Eliminating the Operator Control Unit

H.R. Everett, Estrellina Pacis, Brandon Sights

SPAWAR Systems Center, San Diego

Presented by:

Brandon Sights

Human Factors Engineering Conference

HFE TAG Meeting – Command and Control

Alexandria, VA

November 03, 2004

Towards a Warfighter's Associate: Eliminating the Operator Control Unit

Outline

- Introduction
- Technical Challenges
- Natural Language Understanding
- Effecting the Desired Control
- Autonomous Behaviors

Report Documentation Page

Form Approved
OMB No. 0704-0188

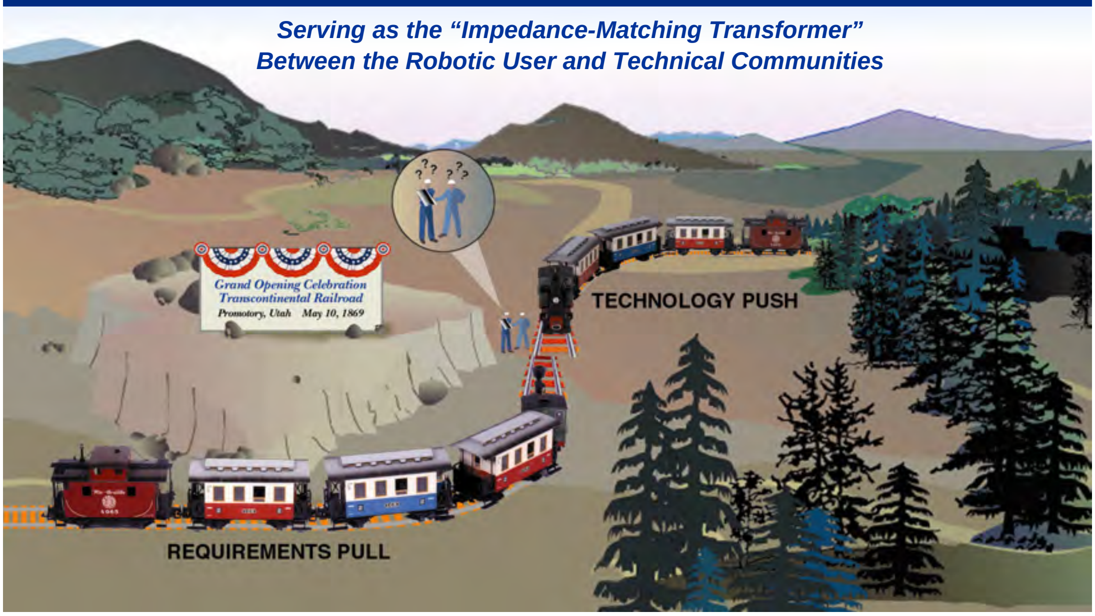
1. REPORT DATE **03 NOV 2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**
4. TITLE AND SUBTITLE **Eliminating the Operator Control Unit**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **SPAWAR Systems Center,53560 Hull Street,San Diego,CA,92152**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**19**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Towards a Warfighter's Associate

Introduction



Towards a Warfighter's Associate

Introduction

- About 200 man-portable robots deployed in-theatre
  - Foster Miller *Talons*
  - iRobot *Packbots*
  - Mesa *Matildas*
  - Remotec *Mini-Andros*
  - EOD Performance Inc. *Vanguards*
- Missions
  - Explosive ordnance disposal (EOD)
  - Scouting unsecured bunkers, buildings, caves

ALL ARE STRICTLY TELE-OPERATED

ALL HAVE PROPRIETARY VENDOR-SPECIFIC OCUs

Towards a Warfighter's Associate

Introduction

- A significant performance trade-off exists
  - How well do the robots assist users in performing their jobs?
  - How much does the OCU interfere with the users' abilities to perform/survive?
- Solution
  - Make robots more functional with greater autonomy
  - Minimize or eliminate the OCU
  - Make robots more desirable for alternative tasks

Towards a Warfighter's Associate

Introduction

- **Near Term Goal: Provide a Common OCU**
  - Simplifies training and logistics support
  - Promotes interoperability
- **Long Term Goal: Completely Eliminate the OCU**
  - Ongoing development efforts to equip warfighter with Voice-Over-IP technologies:
    - Land Warrior, Raytheon Systems Company
    - Advanced Robotic Controller (ARC), Exponent
    - Others
  - Supports bi-directional audio, video, maps
  - This same HW provides all that is required to control the robot

