INTEGRATION OF IP-PACKET DATA TRANSFERS WITHIN UHF DAMA

Gary Huckell, Gary Clinesmith, Sid Graser
SPAWAR Systems Center
San Diego, California

Edward W. Chandler
Milwaukee School of Engineering (MSOE)
Milwaukee, Wisconsin

ABSTRACT

The Navy is planning to update its operational Information Exchange Subsystems to incorporate Internet Protocols (IP) to create a more robust and flexible networking environment. There is also a growing demand for Internet connectivity for mail services and access to data available on the World Wide Web (WWW). The existing military standards for UHF DAMA do not provide for efficient UHF resource utilization among users wanting WWW type data access characterized by dynamically changing data-rate needs for each user. This paper proposes a data-link layer protocol that will efficiently handle the variable-rate data needs of users. The packet format proposed is similar to that used on an Ethernet local area network. It is recommended that the UHF DAMA military standards currently undergoing revision include a protocol for transmitting and receiving variable-rate data.

INTRODUCTION

There is a growing demand for Internet connectivity and World Wide Web (WWW) type data accessing via UHF communication links. Many shipboard military users work in office environments and desire the same connectivity with the Internet or an equivalent military network as is available to them ashore. Often their only way to obtain this connectivity while aboard ship is via a UHF satellite communication (SATCOM) link.

The existing military standards[1,2] for demand-assigned multiple access (DAMA) operation over UHF SATCOM provide for fixed-rate "circuit" services, and fixed-length "message" services. Neither of these mechanisms in the existing DAMA standards can provide efficient UHF resource utilization for WWW type access. A capability is required that allows a time slot on a UHF channel to be shared by many users while providing low latency variable-rate data transfers. The standards for UHF DAMA are currently undergoing revision. These revisions should include a protocol to facilitate the handling of the variable-rate data requirements of users sharing a communication service. In particular, the protocol specified must support the efficient handling of Internet Protocol (IP) datagrams.

One thing that can be done to more efficiently handle IP datagrams over UHF SATCOM is to minimize the IP header information that is conveyed. One recent paper[3] discusses minimizing packet header sizes for efficient tactical operation over radio links. Another paper[4] addresses the problem of handling Transmission-Control-Protocol/IP (TCP/IP) transfers over high-error-rate, large-delay narrowband channels. Our goal is not to develop a specific method for handling the IP datagram format and transfer mechanisms, but to develop a protocol that could be used more generally to accommodate a group of users with dynamically varying data-rate needs.

The revised UHF DAMA standards are to address data transfers at the data-link layer. While the proposed protocol is expected to allow many different network-layer and transport-layer protocols to operate efficiently over UHF satellite channels, its efficiency for supporting a group of terminals using protocols from the TCP/IP suite was an underlying objective. The proposed protocol will also support MIL-STD-188-184[5] communication protocols, allowing simultaneous data exchanges over a single channel.

To accomplish these goals, each terminal communicates using packets similar in structure to frames used on an Ethernet local area network (LAN). While the Ethernet protocol depends on carrier sensing and collision detection to control access to a shared communication channel, that technique cannot be used efficiently over UHF satellite channels due to the approximately 250 milliseconds (ms) of satellite link delay. Protocols used over UHF SATCOM need to minimize the possibility of contention. This paper describes a proposed packet transfer mechanism, called the Variable Rate Data Packet (VRDP) transfer protocol, for use at the data-link layer. Transport-layer protocols, such as the end-to-end protocols in TCP/IP, would be handled by baseband equipments and are outside the scope of this paper.

BACKGROUND

The military UHF SATCOM frequency allocation is divided into a set of independent 5-kHz and 25-kHz bandwidth channels. A pair of UHF Follow-On (UFO) satellites operates in each of four overlapping satellite coverage areas providing around-the-world coverage. A satellite pair operating together provides a total of 78 channels for use within each operating area. Of these 78 channels, there are 42 5-kHz channels, 34 25-kHz channels, and two 25-kHz fleet broadcast downlinks which are fed by jam-resistant SHF and EHF uplinks. Channel capacity is limited by the UHF spectrum allocation for military use, not by an inability to build and launch satellites. Because of the limited number of UHF channels, demand for UHF channels greatly exceeds the available resources.

