



TACTICAL ROBOT TECHNOLOGIES FOR EXTRA TERRESTRIAL EXPLORATION



T M R



Tactical Mobile Robotics (TMR)

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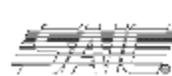
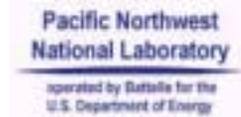
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“Those who cast the votes decide nothing.
Those who count the votes decide everything”
- Josef Stalin



THE TMR TEAM

Academia + Industry + DOE \Leftrightarrow DoD





GOVERNMENT RESEARCH ASSISTANCE





Ground Based Operational Environments



NASA: Extra Terrestrial



- > **“Simple” weather effects**
- > **Minimal human interaction**
- > **Sparse, static**
- > **Optimized *a priori* analysis**
- > **Micro gravity**
- > **Temp / Pressure differential**

DoD: Terrestrial / Urban

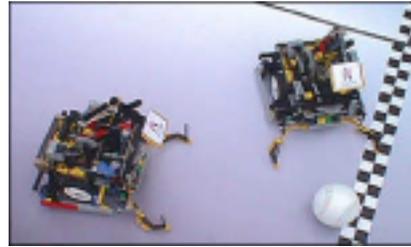


- > **Complex weather effects**
- > **Extensive Human interaction**
- > **Cluttered, dynamic**
- > **Heuristic, hasty planning**
- > **ADAPTIVE execution**
- > **Indigenous interference**
 - **Flora, Fauna**
 - **Humans: Innocent / curious, Hostile / aggressive**



TOY V. TMR

Tactical Robot Imperatives



- > **SOFROB: Tumble Recovery**, (Self righting, Invertible, Anti-Snag, Etc.)
- > **SOUSE 2: Robust Interface: Auto-signal acquisition** (do something less than dumb to recover)
- > **SOUSE 3: Anti- Handling / Anti-Tampering** (OPFOR, indigenous personnel, wildlife, etc.)
- > **SOMROPE: Self-Location**: (accuracy based on situational context)
- > **SOMROPE: Complex Obstacle Negotiation**: OD/OA insufficient

- > **TACTICAL VALUE >> OPERATIONAL BURDEN**
 - robotics niche => denied area access
 - portability => sweet spot



Tactical Value (2)

Survivability

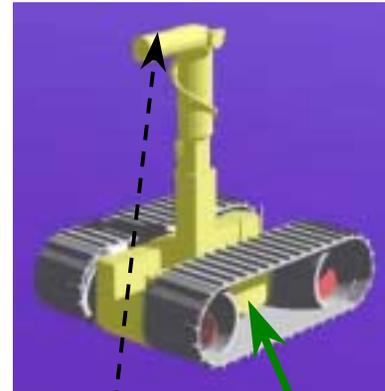


Very Vulnerable

- Impact
- Blinding
- Size limited
- Articulation limited

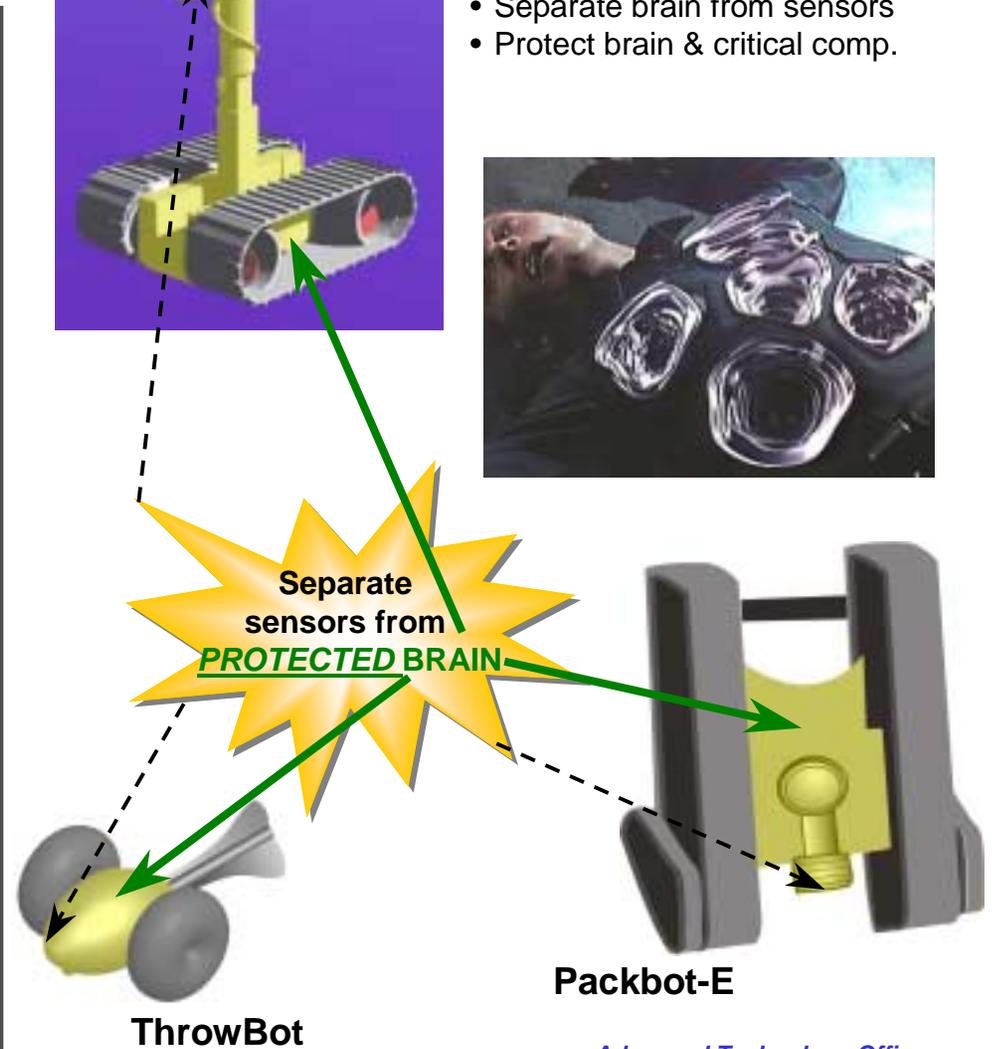
Problems:

- 1) "Sensor Suite & Brain Housing" Is co-located
- 2) Mass, volume, structure dictate energy absorption



Robust Design Flexibility

- Separate brain from sensors
- Protect brain & critical comp.





