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Operational Test and Evaluation Performance Report:

Halcyon FireGround Compass®, Version 1.1

By

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List of Abbreviations

ConOps	Concept of Operations
DHS	U.S. Department of Homeland Security
EKU	Eastern Kentucky University
ESFR	Early Suppression Fast Response
FDSOA	Fire Department Safety Officers Association
FEMA	Federal Emergency Management Agency
FOT	Field Operational Testing
GPM	Gallons Per Minute
IAFC	International Association of Fire Chiefs
IC	Incident Commander
ID	Identification
IEC	International Electrotechnical Commission
IMSI	Incident Management Systems Integration (IMSI) Division
IRB	Institutional Review Board
JSC	Justice and Safety Center
NIMS	National Incident Management System
NFPA	National Fire Protection Agency
OT&E	Operational Test and Evaluation
PASS	Personal Alert Safety System
PSI	Pounds Per Square Inch
SCBA	Self Contained Breathing Apparatus
SOP	Standard Operating Procedure
SSAWG	Security Standards Subject Area Working Groups
S&T	Science and Technology Directorate
UUT	Unit Under Test

1.0 Introduction

This report provides a summary of the findings from the operational test and evaluation (OT&E) of the FireGround Compass, a life safety technology for firefighters sponsored by the U.S. Department of Homeland Security (DHS) TechSolutions program. This operational test and evaluation performance report is designed to provide a summary of the events that took place during the testing activities, which began on June 23, 2008 when TechSolutions received the FireGround Compass test units and performed the initial inspection and calibration. This report also includes a summary of a heat resistance retest conducted on November 13, 2008, per a request from the TechSolutions Program Director.

TechSolutions attempted an earlier operational test and evaluation of the FireGround Compass in April 2008. This effort was halted following the product demonstration and training portion of the test. Details regarding that initial test can be found in Appendix A: Preliminary Test Report – Halcyon FireGround Compass.

1.1 Background

The Field Operational Testing (FOT) of the FireGround Compass was conducted under the auspices of the DHS Science and Technology Directorate's (S&T) TechSolutions program. DHS S&T designed the test plan and procedures, conducted test events with test engineers and subjects drawn from the first responder community, and generated this operational test and evaluation performance report. TechSolutions used the DHS model for standards and compatibility (See Section 1.4) as the basis for the testing of first responder-related technology and equipment.

The FOT:

- Typically involves follow on evaluations for readiness and qualification testing of equipment or technologies that have been acquired and deployed by an end user;
- Is focused upon the end product and uses a field testing methodology;
- Is conducted when no significant research or development is required or it has already been completed;
- Can be used to support evolutionary and incremental acquisition strategies; and
- Can be completed prior to the distribution of production units.

1.2 Document Scope

This OT&E performance report is intended to provide details of the comprehensive operational test of the FireGround Compass conducted by end users. The purpose of the FireGround Compass is to prevent firefighter disorientation in "big box"-type stores and warehouses. It is intended to keep the firefighter moving in a straight line and to lead him or her to a wall or point of egress. This report details the performance of the FireGround Compass in a warehouse setting as well as two additional simulated fire settings, a smoke-filled house and a poured concrete live fire facility, to test the performance of the UUT in both a visually-obscured and heated environments, respectively.

This OT&E performance report details each test series and includes the environmental laboratory tests, the field operational tests, and how each test unit performed in a particular test. The report

also describes each test scenario and how the test units were used and evaluated during each test. In addition to specific test results, a summary of the overall findings of the FireGround Compass and feedback from the test subjects on the ease of use and overall performance of the test unit is included.

The test units submitted for this operational test and evaluation event were treated as production-ready devices. The vendor described the units as commercially-ready models, soon to be made available to the first responder community.

Finally, this OT&E performance report includes interviews with firefighting practitioners who served as test subjects for this test event, resource information on the standards used in the development of the test plan, and additional documents and guidelines that provided the source documentation for all test criteria.

This operational test and evaluation performance report is not intended to endorse or recommend any particular product, but rather provide information for the possible procurement of a technology by the end user; in this case, the first responder community. The results from this test event are presented as observations by the DHS S&T Operational Test & Evaluation team (OT&E team) and do not imply success or failure of the technology.

1.3 Document Overview

The primary purpose of this operational test and evaluation performance report is to give the first responder community information regarding a specific tool intended to be used by firefighters for purposes of location re-orientation.

This operational test and evaluation performance report describes the test objectives, test scope and preparations, the field testing methodology, the test strategy, and the test observations and results adopted by the OT&E team to validate the operational use of the FireGround Compass by firefighting practitioners. This information is meant to be used by the TechSolutions program, which was established by DHS S&T to provide the first responder community with an objective process to evaluate their purchases. This report is accompanied by supporting documentation, which provides the details required to execute the test plan, as well as the results obtained when the OT&E team performed the environmental and operational testing.

Operational and environmental tests and procedures defined in this report were developed and performed by the OT&E team. All original documentation will be maintained by the Eastern Kentucky University Justice & Safety Center, located at 50 Stratton Building, 521 Lancaster Avenue, Richmond, Kentucky 40475.

1.4 References and Manuals

The following documents were referenced in the development of this operation test and evaluation performance report:

- Adoption of Department of Homeland Security (DHS) National Standards, DHS Management Directive 10600.1, August 3, 2004.
- Adoption of DHS Directorate Standards as Department of Homeland Security (DHS) National Standards, DHS Management Directive 10601, September 23, 2004.
- Engineering Drawings, Halcyon Products, Inc. (see Appendix B: UUT Technical Data).

- Essentials of Firefighting, 4th Edition, International Fire Service Training Association, June 1998.
- Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities, Circular No. A-119, Office of Management and Budget, February 10, 1998.
- TechSolutions Concept of Operations: Operational Test & Evaluation, DRAFT, U.S. Department of Homeland Security and G&H International Services, Inc., Washington, D.C., 11 July 2008 (see Appendix C: Draft TechSolutions ConOps – Operational Test and Evaluation).
- FireGround Compass New Product Development Evaluation, Fire Department Safety Officers Association (FDSOA) Conference Survey Summary, November 2006.
- FireGround Compass 2007 Business Plan and 2008 Update to Plan, Halcyon Products, Inc., John Moore, March 2008.
- Fundamentals of Fire Fighter Skills, International Association of Fire Chiefs (IAFC) and National Fire Protection Association (NFPA), Jones and Bartlett, Sudbury, Massachusetts, 2009.
- Homeland Security Standards Subject Area Working Groups (SSAWGs), DHS Management Directive 10602, December 20, 2004.
- International Standard IEC 529/IEC 60529 for Water and Dust Ingress, International Electrotechnical Commission (IEC), Geneva, Switzerland.
- NFPA 1961: Fire Hose, 1997, National Fire Protection Association (NFPA), Quincy, Massachusetts.
- NFPA 1971: Standard on Protective Ensemble for Structural Fire Fighting, National Fire Protection Association (NFPA), Quincy, Massachusetts.
- NFPA 1982: Standard on Personal Alert Safety Systems (PASS), National Fire Protection Association (NFPA), Quincy, Massachusetts.
- NFPA 1994: Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents, National Fire Protection Association (NFPA), Quincy, Massachusetts.
- Recommended Federal Grants Guidance, Public Safety Communications & Interoperability Grants, SAFECOM, Department of Homeland Security, November 2004.
- Review of DHS' Progress in Adopting and Enforcing Equipment Standards for First Responders, Office of Inspections and Special Reviews, U.S. Department of Homeland Security, Washington, D.C., March 2006.
- Testing Overview Document: Halcyon FireGround Compass, TechSolutions program, U.S. Department of Homeland Security and G&H International Services, Inc., Washington, D.C., 12 March 2008.

2.0 Unit Under Test (UUT) Overview

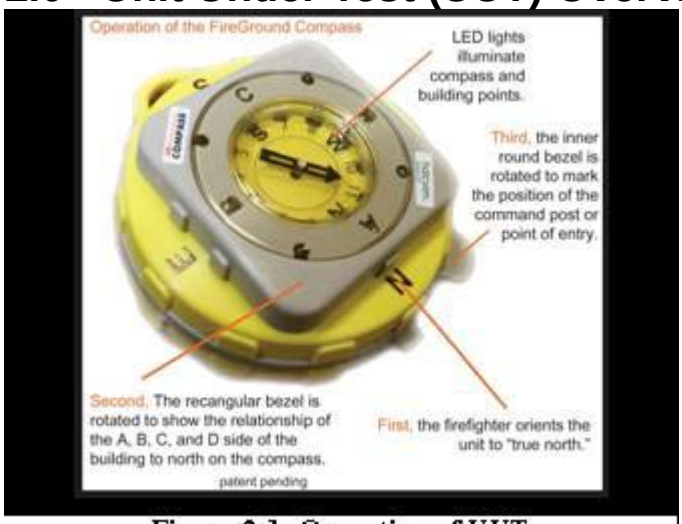


Figure 2-1: Operation of UUT

The OT&E activity focused on the features, functions, and operational readiness of the FireGround Compass, a device manufactured by Halcyon Products, Inc. of Chagrin Falls, Ohio (see Figure 2-1). The FireGround Compass is designed to enable firefighters, their exterior sector officers, and the Incident Commander (IC) to maintain their particular reference point with respect to the fire building or area as they battle interior structural fires.

The product operation combines a compass with two rotating bezels and a light that illuminates the compass and building points. The building bezel is square in shape and is labeled with the letters A, B, C, and D, which represent the sides of the incident building as defined by the National Fire Academy. The command bezel is an inner round bezel that is rotated to mark the position of the command post or point of entry.

To use the UUT, the firefighter orients the unit to the north and rotates the building bezel to show the relationship of the A, B, C, and D sides of the building to north on the compass. The front of the building, or the address side, is usually designated as side A, with sides B, C, and D following in a clockwise direction around the building. The command bezel is then rotated to correspond to the location of the command post or point of entry on the building.

The FireGround Compass is intended to help firefighters re-establish their orientation within a building should they become lost or disoriented. It is intended to serve as a navigational aid and should not replace the firefighter's standard operating procedures (SOP). For more information about the product operation and product features, see Appendix F: Vendor Literature.

3.0 Description of Test Objectives, Environments, and Assumptions

3.1 Test Objectives

The purpose of the OT&E event was to provide an independent evaluation of the UUT in a controllable, repeatable environment. Within the test plan, each test series included a detailed test plan containing objectives, criteria, and procedures specific to the UUT. Additionally, the plan delineated a testing schedule, reporting requirements, and roles and responsibilities for a blended environmental and operational test activity. The original test plan (Test Plan: Halcyon FireGround Compass, Revised 7 April 2008, U.S. Department of Homeland Security) is attached as Appendix D: Test Plan – Halcyon FireGround Compass.

The test plan for each test series required that the system satisfy performance requirements as appropriate at the component, subsystem, and system requirements level. Additionally, the

OT&E team relied on laboratory equipment for environmental testing that was available at Eastern Kentucky University (EKU). The test plan included the following elements:

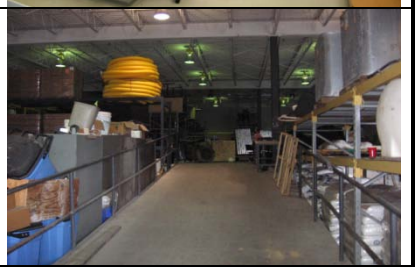
- Objectives;
- Criteria;
- OT&E team personnel;
- Hardware configuration;
- Documentation;
- Procedures; and
- Data collection sheets.

Tailored data collection sheets (see Appendix E: Data Collection Sheets) provided the OT&E team with the primary mechanism for logging all events, observations, measurements, and remarks concerning test conduct. Additionally, the plan identified all facility support requirements that needed to be met to achieve acceptable test conditions. Requirements were met with existing facility materials, resources, and staff.

