Overview and Highlights of Robotics Research and Development at the Space and Naval Warfare Systems Center, San Diego

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OUTLINE

- **ROLE & OVERVIEW**

- **FOCUS AREAS**
  - **Command and Control**
  - **Communications**
  - **C4I Interoperability**
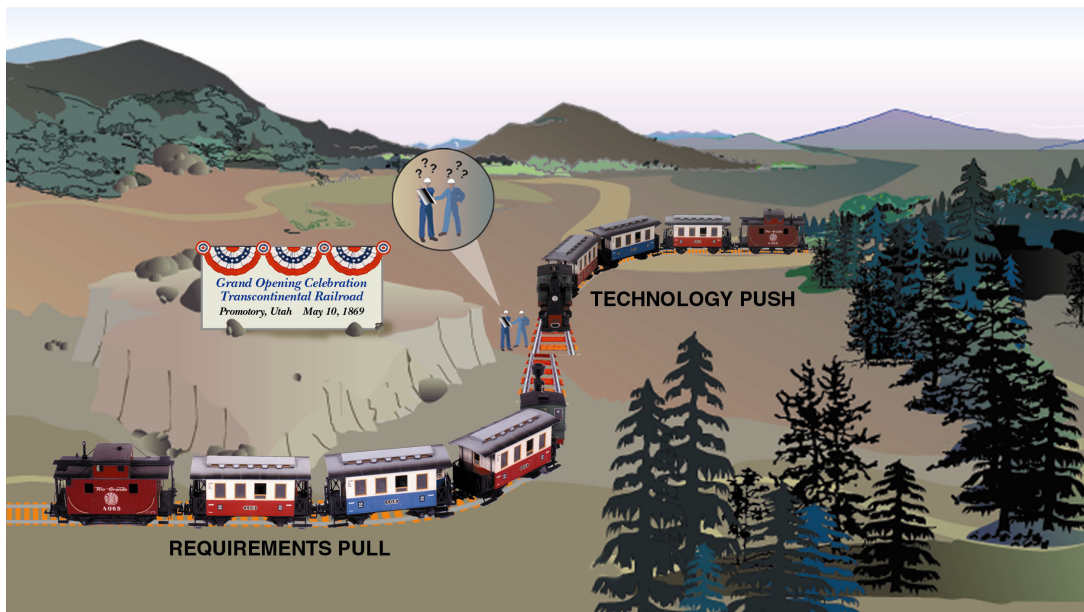 - **Integrated ISR**

- **CURRENT PROJECTS**

SPAWAR Systems Center San Diego
Robotics Test Range
2 miles of Coastline for Unmanned Systems RDT&E

N

Serving as the
"Impedance-Matching Transformer"
Between the Robotics User and Technical Communities

SPAWAR
Systems Center
San Diego

Grand Opening Celebration
Transcontinental Railroad
Promotory, Utah   May 10, 1869

TECHNOLOGY PUSH

REQUIREMENTS PULL

- Provide **network-integrated robotic and distributed sensing solutions.**

- Accomplished through research, development, integration, and **partnering** with industry, academia, and other government agencies.


Unmanned Systems Branch Experience

SPAWAR
Systems Center
San Diego

- **35 scientists and engineers**
- **15 in-house contractors**
- **4 military reservists (Unmanned Systems Reserve Unit)**
- **4 student interns**
- **20 years in unmanned ground vehicles**
- **17 active robotics research and development projects**
- **Infrastructure for UGV, UAV, USV, UUV RDT&E**
- ***Center of Excellence for Small Robots* as designated by OSD JRP**
- **Technical and programmatic support to:**
  - **OSD JRP, UGV/S JPO, PM-FPS, FCS, MANSCEN, CECOM NVESD, ARL, DARPA, DTRA, ONR, NSWG, SOCOM, JPL, others**
  - **Operation Enduring Freedom, Operation Iraqi Freedom, World Trade Center**