Bio Inspired Innovation

Surpass Human Capabilities



> Bio Inspired but mechanically expanded

> Marsupial Operations

- Air – Ground perspective
- Care and feeding
- Collaborative mobility
- Self recovery

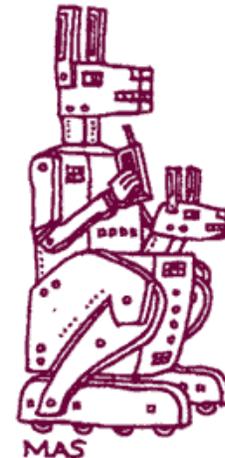
> Adaptive Manipulation

- Adaptive manipulation
- Stable non-compressive grasp
- Variable volume objects
- Confined space access

> Mobility

- Legged Efficiency
- Humanoid bullet magnet

> Human Robot Interface





Goal: *Exploit Freedom of Design*

Exceed Human Exclusive Performance



- **Confined Space Access**
 - OPERATE IN CLUTTER
 - No size constraints => variable volume
 - No articulation constraints => variable geometry
- **Survivability**
 - EMOTIONAL FREEDOM
 - Signature: visual, I.R.
 - Ballistics: small arms, shrapnel
 - Blast effects: over pressure
 - EM: radiation, extreme temps, etc.
- **Hybrid Design**
 - Wheeled tracks
 - Legged wheels
- **Denied Area Awareness**
 - Multi-sensor perspective
 - Ground zero strike assessment
- **Operational Influence**
 - Exploit bottlenecks: stairwells, doorways
 - Distracter / Bullet Magnet / Remote voice
 - NLW juggernaut



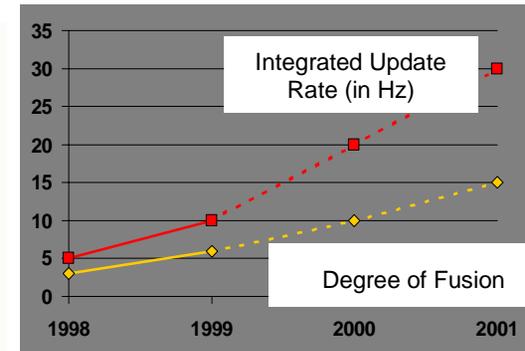
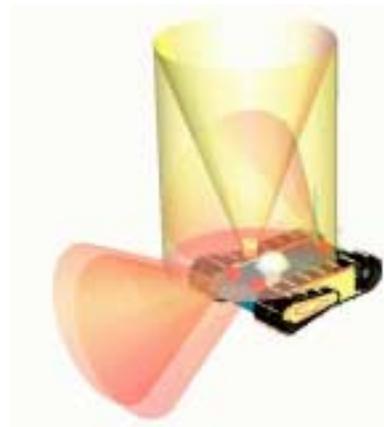
TMR Technical Progress

Phase I Enabling Technology Development



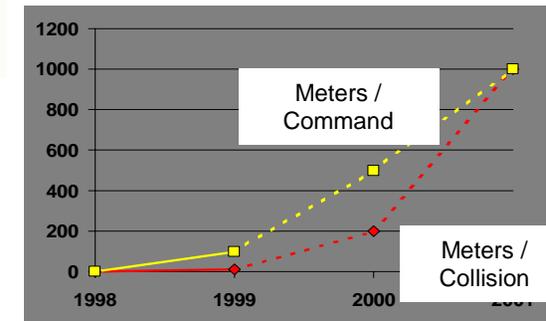
PERCEPTION: on track, **BUT...**

- 20Hz goal on track: @ 10Hz in FY99
- 7 modalities into Sense Net
- **NEED UWB MIR**



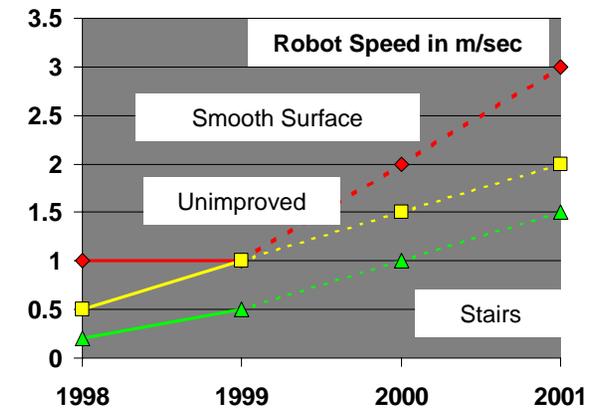
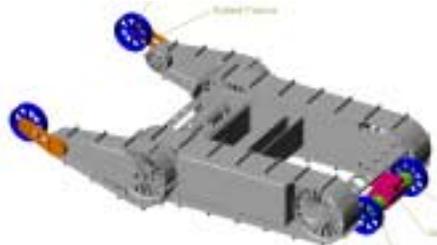
AUTONOMY: exceeded expectations

- 100m/cmd & auto stair climb: FY99
- self recovery behaviors: 01/00
- gradient method results



MOBILITY: below expectations

- stair climb successful in FY 99, but...
- 1m/sec too slow for tactical significance
- **COMPETE** hybrid techniques (wheel/track combo), variable volume, etc
- **SURVIVABILITY !!!**