3.2 Environments

Due to the blended design of the test event, which included both environmental and operational tests, the OT&E team used multiple venues in Richmond, Kentucky. The specific test series were developed to test the UUT in a variety of settings and conditions to ensure that the UUT selected by the DHS TechSolutions program is ready for use by the first responder community prior to deployment in a field environment. The test plan required access to the test venues identified in Table 3-1.

Table 3-1: Test Venues

Test Venue:	Venue Description:	Venue Image:
Justice and Safety Center Eastern Kentucky University Richmond, KY 40475	This facility houses a variety of equipment (oven, immersion tank, etc.) necessary for the environmental tests presented in the test plan.	
Raymond Gabbard Building Eastern Kentucky University Richmond, KY 40475	This facility was used to simulate a warehouse environment and conditions in order to perform the manufacturer beta test.	

Test Venue:	Venue Description:	Venue Image:
Fire Training Center Richmond Fire Department Richmond, KY 40475	This center houses a live fire milieu as well as a simulated smoke house that was used for various tests during the operational section of the test plan.	
Fire Suppression Laboratory Eastern Kentucky University Richmond, KY 40475	This laboratory was used during the operational section of the test plan, and currently houses 24 sprinkler risers.	
Intertek Group Laboratory 3933 U.S. Route 11 Cortland, New York 13045	This laboratory was used specifically for the Heat Resistance retest.	

3.3 Assumptions

Based upon literature provided by the vendor (see Appendix F: Vendor Literature), the OT&E team held several assumptions for this OT&E performance report. These assumptions include the following:

- The FireGround Compass will experience interference if held in close proximity to iron pillars and racks, speaker magnets, electrical panels, cell phones, or rebar in concrete floors and walls.[1]
- The user should avoid proximity to ferrous materials or electromagnetic fields.
- The compass should be held level within 15 degrees.
- The compass itself is waterproof, but the battery compartment is not. If exposed to water, the back of the battery compartment should be removed and blown out or hung up to dry.

[1] Halcyon defines a 2 ft. / 10 ft. rule for the FireGround Compass: Keep FireGround Compass 2ft. off the ground and 10 ft. from iron pillars. Halcyon also recommends keeping the FireGround Compass at least 12 in. from a two-way radio or cell phone.

4.0 Test Preparations

4.1 Human Subjects Approval

In accordance with federal and institutional regulations, any undertaking that investigates and/or collects data on human subjects for research purposes must be reviewed by an Institutional Review Board (IRB) prior to initiation of the project. The IRB is responsible for reviewing all research activities involving human subjects regardless of the source of funding. The IRB used for this test event is a university committee comprising faculty members and a community representative who are appointed by the institution. The mission of the IRB is to promote and safeguard research activities that involve human subjects. In reviewing research proposals that involve the use of human subjects, the IRB assures that appropriate steps are taken to protect the rights and welfare of humans participating as subjects in the research. The IRB is concerned with ensuring that (1) the research has been designed to minimize the risk (physical, social and/or psychological) to human subjects; and (2) all subjects consent and are fully informed about the research and any risks. The IRB has the authority to approve, require modifications, or disapprove research activities.

The OT&E of the FireGround Compass involved the use of human subjects and, therefore, required review and approval by Eastern Kentucky University's IRB. To ensure that the OT&E team took appropriate steps to protect the rights and welfare of the test subjects, the IRB conducted a full committee review of the research proposal, OT&E Test Plan, data collection tools, and informed consent documents. The FireGround Compass evaluation was approved by the IRB on April 9, 2008 (see Appendix G: Human Subjects Approval). The rescheduled test event fell outside of the project approval dates making it necessary to submit a continuation form to the IRB. Approval to continue the project was granted on May 30, 2008 (see Appendix H: Human Subjects Approval – Continuation).

4.2 Selection of Test Subjects

Three test subjects were recruited for the OT&E of the FireGround Compass (see Table 4-1 and Figure 4-1). All three test subjects are certified firefighters with a combined total of twenty-four years of fire service experience. All test subjects are currently employed by the City of Richmond (Kentucky) Fire/Rescue Department.

Table 4-1: FireGround Compass OT&E Test Subject Experience Description

Test Subject	Firefighting Experience
Test Subject A	Test Subject A currently serves as a firefighter and investigator for the City of Richmond Fire/Rescue Department. He is also employed by the Eastern Kentucky University Justice & Safety Center in support of the Federal Emergency Management Agency Incident Management Systems Integration (IMSI) Division's National Incident Management (NIMS) Support Center. Test Subject A has a Bachelor's of Science Degree in Fire and Safety Engineering and over eleven years of firefighting-related experience.

Test Subject	Firefighting Experience
Test Subject B	Test Subject B has been a firefighter with the City of Richmond Fire/Rescue Department for two years. Prior to that he served as a firefighter for the Orange County Fire Authority in Orange County, California. He has over six years of firefighting-related experience.
Test Subject C	Test Subject C has been a firefighter with the City of Richmond Fire/Rescue Department for two years. Prior to that, he served as a firefighter and fire explorer with the City of Blue Ash (Ohio) Fire Department. He has over seven years of firefighting-related experience.

4.3 Procedures Check / Final Facility Preparation

On June 23, 2008, the OT&E team gathered for a dry run of the FireGround Compass test event. The team reviewed each test series and simulated the actions that would occur during the actual test event. The test subjects were onsite during the dry run and provided critical feedback about the test procedures. As a result, some test procedures were modified in accordance with their feedback. This was done to ensure that the procedures were consistent with SOPs in the fire service. An example of such a modification was the addition of a second test subject in each of the operational tests. It is a standard operating procedure for firefighters to work in teams of two. The original test plan called for one firefighter in a number of the test series. Therefore, the test plan was modified to more accurately simulate a real-life situation in which two firefighters would be responding. The second test subject was present during the tests solely to simulate a standard operating procedure and did not play an active role in performing the test procedures.

The dry run revealed other areas in which the test plan required changes. These changes were minor and included fine-tuning the sequence of test procedures, identifying key pieces of data that needed to be gathered during each test, and clarifying the roles each OT&E team member would fulfill during the test event. The OT&E team also revised the data collection sheets to reflect any changes identified in the dry run.

4.4 Pre-Test Inspection and Calibration

The pre-test inspection and calibration consisted of the OT&E team performing the following steps:

- Receiving the shipment of thirty Units Under Test (UUT);
- Unpacking and recording each UUT;
- Assigning unique identification (ID) numbers to each UUT; and
- Testing of basic usability of each unit, which included manipulation of the bezels and lighting mechanism.

Calibration consisted of comparing the “true” north reading from each UUT to a neutral or controlled Brunton NOMAD V2 PRO digital test compass that was part of the laboratory equipment used during the environmental testing phase of the OT&E event (see Appendix I: UUT Acceptance Form).

The pre-test activity was designed to provide independent verification and validation of each UUT's readiness for the OT&E event. The OT&E team conducted the pre-test and evaluation activities in accordance with the DHS-approved test plan and were designed to support the actual test event and ensure realism or operational fidelity.

Figure 4-1: DHS S&T Operational Test and Evaluation Team Receives and Inventories UUTs

4.4.1 Manipulation of Bezels

All UUTs, with the exception of EKU028, functioned with sufficient ease of movement and resistance to maintain a static position once set. The command bezel on EKU028 was noticeably tight and provided more resistance than demonstrated in other UUTs. Since it could not be determined how it would function in the operational test environment, EKU028 was removed from testing.

4.4.2 Lighting Mechanism

The UUT has a built-in lighting capability which allows the device to be read in dark or smoky conditions. The lighting mechanism for the unit is displayed in Figure 4-2. The lighting mechanism is powered by two 3 volt Coin Cell (CR 2450) batteries. All UUTs, with the exception of EKU004, illuminated once the lighting button was depressed. As a result of the light malfunction, EKU004 was removed from testing.

Figure 4-2: UUT Illuminated in the Dark (0 lux)

4.4.3 Calibration / Reference Test

Calibration consisted of comparing the "true" north reading from each UUT to a neutral or controlled test compass (digital) that was part of the laboratory equipment used during the environmental testing phase of the OT&E test event (see Figure 4-3).

The magnetic deviation or variation was recorded as the number of degrees from "magnetic north." Magnetic deviation, as used in this report, refers to the error induced in a compass by local magnetic fields, which must be allowed for along with magnetic declination. Declination, also called variation, as defined in this report denotes the difference between true north and the direction of the earth's magnetic field (see Figure 4-4).

The findings from the Calibration Reference test found that none of the units deviated more than 9° from the reference compass. All units pointed north.

Figure 4-3: Calibration of UUTs

Figure 4-4: Magnetic Declination

4.5 UT Use Summary

In summary, a total of twenty-four UUTs were used during the OT&E event. The OT&E team conducted each test with a different UUT, with the exception of units EKU011, EKU017, and EKU022. These units were used in one prior test each (Mechanical Adjustment Range, Manufacturer Beta Test, and Orientation and Egress in an Obscured Environment respectively) and were inspected and deemed acceptable for use in the Heat Resistance retest.. Table 4-2 provides a list of the UUTs used in the OT&E event, as well as the specific test for which they were used.

Table 4-2: UUTs Used in Each Test Series

UUT ID#	Test
EKU001	Ingress Protection – Immersion
EKU002	Ingress Protection – Immersion
EKU005	Measuring Impact Strength (Concrete Floor)
EKU006	Measuring Impact Strength (Covered Floor)
EKU007	Icing Conditions
EKU008	Icing Conditions
EKU011	Mechanical Adjustment Range Heat Resistance
EKU012	Mechanical Adjustment Range
EKU013	Mechanical Adjustment – Dry Gloves
EKU014	Mechanical Adjustment – HAZMAT Gloves
EKU015	Mechanical Adjustment – Wet Gloves
EKU016	Manufacturer Beta Test

UUT ID#	Test
EKU017	Manufacturer Beta Test Heat Resistance
EKU018	Illumination Test
EKU019	Illumination Test
EKU020	Flame / Heat Test at Live Burn Facility
EKU021	Flame / Heat Test at Live Burn Facility
EKU023	Ingress Protection – Attack Hose
EKU026	Ingress Protection – Attack Hose
EKU022	Orientation and Egress in an Obscured Environment Heat Resistance
EKU025	Orientation and Egress in an Obscured Environment
EKU027	Stowing / Accessing the UUT in Fire Suppression / Inundation Environment
EKU029	Stowing / Accessing the UUT in Fire Suppression / Inundation Environment
EKU030	Stowing / Accessing the UUT

5.0 Test Results and Observations

The OT&E event began on June 24, 2008 at 8:30 a.m. with an overview briefing on the test event, conducted by the OT&E team. This briefing provided an overview on the purpose of the test; testing schedule, venues, roles and responsibilities; and administrative items (see Appendix J: Test Overview Briefing). The OT&E team, vendor, DHS representatives, and all other non-essential testing staff and observers were informed that once the test started, there were to be no interruptions, changes to test procedures, and/or additional testing requests. The floor was opened for questions and comments before the OT&E event began.

The test event continued with the presentation from Halcyon representatives. The vendor was directed to provide training to the test subjects that would be given to any agency or individual that purchased this device. The OT&E team also instructed the vendors that this was their final opportunity to present any information that they wanted the OT&E team to know about the UUT, as once the test started, no additional training or instruction would be permitted.

The Halcyon President and CEO, (hereafter “vendor”) began with a presentation about the company, the history of the UUT, and instructions for the use of the UUT (see Appendix K: Vendor Test Day Presentation). The vendor’s product manager provided the actual training for the test subjects and demonstrated how the UUT should be used. The test subjects were provided with literature about the UUT that would normally accompany the device when purchased (see Appendix F: Vendor Literature). Both the vendor presentation (Appendix K) and the literature provided to the test subjects (Appendix F) described the limitations of the UUT.