Unmanned Systems Collaboration

Organization	Project/Focus
JRP/AFRL/AMRDEC/NIST	Joint Architecture for Unmanned Systems (JAUS)
Army DBBL	Army user test and evaluation
JPL	Stereo vision, obstacle avoidance
INL	Collision avoidance/target tracking/intelligence kernel
BBN	Self-healing ad hoc networks
SWRI	Robotics test and evaluation
SRI	Simultaneous Localization and Mapping (SLAM)
USC	Robotics simulation and device drivers, precision landing
UCSD	Advanced machine vision
NUWC	SPARTAN (ACTD)
Army MANSCEN	Countermine
ARL/UT Austin	Human Presence Detection and Assessment
NSWC Panama City	Joint Unmanned Systems Common Control (JUSC2)
AFRL	Remote Detection Challenge and Response (REDCAR)
Carnegie Mellon Univ.	Beacon-based landmark referencing, countermine
JRP/NUSE2	National Unmanned Systems Experimentation Environment
Singapore Navy	SPARTAN ACTD
NPS	Surveillance and Target Acquisition Network experiment
AFRL/AMRDEC	UGV/UAV Collaborative Engagement Experiment
NG Remotec	Family of Integrated Rapid Response Equipment

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Unmanned Systems Development Approach

The most important criterion for a successful acquisition program is producing a value-added end product that the user needs, will use and appreciate.
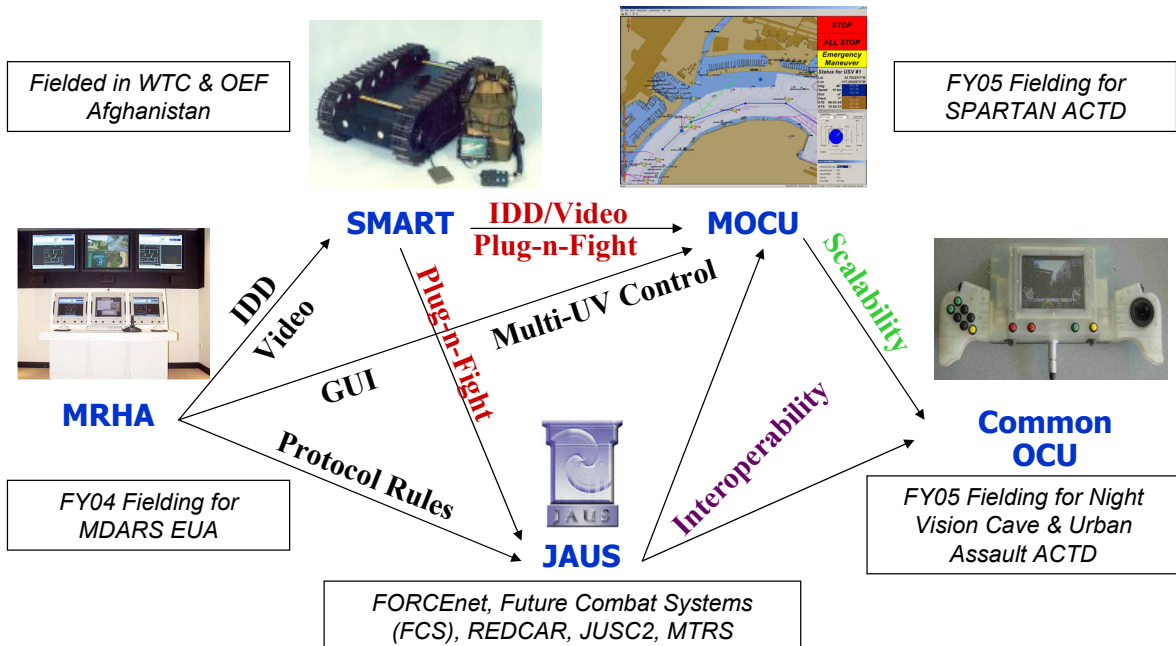
- Close loop with users throughout the design and development process.
- Implement phased rapid-prototyping approach.
- Provide users extensive hands-on evaluation of prototypes.
- Leverage existing experience, systems, technology.
- Modular design, upgradable with new technology.
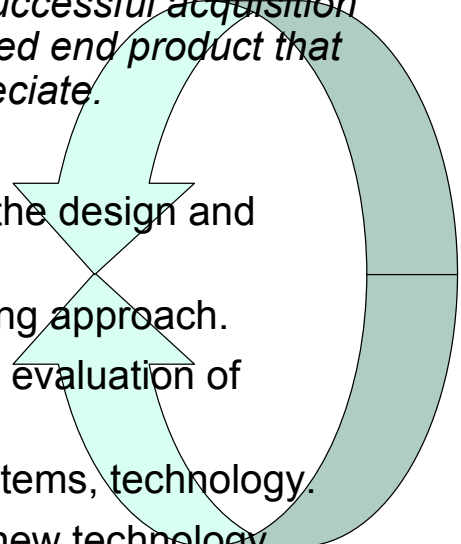
Unmanned Systems Technology Focus Areas

