7.0 Emergency Medical Services (LifeLink)

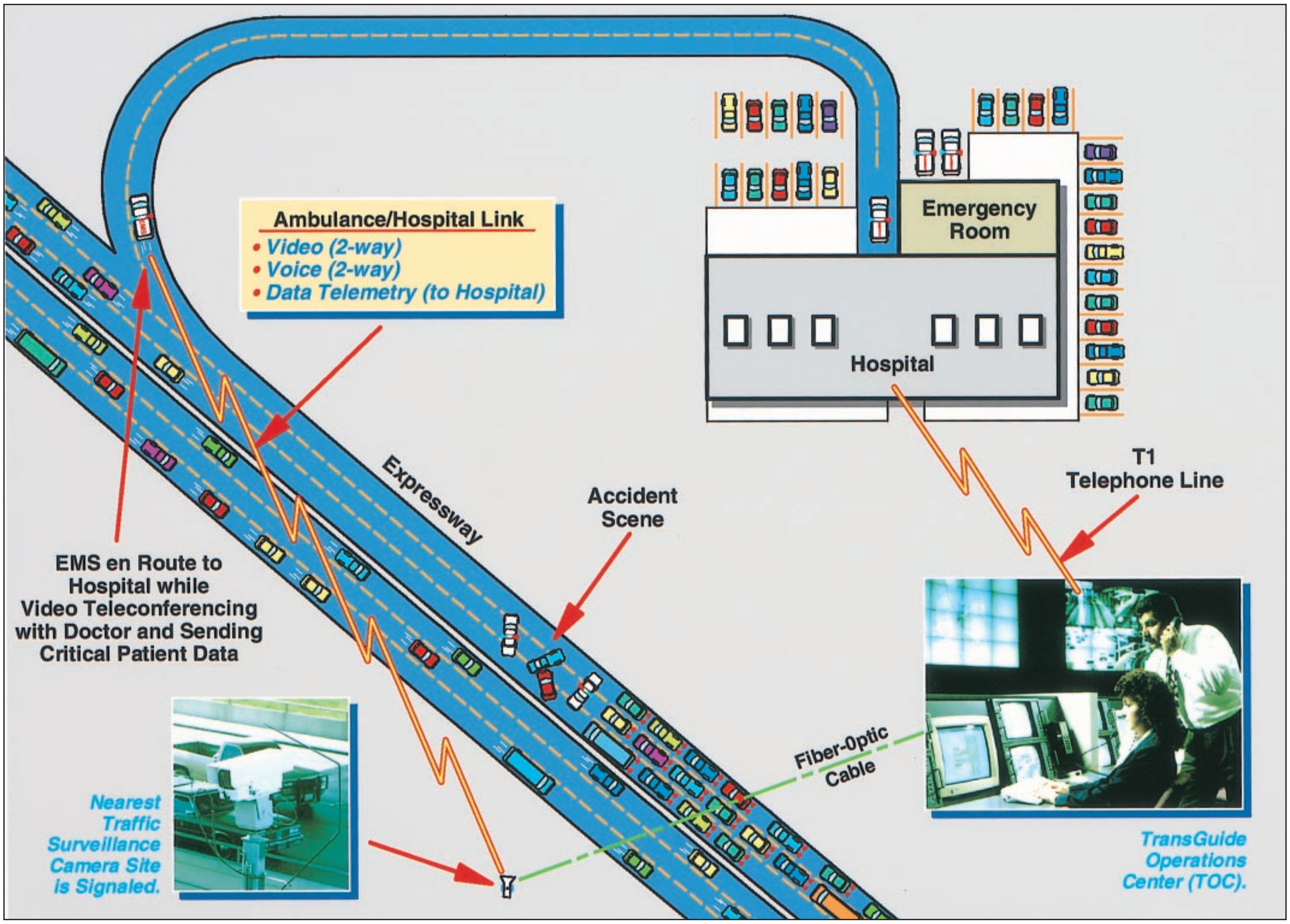

Figure 33. LifeLink Conceptual View

Intelligent Transportation Systems (ITS) strive to enhance traveling conditions by bringing state-of-the-art technologies to the roadways. These technologies typically center on saving time, money, and lives. The LifeLink System saves time through early doctor intervention, saves money by taking advantage of commercial off-the-shelf equipment, and saves lives by bringing life-saving technology to the roadside.

The LifeLink System saves time through early doctor intervention, money by taking advantage of commercial off-the-shelf equipment, and lives by bringing life-saving technology to the roadside.

7.1 Overview

The LifeLink System extends the reach of physicians beyond the walls of the hospital and into ambulances transporting patients. The system transfers audio, video, and data between ambulances and hospitals. In the ambulance, a camera sends to the hospital a view of the patient being transported. The paramedic communicates with the physician in the hospital through a wireless headset, while viewing the physician on a monitor in the ambulance. The LifeLink System routes the patient's vital statistics from a monitoring device in the ambulance through the LifeLink network to a receiving workstation in the hospital. With this additional information, physicians can assess the emergency requirements of a patient in the field prior to the arrival of the ambulance at the hospital. The System also reduces the burden on the paramedic to describe the patient's condition to physicians while en route to the hospital. The net result is increased communication between the ambulance and hospital personnel, earlier intervention, and enhanced patient care. Figure 33 provides a conceptual view of the LifeLink system.

7.2 Design Information

The LifeLink System design focuses on three major functional groups: the communications architecture, the conferencing architecture, and the management and maintenance architecture.

7.2.1 Communications Architecture

At the heart of the LifeLink System lies the communications infrastructure. Figure 34 provides an overview of the LifeLink communications architecture. The LifeLink System establishes a metropolitan area network (MAN) based on IEEE 802.3 Ethernet. In San Antonio, the TransGuide System provides the fiber optic backbone of the system. Spread spectrum radios operating at 2.4 GHz serve as 4 Mbps 802.11-like Ethernet bridges connecting mobile ambulances to roadside ATMS communications hubs, creating a cellular-like coverage scheme. At the roadside ATMS communications hubs, transceivers convert the 4 Mbps Ethernet data from the radios to 10 Mbps Ethernet and transfer the data across a dedicated light channel on the optical fibers. Wave division multiplexers (WDMs) create this dedicated light channel by isolating the LifeLink Ethernet and the TransGuide SONET at

