



TECHNICAL REPORT AMR-AS-04-02

JOINT PROGRAM PLANNING FOR AUSTRALIA/U.S. ROBOT MEDICAL ASSISTANT ON THE BATTLEFIELD

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Aviation and Missile Research, Development, and Engineering Center

April 2004

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13. ABSTRACT (Maximum 200 Words) Advances in both medical technologies and teleoperated robotics have presented opportunities for taking advanced medical care into battlefield situations. Research and development, as well as field capabilities, are reviewed to identify appropriate functional areas for formulation of an advanced integrated medical care system for battlefield casualties. Areas of special interest to the Australians and the United States (U.S.) are identified. A Draft Program Plan (DPP) is formulated based on civilian, as well as military need. Advances in telerobotic surgery have reached the point where surgeries are performed almost routinely where the patient and surgeon are in separate locations. While current civilian procedure and protocol require considerable preparation and setup, the technologies to develop a militarized, quicker reacting system are available. The proposed Program Plan is to prepare a concept definition for a Robot Medical Assistant. The long-term concept would be a robot that could have the capability to perform contact procedures on the patient. Examination and diagnosis would be performed via the tele-presence capability, and treatment would be performed through Virtual Reality (VR) connection between medical specialist located at a home base through the on-site robot.			
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TABLE OF CONTENTS

	<u>Page</u>
I. PURPOSE.....	1
II. BACKGROUND.....	1
III. STATUS OF EFFORTS.....	2
A. Senior National Representatives (SNR) Overview Document.....	2
B. Mesa Associates Study.....	2
C. U. S. Army Medical Research and Materiel Command, Telemedicine and Advanced Technology Research Center (TATRC).....	3
D. After First Treatment – Robotic Surgery.....	4
E. Australia – Defense Science & Technology Organisation Dr. Lucas Comments, 30 October 03.....	4
F. BG Atkinson Comments, 3 November 03.....	5
IV. FOLLOW-ON PLAN.....	6
V. CONCLUSIONS.....	7
REFERENCES.....	9
APPENDIX: BRIEFING CHARTS.....	A-1

I. PURPOSE

Recent advances in both medical technologies and teleoperated robotics have presented opportunities for taking advanced medical care into battlefield situations. Research and development, as well as field ready capabilities, are reviewed to identify appropriate functional areas for formulation of an advanced integrated medical care system for battlefield casualties. Areas of special interest to the Australians are identified as are areas of special interest to the United States (U.S.). A Draft Program Plan (DPP) is formulated based on civilian, and military need, and Australian and U. S. materiel development interests. The DPP is presented as a working document to be revised as more data is acquired and additional coordination is performed.

II. BACKGROUND

Commanders lack tools to obtain real-time, basic information about the physiological status and readiness of their soldiers. These decision makers need to understand their personnel's physiological status and know how a soldier's physical condition could affect productivity, performance, and ultimately the mission. The Land Warrior soldier system and Future Combat System (FCS) are addressing the devices necessary to collect the information about a soldier's physiological condition. In addition to the focus on monitoring the individual soldier's physiological condition to help assess effects on performance, the remote triage sector is evaluating technologies that would assist medics in the field. Since the future technology-enhanced soldier will operate in more widely dispersed groups and on future battlefields that will include urban environments, equipment that supports remote assessments of injuries could be key to reducing the number of fatalities during missions. Technologies that allow the medic to treat a casualty better in the field by using telecommunications are becoming available and are near-term for the medic arriving at the battle scene. By combining these two major areas of current emphasis with robotic technologies, great strides are being made in locating, assessing condition, and extracting the casualty.

A new area of emphasis can now be addressed. Today's combat medics do not have the time and facilities to rapidly apply advanced treatment to casualties on the battlefield. As Lawlor indicates in SIGNAL Magazine, of the soldiers killed in action, 90 percent of those soldiers are located forward of the battalion aid station. Of the soldiers that are killed, 33 percent of the deaths occur during the first hour after injury [1]. This hour is many times referred to as the "golden hour." If a soldier's wounds could be addressed in this hour, the likelihood of survival would be increased considerably. Combat medics make all attempts to provide this needed support in the first hour. Trauma care has evolved into a highly specialized field of surgery where experience and judgment may have a major effect on clinical outcome, yet trauma care on the battlefield is simplistic in comparison. Advances in telerobotic surgery have reached the point where surgeries are performed almost routinely where the patient and surgeon are in separate locations. While current civilian procedure and protocol require considerable preparation and setup, the technologies to develop a militarized, quicker reacting system are available.

III. STATUS OF EFFORTS

This is a review of research and development activity on the topic of Robotic Medical Assistance on the battlefield. The topic is far reaching - from sensors that can determine the physiological condition of a soldier and transmit the data to a medic located in a safe place, to the extreme concept of robotic extensions of expert physicians performing surgical procedures from remote locations.