The purpose of this instructional session was to provide the practical, interactive training the vendor would offer to customers and review of the vendor literature that presents written instruction, as well as the restrictions and disclaimers of the product.

Over the course of two days, the OT&E team conducted a total of thirteen individual, scripted tests. The tests were a combination of both environmental and operational tests. The locations selected for the test event provided the controllable and repeatable environments required for the OT&E event. These included a controlled laboratory environment, a live burn facility, a smoke house, a fire suppression laboratory, an icing environment, and a large storage warehouse. Within these environments, the OT&E team used FOT methodologies to administer tests with the FireGround Compass to evaluate usability and functionality of the product in both laboratory and operational environments. Before, during, and after each individual test, the OT&E team took detailed notes to inform the development of this operational test and evaluation performance report on the UUT. At the request of the TechSolutions program, the heat resistance series was retested after the completion of the initial OT&E event on June 24 and 25, 2008. This retest was performed on November 13, 2008 and was conducted by Intertek Group located in Cortland, New York (see Table 3-1 for a description of the test venue).

The specific tests completed within the laboratory and field environments are listed in Tables 5-1 and 5-2.

Table 5-1: Tests Conducted in Laboratory

Laboratory Tests
Ingress Protection – Immersion
Impact Strength (Concrete and Covered Floor)
Icing Conditions
Heat Resistance
Mechanical Adjustment Range
Mechanical Adjustment – Dry Gloves, HAZMAT Gloves, and Wet Gloves
Stowing / Accessing the UUT
Stowing / Accessing the UUT in Fire Suppression / Inundation Environment

Table 5-2: Tests Conducted in Field

Field Tests
Manufacturer Beta Test
Illumination Test
Orientation and Egress in an Obscured Environment (Smoke House)
Ingress Protection – Attack Hose
Flame / Heat Test (Live Burn Facility)

During the operational tests conducted in the field, all test subjects donned full turnout gear. Full turnout gear refers to the combination of a firefighter's personal protective ensemble (i.e., boots, pants, coat, flash hood, breathing apparatus mask, gloves, and helmet). All turnout gear worn throughout the test event met NFPA Standard 1971: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, which specifies the minimum design, performance, safety, testing, and certification requirements for structural fire fighting protective ensembles and ensemble elements that include coats, trousers, coveralls, helmets, gloves, footwear, and interface components. While donned in full turnout gear, the test subjects also used a self-contained breathing apparatus (SCBA). The SCBA used in the test event met the NFPA Standard 1981: Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Service. Appendix L provides a detailed description of the turnout gear and SCBA used during the test.

After each of the operational tests, the OT&E team conducted a post-test interview (see Appendix M: Post-Test Interview Data) to capture the test subjects' attitudes toward the UUT. The test subjects were taken aside immediately after completion of the test and interviewed separately in order to maintain the integrity of the research design. To gather the information in a timely manner, the OT&E team used a five-point Likert-style scale. A Likert scale is an attitude scale used in research to measure a respondent's feelings, opinions, or attitudes towards a statement, topic, or item. The test subjects were asked to rate the visibility, usability, and functionality of the compass using the five-point scales presented in Table 5-3.

Table 5-3: Post Interview Test Scale

Category:	Instructions:	Scale:
Visibility	Evaluate the light on the unit and rate your ability to see the compass and the bezels.	**1 2 3 4 5** **Very low visibility** **Very high visibility**
Usability	Evaluate the unit based on your ability to orient the compass, set the compass, and use the compass to egress to safety.	**1 2 3 4 5** **Very difficult to use** **Very easy to use**
Functionality	Evaluate the unit based on your experience stowing, carrying, and accessing the compass. Consider other functional elements as well, including the tactile feedback offered by the device.	**1 2 3 4 5** **Not at all functional** **Very functional**

The post-test interviews were conducted after the following test series:

- Manufacturer Beta Test;
- Illumination Test;
- Orientation and Egress in an Obscured Environment;
- Flame / Heat Test at Live Burn Facility;
- Stowing / Accessing the UUT; and
- Stowing / Accessing the UUT in a Fire Suppression / Inundation environment.

These scenarios were designed to simulate the use of the UUT in actual firefighting conditions, such as zero visibility, smoke obscuration, open flame, heat, and water dispersion at various pressures.

The OT&E team conducted a total of ten interviews. An overall summary of the test subject interviews is contained in Table 5-4. Using the Likert Scale described above, with 5 representing the highest score for visibility, ease of use, and functionality, the test subjects provided an average score of 4.4 for visibility, 4.2 for usability, and 4.2 for functionality. Specific information from the post-test interviews can be found within the results of the individual tests.

Table 5-4: Results of Post-Test Interviews

	Visibility	Usability	Functionality
Manufacturer Beta Test (without prior synchronization) – EKU016	4.5	5.0	4.0
Manufacturer Beta Test (with prior synchronization) – EKU017	5.0	4.0	5.0
Illumination – EKU018	4.5	5.0	4.0
Illumination – EKU019	5.0	5.0	4.0
Orientation and Egress in an Obscured Environment – EKU022	3.5	3.0	4.0
Orientation and Egress in an Obscured Environment – EKU025	5.0	4.0	5.0
Flame / Heat Test at Live Burn Facility – EKU021	4.5	5.0	4.5
Flame / Heat Test at Live Burn Facility – EKU020	4.0	3.0	4.0
Stowing / Accessing the UUT in Fire Suppression / Inundation Environment – EKU027 and EKU029	3.5	4.0	3.5
Stowing / Accessing the UUT – EKU030	n/a	n/a	4.0
Average Score	**4.4**	**4.2**	**4.2**

5.1 Ingress Protection – Immersion

5.1.1 Objectives

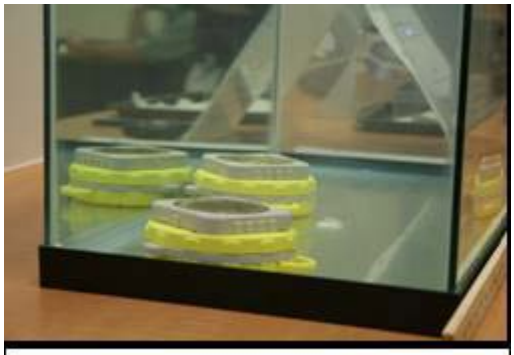


Figure 5-1: Submersion of UUTs

The objective of the Ingress Protection – Immersion test was to determine the ingress protection of the UUT against water penetration after submersion in a tank of water for ten minutes. The test procedures were designed to create a realistic environment for operational evaluation through immersion in water. The UUT was submerged for ten minutes to simulate the potential exposure to water in fire hose streams, dripping water from within a structure, or dropping the device in pooling water on a fire scene. The International Standard IEC 529 for Water and Dust Ingress was used as a reference for developing the test procedures for this test series to mimic a plausible water exposure environment in an operational setting.

5.1.2 Test Conditions[2]

Table 5-5: Ingress Protection – Immersion: Test Conditions

Ingress Protection – Immersion	
Test Number:	FOT08-01-02A
Date:	June 24, 2008
Time[3]:	09:47 a.m. - 10:11 a.m.
Temperature:	71.1° F (21.7° C)
Relative Humidity:	53%
Location:	JSC Laboratory
UUT #1:	EKU001
UUT #2:	EKU002

[2] Before each test, the OT&E team recorded the test number, date, time, location, and UUT ID number(s). The OT&E team also measured and recorded the environmental conditions within the test location to allow for future replication of the test series. These measurements included temperature (measured in both degrees Fahrenheit and degrees Celsius using an HT-306 Thermo Hygrometer), relative humidity (measured as the percent of water vapor in the air using an HT-306 Thermo Hygrometer), and, when appropriate, light (measured in Lumens per square meter (Lux) using an EXTECH Instruments 401025 Light meter).

[3] The test condition "Time" represents the period of time during which the entire test was conducted. The Test Director called for time points to be established at both the start and close of the test; these times are provided here.

5.1.3 Procedures

This test was performed using a thirty gallon tank (30¼ x 12½ x 18¾). The tank was filled to a depth of 15¾" with tap water from the City of Richmond (see Appendix N: Water Composition Report). Using an immersion thermometer, the water temperature was measured at 70.0° F (21.1°C). Two UUTs (EKU001 and EKU002) were submerged in the tank. Both units floated for approximately five seconds before sinking to the bottom of the tank. After an elapsed time of ten minutes, both UUTs were taken out of the tank and placed on a drying tray for inspection.

5.1.4 Observations

After the units had rested ten minutes in the immersion tank, they were removed and placed on a dry inspection tray. Table 5-6 provides detailed observations about each UUT.

Table 5-6: Ingress Protection – Immersion: Observations

	EKU001	EKU002
Exterior Casing	No damage or deformation	No damage or deformation
Building Bezel	Operational	Operational
Command Bezel	Operational	Operational
Light	Operational	Operational
Battery Compartment	Moisture observed	Moisture observed
Circuit Board	Moisture observed, no corrosion, no discoloration	Moisture observed, no corrosion, no discoloration
Batteries	Moisture observed, no corrosion, no discoloration	Moisture observed, no corrosion, no discoloration
Water Intrusion	Moisture under the cover plate	Standing water under the cover plate

5.1.5 Findings

The findings from the Ingress Protection – Immersion test suggest that the UUTs (EKU001 and EKU002) performed as they had prior to the immersion test. The only noticeable change was that water entered the outer plastic lens covering the compass, but this did not affect the compass, lighting mechanism, or operation of the bezels.

5.2 Measuring Impact Strength

5.2.1 Objectives

The objective of the Measuring Impact Strength test was to determine the integrity of the UUT when subjected to various shocks, which included dropping from heights consistent with firefighter use on multiple surfaces. The UUT was tested to survive a drop from six feet onto various surfaces without suffering damages to the outer housing or to the functionality of the UUT.

5.2.2 Test Conditions

Table 5-7: Measuring Impact Strength: Test Conditions

Measuring Impact Strength	
Test Number:	FOT08-01-03
Date:	June 24, 2008
Time:	10:12 a.m. - 10:18 a.m.
Temperature:	72.1° F (22.3° C)
Relative Humidity:	55.0%
Location:	JSC Laboratory
UUT #1:	EKU005
UUT #2:	EKU006

5.2.3 Procedures

The OT&E team secured two test target areas: a concrete floor and a linoleum-covered floor. Using a ladder and ruler, a position 72" (or six feet) above the floor was marked. A UUT was then dropped from the specified height onto the test target areas.

5.2.4 Observations

EKU005 was dropped 72" onto the concrete floor and EKU006 was dropped 72" onto the linoleum floor. Table 5-8 provides detailed observations about each UUT.

Table 5-8: Measuring Impact Strength: Observations

	EKU005	EKU 006
Target Area	**Concrete Floor**	**Linoleum Floor**
Exterior Casing	No damage	No damage
Building Bezel	Operational	Operational
Command Bezel	Operational	Operational
Compass	Operational	Operational
Light	Not Operational- light could not be turned off	Operational

5.2.5 Findings

There was no operational or physical damage observed to EKU006 following the impact strength test on the linoleum floor. Conversely, when EKU005 was dropped onto the concrete floor, the test team observed that the unit landed on the light switch and, upon manipulation, the switch was unresponsive resulting in the light remaining on.

5.3 Icing Conditions

5.3.1 Objectives

The objectives of this test were to determine the ability of the user to read the UUT compass and mechanically adjust bezel settings after a water-immersed UTT was subjected to an environment of icing (below 32° F / 0° C) within a commercial freezer for a period of 10 minutes.

