Unmanned Systems
Research and Development
at
Unmanned Systems Branch, Code 7171
SPAWAR Systems Center Pacific

San Diego, CA

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

Unmanned Systems Branch

- Over 70 in-house personnel
- 45 Government scientists and engineers
- Unmanned Systems Naval Reserve Unit
- 25 years in unmanned ground vehicles
- Over 20 active robotics research and development projects
- Infrastructure for UGV, UAV, USV RDT&E
- Funding from:
  - OSD JGRE, RS-JPO, NAVSEA, PM-FPS, FCS, MANSCEN, CECOM NVESD, ARL, DARPA, DTRA, ONR, NSWG, SOCOM, and others

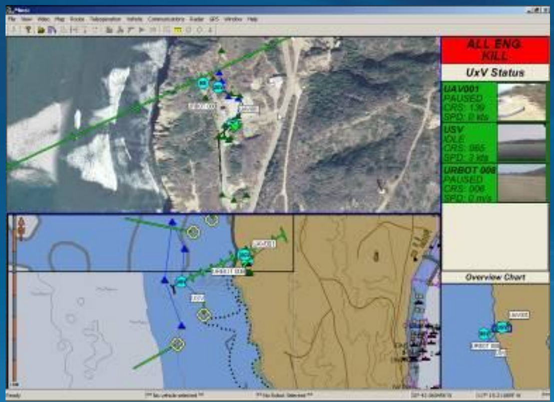
Technology Development Across All Domains
Air, Land, Sea, and C2

Unmanned Aerial Vehicles

Unmanned Ground Vehicles

Unmanned Surface Vehicles

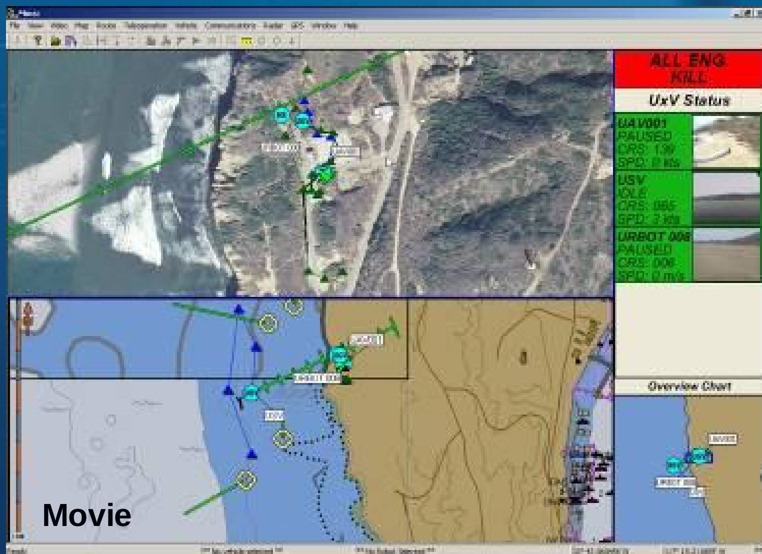
Unattended Munitions



Command and Control

Unattended Sensors

Multi-Robot Operator Control Unit (MOCU)

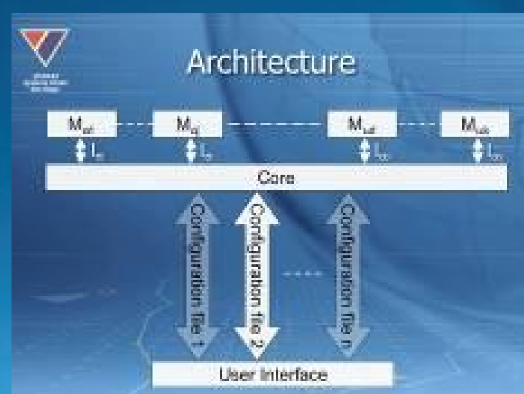


Operational Relevance

- In use as the common OCU for the Littoral Combat Ship (LCS) USV mission modules (ASW and MIW)
- Planned for use in the Navy's Advanced EOD Robotic Systems (AEODRS) program
- In development under the ONR Capable Manpower and Summit (planned for FY10) programs
- Used for the Army's FIRRE and JFPASS JCTD programs (as JBC2S)
- Used for the R3V and Spartan ACTDs
- Used by a wide variety of other government, industry and academic organizations

