A call for action: how can life sciences work better with intelligent systems developers?

DATE: 6/10/00
TO: As broad a distribution as possible in:
- NASA Life Sciences and Space Medicine at the Johnson Space Center (JSC),
- other NASA Centers (especially centers with strong intelligent systems programs, such as ARC, JPL, LaRC, and others),
- other government agencies and the national labs,
- academic departments (particularly in computer science and health informatics),
- and the medical community at large.

FROM: Report from a lunch meeting held at the University of Texas Health Sciences Center in Houston on Friday June 9, 2000

RE: How can Life Sciences work best with the Intelligent Systems Developers? This memo documents the start of a conversation that we hope will stimulate broad community interest.

PRIORITY: Urgent (?), July 11, 2000 is deadline

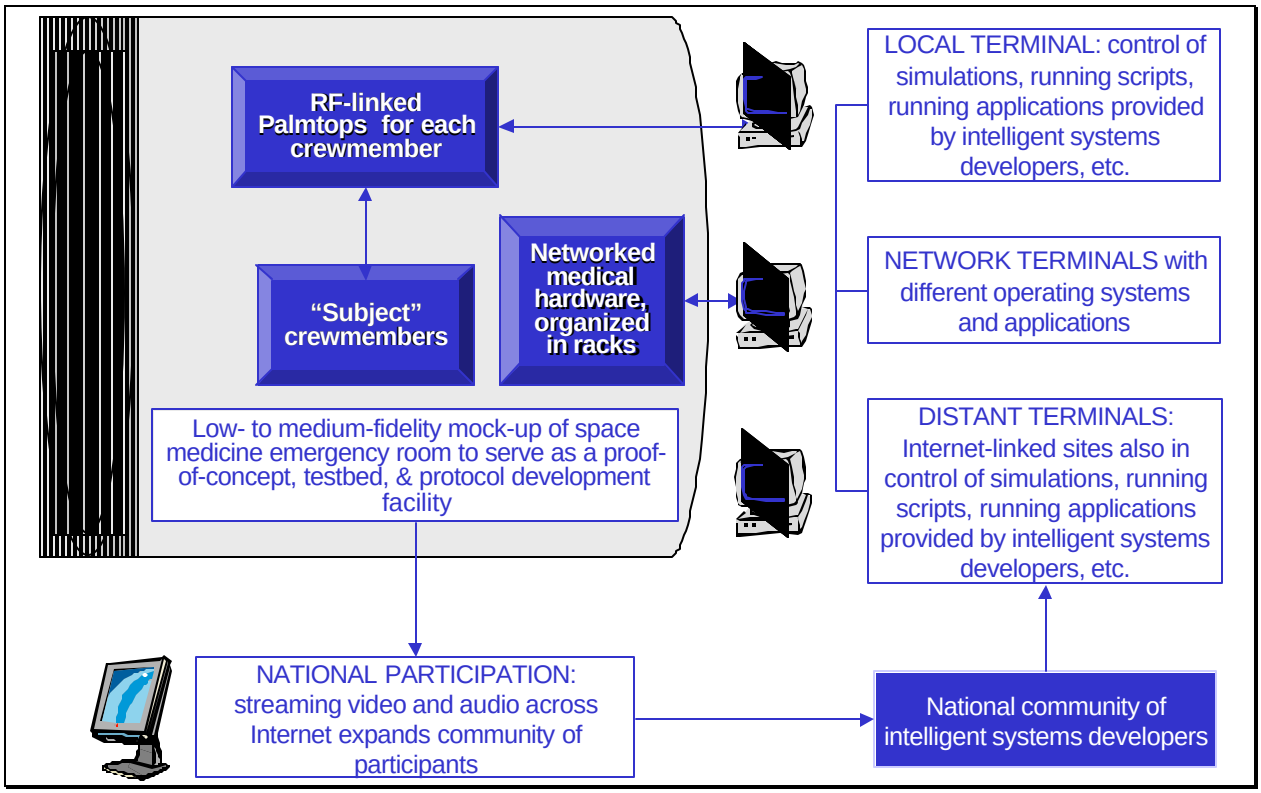
On Friday, June 9, 2000, a group of about 20 met at the University of Texas Health Sciences Center, Houston for the weekly faculty lunch in the Department of Health Informatics. Broadly, we met to cultivate a discussion between NASA Life Sciences and the greater community involved in intelligent systems, health informatics, and other potentially valuable areas relevant to the Human Exploration and Development of Space (HEDS) Enterprise. More specifically, our discussions turned to the concrete: select concepts and ideas that might arise from the common interests of life sciences and intelligent systems. A diverse number of interests were represented at this conversation, from graphical interface designers to specialists in aerospace medicine; we believe that this diversity can be expanded even further, and hope to generate interest through this first meeting and subsequent memo.