5.3.2 Test Conditions

Table 5-9: Icing Conditions: Test Conditions

Icing Conditions	
Test Number:	FOT08-01-08
Date:	June 24, 2008
Time:	10:19 a.m. - 10:42 a.m.
Temperature:	10.8° F (-11.8° C)
Relative Humidity:	29%
Location:	EKU's Stratton Cafeteria
UUT #1:	EKU007
UUT #2:	EKU008

5.3.3 Procedures

Using the Fluke 61 Series Handheld Infrared Thermometer (Serial Number: Q054999), an initial reading of the skin temperature of the UUTs was taken before entering the freezer. The two UUTs (EKU007 and EKU008) were then immersed in a five-gallon bucket containing tap water from the City of Richmond (see Appendix N: Water Composition Report). The bucket containing the immersed UUTs was carried into a Bally F2 walk-in freezer (Serial Number: E2338). The UUTs were removed from the bucket and placed on a clean metal inspection tray. After ten minutes elapsed time, the OT&E team re-entered the freezer and took a reading of the skin temperature of the UUTs. The test subject was then asked to perform a sequence of tests to assess the operability and functionality of each UUT.

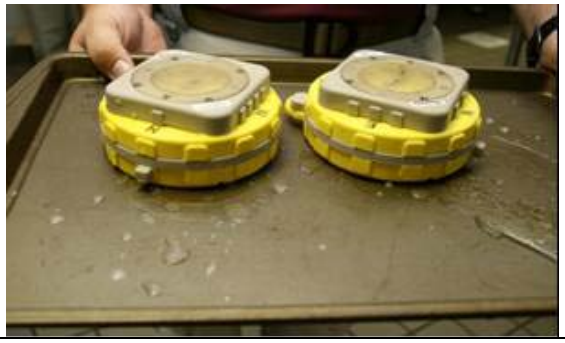


Figure 5-2: Ice Formation on UUTs

5.3.4 Observations

After EKU007 and EKU008 had been in the freezer for ten minutes, Test Subject A entered the freezer and tested the lights and manipulated the bezels on each UUT to confirm normal operation. The building bezel and light operated normally on both EKU007 and EKU008. Table 5-10 provides detailed observations about each UUT.

Table 5-10: Icing Conditions: Observations

	EKU007	EKU 008
Exterior Casing	No damage or deformation	No damage or deformation
Building Bezel	Operational	Operational but felt stiff
Command Bezel	After 360° rotation to clear ice, bezel was operational	After 360° rotation to clear ice, bezel was operational
Compass	Operational	Operational
Light	Operational	Operational
Pre-Test UUT Skin Temperature	68.5° F (20.3° C)	71.0° F (21.7° C)
Post-Test UUT Skin Temperature	-4.0° F (-20° C)	-8.0° F (-22.2° C)

5.3.5 Findings

The findings from the Icing Conditions test indicate that both units continued to be functional when exposed to freezing temperatures.

5.4 Heat Resistance Test

5.4.1 Objectives

The objectives of this test were to determine the thermal stability of the UUT and to measure whether the device would ignite, melt, drip, or separate after thermal exposure. The OT&E team modeled the test after NFPA 1982: Standard on Personal Alert Safety Systems (PASS),[4] which is based on NFPA 1971: Standard on Protective Ensemble for Structural Fire Fighting. This standard outlines the heat resistance test for firefighters' protective garments. In these tests, the garments must withstand a temperature of 260° C (500° F) for 5 minutes without igniting, melting, dripping, or separating. NIST 1474: Technical Notes states:

> Since firefighters' personal protective electronic equipment (example: Personal Alert Safety System PASS) and emergency responder communications equipment (example: radio) perform similar life safety functions, it is reasonable to consider using the NFPA 1971 thermal exposure criteria for testing electronic devices that are used in the same firefighting environments.[5]

[4] NFPA 1982: Standard on Personal Alert Safety Systems (PASS) was revised in 2007 to provide strengthened performance requirements and testing to address the alarm signal degradation issue, which can occur as the result of high temperatures. New high-temperature functionality requirements and testing have the PASS mounted in a circulating hot air oven at 500° F for 5 minutes. Afterwards, the PASS alarm signal must function at or above the required 95 dBA sound level, electronic data logging functions must operate properly, and no part of the PASS can show evidence of melting, dripping, or igniting.

[5] National Fire Protection Association, NFPA 1971 Standard on Protective Ensemble for Structural Fire Fighting, 2000 Edition, Volume 11. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

The intent of this procedure is to expose the UUT to a consistent 500° F for 5 minutes, as defined in NFPA 1971. Due to an equipment limitation in the initial OT&E event, this procedure was not achieved. The limitation was in the heat resistance oven used for the test, which exceeded the 30-second recovery time specified in NFPA 1971 after the UUT was placed in the oven. The specific apparatus and procedures defined in NFPA 1971 for heat testing of clothing and equipment is as follows:

8.6.4 Apparatus

8.6.4.1 The test oven shall be as specified in ISO 17493, *Clothing and equipment for protection against heat – Test method for convective heat resistance using a hot air circulating oven.* Testing shall be carried out at a temperature of 260°C, +6/-0°C (500°F, +10/-0°F).

8.6.5 Procedure

8.6.5.2 The specimen shall be suspended by metal hooks at the top and centered in the oven so that the entire specimen is not less than 50mm (2in) from any oven surface or other specimen, and the air is parallel to the plane of the material.

8.6.5.3 The oven door shall not remain open more than 15 seconds. The air circulation shall be shut off while the door is open and turned on when the door is closed. The total oven recovery time after the door is closed shall not exceed 30 seconds.

8.6.5.4 The specimen, mounted as specified, shall be exposed in the test oven for five minutes +.15/-0 minute. The test exposure time shall begin when the test thermocouple recovers to a temperature of 260°C, +6/-0°C (500°F, +10/-0°F).

8.6.5.5 Immediately after the specified exposure, the specimen shall be removed and examined for evidence of ignition, melting, dripping, or separation.

Intertek Group in Cortland, New York conducted the heat resistance test in conformance to NFPA 1971. A summary of the test conducted by Intertek is provided in the following sections (see Appendix T: Intertek Test Report for a copy of the test report generated by Intertek).

5.4.2 Test Conditions

Table 5-11: Heat Resistance Test: Test Conditions

Heat Resistance Test	
Test Number:	NA
Date:	November 13, 2008
Time:	12:00 p.m. – 2:00 p.m.
Temperature:	NA
Relative Humidity:	NA
Location:	Intertek Laboratory
UUT #1:	EKU011
UUT #2:	EKU017
UUT #3:	EKU022

5.4.3 Procedures

For the purposes of this test, Intertek laboratory personnel followed the specific procedures defined in NFPA 1971, Section 8.6.4 and 8.6.5. These procedures are defined in Section 5.4.1.

The procedures outlined in Section 5.4.1 were used in the heat resistance testing of all three UUTs (EKU011, EKU017, and EKU022). In addition to evidence of ignition, melting, dripping, or separation, the battery compartment, lighting mechanism, and bezel locking positions of each UUT were also examined. The external skin temperatures of the UUTs were measured using a Fluke 61 Series Handheld Infrared Thermometer (Serial Number: 054999). An examination of the compass operation was not conducted, because testing was performed in a metal building structure, which affected the ability of the digital compass to accurately acquire a "true" north reading.

Figure 5-3: UUT Prior to Placement in Oven

5.4.4 Observations

Upon removing EKU011, EKU017, and EKU022 from the oven, the UUTs were initially examined by Intertek staff for evidence of ignition, melting, dripping, or separation as specified in NFPA 1971. The UUTs showed no evidence of ignition or dripping. The command position locator tab on the command bezel on all UUTs became soft and pliable, as did the locking positions for the building and command bezels. When UUTs returned to pretest temperatures, these elements returned to normal rigidity and operation. Separation/warping was evident between the command bezel and the exterior casing on EKU011 and EKU022. The lighting mechanism operated normally on each UUT, and the battery compartment of each UUT showed no damage or abnormalities. Table 5-12 provides detailed observations about each UUT.

Table 5-12: Heat Resistance Test: Observations

	EKU011	EKU017	EKU022
Average Oven Temperature	503.0° F to 509.0° F (261.6° C to 265.0° C)	503.0° F to 507.0° F (261.6° C to 263.8° C)	502.0° F to 504.0° F (261.1° C to 262.2° C)
Oven Recovery Time	17 seconds	18 seconds	15 seconds
Exterior Casing	Separation/warping between the command bezel and the exterior casing.	No damage or deformation.	Separation/warping between the command bezel and the exterior casing.
Building Bezel	Operational, but locking positions were soft immediately after the test. Once the UUT had returned to pretest temperature, the locking stops returned to normal rigidity and operation.	Operational, but locking positions were soft immediately after the test. Once the UUT had returned to pretest temperature, the locking stops returned to normal rigidity and operation.	Operational, but locking positions were soft immediately after the test. Once the UUT had returned to pretest temperature, the locking stops returned to normal rigidity and operation.
Command Bezel	Operational, but locking positions were soft immediately after the test and the command post indicator tab was soft and pliable. Once the UUT had returned to pretest temperature, the locking stops and the command post indicator tab returned to normal rigidity and operation.	Operational, but locking positions were soft immediately after the test and the command post indicator tab was soft and pliable. Once the UUT had returned to pretest temperature, the locking stops and the command post indicator tab returned to normal rigidity and operation.	Operational, but locking positions were soft immediately after the test and the command post indicator tab was soft and pliable. Once the UUT had returned to pretest temperature, the locking stops and the command post indicator tab returned to normal rigidity and operation.

	EKU011	EKU017	EKU022
Compass	Compass needle operated freely; however, an examination of the compass operation was not conducted due the testing being performed in a metal building structure, which affected the ability of the digital compass to accurately acquire a "true" north reading.	Compass needle operated freely; however, an examination of the compass operation was not conducted due the testing being performed in a metal building structure, which affected the ability of the digital compass to accurately acquire a "true" north reading.	Compass needle operated freely; however, an examination of the compass operation was not conducted due the testing being performed in a metal building structure, which affected the ability of the digital compass to accurately acquire a "true" north reading.
Light	Operational	Operational	Operational
Post-Test UUT Skin Temperature	310.0° F (154.4° C)	280.0° F (137.7° C)	287.0° F (141.6° C)
Battery Compartment	No damage or deformation.	No damage or deformation.	No damage or deformation.
Circuit Board	No damage or deformation.	No damage or deformation.	No damage or deformation.
Batteries	No damage or deformation.	No damage or deformation.	No damage or deformation.

5.4.5 Findings

After 5 minutes of exposure at temperatures ranging from 502° F to 509° F in accordance with NFPA 1791, heat effects were evident on the UUTs. Most notably, the locking positions of both the building and command bezels on all UUTs became soft, and the command position indicator tab on the command bezel on all UUTs became soft and pliable. When UUTs returned to pretest temperatures, both the locking positions and the indicator tab returned to normal rigidity and operation on all UUTs. Additionally, evidence of separation/warping was evident on EKU011 and EKU022 between the command bezel and the exterior casing. EKU017 showed no sign of separation/warping. Further, the lighting mechanism, battery compartment, circuit board, and batteries showed no evidence of damage or deformation on all UUTs.

Figure 5-4: UUT Placed in Oven

5.5 Mechanical Adjustment Range

5.5.1 Objectives

The objectives of this test were to demonstrate the normal range of mechanical adjustments to the bezels of the UUT in an operational setting and to verify that users cannot inadvertently bypass or strip the locking/stop mechanisms of the command and building bezels during normal use. This was achieved by manipulating both the building and command bezels of the UUT in a 360° of motion stopping at four stops (90°, 180°, 270°, and 360°) and then repeating this 360° rotation with each bezel five times.[6]

5.5.2 Test Conditions

Table 5-13: Mechanical Adjustment Range: Test Conditions

Mechanical Adjustment Range	
Test Number:	FOT08-01-05
Date:	June 24, 2008
Time:	11:06 a.m. – 11:18 a.m.
Temperature:	71.6° F (22.0° C)
Relative Humidity:	56%
Location:	JSC Laboratory
UUT #1:	EKU011
UUT #2:	EKU012

5.5.3 Procedures

Test Subject A was directed to manipulate the UUT building bezel in a 360° range of motion stopping at four stops: 90°, 180°, 270°, and 360°. Test Subject A was directed to repeat this sequence using the command bezel. Test Subject A was then directed to rotate the building bezel 360° five times in sequence and the command bezel 360° five times in sequence. This test was conducted with two UUTs (EKU011 and EKU012).

