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GUNSHIP PROGRAM WIRELESS HARDWARE AND HEADS-UP WEARABLES TRADE STUDY REPORT

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The purpose of this program was to greatly increase the accessibility and usability of technical documentation required by flight line members and air crews, in particular for the Air Force Special Operations commands' AC-130 Gunships.

The focus of the final report is a trade study, which examined robust portable maintenance aids (PMAs), as deemed necessary to equip maintenance and air crew members for accessing and utilizing electronically formed technical information.

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1. PURPOSE

The system design for the Gunship maintenance system must provide for adequate communications bandwidth and wireless network resources to process the anticipated data rate on the airfield maintenance flight line. The implementation of wireless equipment that can effectively and reliably process the anticipated data load as well as interact with the user under the stress of the operational environment is critical to the success of maintaining the Gunship aircraft on the maintenance flight line.

The purpose of this wireless Trade Study is to provide recommendations for a robust reliable wireless network and a heads-up wearable Portable Maintenance Aid (PMA) Computer to support the electronically transmitted technical manuals to the aircraft maintenance flight line. The objective of this wireless trade study is to recommend a reliable wireless automated system for ease of use for the Gunship maintenance crew. Multiple adjacent independent networks (either static or mobile) on the maintenance flight line for each C130 aircraft being maintained can be accomplished by using wireless bridges which will simultaneously access common resources (servers, databases, master station, etc.) with no interference with other wireless networks. Automating the Gunship maintenance activity will relieve some of the cumbersome paper maintenance manuals being hauled to the airfield and will provide user-friendly lookup of maintenance procedures and checklists for proper maintenance of the Gunship.

In addition, each Gunship maintenance crew member will have a heads-up wearable PMA with a video eyepiece and microphone which will allow him to have total hands-free to work on the Gunship and to request data from the most current accurate version of the Interactive Electronic Technical Manual (IETM). By generating an AIMSS database containing the IETM maintenance data with corresponding bar code numbers from each of the C130 aircraft components in the database, the maintenance crew can use a bar code scanner from the PMA to quickly and efficiently access the proper section of the maintenance manual on-line. Using the voice over IP feature, the maintainer can request further detail look-ups in the manual via voice commands.

This study was conducted by selecting the top six wireless manufacturers or suppliers and evaluating their wireless hardware in the Gunship lab at the Raytheon facility in Fullerton, California. Various PCMCIA cards, access points, bridges, switches, routers, ATMs, antennas, etc. were borrowed from state-of-the-art commercial-off-the-shelf (COTS) wireless manufacturers or suppliers, and the wireless hardware was evaluated. This report provides actual performance data based on quantitative data collection indoors and outdoors, and throughput prediction estimates based on the overall performance of data/voice/video over IP. It also summarizes the various COTS wireless products that met the Gunship requirements to support data, voice, and video over IP on the aircraft maintenance flight line, and can perform reliably and efficiently in the flight line maintenance environment.

2. PROBLEM

Currently, the maintenance and logistics on the C130 Gunships is a cumbersome activity with large volumes of IETMs and limited or no automation. Maintaining operability of the Aircraft is vital to its mission. Having the technical manuals available during maintenance, inspection and checkout of the aircraft is essential to performing these tasks. Storing these various maintenance publications in electronic format reduces the shear volume and logistics associated with hard copy manuals. This trade study was conducted to select the most reliable, robust, efficient, and flexible wireless hardware that can provide the most effective wireless seamless solution to accessing electronic media on the flight line.

Wireless manufacturers and suppliers will reduce storage space and transportation costs associated with alternative hard copy of technical manuals. In that respect, electronic manuals can be centrally located and have the latest change orders incorporated. Thus, electronic manuals can increase the efficiency within the maintenance library to updated releases in a timely manner to assure that the aircraft maintenance crews are using the latest revisions

With each Gunship maintainer using a heads-up wearable PMA with data, voice, and video over IP feature, the maintainer will be able to easily request maintenance data, maintenance checklists, and have total hands free to work on the Gunship aircraft.

3. EVALUATION

3.1 Technical Approach

This trade study is the evaluation of six wireless manufacturers or supplier products. Five of the wireless manufacturers supply the Frequency Hopping Spread Spectrum (FHSS) wireless equipment, and all six supply the Direct Sequencing Spread Spectrum (DSSS) wireless equipment. The objectives of this trade study are as follows:

A. To emulate the transfer the large volumes of the IETMs over a wireless Local Area Network (LAN) and to evaluate the performance of each of the COTS wireless manufacturers or suppliers:

   1. Lucent Technologies (FHSS and DSSS)
   2. Nortel Networks (FHSS and DSSS)
   3. Proxim (FHSS and DSSS)
   4. Symbol Technologies (FHSS and DSSS)
   5. Breezecom (FHSS and DSSS)
   6. Wi-LAN (DSSS only)

   Raylink, a subsidiary of Raytheon manufactures a wireless PCMCIA card with limited capabilities. The Raylink card does not meet the Gunship requirements and was therefore not evaluated in this trade study.

B. To collect and evaluate quantitative data and to make an assessment of which wireless solution is the most robust, reliable, best performance, and has the most potential for growth with the rapidly changing integrated wireless products.

C. To propose the best state-of-the-art high performance wireless network design for setting up antennae and networks on the C130 airfield.

Section 4 contains a discussion of each of the six COTS wireless manufacturers or supplier products, the features of their products, and how their wireless products will meet the Gunship requirements to transfer the IETM data, to transfer video, and to communicate via voice on the flight line using the various wireless networks. This section describes six proof-of-concept demonstration scenarios that will provide an indication of the flexibility of the laboratory capabilities at Fullerton, California. Each of the COTS wireless manufacturers or supplier's hardware that meets the basic Gunship requirements will be further evaluated in each of the six proof-of-concept demonstration scenarios. Extensive laboratory testing was performed to collect, evaluate, and analyze data throughputs to provide a recommendation for the best wireless solution for maximum performance and reliability for the Gunship Maintenance Program. The Fullerton lab environment also has the capabilities to act as a Ground Entry Point (GEP) to validate all interfaces and software. The Fullerton facility can also ensure that the Gunship software is DII-COE compliant by testing on our internal LANs with Raytheon's CII-COE laboratory. The Fullerton facility is ISO9001 certified.

Section 5 contains a discussion on the heads-up wireless PMA from Xybernaut which was used to validate the voice and video over IP requirement. On the PC Windows-based laptops, two voice recognition packages were evaluated:

1. IBM Via Voice
2. Dragon Speak using the Parrot headset

The voice recognition and video evaluation was limited due to the limited number of wireless manufacturers that support video over IP. Since technology is evolving, improving, and ever-changing at such a rapid pace every day, there are better, faster, and more robust voice recognition packages being developed and more wireless manufacturers are developing faster, clearer, better resolution video over IP capabilities.

Section 6 discusses the Raytheon Fullerton lab configurations used to collect data for analysis. Quantitative data was collected and analyzed to compare the various wireless manufacturer's product in order to propose the best recommended approach for automating and saving time and materials on the Gunship maintenance program.

Section 7 discusses the configuration alternatives and quantification of the evaluation criteria. It provides a discussion of the assumptions made in performing the study as well as, major consideration that affected the outcome and recommended alternatives used in selecting a product that will fit the needs for electronic technical manuals. A performance matrix for various manufacturers of wireless devices will clearly show the most reliable solution for automating the Gunship maintenance program. This section will provide a recommended wireless automated proposal concluded from this study and an alternative wireless automated solution.

Section 8 contains future interest from other government agencies and programs that may have similar wireless applications for automating a process or procedure.

4. COTS WIRELESS MANUFACTURERS/SUPPLIERS

4.1 Wireless Manufacturers/Suppliers Evaluated

A select group of six manufacturers/suppliers of wireless equipment was evaluated in this trade study. In evaluating each of the six manufacturer's wireless equipment, all of the wireless access points and bridges used the simple "rubber ducky" antenna. If an HPA or more sophisticated antenna is selected to repeat some of the proof-of-concept demo scenarios, the signal and range data should improve and will increase the data throughputs and performance.

4.1.1 Lucent Technologies

Lucent Technologies manufactures both the FHSS (1 to 2 Mbps) and the DSSS (11 Mbps) wireless equipment. Lucent is one of the leaders in wireless technology and can provide a total solution to supporting the IETM data, voice, and video over IP transfers. Lucent Technologies briefed Raytheon on their wireless hardware and how Lucent's wireless products can support the transferring of data, voice, and video over IP to support the Gunship program.

Lucent Technologies loaned Raytheon the (11 Mbps) DSSS wireless Access Point and 3 DSSS PCMCIA cards for evaluation. Lucent installed the Wave Manager software to monitor the signal, noise, and signal/noise ratio during wireless transmissions. In a clean environment, the DSSS wireless hardware performed well. An anomaly occurred by accident, data was being transmitted from the Raytheon "High Data Link" lab and was interfering with the data transmissions in our communication engineering lab. By using a scope, it was observed that there was interference in our 2.4-GHz bandwidth. The same interference problem was observed when the Wi-LAN DSSS bridges were tested. Several more days of controlled testing was done. The data throughputs and performance was good when transmitting in a clean environment. However, when there is other data being transmitted, the performance of DSSS wireless hardware is degraded and becomes unreliable since DSSS uses only an 11-channel hop sequence. The main problem with applying DSSS is the so-called near-far effect. This effect is present when an interfering transmitter is much closer to the receiver than the intended transmitter. Although the cross-correlation between the intended transmitter code A and the interfering transmitter code B is low, the correlation between the received signal from the interfering transmitter code B and code A can be higher than the correlation between the received signal from the intended transmitter code A. The result is that proper data detection is not possible and the data packet is lost.

