Relief for Maritime Medical Emergencies through Telematics

George Anogianakis, Stavroula Maglavera, and A. Pomportsis

***Abstract*—MERMAID is a European Union (EU)-financed maritime telemedicine project with global reach and 24-h multilingual capability, so as to serve multinational crews working in the isolation of the world's oceans. It provides a model for the provision of healthcare services based on the electronic transmission of medical information via ISDN-based video conferencing. This model is not limited to medical diagnostics, but it encompasses all cases in which the actual delivery of healthcare services involves a patient who is not located where the provider is. Its implementation requires the commissioning of an extensive telecommunications infrastructure that includes both satellite transmission for ship to shore communication and an extensive ground-based network for summoning expert medical help from around the world so as to meet the project's multilinguality requirements and, therefore, the exploration of a number of solutions. In fact, all categories of telemedical applications (audio and video conferencing, multimedia communications, flat file and image transfer with low-, medium-, and high-bandwidth data requirements) are considered, while the full range of network choices (digital land lines, cellular/wireless, satellite, and broadband) are being tested in terms of cost/performance tradeoffs that are inherent to them and the developmental stage each of these options occupies in their lifecycle. Finally, out of that, MERMAID utilizes advanced land-based line transmission technologies to aid the remote patient by making available the specialist care that is best suited in the particular case.**

***Index Terms*— Emergency telemedicine, INMARSAT, maritime, medical guide, multimedia.**

I. Introduction

MERMAID is a European Union (EU) (DGXIII) healthcare telematics program [1], [2], which was created in response to council directives 92/29 and 93/103. These directives provide the basis for using "long distance medical consultation" to protect the safety and health of maritime workers. MERMAID therefore provides an integrated multilingual medical emergency service around the world and use telematics to transfer medical expertise to seaborne vessels [3]. In this respect, it has conducted a survey on telemedicine user requirements [4] that attempted to place maritime telemedicine within the presently emerging framework for practicing telemedicine around the world. The reasoning behind such a survey was that, although MERMAID is strictly a maritime telemedicine and emergency medicine project, it can neither ignore current telemedical developments nor grow into a truly "global 24-h multilingual telemedicine surveillance and emergency service" by isolating itself from other facts of the field of telemedicine [9].

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II. Mermaid Survey

To place the MERMAID survey conclusions into perspective, we must mention that it was compiled on the basis of the replies from 1853 medium and large (>1000 gross tons) oceangoing vessels. According to the Maritime Administration of the United States Department of Commerce [5], this corresponds to 7.5% of the total world merchant marine for this class of vessels. It also corresponds to 2.5% of the world total when all ships over 100 gross tons are taken into account [6]. Finally, it corresponds to approximately 20% of the EU merchant marine capacity.

MERMAID has succeeded in estimating for the first time the size and depth of the maritime telemedicine market, as follows.

1) Merchant marine and the sea-related activities are estimated to employ 1 500 000 workers worldwide. Of these, 410 000 work aboard medium and large ships, 140 000 are officers and 270 000) are deck and engine crew. Officers come to a large extent (>40%) from OECD countries, while crews from developing or underdeveloped countries (>60%).
2) Most ships have an adequate marine communications infrastructure for supporting telemedicine applications, especially those operating at high seas. However, high speed data (HSD) capability is not widely available, and at present, only a small number of ships (<5%) can take advantage of the full spectrum of telemedical services that are technologically feasible (Table I). It is noted that only 18.5% of the vessels surveyed are fitted, so far, with the global maritime distress and safety system (GMDSS), i.e., the new standard in marine safety.
3) Most modern oceangoing vessels have some kind of computer capability. Eighty-five percent of the operators currently use personal computers onboard their vessels, 76% are utilizing telephones and facsimile equipment, and 48% use modems for transferring data to and from their vessels. Operating systems used are either DOS or Windows.
4) Number of marine telemedical calls is estimated between 15 000 and 20 000 per year worldwide. In general, the incidents reported are restricted to either sudden illness (37%) or accidents (63%). Nine out of the ten cases reported as "sudden illness" are in fact "neglected" cases that suddenly deteriorated.