In addition to the scarcity of resources, throughput is very limited on UHF SATCOM channels. Satellite transponders for each channel are nonregenerative and hard-limiting. The nonregenerative satellite transponders do allow terminals to use newly developed modulation and coding techniques, but the hard-limiting prevents use of some bandwidth-efficient modulation techniques that depend on amplitude modulation. Current UHF DAMA waveforms use BPSK and QPSK modulation to operate at user rates as high as 6000 bps over a 5-kHz channel and 32 kbps over a 25-kHz channel. MIL-STD-188-181B[6], for use on dedicated UHF channels, will introduce Multi-h Continuous Phase Modulation, making it possible to operate existing shipboard UHF SATCOM systems at user rates as high as 9600 bps over a 5-kHz channel and at least 48 kbps over a 25-kHz channel.

EVOLUTION OF DAMA

DAMA standards were introduced in an attempt to make more efficient use of the limited UHF SATCOM resources. DAMA provides multiple access to a UHF channel through use of time-division multiple access (TDMA). Using TDMA, channel time is divided into repetitive equal-length intervals known as frames, and frames are subdivided into smaller intervals know as time slots. There are three general types of time slots: (1) orderwire time slots, used for access control and timing, (2) system support time slots, used for terminal ranging and link-quality measurements, and (3) communication time slots, used for baseband communications. A communication time slot can support a half-duplex communication service. Time slots for connections that must operate 24 hours per day are configured for automatic assignment by the DAMA controller. Any user terminal can request use of time slots by transmitting a request in a return orderwire time slot. The channel control system assigns time slots based on availability of resources and the priority of the requested communication service. Point-to-point, conference, and network communication services are currently supported.

The two current DAMA standards that define operation over UHF satellite channels are MIL-STD-188-182A[1] for operation on 5-kHz channels and MIL-STD-188-183A[2] for operation on both 5-kHz and 25-kHz channels. MIL-STD-188-182 protocols were originally developed to support an Air Force requirement for around-the-world messaging among Military Airlift Command (MAC) aircraft. MIL-STD-188-182 can support user data rates as high as 2400 bps and provides a messaging capability. MIL-STD-188-183 protocols were originally developed to allow the Navy to increase circuit availability and reduce radio requirements by multiplexing several networks on each channel. MIL-STD-188-183 can support user data rates as high as 16 kbps, but generally is used in a mode where the maximum data rate available is 2400 bps. The problem of over-demand for UHF resources became so great that the Joint Chiefs of Staff (JCS) mandated a requirement to transition all UHF SATCOM users over to DAMA. JCS made the decision to require all terminals using UHF SATCOM to be certified to be interoperable with both MIL-STD-188-182 and MIL-STD-188-183. While each standard may have been sufficient for its intended purpose, the two standards are not interoperable with each other and are not capable of satisfying all current and developing user requirements. Even with the recent publication of the improved "A" versions for both standards, interoperability and control problems still exist.

DAMA protocols have not kept pace with evolving communication requirements. There are many more requirements for voice circuits now than existed when the original DAMA standards were written, and on 25-kHz channels these requirements compete for the limited number of 2400 bps time slots available. Most of the older transport-layer data-network protocols in use today were designed to operate synchronously over circuits operating at known fixed rates. Many existing data communication requirements are still being satisfied using 75 bps "teletype" networks. Newer data protocols are generally designed to move data asynchronously, i.e. at variable data rates. Because of these and other changes in user needs, the standards are again being updated. An improved capability for handling data-rate-independent protocols is a high-priority goal.

In the updated standards the VRDP protocol would operate within an assigned time slot on a UHF DAMA channel. The time slot could be located on a control channel or on a slave channel (as defined in MIL-STD-188-183A[2]). A slave channel doesn't contain orderwire, allowing a time slot on a slave channel to occupy a greater fraction of the frame. Although the VRDP protocol could operate on a 5-kHz DAMA time slot, lower data rates supported on 5-kHz channels will more severely limit the composite data transfer capability of the protocol. While operating in a time slot, the central controller that issues all assignments can dynamically adjust the size of the time slot based upon the amount of activity in the time slot and other requests for UHF resources.

