A STUDY IN EVOLVING OPERATIONAL CONCEPTS AND NETWORKS

Global Command and Control System – Maritime (GCCS-M) Segments And SKYCAP Assured IP Software

and their application in JOINT/COMBINED EXPEDITIONARY OPERATIONS

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ABSTRACT

The Navy Program Executive Office (C4I and Space) PMW-170 has been at the forefront of new efforts to improve UHF SATCOM bandwidth utilization of existing satellite communications assets. This effort is synchronized with the Navy's transition of legacy information exchange (IXS) circuits to modern IP network based applications. The Assured IP (AIP) project, started by PMW-179 and now managed by PMW-760, is responsible for coordinating multiple projects and programs-of-records (PORs) in order to accomplish IXS-to-IP modernization. SkyCAP is one of the transport protocols being considered by the Assured IP project as described in this document. Most military information systems involve tactical exploitation of TCP I/P networks, which are used to pass data using FTP and other protocols. For many tactical users UHF SATCOM is the only over-the-horizon radio path available; however, the channels are limited in quantity and bandwidth capability. SkyCAP is the name given to a new suite of assured IP data control software modules designed to address the war fighter's network needs and limitations. The SkyCAP proposal was originally presented at MILCOM 2002. Subsequent development work resulted in an initial trial build of this software in Linux configuration. Porting of SkyCAP software to the Windows operating system was completed in December 2004. Operational testing has included the Joint Warrior Interoperability Demonstration (JWID) 2004 and recent field exercises with mine warfare and expeditionary warfare forces. This paper discusses the development and integration efforts associated with SkyCAP and the MEDAL/EDSS segments of GCCS-M resulting in a new data exchange capability soon to be presented to tactical users.

INTRODUCTION

The continued development and maturity of Network Centric concepts of war fighting move more and more of the daily information exchange between and among tactical formations onto the "Global Information Grid". Web-based data access and tactical reporting at higher echelons continue to streamline the movement and flow of information leading to greatly enhanced situational awareness at these levels of command. However, in the "far forward" tactical echelons many of the benefits of these Network Centric concepts cannot be used due to insufficient bandwidth available through tactical radio frequency based systems. These units are generally described as "bandwidth disadvantaged."

Lower echelon commands, here defined as largely Company level and below for USMC commands and "small deck" ships, generally cannot take best advantage of these tools either to report status, request support, or receive orders. The process of transforming the information architecture of these units is critically dependent on

finding new methods to allow network-based (meaning Internet Protocol (IP) traffic) data exchange. Recent developments in exploring new methods of providing tools for "assured IP" data delivery now appear to be nearing the ability to meet minimal IP data exchange requirements of far forward tactical forces. PEO C4I & Space, through its PMW-170 UHF SATCOM office, has been developing a new software suite known as the Sky Channel Access Protocol, or SkyCAP. This new software-based assured IP application is now emerging from lab development into initial field-testing for operational use. While there are other options available to increase overall bandwidth at the tactical level, this paper will only discuss the SkyCAP software suite and its application to current UHF SATCOM capability.

The ability to execute true distributed and collaborative planning for amphibious operations, including ship-to-objective maneuver, selected intelligence and meteorological functions, and plan rehearsal is needed in the fast moving littoral/expeditionary warfare area. As part of an ongoing series of newly developed Tactical Decision Aids (TDA) for the Global Command and Control System – Maritime (GCCS-M), the Office of Naval Research (Littoral Combat Future Naval Capabilities office) has sponsored the development of an expeditionary warfare-planning segment for GCCS-M. This tactical decision aid, called the Expeditionary Decision Support System (EDSS), incorporates operating features of and shares a common database with the existing GCCS-M Mine Warfare Environmental Decision Aids Library (MEDAL) segment allowing extensive data sharing between mine warfare and amphibious warfare planners. Recent additional developments include enhanced tools for USMC land and air assault planners. MEDAL is a current program of record and EDSS is rapidly progressing toward that state.

MARCORSYSCOM was instrumental in confirming the use of both EDSS and SkyCAP capabilities as part of the continuing development of the Command and Control PC (C2PC) suite of tactical software. In late 2004 EDSS was selected for eventual integration as a primary data injector in C2PC while SkyCAP was selected for investigation as an IP communications tool for extending the tactical LAN to mobile field units. This paper discusses the development and integration efforts associated with SkyCAP and the MEDAL/EDSS segments of GCCS-M resulting in a new mobile tactical planning capability soon to be presented to tactical users.

