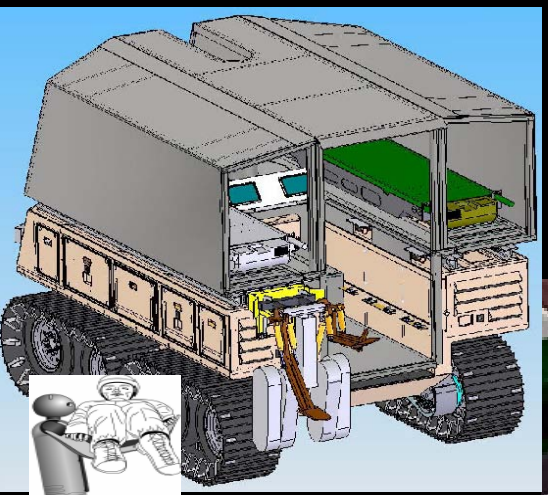
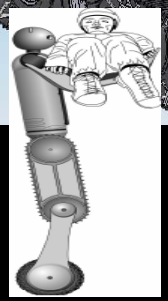
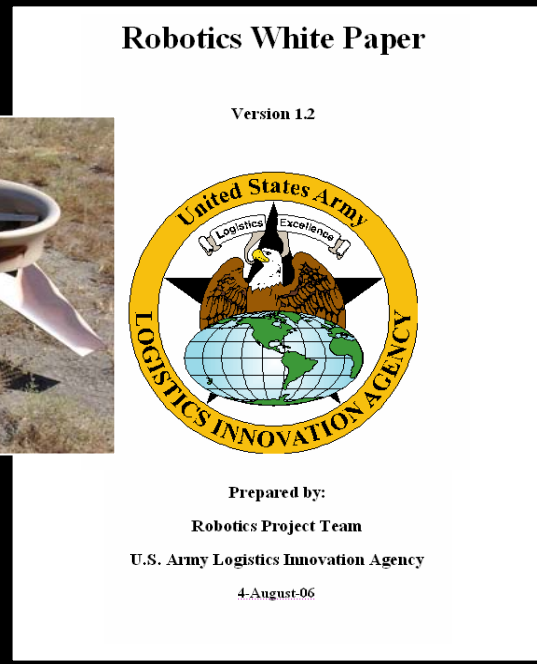
U.S. Army Medical Research and Materiel Command
Telemedicine & Advanced Technology Research Center

USAMRMC TATRC Combat Casualty Care and Combat Service Support Robotics Research & Technology Programs







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Joel Wise, Robotics Joint Program Office, Redstone Arsenal
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Report Documentation Page

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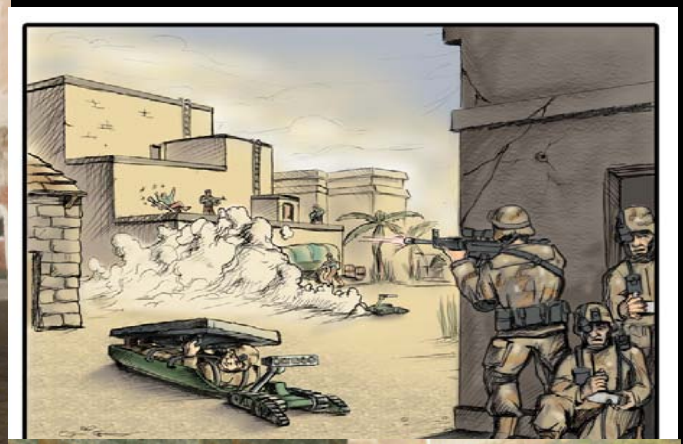
Autonomous Combat Casualty Care



*photos courtesy
Dr. Rick Satava DARPA, Biomedical Program Manager
& Dr. Brian Yamauchi, Irobot, Inc.

Futuristic Concept

Defense Advanced Research Projects Agency (DARPA) & US Army Medical Research & Materiel Command (USAMRMC)

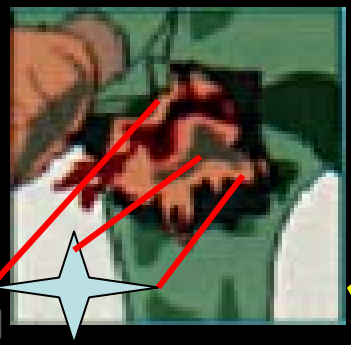
Joint Programs:
Trauma Pod,
Operating Room of the Future
Digital Human,
Robotic Combat Casualty Extraction, Diagnosis, Treatment & Evacuation

Casualty Prevention & Casualty Management

Medical Informatics, Robotics & Nanotechnology

Integrated Technologies – Integrated Technology Management

Warfighter Physiologic Status Monitoring



DARPA, TATRC
MRMC, USARIEM
ISN, USASSC

Advance imaging & sensors

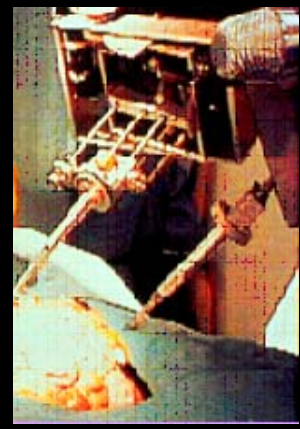
MRMC BIC
USAISR
USARIEM/USASSC

AI Algorithms

Wound Detection

Remote Triage

Status Prediction



Robotic assessment & treatment

DARPA
MRMC

Virtual physiological model of soldier:
- anatomic
- organ systems
- tissue/ cellular
- genomic

DARPA
NLM
MRMC
TATRC

MRMC BIC
TATRC
TMIP/MC4
USARIEM
USASSC

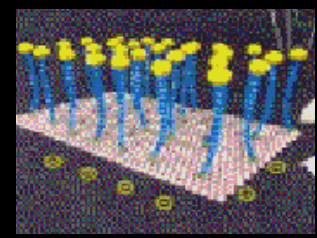
DECISION SUPPORT

SENSOR NETWORK

DATA MANAGEMENT

FIELD DATA COLLECTION

ISN/ARO
MRMC



Heart Rate
Respiration Rate

Motion Detection

Water Intake

Other soldier physiological Sensors (e.g. nano)

Why ROBOTs?

"The more things change, the more they remain the same"
Alphonse Karr

"The Future ain't what it used to be and it never was"
Yogi Berra

- **Most combat medic casualties occur treating soldiers under fire.**
  (per Congressional Medal of Honor statistics)
- **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.**
- **Army Future Combat Systems goal is to require 1/3 of its vehicles to be autonomous by 2015.**
- **Robotic vehicles reduce deployment weight, volume, and requirements for airlift.**

USAMRMC Robotics Research & Development Strategy

- **Develop technologies that contribute to long term Autonomous Combat Casualty Care vision.**
- **Collaborate with DoD Joint Robotics Program, other Army organizations & services, the Defense Advanced Project Agency (DARPA), and allies.**
- **Leverage DOD Science & Technology funding programs including:**
  - Small Business Innovative Research & Technology Transfer Programs (SBIRs and STTRs)
  - Congressional Directed Research Programs.
- **Transition mobile combat casualty care robotics efforts to**
  - Joint Robotics Program
  - Joint Force Protection FIRRE (Family of Integrated Rapid Response Equipment) Program
  - Army Future Combat Systems Program
  - Joint Advanced Concept Technology Demonstrations, *e.g.:*
    - CBRN Unmanned Ground Reconnaissance (CUGR)
    - Robotic Follower
    - Joint Medical Operations Force Health Protection
- **Foster commercialization by leveraging military efforts for civilian applications**

Military Medical Applications of Robotics

- **Objectives:**
  - Reduce human exposure to hazardous situations
    - Combat medics are at significant risk when retrieving and administering aid to casualties under fire, and have one of the highest casualty rates of any military occupational specialty
    - Limit contamination of medical personnel in Chemical, Biological & Nuclear environments
  - Reduce forward support medical "footprint"
    - Provide force multiplier for limited medical manpower
    - Project medical expertise from rear
    - Reduce weight & cube for deployment

- **Applications:**
  - Casualty location, extraction and tactical evacuation
  - En-route care during patient transport
  - Medical supply delivery
  - Remote surgery, examination, or other intervention
  - Medical surveillance

Technology Barriers

non-medical

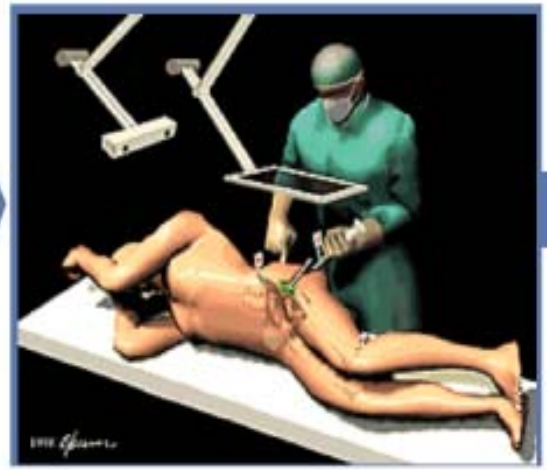
- **Casualty Location**
- **Autonomous operation – UGVs and UAVs**
- **Safe/human rated UGVs and UAVs – shock absorption on UGVs**
- **Adequate secure wireless MESH communication/ longer range UWB**
- **Uncomplicated but powerful universal JAUS compliant OCU (UGV/UAV & payload control)**
- **JAUS messages for application payloads**
- **Mobility in urban and wooded terrain**
- **Speed of operations**
- **Improved onboard power sources**
- **Smaller, lighter Raman/LIBS Laser Spectrometers, telescope and other CBE detection payloads.**

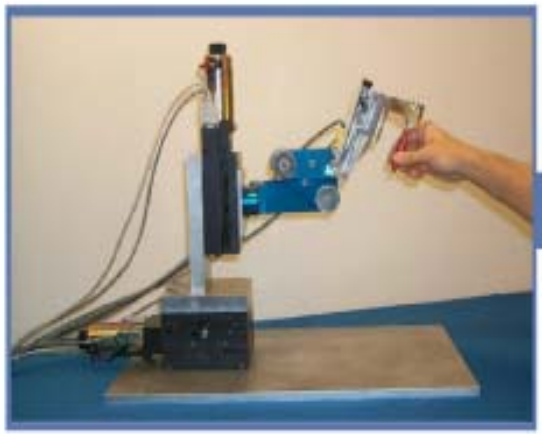
medical

- **Casualty movement and stabilization**
  - Self loading or buddy loading of casualties is insufficient for unconscious casualties or for those too gravely wounded to move themselves
  - Robotic stabilization of broken or partially amputated limbs prior to movement to avoid inflicting additional injury.
- **Providing "human touch" to calm and reassure casualties**
- **Medical knowledge to guide robotic assessment and treatment**
  - Identification of appropriate prognostic and diagnostic markers for trauma
  - Modeling of human response to trauma and therapeutic interventions
  - Remote detection and diagnoses of Chem/Bio agents on human casualties.
- **Advanced realtime imaging and anatomic modeling to appropriately direct physical interventions**

THE OPERATING ROOM OF THE FUTURE

TELEMEDICINE AND ADVANCED TECHNOLOGY RESEARCH CENTER (TATRC), FORT DETRICK, MARYLAND





The OR of the Future consortium has the potential to revolutionize surgery in the U.S. and is a groundbreaking collaboration for TATRC and many of its partners. Since the U.S. is a worldwide leader in medicine, the project may influence the surgical care of all U.S. citizens, as well as benefiting people and institutions throughout the world.

The OR of the Future will provide an Information Rich Environment

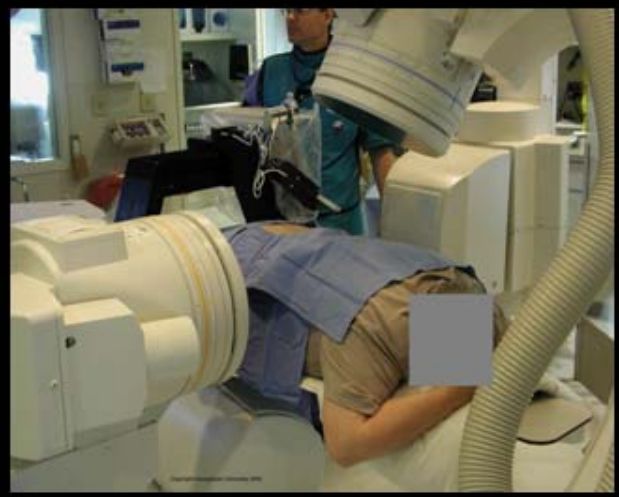
Enabling opportunities for integration, registration, and utilization of preoperative and real-time information sources.