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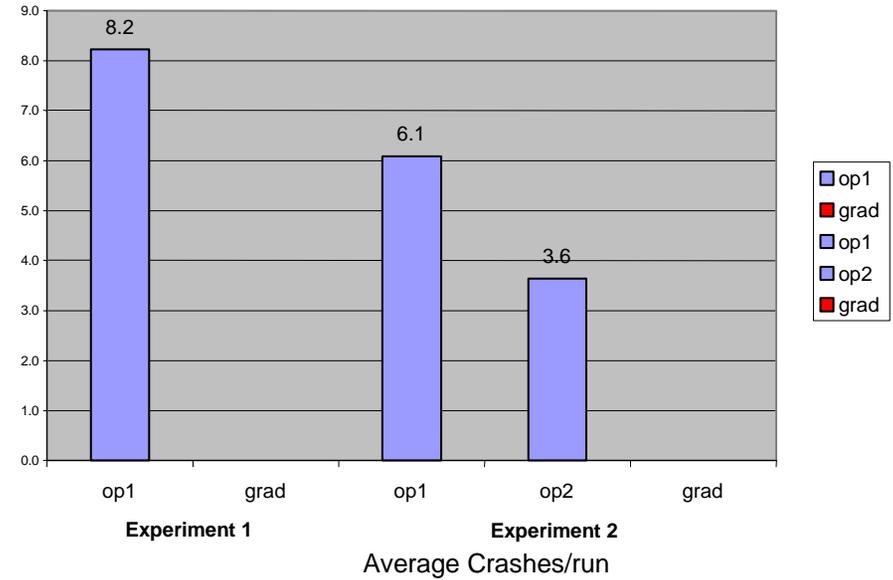
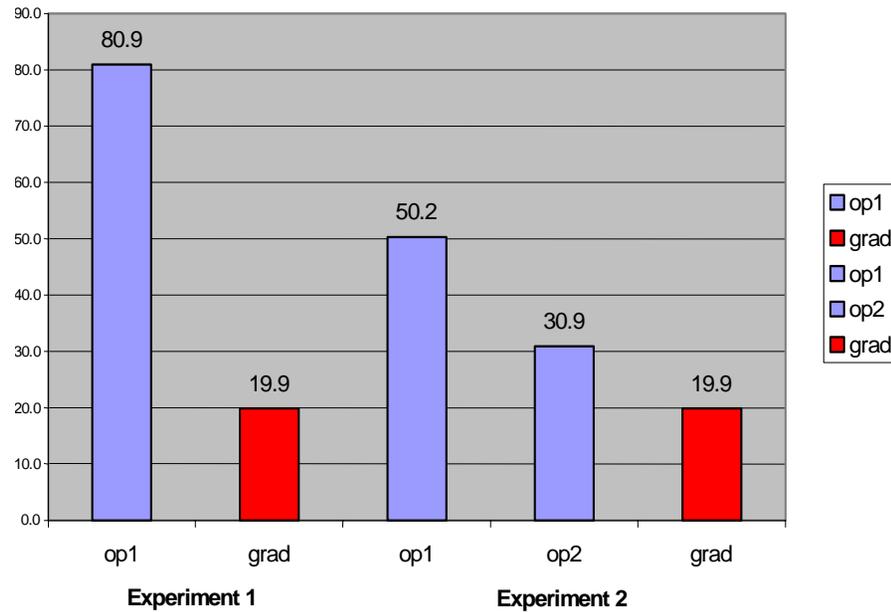


Technical Progress: Autonomy: SRI's Gradient Method

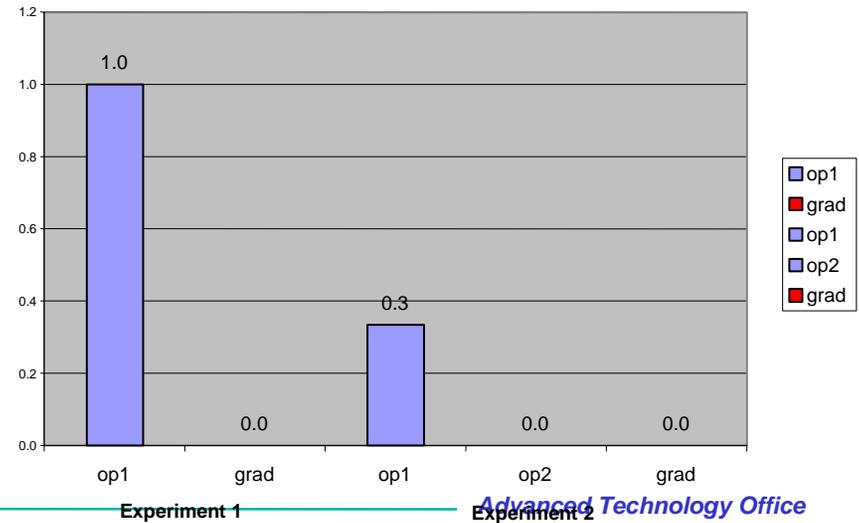


Average Keystrokes/sec

AverageTime (secs)



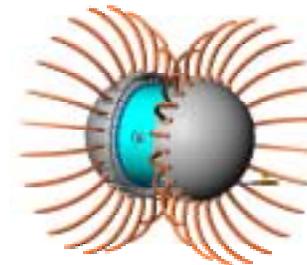
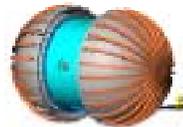
Average Crashes/run