REQUIREMENTS

Operating in either the Windows or Linux operating systems, SkyCAP provides a software-based gateway configuration for higher capacity mini-LAN data exchange (i.e., 4-10 computers on a single RF-based LAN) or as a Windows application intended for use on a single laptop concurrently running GCCS-M 4.X series or C2PC software. SkyCAP is designed to bridge the gap in providing assured IP bandwidth to tactical users using existing tactical radio systems. Minimum hardware configuration is any Pentium III CPU (400 MHz or higher), 128 MB RAM and 20 GB HD space. An inexpensive synchronous serial card is required in order to connect the PC to the radio. SkyCAP executable code only occupies 4 MB of hard drive space. The remaining space is used for temporary storage of files and packet data elements. SkyCAP software features the following major components:

Government owned software based on open source models: Must be able to run on a PC, must not require special hardware other than a commercial synchronous serial card, and remains nonproprietary even with vendor improvements.
Non-token-based TDMA design: Users need only be able to receive the controller signal to know when to transmit. This avoids user-to-user link problems.
Controller and minimum of eight simultaneous, active users: The net operates with a control station servicing a minimum of eight users actively transmitting. Maximum net users can vary up to 64, but should be based on no more than eight users for near-simultaneous transmissions.

Net access and priority interrupts: In two minutes or less, a user can request access to the net. Access will be assigned based on priority and availability. Highest priority users can capture the channel and have exclusive use until another equal- or higher-priority user joins the net.
Auto dynamic slot quantity and size: The number of slots varies with the number of users. Slot size adjusts based on the type of traffic on the net as based by port activity at the controlling station.
Adaptive FEC and data compression: The basic MIL-184 standard provides this function, and it will be retained.
Support new CPM burst rates: SkyCAP is designed to take advantage of the higher continuous phase modulation (CPM) data rates described in MIL-STD 188-181B.
Si**mplex/EMCON broadcast mode:** The control station can use the 184 terminal messaging function to any number of recipients with no acknowledgments required. The control station will be able to assign an I/P tunnel that can be configured for priority, FEC, and simplex or duplex operation. An external device on the network can then access this tunnel to send scheduled or priority traffic to any number of stations on the net and not just the active net participants.
Tunnel access control: SkyCAP functions as a firewall. Traffic can be restricted by setting up tunnels for specific I/P ports allowing only traffic destined for that address and port would be passed across the link, or all traffic on the LAN can be bridged.
Chat and file transfer: SkyCAP provides a peer-to-peer netted chat capability with file transfer. All the basic functions of commercial chat systems are included however SkyChat is designed to use minimum bandwidth and has lower latency than a server based chat system would over the same link.
Remote configurable: With the exception of modem burst rate the controller handles all configuration settings providing for simplified operation.
Advanced IP proxy services: SkyCAP includes a performance enhancing proxy (PEP) called SkyWays. SkyWays is a transparent proxy designed specifically to improve IP transfer and latency over low data rate half duplex links. It provides for packet prioritization, sorting for maximum compression benefit, etc.

OPERATION

The concept of operations for general SkyCAP use is to view the SkyCAP application as just another IP gateway for distributing IP traffic. To a host machine on the wired network side of the SkyCAP computer the host table is adjusted to show the IP address of the SkyCAP computer as the default or primary gateway route. When operating via a router, SkyCAP appears as just another route to advertised IP addresses. SkyCAP software will accept outgoing TCP connection requests and proxy the acknowledgement/negative acknowledgement (ack/nack) functionality within the local LAN. This keeps the TCP connection request from the originating host "live" while SkyCAP negotiates delivery of the IP payloads to the destination. The SkyCAP host at the destination receives the packets and establishes a local TCP connection to the destination to complete delivery. In this manner up to 80 percent of network overhead packet transmission is eliminated. To the user the data simply gets delivered.

