems engineering process.

In short, more recent ADMACS development succeeded because the team did a thorough job of getting the real requirements documented. ADMACS personnel claim to have developed a good roadmap: They knew where they wanted to go, where they were, and where they needed to be. They also had a far-reaching plan that tried to integrate future systems.

The main components of ADMACS are four tactical advanced computer (TAC) servers, four network switches with ATM and Ethernet interfaces, and an uninterruptible power supply. Development of the TAC, one of its key components, provides lessons on how to address struggles with networking and IT systems.

Tactical Advanced Computer Four (TAC-4)

Brandenburg (2001) notes several relevant lessons learned from the TAC-4 contract[1] regarding COTS usage and supportability. Davis (1995) describes TAC-4 as the "fourth generation in a family of workstations designed to satisfy the tactical requirements of the systems commands, type commands, composite warfare/battle group commanders, their subordinate units and command centers."

As Davis highlights, the Navy lacked a structure for supporting TAC-4 systems after the contract warranty period. There was no centralized TAC-4 program office or coordinating activity for support. The experience of the TAC-4 program demonstrates the necessity for a long-term, Navy-wide support structure.

Brandenburg (2001) also noted several more specific problems regarding support.

1. *Component and configuration tracking was poor.* The complete range of TAC-4 components was unknown. The number and types of workstations purchased by the Navy were not tracked.
2. *Data on failures and replacements were imprecise.* Part numbers and true failure counts were uncertain. This was caused in part by poor communication with the supplier.
3. *A complete range of parts was not provided for the fleet.*
4. *Maintenance approaches were shaped more by the original equipment manufacturer than by Navy users.* Users seemingly adopted the original equipment manufacturer's "remove/replace" reparability schemes. No separate preventive maintenance was developed, and direct access to TAC-4 technical experts was lost.
5. *Maintenance supportability was not properly verified.*
6. *There was a lack of available engineering and vending data and information, precluding preventive maintenance and self-sufficiency.* Navy users did not own the data required to support the fielded system. As a result, they had limited ability to assess replacement alternatives and resolve fleet and repair issues quickly.
7. *Across the fleet, Navy personnel were not trained properly and had insufficient knowledge of hardware and software.* The breadth of personnel who needed training was larger than originally anticipated.
8. *There was no technology transfer clause.* The data rights did not transfer to the government at the end of the contract. This forced some users to procure original equipment manufacturer drawing packages.
9. *The technical manuals provided were insufficient*, i.e., they did not provide the range and depth of information to enable proper preventive and corrective maintenance. They also were not available from a central source.
10. *Navy-wide control over configuration changes was lacking, and configuration management devolved to users.*

[1] TAC-4 is the fourth in a line of Navy procurements for the acquisition of computer workstations and servers. Previous procurements resulted in the selection of the Hewlett-Packard (HP) 9020 series systems (Desktop Tactical Computer–1, or DTC-1), Sun Series 4/XXX systems (DTC-2), and HP Apollo 9000 series systems (TAC-3).

APPENDIX F

Case Study: DDG-1000 Total Ship Computing Environment Network

Background

In the 1990s, there was a push to let industry assume risk and have commercial firms design as much as possible and provide turnkey systems. A case in point is the DDG-1000 (*Zumwalt*-class destroyer), for which the whole platform was sent to industry (combat systems, radar, and others were all industry-developed). A turnkey approach was sought to mitigate risk.

TSCE-I Award

In 2005, the Navy awarded the first TSCE-I contract for the DDG-1000 to Raytheon. It provides standardized software, COTS hardware, and supposedly a 60-percent reduction in shipboard personnel (Raytheon, 2007). TSCE is an all-ethernet, all–Internet protocol (IP), Linux-based "solution." It is complex: There are 7 million lines of code in the DDG-1000 software, and this could be a sustainability and supportability challenge.

Raytheon has taken parts of its DDG-1000 software and used it for other efforts, including the Joint Land-Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS). Pieces of DDG-1000 software are going into JFires as well. Several years ago, Raytheon submitted its TSCE-I for potential use on submarines (*Defense Daily,* 2007).