Considering the Gunship maintenance site where there are many different types of communications links happening simultaneously, we evaluated the frequency hop (FHSS) wireless hardware for the IETMs transfers which experienced minimal effects from the other data transmissions in the testing area. The FHSS wireless hardware uses a 79-channel hop sequence, therefore the FHSS experiences a limited number of hits (interference) with each other. This means that if a near-interferer is present, only a number of frequency hops will be blocked instead of the whole signal. From the hops that are not blocked, it should be possible to recover the original data-message and thereby ensuring packet throughput reliability.

Since there were throughput and packet delivery problems with both the Wi-LAN and the Lucent DSSS wireless hardware, Lucent then provided Raytheon with their FHSS wireless PCMCIA cards and Access Point for evaluation. The Lucent FHSS wireless Access Point and three FHSS

PCMCIA cards performed well in both a clean environment and in a heavily transmitted environment.

For proof-of-concept demo scenarios 1, 2, 3, and 6 that were performed in the lab, the Lucent FHSS wireless products had strong signals, good throughput rates for larger data packets, better voice and video than the other wireless products evaluated, and performed very well.

For the peer-to-peer data analysis that was done outside from the roof to a mobile vehicle, the average time to transmit 1400 bytes/packet was 208 milliseconds with a range of approximately 0.3-mile LOS. For scenario 6, a web cam video camera, "Dragon Speak," and a "Parrot" headset was used both indoors and outdoors to seamlessly transfer data from one wireless laptop to another wireless laptop. The average time to transmit data (a large 1400-byte packet), voice and video was from 31 to 138 milliseconds, depending on the range. When a smaller data packet (32 byte) was transmitted from one PMA laptop to another laptop in the laboratory environment (10-foot range between the two laptops and the Jaguar Access Point), the average time to transmit data was from 56 to196 milliseconds. Because of the high wireless protocol overhead, Lucent Technology's technical support recommended that larger packets be transmitted to improve the wireless network's performance and throughput.

4.1.2 Nortel Networks

Nortel Networks manufactures both the FHSS (2 Mbps today and a new product at 11 Mbps that was released in 2Q00) and DSSS (10 Mbps) wireless equipment as well as the Access Point, Passport 6400 ATM/router, the Accelar 8600 router switch, the Baystack 450 switch, and the SL100 PBX (the SL100 PBX is installed at all U.S. Air Force Bases (AFBs)). Nortel Networks briefed us on their wireless hardware and how the Nortel product line can provide the total solution for transferring the IETMs over a wireless network for the Gunship program. Nortel is also one of the leaders of wireless products that support data, voice and video over IP. The VCON video conferencing product and the IVR (Interactive Voice Response) are state-of-the-art products used widely in industry. The performance and analysis of the Nortel VCON video product and the Parafonics IVR interactive voice response equipment was not evaluated. Raytheon tested the voice interface using the "Dragon Speak" software and a "Parrot" headset, and the video interface was tested using a Web Cam Video camera with the "Net Meeting" software. The Nortel Bay Stack video wireless interfaces can be supported by Nortel's SL100 PBX which is already installed at all U.S. AFBs.

In January, Nortel loaned Raytheon 2 FHSS (2 Mbps) PCMCIA cards, a router, the Baystack 450-24T switch, and the wireless Access Point for evaluation. Nortel installed the "PC Site Manager" software package which monitors the signal and transfer rates of the wireless data transfers. The "PC Site Manager" was used for both the indoor and outdoor scenarios to collect and evaluate the performance and reliability of the Nortel 2 Mbps wireless equipment. Nortel hardware is state-of-the-art and is used on the WAAS, GCC, Kuwait, and DD21 programs in the Raytheon facility in Fullerton.

For proof-of-concept demo scenarios 1, 2, 3, and 6 that were performed in the lab, the Nortel 2 Mbps FHSS wireless products had strong signals, good data throughput, data reliability, and performed well.

For the peer-to-peer analysis that was done outside from the roof to a mobile vehicle, the average time to transmit was 258 milliseconds (transmitting 1 million packets/second) with a range of

approximately 0.3-mile LOS and 80-percent signal strength. Due to the road being blocked by buildings, LOS was lost and the "PC site Manager" indicated no signal and no transmission activity. However, when the LOS was reestablished, the "site manager" indicated that the laptops automatically reconnected to the wireless network and the signal strength was displayed. For cenario 6, the IBM "Via Voice" software was used with the Xybernaut heads-up wearable PMA to the laptop. Voice and video over IP was used to invoke Microsoft office commands to transfer data seamlessly from the laptop to the Xybernaut PMA. The average time to transmit 32 byte packets of data, voice, and video was from 10 to 14 milliseconds indoors over a range of from 5 to 120 feet with obstructions from the walls in the building.

The Nortel Bay Networks FHSS wireless products performed well and supported data, voice, and video over IP reliably and efficiently.

4.1.3 Proxim

Proxim manufactures both FHSS and the DSSS wireless products. Proxim has two FHSS wireless products, a frequency hopping system at 2.4 GHZ (1.6 Mbps) and a faster frequency hopping system at 5.0 GHz (10 Mbps). The frequency hopping RangeLAN2 cards, bridges, and access points operate at 2.4 GHz (1.6 Mbps) and the Stratum frequency hopping equipment operates at 5.0 GHz (10 Mbps). Proxim's wireless product's range is 500 m with seamless roaming. Proxim's higher rate FHSS equipment is used in Europe on the flight line using the Proxim Stratum HPA. Proxim loaned Raytheon 3 FHSS RangeLAN2 (2.4 GHz, 1.6 Mbps) PCMCIA cards and an access point for our evaluation in our lab. Proxim wireless products are used on the Air Force IRMDS project, the Marines, Army, Navy, and the NASA Space Shuttle projects. As of this writing of this Wireless Trade Study Report, Proxim does not support the wireless video over IP.

For proof-of-concept demo scenarios 1, 2, 3, the Proxim wireless products had strong signals and performed well. For scenario 6, the voice over IP from the Xybernaut heads-up wearable PMA performed successfully in locating and transferring data on the AIMSS database using the Microsoft Office commands. Using the Proxim wireless access point and PCMCIA cards, all of the data was visible and accessible on the Xybernaut system and two laptops (multipoint test). Proxim does not support video over IP yet; therefore, Proxim is not a potential wireless candidate to support the Gunship IETM maintenance.

4.1.4 Symbol Technologies

Symbol Technologies manufactures both the FHSS (2 Mbps) and the DSSS (11 Mbps) wireless products. Symbol has a proprietary agreement with Intel in developing the higher rate (10 Mbps) FHSS equipment in the 5.2-GHz frequency range which is the current standard in use in Europe; the higher rate FHSS wireless products are scheduled for release in 2001. Symbol supports data/voice/video over IP, which is being used on the TRW Nuance (voice recognition) program. For this Trade Study, Raytheon tested the FHSS (2 Mbps) wireless equipment using a web cam video camera, net meeting software, Dragon Speak software and a Parrot headset. Raytheon also tested the FHSS (2 Mbps) wireless equipment using a PC Desktop PMA interfacing peer-to-peer with the Xybernaut heads-up wireless PMA unit; the Xybernaut PMA used Microsoft voice commands to retrieve data from the Desktop PMA

Symbol has proprietary agreements with Nortel, Cisco, IBM, Intel, and Motorola. Symbol loaned Raytheon the 2-Mbps FHSS wireless PCMCIA cards and Access Point (AP3020-500-US) to

Raytheon. The Symbol Windows NT IP configuration tool was used to monitor the signals and the average time to transmit data between two PMAs. Additionally, the Symbol FHSS Access Point was connected via Ethernet into the Nortel Baystack 450-24T switch. The Nortel FHSS Access Point was also connected via Ethernet into Nortel Baystack 450-24T switch. Two independent FHSS wireless LANs were operating successfully using the same Nortel Baystack switch with no visible throughput or interference problems. The Symbol wireless access point was published to be compatible with other state-of-the-art COTS wireless LAN products, and it was proven in our Fullerton communications engineering laboratory.

For proof-of-concept demo scenarios 1, 2, and 3 that were performed in the lab, the Symbol wireless products had strong signals and performed well in the engineering laboratory environment.

For the peer-to-peer analysis that was done outside from the roof to a mobile vehicle, the average time to transmit was 163 milliseconds (transmitting 1 million packets/second) with a range of approximately 0.5 mile LOS and a 50-percent intermittent signal at 0.5 mile. Due to the road being blocked by buildings, LOS was lost and the NT IP configuration tool indicated out of range and no transmission activity. However, when the LOS was reestablished, the site manager indicated an automatic reconnection to the wireless network and the signal strength was displayed. For scenario 6, the IBM "Via Voice" software was used with the Xybernaut heads-up wearable PMA to the laptop. Voice and video over IP was used to invoke Microsoft office commands to transfer data seamlessly from the laptop to the Xybernaut PMA. The average time to transmit 32 byte packets of data, voice, and video was from 8 to 14 milliseconds indoors over a range of from 5 to 120 feet with obstructions from the walls in the building.

In the outdoors environment, the Symbol FHSS wireless products supported data, voice, and video over IP reliably, but blurred video transmission with delivery latencies at close range (at approximately 200 feet from the Access Point) were observed.

4.1.5 Breezecom

Breezecom manufactures both the FHSS (3 Mbps) and DSSS (11 Mbps) wireless LAN products. Breezecom's FHSS wireless data transfers performed well in the engineering laboratory environment. At this time, Breezecom does not support voice or video over IP; therefore, Breezecom is not considered a viable solution for the Gunship IETM data/voice/video transfers.