Characteristics

- Control multiple heterogeneous vehicles
- Vehicle and protocol type independent
- Modular and scalable
- Flexible User interface
- 3D graphics
- Enables 3rd party development
- Ranked best in Technology and Universality in the JGRE Common Robotic Controller Study



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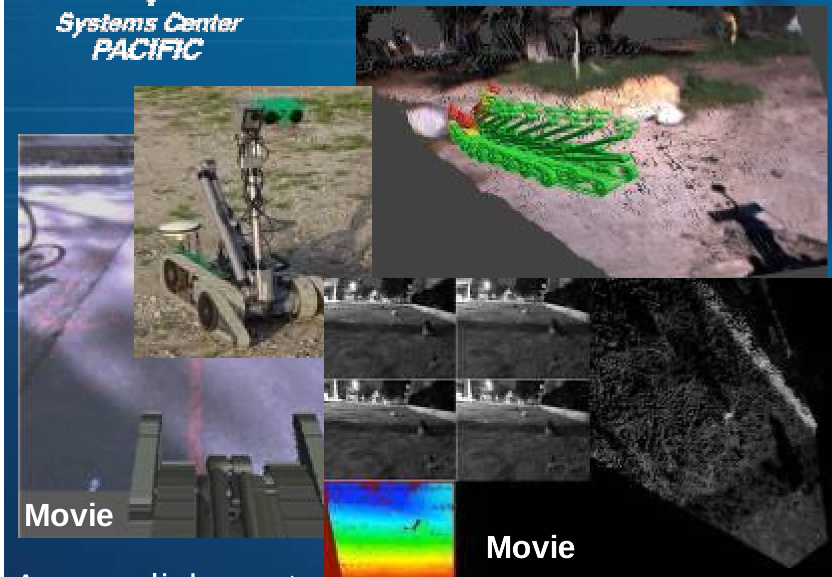
Autonomous Navigation for Small UGVs (ANSU)

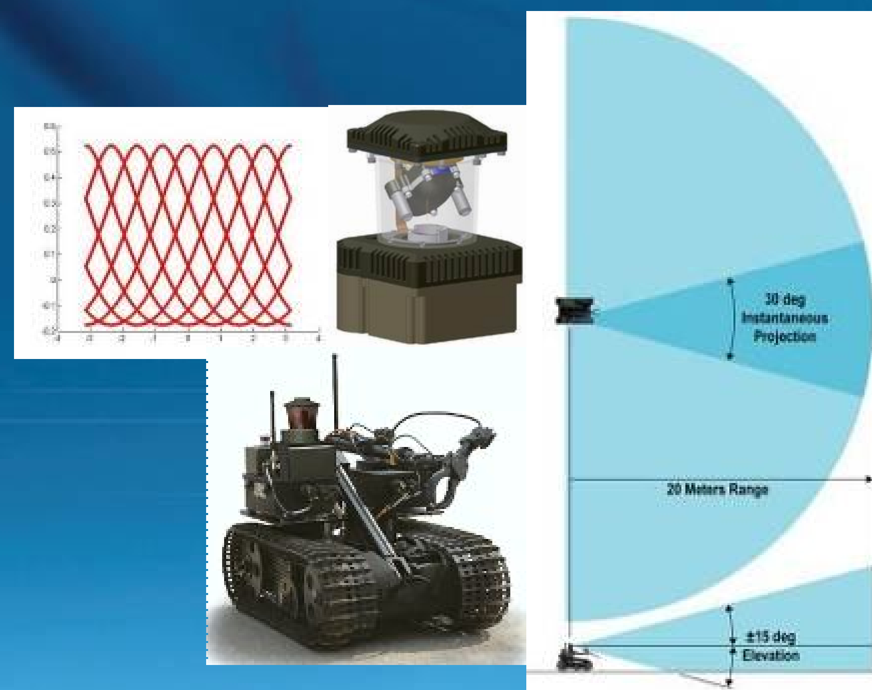


Operational Relevance

- Focusing on moving technologies from the laboratory to a realistic operational environment, specifically technologies that will advance the autonomy of small systems in a practical and robust manner.
- Working to transition software and hardware systems to the EOD UGV programs (MTRS and AEODRS)