According to the developers, this software system is designed to transition to CANES over time, which DDG-1000 has tried to accelerate in the past few years. However, questions remain as to whether the system will be scalable and interoperable with CANES.

Initial Difficulties

One of the major difficulties in the TSCE-I is that IT knowledge levels are insufficient to manage both internal and external communications. Driving factors of the lack of sufficiency are a lack of formalized inline network encryptor (INE) training in the fleet, the frequency of crew transitioning (one-third per year), and the large number of INEs required (389) for the DDG-1000. Approximately half of INEs reported as malfunctioning by the crew were misconfigured, and contractors with the proper training on INEs were involved only in the INE installation. Recommendations for improving these shortcomings include providing more training and more shipboard personnel with INE skills and establishing a reliable remote management capability to effectively monitor the health of all ship networks (Schank et al., 2009).

APPENDIX G

Voice Networks on CVN, LPD-17, and DDG-1000

This appendix leverages lessons learned found in NAVSEA 05 briefings (Bryant, 2008; Bryant and Wolfe, 2008) that focused on voice networks. These briefings covered lessons learned from interior communication networks on CVN-68–class ICAN and the LPD-17–class IVCS:[1]

- A defined end-user concept of operations (CONOPS) is necessary to identify system functional and end-user requirements.
- It is necessary to identify system functional and end-user requirements prior to system concept design.
- Design efforts must concentrate on meeting documented system functional and end-user requirements through appropriate verification methods.
- Targeting new (no shipboard exposure) technologies, equipment, or architecture/configuration requires a risk-analysis and management process with full-scale testing under emulated (or actual) dynamic shipboard conditions (Bryant, 2008).

Design elements that are critical to system operational survivability must not be compromised without evidence-of-proof documentation that the survivability element is no longer applicable. Table G.1 highlights the technical risks found by Bryant (2008) associated with these networking implementations. Bryant concluded that accurate CONOPS, thorough functional requirements, and rigorous testing are necessary for success.

IVCS Documentation Problems Found During Inspection

During inspection of the installed Wirefree Portable Interior Communication System (WPICS) for the LPD-17's IVCS, it was discovered that the ship's force had not registered any system drawings or allowance part lists. This constituted a major risk, per the LPD-17 IVCS's Risk Assessment Report, and required a logistics plan and temporary repair parts supply support to correct this deficiency. Additionally, the ship did not have the correct cable running sheets or other related drawings for the MarCom telephone system. The documentation was not consistent with the "as-built" configuration installed on the LPD-17 and, therefore, reduced the maintainability of the ship. Furthermore, during the inspection of the advanced announc-

[1] IVCS was intended to solve some of the shortcomings of older systems installed on older ships. IVCS combines the features of sound-powered telephones, dial telephones, and intercommunications units into one system. The IVCS can also interface with other shipboard communications systems. The system consists of terminals (user access devices), accessories, and two computer-controlled Interior Communications Switching Centers.

Table G.1
Technical Risks on Interior Communication Networks

Top-Level Acquisition and Design Elements	TSCE-I DDG-1000	IVCS LPD-17	ICAN CVN 68
No interior communication CONOPS	X	X	X
No interior communication system or end-user shipboard functional requirements	X	X	X
No test plan with fully integrated or dynamic shipboard testing	X	X	X
Immature technology: no prior MAC-1 shipboard exposure	X		
Development architecture: no prior MAC-1 shipboard exposure	X	X	X
Developmental hardware: no prior MAC-1 shipboard exposure	X		X
Developmental software: no prior MAC-1 applications	X	X	X
Detailed design technical risks identified	17	30	24

SOURCE: Bryant and Wolfe, 2008.

ing system, it was discovered that there was no onboard maintenance training plan. Since the advanced announcing system was completely unique from any other system, there was also no schoolhouse training available. This deficiency increased the life-cycle cost of the advanced announcing system even more, and, coupled with the fact that the system was configured improperly, the assessment team suggested that the entire system be ripped out and replaced. The designated replacement chosen was the Central Amplifier Announcing System (CAAS) due to its proven reliability and full logistic support.