TABLE I
PERCENTAGE OF VESSELS CAPABLE OF OPERATING OVER THE DIFFERENT MARINE TELECOMMUNICATIONS SYSTEMS

Type	Percentage %
INMARSAT A	55
INMARSAT B	4
INMARSAT C	37.5
Intelfest	0.6
Capability of High Speed Data	5
Modem	13.5
Telephone	56
Fax	49
Radio/Telex	3.7
INMARSAT -M	0.1
MARINET	1.8
TOR	0.1
Mobile Telephone	0.8

5) Forty-three percent of the operators expressed an interest for a 24-h emergency, multilingual and multidisciplinary telemedicine service, while 73% of these operators, who reported their interest for such a service, said they would be willing to pay a subscription for it.

III. REVIEW OF THE COMMUNICATIONS TECHNOLOGIES OF INTEREST TO MERMAID [7], [8]

Communications technologies of interest to MERMAID can be viewed from two main vantage points: transmission media and networking systems. Regarding transmission media, the following subjects can be considered of importance:

1) fiber optics;
2) copper cable (HDSL/ADSL and coaxial cable);
3) satellite communications;
4) cellular radio technologies;
5) wireless data networks;
6) radiotelephony for navigation;
7) radiotelephony on airplanes;
8) radiotelephony on trains.

Similarly, regarding networking systems, the following subjects bear on the MERMAID project and its future infrastructure development strategy:

1) asynchronous transfer mode (ATM);
2) B-ISDN protocol reference model for ATM or I.121 (physical layer, ATM layer, ATM networking, ATM adaptation layer, or AAL);
3) ATM networks and services introduction scenarios;
4) ATM and competitive narrowband services (global networking with N-ISDN);
5) packet switched networks;
6) Internet.

IV. IMPLICATIONS FOR THE MERMAID IMPLEMENTATION

Based on the current mix of marine communications capabilities that exist aboard oceangoing vessels, it has been decided that the MERMAID medical telecommunications software that is currently under construction will be adapted to accommodate all types of maritime users, irrespective of whether they are INMARSAT A, B, or C adherers. Furthermore, it was decided that the medical telecommunication software should include the following:

1) medical record system that can guide the user through patient history and objective examination;
2) multimedia HELP function with text and illustrations, based on the WHO and the EU (DG V) requirements for help at sea, to guide paramedics through all of the diagnostic procedures they have to perform for the teleconsultant and through all of the therapeutical procedures that the teleconsultant might prescribe;
3) database with all of the information on the vessel's stocks of medicine and medical equipment.

The MERMAID telemedical approach itself is a two-level approach that includes the following:

1) basic level at which the MERMAID communication system, which includes a medical record and a HELP/guidance system (all designed with the INMARSAT satellite communication system in mind), is used.
2) second level at which more enhanced and technical sophisticated features, such as interactive video, sound, EKG transmissions, etc., are used; features that can only be used for ships equipped with INMARSAT A or B.

Finally, the development of program modules for training and education of the seafarers in the use of the MERMAID medical communications system will be given top priority, as such modules constitute the firmest basis for the promotion of the proper practice of telemedicine at sea.