4.1.6 Wi-LAN

Wi-LAN only manufactures DSSS (1.5 to 3.0 Mbps) wireless hardware which is capable of long range powerful transmissions. In a commercial application with wireless networks with light overlap, interference is minimal. However, in a roaming heavy overlap wireless network, sideband noise interference disrupted efficient data transmission and successful packet deliveries.

For proof-of-concept demo scenario 5, the Wi-LAN Hopper Plus bridge was used to transfer data files between two laptops. PROBLEM: HDL data transmissions created RF interference and disrupted the wireless data transfer. Using the software package "PROCOM" (which was provided by Wi-LAN) to help monitor the link quality, BER, and the number of packets loss, and the spread spectrum direct sequencing wireless, it was determined that the Wi-LAN bridge was unable to transfer data from the Master to the Remote wireless link. It appeared that the data was not being transferred across the bridge, and very few if any packets were being delivered. However, in a clean RF environment, the Wi-LAN signal was very strong, successful data

transmissions were made, and packets were delivered. The Wi-LAN technical consultants were contacted about the sideband noise to see if there were possible workarounds to this RF interference. The Wi-LAN consultants provided several alternatives (comprehensive site survey, on-going visual and measured inspection of surrounding areas, being the first group to install wireless technology in an unlicensed band).

Considering the Gunship maintenance site where there are many different types of network communications happening simultaneously, a reliable, cost-effective, and efficient wireless network must be established. Therefore, it appears that the Wi-LAN Hopper Plus DSSS bridge cannot meet the Gunship maintenance requirements. Wi-LAN is not considered a viable solution for the Gunship IETM data/voice/video transfers.

4.2 Assumptions

Some assumptions were made during the evaluation of the wireless manufacturers or suppliers. The direct sequencing spread spectrum (DSSS) protocol has faster data transfer rates than the frequency hopping spread spectrum (FHSS) data transfer rates; however, with the requirement for many independent wireless nets on the flight line in close proximity of each other, it was presumed that the frequency hopping protocol had greater probability of throughput because there are more (79) channels that can be used within the maximum dwell time of 400 milliseconds. The direct sequencing has only eleven channels available and for networks in close proximity, the networks must be separated by at least five channels to avoid interference from another network. Because of the near-far effect, the DSSS protocol will experience data throughput problems and undelivered packets (see discussion in section 4.1.1).

All of the products explicitly evaluated in this study were provided by the COTS manufacturers as demonstration units. The equipment's condition and operational status were acceptable for Raytheon to conduct both indoor and outdoor range and throughput performance tests.

4.3 Major Consideration

A major consideration that affected the outcome of the study was the willingness of COTS manufacturers to submit demonstration units for evaluation in a timely manner. Raytheon appreciates the COTS wireless manufacturers technical support and the loan of the wireless network equipment. With the wireless technology rapidly evolving, new faster and enhanced products are being developed every day. For maximum performance, these enhanced products should be tested prior to deployment of the seamless automated wireless network for maintaining the Gunships on the flight line.

4.4 Recommendations and Alternatives

Figure 1 displays the Gartner Group's 1999 evaluation of the wireless LAN Solution manufacturers and suppliers. This is an independent evaluation from the evaluation being performed in the Fullerton lab, and our final analysis will be compared to this evaluation.

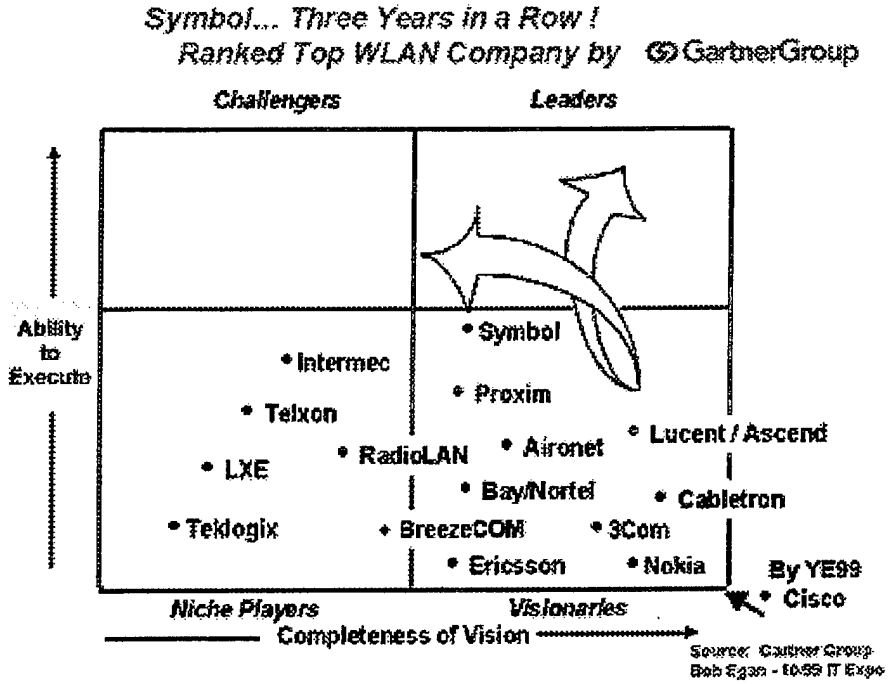

Figure 1. Gartner Group Wireless LAN Evaluation

4.5 Antenna Implementation Recommendations

In the Gunship IETM maintenance flight line, for better range and data delivery performance, directional antennas should be used to provide appropriate area coverage for the Gunship seamless wireless network. Several antenna factors to consider in evaluating and implementing the appropriate area coverage are:

1. Number of users to be serviced by the transceiver
2. The overlap between the transceiver cells – If more than one transceiver (cell) will exist in a wireless network, it is important to have enough overlap between the cells to allow seamless transfers when roaming occurs from one cell to another (maintenance truck traveling through the wireless network).
3. Redundancy – In a wireless network environment, redundancy of antenna coverage is necessary to achieve the appropriate throughput for a given area and/or to reduce the probability of a drop in communication.
4. Potential interference – A way to reduce the probability of interference is to ensure that the antenna's radiation pattern is focused only where you want it to be. This can be accomplished by using quality antennas and mechanically down-tilting the antenna if necessary.
5. Future growth – This should also be considered during the antenna evaluation process of establishing the wireless network. As the system usage increases, certain cell(s) may begin to show signs of reduction in performance. As the network grows, the wireless system design should provide the capacity to add or modify the antenna transceiver capacity and coverage area by the addition of the appropriate equipment such as preamplifiers. A properly designed network system should enable upgrades or adjustments to the wireless system as cost effective as possible.

5. HEADS-UP WEARABLES AND VOICE RECOGNITION SOFTWARE

5.1 Heads-up Unit

One heads-up wearable manufacturers/supplier equipment was evaluated in this trade study.

Xybernaut is one of the leading state-of-the-art manufacturers of a wearable wireless PMA. Xybernaut has provided their heads-up wearable PMA to support the proof-of-concept demonstration scenarios. Several scenarios were tested using the Xybernaut heads-up unit with the 2-inch by 1-inch visual eyepiece. The voice and video over IP scenarios were tested using the Xybernaut heads-up unit. Although the current Xybernaut heads-up unit is bulky and cumbersome, technology is advancing at a rapid pace, which may allow for the production of a smaller streamline design by the time the Gunship seamless automated maintenance plan is deployed.

5.2 Voice Recognition Software

5.2.1 Dragon Speak Software

The Dragon Speak software was used with the Parrot Headset and the WebCam Net Meeting software to transmit data, voice, and video over IP on two laptop PMAs. Data, voice traffic, and video from the WebCam were transmitted simultaneously from both laptops over a wireless LAN, and quantitative data was collected and evaluated. The Access Point from each of the following vendors: Lucent Technologies, Nortel Networks Bay System, and Symbol Technologies was used to seamlessly transmit and receive the data, voice, and video over IP.

5.2.2 IBM Via Voice

The IBM Via Voice software was used to invoke several Microsoft Word commands. IBM Via Voice was used with the Xybernaut heads-up unit to remotely access the AIMSS IETM database and copy selected information to the Xybernaut PMA. Before you can access the AIMSS IETMs via voice, voice recognition software must be developed to link the voice commands to the specific sections of the AIMSS IETM database.

6. FULLERTON LAB TESTING SCENARIOS

6.1 Three Lab Testing Scenarios

Figure 2 shows the Fullerton wireless and ground communications laboratory configuration used to test and evaluate the wireless manufacturer's equipment.

