A Decade of Large-Scale Software Systems Integration and Prototype Development for Army Wideband SATCOM

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Satellite communications (SATCOM) planning, monitoring, and controlling systems developed in the late 1970s and 1980s were predominantly stand-alone "stove-piped" software. Most used nonstandardized data models and databases and had custom interfaces for data input/output. Often, the semantics, units, or format of the data differed between systems. Data transfer between the systems involved error-prone, manual operator entry of data or disk transfers. The ability to correlate data across systems and to control dissemination of data was nonexistent. Achieving situational awareness at the beginning of an operator's shift took hours. In 1994, APL was tasked to design and develop prototype software to bridge this interface gap and provide, over a series of version releases, increasing capabilities for the exchange, management, and correlation of data; situational awareness; and ultimately decision support for Army wideband SATCOM systems. This prototype software is currently installed worldwide at numerous SATCOM operations control and associated management sites.

INTRODUCTION

The Defense Satellite Communications System (DSCS) provides flexible, multitrunk, multipoint wideband, long-haul transmission media for DoD and National Command Authority voice and data users. The system supports the establishment of satellite communications (SATCOM) networks with resources provided by a space segment, a ground segment, and a control segment. The space segment consists of a constellation of 10 geostationary DSCS III communications satellites distributed around the equator that provide line-of-sight (LOS) coverage over the portion of the Earth's surface between 70°N and 70°S latitude. The ground segment consists of Earth terminals that transmit (uplink) and receive (downlink) communications signals using the DSCS satellites as beyond-LOS relays. The control segment includes computer-based DSCS Operations Control Systems (DOCS) in facilities known as DSCS Operations Centers (OCs), which provide the planning, management, and control of DSCS networks.

The OCs are strategically located within the Northern Hemisphere at geographic locations where each is

able to view at least two operational satellites. Within each DOCS suite located in an OC, there is a capability to perform the following functions: network planning, satellite downlink signal spectrum monitoring, satellite communications payload control, electronic counter-countermeasures (ECCM) SATCOM network control, frequency division multiple access (FDMA) SATCOM network control, and tactical ground mobile forces SATCOM network control.[1]

The U.S. Army Forces Strategic Command (USAR-STRAT) and the Defense Information Systems Agency manage the DSCS constellation, with operations conducted at Army bases by the 1st Satellite Control (SATCON) Battalion. To aid in management and operation, the DOCS systems evolved to plan for, control, and monitor the status of the communications links, ground terminals, and satellite payload. For example, the DOCS systems include the following:

- DSCS Network Planning System (DNPS)
- DSCS Automatic Spectrum Analyzer (DASA)
- Production Satellite Configuration Control Element (PSCCE)
- Replacement Satellite Configuration Control Element (RSCCE)
- DSCS FDMA Control Subsystem (DFCS)
- DSCS ECCM Control Subsystem (DECS)

Many of these elements evolved as stand-alone systems with limited or no interconnectivity for passing planning or monitoring data between them. The DNPS originated as a research prototype and was transitioned to a production system. The DFCS and DECS used different custom interfaces for the input of planning data and the output of monitoring data. The interfaces between these systems, when they existed and were used at all, were not employed to perform automated correlation of data across systems. Better integration and correlation were needed to ease operator workload and increase "situational awareness."

Because of the need to interface with the many different DOCS, an integration software developer would need to communicate impartially with many different system development contractors. This need for an unbiased "third party" to develop the prototype integration software made this task an appropriate effort for APL, given the well-established "trusted agent" relationship that the government in general and the Army in particular enjoy with APL.

From its inception in 1994, via the tasking of APL by the Project Manager for Defense Communications and Army Transmission Systems, the primary goals of the DSCS Integrated Management System (DIMS) were as follows:

1. Management and control of the dissemination of planning data to the network control systems

2. Online collection of monitoring data from the existing systems
3. Centralized storage of data, including retention of historical and generated statistics
4. Comprehensive, flexible correlated reporting, allowing data from more than one system to be correlated by user-selectable parameters such as satellite, link, and terminal, as well as by time, and displayed within a single report

These goals, i.e., essentially integration of all DSCS planning, control, and monitoring systems, still form the core of the DIMS functionality. The DIMS acts as the "glue" that binds and interconnects the various systems and facilitates data exchange and interconnectivity (Fig. 1).

To meet emerging needs in the evolving wideband SATCOM arena, the DIMS goals have been expanded to include the integration of new systems supporting the Wideband Gapfiller Satellite (WGS) system; compliance with the Objective DOCS (ODOCS) architecture; and increased support for global, OC, and satellite situational awareness displays via distributed, intersite database communication.[2] These emergent goals were established in response to the Objective DSCS Operations Center (ODOC) Operational Requirements Document (ORD), which stated the need to reduce ODOCS operational staffing by half.