V. GUIDELINES FOR THE IMPLEMENTATION OF THE MERMAID TELEMEDICAL SCENARIO

1) MERMAID capitalizes on the fact that ISDN is the first widely available public network, which is based on international standards, that can provide support for integrated services. This makes it the obvious current choice to support wide area telemedical applications.
2) Communications satellites provide a means of transmitting data between geographically remote locations. The MERMAID choice, INMARSAT, provides a telecommunications capacity, which PTT's may lease to provide worldwide data communications and use for building virtual private networks.
3) MERMAID telemedical scenario considers that the first and foremost piece of information of value to a clinician for reaching a correct diagnosis is the *firsthand contact, view and examination of the patient.* Experience suggests that, in the absence of the visual prompt of the patient's presence, medical practitioners make errors in history taking that result in a number of dangerously incorrect diagnoses. MERMAID, therefore, has adopted telemedicine methods and scenarios that include live images of the patient transmitted to the remote physician and offer the possibility for online interaction, discussion, and consultation with the patient and/or those attending.

4) Experience has shown that, with monitor resolution as low as 200 lines per picture height and 10 frames/s, clinicians are already able to diagnose much more effectively than with voice-only communication. MERMAID will be using image quality considerably above that threshold.
5) Telepresence is the virtual presence of a distant person at a site, giving that person a sense of perception at the site. When added to a medical teleconsultation scenario, such as the one used by MERMAID, it gives all of the benefits of image transfer and enhances the efficiency of the session. In this respect, the following parameters have a significant affect on the feeling of reality:
   a) image size;
   b) image definition;
   c) personalized images;
   d) localizing sound with images.
6) Locally stored but remotely controlled multimedia material will be used to make medical instructions more explicit. The subjects to be covered by this material will include the following, among others:
   a) first aid instructions;
   b) poisoning-related structured history taking;
   c) trauma-related structured history taking;
   d) infectious diseases;
   e) venereal diseases;
   f) emergency treatment of marine disaster victims;
   g) environmental vessel control;
   h) prevention of diseases;
   i) onboard administration of pharmaceuticals;
   j) pharmaceuticals index and dose;
   k) surgical equipment and usage.
7) Three main components necessary to set up the MERMAID telemedical scenario are the following:
   a) *source of expertise*, i.e., definition of land-based stations where physicians standing by (or on call) will be able to offer their services in case of emergency;
   b) *communications channel*, i.e., ensuring communications with open-sea vessels across the globe;
   c) *terminal equipment* for the capture and transmission of visual and audio information. This should be operationally safe within the intended environment, able to support the intended functionality, cost justified, easy to learn, easy to use, adherent to data communication standards to promote versatility and interoperability.
8) Other issues involved in the realization of the MERMAID scenario are the following:
   a) *training*, in particular, self-training applications with possibilities for distance training, substituting formal person-to person interaction by simple point-of-use instructions, explanatory documentation, online multimedia presentation, and help;
   b) *consultation protocols* for both ocean and land-based sites will have an impact on both resource usage and work patterns at both ends;
   c) *medical records*, the representation, content, storage, and integration may prove to be of great importance for the success of the proposed scheme;
   d) *medical practitioner concerns*, while it is possible that the land-based hub will not always feature a medical practitioner with the required expertise, the problem mainly concerns the qualifications of the respondent at the ocean site.

VI. Concept of the MERMAID Application

The total concept provides the person acting as a paramedic onboard a merchant marine vessel with a set of procedures and guidelines that ensure his/her correct response to illness and accidents and guides him/her through these procedures while providing effective communication with the medical teleconsultant. It assumes that, in all but the so-called "minor" cases, the paramedic should seek outside help and advice and will act as the teleconsultant eyes, ears, and hands.

The results of the MERMAID communication user analysis has shown that the INMARSAT C system (using simple text communication) should be included in the MERMAID application. The exchange of data between vessel and shore will be dependent on the equipment onboard. MERMAID supports INMARSAT A and B links for voice, data, still photo, and live video transmissions as well as INMARSAT C for text communication. The application works as follows.

