Interactive Multimedia in the High Performance Organization: Wealth Creation in the Digital Economy

US Army reinvents health care for force XXI

by

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ALLIANCE FOR CONVERGING TECHNOLOGIES

The Alliance for Converging Technologies was formed in early 1994 to conduct large cooperative programs that investigate issues for businesses raised by emerging technologies.

In September 1994, the Alliance launched a new multi-million dollar research, education and strategic planning program entitled *Interactive Multimedia in the High Performance Organization: Wealth Creation in the Digital Economy*. This program addresses strategic issues facing enterprises in health care, manufacturing, education, hospitality/travel, publishing, financial services, retail, government, telecommunications and entertainment industries.

The program identifies how networked interactive multimedia can deliver breakthrough improvements to business and market strategy, organizational high performance and technology infrastructure. It includes industry analysis, case studies, market research and a proprietary approach to designing multimedia-enabled enterprises. The program is "the definitive investigation" of interactive multimedia and the information highway.

This case study on telemedicine in the US Army is one of twenty-five produced as part of the Alliance program.

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US Army reinvents health care for force XXI

The Pentagon is embarking on a set of initiatives designed to reinvent the entire approach to military health care delivery. These initiatives have potentially massive ramifications for the civilian sector as well. Such "learning" by the civilian sector would hardly be new. From Florence Nightingale's 1854 invention of nursing in the Crimean War to the Red Cross blood donor system which grew up during World War II, innovations from the field of combat have reshaped health care delivery everywhere.

The scale of change will be vast, as the Armed Forces operates some of the largest managed health care services in the world. These changes take place in a much larger context – the multimedia-enabled reinvention of warfare itself.

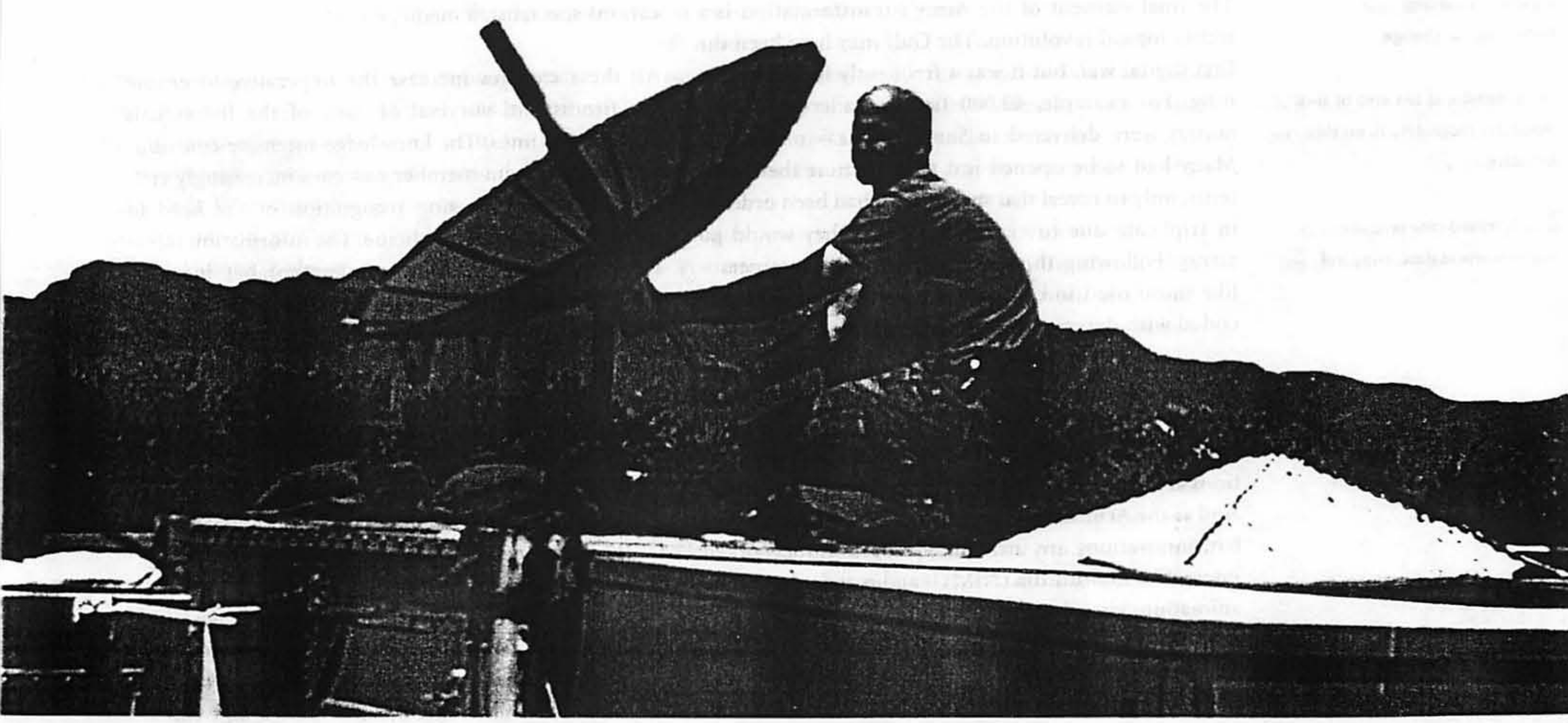
Business context

Kev drivers of the Department of Defense Telemedicine

- Downsizing, new role for Armed Forces
- Team-based management
- NIM-enabled combat environment
- Unacceptably high fatality rates
- Political support

Key facts about the US Army:

- The number of troops in uniform has declined from 780,000 in 1989 to a projected 500,000 in 1995
- 1994 appropriation was $60 billion (a decline from $90 billion in 1989)



"Bob on ISO, Sept. 28, 1994" (source: Department of Defense)

- US Army is mandated to reinvent health care delivery for the entire Armed Forces, in support of the XXI century multimedia-enabled warfighting initiative

- $44 million earmarked for first of several "medical laboratory" technology development initiatives

- Goal is to provide anytime/anyplace delivery of world-class care and support from the best medical centers in the continental US to the soldier in the foxhole

- Pilots in locations like Haiti and Croatia prove viability of baseline concepts

- Key change management issues relate to funds availability, business reengineering and institutional obstacles to rapid organizational and technological change

- See appendix at the end of this report for more details on this initiative

- DoD telemedicine website http://www.matmo.army.mil

The end of the Cold War coincided with severe fiscal constraints in the military. The role of the Armed Forces is also changing dramatically. As a recent Fortune article asked, "now that the Soviet Satan is dead, what does it mean to be a soldier?"[1]

The Gulf was the first digital war. Since then, the US Army has taken a page from the Canadian armed forces and begun shifting its focus from warmaking to peacekeeping. The Army has sent troops to provide police services in Haiti, feed children in Somalia, purify water for Rwandan refugees, fight forest fires in the Pacific Northwest, teach Russian soldiers how to rescue hostages, and teach Colombians how to hunt down drug pushers.