Towards a Warfighter's Associate

Introduction

WARFIGHTER'S ASSOCIATE CONCEPT

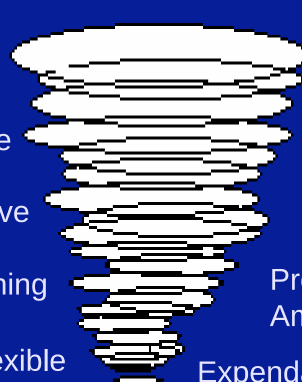
- Sophisticated robotic system
- Accompany warfigher during mission execution
- Synergistic teaming of human and machine
- Uses existing communications equipment
- No dedicated OCU required

Towards a Warfighter's Associate

Introduction

SYNERGISTIC HUMAN-MACHINE TEAMING

Human Characteristics	Machine Characteristics
Extremely Adaptive	More Robust
Very Perceptive	Fearless
Capable of Reasoning	Process/Analyze Large Amounts of Data
Amazingly Flexible	Expendable



Towards a Warfighter's Associate

Introduction

ENVISIONED ROLES OF WARFIGHTERS ASSOCIATE

- Complement and safeguard the human partner
- Handle any high-risk tasks
- Perform mundane and tedious tasks
- Serve as subject matter expert on demand
  - Field interpret/translate foreign language
  - Provide repair/maintenance instructions
  - Oversee field medical procedures
  - With internet access, provide limitless knowledgebase

Towards a Warfighter's Associate

Introduction

CONCEPT DEVELOPMENT PLATFORM

- Leveraging existing laboratory prototype
- Sophisticated navigation, collision avoidance, mapping, and surveillance schemes
- 90-amp-hour battery
- Extensive self diagnostics
- Size compatible with SICK laser

ROBART III

Towards a Warfighter's Associate

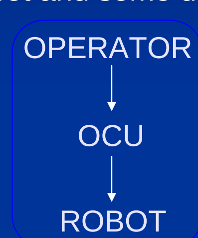
Technical Challenges

- **Mobility**
  - Many different options (wheels, tracks, legs)
  - Other development efforts addressing this issue
- **Navigation**
  - Localization & collision avoidance
  - Fairly robust solutions currently available
- **Power**
  - Improved power sources will be required
  - Other efforts addressing this issue
- **Command & Control**
  - Need to reduce operator control burden
  - Major thrust of our effort

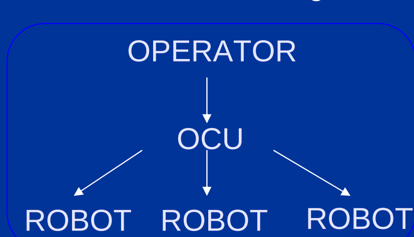
Towards a Warfighter's Associate

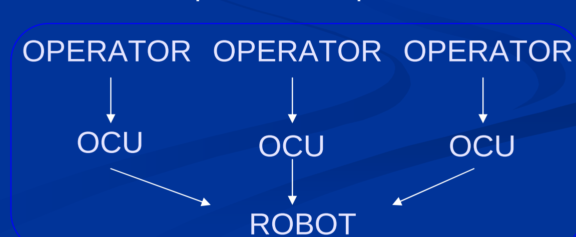
Command & Control

In the beginning, there was a one-to-one correspondence between the robot and some dedicated controller



This is evolving to multi-robot, multi-operator complexities





Towards a Warfighter's Associate

Command & Control

- Eliminated prior one-to-one robot/CPU association
- Allowed multiple robot control including robots of different types

OPERATOR
↓
OCU
↙ ↓ ↘
ROBOT ROBOT ROBOT

MDARS Multiple-Resource Host Architecture

Towards a Warfighter's Associate

Common OCU

SSC-SD's Common OCU, which runs the Multi-Robot Operator Control Unit (MOCU)

- One operator can control multiple robots as with MRHA
- Multiple operators can now control same robot
- Will support handoff from team to team
- Plug-n-play modular I/O