CHARACTERISTICS OF AN IP CHANNEL

When Internet protocols are used for exchanging e-mail or WWW browsing, the user typically spends the majority of a session reading or typing. Both of these actions require very little channel capacity. Typical TCP/IP datagrams used during these periods contain less than forty bytes of data. The user typically spends a relatively small amount of time sending and receiving email, or downloading files, actions requiring much more channel capacity. While little channel capacity may be required during times of low activity, there is still a requirement to send and receive each IP datagram with minimum delay since the TCP/IP flow-control protocols are sensitive to time delay. The VRDP protocol dedicates a subslot within the VRDP time slot to each connected terminal. This dedicated user subslot provides a contention-free transmit opportunity in every DAMA frame (1.3866 seconds), guaranteeing minimum latency for short data packets. The dedicated subslot has sufficient capacity to completely satisfy the communications needs for many users. The portion of the VRDP time slot not dedicated, called the shared portion, is used to communicate longer data packets, providing the variable data-rate capability. A combination of centralized and distributed control is used to allocate the shared portion of the VRDP time slot.

A terminal's ability to operate on a VRDP service depends on both its design and mission. Because of the approximately 250 ms of satellite link delay, terminals that transmit and use half-duplex radios cannot depend on being able to receive bursts from every connected terminal. Since the VRDP distributed-control protocol proposed here requires all connected terminals to receive all bursts in the VRDP time slot, half-duplex terminals are limited to the use of the centralized control protocols to transmit in the shared portion of the frame. It is anticipated that many terminals will be able to connect to IP services over an asymmetric communication link, using Global Broadcast Service (GBS) for the high-speed downlink and UHF SATCOM for the low-speed uplink (the reach-back channel). These terminals will have low average uplink bandwidth requirements and could operate transmit-only in their dedicated subslots. The terminal being used to receive this reach-back data could operate receive-only, but its receiver would need to be dedicated to the VRDP time slot. Terminals that both transmit and receive normally require a full-duplex radio dedicated to the VRDP service since packets addressed to these terminals can occur during any portion of the VRDP time slot.

Terminals that must perform active ranging can continue to range on their home channel if ranging does not interfere with communications on the VRDP time slot. Terminals that must dedicate their radio to the VRDP service can range by measuring the round-trip delay of any transmitted burst. When the VRDP service is allocated the full capacity of a channel, multi-port terminals needing to both transmit and receive within the VRDP time slot are required to give up normal multi-port operation. The future utility of multi-port terminals needs to be addressed since the multi-port concept is closely associated with the idea of fixed-rate communication services. VRDP protocols will allow any terminal connected to a VRDP service to establish multiple virtual circuits. DAMA control would be simplified if each terminal used only a single address.

DESCRIPTION OF PROTOCOL

As is the case with the existing UHF DAMA standards, a terminal begins its operation by acquiring the orderwire sent by the channel controller on the terminal's "home channel," and achieving range lock either by transmitting a range burst and measuring round-trip delay or through passive ranging methods. The terminal then transmits a request-type orderwire message, indicating that the request is for a VRDP service by using a prearranged network address for the service. The request also indicates if the terminal will be operating transmit-only, receive-only, or will both transmit and receive. The channel controller responds by transmitting an orderwire message to assign the terminal to the VRDP service. The orderwire message from the controller informs the connecting terminal of the channel and time slot on which the VRDP service is operating, the position of a dedicated user subslot within the VRDP time slot (for transmitting terminals only), and the number of dedicated user subslots in the VRDP time slot.

While the orderwire message from the channel controller needs to be addressed directly to a connecting terminal, the message includes the VRDP network address to allow all connected terminals to identify the message. The channel controller sends status and makes global changes to the operation of the VRDP service by addressing these orderwire messages directly to the network address associated with the service. All terminals operating on a VRDP time slot must continue to receive their home channel controller's orderwire messages. In addition to monitoring for orderwire messages that directly affect individual terminals, terminals must receive all orderwire messages affecting the operation of the VRDP service. Terminals use the home channel orderwire to request disconnection from a VRDP service and to change the terminal's operational mode. When a terminal is disconnected from a VRDP service, the channel controller may need to adjust the dedicated user subslot assignments to fill in the unused subslot.