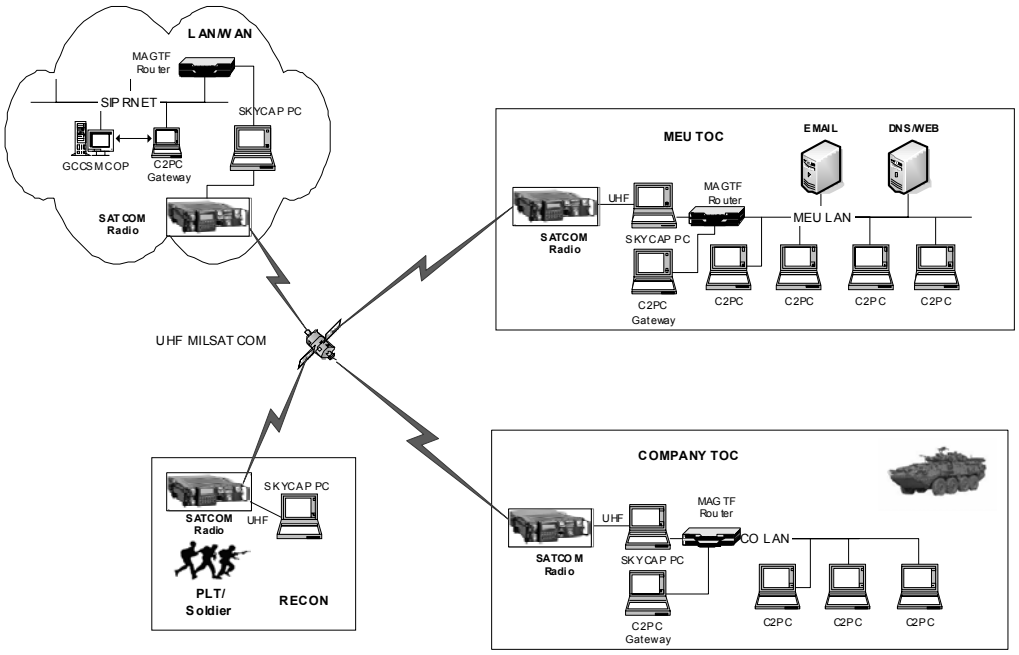
This direct proxy function for most IP traffic results in the originating and destination hosts knowing no difference in normal LAN data exchange functionality. For example, within GCCS-M or C2PC applications the normal LAN interface (NETWORK or NETPREC) may be activated and data routed to destinations via these interfaces as if the computer were connected on a physical wired LAN. SkyCAP handles the data distribution and acknowledgements. Typical IP packet delivery speeds will vary according to the bandwidth available over the RF link. SkyCAP software is capable of normal data exchange ranging from as low as 9.6 Kbps to T1 (1.54 Mbps).

Due to extended data handling latency inherent in Demand Assigned Multiple Access (DAMA) circuits, SkyCAP requires a dedicated satellite channel, and in fact creates its own TDMA network among the SkyCAP nodes. When used on a 25 KHz dedicated channel SkyCAP has routinely exhibited data rates in excess of 38 Kbps with very low bit error rates. When used on 5 KHz channels SkyCAP typically delivers 9600 bps data rates. Continued development of data proxies, data compression and data encoding techniques appear to offer even greater effective throughput in the future.

Operational Architecture

Insertion of SkyCAP into the existing GCCS-M/C2PC architecture is relatively straightforward. In lieu of static routes via hard-wired routers currently passing over-the-horizon IP traffic via large, wideband communications systems, the SkyCAP host may be used as an alternate route to specific field mobile tactical units or ships. These units are identified by the assigned IP addresses in their tactical computer systems. In general the SkyCAP server, either a 1RU Linux computer or Windows server, is generally rack mounted in a shipboard or major command post ashore environment, acts as the principal relay point for either direct GCCS-M to GCCS-M traffic or for C2PC Gateway to C2PC Gateway traffic.

The remote tactical node is generally served by a single Windows laptop computer running either GCCS-M 4.X series software or a C2PC client application along with SkyCAP software. These two arrangements are shown in the following diagram.



This configuration allows the SkyCAP system to act as the assured IP "pipe" to pass all types of network data via one of three methods:

a. The system can serve as a direct extension of standard GCCS-M network communications.
b. The system can serve as a C2PC Gateway to C2PC Gateway path serving multiple remote C2PC workstations.
c. The system can support individual high priority mobile units, such as RECON team, with direct connectivity to the C2PC Gateway.