Robotic Surgery and Telerobotic Surgery

Telementoring Laparoscopic video

Telepresent surgery robotic arm

Penelope III



Robotic Surgical Scrub Nurse

Michael Treat
Columbia University

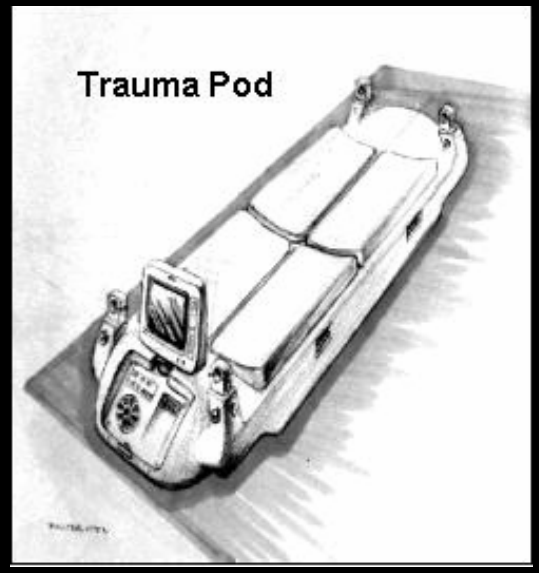
DaVinci Robotic Surgical System

Tim Broderick,
University of Cincinnati & (independently)
COL Noah Schenkman,
Walter Reed Army Med Center

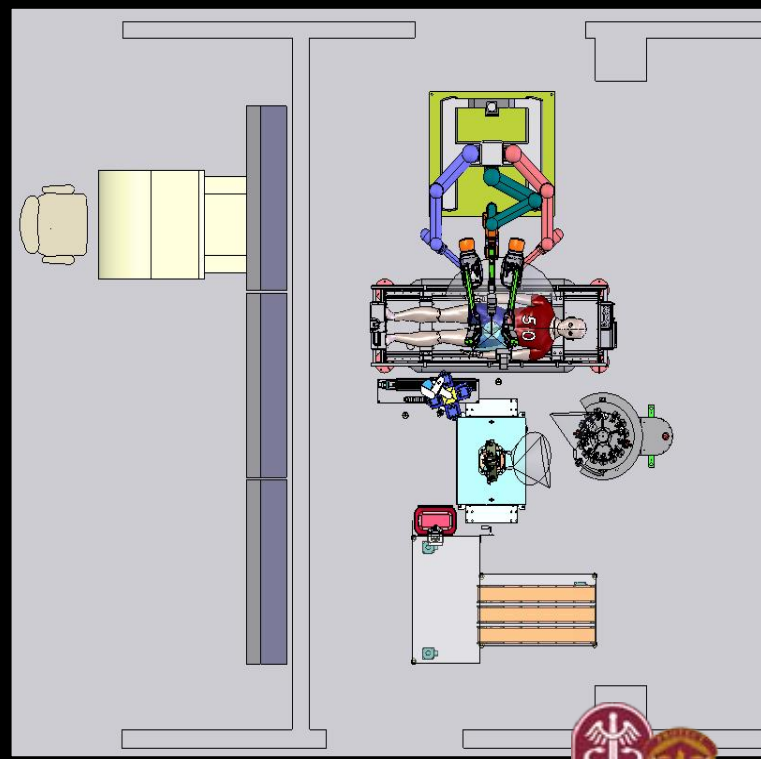
Robotic percutaneous needle insertions system

Kevin Cleary, Georgetown University

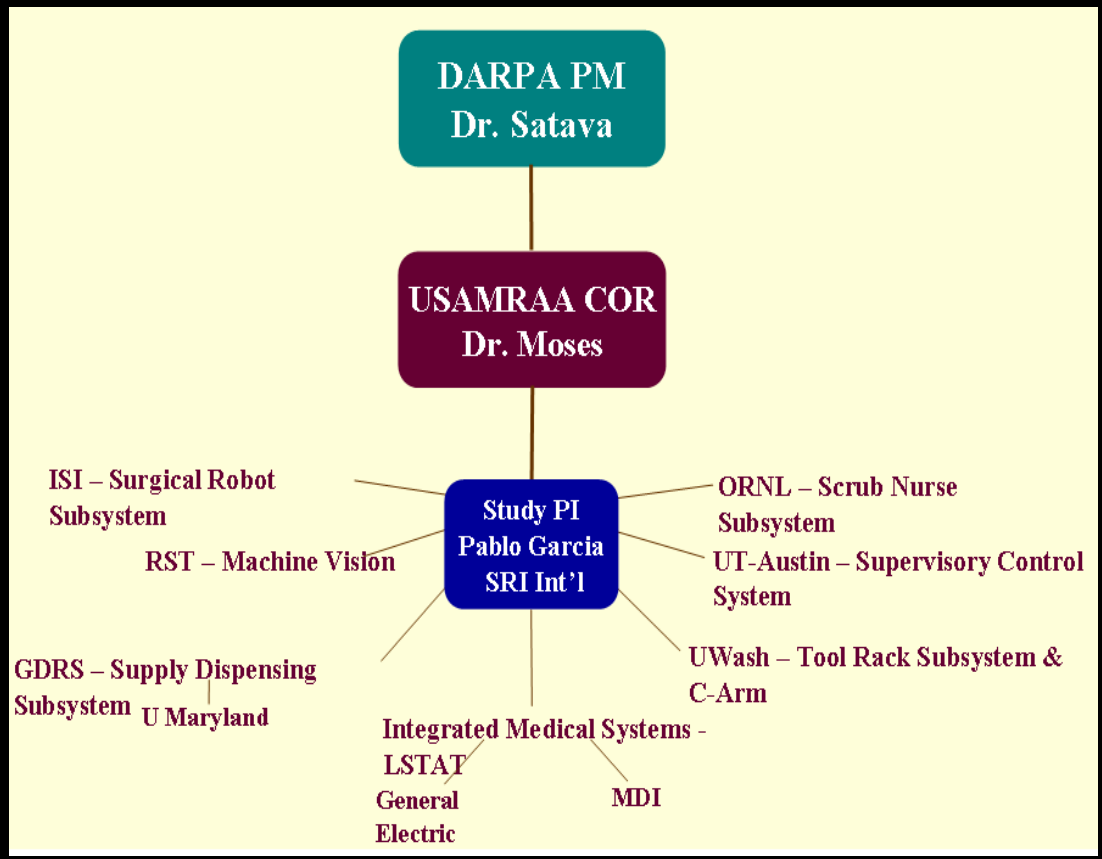
Phase I DARPA Trauma Pod



- The Trauma Pod team consists of a consortium of investigators of which there is a single Primary Investigator- SRI
- Goal: To demonstrate the feasibility of performing a surgical procedure without a human Surgeon, Circulating Nurse or Scrub Tech in the operating room
- A system of systems
  - Patient Registration System
  - Robotic Surgery System
  - Imaging System
  - Life Support for Trauma & Transport System (LSTAT)
- First year a proof of concept demonstration:
  - ✓ Tool Rack Subsystem
  - ✓ Scrub Nurse Subsystem
  - ✓ Supply Dispensing Subsystem



Trauma Pod Team



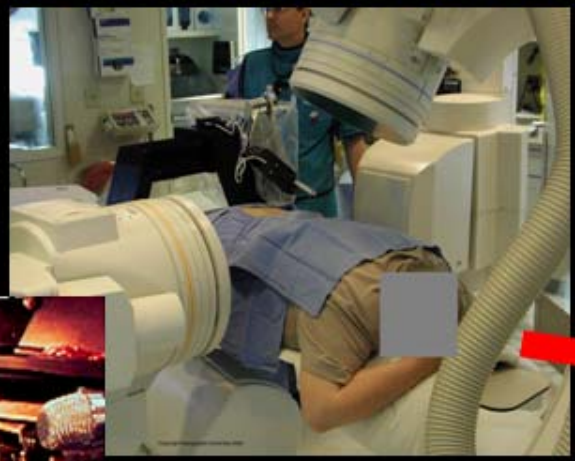
Robotic Component:

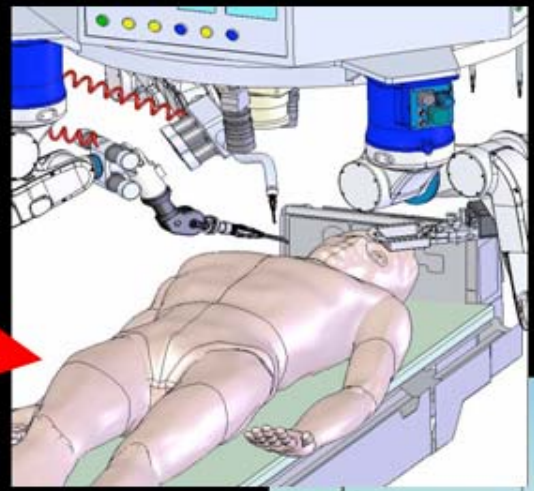
- ✓ SRI- integrator and communicator for the demonstration including software and all necessary coordination
- ✓ Intuitive Surgical- provides the robotic system and its maintenance
- ✓ ORNL- scrub nurse subsystem developer
- ✓ UTEXAS- supervisory control system is responsible for voice activation and collision avoidance
- ✓ UWASHINGTON - tool rack subsystem and possible use of C-Arm as an ancillary robotic system
- ✓ Robotic Surgical Tech - machine vision and surgeon lead for the medical review board
- ✓ General Dynamics with UMARYLAND - supply dispensing subsystem and inventory control software.

  -Coordinating an electronic record for the overall system

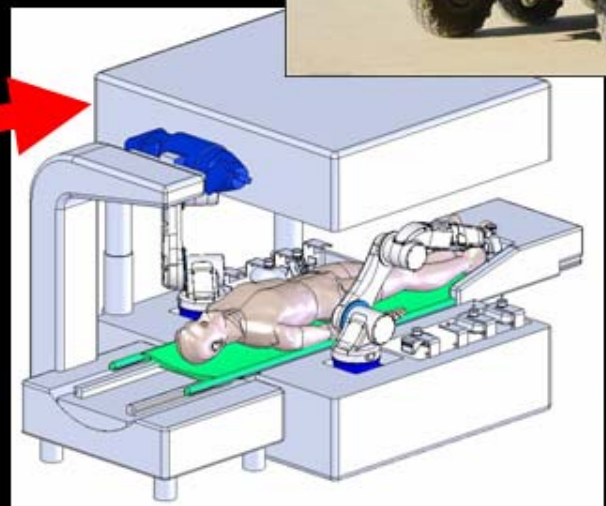
- **Life Support for Trauma and Transport (LSTAT) and Imaging Component:**
  - ✓Integrated Medical Systems - patient registration coordinator, LSTAT platform
  - ✓General Electric – designs the deployable imaging system
  - ✓Multi-Dimensional Imaging - designs a far-forward imaging system

DARPA & MRMC Leveraging Civilian Telerobotics research: Teleoperated Trauma Pod inside Combat Medical Vehicle





Phase II Trauma Pod Concept



DOD Joint Robotics Program
Army PM, Force Protection
Family of Integrated Rapid Response Equipment (FIRRE)

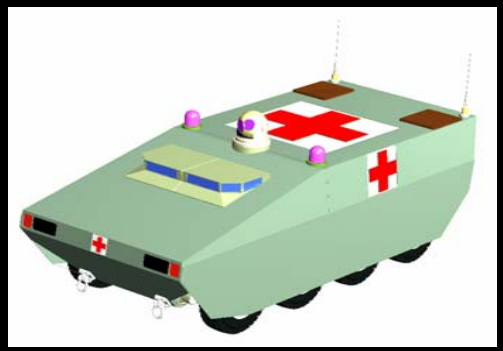
Tactical Amphibious Ground Support (TAGS)

Chartered missions include:

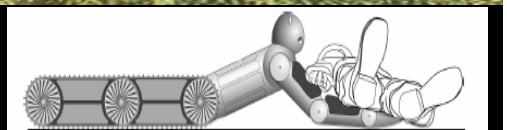
- **Persistent perimeter/installation surveillance for intruder detection, assessment, and response**
- **Explosive ordnance detection and disposal**
- **Tactical force protection operations**
- **Detection, removal and remediation of chemical, biological, nuclear, and radiological hazards**
- **Location, assessment, treatment, & evacuation of combat casualties.**

Proof of Concept *for Leveraging Army Future Combat System Unmanned Ground Vehicles for Medical Applications*