- **Command and Control (C2)**

- **Communications**

- **C4ISR Interoperability**

- **Multi-dimensional ISR**

Unmanned Systems Command and Control (C2)

Fielded in WTC & OEF Afghanistan

FY05 Fielding for SPARTAN ACTD

SMART — IDD/Video Plug-n-Fight → **MOCU**

MRHA

IDD Video

Plug-n-Fight

Multi-UV Control

GUI

Protocol Rules

Scalability

Interoperability

JAUS

Common OCU

FY04 Fielding for MDARS EUA

FY05 Fielding for Night Vision Cave & Urban Assault ACTD

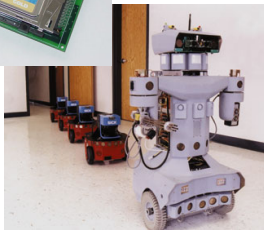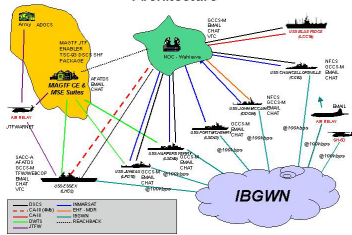*FORCEnet, Future Combat Systems (FCS), REDCAR, JUSC2, MTRS*

Unmanned Systems Communications

AMCR

Compact high-bandwidth ad hoc networking digital radio that proactively updates and maintains network connectivity

Scalable, Robust, and Secure Network Communications For Unmanned and Manned Systems

FORCEnet LOE & IPD Architecture

IBGWN

Sponsors:
SSC San Diego
ONR
DARPA
DTRA
PM-FPS

Organic high capacity IP-based Line-Of-Sight netted communications for Navy Battle Groups with enhanced, robust survivable SIPRNET access

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Unmanned Systems C4I Interoperability
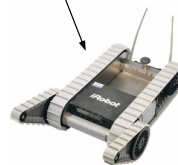
Matilda

Common Controller

URBOT

Andros
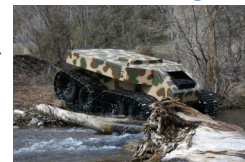
Eel

Packbot

TAGS

Sponsors:
JRP
PM-FPS

SSC San Diego
NSWC-PC (Navy)
AMRDEC (Army)
AFRL (Air Force)
AAC/WMO (Air Force)
Remotec/Apple Aid
Autonomous Solutions
iRobot

Joint Architecture for Unmanned Systems (JAUS)
- JAUS is standards-based approach defining common message sets
- Operator Control Unit (OCU) Experiment - Dec 2003 (SSC San Diego)
  - 9 organizations – 5 DoD and 4 industry
  - 6 Unmanned Ground Vehicle (UGV) systems
    - Each UGV dynamically registers with every OCU
    - Each OCU displays status of all UGVs on network
    - Each OCU is able to take control and drive any UGV

JAUS

Unmanned Systems
Multi-Dimensional ISR

Air/Land/Sea Situational Awareness from Robotic Operations Command Center
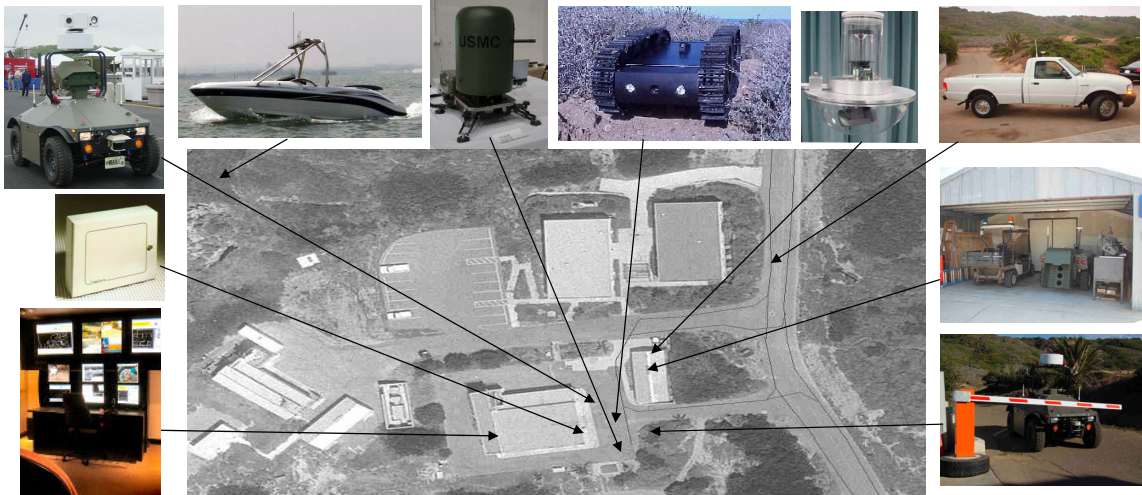
Integrated Force Protection (IFP)

