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Performance Assessment of a Hybrid Radar and Electro-Optical Foreign Object Debris Detection System

June 2012

Final Report

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16. Abstract

In 2007, the Federal Aviation Administration (FAA) Airport Technology Branch conducted a performance assessment of the FODetect®, a hybrid radar and electro-optical foreign object debris (FOD) detection system developed by Xsight Systems, Ltd. This assessment included the system's capability to detect objects of various shapes, sizes, and materials at all locations on the runway surface. The system's capability to detect FOD during both nighttime and daytime conditions, in periods of sun, rain, mist, fog, and snow, was also assessed.

The FODetect system was initially demonstrated in January 2008. Following the demonstration, a more comprehensive performance assessment of the technology was conducted at the Boston Logan International Airport. The performance assessment was initiated in June 2008 with a test schedule that continued until May 2009. Researchers conducted several test sessions to assess the FODetect's capability to detect selected FOD items. The tests focused on hybrid sensor characteristics, specifically the joint capabilities of radar and electro-optical sensors operating together.

The FODetect system was able to detect the objects of various shapes, sizes, and materials on runway surfaces and perform satisfactorily in nighttime, daytime, sun, rain, mist, fog, and snow conditions, as required by FAA Advisory Circular 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment."

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LIST OF ACRONYMS

AC	Advisory Circular
AOA	Aircraft operations area
BOS	Boston Logan International Airport
CEAT	Center of Excellence for Airport Technology
EO	Electro-optical
FAA	Federal Aviation Administration
FOD	Foreign object debris
GUI	Graphical user interface
PVC	Polyvinyl chloride
RCS	Radar cross section
RU	Radar unit
SDU	Surface detection unit
SOC	System Operations Console

EXECUTIVE SUMMARY

In 2007, the Federal Aviation Administration Airport Technology conducted a performance assessment of a new hybrid radar and electro-optical Foreign Object Debris (FOD) detection system technology, the FODetect® system, developed by Xsight Systems, Ltd. Preliminary assessment of the FODetect was completed in June 2007, and the University of Illinois Center of Excellence for Airport Technology (CEAT) developed plans for a performance assessment of this new technology based on a sensor-oriented test program. CEAT submitted documentation for approval of an experimental FODetect system installation at Boston Logan International Airport (BOS) in September 2007. FODetect installation was completed in early 2008, and the performance assessment program was implemented in June 2008 with a test schedule intended to evaluate detection performance under typical airport operational conditions and under different environmental conditions. The test protocol developed by CEAT represented a compromise between a sensor-focused test design and an assessment of the performance of a new detection technology design that integrated radar and electro-optical sensor information using advanced software in a new hybrid detection system. The design of the assessment study preceded publication of Advisory Circular (AC) 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment," but was designed to capture the fundamental characteristics and requirements for radar and electro-optical sensors; specifically accounting for the hybrid technology developments of Xsight Systems, Ltd.

This report provides a review of the FODetect performance assessment, which included radar and electro-optical testing, and an assessment of the new, hybrid detection technology introduced by the Xsight in the FODetect system. CEAT's test approach, developed in advance of the publication of AC 150/5220-24, involved two coordinated assessment approaches. One approach focused on sensors using targets specific to sensor type. Xsight assisted in the tests by operating the FODetect system in an operational test mode to allow group placement of standard targets. Detections were associated with sensor type, but the final results reflected the full use of Xsight's hybrid technology in which fusion of radar and electro-optical sensor information was achieved through advanced processing software. The second approach focused on FODetect hybrid system performance in which tests were conducted in the operational mode of the FODetect system. For these tests, FOD items that met the requirements in Section 3.2b (1) (c) of AC 150/5200-24 were provided by Xsight. A long-term operational analysis of the FODetect system was not part of this assessment, although information from an operational analysis at BOS is included in this report.

In the CEAT performance assessment, radar and electro-optical sensor performance was evaluated and tested under different environmental conditions. The FODetect system performed according to Xsight's product specifications and met the performance requirements identified in AC 150/5220-24. For basic functions, the FODetect system

- provided surveillance in the aircraft operations area (AOA) as specified by the airport.

- detected and located single and multiple FOD items on the AOA and provided the alert time and the location.

- provided an alert to the user when FOD was detected.

- operated in conjunction with, and did not interfere with, airport and aircraft communication, navigation, and surveillance systems.

- operated in conjunction with and without interference from normal airport and aircraft operations.

- provided a data record of detected FOD, allowing for equipment calibration and maintenance and for analysis of the FOD event.

In the area of detection performance, the FODetect

- met requirements for location accuracy.

- met requirements for inspection frequency.

- provided surveillance of an entire runway.

- met specifications for clear-weather, dry-pavement conditions with a system detection meeting Section 3.2b (1) (c) requirements with 100% detection of FOD items.

- met AC specification for clear-weather, dry-pavement conditions with detection rate of a standard target of 98%.

- provided alerts of FOD presence on the runway and provided location information to facilitate removal.

For system output, the CEAT tests revealed that the FODetect

- provided an image of the detected objects

- provided a digital data record of operations that included the alert time, the date, and the location of the FOD object.

- provided digital data that could be presented in a number of formats.

- provided digital data suitable for management that can meet the needs of multiple airports.

1. INTRODUCTION.

As part of the Federal Aviation Administration (FAA) Airport Technology Research and Development Program, the University of Illinois Center of Excellence for Airport Technology (CEAT) has been supporting research and development activities of the FAA William J. Hughes Technical Center for more than 10 years. In 2004, the FAA initiated a program to evaluate foreign object debris (FOD) detection systems. The system that is the subject of this assessment is the Xsight Systems, Ltd. FODetect®, which is a stationary hybrid radar and electro-optical FOD detection system. The system consists of a radar unit (RU) and an electro-optical (EO) sensor working together in a single surface detection unit (SDU) that incorporates advanced software to fuse detection data from the two sensors. Multiple SDUs are required for runway coverage.

A preliminary assessment of the FODetect was completed in June 2007, and CEAT developed plans for a performance assessment of this new technology based on a sensor-oriented test program. CEAT submitted documentation to the FAA for installation approval of an experimental FODetect system installation at Logan International Airport (BOS) in Boston, Massachusetts, in September 2007. CEAT submitted documentation for FAA form 7460 approval in September 2007. The 7460 application was approved in December 2007 with no waivers required. The installation of the FODetect was completed in early 2008. The performance assessment program was implemented in June 2008 with a test schedule intended to evaluate detection performance under typical airport operational conditions and under different environmental conditions. The test protocol developed by CEAT represented a compromise between a sensor-focused test design and an assessment of the performance of a new detection technology design that integrated radar and EO sensor information using advanced software in a new hybrid detection system. Assessment study designs preceded publication of Advisory Circular (AC) 150/5220-24 [1], referred to as the AC in this report, which lists requirements for a hybrid FOD detection technology. The CEAT study designs incorporated targets appropriate to both radar and electro-optical sensors for the performance assessment. Detection results accounted for the hybrid technology developments of Xsight Systems, Ltd, in which the response from both sensor types were fused to provide a system response. Test campaigns were conducted from June 2008 through May 2009.

2. OBJECTIVE.

The objectives of the assessment were to determine the performance of the FODetect system and to develop requirements and standards for FOD detection technologies. With publication of the AC [1], performance requirements were identified by the FAA. This report describes the performance of the FODetect and considers whether the assessment data is relevant to the requirements described in the AC.

3. PERFORMANCE REQUIREMENTS FOR FOD DETECTION SYSTEMS.

In September 2009, the FAA published AC 150/5220-24 [1]. This AC established specifications, as shown in table 1, for a range of FOD detection technologies, including:

- A stationary hybrid radar and EO system, such as the FODetect
- A stationary radar system
- A stationary EO system
- A mobile radar system

In this report, the requirements in AC 150/5220-24 are used as a focus of the performance assessment for the FODetect system and provide the performance criteria for technology evaluation.

Table 1. The AC 150/5220-24 Performance Requirements [1]

AC Category	AC Performance Requirement for FOD Detection Systems
Basic Functions	Equipment must perform the following functions: 1. Provide surveillance in the Airport Operations Area (AOA) as specified by the airport. 2. Detect and locate single and multiple FOD items on the AOA. 3. Provide an alert to the user when FOD has been detected. 4. Operate in conjunction with, and not interfere with, airport and aircraft communication, navigation, and surveillance systems. 5. Operate in conjunction with, and without interference from, normal airport and aircraft operations (e.g., aircraft and vehicle movements). 6. Provide a data record of detected FOD, allowing for equipment calibration and maintenance, and for analysis of the FOD event.
Detection Performance: Object Detection	Systems must be able to detect the following objects; mobile systems must provide this performance at a minimum speed of 20 mph (30 km/h): 1. An unpainted metal cylinder measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter 2. A white, grey or black sphere, measuring 1.7 in. (4.3 cm) in diameter (i.e., a standard size golf ball)

Table 1. The AC 150/5220-24 Performance Requirements [1] (Continued)

AC Category	AC Performance Requirement for FOD Detection Systems
Detection Performance: Object Detection (Continued)	3. 90% of the following group of objects when placed within a 100 by 100 ft (30 by 30 m) square in the desired coverage area. One item from each category must be included in the group, and each item must measure no larger than 4 in. (10 cm) in any dimension unless otherwise specified: • a "chunk" of asphalt or concrete • any portion of a runway light fixture (in-pavement or edge light) • an adjustable crescent wrench up to 8 in. (20 cm) long • a deep socket at least 2 in. (5 cm) in length • a piece of rubber from an aircraft tire • a distorted metal strip up to 8 in. (20 cm) in length • fuel cap (aircraft or automotive) • a lug nut • a hydraulic line (from aircraft or ground support equipment) up to 8 in. (20 cm) in length • a white polyvinyl chloride (PVC) pipe of 2 in. (5 cm) in diameter 4. Any two of the objects above, located no more than 10 ft (3 m) apart from each other, identified as separate objects.
Detection Performance: Location Accuracy	Systems must provide location information for a detected object that is within 16 ft (5.0 m) of the actual FOD object location. Note: This standard is based on the average accuracy of hand-held GPS devices, which most airport operators will use when retrieving detected FOD. Airport operators using non-visual detection systems, who require greater location accuracy, can procure optional components that enable the system to have visual detection capabilities.
Detection Performance: Inspection Frequency	For continuous detection systems: These systems must provide continuous operation from fixed sensors to allow for the continuous inspection of runway surfaces during flight operations. The duration of flight operations is dependent on the airport and specified by the user. For mobile detection systems: The system must provide a mobile operation capability to enhance mandated airport safety self-inspections (per AC 150/5200-18 [2]). The frequency of inspections is dependent on the airport and specified by the user.