FCS Medical Evacuation & Treatment Vehicles (MTV)



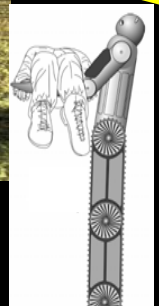
Tactical Amphibious Ground System (TAGS)



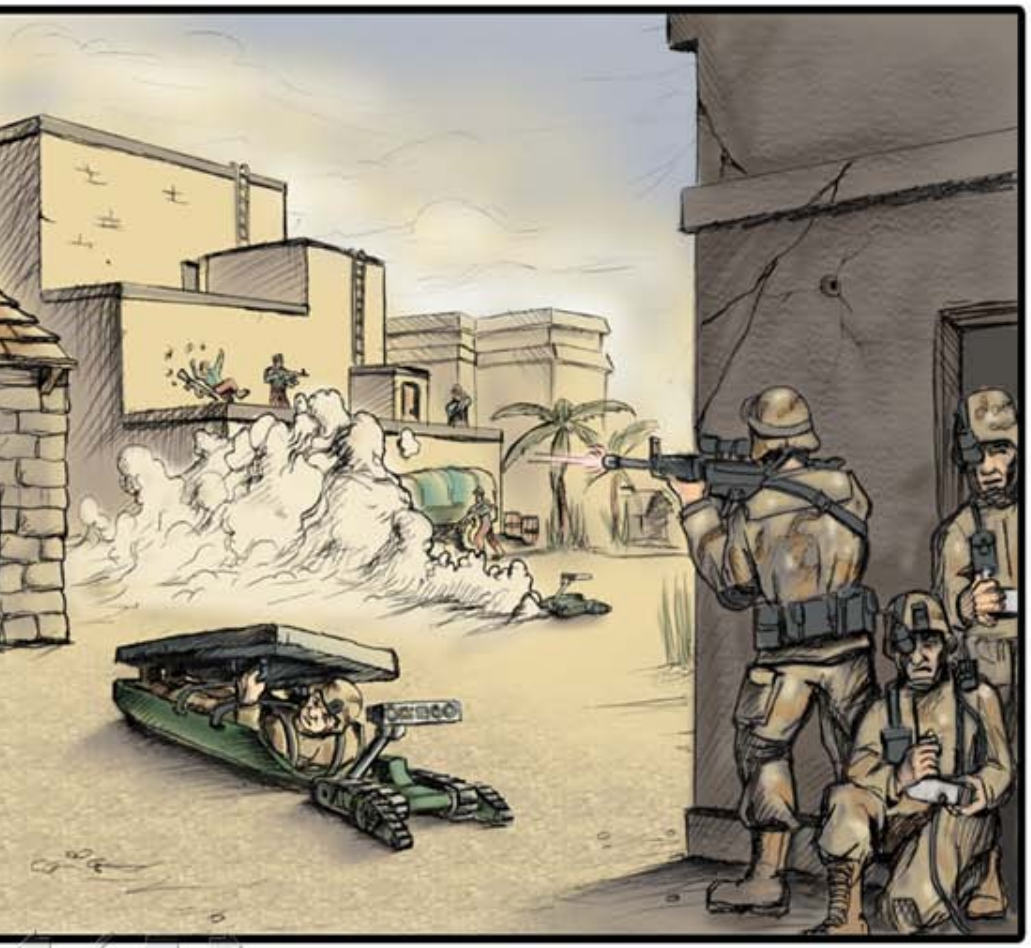
Armed Recon & Assault Vehicle (ARV)

Multifunction Utility Logistics Equipment (MULE)

Small Unmanned Ground Vehicle (UGV)



Casualty Extraction
Irobot Packbot "Valkyrie"
SBIRs *A02 – 179*



Irobot

Bloodhound & Valkyrie Packbots

Bloodhound navigation prototype with laser rangefinder

TATRC

Irobot

Bloodhound &
Valkyrie Packbots

Refocused Irobot Packbot research effort toward CBR detection, soldier monitoring, & casualty location functions.

Bloodhound navigation prototype with laser rangefinder

Life Support for Trauma and Transport (LSTAT)

Portable information technology enabled Intensive Care Unit (ICU)

- **Physiological Monitoring**
- **Telemedicine**
- **Autonomous intervention**

Integrated with Robotic Evacuation Vehicle

Ventilator with On-board Oxygen
Fluid/Drug Infusion
Suction
Defibrillator
Blood Chemistry Analysis
Patient Physiological Monitoring
Data Logging with Communications Connectivity
Sophisticated Power & System Data Management
Up to 2 hours of life support

170 lbs.

LSTAT Systems field tested in IRAQ

*** photos courtesy**
Fred Pierce, WRAI
Todd Kneale
Integrated Medical Systems

Robotic Combat Casualty Extraction & Evacuation (RCCE&E)

System of systems

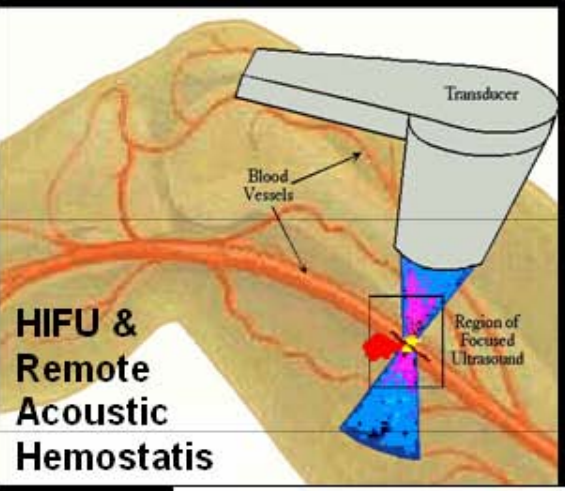
SBIR A02-179 – Phase II

Applied Perception, Inc.

US Army Medical Research & Materiel Command
US Army Tank Automotive Research, Development, & Engineering Center
DoD Joint Ground Robotics Enterprise

Robotic Combat Casualty Care Payloads

System of systems



Serpentine Robotic Manipulator Arm
Howie Choset, Carnegie Mellon University

Stand-off Vital Sign Acquisition Payload
Jean-Denis Hurtubise, Telemedic

Robotic HIFU Manipulator Arms
1) John J. Hu, PhD, Energid Corp.; Kullervo Hynynen, MD, Brigham and Woman's Hospital
2) Ralf Seip, PhD, Focus Surgery Corp; Jason Wheeler, MSEE, Sandia National Laboratory

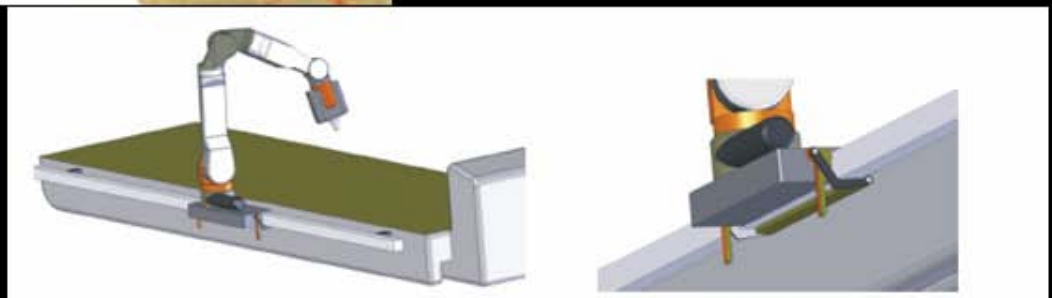
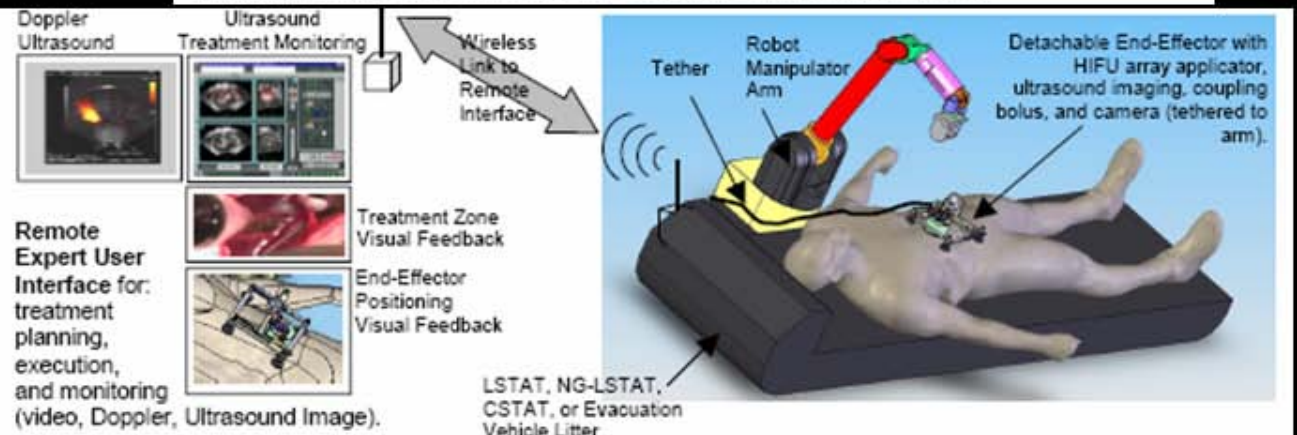
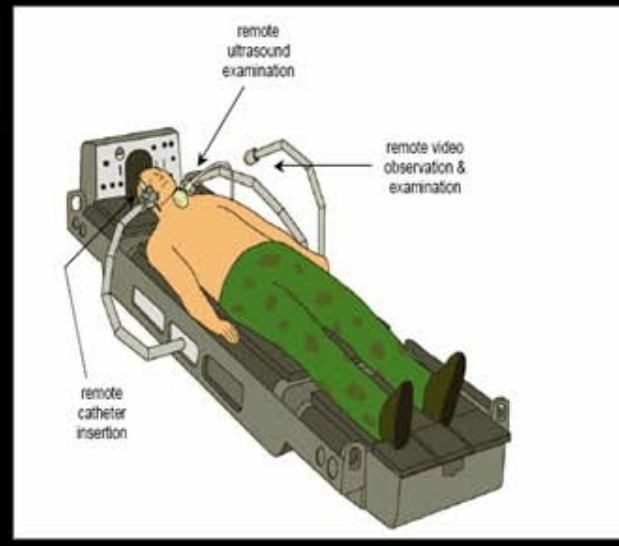
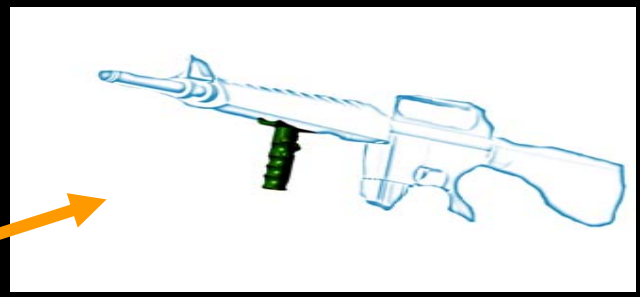
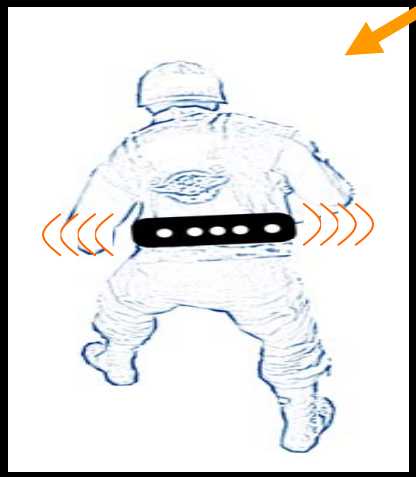


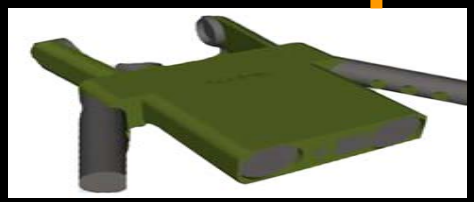
Figure 19: A clamping mechanism for slave robot integration with LSTAT. The left picture shows a HIFU robot arm mounted on an LSTAT. On the right is a close-up picture of the mounting mechanism.