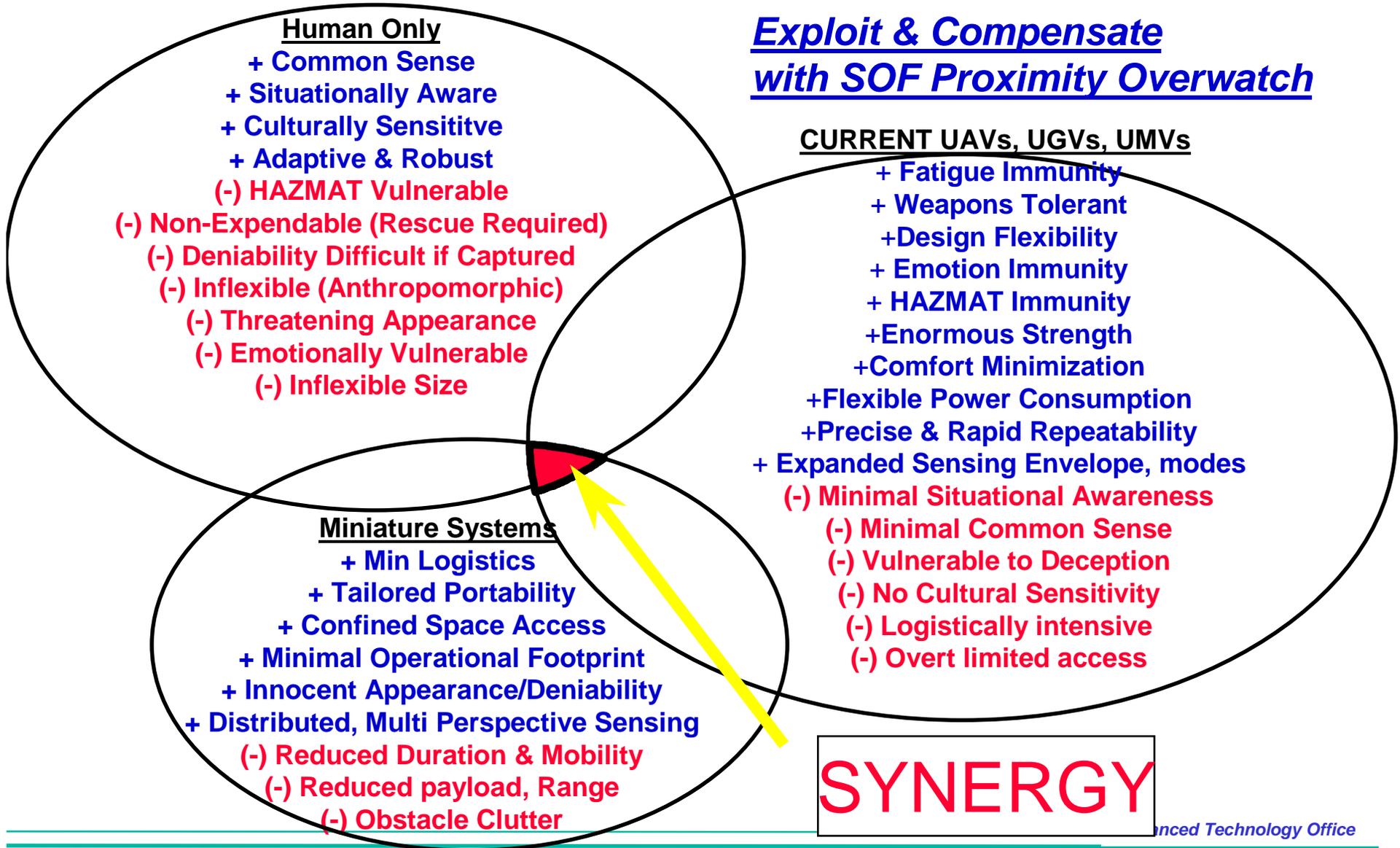
TMR Systems Development Progress

Phase II Platform Design and System Integration





Tactical Mobile Robotics Synergy



Exploit & Compensate with SOF Proximity Overwatch

CURRENT UAVs, UGVs, UMVs



UGV OCU v. TMR RSIU



> Operator Control Unit (OCU)

- Tele-op oriented
- Generally assumes dumb robot
- Immersive
- Exhausting
- Single platform oriented
- Hand carried joy stick / lunchbox

> Robot Supervisor Interface Unit (RSIU)

- Non distracting
- “Simple” decisions offloaded to robot
- Robust self correcting behaviors executed on board
- Heterogeneous Multi-platform control





Progress: Human Robot Interface

Alert Based Human Robot Supervision



- > **Hardware:** gloves, bone- phones, geo-tactile pads, wearable computer
- > **Objective Offload simple decisions to robot**
 - > Obstacle detection, avoidance, negotiation
 - > Simple maneuver & target approach
- > **ALERT BASED human override for complex decisions**
 - > Task complete enough?
 - > Route blocked, re-plan or breach?
 - > Exploit opportunity?
 - > Engage self protection?



robot_2.avi

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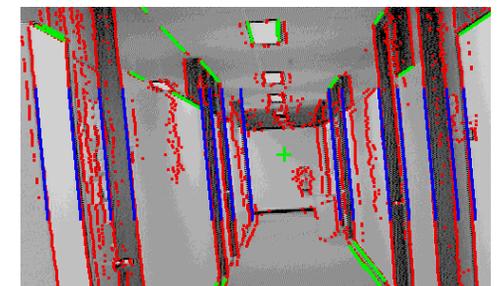
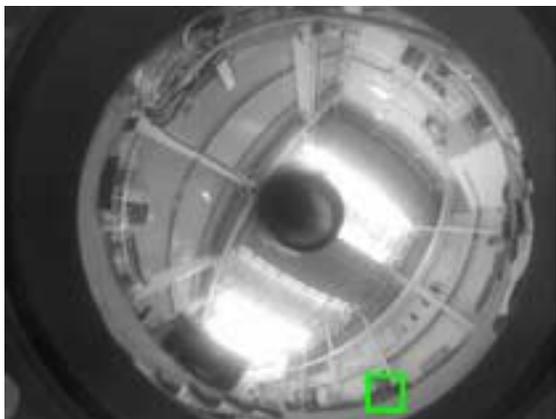
Perceptual Expansion



Omni-camera de-warping



Visual Servo Template Selection





TMR Experimentation Process



No Picture



Initial HRI Experimentation Results

trend toward specialized skill set



> Research Questions

- New MOS?
- New organization?
- What do we measure as correlation of competence?
 - Individual
 - collective

> Initial conclusions

- ASVAB score inadequate
- Spat-A tests have initial correlation to
- Multi-modal human threshold



