



*Systems Center*  
**PACIFIC**

# Unmanned Systems Research and Development at SPAWAR Systems Center Pacific

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

# Unmanned Systems Expertise

- Over 90 in-house personnel
- 60 Government scientists and engineers
- Unmanned Systems Naval Reserve Unit
- 25 years in unmanned ground and air vehicles
- 40 years in unmanned undersea vehicles
- Over 25 active robotics research and development projects
- Infrastructure for UGV, UAV, USV, UUV RDT&E
- OSD JRP-designated *Center of Excellence for Small Robots*
- Funding from:
  - OSD JGRE, RS-JPO, NAVSEA, PM-FPS, FCS, MANSCEN, CECOM NVESD, ARL, DARPA, DTRA, ONR, NSWG, SOCOM, and others

# Robotics Outdoor Test Range

- Paved & unpaved roads
- Off-road terrain
- Bunkers & tunnels
- VTOL UAV flight range
- Ocean access

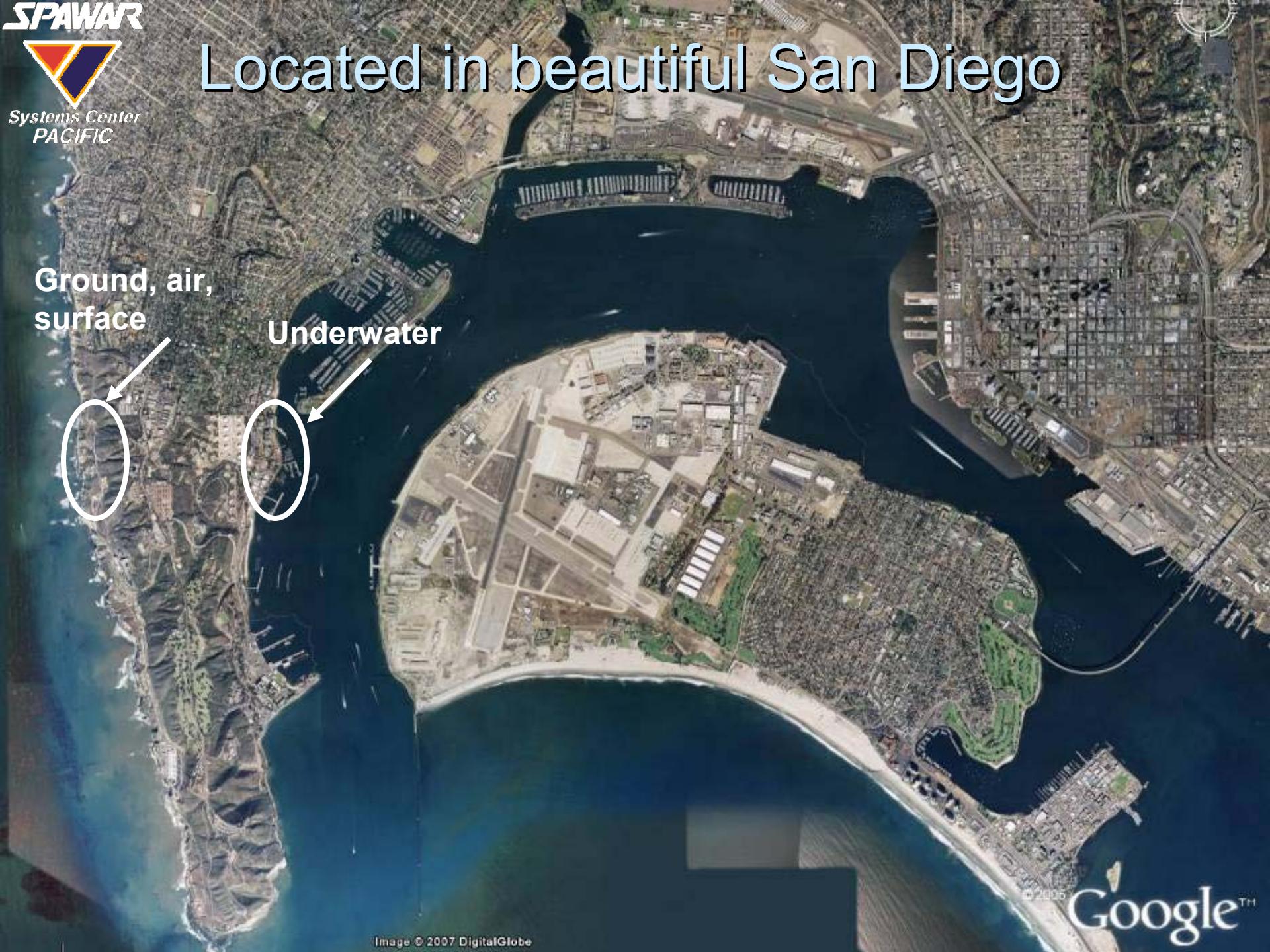




# Located in beautiful San Diego

Ground, air,  
surface

Underwater



# Collaboration

<u>Organization</u>	<u>Project/Focus</u>
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
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), LCS ASW MM
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
NPS	Surveillance and Target Acquisition Network experiment
AFRL/AMRDEC	UGV/UAV Collaborative Engagement Experiment
NG Remotec	Family of Integrated Rapid Response Equipment
....	

