US&R Robot Requirements Workshop I

Dear Workshop Participants:

First of all, thank you for participating in a successful first workshop. Excellent progress was made in identifying and capturing your key requirements for development of robotics applied directly toward US&R roles and tasks.

As we discussed at the close of the workshop, this document provides a synopsis of the requirements captured during your discussion. We would like you to review the results, verify that they reflect the group's consensus view, and use the attached Excel spreadsheets to submit your priorities and desired availability for the defined requirements. Your feedback on these priorities will be compiled and sent back for your review prior to the next workshop. As you review these requirements, you will note that several of those listed are preceded by a question mark (?). These indicate proposed requirements and suggested organizational changes discussed immediately prior to the close of the workshop. Please also add any additional requirements you consider missing.

This document also provides additional information to help with your requirements review. You will find an overview of the program (as discussed at the workshop), a brief summary of the workshop, and a detailed explanation of how to submit your requirements feedback.

Program Goals

Application-specific robot standards and repeatable performance testing with objective performance metrics will accelerate the development and deployment of mobile robotic tools for US&R responders, enhancing the effectiveness of these teams while reducing the risks to personnel during disaster response. Currently, no such standards or performance metrics exist.

In order to address this need, the DHS Science and Technology (S&T) Directorate initiated an effort in fiscal year 2004 with the National Institute of Standards and Technology (NIST) to develop comprehensive standards related to the development, testing, and certification of effective robotic technologies for US&R applications. These standards will address robot mobility, sensing, navigation, planning, integration into operational caches, and human factors. Such standards will allow DHS to provide guidance to local, state, and federal homeland security entities regarding the purchase, deployment, and use of robotic systems for US&R applications.

This standards development effort focuses on fostering collaboration between US&R responders, robot vendors, and robot developers to generate consensus standards for task

specific robot capabilities and interoperability of components. Furthermore, the effort includes the development and administration of technology readiness level (TRL)

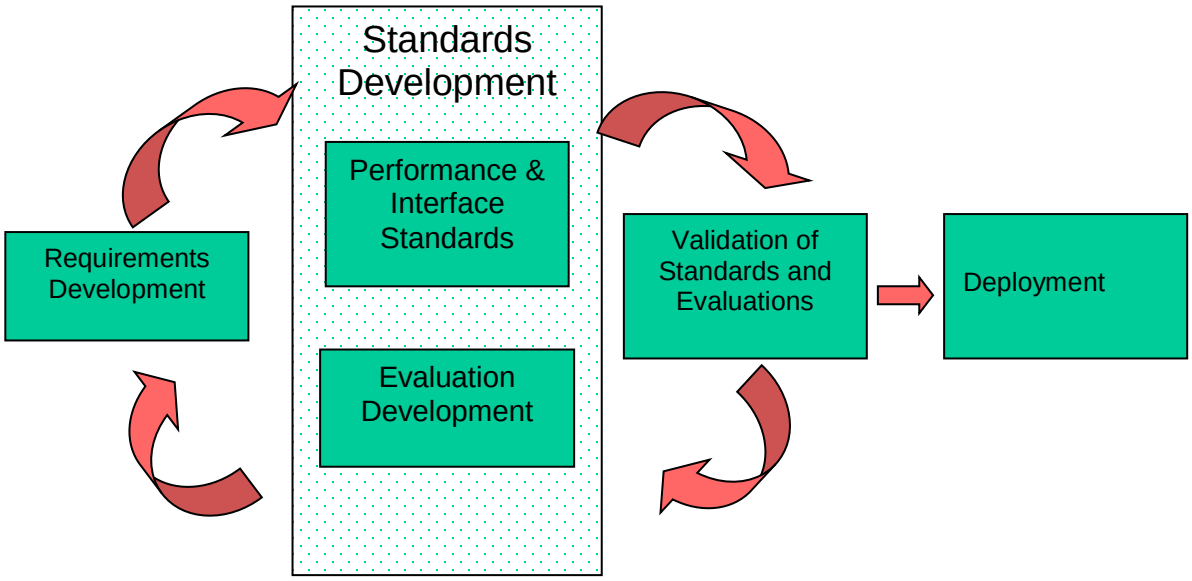

Figure 1: DHS US&R Robot Standards Process

assessment exercises. These exercises will generate statistically significant performance data for developmental and field-able robotic systems.