Shifts in priorities and fiscal constraints are two of the key factors driving change in the Armed Forces. A third, which complements the first two, is a fundamental change in management style. The Armed Forces, traditionally the archetypal model of command-control organization design, is moving to a team-based model. This was proclaimed by Colin L. Powell in a November 11, 1991 message from the Chairman of the Joint Chiefs of Staff: "... all must believe that they are part of a team, a joint team, that fights together to win." The Army uses team-building organization consultants to develop innovative and egalitarian training procedures in which errors made by colonels are dissected in front of the troops.

The final element of the Army's transformation is a technological revolution. The Gulf may have been the first digital war, but it was a frequently flawed beginning. For example, 40,000 tractor-trailer-sized containers were delivered to Saudi Arabia – unmarked. Many had to be opened just to determine their contents, only to reveal that many items had been ordered in triplicate due to expectations that they would go astray. Following this experience, Army containers – like those used in civilian transport – have been bar-coded with descriptions of their contents.

This is one tiny example of how new information technologies are transforming the Armed Forces. In a reversal of historic trends, many technology innovations are being imported from the civilian environment. And as the Armed Forces move to a new model of combat, innovations are increasingly based on networked interactive multimedia (NIM) – audio, video, real time animation, virtual reality and kinetic feedback.

The instantaneous, anytime/anyplace access to information in the battlefield of the future will, if anything, further reinforce the new team-based approach to combat management. *Fortune* cited Brigadier General Bert Maggart, responsible for the Army's battle lab for mounted operations at Fort Knox, Kentucky:

> *He bangs a forefinger on a baffling grid map that displays tanks scattered over rugged terrain. "I want to teach lieutenants to see everything that a colonel can see here," he says, pointing out a troubling paradox that will face the Information Age army. The colonel in command of 50 tanks will know in massive detail and second by second where they are, how much fuel they will have, and so on, but the battle will unfold so rapidly he will have knowledge without control.*[2]

Thus, the lieutenant in charge of four of those tanks will be on his own. So Maggart's captains devise simulated battles that will age lieutenants in a hurry, such as scenarios in which the colonel is killed and they have to take over the battalion.

A key aspect of the new environment is reduced people intensity. In 1860, a single battalion could typically hold 10-30 acres of territory. By World War II this had increased to 100-1,000 acres. But by 1990, a single battalion might be managing 10,000 to nearly 100,000 acres. The 11 man infantry squad is turning into a five person, multidisciplinary fighting team, including mixed infantry, a communications specialist, a medic, etc.

All these changes increase the imperative to ensure the fitness and survival of each of the individuals at the front lines. The knowledge-intensive contribution of each team member becomes increasingly critical, hence the growing recognition of the need to provide effective telemedicine. The information infrastructure which enables seamless combat management can also support a seamless approach to delivering health maintenance and anytime/anyplace telemedicine.

Unacceptably high fatality rates

> *We have not made a difference in the past 150 years in decreasing the number of those killed in action. We have made a difference in the survival of the wounded, bringing mortality down from 22.5 % to 2 or 3 %. But 20 % are still killed in action. We think that the new technologies – telemedicine and virtual reality – will make a difference... We also think this will make a difference*

for civilian medicine. If telemedicine had been available at the time, we would have 10,000 fewer names on the Vietnam Memorial.

With these comments, Brigadier General Russ Zajtchuk, Commander of the US Army Medical Research and Materiel Command (MRMC), opened a February 1995 supplier conference of the Medical Federated Laboratory (MFL) for initiatives in combat casualty care.

Having sustained 80 percent of US military casualties in the wars of the past, the Army believes that it has a primary interest in addressing this problem for the wars of the future. There is some evidence to suggest that fatalities could be reduced by as much as 60% with the effective use of telemedicine in combination with improved intelligent communications facilities at the level of the individual combatant.

Half this improvement would derive directly from telemedicine. In a recent military exercise, MRMC concluded that the lives of three of 10 "dead" soldiers might have been saved had an effective telemedicine infrastructure been in place. The first of the three got lost; no one knew that he was still alive and in need of help. The second, with a tension pneumothorax injury, was, according to current doctrine, untreatable in the field; with telemedical support, his life could have been saved. The third soldier was wounded in the face and unable to call for help; he died four hours later.

The other half of the improvement would result from a military information infrastructure that enables combatants to distinguish friends from enemies. Dr. Neale Cosby is the director of the simulation center at the Department of Defense's (DoD) Institute for Defense Analysis. He states that 30% of combat fatalities are due to actions – typically mistakes – of "our own people!"

Political support

On September 1, 1994, Assistant Secretary of Defense Stephen C. Joseph announced the establishment of a telemedicine test bed. A week later, he mandated the Army to take the lead by nominating the Army Surgeon General as the DoD's executive agent for telemedicine activities. Dr. Joseph also directed the Army Assistant Surgeon General for Research and Development to develop a management plan for telemedicine test bed projects.

The program has broad and growing support. The Army Chief of Staff, General Gordon R. Sullivan, has described the Medical Department as "...the Army's first Force XXI major command." In a 1994 message to general officers, Major Sullivan stated that the Medical Department would be the first unit to prepare itself for the "information-based, power-projection Army of the 21st century."[3]

House Speaker Newt Gingrich endorsed the initiative in a January 30, 1995 speech to the American Hospital Association:

> *I come here today to ask the American Hospital Association and all of its members to profoundly rethink your stance and your assumptions, to literally say erase the board. I don't care what your positions were as of nine this morning, just drop all of them and rethink it ... if we could cut three to five years out of the transition from R&D to treatment, and if we could be networked to things like the Internet, so that every doctor and every hospital has equal access, equal information, so that literally when you walk in, you're entering the world body of knowledge ... and I'll tell you, people like the US Army are doing it. They're trying to design systems where a soldier who's been shot and has a particular problem is by distance medicine being connected directly from the field hospital to the finest specialist on the planet. Now we can do that for our young men and women in uniform because we have a large system, systematically thinking through it. But then we ought to transfer that to everybody else.*

However, defense budgets – like those in all parts of government – are undergoing major cuts in every area. In defending the plan to deliver a telemedicine infrastructure, planners insist that no dollars be added to military health care costs. The Medical Advanced Technology Management Office (MATMO), responsible for leading the Army's initiatives in this arena, faces the daunting challenge of convincing sponsors of existing programs to divert funds to this ground-breaking initiative.