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

Robotic  
Systems  
Pool



Networked Remotely  
Operated Weapons



Technology Transfer

Common Operator  
Control Unit  
(Common OCU)



Automatically Deployed  
Communication Relays



Man-Portable Robots



Adaptive  
Mission  
Planning



Unmanned Surface  
Vehicle Technologies



Unmanned Underwater  
Vehicle Technologies



# Unmanned Surface Vehicle (USV)

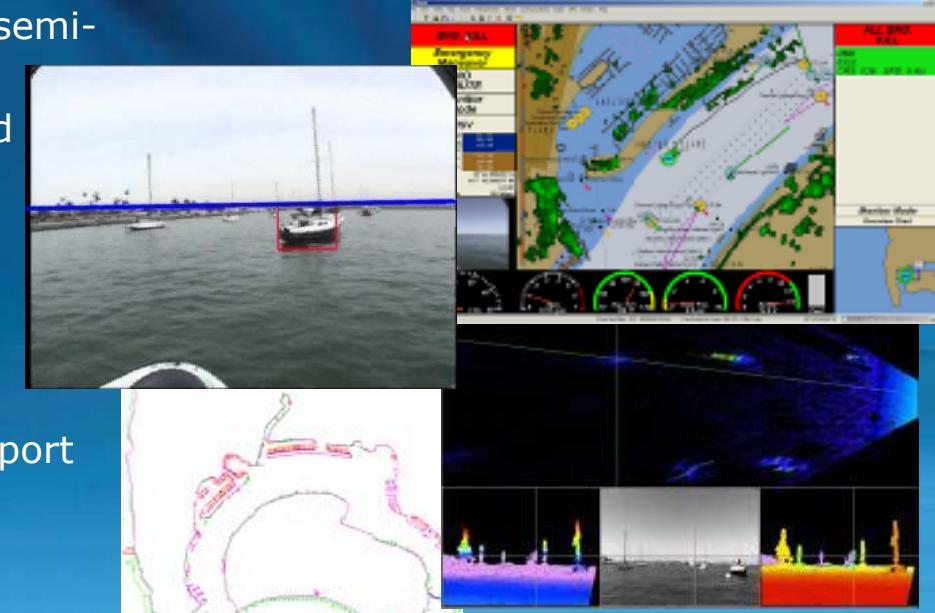


## Operational Relevance

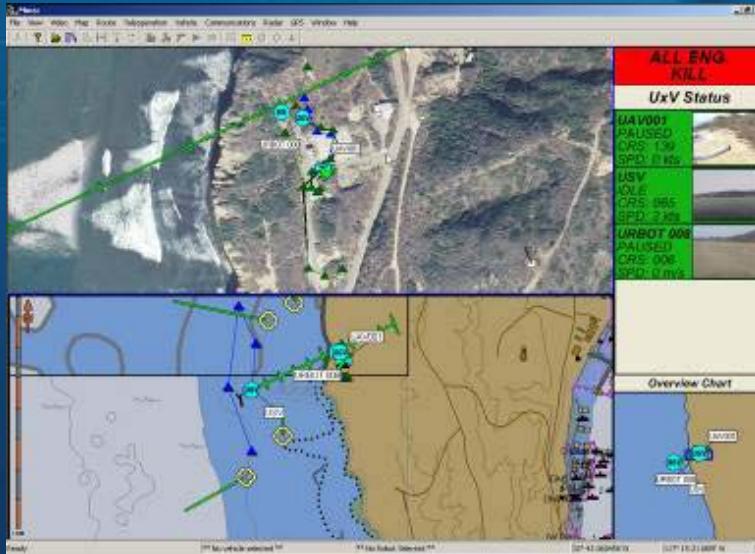
- Used to remove the warfighter from dangerous environments and for force multiplication.
- Intended for Tactical and Force Protection:
  - Special Warfare force projection and reconnaissance
  - MCM: detection, inspection, classification and possible neutralization
  - Port and harbor surveillance and 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)

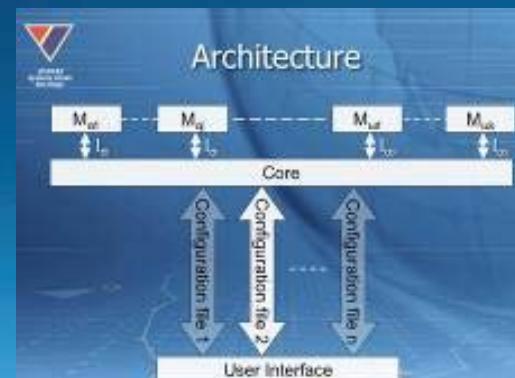


# Multi-Robot Operator Control Unit (MOCU)



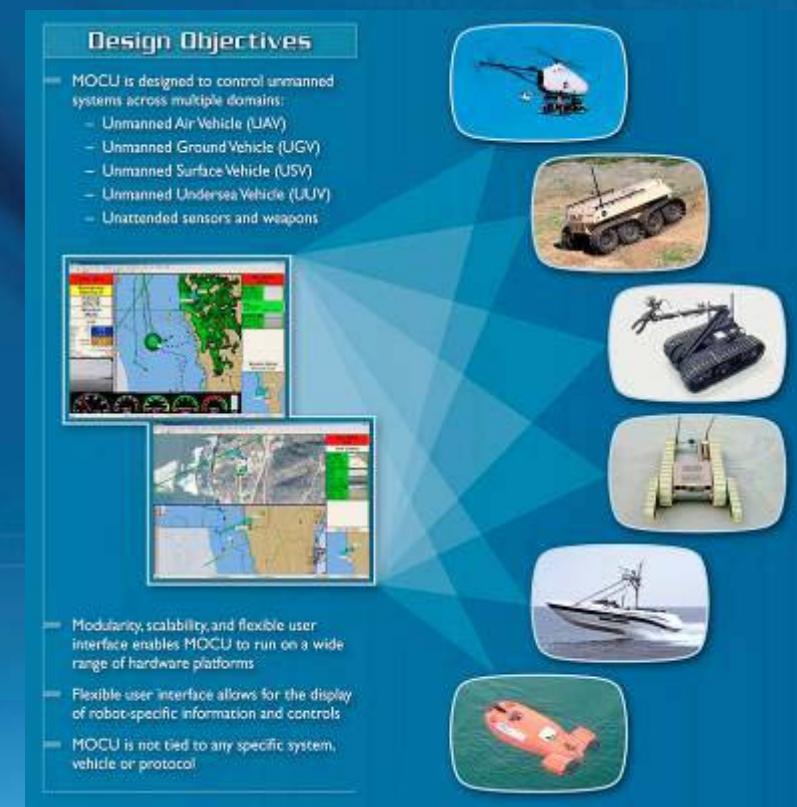
## Characteristics

- Control multiple sets of heterogeneous sets of vehicles
- Vehicle and protocol type independent
- Modularity
- Scalability
- Flexible User interface