In order to ensure the relevance and viability of robots to US&R, the program follows a multi-year, iterative process, shown conceptually in Figure 1. The high-level effort areas and corresponding timeline are shown in Figure 2. To ensure that results are available as

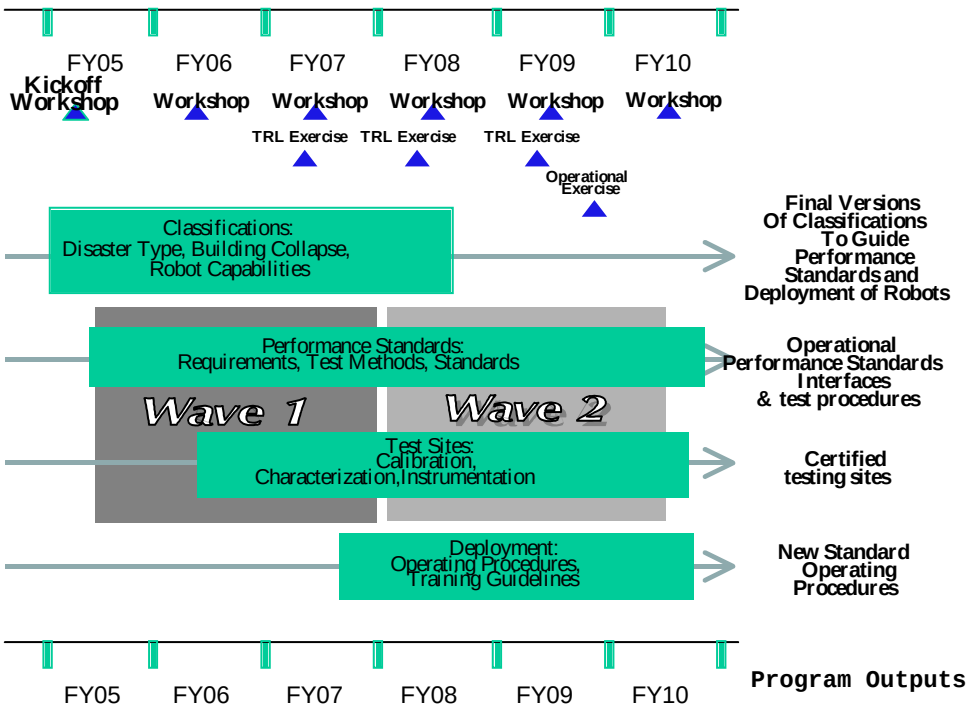

Figure 2: High-Level Timeline for US&R Robot Standards Program

soon as possible, the effort is staged into two "waves," with the highest priority requirements (that appear to be technologically attainable) being deployable in the FY07-FY08 timeframe. A second wave promulgates the remaining performance and interface standards.

The entire program is structured to ensure that the end-users' needs are captured and addressed. Therefore, there will be annual workshops to monitor progress as well as several events that allow responders to test out the robotic equipment in realistic environments and situations, shown on the timeline as technology readiness level (TRL) assessment exercises. The requirements defined by the responders will be the foundation for constructing robot performance measures along with testing and evaluation (T&E) protocols that will provide reproducible methods for assessing and comparing the effectiveness of overall robotic systems and key components. Test sites that can be used to realistically evaluate the robot's capabilities will be developed along with the supporting measurement infrastructure to characterize the various situations that are present and capture robot performance. Ultimately, the goal is to have one or more test sites certified as capable of evaluating robots against the program's resulting performance standards and provide ongoing robot conformance testing. Finally, in recognition that these novel tools need to be integrated into existing responder operations, new standard operating procedures may be developed, along with the corresponding training and deployment plans.