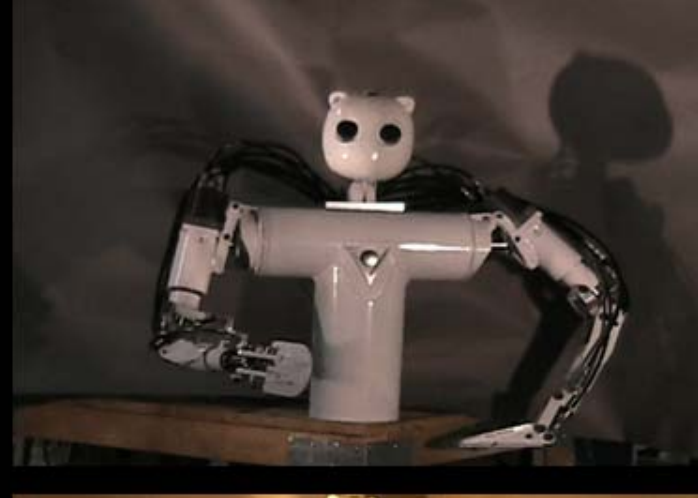






Human – Robot Interface Initiatives
Anthrotronix Inc.
ARL-TATRC Phase II Plus SBIR

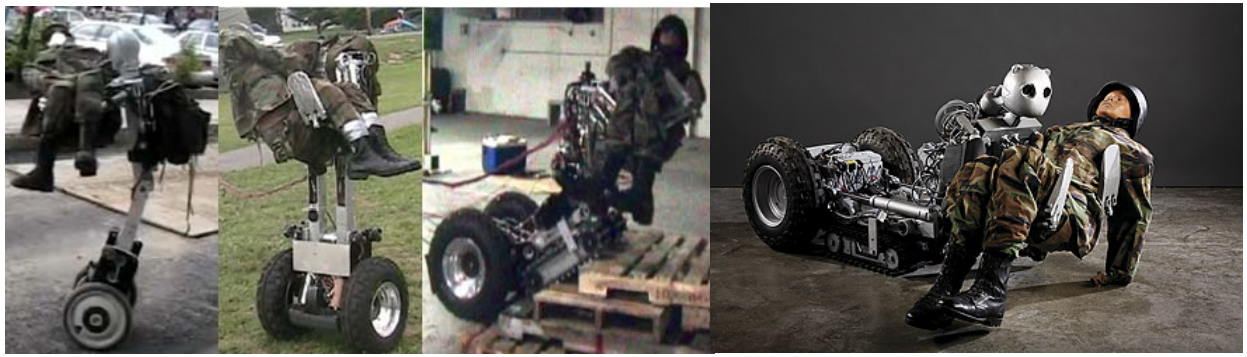
BEAR



Performance Profile

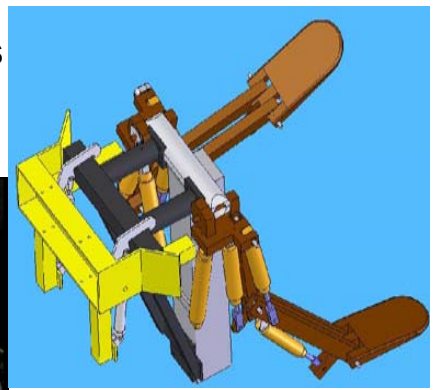
(Work Completed & Objective Configuration)

Battlefield Extraction - Assist Robot (BEAR)

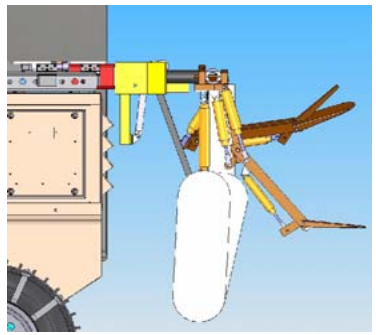


Lab Prototypes 1-3

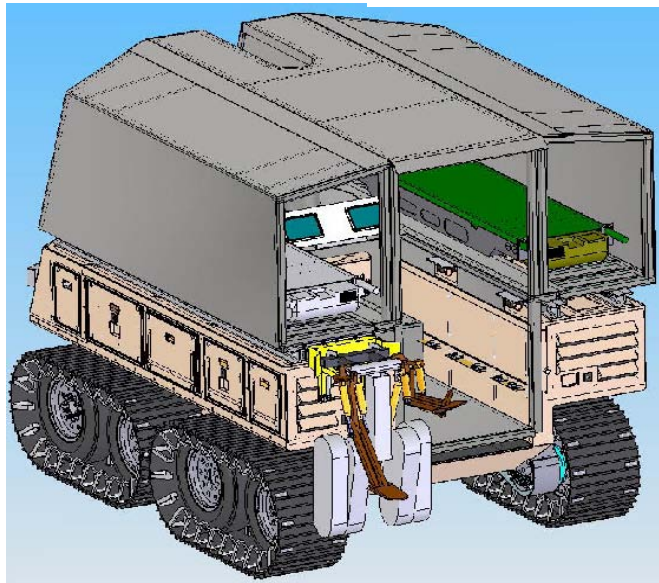
Operational Prototype Torso, Arms, Hydraulics & “Backpack” Interface Module for TAGS-CX



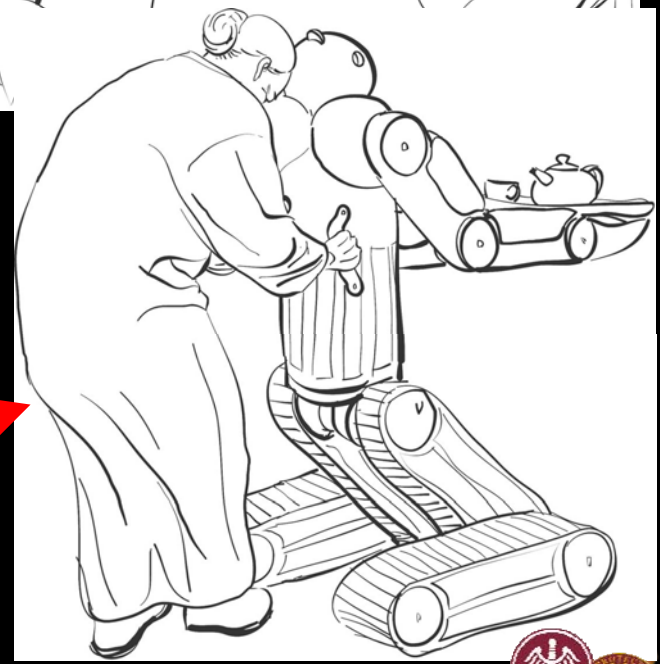
Operational Prototype Objective Configuration



Integration with TAGS-CX configured for CASEVAC

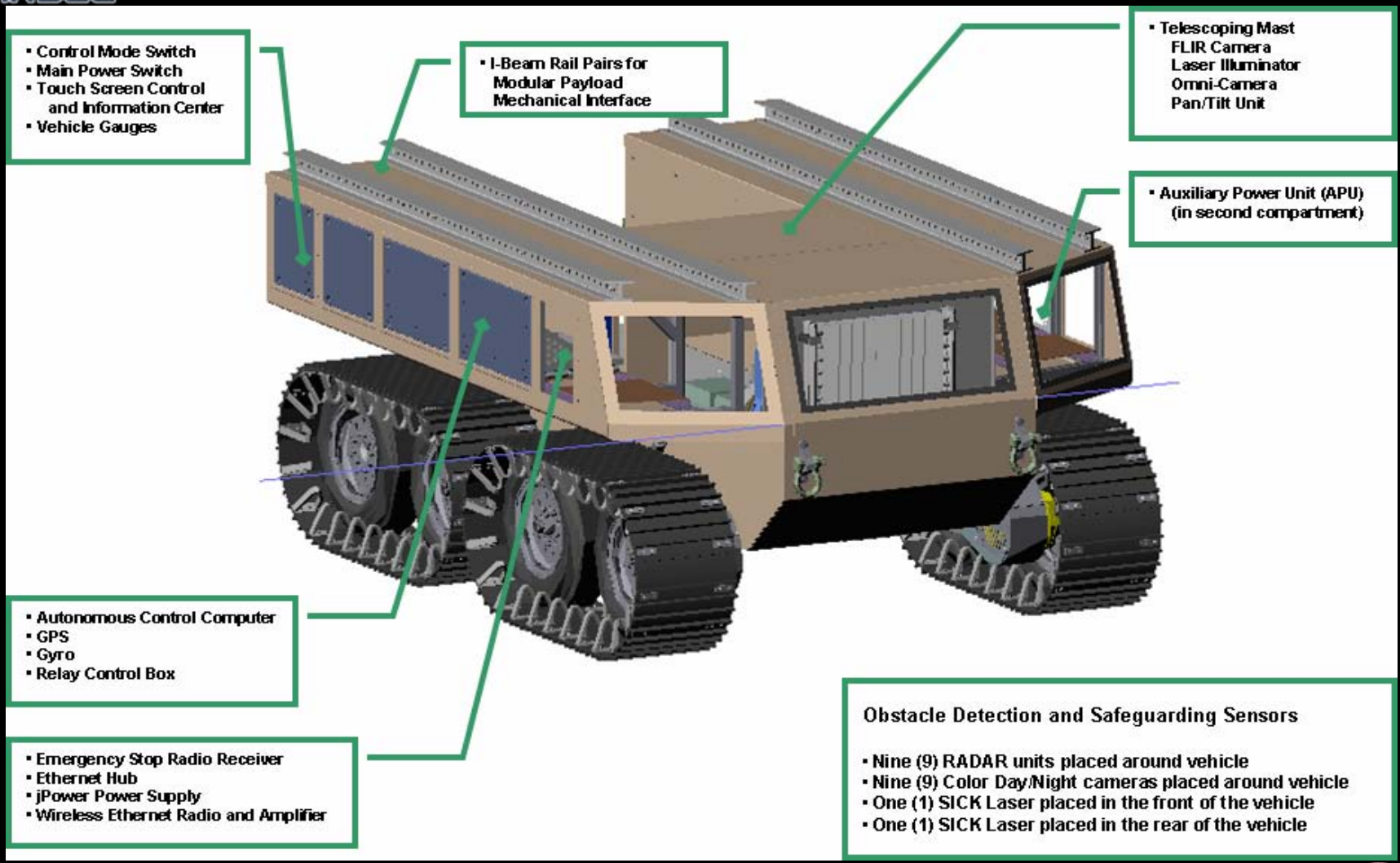


TATRC & Congressional Directed Research Partners: Leveraging Combat Casualty Care Robotics Research Home Health Care

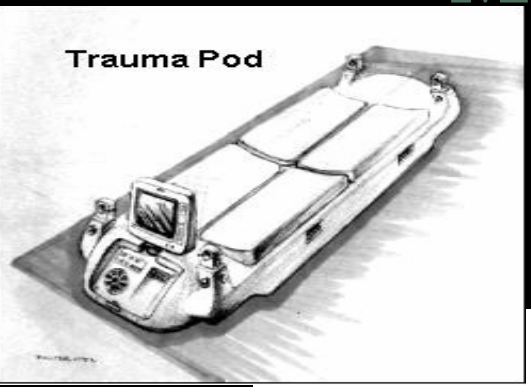


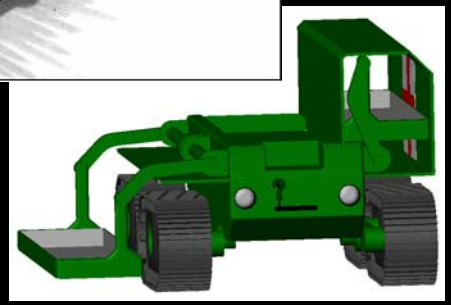
DARPA

TARDEC Tactical Amphibious Ground System – Common Experimental (TAGS-CX)

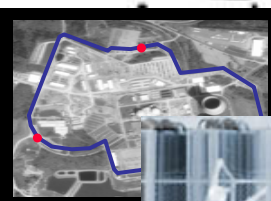


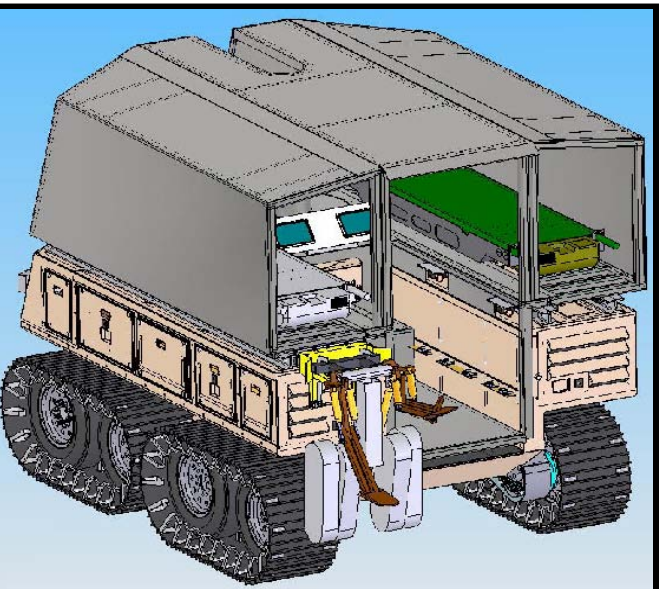
TARDEC Skunkworks
Multi-mission Reconfiguration