## Operational Relevance

- Used for the R3V and Spartan ACTDs
- Used as the common OCU for the Littoral Combat Ship USV programs (ASW and MIW)
- Used for the Army's FIRRE program (as JBC2S)
- Used by a wide variety of other government, industry and academic organizations



# Mobile Detection Assessment Response System (MDARS)



## Operational Relevance

- Technical Director for the Army PM-FPS' MDARS program.
- Robotic platforms autonomously patrol DoD storage sites and air bases, along pre-programmed paths using differential GPS.
- 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 on munitions storage bunkers.

## Accomplishments & Milestones

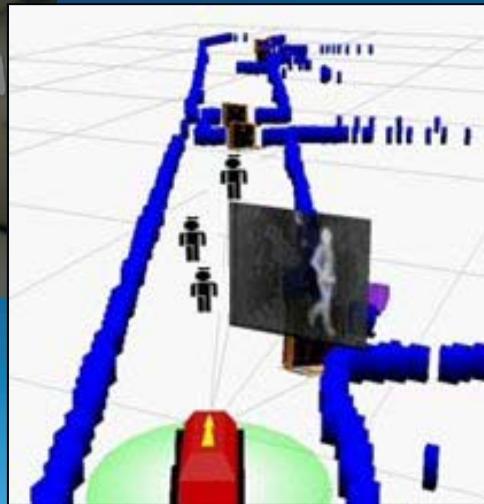
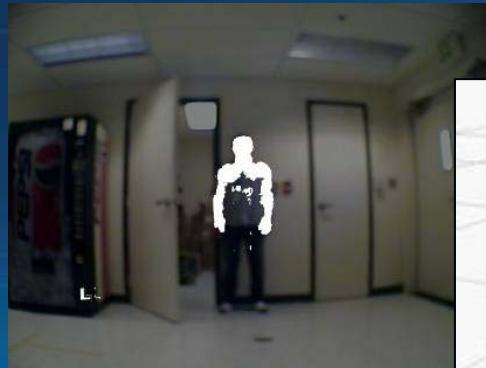
- BAA contract for platform development awarded in 1993.
- Led system integration and tests of BAA prototype, 1993-1998.
- BAA Final Demonstration successfully conducted in October 1998.
- Passed Technical Feasibility Testing (TFT) conducted by U.S. Army Test Command in May 2000.
- System Development 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 in December 2007.
- Currently leading the MDARS Modernization Effort—incorporating user-requested capabilities: detection on the move, weaponization, ICIDS, etc.



# Human Motion/Presence Detection

## Physical Security Applications

- Current state: MDARS Intruder Detection and Assessment
  - Requires sensors to be stationary
  - Fuses STS Radar, FLIR, and daylight cameras
- New MDARS requirements:
  - Detection of human presence to a range of 300m
  - 360 degrees horizontal, +/-30 degrees vertical
  - Detect from moving platform
  - Integrate Radar, Ladar, FLIR, and video



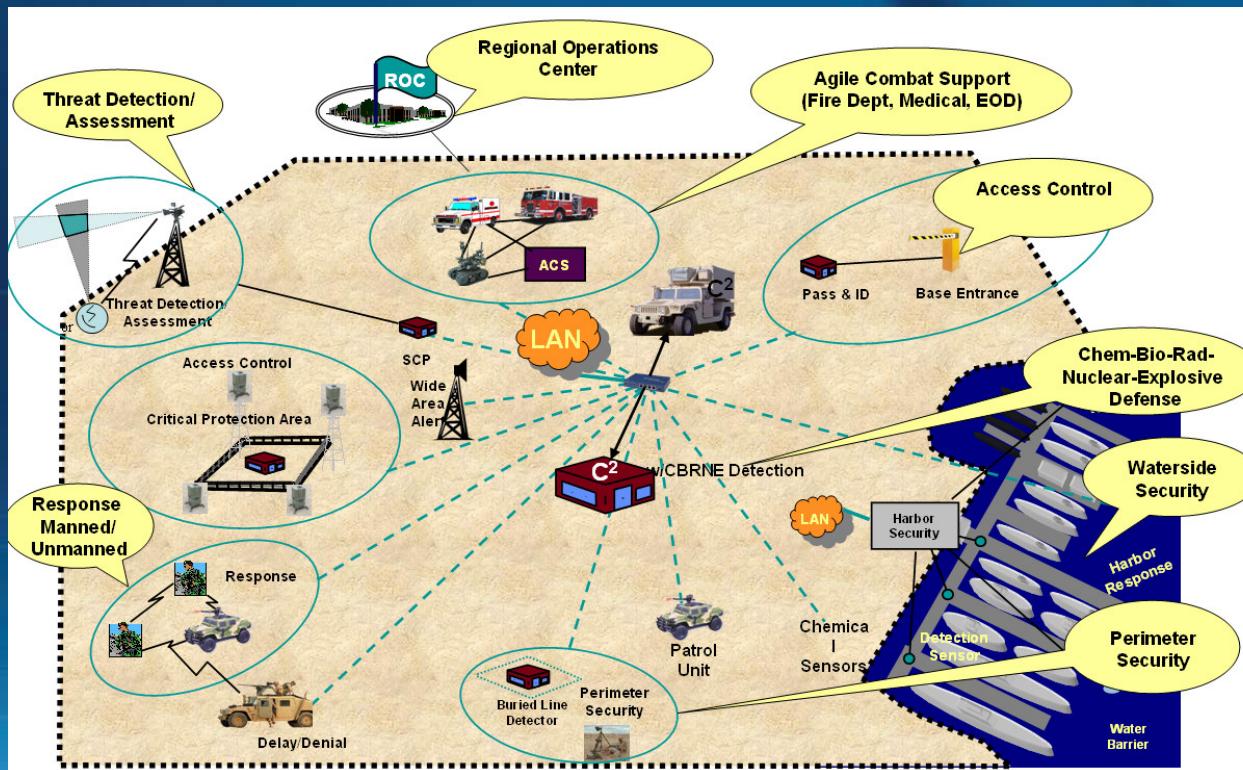
## Change Detection on the Move: 2-stage process

