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IN SHORT

TOWARD CRIMINAL JUSTICE SOLUTIONS

NIJ

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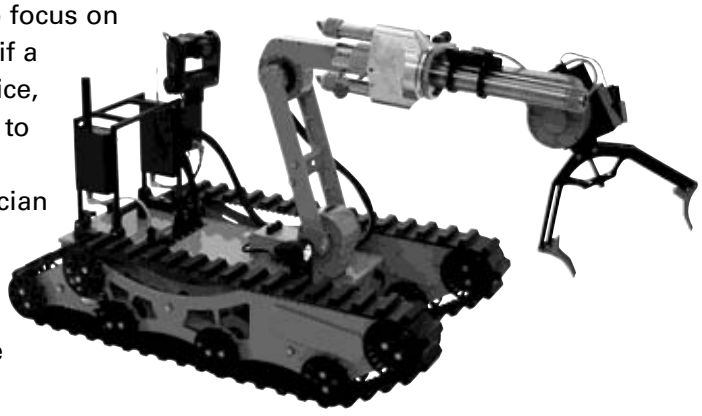
Vanguard Robot Assessment

THE PROBLEM

The law enforcement community needs a low-cost robot that can reduce or eliminate the time of danger for a bomb technician who must inspect, x-ray, and disrupt an explosive device—preferably in its original place but sometimes relocated. Sensors and tools must be placed close to a suspect device. Approaching a device can be dangerous, since points along the path may be booby-trapped. Even when a bomb technician uses great care in inspecting or handling an explosive device, the possibility exists that the bomber is waiting nearby to remotely detonate the device or a secondary device when the bomb technician is within range. An effective robot can reduce or eliminate the risk of potentially deadly scenarios and allow a bomb technician to focus on disabling the device. Even if a robot cannot disrupt a device, it can still relay information to aid in selecting tools and procedures before a technician approaches a device. In addition, events recorded by a robot's camera can provide evidence for future forensic purposes.



Background

In 1999, the National Institute of Justice (NIJ) published the *Inventory of State and Local Law Enforcement Technology Needs to Combat Terrorism,* which outlined the law enforcement community's need for improved robots to disarm and disable explosive devices. In 2000, NIJ funded Battelle Memorial Institute to conduct a practitioner-based assessment of requirements for developing a cost-effective bomb-disposal robot for use by State and local bomb squads. This effort produced the *Law Enforcement Robot Technology Assessment,* which discussed the current state of robotics technology and presented the following design criteria for an effective bomb-disposal robot:

- The ability to pick up a 35-pound object that is 18 inches or more ahead of the vehicle without tilting or becoming unstable.
- A functional range of 300 to 450 yards from the operator.
- The ability to operate for 8 to 13 hours a month for training and real scenario purposes.
- The ability to operate normally in temperatures between -40 and 120 degrees F for from 2 to 4.5 hours using an internal power source.
- Monthly maintenance time of 0.5 to 2 hours.
- Annual maintenance cost of $300 to $500.
- A speed objective of 1.5 to 3 miles per hour.
- Weight of 130 pounds or less for the mobile portion of the system to permit easy carrying; weight of 170 pounds or less for a two-man lift.
- Cost of $31,000 or less.

The most critical shortcoming of bomb-disposal robots is the high cost. Most bomb squads in the United States cannot afford them.

Vanguard Robot Assessment Study

Scope. Using private funds, EOD Performance, Inc., designed and produced the Vanguard robot to meet the design specifications outlined in the *Law Enforcement Robot Technology Assessment.* NIJ awarded Battelle, the company that developed the assessment, funds to conduct an independent technical and operational analysis of the Vanguard robot system's ability to satisfy these specifications. The study also recommended improvements.

Battelle's assessment of the Vanguard robot included the following:

Evaluation phases. The analysis was conducted in three phases.

- *Technical evaluation:* Compared the Vanguard platform to the performance measures identified in the *Law Enforcement Robot Technology Assessment.*

- *Operational evaluation:* Provided feedback from military and civilian bomb-disposal operators on the Vanguard system's ability to meet task and mission requirements.
- *Enhancement evaluation:* Recommended improvements to the Vanguard robot system to make it more beneficial to the law enforcement community, based on deficiencies or shortcomings identified during the technical and operational evaluations.

