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Office of Research and
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Washington, DC 20591

# Performance Assessment of a Radar-Based Foreign Object Debris Detection System

February 2011

Final Report



U.S. Department of Transportation
**Federal Aviation Administration**

## NOTICE



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16. Abstract

In 2004, the Federal Aviation Administration (FAA) Airport Technology Research and Development Team initiated a research program to conduct a performance assessment of the QinetiQ, Ltd. Tarsier Foreign Object Debris (FOD) detection radar system. The purpose of this assessment was to identify key operational characteristics and limitations of the system at an active air carrier airport, including the system's ability to detect objects of various shapes, sizes, and materials at all locations on the runway surface. The system's ability to detect FOD during both nighttime and daytime conditions, in periods of sun, rain, mist, fog, and in light and heavy snow was also assessed.

In January 2005, the FAA developed plans for a comprehensive performance assessment of the technology at the Providence T. F. Green International Airport. Installation of the Tarsier system was completed in April 2007. Extensive data collection campaigns were conducted from June 2007 to March 2008. At the conclusion of the data collection process, the FAA had sufficient data to conclude the performance assessment. The QinetiQ Ltd. Tarsier FOD detection radar system was found to detect the necessary objects of various shapes, sizes, and materials on the runway surface and was able to 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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|---|---|
| AC | Advisory Circular |
| AOA | Airport operations area |
| CEAT | Center of Excellence for Airport Technology |
| $dBm^2$ | Decibels below milliwatt squared |
| FAA | Federal Aviation Administration |
| FOD | Foreign Object Debris |
| GHz | Gigahertz |
| GUI | Graphical User Interface |
| Hz | Hertz |
| PVC | Polyvinyl chloride |
| PVD | Providence T. F. Green International Airport |
| RCS | Radar cross section |
| YVR | Vancouver International Airport |

# EXECUTIVE SUMMARY

In fiscal year 2004, the Federal Aviation Administration initiated a research program to conduct a performance assessment of a foreign object debris (FOD) detection radar, the QinetiQ, Ltd. Tarsier® T1100 FOD detection system. Following an initial technological review of a June 2004 demonstration at Vancouver International Airport, British Columbia, Canada, a preliminary demonstration of the system was completed at the John F. Kennedy International Airport in January 2005. As a result of the preliminary demonstrations, plans were developed for a comprehensive performance assessment of the technology.

In 2006, the Providence T. F. Green International Airport was selected as the site for the Tarsier system installation. Installation was completed in April 2007 and a performance assessment program was implemented in June 2007 with a testing schedule intended to evaluate detection performance under typical airport operational conditions and under different environmental conditions. As part of the Federal Aviation Administration Airport (FAA) Safety Technology Research and Development Program, research teams from the University of Illinois Center of Excellence for Airport Technology (CEAT) developed the performance assessment protocol and implemented testing procedures appropriate to the technology and the setting.

This report provides a review of the performance assessment of the Tarsier FOD detection system. Performance requirements are based on FAA Advisory Circular (AC) 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment," which details parameters for a FOD detection system's basic functions, detection performance, and system output. CEAT performance assessment emphasizes standard target testing. An assessment of operational issues was also performed.

The Tarsier performed according to QinetiQ product specifications and met performance requirements identified in AC 150/5220-24 for dry pavement and inclement weather conditions. For basic functions, the Tarsier FOD detection system

- provided surveillance in the airport operations area (AOA) as specified by the airport.
- detected and located single and multiple FOD items on the AOA.
- 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 Tarsier FOD detection system

- exceeded requirements for location accuracy.
- met requirements for inspection frequency.
- provided surveillance of an entire runway.
- met AC specifications for clear weather, dry pavement, conditions with a detection rate of a standard target of 98%.
- met QinetiQ specifications for inclement weather detection with a detection rate of 100% for the target specified by QinetiQ.
- met specifications for detection of 10 categories of items required in the AC with a detection rate of 100%.
- provided alerts of FOD presence on the runway and provided location information to facilitate removal.

For system output, CEAT testing revealed that the Tarsier FOD detection system

- provided a digital data record of operations that included an alert time and 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, which can meet the needs of multiple airports.

## 1. INTRODUCTION.

As part of the Federal Aviation Administration (FAA) Airport Safety Technology Research and Development Program, the University of Illinois Center of Excellence for Airport Technology (CEAT) has been supporting the FAA William J. Hughes Technical Center research and development activities for more than 10 years. In 2004, the FAA initiated a program to evaluate foreign object debris (FOD) detection systems used within airport operations areas (AOA). The initial system selected for assessment was a radar-based system developed by QinetiQ, Ltd., the Tarsier T1100 FOD detection radar. CEAT conducted a technology evaluation in June 2004 at Vancouver International Airport (YVR) and then completed a preliminary demonstration of the technology in January 2005 at John F. Kennedy International Airport. Following that demonstration, plans were developed for a comprehensive, long-term performance assessment of the technology. In 2006, the Providence T. F. Green International Airport (PVD) was selected as the site for the Tarsier system installation. Installation was completed in April 2007, and a performance assessment program was implemented to evaluate detection performance at an operational airport under different environmental conditions. Test campaigns were conducted from June 2007 through March 2008. In addition to field-based testing, an operational analysis was performed using reports and interviews with airport personnel from PVD and from YVR, where a Tarsier FOD detection system was installed in 2007.

## 2. OBJECTIVE.

The overall goal of the assessment was to determine the performance of the FOD detection system and to develop requirements and standards for FOD detection technologies. With publication of Advisory Circular (AC) 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment" [1], performance requirements were identified by the FAA. This report provides a review of the performance of the Tarsier FOD detection system considering CEAT assessment data 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. This AC established specifications, as shown in table 1, for a range of FOD detection technologies, including:

- the Tarsier® FOD detection system
- a hybrid radar/electro-optical system
- an intelligent vision-based system
- a mobile radar system

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

Table 1. AC 150/5220-24 Performance Requirements

| AC Category | AC Performance Requirement for FOD Detection Systems |
|---|---|
| Basic Functions | Equipment must perform the following functions:<br>1. Provide surveillance in the AOA as specified by the airport.<br>2. Detect and locate single and multiple FOD items on the AOA.<br>3. Provide an alert to the user when FOD has been detected.<br>4. Operate in conjunction with, and not interfere with, airport and aircraft communication, navigation, and surveillance systems.<br>5. Operate in conjunction with, and without interference from, normal airport and aircraft operations (e.g., aircraft and vehicle movements).<br>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):<br>1. An unpainted metal cylinder measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter<br>2. A white, grey, or black sphere measuring 1.7 in. (4.3 cm) in diameter (i.e., a standard size golf ball)<br>3. 90% of the following 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:<br>• a “chunk” of asphalt or concrete<br>• any portion of a runway light fixture (in-pavement or edge light)<br>• an adjustable crescent wrench up to 8 in. (20 cm) long<br>• a deep socket at least 2 in. (5 cm) in length<br>• a piece of rubber from an aircraft tire<br>• a distorted metal strip up to 8 in. (20 cm) in length<br>• a fuel cap (aircraft or automotive)<br>• a lug nut<br>• a hydraulic line (from aircraft or ground support equipment) up to 8 in. (20 cm) in length<br>• a white 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. |

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

| AC Category | AC Performance Requirement for FOD Detection Systems |
|---|---|
| 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.<br>Note: This standard is based on the average accuracy of hand-held GPS devices, which most airport operators use when retrieving detected FOD. Airport operators using nonvisual 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: 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.<br>For mobile detection systems: The system must provide a mobile operations 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. |
| Detection Performance: Detection Response Time | Systems must have the capability of providing rapid detection of a FOD occurrence in the area being scanned.<br>For continuously operating FOD detection systems designed to provide between-movement alerts: The system must provide inspection of runway surfaces between aircraft movements.<br>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. |
| 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.<br>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 less importance, with a decreasing level of priority from other paved movement areas down to nonpaved, nonmovement areas.<br>The manufacturer of a FOD detection system must notify the airport operator of any locations within the specified surveillance area where detection would not be possible. |

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

| AC Category | AC Performance Requirement for FOD Detection Systems |
|---|---|
| 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.<br>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.<br>2. Systems must have site-specific performance specifications that include:<br>• performance during clear weather conditions.<br>• performance during inclement weather conditions.<br>• 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.)<br>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 to determine if immediate object removal is necessary.<br>• 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:<br>- For systems with visual detection capabilities: one per day as averaged over any 90-day period.<br>- For systems without visual detection capabilities: three per day as averaged over any 90-day period.<br>Note: Small items may be moved by wildlife or blown away before airport operators have a chance to investigate FOD alerts. |

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

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

GPS = Global positioning system
PVC = Polyvinyl chloride

## 4. TARSIER SPECIFICATIONS.

The Tarsier FOD detection system is based on a radar sensor that is located on a tower. The primary sensor is a 94-gigahertz (GHz) coherent radar. This millimeter wavelength radar is capable of detecting small targets at long distances, with a claimed smallest detection of a 0.39-in. (10-mm) metal fitting in normal operation. The primary performance criterion is detection of a target with a reflectivity of -20 $dBm^2$ at a range of 0.62 mi (1 km) in dry weather conditions, and of 0 $dBm^2$ in adverse (rain and snow) weather conditions. The radar head is designed to sweep along the runway length. A single scan requires 70 to 90 seconds to complete.