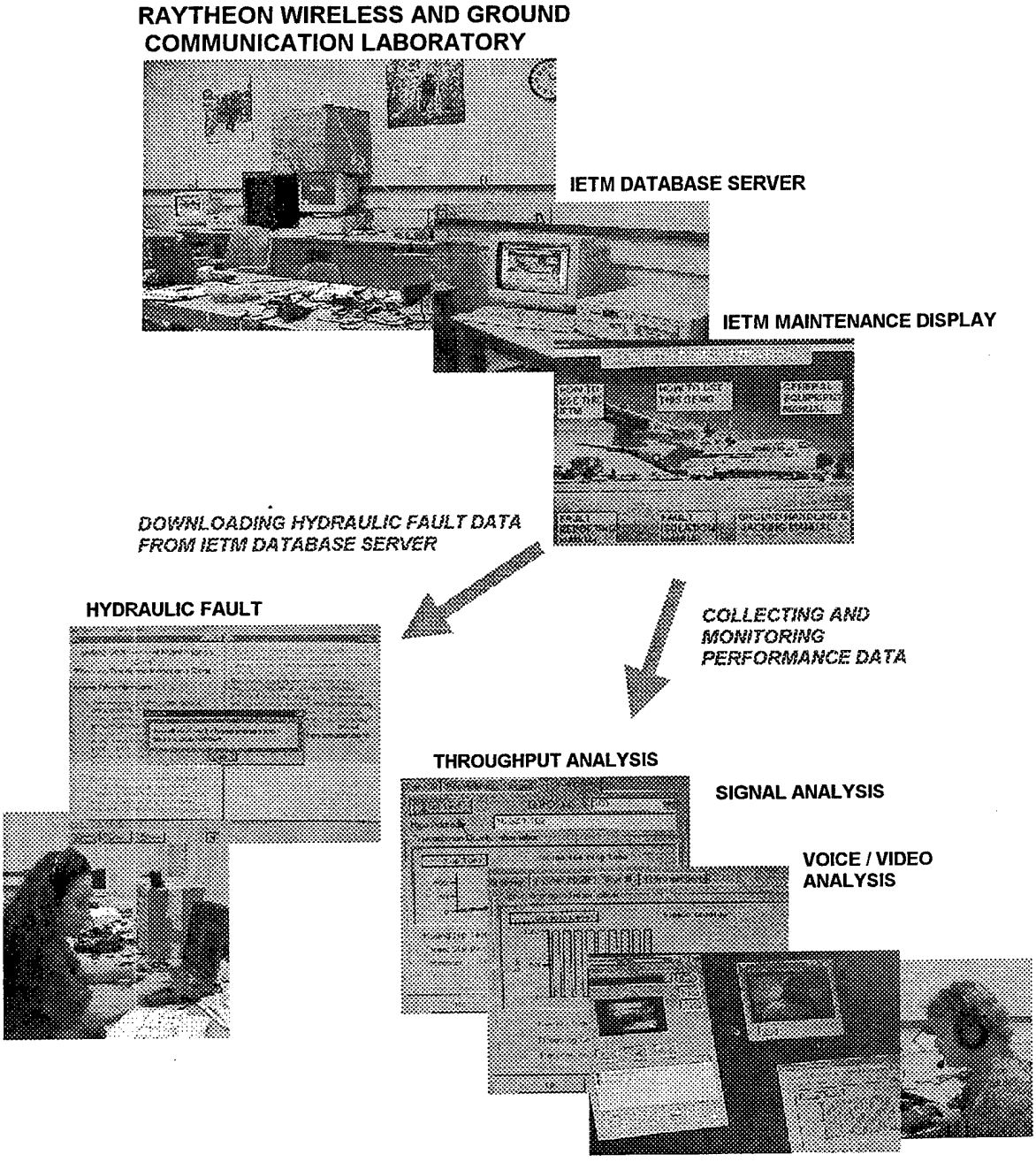

Figure 2. Fullerton Wireless and Ground Communications Laboratory

6.1.1 Peer-to-Peer Wireless Configuration in Lab

Figure 3 shows the peer-to-peer wireless configuration that was used in the lab to evaluate the six COTS wireless manufacturers and suppliers. The Nortel FHSS, the Proxim FHSS, the Symbol FHSS, and the Breezecom FHSS wireless hardware was tested in the lab and the results are summarized in Table 3. The Lucent DSSS and Wi-LAN DSSS wireless hardware was also tested in the lab, and it was determined that DSSS will not meet the Gunship IETMs requirements.

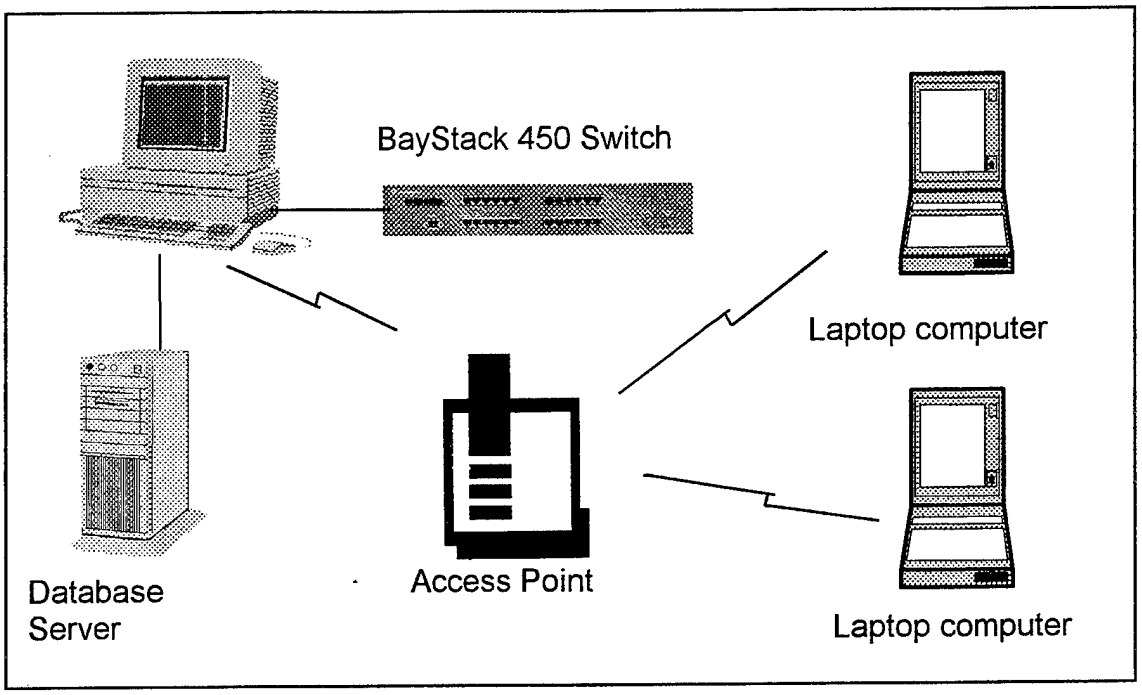

Figure 3. Peer-to-Peer Wireless Configuration

6.1.2 Peer-to-Peer Wireless Configuration Outdoors

Figure 4 shows the peer-to-peer wireless configuration that was used outdoors to evaluate the six COTS wireless manufacturers and suppliers. A laptop and a COTS manufacturer's access point was set up on the roof of Raytheon's building 617 in Fullerton, California. A laptop or the Xybernaut heads-up wearable PMA unit was used in a vehicle which moved slowly collecting data (signal strength, range, and average times to transmit packets of data). The Nortel FHSS and the Symbol FHSS wireless hardware was tested from the rooftop and the results are summarized in Table 3.

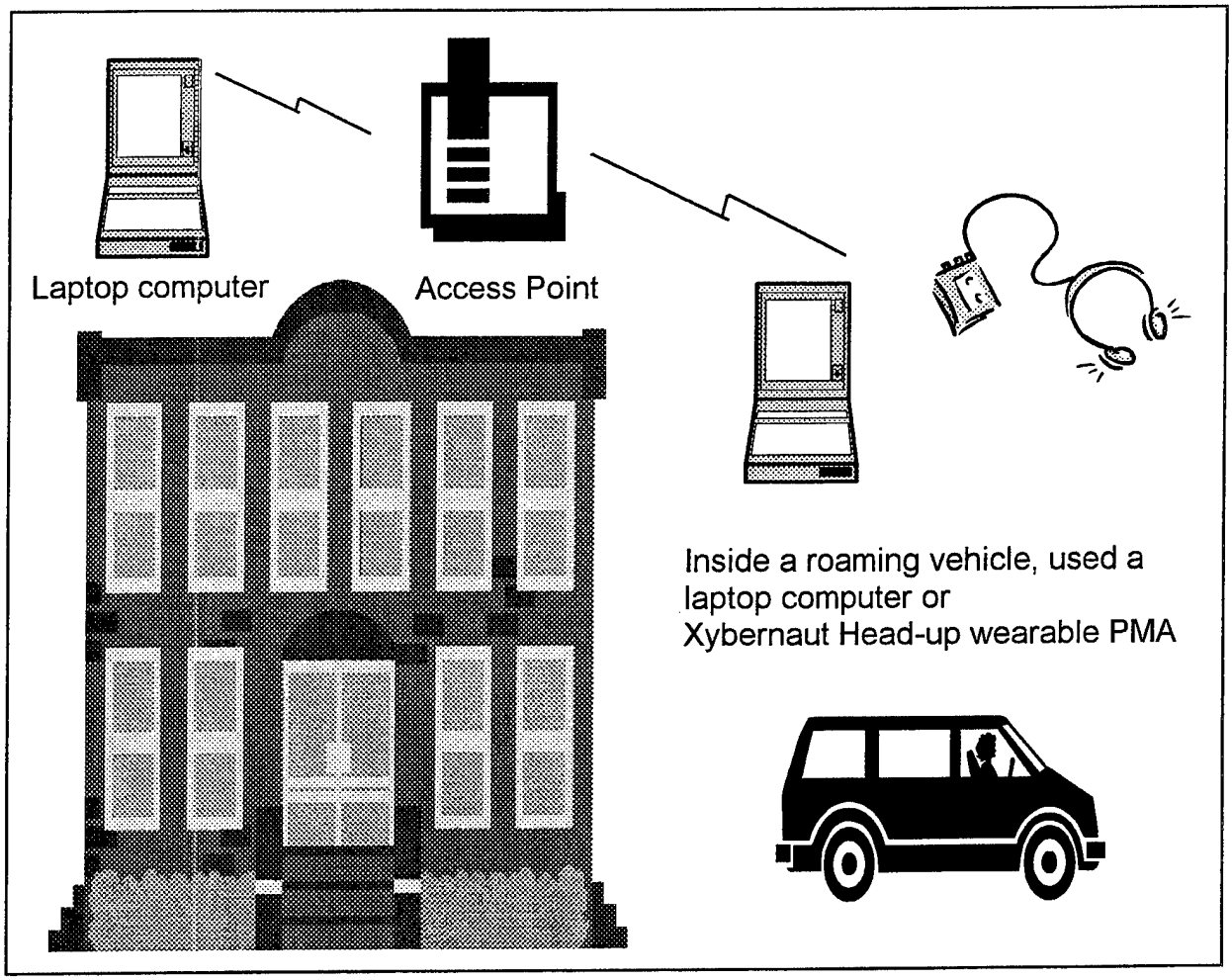

Figure 4. Peer-to-Peer Wireless Configuration

6.2 Six Proof-of-Concept Demonstration Scenarios

The six proof-of-concept demonstration scenarios are described in the following subparagraphs.