A. Senior National Representatives (SNR) Overview Document

A convenient starting point for discussions of a joint Australian and U.S. program is the 23 July 2003 message from Dr. Michael Lucas, subject: "Summary of Teleconference on Medical Robots." This message summarized a telephone call between Australian and U.S. parties and documented some planning steps. One goal identified in this message was to capture the program requirements, identify the main players, and draft a plan of how to proceed to a demonstration (the plan is a "joint team effort" representing a U.S. and Australian proposal). All members will contribute to the plan. Dr. Lucas and BG Atkinson will put together notes on what the first part of the development, the first goals, would look like [2]. The SNR paper and six briefing charts "Unmanned Tele-remote Robots as Medical First Aid on the Battlefield" 9 through 13 May, 2003, Lucas, Krstic, Atkinson, Lozo, and Hutchins, was offered by Dr. Lucas as the starting point for the effort. The SNR paper indicates the concept to be developed and demonstrated is that of a chair-sized, tele-remote robot that could be used to administer first aid to a wounded combatant on a hostile battlefield, stabilizing the patient until the area can be secured and medivac procedures can be initiated. The paper identifies the use of Virtual Reality (VR) for surgical training and calls out Commonwealth Science Industrial Research Organization's (CSIRO's) "very active and successful" VR Program. It proposes a near-term program to (a) develop robots capable of giving medical assistance under appropriate tele-operation and take part in safe evacuation of casualties; (b) develop tele-remote VR tools for medical officers; (c) develop the communications and protocols to allow safe, long-range usage; and (d) develop military medical doctrine for use of tele-remote robots and VR. The longer range goal is to solve the problem of casualty assistance/evacuation by providing tele-operated robots and VR to make medical teams available at many different locations, yet out of harms way [3, 4].

B. Mesa Associates Study

In the October through December 2003 timeframe, the U.S. contracted with Mesa Associates, Inc. to prepare a report of project activity in industry, academia, and government related to the use of robotics for medical assistance. The purpose was to review the status of technology developments, hardware demonstrations, and areas of interest within the robotic research and development community [5]. The report includes an extensive listing of subsystem items that could support a robotic medic. The Personal Status Monitor (PSM) senses and transmits the soldier's location and vital signs. The Torso Penetration Sensor (TPS) detects entry and exit wounds and uses acoustic sensors to track a fragment path; additional sensors and processing provide readout of biological damage. There are also a Non-Invasive Burn Analyzer, a Non-Invasive Lactate Sensor (an important indicator of oxygen debt), Handheld Ultrasound (currently in use in the field), and other developmental items.

Mesa Associates reviewed public literature to identify organizations addressing technologies associated with field medic support. For instance, the University of Washington is working on a microfluidic chemical analytical system to monitor blood chemistry in out-of-hospital situations. Titan Corporation is developing a Mobile Integrated Diagnostic and Data Analysis System (MIDDAS), a glove, worn by a medic, with built-in sensors that allows him to perform an Electrocardiogram (EKG) measuring pulse rate, core body temperature, blood-oxygen level, heart rate variability, and blood pressure. The data is available on-site to the medic and can be transmitted to a laptop or computer at a hospital. The blood pressure check can be performed in less than 8 seconds and by quickly testing many wounded, associated software can help determine which patients need treatment most urgently. Los Alamos National Laboratory, in collaboration with the University of New Mexico Medical School, is developing a compact breath sensor to quickly screen potential victims to distinguish between influenza and infection or exposure to a biothreat agent. The Study Report contains descriptions of many more related subsystems and the organizations involved with research and development.

The study included demonstration plans to show a practical approach to combining some of the medical subsystems with a robotic vehicle in militarily relevant situations. The robotic platform would address mobility, ease of control, accuracy of movement, speeds of movement, payload capacities, and stability issues related to medical packages. The medical portion of the demonstration vehicle would address locating medical casualties, remote triage, types of medical treatments allowable given the operator's remote control functions and the battlefield environment, manipulator arm positional accuracy and functionalities, and casualty removal methods. The report proved to be a very comprehensive documentation of work being done to support the dangerous patient-to-medic interaction on the battlefield. Addressing the "golden hour," when aid is essential for survival, and the danger and workload on the human medic clash, is the central theme of this report.

C. U.S. Army Medical Research and Materiel Command, Telemedicine and Advanced Technology Research Center (TATRC)

TATRC is performing extensive work in the area of robotic medical assistance applications. They are leading SBIR Programs A01-184 and A02-179. Robotic Medic Assistant (SBIR A01-184) is being conducted by Irobot [6, 7]. The goal is to develop a laboratory prototype that will demonstrate a representative sample of the following tasks: (a) find patients in urban and field terrains; (b) identify patients as friend or foe; (c) communicate with and facilitate communications between patient and medic; (d) assess patient to determine whether alive or dead, determine most critical injuries, perform remote triage; (e) perform some simple first aid functions such as clear the airway, apply pressure bandage, inject narcotics or hemorrhage retarding drugs, immobilize serious fractures, etc.; (f) protect patient from further injury and from hostile attack; and (g) lift, move, carry, tow, or otherwise execute patient recovery from hazardous to safe areas where they can be attended by human medics. The Phase II effort was not funded; however, the project is being pursued under related work in combination with a proposal from Foster Wheeler. Irobot is expected to deliver a prototype by the end of September 2004.

Robotic Casualty Extraction (SBIR A02-179) is being conducted with Irobot and Applied Perception, Inc. This effort involves building a prototype robotic patient recovery system with teleoperation, semi-autonomous control capabilities implemented on a marsupial robotic vehicle pair. The larger Robotic Evacuation Vehicle (REV) is for long-range patient evacuation (from first responder medic to forward casualty collection and treatment site), and the smaller Robotic Extraction Vehicle (REX) is for short-range patient extraction (from the site of injury to first responder medic). The REX will have patient detection capabilities using technologies; e.g. long wave Infrared (IR) camera or color image segmentation, to locate casualties. TATRC's objective is a proof-of-concept feasibility demonstration of potential medical applications of the Army FCS Small Unmanned Ground Vehicle (UGV) and FCS MULE robot. This project is scheduled for demonstration in June 2005.

D. After First Treatment - Robotic Surgery

Many hospitals throughout the world are performing robotic surgery on a routine basis. A group of doctors at New York's Mount Sinai Medical Center were at the controls of the system that removed the gall bladder of a woman in Strasbourg, France. The concern was the delay time for transmissions, 200 milliseconds being considered an upper limit to provide adequate reaction time if an instrument touched the wrong spot causing bleeding. Using a fiber-optic connection, they achieved 160 millisecond roundtrip delay [8].