Accomplishments

- Continuing to develop improved autonomy functions and sensors
  - Funding GDRS to develop a miniature dual-axis scanning LADAR
  - Funding NASA JPL to continue to investigate nighttme stereovision and more advanced traversability analysis
- Demonstrated various autonomous navigation behaviors to EOD users
  - Waypoint navigation (w & w/out obstacle avoidance)
  - Guarded tele-op, retro-traverse, point-and-click drive
  - 3D scene building for improvement operator SA



Urban Environment Exploration (UrbEE)

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Exploration results of two office buildings and surrounding areas at SSC

Sensor, robot position, and map data aided operators while they searched for tactical items at Molnar MOUT, Ft. Benning

<u>Operational Relevance</u>

- Enhance teleoperated systems with COTS sensors and autonomous behaviors to reliably perform in urban environments
- Objective tests/experiments regularly conducted to metric performance to assess and advance TRLs

<u>Joint Experiment at Molnar MOUT, Ft. Benning, GA</u>

- Conducted with ARL: HRED (Human & Research Engineering Directorate), ARL: CISD (Computational and Information Sciences Directorate), and Think-a-Move, Ltd.
- ACS framework enabled a variety of behaviors to be tested at each level of autonomy

ACS with UrbEE behaviors integrated on an iRobot PackBot Scout was used at Building Recon station

Soldiers operated the robot from a separate building, while HRED data collectors observed

<u>Software Technology Development</u>

- Within Autonomous Capability Suite (ACS) framework
  - Non-GPS navigation – enhanced localization and path planning without GPS
  - Seamless transition between outdoor and indoor environments
  - Automatic return-to-comms; retro-traverse
  - Large-scale, multi-story mapping and efficient exploration strategies for varying structure types (size, clutter, # of floors)
  - Stair detection, climbing, and descending

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Urban Environment Modeling (UrbEM)

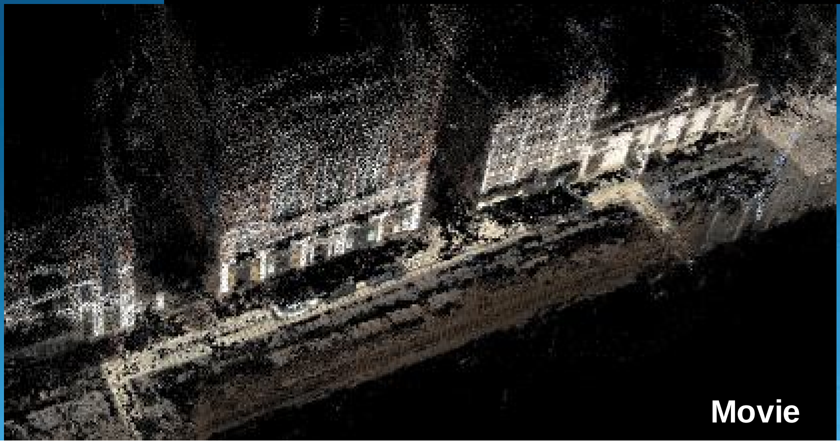
Movie

Operational Relevance

- Develop, mature, and demonstrate technologies that will provide rich 3-dimensional models of complex urban environments from the ground perspective. The models will be used for UGV path/mission planning, navigation, and localization and possibly by the warfighter as a mission planning and training tool.