## 5. TARSIER INSTALLATION AT PVD.

The installation of the Tarsier at PVD consisted of two radar sensors located on towers with a maximum height of 27 ft (9 m), which provided full coverage of Runway 5/23, figure 1. The

runway is 7166 ft (2184 m) long and 150 ft (46 m) wide. The runway surface is grooved asphalt with a slight crown. A northern sensor, figure 2, was placed north of the fire station on the east side of the runway, positioned at North (N) 41º 43' 09.6"/ West (W) 071º 26' 00.5" at an elevation of 49.4 ft. The southern sensor, figure 3, was placed north of taxiway "T" on the west side of the runway, positioned at N 41º 43' 33.4"/W 071º 25' 17.8" at an elevation of 47.9 ft.

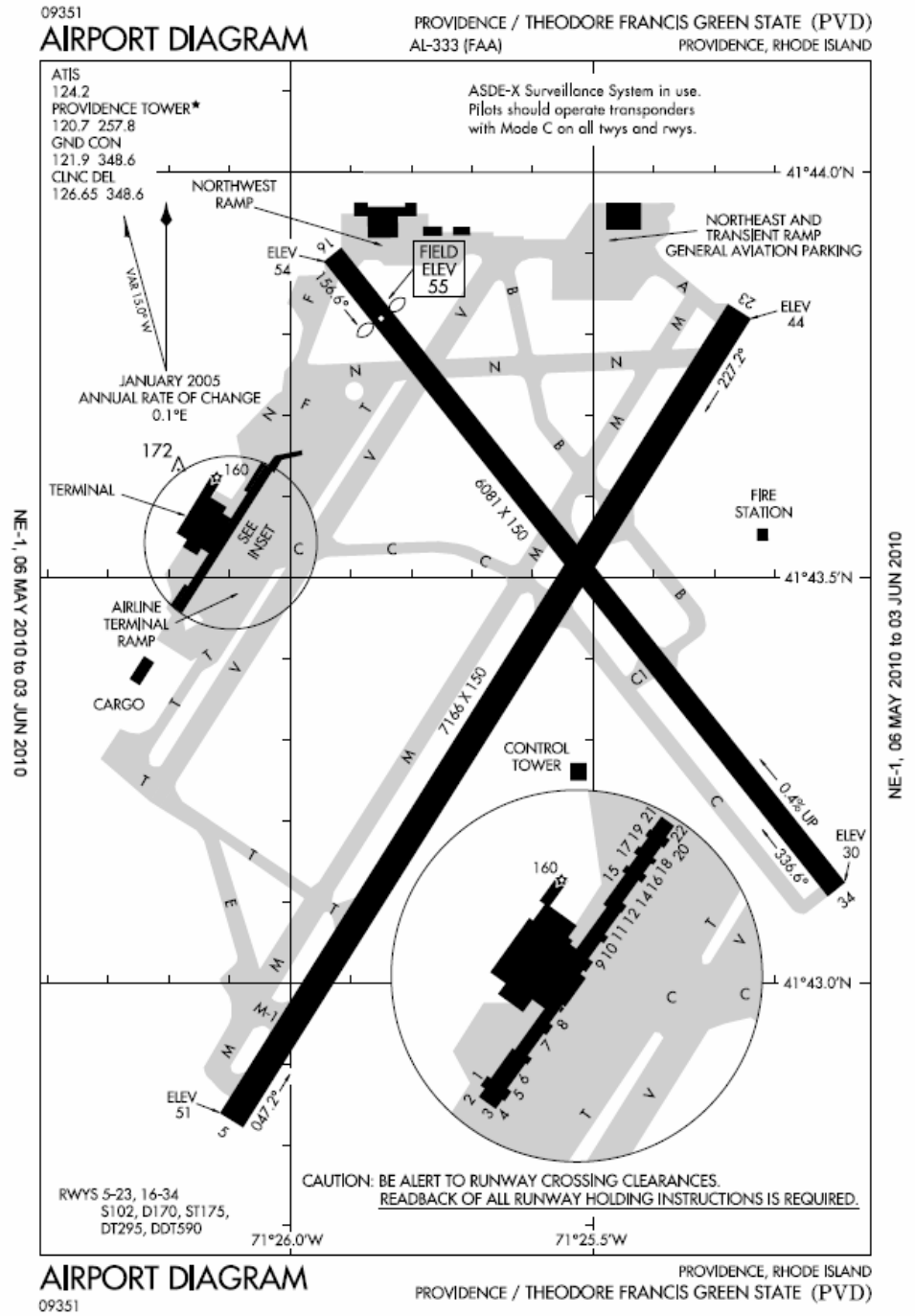



Figure 1. Airport Diagram of PVD


Figure 2. North Radar Tower at PVD


Figure 3. South Radar Tower at PVD

Field visits were made by CEAT to collect data on PVD. Data collection included a detailed survey of Runway 5/23 and nearby taxiways that noted the position of lighting fixtures and other features of the runway. Surveys were also made of potential positions for the radar towers.

QinetiQ completed the site-selection process using Tarsim, a proprietary radar coverage prediction software tool. The tool generated performance predictions based on required radar performance (i.e., signal strength versus range), using the known parameters of the Tarsier radar and a nominal target size. The tool considered the full three-dimensional geometry of the airport, including runway crown height, runway gradient, and radar tower height. From the measured data, the tool then predicted radar signal-to-clutter performance for small targets at small detection angles. A key requirement of the site design was to choose sites where the radar could be mounted high enough to scan over the runway crown to the far side of the runway, yet not interfere with safety zones defined for the airport. Positioning was also limited by line-of-sight obstructions. The output of the model is a prediction of detection performance over the entire runway surfaces and precise design information for the radar positions. QinetiQ used this data to position, and then design, radar towers. QinetiQ also developed commissioning and operational plans.

The plans produced by the modeling were used to complete an FAA 7460 application, which was submitted in June 2006. Construction began in November 2006. The base for each tower was a poured concrete pad. Soil borings provided data for foundation stability, and the pads were installed by PVD personnel. PVD met sensor power requirements by providing electrical and data service connections and supported connectivity to its operational center, where sensor control and alert functions were provided. The radar head required 110V 60 hertz (Hz) electrical power to a maximum of 4 Amps. The environmental control unit required 110V 60 Hz electrical power rated at a maximum of 40 Amps. The radar system became operational in March 2007 and was followed by QinetiQ commissioning tests.

## 6. TARSIER ASSESSMENT PROTOCOLS.

### 6.1 THE FOD ITEMS USED IN TESTING.

The standard FOD item used in the Tarsier FOD detection system performance assessment conformed to the specifications in AC 150/5220-24. The target was a metal cylinder, measuring 1.2 in. (3.1 cm) high and 1.5 in. (3.8 cm) in diameter, which was painted on each end with ultraviolet and fluorescent paint to enable after-dark visual detection by CEAT researchers. The target, shown in figure 4, provided a consistent reflectivity for radar detection (a nominal -20 decibel below milliwatt$^2$ (dBm$^2$) radar cross section (RCS)) and conformed to QinetiQ's specifications for a standard target. The target was used in all Tarsier performance assessments and was also used to determine system performance under inclement weather conditions.