The draft follow-on to the ODOC ORD, called the Wideband SATCOM Operational Management System (WSOMS) ORD, makes specific reference to the evolution of a decision support capability to further realize the goal of reduced staffing. This capability is seen as growing out of the current DIMS data management and situational awareness capabilities.
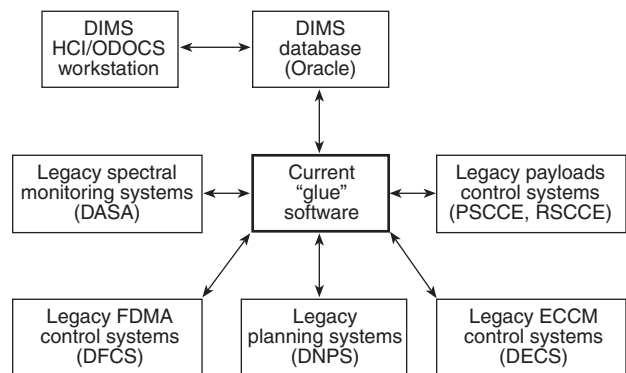
Figure 1. The DIMS database acts as the "glue" that loosely connects the other DOCS systems at the data layer. Some of these connections were established using existing interfaces and databases; others were achieved by "backdoor" mechanisms, where no formal interface existed.

MEETING USER NEEDS

There are two primary types of DIMS users: DSCS network controllers (operational users) and DSCS network managers (management users). The network controllers operate DIMS within an OC to handle the day-to-day tasking of controlling and troubleshooting the operations of the network, from the constellation to the Earth terminals. The network managers operate DIMS from DSCS management sites to provide overall direction to the operations sites and Earth terminals. All users may perform troubleshooting and trend analysis using DIMS and may rely on DIMS for obtaining current situational awareness; however, their scope of concern varies.

Because of the complexity of creating a large-scale system to accommodate the needs of multiple, distinct users in interfacing with multiple DOCS systems and providing the desired degree of customizability, correlation, and situational awareness capability, DIMS was envisioned in phases, to be delivered to the government as prototype versions. The first version (v1.0) was delivered in 1997.

The next section describes this initial version and the other versions that followed it up to the current version 5.0. The following two sections explore in depth two of the more revolutionary prototype capabilities added to DIMS since its inception: the *ad hoc* data viewers (referred to simply as data viewers in the remainder of this article) and the global situational awareness provided by the world-wide views (WWV).

DIMS Version Overview

Version 1.0 of DIMS collected DOCS data using disparate communications protocols, including DECNET, X.25, TCP/IP, APL-developed FORTRAN interprocess communications software, and proprietary interfaces. A human–computer interface (HCI) application enabled the operator to disseminate planning data from the DNPS to the DASA. Users could view planning and status data reports that were created to mimic or expand upon native DOCS reports at a single centralized DIMS workstation. These reports contained planned and/or current satellite or network measurement data, often with correlative predicted values, that showed the operator the status of the overall communications system (both the equipment and the network). Management users were given remote reporting capability and data access to each OC over the DOCS wide area network. DIMS v1.0 also provided remote access for users at one OC to view data stored at another OC.

Version 2.0 built upon the capabilities of v1.0 to further integrate, simplify, and improve DSCS network management tasks. It provided new and enhanced system interfaces, added correlated reports, increased printing capabilities, resolved numerous outstanding problems discovered in v1.0, and significantly improved

overall system performance. The performance enhancements included better system navigation capabilities, database and network adjustments to drastically reduce data store-and-retrieve times, and a radical modification to the system disk configuration to greatly improve overall reliability and availability.

Version 3.0 moved off an X-Windows–based HCI platform to a Windows NT–based PC-compatible platform and introduced the flexible data viewers. The data viewers are HCI software written in C++ that, combined with comprehensive Oracle data views, provide configurable reporting capabilities, enabling end users to create, modify, save, and exchange customized reports. The data viewers enabled field selection, formatting, sorting, filtering, mathematical conversion, and new field derivation; made DIMS very responsive to change; and freed APL from the time-consuming report development process.

Version 4.0 provided the WWV capability, allowing the user for the first time to see globally correlated data and status information derived by a set of server-side rules. Using scheduled replication of site-current data at each OC via the DOCS wide area network, the WWV gives a situational awareness display that indicates the status of all elements of the DSCS network.

Version 5.0 provided the "full-up" implementation of the interface with the forthcoming RSCCE. Although originally scoped for release in DIMS v2.0, the interface was subsequently removed, scoped again in v4.0, and fielded but never used. This interface was scoped, tested, and fielded anew with DIMS v5.0. In addition, changes were made to the Operational Database Control report in DIMS to modify the way that plan data are disseminated to the DOCS systems in preparation for the arrival of the ODOCS-compliant systems scheduled to be fielded along with DIMS v5.1 and DIMS v5.2.