Medical Federated Laboratory Competition

MATMO's planning and policy formulation activities are funded and have been under way since the fall of 1994. A number of test exercises are being conducted in remote locations such as Macedonia and Haiti (the latter is described in this case study).

On May 12, 1995, MATMO issued a competition document inviting industrial partners to join in the formation of a Medical Federated Laboratory. Proposals were due June 15, with publication of selections scheduled for July.

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Brigadier General Russ Zajtchuk
Commander, US Army Medical Research and Materiel Command

MedFed, as it is called, will develop the first two key advanced technology packages – telecommunications and information distribution, and distributed interactive simulation.

When the program was initially announced, only $1.5 million in funding was available for the first 18 months of the projected five year program. However, substantial allocations (subject to annual review) were made by the time the final announcement and partner solicitation was issued on May 12, 1995. For the telecommunications and information distribution element, $20 million in government funds are budgeted over the five years. An additional $24 million will be provided for the second element, distributed interactive simulation.

To qualify for participation in the MedFed program, interested parties are required to form consortia led by a health services provider, and including an industry partner and two academic institutions. The Army recognizes the market leverage that a winning consortium will gain: "a new cooperative relationship between the private sector and government scientists and engineers... will fully exploit dual-use technology and serve to form an industrial base for telemedicine germane to combat casualty care."[4] Oddly enough, bidders are not required to provide any matching funding, though the Alliance believes that such an offer might help a bidder to win.

This initiative will, over the long run, change existing procedures and power relationships. Some vested interests are not always enthusiastic about providing funds for programs that might undermine established ways of doing things.

ENTERPRISE NIM STRATEGY

Advanced warfighting

The Department of Defense is using a vast array of networked interactive multimedia technologies to radically reengineer its doctrines and capabilities in pursuit of "decisive victory in land, sea and air combat."[5] Although this dimension is not central to the telemedicine focus of the case study, we will describe it in some detail because it provides a strategic context for the T-Med initiative, and it is a powerful illustration of emergent mission-critical NIM applications.

At the core are two real time response components enabled by "battlefield digitization." The first is the delivery of information to field-level decision-makers via a shared view of the battlefield – providing real time "situational awareness" down to the lowest level of activity. The second is real time force synchronization of all operating elements in the field.

The vision is to use digital technologies to provide an instantaneous, common picture for coordinating all battlefield functions: combat, combat support and combat service support. "Computers with advanced software, linked by state-of-the-art telecommunications architecture to biosensor data, advanced displays, automated analysis tools, and distributed interactive simulation will provide soldiers, Marines, airmen and their units with unparalleled decision-making information."[6]

Many of the innovations for the new approach to combat will be derived from breakthroughs in the field of battlefield simulation.

Dr. Cosby explains that underlying and enabling the new approach to battlefield strategy is the convergence of three modes of battlefield simulation:

- *Live exercises involving operations with real equipment in the field.* This approach, at least 25 years old, has seen little innovation in the past two decades.

> "We no longer have medical information;
> we have information with a medical flavor.
> We no longer have blood and guts;
> we have bits and bytes."
>
> Col. Richard Satava
> Medical Program Office
> Advanced Research Projects Agency[7]

- *Constructive simulations* involving war games, models and analytical tools. Although it is computer based, constructive simulation has produced few innovations since the 1960s.

- *Virtual simulation* – based on interactive multimedia including audio, video, real time animation and virtual reality – has been the focus of innovation during the past 10 years.

The Advanced Research Projects Agency (ARPA) spent $335 million on virtual simulation technology development during 1985-90. Now the Army is investing $2 billion to deliver an interoperating network of simulators to its locations around the world. Various types of simulators are available, including strategic operations (involving human controllers, observers and umpires), battle force tactical training, aircraft simulators and virtual prototypes. All these capabilities exist today.

Until recently, "objects" used in military virtual simulations were "things": tanks, jungles, buildings, etc. New virtual combat environments have people as elements in the playing field. These simulations require individual communications with each person so that they can perform authentically in the virtual world.

The real simulation payoff depends on the convergence of all three modes – live, constructive and virtual. ARPA's Advanced Distributed Simulation program will, over the next 10 years, focus on tying these three modes together seamlessly, with anytime/anyplace delivery via a global information highway. Applications will range from the practical (e.g., tank acquisition planning) to the critical (preparing for and conducting wartime engagements). A benchmark goal is to be capable of delivering a digital representation of any hill in the world within 72 hours for any required simulation exercise. All parties will be able to participate in a rehearsal without leaving their home base – reducing the time costs and security risks entailed in gathering people together.

The model environment for multimodal simulation is not merely the head-mounted display. It will be more like a three-sided cave, where weapons, systems, people and geographies are all projected.

Tools for simulation exercises will also support live combat. These range from equipment for individual soldiers (e.g., "Dick Tracy" wristband intelligent communicators) to real time combat visualization systems for command personnel.

Critical to the success of this initiative – and the most difficult challenge – is the design of "synthetic forces." These must be behaviorally accurate, intelligent, scaleable and autonomous. System complexity increases geometrically with the addition of every combat system (e.g., a tank); the problem gets even more challenging when simulations of humans are added. ARPA's intent is to enable the creation and management of synthetic forces via a to-be-developed command and control simulation interface language, and the creation of "intelligent command entities" – smart objects that are capable of functioning autonomously and unpredictably.

A second challenge is the creation of "synthetic environments" – data bases that portray multiple, realistic, multi-dimensional battlespaces, and that are accurate down to meters or centimeters. These include dynamic environments, dynamic terrains, weather effects and electromagnetic phenomena. Other core technologies, as illustrated in Figure 1, include networking (bandwidth reduction for large-scale exercises, dynamic multicasting, network encryption and high performance application gateways), simulation support, and interfaces between live instrumentation and synthetic entities.