Perceptual Metrics

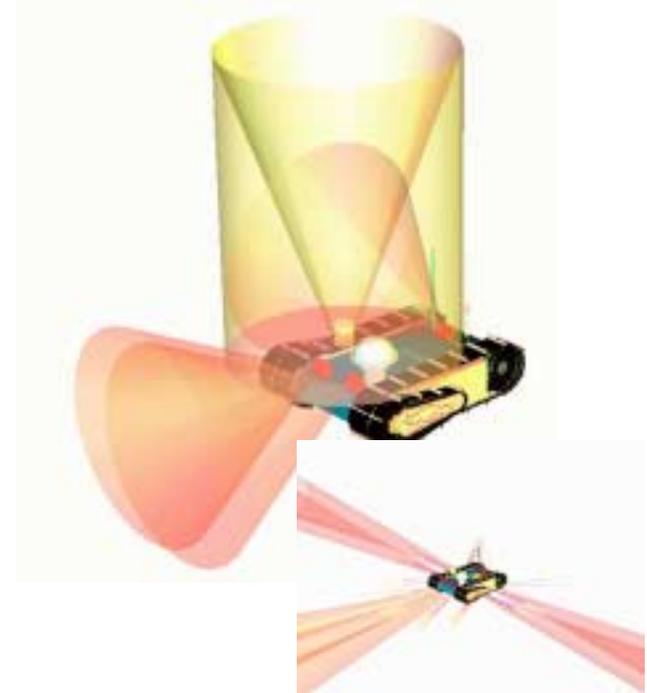
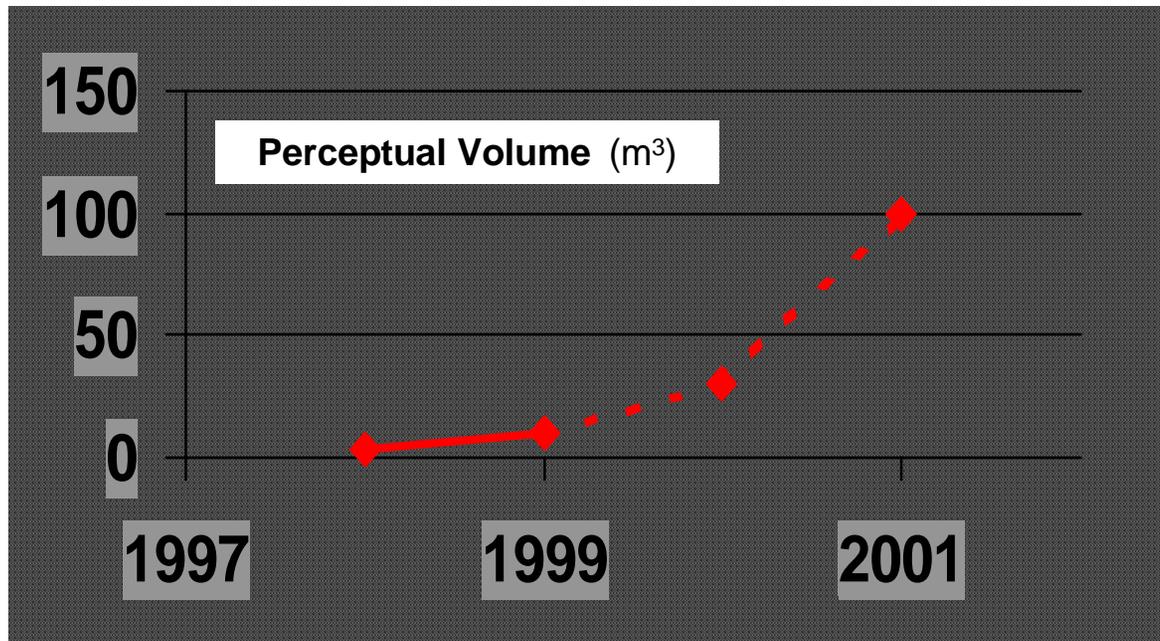
Task 0200 Perception: External Aggregate



Minimum Useful Resolution (MUR) is defined as the minimum resolution needed to have a reasonable chance of accomplishing a useful task (such as a 90% probability of visual identification of a human at a given range, localization of the sound of a rifle bolt closing, etc.).

Effective Performance Span (EPS) is defined as the volume of coverage (in cubic meters) from an organic TMR sensor, outside of which its resolution falls below the **MUR** threshold.

Perceptual Volume (PV_t) is defined as the sum of EPS volumes which contributes to the overall awareness of a TMR's external environment across all available sensing modalities for a specific task.



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Human Perceptual Fusion Threshold (s)



> Now:

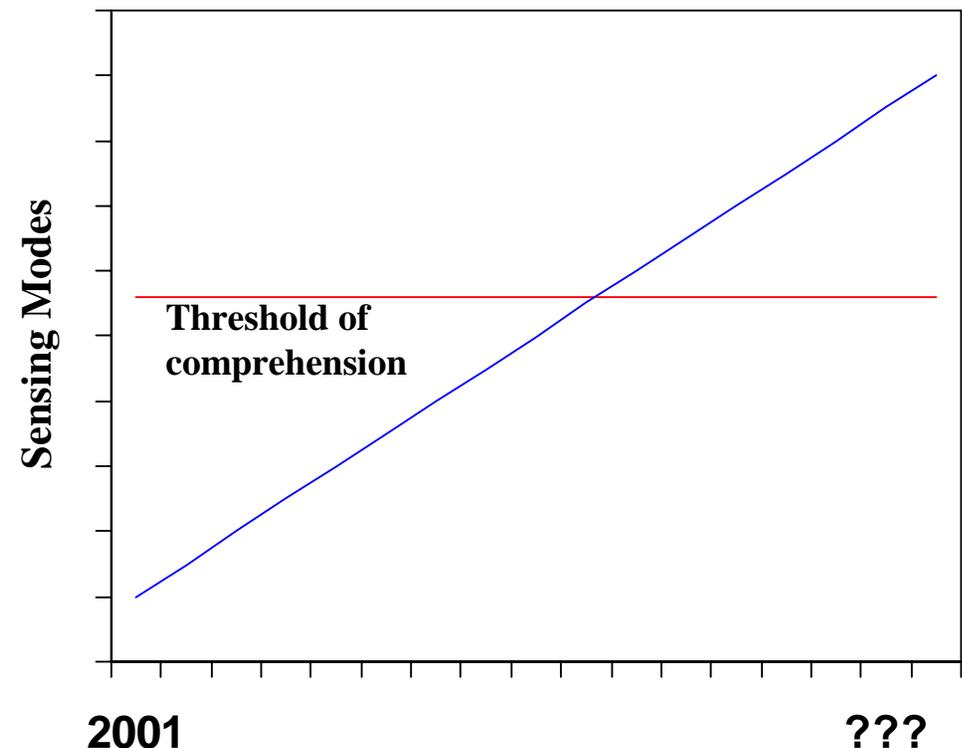
- Tele-operated platforms generally < 5 modalities

