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# Long Term FOD Detection from a Continuous Runway Scanning Technology

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Since 2004, a performance assessment of FOD detection technologies has been part of the FAA Airport Safety Technology R&D Program at the William Hughes Technical Center, Atlantic City, NJ.

The University of Illinois Center of Excellence for Airport Technology (CEAT) has been the performing partner in these performance assessments, conducting field testing and supporting the development of standards and requirements for Advisory Circulars working under a cooperative agreement with the FAA.

# The FAA/CEAT Program

- The FAA/CEAT performance assessment program was developed to test new FOD detection technologies using a science-based assessment approach.
- Assessments were completed for continuously scanning technologies using radar, electro-optical, and hybrid radar/electro-optical scanners, and a mobile radar technology.
- Advisory Circular 150/5220-24, "Airport Foreign Object Debris (FOD) Detection Equipment" was published 9/30/2009.

# The FAA/CEAT Program

- Reports on the FOD detection technology performance assessments are available\*:

DOT/FAA/AR-10/33 "Performance Assessment of a Radar-Based Foreign Object Debris Detection System" February 2011

Reports on Electro-Optical and Mobile Technologies are in the final stages of publication; the report on hybrid technologies is with editors.

\* Available at:

<http://www.airporttech.tc.faa.gov/safety/downloads/>

# Continuous FOD Surveillance

Continuous FOD detection systems have been installed at several airports. In 2009 the Changi Airport Group (CAG) requested the assistance of CEAT in commissioning tests of the iFerret FOD Detection System at Singapore's Changi International Airport (SIN).

This established a working relationship between the CAG and CEAT.

In early 2011 CEAT approached the CAG requesting access to FOD surveillance data collected during normal operations of the continuous FOD detection system.

Continuous FOD surveillance has added a new dimension to FOD management.

Possibly the most important benefit is that continuous operations provide information on what, where and how much, FOD is present on airports - when!

Continuous FOD surveillance is a game changer for airport management in many ways!

# The CEAT FOD Characterization Program

CEAT has developed a research program to better understand, and characterize FOD at commercial airports. This research will compile information on FOD occurrence, type, and location from many airport partners.

The detailed operational records of the iFerret FOD Detection System at SIN provided an excellent resource for the characterization of FOD on runways over a long time period.

# History of Continuous Detection at SIN

- In 2006, Changi Airport partnered a Singapore technology firm, Stratech Systems Ltd, to develop and test a prototype computer vision-based runway foreign object detection system that provides around the clock runway surface surveillance – the iFerret system.
- With innovation funding from the Singapore government, a proof-of-concept was successfully completed in 2007
- Stratech Systems Ltd was selected to install iFerret systems for both runways at Changi Airport in 2008
- The installation met commissioning requirements and began operation in 2009, and after a period of live trials and refinements has been used operationally at SIN.

# CAG Design Requirements for the continuous FOD detection system at SIN

Provide:

- A non-intrusive detection technology
- 24x7 all-weather continuous surveillance
- Detection of all foreign object material types down to ~4cm object size reliably with short scanning cycle time
- Provide accurate location information for the FOD objects detected
- Users with a full visual assessment of the FOD objects
- Continuing operating under changing background and environmental conditions to minimize false alarms
- A cost-effective and friendly to maintain and operate system