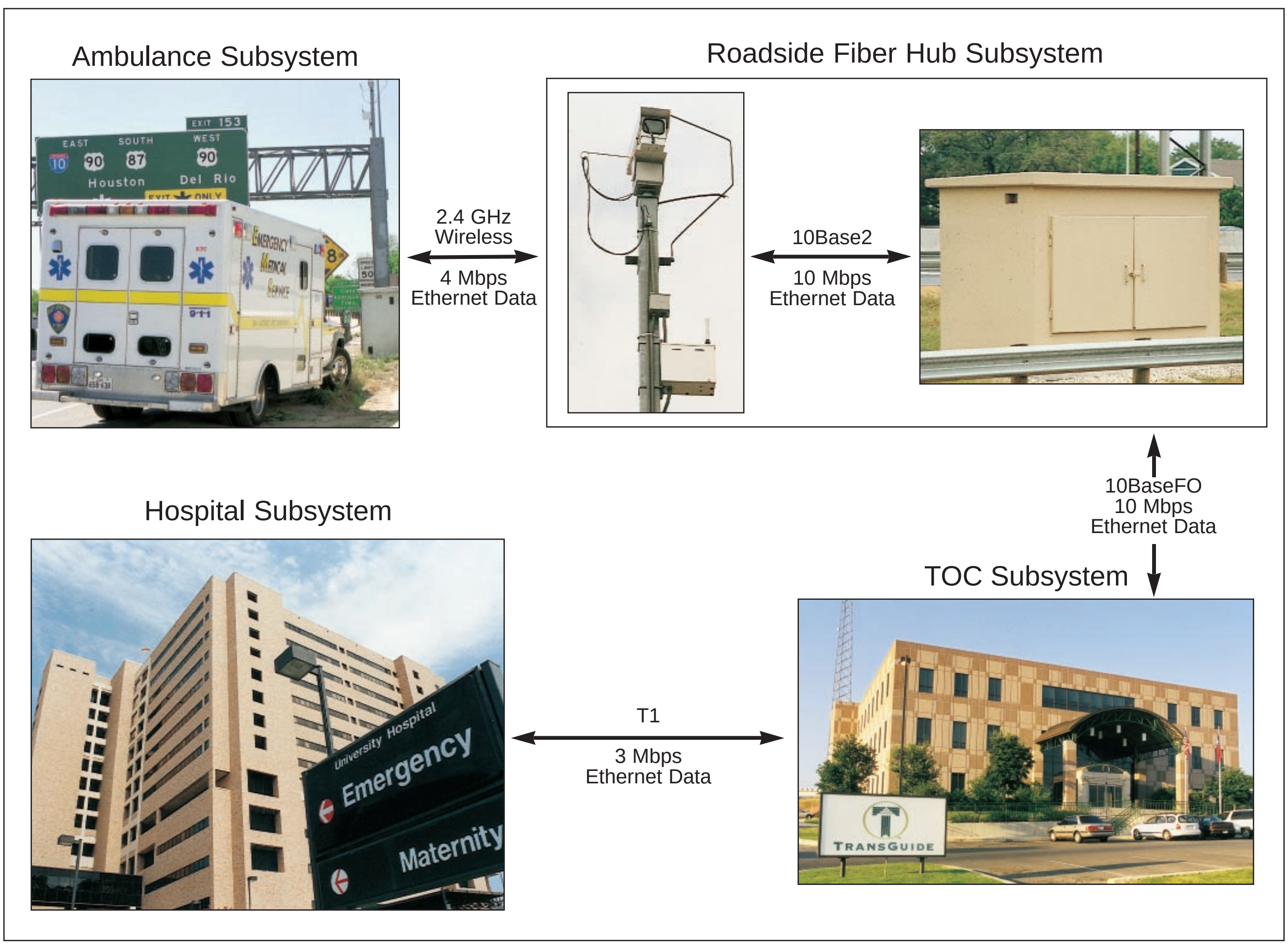

Figure 34. LifeLink Functional Overview

different wavelengths. Each roadside ATMS communications hub connects via optical fibers to the TOC. At the TOC, an Ethernet switch directs the data between the distributed roadside ATMS communications hubs and the appropriate hospital. For data transfers with the hospitals, the switch converts the 10 Mbps Ethernet to either 100 Mbps Ethernet for fiber-optic communications or to 3 Mbps (1.55 Mbps each direction) Ethernet for T1 leased line communications.

7.2.1.1 Ambulance Communications Architecture

The LifeLink System provides an ambulance with a mobile communications link to fixed radios located along portions of the San Antonio freeway system. This wireless Ethernet link enables LifeLink-equipped ambulances on or near portions of the San Antonio freeway system to conduct two-way data communications with medical personnel at a hospital. Video, audio, and patient monitoring data travel across this communications path between an ambulance and a hospital.

The PC Enclosure shown in Figure 35 serves as an access point into the LifeLink communications infrastructure. Inside the enclosure, a wireless Ethernet bridge (WEB) establishes a spread spectrum radio frequency link into the communications network through a 2.4 GHz antenna mounted on the roof of the ambulance. The WEB interfaces with a ruggedized PC over 10BaseT Ethernet as shown in Figure 36. The ruggedized PC contains a network interface card (NIC) for data transfer between the conferencing computer and the communications infrastructure.

7.2.1.2 Roadside Fiber Hub Communications Architecture

The TransGuide roadside fiber hubs serve as entry points into the wired backbone of the LifeLink communications infrastructure. WEB radios mounted on TransGuide ATMS camera poles link with WEB radios in ambulances to connecting wireless

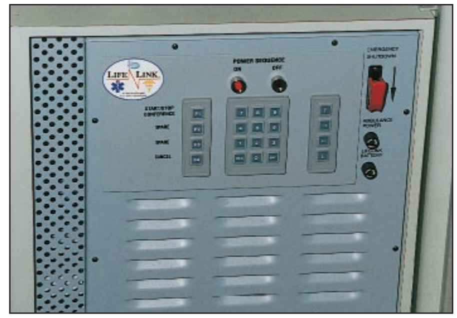

Figure 35. PC Enclosure

Ethernet data with wired Ethernet data. Figure 37 illustrates the equipment and connectivity of a typical LifeLink-equipped roadside fiber hub. An environmental radio enclosure mitigates the effects of temperature on the WEB and provides a means of mounting to the camera pole. The spherical RF radiation pattern of the WEB creates a coverage cell. An RF communications link with the WEB automatically establishes when an ambulance enters the coverage cell and continues until the ambulance exits the coverage cell.