5.5.4 Observations

Test Subject A followed the test procedures using EKU011 and EKU012. Table 5-14 provides detailed observations about each UUT.

[6] Using a pre-determined number of bezel rotations ensures that the same conditions are applied to both UUTs. There is no significance to using this particular number of rotations. It simply allows for repetition and future repeatability of the test.

Table 5-14: Mechanical Adjustment Range: Observations

	EKU011	EKU 012
Exterior Casing	No damage	No damage
Building Bezel	Operational	Operational
Command Bezel	Operational	Operational
Compass	During the rotation of the command bezel, the needle became stuck at the 11 o'clock position (270°). After moving the unit back and forth, the needle released its position and resumed normal operation.	Operational
Light	Operational	Operational

5.5.5 Findings

The Mechanical Adjustment Range test was intended to test the range of mechanical adjustments of the UUT's building and command bezels. Once the unit was manipulated according to the prescribed sequence of test events, the unit's light and compass function was tested. One of the units (EKU012) performed without any notable abnormalities. The other unit (EKU011), however, experienced an abnormality. After the test subject rotated the command bezel, the needle on the compass became stuck. It is not certain if the manipulation and rotation of the bezel was the direct cause for the compass needle to stick. It is certain, however, that after a series of manipulations the compass on EKU011 malfunctioned temporarily. Only after moving the UUT back and forth did the compass resume functionality.

5.6 Mechanical Adjustment – Dry Gloves, HAZMAT Gloves, and Wet Gloves

5.6.1 Objectives

The objective of this test was to determine the full range of expected mechanical adjustments to the UUT while donned in standard bunker gear with dry gloves, with HAZMAT gloves, and with wet gloves. The test subject achieved this by holding the UUT in one gloved hand while manipulating the bezels and compressing the light switch with the other gloved hand. The test subject repeated the test procedures while wearing dry gloves, HAZMAT gloves, and wet gloves.

5.6.2 Test Conditions

Table 5-15: Mechanical Adjustment – Dry Gloves, HAZMAT Gloves, and Wet Gloves: Test Conditions

Mechanical Adjustment - Dry Gloves, HAZMAT Gloves, and Wet Gloves	
Test Number:	FOT08-01-09
Date:	June 24, 2008
Time:	11:22 a.m. – 11:40 a.m.
Temperature:	72.7° F (22.6° C)
Relative Humidity:	49%
Location:	JSC Laboratory
UUT #1:	EKU013
UUT #2:	EKU014
UUT #3:	EKU015

5.6.3 Procedures

Test Subject A was directed to grasp the UUT in one hand while holding it at a 90° angle from his body. With his other hand, Test Subject A turned the UUT light on and off and adjusted the building and command bezels. This test was conducted three times with Test Subject A wearing three different types of gloves: dry gloves, HAZMAT gloves (butyl rubber unsupported gloves), and wet gloves. For the wet gloves test, Test Subject A donned a pair of standard structural fire ensemble gloves and dipped both hands in a bucket of tap water from the City of Richmond (see Appendix N: Water Composition Report).

Figure 5-5: Manipulation of UUT with Wet Standard Structural Fire Gloves

5.6.4 Observations

Test Subject A had no difficulty using the UUTs (EKU013, EKU014, and EKU015) while wearing the three different types of gloves. Table 5-16 provides detailed observations about each UUT.

Table 5-16: Mechanical Adjustment – Dry Gloves, HAZMAT Gloves, and Wet Gloves: Observations

	EKU013	EKU014	EKU015
Type of Gloves	Dry Gloves	HAZMAT Gloves	Wet Gloves
Exterior Casing	No damage	No damage	No damage
Building Bezel	Operational	Operational	Operational
	EKU013	**EKU014**	**EKU015**
Command Bezel	Operational	Operational	Operational
Compass	Operational	Operational	Operational
Light	Operational	Operational	Operational

5.6.5 Findings

The test subject had no difficulty using the UUT while wearing dry gloves, HAZMAT gloves, and wet gloves. The compass was operational throughout the test and no anomalies were observed.

5.7 Manufacturer Beta Test

5.7.1 Objectives

The objectives of the test were to replicate the test procedures of the manufacturer-designated beta test. The manufacturer beta test evaluates the ability of a disoriented firefighter to use the UUT to egress a warehouse facility. The manufacturer beta test includes two test series: 1) with synchronization of the UUT between the incident commander (IC) and the test subject prior to entry into the building, and 2) without synchronization of the UUT between the IC and the test subject prior to entry into the building.

5.7.2 Test Conditions

Table 5-17: Manufacturer Beta Test: Test Conditions

Manufacturer Beta Test	
Test Number:	FOT08-01-01
Date:	June 24, 2008
Time:	1:38 p.m. – 2:02 p.m.
Temperature:	77° F (25.0° C)
Relative Humidity:	46.6%
Light	0 lux

Manufacturer Beta Test	
Location:	Gabbard Building
UUT #1:	EKU016
UUT #2:	EKU017

5.7.3 Procedures

This test was performed at the Raymond Gabbard Building on the EKU campus, which is currently being used to store surplus equipment. The Gabbard Building is a 15,184 square foot warehouse with metal reinforced concrete block walls, a concrete foundation, a flat roof, and high bay lighting. Points of egress included three doors and a large bay opening. With all points of egress sealed, a light reading of 0 lux was achieved.

This location was chosen for the manufacturer beta test so that the UUT could be tested in a warehouse facility with test subjects donned in full turnout gear. The test was conducted twice, once with synchronization of the UUT between the incident commander (IC) and the test subject prior to entry into the building, and once without synchronization prior to entry into the building.

To begin the test of the UUT without prior synchronization, the test subject in possession of the UUT was blindfolded and led into the warehouse by a second test subject. The blindfolded subject was led to a pre-determined area with zero visibility. A light reading of 0 lux was measured at the pre-determined area. The test subject in possession of the UUT was asked to turn 360° for 5-10 seconds to achieve disorientation. The test subject was then directed to set his compass at the direction of the IC over two-way radio communication. Once the UUT was set as prescribed by the IC, the test subject was directed to make his way out of the warehouse using the UUT. Upon exiting the warehouse, the test subject was asked to evaluate the visibility, usability, and functionality of the UUT.

To begin the test of the UUT with prior synchronization, the test subject in possession of the UUT was blindfolded and led into the warehouse by a second test subject. The blindfolded subject was led to a pre-determined area with zero visibility. A light reading of 0 lux was measured at the pre-determined area. The test subject in possession of the UUT was asked to turn 360° for 5-10 seconds to achieve disorientation. The test subject was then directed to make his way out of the warehouse using the preset UUT. Upon exiting the warehouse, the test subject was asked to evaluate the visibility, usability, and functionality of the UUT.

5.7.4 Observations

The test was first conducted without synchronization of the UUTs (EKU016 and EKU017) prior to entry into the building. Test Subject C led Test Subject A, who was blindfolded, into the warehouse to a pre-determined area of zero visibility. Once Test Subject A was in place and disorientation had been achieved, Test Subject A radioed the IC for directions on how to set his compass. The IC and Test Subject A had no difficulty with this procedure. Once the UUT (EKU016) was set as prescribed by the IC, Test Subject A used the UUT to navigate his way out of the warehouse.

Upon exiting the building, Test Subject A was asked to evaluate the visibility, usability, and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject A indicated that when the light on the UUTs was on, the visibility was a 4.5.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject A provided the UUT a rating of 5. Test Subject A did state that the needle vacillated at certain points, which he surmised was the result of the limitations of the UUT as outlined in the vendor presentation (i.e., the presence of concrete rebar, iron racks, speaker magnets, etc.). Test Subject A stated that in following the compass, he ran into obstacles that required him to stop and reorient himself to find a better path.

Test Subject A's Rating	
Visibility	**4.5**
Usability	**5.0**
Functionality	**4.0**

Table 5-18: Manufacturer Beta Test: Test Subject A's Post-Test Interview Results

Functionality: Test Subject A was asked to rate the functionality of the UUT using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A rated the functionality as a 4. Test Subject A stated that the UUT was easy to use with gloved hands, but there was some difficulty stowing and retrieving the unit.

The test was then conducted with synchronization of the IC and the test subject's UUTs (EKU016 and EKU017 respectively) prior to entry into the building. Test Subject C led Test Subject B, who was blindfolded, into the warehouse to a pre-determined area of zero visibility. Once Test Subject B was in place and disorientation had been achieved, the test subject was directed to egress to safety using the UUT.

Upon exiting the building, Test Subject B was asked to evaluate the visibility, usability, and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject B indicated that when the light on the UUT was on, the visibility was a 5.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject B provided the UUT a rating of 4. Test Subject B stated that since the UUT was set prior to entry, all he had to do was remove it from his pocket, orient it to north and make a rapid egress from the building. According to Test Subject B, this was very easy to do.

Test Subject B's Rating	
Visibility	**5.0**
Usability	**4.0**
Functionality	**5.0**

Table 5-19: Manufacturer Beta Test: Test Subject B's Post-Test Interview Results

Functionality: Test Subject B was asked to rate the functionality of the compass using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject B rated the functionality as a 5. Test Subject B stated that the UUT was easy to stow and access due to the large size of the UUT. Test Subject B did note that there could be some safety concerns when using the UUT because it requires you to look down at it frequently.

5.7.5 Findings

In the Manufacturer Beta Test, both test subjects were able to use the UUT to navigate their way out of the warehouse. One test subject experienced a vacillation of the compass needle in the warehouse facility, which is consistent with the limitations outlined by the vendor.

5.8 Illumination Test

5.8.1 Objectives

The objectives of this test were to determine the legibility/recognition of the compass markings (compass directional points) and bezel positions (building points) while illuminated by the compass light in an area of zero visibility.

5.8.2 Test Conditions

Table 5-20: Illumination Test: Test Conditions

Illumination Test	
Test Number:	FOT08-01-07
Date:	June 24, 2008
Time:	2:03 p.m. – 2:09 p.m.
Temperature:	76.6° F (24.8° C)
Relative Humidity:	46%
Light:	0 lux
Location:	Gabbard Building
UUT #1:	EKU018
UUT #2:	EKU019

5.8.3 Procedures

This test was performed at the Raymond Gabbard Building on the campus of EKU. Test Subject A, in possession of EKU018, and Test Subject B, in possession of EKU019, donned in full turnout gear, entered the warehouse. The light in the warehouse was measured before turning on the UUT light, which was recorded at 0 lux. The light was then measured again after turning the UUT light on. Once the light was on, the test subjects evaluated the visibility of the UUTs while manipulating the bezels. Upon exiting the warehouse, the test subjects were asked to evaluate the visibility, usability, and functionality of the UUTs.

5.8.4 Observations

Once inside the warehouse, Test Subject A was directed to switch EKU018's light on. The light was measured at 1 lux. Test Subject A was then asked to manipulate the building and command bezels to assess the visibility of the compass face and directional points.

Upon exiting the warehouse, Test Subject A was asked to rate the visibility, usability, and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject A indicated that when the UUT light was on, the visibility was a 4.5. Although the light illuminated the compass, Test Subject A reported that it was somewhat difficult to find the command bezel in the dark.

Test Subject A's Rating	
Visibility	**4.5**
Usability	**5.0**
Functionality	**4.0**

Table 5-21: Illumination Test: Test Subject A's Post-Test Interview Results

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject A provided the UUT a rating of 5. Test Subject A stated that the light switch was hard to locate in the dark and it was difficult to differentiate between the light switch and the command bezel. Once the light switch was found, Test Subject A stated it was easy to activate.