The First Requirements Workshop

The kickoff workshop, held Tuesday November 16 and Wednesday November 17 at NIST, convened an advisory group comprised of FEMA Task Force members. The intent of the workshop was to develop the performance requirements for US&R robots from an end-user's and domain expert's perspective. In order to encourage open discussion and let the requirements flow from the eventual users, the workshop was limited to responders only – no technology developers or vendors were invited.

A total of 25 participants attended representing 18 of the 28 FEMA task forces. Attendees are listed in Appendix A. A National Guard representative who focuses on civil support also attended. DHS attendees included Bert Coursey, Jennifer Coughlin, Peter Shebel, Peter Smalley (FEMA), and Larry Skelly (EP&R Portfolio, PPB). John Blitch (Blitz Solutions Inc.) was included to provide expertise in current military robotic capabilities and to provide input as a former program manager for robotic technology development. Invitations to interested Standards Development Organizations were sent out, but due to the short notice, only Underwriter's Laboratory sent a representative. UL is active in the area of robot safety standards. We expect other such organizations will attend future workshops.

The feedback from the participants was extremely helpful. The group made excellent progress in defining requirements, but at least two more workshops will be required to finish the job. US&R is a multi-disciplinary and varied set of activities, so it is not

feasible to capture all the requirements in the course of a day and a half. The tentative schedule is to hold the next workshops in mid-January and mid-February, and if necessary, conduct a final workshop mid-March. A final report will be produced in April.

The workshop began with a discussion of terminology on Tuesday morning. Participants were asked to provide their definitions of "robot" and to share any experience they may have had with robots. Organizers asked responders to provide "war stories" to help begin the gap analysis: reflecting on situations that didn't work well to see where there are opportunities to apply new technologies. Responders also were queried about what information they sought when they first arrive at a disaster site. They are interested in ascertaining the cause of collapse and expected building occupancy (type of building use, time of day, number and nature of potential victims, and potential for hazardous materials). Basic responsibilities during a rescue effort were defined as reconnaissance, primary search, structural assessment, stabilization, medical, rescue, monitoring, hazmat, etc. The working group identified two particular roles, reconnaissance and primary search, as the two highest priorities. Based on this, the following two scenarios (Table 1) were defined to guide the requirements analysis:

Table 1: Scenario Descriptions Used to Elicit Requirements

	Scenario A	**Scenario B**
Description	Upper stories of a multi-story pancake collapse	Subsurface voids
Characteristics	Soft stories in the middle, undetermined stability, uneven terrain, sloped floor with holes, variable debris size, high hazmat potential, and poor visibility	Downwardly accessible void spaces, twisted/turning access (i.e., searchcam can't reach or turn necessary corners), variety of materials, complex orientations of support surfaces, sufficiently complex to cause spatial disorientation, hot, may be wet, high hazmat potential, and poor visibility
Representative Image		

Main classes of robots were also identified based on the aperture size they would fit through: **2 inch bore hole**, a typical **24 inch triangular hole**, and a **standard doorway**. An **aerial platform** was the fourth class of robot identified, as it could address particular situations, such as upper stories that are of unknown stability and are difficult to reach.

Tuesday afternoon began with an introduction to Integrated Product and Process Development (IPPD) methods and the Dynamic Insight software tool, which is being used to capture and document the requirements. Dynamic Insight captures customer requirements in detail, including the objective values and thresholds, and how the requirements will be measured for conformance. Candidate technologies (in our case, robotic systems from particular vendors) can later be evaluated with respect to the requirements and the results will be visually highlighted through radar charts.