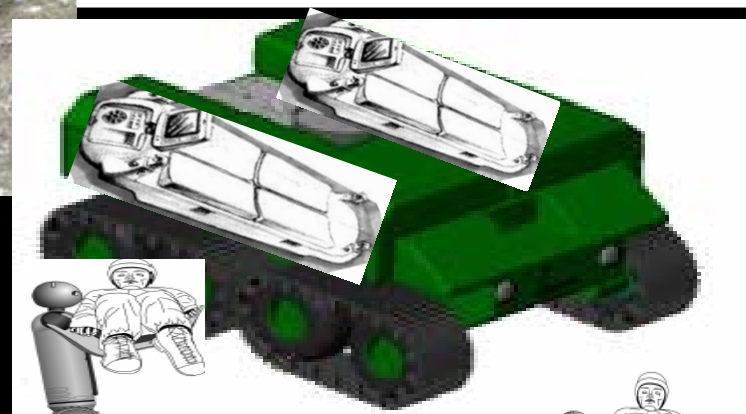


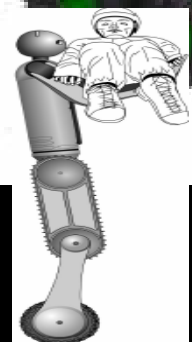
Joint Architecture for Unmanned Systems (JAUS) -compliant payloads allow for easy mission reconfiguration

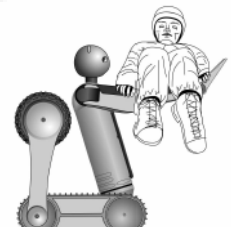




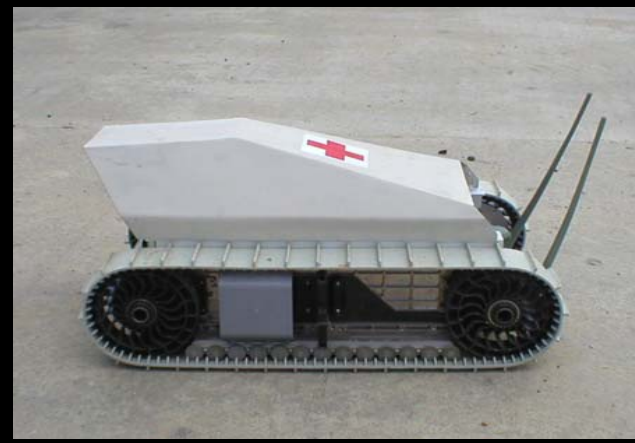
The same platform can be used for multiple missions





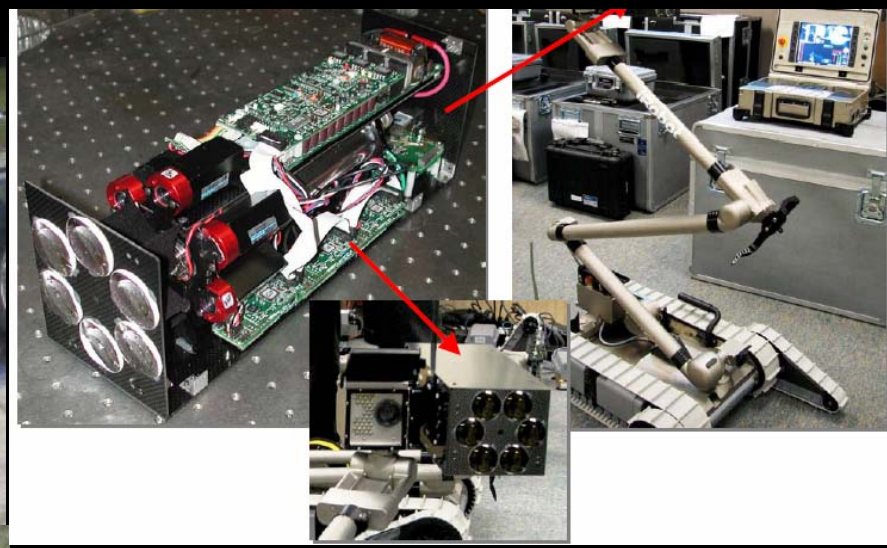


Robotic Detection & Diagnosis of Chemical &Biological Agents



CHARS

CHemical Weapons
Hazardous gases
Radiological Sensors



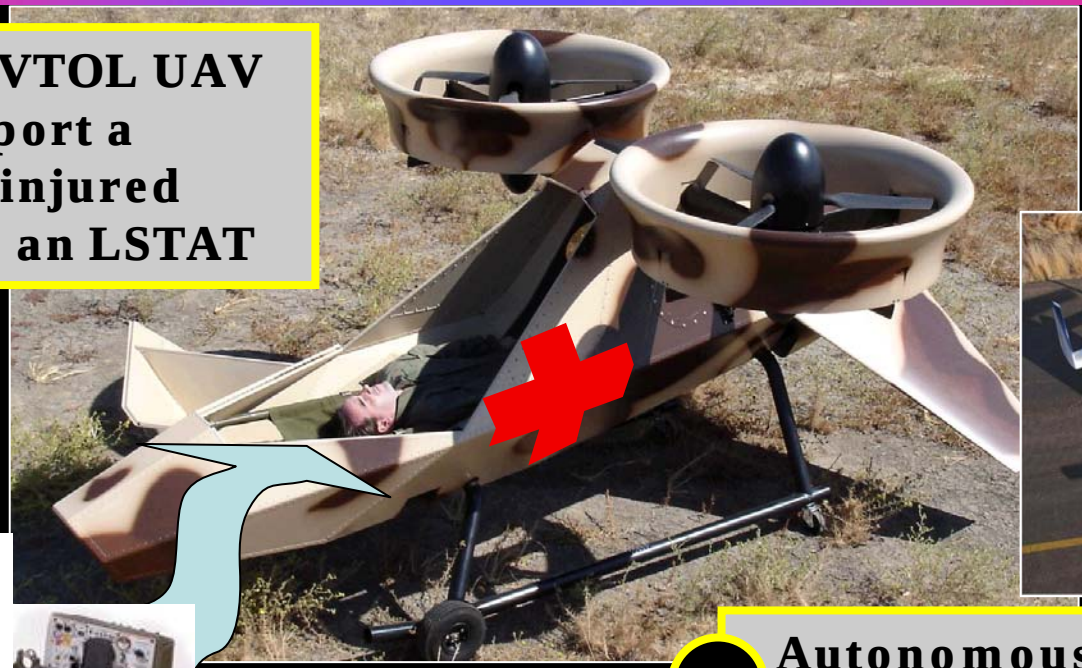
TATRC Phase II SBIR/STTRs

Raman & Laser-induced
Breakdown Spectroscopy (LIBS)
for chem/bio agents & explosives

UAV -Combat Medic Collaboration for Resupply & Evacuation

SBIR OSDO6-UM8

1 **Autonomous VTOL UAV to transport a wounded/injured individual on an LSTAT**



Several VTOL UAV options

Life Support for Trauma and Transport (LSTAT)

A former DARPA Project

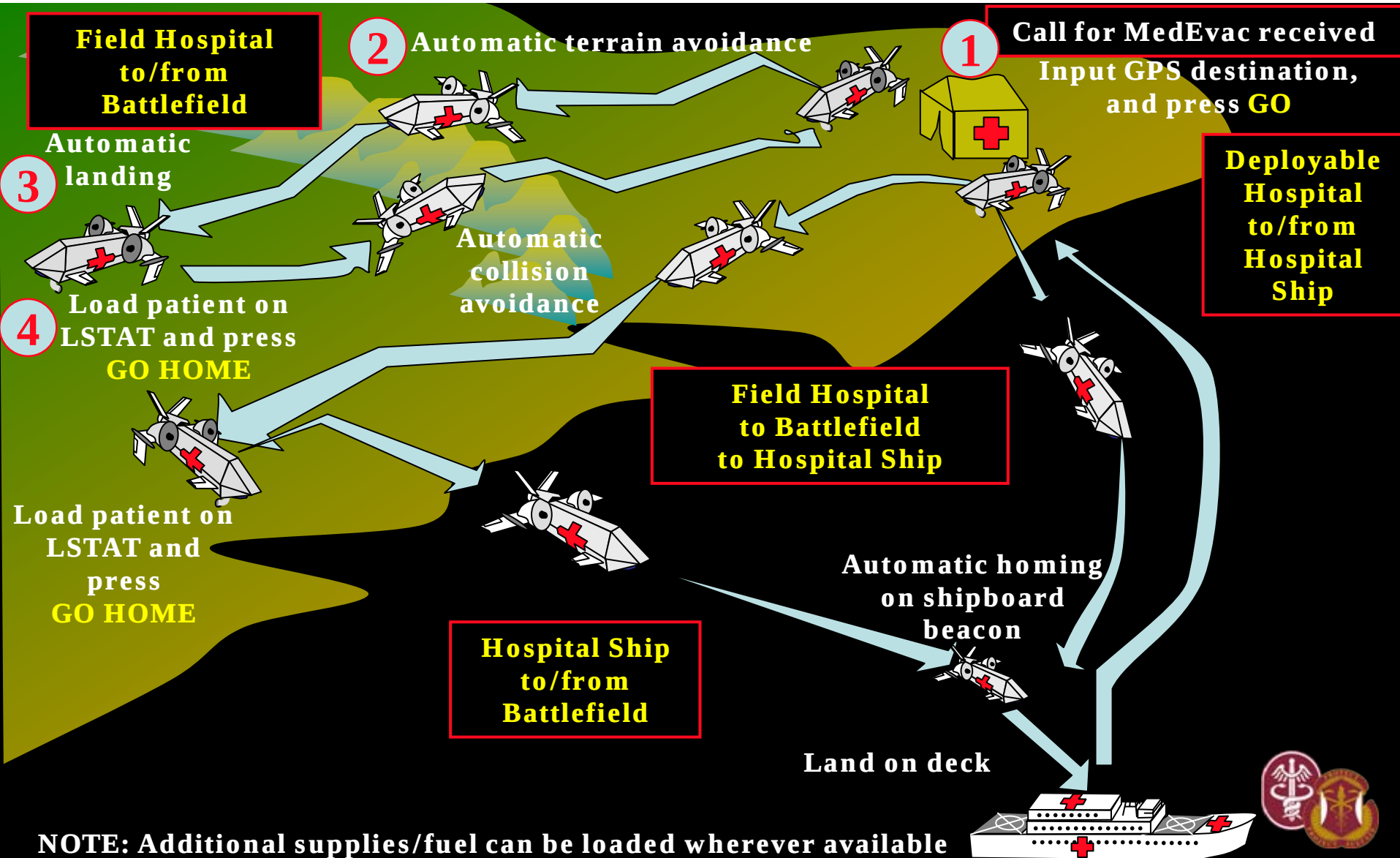
info

2 **Autonomous VTOL UAV to rescue an individual**

3 **Autonomous VTOL UAV for logistic support directly to the unit**

Concept of Operations – MedEvac (Navy/USMC)