6.2.1 Scenario 1

This scenario represents a minimal deployment, which places a technician at a local location with only his laptop computer but has access to a hard local area network interface or server. The user will be able to log onto the network and local server and download the appropriate material to his local laptop. Figure 5 shows the configuration of the wireless hardware used to test scenario 1.

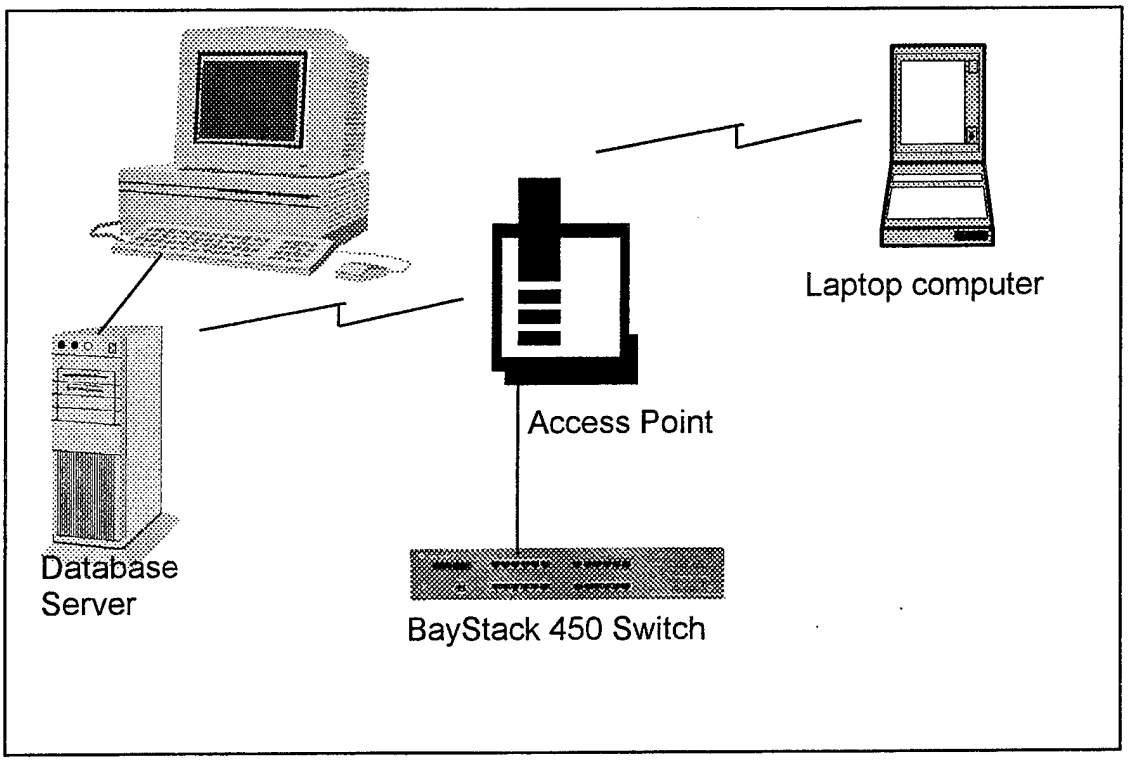

Figure 5. Scenarios 1 and 2 Wireless Configuration

6.2.2 Scenario 2

This scenario also represents a minimal deployment, and places a technician at a remote location with only his computer. When the technician chooses to run a TO he is presented with a dialog box that shows the available choices. Dialog boxes are customized for each of the customer's current needs and requirements. The technician is able to select a local TO's (i.e., stored on the hard drive of the technician's computer) or a remote server that accompanied the deployment. The first action is running a local TO from his laptop. This is to be considered the primary mode of operation. The alternative is to select a TO that is resident on the remote server that was updated and accompanied the deployment. Figure 6 shows the configuration of the wireless hardware used to test scenario 2.

6.2.3 Scenario 3

This scenario is typical of a supply base or large scale deployment environment where the Users are connected to a server, which act as a local hub. An Ethernet connects the users to the local hub. This configuration adds an additional set of capabilities to those described in scenario 1. The user is able to select downloaded data on his local machine, on the local hub, or on the central hub server. The user can also select files to be downloaded from the local hub to the local machine. The central hub server can be used as a distributed processing coordinator, which would allow access to other legacy databases which, may be required for use by required personnel. Figure 7 shows the configuration of the wireless hardware used to test scenario 3.

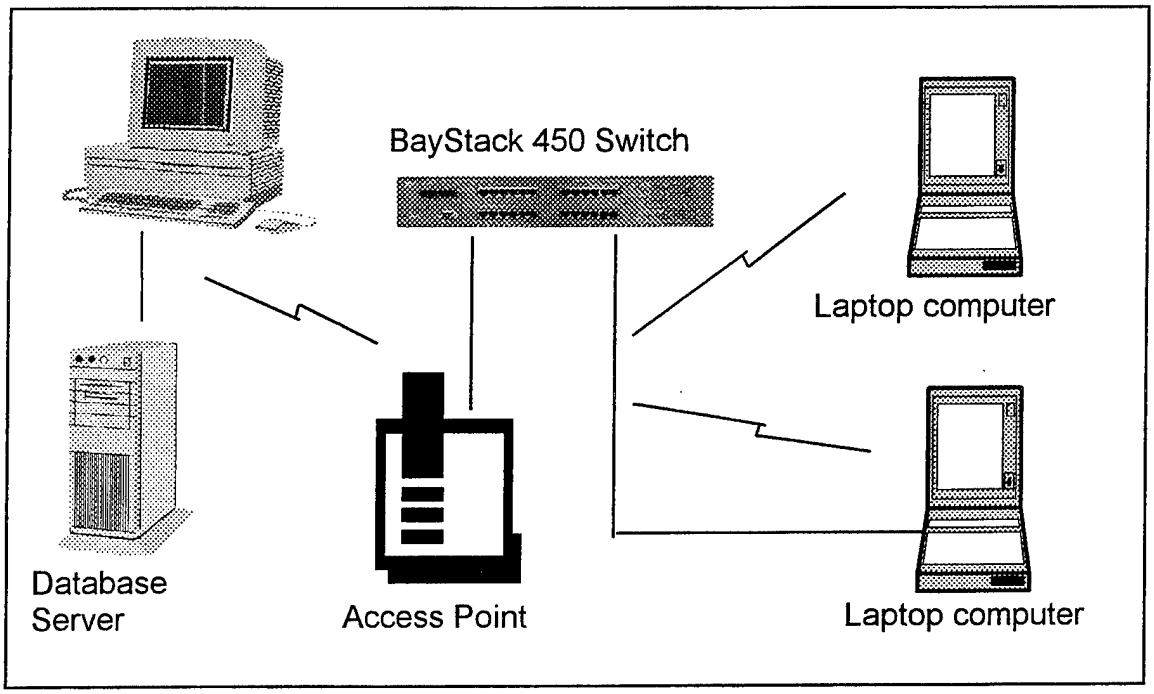

Figure 6. Scenario 3 Wireless Configuration

6.2.4 Scenario 4

This scenario represents an environment in which the users are connected to the Orion Network or a System 2000 relay and central hub server by an existing legacy network. This may represent any Air Force, Navy or Marine Corps logistical supply depot where an existing heritage LAN is used to provide a link between an antenna subsystem mounted at the supply depot and technicians located at the JSF's aircraft's maintenance locations. Figure 7 shows the configuration of the wireless hardware used to test scenarios 4 and 5. Using a Web camera, verify voice and video over IP.