Table 1. The AC 150/5220-24 Performance Requirements [1] (Continued)

AC Category	AC Performance Requirement for FOD Detection Systems
Detection Performance: Detection Response Time	Systems must have the capability of providing rapid detection of an FOD occurrence in the area being scanned. For continuously operating FOD detection systems designed to provide between-movement alerts: The system must provide inspection of runway surfaces between aircraft movements. For other continuously operating FOD detection systems: The system must provide inspection updates as specified by the airport, generally within 4 minutes of an FOD occurrence.
Detection Performance: Surveillance Area	The airport operator will specify the desired surveillance (detection) area in the AOA requiring FOD detection. This area is generally based on the airport's FOD management plan. The primary area of coverage is the runway; certain portions of the runway may be specified by the airport operator if full coverage is not feasible. Other areas are of lesser importance, with a decreasing level of priority from other paved movement areas down to non-paved, non-movement areas. The manufacturer of an FOD detection system must notify the airport operator of any locations within the specified surveillance area where detection would not be possible.
Detection Performance: Performance in Weather	Systems must demonstrate detection performance under clear and inclement weather conditions. Under clear weather conditions, the pavement of the AOA is expected to be dry; under inclement weather conditions, the pavement will be wet with rain, snow, or mixed precipitation. 1. Detect objects under rainfall or snow conditions (e.g., having a specific intensity, duration, and frequency) for a two-year category of storm in the local region as specified in CLIM 20, Climatology of the United States No. 20 [3]. More stringent requirements may be specified by the user. 2. Systems must have site-specific performance specifications that include: • performance during clear weather conditions • performance during inclement weather conditions • Amount of time required for the system to recover after a rain or snow storm (e.g., to return to clear-weather performance capabilities after adverse weather conditions subside, defined as when precipitation of rain or snow ends.

Table 1. The AC 150/5220-24 Performance Requirements [1] (Continued)

AC Category	AC Performance Requirement for FOD Detection Systems
Detection Performance: Performance in Weather (Continued)	All systems must demonstrate detection performance during daylight, nighttime, and dawn/dusk operations.

System Performance: Alerts and Alarms	Systems must be able to alert the system operator to the presence of FOD in scanned areas, providing airport management with enough information to assess the severity of the hazard in order to determine if immediate object removal is necessary.
	
	   ■ False alarms (an alert causing the airport operator to take action to remove an FOD object that does not exist) should be minimized and must not exceed:
	      o For systems with visual detection capabilities: one per day as averaged over any 90 day period
	      o For systems without visual detection capabilities: three per day as averaged over any 90 day period.
	Note: Small items may be moved by wildlife or blown away before airport operators have a chance to investigate FOD alerts.

System Output: Detection Data	All systems must automatically provide a data record on detected FOD.
	
	1. Records must contain:
	    • Alert time and date
	    • Location of FOD object
	2. Capturing the following information is recommended, but not required:
	    • Description of FOD detected or retrieved (e.g., size, name, type, serial number)
	    • Time and date of FOD retrieval
	    • Time and date of disposition of alert
	    • Name of personnel detecting/investigating FOD item
	    • Image of the FOD object retrieved (if available)
	    • Chain of custody information

System Output: Data Presentation	FOD detection data can be provided in a coordinate scheme, on maps of the airport, in an operator's console, or broadcast to mobile units. The selection of information options will be specified by the airport, consistent with airport systems operations.
System Output: Data Management	Data collected in the FOD detection process should be digitally recorded. Data systems should have the capability to retain the data for at least 2 years after the detection event.

4. FODetect CHARACTERISTICS AND SPECIFICATIONS.

The FODetect system provides a fusion of RU and EO sensors that are mounted together in a scanner unit located near the surface to be scanned. The sensors include a 76- to 77-GHz radar and a video camera (figure 1). This SDU is supported by image- and radar-processing software. FODetect provides continuous surveillance of scanned surfaces with a distributed sensor system that uses SDUs that are integrated into existing runway or taxiway edge light infrastructure (figure 2). However, depending on the installation, a separate infrastructure may be used.

Figure 1. An SDU

Figure 2. The FODetect Sensor With Targets on the Runway at BOS

The SDU uses new hybrid technology, which combines a millimeter-wave RU capable of detecting targets that reflect radar energies and an EO sensor with near infrared illumination that captures images under variable lighting conditions. The FODetect system uses Xsight proprietary radar- and image-processing software to merge input from the two sensors into one usable detection result. The SDU contains mechanical systems for continuous scanning and includes a local processing unit connected to the server. The server provides system integration and the operator interface. Each SDU scans a portion of the runway and analyzes the data locally to detect FOD. When FOD is detected, the FODetect operator receives an audio and visual alert from the unit detecting the FOD item. The FODetect System Operations Console (SOC) supports operator analysis of the alert to determine FOD presence and hazard. The SOC provides the operator with the FOD location, and the SDU includes a built-in laser pointer for highlighting FOD locations for efficient removal of FOD at night. The FODetect system is designed to use multiple SDUs that sweep along the runway length, with each sensor covering approximately 200 ft (60 m). Xsight literature states the FODetect system multisensor deployment provides complete scans in 30 seconds. This provides rapid individual item detection and can provide information between aircraft movements.

In the performance assessment, targets were selected to evaluate radar and optical target consistency. The FODetect system performance was assessed using the hybrid technology developed by Xsight. Targets included a metal cylinder for the RU sensor and white, grey, and black PVC cylinders for the EO sensor. All cylinders were the same size. The use of these targets in the CEAT testing accounted for the hybrid technology developments of Xsight Systems, Ltd.

5. THE FODetect INSTALLATION AT BOS.

The installation at BOS consisted of ten sensors, five on each side of the runway, located at edge light positions on Runway15R/33L, as shown in figure 3. Paired sensors were used to scan the 150-ft (46-m) width of the runway between the runway's edge lines. The installation at BOS was on an operational runway and provided an opportunity to test the fusion capability of the system, whereas data from multiple sensors could be fused together to produce an operational system. The test campaigns were executed using the six sensors located in the center of the ten sensor array. The SDUs selected for use in each assessment campaign scanned approximately 600 ft (180 m) of the runway. In this test, only one side of the runway, with a single sensor, was used. This single SDU scanned from the edge line to the runway center line. The locations of FODetect sensors at BOS, shown in universal transverse mercator* 18 with a reference ellipsoid of North American Datum 83, are provided in table 2.

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* The system layout used for the evaluation of the FODetect system was designed as a partial installation that allowed for the assessment of the sensors' capability to operate as a complete system.

Table 2. Locations of FODetect Sensors at BOS in UTM 18, Reference Ellipsoid NAD 83

Sensor Designation	Latitude	Longitude
1A	4698590.22333	828379.28237
1B	4698552.03317	828344.49337
2A	4698627.87461	828338.43248
2B	4698589.55998	828303.42110
3A	4698665.44841	828297.38446
3B	4698627.17240	828262.38697
4A	4698703.07805	828256.29404
4B	4698664.78194	828221.32599
5A	4698740.67911	828215.21481
5B	4698702.39047	828180.25394
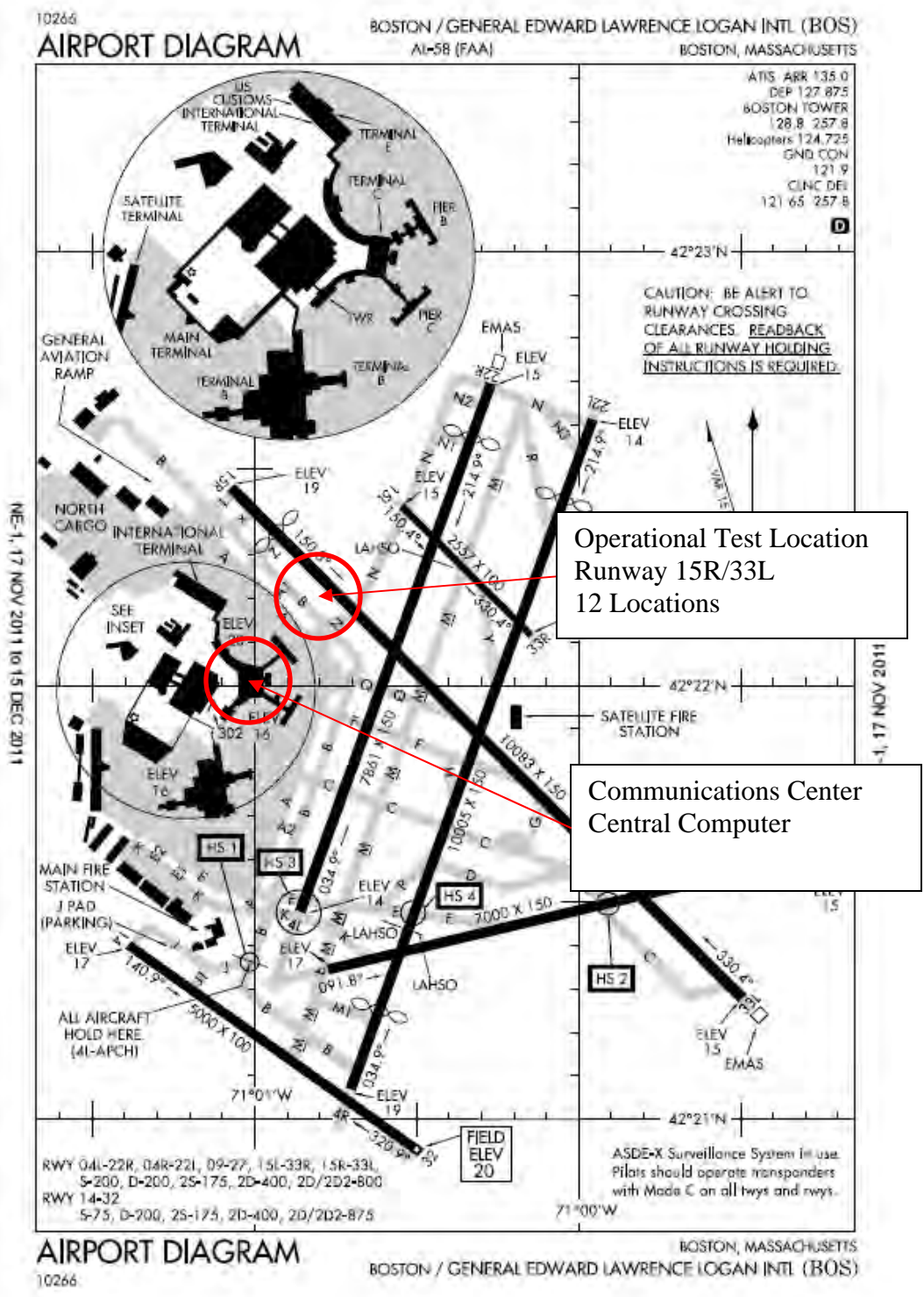
Figure 3. Airport Diagram of BOS