A doctor at St. Joseph's Healthcare Hamilton in Ontario, Canada, performed telerobotic laparoscopic surgery on a patient 250 miles away. Reliable, redundant network communications were essential to ensure positive control of the three-armed ZEUS robot [9].

Surgeons at the University of Chicago are treating patients with the da Vinci robotic system. The surgeon sits at a console that provides a magnified Three-Dimensional (3-D) image; his wrists and hands are attached to glove-like sensors, which guide the tools on the robot's arms which are located a few feet away in the same room. The tools have more degrees of freedom than standard laparoscopic instruments, allowing the surgeon to cut, sew, cauterize, suction, and remove tissue with considerable precision. The computer controlled system can even reduce a surgeon's minute tremors. One trade-off, however, is loss of tactile sensation. The surgeon has no feedback of pressure on tissue or even how tight knots are tied [10]. This shortcoming is being addressed in many research labs, including Australia's CSIRO [11, 12].

E. Australia - Defence Science & Technology Organisation Dr. Lucas Comments, 30 October 03

Dr. Lucas provided input in response to U.S. briefing charts, 30 October 03. The briefing charts were a snapshot of the study work being done by Mesa Associates. The study was concentrating on the early end of the patient/medic interaction. Dr. Lucas suggested revising the problem statement to emphasis patient/robot interaction during the "golden hour." The problem to be addressed is the lack of appropriately skilled medical and paramedical staff close to or on the battlefield. The current shortages of medics and medical staff available for battlefield assignment are expected to worsen in the future. The need for more specialized medical treatment during the "golden hour" is expected to increase. In the future, skilled medical staff

must be in a safe location and yet be readily available to exercise their skills in many different geographical places. The proposed solution is to use tele-operated robots as extensions of medical staff, who through VR interfaces, are able to effect the required care. With tele-presence, the medical staff can use sensors as they would in the normal course of their duties. In summary, the robot becomes the medic on the battlefield. Other programs are addressing the aspects of locating and retrieving casualties [13, 14]. Subsequent discussion with Dr. Lucas expanded the program interest into civilian use as well. There is a shortage of specialized medical personnel in remote areas of Australia. There is also a need for a medical robot that could be quickly delivered to disaster sites; e.g. earthquake, explosions, structure collapses, bio-terror or nuclear accident sites. Some of these sites may be too dangerous for human medical teams. Robots could be sent into situations without regard for their safety or accommodation.

F. BG Atkinson Comments, 3 November 03

BG Atkinson provided comments on prioritization of the medical robotics program. The pivotal area is the telecommunication link. The VR surgery and robotics surgery is progressing and the leading areas will require monitoring and recruitment to the project. The development of a robot, or combination with a multi-purpose military robot, would be the third priority, with development of combat casualty management techniques.

The telemedicine link would transmit data to a medical officer and provide control of intravenous or intra-osseous line with fluids, antibiotics, and analgesics. This is a reasonable goal for a robot in urban warfare and at long distance for special forces. He refers to the “golden hour” and the need to manage A(airway), B(breathing), and C(circulation). In addition to the fluid line, he would add the capability to provide direct control of hemorrhage with pressure and thrombotic agents. He further states that 70 percent of combat casualties are peripheral. The medical robot will also be able to provide treatment to non-combatants [15].

IV. FOLLOW-ON PLAN

The proposed Program Plan is to prepare a concept definition for a Robot Medical Assistant. A working group of individuals from Australia and the U.S. would prepare a detailed plan including cost, schedule, and deliverables. As a starting point, the following two-phase concept definition is presented. The near-term concept is described as follows. The robot would be capable of navigating to an injured soldier and giving medical assistance under appropriate tele-operation and take part in safe evacuation of casualties. Navigation could be assisted by providing remote control capability to a soldier in line-of-sight, or navigation could be assisted by real-time UAV video. In essence, many programs are working navigation problems and this project need not address them. The medical procedures assigned to the near-term robot would be quite basic, involving minimal contact with the casualty. The robot would provide tele-presence capability that would allow medical specialists of the appropriate skill to examine the patient and perform treatment via an on-site soldier or medic. In other words, there would be another soldier or a human medic on site. The robot would provide telecommunications and the on-site individual would perform the prescribed action. The long-term concept would be a robot that could have the capability to perform contact procedures on the patient. Examination and diagnosis would be performed via the tele-presence capability, and treatment would be performed through VR connection between medical specialist located at a home base through the on-site robot. The robot may be a universal machine which could be adapted for various battlefield uses. When it is outfitted for medical use, its mobility control functions need not change. When the robot arrives at the location of a casualty, control of the manipulator arm(s) would be assumed by medical personnel located well away from the danger area. Through tele-presence and VR, medical treatment would be performed on the casualty.

Preliminary understanding of a division of responsibility for a joint program follows. The Australian representatives are interested in further development of VR medical procedures and development of tele-remote VR tools for medical officers. They would provide work on the surgical center where medical specialists are located to administer aid via telecommunications. The U.S. representatives are interested in providing the robot and manipulator arm(s). The telecommunications link and development of the communications and protocols to allow safe long-range usage, development of military medical doctrine for use of tele-remote robots and VR, would be a cooperative effort between the two organizations. More detailed definitions of technical assignments would be developed by the working group.

V. CONCLUSIONS

The time is right to define a Program Plan for a joint Australia/U.S. Robot Medical Assistant on the Battlefield. The military need for advanced medical treatment during the “golden hour” after injury remains. Other sensor and robotic applications are addressing the problems of locating and extracting casualties. The efforts needed to integrate technology developments in robotics, communications, and medical trauma care and apply them to a battlefield medical treatment system should be defined in further detail, funding sources should be explored, and both Australian and U.S. military needs should be documented.

