Standards Development for Wireless Communications for Urban Search and Rescue Robots

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Photographs by Raymond Sheh

Program Overview

Goal: Accelerate development and deployment of mobile robotic tools for US&R responders

- enhance team effectiveness
- reduce risks to personnel during disaster response

Program initiated in FY 2004 by DHS Science and Technology Directorate with NIST as technical lead

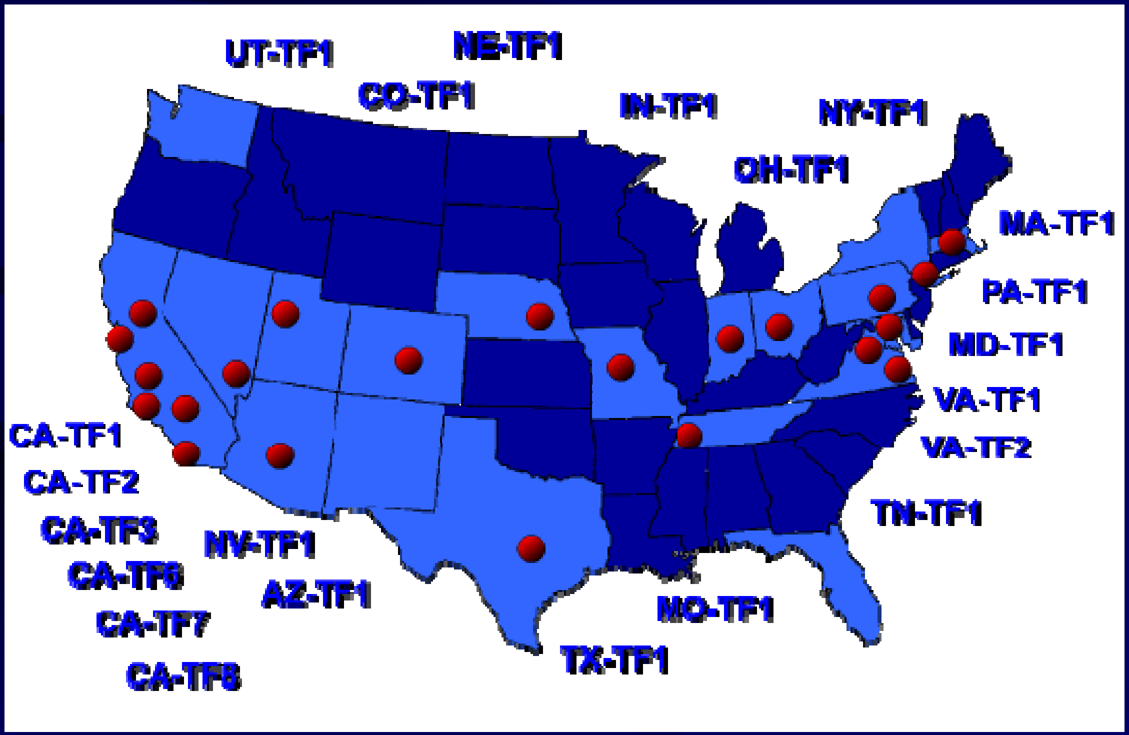
Consensus Standards Development

Collaboration between US&R responders, robot vendors, and government researchers

- Statement of requirements
- Technology readiness level assessment exercises
- Participate in standards development process

End Users of US&R Robots are Involved in Standards Development

- Derive the Statement of Requirements
- Participate in field tests, rate ease of use, utility of robots



US&R task force participation in robot requirements workshops

ASTM Standard E54.08

Operational equipment subcommittee within the Homeland Security Applications Committee E54

- Visual acuity
- Mobility
- Directed perception
- Manipulator dexterity
- Communications

ASTM radio communication standards development effort:

(1) Committee formed consisting of design engineers, communications experts, users of US&R robots. *August 2006*