6. THE FODetect ASSESSMENT PROTOCOLS.

FODetect assessment protocols reflected the need to test in both operational test mode and normal operational mode. The operational test mode used the same targets deployed in the same location in all assessment campaigns. In this test, the system operated in an operational test mode in which, prior to target placement, clear field scans were completed, the sensors were inactivated, the targets were placed, and the detections were scored. In the operational mode, the system operated continuously and targets were placed within the test area while the sensors were scanning other areas of the runway. In the operational mode, the detection alerts were the same as would be expected in normal operations

6.1 THE FOD TEST ITEMS.

To meet AC 150/5220-24 performance requirements, a set of vendor-selected test items (shown in figure 4) were used in the tests. These items conformed to the specific requirements of Section 3.2b (1) (c) of the AC.

Figure 4. The AC-Compliant FOD Items Used in the Performance Tests

6.2 THE RU AND EO SENSOR TESTS.

The RU and EO test program was conducted from June 2008 to May 2009 at BOS. The FODetect performance assessment used a set of standard targets selected by CEAT to best assess RU and EO sensors. These items were similar to radar and optical targets specified by AC 150/5220-24 and included a metal cylinder with a nominal -20-dBm^2 radar cross section (RCS) to test the RU sensor and plastic PVC cylinders of different colors to test the EO sensor, as shown in figure 5. These targets were slightly larger than the 0.8-in. (2-cm) target listed in AC 150/5220-24, measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter. A standard group of targets, consisting of a metal cylinder and black, grey, and white plastic PVC cylinders, was placed in a line 12 in. (30 cm) apart at locations on the runway test grid.
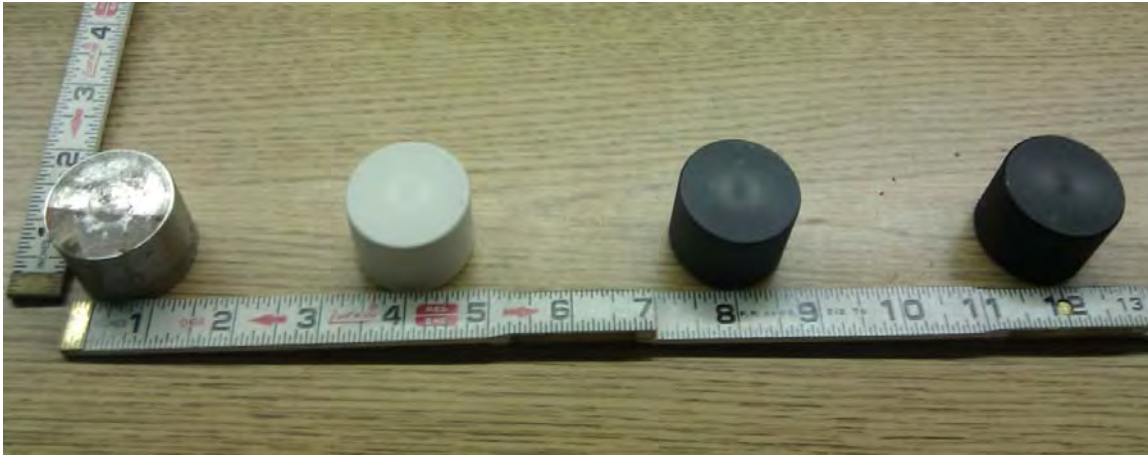
Figure 5. Standard Targets Used to Assess the FODetect System

6.3 RUNWAY TEST LOCATIONS.

The runway tests were conducted using the FODetect installation at BOS. For the FODetect system performance assessment, items were placed in relation to a single sensor. System redundancy was provided by overlap in detection zones with adjacent sensors.

For the RU and EO sensor tests, the test plan used a test rectangle that was developed for a single SDU. Test locations were based on sensor position, definition of sensor coverage areas, and selection of target placement locations. Although ten units were installed, only the middle six SDUs were used for this assessment, three on each side of the runway at 200-ft (61-m) intervals (figure 6). The test plan used a single SDU, e.g., the SDU labeled 3A in figure 6, located at the center of the SDUs installed on the north side of the runway. For SDU 3A, the expected detection rectangle was defined by a length of half the distance to each of the adjacent SDUs (100 ft or 31 m) and a width from the edge line to the runway center line (75 ft or 23 m). This produced a target rectangle with a length of 200 ft (60 m) and a width of 75 ft (23 m). Targets were placed near the 100-ft (30-m) limit on the four corners of the rectangle (C1, C3, C7, and C9). Targets were also placed across the width of the rectangle at its center (C4, C5, and C6). Additional targets were placed 30 ft (10 m) beyond the ends of the rectangle (C2 and C8) to assess system detection and sensor redundancy. Figure 7 shows the standard target placement for all tests.
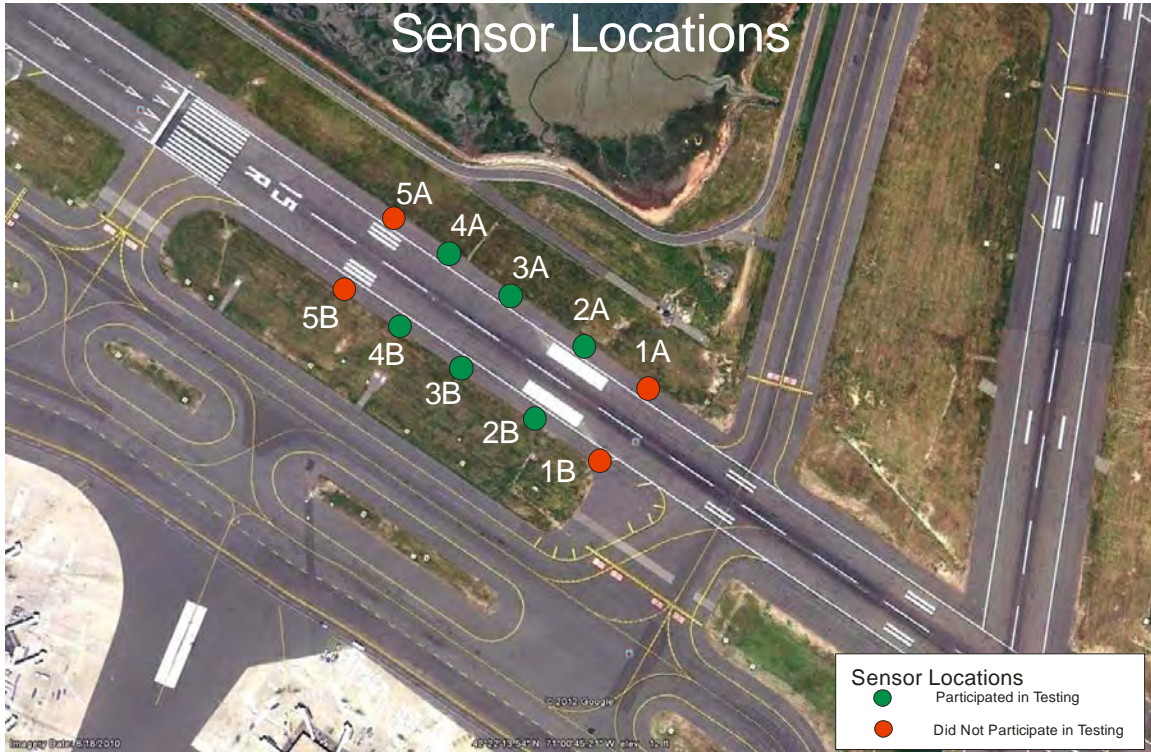
Figure 6. Location of Sensors on Runway 15R at BOS
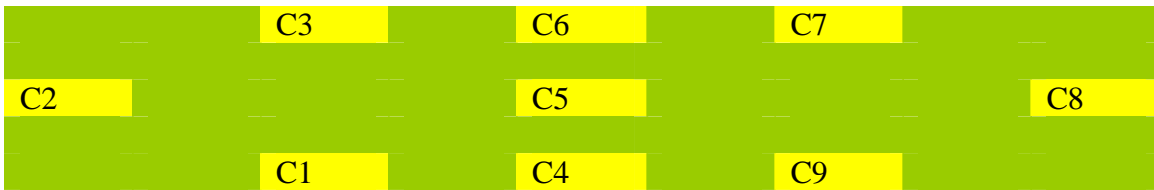
Figure 7. Target Locations Within and Outside of the Test Rectangle