- *Step 1:* The paramedic decides if it is a case of a minor ailment, illness, or accident. The questions asked and the data required in each case are different. Guidelines will be provided to assist the paramedic in deciding whether to call a teleconsultant.
- *Step 2:* A medical record is created with the following information: basic information on the patient's condition, acquired by the paramedic through the applications guidance; information on the vessel and crew, obtained from the local database to reduce the information the paramedic has to gather in an emergency; and information on the vessel's stock of medicine.
- *Step 3:* The application guides the paramedic to provide information about the patient history and examination and pictures and drawings for the communication.
- *Step 4:* The data are sent to the teleconsultant through the INMARSAT system using the available communication means. The teleconsultant's replies are dependent on the communication means as well. A scaleable system ranging from simple text (INMARSAT C) to full video conferencing (INMARSAT A or B with HSD) is supported by the MERMAID system.
- *Step 5:* The teleconsultant from the MCC replies to the paramedic on board the SV. The teleconsultant may suggest a course of treatment, ask for more clinical data, or guide the paramedic through a procedure. The teleconsultant is able to enter the multimedia guide and use the procedures shown to aid the paramedic.

VII. MERMAID Application Overall Configuration

The MERMAID application has been configured as shown in Figs. 2 and 3. The messaging system on the sea vessels

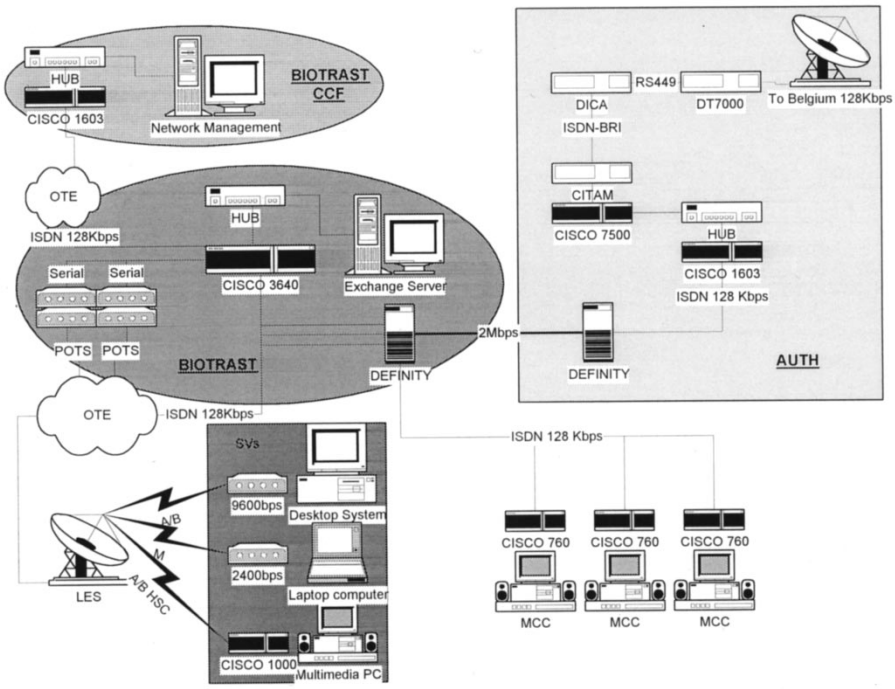

Fig. 1. MERMAID hardware configuration.