- Force projection using unmanned vehicles
- Situational awareness from unmanned sensors
- Less-than-lethal weapons on unattended munitions
- Coordination with manned response forces
- Fixed and contingency autonomous operations

Robotic Operations Command Center (ROCC)

- C4ISR using multiple unmanned systems
- Graphical displays for video, map, and status
- Seamless data, video, and audio using wireless digital communications
- Prioritizes events, alarms, and warnings

Active Projects

Mobile Robot Knowledge Base (MRKB)

http://robot.spawar.navy.mil

Operational Relevance

- **Provides robotic system developers, program managers, and customers with a web-accessible, centralized knowledge resource for mobile robot components, subsystems, mission payloads, and platforms.**
- **Minimize redundant product research efforts, maximize efficiency and responsiveness.**
- **Facilitates technology transfer.**
- **Supports JRP small robot pool.**

Development History

- **Small Robot Technology Database launched April 1999.**
- **Mobile Robot Technology Knowledge Base internal launch Oct 2001, initial public launch Dec 2001.**

Segway Robotic Mobility Platform (Segway RMP)

Operational Relevance

- **Funded by DARPA / IPTO for MARS performers.**
- **Providing a reliable, cost-effective, robotic mobile platform based on the Segway HT.**
- **Agile and rugged: can turn in place, carry 100 lbs of payload at up to 8 mph (in self-balancing mode); >200 lbs and > 8 mph in tractor mode.**
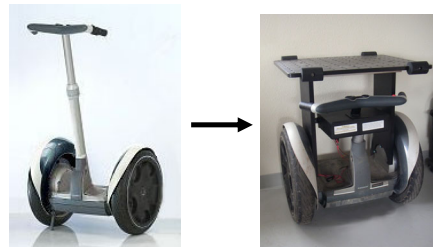
Accomplishments

- **Supervised the conversion of 15 HTs into RMPs.**
- **Distributed RMPs by loan agreements to 13 university and government research institutions.**
- **Created a central web site for collection and dissemination of research results and feedbacks.**
- **Held Segway RMP workshops.**
- **Explored military uses of the RMPs:**
  - **Providing mobility to the LSTAT medical life support transporter**
 - **Demonstrating leader/follower logistics transportation**

Distributed Interactive Video Arrays (DIVA)

Operational Relevance

- **Multi-purpose automated surveillance of arbitrarily large areas.**
- **Applications include:**
  - **Coordinated object detection, recognition, and tracking with omni-directional and pan-tilt-zoom cameras.**
  - **Event-driven pan-tilt-zoom (e.g. license plate reading).**
  - **Assisting robot navigation and tasks via compliance with MHRA protocol in combination with radio data/video link.**
  - **Customized, application-dependent views from pan-tilt-zoom or omni-directional cameras.**
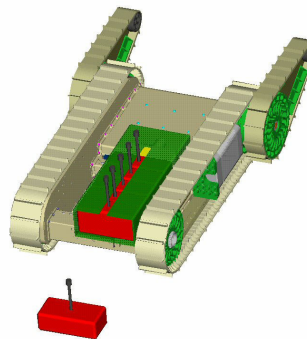
Technology Development

- **Developed a portable, deployable vision sensor and processing unit that can be easily reconfigured and extended, depending upon mission requirements.**
- **Wireless communication and distributed processing to perform tasks such as long-range tracking.**
- **Completely self contained and self-powered for stand-alone, perpetual usage.**