Discussion: Integrated Versus Federated Designs

One viewpoint is that a federation of networks may actually be best for the complex shipboard environment. A case in point may be voice networks discussed in this section. Many in the carrier community, based on experience with the ICAN implementation, argue that a federated approach is more pragmatic.

Sharing a single physical network can place a heavy strain on a ship network, especially when one considers the diverse functions and their demands on network performance (e.g., videoconferencing; VoIP; email; and the control of the hull, mechanical, and electrical functions and ship maneuvering.) This is especially true for IP and other packet-switched networks, which are not designed for real-time control and inherently permit out-of-order packet delivery. Although the IP includes QoS features, such as integrated services and DiffServ, an IP network may still be hard-pressed to deliver hard real-time guarantees, especially when it is also asked to carry large-volume, multimedia traffic, such as VoIP or videoconferencing, which may have its own (soft) real-time requirements. This argues for isolating critical real-time functions on their own physical networks, where they can utilize whatever special-purpose protocols are necessary to provide hard real-time guarantees and where they can be uninhibited by lower-priority traffic.

Our reading and interviews suggest that a middle ground between integration and federation may be the safest and most flexible approach.

Program Descriptions

This appendix provides a brief description of the systems that will be consolidated. All of the descriptions are direct quotes from the SPAWAR website, unless noted otherwise (PEO C4I, n.d.).

Automated Digital Network Systems (ADNS)

ADNS is the bandwidth optimization Program of Record for the Navy. ADNS provides the only Quality and Class of Service routing for multi-service voice, video, and data domains across the available radio frequency paths that make up the Ship/Shore Wide Area Network (WAN). This WAN is used to support internal dissemination of information, as well as external connectivity to SIPRNET, NIPRNET, and non-U.S. Local Area Networks. ADNS is deployed on ships, submarines, aircraft, and at shore sites as the Navy's entry point to Navy tactical/strategic and Global Information Grid resources and services.

Integrated Shipboard Networks Systems (ISNS)

ISNS provides Navy ships with reliable, high-speed secret and unclassified Local Area Networks. ISNS provides the network infrastructure, basic network information distribution services, and access to the DISN Wide Area Network (Secure and Nonsecure Internet Protocol Router Network–SIPRNET and NIPRNET), which are used by other hosted applications or systems such as NTCSS, GCCS-M, DMS, NSIPS, NMCP, NAVMPS, TBMCS, and TTWCS. It enables real-time information exchange within the ship and between afloat units, component commanders, shore sites, and fleet commanders.

Sensitive Compartmented Information Networks (SCI)

The primary mission of SCI Networks includes providing special intelligence shipboard analysts with access to national and service strategic and tactical databases. SCI Networks is the transport medium providing special intelligence data and secure WAN IP access to ship and shore national Web sites, and signals intelligence and intelligence databases for seamless interaction between shore, surface, submarine, and airborne special intelligence LANs. SCI Networks also provides network enterprise services critical to operational availability of time sensitive indications and warning data, GCCS-M and DCGS-N special intelligence analytic capabilities, and implementation of advanced tactical cryptologic sensor functionality.

Submarine Local Area Network (SubLAN)

SubLAN provides Navy submarines with reliable high-speed secret, sensitive but unclassified and top secret Local Area Networks. When the SubLAN network is combined with other subsystems, it delivers an end-to-end netcentric warfare capability. AN/USQ-177 Variants (V)1,2,3,4 provide network infrastructure, including an Unclassified Wireless Local Area Network, servers, and the Common PC Operating System Environment, which provides the server and operating system environment for other applications such as Non-Tactical Data Processing System.