NASA currently has large programs underway that apply intelligent systems to space science—thus permitting robotic probes to explore the Solar System and beyond—to terrestrial aviation, and to aerospace. The Agency has long understood the need for intelligent systems in controlling flight systems and in guiding humans and their surrogates on excursions to Low Earth Orbit (LEO) and beyond; we have nonetheless only begun to expand the scope of intelligent systems into the arena of emergency medical care for our crewmembers. While NASA's emphasis in the past was indeed appropriate, the future will bring longer missions, meaning more isolation from Earth, and increasing risks to crewmembers, especially as they perform the equivalent of hard-hat construction activities in space or on planetary surfaces. So we can expect that NASA will direct more time, effort, and funding towards the application of intelligent systems to the challenges of human spaceflight: maintaining the nominal health of our

astronauts and managing as necessary the medical emergencies that could gravely darken the history of human spaceflight.

An Initial Concept for Collaboration

The discussion was opened by one of us with a description of an approach to development that mimics some of the advantages of the NASA Intelligent Synthesis Environment (ISE). Imagine an inexpensive mockup, made of wood, metal, foam and plastic, that looks like a hypothetical emergency room on the Moon, Mars, or in space. This simple and inexpensive mockup with its network of terminals represents a fundamental step in modeling an emergency room in space. To the extent necessary to simulate a medical emergency, the facility would be outfitted with standard medical hardware. Perhaps six or more IBM-compatible computers would line the walls of the mockup and could serve to simulate medical data and provide intelligent support to a test crew. Some of the medical data and simulations would be created by engineers and scientists sitting at terminals just outside the mockup, while others could be located anywhere in the nation and participate via the Internet. Data collection can also occur at both points.



The crewmembers for each simulation would use the latest RF-linked palmtop computers to communicate with the intelligent systems in the mockup and with researcher/developers at other sites. A series of cameras could provide live video to developers taking part in the simulations, or even serve as a video record for public consumption.

Medical scientists and flight surgeons at JSC could work with intelligent systems developers to script emergency procedures and to develop an overall concept for a medical emergency room in space. This same mockup would then be used as a model to create and test intelligent medical systems.

How is such a facility valuable? Imagine a situation in which the only physician-crew member of a mission has received a crushing blow to the spleen, perhaps while setting up mining equipment on the Moon, assembling elements of the International Space Station, or working on the surface of Mars to drill beyond the permafrost. The best students of medical emergency procedures among the remaining crew take on the role of primary and alternate leaders of the emergency response team. The leaders begin to complete a medical record as the injured physician is brought into the crew vehicle. They have monitored the patient's medical data, such as EKG and blood pressure, while the activity was being carried out and fear the worst – uncontrolled internal hemorrhage. The patient is removed from the extra-vehicular activity (EVA) suit and placed on an examination table that the other crewmembers have set up in the emergency room (ER) or area.