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**APPENDIX
BRIEFING CHARTS**



**Aviation and Missile Research,
Development and Engineering Center
U.S. Army Research, Development, and Engineering Command**



**Joint Program Planning for Australia / US
Robot Medical Assistant on the Battlefield
27 Feb 2004**

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Outline



- Purpose
- Background
- Status of Effort
 - SNR Overview Document
 - Mesa Associates Study
 - TATRC
 - Robotic Surgery
 - DSTO
- Follow on Plan
- Conclusion



Purpose



- Review advances in medical technologies
- Review advances in teleoperated robotics
- Identify areas of interest to Australia and US
- Propose a working group to draft program plan
 - military & civilian needs
 - Australia & US developmental interests



Background



- Commanders lack tools to obtain real-time physiological data on soldiers (Readiness)
- Battlefield Medical staff is isolated from Medical Specialists
- Treatment is critical during the “golden hour”
- Telecommunications advances can improve the flow of information and the level medical treatment available on the battlefield
- Application of robotics and virtual reality tele-presence to battlefield can impact quality & level of medical care



Senior National Representatives (SNR) Overview Document



“Unmanned Tele-remote Robots as Medical Assistants on the Battlefield”

- **Chair size robot to administer first aid (Stabilize patient then Medivac)**
- **Develop Virtual Reality tools for Medical Officers**
- **Develop communications and protocols for long range use**
- **Develop military medical doctrine for tele-remote robots and VR**



Mesa Associates, Inc. Study



“Teleoperated Robotic Medical Assistance On the Battlefield Concept Study”

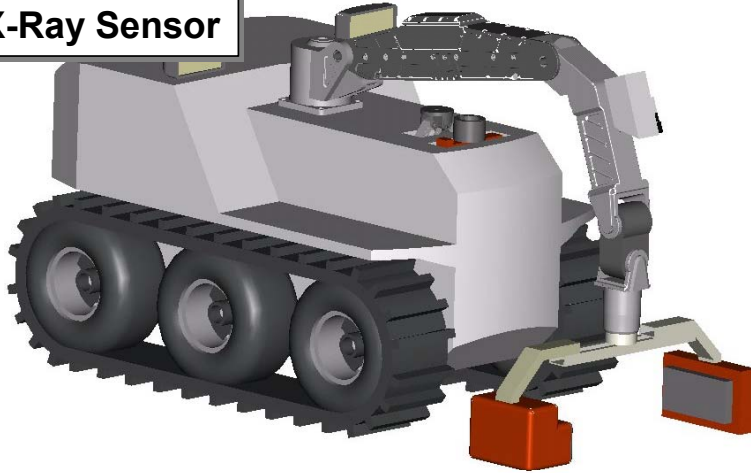
- Purpose was to review the status of technology developments, hardware demonstrations, and areas of interest within the robotic research and development community, for example:
 - Personal Status Monitor
 - Torso Penetration Sensor
 - Mobile Integrated Diagnostic and Data Analysis System
- Sample demonstration concepts were formulated
- Emphasis was on getting help to the soldier within the “golden hour”