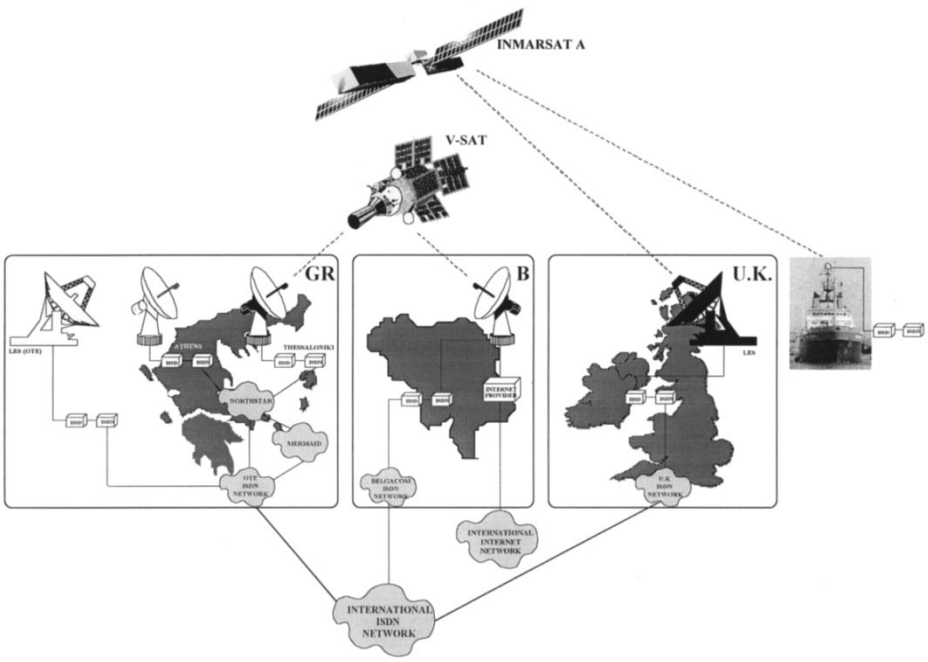

Fig. 2. MERMAID communications network layout. The diagram includes the VSAT connection between Greece and Brussels, where MERMAID is running a demonstrator of its services, through the EHTO Observatory (an activity financed by the European Commission-DGXIII) and the United Kingdom, where the Electrodiagnostic Center provides medical advice to eye-related problems.

(SV's) communicates initially with the ground central station (GCS) in Greece (BIOTRAST), as shown in Fig. 1. The GCS then determines which of the medical care centers (MCC's) should be capable of dealing with the SV's request for assistance. The choice of MCC depends on the origin of the SV, location, language spoken on the SV or of the paramedic, and casualty and availability of the MCC. There are three modes of operation in the software.

1) Off-Line Operation: In this mode, the user has no connection at all with the GCS or any MCC. The program executes local jobs, that is, jobs that only require access to the onboard database, e.g., settings of the program, the multimedia medical guide, crew records, drugs, green status reports, etc.

2) Messaging Indirect Communication: In this mode, the SV's send e-mail messages to the MCC's through a mail server that resides in the GCS. An e-mail message can contain