Accomplishments

- Working with the University of Washington
  - Adapt technology licensed to Microsoft for PhotoSynth
  - Add multi-view stereo to the pipeline
  - Investigate addition of spatial phase video data
  - Made significant improvements to the speed of the pipeline and ability to scale to much larger image sets



Movie

EOD Tech Development and Support

Operational Relevance

- Provide technical support to NAVEODTECHDIV for EOD UGV programs including the current MTRS program (Packbot and Talon) and the Advanced EOD Robotic Systems (AEODRS) program for the next generation of EOD UGVs.

Accomplishments

- Supporting AEODRS with MOCU as the common controller for the family of systems as well as program IPT support
- Supporting MTRS with common control (MOCU), a hardened autonomy payload, and a communications repeater system for operational assessment
- Integration of EOD tools to the MTRS EOD UGVs
- Demonstration of basic autonomy on EOD robots
  - Waypoint navigation, obstacle avoidance, retro-traverse, click-to-drive, etc..

3D Visualization for EOD Robots (3DVis)

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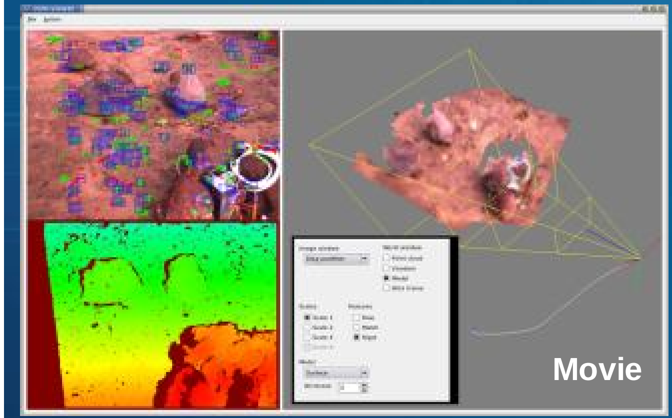
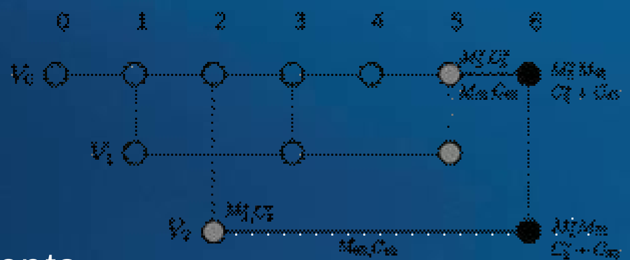


Operational Relevance

- Developing a system that will allow an EOD UGV to build a high-resolution 3D model of an object of interest and allow the operator to view and control the UGV manipulator in a virtual environment using that mode. This will substantially improve the operator's situation awareness and perception of where the end effector is relative to the object



Accomplishments

- Working in NASA JPL and UNC Chapel Hill
  - JPL is using stereovision with VO and VSLAM, local and global stereo methods
  - UNC is using stereovision with a spatial phase camera, KLT VO, and structure-from-motion
- Focus is on reduce computation time while increasing fidelity and accuracy

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Miniature 3D Spatial Phase Camera

Operational Relevance

- Mature, miniaturize and further develop the 3D Spatial Phase Imaging (SPI) technology. SPI technology addresses fundamental limitations of other sensors such as stereovision and lidar. The SPI sensor is not a range sensor but does provide 3D surface detail in far greater resolution then other current technologies. When combined with a range sensor the SPI sensor will greatly enhance the perception capabilities of UGVs.

Accomplishments

- Working with Photon-X to mature and miniaturize the SPI sensor
  - Porting and parallelizing SPI algorithms to the Hyper-X processor
  - Developing algorithms to capitalize on this technology for UGV perception (navigation, 3D modeling, gesture recognition, etc.)

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.
- 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.
- Led system integration and 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 2001.
- Early User Appraisal (EUA) at Hawthorne Army Depot in 2004 – 2005.
- Passed Milestone C in December 2006.
- Production contract awarded to GDRS in 2007.
- Currently leading the MDARS Modernization Effort—incorporating user-requested capabilities: detection on the move, weaponization, ICIDS, etc.