- Stage 1: Anomaly Detection
  - Mapping algorithm detects anomalies
  - Location of anomaly is tagged into the map
- Stage 2: Verification of Human Presence
  - Location of anomaly is sent to thermal presence detection system to classify
  - Icon representations of confirmed human presence are embedded into map

# Force Protection Joint Experiment (FPJE)

## Operational Relevance

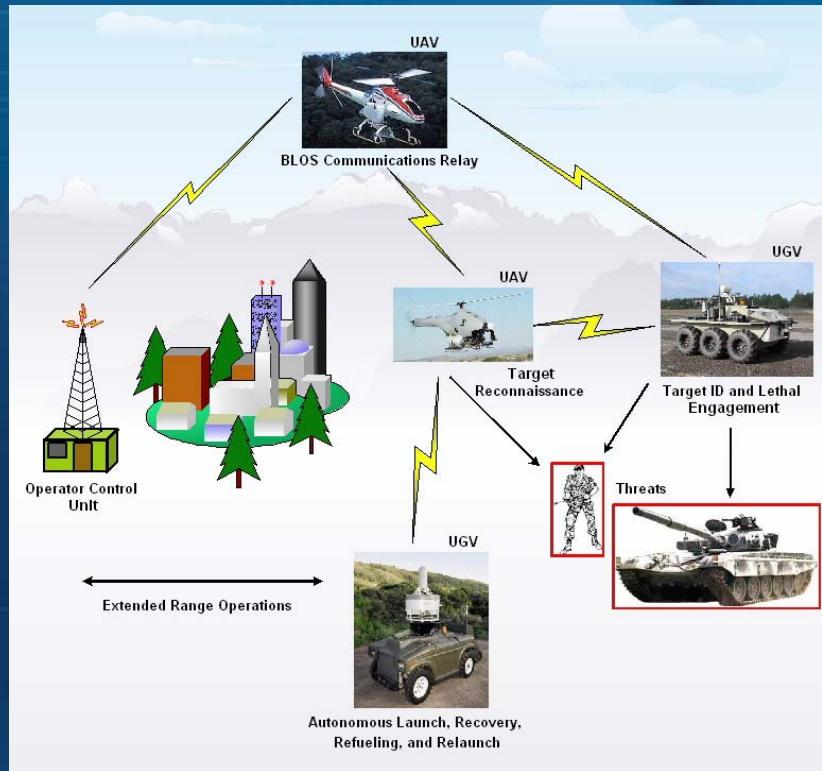
- Identify Force Protection solutions candidates for the Joint Force Protection Advanced Security System (JFPASS) JCTD
- Assess the feasibility of integration, automation and fusion of information
- Integrate Physical Security and CBRNE
- Exercise Joint CONOPS and TTPs
- Provide insight and analysis based on assessments and experiment results



## Accomplishments

- Demonstrated integration of:
  - lethal/non-lethal UGVs,
  - ground surveillance radars,
  - unattended ground sensors,
  - fiber optic fence sensors,
  - daylight/thermal/laser-illuminated imagers,
  - sniper detection sensors,
  - chemical, biological, and radiological sensors,
  - plume modeling.
- Conducted 4 operational assessments of CONOPS, TTPs, operator workload, and operational effectiveness
- Extended and integrated the SEIWG ICD-0100 XML protocol into JBC2S for Force Protection interoperability

# 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
- Forward deployment, launch, recovery, and refueling of a VTOL UAV by a UGV
- Target ID and lethal engagement

# Autonomous UAV Mission System (AUMS)

## Operational Relevance

- SSC-SD's portion of JCTE
- 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 and total UAV time on station
- Supports a variety of RSTA, site security, and Force Protection applications



## Accomplishments

- Developed an automated launch and recovery platform for use with a variety of Class 1 and Class 2 VTOL UAVs
- Established UAV test facility
- Developed automated refueling system for iSTAR UAV
- Demonstrated precision autonomous landing for a small VTOL demonstration UAV