Bottom Line

Vanguard platform performance, in most areas of concern, is equal to or better than that of other systems (see exhibit 1). It satisfies a large percentage of the requirements specified in the *Law Enforcement Robot Technology Assessment,* including the key item of cost: the Vanguard, at $31,000, costs about half as much as the Mini-Andros and the RMI–10. The Vanguard earned a higher score than comparable systems in the successful completion of tasks commonly encountered by bomb-disposal technicians (see exhibit 2). However, it did not satisfy the requirements for speed and mission duration. The evaluators suggested enhancements to address the attribute and task deficiencies identified during the evaluation that would increase the benefits of the Vanguard robot system to the law enforcement practitioner community (see exhibit 3). Based on these findings, EOD has modified the Vanguard. NIJ is funding an evaluation of the modified version.

Exhibit 1. Comparison of robots' key attributes

Attribute (in order of priority)	Threshold value	Objective value	Importance weighting factor[1] (%)	Mini-Andros[2]			Pedsco RMI–10[2]			HDE MURV–100[2]			Vanguard		
				Info	Value[3]	Score[4]	Info	Value[3]	Score[4]	Info	Value[3]	Score[4]	Info	Value[3]	Score[4]
Cost	$31,000	$20,000	21.2	$60,000	0.5	10.6	$50,000	0.6	12.7	$25,000	1.0	21.2	$31,000	1.0	21.2
Manipulator lift capability	35 lbs.	45 lbs.	13.7	15 lbs.	0.4	5.9	75 lbs.	1.0	13.7	10 lbs.	0.3	3.9	35 lbs.	1.0	13.7
Operating range	300 yds.	450 yds.	13.5	200 yds.	0.7	9.0	330 yds.	1.0	13.5	330 yds.	1.0	13.5	400 yds.	1.0	13.5
Training/ utilization requirements	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mission duration	2 hrs.	4.5 hrs.	11.2	4 hrs.	1.0	11.2	5 hrs.	1.0	11.2	3 hrs.	1.0	11.2	1.5–2+ hrs.	0.8	8.4
Maintenance requirements	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Annual maintenance cost	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Speed	1.5 mph	3 mph	6.8	1.1 mph	0.7	5.0	2.5 mph	1.0	6.8	0.85 mph	0.6	3.9	0.7 mph[5] 1.2 mph	0.5	3.2
Weight	130 lbs.	95 lbs.	6.8	190 lbs.	0.7	4.7	140 lbs.	0.9	6.3	45 lbs.	1.0	6.8	103 lbs.	1.0	6.8
Total score			**73.2**			**46.4**			**64.2**			**60.5**			**66.8**

Source: Battelle, *Law Enforcement Robot Technology Assessment,* Washington, DC: U.S. Department of Justice, National Institute of Justice, April 2000. (Available online at http://www.justnet.org/jpsg/robotassessment/robotassessment.html.)

[1]Based on practitioner community survey conducted for NIJ's *Law Enforcement Robot Technology Assessment.*

[2]Based on manufacturer's information as reported in *Law Enforcement Robot Technology Assessment.*

[3]Value is presented as a fraction of 1, which represents full capability.

[4]Score is derived through multiplication of importance and value.

[5]0.7 mph is the speed with tracks; 1.2 mph is the speed in the wheeled configuration.

Dark shading indicates attribute did not satisfy threshold value.

Light shading indicates attribute may satisfy threshold value, depending on mission.