Joint Force Protection Advanced Security System (JFPASS) JCTD

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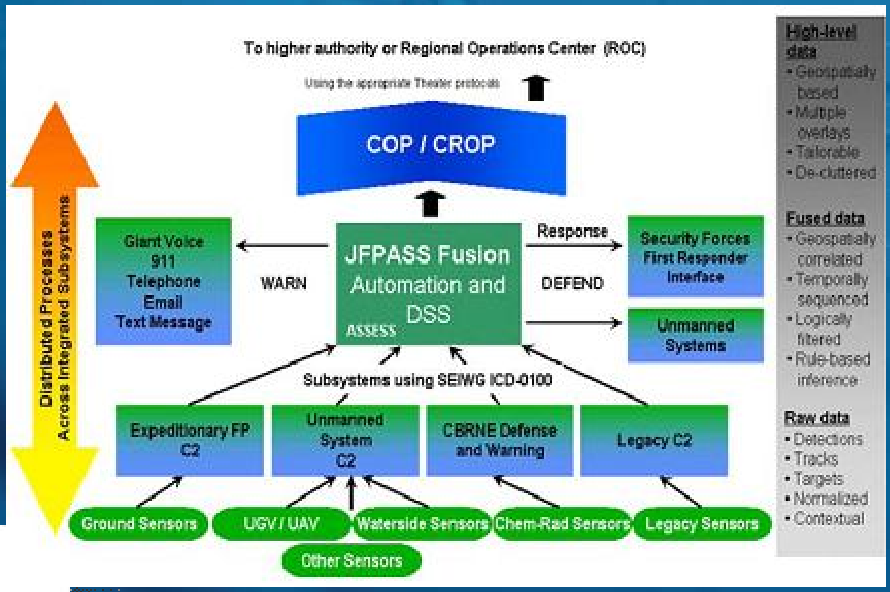
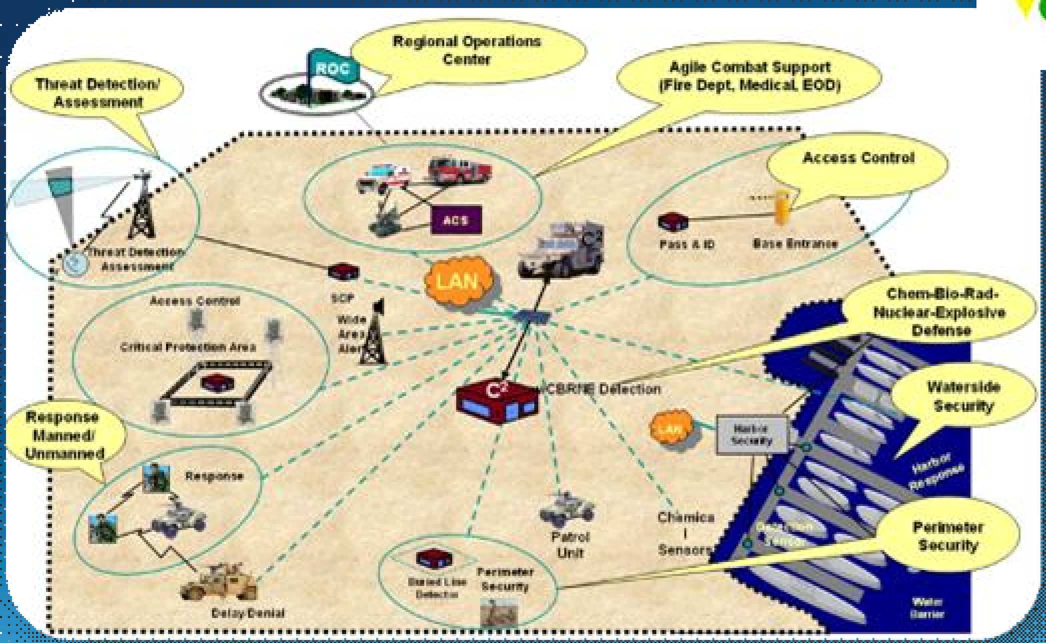