Dr. Cosby points out that many aspects of this challenge are intriguing. How do you place a virtual target in the gunsights of a real tank? How do you link a real airplane into the head-mounted device of a pilot flying a simulated F-16?

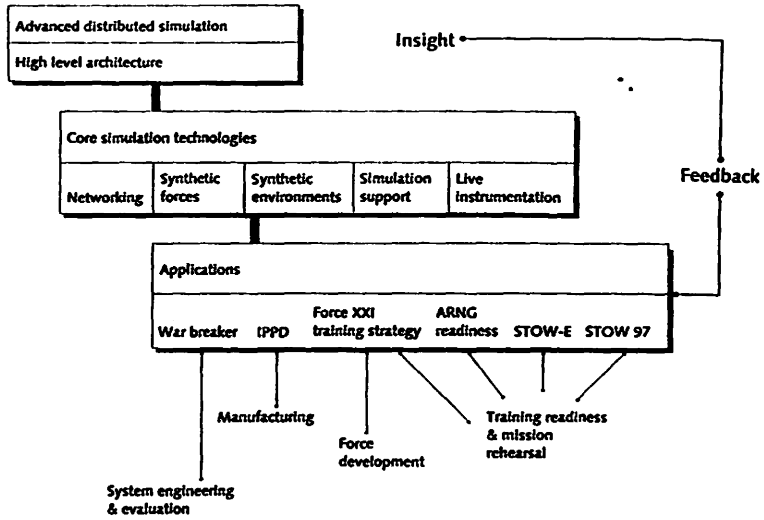

Figure 1 - The Approach, (source: ARPA)

A prototype of this environment – Synthetic Theater of War Europe – was demonstrated in 1994. It tied together live, virtual, and constructive simulations seamlessly at the individual brigade (colonel) level.

A Synthetic Theater of War (STOW-97) is planned to be operational by 1997. A three-star commander will then be capable of working a simulation that combines simulated and live forces. The commander will neither know nor care which forces are "real" and which are "virtual."

The Army's telemedicine strategy

The Army's telemedicine strategy falls under the jurisdiction of Brigadier General Russ Zajtchuk, who commands the US Army Medical Research and Materiel Command (MATMO) based in Fort Detrick, Maryland. Operational leadership of the MATMO team is provided by Colonel Fred Goeringer.

It is an interesting experience to visit the MATMO unit located at the heart of an old, established Army base. Driving into Fort Detrick and wandering into various buildings to get directions, you can't help but get a Beetle Bailey feeling about the place. When you arrive at the MATMO offices, tucked away on the second floor over a small production plant facility, the atmosphere comes to life. Graphic displays proudly convey (and sell) the unit's high tech humanitarian achievements. High end Sun and Mac workstations are scattered everywhere. Every office has papers piled high, and everyone is in a hurry. In a sea of time-clock punchers, the people at MATMO – both in uniform and in civvies – are putting in 60 plus hour weeks and have barely any time to converse with a visitor.

The excitement is palpable. "The reason people work here is because they think they can make a difference – and because of the quality of leadership from people like Col. Goeringer," says coordinator Jesse Edwards.

Col. Goeringer describes the T-Med vision as creating a capability to project the best possible health care resources into the most difficult to serve, expensive to serve and underserved environments. "Telemedicine projects world class health care to patients and providers, anytime, anywhere." He points out that MATMO and the US Army conducted a number of successful experiments in 1994-95, in places like Skopje (Macedonia), Zagreb (Croatia) and Port au Prince (Haiti – described in more detail herein).

Col. Goeringer describes three major themes:

1. *Real time.* Telemedicine is evolving toward real time clinical delivery capabilities.

   Example: teleradiology and other forms of diagnostic imaging. Seventy percent of patients require one or more forms of imaging, but turnaround times for diagnosis can be as great as three days. Network transmission of diagnostically accurate images, combined with voice recognition, will enable specialists to deliver responses on the fly.

2. *Process re-engineering.* Telemedicine is an enabler and driver of military medicine process re-engineering, with ramifications for the civilian sector as well. "We're no longer hampered by waiting for the silver bullet in technology. Our challenge is to use and integrate the technology as a process re-engineering enabler," comments Col. Goeringer.

   The current model of radiology is based on a main X-ray department where equipment is housed and radiologists hang their hats. Departments – intensive care, emergency, outpatient facilities, wards, and so on – must send patients "to X-ray." The image is produced and "stored" as a physical print (rather than a digital file). Clinicians must then await the diagnostic response from a radiologist. In addition to simple delays, this process presents a variety of other problems. Images are frequently misfiled, lost, or stolen; the latter often occurs when, for example, a teaching physician comes across a great image for making a point in a class presentation. When several specialists need to review a single physical image, the logistics and time delays can be problematic. It is typically prohibitive to obtain a consultation from a specialist who resides at a distance from the care facility.

In the "virtual hospital," supported by high performance networks, radiologists and other clinicians will be distributed to the departmental front lines. Diagnostic images, live video examinations, and other data will be delivered to clinicians anytime/anyplace.

3. *Internetworked clinical delivery structure.* Col. Goeringer approvingly refers to Alvin Toffler's statement that organizations, and their use of information, are shifting from hierarchy to adhocracy, with time and distance independence – "the emerging basis of change for diagnostic information."

The Army has quantified the potential benefit through operations research. Today's model of health care delivery is an incompletely linked collection of nodes. Each node (typically an individual hospital) operates autonomously, and with limited and conditional access to resources located in other places. By contrast, as Figure 2 suggests, internetworked clinical delivery is based on a grid model.

On one axis are the "spokes" – people who need health care, whether they are difficult to serve, expensive to serve, underserved, or simply in need of timely special attention. They could be in foxholes in the Persian Gulf, military bases above the Arctic Circle, or anywhere else. On the other axis are the hubs: people who can provide health care. These could be front line medics, physicians in a mobile hospital only a few miles away from the front lines, or one-of-a-kind world-class specialists at Walter Reed Medical Center.

The Army's operations researchers show that, while the old model gives a wounded soldier support from one or two "nodes," this model provides life-saving opportunities from N^2-1 nodes (where N is the total number of nodes in the network).