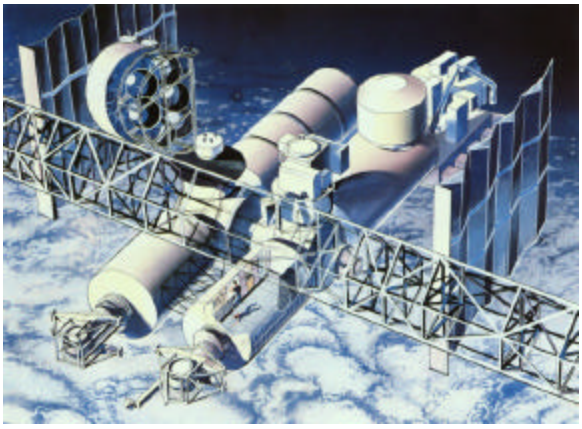
The work of the team is controlled by intelligent medical systems that work with the leaders to identify tests need to be run or treatments to be administered. Other crewmembers take advantage of the decision support information by initiating test protocols or preparing test equipment for use. As tests are ordered, assisting crewmembers view instructions on their Palmtop computers that provide the location of supplies and instruments and describe procedures for setting them up. One crewmember draws blood while others hook up the diagnostic equipment for electronic monitoring of vital signs. Shortly, the situation is determined to be a serious one. The crew and the cadre of intelligent systems work in concert to handle the situation as efficiently as an any Earth-based team of physicians and nurses in any emergency room.

The above scenario is only of many that can be envisioned with such an IS mock-up. Many other scenarios could be imagined: from routine physical exams and standard monitoring tasks to treating decompression illness or any significant medical emergency that a crew might encounter in a future space mission.

By harnessing the power of networked simulations, recordings, and data collections, the community of users and participants grows exponentially. IS developers at other NASA Centers, such as the Jet Propulsion Laboratory and Ames Research Center, or at any academic institution or other government agency, could work with medical or health informatics professionals near their location, and with experts in space medicine at the Johnson Space Center. These collaborations would be especially valuable for IS development in areas such as:

- automated reasoning,
- human-centered computing,
- intelligent data understanding,
- revolutionary computing,
- robotics,
- autonomy,
- software synthesis,
- verification and validation,
- knowledge modeling/sharing,
- performance enhancement systems,
- knowledge discovery for scientific understanding,
- data mining and conditioning,
- machine learning for decision-making and action,
- biology-inspired and physics-inspired approaches to computing

can join with those working in academic departments of health informatics, with the National Space Biomedical Research Institute (NSBRI) — a consortium of universities— or with anyone they choose to work in areas such as:



- intelligent medical records,
- telehealth in various medical specialties and different settings, e.g., rural, military, decision support,
- medical databases,
- the human-machine interface in medical systems,
- health information systems,
- cognitive science in health care systems,
- multimedia intelligent medical training,
- data visualization in medicine,
- data mining,
- knowledge modeling in medicine, or
- any of a number of specialties in health informatics.

The JSC Space and Life Sciences Directorate could begin by pledging to post considerable information about our thinking, our research, and our plans on the Internet. We know that the intent of the aerospace medicine community is to begin posting important lectures on the Internet. (see links to UTMB Aerospace Medicine [especially the video clips!] and links to UTHSCH Lecture Series.)

In the spirit of this open collaboration, we can begin to imagine the advantageous outcome if we all work together in an open source, open data, environment with code and documents published on the World Wide Web as soon as they are ready for public consumption Internally, all the scientists and engineers working on mockup projects can share data and code across more secure Internet connections.