OPERATOR OPERATOR OPERATOR
↓ ↓ ↓
OCU OCU OCU
↘ ↓ ↙
ROBOT

Towards a Warfighter's Associate

Common OCU Hardware

- Handheld unit

Top

Snap-on Controller

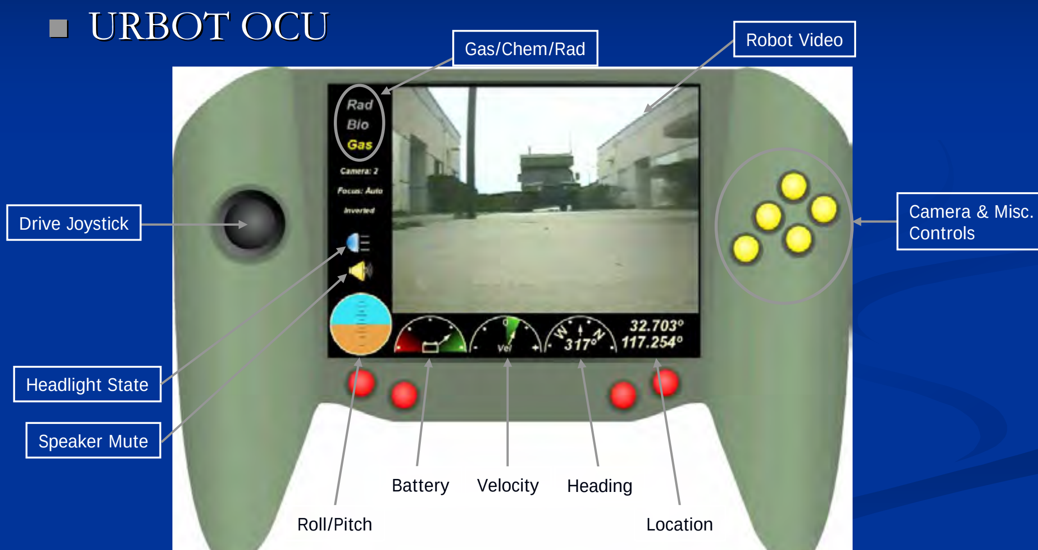
Bottom

Features:
- Common Display Unit
- Snap-on controllers (left and right)
- 6.4" Sunlight readable display
- Real-time video display
- Robot status display w/ gauges

Towards a Warfighter's Associate

Sample OCU

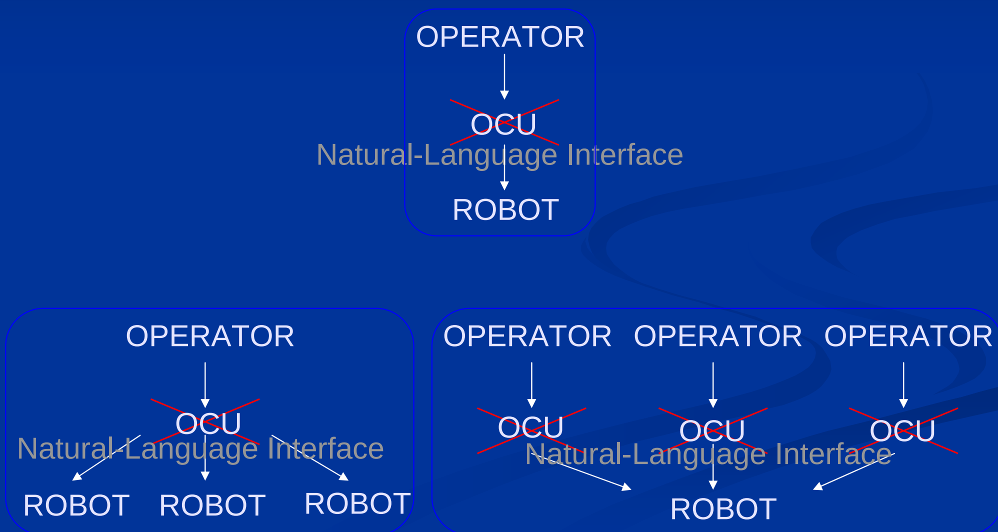
- URBOT OCU



Towards a Warfighter's Associate

Command & Control

LONG TERM GOAL: ELIMINATE OCU ALTOGETHER



Towards a Warfighter's Associate

Natural Language Interface

Bidirectional Voice I/O Requirement

- Generate speech (speech synthesis)
  - Very mature technology
  - Unlimited vocabulary
- Understand speech
  - Recognize spoken words
  - Parse resultant text
  - More difficult to do