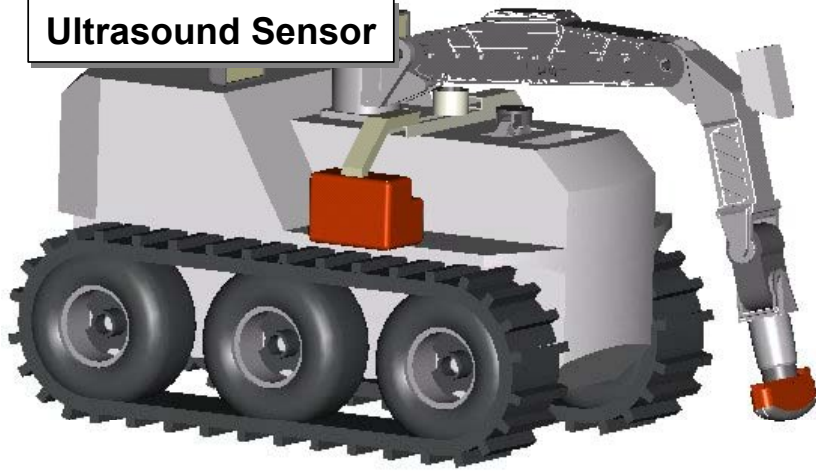
Mesa Concepts



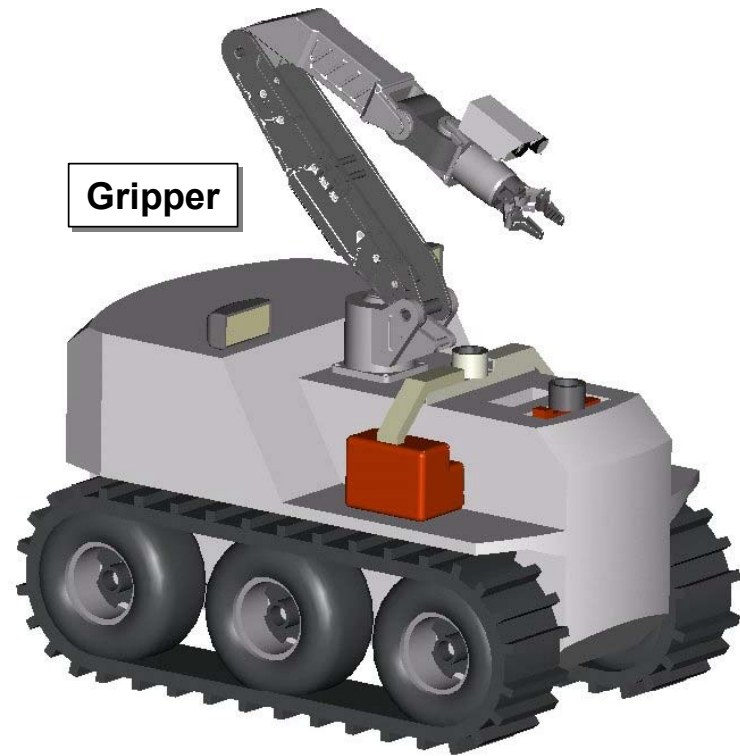
X-Ray Sensor



Ultrasound Sensor



Gripper



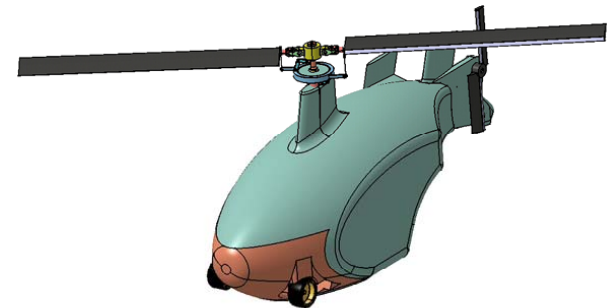


UTAGS

Concept Description



- The UTAGS team consists of a UAV “Quarterback” and one or more small UGVs
- The UAV can perform multiple roles as part of UTAGS:
 - Precision delivery/recovery of UGV platforms
 - Long-range datalink relay
 - GPS referenced mapping (EO/IR/LADAR) of target area for assisted teleoperation of UGVs
 - Semi-autonomous navigation of UGVs (waypoints, obstacle detection)
 - Image/sensor processing of UGV data
 - RSTA/TD with onboard sensors
 - Target engagement with onboard weapons
- The small UGVs can also perform multiple roles:
 - RSTA/TD
 - Countermine
 - CBRN detection
 - Target engagement



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UTAGS

(a concept)





**U.S. Army Medical Research & Materiel Command
Telemedicine & Advanced Technology Research Center**



Army SBIR Projects:

A01 – 184 Robotic Medic Assistant Irobot

**A02 – 179 Robotic Patient Recovery Irobot
Applied Perception**

- **Most combat medic casualties occur treating soldiers under fire.**
- **Many soldier casualties occur when providing buddy aid.**
- **Prevalence of urban operations in peace keeping/humanitarian missions**
- **Operations in hazardous and contaminated areas due to increased threat of weapons of mass destruction.**

POC: Dr. Gary Gilbert, Army Medical Research & Materiel Command (301) 619-4043



AMRMC/TATRC Robotic Medic Assistant A01-184 SBIR Status



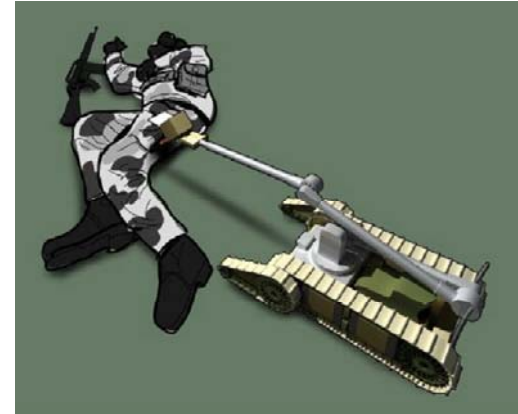
- PHASE I: Conceptual and technical model.
- PHASE II: Laboratory prototype robot or team of robots which demonstrates a representative sample of the following tasks:
 - a. Find patients in urban and field terrains.
 - b. Identify patients as friend or foe.
 - c. Communicate with and facilitate communications between patient and medic.
 - d. Assess patient to determine whether the patient is alive or dead, determine most critical injuries, perform remote triage (expectant, immediate, routine).
 - e. Perform some simple first aid functions such as clear the airway, apply pressure bandage, inject narcotics or hemorrhage retarding drugs (e.g. Factor 7), immobilize serious fractures, etc.
 - f. Protect patient from further injury and from hostile attack.
 - g. Lift, move, carry, tow, or otherwise execute patient recovery from hazardous to safe areas where they can be attended by human medics.



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AMRMC/TATRC Robotic Medic Assistant A01-184 SBIR Status



- PHASE I: Complete.
- PHASE II: Was not funded. However, some related work was funded in combination with proposal from Foster Wheeler. Irobot is expected to complete the deliverable prototype by end of Sep 04.

POC: Dr. Gary Gilbert, Army Medical Research & Materiel Command (301) 619-4043



Robotic Casualty Extraction (SBIR A02 – 179)



Irobot



Bloodhound navigation prototype with laser rangefinder



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Robotic Casualty Extraction

(SBIR A02 – 179)



Status

Phase I - Initial investigation of relevant technologies. Dec '02 – Jul '03.
Completed.

Phase I Option - Produce detailed system design. Jul '03 – Nov '03.
Completed.

Phase II - Start. Nov 03.
- Demo of navigation and individual sensing technologies. Jun '04.
- Demo of initial patient detection technologies. Dec '04.
- Final demo of patient detection and recovery. Jun '05.
- Final demo of robotic sentry application. Sep '05.