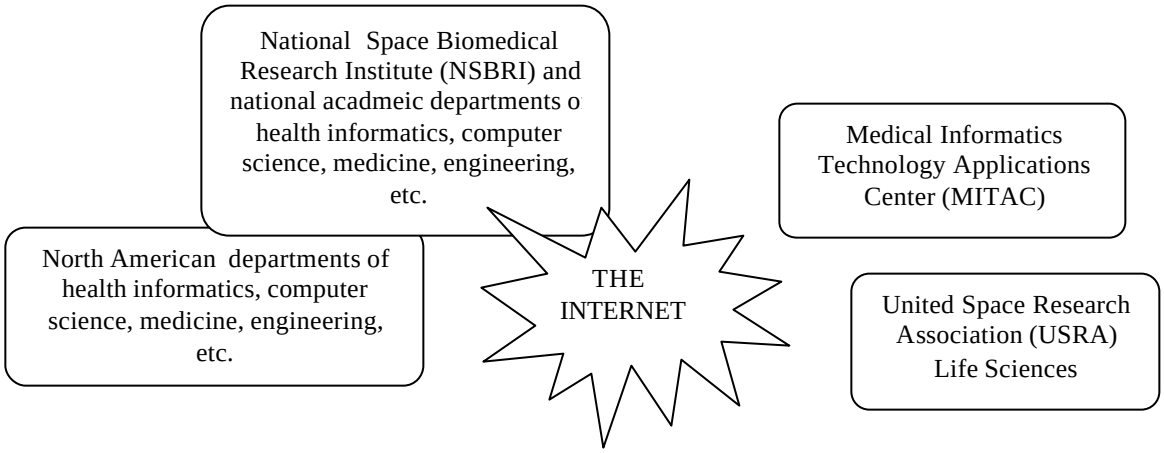
Such a mockup, with all of the source code, applications, etc., would eventually become a commercially equipped version of the future flight emergency rooms. Many of the intelligent systems and all the human medical data would initially be simulated, but with the progression of time, such a mockup would become an inexpensive vehicle for testing hardware, procedures, communication techniques, training technologies, etc. At any point in time it would represent of the best thinking on how to employ intelligent systems technology to human health care in space.

Above is a graphical model of the potential interactions – between NASA Centers, academia, other government agencies, the national labs, etc. – that could promote national cooperation and focus on intelligent systems for the future spacefarer. Intelligent medical systems, including advanced crew training methods applied to medical emergencies and automated human-machine cooperation in medicine, are an excellent way for NASA to apply its considerable background in intelligent systems to extend human reach beyond our grasp as we enter the next millennium.

While this first meeting dealt with a variety of ideas for facilitating partnerships between people in the IS community and NASA Life Sciences, the conversation is by no means over. It is just beginning and we need to hear from you. We are writing this memo with the hopes that you, our reader, will help us learn how best to serve the community of intelligent system developers should they choose to work on the intelligent medical systems that will enable humans to take the next steps outward. In the spirit of the ISE, we can begin to share information and to collaborate from distant locations to enable future explorations by humankind within the solar system.

The Intelligent Systems Program NRA

The Intelligent Systems Program NRA (http://procurement.nasa.gov/cgi-bin/EPS/sol.cgi?acqid=31961) was released on June 12, 2000. This initiative would indeed aid in the leveraging of existing government and university research. It is also geared toward feeding the best of mature, and relatively inexpensive, commercial technologies into NASA's future human missions.



From this solicitation, we know that the current intent is to provide awards "from $200K per year for individual PI or small team . . . to $1M per year for larger team or collaborative efforts". Imagine the possibility of an award of a $1M effort that supported the initial buildup of a photogenic mockup, as described above, along with a few smaller projects. According to the NRA, NASA Civil Servant salaries are not paid from NRA funds (we have a separate fund for that), and anything that a NASA center would like to donate is allowed pending the approval of Center management. The NRA encourages "participa[tion] in collaborative activities with other IS Program participants in the second and third year of their research activities," and the very intent of this initiative is create such a cooperative program.

Clearly, a strong program in developing intelligent emergency medical systems (IEMS) of the future would include a cluster of studies that could conceivably fall into almost any area of the NRA.

TA-1 Automated Reasoning: An IEMS, for example, will require considerable automated reasoning if it is to allow a small team of non-medical professionals to perform as well as a standard emergency medical team. Data will be collected and processed in operational realms incompatible with human perceptual and cognitive speeds. Fleets of autonomous agents will work with a human crew to save a human life. To get the required level of system intelligence we must place automated software synthesis into the hands of non-programmer, medical professionals, who will be able to use medical notations and concepts that are natural to their domain.

TA-2 Intelligent Data Understanding: An IEMS system is the clearest example of a data-gathering and -analyzing system. Volumes of data, including diverse types of medical records and a multiple channels of physiological data, must be analyzed and critical decisions about treatments made. During the human missions of the future, the primary task during a medical emergency will require the transformation of this distributed and complex data into knowledge. Data mining, knowledge discovery for scientific, medical, and engineering understanding, and machine learning for decision making and action are all critical components of a future IEMS. Humans must be aided by machines that process the data, extract information, recognize interesting patterns, and make critical correlations or probability judgements. Advanced data visualization techniques, as well as other approaches to conveying complex materials into human understanding, provide representations for a crew as it seeks to take the right actions.