A coaxial cable provides a half duplex 10Base2 Ethernet connection between the WEB and a full-to-half duplex converter as shown in Figure 37. Due to the distance between the long lengths of optical fiber used in the LifeLink system, full duplex Ethernet is necessary because it allows for greater physical separation between transmitter and receiver laser transceiver pairs. Therefore, the full-to-half duplex converter is used to convert between the full and half duplex modes. A 1550-nm

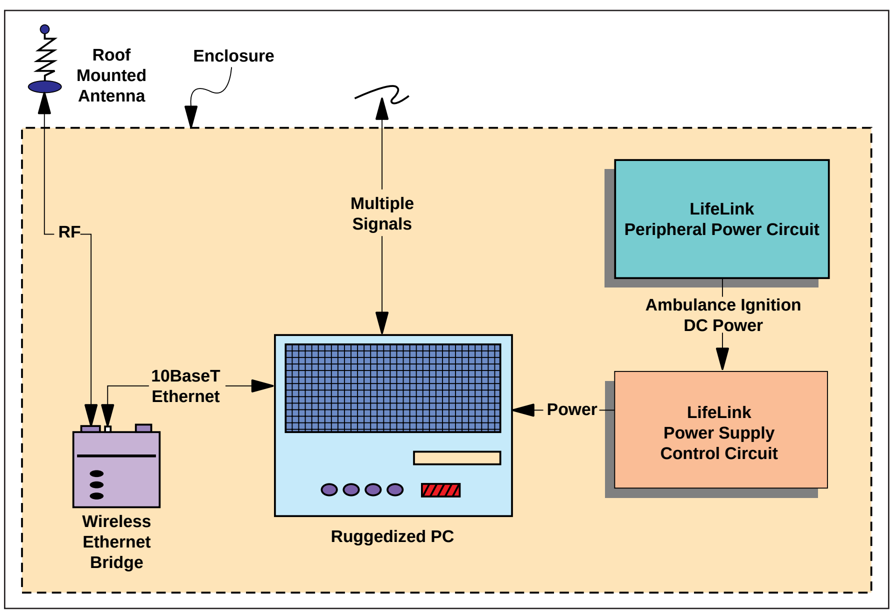

Figure 36. LifeLink PC/Radio/Power Supply Enclosure

laser transceiver is attached to the full-to-half duplex converter's attachment unit interface (AUI) full duplex port. Fiber jumpers connect the laser transceiver to a pair of WDMs. The WDMs allow the LifeLink data to operate independently of the existing 1310-nm TransGuide data. WDMs function as prisms, joining the 1310-nm and 1550-nm light wavelengths onto the same fiber for isolated transmission to the central ATMS facility. Because WDMs are a passive device, they also function in the reverse operation by separating a combined light signal back to the individual components. In the LifeLink system, WDMs allow 10BaseFO LifeLink Ethernet data to share the "Protect" ATMS fibers between the roadside fiber hub and the central ATMS facility as shown in Figure 37.

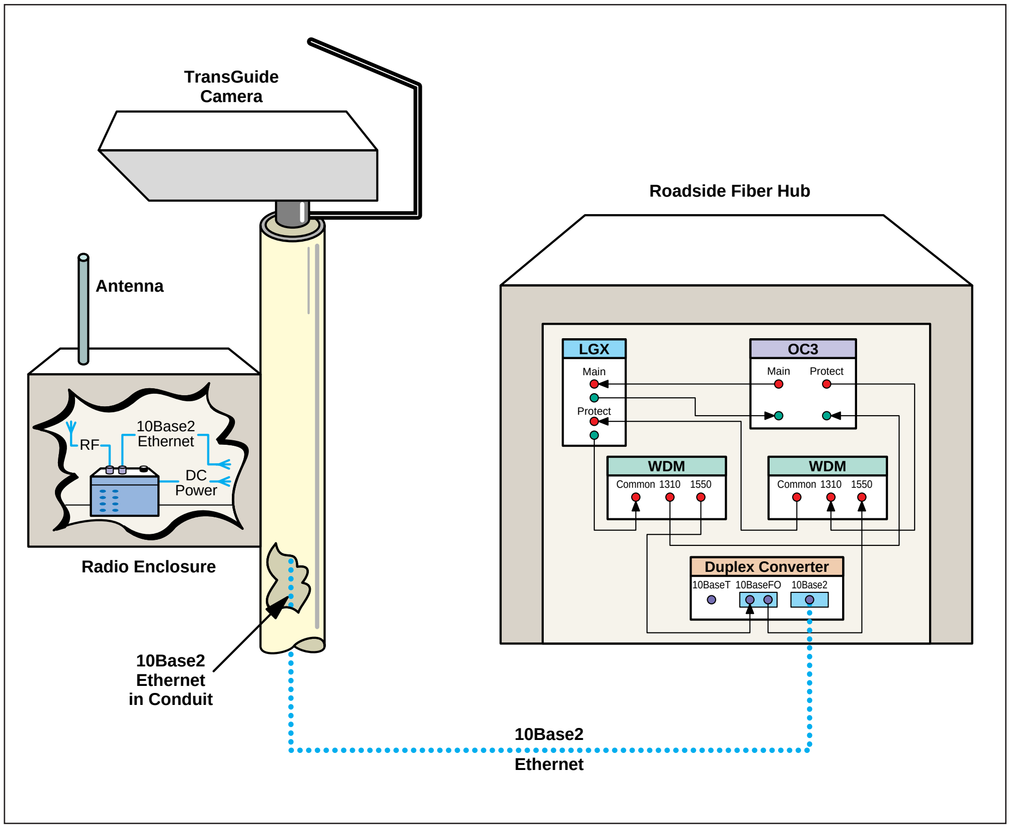

Figure 37. LifeLink Roadside Fiber Hub Subsystem

7.2.1.3 TransGuide Operations Center Communications Architecture

The TOC serves as the central facility for both ATMS and LifeLink data. WDMs join and separate ATMS and LifeLink light wavelengths on the TransGuide optical fibers as shown in Figure 38. Optical fibers connect