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b.ppt



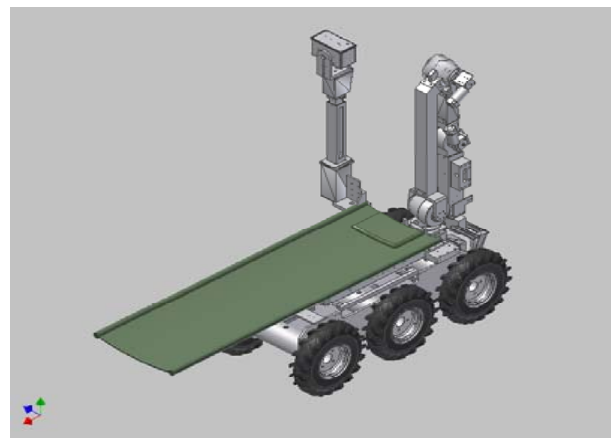
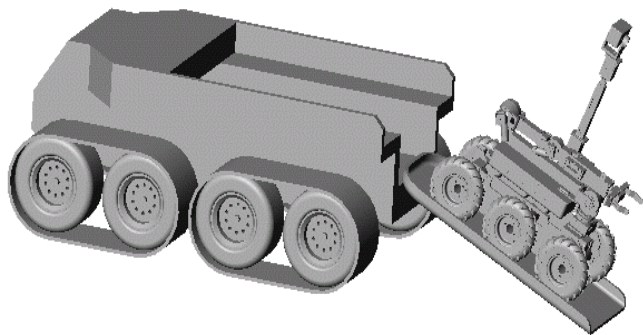
Robotic Patient Recovery



A Robotic System for Wounded Patient Extraction and Evacuation From Hostile Environments

U.S. Army SBIR A02-179 – Phase II

USAMRMC, USATARDEC, OSD & Applied Perception Inc.



POC: Dr. Gary Gilbert, Army Medical Research & Materiel Command (301) 619-4043



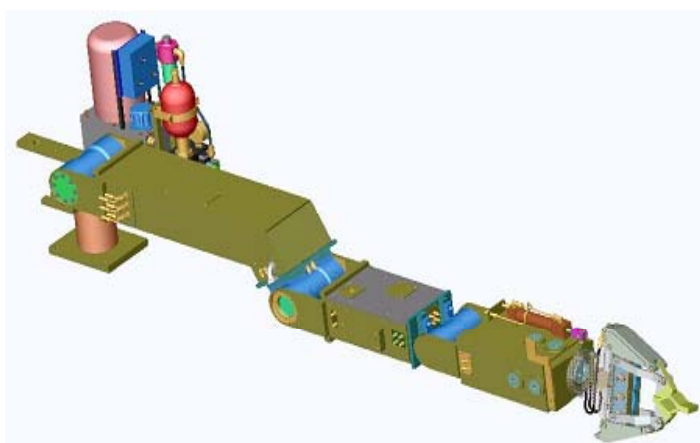
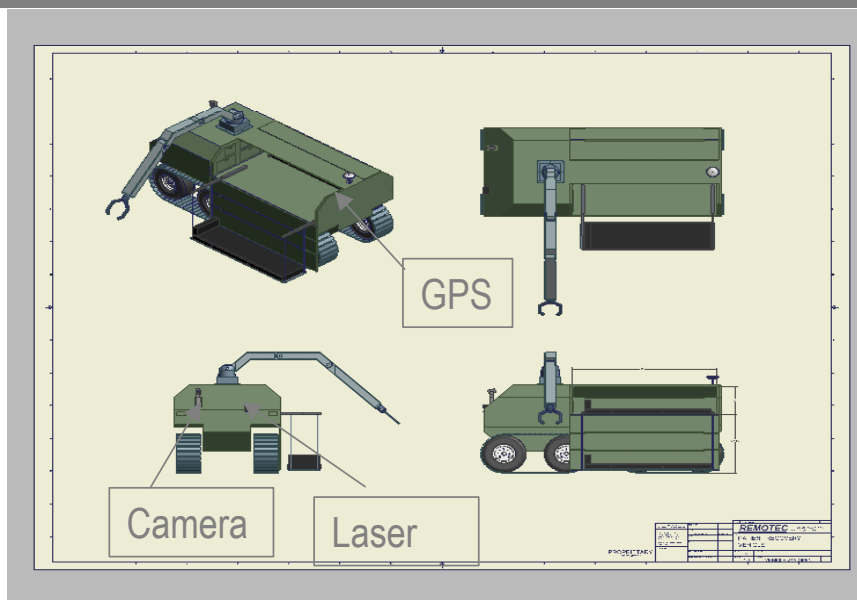
Evacuation Vehicle Concept Design



**Amphibious MULE-like Robot,
1500 lbs payload, 60 HP Diesel
engine.**

**150 lb lift capacity hydraulic
manipulator.**

**7 degrees of freedom; 8 feet
reach**



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Robotic Surgery



New York's Mount Sinai Medical Center-

Doctors control gall bladder removal from patient in France. Fiber optic connection allowed 160 millisecond round trip time delay.

St. Joseph's Healthcare Hamilton, Ontario, Canada-

Telerobotic laparoscopic surgery using ZEUS robot 250 miles away.

University of Chicago-

Da Vinci robot used to perform surgery. Robot has greater freedom of movement, can work through smaller incisions, filters out surgeon's minute tremors.



Initial Study Comments

(Dr. Lucas, 30 Oct 03)

1. When a soldier is wounded how do we get care to that soldier.
2. There is a lack of appropriately skilled medical and paramedical staff close to or on the battlefield.
3. It is in many cases important to get care to the patient quickly (the concept of the golden hour).
4. We would like skilled medical staff to be in any one of a number of locations instantly.
5. We would like those medical staff to be safe and still be able to operate in hazardous combat environments.