The US&R robot requirements for performing Recon during Scenario A were tackled first, although it was later recognized that much of the discussion encompassed Primary Search tasks so some re-categorization will likely occur at the start of the next workshop. Generally, the group tried to honor current operating procedures by emphasizing that Recon is "fast and light" and is used to perform triage, while Primary Search is more methodical. Most of the resulting high level requirements categories are shown in Figure 3 (some are not shown in the scrollable window, but all are visible in the spreadsheets). There were general categories of requirements for the Recon role discussed: chassis, minimum capabilities, cost, human factors, and logistics. The principal tasks for the Recon role were identified as: initial detection, structural assessment, mapping (3D), hazmat, and forensics (tasks are listed in alphabetical order in the scrollable window). These formed main requirement categories for the Scenario A Recon role that were further refined into detailed requirements as shown in Figure 4 and Figure 5. Several of the requirements listed are preceded by question marks (?), which indicate proposed tasks and suggested organizational changes discussed immediately prior to the close of the workshop. These issues will be discussed and ratified at the beginning of the next workshop.

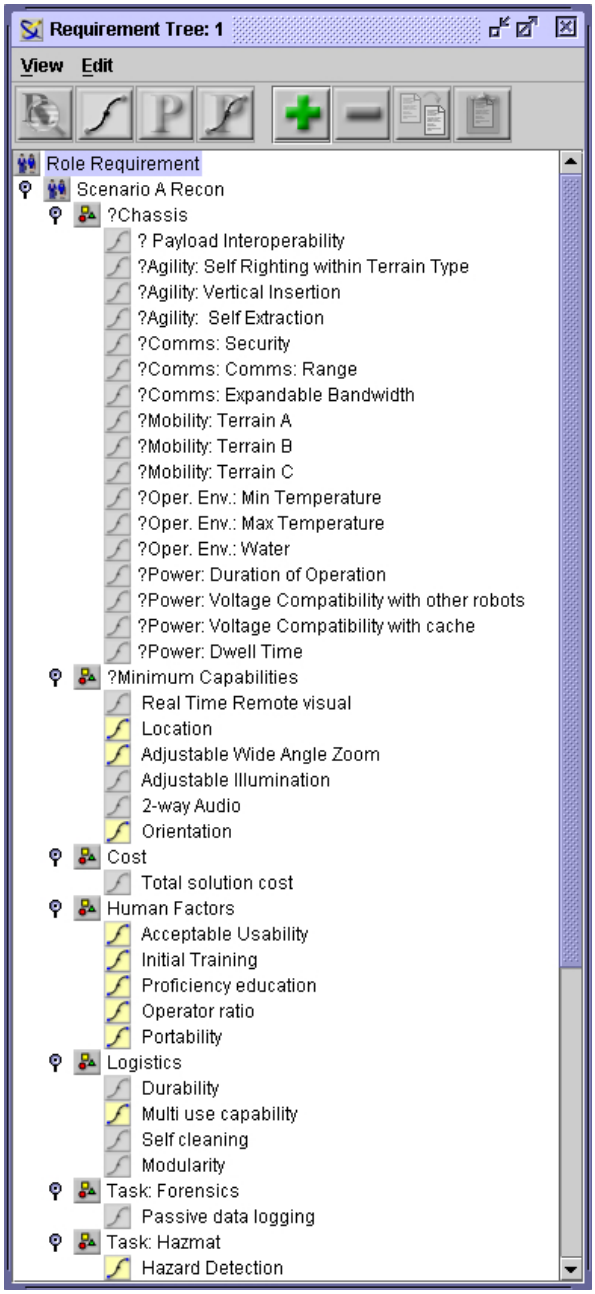

Figure 3: Preliminary Requirements Tree for the Recon Role (scrollable hierarchical list)