> Future:

- “Smart” robots will have >> 5 sensing modalities
- Perceptual volume for future robot will increase significantly

> ISSUE:

- **Where is the threshold of human absorption?**
- **Need in human control skills or robot autonomy?**
- **How much to each?**



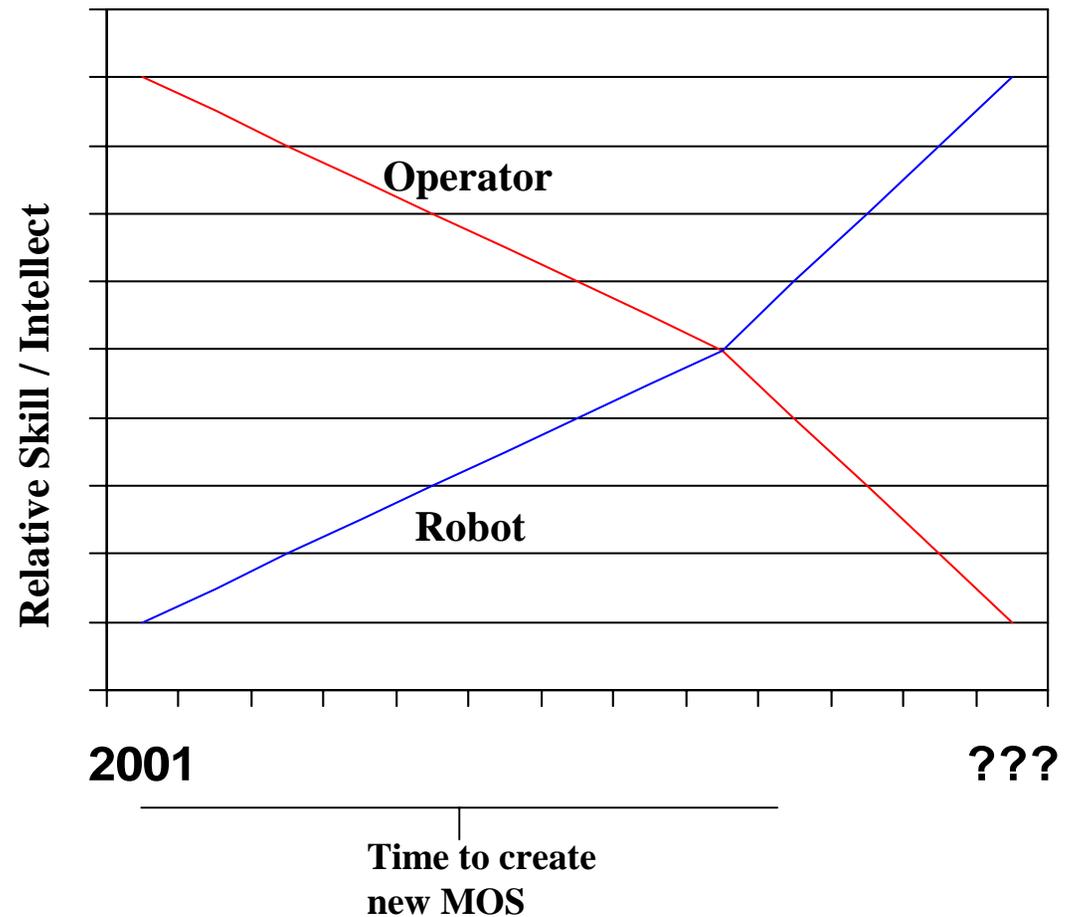


TMR HRI Paradox

Specialized Skill v. Robot Autonomy



- > **Now:**
 - “Dumb” robots need “Smart” humans to compensate for complex situational management
- > **Future:**
 - “Smart” robots will require much less supervision
- > **Paradox:**
 - **Need in human control skills or robot autonomy?**
 - **How much to each?**





Disaster Response Robot Potential

Augment Human Performance



- **Hazmat Assessment**
 - Extended mission duration
 - Avoid de-contamination
 - One way movement
 - Destroy on site
- **Structural Collapse SAR**
 - Remote triage
 - Dynamic shoring
- **Suspicious Device Investigation**
 - UXO
 - WMD





Backup Slides



Actually stopped right here...