225m   290m

Omni Field of View   PTZ FoV
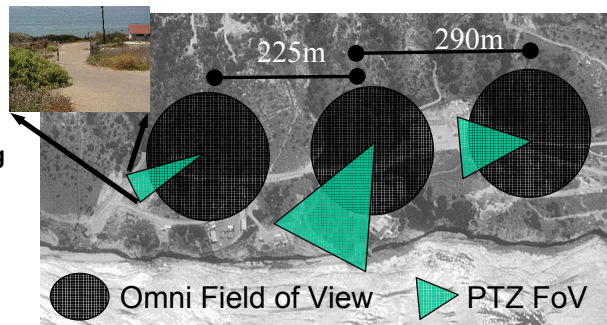
Automatically Deployed Communication Relays (ADCR)

Operational Relevance

- **Transitioned from DARPA-funded Autonomous Mobile Communication Relays (AMCR) project.**
- **Demonstrates automatic maintenance of high-bandwidth communication link between advancing robot and remote operator.**
- **Relay deploying module automatically ejects relay "bricks" as needed.**
- **Three systems being developed, for:**
  - **SSC San Diego's URBOT**
  - **NAVEODTECHDIV's EOD PackBot**
 - **TARDEC's TAGS and Wolverine UGVs**

Technology Development (in conjunction with BBN)

- **Developed a compact high-bandwidth ad hoc networking digital radio that proactively updates and maintains network connectivity. Over 100 of these radios are being used at seven robotics research institutions across the US.**
- **Developed network monitoring and relay deployment software.**

ROBART III

Operational Relevance

- Incorporates a supervised autonomous navigation system configured to support minimally attended operation in previously unexplored interior structures.
- Continued R&D for future applications of reflexive teleoperation for control of non-lethal weapons and distributed master/slave robotic sensor networks.
- Serves as a transition platform for the evaluation and integration of new technologies.
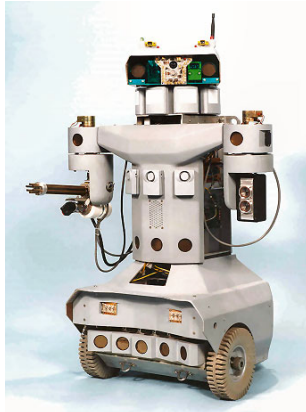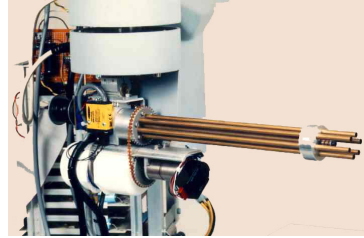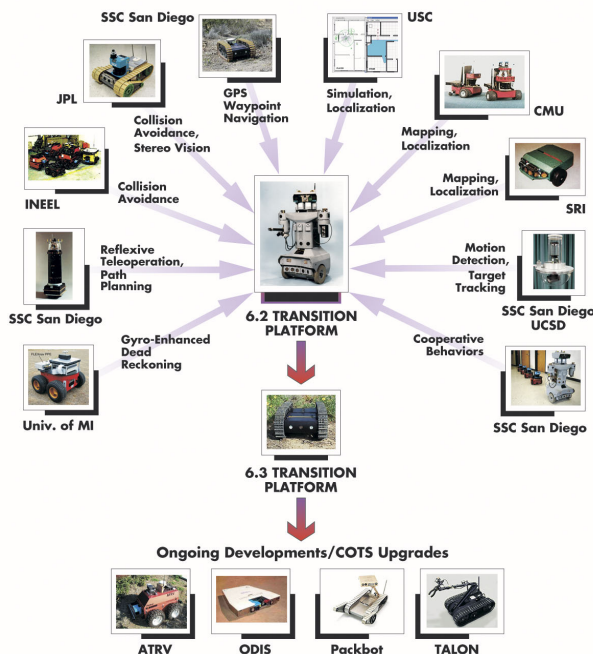
Accomplishments

- Developed an "Ortho-Mode" navigation strategy which exploits the fact that the majority of man-made structures are characterized by parallel and orthogonal walls.
- Integrated arc-based free-space reflexive collision avoidance algorithms developed by JPL.
- Demonstrated a "Search-and-Destroy" scenario that integrates vision-based target identification and tracking with non-lethal weapon control in response to a perceived threat.