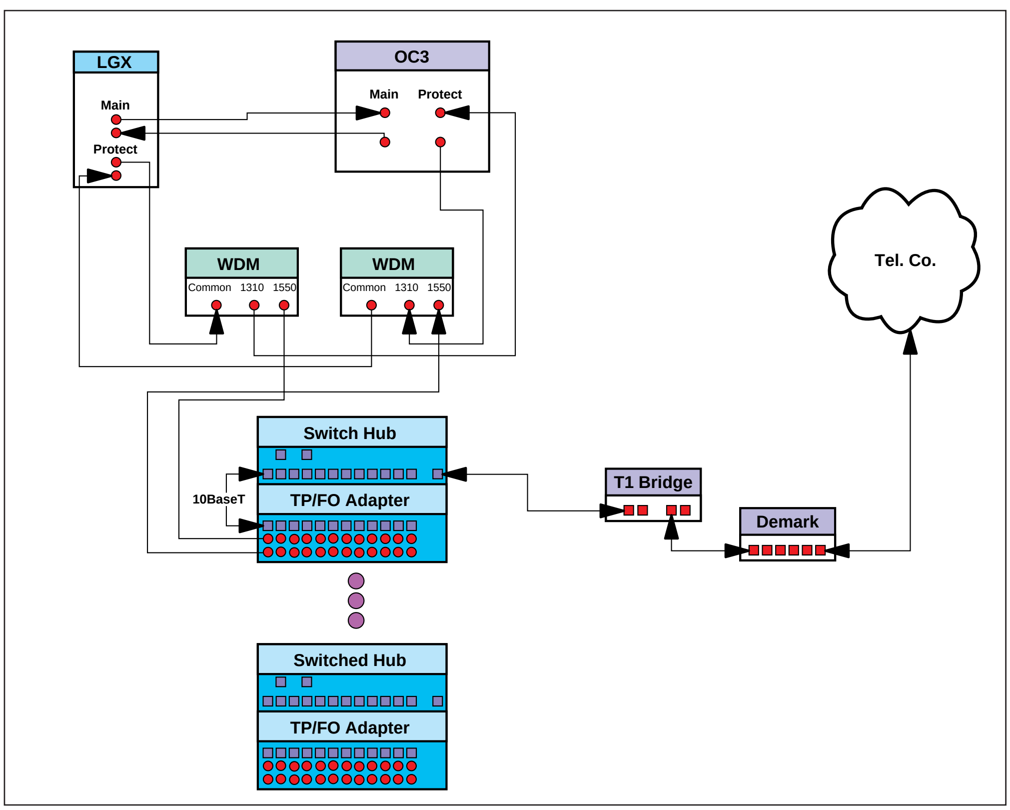

Figure 38. LifeLink TOC Subsystem

the WDMs to the 1550-nm laser transceivers, enabling the 10BaseFO Ethernet communications with the roadside fiber hub. A category-5 (CAT-5) unshielded twisted pair (UTP) cable provides a 10BaseT Ethernet connection between the laser transceiver and a switched Ethernet hub. The laser transceivers associated with each of the LifeLink roadside fiber hubs connect to the switched Ethernet hub. The switched Ethernet hub reads the destination header for each data packet received from a port on the hub and transmits the data packet out the appropriate port. This switching method effectively joins the coverage cells of each roadside fiber hub WEB to establish a cellular-like RF network. Figure 39 shows this cellular-like coverage area of the current LifeLink system created when the switched Ethernet hub connects the WEBs together. Ambulances can therefore drive through multiple cells and still maintain their connection with the hospital.

The hospital connects to a port on the switched Ethernet hub similar to the roadside fiber hubs. A CAT-5 UTP cable provides a 10BaseT Ethernet connection between the switched Ethernet hub and a T1 Bridge as shown in Figure 38. The T1 Bridge converts data between 10BaseT Ethernet and 3 Mbps DS1 telephony data. The wide area network (WAN) port on the T1 Bridge connects to the T1 Demark provided by the telephone company. Telephony data travels on a dedicated channel in the public switched telephone network between the T1 Demark in the TOC and the T1 Demark in the hospital.

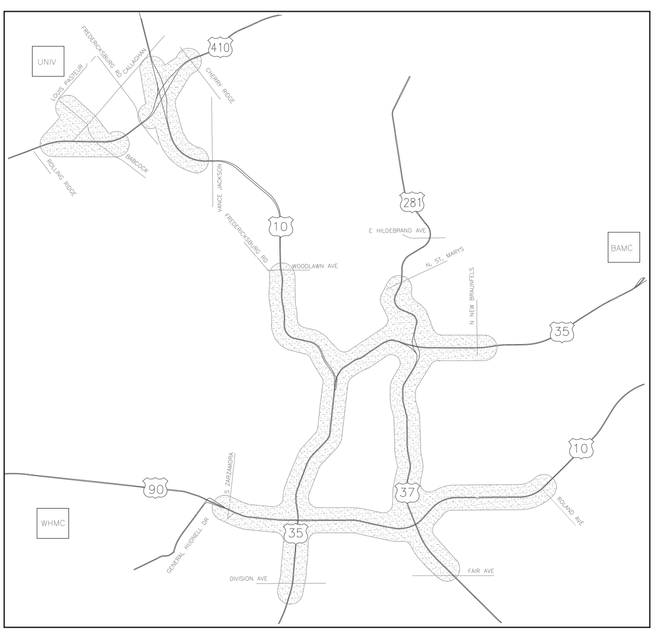

Figure 39. LifeLink Coverage Map

7.2.1.4 Hospital Communications Architecture

The LifeLink system provides a hospital with a communications link to LifeLink-equipped mobile ambulances on or near portions of the San Antonio freeway system. A LifeLink hospital node offers two-way data communications from the hospital to medical personnel in an ambulance. Video, audio, and patient monitoring data travel across this communications path between a hospital and an ambulance.

The hospital T1 Demark serves as the connection point into the isolated Public Switched Telephone Network (PSTN) telephony data channel providing the LifeLink communications connectivity. Figure 40 illustrates the hospital communications connectivity. A copper cable connects the T1 Demark to the T1 Bridge. A CAT-5 UTP cable provides a 10BaseT Ethernet connection between the T1 Bridge and the NIC in the PC Tower. The NIC transfers data between the conferencing computer and the communications infrastructure.

7.2.2 Conferencing Architecture

LifeLink conferencing architecture provides capture, transmission, and display of video, audio, and patient-monitoring data. The LifeLink conferencing hardware located in the ambulance and hospital acquires and presents the conferencing data. The LifeLink conferencing software processes the data and provides a simplified user interface requiring minimal interaction.

7.2.2.1 Ambulance Conferencing Architecture

Each LifeLink ambulance is equipped with the hardware displayed in Figure 41. Figure 42 provides an overview block diagram of the major LifeLink ambulance components. The PC enclosure shown in Figure 35 provides the main point of interaction between the LifeLink system in the ambulance and the system operator. The ruggedized PC located within the PC enclosure contains a video conferencing codec. This codec supports video capture, compression, and playback using