Combined Enterprise Regional Information Exchange System–Maritime (CENTRIXS-M)

CENTRIXS-M utilizes multiple security levels technology to support simultaneous access on a single thin-client workstation to multiple networks representing several different security levels, enclaves, and communities of interest, including SIPRNET, CENTRIXS 4-EYES, KOR, JPN, Multi-Coalition Forces Iraq (MCFI), Combined Naval Forces CENTCOM (CNFC), Combined Maritime Forces Pacific (CMFP), and Global Counter-Terrorism Force (GCTF). The capability will greatly improve timely access to operational information on various enclaves in a dynamic coalition environment. This system will also result in significant reductions in system administration and the number of hardware devices at a given workstation.

Video Information Exchange System (VIXS)

VIXS, the Video Exchange Information System, is used for tactical video teleconferencing (multipoint secure video teleconferencing [VTC]) between carriers and large-deck amphibious ships. Shipboard systems connect this exchange system to the joint world-wide intelligence communication system (JWICS) VTC system (Friedman, 2006).

Global Command and Control System–Maritime (GCCS-M)

GCCS-M provides maritime commanders at all echelons with a single, integrated, and scalable Command and Control system. GCCS-M fuses, correlates, filters, maintains, and displays location and attribute information on friendly, hostile, and neutral land, sea, and air forces, and integrates this data with available intelligence and environmental information to support command decisions.

Distributed Common Ground System–Navy (DCGS-N)

DCGS-N provides the Navy's Intelligence, Surveillance, Reconnaissance and Targeting system a standardized means of ingesting, processing, exploiting and disseminating all-source intelligence data. DCGS-N also initiates connectivity to the joint service and intelligence community enterprises.

Bibliography

Bass, Tim, and Roy Mabry, "Enterprise Architecture Reference Models: A Shared Vision for Service-Oriented Architectures," draft submitted to MILCOM 2004, March 17, 2004. As of January 15, 2009: http://www.enterprise-architecture.info/Images/Defence%20C4ISR/enterprise_architecture_reference_models_v0_8.pdf

Beel, Joe, "CANES Overview Brief for the Society of Naval Engineers," June 18, 2009.

Birnbaum, Z. W., "On the Importance of Different Components in a Multicomponent System," in P. R. Krishnaiah, ed., *Multivariate Analysis II,* New York: Academic Press, 1969, pp. 581–592.

Boehm, Barry, *Software Engineering Economics,* New York: Prentice Hall, 1981.

Boudreau, Michael, "Acoustic Rapid COTs Insertion: A Case Study in Spiral Development," NPS-PM-06-041, October 30, 2006.

Brandenburg, Craig, "U.S. Navy COTS: A Double-Edged Sword," briefing, National Defense Industrial Association Conference, Dallas, Tex., October 22–25, 2001.

Bryant, Gregory, "Interior Communications (IC) Way Ahead," briefing, Interior Communications Voice Symposium, Charleston, S.C., December 2, 2008.

Bryant, Gregory, and Allen Wolfe, "IC Voice Design and Acquisition: Comparison and Contrast," briefing, Interior Communications Voice Symposium, Charleston, S.C., December 2–4, 2008.

Burbank, Jack L., and William T. Kasch, "COTS Communications Technologies for DoD Applications: Challenges and Limitations," *Military Communications Conference*, Vol. 3, 2004, pp. 1172–1178.

CANES Program Office, *Capability Development Document for Consolidated Afloat Networks and Enterprise Services,* Version 2.0, January 2008a.

———, *Capability Development Document (CDD) for Consolidated Afloat Networks and Enterprise Services (CANES) Increment 1*, Version 2.0.3, March 2008b.

———, *Architecture Specification for Consolidated Afloat Networks and Enterprise Services (CANES) Increment 1*, Version 2.4.2, May 2009a.

———, *Functional Specification for Consolidated Afloat Networks and Enterprise Services (CANES) Increment 1,* Version 1.3.2, May 2009b.

———, *Architecture Specification for Consolidated Afloat Networks and Enterprise Services (CANES) Version* 1.4.2, 2010.

Chief of Naval Operations, Consolidated Afloat Networks and Enterprise Services (CANES) Initial Implementation and Action, December 2009. As of June 9, 2011: http://www.public.navy.mil/spawar/PEOC4I/Documents/CORRECTED%20COPY%20CANES_Initial%20Implementation%20Msg%20071927Z_VADM%20Dorsett_7Dec09.pdf

CNO—*See* Chief of Naval Operations.