The channel controller is also responsible for selecting one of the terminals connected to the VRDP service to be the service controller for the VRDP service. The service controller performs the centralized portion of the centralized- and distributed-control mechanism used to allocate the shared portion of the VRDP time slot. The service controller is always assigned to the first dedicated user subslot of the VRDP time slot and must have a full-duplex radio available for the full duration of the VRDP time slot.

Terminals request access to the shared portion of the time slot by setting fields within the header of dedicated user subslots. The shared portion of the VRDP frame is cooperatively allocated among terminals requesting additional bandwidth using a combination of centralized and distributed-control. While the use of distributed-control mechanisms avoids the signaling overhead and lengthened response time that can be associated with a centralized controller, it also introduces the possibility of control instability. In any VRDP time slot where a terminal's request to transmit in the shared portion of the VRDP time slot is not received by all other terminals, there is the possibility of non-use or contention. In addition, the satellite link delay (280 ms maximum) interferes with the distributed control mechanism's ability to allocate the first 280 ms of the shared portion of the VRDP time slot. Terminals occupying the last few dedicated user subslots preceding the shared portion of the VRDP time slot do not receive all requests from preceding terminals until well into the shared portion of the time slot.

The service controller uses more stable centralized control mechanisms for the more difficult allocation decisions and solves the fundamental problem associated with half-duplex terminals not being able to hear all activity in the VRDP time slot. The service controller uses requests received during the previous VRDP time slot to make allocation decisions for the current time slot. All unfulfilled requests from the previous VRDP time slot are arbitrated by the service controller, then dedicated allocations, good for only the current time slot, are broadcast in the header of the service controller's dedicated user subslot to all terminals. Unfulfilled requests remaining from the previous VRDP time slot will almost always solve the "first 280 ms problem." New requests in the current time slot compete only for the shared portion of the VDRP time slot not allocated by the service controller.

The distributed control allocation mechanism is intended to be simple since complex issues dealing with fair allocation of the shared portion of the VRDP time slot are performed by the service controller. Space not allocated by the service controller is allocated to unfulfilled requests in the current VRDP time slot based only on priority and order received. During high activity periods, when the shared capacity is being completely allocated by the service controller, terminals requesting additional time will suffer one frame of latency in attaining extra bandwidth. The extra frame of latency under these conditions is not significant since it will usually occur during periods where all of the capacity of the VRDP time slot is being used. Figure 1 shows the structure of the VRDP time slot.

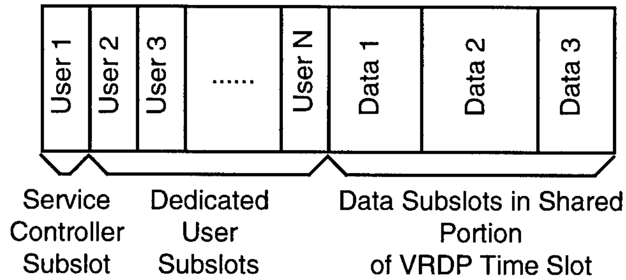

Figure 1. VRDP Time Slot Structure

SUBSLOT FORMATS

This format is similar to an Ethernet frame. Following below are descriptions of the fields in the dedicated user subslot. The length of the data field is fixed at 128-bytes, large enough to hold a minimum-sized TCP/IP datagram with an 88-byte data payload. The length of the dedicated user subslot, including preamble and guard time, is 37.66 ms. Subslot information will be encrypted using a time of day encryption method similar to what is currently used for DAMA orderwire. The Time Slot Number (TSN) will be composed of the frame count from the home control channel supplemented by a value that is based on the location of the subslot within the VRDP time slot. Figure 2 shows the structure of the Variable Rate Data Packet.

