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Knight Robot Report

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Executive Summary

Operational experimentation of the Knight robot was conducted on July 29, 2015, at a New York City Police Department facility at Floyd Bennett Field in Brooklyn, New York. First responder evaluators from law enforcement agencies and fire departments in New York, New Jersey, and Maryland took part in this event.

The Knight is a commercially available unmanned ground vehicle (UGV) produced by WM Robots, LLC (WMR) that is designed for explosives detection and removal. It is equipped with an independently controlled surveillance camera arm and a seven-joint manipulator arm that can lift a maximum of 60 to 300 pounds, depending on the degree of arm extension. The manipulator arm has a gripper tool, a pan/tilt camera, and numerous ports and mounting brackets for connecting lights, sensors and other devices. The UGV, surveillance arm, and manipulator arm can be operated wirelessly via separate, dedicated controls at standoff distances exceeding 600 meters.

For OpEx, the Knight's manipulator arm was configured with the HAZPROBE, a robotic boring and inspecting tool developed by WMR. The HAZPROBE drills through the walls of vehicles, shipping containers and buildings, and then automatically inserts a self-illuminating pan-and-tilt camera. It also has a window-breaking tool that provides another way to gain access to interior spaces.

A WMR representative briefed evaluators on the Knight's capabilities, who then observed a second WMR representative operate the Knight remotely to inspect a mock threat vehicle. The inspection involved viewing the vehicle exterior using cameras mounted on the Knight, and then drilling a hole and inserting a camera into the vehicle using the HAZPROBE tool. The interior of the vehicle was also accessed and viewed by breaking a passenger window.

Evaluators indicated that the Knight was a good platform for use with large inspection tools such as the HAZPROBE, but the large size that made the Knight well suited as a platform for the HAZPROBE had the disadvantage of limiting the range of locations it could access. The Knight/HAZPROBE combination performed very well at the tasks of drilling into and viewing the interior of enclosed spaces, but evaluators had some reservations about performing inspections this way, stating that vehicle-borne explosive devices might in some cases be triggered by vibrations. However, this was noted to be a drawback to existing approaches as well. It was also noted that some organizations currently use personnel in bomb suits to manually inspect threat vehicles and containers; so the Knight/HAZPROBE is a technology that could provide an alternative to having bomb squad personnel perform this hazardous task. Evaluators noted that mobile backscatter X-ray equipment can non-invasively inspect vehicles, thus the Knight/HAZPROBE combination might only be useful for inspecting objects that cannot be imaged with backscatter x-ray equipment or by organizations that do not have access to mobile backscatter x-ray technology. Responders suggested that the Knight's remote control unit be made simpler and more like other control units they were familiar with. They also suggested that future versions of the Knight should be capable of returning to its starting point when communications with the unit's control equipment are lost.

Table of Contents

1 Introduction

Knight is an unmanned ground vehicle (UGV) developed by WM Robots, LLC (WMR) for explosives detection and removal applications. It is equipped with surveillance and manipulator arms and can be operated remotely at distances of up to 600 meters from its operator. In the experiment described in this report, Knight was configured with the HAZPROBE, a tool developed by WMR to drill into and view the interior of confined spaces.

On July 29, 2015, Knight was the subject of operational experimentation during the Department of Homeland Security Science and Technology Directorate's (DHS S&T) Urban Operational Experimentation (OpEx) event organized by the National Urban Security Technology Laboratory (NUSTL). New York City Fire Department, New York City Emergency Management, New York City Police Department and Port Authority of New York and New Jersey subject matter experts supported the OpEx by selecting the technologies and working with NUSTL scientists to plan the experimentation scenarios and arrange test venues. Responders from these agencies and members of the First Responder Resource Group experimented with the technologies and provided feedback and observations. Table 1 lists all of the technologies that were included in this event. Technologies assessed during this event were selected with input from local first responder agencies and met capability gaps identified in the Project Responder 4 National Technology Plan for Emergency Response to Catastrophic Incidents [1].