SkyCAP can generally support 6-8 network "nodes" in such a configuration on any given satellite channel. Total number of hosts supported is a maximum of 64. The directly supported nodes are those that are likely to be continuously or nearly continuously transmitting. Thus, while the maximum number of nodes on any SkyCAP link is 64, only 6-8 of those should be transmitting or queuing to transmit at any given time. With C2PC the system performs much better when operating in the gateway-to-gateway configuration.

The inclusion of EDSS capability into the C2PC suite of software segments will allow better use of the Rapid Response Planning Process (R2P2) via the integrated planning tools built within the EDSS segment. These tools include:

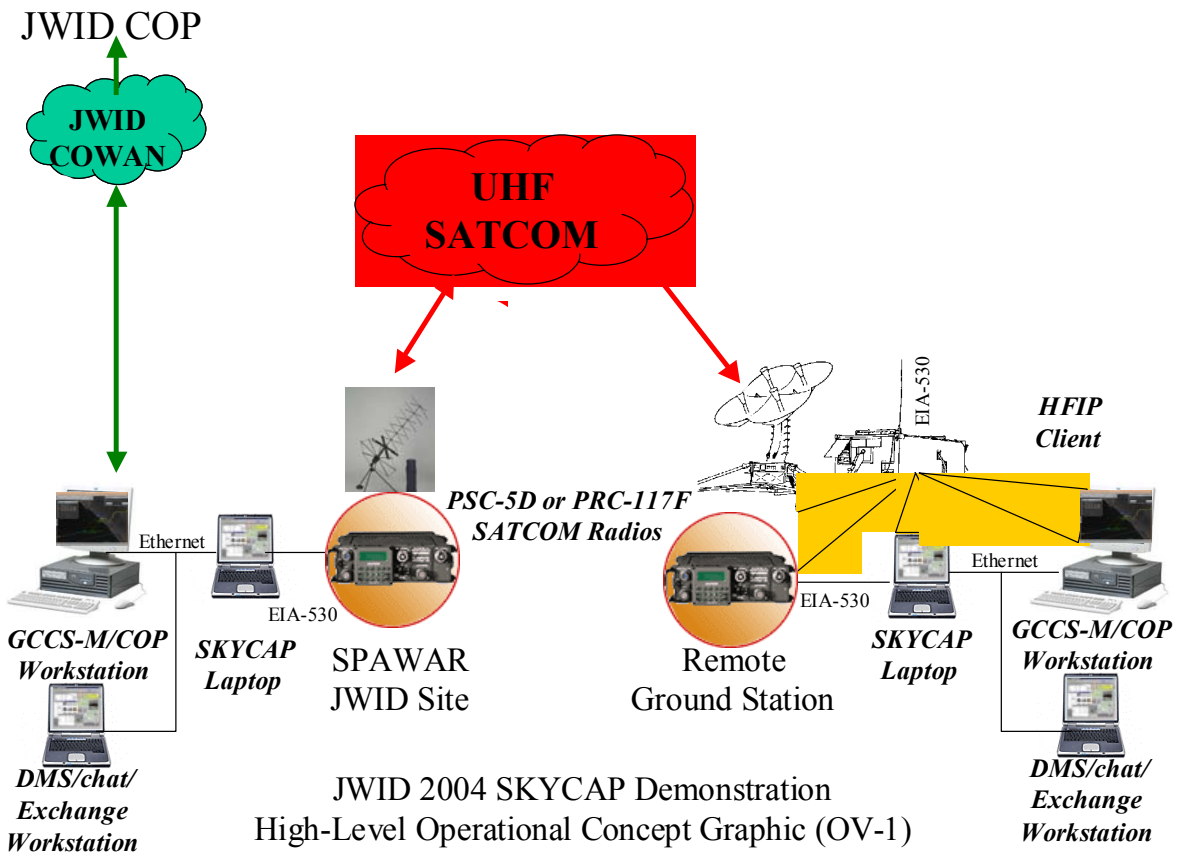
a. Automated distribution of assault geometry and transit paths
b. Linkage to mine warfare reports
c. Automated importation of landing serial data from current USMC logistics systems such as MDSS II and ICODES.
d. Improved tracking of ship to shore movement status including automated Personnel, Cargo and Vehicle components of the PCVT report. NOTE: EDSS handles the Time portion of PCVT via manual input of voice reports as they occur.
e. Automated assignment of serial items to assault craft
f. Automated timing calculations based on adjustment to H and L Hour
g. Distributed database generation with ability to "merge" separately prepared databases into a common plan at the higher staff level

The shift of both MEDAL and EDSS into the Windows operating environment (via the GCCS-M 4.X operating environment) also implies that field mobile units and small ships can consider operating Windows laptops with GCCS-M 4.X software and either MEDAL or EDSS (or both) segments while simultaneously running SkyCAP for data exchange. These advances have resulted in recent Navy approval of specific Naval Change Requests authorizing laptop configurations of both MEDAL and EDSS for use on various platforms.