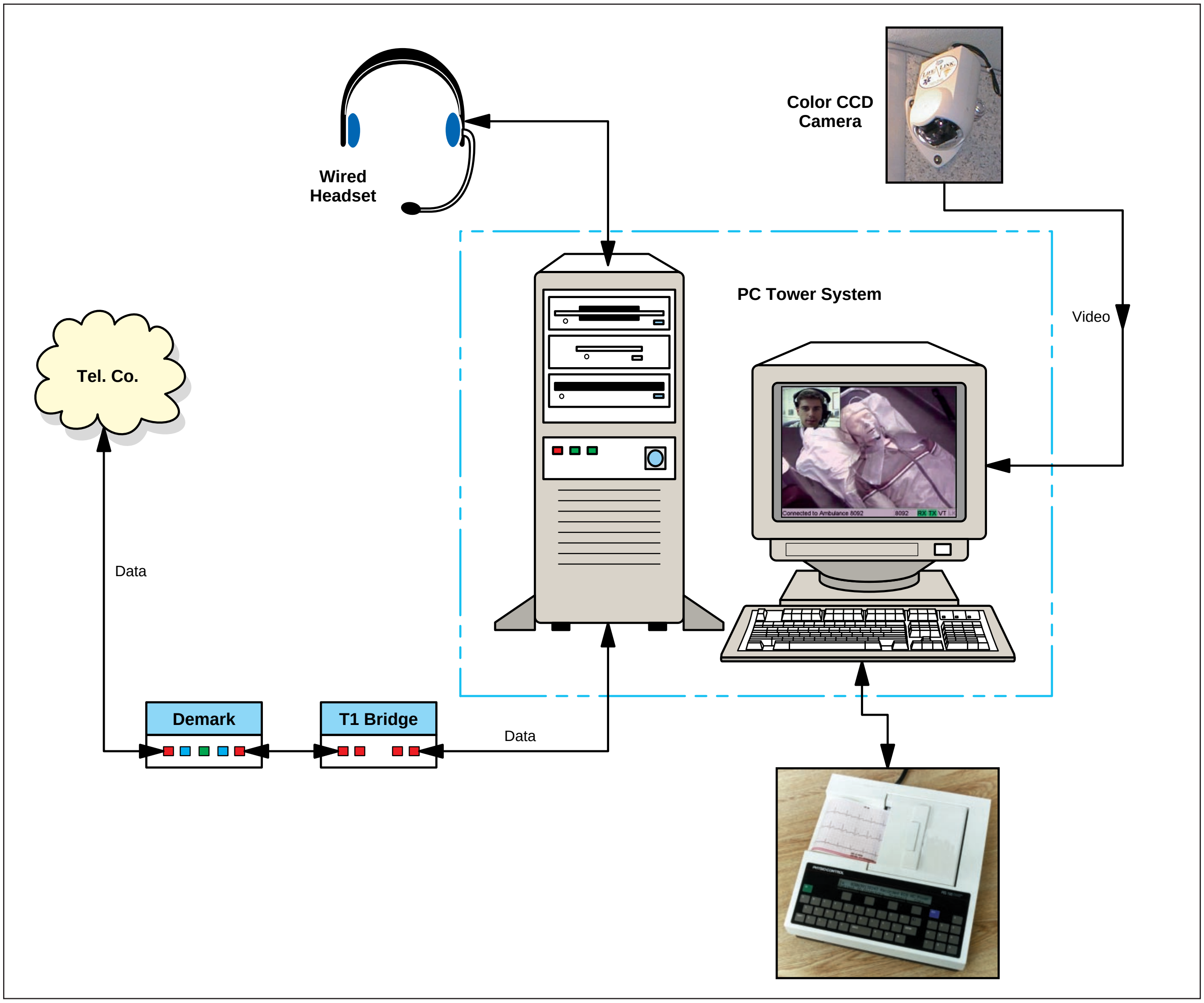

Figure 40. LifeLink Hospital Subsystem

Figure 41. LifeLink Ambulance Components

the H.261 standard. Video capture occurs at common intermediate format (CIF) resolution (352 × 240), 15 frames per second, and a data rate of 512 kbps. The codec also compresses and uncompresses audio using the G.722 standard. A graphics adapter with an advanced set of "Direct-Draw" command support works with the codec to send the video to the monitor with highest possible fidelity. The front face of the PC enclosure shown in Figure 43 offers controls to operate the LifeLink system in the ambulance.

The Main Display and Camera shown in Figure 44 serve as the primary video output and input for the LifeLink system in the ambulance. The Main Display shows the received image from the hospital and status information. At system power up, the

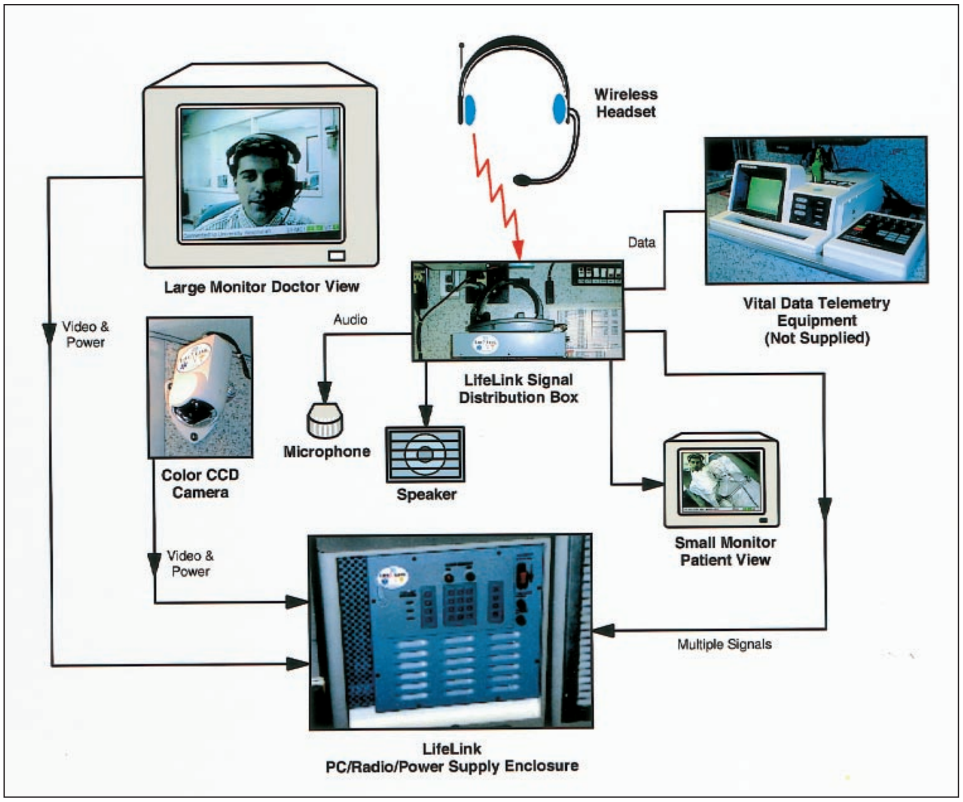

Figure 42. LifeLink Ambulance Subsystem

camera defaults to a home position pointing at the upper portion of the gurney with auto focus enabled. This position provides a full view of the head and upper body cavity of the patient under transport. An infrared remote control offers manual positioning and camera control. NTSC video travels on a coaxial cable from the camera to the codec whenever power is present.