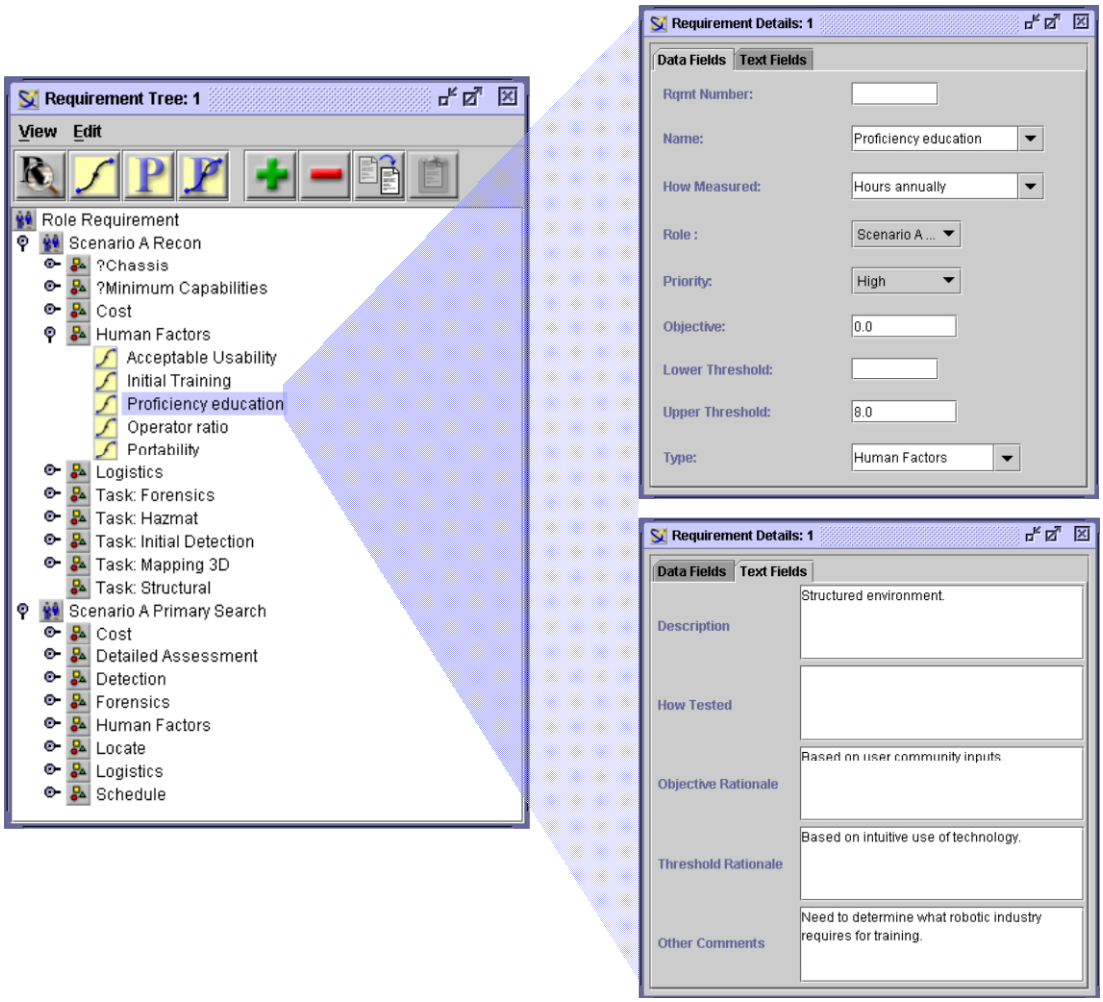

Figure 4: Expanded requirements capture for Proficiency Education within the Human Factors category. Types of requirements data to be defined is shown in the Requirements Details and