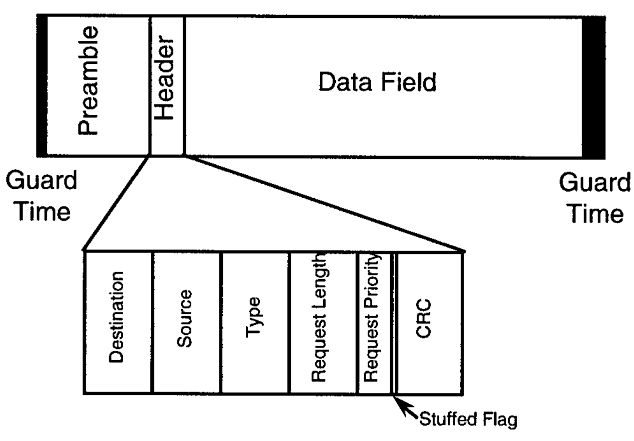

Figure 2. Variable Rate Data Packet

Preamble:
The Preamble field consists of 96 bits of alternating 1's and 0's, followed by a 26-bit framing sequence, then 22 bits of data rate and modulation information. It is from a proposed version of MIL-STD–188-181B.

Destination Address:
The Destination Address field contains the sixteen-bit address of a terminal port, a network address, or all 1's for broadcast to all users on the VRDP service. A standard address resolution protocol (ARP) can be used to map IP addresses to the terminal addresses or a fixed mapping (registered database) can be used.

Source Address:
The Source Address field contains the sixteen-bit terminal port address of the transmitting terminal.

Type:
This sixteen-bit field is analogous to the Ethernet type field, identifying the higher level protocol in use.

Request Length:
A non-zero value in this fifteen-bit field indicates a request for access to the shared portion of the VRDP time slot. This field is set to the number of bytes of data the terminal has queued for transmission. This field is set to zero when the terminal needs no additional bandwidth. While the maximum length of the data field for a burst within the shared portion of the VRDP frame is 1492 bytes, this field accommodates requests for longer lengths to allow the service controller to plan future allocations.

Request Priority:
This eight-bit field contains the priority of the request for access to the shared portion of the VRDP frame. A value of "0" indicates the lowest priority and "FF Hex" indicates the highest priority.

Stuffed Flag:
This one-bit field is set to "0" when stuffing was not necessary in the data field and set to "1" if stuffing was used.

CRC:
The cyclic redundancy check (CRC) is a sixteen-bit value calculated over the control and data fields.

Data:
The Data field contains the data payload, and stuff bits as necessary, to fill the 128-byte field. Stuffing consists of inverting the last bit of the data payload and using it to fill the unused bits in the data field.

Guard Time:
A 1.75-ms interval is planned between subslots to prevent transmission overlaps that could occur due to terminal range inaccuracies. To be consistent with MIL-STD-188-183A, 0.5 ms of the guard time precedes the burst and 1.25 ms follows the burst.

The format and function of the service controller's dedicated user subslot are identical to those for the dedicated user subslot described above, except for the inclusion of extra fields for the broadcast of VRDP service parameters and allocation decisions for the current time slot.

The format and function of the data subslot are similar to those for the dedicated user subslot described above. The data subslot does not contain Request Length or Request Priority fields since requests are made only within dedicated user subslots. The Data field contains a variable length data payload with a maximum length of 1492 bytes. A sixteen-bit Data Length field is added and contains the length of the Data field in bits. Stuffing is not used in the Data field and no Stuffed Flag is included.

CONCLUSION AND FUTURE WORK

The demand for IP related services is growing among military users. Many of these users are in remote locations without access to wired IP networks. Typically, the only way for these users to have IP access is via satellite links. The protocol described here is a preliminary proposal for providing efficient IP type services using a UHF DAMA SATCOM channel. It has not yet undergone the scrutiny of simulation and rigorous testing, but it is a starting point for developing a new data-link layer protocol to be incorporated into the revised UHF DAMA standards for higher-layer messaging and other data transfer applications.

A major concern with the VRDP protocol as presented is the limited number of simultaneous users that can be supported. In addition, when users are inactive, their dedicated subslots waste valuable communication resources. To increase the number of users that can be accommodated, and to improve efficiency, the VRDP protocol should use a mixture of dedicated and contention user subslots. When idle, terminals would give up their dedicated user subslots. When a terminal again needs to transmit, contention user subslots would be used to capture a new dedicated user subslot.