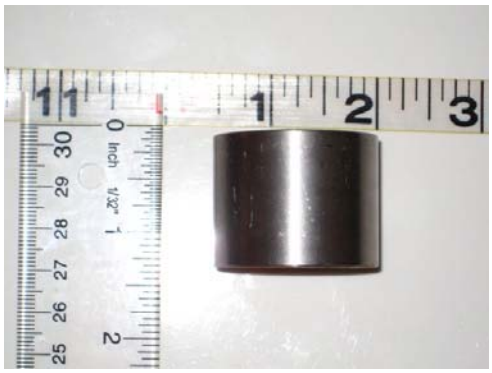


Figure 4. Primary Target Used to Assess the Tarsier FOD Detection System

6.2 RUNWAY TEST LOCATIONS.

Runway test procedure development at PVD was initiated with the identification of target placement locations. Target placement included consideration of radar coverage and overlap and range-to-targets based on expected system performance, figure 5. As shown in table 2, six target placement locations were identified:

- two at the runway ends approximately 16 ft (5 m) from the end light location
- four at approximately 1750 ft (530 m) intervals along the runway

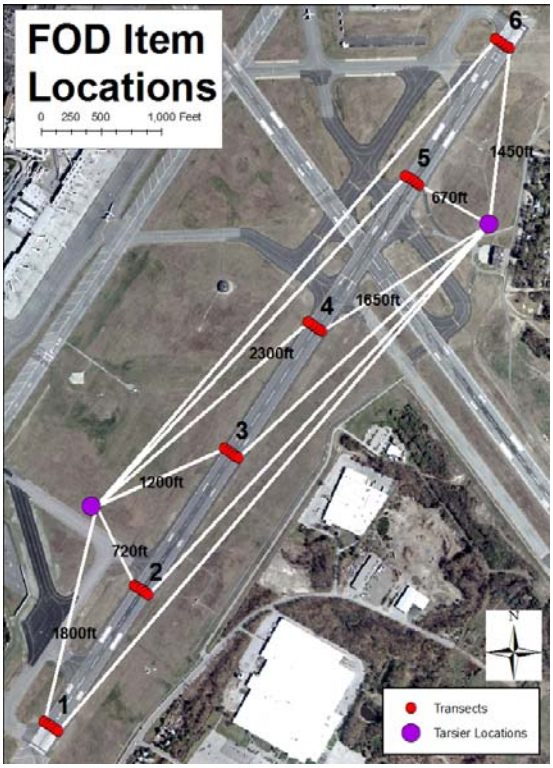



Figure 5. Target Locations Along the Length of Runway 5/23 (Distances rounded)

Table 2. Target Location Distance From Radar Sensors

| Transect | Distance From North Radar 1 ft (m) | Distance From South Radar 2 ft (m) |
|---|---|---|
| 1 | 5494 (1675) | 1821 (555) |
| 2 | 4160 (1268) | 723 (220) |
| 3 | 2834 (864) | 1168 (356) |
| 4 | 1647 (502) | 2322 (708) |
| 5 | 668 (204) | 3738 (1140) |
| 6 | 1454 (443) | 5075 (1547) |

The Tarsier radars have an instrumented range of 1.25 mi (2 km) but, by design, are always sited so that no FOD items can fall on a runway surface more that 0.6 mi (1 km), which is the operational range specified for each sensor. This provides a deliberate overlap, affording dual-sensor coverage for a typical runway. Performance assessment test locations were selected to fully test detection capabilities by placing them within and beyond the specified detection distances provided by QinetiQ. Data from locations 3, 4, and 5 were used in the performance analysis because these locations met range requirements for both radar sensors simultaneously. At more than 0.6 mi (1 km) from one or both sensors, locations 1, 2, and 6 did not meet simultaneous range requirements. These data were not used in the performance analysis but is reported for informational purposes.

## 6.3 PERFORMANCE ASSESSMENT METHODS.

Final assessment procedures were developed to accommodate the specific capabilities of the Tarsier.

### 6.3.1 Targets.

Targets conformed to AC 150/5220-24 specifications and were approved by QinetiQ as appropriate for the sensor technology. The performance assessment procedure developed by CEAT used the same target type for all assessments. When tests were conducted periodically over several months, a calibration/intercalibration result was achieved that provided assurance of the functioning of the system.

At each target location, a five-item transect across the runway was established for the tests. The distance between items in each transect was approximately 25 ft (7.5 m), allowing even placement of five targets between the runway edge lines.

For the inclement weather tests, larger targets meeting QinetiQ specifications were used. These targets provided a nominal -10-$dBm^2$ and a 0-$dBm^2$ RCS.

6.3.2 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 RX 1250 SmartRover and differential global positioning system 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 Tarsier for each target. Location accuracy was assessed in July 2007.

## 7. TARSIER PERFORMANCE ASSESSMENT RESULTS AND DISCUSSION.

### 7.1 STANDARD TARGET DETECTION.

Test results for the standard target under dry pavement conditions are presented for all test campaigns. Two tables are provided. Table 3 shows the results for locations 3, 4, and 5, which were located within approximately 0.6 mi (1 km) of the radar sensors. The results confirm sensor detection capabilities based on QinetiQ specifications and AC requirements. Table 4 provides the results for locations 1, 2, and 6, which were located beyond 0.6 mi (1 km) of a radar sensor. These results provided a sense of runway coverage achieved by the integrated system of two sensors for the entire length of the runway. The results were affected by a consistent failure of the system to detect one target in location 1. This was caused by a depressed area of runway surface, which meant that the "look down" angle from the south tower was insufficient to allow the radar to detect all items placed on the surface. This coverage limitation was identified by QinetiQ based on predictions of the Tarsier computer modeling tool during the initial design process. The solution to the problem would have been to use a higher (by approximately 3.2 ft (1 m)) tower. However, at the time of installation, the base elevation of the Tarsier radar towers was not structurally qualified above 23.6 ft (7.2 m). CEAT established a testing protocol that accepted this condition and reports full results that indicate a lower detection rate for targets in location 1 and a corresponding reduction in total target detections.

Table 3. Detection Results for Ranges Within Approximately 0.06 mi (1 km)

| Location | Number of Targets | Number of Detections | Percentage of Detections |
|---|---|---|---|
| 3 | 40 | 40 | 100 |
| 4 | 40 | 40 | 100 |
| 5 | 40 | 40 | 100 |
| Total | 120 | 120 | 100 |

Table 4. Detection Results for Ranges Beyond Approximately 0.06 mi (1 km)

| Location | Number of Targets | Number of Detections | Percentage of Detections |
|---|---|---|---|
| 1 | 40 | 33 | 83 |
| 2 | 40 | 40 | 100 |
| 6 | 40 | 39 | 98 |
| Total | 120 | 112 | 93 |

## 7.2 LOCATION ACCURACY.

The accuracy of reported locations for detected targets was determined for each Tarsier radar sensor, figure 6.

- From the north radar, the average difference was 3.3 ft (1 m); the maximum difference (location 6) was 7.0 ft (2.1 m); the minimum difference (location 4) was 0.4 ft (0.1 m).

- From the south radar, the average difference was 2.5 ft (0.7 m); the maximum difference (location 2) was 4.5 ft (1.3 m); the minimum difference (location 3) was 0.65 ft (0.2 m).

- The average difference between the surveyed point and the location provided by either of the radars was 3.0 ft (0.9 m).