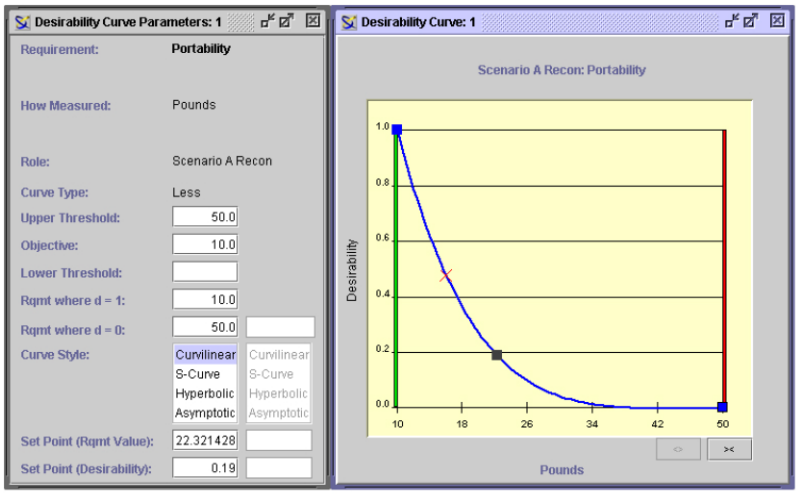

Figure 5: Example requirements definition for robot Portability within the Logistics category. The definition includes the unit of measure, performance objective, and thresholds of acceptability. The desirability curve captures the user's preference within the defined range of performance.

To provide further indication of the detail that is defined for each requirement of a given category or task, some example requirements under the Minimum Capabilities category are listed in Figure 6. The weight field is used to impose schedule desirability onto particular requirements. For instance, requirements given a weight of 5 are desired within six months of completing the requirements definition process.

Requirement	Priority	How Measured	Objective	Lower Threshol	Upper Threshol	Weight	Comments
: Real Time Remote visual	High	Clarity (Hi Definition)				5	Scale 1 - 5: 5 = Available within 6 months; 4= 12 months; 3=18 months; 2=24 months, 1=30 months
: Location	Low	relative meters	1		10	5	
: Adjustable Wide Angle Zoom	High	Optical (x)	20	10		5	
: Adjustable Illumination	High	Lumens				5	
: 2-way Audio	High	db				5	
: Orientation	High	Number	3	2		5	

Figure 6: Example requirements including the weighting, which indicates the timeframe in which each requirement is desired by the responders

Once a comprehensive requirements capture is complete for the defined roles and tasks of each scenario, an overlay of proposed solutions will be conducted. The IPPD software will use the identified metrics to facilitate quantitative comparisons of differing technical approaches. It can also graphically highlight the trade-offs with "radar charts," in which the requirement categories are shown as the main spokes (see Figure 7a). For illustrative purposes, Figure 7b shows a candidate solution from a fictitious vendor evaluated against all the various requirements to produce a usable radar chart. The green region highlights conformance with stated requirements (how well the proposed solution meets the requirement objectives, thresholds, and desirability curves), while the red region highlights the perceived technical risks associated with the proposed solution.

This process will be continued at subsequent workshops until the requirements are defined to a sufficient level of granularity and completeness.