(2) Scope defined in ASTM work item. Focus on "Wave 1" of LOS and NLOS communications

Proposed Title: Evaluating the Performance of Radio (Wireless) Communication Links used for the Control and Telemetry Systems on Urban Search and Rescue Robots

Introduced: 01/2007; Target Ballot Date: 08/2007

ASTM radio communication standards development effort:

(3) Discovery: Evaluate technical characteristics of the systems (data types, rates, frequencies, physical environment…). *Field tests.*

(4) White paper covering some of the high-level physical issues (bandwidth/data rate, electromagnetic immunity, signal loss in representative environment, state-of-the art in mitigating performance issues). *In process.*

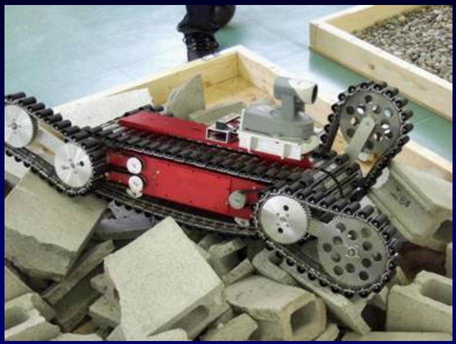
(5) Testing: Develop and verify specific field-performance tests. *Upcoming work.*

Overview of Wireless Tests During US&R Robot Field Tests

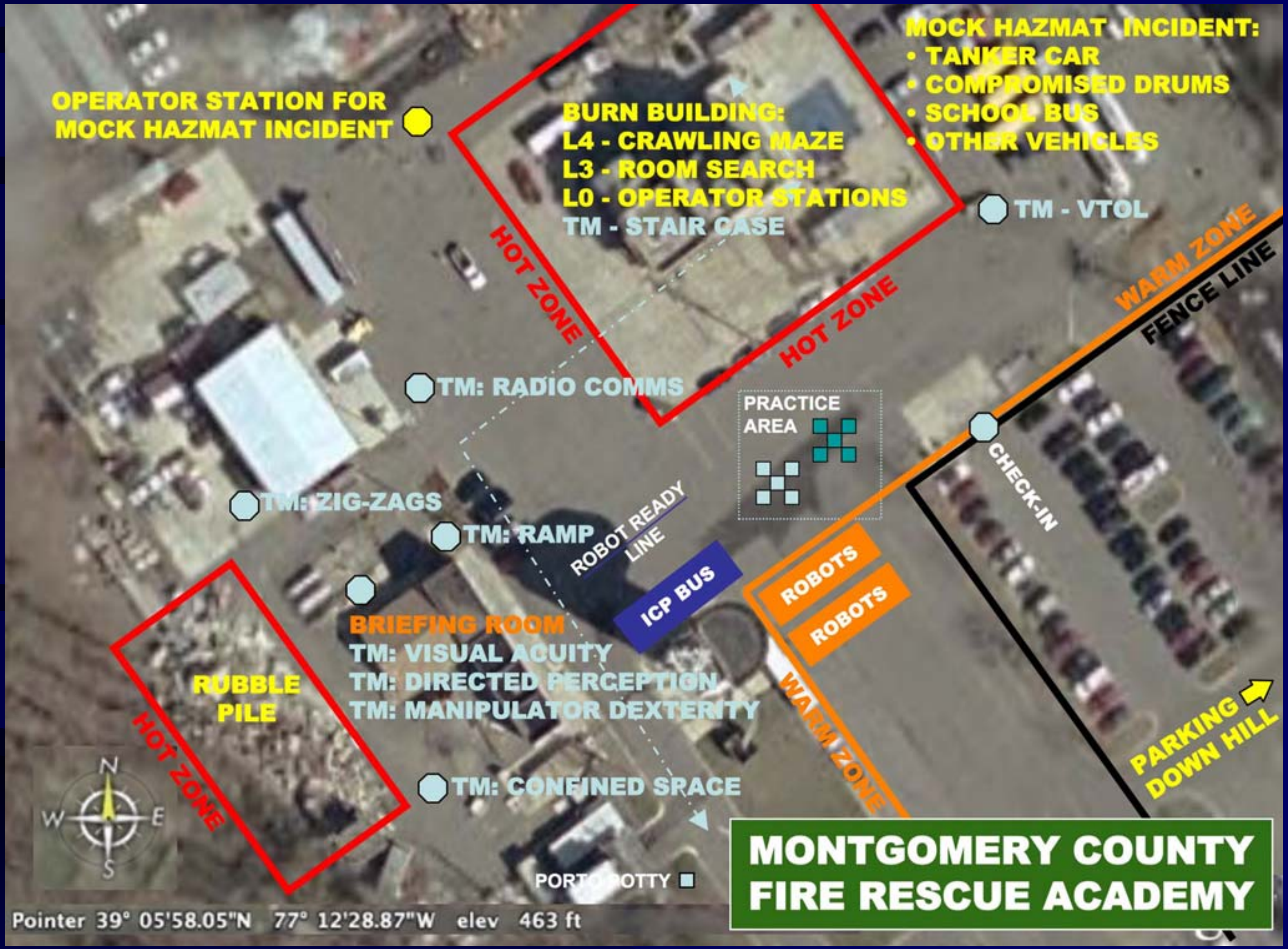
Montgomery County Fire Rescue Academy
Aug. 19-21, 2006