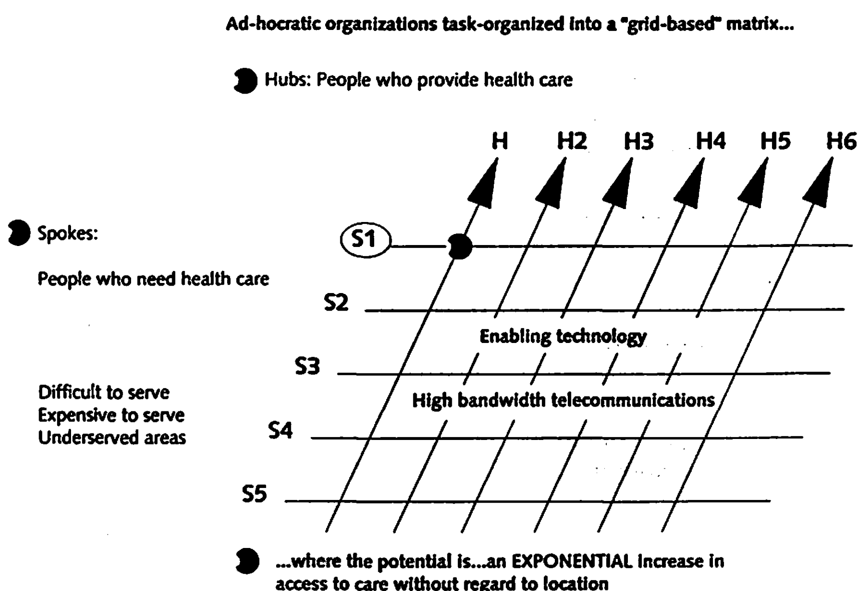

Figure 2 – Department of Defense Telemedicine

Seven strategic principles

MATMO refers to seven strategic principles for re-engineering the delivery of military health services. They are repeated here, not just because of their relevance to telemedicine, but because of their ready transferability to other NIM application areas:

1. *Readiness orientation.* Military telemedicine will focus on the evolving nature of military battlespace and the military medical environment to support assigned or implied operational missions.

2. *Patient focus.* Telemedicine will proactively focus on developing total access for difficult to serve, expensive to serve, and underserved patients who rely on military medicine for prevention, diagnosis and treatment.

SEVEN STRATEGIC PRINCIPLES

1. **Readiness orientation**
2. **Patient focus**
3. **Rapid prototyping and process re-engineering**
4. **Outcomes-based metrics**
5. **Open and integrated system architecture**
6. **Leveraged development**
7. **Sound business practices**

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SIX PROGRAM AREAS

FOUR MAJOR LAYERS OF A RE-ENGINEERED, TELEMEDICINE-ENABLED DELIVERY AND SUPPORT SYSTEM

1. Far forward telemedics appliques – "the foxhole"
2. Mobile medical mentoring vehicle
3. Deployable digital field hospital
4. Expert host medical center

TWO KEY ENABLERS OF THE NEW ENVIRONMENT

5. Technology transfer from the Advanced Research Projects Agency (ARPA)
6. Technology integration/support services

3. *Rapid prototyping and process re-engineering.* The test bed will use rapid prototyping and process re-engineering for development of new medical practice and advanced technology applications.

4. *Outcomes-based metrics.* Test bed projects must have potential for measurable, reproducible improvement of outcomes. Outcomes evaluation will combine peer review, clinical trials, economic analysis, and statistical techniques to ensure quality, access and cost benefit.

5. *Open and integrated system architecture.* Test bed projects will be designed to achieve interoperability, scaleability and upgradeability. Moreover, they will totally integrate with existing DoD medical systems to provide patient- and provider-friendly systems.

6. *Leveraged development.* The demands of advanced technologies mandate outreach and collaboration with academia, industry and other government agencies to leverage development. Commercial and/or Government Off-the-Shelf (COTS and GOTS) technology use will be maximized.

7. *Sound business practices.* Test bed project management will utilize a management approach that follows sound business practices.

Six program areas

T-Med, as it is sometimes called, has six major program areas. Each already exists in prototype and/or early design. Comprehensive funding for all these projects is still being pulled together. Four of these programs represent the major layers of a re-engineered, telemedicine-enabled delivery and support system. The other two areas – technology transfer from the Advanced Research Projects Agency (ARPA) and technology integration/support services – will provide key enablers of the new environment.

The four layers of the re-engineered telemedicine system will be "totally integrated, from the foxhole to the specialty care medical center." Its focus is on five key NIM application types: visualization of information, information delivery, training, personal communications, and equipment and process control. Primary media will be video, real time animation and audio. Virtual reality will provide integration with ARPA's Advanced Distributed Simulation program. In the future we expect to see kinetic feedback used in simulations and telesurgery. In addition, a key thrust for today's environment is the capture, digitization, storage and transmission of high resolution static medical images.

1. *Far forward telemedics appliques - "the foxhole"*

This is the delivery of telemedicine to the front lines, whether for combat, peacekeeping, or just plain active duty, with a primary focus on combat. The goal is to deliver time-critical, distance-independent, pre-hospital, demand-driven casualty care management and consultation in so-called "far forward" facilities. "Telemedics" in combat battalions will be provided with networked communications to primary care physicians and other specialists. The idea is to improve the quality of resuscitative care, speed evacuations, and achieve better treatment at battalion aid stations. In addition, the real time far forward telemedical information will permit better overall medical decision support, as well as improved command/control capabilities for combat operations.

2. *Mobile medical mentoring vehicle*

The second layer is a flexible, highly mobile "Swiss Army knife" of military telemedicine. In addition to an array of medical supplies, the all-terrain vehicle will carry higher bandwidth communications systems than can be practically provided to front line telemedics. The vehicle will provide links to expert specialists in a wide variety of locations, with live video and high resolution static diagnostic image media. MATMO expects to work closely with the Federal Emergency Management Agency (FEMA) and NASA in developing the vehicle.

3. *Deployable digital field hospital*

This is a highly mobile, telemedicine-enabled evolution of the conventional "M.A.S.H." 35 acre military field hospital, designed to deliver "high throughput patient care." In major deployments, both for warmaking and peacekeeping, the field hospital will be the primary point of patient care and specialist support. Electronic diagnostic imaging will provide dramatic improvements in the ability to save, transmit and move patient records. Personnel will be equipped with wireless hand-held communicators, to improve crisis responsiveness and the quality of patient management. High speed video, audio and digital image communications will reach out to the front lines and to specialists back home.