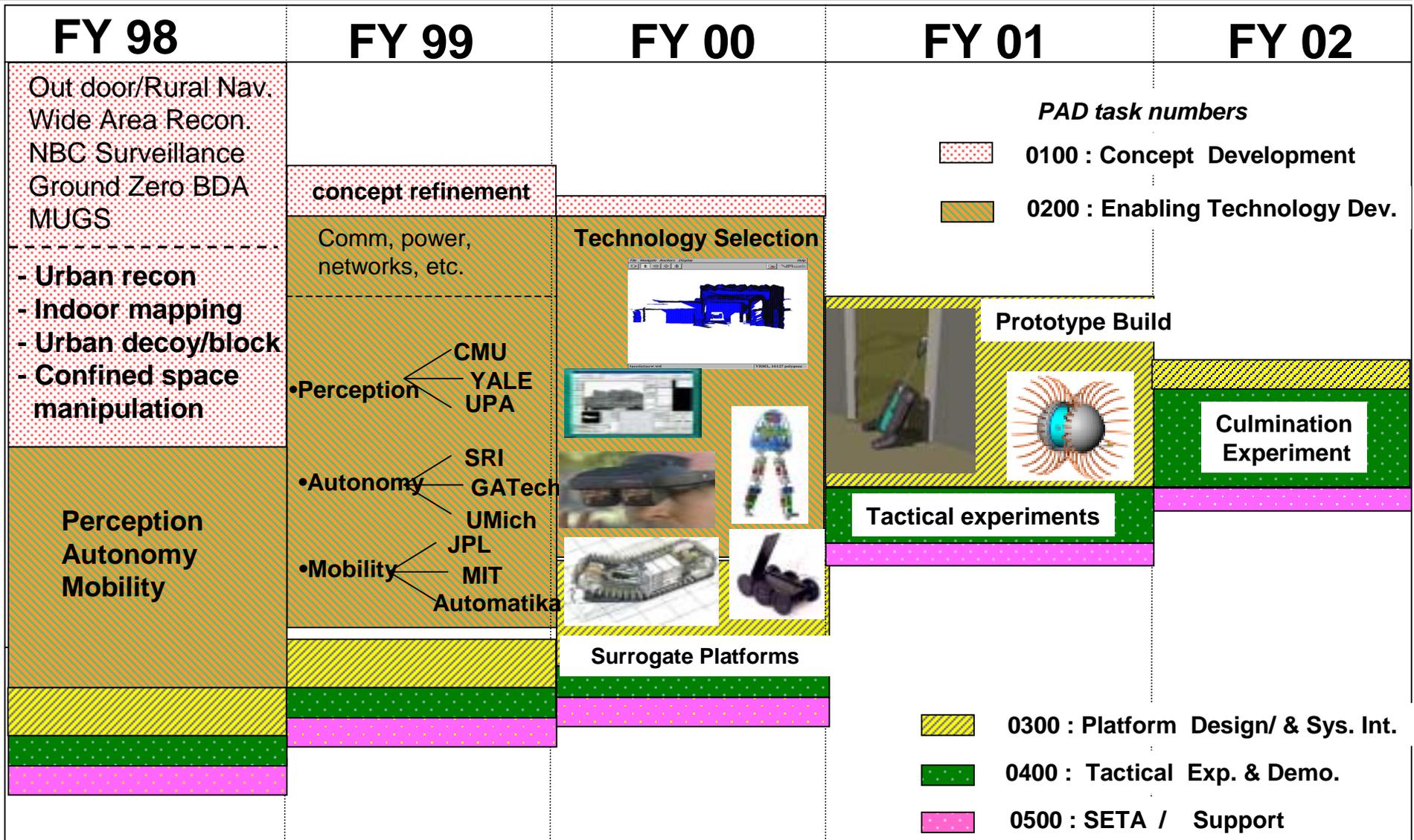
SUMMARY



- > **Many shared interests**
 - **High risk**
 - **High payoff**
- > **Specialization trend in HRI warrants significant attention**
- > **Perceptual metrics are incomplete - further development required**



Program Schedule





Tactical User Acceptance Challenge

Luddite Effect



*"I'll try your robot, but if it drops even one sample,
I'm bringing back Bob."*

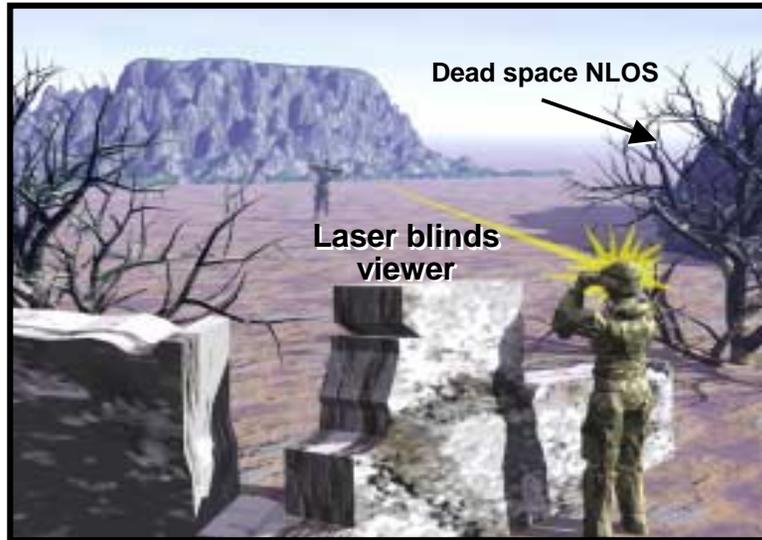


Tactical Value (3)

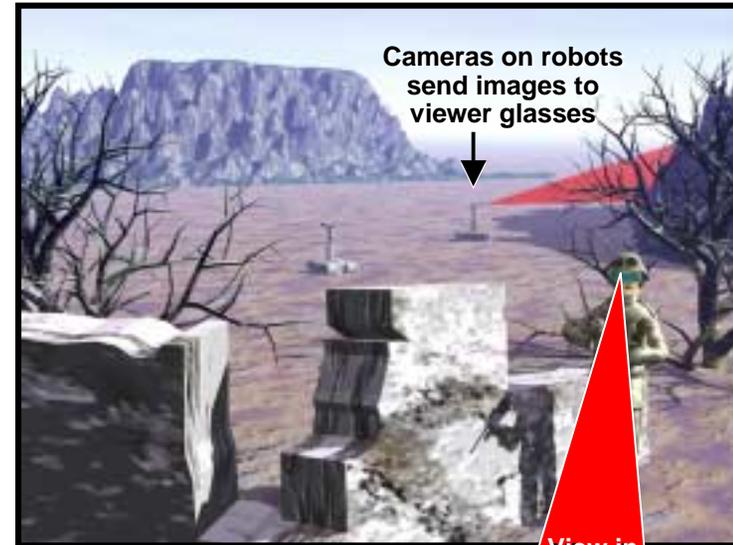
Denied Area Awareness: Multiple Perspective