Technology Transfer

Navigation Technologies

SSC San Diego
USC
JPL
GPS Waypoint Navigation
Simulation, Localization
CMU
Collision Avoidance, Stereo Vision
Mapping, Localization
Collision Avoidance
Mapping, Localization
INEEL
SRI
Reflexive Teleoperation, Path Planning
Motion Detection, Target Tracking
SSC San Diego
SSC San Diego UCSD
Gyro-Enhanced Dead Reckoning
6.2 TRANSITION PLATFORM
Cooperative Behaviors
Univ. of MI
SSC San Diego
6.3 TRANSITION PLATFORM

Ongoing Developments/COTS Upgrades

ATRV   ODIS   Packbot   TALON

Operational Relevance

- Improves functionality and autonomy of small mobile robots.
- Harvests state-of-the art results of prior and ongoing robotic technology development efforts.
- Integrates various researched algorithms into a complete, single system.
- Optimizes a reconfigurable software framework for cross-platform compatibility.
- Provides a convenient enabling mechanism for the subsequent transfer into other programs.

Accomplishments

- Dead Reckoning – U of MI
- Collision Avoidance – NRL/INL, JPL
- Localization/Mapping – USC, CMU, SRI
- Motion Detection/Target Tracking – UCSD
- "Augmented Virtuality" – INL
- Simulation, Device Drivers – USC
- Cooperative Behaviors – DARPA/MARS

# Man Portable Robotic System (MPRS)

Operational Relevance

- Removes warfighters from dangerous environments by providing remote inspection and surveillance.
- Intended for Tactical and Force Protection:
  - Urban reconnaissance in tunnels and sewers.
  - Remote surveillance for Special Forces.
- Digital telemetry link of voice/video/data to any command center with an IP-based network.
- Technology transfer platform for DARPA TMR.
- Amphibious/land-based marsupial delivery capability.

Accomplishments

- Successfully participated in Concept Experiment Plan at Fort Leonard Wood, MO, October 1999.
- Fabricated four hardened systems for participation in the Joint Contingency Force Advanced Warfighter Experiment at Fort Polk, LA, September 2000.
- Developed a semi-autonomous waypoint navigation capability in 2002
- Developed a Chemical, Radiological and Environmental sensor suite for the US Army Chemical School in 2003.
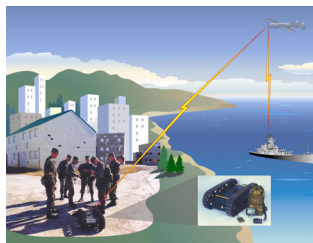
Unmanned Surface Vehicle (USV)

Operational Relevance

- Used to remove the warfighter from dangerous environments and for force multiplication.
- Intended for Tactical and Force Protection:
  - Special Warfare force projection and reconnaissance
  - MCM: detection, inspection, classification and possible neutralization
  - Port and harbor surveillance and security
  - Marine Hydrographic Surveying
  - Environmental/chemical Sensing

Development Plan

- Build on lessons learned in FBE-J with SAIC Owl:
  - Larger platform required for sensor deployment
  - Reliability is crucial
- Convert Sea-Doo Challenger 2000 jet boat for semi-autonomous operation.
- Port SMART and URBOT hardware/software for teleoperation and waypoint navigation.
- Work with SPARTAN ACTD to jointly develop USV capabilities:
  - Develop SPARTAN Command and Control System
  - Develop over-water collision avoidance

Mobile Detection Assessment Response System (MDARS)

Operational Relevance

- Robotic platforms autonomously patrol DoD storage sites and air bases.
- Robots navigate along pre-programmed paths using differential Global Positioning System (DGPS).
- Multi-layer sensor fusion of laser, stereo vision cameras, and radar provides Obstacle Avoidance.
- Robots detect and assess potential intruders, monitor inventory, and check the status of Interior Locking Devices (ILD) on munition storage bunkers.

Accomplishments & Milestones

- BAA contract for platform development awarded in 1993.
- Integrated BAA platform with Multiple Resource Host Architecture for command and control.
- Led system integration and engineering tests of BAA prototype, 1993-1998.
- BAA Final Demonstration successfully conducted in October 1998.
- Passed Technical Feasibility Testing (TFT) conducted by U.S. Army Test Command in May 2000.
- System Development and Demonstration (SDD) contract awarded in late 2001.
- Early User Appraisal (EUA) at Hawthorne Army Depot in September 2004 – July 2005.