Davis, Jr., Walter J., "Moving Forward," *CHIPS*, April 1995.

Defense Daily, "Defense Watch," April 23, 2007. As of January 15, 2009: http://findarticles.com/p/articles/mi_6712/is_15_234/ai_n29347469/pg_1?tag=artBody;col1

Defense Science Board, Task Force on DoD Policy and Procedures for Acquisition of Information Technology, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C., 2009.

Denning, Peter J., Chris Gunderson, Rich Hayes-Roth, "The Profession of IT: Evolutionary System Development," *Communications of the ACM*, Vol. 51, No. 12, December 2008.

Department of the Navy, Fiscal Year (FY) 2011 Budget Estimates, Justification of Estimates, Other Procurement, Navy, Budget Activity 2, February 2010. As of January 16, 2011:
http://www.finance.hq.navy.mil/fmb/11pres/OPN_BA2_BOOK.pdf

Friedman, Norman, *The Naval Institute Guide to World Naval Weapon Systems*, 5th ed., Annapolis, Md.: U.S. Naval Institute Press, 2006.

Gartner, Inc., "Gartner Says Start Managing Information, Not Just Technology," press release, October 25, 2006. As of January 15, 2009:
http://www.gartner.com/it/page.jsp?id=546409

Gibson, Virginia Rae, and James A. Senn, "System Structure and Software Maintenance Performance," *Communications of the Association for Computing Machinery*, Vol. 32, No. 3, March 1989, pp. 347–358.

Global Security, "SSN-774 Virginia-Class New Attack Submarine [NSSN] Centurion," web page, n.d. As of November 23, 2011:
http://www.globalsecurity.org/military/systems/ship/ssn-774.htm

Hansen, Louis, "Navy Ship $840 Million over Budget and Still Unfinished," *Virginian-Pilot*, June 30, 2007. As of December 9, 2008:
http://www.defense-aerospace.com/cgi-bin/client/modele.pl?prod=84137&session=dae.31670639.1197586699.4dYVZH8AAAEAAAMNJeUAAAAB&modele=feature

Hong, John, "Network Consolidation Study Overview Briefing for Mr. Carl Siel, ASN(RDA) Chief Engineer," San Diego, Calif., August 29, 2007.

"Human Error Is the Primary Cause of UK Network Downtime; Intelliden Research Reveals That Lack of Standardization and Fat Fingers Cost Large Corporations and Governments Millions in Lost Revenue," M2 Presswire, November 6, 2003. As of November 23, 2011:
http://www.sourcewire.com/releases/rel_display.php?relid=17623

IHS, "Navy Awards Contract for Additional LPD 17 Class Ships," press release, June 14, 2006. As of November 23, 2011:
http://www.ihs.com/news/2006/navy-lpd17-contract.htm

Information Technology Infrastructure Library, *Service Management,* London: Office of Government Commerce, 2007.

Jackson, William, "Carrier's Net Runs Aground," *Government Computer News*, November 16, 2001. As of November 14, 2011:
http://www.gcn.com/print/20_33/17535-1.html

Johnsson, M., B. Ohlman, A. Surtees, R. Hancock, P. Schoo, K. Ahmed, F. Pittman, R. Rembarz, and M. Brunner, "A Future-Proof Network Architecture," *Mobile and Wireless Communications Summit 2007*, July 2007.

Kiczales, Gregor, John Lamping, Anurag Mendhekar, Chris Maeda, Cristina Videira Lopes, Jean-Marc Loingtier, and John Irwin, "Aspect-Oriented Programming," *Proceedings of the European Conference on Object-Oriented Programming (ECOOP),* Finland: Springer-Verlag, 1997.

Kuhn, D. Richard, "Sources of Failure in the Public Switched Telephone Network," *IEEE Computer*, Vol. 30, No. 4, April 1997, pp. 31–36.