User-Definable Correlation
via Data Viewers

The software development and release process is often long, painstaking, and expensive. The DIMS users wanted a means to create new reports without having to repeat an extensive software release process. In addition, each OC has a few highly trained and experienced managers but is mainly staffed by less experienced analysts. It was therefore desired to enable the most experienced managers to dynamically create new reports as needed to simplify the tasking and reduce the workload of the analysts, who constantly monitor for trouble indications.

In response, APL proposed and created the data viewers in DIMS v3.0 to enable managers to create a data report "on the fly," name and save the report, and then add the report to a "favorites" menu for immediate use by the analysts. Two primary types of data viewers were required: tabular (for viewing a current snapshot of data) and graphical (for viewing historical time-series data).

Following an object-oriented design approach, APL started with a basic form called a main form, which displays the status and classification that is common to all DIMS reports and fundamental to each of the data viewers. Figure 2 shows the data viewer hierarchy, where each viewer inherits the properties of those above it and extends the parent functionality. The table viewer adds tabular viewer functionality to the main form; the graph viewer adds graphical viewer functionality to the DIMS table viewer; and the smart link table, smart link graph, and smart channel graph viewers each add different logic to the table and graph viewers to assist the user with data selection.

Current measurement data collected from the control and monitoring systems are displayed in reports created using the DIMS table viewer, which inherits the properties and functionality of the DIMS main form. This viewer contains up to 12 tabbed sheets, each of which represents a data set, and has a configurable grid to display the data and one or more components for filtering those data.

During the report creation process, the report designer selects the source data set for each tab sheet, the columns to include in the report, the display characteristics (including the presentation format, precision, justification, alarm thresholds and colors, column ordering, and default sort column), and the data filtering components used to select the data. The report design may be saved to a settings file at any time. A settings file may be inserted into the favorites menu and may be e-mailed to other operations and management sites. Because all reports (including those designed by APL and delivered with the baseline DIMS software) are based on settings files, they can be custom-modified by the user to produce variations on that report, which can then be saved and used.

From the monitoring data that DIMS collects, statistical and historical data sets are produced and displayed in reports created using the DIMS graph viewer, which inherits the properties and functionality of the DIMS table viewer. The graph viewer adds a chart that allows the graphical display of time-series data from any of the selected data sets. During the report design process, the report designer selects the desired data sets and fields to be graphed and the desired display characteristics, such as line color and style (Fig. 3).

In addition to these primary data viewers, APL added built-in data correlation to provide a level

Figure 2. The hierarchy for DIMS data viewers. The DIMS HCI software was developed using object-oriented design and development in the C++ language, although some newer, non-HCI elements are being written in Java.

of "smartness" to streamline user selection of filtering choices. These viewers are referred to as "smart" viewers. The data displayed within a smart viewer can be correlated because each data set in the report uses the same filter choices for identifiers, such as satellite, link, or channel; that is, the data are presented such that only data from a single satellite and link or a single channel may be displayed at one time, and changes in these selections are automatically propagated across all data sets. In contrast, the non-smart viewers allow data from any satellite, link, or channel to be displayed together in any combination.

A smart viewer also helps the user by prefiltering lists of other identifiers, such as terminal and channel, and sometimes preselects a specific identifier for receive

Figure 3. A screen capture of a DIMS graphical data viewer. Seven data sets contain historical performance and measurement data for a communications link, AOA509; the graph at the top displays three measures of historical link performance.

or transmit terminals or channels. For example, with a data set containing measurements made at the receive terminals, the receive terminal selection component is populated with that link's receive terminals only, while the default receive terminal selected is the receive terminal requiring the most transmit power for a given desired quality of service, also referred to as the "most disadvantaged" receive terminal.

This additional capability has been prototyped to apply to link and channel selection in the DIMS smart link table and smart channel table viewers, which are derived from the DIMS table viewer, and in the DIMS smart link graph and smart channel graph viewers, which are derived from the DIMS graph viewer.

The data viewers provide a flexible, efficient means to view both tabular and graphical correlated performance data and to set alarm thresholds against the data. However, the thresholds are essentially range limits, used to test boundary conditions only, and apply to only one data element at a time. The number of reports necessary to see emerging alarm states precludes viewing them all simultaneously. Checking many predefined and original reports at the start of an operator's shift to achieve and maintain situational awareness is time-consuming. A faster, more configurable, and concise method was therefore needed to achieve both initial and ongoing situational awareness.

Global and Local Situational Awareness

Communications links and equipment performance may on occasion move beyond the expected or desired range, often causing a degradation of quality of service for individual users. Within wideband SATCOM network management systems, such anomalies may range from a single transmit terminal generating too much power (and thus effectively jamming other satellite users) to a satellite antenna being improperly configured or aimed. These detected anomalies may generate monitoring alarms to notify the operator and possibly other DOCS systems of the problem. The monitoring alarms can be generated by any of the DOCS monitoring systems, including DIMS.