# Automatically Deployed Communication Relays (ADCR)

## Operational Relevance

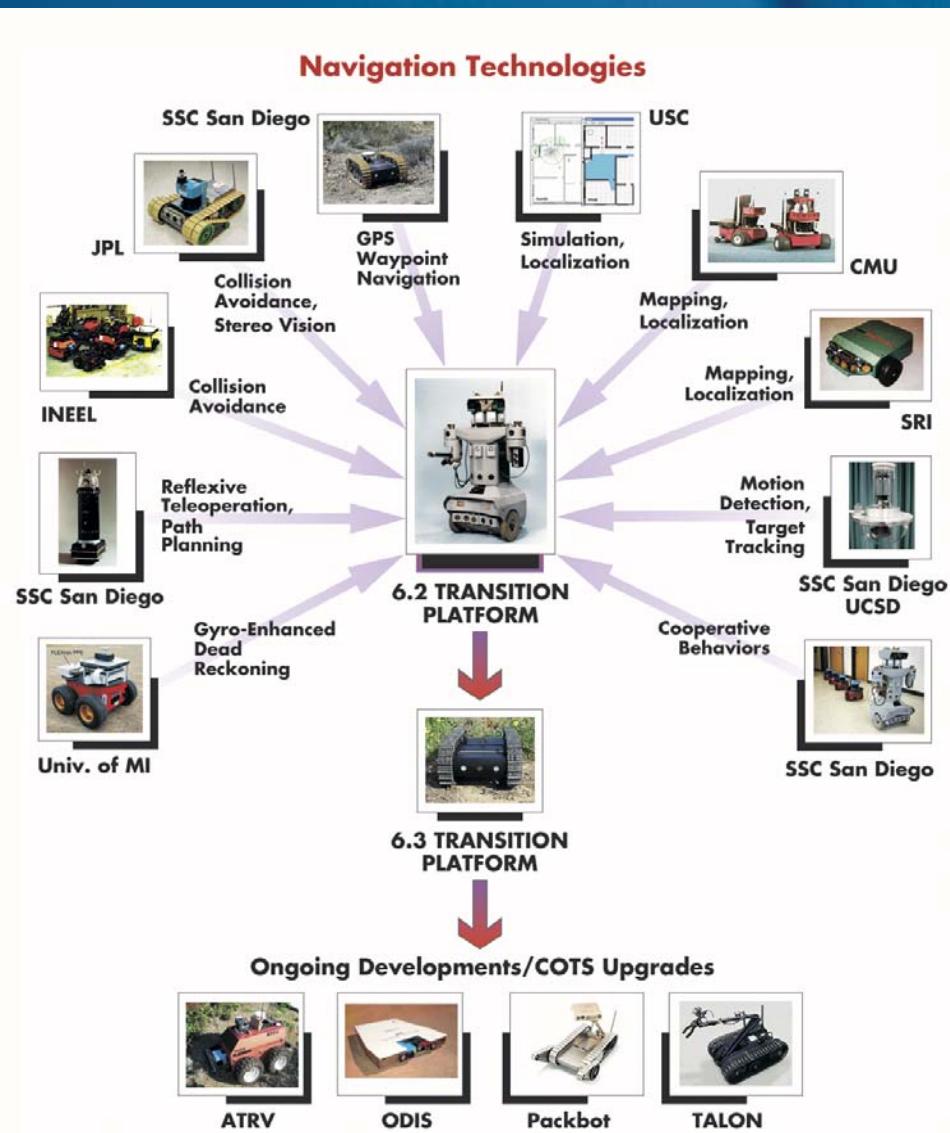
- Transitioned from DARPA-funded Autonomous Mobile Communication Relays (AMCR) project.
- Demonstrates automatic maintenance of high-bandwidth communication link between advancing robot and remote operator.
- Relay deploying module automatically ejects relay "bricks" as needed.
- Next step: concept exploration of *leave-behind networked sensors and other payloads*.



## Technology Development

- Self-righting relay brick with extending antenna.
- Deployment module carrying six relay bricks.
- Four complete systems produced.
- Next-generation systems being developed: smaller, more rugged, higher bandwidth, more secure.

# Robotics Technology Transfer



## Operational Relevance

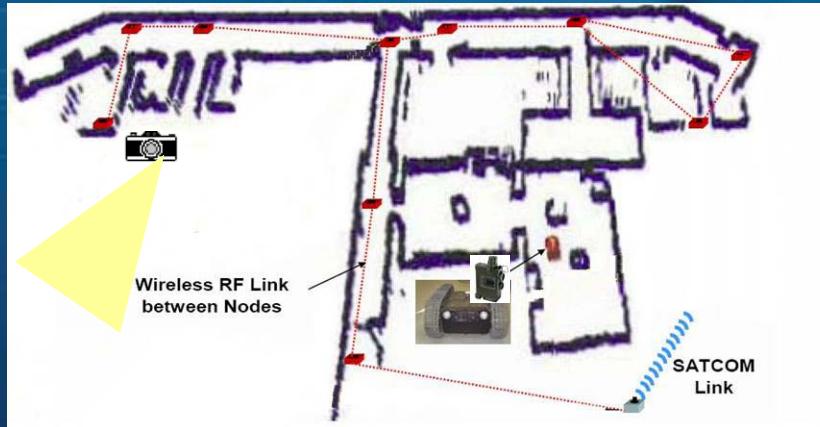
- Increase autonomy for ground robots.
- Harvests state-of-the art results of prior and ongoing robotic technology development efforts.
- Integrates various researched algorithms into a complete, single system.
- Optimizes a reconfigurable software framework for cross-platform compatibility.
- Provides a convenient enabling mechanism for the subsequent transfer into other programs.
- Enhances platform capabilities, human-robot interfaces, and behavior architecture.
- FY08 focus: *urban environment exploration*.

## Accomplishments

- Collision Avoidance – NRL/INL, JPL
- Localization/Mapping – USC, CMU, SRI
- GPS Waypoint Navigation – SSC SD
- Navigation in GPS-denied Areas – SSC SD
- Human Presence Detection – UT Austin
- Augmented Virtuality – INL
- ....