Lientz, B. P., and E. B. Swanson, "Characteristics of Application Software Maintenance," *Communications of Association for Computing Machinery,* Vol. 22, No. 6, June 1978, pp. 466–471.

Lockheed Martin, "Acoustic Rapid COTS Insertion (ARCI)," web page, n.d.

Matteo, Donald, Mark Rubin, William Clair, and Richard Bailer, "Program Manager Advisory Group (PMAG) Recommendations for the Integrated Communications & Advanced Network (ICAN)," PEO Aircraft Carriers, June 9, 2004.

McLaughlin, Laurianne, "Future-Proof Your Network," *Network World*, July 18, 2005.

Miller, Chris, "PEO C4I Overview and Way Ahead for AFCEA NOVA," PEO C4I briefing, April 5, 2007.

Nagle, David, "ICAN Performs Well During Nimitz Exercise," press release, U.S. Navy, January 28, 2003a. As of January 15, 2009:
http://www.navy.mil/search/display.asp?story_id=5571

———, "Integrated Communications Network Performs Well in Nimitz Exercise," *Wavelength,* March 2003b.

National Research Council, *C4ISR for Future Naval Strike Groups,* Washington, D.C.: National Academies Press, 2006. As of March 13, 2012:
http://www.nap.edu/catalog.php?record_id=11605

———, *Achieving Effective Acquisition of Information Technology in the Department of Defense*, Washington, D.C.: National Academies Press, 2010. As of November 13, 2011:
http://www.nap.edu/catalog.php?record_id=12823

NAVAIR Lakehurst, fact sheet, 2002.

Navy Program Executive Office, Command, Control, Communications, Computers, and Intelligence, *PEO C4I Master Plan*, Version 3.0, August 7, 2009.

———, "Products and Services," web page, n.d. As of November 23, 2011:
http://www.public.navy.mil/spawar/PEOC4I/ProductsServices/Pages/default.aspx

O'Brien, Pat, "Applying US DoD Human Engineering Methods to Reduce Procedural Error Related Outages," *Proceedings of the 4th International Symposium on Service Availability*, Berlin: Springer, 2007, pp. 145–154.

O'Regan, Graham, "Introduction to Aspect-Oriented Programming," OnJava.com, January 14, 2004. As of January 15, 2009:
http://www.onjava.com/pub/a/onjava/2004/01/14/aop.html

Obert, Kathy, "Integrated Communications and Advanced Networks: Road Map," briefing, 1999.

Office of the Secretary of Defense, A New Approach for Delivering Information Technology Capabilities in the Department of Defense, November 2008.

PEO C4I—*See* Navy Program Executive Office, Command, Control, Communications, Computers, and Intelligence.

Porche III, Isaac R., Katherine Comanor, Bradley Wilson, Matthew J. Schneider, Juan Montelibano, and Jeff Rothenberg, *Navy Network Reliability: Models, Metrics, and Tools*, Santa Monica, Calif.: RAND Corporation, MG-1003-NAVY, 2010. As of September 21, 2011:
http://www.rand.org/pubs/monographs/MG1003.html

Program Executive Office, C4I, *Concept of Operations (CONOPS) for Application Integration (AI),* Version 1.1, December 2009.

Program Manager, Tactical Networks, *Consolidated Afloat Networks and Enterprise Services (CANES) Acquisition Strategy,* January 2009a.

———, *Consolidated Afloat Networks and Enterprise Services (CANES) Acquisition Strategy, Revised,* October 2009b.

———, *Consolidated Afloat Networks and Enterprise Services (CANES) Acquisition Strategy,* Version 2.2, March 2010.

Project Definition Document for Teleport Integrated Access Device in Support of the Tactical Switching Program, August 9, 2005.

Project Definition Document for Shore Telephony, November 2006.

Public Law 105-270, Federal Activities Inventory Reform Act, 1998.