16 different models of ground vehicles, 2 models of wall climbers, and 3 models of aerial vehicles



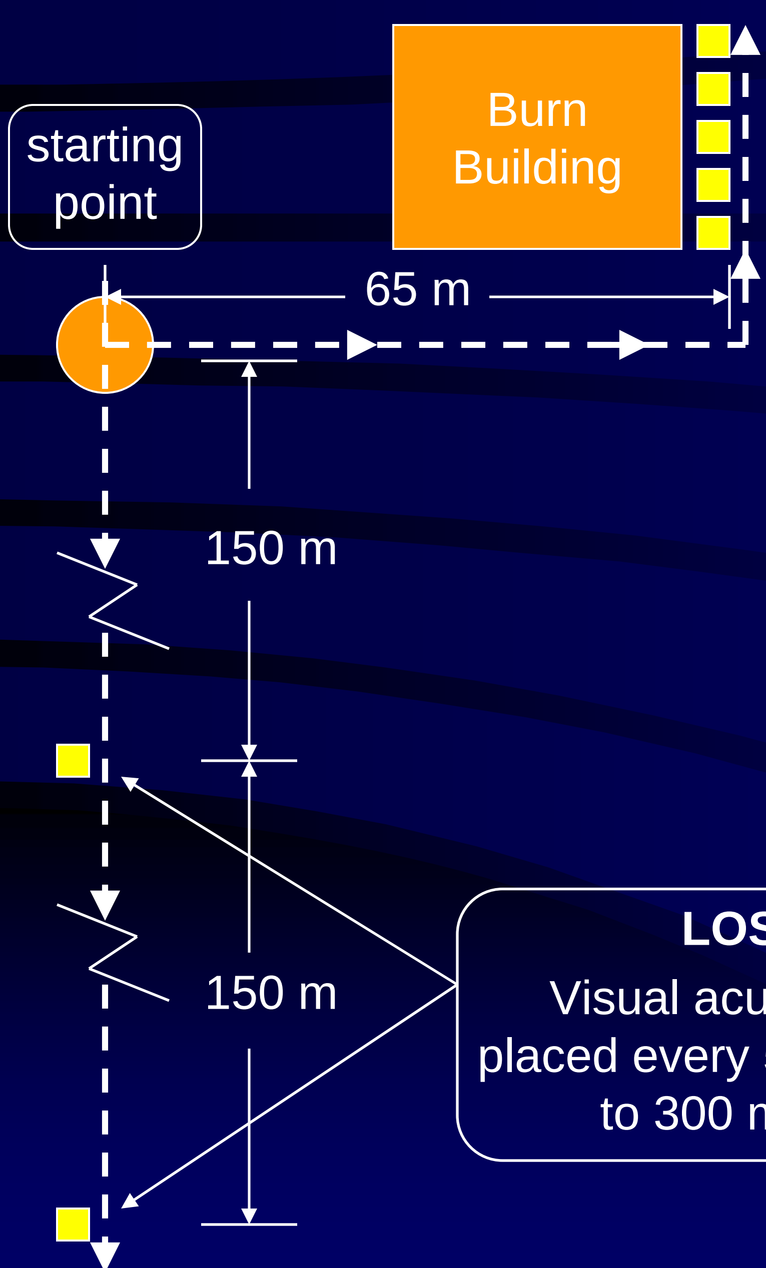




Overview of the US&R robot test site