Recent Operational Testing

The configuration shown below was tested by SPAWAR during the Joint Warrior Interoperability Demonstration (JWID) 2004 event (June 2004). SkyCAP was inserted into the normal network IP traffic flow between the main JWID "TOP COP" GCCS tactical picture and a remote GCCS-M node simulating a detached unit. Both GCCS machines were using only their normal NETPREC network interfaces.

This configuration was chosen as the most likely use of SkyCAP functionality in conjunction with GCCS-M data exchange systems. Typical GCCS-M OTH-Gold messages are on the order of 1-2 Kilobytes of data transmitted as ASCII text messages. Within the MEDAL and EDSS segments, these messages make up a very small percentage of overall GCCS-M data exchange. As a result a SkyCAP network supporting MEDAL or EDSS data exchange does not come close to using the available bandwidth. However, when all GCCS-M track distribution (contact and J-Unit) messages are included the SkyCAP link can become very crowded as a result of the increased numbers of messages.



JWID 2004 SKYCAP Demonstration
High-Level Operational Concept Graphic (OV-1)

The JWID Assessment Team provided assessment of SkyCAP as a potential tool for extending the GCCS/GCCS-M tactical picture. The following comments are extracted from the JWID 2004 Assessment:

"SkyCAP is a GOTS software data control solution to provide netted I/P access over half duplex low data rate satellite and terrestrial RF links. The SkyCAP goal was to provide assured IP connectivity for tactical data systems including mail, web browsing, ftp, chat and other network functions. HF IP, a similar STANAG 5066 based system designed for terrestrial comms, showed potential for use on other tactical (HF/VHF) radio networks.

The objective for SkyCAP was to demonstrate Situational Awareness. SkyCAP demonstrated significantly improved methods of providing IP connectivity to existing GCCS-M tactical decision aids using current tactical radio systems. For the capabilities that were demonstrated in JWID, using the hardware and system set-up listed in this report, this trial was successful.

- *SkyCAP successfully demonstrated objective of Situational Awareness. The SkyCAP/EDSS combination demonstrated significantly improved methods of providing IP connectivity to existing GCCS-M tactical decision aids using current tactical radio systems.*
- *As viewed from the SPAWAR site, SkyCAP successfully demonstrated the SkyCAP SATCOM assured IP software suites.*
- *SkyCAP demonstrated the capability to perform as RF extensions of the wired LAN for all types of IP-based traffic.*

- *The systems successfully passed the following types of data:*
    - *Standard GCCS-to-GCCS traffic in the form of USMTF/OTHG text messages via the GCCS NETWORK/NETPREC interfaces to a remote node representing a small tactical field unit. This was accomplished via both standard shipboard (WSC-3) and field manpack (PRC-117F) radio systems.*
    - *C2PC traffic as an extension of the GCCS track picture from one master Gateway to two remote Gateway/client workstations representing small ships. This was accomplished using standard field HF radio systems.*
    - *Imagery files (JPEG format was used, although any file type was possible).*
    - *Chat using Microsoft Chat.*
    - *Web browsing using standard Internet Explorer.*

Principal problems noted were the tendency of the JWID TOP COP to overload the low-bandwidth RF links when there were large amounts of tracks and track movement. Both SkyCAP and HFIP appeared to work best in this environment when the tracks being transmitted were limited to specific geographic areas, both reducing the number of track update transmissions and the total numbers of tracks. This did not appear to affect the chat circuit or file transfers as much because they used much less bandwidth than the near constant track update stream. This validates probable use of these systems as "local tactical" extensions of the wired network vice "global" data pipes for large volumes of traffic."