Operational Relevance

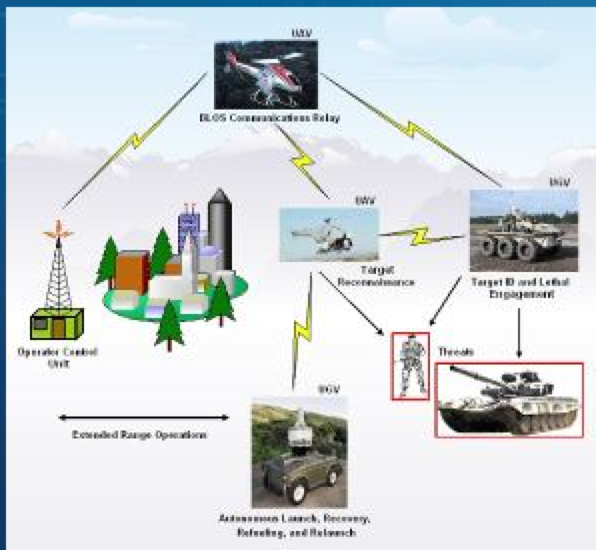
- Demonstrate integrated Force Protection (FP) C2 environment – a Joint capability
- Demonstrate fixed and expeditionary FP C2
- Integrate sensor inputs with automated (unmanned) response systems
- Serve to bring FP stakeholders together to define vision for Joint FP
- Leave-behind a capability with sustainment plan in FY09-FY10
- Operational Sponsor is USEUCOM



Accomplishments

- Formalized JFPASS functional requirements (FRD)
- Extended C2 system to operate with ICX middleware
- Conducted multiple integration assessment activities at Eglin AFB
- Conducted Technical Demonstration (TD-1) at Eglin AFB
- Began installation of operational FP equipment at OCONUS site

Joint Collaborative Technologies Experiment (JCTE)



Operational Relevance

- Integrate collaborative technologies that support teaming communications, sustainment, and engagement in manned-unmanned teaming applications
- Effort to develop the capabilities needed to support collaborative behaviors between unmanned systems
- Joint effort from three services
  - SPAWAR, AFRL, AMRDEC
- Demonstration to validate hardware and software with an emphasis on JAUS compliance

Accomplishments

Demonstrated:

- Beyond Line Of Sight (BLOS) range extension through a UAV-borne communications relay (AFRL)
- Forward deployment, launch, recovery, and refueling of a VTOL UAV by a UGV (SSC-P: AUMS)
- Target ID and lethal engagement (AMRDEC)

Automatic Payload Deployment System (APDS)

Operational Relevance

- Based on the Automatically Deployed Communication Relays (ADCR) system.
- Demonstrates extended range and non-line of sight operations by deploying relaying radios.
- Demonstrates automatic deployment of leave-behind sensors.
- Capable of delivering supplies and other payloads.

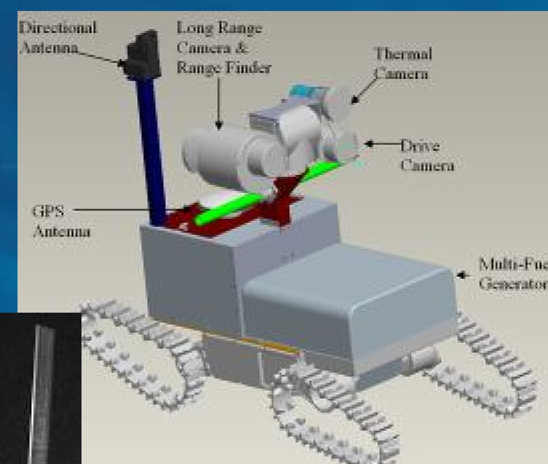
Technology Development

- Smaller footprint than the original ADCR system.
- Improved mast lift mechanism for raising antennas and sensors.
- Use of higher bandwidth radios minimizes latency of vehicle response to operator commands.
- Deployer unit can carry variable sized payloads.