- Light blue = radio communication test paths
- Top line = non line of sight tests
- Lower line = line of sight test going along the driveway

Radio Communication Test Layout



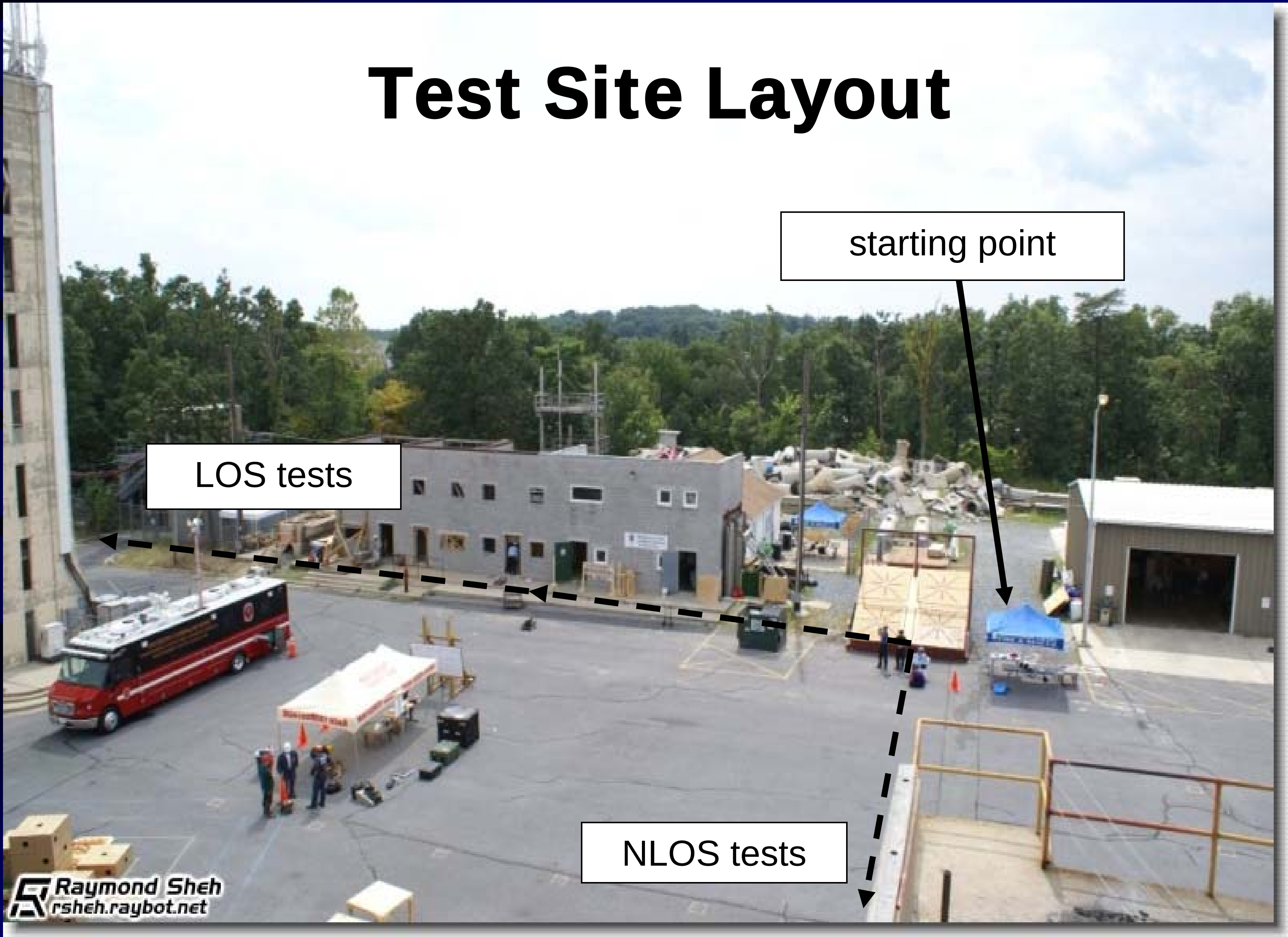
NLOS tests:

Visual acuity eye charts placed behind building

LOS tests:

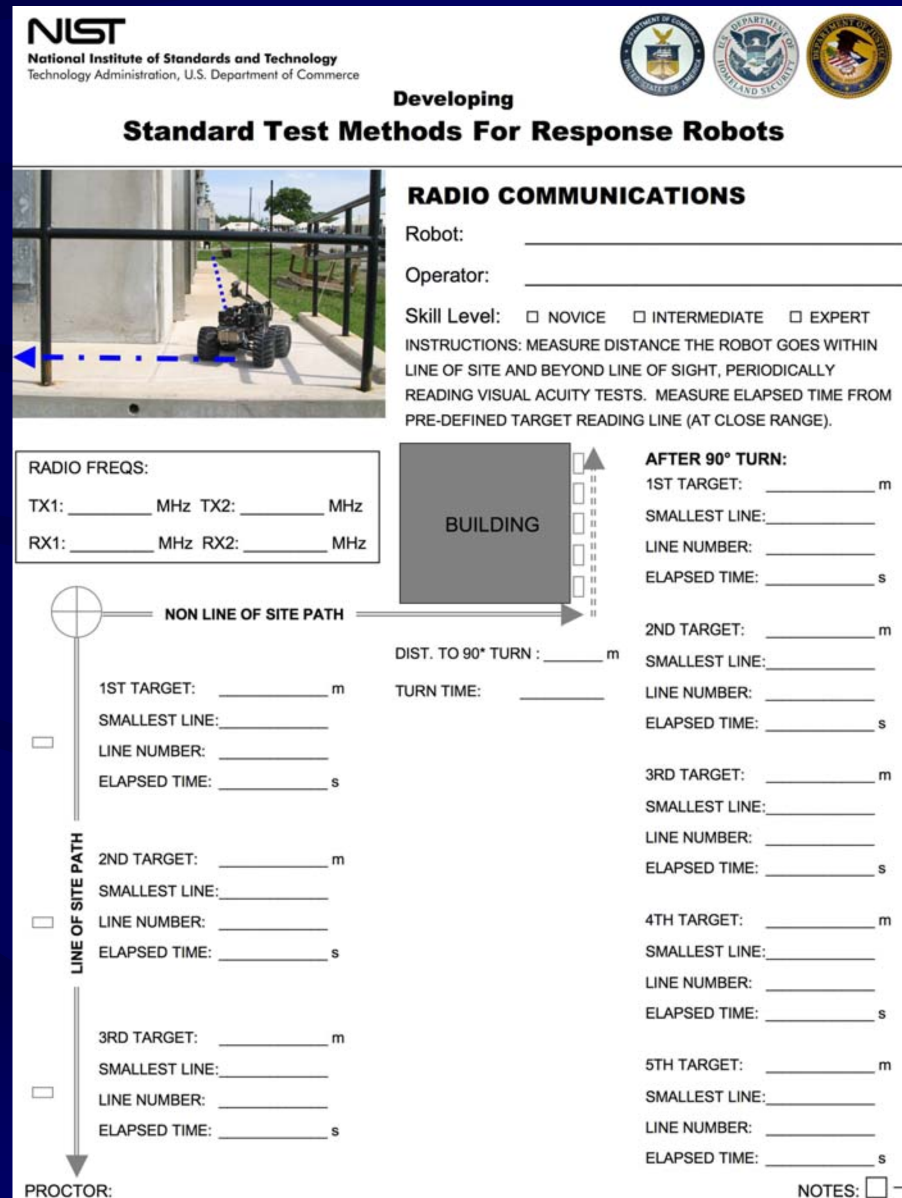
Visual acuity eye charts placed every 50 m from 150 m to 300 m from start