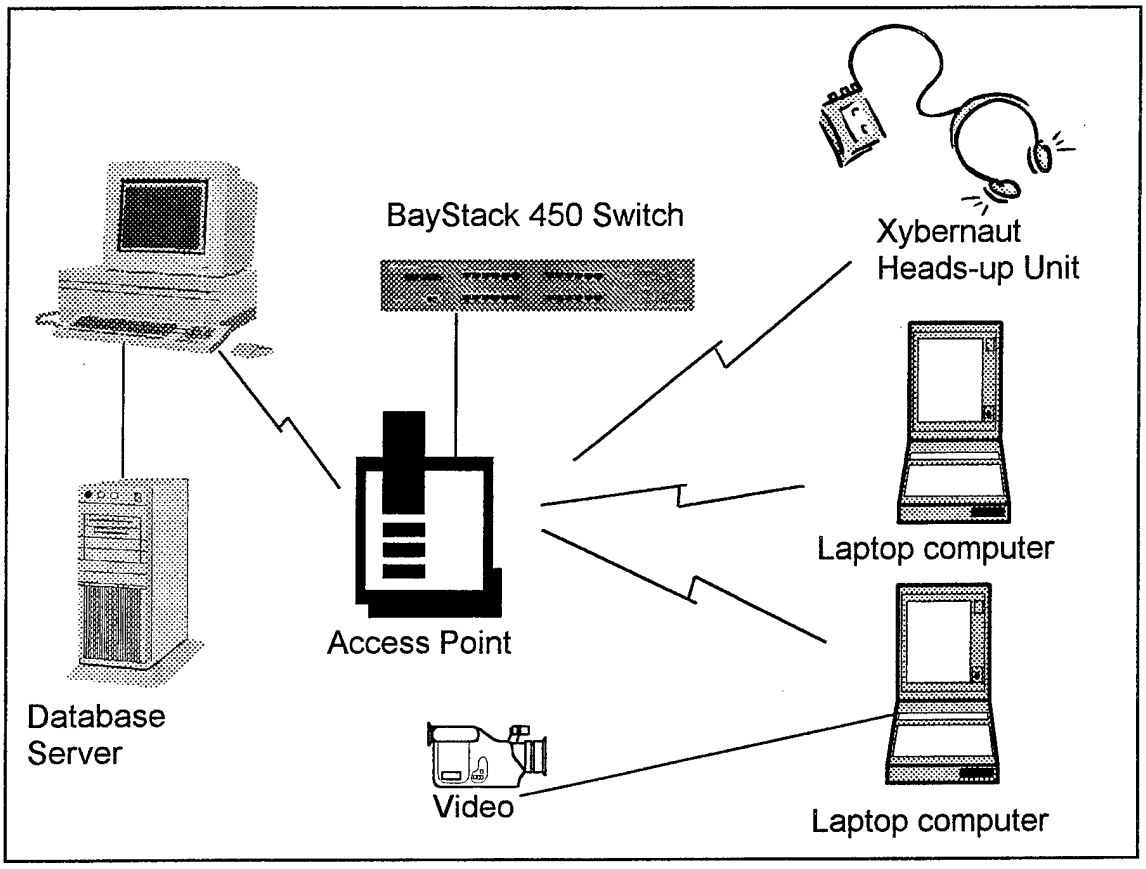

Figure 7. Scenarios 4 and 5 Wireless Configuration

6.2.5 Scenario 5

This scenario represents an environment in which the users are connected to a wireless bridge that is located at a fixed location. The fixed location serves as a depository for information gathered by fixed or mobile locations with line of sight connectivity. The line of sight network is a single channel voice or a high quality video link, which could be an extension of the System 2000 or the Orion network. This scenario provides a high quality direct line of sight link with the maintainers via a wireless antenna mounted on a hangar, flight line or ships superstructure. This link should be considered to be part of a point to point circuit on a LAN type network as it behaves as an extension of a typical Ethernet using TCP/IP and FTP protocols. Figure 7 also shows the configuration of the wireless hardware used to test scenario 5.

6.2.6 Scenario 6

This scenario represents an environment in which the maintenance technicians operate hands free and roam effortless from one job requirement to the next while conducting various maintenance activities. This could be at a ground base activity such as an Air Force Logistics Supply Center, on a fixed flight line or on board a U.S. Navy ship in port or at sea. The concept is that the personnel are roaming within line of sight relay from a servicing hub. When connected via a wireless bridge to a local server the Heads Up Display visually presents selected information to the technician along with the capability of a Voice over IP circuit connected via a wireless Ethernet. This provides the technician with the capability to run voice circuits and interactive video links and to initiate current Technical Service orders on demand. Figure 8 shows the configuration of the wireless hardware used to test scenario 6.

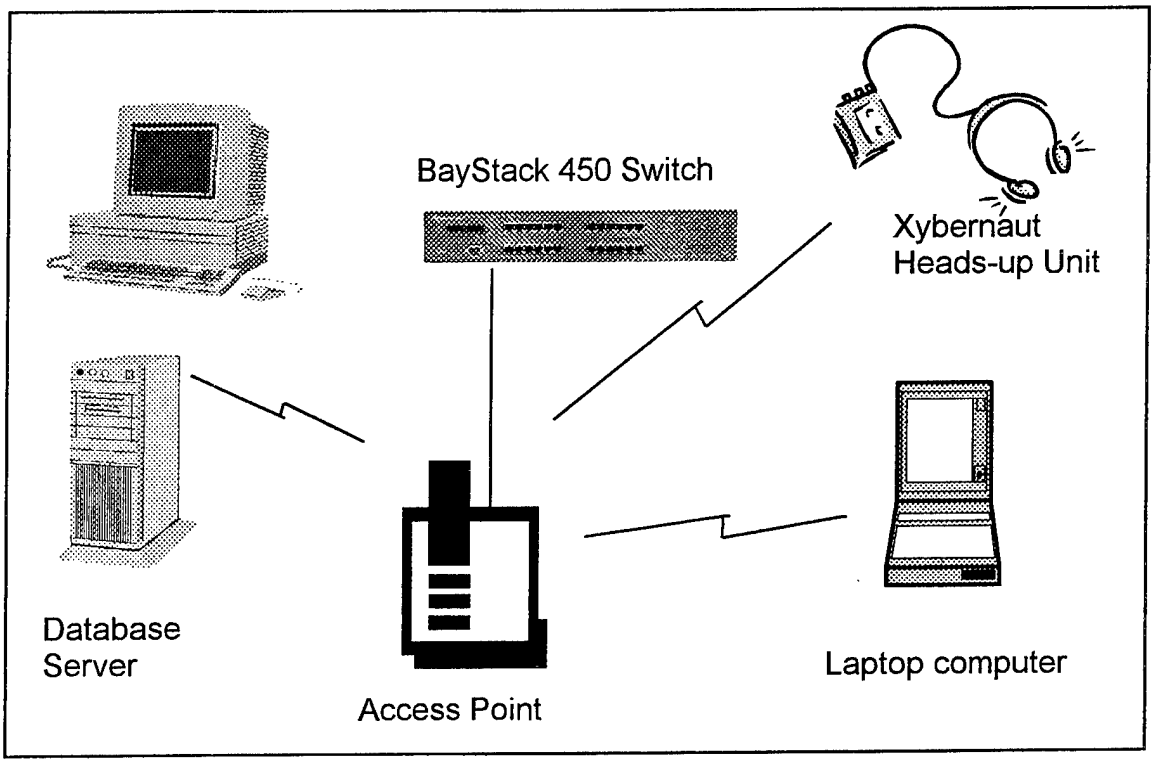

Figure 8. Scenario 6 Wireless Configuration

7. RECOMMENDATIONS AND CONCLUSIONS

This section documents the recommendation of the best and most reliable wireless solution for transferring the IETMs over a wireless network in the Gunship maintenance flight line.

Raytheon has performed an extensive study on wireless networks in order to provide an innovative engineering solution for today's RF, wireless and Spread Spectrum needs, utilizing state of the art COTS wireless manufacturer's technologies along with the newest and most resourceful networking technologies currently available.

7.1 Evaluation and Weighting Criteria

Table 1 lists the wireless manufacturer's performance factors with the important factors weighted for consideration in selecting a wireless manufacturer or supplier's equipment.

Table 1. Wireless Manufacturer or Supplier Selection Criteria

Value	Wireless Characteristic/Performance Factor
6	Fastest and most reliable data throughput
5	Range
4	Signal strength
3	Voice performance
2	Video performance
1	Latencies

7.2 Evaluation Criteria

The performance and reliability characteristics provided by the manufactures, or derived during the evaluation, were assessed for each of the six proof-of-concept demo scenarios. For all scenarios, compatibility with the requirement objectives was the essential focus in this assessment. I.e., signal strength, data throughput (speed in which to handle physically large documents and diagrams), range, use of a docking station or remote terminal, wireless local area network (WLAN) performance, voice and video performance, and latencies were kept in mind while evaluating the wireless products performance.

All the quantified data collection, distances, data transfer reliability (number of packets lost), network interaction, speed of service, and the seamless functionality of the wireless network will be considered in recommending the best wireless solution for the Gunship Program.

7.3 Recommended Wireless Manufacturer or Supplier

The best choice for a wireless manufacturer or supplier to provide the total solution to support the flight line maintenance for the Gunship Program was determined between the following three wireless manufacturers: Lucent Technologies WaveLAN FHSS products, Nortel Bay Networks FHSS products, and the Symbol Technologies FHSS products. All three manufacturer's support data, voice, and video over IP. Each of the manufacturer's access points, rubber ducky antennas, switches, and PCMCIA cards were tested from the Fullerton lab to the outside parking lot (there

were some building obstructions in the parking lot). Quantitative data was collected for voice and video transmissions, and quantitative data was collected for two-way data, voice, and video simultaneous transmissions from each of the laptop PMAs.

Each of the three manufacturer's equipment was tested and average transmission times from peer-to-peer PMAs were calculated with observations noted in Table 3. The Lucent WaveLAN access point and their wireless PCMCIA FHSS hardware video was superior to both the Nortel and Symbol video web cam kodaks. As we increased the range distance from the Lucent access point, Lucent's video performed the best. The Quality of Service (Qos) of the Lucent voice and video displayed latencies as the range was increased; however, the Lucent video remained clear to approximately 750 feet. Lucent's video became jerky and shaky with approximately 1- to 2-second latencies at approximately 650 feet, but the video Kodak remained clear and distinct. At 750 feet in the parking lot, LOS obstructions prevented further testing. The Lucent data, voice, and video average transmission times were compared to the Nortel Bay Networks and the Symbol Technologies average transmission times.

Symbol Technologies average transmission times for transmitting data only were the best; however, the voice and video quality were poor as we increased the range from the access point. Two-way data, voice, and video were transmitted simultaneously and the Symbol video quality began degrading and becoming blurred at approximately 200 to 250 feet and continued to degrade and become choppy, fuzzy, and blurred as the range from the access point was increased. The Symbol voice quality was clear, but latencies and some echoing were observed at approximately 500 feet, and at 600 feet with some building obstructions, the voice began to break up and become choppy. Symbol's video displayed long pauses and delayed video delivery latencies which were bad at approximately 600 feet.