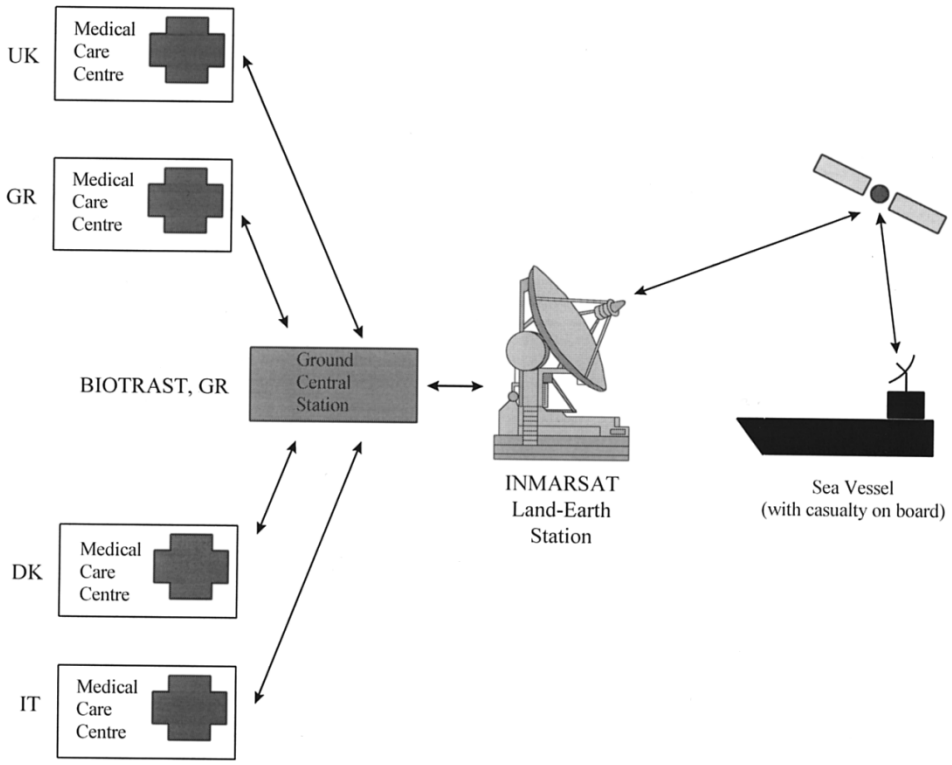

Fig. 3. MERMAID application overall configuration.

text, blue or red status reports, static images taken by a digital camera, sound and video clips. A message can also contain certain commands for allowing the MCC's the ability to control the software display on the SV. In this mode of operation, a conversation between the SV's and the MCC's begins, initiated by the SV sending a blue or red status report, and it is implemented in the form of messages that are sent and responded to. In this mode, the teleconsultant in the MCC can request more information from the SV, remotely launch the multimedia medical guide to show to the paramedic or SV user how a certain medical process can be accomplished, or simply send a small answer informing him/her of the required procedure to treat the injury.

3) Conferencing Mode and On Line Communication: In this mode, there is a direct communication between the SV and the MCC. This mode is normally initiated by the MCC after receiving a red status report about an accident from an SV or whenever the teleconsultant at the MCC decides that an online examination is necessary. This mode can also be initiated by the SV if medical conferencing is urgently required. The SV can query the server in the GCS to see which MCC's are currently logged in and available and start a conference with any of them. This mode supports indirect communication as well as video and audio conferencing when supported by the SV.

VIII. Modules of the MERMAID Software (Fig. 5)

1) Graphics User Interface (GUI): The GUI is a set of visual components and the main program code that initializes and created all main objects of the program. The Windows'95 backbone to the program was adopted to ensure easy and proper management of the system by the GCS. The MERMAID GUI is a typical Windows'95 user interface made as simple as possible.

2) System Manager: The core of the software is the system manager, which keeps a list of all services that are available in the system and a list of handlers, one for each of those systems. It receives the user requests and routes the events to the appropriate service handler. *Services* include the patient database, drugs database, address database, system settings, and mailer. *Handlers* are links between the system manager and the services.

3) Messaging System: This object handles *messages* and *attachments* and keeps a list of *mail sockets* for sending and receiving e-mail messages.

4) Crew Member Module: It is responsible for handling the crew general data records and medical history records and offering the user interface for adding/removing/updating crew records.

5) Drugs Module: It provides the user interface for handling the database of the drugs that are available in the SV. The drug module uses the same drugs database used by the drug expert system.

6) Medical Report Generators: There are three report generators: green, blue, and red. Corresponding to the graveness of the situation (doctor's intervention is not required—record keeping only—advice is sought, accident, or rapid deterioration of crewman's condition).

7) Image Module: This is responsible for acquiring images from a digital camera attached to the computer, storing them, and redisplaying them.