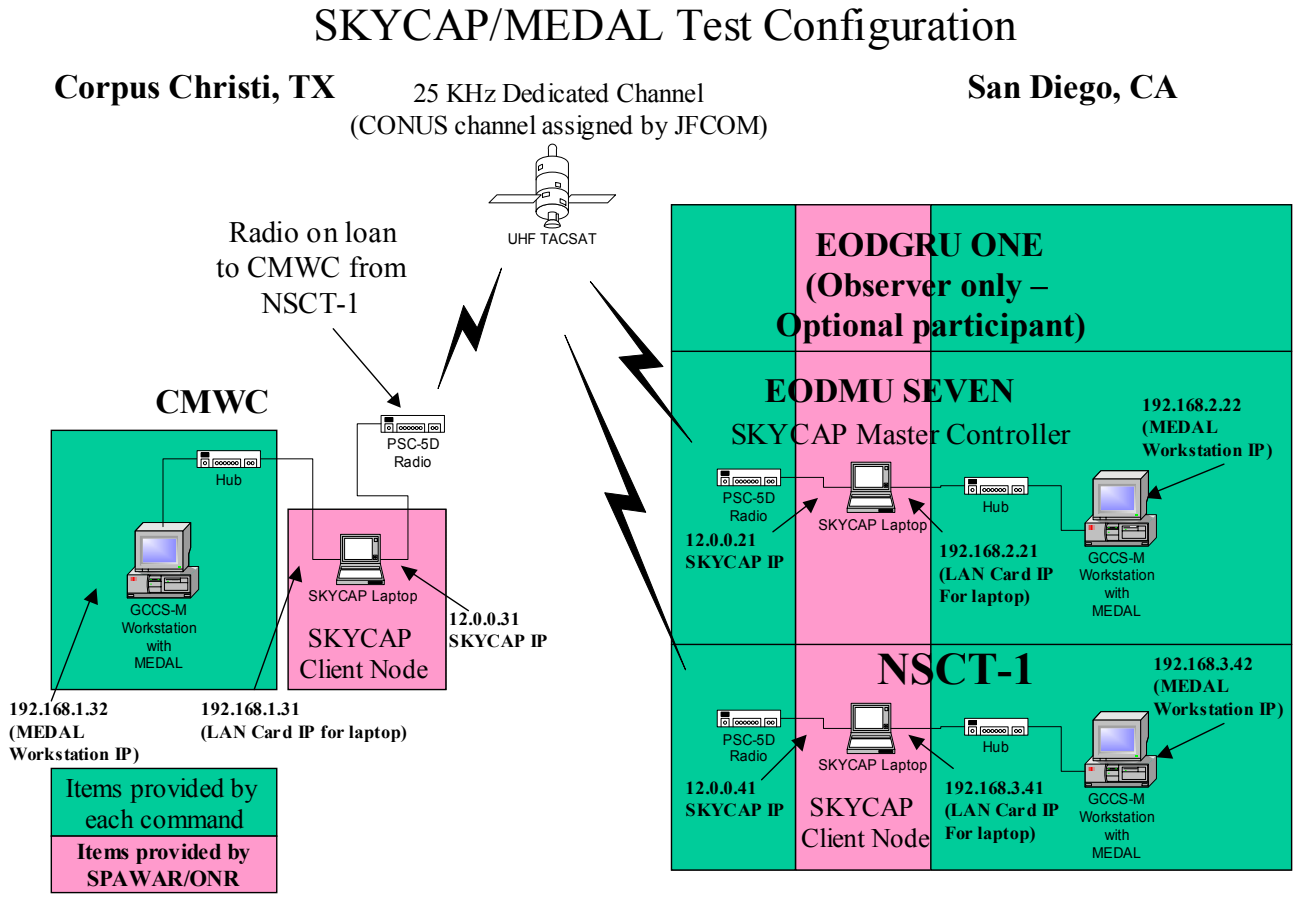
The following additional items were pertinent to the overall SKYCAP performance in JWID 2004:

a. SkyCAP was successful in demonstrating GCCS track and overlay distribution using either 25 KHz or 5 KHz dedicated satellite channels.
b. Data rate for 25 KHz was 38.4 Kbps. Data rate for 5 KHz channel was 9600 bps.
c. Active track databases were in excess of 400 tracks for much of the event. SkyCAP tends to perform better in keeping track databases in synchronization when tracks are filtered by the originating station to certain geographic areas. This is in keeping with a view of using SkyCAP in a "local tactical" mode vice a general "world wide" IP delivery/transport service.
d. Careful track management is required when using SKYCAP as the primary method of track message delivery.
e. Tunneling was activated during various test periods. Tunneling, when configured and operating correctly, can significantly reduce (i.e., by a factor of more than 50%) TCP connection/handshaking message packets.
f. SkyCAP performance was validated on standard shipboard radio systems (WSC-3) and field tactical radio systems (PRC-117F/PSC-5D).
g. EDSS and MEDAL OVLY2 messages were easily exchanged between the GCCS nodes validating SkyCAP as a method to extend these Tactical Decision Aids to field environments.