Nortel's average transmission times were not as good as Lucent's; however, the video performed almost as well as the Lucent WaveLAN equipment. Although the Nortel video was jerky and shaky with latencies observed at approximately 300 feet, the video remained clear. The Nortel video became choppy, fuzzy, and had latency delays for transmitting video at approximately 400 feet from the access point, but the video was still discernable. Nortel Networks has a Parafonics IVR interactive voice response system and proprietary VCON video available which can be used for better voice and video transmissions. The Parafonics IVR and the VCON video were not available for evaluation.

For each of the wireless vendor's products, the voice and video performance was subjectively evaluated, and Lucent Technologies again proved to be the frontrunner with respect to range, clarity, and minimal delivery latencies. Overall, Lucent Technologies hardware throughput performed unequivocally better and more reliably than the other wireless frequency hop (FHSS) hardware. See Table 3, which provides a summary of the performance and throughput analysis for the transmission of video, voice and data simultaneously between two PMAs.

Lucent Technologies previous FHSS wireless experience and their technical support in providing and recommending the appropriate interface hardware (such as routers, switches, antennas, etc.) required to support the Gunship IETM seamless dissemination of information in a wireless network will ensure the success of automating the Gunship maintenance on the flight line.

Table 2. Peer-to-Peer Voice, Video, and Data Analysis

	LUCENT TECHNOLOGIES					NORTEL NETWORKS					SYMBOL TECHNOLOGIES				
APPROX RANGE (feet)	TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 1400 bytes (ms)	SUM-MARY Avg TX Time per 1400 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time pe 32 bytes (ms)	
50	**23**	**34**	**26**			**14**	**41**	**23**			**8**	**58**	**18**		Symbol prioitizes voice and video
	23	57	32			12	801	100			40	142	67		
	23	37	28			13	799	56			47	58	49		
	24	86	34			13	68	23			11	25	12		
	25	56	36	**31**		12	793	56	**52**					**37**	
70	**23**	**61**	**36**			**60**	**208**	**67**			**11**	**55**	**24**		
	23	71	37			56	103	68			11	118	27		
	26	64	41			72	307	95			11	38	19		
	26	79	42			56	221	83			11	54	26		
	28	45	36	**38**		59	105	70	**77**					**24**	
70	**30**	**47**	**37**		Transmit data, voice, video	**70**	**1450**	**264**		Transmit data, voice, video	**13**	**233**	**132**		Two-way data, voice and video occurring simultaneously
	29	44	33			62	610	204			16	273	120		
	29	34	32	**34**		72	307	195	**221**		16	250	155	**136**	
100	**24**	**135**	**48**			**55**	**103**	**65**			**11**	**56**	**44**		
	27	43	32			59	493	127			12	59	52		
	29	61	39			54	183	67			11	48	16		
	30	46	35			59	183	72			11	55	20		
	22	59	35	**38**					**83**					**33**	
150	**24**	**102**	**54**			**61**	**94**	**71**			**11**	**647**	**52**		
	25	57	36			58	171	75			12	69	28		
	23	74	40			61	351	52			11	408	63		
	27	78	38			55	78	64			11	661	52		
	27	69	40			56	236	68							
	29	83	42	**42**					**66**					**49**	
150	**31**	**81**	**49**			**56**	**124**	**48**			**53**	**349**	**169**		Two-way data, voice and video occurring simultaneously
	28	105	49			58	252	74			42	347	157		
	28	60	37			65	579	86			16	347	178		
	32	118	55								9	252	97		
	28	53	38	**46**					**69**		28	295	156	**151**	

Table 2. Peer-to-Peer Voice, Video, and Data Analysis, cont.

	LUCENT TECHNOLOGIES					NORTEL NETWORKS					SYMBOL TECHNOLOGIES				
APPROX RANGE (feet)	TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 1400 bytes (ms)	SUM-MARY Avg TX Time per 1400 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)	
200	21	103	27			12	32	22			11	32	18		Video quality degrading
	22	169	63			61	234	87			12	49	17		
	21	46	27			65	226	85			11	61	19		
	21	47	27			56	146	59			11	128	22		
	21	48	27	34		54	140	50	61					19	
200	26	137	60		Transmit data, video, voice	65	767	175		Transmit data, video, voice - Video - some jitter when sending data	52	567	245		Two-way data, voice and video occurring simultaneously
	24	59	31			152	706	246			154	567	297		
	24	53	39			55	660	175			129	621	294		
	33	104	49			54	83	66			108	492	244		
	28	56	39	44					166		34	372	193	255	
250	31	64	39			67	917	142			12	47	20		Video quality degrading - some minor latencies
	31	76	47			60	84	68			12	51	22		
	32	86	59			61	86	71			11	61	24		
	34	58	41												
	35	112	56	48					94					22	
300	24	75	39			67	1291	165		Video latencies	12	63	25		
	24	106	41			54	72	59			11	41	18		
	23	76	37			59	128	73			11	71	22		
	22	56	31			63	1570	83			11	126	28		
	24	134	49	39					95					23	
350	36	118	59		Video minor latencies, slower	59	209	73		Video minor latencies, audio degrading with pauses	13	682	54		O/S laptop dropped out of net mtg; reinitiated call
	36	74	47			60	1576	581			12	19	19		
	37	62	50			62	1333	227			11	17	17		
	37	64	48			112	1662	519			12	18	18		
	36	67	52	51		132	288	195	319		11	18	18	25	
400	34	114	52			63	338	95		Slower voice and jerky video	12	123	22		Voice good, video poor w/ ~1sec
	38	149	57			95	702	56			12	65	21		
	32	233	94			64	159	83			12	113	21		
	29	121	82								12	50	18		
	35	96	56	68					78					21	

Table 2. Peer-to-Peer Voice, Video, and Data Analysis, cont.

	LUCENT TECHNOLOGIES					NORTEL NETWORKS					SYMBOL TECHNOLOGIES				
APPROX RANGE (feet)	TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 1400 bytes (ms)	SUM-MARY Avg TX Time per 1400 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time pe 32 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time pe 32 bytes (ms)	
450	**33**	**59**	**41**		Video slower but clear ~ NASA Space CAM	**60**	**127**	**75**		Video getting choppy and voice breaking up	**12**	**101**	**24**		
	39	98	52			60	93	68			12	101	24		
	38	72	52			64	166	70			11	29	17		
	37	65	49			62	117	75							
	37	65	47	**48**		70	131	77	**73**					**22**	
450	36	148	87		Transmit Data, video, voice	86	1617	142		Transmit Data, video, voice -Lost a few packets	19	706	258		Transmit Data, video, voice
	34	151	68			64	154	97			31	468	235		
	33	62	46			62	271	98			31	478	226		
	28	80	44	61		70	231	72	102		58	582	254	243	
500	**28**	**64**	**39**			**106**	**406**	**86**		BATTERY LOW. Video latencies and poor quality, voice is breaking up	**13**	**46**	**16**		Clear voice and fuzzy video w/1 sec delays
	27	70	37			131	163	29			13	30	18		
	32	58	41			62	101	65			12	24	15		
	31	83	44			65	1718	240							
	23	66	35	**39**					**105**					**16**	
500	23	233	65		Transmit Data, video, voice	NO DATA SENT				Transmit Data, video, voice -Outside laptop died twice, but voice still working	18	662	195		Transmit Data, video, voice -Voice echos when sending data, video delays
	26	154	63								17	1010	252		
	25	180	76								140	981	464		
	24	119	56	65					0					304	
550	**29**	**93**	**51**			**100**	**328**	**214**		Lost a few packets	**14**	**114**	**26**		
	30	73	40			60	1250	189			13	131	34		
	28	72	43			61	1255	192			13	97	21		
	23	116	63	**49**		68	1349	137	**183**					**27**	
550	31	198	65		Transmit Data, video, voice	NO DATA SENT				Transmit voice only - Outside laptop died 3 times& no data was sent	18	889	339		Transmit Data, video, voice ~ O/S laptop died & restarted
	24	168	90								101	1140	484		
	27	154	66	74					0		12	347	81	301	

Table 2. Peer-to-Peer Voice, Video, and Data Analysis, cont.

	LUCENT TECHNOLOGIES					NORTEL NETWORKS					SYMBOL TECHNOLOGIES				
APPROX RANGE (feet)	TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 1400 bytes (ms)	SUM-MARY Avg TX Time per 1400 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)	
600	41	152	65			150	333	223		POOR VOICE AND VIDEO QUALITYJERKY. Lost a few packets	14	29	18		Choppy video, w/long delays and pause, clear voice
	36	74	47			124	905	279			12	28	16		
	36	154	59			153	235	181			14	125	27		
	35	128	60	58		56	102	162	211		13	111	23	21	
600	38	204	111		Transmit Data, video, voice simultaneously	NO DATA SENT				Outside latptop died 3 times& no data was sent	63	1168	510		Transmit Data, video, voice - Voice breaking up and choppy; video is choppy w/long delays
	40	386	163								78	1270	473		
	37	259	117								55	1322	458		
	36	338	156	137					0		108	1019	505	487	
650	31	210	55		Video has latencies, but is still clear; voice is breaking up	57	610	100		POOR VOICE AND VIDEO QUALITYJERKY. Lost a few packets	12	75	21		Bad video, voice is still clear
	41	83	51			57	1244	170			12	22	15		
	42	121	61			56	602	96			12	88	19		
	27	96	61			59	552	101			13	29	17		
	36	103	67	59					117					18	
650	36	279	118		Transmit Data, video, voice simultaneously	NO DATA SENT				No data was sent	14	366	63		Transmit Data, video, voice - Voice echos & breaks up, video choppy w/long delays
	38	231	108								147	887	447		
	38	277	110	112					0		74	769	347	286	
700	34	93	51		Video clear, delay in TX, jerky picture; voice is breaking up						14	124	21		Bad video, voice is still clear
	34	109	46								13	141	24		
	37	60	42								13	51	18		
	36	72	47								12	70	20		
	39	64	44	46					0					21	
700	36	184	82		Transmit Data, video, voice - Video clear, delay in TX, jerky picture, voice is breaking up					No data was sent	18	1141	348		Bad video, voice is poor (broken up), & pkts are being lost
	36	151	63								73	944	435		
	36	148	58								163	806	394		
	39	205	102	76					0		96	810	397	394	