Intelligence, Surveillance, Reconnaissance (ISR) Robot

Operational Relevance

- Provide a persistent unmanned ground surveillance and reconnaissance capability.
- Ability to conduct continuous covert unmanned surveillance from a remote location (analogous to a human occupied observation or listening post).
- Ability to utilize long-range teleoperation with low latency NLOS communications and semi-autonomous behaviors.



Technology Development Goals

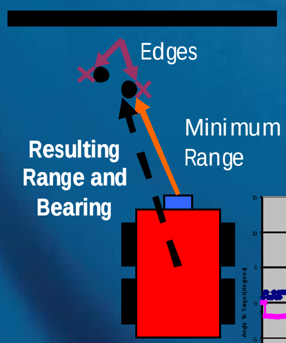
- Power duration of up to 72 hours
- Extended-range communications
- Integrated, configurable sensor suite
- Ability to maneuver semi-autonomously

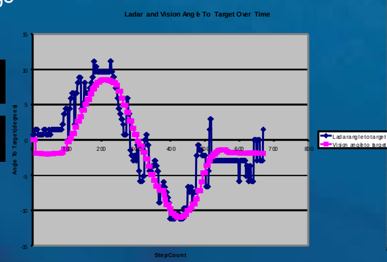
Human Motion/Presence Detection

Operational Relevance

- Address any robotic operation requiring a ground vehicle to detect, respond to, and interact with a human
- Provide safe operations of ground vehicles where people are present

Example sensor fusion analysis





Example behavior development & analysis based on positive detection

Small Vehicle Solution:

- Example Applications: safe operations, robot self-defense, person tracking and following, tactical behaviors, human-robot teaming
- Fused sensor solution: color-thermal-lidar
- Investigating EO & LWIR stereo from Sarnoff
- Software development within ACS
- If a priori data is available, employ 2-stage change detection-based process:
- Detect anomalies and tag their locations
- Verify if anomaly is human or not

Large Vehicle Solution:

- Target Application: Physical Security for MDARS Intruder Detection and Assessment
- New MDARS requirements:
  - Detection of human presence to a range of 300m
  - 360 degrees horizontal, +/-30 degrees vertical
  - Detect from moving platform
  - Pursuing new radar solution from GDRS

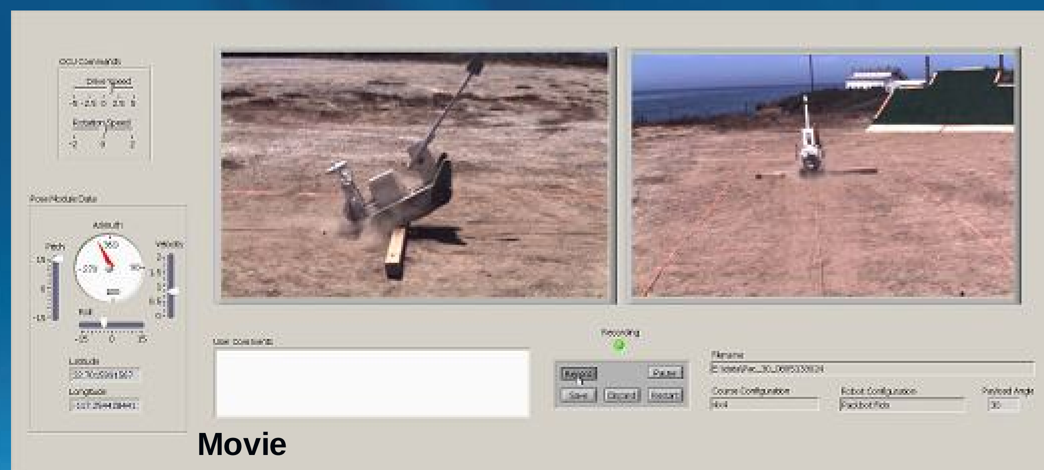
Countermine,Mobility, Marking, Autonomy, and Detection (CMMAD) – Mobility Testing and Mine Marking

Operational Relevance

- Determine how CMMAD payloads influence the mobility of the iRobot Packbot MTRS MKI and QinetiQ Talon MTRS MKII UGVs

Accomplishments

- Mock payloads, dynamic measurement systems, and real-time recording capabilities developed
- Thorough testing completed with documented results
- Recommendations made to the Army
- Mine marking AoA conducted and several alternative prototyped



Mine Marking Movie

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).
- Integrated with autonomous surveillance, detection, and automated target tracking.
- Demonstrated operation from unmanned MDARS UGV in April 2005.