# Examples of recent TechTXFR collaborations

Collaborative R&D with the *Center for Commercialization of Advanced Technologies (CCAT)*



*CornerTurn, LLC*: Deployment of leave-behind sensor nodes using the ADCR system



*Space Micro Inc.*: Autonomously detect, identify, and locate radiation sources



*SAIC*: Demonstrate Bird Dog/Warfighter's associate concept

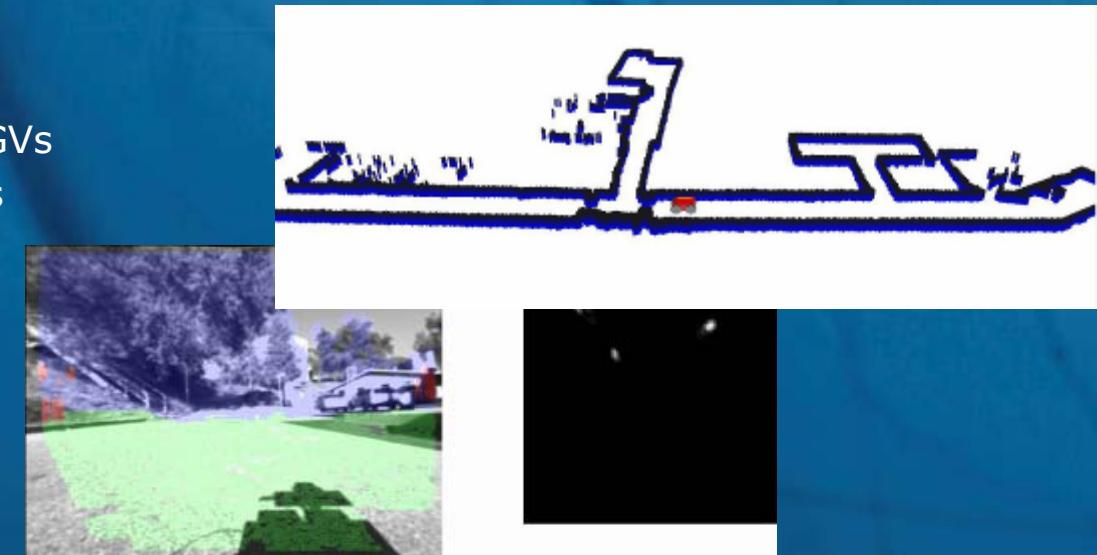


*iRobot Corp.*: Develop the Navigator (lidar, INU) and stereo vision payloads

# Autonomous Navigation for Small UGVs

## Operational Relevance

- Increase effectiveness of future small UGVs
- Overcome size and height disadvantages
- Open up new applications
- Target technologies:
  - Obstacle detection and avoidance
  - Non-GPS waypoint navigation
  - Retro-traverse
  - Guarded teleoperation
  - Leader-follower



## Accomplishments/Plans

- Focus on small, light-weight, low-power sensors and algorithms tailored for sensor and platform characteristics
- Jointly developed the SmartCam with JPL
- Currently working on a full FPGA implementation, giving full frame-rate stereo vision at high resolution
- Evaluating miniature ladar for Simultaneous Localization and Mapping (SLAM)

# 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.
- Metal Storm electronic weapon systems being considered.



# EOD Robotics Technology



## Operational Relevance

- Support NAVFEDTECHDIV on the Man-Transportable Robotic System (MTRS) Continuous Improvement Program and the Cooperative Robotics Program.
- Provide EOD tools integration with MTRS platforms.
- Demonstrate advanced technologies for increased autonomy.

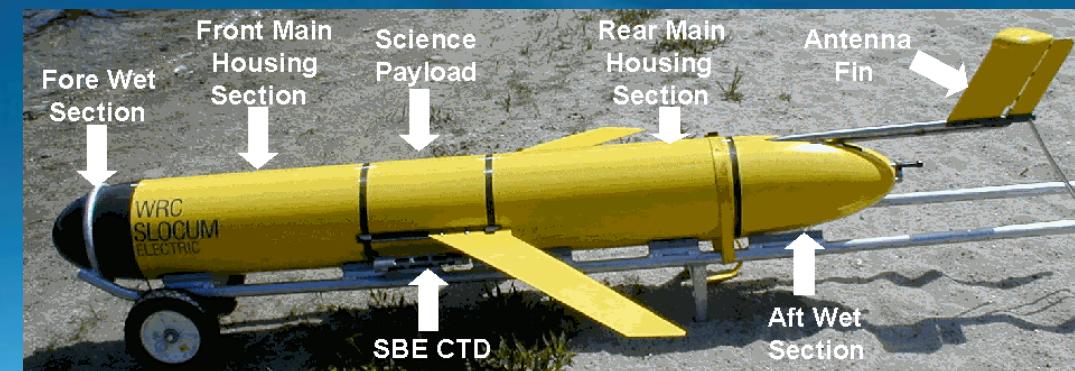
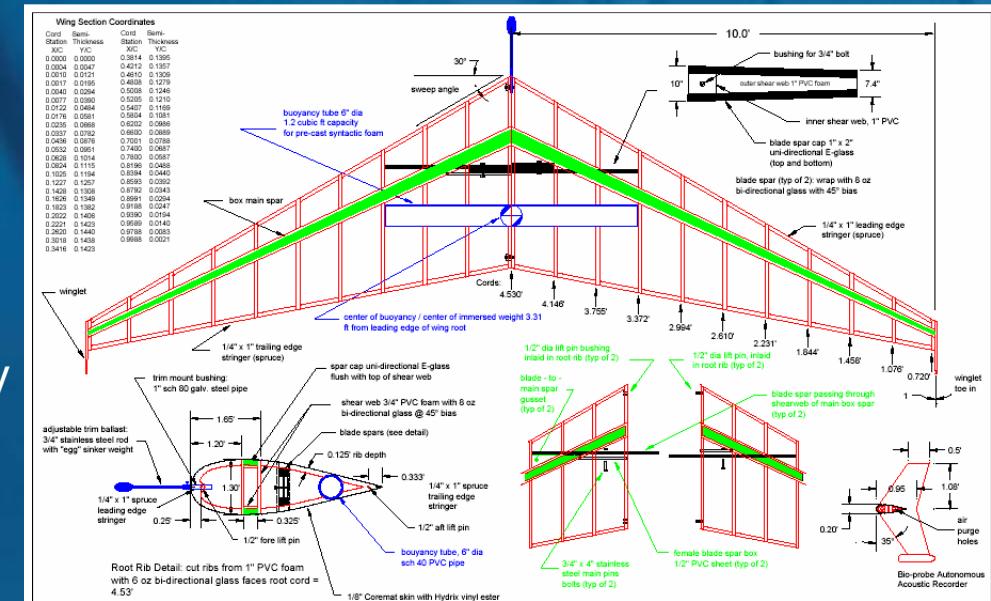
## Development History