TA-3 Human-Centered Computing: An IEMS system is the perfect example of a system that would benefit greatly by a human-centered computing approach. The emergency room is certainly a place in which intelligent systems and human beings can work in concert to extend human cognitive and perceptual capabilities. We need to understand how teams of crew and software agents work best together and what we can do to improve attention and concentration during difficult and stressful tasks. Furthermore, we must advance our understanding of the use of decision-making systems with human partners, as well as how computers can help humans improve their communications and teamwork. We need to develop technologies for embedded (on-board) training and aiding—-which often means delivering protocols and media clips just-in-time so that they are always keyed to the understanding and capabilities of the individual crew. In the emergency room of NASA's future new operator interfaces, such as augmented reality, wearable computer systems, etc., will be essential, as will need novel human/machine interfaces.

Here are some sample projects that could benefit by life sciences-IS collaborations:

TITLE : Autonomously Supplied and Supported Medical Trauma Care

PROBLEM STATEMENT

As we travel farther from Earth and remain there for longer periods of time, the need for autonomy in health care systems greatly increases. Challenges to such long distance, long-duration missions include: small crew size, communication delays, the need for minimum system mass, the inability to bring a whole

hospital and staff to provide health care in space, etc. Intelligent medical systems must be constructed that can compensate for these challenges in the space flight environment. Significant trauma, for example, requires the effective capabilities of a large medical team, yet it might need to be supplied by only one or two crewmembers. New techniques that augment human capabilities, such as intelligent system mentors, decision support software, case-based reasoning, advanced data visualization, automated data mining and trending, and other technologies must be applied to make future medical systems more autonomous for human space flight. The proposed research and technology development would apply intelligent systems technology to trauma care on Earth as a model of trauma care in space.

IMPORTANCE/ IMPACT OF PROPOSED RESEARCH ON SOLVING PROBLEM

This is an enabling technology for future HEDS missions, such as lunar and Mars exploration and colonization, and is a critical supporting technology for in-space construction activities like the ISS or any other mission where rapid response to medical emergencies can mean the difference between life and death.

TITLE: Knowledge-Based System Shell for Medical Applications

PROBLEM STATEMENT

Practice of medicine in space is confounded by severe restrictions on vehicle and personnel resources. Current medical operations concepts rely on non-physician Crew Medical Officers with minimal medical experience who are supported by extensive communications with Earth-based medical personnel. As we move to longer duration missions, travel further from Earth or attempt more dangerous activities like significant construction activities in space, the need for intelligent medical systems increases significantly.

Expert or knowledge-based systems have long been applied to medical diagnosis. In fact, the earliest expert system shells were developed from medical diagnostic applications or were used for medical purposes. Perhaps the most difficult step in building an expert system for medical diagnosis involves inputting the expert information. Visual programming techniques might be used with expert systems shells, like the ER developed CLIPS (spell out) or one of its off-shoots, to simplify the task of entering medical or scientific knowledge rapidly and unambiguously. A really important contribution would call upon both knowledge engineers and medical scientists/physicians to create the appropriate structure for such a system and the intelligent interface for such a tool. The generation of an easy-to-use tool for knowledge entry would allow physicians and scientists to make their own diagnostic aid tools. Hooks for tying in user-initiated multimedia, such as images or audio would lead the user through the appropriate stages of diagnosis: testing, interpretation, etc. Additionally, during its use, such a system should provide coherent reasons for its decisions in medical diagnosis. Information about possible treatments, both text and multimedia, could be presented along with the diagnosis and related reasoning. Application of the system would first be in small areas of diagnosis (e.g., diagnosis of bacterial infection) or other decision support areas and would allow the synthesis of knowledge into larger knowledge bases.