In DIMS v4.0, a new functionality was prototyped to give a quick overview of the statuses and alarms pertinent to three distinct user perspectives: the first comprises the health and status of both the global satellite constellation and OC sites; the second involves the health and status of the satellites, systems, terminals, and communications links for which a single OC is responsible; and the third encompasses the specific health and status of a single satellite and the associated terminals and links. Collectively, this prototype functionality is the WWV.

The initial prototype of the WWV as implemented in DIMS v4.0 consists of three displays: the global view, the OC view, and the satellite view. Each view presents a set of health and status information that is customized to the specific perspective of the user. The intention is that managers, especially upper management, focus on the global view for situational awareness, site managers at the OCs focus on the information in the OC view, and analysts responsible for a single satellite focus on the satellite view.

Each WWV display has a common look and "feel" and features cross-linking to other WWV displays. A class of display elements, called alertable icons, is used to display the status of entities such as satellites, OCs, systems, or other ground equipment. Alertable icons are also used to display measurements such as the channel percent power bar graphs shown on the global and satellite views.

There are three levels of visible alarm status: nominal, warning, and alert. Equipment and system status may also display as offline/maintenance. Finally, any alertable icons may have a "no data" status, which means a lack of sufficient or timely data. Each of these five statuses is represented visually by a user-configurable color. Statuses are determined by applying predefined rules against current data, both from the local site and from all remote sites. These rules reside within the database and periodically update the statuses, which are then queried by the HCI and displayed for the user. A distinct set of rules applies to each WWV display, allowing differentiation of alert sensitivities. Some rules have user-modifiable threshold values to support dynamic operational concerns. All WWV rules are established and change is managed by a Rules Configuration Control Board whose members represent Army users and government sponsors. When an alarm (i.e., a warning or an alert status) is present, each alertable icon representing the alarmed item allows the current alarm to be examined via a right-click "Examine" menu item. Examining an alarm causes detailed alarm information to be displayed.

The global view (Fig. 4) is designed to give managers a high-level view of the status of the satellite constellation and the OCs. This display is less sensitive to individual alerts, such as a single link or terminal failure or degradation, so as to not overwhelm the user with alert indications. However, individual alerts that occur over a significant portion of a single channel or a satellite would be displayed at the global level. The global view is distinct from the OC view and the satellite view in that each new alert status displayed for any alertable icon, when first shown, causes the alertable icon to blink between the user-defined alert color and the user-defined "no data" color in order to highlight the presence of the new alert. The blinking continues until the alert is acknowledged. The OC view focuses on the responsibilities of the individual OC in terms of the satellites, systems, terminals, and links for which the OC has control or monitoring responsibilities. Unlike the global view, the
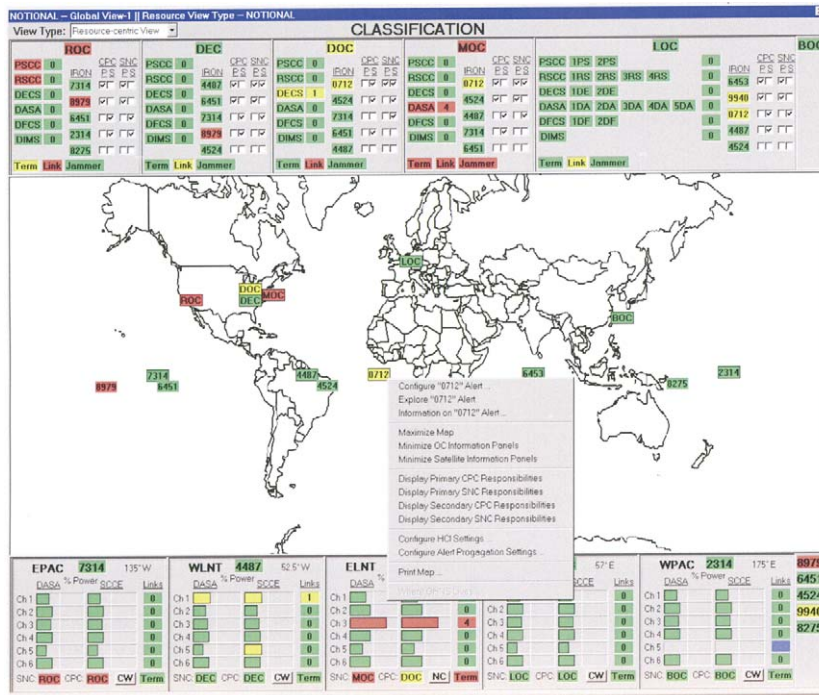
Figure 4. The global view within the WWV shows the highest-level picture of the current state of the communications systems and network. Designed for managers, it is of lower sensitivity but higher scope than the other WWV displays.