Test Site Layout



Radio Communication Tests

- Robots move along LOS or NLOS course
- Proctor records success/failure at each target



NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Developing
Standard Test Methods For Response Robots

RADIO COMMUNICATIONS

Robot: ____________

Operator: ____________

Skill Level: ☐ NOVICE ☐ INTERMEDIATE ☐ EXPERT

INSTRUCTIONS: MEASURE DISTANCE THE ROBOT GOES WITHIN LINE OF SITE AND BEYOND LINE OF SIGHT, PERIODICALLY READING VISUAL ACUITY TESTS. MEASURE ELAPSED TIME FROM PRE-DEFINED TARGET READING LINE (AT CLOSE RANGE).

RADIO FREQS:
TX1: ______ MHz TX2: ______ MHz
RX1: ______ MHz RX2: ______ MHz

BUILDING

NON LINE OF SITE PATH

DIST. TO 90° TURN : ______ m
TURN TIME: ______

LINE OF SITE PATH

1ST TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

2ND TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

3RD TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

AFTER 90° TURN:

1ST TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

2ND TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

3RD TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

4TH TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

5TH TARGET: ______ m
SMALLEST LINE: ______
LINE NUMBER: ______
ELAPSED TIME: ______ s

PROCTOR:

NOTES: ☐

Radio Communication Tests

Data that were collected include:

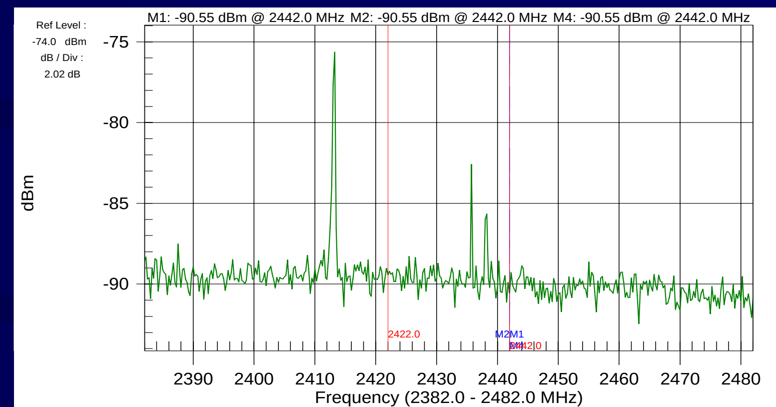
- frequency of operation
- type of data transmitted (i.e., video or control)
- output power level
- hardware such as antennas and antenna placement
- radio-interference environment
- physical environment