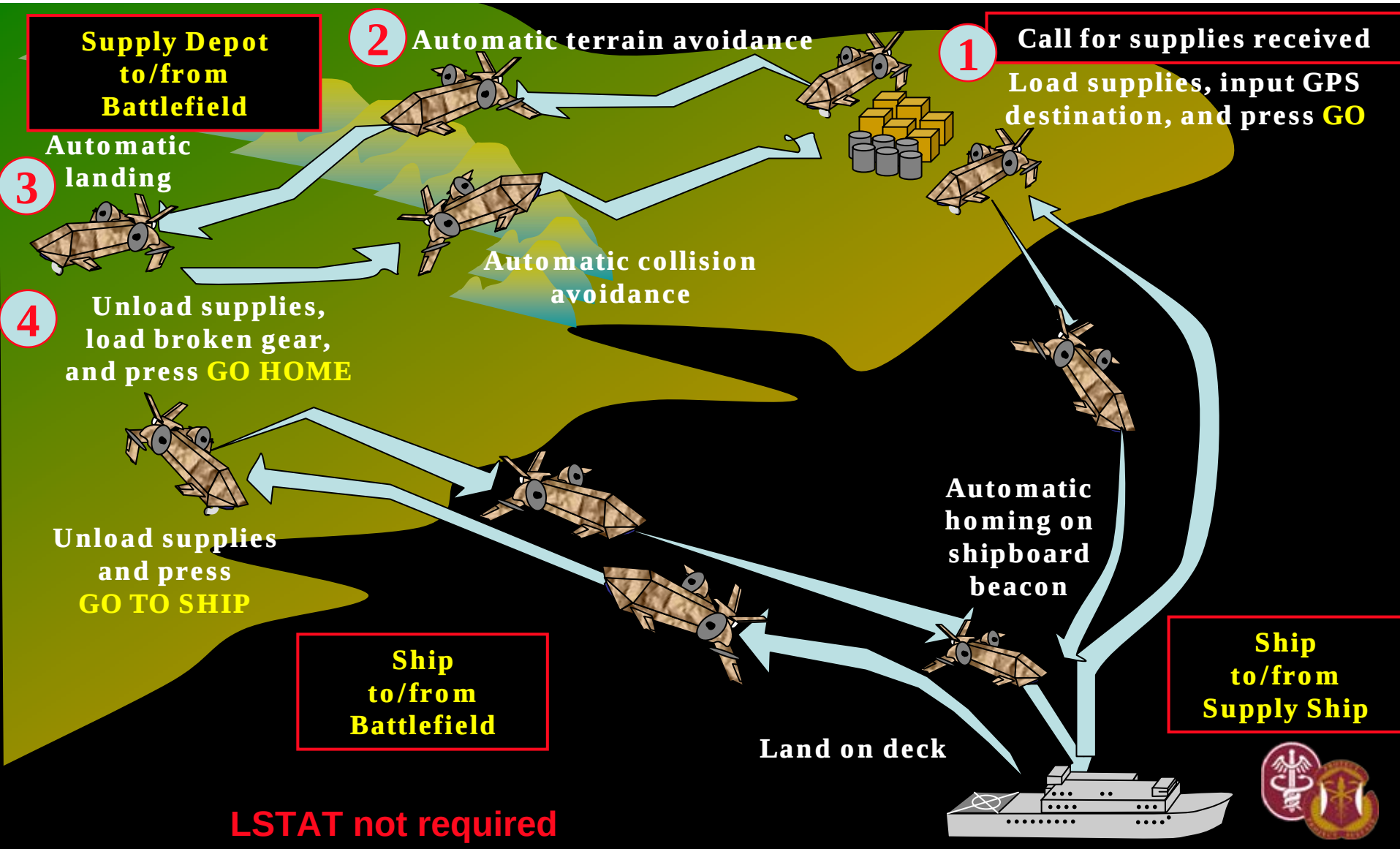
Autonomous transit from medical unit, to pick-up point, and back using GPS and beacon



NOTE: Additional supplies/fuel can be loaded wherever available

Concept of Operations - Logistics

Autonomous transit from supply depot, to destination, and back using GPS and/or beacon



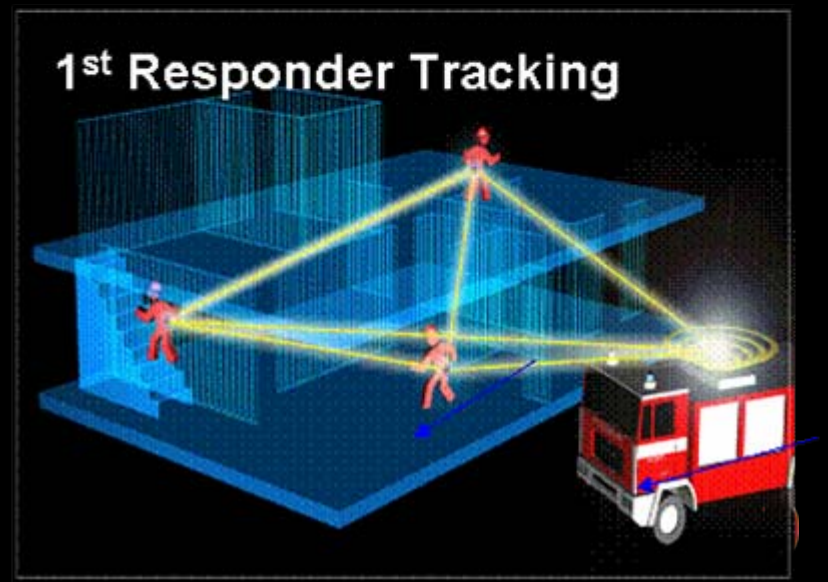
Army Research Lab Ultra Wide Band Mesh Network Communication Project

Innovative Wireless Technology Inc.

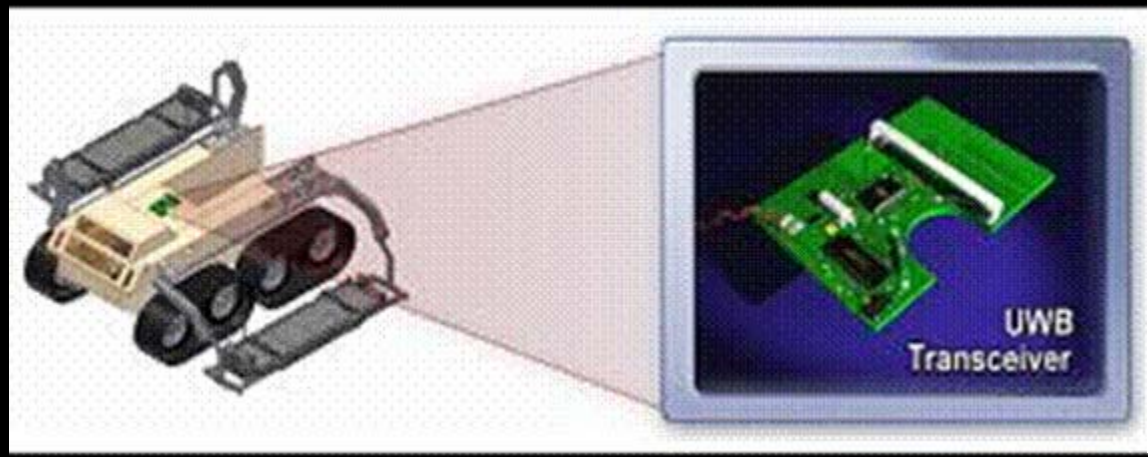
- **Objectives**
  - Develop innovative algorithms for geo-location using Ultra Wide Band (UWB) communications.
  - Define a suitable architecture for real-time implementation of the UWB geolocation system .

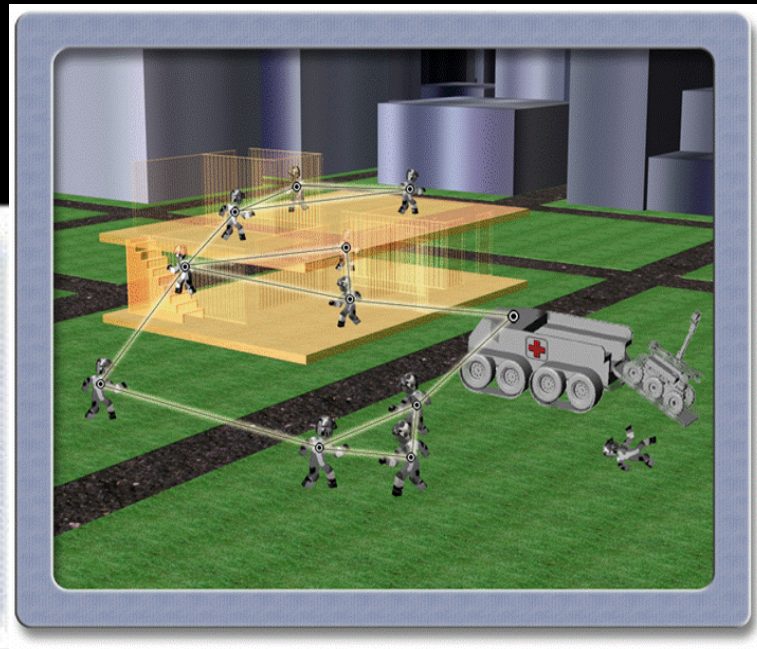
- **Multi-band**

  Orthogonal Frequency Division Multiplexing (OFDM) (UWB)
  - Investigate UWB Multi-band OFDM design approach
  - Transition to UWB Multi-band OFDM



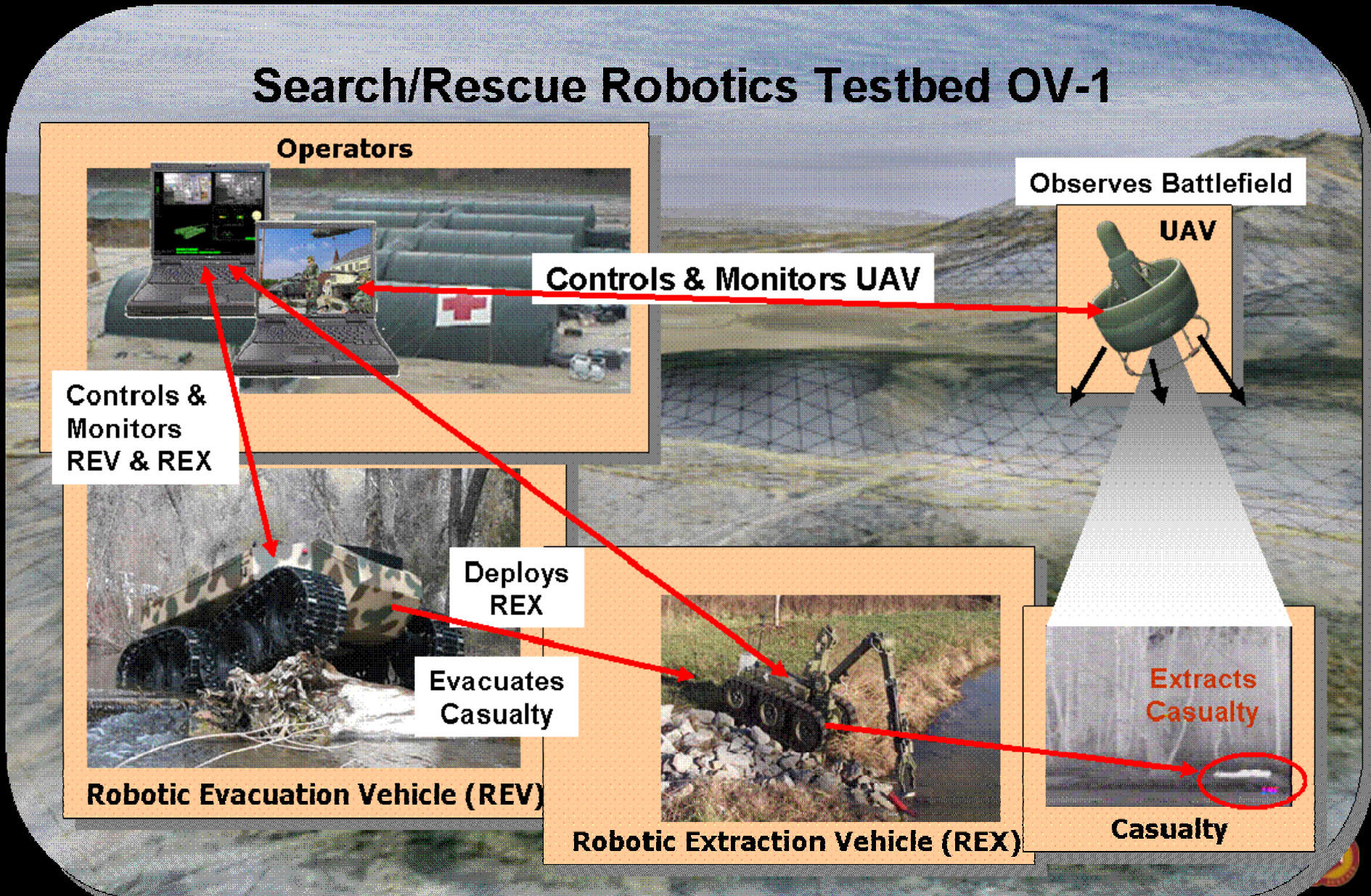
Adapting UWB technology to Command & Control of Forward Deployed Medical Assets & Robots