The principal problem noted during JWID 2004 concerned the requirement for careful track management when using SkyCAP to extend the wired GCCS network to the field. Large track databases with a high degree of track movement can clog a low bandwidth pipe very quickly resulting in increasing time-late status for track updates. While JWID did not support a Force Over-The-Horizon Track Coordinator (FOTC) environment, such procedural control of track management to reduce those tracks sent via SkyCAP would certainly ease the situation.

SkyCAP and MEDAL

Following the successful JWID demonstration SPAWAR PMW-170 began negotiations for a series of follow-on field exercises with mine warfare forces, specifically highly mobile Explosive Ordnance Disposal (EOD) detachments and Naval Special Clearance Team One field detachments. A series of field tests resulted in the successful use of SkyCAP to pass MEDAL mine warfare data over 25 KHz and 5 KHz SATCOM and selected Line-of-Sight (LOS) channels in March 2005. The initial desire of this series of tests was to validate SkyCAP performance while acting as a conduit for MEDAL data generated by small mobile Unmanned Underwater Vehicle (UUV) detachments. These detachments use a variety of technologies to search for mines, with the resulting data imported directly into MEDAL. These detachments are usually operating in field locations far removed from standard network connectivity. However, each of the commands has a full complement of UHF SATCOM-capable radio systems, which were normally used for voice only operations. The configuration for this series tests is shown in the following diagram.



Initial testing showed that careful attention must always be paid to network routing tables and physical connections between the components of the test. However, a successful test involving a full "MEDAL System Operational Verification Test (SOVT)" was accomplished on 1 March 2005 using assets from Naval Special Clearance Team One. This test was completed under rigorous field conditions with use of live Pacific UHF tactical (FSC and UFO series) satellites with "look angles" of less than 10 degrees. The ability of SkyCAP to perform successful GCCS-M-to-GCCS-M data exchange in these conditions at the margins of satellite viewing capability demonstrated the built-in automatic forward error correction functionality inherent in SkyCAP. During these tests, observed by Navy personnel from NSCT-1 and EOD Mobile Unit Seven, the full range of GCCS-M and associated network traffic such as chat and file/image transfer were all accomplished.

Subsequent testing included multiple field events with Explosive Ordnance Disposal Mobile Unit Seven in San Diego. These tests centered on the ability of SkyCAP to provide data connectivity while operating in UHF Line-of-Sight (LOS) mode. These tests were structured around the requirement to use SkyCAP to transmit mine contact and imagery snippet information from small boats operating in conjunction with EOD missions. Over the course of several weeks in March and April the EODMU-7 communications teams were successful in relaying chat and file transfer functions via the UHF LOS path at data rates up to 64 Kbps.

The success of these tests resulted in a proposal to use SkyCAP in a major Homeland Defense exercise called Lead Shield III in May 2005. During this exercise, which is still in the planning stage as of the preparation of this paper, SkyCAP is being proposed for use in a combined Navy (EOD units and NSCT-1) network for GCCS-M/MEDAL data distribution. Results of this exercise are expected to be a major factor in ongoing consideration by the Coast Guard for use of SkyCAP as an air-to-ground IP data path for C-130 maritime patrol aircraft.

Summary

The ability of SKYCAP to link remote tactical units and stations via a common IP pipe means even greater ability to generate and disseminate command and control data to all units in a timely manner. Insertion of the SKYCAP segment into the GCCS-M/C2PC environment will provide increased options for providing IP bandwidth to tactical units using their existing legacy communications systems. Coupling this development with EDSS in the C2PC software suite and MEDAL for mine warfare forces will provide more rapid distributed operational planning. Ongoing SKYCAP and EDSS/MEDAL development is at the forefront of providing improved Power to the Edge for today's warfighters.