Clearly there are similarities between the structures of existing UHF DAMA frames and proposed VRDP time slots (see Figure 1). The existing UHF DAMA protocols provide time-varying allocations of time slots within DAMA frames, but the allocations are always for fixed-rate or fixed-length transfers. The proposed VRDP protocol provides time-varying allocation of subslots within VRDP time slots, and the subslots best serve applications that do not have to operate at fixed user rates over extended time periods. With VRDP services, the DAMA controller can move user terminals to different VRDP time slots, other time slots, or other channels, and in some limited cases allow particular user terminals to operate in services on several time slots (some of which could be VRDP time slots) and/or channels simultaneously. Although some of the baseband data-networking equipment currently in use was designed to operate through fixed-rate data links, other than voice communication, most of the communication needs are not inherently fixed-rate transfers. For this reason, the proposed VRDP protocol with its built-in DAMA-based variable-rate resource allocations may have a lot of potential as an important element in future DAMA-based systems.

REFERENCES

1. MIL-STD-188-182A, Department of Defense Interface Standard, "Interoperability Standard for 5-kHz UHF DAMA Terminal Waveform," 31 March 1997, U.S. DoD.

2. MIL-STD-188-183A, Department of Defense Interface Standard, "Interoperability Standard for 25-kHz TDMA/DAMA Terminal Waveform (Including 5-kHz and 25-kHz Slave Channels)," 20 March 1998, U.S. DoD.

3. J. W. Strater, "A Reliable Transport Protocol for the Tactical Internet," MILCOM'97 Conference Proceedings, vol. 1, pp. 167-171, Nov. 1997.

4. J. S. Stadler, "A Link Layer Protocol for Efficient Transmission of TCP/IP Via Satellite," MILCOM'97 Conference Proceedings, vol. 2, pp. 723-727, Nov. 1997.

5.MIL-STD-188-184, Department of Defense Interface Standard, "Interoperability and Performance Standard for the Data Control Waveform," 20 Aug 1993, U.S. DoD.

6. MIL-STD-188-181B, Department of Defense Interface Standard, "Interoperability Standard for Single-Access 5-kHz and 25-kHz UHF Satellite Communications Channels," Coordination Draft (unreleased), 25 August 1998, U.S. DoD.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1998	Professional Paper

4. TITLE AND SUBTITLE

Integration of IP-Packet Data Transfers Within UHF DAMA

5. FUNDING NUMBERS

PR: CH77
PE: OPN
WU: DN305503

6. AUTHOR(S)

G. R. Huckell(1), G. Clinesmith(1), S. Graser(1), and E. W. Chandler(2)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Space and Naval Warfare Systems Center(1)
San Diego, CA 92152–5001

Milwaukee School of Engineering(2)
Milwaukee, Wisconsin

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Space and Naval Warfare Systems Command
San Diego, CA 92110-3127

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENTR	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT *(Maximum 200 words)*

The Navy is planning to update its operational Information Exchange Subsystems to incorporate Internet Protocols (IP) to create a more robust and flexible networking environment. There is also a growing demand for Internet connectivity for mail services and access to data available on the World Wide Web (WWW). The existing military standards for UHF DAMA do not provide for efficient UHF resource utilization among users wanting WWW type data access characterized by dynamically changing data-rate needs for each user. This paper proposes a data-link layer protocol that will efficiently handle the variable-rate data needs of users. The packet format proposed is similar to that used on an Ethernet local area network. It is recommended that the UHF DAMA military standards currently undergoing revision include a protocol for transmitting and receiving variable-rate data.

Published in Proceedings of MILCOM'98, pp. 452-456, October 1998.

14. SUBJECT TERMS

Mission Area: Communications
demand assigned multiple access (DAMA)
Internet Protocols (IP)
Transmission-Control-Protocol/IP (TCP/IP)
UHF satellite communication (SATCOM)
Variable Rate Data Packet (VRDP)

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	Same as Report

21a. NAME OF RESPONSIBLE INDIVIDUAL	21b. TELEPHONE *(include Area Code)*	21c. OFFICE SYMBOL
G. R. Huckell	(619) 553-2141	Code D844