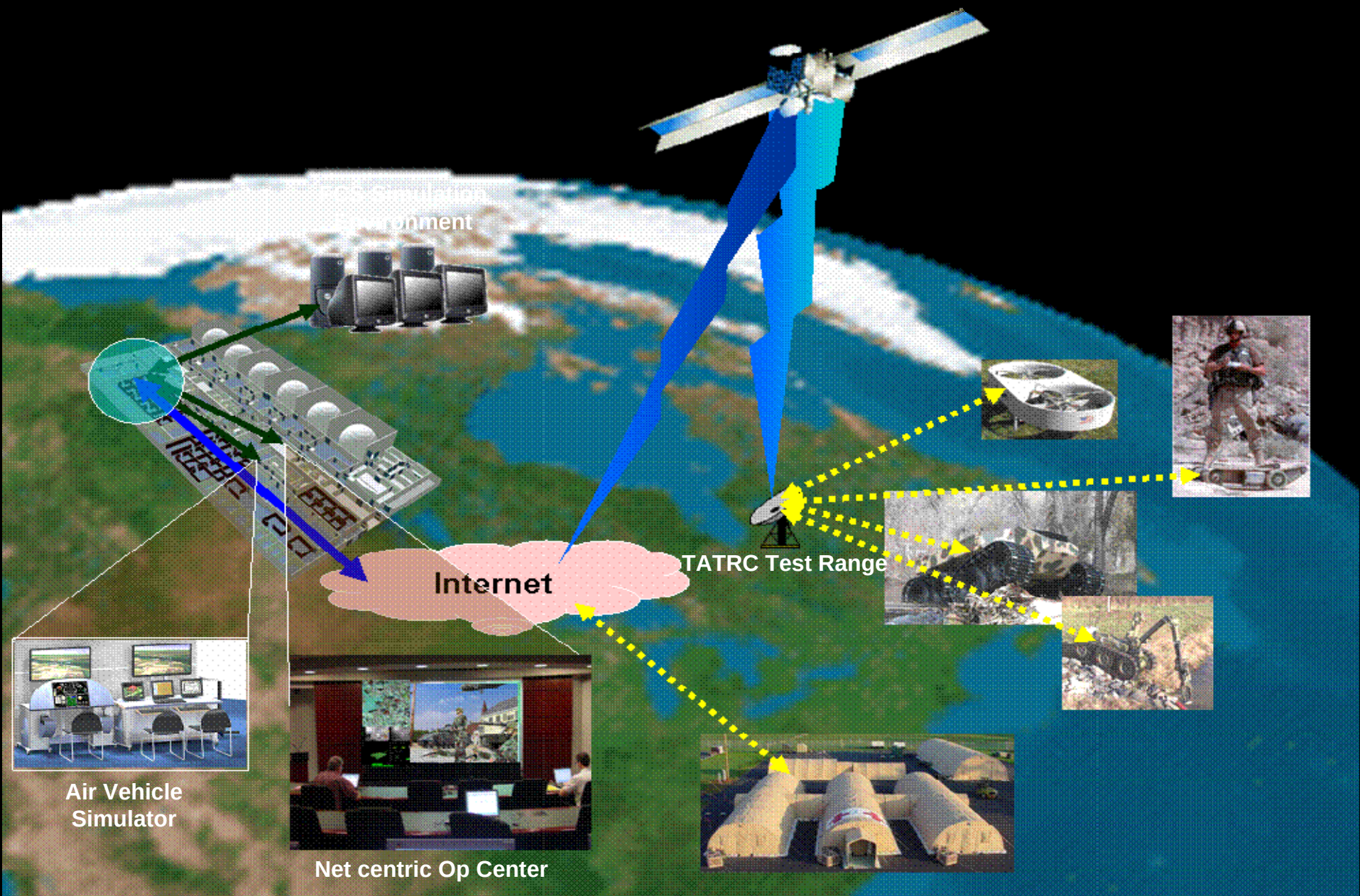


- Implement Secure UWB Communications Link with Forward Medical Treatment Facilities.
- Integrate UWB wireless communication node with prototype robotic combat casualty extraction & evacuation system
  - Marsupial robotic vehicle pair incorporating teleoperation, semi-autonomous and autonomous control capabilities
  - Supports ad-hoc, mesh networking with indoor and outdoor geo-location capability

Future Combat Systems Robotics
Modeling & Simulation Environment Boeing Inc.



Future Combat Systems Robotics
Modeling & Simulation Environment Boeing Inc.

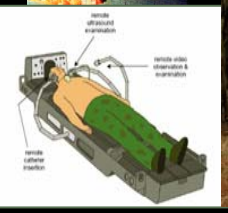


MRMC RDECOM

TATRC - TARDEC- RJPO - ARL

Develop Robotic Combat Casualty Payloads for Unmanned Ground Vehicles

(Army Marine Corps Ground Robotics Master Plan v2)



TATRC

TARDEC

TATRC - ECBC - TARDEC- RJPO - ARL

Force Health Protection Payloads for Unmanned Ground Vehicles

(Army Marine Corps Ground Robotics Master Plan v2)

CUGR

TATRC - ARL

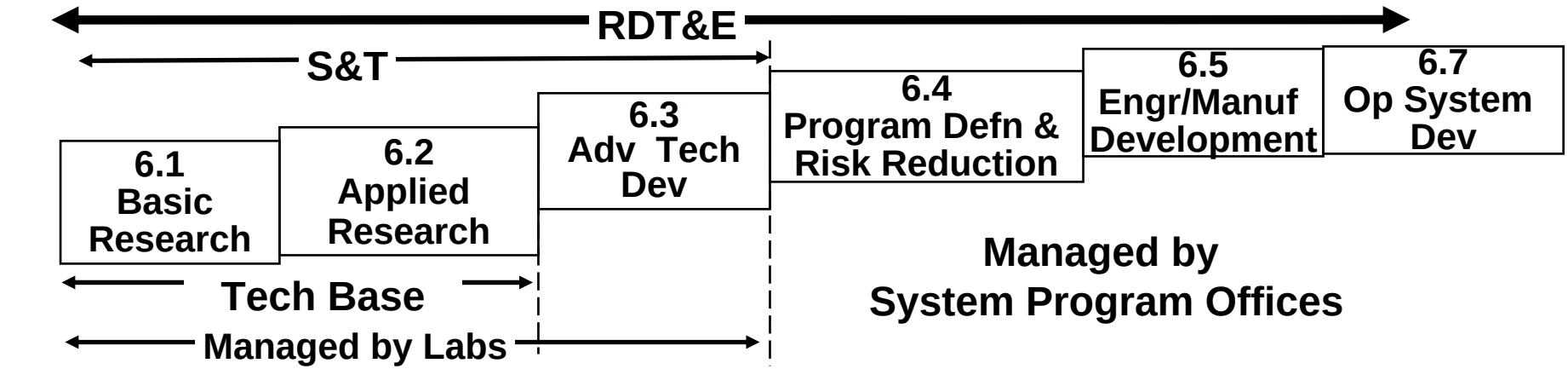
Ultra Wide Band (UWB) Mesh Communications

Orthogonal Fr equency Division Multiplexing (OFDM)

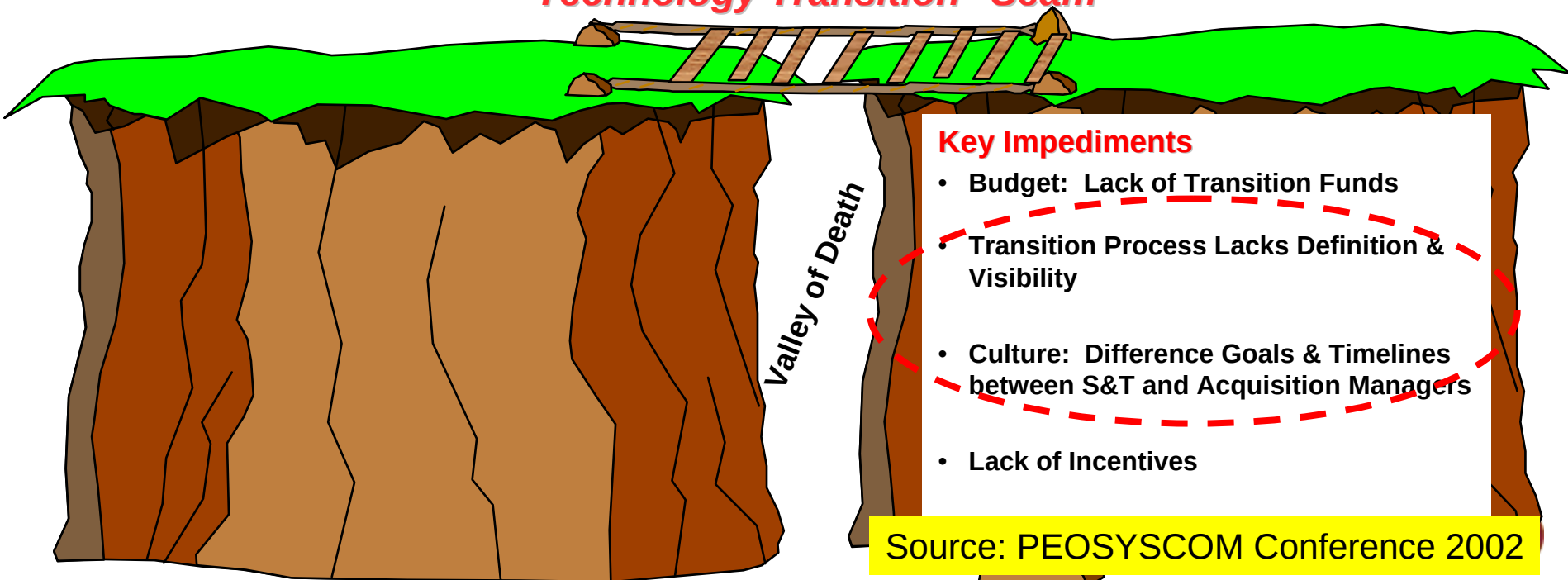
SBIR Phase II Plus

(Army Marine Corps Ground Robotics Master Plan v2)

Speeding Technology Transition "The Challenge"



Technology Transition "Seam"



Key Impediments

- **Budget: Lack of Transition Funds**
- **Transition Process Lacks Definition & Visibility**
- **Culture: Difference Goals & Timelines between S&T and Acquisition Managers**
- **Lack of Incentives**

Source: PEOSYSCOM Conference 2002

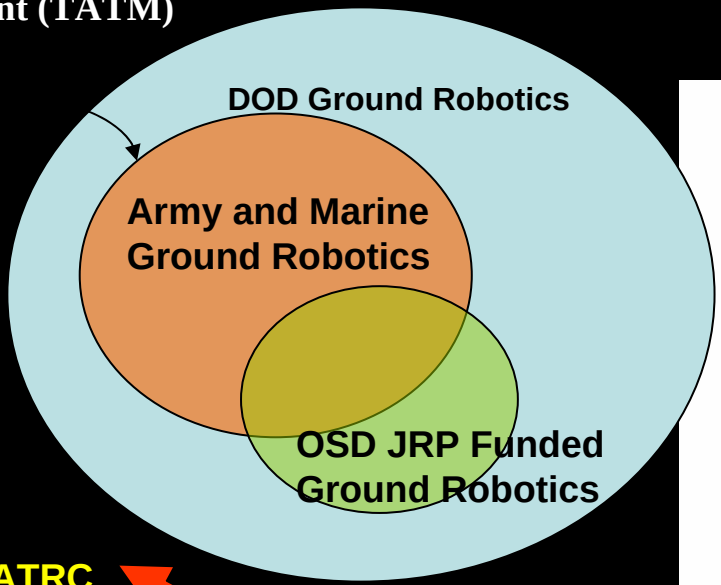
Army – Marine Corp Ground Robotic Master Plan

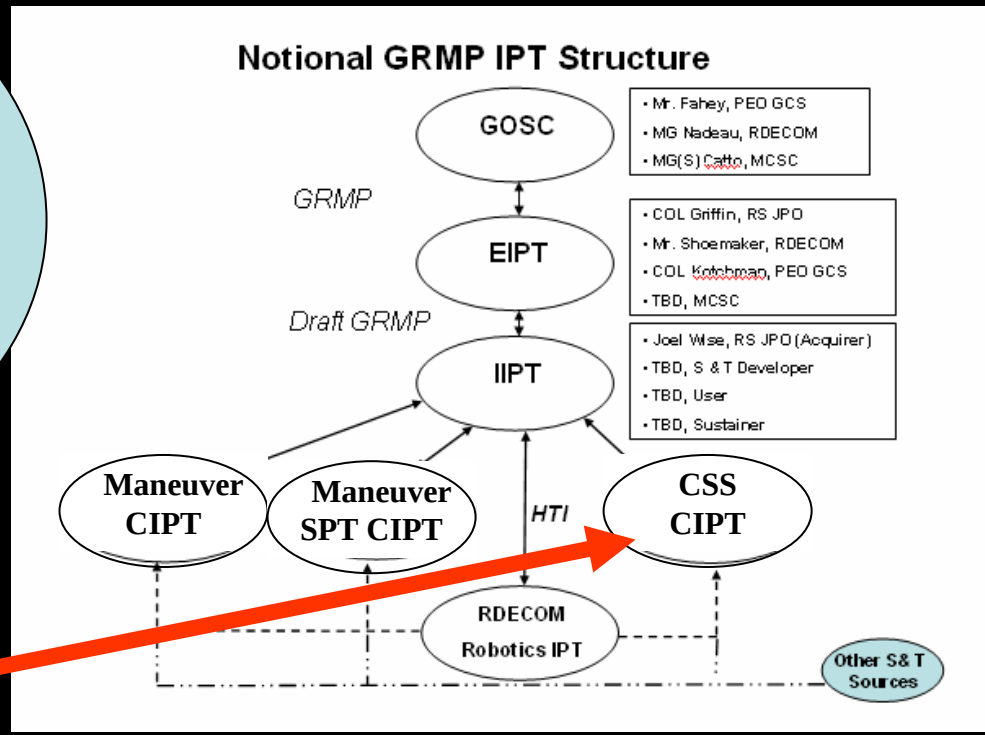
DOD Robotics Joint Program – Huntsville, USARDECOM, USMCSC

For Army and Marine Corps Ground Robotics Initiatives…..