Exhibit 2. Robot performance rankings: Combined evaluations

Functions	Ability required (%)*	Mini-Andros[1] Completion[2] (%)	Mini-Andros[1] Weighted score	RMI–101[1] Completion[2] (%)	RMI–101[1] Weighted score	HDE MURV–100[1] Completion[2] (%)	HDE MURV–100[1] Weighted score	Vanguard Completion[2] (%)	Vanguard Weighted score
Mobility tasks									
Traverse through "clean" areas	62.5	100.0	62.5	100.0	62.5	95.0	59.4	100.0	62.5
Negotiate curbs	52.5	95.0	49.9	65.0	34.1	60.0	31.5	100.0	52.5
Operate in short grass (urban standards)	38.8	75.0	29.1	95.0	36.8	85.0	32.9	100.0	38.8
Traverse through "difficult" areas	27.5	70.0	19.3	82.5	22.7	55.0	15.1	89.5	24.6
Climb short run of stairs (e.g., front steps)	20.0	95.0	19.0	20.0	4.0	30.0	6.0	87.5	17.5
Operate in long grass	12.5	57.5	7.2	86.7	10.8	70.0	8.8	100.0	12.5
Traverse snow, ice, mud, puddles	8.8	56.7	5.0	62.5	5.5	60.0	5.3	89.5	7.9
Maneuver between vehicles, tight landings, buses, airlines	7.5	100.0	7.5	72.5	5.4	95.0	7.1	90.5	6.8
Negotiate stairways (long run)	4.3	95.0	4.0	15.0	0.6	15.0	0.6	81.8	3.5
Operate in "heavy" vegetation—unimproved wooded area	0.5	46.7	0.2	65.0	0.3	43.3	0.2	89.5	0.4
Total (maximum total score = 234.9)			**203.7**		**182.7**		**166.9**		**227.0**
Manipulation tasks									
Relocate packages to blast containment system	25.3	85.0	21.5	85.0	21.5	45.0	11.4	83.3	21.2
Relocate packages to other area	15.0	92.5	13.9	90.0	13.5	75.0	11.3	93.5	14.0
Deploy objects through the window of a home	11.3	20.0	2.3	80.0	9.0	13.3	1.5	40.0	4.5
Inspect, disrupt, move from under vehicles, couches, etc.	10.0	72.5	7.3	75.0	7.5	50.0	5.0	93.3	9.3
Enter door with knob	8.8	77.5	6.8	20.0	1.8	53.3	4.7	90.0	7.9
Deliver countercharge smaller than 2L bottle	7.5	80.0	6.0	93.3	7.0	90.0	6.8	100.0	7.5
Deliver countercharge larger than 2L bottle	2.5	60.0	1.5	73.3	1.8	50.0	1.3	100.0	2.5
Enter door with striker	2.5	52.5	1.3	60.0	1.5	40.0	1.0	50.0	1.3
Deploy objects through the window of a car	1.8	45.0	0.8	65.0	1.1	66.7	1.2	100.0	1.8
Total (maximum total score = 84.7)			**61.4**		**64.7**		**44.2**		**70.0**
Disruption tasks									
Disrupt using 1 disrupter	57.5	80.0	46.0	65.0	37.4	6.7	3.8	85.7	49.3
Disrupt package, briefcase	41.3	86.7	35.8	95.0	39.2	6.7	2.8	81.8	33.8
Disrupt pipe bombs	28.8	86.7	24.9	60.0	17.3	6.7	1.9	80.0	23.0
Disrupt using more than 1 disrupter	15.0	0.0	0.0	20.0	3.0	0.0	0.0	0.0	0.0
Deploy weapons	13.3	40.0	5.3	80.0	10.6	0.0	0.0	88.9	11.8
Disrupt letter bombs	9.3	86.7	8.0	80.0	7.4	6.7	0.6	86.0	8.0
Total (maximum total score = 165.2)			**120.0**		**114.9**		**9.1**		**125.9**
Deploying tools and sensors									
Perform diagnostics with x-ray	0.5	0.0	0.0	66.7	0.3	46.7	0.2	0.0	0.0
Perform chem, bio, hazmat detection	0.3	100.0	0.3	40.0	0.1	0.0	0.0	0.0	0.0
Deploy tools (saw, drill)	0.3	20.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Perform nuclear material detection	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (maximum total score = 14.4)			**0.4**		**0.4**		**0.2**		**0.0**
Duration									
Operate >1 hour on a single mission	47.5	100.0	47.5	70.0	33.3	85.0	40.4	100.0	47.5
Operate >2 hours on a single mission	43.8	100.0	43.8	0.0	0.0	50.0	21.9	30.0	13.1
Operate >4 hours on a single mission	8.8	66.7	5.8	0.0	0.0	35.0	3.1	0.0	0.0
Total (maximum total score = 100)			**97.1**		**33.3**		**65.4**		**60.6**

Source: Battelle, *Law Enforcement Robot Technology Assessment*, Washington, DC: U.S. Department of Justice, National Institute of Justice, April 2000. (Available online at http://www.justnet.org/jpsg/robotassessment/robotassessment.html.)