OC view has a high level of sensitivity to individual alert conditions in order to quickly detect problems and allow them to be corrected as they occur and before they can become larger concerns. The satellite view focuses on the health and status of a single satellite and all of the systems, terminals, and links related to that satellite, regardless of the OC in which these systems reside. Like the OC view, the satellite view has a high level of sensitivity to individual alert conditions.

In later versions of the WWV implementation, it is planned to incorporate new systems into the various existing and some new views, expand the number of subviews, expand the cross-navigation capabilities between views and other predefined tabular and graphical reports, and redesign the rule generation and implementation architecture to use modern COTS-based rule engines to better support user prototyping and customization of WWV rules.

FUTURE USER GOALS

As with most software systems, user requirements tend to expand as the system is used and as new system-wide requirements emerge. Many of the experience-driven, "internal" requirements are entered as change requests by the user community and are brought forward for consideration when current and future versions of the DIMS software are scoped. However, system-wide or "external" changes are impacting the DIMS software in the following areas: ODOCS system

integration architecture, DoD-driven information assurance initiatives, and, most recently, the transformational communications initiative. The following sections detail each of these areas and their impact on DIMS development.

Integration Architecture

The WGS, the next-generation DoD wideband satellite system, is set to launch around the end of 2005. To add satellite network planning and control for the WGS, several new ODOCS systems, specifically the Common Network Planning System, Integrated Monitoring and Power Control System, and Gap-filler Satellite Configuration and Control Element, are being developed for installation in the OCs during 2005 and 2006. DIMS v5.1 and v5.2 will add support for these system interfaces, provide ODOCS software services (OSS) to facilitate ODOCS system integration, and include additional support for the WGS.

Integration efforts for the previous DOCS systems were based on Interface Control Documents (ICDs) that were unique to each interface and were created against existing, fielded systems. The new WGS-related systems are being developed in parallel with the DIMS version that is scoped to support them, making the task of defining the interfaces more difficult. Since the new systems are not yet complete, the interfaces need to be more loosely defined to accommodate late changes to requirements.

The OSS facilitates ODOCS system integration at the HCI (navigation) layer, the application communication (messaging) layer, and the data layer through distinct services: the ODOCS HCI Navigation Service (OHNS), the ODOCS System Control Service (OSCS), and the ODOCS Database Management Service (ODMS), respectively. Each service provides a standard mechanism for the interface among all of the ODOCS-compliant systems. All of these services, collectively known as OSS v1.0, will be developed and delivered with DIMS v5.1.

Within a single workstation, the OHNS is the service that brokers navigation requests between ODOCS system HCIs. Navigation requests are user-initiated and include the desired target as well as the current data "context" of the source field or report, i.e., a link, a site, a terminal, and/or a satellite. This service is used to allow rapid user navigation in order to manually investigate, explore, or troubleshoot throughout the system.

Within a single OC, the OSCS provides an intersystem message bus, allowing an ODOCS system to broadcast predefined messages to other ODOCS systems. This service allows status interchange and well-defined communications among multiple ODOCS systems. In addition, within a single OC, the ODMS enables intersystem data exchange. This service provides read-only access to the public data of other systems. In this way, planning, monitoring, and status data can be retrieved by a system regardless of the source of the data.

DIMS v5.1 will be fully ODOCS-compliant, i.e., it will fully interface with all other ODOCS-compliant systems via the appropriate service.

Information Assurance

In November 2003, the Department of the Army published Army Regulation 25–2 (Information Assurance). This document details the Army Information Assurance Program (AIAP), which is a comprehensive approach intended to protect unclassified, sensitive, or classified information stored, processed, accessed, or transmitted by Army information systems.

The DIMS software and the development team were affected on many levels by the new regulation. In accordance with the DoD Information Technology Security Certification and Accreditation Process (DITSCAP), the DIMS team was tasked to draft sections of the System Security Authorization Agreement (SSAA), which evaluates the potential impact from likely threats and vulnerabilities associated with the architectural and operational components of the DOCS and suggests countermeasures to mitigate identified vulnerabilities.

A Security Readiness Review (SRR) procedure was generated for each SSAA-defined component, providing a textual description of the tests that should be applied, along with an accompanying security checklist. When the checklists were applied against the corresponding DOCS components, the results were myriad potential vulnerabilities. Increasing the complexity of the situation were the tightly coupled, and sometimes overlapping, areas of responsibility shared among APL, government agencies, operations staff, and government contractors. This necessitated the close coordination and cooperation of all involved parties. Coordination was enabled by a regular series of meetings in which the analysis of each vulnerability, assignment to a responsible party, determination of a mitigating factor, and arrangement for testing were specified and tracked. Although no particular finding required extraordinary efforts to remedy, the entire process of correcting all findings spanned more than 6 calendar months.