4. *Expert host medical center*

A number of medical centers in the US will be equipped with video, audio and digital image medicine capabilities, enabling the best experts in the world to provide direct battlefield support. As the system matures, it will provide direct access on an anytime/anyplace basis. The network will include both military and civilian hospitals, drawing on the broadest possible variety of specialists. This wide-ranging access to specialists is a key goal of the initiative, given the wide diversity of medical problems that are encountered in the front lines.

Enhanced digital applications will also be provided within the tertiary care facility. Local area networks will provide specialists at multimedia medical image workstations with instant access to digitally archived patient records. The three hospitals slated for initial deployment will, because of their time zone positions, be capable of ensuring daytime quality service delivery on a nearly 24 hour basis.

5. *Technology transfer from ARPA*

The fifth key thrust involves working with ARPA to rapidly design, manufacture and deploy advanced medical technologies and systems. ARPA currently has over 20 such projects. High payoff applications under development, as described by Shaun Jones of ARPA and the US Navy, include:

- Battlefield advanced diagnostic and diagnostic imagery technologies. These include a personnel status monitor (a "Dick Tracy watch" with satellite communications), a critical care evacuation pod or "smart litter" with built-in patient monitoring and telemetry systems, digital battlefield imagery, a real time 3D ultrasound imager, and a cellphone-size arterial blood gas analyzer capable of providing a reading in 60 seconds.

- Battlefield medical/surgical intervention technologies designed to "project the surgeon's dexterity to the field," including "golden hour therapeutics" to lower shock patient metabolism and remote telepresence surgery (project name MEDFAST). These technologies are experimental.

- Basic telemedicine using video and audio conferencing: human interfaces, telepathology, combat telemedicine demonstrations

- Medical simulation: synthetic environments for battlefield simulation of medical interventions

ARPA has already received serious expressions of civilian interest in the "Dick Tracy" patient status monitor, which will collect and distribute locational and physiological data anywhere via satellite. Within the government alone, the Department of Prisons, the Department of Health and Human Services and several other agencies see potential for large-scale deployment within three to five years.

6. *Technology integration/support services*

The final thrust of the program provides telecommunications support, integration of the other five thrusts, interfaces to other systems, and ongoing operational sustainment. A key research initiative involves participation in the advanced warfighting initiatives described in the preceding section. Among the expected outcomes are improved techniques for telecommunications and medical image compression, not to mention the opportunity to rehearse the use of telemedicine in new combat environments.

Telemedicine test bed

The telemedicine test bed, under the direction of MATMO, is a series of initiatives designed to rapidly move telemedicine from concept to deployment on an incremental basis. This includes the Medical Federated Laboratory and an ongoing series of live field deployments in remote locations such as Macedonia, Croatia and Haiti. The Haiti trial is described in the following case study.

APPLICATION - TELEMEDICINE IN HAITI

US troops were sent to Haiti in September, 1994 in what was known as Operation Uphold Democracy. As would be typical for such deployments, they were accompanied by a mobile health care facility, in this case the 28th Combat Support Hospital (CSH). MATMO deployed a mobile telemedicine unit to the CSH, based in Port au Prince, from September 29 to January 15, 1995. The telemedicine unit provided support consultation links between the CSH and the Walter Reed Army Medical Center in Washington, DC.

The networked media that facilitated telemedical consultations were audio and videoconferencing, plus a significant amount of high resolution static images. The primary interactive media application types were personal communications and information delivery – both facilitated by videoconferencing. As mentioned, conference-based consultation supported by high resolution static diagnostic images made an important contribution.

The field telemedicine support team consisted of a physician and a telemedicine/communications expert.

Haitian Surgical Society (Source: Department of Defense)

They submitted an electronic request form to Walter Reed for each consultation. The form included pertinent clinical and demographic data, high resolution digital still images, digitized X-rays (from film) and digital dental images (when required).

Walter Reed specialists reviewed each form. When appropriate, the teams scheduled and conducted an interactive video telemedical consultation, in some cases with a patient presentation. Patients were primarily US Army personnel, but a number of Haitian civilians also received treatment.

Technology environment

The telemedicine package used off-the-shelf components. It included a low-speed video telemedical conferencing unit (Apple Macintosh 8100 "hardened" by Compression Labs Inc., Fairchild SM2800 satellite modem, Sony color monitor). Other cameras included a Compression Labs GraphiCam document camera, Canon Super 8 video camera, Scalar VMS-70 CCD videolupe dental scope, and an AndriesTech dermatology scope.

Initially, two Ultralite Mobile Telesystems Inc. TCS-9700 satellite dishes provided full duplex, 56 Kbps communications via the International Maritime Satellite System (INMARSAT). This facility supported video, audio, telephone, modem and fax transmissions. The INMARSAT signal was picked up by a COMSAT earth station in Southbury, Connecticut and transmitted to Walter Reed via a commercial 56 kbps land link.

Network bandwidth was boosted dramatically in mid December, when the Army Space Command delivered a T1 VSAT and provided access to the NASA ARPA Advanced Communications Technology Satellite system. As a result, full motion video communications were initiated between the CSH and Walter Reed. Consultations conducted via the T1 link included oral surgery, neurology and three dermatology examinations. Interactive remote telepathology and orthopedic joint examinations were also conducted, using various data rates as concept validation tests.

Other components included an XRS 8 bit X-ray film scanner/digitizer, Nikon N90 camera with Kodak DCS 420 digital image capture system, Apple Macintosh Quadra computer and printer, and a fax machine.

The physical environment became an issue. To promote clinical interaction, the telemedicine clinic was initially set up in an outdoor warehouse bay beside the CSH emergency treatment tent. This turned out to be a mistake. The clinic was assaulted by frequent dust storms and heat waves during the day, and by torrential downpours in the evening. Patient privacy was nonexistent. The clinic finally moved into an enclosed, environmentally controlled space. Evidently, if mobile military telemedicine is to succeed, the equipment will need to be more robust.

APPLICATION RESULTS

The research team reached several key conclusions:

- Telemedicine can be used effectively in a deployed military environment.
- Remote consultations have a significant impact on treatment and evacuation decisions.
- Telemedicine is most effective where subtle visual information (e.g., in dermatology) makes a difference.

When electronic examination tools can be used, the consulting specialist and patient can be in different locations.