- Develop an integrated ground robotics plan that presents logical ties and transition points between robotics development programs, acquisition programs and science and technology efforts
- A single location to find program description, requirements traceability, schedules, technology readiness levels, funding, deliverables, objectives and ties to other robotics programs or spirals to the field
- Uses Systems Engineering process management software tool: Technology Assessment and Transition Management (TATM)

- MCWL
- REF
- RS JPO
- PM FPS
- AMRDEC
- TARDEC
- ARDEC
- ARL
- OSD JRP
- CASCOM
- MRMC – TATRC
- DCDD AMEDD C&S





12 April 2006

CHARTER

COMBAT SERVICE SUPPORT COORDINATING INTEGRATED PROCESS TEAM (CIPT) FOR ARMY MARINE GROUND ROBOTIC MASTER PLAN TEAM

PURPOSE:

To manage the Technology Assessment and Transition Management (TATM) Process for Combat Service Support (CSS) applications of robotics technologies to be included in the Army /Marine Corps Ground Robotics Master Plan. This Coordinating Integrated Process Team (CIPT) will assess, FOCs/FNCs and capability gaps, ongoing or emerging Science and Technology projects and Acquisition /Contingency programs with potential for CSS ground robotic applications; consolidate, prioritize, and identify issues and impacts; and recommend technologies for transition to ground robotic acquisition systems.

TRADOC Army Capabilities Integration Center (ARCIC)
Sub-Capability Gaps which may be areas for potential robotic solutions

2. Protect the Force in Counterinsurgency Operations

Tactical Maneuver Sub Gaps

1) Stand off IED detection, neutralization, destruction and detonation
2) Ability to remotely clear dangerous areas with robots
3) Ability to clear MSR daily of mines /IED with vehicles / robots.
4) Ability to clear unexploded ordnance
5) Cache detection system

Fixed Site Security Sub Gaps

2) Physical Security. Portable barriers, vehicle inspection system.
3) Ability to detect and warn Soldiers of CBRN and toxic industrial agent/hazard releases

4. Logistics and Medical in COIN and non-contiguous battlespace

1) Enhance force health protection
2) Robust command, control, communications (C3) structure for convoy / ambulance operations along LOC.

CSS FOCS

- FOC-09-06 Global Casualty Care Management & Evacuation (TRADOC Pam 525-66)
- FOC-09-01 Sustainability (TRADOC Pam 525-66)
- FOC-09-02 Global Precision Delivery (TRADOC Pam 525-66)

US Navy Free Form Medical Deterrent System (FFMDS)

Maritime Forces of 2030 (MF2030)

- **MF2030 advanced battlefield transport will make use of unmanned autonomous Vehicles (UMAV):**
  - **to limit the number of humans put at risk.**
  - **for combat casualty care and evacuation.**
  - **for far-forward delivery of critical medical supplies and other exigent medical capabilities precisely when and where they are needed.**
  - **to facilitate medical communications with disadvantaged users, on remote and inaccessible battlefields.**
- **Advanced life support systems such as the Army's LSTAT will improve enroute care, while the wounded are transported to advanced care facilities for anabiosis and reconstitution.**
- **Telemedicine , including robotics-enhanced surgery, will serve as a force multiplier for injury assessment/consultation.**
- **Advanced technology will support 3-D holographic presentations of patients, including virtual imaging of internal injuries and structures through virtual computerized axial tomography,**
- **Diagnostic microdevices will be ingested or injected into the body, to inspect and report in vivo on the condition of the gastrointestinal tract and circulatory system.**
- **Injectable nanomachines will home precisely to internal sites of injury within the body, and effect micro-repairs at the cellular level.**

*Captain James R. Campbell, MSC, USN, CNO Strategic Studies Group, Newport, RI; Stephen Giebner, M.D., Naval Operational Medicine Institute, Pensacola, FL; Captain Timothy Thompson, MSC, USN, Navy Warfare Development Command, Newport, RI; and Eric Eisenstadt, PhD, Defense Advanced Research Projects Agency, Alexandria, VA.

TRADOC Pam 525-66 Future Operating Capabilities (FOC) supporting AMEDD Robotics

- **FOC-09-06: Global Casualty Care Management and Evacuation.**
  - **Utilize unmanned vehicles, robotics, and advanced standoff equipment**
    - **Recover wounded Soldiers from high-risk areas, with minimal exposure.**
    - **Facilitate immediate evacuation and transport, under the harshest combat or environmental hazard conditions.**
    - **Medical evacuation platforms must provide "enroute care"**
    - ***Note: all Evacuation platforms must be attended when transporting casualties per AMEDDC&S***
  - **Automated and semi-automated servo-controlled sensor/actuator systems for life support.**
  - **Advanced storage systems and transportation devices to ensure temperature integrity and in-transit visibility.**

AMEDD Initial Capabilities Documents (ICD) supporting Robotics

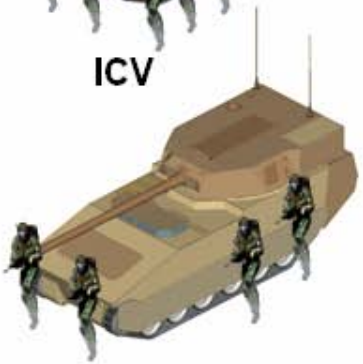
- **Theater Combat Casualty Care ICD**
  - **Addresses FOC-09-06: Global Casualty Care Management and Evacuation**
- **Short Description:**
  - **Future Soldiers will utilize unmanned vehicles, robotics, and advanced standoff equipment to recover wounded and injured Soldiers from high-risk areas, with minimal exposure.**
  - **These systems will facilitate immediate evacuation and transport, under even the harshest combat or environmental hazard conditions.**

Standard MEDEVAC and Nonstandard CASEVAC with accompanying First Responder level care

Manned Systems

ICV

C2V



Mounted Combat System

Reconnaissance and Surveillance

NLOS Cannon

Battlefield Extraction-Assist Robot

Unmanned Air Platforms

UAV III

UAV II
UAV I

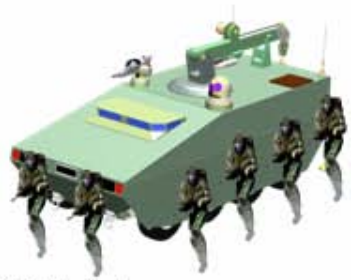
UAV IV A/B

Unmanned Ground Vehicles

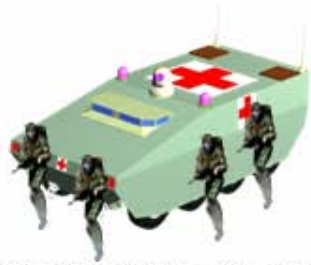
Armed Robotic Vehicle

Small UGV

Mule
(Attended when used for CASEVAC)



FCS Maintenance and Recovery Vehicle



Medical Treatment/ Evacuation

United States Army Logistics Innovation Agency

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Logistics Management Specialist
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Robotics White Paper

Version 1.2

Prepared by:

Robotics Project Team

U.S. Army Logistics Innovation Agency

4-August-06

Robotics Assessment

- Six key technology drivers identified with expected technology developments over 5,10,20 years
  - Power, Mobility, Sensors, Software, Computer\CPU, Communications
- Potential Logistics Applications Identified over 5,10,20 years
- Developed logistics support implications, observations and recommendations

Gladiator Tactical Unmanned Ground Vehicle

MDARS Semi-Autonomous Physical Security Vehicle (Milestone C planned for Dec 06)

Planned FCS Logistics Applications

- **Only one unmanned logistics platform is planned as part of the Future Combat System (FCS), the MULE-T**
  - The FCS MULE-T vehicle will carry approximately one ton of equipment for dismounted infantry squads and will be capable of traversing difficult terrain
  - While not unmanned, the FCS recovery and maintenance vehicle and the medical treatment and evacuation vehicle will employ many of the same basic technologies and could be adapted to more autonomous operation
- **Robotic leader/follower technology research is focused on the maturation & demonstration of robotics technology required for early insertion into FCS and could be used to minimize dangerous truck supply/operations**

Congress set a goal through the National Defense Authorization Act (FY 2001, H.R.4205, Sec. 217) for the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that by 2010, one-third of the operational deep strike aircraft of the Armed Forces are unmanned; and by 2015, one-third of the operational ground combat vehicles of the Armed Forces are unmanned.

DARPA
Robotic Follower

TARDEC
Leader Follower

MULE

Potential Logistics Applications – Near to mid Term

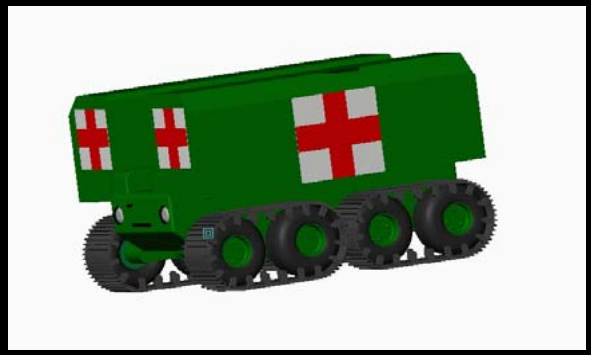
- Leader/follower movement of assets within ports, staging areas and to forward deployed troops
- Unmanned precision airdrop
- Automated ship loading and offloading using robotic MHE and exoskeleton-assisted systems to multiply human lift capacity
- Automated pallet assembly with improved global inventory tracking and control
- Telemedicine and Telesupport capabilities for difficult maintenance problems
- Sensor-based prognostics and diagnostics to schedule parts delivery and weapons system maintenance

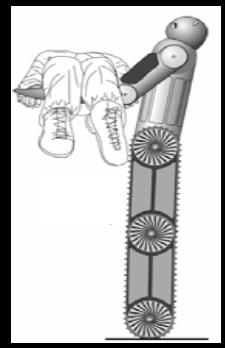
Robotics Logistics Implications, Observations and Recommendations

- Need to refine and institutionalize rapid equipment fielding capabilities with integrated logistics support capabilities/structures/plans/training
- Additional standards and architecture work is required to help ensure future interoperability and interchangeability
- Remote operation of robots may stress secure communications capabilities in the near term
- Autonomous operation will require new software, creative solutions, new rules of engagement, and process changes
- Potential Robotics policy implications:
  - Maintenance actions could invalidate the platform security accreditation and present some unique operations security challenges
  - Policy in terms of interchangeability of service assets, and accountability may need to be updated to address unmanned systems
  - DOD Wireless Communications policy will require future update to ensure compatibility with Swarm MANET, Software Defined Radio, and other advanced wireless Comms

U.S. Army Medical Research and Materiel Command
Telemedicine & Advanced Technology Research Center
Cutting Edge Medical Technology

Robotic Combat Casualty Care Extraction & Evacuation S&T Programs





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