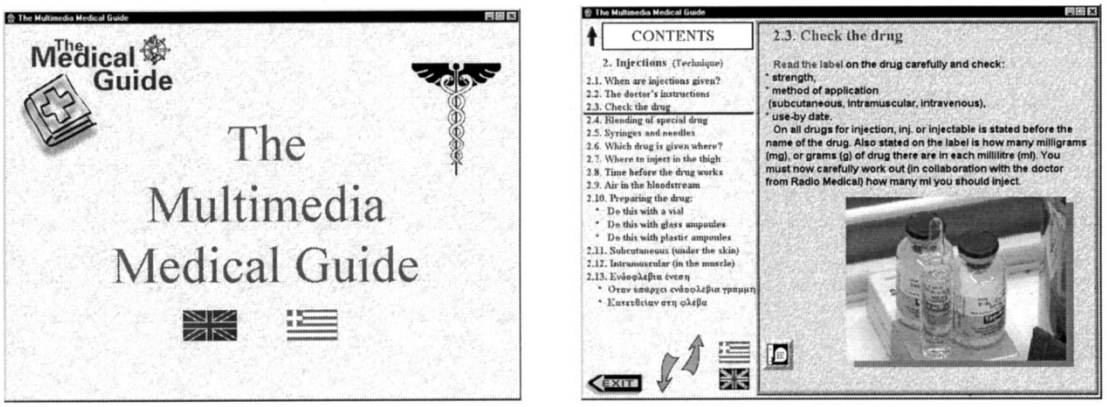

Fig. 4. MERMAID multimedia medical guide.

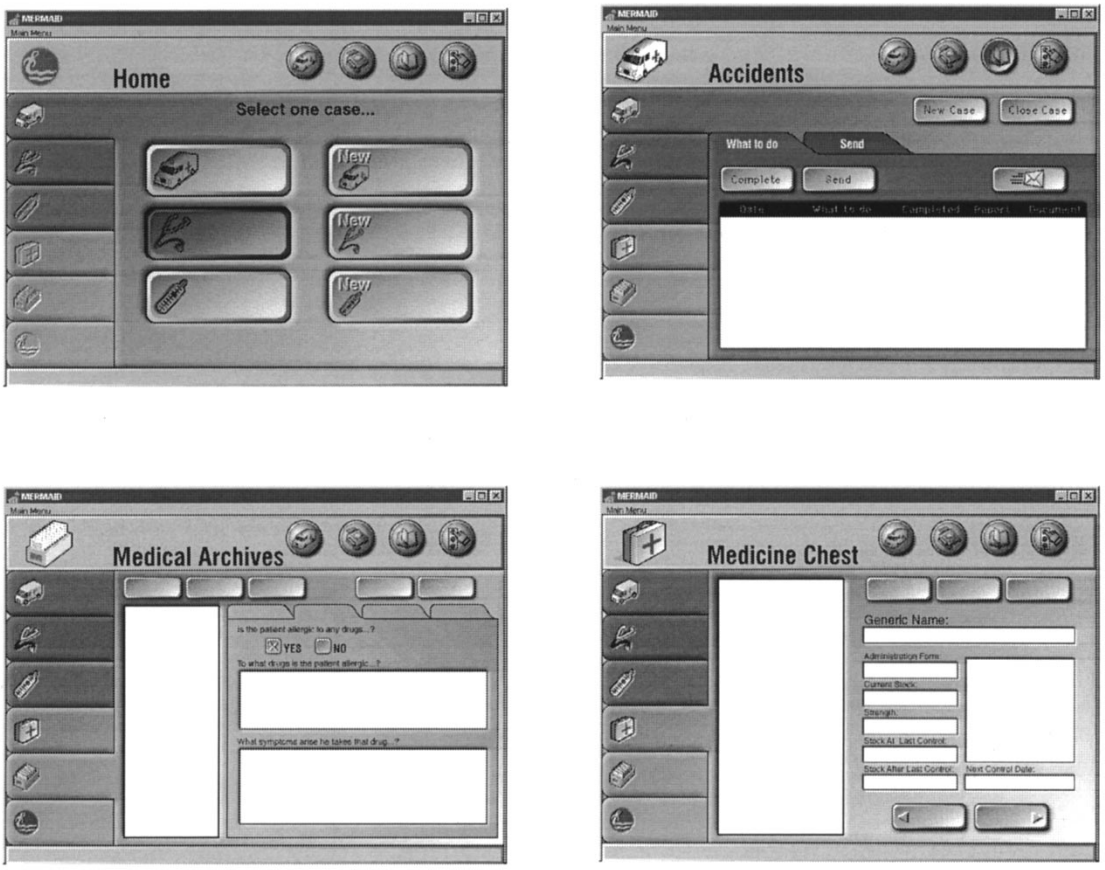

Fig. 5. MERMAID software.