Towards a Warfighter's Associate

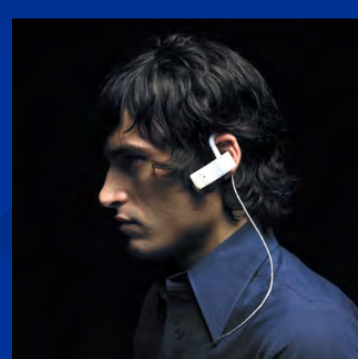
Voice Recognition

- Recognition Algorithm: Incoming Speech ⟶ Text String
- Commercial Voice-Recognition
  - Exploits high signal-to-noise ratio w.r.t. incoming audio stream
  - Speak directly into a boom mike/telephone mouthpiece
  - Pre-taught voice signatures
- Battlefield Environment
  - Much noisier unstructured environment
  - Increase in voice pitch, speed, volume when under stress

Towards a Warfighter's Associate

Voice Recognition

- Bone-conduction Headsets
  - Microphone as well as earphones
  - Acoustically coupled with the bone structure of the skull
- *Jawbone*
  - Two audio microphones
  - Bone-conduction sensor
  - DSP to subtract background noise

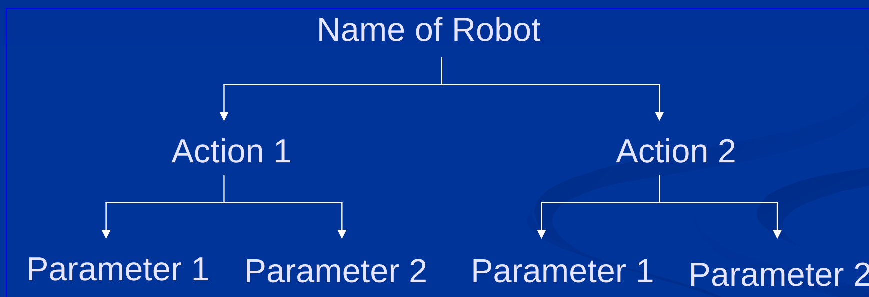


Jawbone

Towards a Warfighter's Associate

Text Parsing

- SIMPLISTIC CASE: Translating structured text string into a command using layered-menu conditional-branching approach



- MORE DIFFICULT CASE: Parsing lengthy unstructured text
- WARFIGHTER'S ASSOCIATE: Needs are in the middle
  - Semi-structured text
  - Fairly short phrases

Towards a Warfighter's Associate

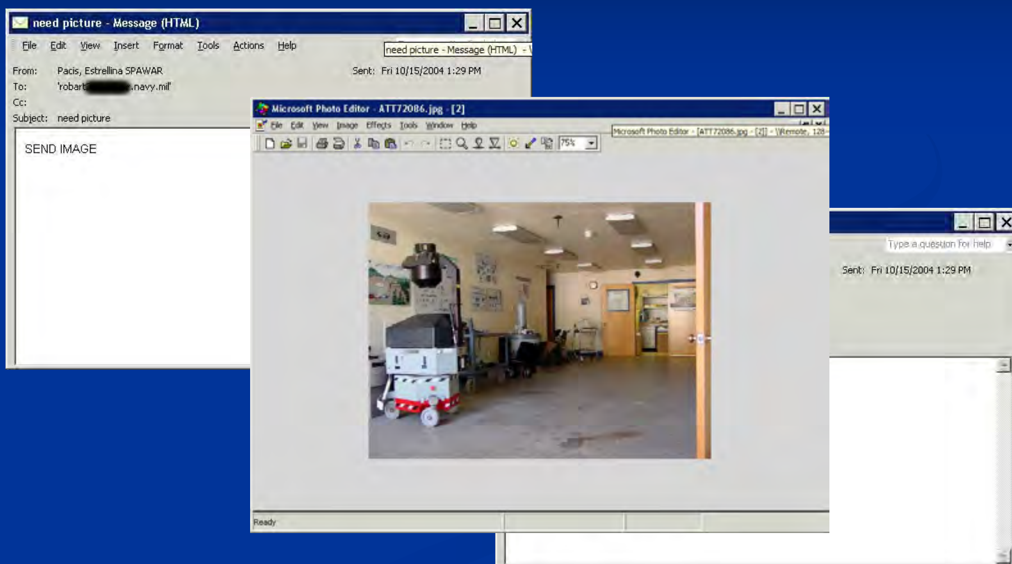
Text Parsing

- Developed prototype unstructured text parser
  - Accepts dictated or typed text input
  - Email interface allows independent development
    - Decouples speech-recognition errors
    - Provides useful robot-human interface

ROBART III

Towards a Warfighter's Associate

Email Interface



Email sent to and received from *ROBART III* requesting an image.