Spectrum Analyzer Data

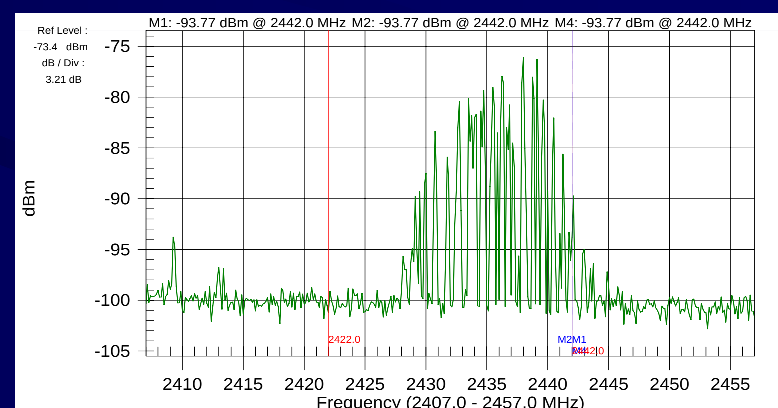
For most robots

Control: narrowband 900 MHz or 2.4 GHz

Video: wideband 2.4 GHz 802.11b or 802.11g



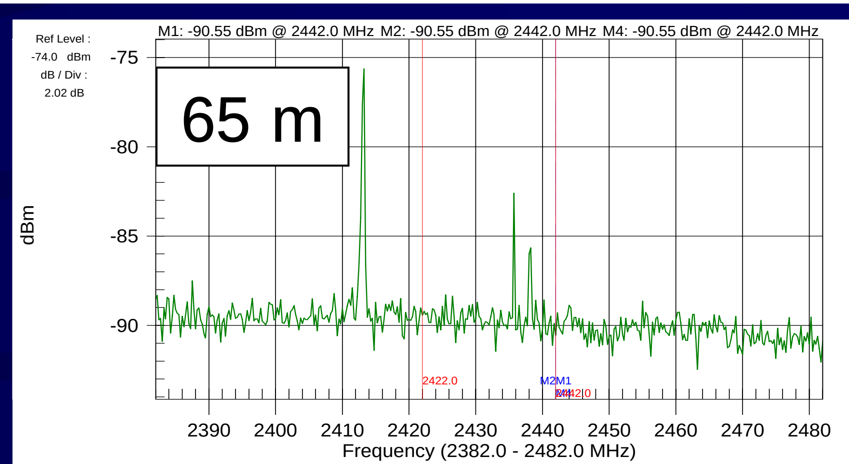
2.4 GHz narrowband control

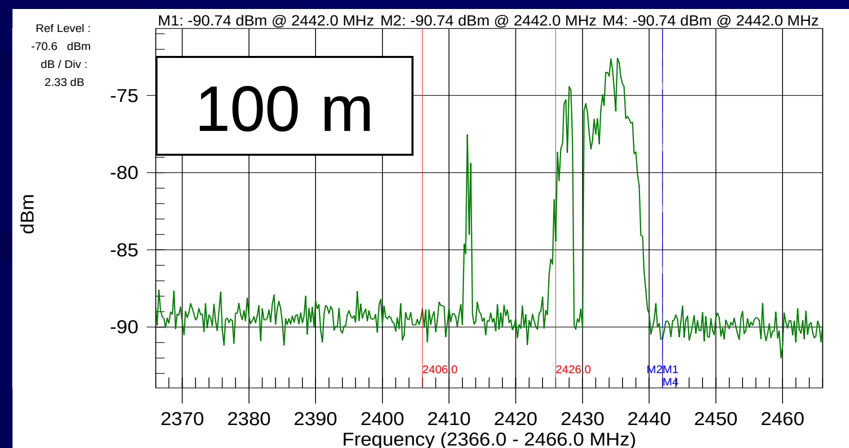


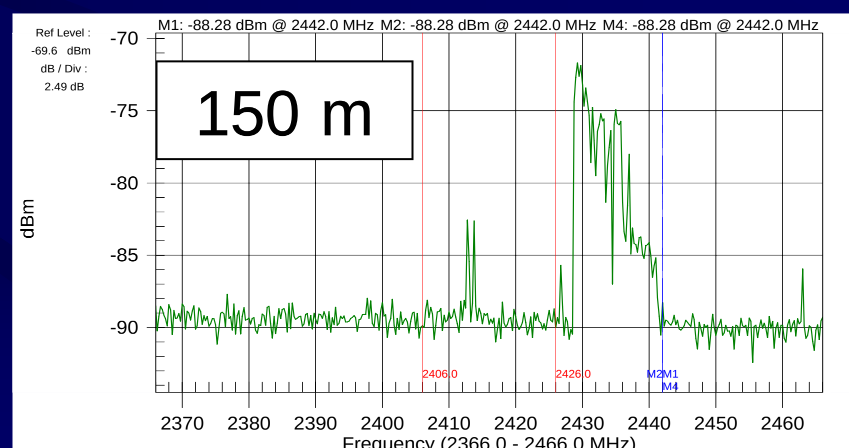
2.4 GHz wideband video

Radio Interference Example:

- Robot uses analog video link transmitting at 2.414 GHz
- Second robot transmits wideband data using 802.11b
- As first robot moves away, second robot's signal interferes with reception







Summary of results for wireless communication testing

15 robots were tested

- Output powers from 100 mW to 2 W
- 6 robots used 2.4 GHz band for control
- 10 robots used 2.4 GHz band for video
- 10 robots had issues with radio interference from other robots
    - In band or adjacent band
    - Out-of-band, high power
- 8 robots failed either LOS test, NLOS test, or both because of interference related issues

Table 1: Summary of Data Collected August 19-20 at the Montgomery County Fire Rescue Training Academy

Robot	Video (MHz)	Control (MHz)	Output Power (W)	Success	Failure Due to Interference	Issues with Interference
1	2400	900	0.5	--	NLOS	yes
2	2432	2432	0.2	LOS, NLOS	--	no
3	2437	2437	0.2	LOS, NLOS	--	no
4	2414	2414	?	--	LOS, NLOS	yes
5	2400 (analog)	900	?	--	LOS, NLOS	yes
6	2400	2400	1	LOS, NLOS	--	yes
7	1760	900	1 control, 2, video	LOS, NLOS	--	no
8	1756	900	?	--	LOS, NLOS	yes
9	2400	35	0.1?	--	LOS, NLOS	yes
10	1400	35	0.1?	LOS, NLOS	--	no
11	5200	5200	?	NLOS	--	yes
12	2400	2400	?	LOS, NLOS	LOS, NLOS	yes