Another complicating factor was the classification of the vulnerabilities. Since the system contains and processes classified data, the platform (i.e., the hardware, operating system, and software) at the sites is also considered classified. Specific vulnerabilities related to a classified platform are classified if they relate the vulnerability back to a specific machine, making discussions and solutions more difficult.

The AIAP/DITSCAP requirements were not applied to DIMS until several versions of the software had been delivered. Although APL was able to apply the required changes to the current version, the DIMS development schedule was expanded to include tasks for continuous SRR self-evaluation of the software using the frequently revised SRR procedures and checklists.

Transformational Communications

The Transformational Communications Architecture (TCA) will evolve current and developing satellite communications systems with a goal of providing standards-based spaceborne and ground systems for interoperable data connectivity to all echelons of the military.[3] In addition, the TCA will provide a global, satellite-based Internet protocol environment with an integrated network management system and system-wide security management.

As a component of the Global Information Grid (GIG), DSCS and WGS will serve as part of the network transport segment for the TCA. While DIMS plays no direct role in enabling the TCA over the GIG, it is integral to the management and operation of these networks, and the impact of the TCA on the DSCS and WGS will have considerable requirements- and operational-level impact on future versions of the DIMS.

SOFTWARE TRANSITION TO GOVERNMENT

As APL completes efforts to prototype the DIMS software to incorporate new system interfaces and to meet current and future user-defined information management requirements, the time will arrive for transitioning DIMS to the government for ongoing software maintenance and support. Responsibility for all future software changes and problem resolution will transition to the Communications and Electronics Research, Development and Engineering Center, Software Engineering Center in Ft. Monmouth, New Jersey.

Transition Issues

With each release of DIMS to date, APL has delivered requirements, interface, and design documentation and source code. During software transition, there will be a final handover of responsibility, requiring an even greater transfer of information. At that time, APL will turn over all of the software and hardware that was purchased for use in the DIMS test facility.

For most of a decade, Building 48 at APL was dominated by computer systems that were used to support DIMS development efforts. It now also includes government-furnished systems such as a DNPS, a DFCS, and

a DASA. Known currently as the DIMS Test and Integration Facility, it is designed to provide a high-fidelity simulation of a real-world OC in order to develop and test the DIMS software.

Approach

The transition of DIMS to government maintenance has been scoped for inclusion in DIMS v6.0. APL has proposed the addition of government-designated contract personnel to work within the Laboratory's current development team to prepare them to assume the DIMS maintenance role. However, because of the short-term relocation required and the difficulty in identifying that far in advance of the transfer the personnel who would take responsibility of the transitioned DIMS, this step has been difficult to initiate.

A transition plan will be created at the beginning of DIMS v6.0 development. This plan will determine the division of DIMS functionality between APL and the government. It includes the transfer of government property, DIMS requirements and interface documentation, source code and installation package repositories, software problem report databases, and end-user documentation such as the user's guide, installation guide, and administration manual.

However, some features of DIMS, such as the WWV capability, may not be transitioned to the government, but rather retained as part of a follow-on task in order to continue the innovation of this situational awareness capability. For example, a future effort may extend the WWV into a more comprehensive decision support and situational awareness system.

FUTURE DIRECTIONS

With the transition of DIMS to government maintenance and support, the door will open for APL to prototype additional advanced capabilities required by the user. One key area already defined for APL follow-on work after DIMS is to prototype a wideband SATCOM decision support capability that would extend beyond the current boundaries of DIMS and reach across all of the ODOCS systems.

Decision support plays an increasingly important role in command and control activities and has been identified as one of APL's flagship areas in information processing and information management.[4] Confirming the validity of this, the Army Strategic Command (ARSTRAT) has expressed the need for a decision support capability within the wideband SATCOM domain as a necessary means for fulfilling the objectives of the WSOMS ORD. Those objectives include reduced operator training, operator workload, and staffing levels. ARSTRAT has initially postulated the requisite decision support capability as comprising manager-configurable rule sets for triggering intelligent responses

to violations of performance standards based on the analyses of correlated or fused performance metrics. Since this follow-on capability is expected to exist outside of (but in coordination with) DIMS, the Laboratory is expected to develop it as a separate, ongoing prototype activity after the DIMS software is transitioned to the government.