Australia
Defense Science & Technology Organisation (DSTO)



DSTO Recommendation

The Robot becomes the Medic on the Battlefield
Deliver anywhere
Safety not a concern
Civilian use also



BRIG Atkinson

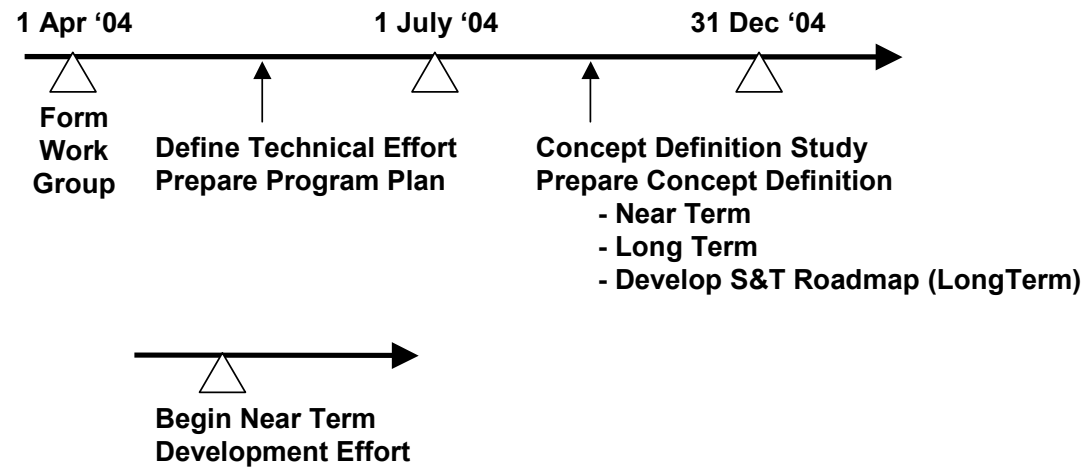
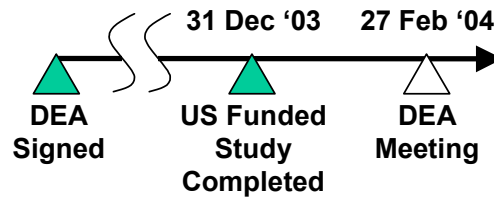


Telecommunications Link is Pivotal

- Transmit data
- Control intravenous line
- Manage Airway, Breathing, Circulation (“golden hour”)
- Control hemorrhage 70% of casualties are peripheral



Suggested Schedule of Events





Follow-on-Plan



- Form a Working Group representing Australia and the US
- Prepare a detailed Plan including cost , schedule , and deliverables
- Consider preliminary

Near-Term Concept: Robot capable of navigating to an identified casualty. Navigation may be aided by a soldier with line-of-sight remote control and assisted by UAV real time video. Medical procedures assigned to the near-term robot involve minimal contact with casualty. The robot will provide tele-presence for medical specialists to assist an on-site medic diagnose and treat patient.

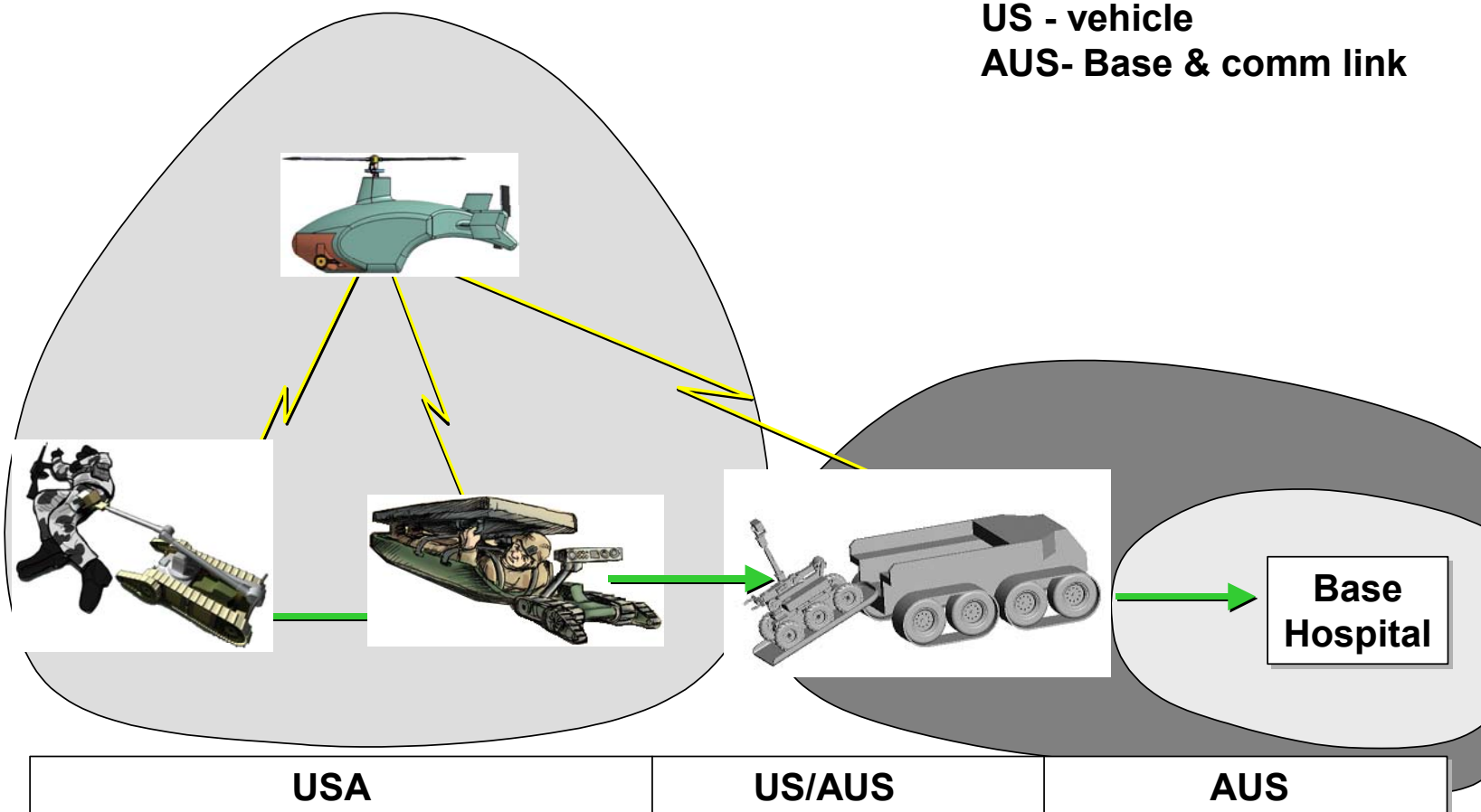
Long-Term Concept: The robot would perform contact procedures on the patient. Virtual reality tele-presence coupled with manipulator arm(s), special medical instruments medical procedures would be demonstrated.