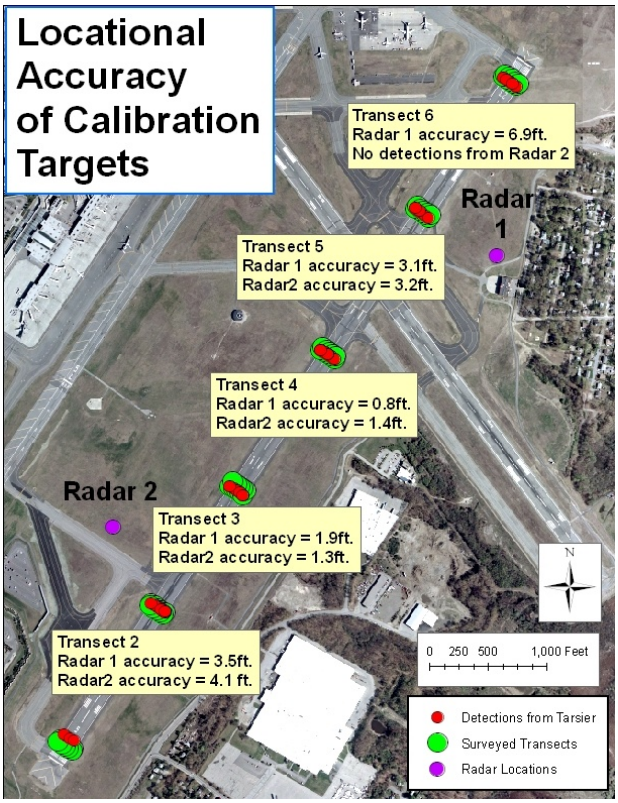


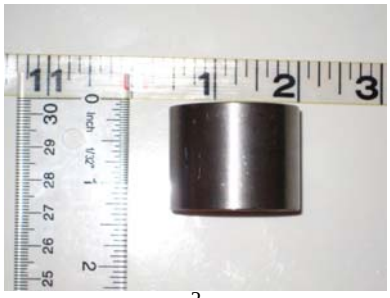

Figure 6. Accuracy of Reported Location for Standard Targets

## 7.3 DETECTION UNDER VARIABLE WEATHER CONDITIONS.

The performance assessment program was planned over approximately 1 year so that assessments could be made under different environmental and weather conditions. Test campaigns were scheduled based on the assumption that a range of weather conditions would occur during the assessment. Unfortunately, the selected dates provided little variability in weather conditions. For all but one scheduled test campaign, the pavements were dry and clear. The results from testing during the single rain storm event are provided.

Assessment schedules were then modified to provide testing during winter conditions to obtain test data related to snow events. A snow event is a challenge for a FOD detection system because snow and ice create natural FOD. Mechanical breakdowns or failure of snow removal equipment may also leave FOD. Winter operations at an airport are also a critical time for operations personnel because runways and other airport surfaces must be cleared rapidly and safe operational conditions assured. Because snow clearing and FOD testing on runways are incompatible, CEAT coordinated with PVD staff to conduct tests following snow events when runways were clear, but a potential existed for snow and ice contamination.

Standard targets with a nominal -20-dBm$^2$ RCS and targets with a nominal -10-dBm$^2$ and 0-dBm$^2$ RCS were used for testing under variable weather conditions. The larger targets were a cylinder measuring 2.5 in. (6.3 cm) high and 2.0 in. (5 cm) in diameter with a nominal -10-dBm$^2$ RCS and a cylinder measuring 4.5 in. (11.4 cm) high and 3.0 in. (7.6 cm) in diameter with a nominal 0-dBm$^2$ RCS. The targets are shown in figure 7.



-20-dBm$^2$ cylinder

-10-dBm$^2$ cylinder

0-dBm$^2$ cylinder

Figure 7. Calibration Items

7.3.1 Rain Event.

The October 2007 test campaign was initiated in a light drizzle at approximately 02:00. After deployment and detection of the calibration targets, a rain squall moved over the runway from south to north. With targets in place, it was possible to observe changes in detection during the storm event. In general, some detected targets were lost to the radar, and then detected again. Table 5 provides a summary of detections during the rain event showing that some targets were continuously detected. Figure 8 provides information on detection timing for location 4, providing information on the system's recovery time when a target is lost.

As shown in table 6, the 0-dBm$^2$ targets were detected during the rain event and variable detection was noted for standard targets. Standard targets were detected in the early part of the rain event. They were not detected during the peak of the event (approximately 02:37-02:42). However, detection was re-established after the rain squall had passed, approximately 8 minutes after the beginning of the rain squall.

Table 5. Detections at Locations 3 to 5 During October 2007 Rain Event

| | | Location Along Runway 5/23 | | |
|---|---|---|---|---|
| Transect | Target | 3 | 4 | 5 |
| B1 | 0-dB cylinder | D | D | D |
| B2 | -10-dB cylinder | D | D | |
| B3 | -20-dB plastic cylinder | | | |
| B4 | -10-dB cylinder | D | D | D |
| B5 | 0-dB cylinder | D | D | D |
| 1 | -20-dB cylinder | | D | |
| 2 | -20-dB cylinder | D | D | |
| 3 | -20-dB cylinder | | | |
| 4 | -20-dB cylinder | | | |

D = Detection

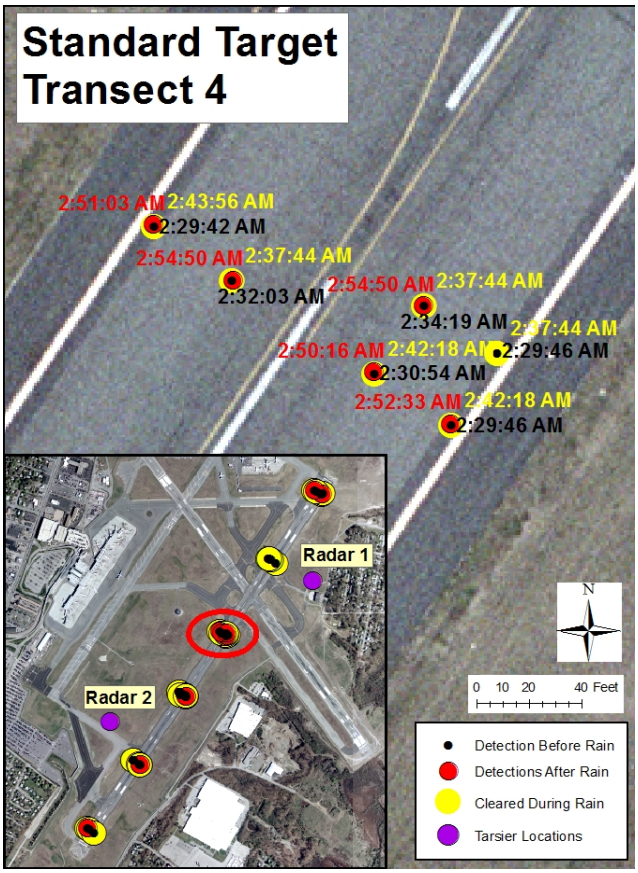



Figure 8. Detection Timing for a Single Location During October 2007 Rain Event

Table 6. Target Detection Sequence at Location 4 During October 2007 Rain Event

| | Last Time Target Detected | Time of System-Recorded Reset | Time Target Reacquired |
|---|---|---|---|
| 1 | 02:30 | 02:38 | Not detected |
| 2 | 02:34 | 02:38 | 02:55 |
| 3 | Not detected | Not detected | Not detected |
| 4 | Not detected | Not detected | Not detected |
| 5 | Not detected | Not detected | Not detected |
| B1 | 02:29 | 02:42 | 02:52 |
| B2 | 02:30 | 02:42 | 02:50 |
| B3 | No target | No target | No target |
| B4 | 02:32 | 02:37 | 02:54 |
| B5 | 02:29 | 02:43 | 02:51 |

Note: Reset occurred during the rain squall, and rain continued after the reset. Actual end of rain was not recorded, although time to reacquisition was estimated to be 10 minutes or less.

7.3.2 Winter Weather.

7.3.2.1 January 24-25, 2008.

Performance tests were conducted during three periods in early 2008 when snow was present on the airport. On January 24 and 25, 2008, a snow event was assessed. Snow flurries were observed in the afternoon of January 24, 2008, with some accumulation on the runway margins, but runway conditions remained clear and dry. Throughout the event, the 0-dBm$^2$ targets were detected. On January 24, 2008, 52 of the 60 targets were detected, producing a detection rate of 87%. Targets included -10-dBm$^2$ and 0-dBm$^2$ RCS cylinders. Table 7 shows the detected targets. On January 25, 2008, the more reflective targets were not used and only 30 -20-dBm$^2$ RCS targets were placed on the runway; 28 targets were detected for a detection rate of 93%, see table 8. If either or both radars detected an object, it was marked with a D.