Decision Support

"Decision support" is a phrase that has been generically used to indicate everything from a stand-alone spreadsheet all the way to full-up knowledge-based systems that span large decision domains. In addition, APL has found that decision support traditionally refers to support for one or more decision makers charged with making unstructured, strategically oriented decisions.
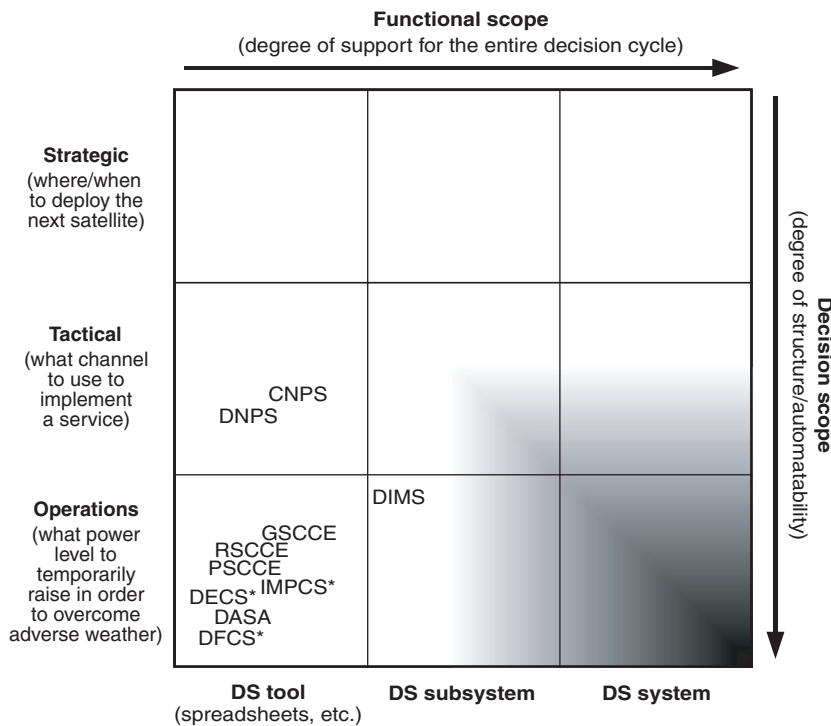
Because of the inherent ambiguity of the phrase, it may be useful to introduce a proposed taxonomy of what decision support can mean. On this notional spectrum of meanings, let the first axis represent functional scope. On one end of this axis is the "decision support tool," a system that addresses an isolated facet of decision making. At the other end of this axis is the "decision support system," a system that addresses end-to-end decision making, from situation monitoring and detection, through decision model construction and validation, to solution generation and selection, and on through to solution implementation and tracking. Between these two extremes lies the "decision support subsystem," often an incomplete collection of loosely integrated decision support tools. The second axis represents decision scope. On one end are "strategic" decisions, and at the other end are "operations" decisions, with "tactical" decisions filling the middle (Fig. 5).

The goals represented within the WSOMS ORD have an "operations" focus. This allows some simplification, since the decision model construction and validation facet, required in strategic systems, collapses to only decision model selection and instantiation. Concurrently, task automation becomes much more of a focus as the structured nature typical of operations decisions makes automation more feasible. This leads to the concept of "operations decision support" as depicted in Fig. 6.

The APL vision for implementing this concept is a "framework of frameworks" decision support system architecture that facilitates

- Configurable, modular integration/incorporation of existing and future decision support models/tools
- Configurable automation of each decision cycle (to the extent possible)
- Explanation of system decisions to promote confidence and to transfer/increase expertise
- Collection of feedback from system operators to enhance decision support rule evolution

Functional scope
(degree of support for the entire decision cycle)

Strategic
(where/when to deploy the next satellite)

Tactical
(what channel to use to implement a service)

CNPS
DNPS

Operations
(what power level to temporarily raise in order to overcome adverse weather)

DIMS

GSCCE
RSCCE
PSCCE
DECS* IMPCS*
DASA
DFCS*

Decision scope
(degree of structure/automatability)

DS tool
(spreadsheets, etc.)

DS subsystem

DS system

Figure 5. The functional capability of automated decision systems ranges from a small support tool to a full system. The types of decisions range from daily operations to strategic planning. Within this plane, APL's envisioned decision support (DS) system lies in the "Operations/DS system" corner (shaded area). (*While control systems necessarily implement/automate entire decision cycles for a limited set of control decisions, in this context we are more concerned with the human-in-the-loop configuration management of the control parameters that drive these control systems as well as the detection and correction of any unaccounted-for events/cross-effects that may occur within/between the network resources under their control.)


Operational systems

Data warehouse

Automated targeted pattern recognition (expert systems, neural networks, genetic algorithms, etc.)

Intelligence

Automated implementation and tracking of selected solutions

Implementation

Modeling

Automated recommendation/ selection and instantiation of prebuilt decision analysis models

Operational systems

Analysis

Model management system

Expert advice for generating solution alternatives and performing specific what-if, goal-seeking, sensitivity, etc., analyses

Figure 6. An end-to-end operations decision support concept.