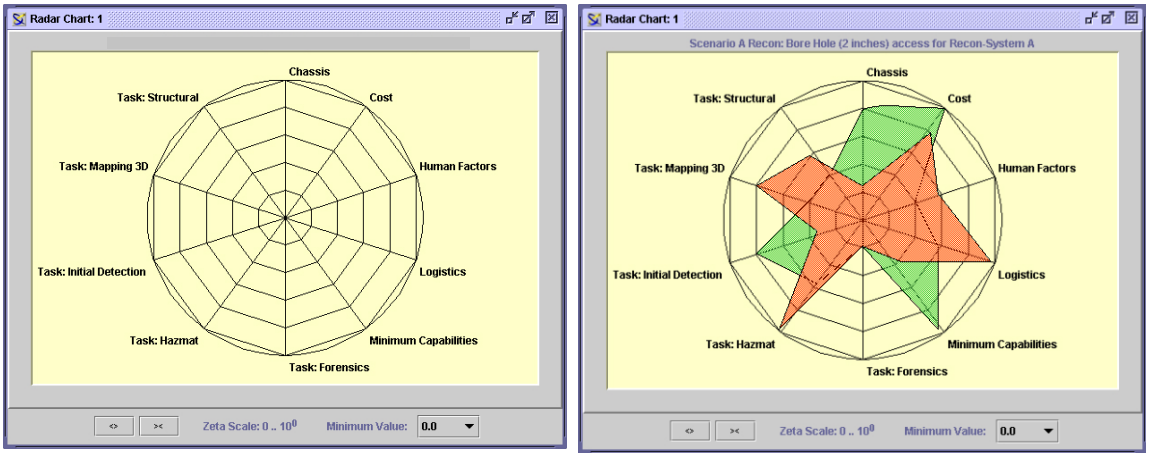

Figure 7: Example "radar chart" graphically shows conformance and risk trade-offs for a proposed robotic system (which fits through a 2" bore hole) applied to Scenario A Recon role.

Interim Tasks Between Requirements Workshops

We thank you again for your participation and valuable contribution at the first workshop. We would like to use the time between workshops to refine the discussion that was captured and gather additional information. Toward that end, we have attached the **Scenario A Recon** role list of categories and tasks captured in Excel spreadsheets for you to view and edit. We ask that you use these spreadsheets to provide additional input, refining the data we already captured and adding ideas you have undoubtedly come up with since the workshop.

Remember that at the close of the last workshop, the consensus was leaning toward re-categorizing many of the requirements currently listed under Recon, moving them into Primary Search -- maybe combined with more stringent objectives and thresholds. The theory was that an appropriate Recon robot may be a stripped down Primary Search robot. We will begin the next workshop with this discussion, and ratify as a group all changes to the list of requirements or organizational groupings for Recon before moving on to define Primary Search.

So focusing on the **Scenario A Recon** role only, see the attached spreadsheet and please provide the following feedback:

(1) Review the requirements listed within each category or task (that is, within each sheet) for completeness. Each category and task is captured on its own sheet accessible from the tabs at the bottom of the screen. Add new requirements for any category or task below the existing list in the cells provided. You may add more rows if necessary. Please pay particular attention to categories or tasks that we did not address (no requirements noted). For example, *Task; Structural* has no requirement entries. If other team members could help define these requirements, please include their ideas in your team's reply. If you have ideas for additional categories or tasks, please send them as text along with your reply.

(2) Prioritize the requirements within each category or task (that is, within each sheet) by typing in HIGH, MEDIUM, or LOW in the highlighted "Priority" column. Consider each requirement only against the others in the same category or task. If you think that a particular requirement is not necessary, prioritize it as LOW.

(3) If you understand the units of measure noted by the group that appear in the "How Measured" column, you may edit or change the "Objective" or "Threshold" values for any requirement. Please pay particular attention to requirements where we captured the units, but captured no value. Many of these values should be based on existing equipment currently available. If you have such equipment, please provide the acceptable values (example: *Minimum Capabilities; Adjustable Illumination; Lumens*).

(4) Fill in the highlighted "Desired Availability" column associated with each requirement to capture your desired timeline (this was referred to as the "Weight"

during the workshop and in the discussion above). This should be done relative to the other requirements within each category or task (within each sheet), but is different than the "Priority" you previously noted. The "Desired Availability" value will govern much of the assessed risk in a candidate technology – technology providers and researchers will eventually answer whether a proposed technology can meet the stated requirements within the desired timeframe. There may be high priority requirements, say sensing through re-enforced concrete walls, which may be technologically achievable but not in a short timeframe (and so certainly not within the cost constraints noted elsewhere). If a short timeframe is insisted upon, certain technologies may be considered unfavorable as too risky. So identify the desired timeframe based on the "Objective" and "Threshold" values set for that requirement, understanding that you may be willing to wait for certain advanced capabilities, and that the timeframe will not affect your stated "Priority" of importance for that requirement which is captured separately.