Table 7. Tarsier System Detections of Cylinders on January 24, 2008

| | | Location Along Runway 5/23 | | | | | |
|---|---|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 | 5 | 6 |
| B1 | 0-dB cylinder | D | D | D | D | D | D |
| B2 | -10-dB cylinder | D | D | D | D | D | |
| B3 | -20-dB plastic cylinder | D | D | D | D | D | |
| B4 | -10-dB cylinder | D | D | D | D | D | D |
| B5 | 0-dB cylinder | D | D | D | D | D | D |
| 1 | -20-dB cylinder | D | D | D | D | D | |
| 2 | -20-dB cylinder | D | D | D | D | D | |
| 3 | -20-dB cylinder | D | D | D | D | D | |
| 4 | -20-dB cylinder | D | D | D | D | D | |

D = Detection

Table 8. Tarsier System Detections of Cylinders on January 25, 2008

| | | Location Along Runway 5/23 | | | | | |
|---|---|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | -20-dB cylinder | D | D | D | D | D | D |
| 2 | -20-dB cylinder | D | D | D | D | D | D |
| 3 | -20-dB cylinder | D | D | D | D | D | |
| 4 | -20-dB cylinder | D | D | D | D | D | D |
| 5 | -20-dB cylinder | | D | D | D | D | D |

D = Detection

7.3.2.2 February 12-13, 2008.

Another snow event was assessed on February 12 and 13, 2008. On February 12, 2008, at 19:05, it began to snow. Prior to the snow, there was rainfall. At 23:20, the snow became mixed with ice. On February 13, 2008, at 00:11, the snow and ice changed to freezing rain that lasted until approximately 04:00. Rain and mist continued all day on February 13, 2008. Access to the runway for testing was obtained on early February 13, 2008. Targets were placed on the runway at approximately 01:30, following snowplows that cleared the runway. Targets were only placed on locations 1-4. After the tests were initiated, airport staff requested a clear runway to spread deicing fluids, so the targets were retrieved in the order that they were placed. This allowed a minimum of 10 minutes for target detection. During the test, CEAT researchers observed the formation of an ice sheet across the runway. The detection results are provided in table 9. During this test, 100% of the 0-$Bm^2$ targets were detected and 19 of the 40 smaller targets were detected for a detection rate of 47.5%. If either or both radars detected an object, it was marked with a D.

Table 9. Tarsier Detections for Targets Placed on February 13, 2008, at 01:40

| | | Location Along Runway 5/23 | | | |
|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 |
| B1 | 0-dB cylinder | D | D | D | D |
| B2 | -10-dB cylinder | D | D | D | D |
| B3 | -20-dB plastic cylinder | | | | |
| B4 | -10-dB cylinder | | D | D | D |
| B5 | 0-dB cylinder | D | D | D | D |
| 1 | -20-dB cylinder | | | | |
| 2 | -20-dB cylinder | | | D | D |
| 3 | -20-dB cylinder | | | D | D |
| 4 | -20-dB cylinder | | | | |

D = Detection

Heavy rain was experienced throughout the day on February 13, 2008. Approximately 2 hours prior to the test initiation at 01:00 on February 14, 2008, rain began to decrease in intensity. During the test campaign, a light rain was observed. Therefore, this test campaign provided information on wet pavement detection. Again, 100% of the 0-$dBm^2$ targets were detected, with a 75% detection rate for the smaller targets. The detection results are shown in table 10.

Table 10. Tarsier Detections for Targets Used in Wet Pavement Testing on February 14, 2008

| | | Location Along Runway 5/23 | | | | | |
|---|---|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 | 5 | 6 |
| B2 | -10-dB cylinder | D | D | D | D | D | D |
| B3 | -20-dB plastic cylinder | | | | | | D |
| B4 | -10-dB cylinder | D | D | D | D | D | D |
| B5 | 0-dB cylinder | D | D | D | D | D | D |
| 1 | -20-dB cylinder | | D | D | D | D | D |
| 2 | -20-dB cylinder | | D | D | D | D | D |
| 3 | -20-dB cylinder | | D | D | D | D | D |
| 4 | -20-dB cylinder | | | D | | D | |
| 5 | -20 dB cylinder | | D | D | | D | |

D = Detection

7.3.2.3 February 22-25, 2008.

A performance assessment was conducted in association with a snow event that occurred February 22-25, 2008. Snow began to fall on February 22, 2008, and continued through the day. Tests were conducted between 23:00 on February 23, 2008, and 02:00 on February 24, 2008. Airport operations required that the airport be kept open, but PVD operations staff accommodated a limited test scheme. In this limited test scheme, targets were placed only on two locations and then retrieved after approximately 10 minutes. During the tests, ice was present on the edges of the runway. No precipitation fell during the evaluation period. Targets were first placed at locations 3 and 4 at approximately 00:30, then at locations 1 and 2, and finally at locations 5 and 6, with testing completed at approximately 01:30.

In this test, all the 0-dBm$^2$ targets and 59 of the 60 targets placed were detected for a total detection rate of 98%. Table 11 shows the cylinders that were detected. If either or both radars detected an object, it was marked with a D.

On the following day, February 25, 2008, targets were again deployed. No snow or other precipitation was observed during these tests, although some snow and ice were still present on the airport. In this test, 59 of the 60 targets were detected for a detection rate of 98%. Detection results are shown in table 12. If either or both radars detected an object, it was marked with a D.

Table 11. Tarsier System Detection Performance Following Snow Events

| | | Location Along Runway 5/23 | | | | | |
|---|---|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 | 5 | 6 |
| B2 | -10-dB cylinder | D | D | D | D | D | D |
| B3 | -20-dB plastic cylinder | D | D | D | D | D | D |
| B4 | -10-dB cylinder | D | D | D | D | D | D |
| B5 | 0-dB cylinder | D | D | D | D | D | D |
| 1 | -20-dB cylinder | D | D | D | D | D | D |
| 2 | -20-dB cylinder | D | D | D | D | D | D |
| 3 | -20-dB cylinder | D | D | D | D | D | D |
| 4 | -20-dB cylinder | D | D | D | D | D | D |
| 5 | -20-dB cylinder | | D | D | D | D | D |

D = Detection

Table 12. Tarsier System Detections of Cylinders on February 25, 2008

| | | Location Along Runway 5/23 | | | | | |
|---|---|---|---|---|---|---|---|
| Transect | Target | 1 | 2 | 3 | 4 | 5 | 6 |
| B2 | -10-dB cylinder | D | D | D | D | D | D |
| B3 | -20-dB plastic cylinder | D | D | D | D | D | D |
| B4 | -10-dB cylinder | D | D | D | D | D | D |
| B5 | 0-dB cylinder | D | D | D | D | D | D |
| 1 | -20-dB cylinder | D | D | D | D | D | D |
| 2 | -20-dB cylinder | D | D | D | D | D | D |
| 3 | -20-dB cylinder | D | D | D | D | D | D |
| 4 | -20-dB cylinder | D | D | D | D | D | D |
| 5 | -20-dB cylinder | | D | D | D | D | D |

D = Detection

## 8. TARSIER DETECTION OF STANDARD FOD ITEMS AS REQUIRED BY AC 150/5220-24.

The specifications/criteria provided in AC 150/5220-24 include the requirement that the FOD detection system manufacturer demonstrate detection performance with targets that simulate actual FOD items. As specified in the AC, the FOD detection system should detect 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 (Note: 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) in length
- 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
- a 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 2 in. (5 cm) in diameter
- any two of the objects above, located no more than 10 ft (3 m) apart from each other, identified as separate objects

QinetiQ selected a group of targets that were then presented to CEAT, as shown in figure 9. CEAT observed the placement of 10 items, one from each category listed in the AC, in a rectangle approximately 100 by 100 ft (30 by 30 m). In the observed test, the Tarsier FOD detection system detected 100% of the FOD items. CEAT also observed tests in which FOD items were placed no more than 10 ft (3 m) from each other and confirmed that these items were detected.

Figure 9. Items Selected by QinetiQ to Meet AC Detection Requirements

## 9. TARSIER ASSESSMENT BASED ON AC 150/5220-24 SPECIFICATIONS.

CEAT performance assessment of the Tarsier FOD detection radar installation at PVD is based on specifications/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 13 summarizes the Tarsier performance as it relates to AC 150/5220-24. Sections 9.1 through 9.3 provide a narrative analysis of the Tarsier's conformance to the AC performance specifications.