- Designed and prototyped MTRS Mk1 (PackBot) and Mk2 (Talon) deployment mechanisms for disruptors and other EOD tools.
- Demonstrated technologies on MTRS platforms for:
  - GPS and non-GPS waypoint navigation
  - Video-based waypoint selection
  - Retro-traverse
  - Guarded tele-operation
  - 3D visualization
  - Simultaneous Localization and Mapping
  - Human Following
  - Multi-vehicle control (from single OCU)

# Underwater Gliders

*SSC is exploring and supporting a number of applications for undersea glider technology*

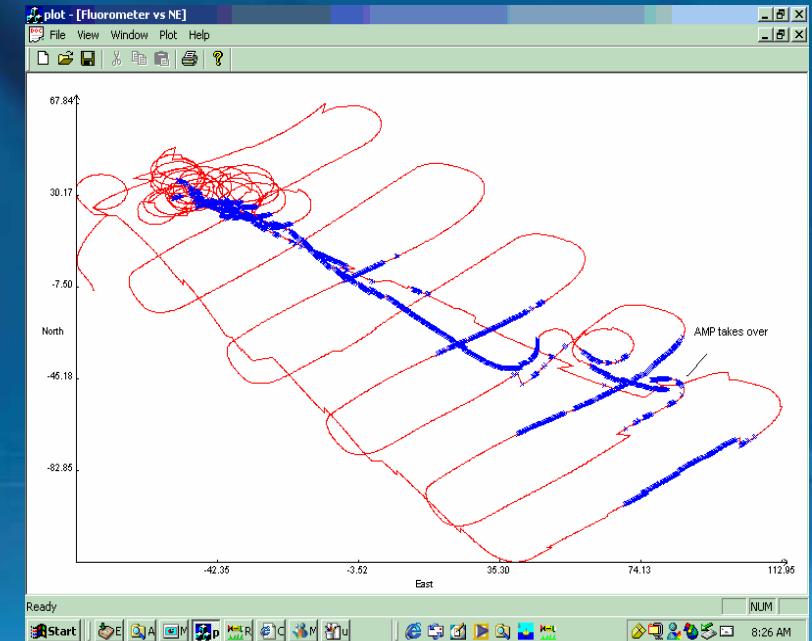
- Fixed Wing Glider
  - Form Factor Research
  - Missions/Payloads
  - Testing
- Surveillance Systems Demos
  - DADS Communication Gateway
  - Acoustic Surveillance Glider



# UUV Autonomous Controls: Adaptive Mission Planner

*The Adaptive Mission Planner, developed with UC Riverside, provides the vehicle with behavior-based, control commands using real-time sensor data.*

*The planner allows for higher-level autonomy for the UUV.*



Data Plot from AMP computer, 2003

# Mobile Robot Knowledge Base (MRKB)

<http://robot.spawar.navy.mil>



The screenshot shows the homepage of the MRKB. At the top, there's a navigation bar with links for File, Edit, View, Favorites, Tools, Help, Back, Forward, Stop, Home, and Links. The address bar shows the URL <http://robot.spawar.navy.mil/>. The main header features the text "Mobile Robot Knowledge Base" with a small robot icon, and "Joint Robotics Program" with a "TOP SECRET" classification stamp. Below the header, there are three tabs: "Technology Database", "Robot Pool", and "Technology Transfer". On the left, a sidebar lists various links under categories like Tech Database Home, Robot Pool Home, Tech Transfer Home, and others such as SSC Products, Navigation, Wireless Nodes, Object Avoidance, RSTA, Mission Payloads, Robotics Software, Platforms, Robotics Library, Site Sponsors, Contact Us, Robotics Newsletter, Robotics Home, and more. The central content area is titled "Mobile Robot Technology Database" and contains a brief description of the knowledge base's purpose and history. It also includes a note about clicking the menu to search or browse the database. Below this, there's a "Partners" section with logos for PM RUS, Office of the Secretary of Defense, and SPAWAR Space and Naval Warfare Systems Command. A footer at the bottom states: "This site is a resource for robot developers, program managers, and users. It is sponsored only by government organizations to ensure unbiased representation of components, subsystems, and platforms." The footer also includes a statement that it is an official U.S. Navy web site, links to Privacy and Security Notice and Contact Webmaster, and a note that it was last updated on Monday, November 10, 2003.