The signal distribution enclosure and attached components shown in Figure 45 provide several functions for the LifeLink system operator in the ambulance. Figure 46 provides a block diagram of the signal distribution enclosure components. A 900 MHz wireless headset resting on top of the signal distribution enclosure provides the primary audio link to the hospital. A toggle switch on the side of the signal distribution enclosure shown in Figure 46 provides an option to use the attached speaker and microphone instead of the headset. This option is intended only for circumstances in

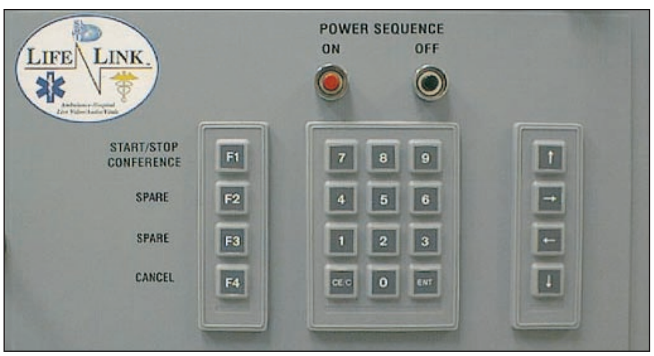

Figure 43. PC Enclosure Front Panel Controls

Figure 44. Main Display and Camera

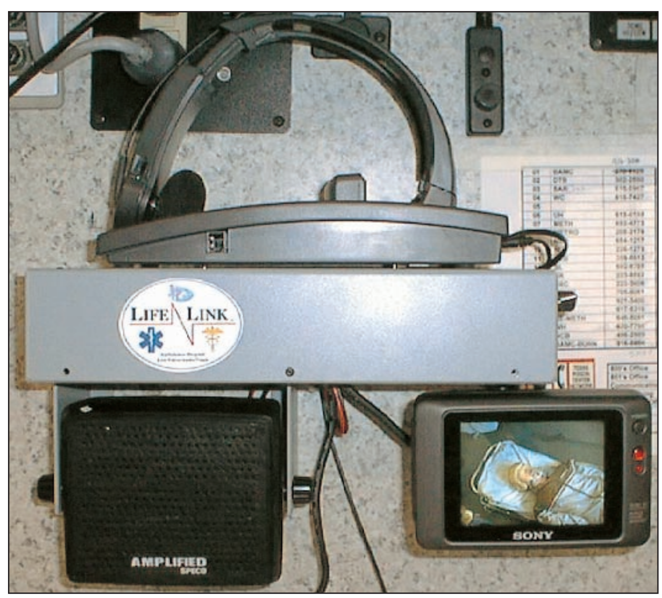

Figure 45. Signal Distribution Enclosure

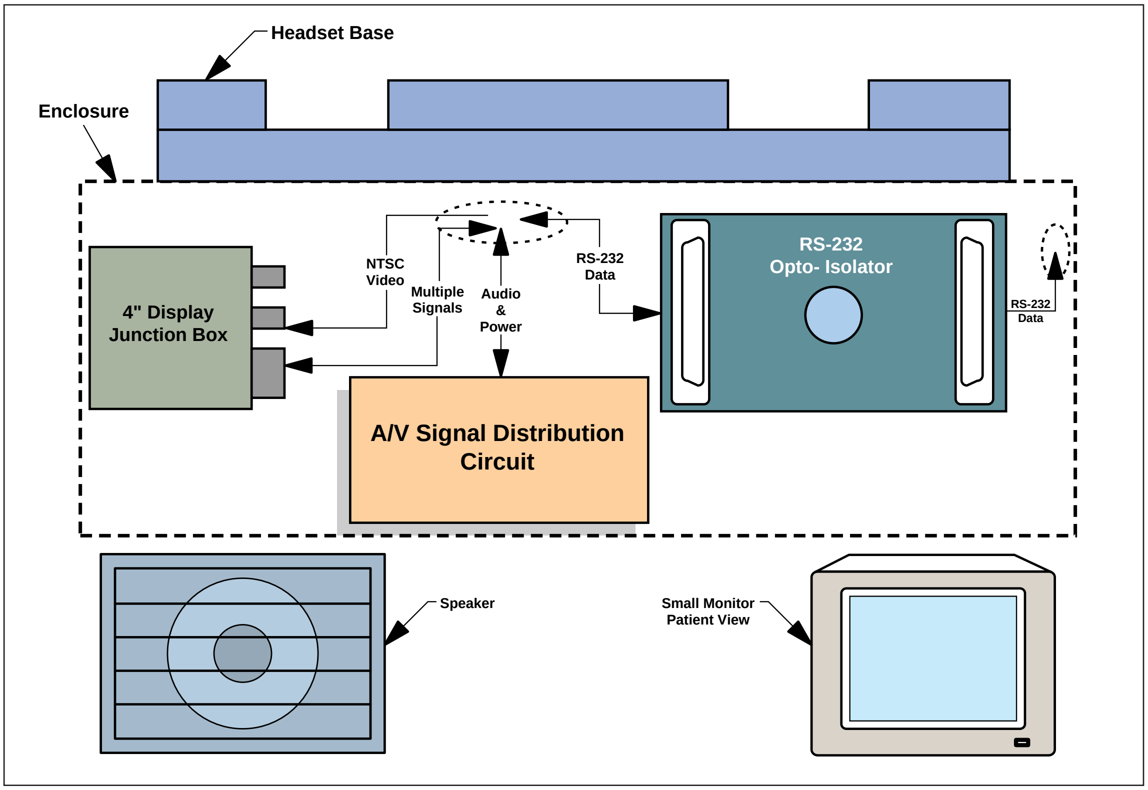

Figure 46. LifeLink Signal Distribution Enclosure

which it is necessary for the patient to participate in the audio portion of the conference. The volume control knob offers limited control over the speaker audio level when the speaker is in use.

A 4-inch local view monitor shown in Figure 45 displays the field of view of the camera. An open video feed is present any time the LifeLink system is active, even without a conference. This local view monitor indicates the field of view offered by the ambulance camera and provides positioning feedback when the remote control is used to change the view sent to the hospital.

The LifeLink conferencing system includes a means for transmitting patient-monitoring data to the hospital. A vital data telemetry port on the side of the signal distribution enclosure shown in Figure 47 offers the capability to connect patient monitoring equipment to the LifeLink system in the ambulance for automated transmission to a receiving station in the hospital during an active conference. Two different patient-monitoring systems supported by the LifeLink conferencing system include the Protocol Systems ProPaq Encore 250EL shown in Figure 48 and the Physio-Control LifePak 11 shown in Figure 49. Although these units are not