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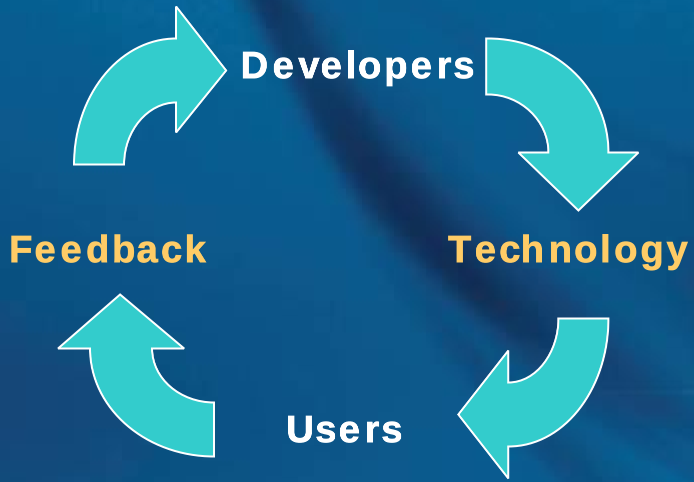
Robotic Systems Pool (RSP)

Accelerates the technological advance of US military forces and law enforcement by making the latest robotic technology available through no cost loans.

- 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.



Spiral Development

World Trade Center

Iraq/Afghanistan

Remington

Inuktun

ARA

Foster-Miller

Allen-Vanguard

SSC San Diego

iRobot

Utah State University

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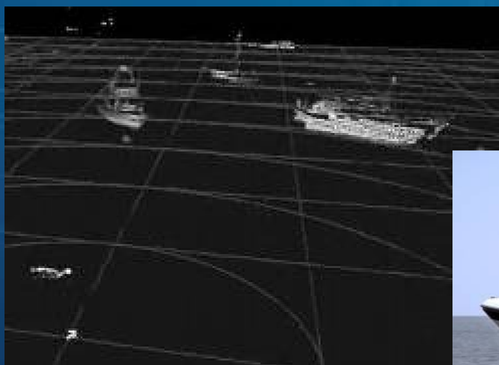
Unmanned Surface Vehicle (USV)

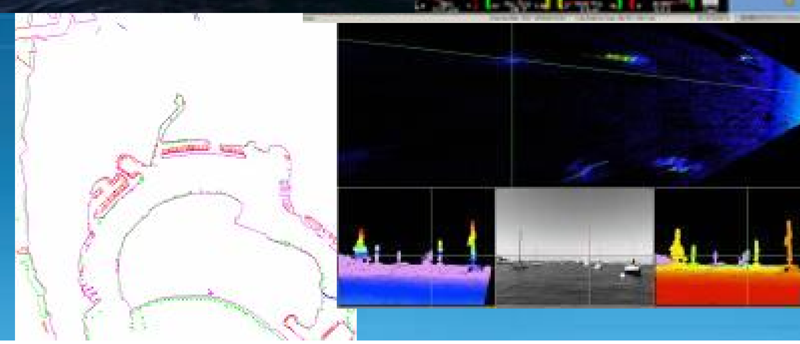


Operational Relevance

- 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

Accomplishments

- Converted Sea-Doo Challenger 2000 jet boat for semi-autonomous operation.
- Port UGV hardware/software for teleoperation and waypoint navigation.
- Develop obstacle avoidance capability for fully autonomous navigation
  - Deliberative path planning
  - Reactive obstacle avoidance
- Develop and integrate sensor technologies to support autonomous operation
  - Digital ARPA Radar
  - Vision (stereo and monocular)
  - Multi-line scanning LADAR



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