Because the scan angle is an important factor in detection, standard target group strings were placed either parallel or perpendicular to the runway center line. All target groups were parallel to the runway center line except for locations C1 and C9, which were placed perpendicular to the runway center line. Orientation of the target group is shown in figure 8.
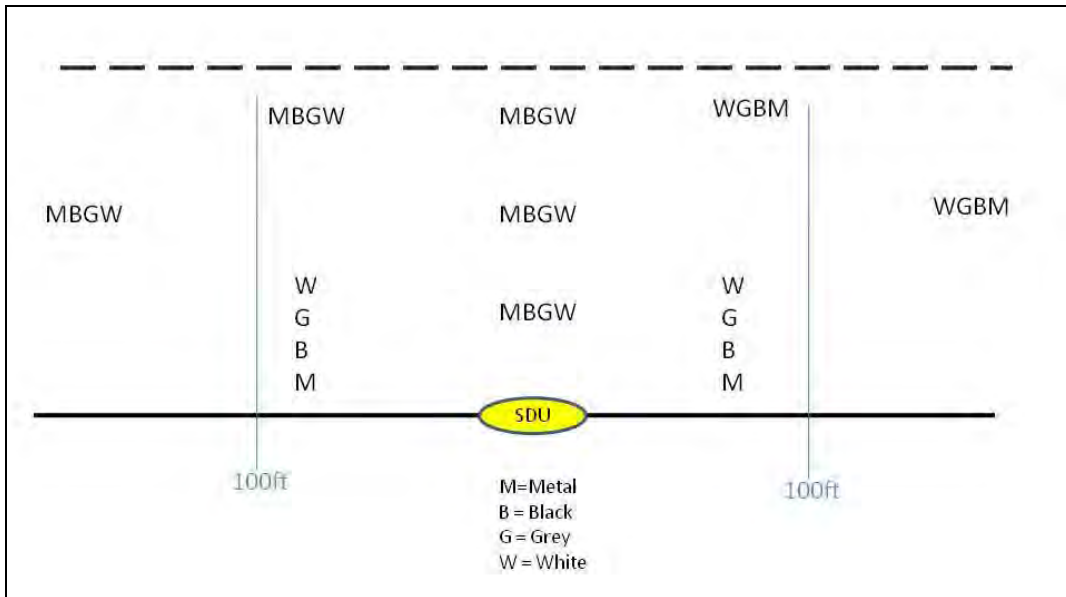
Figure 8. Target String Orientation in the Test Rectangle

With a nominal dimension for the test rectangle of 200 ft (60 m) long by 75 ft (23 m) wide, the distance to target locations varied from approximately 12 ft (4 m) for the location nearest the sensor to 119 ft (36 m) for the two corner locations near the runway center line (figure 9). Targets outside the test rectangle were 127 ft (39 m) from the tested sensor.
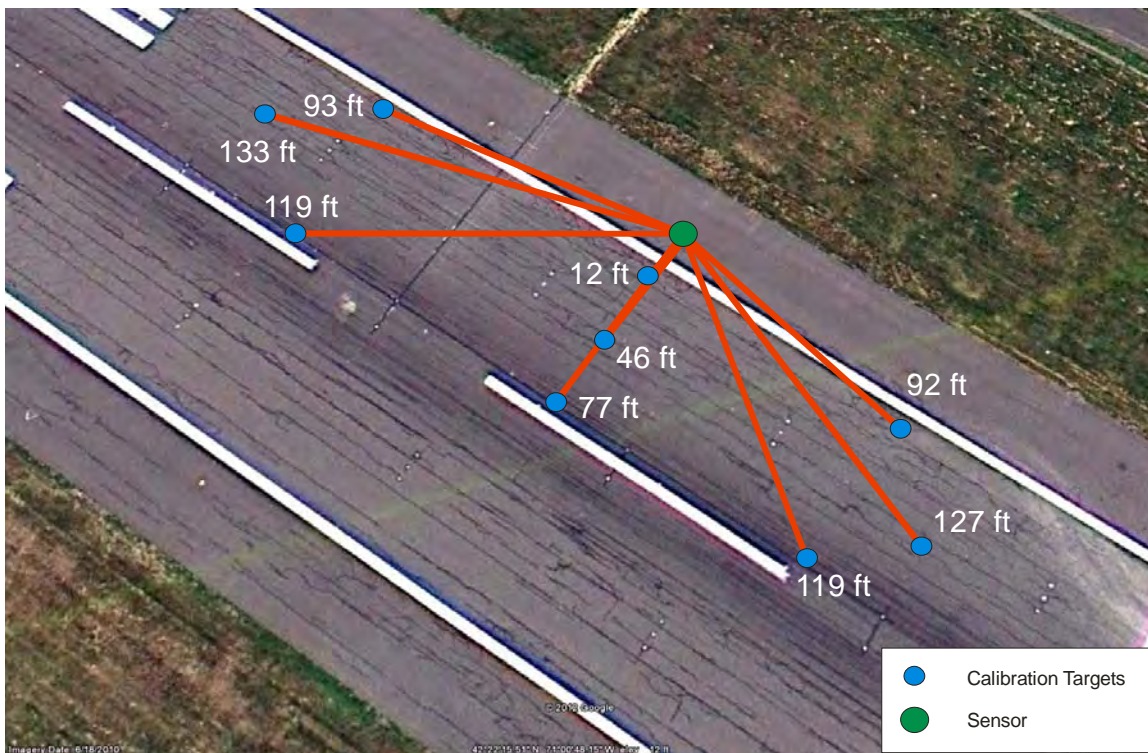
Figure 9. Distance From the SDU to Target Locations in the Test Rectangle

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6.4 PERFORMANCE ASSESSMENT METHODS.

Two performance assessment methods were used. The first method assessed FODetect system performance and the second method tested RU and EO sensor performance.

6.4.1 The FODetect System Performance.

FODetect system performance was conducted with targets conforming to Section 3.2b (1) (c) of the AC. The FODetect system was used in the operational mode in which all SDUs scanned the runway. FOD items were placed randomly on the runway when the SDU scan position allowed access to the runway. Using this FOD item deployment procedure, it was possible to assess a system operation that incorporated multiple sensors in FOD item detection. Following FOD item detection, an alert was generated, the FOD item was assessed by the SOC operator, data management confirmed, and the item was removed with the note "item removed" indicated in FODetect system records. This procedure was used to place single and multiple FOD items in a single detection test.

6.4.2 The FODetect Sensor Tests.

FODetect sensor tests were conducted during multiple test campaigns from June 2008 through March 2009.

Test procedures were standardized for all sensor test campaigns. The FODetect system was operated in the operational test mode, which allowed experimental placement of targets in the test rectangle. The operational test mode varied from normal operation in two ways: (1) a clear field scan was completed before each test because targets were repeatedly placed in the same location so it was necessary to update the background model between each target placement; and (2) a full scan of the test rectangle was completed before the SDU scan process was stopped. Xsight provided a specialized display mode that allowed a CEAT observer to note initial detections as scans progressed. Although the performance assessment was primarily designed to evaluate a single SDU's detection capability, the experimental design placed targets beyond the expected detection rectangle to test system performance by incorporating adjacent SDUs. Although the target group included items specific for RU and EO sensors, individual items in the target group could be acquired by either sensor. The hybrid technology developed by Xsight provided fusion of the data from both sensors in final detection analysis.

The operational test mode proceeded in three steps. First, a clear field scan was made by the sensor and then sensor motion was stopped. Second, targets were placed as required on the runway surface, and the detection scan was initiated. Each detection scan consisted of the sensor completing an approximately 180° scan and then returning to the starting point. As items were detected, the detection was identified by a red polygon around the item on the SOC screen. Although detections could be from RU or EO sensors, the hybrid system provides a fusion of sensor data and it was not possible to specifically relate a detection to a specific sensor type. Because the FODetect system was used in the operational mode, further review of SDU data was necessary to confirm all detections. This resulted in two detection results: the first was an initial detection confirmed by a CEAT console observer, and the second was a final detection count provided by Xsight following data review. All detection data for a test was recorded, and the

final performance data was based on full hybrid capabilities of the FODetect system. Because detection time for some items was observable, the time was recorded; detection times for items not observed on the console were developed from the record review.

6.4.3 Location Accuracy.

AC 150/5220-24 contains specifications for FOD detection system location accuracy. To assess location accuracy, each target position was surveyed using a Leica Geo Systems® RX1250 SmartRover and differential GPS survey techniques with an accuracy of millimeters in the X/Y plane. Each location was then compared to the latitude and longitude provided by the FODetect for each target. Location accuracy was assessed in July 2007.

7. THE FODetect PERFORMANCE ASSESSMENT RESULTS AND DISCUSSION.

7.1 THE FODetect SYSTEM PERFORMANCE.

In July 2011, a system performance test was conducted using the same system layout in the earlier performance assessment discussed in section 6. In this test, conducted on dry pavement during daylight hours, the FODetect system detected 100% of the FOD items listed in Section 3.2b (1) (c) of the AC. The performance assessment verified that the FODetect system could detect two items spaced 3 ft (1 m) apart and multiple items, including two small items approximately 6 in. apart and rubber and asphalt materials (typical of a burst tire or distribution of pavement materials from a runway surface failure) some distance apart. The typical time to detection was related to the operational mode where a scan was completed. If an item was detected, the operator assumed control of the SDU and the FOD item was verified and identified. Time to detection in this mode was 60 seconds or less.