Table 1. Technologies Included in OpEx 2015

Product Name Manufacturer	**Description**
Situational Head Up Display Avon Protection Systems	Micro Liquid Crystal Display (LCD) with full color widescreen layout built into face shield
Tridion™-9 PerkinElmer	Portable Gas Chromatography/Mass Spectrometry (GC/MS) system that provides identification of volatile and semi-volatile organic hazards in the field in less than three minutes
BioFlash-E Biological Identifier PathSensors	Portable and rapid aerosol sample collection and identification of up to 16 biological threat agents
Fido B2 IBAC FLIR	Networked array of portable biosensors
Internet of Things for First Responders BAE Systems	Networked sensors that use a long-range wireless protocol capable of concrete penetration to send signals through a network aggregator
Knight Robot/HAZPROBE WM Robots	All-terrain robot with a manipulator arm, cameras, and a boring and inspecting device that can drill through walls for bomb tech personnel to inspect suspect abandoned vehicles or objects
RepKnight ADI Technologies	Monitors and analyzes social media with geolocation feature
X-Ray Scanning Rover Smart Imaging Systems	An x-ray scanner integrated into a custom-built robot that is designed to rapidly screen suspicious left-behind bags or parcels on the ground

1.1 Purpose

The Knight operational experiment was intended to provide first responder evaluators with an opportunity to evaluate the Knight, configured with the HAZPROBE, for first responder use. The purpose of generating feedback from first responders is to provide the manufacturer, WMR, with information useful in optimizing the Knight and HAZPROBE for field use by first responders, and to help inform S&T about responder needs to guide future homeland security investments in this technology area.

1.2 Objective

This experimentation is designed to allow responders to experience the use of the Knight robot in operational settings, and to offer feedback and suggestions to WMR that could enhance the product capabilities for first responder operations.

1.3 Responder Capability Need

The ability to detect and analyze passive and active threats in real time is one of the capability needs identified by first responders participating in the Project Responder 4 study. The Knight UGV configured with the HAZPROBE is a technology that could address this capability need during incidents involving possible bomb threats.

1.4 Product Description

The Knight is an UGV equipped with a surveillance arm and a separate seven-joint manipulator arm that can lift a maximum of 60 to 300 pounds, depending on the degree of arm extension; the manipulator arm is equipped with a detachable gripping tool. The UGV and its two arms have numerous data ports and mounting brackets for connecting lights, sensors, and other devices. Its operator control unit (OCU) has separate, dedicated controls for the UGV, surveillance arm and manipulator arm. The user can view camera feeds from the robot on an OCU video display screen, and control the UGV and manipulator arm at distances exceeding 600 meters via a wireless link and at distances of up to 150 meters via a fiber optic cable. The Knight weighs about 700 pounds as configured for OpEx. The UGV and OCU are powered by rechargeable lithium-ion battery packs providing an operating time of approximately five hours.

The Knight's manipulator arm was configured with the HAZPROBE, a robotic boring and inspecting device for bomb disposal applications developed by WM Robots (see Figure 1). The HAZPROBE is designed to remotely inspect behind objects or inside a suspect vehicle or container. It has a window-breaking bit and an assortment of drill bits for penetrating through different kinds of media. It senses when drilling is complete, at which point the drill bit automatically ejects and an in-shaft camera extends into the compartment. The camera has pan and rotate functions and a self-illuminating light emitting diode ring, and can be interchanged onsite with plug-in color or near infrared modules.

Figure 1 – The Knight Robot with HAZPROBE

2 Experimentation Design

A detailed description of the experimentation design can be found in the Experimentation Plans for the Knight robot [2]. The experimentation scenario was developed with input from responders, WMR representatives and NUSTL's OpEx team to simulate a response to a mock vehicle threat.

2.1 Event Design

The experimentation convened with a group of first responder evaluators to learn about the features and capabilities of Knight and to observe and experiment with how it could be used along with HAZPROBE to inspect a mock threat vehicle. This enabled the first responders to provide informed feedback about the use of the Knight as a bomb detection and disposal tool.

2.2 Summary of the Operational Experimentation

On July 29, 2015, a group of evaluators, comprised of bomb squad and first responder representatives from the New York City Police Department (NYPD), Port Authority of New York and New Jersey Police Department and the Montgomery County Fire and Rescue (Maryland), convened at an NYPD facility at Floyd Bennett Field in Brooklyn, New York, to participate in operational experimentation with the Knight, configured with the HAZPROBE tool.

Activities began in an indoor training room setting with a presentation by the NUSTL experimentation director about the OpEx program, the purpose of the Knight operational experiment and a brief safety orientation. A representative from WMR then provided information about the features and capabilities of the Knight and the HAZPROBE tool it was configured with.

Participants went to an outdoor area for the experimentation session, in which the Knight, configured with the HAZPROBE, was used to inspect a mock threat vehicle provided by the NYPD

(see Figure 2) as the test subject. A WMR technical representative operated the Knight during the threat vehicle inspection using the OCU, which was located approximately 40 meters from the mock threat vehicle. Communication between the Knight and the OCU was by a radio link.