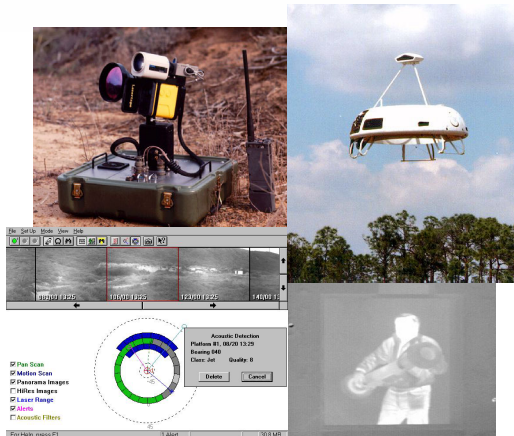# Family of Integrated Rapid Response Equipment (FIRRE)

Operational Relevance

- Multi-phase integration and development effort aimed at fielding advanced unmanned force protection systems to forward-deployed forces.
- Near-term goal: address an existing Operational Needs Statement for fixed-perimeter force protection at captured ammunition sites in Iraq.
- Long-term goal: a fully integrated force protection system of systems that employs a variety of fixed and mobile supporting technologies
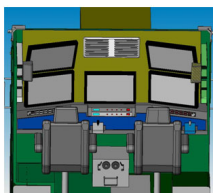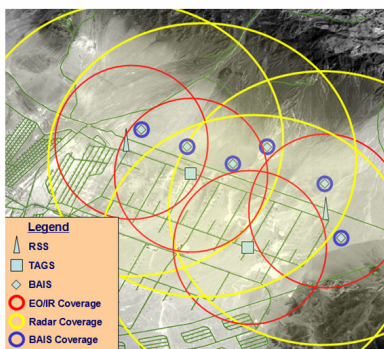
Accomplishments

- Hosted a demonstration of the near-term concept in November 2004 and performed an Integration Assessment at Hawthorne Army Depot in May 2005.
- Demonstrated integration of AN/PPS-5 ground surveillance radar, the Battlefield Anti-Intrusion System (BAIS) unattended ground sensors, and the Remotec Tactical Amphibious Ground Surveillance (TAGS) vehicle.
- Developed a Remote Sensor Station (RSS) that consists of a portable tower, military GENSET, AN/PPS-5 radar, BAIS receiver, EO/IR surveillance cameras, and a thermally regulated electronics enclosure.

Legend
- RSS
- TAGS
- BAIS
- EO/IR Coverage
- Radar Coverage
- BAIS Coverage

Mission Payload Package (MPP)

Operational Relevance

- Providing a rapidly deployable, man-portable remote surveillance, detection and assessment capability.
- Intended for Base Security and Force Protection Scenarios:
  - Extended perimeter surveillance.
  - Automated intruder detection and tracking.
- Digital telemetry link of voice/video/data to any command center with an IP-based network.

Accomplishments

- Spin-off from the Multipurpose Security and Surveillance Mission Platform (MSSMP) project, formerly known as the Air Mobile Ground Security and Surveillance System (AMGSSS).

- Added omni-directional camera, automatic target tracking and cueing.

Networked Remotely Operated Weapon System (NROWS)

Operational Relevance

- Standalone networked weapons platform provides remote lethal response to intruders.
- Fixed installation or deployed by UGV to provide remote response capability for security operations and other tactical missions.
- Provides real-time unattended weapons pod that extends delay/denial response capabilities at high-value installations or in tactical scenario.
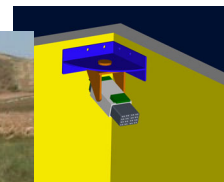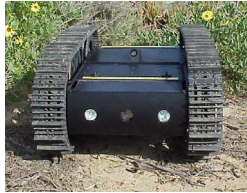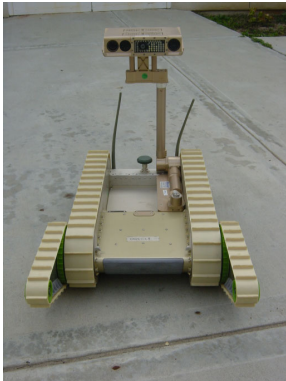
Technology Development

- Uses a distributed TCP/IP network control-communication architecture.
- Allows for flexible integration and operation of multiple platforms from a single control station.
- Communications incorporate anti-jamming, encryption, or low probability of intercept/low probability of detection (LPI/LPD) methods.
- Integrated with autonomous surveillance, detection, and automated target tracking.
- Demonstrated operation from unmanned MDARS UGV in April 2005.
- Metal Storm electronic weapon systems being considered.