Table 2. Peer-to-Peer Voice, Video, and Data Analysis, concluded

	LUCENT TECHNOLOGIES					NORTEL NETWORKS					SYMBOL TECHNOLOGIES				
APPROX RANGE (feet)	TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 1400 bytes (ms)	SUM-MARY Avg TX Time per 1400 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)		TX Time Low (ms)	TX Time High (ms)	Avg TX Time per 32 bytes (ms)	SUM-MARY Avg TX Time per 32 bytes (ms)	
750	805	1110	140		Video clear, delay in receiving transmissions, jerky picture; voice is breaking up					POOR VOICE AND VIDEO QUALITY JERKY, Lost a few packets					No video or voice
	89	379	67												
	67	831	208	138					0					0	

7.4 Alternate Wireless Manufacturer or Supplier

The runner up in this trade study evaluation is Nortel Bay Networks teamed with Symbol Technologies. Because Symbol Technologies has a proprietary agreement with Nortel, Intel, IBM, and Cisco, the wireless teaming agreement can be accomplished easily. Nortel's Bay Networks FHSS equipment can be integrated with their proprietary Parafonics voice software and their VCON video kodak which then can be used with the Symbol bar code scanners for ease of integration and support of the seamless wireless networks on the maintenance flight line. Symbol Technologies compatibility with most other wireless vendor products is also an added advantage in implementing the total wireless solution. Symbol Technologies and Nortel Bay Networks wireless products: FHSS PCMCIA cards, Access Points, Bridges, Switches, Routers, and directional Antennae are compatible and interchangeable and can function together seamlessly in the same network to provide a total solution; however, their web cam video and voice performance and throughput was outperformed by Lucent Technologies. Nortel Bay Networks management utilities and site survey tools are better than the Lucent site management tools. Using Nortel Bay Networks utilities and tools will facilitate determining the minimum number of access points required for each network on the maintenance flight line and can assist in estimating where additional access points should be placed for redundancy to prevent the probability of a drop in network communications. Nortel's utilities will better monitor the performance throughputs and signal strengths than the current existing Lucent utilities.

Nortel backbone (Switch and ATM/Router) in combination with the Nortel Bay Networks wireless PCMCIA cards and the Symbol Technologies wireless PCMCIA cards. The Nortel Switch is compatible with both the Symbol Technologies and Proxim wireless Access Points and PCMCIA cards. Symbol Technologies hardware throughput performed unequivocally better and more reliably than the other wireless frequency hop hardware. Symbol Technologies compatibility with most other wireless vendor products is also an added advantage in implementing the total wireless solution.

7.5 Composite Summary

Table 3, COTS Wireless Manufacturers Comparison Matrix, shows the overall summary of all wireless hardware evaluated during this trade study.

Table 3. COTS Wireless Manufacturers Comparison Matrix

Company Name	Product Description	Protocol	FQ Band	WL Data Rate	Range	Data through-put in lab	Data throughput on roof	Voice	Video	Advantages	History
LUCENT	WAVE LAN	DSSS	2.4GHz	11 Mbps	in lab=500 ft w/signal at -87dBm on roof= NO TESTING PERFORMED	RESULTS VARIED AND ARE NOT VALID	NOT EVALUATED	Opti-Air Digital Voice	Opti-Air Digital Video or RoseTel Kodak	Opti-Air Data/Voice/ Video using laser light w/ range of 1.5 miles	Lucent WL HW used in Palmdale to support Boeing
LUCENT	WAVE LAN	FHSS *Used **1400 byte packets**	2.4GHz	1-2 Mbps	In lab=700 ft w/signal at 50% *on roof=0.3 miles w/signal at 60-70%	From= 4 to 186 ms/pkt * **105 ms/pkt**	From= 24 to 889 ms/pkt * **157 ms/pkt**	**Transmission range from 21 to 1110 ms/pkt,** range=750 ft with rubber ducky antenna, ***Average transmission time from 31 to 208 ms/pkt**			Chicago Stock Exchange – Arbitrade * Beaufort School District
NORTEL	PCMCIA WL PC cards, switch, router, 650 WL Access Point	FHSS (model 650 series) *Used **32 byte packets**	2.4GHz	1-2Mpbs	in lab=700 ft w/signal at 50% * on roof=0.3 miles w/signal at 80-85%	from= 7 to 403 ms/pkt * **171ms/pkt**	from= 8 to 515 ms/pkt * **258ms/pkt**	**Transmission range from 12 to 1718 ms/pkt,** range=650 ft with rubber ducky antenna, ***Average transmission time from 52 to 319 ms/pkt** Parafonics IVR interactive voice response and VCON video available for better performance		PBX SL100 installed at all US AFBs (can use ethernet card to support voice over IP), ATM/Router pkg together	WAAS, DD51, GCC - uses ATM/RTR combination hardware
NORTEL		DSSS (model 660 series)	2.4GHz		NOT EVALUATED						
PROXIM	Range LAN2- 7400 PC Card, Bridges, Ethernet Access Point	FHSS *Used **32 byte packets**	2.4GHz	1.6-3.0 Mbps	in lab=600 ft * on roof=NO TESTING PERFORMED	from= 7 to 403 ms/pkt * **198ms/pkt**	NOT EVALUATED	NOT EVALUATED **VIDEO OVER IP SUPPORT DOES NOT EXIST YET**		IR wireless LAN product, High Power Stratum Antenna with good range	IRMDS (Air Force), Marines, Navy, Army, NASA Space Shuttle projects (used wireless LANs within the Space Shuttle)
PROXIM		FHSS - used in Europe	5.0GHz (on flt line)	10 Mbps	NOT EVALUATED						
SYMBOL TECH	PCMCIA WL PC cards, Access Point (AP3020-500-US)	FHSS *Used **32 byte packets**	2.4GHz	1-2 Mbps	in lab=950 ft w/signal at 50% * on roof=0.5 miles w/signal at 50-60%	from= 8 to 585 ms/pkt * **272ms/pkt**	from= 8 to 420 ms/pkt * **163ms/pkt**	**Transmission range from 8 to 1322 ms/pkt,** range=700 ft with rubber ducky antenna, ***Average transmission time from 19 to 487 ms/pkt** Symbol uses a Proprietary Voice Recognition Program (Nuance) and Proprietary Video Equipment through teaming with IBM in Rochester, MN.		Proprietary agreements with Nortel, Intel, Cisco, IBM, Motorola	TRW Nuance Program uses data/voice/video over IP. FUTURE: FHSS @ 5.2GHz with 5.0-10.0 Mbps already used in Europe
SYMBOL TECH		DSSS	2.4GHz	11 Mbps	NOT EVALUATED					Wireless HW compatible with other mfg. Wireless HW	
BREEZECOM	Breezenet PC Card, Access Point	FHSS	2.4GHz	3 Mbps	NOT EVALUATED						W/L at Laughlin AFB
		DSSS	2.4GHz	11 Mbps	in lab=2500 ft w/signal at 50% * on roof=NO TESTING PERFORMED	RESULTS VARIED AND ARE NOT VALID	NOT EVALUATED	NO	NO	Good mobility and seamless roaming architecture	No voice or video over IP
WI-LAN	Wireless Ethernet Bridge	DSSS	2.4GHz	1.5-3.0 Mbps	30.5km	RESULTS VARIED AND ARE NOT VALID	NOT EVALUATED	NO	NO	Good Til-Tek HPA	Northern Lights School District WAN with strong signals going long range

*Note that rows with highlighted left borders contain the summary of the FHSS wireless manufacturers.

8. FUTURE INTEREST

Mobile wireless devices and new innovative wireless concepts will drive the growth of the Wireless LAN market in the Air Force, Navy, Marines, Army and commercial aircraft industry. The future of wireless technology and wireless concepts is evolving rapidly. The future of smaller PMAs (e.g., a Palm VII with an IR link to a laptop or a portable 14-inch screen with IR Link and Memory Modules) and wearable PMAs with faster and smaller wireless hardware allows efficient reliable data, voice, and video transmissions to occur simultaneously on adjacent separate

networks accessing common resources (servers, database, etc.). Multiple aircraft can share reliable data and voice resources while roaming seamlessly amongst the outdoor networks. Many security features and redundancy ensure that only authorized users can efficietly access their aircraft networks with no interference from the adjacent and surrounding networks.

Raytheon is working on the JSF RFP. For the JSF Proposal, Raytheon will make wireless network recommendations based on the results of this trade study for the JSF wireless maintenance and ground communications.

The Air Force Research Laboratory (AFRL) has visited the Raytheon facility in Fullerton, California for an informal wireless briefing. AFRL is also interested in implementing wireless networks for several Air Force applications and initiate a technology transfer exchange in the wireless and ground sub system network areas.

Venntronix, an Army contractor from Fort Monmouth, New Jersey, is interested in adding the uses of wireless for satellite and ground communications to their Junior Military Training Curriculum. They have expressed interest in our wireless study of the wireless equipment and have asked Raytheon to support the coordination and generation of the training curriculum and training aids.

Other military and Government agencies have expressed interested in implementing state-of-the-art wireless networks in their facilities for various applications. With the rapidly evolving wireless technology becoming lighter, smaller, having higher throughputs and greater range with more robust communications, the ease-of-deployment is making the use of wireless is becoming more attractive to commercial as well as Government users.