Figure 47. Signal Distribution Enclosure Side View

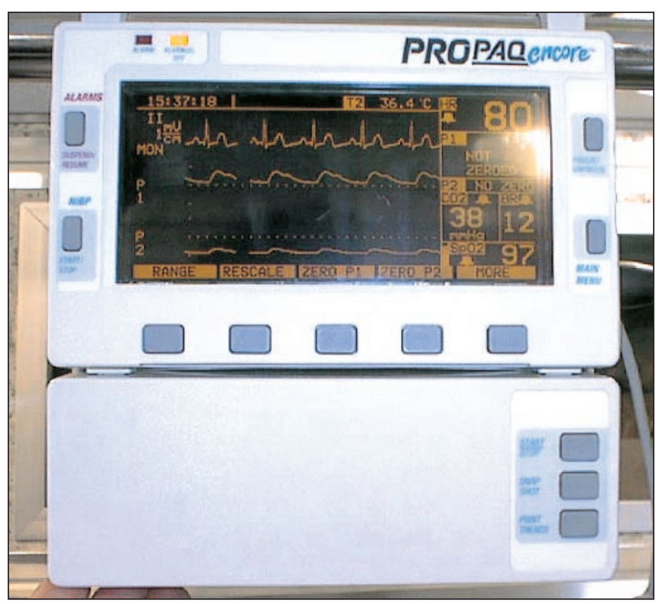

Figure 48. Protocol Systems Propaq Encore 250EL

Figure 49. Physio-Control Lifepak 11

part of the LifeLink System, the LifeLink System does provide a transparent RS-232 serial telemetry link, enabling the ambulance patient-monitoring equipment to transmit this information in real time to compatible vital statistics data display equipment at the hospital. The LifeLink System does not perform any special processing of the transmitted data, but does provide one extended RS-232 link between onboard vital statistics equipment and the remote hospital display monitor. The LifeLink System does not provide power for patient-monitoring equipment since internal batteries provide their power. This patient- monitoring capability enables the hospital personnel to review the data while the patient is en route to the hospital. The two related patient-monitoring receiving systems are supported by the LifeLink hospital conferencing system. They include the Protocol Systems Acuity Monitoring System shown in Figure 50 and the Physio-Control RS-100 Receiving Station shown in Figure 51.

An intelligent power management system utilizing a reserve battery monitors and regulates the power supplied to the LifeLink system. The intelligent power management system allows for operation when consistent ignition power is present, performs graceful shutdowns upon the loss of consistent ignition power, and offers an emergency shutdown mechanism. Switches on the LifeLink control panel shown in Figure 43 allow the user to control power-up, power-down, and emergency shutdown. The intelligent power management system's backup battery automatically charges during normal operation and provides momentary LifeLink System power when ignition power is lost.

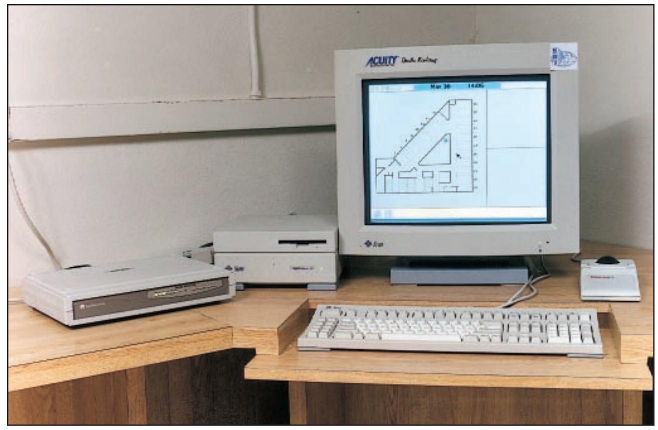

Figure 50. Protocol Systems Acuity Monitoring System

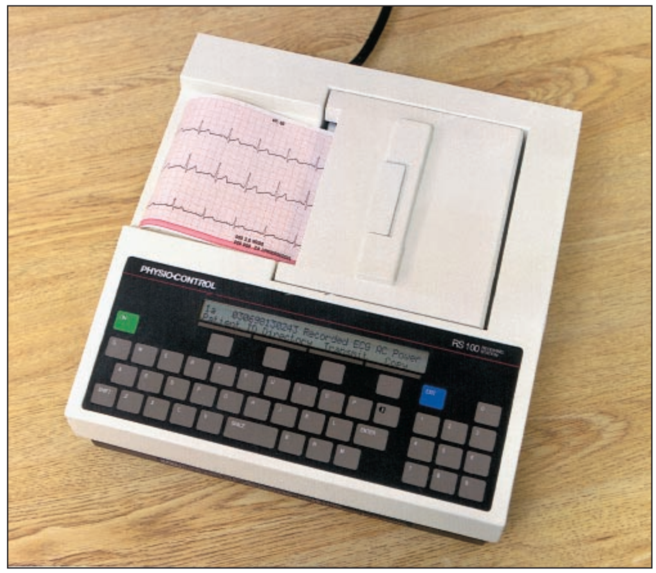

Figure 51. Physio-Control RS-100 Receiving Station

7.2.2.2 Hospital Conferencing Architecture

The PC Tower shown in Figure 52 provides several functions for the LifeLink System operator in the hospital. A video conferencing codec and graphics adapter within the PC Tower process the conferencing data in the same manner described for the ambulance. An attached keyboard serves as the main interaction point between the LifeLink system and the hospital operator. A wired headset connected to the PC Tower provides the primary audio link to the hospital.

The Hospital Display and Camera shown in Figure 52 serve as the video output and input for the LifeLink system in the hospital. The Hospital Display shows the received image from the ambulance, a smaller local view, and status information. At system power up, the camera defaults to a home position pointing at the upper portion of the chair in front of the Hospital Display with auto focus enabled. This position is intended to provide a facial view of the hospital LifeLink system operator. The camera comes with an infrared remote control that can be used by the system operator to manually position and control the camera, enabling adjustment for different hospital LifeLink System operators. The smaller local view displays the field of view offered by the local camera when the remote control is used to change the view sent to the ambulance.

A serial port on the back of the PC Tower offers the capability to connect a patient-monitoring receiving station to the LifeLink System in the hospital for automated reception in the hospital during an active conference.

7.2.2.3 LifeLink Conferencing Software

The LifeLink application is intended to be as easy to use as possible. This ease in use is accomplished by minimizing the operations that need to be performed and by minimizing the actions needed to perform a given operation. Most operations require only one or two keystrokes.

Upon power-up, the ambulance and hospital computers automatically load the operating system and LifeLink software application. From the system-ready screen shown in Figure 53, a two-digit hospital code entered on the ambulance keypad shown in Figure 43 activates a conference with the hospital. During an active conference, the LifeLink System provides the hospital node operator with a full-screen image of the patient shown in Figure 54. A small picture-in-picture image fills the upper left corner of the screen with the local image being sent to the ambulance. The LifeLink System provides the ambulance node operator with a separate large screen view (10.4-inch display panel) of the hospital physician shown in Figure 55. A small screen view (4-inch display panel) shows the patient image being sent to the hospital node. The dual ambulance display concept was implemented to minimize the possibility of the patient seeing the transmitted image showing severity of injury. The smaller display is located in an area that cannot easily be viewed by the patient. A status bar