Separate from the decision-support–specific topics discussed thus far, this vision also sits atop the concepts and technologies of modern OSS, which includes Service-Oriented Architecture and Business Process Management Systems (BPMS) (as exemplified by the TeleManagement Forum's New Generation Operations Systems and Software initiative).

APL has already prototyped two elements of the overall architecture. The first is a presentation-layer framework that implements a domain-independent operator workspace, which can be configured to any domain using "plug-ins" and Web portal technologies. The second is a monitoring and detection framework for situation diagnoses that employs the techniques of problem-solving methods and ontologies, thus enabling arbitrary knowledge representations (e.g., Bayesian networks, fuzzy logic, etc.) to be incorporated as knowledge components in a generic diagnostic process.

For the near future, planning has begun for the development of a BPMS-based prototype that manages end-to-end decision cycles and their related subprocesses. The goal of this initial prototype effort is to engineer a system that meets the needs of the current users and retains, as much as possible, the flexibility to support future sponsor decision support needs.

SUMMARY

The need for the DIMS originated from a desire to integrate "stovepiped" DOCS and to increase user situational awareness of the state of the entire satellite constellation and associated communications network and ground systems. The DOCS were already fielded and had established interfaces. Missing was the central integration and correlation engine. The work of gathering, exchanging, and correlating the data across the DOCS subsystems was accomplished after the interfaces within the ICDs were defined and captured.
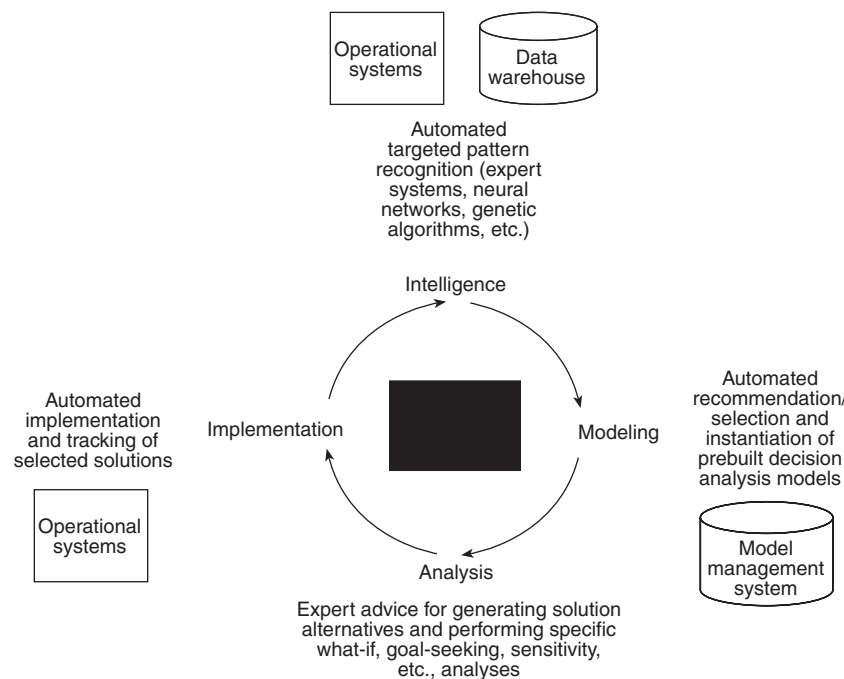
Later versions of DIMS provided better ways to view and correlate the data and increased situational awareness through specialized, globally correlated reports. Also, additional DOCS were fielded and the corresponding interfaces were added to DIMS.

Throughout this evolutionary prototyping process, considerable systems engineering occurred in solving unique hardware and software interface problems, determining appropriate correlation algorithms for DOCS system-wide data, and providing global situational awareness. APL's trusted agent role was relied upon to ensure an unbiased integration while the interfaces were established and, later, while the prototype software was tested and delivered.

The challenges faced in the current developmental prototypes, DIMS v5.1 and v5.2, are no less daunting. The interfaces of the new ODOCS systems currently being developed for use with the WGS are constantly changing as these systems mature. There is no fixed baseline software from which to derive an ICD. DIMS development must be flexible and constantly ready to change interfaces, and even requirements, late in the development cycle in order to endure this dynamic environment.

Even when DIMS is transitioned to government software maintenance and fielding, the proposed follow-on decision support prototype will be no less dynamic, relying on the (still dynamic) data from each ODOCS-compliant system as input to a decision support engine filled with customizable (and thus dynamic) rules. The software engineering methods that were used successfully on DIMS will need to be further evolved to accommodate a new kind of software prototype, with perhaps even a different software development model.

Looking back on the past decade, the DIMS prototype development effort has provided excellent experience in large-scale software engineering in a dynamic environment. The next decade will require the use of these experiences and lessons learned to facilitate the creation of an ODOCS-wide decision support and situational awareness capability in an increasingly dynamic environment.

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