Towards a Warfighter's Associate

Effecting the Desired Control

Requires some common frame of reference

to which both human & robot can relate

- Robo-Centric – Relative to robot itself
- Vision-Centric – Relative to robot's camera view
- Model-Centric – Relative to absolute world model

COMBINATION OF THESE APPROACHES PROVIDES THE MOST FLEXIBILITY

Towards a Warfighter's Associate

Robo-Centric Reference

- Relative to robot itself
  - Send low-level motion commands (turn left, right)
  - Initiate sensor-assisted motion (follow the wall to the left)
- Control camera gaze (pan left, pan right)
- Too restrictive and operator intensive in general

SPAWAR Systems Center San Diego

Towards a Warfighter's Associate

Vision-Centric Reference

- Relative to robot's camera view
- Operator looking at video feedback
  - Provides direction based on common video image
  - "Enter doorway in front of you"
  - Vision system looks for and highlights doorway
- Can also illuminate attributes of interest with laser pointer

SPAWAR Systems Center San Diego

Towards a Warfighter's Associate

Vision-Centric Reference

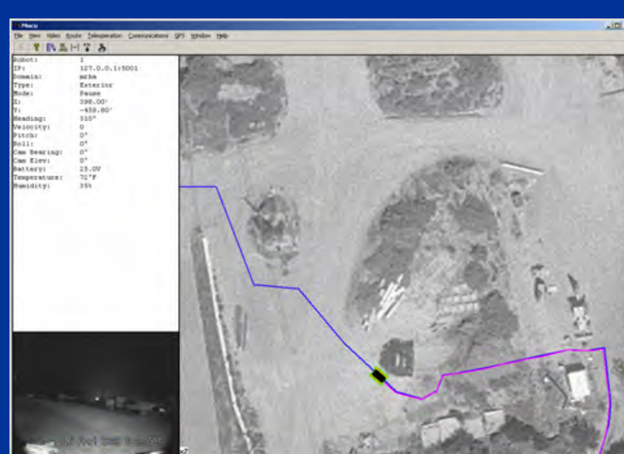
- Very appropriate for high-level weapon control
  - Database of targets and their vulnerabilities
  - Search-and-destroy:
    - Identifies object
    - Zooms in on vulnerability
    - Non-lethal weapon cued

Search Algorithm on *ROBART III*

Towards a Warfighter's Associate

Model-Centric Reference

- Relative to an absolute world model
- Outdoors – GPS
  - *MOCU*
  - Operator draws desired route
  - Alternatively selects waypoints or goal destination



MOCU Display

Towards a Warfighter's Associate

Model-Centric Reference

SPAWAR Systems Center San Diego

- Indoors – GPS not available
  - Must localize using range data from surroundings
  - *MDARS-I* had a priori map
    - Executes virtual paths to predefined nodes
    - Not practical in tactical applications

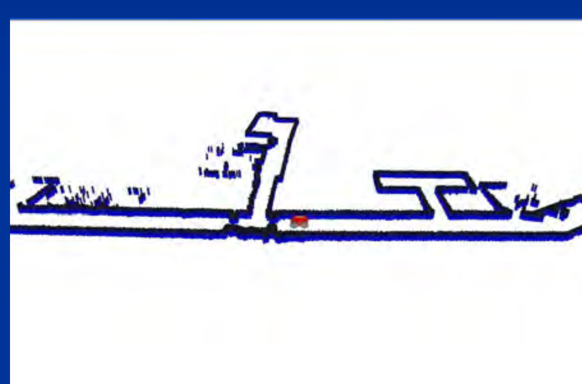
MDARS-I patrolling Camp Elliot Warehouse in 1995.