IMPORTANCE/ IMPACT OF PROPOSED RESEARCH ON SOLVING PROBLEM

This is an enabling technology for future HEDS missions, especially if they include lunar and Mars visitation and colonization, and is a critical supporting technology for in-space construction activities like ISS or any other mission where rapid response to medical emergencies can mean the difference between life and death.

CURRENT STATUS

At present no one here is working on an easily programmed system shell for medical applications in diagnosis, treatment or therapy for space flight applications. This tool would enable the generation of a large number of specific applications.

APPROACH

The approach is to generate a shell for visually programming medical diagnostic, treatment, and training systems to be used in space flight operations. As such, it enables many applications of this technology in the medical arena. We believe that this is an important element of a coherent program in intelligent medical systems.

TITLE: JUST-IN-TIME TRAINING FOR MEDICAL CARE

PROBLEM STATEMENT

The practice of medicine in space is confounded by severe restrictions on vehicle and personnel resources. Current medical operations concepts rely on non-physician Crew Medical Officers with minimal medical experience who are supported by extensive communications with Earth-based medical personnel. As we transition to longer duration missions, that mean travel further from Earth, or involve more dangerous activities, such as significant construction activities in space, the need for autonomous medical care greatly increases.

A particularly relevant application is training for health care: how could we develop an AI-aided method of teaching that works in just in time? For example, we could create an intelligent authoring tool that would allow people of different capabilities to run through the process of dressing wounds based on the particular problem that they have at the time? This approach limits information and training to the specific case at hand; there is no need to learn about minor burns if the injury involves critically burned tissues. Furthermore, training screens on the stabilization and treatment of such burns might be different for a physician than for a geologist. Authoring tools could also employ intelligent systems to adjust the difficulty of the medical training to the individual user's knowledge and skills. For example, a detailed course on the anatomy of the maxilla might not be applied to an instant problem, but could instead be of general use to anyone who wanted to learn anatomy.

IMPORTANCE/ IMPACT OF PROPOSED RESEARCH ON SOLVING PROBLEM

This is an enabling technology for future HEDS missions, such as lunar and Mars exploration and colonization, and is a critical supporting technology for in-space construction activities like the ISS, and any other mission during which continuous and just-in-time training is of value.

CURRENT STATUS

No one at JSC or anywhere else that we know of is currently involved in developing authoring tools suitable for in-flight intelligent training in the medical area.

APPROACH

The approach is to generate an application for authoring/programming intelligent medical training systems for space flight applications. We believe this is an important element of a coherent program in intelligent medical systems.

But Why Intelligent Medical Systems?

Someday humans will walk again on the Moon or, for the first time, set foot on the red sands of Mars.

The latter is a journey so far from Earth that our current conventions of life and work on-orbit will be nearly obsolete. Even the simple act of sending communications back to Earth will require up to 20 minutes each way. Everything that a crew of 4 to 6 might need during their 6-month journey to the Red Planet and during their 1.5-year stay on its surface must be brought with them. The spacecraft will be their whole world – a complete ecosystem – and a Mars crew will be utterly dependent on its near-perfect functioning for survival.

In this sense, the success of a Mars mission means that both crew and machine must make vital decisions and respond in real time, with little forgiveness for error. Far worse, the crew will be faced with a flood of highly technical and often incomplete or uncertain data – data that must be organized and interpreted before it can be understood or used. And as always, the mission will demand intense performance, far beyond what a crew of 6 could reasonably be expected or trained to do.

To realize such a mission will require extensive support from intelligent systems. In essence, machines must act as crew multipliers by allowing each crewmember to do the work of many. The spacecraft systems themselves, a network of intelligent systems, literally become "human equivalent" helpers. Equally important, training must be maintained during the course of a multi-year mission; this will call for the use of intelligent systems to provide in-flight training and decision support. Such training systems might be based on virtual reality and virtual environments, augmented reality, or similar technologies that can be delivered just in time. As the distinctions between decision support, automated care, training, and communications blur, so must the capabilities demanded of these systems.

Please visit at the SmartSystems 2000 website for details on a conference to be held Sept 6-8, 2000 on beautiful Clear Lake across from Johnson Space Center!

http://www.smart.systems.org