Today



Tomorrow



View in glasses

- Concealed NLOS threats now visible
- Multiple perspectives
- Laser immunity
- Increased range
- Robot can "see" directed energy



Robot # 1



Robot # 2



Robot # 3

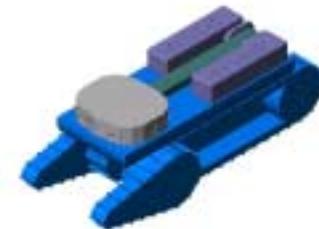
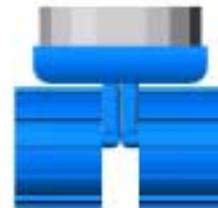
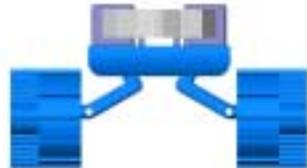
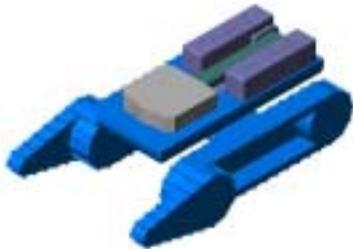
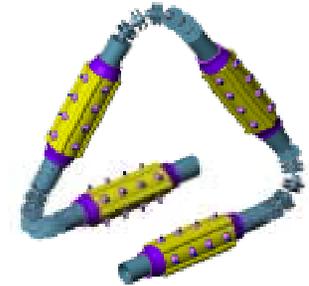


Tactical Value (4)

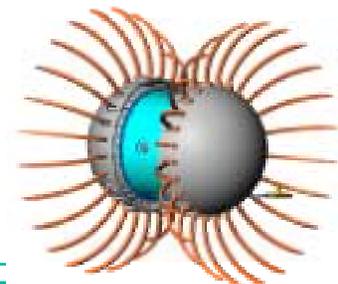
Confined Space Access



- **Variable Geometry**
 - Trade one axis for another
 - Confined space maneuver



- **Variable Volume**
 - Increase/decrease entire cross section
 - Greatly enhanced agility
 - Manipulate environment via expansion





Disaster Response Value (2)

Structural Collapse SAR



- **Confined Space Survey**
 - map collapsed area & void spaces
 - locate victims
 - conduct remote triage of victims
- **Structural Manipulation**
 - maneuver shoring materials into place
 - deliver sustenance to trapped victims
 - surgical breaching
- **Augment Resources**
 - wide area search (semi-auto wander)
 - canine search exploitation
 - free humans to concentrate on extraction



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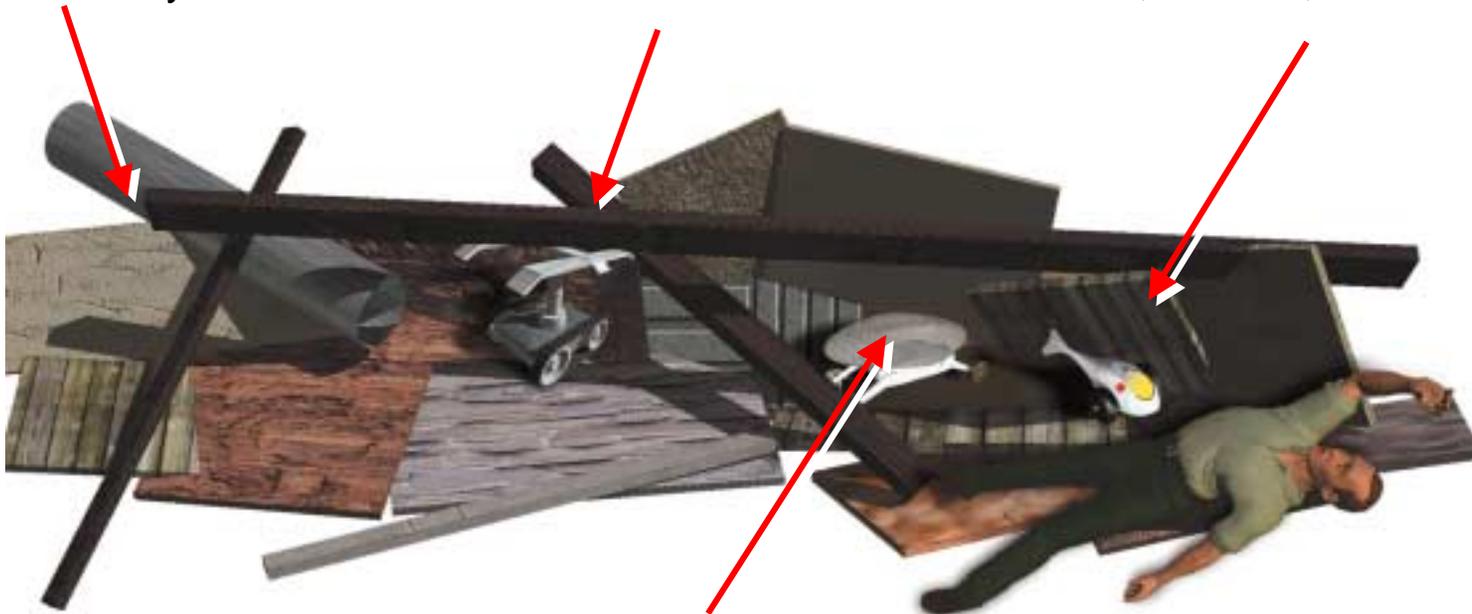
Robot Assisted Urban Search and Rescue (ROBSAR)



1. Robots enter conduit, too small for human entry

2. Jackbot uses hydraulics to shore up collapsed structure

3. Throwbot interacts with victim, using 2-way audio, camera, sensors



4. Airbot airbag inflates for rapid, adaptive shoring to protect victim from subsequent collapse (aftershocks, etc.)