Table 13. Summary of Tarsier 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. |
| 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, and not interfere with, airport and aircraft communication, navigation, and surveillance systems. | In operation from March 2007 to March 2008; 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 March 2007 to March 2008; no interference reported. |
| 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). | Consistently detected these items when placed with standard targets. |
| 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:<br>• a “chunk” of asphalt or concrete<br>• any portion of a runway light fixture (in-pavement or edge light)<br>• an adjustable crescent wrench up to 8 in. (20 cm) long<br>• a deep socket at least 2 in. (5 cm) in length<br>• a piece of rubber from an aircraft tire<br>• a distorted metal strip up to 8 in. (20 cm) in length | When targets from each category were placed in a rectangle that was located a minimum of 1000 ft (300 m) from the sensor, the Tarsier FOD Detection System detected 100% of the targets. |

Table 13. Summary of Tarsier Performance Related to AC 150/5220-24 Specifications (Continued)

| AC Category and Performance Requirement | CEAT Findings |
|---|---|
| Detection Performance: Object Detection (Continued) | |
| • a fuel cap (aircraft or automotive)<br>• a lug nut<br>• a hydraulic line (from aircraft or ground support equipment) up to 8 in. (20 cm) in length<br>• a white PVC pipe 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. | Met 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 3 ft with a maximum difference of approximately 7 ft. Exceeded AC requirement. |
| 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.<br>Mobile Detection Systems. The system must provide a mobile operation's 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 specification. |
| 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.<br>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 approximately 1 minute met AC requirement for typical PVD movement activity.<br>Met AC requirement for 4-minute updates. |

Table 13. Summary of Tarsier 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. | Manufacturer provided runway coverage, meeting AC requirement. |
| The manufacturer of a FOD detection system must notify the airport operator of any locations within the specified surveillance area where detection would not be possible. | Manufacturer identified a location with limited detection. |
| 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. More stringent requirements may be specified by the user. | Testing conducted under rainfall and snowfall conditions, but testing did not produce results for specific frequency events. Detection rate of 100% for the 0-$dBm^2$ target specified by QinetiQ. |
| 2. Systems must have site-specific performance specifications that include: | |
| • performance during clear weather conditions | • Met requirements for clear weather conditions |
| • performance during inclement weather conditions | • tests were conducted during a rain event that produced detection degradation and recovery |
| • 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 minutes of target loss during event passage |
| 3. All systems must demonstrate detection performance during daylight, nighttime, and dawn/dusk operations. | System was tested after snowfall and runway clearance; the system performed during snowfall conditions.<br>System performed under all lighting conditions. |

Table 13. Summary of Tarsier 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:<br>• For systems with visual detection capabilities: one per day as averaged over any 90-day period.<br>• For systems without visual detection capabilities: three per day as averaged over any 90-day period.<br>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.<br>Assessment did not incorporate operational analysis to determine conformance to this specification.<br>For a 60-day period, 26 false alarms were recorded and 2 occurred on the same day, meeting AC requirements. |
| System Output: Data Detection | |
| 1. Records must contain:<br>• Alert time and date<br>• Location of FOD object<br>2. Capturing the following information is recommended, but not required:<br>• Description of FOD detected or retrieved (e.g., size, name, type, serial number)<br>• Time and date of FOD retrieval<br>• Time and date of disposition of alert<br>• Name of personnel detecting/investigating FOD item<br>• Image of the FOD object retrieved (if available)<br>• Chain of custody information | Met AC specification. |
| 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. |

9.1 BASIC FUNCTIONS.

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

The Tarsier was installed at PVD and provided continuous surveillance of Runway 5/23. This surveillance met the requirements of the airport for this technology demonstration.

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

The Tarsier 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.

9.1.3 Provide an Alert to the User When FOD Has Been Detected.

The Tarsier provided visual and audible alerts of FOD detected at the central console. The system also provided alerts on a remote system that used wireless connectivity to a hand-held unit.

9.1.4 Operate in Conjunction With, and not Interfere With, Airport and Aircraft Communication, Navigation, and Surveillance Systems.

Operation of the Tarsier occurred with no interference to aircraft communication, navigation, or surveillance technologies. Through the normal FAA 7460 application process, radio frequency issues were reviewed and installation and operation of the Tarsier followed normal approval processes of the FAA and the Federal Communications Commission.

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

The Tarsier was operated during the performance assessment without 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.

9.1.6 Provide a Data Record of Detected FOD, Allowing for Equipment Calibration and Maintenance, and for Analysis of the FOD Event.

The Tarsier provided a digital record of calibration, any maintenance activity, and all FOD alerts associated with detections on Runway 5/23.

9.2 DETECTION PERFORMANCE.

9.2.1 Object Detection.

The Tarsier was 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 $dBm^2$.

A test conducted by QinetiQ was observed by CEAT. The test placed items from the ten categories of FOD listed in the AC in a test rectangle located a minimum of 1000 ft (300 m) from the radar sensor. All the items were detected by the Tarsier FOD Detection System using normal operational modes of the system. CEAT also observed tests that detected FOD items less than 10 ft (3 m) from each other.

9.2.2 Location Accuracy.

The Tarsier provided location information that, when compared to surveyed position, resulted in an average difference between the surveyed point and the location provided by the system that exceeded AC 150/5220-24 requirements. The average difference between surveyed and reported position was 3.0 ft (0.9 m), which exceeded the AC 150/5220-24 requirement that the detected object be within 16 ft (5.0 m) of the actual FOD object location.

9.2.3 Inspection Frequency.

The Tarsier installed at PVD provided continuous detection of the target runway for the period defined by the performance assessment (June 2007 to March 2008), which met AC 150/5220-24 specifications for continuous operation and continuous inspection of runway surfaces during flight operations.

9.2.4 Detection Response Time.

During the performance assessments, detection of FOD items was generally completed within a scan time of less than 1 minute and a confirmed detection time of less than 4 minutes.

9.2.5 Surveillance Area.

The Tarsier provided coverage of Runway 5/23 at PVD, providing surveillance of the entire runway.

9.2.6 Performance in Weather.

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

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

The Tarsier operated during inclement weather, and detections were verified during rainfall, sleet, and snow conditions. In all tests, the QinetiQ specifications for inclement weather were met 100% of the time. The system was assessed during a rainfall event where heavy rain limited detection. In this event, system detection was lost for 2 to 3 minutes with partial detection capability restored in 2 to 4 minutes with full recovery of detection capability in 9 minutes.

The Tarsier was tested exclusively at night when Runway 5/23 was available, so no assessment under different lighting conditions was completed for this technology. Analysis of operational data indicated that there was no influence of lighting on sensor performance.

9.2.7 Alerts and Alarms.

The Tarsier provided alerts of FOD presence on the runway and provided location information to facilitate removal. The system installed at PVD did not include a visual analysis capability, so each alert required airport personnel to inspect the location to identify FOD characteristics. In this operational mode, all FOD items were removed independent of severity of hazard.

The CEAT performance assessment program was designed to place known objects on airport surfaces and determine detection performance. No false alarm data was developed in this assessment. An assessment of false alarms must await reporting from operational installations of this technology.

9.3 SYSTEM OUTPUT.

9.3.1 Detection Data.

The Tarsier provided a digital data record of operations that included an alert time and date and the location of the FOD object. Recordkeeping by PVD operations personnel provided additional information on FOD type, retrieval information, and personnel completing the report.

9.3.2 Data Presentation.

The Tarsier provided digital data that could be presented in a number of formats. The basic graphical user interface (GUI) provided an aerial photograph of the airport and 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 the FOD location.

9.3.3 Data Management.

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

10. OPERATIONAL ANALYSIS.

Over the course of the tests, the operations personnel used the Tarsier system to identify FOD on the runways. Occasionally, the staff checked the computer for alarms and investigated possible FOD. Table 14 lists FOD investigations based on the Tarsier system at PVD from June through August 2007. Many small items were found. Occasionally, alarms occurred, and no item was found. This record indicates that 8 of 26 alarms resulted in no FOD being found. One possible explanation for these false alarms is that CEAT researchers observed that windblown vegetation could cause an alert; these items could blow away by the time the staff arrived to search for the item producing the alert. Another possible explanation is that an item was so small that it was difficult or impossible for personnel to find. AC 150/5220-24 requires location within 30 ft

(10 m) for an item 2 by 2 by 2 in.; successfully searching an area of this size can be very difficult, especially if the color of the item blends with the color of the runway. Note that the biologic targets, such as birds or a turtle shell, were often found. The system also alerted personnel to grass beginning to grow between runway tracks.