Robotic Medical Assistant Concepts



AUS - US unit
US - vehicle
AUS- Base & comm link

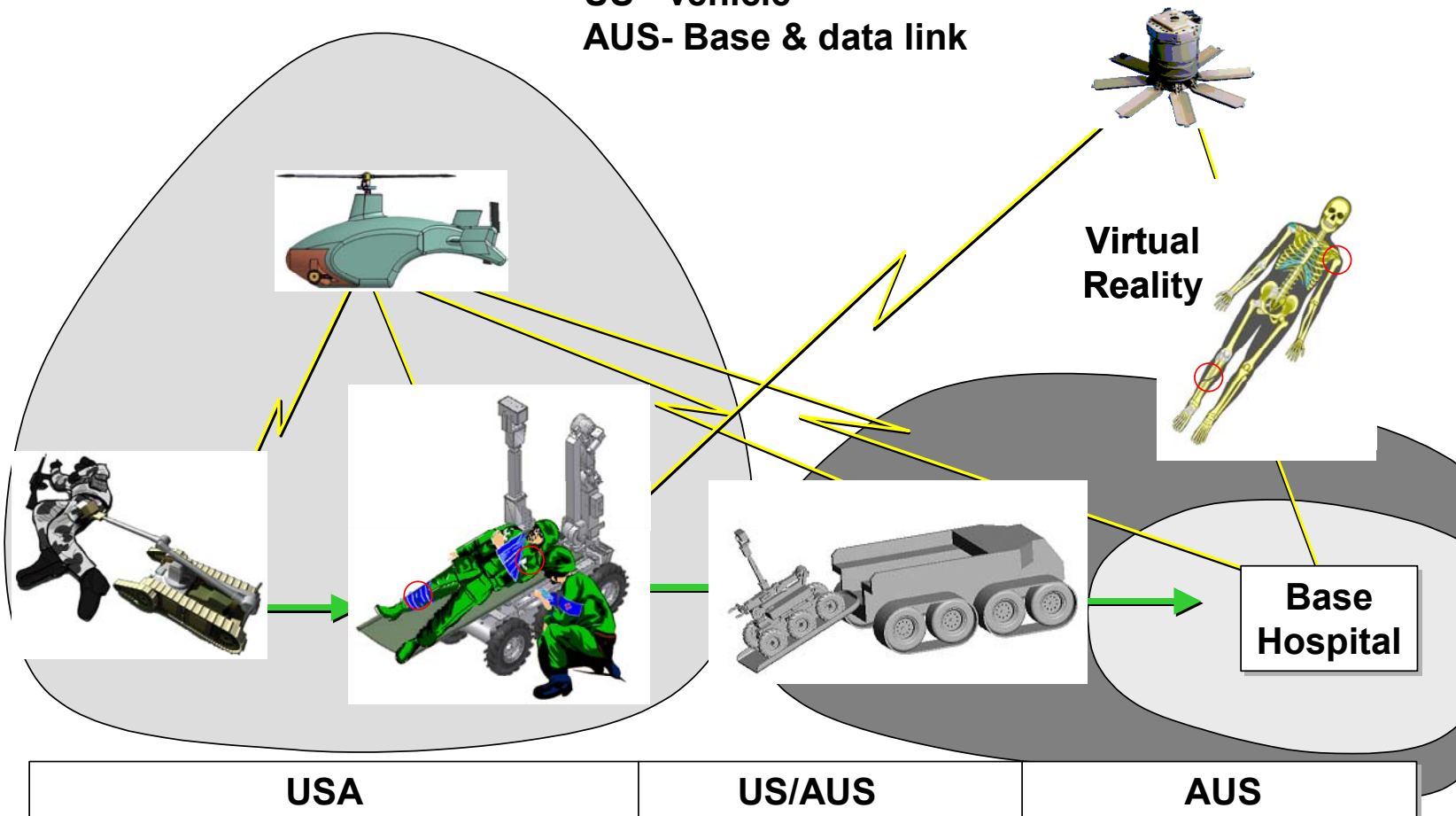




Robotic Medical Assistant Concepts



US - vehicle
AUS- Base & data link





Conclusions



- **Medical sensors and robot navigation technologies are being developed to locate and extract casualties**
- **Military needs advanced medical treatment on the battlefield during “golden hour”**
- **Efforts are needed to integrate technology developments in robotics, communications, and medical trauma care**
- **Australia and US should form a working group to define a Program Plan to develop a concept for a Robot Medical Assistant**
- **Both Parties should investigate possible funding sources**

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