Please recall the scale we've established regarding the "Desired Availability" timeframes (*aka* "Weight"). These timeframes will be considered as starting from the end of the requirements capture process:

5 = Available within 6 months
4 = Available within 12 months
3 = Available within 18 months
2 = Available within 24 months
1 = Available within 30 months

That's it! We thank you for your time, and for the time of the team members you have culled for information. Please modify the Excel filename with your team name (i.e. MD-TF1), or other organizational unit, and return by December 31st to usar.robots@nist.gov along with any other input.

Also during this interim process, we will try to include a limited number of new representatives from particular disciplines, such as structural, that were not able to attend the first workshop. If you have candidates you think would be particularly helpful, please forward their contact information to us so that we may get them involved.

Near-Term Activities

Additional requirements workshops are being planned for late January and February to complete the requirements definition process. Standards Development Organizations will again be invited to attend these in order to afford them an opportunity to become familiar with the effort and to be better positioned to propose hosting the eventual standards. As with the first workshop, technology developers and vendors will not be included. A report will be published in April 2005 to detail the finalized requirements. The highest priority requirements will be used to formulate the Wave 1 strategy to develop appropriate standards.

Some parallel activities will include visits to several of the key training facilities across the country. The intent will be to utilize one or more of these facilities in the coming year to conduct preliminary exercises that bring technology vendors/developers together with emergency responders to discuss the captured requirements in a setting that allows existing technology demonstrations along with operational training scenarios (similar to an exercise conducted at the NASA-Ames Disaster Assistance and Rescue Team facility in May 2004). These exercises serve several purposes: they bring together responders and technologists to allow the informal assessment of advanced technologies, they unveil robotics-related issues in current training facilities, and they allow NIST the opportunity to develop techniques to characterize and instrument sites to verify robot conformance with the specifications that this program will produce.

Next Workshop Dates

The following dates are scheduled for subsequent requirements workshops. Similar to the first workshop, travel reimbursements will be available for a limited number of emergency responder organizations.

Jan. 26, 27, morning of 28 (Wed, Thurs, Friday)

Feb. 23, 24, morning of 25 (Wed, Thurs, Friday)

If necessary:
Mar. 23, 24, morning of 25 (Wed, Thurs, Friday)

Appendix A – Task Force Participant List

AZ-TF1	Lloyd Randall	Lloyd.d.randall@phoenix.gov
CA-TF2	Rory Rehbeck	rrehbeck@lacofd.org
	Bill Monahan	bmonahan@lacofd.org
	Tom Haus	TJH3858@lafd.lacity.org
CA-TF3	Harold Schapelhouman	harolds@menlofire.org
	Roger Miller	ramiller@mail.arc.nasa.gov
CA-TF6	David Lesh	dlesh@riversideca.gov
CA-TF7	Ford Davies	webmaster@sacfire.org
CA-TF8	Richard Leap	RALeap@aol.com
IN-TF1	Sam Stover	techsearchintf1@yahoo.com
MA-TF1	Bradford Stocks	hollywoodlfd33@verizon.net
	Bruce Naslund	tunnelrat1@aol.com
MD-TF1	Michael Steed	Michael.steed@montgomerycountymd.gov
NE-TF1	Michael Conditt	mconditt@ci.lincoln.ne.us
NY-TF1	George Hough	gch9@optonline.net
	Randy Miller	RSM1811@aol.com
OH-TF1	Kevin Clemens	WRTR@aol.com
PA-TF1	Martyn Nevil	patf1_eplo@state.pa.us
TN-TF1	Anthony Fisher	tntf1@tonyfischer.com
TX-TF1	Robert McKee	bob.mckee@teexmail.tamu.edu
UT-TF1	Trevor Tallon	TrevorTallon@yahoo.com
	Jens Lund	jmlund@msn.com
VA-TF1	Tom Griffin	searchdawg@aol.com
VA-TF2	Mark Hundley	mhundley@vbgov.com
	Jim Ingledue	jingledu@vbgov.com