[1]Based on practitioner evaluations as detailed in *Law Enforcement Robot Technology Assessment.*

[2]Completion is the unassisted performance of the task.

*Percentage of missions in which this task would be performed.

Limitations Training requirements, maintenance requirements, and maintenance costs were not evaluated because accurate assessments of those factors require a longer evaluation period.

Audience Federal, State, and local policymakers; public safety administrators; and bomb technicians.

More Information See *Inventory of State and Local Law Enforcement Technology Needs to Combat Terrorism* at http://www.ojp.usdoj.gov/nij/pubs-sum/173384.htm and *Law Enforcement Robot Technology Assessment* at www.justnet.org/jpsg/robotassessment/robotassessment.html.

Exhibit 3. Vanguard product improvement plan

Limitations	Proposed systems capabilities
Mission duration 1.5 hours	Include a larger battery to give mission duration of 2 – 2.5 hours (fitting in a 10 ampere hours (Ah) battery), design a new battery lid and pouch, and conduct a stair-climbing study.
Single firing circuit	Include multiple firing circuits and new wiring to integrate three firing circuits and change the user interface software to reflect each circuit. Also rewire one circuit to use as a power-tool outlet (24 volts).
Claw camera has no light	Integrate two light-emitting diode (LED) lights with the claw camera. Requires new camera housing, new wiring, and cables.
No joystick controller	Technician will be able to plug in any universal serial bus (USB) joystick. Involves software programming.
Standard circuit breaker	Include self-resting circuit breaker. Add self-resting breaker on the electric board and change main power breaker to on/off switch.
Basic weather resistance	Implement a seal and gasket to waterproof the robot. Involves approximately 15 dies.
Firing system not isolated	Isolate the firing system. Requires material change, new wiring, and adding relay in the electronic box.
Plastic pan/tilt motor housing	Include aluminum pan/tilt motor housing, with better low-light infrared camera. Cover pan/tilt camera from collecting raindrops. Add connector to camera instead of hardwiring.
Low-screen visibility outdoors	Program a new user interface with high-visibility colors. Supply a laptop hood standard with each robot. Supply power to connect head-up display.
Limited RF signal –Fixed RF antennas –Low-grain antenna on robot end	Redesign command station to separate radio frequency (RF) antennas. RF signal will be improved if the command station is inside the bomb truck and if antennas are outside the truck on a tripod with their own power supply. Use a high-grain antenna and signal amplifier.
Manual arm deploy	Include arm automatic deploy. Requires software programming and hardware changes to implement.
Fires only Proparms 20 mm recoilless disrupter	Design and integrate a pan mitigation system to enable occasional use of the pan disrupter. Work will include a study on firing effects on the robot after 100 shots of use.
No x-ray capabilities	Integrate real-time digital x-ray system. The goal is to use the x-ray system command station to drive the robot and eliminate the need for two laptops.
Top speed is only 0.7 mph	Increase speed to 1.3 mph. Requires new motors, new wiring, and software. New motors will create high electric noise and cause board to reset; electronic troubleshooting is required for new motors to work properly.
Track's height designed for 7.5-inch-high stairs	Redesign track's height to climb standard 8-inch-high commercial stairs.
Track's cleats glued in place and only 0.5 inch high	Mold cleats in place and increase height to 0.75 inch to improve durability.
Limited electronics expansion	Include new electronic board with surface-mounted components and improved connectors to improve overall durability and vibration against disrupter pressure. New electronics will have a faster processor and more memory to allow multifunction, arm deploy, a safer firing circuit, and support for faster drive motors. Also, it allows for future expansion, like automatic arm stow, distance feedback, and zoom camera control.
One-way audio	Two-way audio on RF.

Note: Upgrades should be completed by April 2004.

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