Functionality: Test Subject A was asked to rate the functionality of the compass using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A provided a rating of 4 and stated that the stowing and accessing of the UUT in the dark was not difficult.

After Test Subject A completed the illumination test procedures using EKU018, Test Subject B was directed to switch EKU019's light on. The light was measured at 1 lux. Test Subject B was then asked to evaluate the visibility of the compass while manipulating the building and command bezels.

Upon exiting the warehouse, Test Subject B was asked to rate the visibility, usability, and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject B indicated that when the UUT light was on, the visibility was a 5. Test Subject B did note that although the light illuminated the compass, it was difficult to find the command bezel in the dark.

Test Subject B's Rating	
Visibility	**5.0**
Usability	**5.0**
Functionality	**4.0**

Table 5-22: Illumination Test: Test Subject B's Post-Test Interview Results

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject B provided the UUT a rating of 5. Test Subject B stated that the light switch was hard to locate in the dark.

Functionality: Test Subject B was asked to rate the functionality of the compass using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject B provided a rating of 4 and stated that the feedback from the unit was helpful.

5.8.5 Findings

The Illumination Test demonstrated that the light on the compass was helpful in allowing visibility of the compass in an environment of zero visibility. The light on the compass illuminates the face of the compass as well as the directional indicators (i.e., N, S, E, and W). Test Subjects A and B each noted that because the command bezel and light switch are not illuminated, they can be difficult to locate in the dark. The test subjects also reported that it was

difficult to differentiate between the light switch and the command bezel in the dark due to their similarities in shape, size, and location on the device.

5.9 Stowing / Accessing the UUT

5.9.1 Objectives

The objectives of this test were to determine the ease of accessing, stowing, and carrying the UUT in the pocket of a firefighter's standard turnout gear from three positions (standing upright, kneeling, and lying face down) and to assess whether the command and/or building bezels remained in a pre-set position during stowing and/or accessing of the UUT[7].

5.9.2 Test Conditions

Table 5-23: Stowing / Accessing the UUT: Test Conditions

Stowing / Accessing the UUT	
Test Number:	FOT08-01-12
Date:	June 24, 2008
Time:	2:36 p.m. – 2:41 p.m.
Temperature:	74.3° F (23.5° C)
Relative Humidity:	59%
Location:	Field Site- Fire Suppression Laboratory
UUT #1:	EKU030

5.9.3 Procedures

The test subject evaluated his ability to stow, carry, and access the UUT from three different positions (standing upright, kneeling, and lying face down) while wearing standard turnout gear and assessed whether the command and/or building bezels remained in a pre-set position after stowing and/or accessing. The pocket the test subject used was on the lower section of his pants and was measured at a standard size of 10" x 9" x 2". Firefighting turnout gear differs from department to department and is often an individual choice. Not all firefighting pants may have pockets for stowing devices. As Figure 5-6 illustrates, the test subject for this event did have a pocket on each pant leg.

Figure 5-6: Stowing of the UUT

5.9.4 Observations

Before beginning the standing upright portion of the test, the starting position of the UUT (EKU030) was recorded. Test Subject A was directed to stow the UUT in his pocket. Test

[7] The UUT was designed specifically for stowing in the firefighter's pocket. The manufacturer noted that the device was not intended to be clipped to the firefighter's gear.

Subject A did have difficulty opening his pants pocket wide enough to drop in the UUT. Test Subject A was then directed to remove the UUT from his pocket. This was done without difficulty. The building bezel and command bezel were examined and it was concluded that no change in the position of the bezels had occurred.

Before beginning the kneeling portion of the test, the starting position of the UUT (EKU030) was recorded. Test Subject A was directed to kneel and stow the UUT in his pocket. Test Subject A was then directed to remove the UUT from his pocket. Once the test subject retrieved the UUT, the building bezel and command bezel were examined and it was concluded that no change in the position of the bezels had occurred.

Before beginning the prone portion of the test, the starting position of the UUT (EKU030) was recorded. Test Subject A was directed to lie down and stow the UUT in his pocket. Test Subject A was then directed to remove the UUT from his pocket. Once Test Subject A retrieved the UUT, the building bezel and command bezel were examined and it was concluded that no change in the position of the bezels had occurred.

Upon completion of the test, Test Subject A was asked to evaluate the functionality of the UUT based on his experiences during the test. The questions on visibility and usability were omitted because they were not relevant to this particular test.

Functionality: Test Subject A was asked to rate the functionality of the UUT using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A provided a rating of 4. Test Subject A reported that he had some difficulty getting his pocket open while trying to stow the UUT. The UUT was easy to retrieve, and Test Subject A indicated that the large size of the UUT made stowing and retrieval from his fire gear pants pocket easy. There were no changes in the bezel positions as a result of stowing or accessing the UUT in any of the three positions.

Test Subject A's Rating	
Functionality	**4.0**

Table 5-24: Stowing / Accessing the UUT: Test Subject A's Post-Test Interview Results

5.9.5 Findings

Overall, the test subject was able to stow and retrieve the UUT in a standing, kneeling, and prone position with little to no difficulty.

5.10 Stowing / Accessing the UUT in Fire Suppression / Inundation Environment

5.10.1 Objectives

The objective of this test was to evaluate the visibility, usability, and functionality of the UUT and the mechanical integrity of the settings when a firefighter is subjected to a steady stream of water from an overhead fire suppression sprinkler system.

Table 5-25: Stowing / Accessing the UUT in Fire Suppression / Inundation Environment: Test Conditions

Stowing / Accessing the UUT in Fire Suppression / Inundation Environment	
Test Number:	FOT08-01-S1
Date:	June 24, 2008
Time:	2:47 p.m. – 2:57 p.m.
Temperature:	75.7° F (24.3° C)
Relative Humidity:	61%
Location:	Field Site- Fire Suppression Laboratory
UUT #1:	EKU029
UUT #2:	EKU027

5.10.2 Procedures

This test was conducted in the fire suppression/inundation chamber at the Ashland Building on the EKU campus. The sprinkler head selected for this test was the 2001 Central Sprinkler Corporation ESFR Pendant, with a PSI of 50 at the gauge and a flow of 119 GPM. After recording the starting position of the UUT (EKU029), the test subject stowed the UUT in his pocket and entered the chamber. At that time, the fire suppression system was released and the test subject was directed to use one gloved hand to remove the UUT from his pocket and observe the unit for any changes in position. The test subject was then directed to evaluate the visibility, usability, and functionality of the unit by checking the light and manipulating the bezels. Once the fire suppression system was turned off, the UUT was examined for signs of damage and water intrusion. Later, the test subject was interviewed about his experience using the UUT in the suppression / inundation environment. This test was conducted with a second UUT (EKU027) to establish repeatability of test results and to ensure that there were no anomalies in the UUT that could affect the results of the test.

5.10.3 Observations

During the course of the test for each UUT (EKU029 and EKU027), Test Subject A confirmed that there were no changes in the position of the building bezel or the command bezel. Test Subject A confirmed that he could read and manipulate the UUT. Each UUT was examined for signs of damage and water intrusion. The light, compass, building bezel, and command bezel were all operational. Table 5-26 provides detailed observations about each UUT.

Table 5-26: Stowing / Accessing the UUT in Fire Suppression / Inundation Environment: Observations

	EKU029	EKU027
Exterior Casing	No damage	No damage
Building Bezel	Operational	Operational
Command Bezel	Operational	Operational
Light	Operational	Operational- Light in the center of the compass blinked several times and then remained on and could not be turned off. The other lights were working properly.
Water Intrusion	Moisture under the lens	Moisture under the lens

Upon completion of the test, Test Subject A was asked to evaluate the visibility, usability, and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject

A indicated that when the UUT light was on, the visibility was a 3.5. According to Test Subject A, the heavy stream of water from the deluge sprinkler head made it difficult to see the UUT. Moreover, it was noted by Test Subject A that the light was helpful in aiding visibility of the UUT overall.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject A gave the UUT a rating of 4. Test Subject A reported that using the UUT in a wet environment was fairly easy and was not that much different than using it in a dry environment.

Functionality: Test Subject A was asked to rate the functionality of the compass using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A provided a rating of 3.5. Test Subject A reported that it was easy to maneuver and the only difficulty was getting the command bezel past the loop on the UUT.

Test Subject A's Rating	
Visibility	**3.5**
Usability	**4.0**
Functionality	**3.5**

Table 5-27: Stowing / Accessing the UUT in Fire Suppression / Inundation Environment: Test Subject A's Post-Test Interview Results

5.10.4 Findings

According to the test subject, using the UUT in a wet environment during the Stowing / Accessing the UUT in a Fire Suppression / Inundation Environment test was similar to using the UUT in a dry environment. The test subject did report difficulty seeing the UUT as a result of the heavy stream of water from the sprinkler system. Both UUTs (EKU029 and EKU027) were operational after the completion of the test, but the center compass light on EKU027 blinked several times and then remained on and could not be turned off during the inspection of the unit.

5.11 Orientation and Egress in an Obscured Environment

5.11.1 Objectives

The objective of this test was to evaluate the effective use of the UUT to aid the egress from an obscured environment by a firefighter who has become disoriented in a building due to low or obstructed visibility and other firefighting conditions such as flames, excessive heat, water, debris, etc. This was judged against a firefighter in similar circumstances who is not in possession of a UUT and is relying solely on firefighting SOPs for egress in low to no visibility.

5.11.2 Test Conditions

Table 5-28: Orientation and Egress in an Obscured Environment: Test Conditions

Orientation and Egress in an Obscured Environment	
Test Number:	FOT08-01-S3
Date:	June 25, 2008
Time:	9:21 a.m. – 10:12 a.m.
Temperature:	83.12° F (28.4° C)
Relative Humidity:	40%
Light:	1 lux
Location:	Field Site- Richmond Fire Department
UUT #1:	EKU022
UUT #2:	EKU025

5.11.3 Procedures

This field test was conducted at the City of Richmond Fire/Rescue Department Fire Training Center's smoke house. The smoke house is a 1,421 square foot facility designed to simulate a standard residential construction. It is a wood frame construction with a drywall-finished interior built on a concrete block foundation. The total area searched by the firefighters during the test included a large sitting room with couches and chairs, one bathroom, and three bedrooms. Two rooms were off-limits during the testing, including a room which housed the smoke machine and a bedroom being used for storage for the City of Richmond. Every room except the bathroom contained at least one source of natural light. The windows in each room were darkened with black curtains for the test event.

Figure 5-7: Smoke House Training Facility

Before the test began, the house was filled with theatrical smoke to a density that obscured visibility using an MBT

FM9000Z smoke generation device. An object was taken into the house and hidden. Three test subjects donned in full turnout gear participated in the test. Test Subjects A and B rotated roles as the IC and the primary test subject. Throughout the course of the test, Test Subject C accompanied the primary test subject into the smoke house in order to simulate standard operating procedure. The test subjects performing the test were each asked to conduct the test twice, once with a UUT and once without.

Upon entering the house, the primary test subject was asked to close his eyes and allow Test Subject C to lead him to the rear of the house. Test Subject C was directed to turn the primary test subject 360° for 5-10 seconds in order to achieve disorientation. The primary test subject was then directed to find the hidden object and radio the IC once the object was found. The primary test subject used a search pattern consistent with best practices in the field of firefighting.[8] The direction of the search was based solely upon personal preference and environmental circumstances. During the test, the primary test subject adhered to the common practice of maintaining contact with the wall during a search. If the primary test subject was in possession of the UUT, he was directed to make a rapid egress from the smoke house using the UUT as a navigational aid once the object was found. This required a deviation from the standard operating procedure of maintaining contact with the wall. If the primary test subject was not in possession of the UUT, he was asked to follow standard operating procedures for making a rapid egress from the smoke house once the object was found, which including maintaining contact with the wall.