- Telemedicine improves the learning and confidence of front line health care providers

- Effective field technical support is critical

- The right specialists must be available at the right time when a consultation is needed. Conversely, the attending health care provider at the front line must have the clinical expertise to carry out the recommendations of the remote specialist.

- Telemedicine is a voracious consumer of computing and communications power. High bandwidth (T1) full-motion video benefits a variety of telemedicine applications. Lower speed communications can meet the need in some specific situations, such as batch transmission of diagnostic images. For useful levels of resolution, high density helps: 12 bits per pixel are better than eight.

- Cost is an issue. The technology is currently expensive, the telecommunications infrastructure is lacking, and telemedicine is only effective in a minority of situations.

- Once the telemedicine infrastructure is in place, it supports a variety of other important activities, such as preventive medical consultations, continuing medical education, materiel and logistics support and photo documentation

The Army team conducted 30 telemedicine consultations in Haiti, primarily in dermatology, radiology and hand surgery. They were all conducted prospectively; findings and treatment plans were captured in a database.

Analysis suggested that 50% of the consultations resulted in a significant modification of the treatment plan. In addition, 17% of the consultations made a significant impact on the patient evacuation plan. Similar results came out of pilots in Somalia, Croatia and the Pacific Rim.

The full-motion video T1 link supported remote telemedical examinations, not only via super 8 video, but also with specialized video examination tools like the videolupe dental scope and the dermatology scope. The results were dramatic:

- Walter Reed dermatologists reported that they could see the vascularity of skin lesions better with the networked dermatology scope than they might with their own eyes at close range.

- Oral surgeons diagnosed a mucous cyst remotely with the aid of the hand-held dental camera.

- A Walter Reed specialist guided a front line telemedic through a dynamic joint examination. The telemedic (working on the patient) and the specialist (working on a model) were able to simultaneously observe each others' hand positions, and modify techniques in near real time.

- A remotely guided complete neurological examination of a Haitian patient produced a diagnosis of optical nerve damage. The Walter Reed examining physician used the super 8 camera to conduct a cranial nerve examination. He saw fine details like a consensual pupillary light response in a blind eye, and observed the patient's dysfunctional walking pattern. The video was supplemented with transmission of CT scanner images and digitized plain film images of the patient's skull. These images revealed microcalcifications of the brain, and suggested a possible diagnosis of neurocysticercosis caused by the tæniasolium parasite, which is endemic to Haiti. The diagnosis – developed entirely through telemedicine – was confirmed when blood serum samples were tested by the Center for Disease Control in Atlanta, Georgia.

- A pathologist at Walter Reed examined a slide preparation via high resolution digital "frame captures." A technician at the Port au Prince CSH essentially became the hands of the pathologist as he explored various areas of the slides.

T1 and video were not essential in every situation. The 56 Kbps link was satisfactory for still image transmissions.

ORGANIZATIONAL IMPACTS

According to Col. Goeringer and the members of his team, the main obstacles to the success of this initiative relate to corporate and organizational change, not to technology. The strategic changes are massive, including clinical protocols, DoD acquisition policies and management, configuration control and corporate culture. In addition, the so-called tactical issues include:

- Identification and modulation of future funding levels for telemedicine
- Lack of standards in this rapidly emerging field
- Acquisition rules and regulations which make it difficult for the Armed Forces to keep pace with emerging technologies
- Lack of peer-reviewed research into the clinical efficacy of telemedicine
- Lack of comprehensive investment information
- Uncertainties regarding the legal implications of telemedicine

Jesse Edwards points out that health care – particularly in the military – is one of the last major industries to undergo the transition to the new corporate order. Most other service and manufacturing enterprises have recognized the need for lean, nimble reengineered business processes delivered by compact, empowered, team-based organizational units.

Acquisition rules

The shift entails a new paradigm of acquisition by the Armed Forces. The present model is based on a seven-year planning and budgeting cycle, which is documented in over 1,000 pages of the Federal Acquisition Requirements (FAR) standard. Responding to (occasionally legitimate) concerns about corruption, the FAR states how to define requirements and manage bidding and selection to ensure competition.

In addition, during the early 1980s, the US Congress concluded that computer acquisitions in the federal government might get out of hand, and legislated the Federal Information Management Requirements. This separate set of rules is driven by a positive thrust toward compatibility and standards. However, it also assumes an outdated, centralized model of computing, and implicitly encourages implementors to do nothing rather than implement technologies that are not compatible with the installed base.

With advanced technologies, there are often only one or two capable suppliers; rules that enforce seven-year plans, competitive bidding and narrow concepts of standardization block innovation. By thwarting the implementation of the best solutions, the rules produce high costs and low effectiveness.

Col. Goeringer points out that the Army is redefining its systems lifecycle. Unlike in the traditional sequential model, rapid prototyping shows parallelism among various "phases" (Figure 3). These include continuous and ongoing concept exploration, requirements doctrine design, advanced development, fielding and sustainment.

Institutional obstacles to change run deep. The new approach requires flexibility in job definitions and personnel assignments. MATMO's very mission has already changed several times in its short existence. People's work can change radically, as often as every couple of months – and they need to be motivated to give their best while working exceptionally long hours. But the rules say that every "job" needs an "authorization" supported by a "job description" showing the hours needed to perform each specific task.

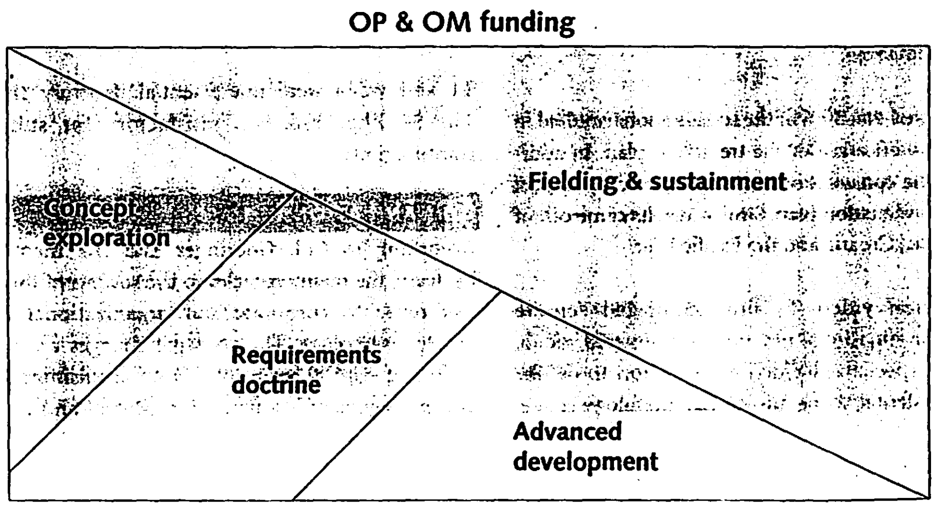

Figure 3 – Rapid prototyping

Telemedicine is an amorphous cloud, in which hang a few jewels of clarity. Many domains of opportunity remain to be defined, and the future shape of telemedicine remains shrouded in mist.