7.2 SENSOR/HYBRID TECHNOLOGY PERFORMANCE.

A series of tests were conducted from June 2008 to May 2009 to evaluate sensor capabilities under different lighting conditions (daylight, dusk, and night), and under different weather conditions. These different conditions were selected to challenge the capability of each type of sensor type and provide information compatible with other FOD detection technology assessments performed by CEAT. In these tests, the same targets and locations were used as those discussed in section 6.3. This allowed researchers to determine the system's ability to detect items within the 200- by 75-ft test rectangle and determine the system's ability to detect objects 30 ft beyond the sides of the test rectangle. Researchers were able to measure the detection rate for each target within a target group, and were then able to calculate the detection percent rates for all the targets placed, sorted by target type and color. The results of these tests for all testing conducted during daylight with dry runway pavement conditions are summarized in tables 3 and 4. Table 3 provides the results for targets detected within the 200- by 75-ft test rectangle and table 4 provides the results for all targets detected both inside and outside of the test rectangle.

Table 3. Detection of Standard Targets Placed in the Detection Rectangle Providing Initial Test Results and Record Review Results

Color	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Average Time to Initial Detection (sec)	Total Detections After Record Review	Percent of Detections After Record Review	Average Time to Detection Based on Record Review (sec)	Combined Average Time to Detection for all Detections (sec)
Black	146	133	91	39	144	99	90	43
Grey	147	134	91	33	143	97	90	37
White	147	143	97	28	146	99	90	29
Metal	147	140	95	29	145	99	91	31
Total	587	550	94	32	578	98	90	35

Table 4. Detection of all Standard Targets Providing Initial Test Results and Record Review Results

Color	Number of Targets	Number of Detections	Percent Detected
Black	198	180	91
Grey	198	182	92
Metal	198	186	94
White	198	188	95
Total	792	736	93

These data indicate that a 94% detection rate based on initial observations is improved to 98% when full hybrid capabilities of the FODetect system are available, as is the case in the operational mode. The time-to-target detection averaged 32 seconds for 94% of the targets, while the average time to detection for those targets after record review was 90 seconds. The combination average time to detection for all detections is calculated by averaging the time to initial detection and the average time to detection after record review. In this test, the combination average time to detection for all detections was 35 seconds.

Because range-to-target is an important consideration and a component of the AC, an analysis was completed that listed detections by position in the test grid. Table 5 provides the detection results for all test campaigns by test location.

Table 5. Detection of Standard Targets by Target Location Providing Initial Test Results and
Record Review Results

Position	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Average Time to Initial Detection (sec)	Total Detections After Record Review	Percent of Detections After Record Review	Average Time to Detection Based on Record Review (sec)	Combined Average Time to Detection for all Detections (sec)
C1	84	79	94	1	82	98	91	4
C2	84	78	93	18	79	94	100	19
C3	84	78	93	17	84	100	91	22
C4	84	79	94	72	84	100	91	73
C5	84	78	93	42	80	95	89	43
C6	84	80	95	34	84	100	91	37
C7	84	77	92	36	82	98	91	39
C8	84	83	99	40	84	100	105	41
C9	83	79	95	23	82	99	89	25
Total	755	711	94	-	741	98	-	-

This data suggests that detection capability is consistent throughout the test grid and that
placement of target strings in different orientations to the SDU did not significantly change
detection performance.

Lighting conditions may influence detection in the FODetect, which combines EO sensors that
may be influenced by lighting conditions and RU that is not influenced by lighting conditions.
Although test opportunities were limited by runway availability, performance analysis included
testing in daylight, at night, and during dusk when lighting conditions were changing. Results
for detections under different lighting condition are shown by target color and by target location
in tables 6 through 11.

Table 6. Daylight Detection of Standard Targets Providing Initial Test Results and Record
Review Results

Color	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Total Detections After Record Review	Percent of Detections After Record Review
Black	152	150	99	150	99
Grey	153	149	97	149	97
White	153	152	99	152	99
Metal	153	150	98	150	98
Total	611	601	98	601	98

Table 7. Daylight Detection of Standard Targets by Target Location Providing Initial Test Results and Record Review Results

Position	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Total Detections After Record Review	Percent of Detections After Record Review
C1	68	66	97	66	97
C2	68	63	93	63	93
C3	68	68	100	68	100
C4	68	68	100	68	100
C5	68	68	100	68	100
C6	68	68	100	68	100
C7	68	66	97	66	97
C8	68	68	100	68	100
C9	67	66	99	66	99
Total	611	601	98	601	98

Table 8. Nighttime Detection of Standard Targets by Color Providing Initial Test Results and Record Review Results That Include EO and Radar Detection Times

Color	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Average Time to Initial Detection (sec)	Total Detections After Record Review	Percent of Detections After Record Review	Average Time to Detection Based on Record Review (sec)	Combined Average Time to Detection for all Detections (sec)
Black	18	5	28	105	18	100	159	144
Grey	18	9	50	73	18	100	159	116
White	18	15	83	57	18	100	159	74
Metal	18	13	72	49	18	100	159	80
Total	72	42	58	-	72	100	-	-

Table 9. Nighttime Detection of Standard Targets by Target Location Providing Initial Test Results and Record Review Results

Position	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections*	Total Detections After Record Review	Percent of Detections Following Record Review*
C1	8	5	-	8	-
C2	8	7	-	8	-
C3	8	2	-	8	-
C4	8	3	-	8	-
C5	8	6	-	8	-
C6	8	4	-	8	-
C7	8	3	-	8	-
C8	8	7	-	8	-
C9	8	5	-	8	-
Total	72	42	-	72	-

*Due to the small target sampling (due to restricted access to runway at night), these percentages are statistically insignificant and were not calculated. Columns are shown to provide consistency with report data for other FOD detection technologies.

Table 10. Dusk Detection of Standard Targets by Color Providing Initial Test Results and Record Review Results That Include EO and Radar Processing Times

Color	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Total Detections Following Record Review	Percent of Detections Following Record Review	Average Time to Initial Detection (sec)	Average Time to Detection Based on Total Detection (sec)
Black	18	17	94	17	94	111	111
Grey	18	17	94	17	94	111	111
White	18	17	94	17	94	111	111
Metal	18	17	94	17	94	111	111
Total	72	68	94	68	94		

Table 11. Dusk Detection of Standard Targets by Target Location Providing Initial Test Results
and Record Review Results

Position	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Total Detections Following Record Review	Percent of Detections With Record Review
C1	8	8	100	8	100
C2	8	8	100	8	100
C3	8	8	100	8	100
C4	8	8	100	8	100
C5	8	4	50	4	50
C6	8	8	100	8	100
C7	8	8	100	8	100
C8	8	8	100	8	100
C9	8	8	100	8	100
Total	72	68	94	68	94

7.3 LOCATION ACCURACY.

The AC stated that FOD detection systems must provide location information for a detected object that is within 16 ft (5.0 m) of the actual FOD object location. To validate the location accuracy, CEAT used survey methods and locations as reported by the FODetect system, as shown in table 12.

Table 12. Results of the Comparison Between Surveyed and Reported Locations

Position	Number of Records	Average (ft)	Minimum (ft)	Maximum (ft)	Standard Deviation	Distance From Sensor to Location (ft)
C1	27	5.70	1.50	20.00	4.60	93.5
C3	27	3.90	0.90	16.00	2.80	118.0
C5	26	2.00	0.68	3.40	0.60	45.0
C6	28	3.10	0.30	13.20	2.80	74.5
C7	26	2.90	0.29	7.30	2.00	117.5
C9	28	12.50	0.45	25.60	7.50	92.0
Total	162	5.02	0.29	25.60		

The average difference between the surveyed location and the position reported by the FODetect was 5.02 ft (1.53 m). There was variability in accuracy with smaller differences in location in the middle of the grid, positions C5 and C6. Location C5, which was closest to the sensor, had the lowest difference in location, averaging 2 ft (0.63 m). The greatest difference in reported and actual position was 25.6 ft (7.81 m) for C9.

Lighting conditions can affect the location reporting. Table 13 provides a summary of the results for location accuracy considering lighting conditions during the day, through the changing lighting at dusk, and at night.

Table 13. Results of the Comparison Between Surveyed and Reported Locations During Different Lighting Conditions

Lighting Condition	Number of Records	Average (ft)	Minimum (ft)	Maximum (ft)
Daylight	127	5.1	0.3	25
Dusk	29	4.5	0.5	13.5
Nighttime	6	7	1	16

7.4 DETECTION UNDER VARIABLE WEATHER CONDITIONS.

The performance assessment program was planned over approximately one year so that assessments could be made under different environmental and weather conditions. The test campaign schedule at BOS was arranged to provide six monthly campaigns with the expectation that adverse or inclement weather would occur during one or more of the scheduled test periods. Unfortunately, only one test, which was conducted in March at dusk, had rainy conditions. To provide data from adverse weather, specifically snow, additional tests were planned to sample during periods of high snowfall probability and, if that failed to produce needed test results, to send teams to BOS on short notice to sample after-snow events. Testing during snow events was difficult because runway access during snow emergencies precluded sampling during the event. However, the CEAT team was able to sample two after-snow events providing data from snow-contaminated runways. Table 14 provides results for the detection rate for standard targets under different weather conditions.

Table 14. Detection of Standard Targets Associated With Adverse Weather Conditions

Weather	Lighting Condition	Targets	Number of Initial Observed Detections	Percent of Initial Observed Detections	Total Detections Following Record Review	Percent of Detections Following Record Review
After snow	Day	108	104	96	107	99
After snow total		108	104	96	107	99
Light rain	Dusk	72	58	81	58	81
	Night	36	35	97	35	97
Light rain total		108	93	86	93	86
Normal	Day	610	601	99	601	99
	Dusk	108	99	92	104	96
	Night	72	42	58	72	100
Normal total		790	742	94	777	98

During the tests on April 1, 2009, light rain fell at dusk. This provided test results for rain and changing light conditions. The CEAT weather station indicated that rain began at 19:48 with a rainfall accumulation of 0.508 mm by 20:32. Field notes indicate a light drizzle at 18:33 with rainfall varying in intensity through the final test, which was completed at 19:48. Table 15 provides a summary of detections by target type during rain.