## Development History

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

## Operational Relevance

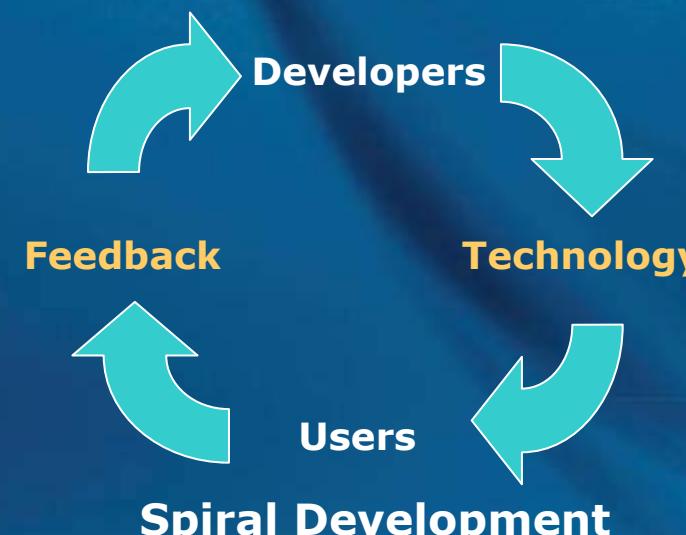
- Provides robotic system developers, program managers, and customers with a web-accessible, centralized knowledge resource for mobile robot components, subsystems, mission payloads, and platforms.
- Minimize redundant product research efforts, maximize efficiency and responsiveness.
- Facilitates technology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



This screenshot shows a search results page for "Unmanned Aerial Vehicle" on the MRKB. The top navigation bar includes "Technology Database", "Robot Pool", and "Technology Transfer". The main content area is titled "Unmanned Aerial Vehicle Results" and displays a grid of 17 items, each showing a thumbnail image of a different UAV model. To the right of the grid is a search form with fields for "Name", "Description", "Category", "Type", "Size", and "Status". The search results page also includes a "Search" button and a "Mobile Robot Knowledge Base Footer" at the bottom.

# Robotic Systems Pool (RSP)

- 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.



World Trade Center



Iraq/Afghanistan



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

Remington



ARA



Allen-Vanguard



Foster-Miller



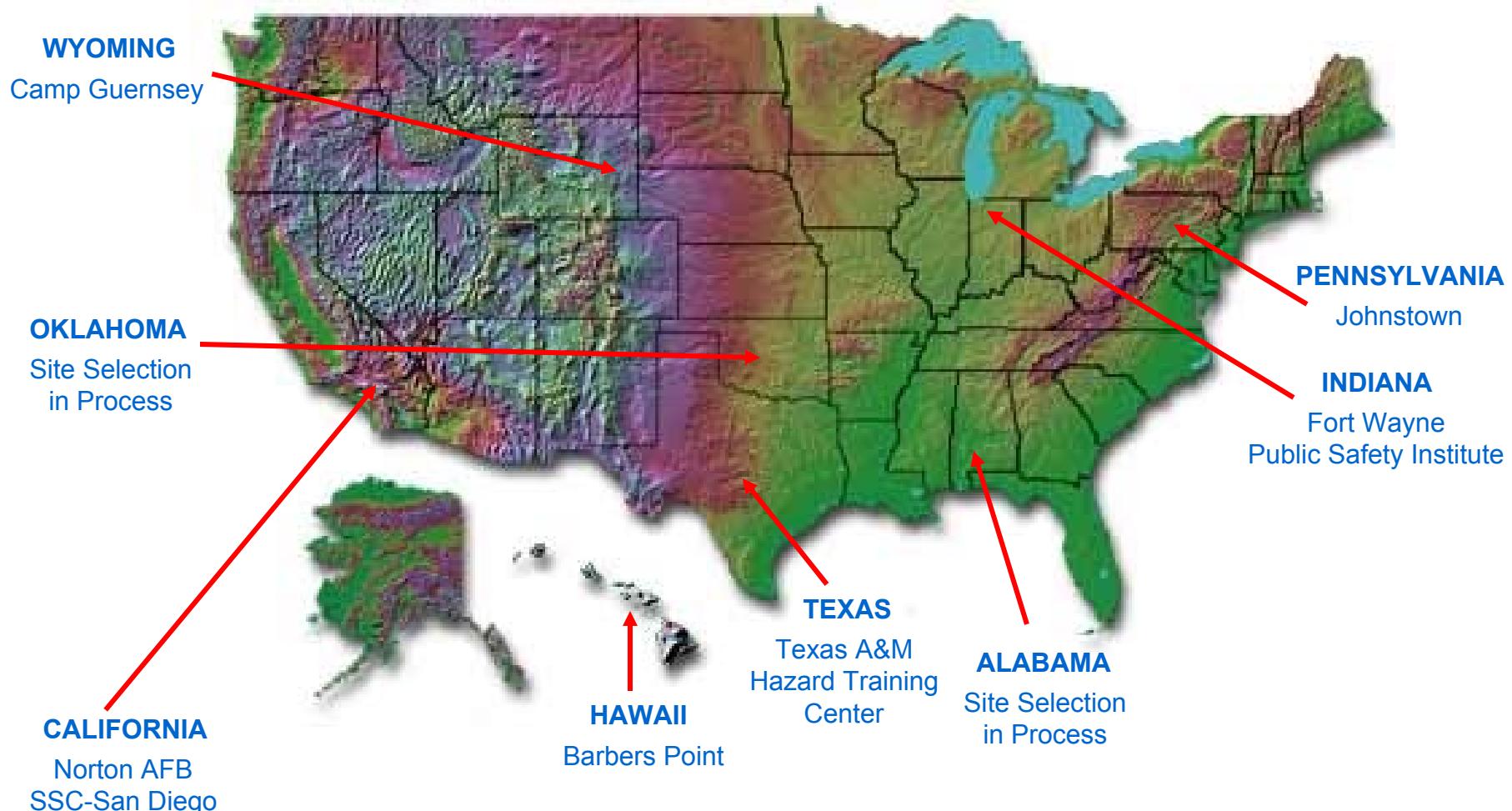
iRobot



Utah State University



# ASD (HD&ASA) Section 1401 Technology Outreach Centers





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