Raytheon, "Raytheon's Shipboard Wide Area Network Ready for Navy's Next Generation Amphibious Transport Dock Ship, LPD 17," news release, April 21, 2003. As of March 26, 2012: http://www.prnewswire.com/news-releases/raytheons-shipboard-wide-area-network-ready-for-navys-next-generation-amphibious-transport-dock-ship-lpd-17-70885087.html

———, "Raytheon Delivers Source Code for DDG 1000 Total Ship Computing Environment Infrastructure Software," news release, November 7, 2006. As of January 15, 2009: http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/11-07-2006/0004468826&EDATE=

———, "Navy Approves Raytheon's Zumwalt Total Ship Computing Environmental Infrastructure," press release, October 30, 2007.

Rosenberg, Barry, "Unified Approach: U.S. Navy Plans to Consolidate Networks," *C4ISR Journal*, June 1, 2008. As of January 15, 2009: http://www.c4isrjournal.com/story.php?F=3502538

Schank, John F., Christopher G. Pernin, Mark V. Arena, and Susan K. Woodward, *Controlling the Cost of C4I Upgrades on Naval Ships*, Santa Monica, Calif.: RAND Corporation, MG-907-NAVY, 2009. As of September 21, 2011: http://www.rand.org/pubs/monographs/MG907.html

Schank, John F., et al., Trip Notes, SSC-SD Code 287 visit to CVN platform, August 14, 2006.

Schwartz, Mike, "USS NIMITZ (CVN 68) ICAN: INSURV INBRIEF," briefing, June 28, 2002.

Snaith, Pam, "The Changing Face of Network Management," *CA Enterprise Systems Management*, October 2007. As of January 15, 2012: http://www.technologyexecutivesclub.com/Articles/infrastructure/network.php

Space and Naval Warfare Systems Command, SPAWARINST 4720.1, February 14, 2006.

SPAWAR—*See* Space and Naval Warfare Systems Command.

Stark, George E., *Measurements to Manage Software Maintenance*, Colorado Springs, Colo.: MITRE Corporation, 1997.

Stull, Mark, briefing to the C4I executive committee, April 16, 2007.

Tolk, Andreas, and James Muguira, "The Levels of Conceptual Interoperability Model," paper presented at the Fall Simulation Interoperability Workshop, Orlando, Fla., September 2003.

Tung, Teresa, and Jean Walrand, "Providing QoS for Real-Time Applications," University of California, Berkeley, 2003. As of January 15, 2009: http://walrandpc.eecs.berkeley.edu/Papers/TeresaQoS.pdf

"U.S. Navy Awards Lockheed Martin Continued Submarine Sonar Upgrade through ARCI Program," Defense Update, January 18, 2011. As of February 22 2012: http://defense-update.com/20110118_arci_sonar.html

U.S. Navy, *Navy Training System Plan for the Aviation Data Management and Control System*, N78-NTSP-A-50-0009/A, March 2002. As of January 15, 2009: http://www.globalsecurity.org/military/library/policy/navy/ntsp/admacs-a_2002.pdf

Under Secretary of Defense for Acquisition, Technology and Logistics, "Implementing Directive for Better Buying Power—Obtaining Greater Efficiency and Productivity in Defense Spending," memorandum, November 3, 2010.

Walsh, Edward J., "Navy's NIIN Aims for Single IT Shipboard Network Backbone," *Military and Aerospace Electronics*, November 2000. As of January 15, 2009: http://www.militaryaerospace.com/articles/print/volume-11/issue-11/news/navys-niin-aims-for-single-it-shipboard-network-backbone.html

Wikipedia, "Differentiated Services," last updated December 5, 2008. As of January 15, 2009: http://en.wikipedia.org/wiki/Differentiated_services

Yamamura, Tetsuay, Kouji Yata, Tetsujiro Yasushi, and Haruo Yamaguchi, "A Basic Study on Human Error in Communication Network Operation," *Proceedings of the Global Telecommunications Conference, 1989, and Exhibition, Communications Technology for the 1990s and Beyond*, IEEE, 1989.

Yau, S. S., and T. J. Tsai, "A Survey of Software Design Techniques," *IEEE Transactions on Software Engineering*, June 1986, pp. 713–721.