Table 15. Detection of Standard Targets Associated With the April 1, 2009 Tests

Time	Solar Radiation	Weather	Placements				Detections			
			White	Grey	Black	Metal	White	Grey	Black	Metal
18:33	4	Drizzle	9	9	9	9	7	7	7	7
19:03	0	Drizzle	9	9	9	9	8	7	7	4
19:24	0	Light rain	9	9	9	9	8	8	8	8
19:48	0	Light rain	9	9	9	9	9	9	9	8
		Total	36	36	36	36	32	31	31	27
All other tests during the campaign			216	216	216	216	205	202	200	202

On January 7, 2009, several inches of winter precipitation fell at BOS including rain, freezing rain, freezing drizzle, mist, ice pellets, and snow. The NOAA weather station at BOS recorded 1.1-in. (2.8-cm) snow accumulation with a liquid total of 1.17 in. (3.0 cm) of wet precipitation. Winter operations went into effect, and the runways were plowed. Testing was conducted on the following day, January 8, 2009. At that time, snow remained around the sensors, as shown in figure 10. Another winter storm passed through the area from January 10 through 12, 2009. On January 10, 0.7 in. (1.8 cm) of snow accumulation and a total liquid accumulation of 0.05-in.

(0.1-cm) wet precipitation was measured by the NOAA weather station. On January 11, the NOAA weather station noted snow, fog, mist, and haze at BOS. A total of 4.8 in. (12.2 cm) of snow fell on January 11 with a liquid total accumulation of 0.35 in. (0.9 cm). Runway access was provided on January 13, 2009; there was snow and ice around the sensors and on parts of the runway, as shown in figure 11. The test procedures for snow conditions were modified from standard procedures. Target placement was accomplished from the runway center line to avoid tracking snow on to the runway.

Figure 10. Snow Around Sensor on January 8, 2009

Figure 11. Runway Conditions on January 13, 2009

The test results with snow on and around the runway are provided in table 16. All tests were conducted during daylight hours.

Table 16. Detection of Standard Targets Associated With the January 2009 Tests

Date	Solar Radiation	Placements				Detections			
		White	Grey	Black	Metal	White	Grey	Black	Metal
1/8/2009	386	9	9	9	9	8	9	9	9
1/13/2009	152	9	9	9	9	8	9	9	5
Total		18	18	18	18	16	18	18	14
All other tests during the campaign		162	162	162	162	159	159	160	159

8. FODetect ASSESSMENT BASED ON AC 150/5220-24 SPECIFICATIONS.

The CEAT performance assessment of the FODetect system at BOS is based on specifications and criteria provided in AC 150/5220-24. The AC lists specifications for basic functions, detection performance, and system output. Based on data collected during the performance assessment, table 17 summarizes FODetect performance as it relates to AC 150/5220-24, and sections 8.1 through 8.3 provide a narrative analysis of the conformance of FODetect to AC performance specifications.

Table 17. Summary of FODetect Performance Related to AC 150/5220-24 Specifications

AC Category and Performance Requirement	CEAT Findings
Basic Functions	
1. Provide surveillance in the AOA as specified by the airport.	Met AC specification for a detection zone that included an entire runway, although only a portion of Runway 15R was covered by the FODetect system.
2. Detect and locate single and multiple FOD items on the AOA.	Detected and located single and multiple FOD items in detection zones.
3. Provide an alert to the user when FOD has been detected.	Provided visible and audible alerts.
4. Operate in conjunction with, but not interfere with, airport and aircraft communication, navigation, and surveillance systems.	In operation from June 2008 through May 2009; no interference reported.
5. Operate in conjunction with, and without interference from, normal airport and aircraft operations (e.g., aircraft and vehicle movements).	In operation from June 2008 through May 2009; no interference reported.

Table 17. Summary of FODetect Performance Related to AC 150/5220-24 Specifications
(Continued)

AC Category and Performance Requirement	CEAT Findings
Basic Functions (Continued)	
6. Provide a data record of detected FOD, allowing for equipment calibration and maintenance, and for analysis of the FOD event.	Full data record for period of operation provided; equipment was calibrated and maintained; multiple FOD events recorded.
Detection Performance: Object Detection	
1. An unpainted metal cylinder measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter.	Detected standard target with these dimensions.
2. A white, grey, or black sphere measuring 1.7 in. (4.3 cm) in diameter (i.e., a standard size golf ball).	Detected standard targets with these dimensions.
3. 90% of the following group of objects when placed within a 100 by 100 ft (30 by 30 m) square in the desired coverage area. One item from each category must be included in the group, and each item must measure no larger than 4 in. (10 cm) in any dimension unless otherwise specified: • A "chunk" of asphalt or concrete • Any portion of a runway light fixture (in-pavement or edge light) • An adjustable crescent wrench up to 8 in. (20 cm) long • A deep socket at least 2 in. (5 cm) in length • A piece of rubber from an aircraft tire • A distorted metal strip up to 8 in. (20 cm) in length • Fuel cap (aircraft or automotive) • Lug nut • Hydraulic line (from aircraft or ground support equipment) up to 8 in. (20 cm) in length • White PVC pipe of 2 in. (5 cm) in diameter	Detected 100% of the FOD item types.

Table 17. Summary of FODetect Performance Related to AC 150/5220-24 Specifications
(Continued)

AC Category and Performance Requirement	CEAT Findings
Detection Performance: Object Detection (Continued)	
4. Any two of the objects above, located no more than 10 ft (3 m) apart from each other, identified as separate objects.	Exceeded AC specification.
Detection Performance: Location Accuracy	
Systems must provide location information for a detected object that is within 16 ft (5.0 m) of the actual FOD object location.	Provided average location accuracy of approximately 5.1 ft (1.6 m) with a maximum difference of approximately 25 ft (7.6 m). Met AC requirement for average accuracy.
Detection Performance: Inspection Frequency	
Continuous Detection Systems. The system must provide continuous operation from fixed sensors to allow for the continuous inspection of runway surfaces during flight operations. The duration of flight operations is dependent on the airport and specified by the user. Mobile Detection Systems. The system must provide a mobile operations capability to enhance mandated airport safety self-inspections (per AC 150/5200-18). The frequency of inspections is dependent on the airport and specified by the user.	Met AC specifications.
Detection Performance: Detection Response Time	
For continuously operating FOD detection systems designed to provide between-movement alerts: The system must provide inspection of runway surfaces between aircraft movements. For other continuously operating FOD detection systems: The system must provide inspection updates as specified by the airport, generally within 4 minutes of a FOD occurrence.	Scan time of as little as 30 seconds met AC requirement for typical BOS movement activity, with detection also occurring in as few as 30 seconds. Met AC requirement for 4-minute scan time.

Table 17. Summary of FODetect Performance Related to AC 150/5220-24 Specifications
(Continued)

AC Category and Performance Requirement	CEAT Findings
Detection Performance: Surveillance Area	
The primary area of coverage is the runway; certain portions of the runway may be specified by the airport operator if full coverage is not feasible. Other areas are of lesser importance, with a decreasing level of priority from other paved movement areas down to nonpaved, nonmovement areas. The manufacturer of an FOD detection system must notify the airport operator of any locations within the specified surveillance area where detection would not be possible.	Manufacturer provided runway coverage meeting AC requirement. No areas without detection were identified.
Detection Performance: Performance in Weather	
1. Detect objects under rainfall or snow conditions (e.g., having a specific intensity, duration, and frequency) for a 2-year category of storm in the local region as specified in CLIM 20, Climatology of the United States No. 20 [3]. More stringent requirements may be specified by the user. 2. Systems must have site-specific performance specifications that include: • performance during clear weather conditions • performance during inclement weather conditions • amount of time required for the system to recover after a rain or snow storm (e.g., to return to clear-weather performance capabilities after adverse weather conditions subside, defined as when precipitation of rain or snow ends. 3. All systems must demonstrate detection performance during daylight, nighttime, and dawn/dusk operations.	Tests were conducted under rainfall and snowfall conditions, but testing did not produce results for the storm intensity requirements listed in the AC. Met requirements for clear weather conditions; testing was conducted during a rain event with no appreciable reduction of detection capability. The system was tested after snowfall and runway clearance; the system performed during snowfall conditions. System performance under variable lighting conditions found detection performance generally unchanged, although detection time was extended.

Table 17. Summary of FODetect Performance Related to AC 150/5220-24 Specifications
(Continued)

AC Category and Performance Requirement	CEAT Findings
Detection Performance: Alerts and Alarms	
False alarms (an alert causing the airport operator to take action to remove a FOD object that does not exist) should be minimized and must not exceed: • For systems with visual detection capabilities: one per day as averaged over any 90-day period • For systems without visual detection capabilities: three per day as averaged over any 90-day period. Note: Small items may be moved by wildlife or blown away before airport operators have a chance to investigate FOD alerts.	False alarms minimized during assessment. Assessment did not incorporate an analysis of a runway FODetect system that would allow determination of conformance to this requirement.
System Output: Data Detection	
1. Records must contain: • Alert time and date • Location of FOD object 2. Capturing the following information is recommended, not required: • Description of FOD detected or retrieved (e.g., size, name, type, serial number) • Time and date of FOD retrieval • Time and date of disposition of alert • Name of personnel detecting/investigating FOD item • Image of the FOD object retrieved (if available) • Chain of custody information	Met AC specification.

AC Category and Performance Requirement	CEAT Findings
System Output: Data Presentation	
FOD detection data can be provided in a coordinate scheme, on maps of the airport, in an operator's console, or broadcast to mobile units. The selection of information options will be specified by the airport, consistent with airport systems operations.	Met AC specification.
System Output: Data Management	
Data collected in the FOD detection process should be digitally recorded. Data systems should have the capability to retain the data for at least 2 years after the detection event.	Met AC specification.