5.11.4 Observations

Test Subject A, received a pre-set UUT (EKU022), with its command bezel set to correspond with the A side of the building bezel. Test Subject A was accompanied by Test Subject C, entered the smoke house and headed towards the rear of the building. After achieving disorientation, Test Subject A was directed to find the hidden object and radio the IC once the object was found. Test Subject A used a right hand search pattern to locate the object. The object was hidden in the first bedroom on the right. Once the object had been found, Test Subject A was directed to make a rapid egress from the building using the UUT.

Upon exiting the smoke house, Test Subject A was asked to evaluate the visibility, usability and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject A indicated that when the UUT light was on, the visibility was a 3.5. Without the light on, the visibility was very limited. Although the light illuminated the UUT, the light reflected off the smoke and there was a glare that made the UUT somewhat difficult to see.

Test Subject A's Rating	
Visibility	**3.5**
Usability	**3.0**
Functionality	**4.0**

Table 5-29: Orientation and Egress in an Obscured Environment: Test Subject A's Post-Test Interview Results

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject A gave the UUT a rating of 3. Test Subject A stated that when he engaged in rapid movement after locating the item, the UUT

[8] Essentials of Firefighting, 4th Edition, International Fire Service Training Association, June 1998.

needle vacillated significantly. Test Subject A also reported that while the UUT did take him to a wall on the A side of the building, it was an interior wall, parallel with the A side wall. Test Subject A had to follow the compass back out into the hallway, reorient himself, and attempt again to make it to the exterior wall on the A-side of the building.

Functionality: Test Subject A was asked to rate the functionality of the compass using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A provided a rating of 4. Test Subject A had to use both hands, one to hold the item and one to hold the UUT, which made it difficult to maintain contact with the wall. Test Subject A reported that the UUT did maintain the settings that were pre-set before he entered the house.

The test procedures were repeated by Test Subject B, in possession of a pre-set UUT (EKU025), accompanied by Test Subject C. The test subjects entered the house and headed towards the rear of the building. After disorientation had been achieved, Test Subject B was directed to find the hidden object and radio the IC once the object was found. The object was hidden in the first bedroom on the right. Test Subject B used a right hand search to locate the object. Once the object had been found, Test Subject B was directed to make a rapid egress from the building using the UUT.

Upon exiting the smoke house, Test Subject B was asked to evaluate the visibility, usability and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject B indicated that when the UUT light was on, the visibility was a 5. Without the light on, the visibility was very limited.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject B gave the UUT a rating of 4. Test Subject B stated that because the UUT gives you a direct path towards the door, it allows for a much more rapid egress.

Functionality: Test Subject B was asked to rate the functionality of the UUT using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject B provided a rating of 5. Test Subject B reported that the large size was good for accessing and stowing the UUT. Test Subject B did report that looking down at the UUT to use it could pose a potential danger because it draws the user's attention away from potential obstacles in their path.

Test Subject B's Rating	
Visibility	**5.0**
Usability	**4.0**
Functionality	**5.0**

Table 5-30: Orientation and Egress in an Obscured Environment: Test Subject B's Post-Test Interview Results

5.11.5 Findings

The objective of this test was to assess the ability of a firefighter to effectively use a UUT to aid the egress from a smoke-filled environment. The test subjects were able to use the device as a navigational aid to successfully egress to safety.

5.12 Ingress Protection- Attack Hose

5.12.1 Objectives

The objective of this test was to evaluate the impact resistance and water resistant properties of the UUT when subjected to direct exposure to a water stream from a 1¾" double jacket cotton fire hose with an Akron Turbo Jet combination nozzle in an operational setting. This was achieved by securing the UUT to a wooden frame and, from a distance of 30 feet, dousing both the front and back of the UUT for 30 seconds with water from the previously described hose.

5.12.2 Test Conditions

Table 5-31: Ingress Protection – Attack Hose: Test Conditions

Ingress Protection - Attack Hose	
Test Number:	FOT08-01-02B, FOT08-01-S2
Date:	June 25, 2008
Time:	10:24 a.m. – 10:45 a.m.
Temperature:	90.3° F (32.4° C)
Relative Humidity:	38%
Location:	Field Site- Richmond Fire Department
UUT #1:	EKU023
UUT #2:	EKU026

5.12.3 Procedures

For the Ingress Protection – Attack Hose test, the UUT was secured to a wooden frame and propped up against a concrete wall for stability. From a distance of 30 feet, the UUT (EKU023) was doused with water from a 1¾" double jacket cotton using an Akron Turbo Jet combination nozzle with a flow of 125 GPM. The UUT (EKU023) was doused on the front side for 30 seconds, then turned over and doused on the back side for 30 seconds. The UUT (EKU023) was then visually inspected for signs of water intrusion and for damage of the exterior casing or compass components. This test was conducted with a second UUT (EKU026) to establish repeatability of test results and to ensure that there were no anomalies in the UUT that could affect the results of the test.

Figure 5-8: Akron Turbo Jet Nozzle

d Compass,

Figure 5-9: Direct Exposure of UUT to Attack Hose

Figure 5-9: Akron Turbo Jet Nozzle

Figure 5-10: Direct Exposure of UUT to Attack Hose

5.12.4 Observations

The first part of the test was conducted using an attack line water hose with a pressure of 100 PSI. The front and back side of EKU023 were doused by the water stream for 30 seconds each. Upon visual inspection, there appeared to be no structural damage to the unit. All compass components appeared to be functioning normally.

The second part of the test was conducted using an attack line water hose with a pressure of 125 PSI. The front side of EKU026 was doused by the fire hose for 30 seconds. The back side of the EKU026 was doused by the hose for 22 seconds. After 22 seconds, the UUT fell off the wooden frame to which it was mounted. Upon visual inspection, there appeared to be no structural damage to the unit. All compass components appeared to be functioning normally. Table 5-32 provides detailed observations about each UUT.

Table 5-32: Ingress Protection – Attack Hose: Observations

	EKU023	EKU026
Exterior Casing	No damage	No damage
Building Bezel	Operational	Operational
Command Bezel	Operational	Operational
Light	Operational	Operational, however, light in center of compass remained on and could not be turned off.
Battery Compartment	Moisture observed	Moisture observed
Circuit Board	Moisture observed	Moisture observed
Batteries	Moisture observed	Moisture observed
Water Intrusion	Moisture under the lens	Moisture under the lens

5.12.5 Findings

With the exception of some condensation and water droplets under the outer lens of the compass, both UUTs (EKU023 and EKU026) were operational at the conclusion of the test. The lighting element of EKU026, however, remained on and could not be turned off.

5.13 Flame / Heat Test at Live Burn Facility

5.13.1 Objectives

The objective of this test was to determine the usability of the UUT to a firefighter wearing standard turnout gear in a live burn facility.

5.13.2 Test Conditions

Table 5-33: Flame / Heat Test at Live Burn Facility: Test Conditions

Flame / Heat Test at Live Burn Facility	
Test Number:	FOT08-01-06, FOT08-01-11
Date:	June 25, 2008
Time:	10:52 a.m. – 11:15 a.m.
Temperature:	88.2° F (31.2° C)
Relative Humidity:	43%
Light:	41 lux
Location:	Field Site- Richmond Fire Department
UUT #1:	EKU021
UUT #2:	EKU020

5.13.3 Procedures

This test was conducted at the City of Richmond Fire/Rescue Department Fire Training Center's live burn training facility. Staff from the City of Richmond Fire/Rescue Department were onsite to start the fire and monitor the safety of all participants and observers during the live burn. The City of Richmond Fire/Rescue Department started the fire in the live burn facility using wooden pallets and cardboard boxes filled with straw. The level of smoke obscuration created by the live burn was described by the test subjects as "light smoke."

At 11:00 a.m., Test Subject B entered the live burn facility and measured the temperature with the Fluke 61 Series Handheld Infrared Thermometer (Serial Number: Q054999). The ceiling temperature was 530° F (276.7° C) and the floor temperature was 167° F (75° C). Test Subject A, accompanied by Test Subject C, was directed to enter the live burn facility. Test Subject A, donned in full turnout gear, entered the facility in possession of the UUT. Neither test subject was in possession of any other firefighting equipment. Test Subject A was directed to evaluate the visibility, usability, and functionality of the UUT while standing and while kneeling as near as possible to the actual fire burn site. The test was repeated with Test Subject C to account for

user difference in the use of the UUT, establish repeatability of test results, and ensure that there were no anomalies in the UUT that could affect the results of the test.

5.13.4 Observations

Test Subject A, in possession of EKU021, entered the live burn facility accompanied by Test Subject C. Once inside, Test Subject A removed the stowed UUT from his pocket. While standing approximately eight feet from the fire, Test Subject A activated the light on the UUT and manipulated the building and command bezels in order to evaluate visibility, usability, and functionality. While kneeling approximately 12 feet from the fire, Test Subject A repeated the previous actions. After approximately four minutes, Test Subject A exited the live burn facility.

Upon exiting the live burn facility, Test Subject A was asked to evaluate the visibility, usability and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject A indicated that when the UUT light was on, the visibility was a 4.5. Test Subject A stated that the unit was visible at a 90° angle from his body and the operational obstructions to visibility were minimal. While the light from the fire did illuminate the UUT, the light on the UUT was necessary in order to see the compass markings on the UUT.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject A provided the UUT a rating of 5. Test Subject A reported that he was unable to get the UUT to center on North. Test Subject A tried moving it away from potential sources of magnetic activity (doorways, speaker magnets, etc.), but the compass did not appear to be functioning properly. The UUT compass needle vacillated throughout the test. The UUT compass needle moved continuously in a random motion both clockwise and counterclockwise. Test Subject A was unable to get the UUT compass needle to stabilize on true north and, therefore, was unable to report the degree of vacillation of the needle. Test Subject A estimated that it moved anywhere from 15° to 90° in both directions.

Please note that specific information from the post-test interviews can be found within the results of the individual tests. These post-test interviews provide a more detailed assessment of the visibility, usability, and functionality of the UUT, which may not correspond to the numerical rating assigned by the test subject.

Functionality: Test Subject A was asked to rate the functionality of the UUT using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject A provided a rating of 4.5. Stowing and accessing the UUT while kneeling was more difficult than doing so while standing.

Test Subject A's Rating	
Visibility	**4.5**
Usability	**5.0**
Functionality	**4.5**

Table 5-34: Flame / Heat Test at Live Burn Facility: Test Subject A's Post-Test Interview Results

Test Subject C, in possession of EKU020, entered the live burn facility accompanied by Test Subject A. Once inside, Test Subject C removed the stowed UUT from his pocket. While standing approximately 12 feet from the fire, Test Subject C activated the light on the UUT and manipulated the building and command bezels in order to evaluate the visibility, usability, and functionality. Test Subject

C kneeled and repeated the previous series of actions. After approximately 2 minutes, Test Subject C exited the live burn facility.

Upon exiting the live burn facility, Test Subject C was asked to evaluate the visibility, usability and functionality of the UUT based on his experiences during the test.

Visibility: Using a scale of 1 to 5 (1= Very low visibility; 5= Very high visibility), Test Subject C indicated that when the UUT light was on, the visibility rated a 4. Test Subject C stated that the unit was visible at a 90° angle from his body.

Usability: When asked to evaluate the ease of use using a scale of 1 to 5 (1= Very difficult; 5= Very easy), Test Subject C provided the UUT a rating of 3. Test Subject C reported that he was unable to find true north using the UUT compass. As a result, Test Subject C surmised that the UUT compass was providing a false reading. The UUT compass needle spun and jumped around to such a degree that an exact calculation of the deviation in measurement could not be assessed.

Test Subject C's Rating	
Visibility	**4.0**
Usability	**3.0**
Functionality	**4.0**

Table 5-35: Flame / Heat Test at Live Burn Facility: Test Subject C's Post-Test Interview Results

Functionality: Test Subject C was asked to rate the functionality of the UUT using a scale of 1 to 5 (1= Not at all functional; 5= Very functional). Test Subject C provided a rating of 4. Test Subject C reported that stowing and accessing the UUT was done without difficulty.