Table 14. Record of Tarsier Usage at PVD From June 2007 to August 2007

| Date | Time | Weather Conditions | FOD Found | Description of FOD Found |
|---|---|---|---|---|
| 6/5/2007 | 11:10 | Hazy/Clear | No | Nothing found |
| 6/7/2007 | 11:16 | Hazy/Clear | No | Old core hole |
| 6/9/2007 | 15:00 | Overcast | n/a | Large dead turtle northwest of runway 16 |
| 6/15/2007 | 17:42 | Dry/Sunny | No | Nothing found |
| 6/15/2007 | 18:42 | Dry/Sunny | No | Nothing found |
| 6/15/2007 | 14:27 | Dry/Sunny | Yes | Osprey eating a fish—driven off |
| 6/17/2007 | 02:07 | Scattered Showers | Yes | Threshold light lens cover |
| 6/17/2007 | 02:10 | Scattered Showers | Yes | Edge light cover |
| 6/18/2007 | 10:25 | Dry/Sunny | No | Alarm cleared, nothing found |
| 6/26/2007 | 07:27 | Haze | No | Nothing found |
| 7/2/2007 | 07:15 | Clear | Yes | Screen fastener in shoulder |
| 7/6/2007 | 21:30 | Clear | No | Nothing found |
| 7/9/2007 | 12:20 | Clear | Yes | Washer, pebble |
| 7/20/2007 | 15:15 | Clear | No | Nothing found |
| 7/31/2007 | 05:02 | Not Noted | Yes | Large piece of cracked seal, dove resting on pavement |
| 7/31/2007 | 08:20 | Not Noted | Yes | Large piece of cracked seal |
| 8/1/2007 | 06:28-06:44 | Not Noted | n/a | Grass in pavement cracks |
| 8/1/2007 | 17:20 | Clear | No | Nothing found |
| 8/2/2007 | 16:25 | Clear | Yes | Small piece of rubber |
| 8/4/2007 | 23:25 | Partly Cloudy | Yes | 12- by 8-in. aircraft panel from B-737 engine |
| 8/6/2007 | 19:40 | Overcast | Yes | Weed in crack |
| 8/7/2007 | 03:42 | Not Noted | Yes | Screw, metal clip, crackfill |
| 8/7/2007 | 08:29 | Fog | Yes | Small stone |
| 8/7/2007 | 10:00 | Overcast | No | Nothing found |
| 8/9/2007 | 00:49 | Clear | Yes | Live dove sleeping—flew away |
| 8/9/2007 | 02:28 | Clear | Yes | Dead dragon fly |
| 8/11/2007 | 23:50 | Clear | Yes | Pigeon |

In October 2010, QinetiQ reported that the Tarsier FOD Detection System had been installed at multiple airports. These installations included Vancouver International Airport (operational status 1/07), London Heathrow International Airport (operational status South Runway 1/2008; North Runway 1/2009), Dubai International Airport (operational status 9/2008), Doha International Airport (operational status 1/2009), and RAF Boscombe Down (operational status 3/2008). Personnel from Vancouver International Airport have regularly reported on Tarsier performance at professional meetings, but no comprehensive reporting has been released to date.

QinetiQ has developed an advanced GUI, which is a FOD data "toolbox" application that integrates FOD detection information and camera images. This toolbox addresses issues in Section 6 of AC 150-5210-24 related to data collection and analysis and provides the foundation for a FOD reporting system. For example, the toolbox provides access to FOD information on date and time of detection and retrieval, an image of the FOD item and its location, the prevailing weather, and personnel information. Figures 10 through 14 show examples of the QuintiQ toolbox components.

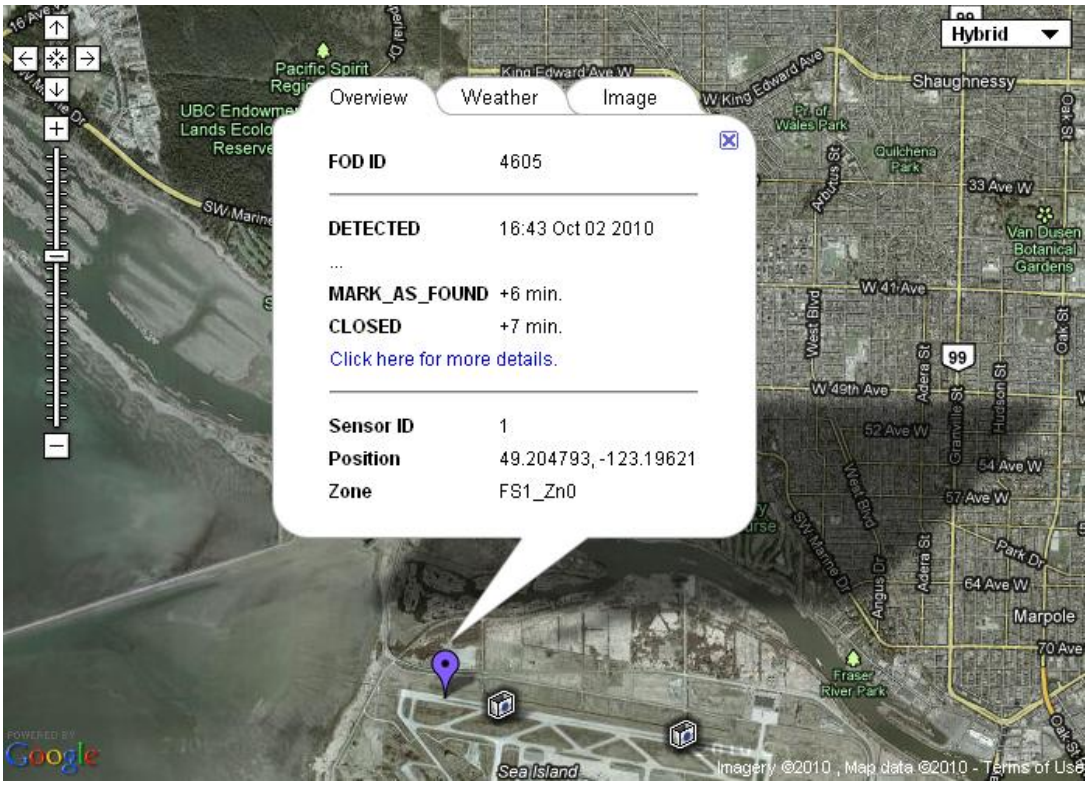



Figure 10. An Example of the QinetiQ FOD Toolbox Page Providing an Overview of the Detection

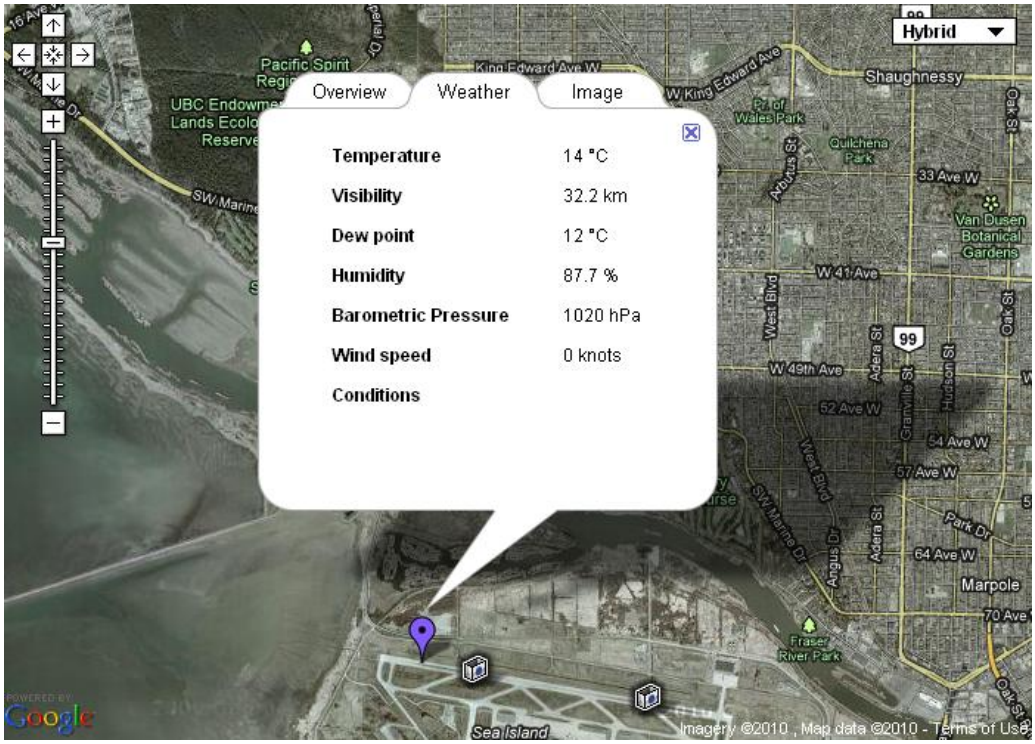



Figure 11. An Example of the QinetiQ FOD Toolbox Page Providing Weather Information at the Time of FOD Item Detection/Retrieval