As entire business functions are redesigned, the time and effort involved in documenting requisitions become intrinsic barriers to change. The result: a rapidly self-mobilizing law of diminishing returns.

Staffers controlling vital areas such as contracting, resources, and personnel hold veto powers over the line, and often lack the customer service focus which has turned the tide in many private sector companies. Suppliers (some known as "beltway bandits") have built their own monolithic systems which match those of the government. This self-reinforcing system is the basis of "cost-plus" contracts, guaranteed markups, and hidden government subsidies for private sector research.

MATMO's important initiative to set up a Medical Federated Laboratory seeks to change the paradigm by inviting the private sector to join in the development of new telemedical technologies. To facilitate the transition, Army management has found ways to treat MATMO as an exception to these rules, but the underlying problems remain and crop up frequently.

Clinical issues

A key issue here is potential resistance to change by the front line care giver. Physicians are trained to be independent – to have confidence in their ability to make the right judgments on their own. The decision to call for a specialist or a second opinion is an autonomous one. With telemedicine, will patients and institutions increase the pressure on the individual caregiver to seek help? Will caregivers resist, and will patients suffer as a result? The early evidence is inconclusive, and shows that individuals will react differently. Some resist, due to fear of technology or the desire to maintain control. Others see telemedicine as an opportunity to improve quality of service, and to learn from the best minds in the field.

Jesse Edwards points out that practitioner resistance to telemedicine is often well founded. "Most telemedical systems are designed to hardwire the consultation and meet the needs of the tertiary care center. We haven't done the hard thinking about what the provider needs, where the patient is."

MATMO's strategy is to have "docs talk to docs," to find specialists, who understand the benefits of telemedicine, to talk to their peers.

Another question that arises from this and other trials is: which clinical needs provide the greatest opportunity for improvement through telemedicine? MATMO technical officer Robert E. DeTreville suggests that telemedicine is an amorphous cloud, in which hang a few jewels of clarity. Many domains of opportunity remain to be defined, and the future shape of telemedicine remains shrouded in mist.

It makes sense to ask which areas have the greatest need and potential for service improvement through telemedicine. Medical imaging was an early winner, and continues to spearhead telemedical initiatives in many settings. Teledentistry has shown good results on the diagnostic side, because of the use of both video-based and static image systems. Similarly, telemedicine for dermatology has been very successful (color and texture are important in dermatology, mandating high resolution systems). Telesurgery is still in its early days, but gaining fast. "Flight simulators" for rehearsing operations are coming into use, and surgical telerobotics is being tested today.

Jesse Edwards points out that while most people equate telemedicine with real time teleimaging, other paradigms show equal or greater promise. He cites some examples which illustrate how telemedicine can and should be part of every physician's repertoire:

- Store and forward (electronic mail) distribution of clinical data permits, for example, the transmission of videos for consultations: "have a look at this white blood count," or "see how this person walks"

- Computer-aided diagnosis can improve productivity and quality. For example, it can identify the 70-90% of mammograms which are normal, changing the paradigm to diagnosis by exception.

- The Internet and other online services can be used to great effect in various ways. For example, a physician being sent to Macedonia can post a query to find out what endemic diseases to bone up on prior to making the trip.

Mr. Edwards sees an opportunity for an interactive decision support database application for making choices about telemedicine based on various factors, such as need, potential for solution and cost/benefit ratio.

TECHNOLOGY ISSUES

Telecommunications

MATMO's Col. Neil Fay begins by saying "I volunteered for this posting because of the serious opportunity to make a difference ... My prejudice is not the big hospitals, but the person who won't get the attention: the soldier who's bleeding in the foxhole."

He identifies four natural "step levels" for telemedicine telecommunications planning. "Our goal is to do the most with the least amount of bandwith":

- 14.4 kilobit per second facilities support voice, text and single image transmissions

- 56 kilobits per second is "the current state of the art, but we're hoping that will change." This is adequate for video or batch still imagery, as well as low resolution real time video and voice – typically used in aid stations, by area support medics and even at the battalion level.

- T1 (1.5 Mbps) links support full-motion video and real time still video. T1 is found in some deployed land hospitals.

- DS3/ATM (45 Mbps) supports real time multimedia, and is the target environment of the 21st century warfighter environment. "We're on the right side of the cost curve," comments Col. Fay. "We're working with DISA to see how ATM can be deployed on the battlefield."

Anticipating concerns about excessive technophilia, Col. Goeringer cautions "we don't want to buy the whole staircase – we want to function appropriately at each level."

– David Ticoll

Notes:

1 Lee Smith, "New Ideas from the Army (Really)," *Fortune*, September 19, 1994, 204.

2 *Ibid.*, 211.

3 *The Mercury* (US Army Medical Department newsletter), February 1995, 1.

4 US Army Medical Research & Materiel Command, *Medical Federated Laboratory Information Package for Initiatives in Combat Casualty Care.* Final as of May 12, 1995, Version 1.0, 6.

5 *Ibid.*

6 *Ibid.*

7 Nancy Tomish, "Telepresence: Changing the Focus of Medicine," *US Medicine*, May 1995.

8 Col. Fred Goeringer and Brig. General Russ Zajtchuk, *The Medical Advanced Technology Management Office*, unpublished paper, March 1995.

9 Many of the facts regarding the Haiti deployment are derived from an unpublished paper by Robert E. Detriville, Stephen D. Scotti, Morgan P. Williamson, Eric J. Olson, Linda Brink, Ken Ilse and Peter Kafara, "Teleradiology and telemedicine using advanced communications technology satellite and international maritime satellite at varying bandwidths" (1995).

10 1.54 megabits per second, very small aperture terminal.