The vehicle inspection activity consisted of several tasks. First, the Knight approached the vehicle from a starting point close to the OCU, and the exterior of the vehicle was viewed at the OCU via video feed sent from the Knight. The HAZPROBE then drilled a hole and inserted its camera into the interior of the rear cargo compartment of the vehicle; the camera's video feed was sent to and viewed at the OCU (see Figure 2). Next, a passenger window of the vehicle was broken and removed, and the interior of the vehicle's passenger compartment was viewed at the OCU using the Knight's video camera. Evaluators were given an opportunity to maneuver the Knight and its manipulator arm under supervision of the WMR technical representative to get a better feel for remote operation of the Knight via the OCU. One evaluator drove the Knight around the mock threat vehicle and operated the manipulator arm to inspect the vehicle's interior. The Knight was then driven back to its starting point to complete the experimentation session. Evaluators observed the Knight and HAZPROBE perform the planned experiment tasks, watched the WMR representative operate the Knight and HAZPROBE from the OCU, and viewed the video feeds transmitted back to the OCU. There was one significant variation from the test plan. The test plan called for the Knight to also inspect a cargo container, but it was not possible to obtain one, so this part of the planned experiment did not occur.

The evaluators then returned to the training room for a debrief session led by the experimentation director, in which responders provided comments to, and asked questions of, the WMR representatives. During the outdoor experimentation and the debrief session, the evaluators' questions and comments were recorded by NUSTL data collectors.

Figure 2 – The Knight robot with HAZPROBE preparing to drill into suspect vehicle

3 Results

3.1 User Feedback

The experimentation convened with a group of first-responder evaluators to learn about the features and capabilities of Knight, and to observe and experiment with how it could be used to inspect a mock threat vehicle. This enabled the first responders to provide informed feedback about the use of the Knight as a bomb detection and disposal tool.

The evaluators commented that the size and weight of the Knight UGV, compared to other bomb squad UGVs, made it a very good platform for larger pieces of equipment like the HAZPROBE. They also indicated that the strength of the Knight made it potentially useful for other applications, for instance, dragging an injured person away from an area that is too hazardous to send a human rescuer into. The HAZPROBE was judged to perform the tasks it was designed for well. However, evaluators also stated that large size and the weight of the Knight UGV had the potential drawback of making it unable to access places where it might be needed, and that the HAZPROBE might be too large and heavy to be operated optimally by smaller bomb squad UGVs.

Evaluators expressed concerns that vibration produced by the HAZPROBE drilling into a vehicle compartment containing explosives might trigger the device. However, some evaluators stated that they mount power tools onto the UGVs they currently use to carry out the drilling task the HAZPROBE performed during the experiment, thus this drawback is not limited to the HAZPROBE. Some evaluators stated that in their organizations individuals wearing bomb suits sometimes manually inspect possible threat vehicles or containers, so the Knight/HAZPROBE configuration could be a technological solution that reduces the risk to individuals performing such a task. Some evaluators indicated that their organizations use mobile backscatter x-ray systems to non-invasively inspect threat vehicles and felt the Knight/HAZPROBE configuration would only be useful for inspecting objects with thicker exterior walls that their backscatter x-ray devices cannot properly image. However, they acknowledged that many organizations did not have access to backscatter x-ray systems.

Many, but not all, of the evaluators felt that the current version of the Knight's OCU was somewhat outdated, and should be simpler to use and more like the control devices they are already familiar with, such as a steering wheel as opposed to a joystick. Several evaluators expressed concerns about controlling the Knight using a fiber-optic cable connection. They felt that the cable might become tangled, possibly interfering with the operation of the Knight. They also felt that the 500 foot operating range provided by the fiber optic cable link was somewhat limiting. The fiber optic cable link was not demonstrated during the day's experiment, so these comments were not based on actual operation of the Knight. The Knight is not programmed to automatically return to its starting point if it loses its link to the OCU; evaluators suggested that an auto return capability would be a valuable feature to incorporate into future versions of the Knight.

4 References

1. Project Responder 4: 2014 National Technology Plan for Emergency Response to Catastrophic Incidents (July 2014). Prepared for Department of Homeland Security by the Homeland Security Studies and Analysis Institute, Falls Church, Virginia (http://www.homelandsecurity.org/) Publication Number RP13-17-02.
2. Urban Operational Experimentation Plan for the Knight Robot and X-ray Scanning Rover. July 2015. OpEx-T-PL-1 NUSTL.

5 List of Acronyms Used

DHS	-	Department of Homeland Security
LLC	-	Limited Liability Corporation
NUSTL	-	National Urban Security Technology Laboratory
NYPD	-	New York City Police Department
OCU	-	Operator Control Unit
OpEx	-	Operational Experimentation
S&T	-	Science and Technology Directorate
UGV	-	Unmanned Ground Vehicle
WMR	-	WM Robot, LLC