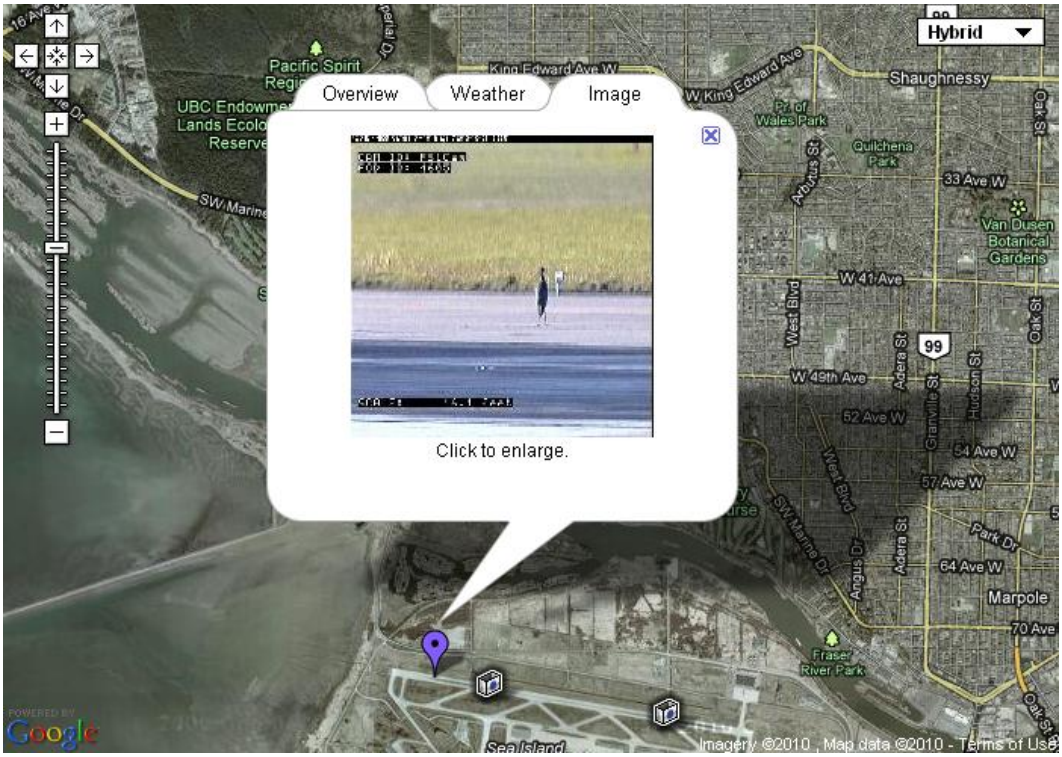



Figure 12. An Example of the QinetiQ FOD Toolbox Page Showing a FOD Image (i.e., a bird)

FOD Life Cycle for ID 120895

| Event Type | Time | Initiator | Username | Radar ID | Radar Count | Latitude | Longitude | Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|
| DETECTED | 07:46 Oct 05 2010 | System | _ | 4 | 1 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |
| ACKNOWLEDGED | 07:46 Oct 05 2010 | User | Admin | 4 | 1 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |
| RE-ALARMED | 07:56 Oct 05 2010 | System | _ | 4 | 1 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |
| ACKNOWLEDGED | 07:57 Oct 05 2010 | User | Admin | 4 | 1 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |
| NO_LONGER_DETECTED | 07:57 Oct 05 2010 | System | _ | 4 | 0 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |
| MARK_AS_FOUND | 07:58 Oct 05 2010 | User | Admin | 4 | 0 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | pied wagtail sitting on lamp seagull team detailed |
| CLOSED | 07:58 Oct 05 2010 | User | Admin | 4 | 0 | 51.464855155934 | -0.481138180597937 | SOUTH_WEST_1 | _ |


Figure 13. An Example of the QinetiQ FOD Toolbox Report Elements Providing Reporting Data Table, FOD Item Picture, and Location of FOD

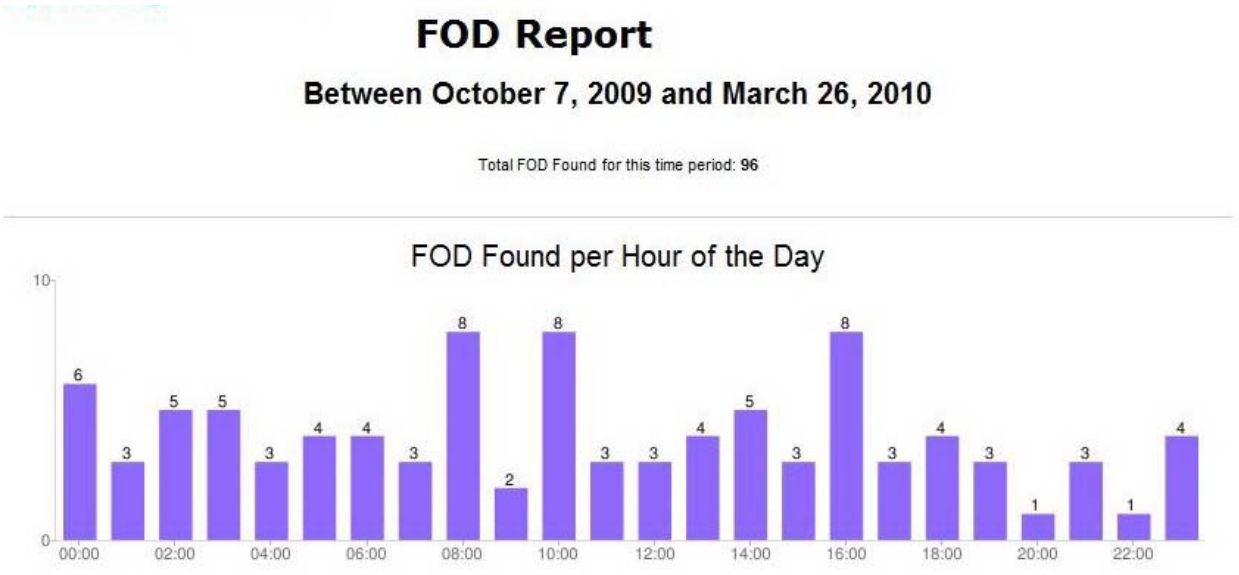



Figure 14. An Example of the QinetiQ FOD Toolbox Report Providing a Chart of FOD Items Found per Hour

## 11. CONCLUSIONS.

The Tarsier® Foreign Object Debris (FOD) Detection System was installed at Providence T. F. Green International Airport by QinetiQ, Ltd. A performance assessment program consisting of calibration/intercalibration tests, performance tests, blind tests, and an operational evaluation was initiated in June 2007 and completed in March 2008. In this performance assessment, test campaigns were completed under different weather conditions. The Tarsier performed according to QinetiQ product specifications and met performance requirements identified in Advisory Circular (AC) 150/5220-24, "Airport Foreign Debris (FOD) Detection Equipment." Additionally, the QinetiQ FOD Toolbox addresses issues in Section 6 of the AC related to data collection and analysis and provides the foundation for a FOD reporting system.

## 12. REFERENCES.

1. AC 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment," September 30, 2009.

2. AC 150/5200-18, "Airport Safety Self-Inspection," April 23, 2004.

3. National Climatic Data Center, "Climatology of the United States No. 20 (CLIM20)," U.S. Department of Commerce, 1971-2000. http://www.ncdc.noaa.gov/oa/documentlibrary/pdf/eis/clim20eis.pdf