8.1 BASIC FUNCTIONS.

8.1.1 Provide Surveillance in the AOA as Specified by the Airport.

The FODetect was installed at BOS and provided continuous surveillance of a portion of Runway 15R. This surveillance met the requirements of the airport for this technology demonstration.

8.1.2 Detect and Locate Single and Multiple FOD Items on the AOA.

The FODetect was able to consistently locate single and multiple FOD items on the AOA under a variety of test conditions during the approximately 1-year performance assessment conducted by CEAT.

8.1.3 Provide an Alert to the User When FOD has Been Detected.

The FODetect provided visual and audible alerts of FOD detected at the central console located in the BOS operations tower.

8.1.4 Operate in Conjunction With, and Without Causing Interference to, Airport and Aircraft Communication, Navigation, and Surveillance Systems.

Operation of the FODetect occurred without causing interference to aircraft communication, navigation, or surveillance technologies. Through the normal FAA Form 7460, Notice of Proposed Construction or Alteration application process, approval was obtained without any discrepancies. Radio frequency interference, installation location, and operation of the FODetect were all approved following typical FAA and Federal Communications Commission processes.

8.1.5 Operate in Conjunction With, and Without Receiving Interference From, Normal Airport and Aircraft Operations.

The FODetect was operated during the performance assessment without receiving interference from normal airport and aircraft operations. Detection algorithms in the system differentiated between stationary and moving targets, and no false alarms were associated with vehicles or aircraft.

8.1.6 Provide a Data Record of Detected FOD That Allows for Equipment Calibration and Maintenance and for Analysis of the FOD Event.

The FODetect provided a digital record of calibration, maintenance activity, and all FOD alerts associated with detections on Runway 15R.

8.2 DETECTION PERFORMANCE.

8.2.1 Object Detection.

The FODetect system was able to detect all FOD items required in Section 3.2b (1) (c) of the AC. The performance assessment verified detection of multiple objects when placed within a 100- by 100-ft (30- by 30-m) square in the desired coverage area. The performance assessment also confirmed detection of two objects located no more than 10 ft (3 m) from each other and confirmed identification as separate objects.

In sensor testing, the FODetect sensors were able to consistently detect an unpainted metal cylinder measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter that provided a nominal RCS of -20 DBm^2. The FODetect system was also able to consistently detect white, grey, and black plastic cylinders of the same dimension.

8.2.2 Location Accuracy.

The FODetect provided location information that, when compared to surveyed position, resulted in an average difference between the surveyed point and the location that met average accuracy requirements of AC 150/5220-24. The average difference between surveyed and reported position was 5.1 ft (1.6 m) with a greatest difference in reported and actual position of 25 ft (7.6 m). This performance met AC 150/5220-24 requirements that the FOD detection systems provide location information for a detected object that is within 16 ft (5.0 m) of the actual FOD object location. The FODetect system met this requirement in average detection accuracy.

8.2.3 Inspection Frequency.

The FODetect system installed at BOS provided continuous detection of the target runway for the period defined by the performance assessment, June 2008 to May 2009. This operation met the AC 150/5220-24 specification for continuous operation, and the system provided continuous inspection of a portion of Runway 15R during flight operations.

8.2.4 Detection Response Time.

The FODetect is designed to provide between-movement alerts to FOD presence. During the performance assessments, detection of FOD items was generally completed within a combined average time to detection for all detections of 60 seconds, although detection times could be as low as approximately 30 seconds. The FODetect provides between-movement detection of FOD items.

8.2.5 Surveillance Area.

The FODetect system provided partial coverage of Runway 15R at BOS. Five sensor pairs were installed on the runway, although, for the purposes of the evaluation and to make the process manageable, only three pairs were used.

8.2.6 Performance in Weather.

The FODetect was assessed during dry and wet pavement conditions. Although testing was completed during one rainstorm and several days of mixed rain, sleet, and snow, it was not possible to complete testing during a 2-year category of storm in the local region.

The FODetect met AC 150/5220-24 performance specifications for clear weather, dry pavement conditions with a standard target system detection average of 98%.

The FODetect operated during inclement weather, and detections were verified during rainfall, sleet, and snow conditions.

The FODetect was tested during one rain event at dusk. All other adverse weather testing was conducted during day light.

8.2.7 Alerts and Alarms.

The FODetect provided alerts of FOD presence on the runway and provided video images of detected items and location information to facilitate removal.

The CEAT performance assessment program was designed to place known objects on airport surfaces and determine detection performance. No false alarm data were developed in this assessment. An assessment of false alarms must await full operational installations of this technology. It is assumed that false alarms will be minimized because the system operator will be able to use the FODetect camera capability to visually verify alarms. Hence, false alarms may result in more attention to system operations but have no effect on the airfield.

The FODetect system provided a laser designation system to assist in FOD item location at night. This system capability was not assessed in this assessment.

8.3 SYSTEM OUTPUT.

8.3.1 Detection Data.

The FODetect provided a digital data record of operations that included an alert time and date and the location of the FOD object.

8.3.2 Data Presentation.

The FODetect provided video and digital data that could be presented in a number of formats. The basic graphical user interface (GUI) provided a real-time video image of the scanned surfaces supplemented by a line drawing of runway infrastructure. In addition to specific locations of detected FOD contained in the digital record, the GUI provided a visual representation of FOD location and a visual representation of the detected FOD.

8.3.3 Data Management.

The FODetect provided digital data that is suitable for management and can meet the needs of multiple airports.

9. OPERATIONAL ANALYSIS.

Operational performance tests of the FODetect system were not conducted by CEAT during the performance assessment, although researchers were able to review the FODetect data management reports and obtain input from BOS operations personnel.

Installation of the FODetect system at BOS included the installation of a SOC in the BOS Communications Center where BOS operations staff were able to receive system alerts, access real-time video/visual information on the alerts, and respond to the alert. Although the BOS installation only provided surveillance of a portion of Runway 15R, BOS operation personnel reported numerous alerts. A summary of items producing the alerts are provided in figure 12. The highest number of alerts was produced by wildlife, including the first report of a coyote on the airport (figure 13).
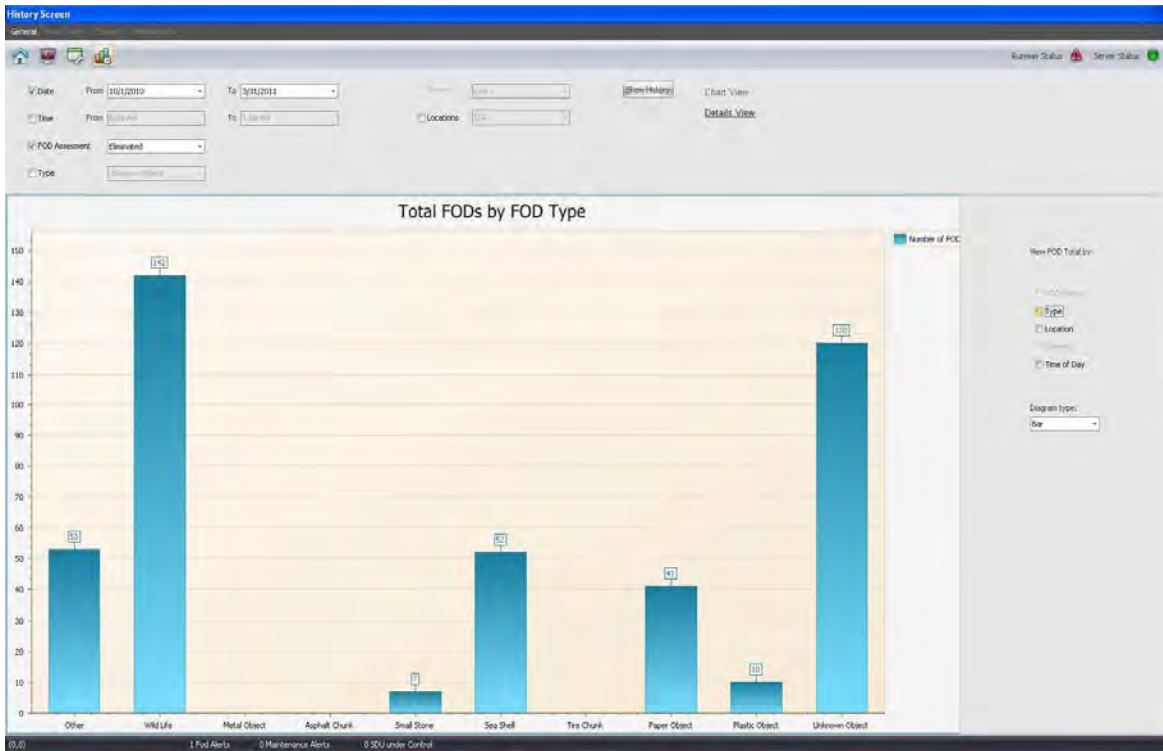
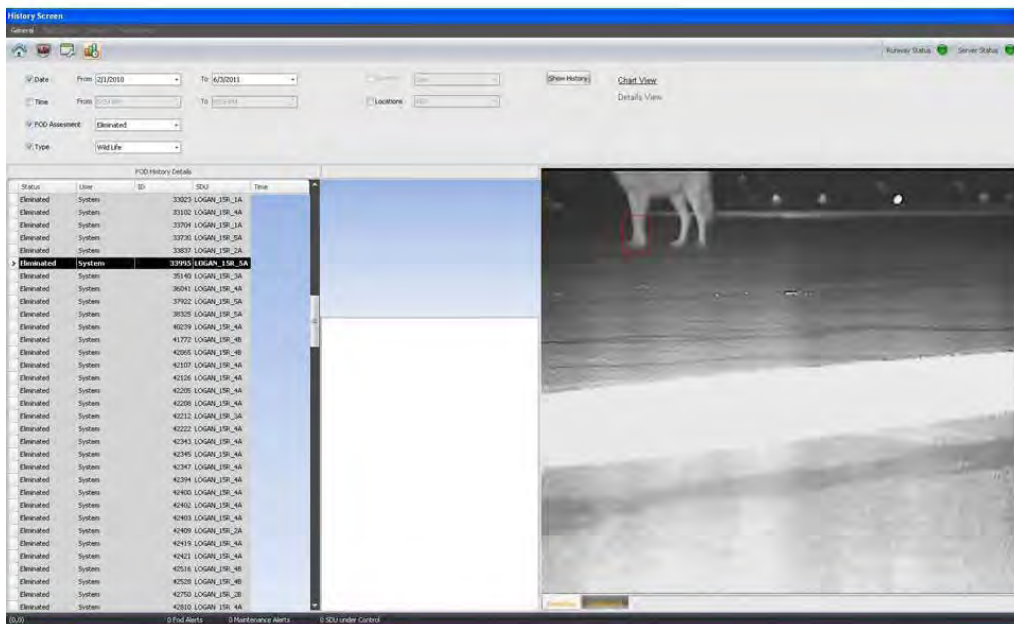Figure 12. A Screen Shot of a Typical GUI Screen Showing a Summary of the FOD Items Found

Figure 13. The FODetect Console Detection Screen (In this case, showing the detection of a coyote on the runway during nighttime.)