8) Audio Module: This offers an *attachment* that keeps the data of the sound recorded and a *wizard* that actually records the clip and is capable of playing it back. All audio clips are *attachments.*

9) Video Module: This offers the video clip attachment and wizard. The attachment keeps the data of the video clip, and the wizard is responsible for recording the clip and playing it back. An MPEG algorithm was originally considered for the compression of the video clips. However, the emergence of the new video compression standard, H324, was considered a better option. This is a compression algorithm of motion video that does not support sound. However, this is not a limitation because the purpose of the video clip attachment is to provide the doctor with information that cannot be provided through still images, for example, the way the patient walks. A number of video frame grabbers that support H324 are being assessed. Frame grabbers, which are provided with an SDK and support Windows'95 and NT, will enable the integration of video as an *attachment* to a message. One of the frame grabbers, Osprey 1000, provides video and audio capture and compression in a variety of formats. Osprey will allow most video-based multimedia applications, such as store and forward as well as on line video conferencing. Osprey allows simple integration of hardware and software through standard industry interfaces.

The grabber supports the majority of ITU standards, which ensure any communication protocol can be used.

10) IP-Based Audio Phone: This is responsible for offering an audio conferencing channel over a TCP/IP network.

11) IP-Based Video Phone: This provides a video conferencing channel over a TCP/IP network. The video and audio processor described in the video module, which captures and compresses the images, is capable of being used for the video conferencing mode possibly using Microsoft's NetMeeting.

12) International: This is keeps track of the strings and spoken messages that exist in different languages. It is responsible for returning the correct string and the correct sound clip, depending on the language that is selected.

13) Multimedia Medical Guide: The multimedia guide, as shown in Fig. 4, offers a set of images, sounds, and videos that explain certain processes, like taking blood pressure, making an injection, etc. It is a multimedia database that can be browsed by the user any time and launched by the main program to explain a certain process to the user, if a doctor requests it.

14) Drug Expert System: This small system is called whenever the software is about to suggest that a drug is required in a green status situation. It will try to prevent the user from making any mistakes, like administering a drug that conflicts with another drug that the patient is currently taking.

IX. Conclusions

MERMAID attempts to combine mobile satellite technologies, VSAT technologies, and ISDN protocols to realize a global state-of-the-art system for the provision of healthcare services to the maritime sector. In this respect, it must be pointed out that the technologies chosen guarantee the following:

1) *reliability* since the technological platforms that were chosen have been extensively tested over the past 20 years;
2) *continuity* since bandwidth is easily upgradable to at least 2 Mbps over the existing technological platforms;
3) *seamless connectivity* since the technological platforms that were chosen have been fully integrated into the worldwide telecommunications networks;
4) *ease of upgrading* to technologies that are natural successors to ISDN (ATM, xDSL);
5) *implementation at the lowest possible cost* since they utilize (and interface) existing and implemented technologies for every branch of the proposed MERMAID network;
6) *downward compatibility* since all technologies chosen can accommodate smaller scale implementations. For example, besides HSD, INMARSAT A can accommodate different levels of interaction, all of which can be utilized for telemedical purposes.

It must be stressed, however, that, at present, MERMAID has been focusing strictly on commercial maritime-oriented satellites (INMARSAT family), despite the fact that it is technologically feasible to expand the MERMAID concept so that other satellite constellations (ku, MEO, LEO) can be used.

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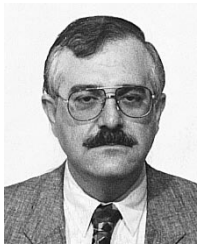

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