13	2400	?	0.1	--	LOS, NLOS	yes
14	2400	2400	?	LOS	NLOS	yes
15	900	75	?	--	--	--

Interference Mitigation Techniques

- Frequency coordination: Easier in licensed frequency bands than in ISM bands
- Transmission protocols: Use of access schemes designed for use in crowded environments
- Use narrower frequency bands: Maximize signal-to-noise ratio, enables use of licensed bands
- Increase output power: Can increase interference, health risks
- Priority access: First responders granted access over civilian use
- Multi-hop communications: Use of repeaters or mesh networking

Where do we go from here?

- Additional tests will provide propagation data in key robot environments: tunnels, large buildings, free range, stand-off situations
- Develop performance metrics that capture essential communication behavior
- Develop controlled tests that replicate key environmental phenomena (range of signal levels, radio interference, multipath)
- Incorporate performance metrics and tests into ASTM standard

For More Information

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National Institute of Standards and Technology

Questions?

General Communications Requirements

(1) Expandable Bandwidth: Will support additional operational components without loss of data transmission

(2) Range – Beyond Line of Sight: Must be able to ingress specified number of feet in worst-case collapse.

(3) Security: System must be shielded from jamming interference and encrypted.

(4) Range – Line of Sight

(5) Data Logging – Status and Notes: Ability to pick up and leave notes.