Common Operator Control Unit (Common OCU)

Operational Relevance

- **A small, lightweight (OCU) capable of controlling many robotic systems (including URBOTs and PackBots)**
- **Support Night Vision and Electronics Sensor Directorate (NVESD) development and integration of vision sensors on the URBOT and/or PackBot**

Technology Development

- **Fabricated rugged, water-tight, ergonomic handheld device**
- **Implemented plug-in controllers**
- **Improved display capabilities**
- **Developed modularized software**
- **Based on a Scalable OCU architecture**

Autonomous UAV Mission System (AUMS)

Operational Relevance

- **Develop an automated system for a UAV to be launched, captured, refueled, and re-launched**
- **Can operate from USVs, UGVs, HMMWVs, and fixed stations**
  - **Decreases time and personnel required to refuel UAV**
  - **Increases the number of missions the UAV can complete**
- **Applicable to MDARS, REDCAR, FCS, PerceptOR, and SPARTAN programs**

Accomplishments

- **Developed and tested several fixtures for launch and recovery of iSTAR UAV from MDARS UGV**
- **Established UAV test facility**
- **Developed automated refueling system for iSTAR mockup**
- **Working with USC on precision landing**

Tactical Mobile Robots (TMR)

Operational Relevance

Support Future Combat Systems, Homeland Security, and Search and Rescue payload requirements
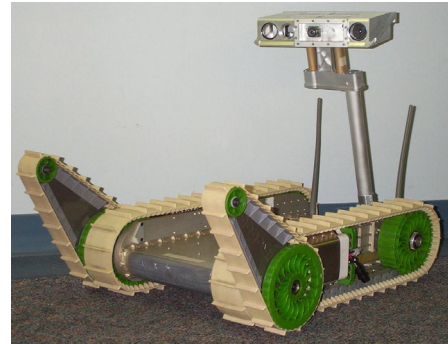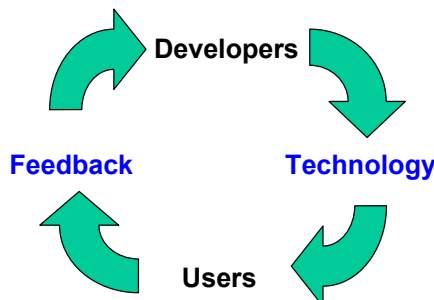
Technology Development

- Payload development and integration
    - Explorer Head and Neck Assemblies
    - Wearable OCUs
    - Chemical and radiological sensor modules
- Software enhancements
    - JAUS compatible command set
    - Software Application Programming Interface (API)
- Hardware acquisitions
- Maintenance support

Robotic Systems Pool (RSP)

Accelerates the technological advance of US military forces and law enforcement by purchasing the latest robotic technology and making it available to government agencies.

- Provides government agencies at all levels with the opportunity to evaluate and experiment with mobile robots in their own unique operational domains.

- Users can make appropriate acquisitions of robots based on their experience.

- Robot Developers benefit from the users feedback and recommendations, enabling them to improve their designs and better meet the emerging needs.

Developers

Feedback

Technology

Users

Inuktun

Foster-Miller

iRobot

SSC San Diego

Utah State University

World Trade Center   Iraq/Afghanistan

Robotic Systems
Combat Support Platoon

Operational Relevance

- Provides forward-deployed robotic systems repair technician support, to include repair, refit, maintenance, and data collection for Explosive Ordnance Disposal (EOD) robotic systems as part of the RS JPO SKISKY fielding effort.
- Provides stateside pre-deployment robotic systems operator and maintenance training for users and technicians.
- Provide stateside logistics support.

Accomplishments

- RSCSP established in early 2004, consists of highly technically-competent Navy Reservists.
- At least two platoon members are providing repair services for EOD robots at the Joint Robotics Repair Facility in Baghdad at any time.
- Ensuring the operational readiness of over 200 man-portable EOD robots in theater.
- Four training sessions held and over 60 EOD technicians trained between February and September 2004.

For Additional Information

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http://www.spawar.navy.mil/robots/