Towards a Warfighter's Associate

Model-Centric Reference

SPAWAR Systems Center San Diego

- SRI International
  - No a priori knowledge
  - SLAM
- INEEL
  - Collision Avoidance
  - Grow to "3D" representation
  - Awkward to send coordinates (i.e., go to 1200, 3250)

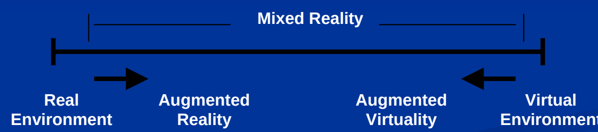


Autonomously exploring Battery Woodward (an underground WWII bunker) at SSC-SD

Towards a Warfighter's Associate

Model-Centric Reference

Reality-Virtuality Continuum as proposed by Milgram



Real Environment – Robot's video feedback

Virtual Environment – Represented by SLAM model

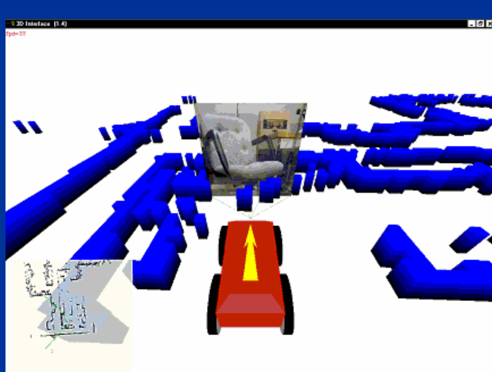
Augmented Reality – Link additional info to video image as pop-up overlay

Augmented Virtuality – Link additional info from other sensors (or from operator) to SLAM model

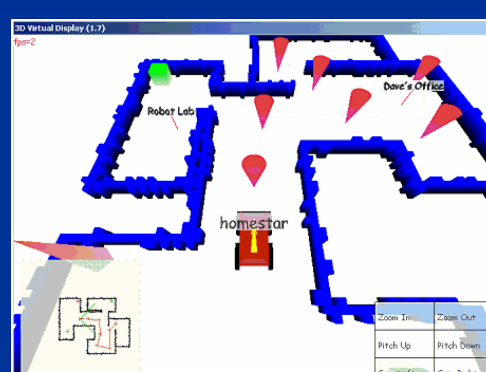
Towards a Warfighter's Associate

Model-Centric Reference

Augmented Virtuality – link additional sensor info to SLAM model



Virtual model fused with video image input from video sensor onboard the exploring robot.



Virtual model fused with room identification tags from operator input.

Towards a Warfighter's Association

Providing high-level (natural-language) direction implies the robot must be able to execute high-level autonomous behaviors.

- What do we have working now?
- What are we going to do next?
- What's further down the road?

Towards a Warfighter's Associate

Autonomous Behaviors

Working Now:

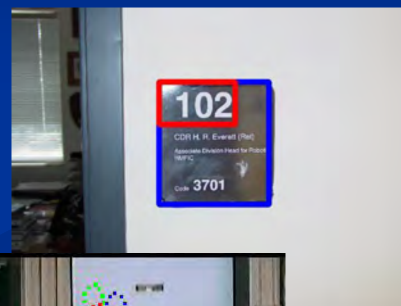
- Basic/high-level mobility commands
- Explore & map structure
- Building sweep
- Surveillance
- Motion detection
- Target following video
- Weapon control
- Convoy capability video
- Progressive sleep mode
- Automated recharging or refueling
- Self diagnostics
- Send/receive email with attachments

Towards a Warfighter's Associate

Autonomous Behaviors

Focus in FY-05:

- Simplistic sign interpretation
- GPS waypoint navigation
- Visual landmark homing
- Motion detection-on-the-move



SSC-SD

Perceptek

Towards a Warfighter's Associate

Autonomous Behaviors

Investigating further down the road:

- Complex sign interpretation
- Face recognition
- License-plate capture
- Foreign-language interpretation

Towards a Warfighter's Associate

Conclusion

- Need more autonomous robotic functionalities
  - Technology Transfer program improves functionality and autonomy of candidate platforms.
- Need to lessen control burden on operator by minimizing/eliminating the OCU
  - Common OCU (standardized, modular, plug-n-play)
  - Natural-language interface
  - Common frame of reference incorporating robot-, vision-, and model-centric
  - Expansion of SLAM model for augmented-virtuality