Figure 52. PC Tower and Hospital Display and Camera

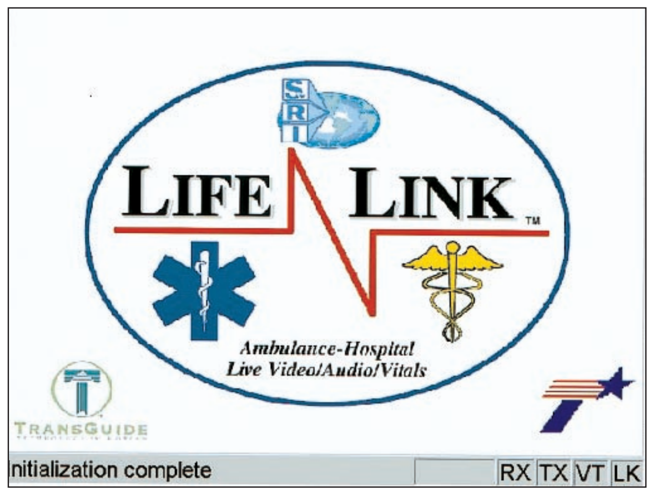

Figure 53. Ambulance System-Ready Screen

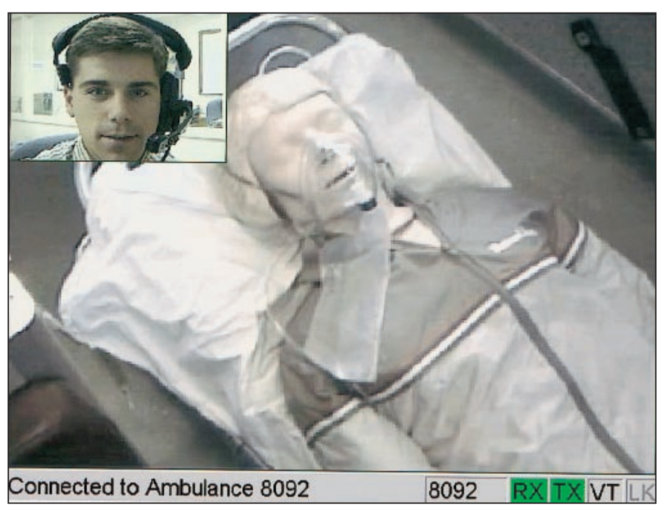

Figure 54. Hospital Conference Screen

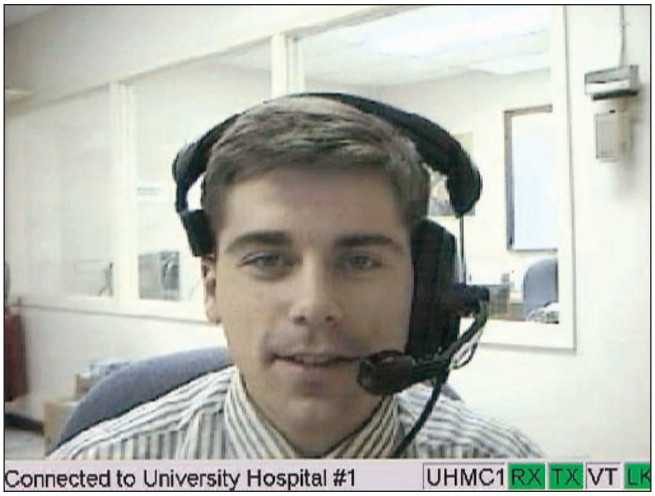

Figure 55. Ambulance Conference Screen

located along the bottom edge of the large displays at each end of an active videoconference session includes the identity of the current remote node, the remote node's abbreviated name, and indicators for video transfer, data transfer, and RF link status. The software provides for bi-directional voice communication between the hospital and ambulance LifeLink System operators via a single headset provided at each end of the videoconference. A separate data channel has also been included for the transmission of optional patient-monitoring data from terminal equipment in the ambulance to a remote display terminal at the hospital. The vital statistic data channel provides an RS-232 link operating at 38.4 kbps.

The hospital node contacted by the ambulance is called the control node. This node is capable of both bi-directional audio and video communication with the ambulance. The control node can also receive patient-monitoring data if the ambulance and hospital node are equipped with the appropriate monitoring receiving equipment. An ambulance can communicate with only one hospital control node at a time. The operator at the hospital control node can transfer the control node function to another hospital node, but the original control node will be disconnected from the conference. The hospital control node operator can also connect other hospital nodes into the videoconference session as consultant nodes. The hospital operator at the consultant node can listen to the ambulance audio and view the video from the ambulance. Audio participation at the consulting node is limited to traditional means such as standard telephone communications.

7.2.3 Management and Maintenance Architecture

A Simple Network Management Protocol (SNMP) network management computer has been installed at the TOC to be used for LifeLink management and maintenance support. The SNMP computer can be used to access status and control registers of the switched Ethernet hub and WEB radios. The SNMP computer is also a conference-capable computer configurable for end-to-end conferencing diagnostics. Maintenance personnel can use the SNMP computer to monitor network performance and traffic, to aid in network problem determination, and to provide network access security.

7.3 Tradeoff Decisions

Many tradeoffs were made during the development of the LifeLink system. Table 10 lists the top four tradeoff decisions and the rational for selection.

7.4 Summary

Since the early stages of development, the LifeLink system has been a focal point illustrating the life-saving benefits of ITS. The LifeLink project has successfully demonstrated the ability to provide a video, audio, and vital data link between a mobile ambulance and a hospital. The LifeLink communications system supports high-bandwidth information transfers predominately utilizing cost-effective COTS equipment. The unique communications link allows emergency care providers to save valuable time through earlier awareness and intervention. Finally, the system is expected to save lives due to the volume of life-critical information exchanged, the increased awareness, the earlier interventions, and the more efficient management of life-saving resources. As the LifeLink coverage area expands, the life-saving benefits are expected to similarly increase.

Table 10. LifeLink Design Tradeoffs

(Selected technology is highlighted in yellow.)

Issue	Option	Benefits	Detractors	Rational
RF Link	2.4 GHz Spread Spectrum	No FCC Licensing required; 4 Mbps Ethernet data.	Limited coverage area.	Full motion video requires a faster data rate than current cellular telephones can support.
	Cellular Telephone	Wide Coverage Area.	Limited data rate (maximum of 14.4 kbps)	
Optical Fiber Interface	WDM	Combined light travels in same direction at different wavelengths; established technology.	More expensive than Splitter/ Combiners.	Preliminary testing demonstrated a greater potential for data corruption using Splitter/Combiners; WDMs introduce less optical attenuation into the system.
	Splitter/ Combiner	Less expensive then WDMs.	Combined light travels in opposite direction at same wavelength; power level sensitive.	
Conferencing Codec	H.320 Based	Performance optimized over life span of standard.	Intended for loss-less ISDN networks.	The H.261 product offered additional benefits of Windows NT support, PCI interface, Visual C++ software development and Video for Windows support.
	H.261 Based	Intended for Ethernet-based lossy networks.	Lacks performance optimization of H.320.	
Ambulance Computer	Laptop	Less expensive.	Requires a docking station for the codec; docking station requires AC power.	Docking stations are intended for office environments and not mobile applications.
	Ruggedized PC	Designed for rougher environments; DC power option; more expansion slots.	More expensive.	