The data management capabilities in the FODetect system are provided in an FOD detection toolbox developed by Xsight. This data management supports Section 6 of the AC, which specifically addresses issues of data collection, data analysis, and support for an FOD reporting system.

A typical GUI screen capture from a generated report is provided in figures 13 through 15. These figures show a system summary on the left that includes alert status, user, alert ID, SDU reporting the FOD item and time. In the middle of the screen, specific information about the item detected is provided and, to the right, an image of the item producing the alert.

The FOD detection toolbox provides the user with multiple options to retrieve alert data from the FODetect system. These options are provided in drop-down menus; the following data can be obtained by searching by date, FOD item type, alert status, and location. In general, the type of data available includes:

- SDU detection of the FOD item, providing runway location

- Date and time of FOD detection, confirmation, and retrieval

- Current status of FOD alert (e.g., detected, confirmed, and retrieved)

- Description of FOD retrieved (category, size, and color)

- Location of FOD object

- An image of the FOD object detected, including still images or video depending on operator input

- Date and time of recovery team acknowledgement and alert clearance time (from hand-held device)

- Addition of images from other sources to the FODetect record

- Image retrieval and video playback and export of FOD event for post-analysis

- Graphical plots of FOD data

The FODetect system also allows the user to incorporate additional information about an FOD event, which then becomes part of the alert record. For example, figure 15 shows how a photograph taken by a field camera can be incorporated into the alert record.
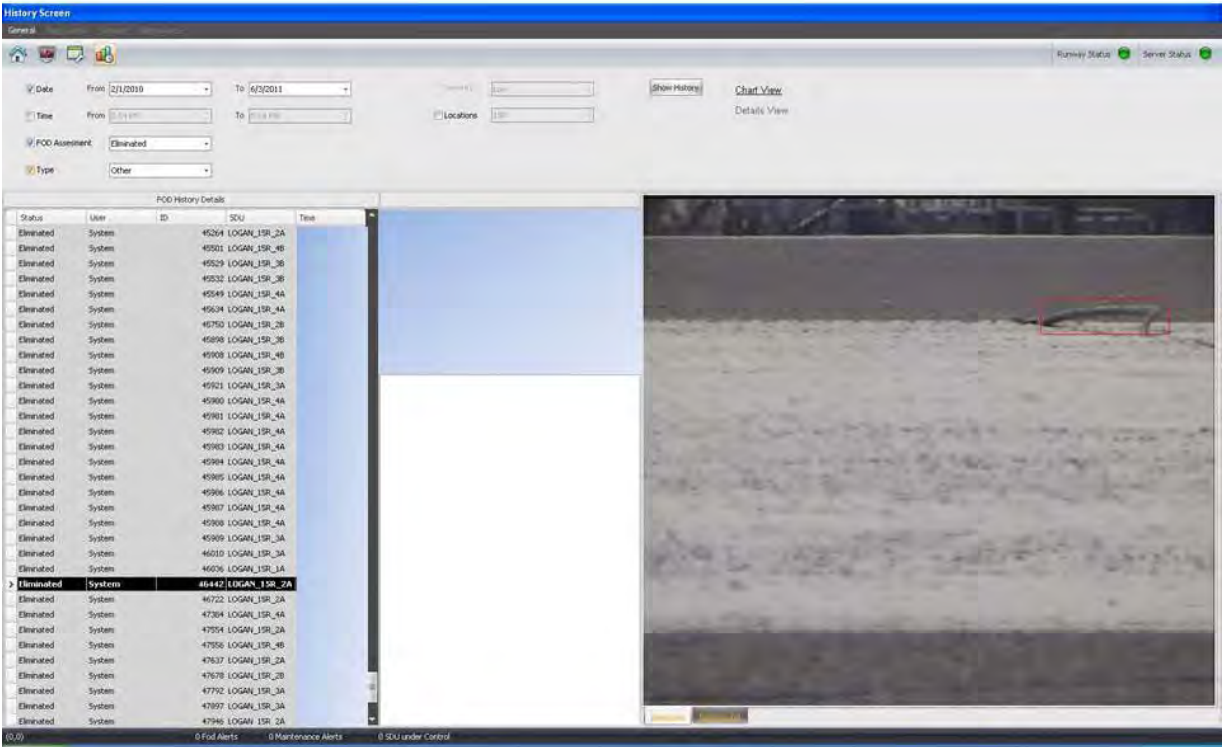
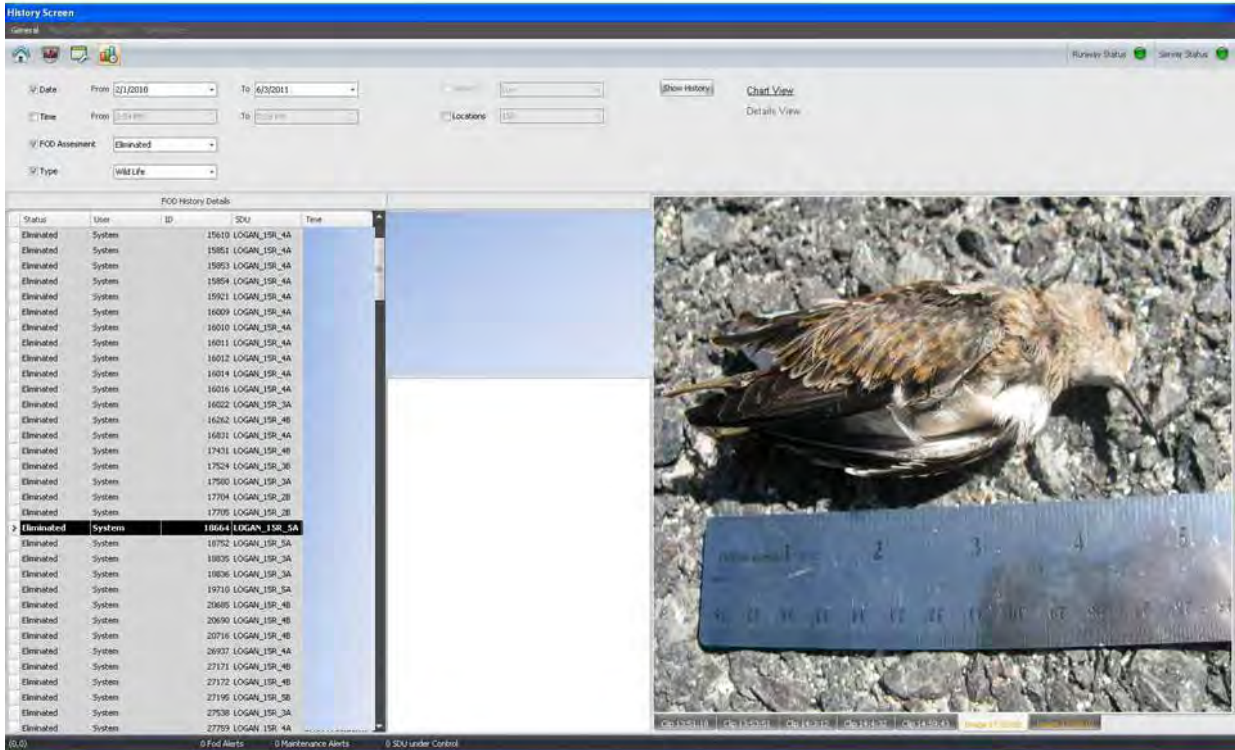Figure 14. Alert Record for Loose Expansion Joint Material on the Runway

Figure 15. A Hand-Held Camera Photograph Incorporated Into the Alert Record

10. CONCLUSIONS.

The FODetect®, a hybrid foreign object debris (FOD) detection system, was installed and operated at Boston Logan International Airport by XSight, Ltd. A performance assessment program consisting of an evaluation of the FODetect system in operational mode was conducted from June 2008 through July 2011. In this performance assessment, test campaigns were completed under different weather conditions. The FODetect system performed according to product specifications and met performance requirements identified in Advisory Circular 150/5220-24. System tests under different lighting and environmental conditions provide insight into sensor and system capability. The performance assessment also provided an opportunity to demonstrate the hybrid capability, i.e., merging input from radar and camera technologies. Additionally, FODetect data management supports Section 6 of AC 150/5210-24, specifically addressing issues of data collection and data analysis and providing support for an FOD reporting system.

11. REFERENCES.

1.   Federal Aviation Administration, "Airport Foreign Object Debris (FOD) Detection Equipment," Advisory Circular 150/5220-24.

2.   Federal Aviation Administration, "Airport Safety Self-Inspection," Advisory Circular 150/5200-18.

3.   Climatology of the United States No. 20 (CLIM20), Monthly Station Climate Summaries, National Climate Data Center.