5.13.5 Findings

The objective of the Flame / Heat Test was to assess the visibility, usability, and functionality of the UUT in a live burn environment. This test was designed to simulate the conditions a firefighter would face if he or she was attempting to use the UUT in a live burn environment. The structural integrity of the UUT was maintained throughout the test. The UUT remained intact, and was both visible and functional in the live burn environment.

The most significant problem the test subjects faced concerned the usability of the UUT in the live burn facility. Both test subjects reported that the UUT provided false readings throughout the test. Neither subject was able to find true north using the UUT due to the needle vacillating significantly while inside the live burn facility.

6.0 Summary of Test Results

On June 24 and 25, 2008, the DHS S&T Operational Test & Evaluation (OT&E) team conducted an operational test and evaluation of the Halcyon FireGround Compass, a tool intended for use primarily by firefighters to assist them with orientation and egress in large scale warehouses with multiple openings. During this test event, the OT&E team subjected the FireGround Compass to a series of field tests to evaluate functionality and usability on an operational level (see Table 6-1). The OT&E team also conducted a series of specific tests within controllable laboratory environments to evaluate functionality and usability on the component, subsystem, and system requirements levels. In addition to the OT&E test event conducted by the OT&E team, Intertek Group conducted a retest of the heat resistance test series at the request of the TechSolutions Program Director. This singular, specific test was conducted on November 13, 2008 at an Intertek laboratory located in Cortland, New York.

While each specific test series within the operational test and evaluation event were independent from each other, the OT&E team identified commonalties in the test results. For example, in each test series in which the UUT was subjected to water, the OT&E team found moisture underneath the compass cover plate. This water did not render the UUT inoperable. Additionally, while the battery compartment is not waterproof (as stipulated by the vendor; see Appendix K: Vendor Literature), it should be noted that the OT&E team found water within the battery compartment in most of the test series in which the UUT was subjected to water. This water within the battery compartment did not render the UUT inoperable. The vendor recommends that if the unit is exposed to water, the back of the battery compartment should be removed and the unit should be blown out or hung up to dry (see Appendix K: Vendor Literature).

Test result observations revealed vulnerabilities of the UUT following exposure to water at pressure and in high volume. The UUT was subjected to water at pressure and in high volume in specific test series, which included pressures and flows at 50 PSI/119 GPM and 125 PSI/125 GPM. Following exposure to water pressure of 125 PSI, the lighting element in the center of the compass of the UUT remained illuminated and could not be switched off. Again, it must be noted that, according to the vendor, the UUT's battery compartment is not designed to be waterproof (see Appendix K: Vendor Literature).

The OT&E team observed similarities in compromises to the lighting mechanism in the test series that subjected the UUT to impact. For example, when the UUT was dropped from a height of 72" (or six feet) onto a concrete floor, the UUT landed on its light switch. Upon manipulation afterwards, the switch was unresponsive, resulting in all of the lighting elements remaining illuminated.

The importance of an operable lighting mechanism was particularly evident during the following test series: Manufacturer Beta Test, Illumination Test, Orientation and Egress in an Obscured Environment, Flame/Heat Test at Live Burn Facility, and Stowing/Accessing the UUT in Fire Suppression/Inundation Environment. The test subjects acknowledged that the UUT's light was helpful for visibility of the compass in environments of low visibility. A limitation of the lighting mechanism noted by the test subjects during the Illumination Test was that it was difficult to differentiate between the light switch and the command bezel in the dark, as they are similar in shape, size, and location on the device.

While the test series revealed limitations in the lighting mechanism of the UUT, observations from additional controlled laboratory test series illustrated the ability of the outer construction of the UUT to withstand damage. For example, other than the previously noted lighting mechanism limitations, the OT&E team observed no other operational or physical damage to the UUT following the impact strength test series. This series included dropping the UUT from a height of 72" (or six feet) onto concrete and linoleum-covered floor surfaces.

The UUT also remained functional when subjected to icing conditions. After being fully immersed in water and placed in a freezer at 10.8° F for a period of 10 minutes, the UUT remained fully operational.

Another resistance test series subjected the UUT to temperatures in the range of 502° F to 509° F for five minutes in order to observe its thermal stability or heat resistance in accordance with NFPA 1971 Two of the three UUTs tested showed signs of separation/warping between the command bezel and the exterior casing. Additionally, the locking positions of both the building

and command bezels on all three UUTs became soft, and the command position indicator tab on the command bezel on all three UUTs because soft and pliable. Once the three UUTs returned to pretest temperatures, both the locking positions and the indicator tab returned to normal rigidity and operation on all three UUTs. Further, the lighting mechanism, battery compartment, circuit board, and batteries showed no evidence of damage or deformation on all three UUTs. While the UUTs show some melting and warping effects after a five minute exposure to 500° F, it is undetermined how long the UUTs could withstand an exposure to 500° F before the unit would suffer irreparable and/or irreversible damage.

In order to simulate use, the OT&E team executed specific test series in laboratory settings to observe how the UUT performs. The ability of firefighters to easily use and manipulate equipment by hand while wearing standard turnout gear gloves is essential. Specific test series focusing on this aspect revealed no difficulties in using the UUT while wearing dry gloves, HAZMAT gloves, and wet standard structural fire ensemble gloves. Additional test series evaluated the ability to stow and access the UUT while dressed in standard turnout gear as described in Sections 5.9 and 5.10. Test series observations indicated that overall the ability to stow the UUT in the specified pocket, and access the UUT in standing, kneeling, and prone positions was executed with little to no difficulty.

Additional test series focusing on the UUT's mechanical adjustment range evaluated the full range of expected mechanical adjustments to the UUT's building and command bezels. One UUT performed without any notable abnormalities, while another UUT experienced an abnormality after the command bezel was rotated, causing the needle on the compass to stick. Direct cause and effect between these two actions could not be determined. Only after moving the UUT back and forth did the compass resume normal functionality.

In addition to the laboratory test series, the field test series enabled evaluation of the UUT's functionality and usability in a more realistic, operational environment. Test series conducted in warehouse and smoke-obscured environments illustrated that the UUT aided the test subjects in navigating their way to safety and confirmed that the UUT is usable in such facilities.

In addition to the field environments above, the OT&E team evaluated the UUT in a flame/heat test series to assess the UUT in the conditions a firefighter would face if he or she was attempting to use the UUT in a live burn environment. The structural integrity of the UUT was maintained throughout the test series, during which it was subjected to an environment where internal temperatures ranged from 167° F at the floor to 530° F at the ceiling. Overall, the UUT was both visible and functional in the live burn environment. Test subjects observed a usability problem with the UUT during the test series when the UUT prevented the test subjects from finding true north as the compass needle vacillated significantly. The same vendor-defined limitations were observed in the test series that occurred in the warehouse when test subjects experienced similar limitations of the device.

In conclusion, aside from the constraints with the lighting mechanism detailed above and those consistent with the limitations stipulated by the vendor, the OT&E team observed the FireGround Compass to be operational in smoke-obscured, warehouse, and live burn environments. This observation was supported by interviews with test subjects after each of the operational and field tests. Additional operability (i.e., usability and functionality) and limitations in operability of the FireGround Compass were observed in other test series conducted in controlled laboratory environments. It must be noted that despite these

observations, the primary purpose of this operational test and evaluation performance report is to provide the first responder community information regarding a specific tool intended to be used by firefighters for purposes of location re-orientation.

While this operational test and evaluation report illustrates operational capabilities and limitations of the FireGround Compass, the results from this operational test and evaluation event are presented as observations by the OT&E team, and do not imply success or failure of the FireGround Compass or its readiness for field deployment. This operational test and evaluation performance report is not intended to endorse or recommend any particular product but rather to be used as information in the possible procurement of a technology by the end user, in this case, the first responder community.

Table 6-1: Summary of Test Results

UUT ID#	Test Series	Damage Observed	Summary
EKU001	Ingress Protection – Immersion	Yes	Moisture was observed underneath the compass cover plate as well as on all components within the battery compartment. See Section 5.1.4 for more information.
EKU002	Ingress Protection – Immersion	Yes	Moisture was observed underneath the compass cover plate as well as on all components within the battery compartment. See Section 5.1.4 for more information.
EKU005	Measuring Impact Strength (Concrete Floor)	Yes	Light could not be switched off after it was activated when UUT came in contact with the concrete floor. See Section 5.2.4 for more information.
EKU006	Measuring Impact Strength (Covered Floor)	No	No damage to the UUT was observed as a result of the test series.
EKU007	Icing Conditions	No	No damage to the UUT was observed as a result of the test series.
EKU008	Icing Conditions	No	No damage to the UUT was observed as a result of the test series.
EKU011	Mechanical Adjustment Range	No	No damage to the UUT was observed as a result of the test series.
	Heat Resistance	Yes	Separation/warping was evident between the command bezel and the exterior casing. The locking positions of the building and command bezels became soft. The command position indicator tab on the command bezel became soft and pliable. Both the locking positions and the command position indicator returned to normal rigidity and operation after the UUT has returned to pretest temperature. See Section 5.4.4 for more information.

UUT ID#	Test Series	Damage Observed	Summary
EKU012	Mechanical Adjustment Range	No	No damage to the UUT was observed as a result of the test series.
EKU013	Mechanical Adjustment – Dry Gloves	No	No damage to the UUT was observed as a result of the test series.
EKU014	Mechanical Adjustment – HAZMAT Gloves	No	No damage to the UUT was observed as a result of the test series.
EKU015	Mechanical Adjustment – Wet Gloves	No	No damage to the UUT was observed as a result of the test series.
EKU016	Manufacturer Beta Test	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
EKU017	Manufacturer Beta Test	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
	Heat Resistance	Yes	The locking positions of the building and command bezels became soft. The command position indicator tab on the command bezel became soft and pliable. Both the locking positions and the command position indicator returned to normal rigidity and operation after the UUT has returned to pretest temperature. See Section 5.4.4 for more information.
EKU018	Illumination Test	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
EKU019	Illumination Test	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.

UUT ID#	Test Series	Damage Observed	Summary
EKU020	Flame / Heat Test at Live Burn Facility	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
EKU021	Flame / Heat Test at Live Burn Facility	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
EKU022	Orientation and Egress in an Obscured Environment	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.
	Heat Resistance	Yes	Separation/warping was evident between the command bezel and the exterior casing. The locking positions of the building and command bezels became soft. The command position indicator tab on the command bezel became soft and pliable. Both the locking positions and the command position indicator returned to normal rigidity and operation after the UUT has returned to pretest temperature. Se Section 5.4.4 for more information.
EKU023	Ingress Protection – Attack Hose	Yes	Moisture was observed underneath the compass cover plate as well as on all components within the battery compartment. See Section 5.12.4 for more information.
EKU026	Ingress Protection – Attack Hose	Yes	Moisture was observed underneath the compass cover plate as well as on all components within the battery compartment. The individual light in the center of the compass remained illuminated after light switch was depressed and all other lights turned off. See Section 5.12.4 for more information.
EKU025	Orientation and Egress in an Obscured Environment	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.

UUT ID#	Test Series	Damage Observed	Summary
EKU027	Stowing / Accessing the UUT in Fire Suppression / Inundation Environment	Yes	Moisture was observed underneath the compass cover plate. The individual light in the center of the compass remained illuminated after light switch was depressed and all other lights turned off. See Section 5.10.3 for more information.
EKU029	Stowing / Accessing the UUT in Fire Suppression / Inundation Environment	Yes	Moisture was observed underneath the compass cover plate. See Section 5.10.3 for more information.
EKU030	Stowing / Accessing the UUT	NA	The test series and test objectives did not subject the UUT to any type of force or resistance which could have resulted in damage to the UUT.