# Installation at Changi Airport

Runway 2

Runway 1

02C

02L

20C

20R

Node 24

Node 12

Node 13

Node 1

BUDGET  
TERMINAL

TERMINAL 2

CONTRO  
L  
TOWER

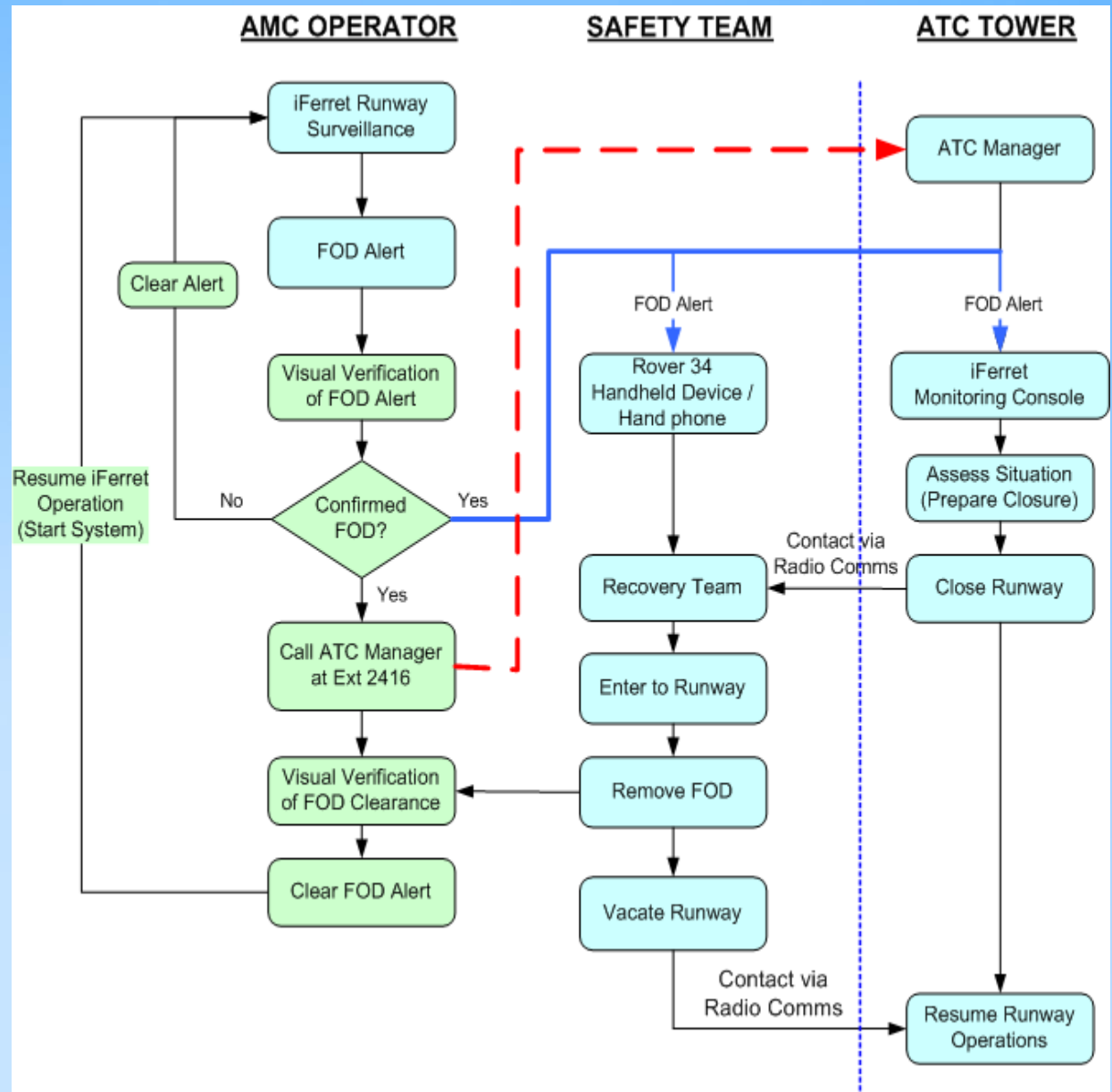
TERMINAL 3

TERMINAL 1



# Process Flow for System Operation

Consoles are located in the control tower and there is coordination among the operations center, ATC services, and field personnel.



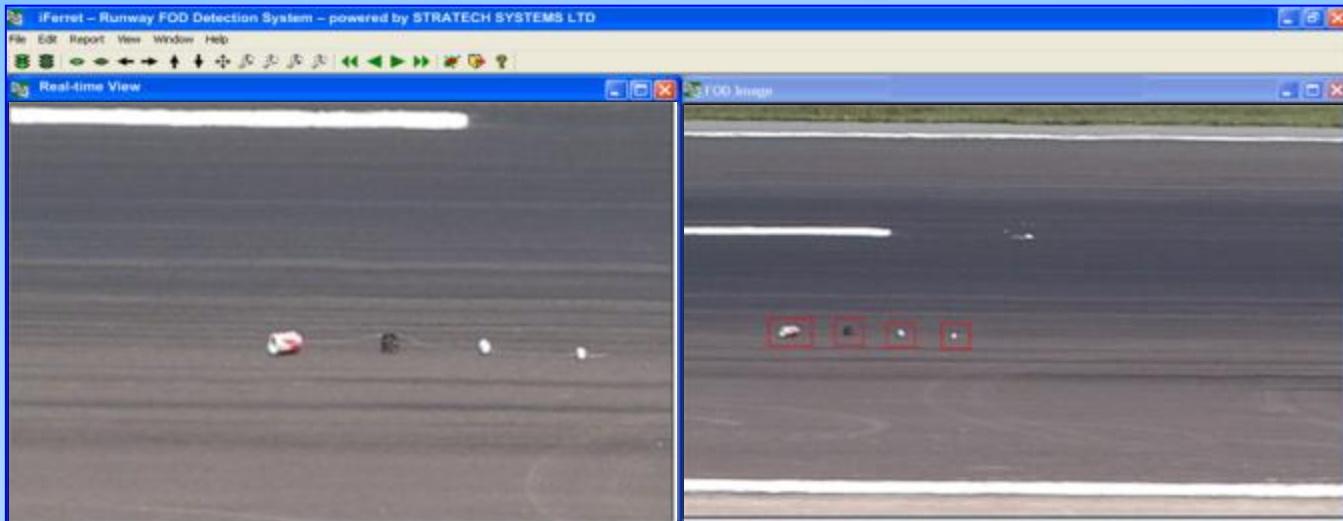
# Alert Characteristics

1. Upon detection of an item that is stationary for a minimum of 30 sec. the system provides a visual and audible alert via a console in the control tower (#3).
2. The tower operator has information on a screen that provides location, and an image of the FOD detected.

# Alert Characteristics – Operator Interface

1 →

Real time  
Zoom-in  
View

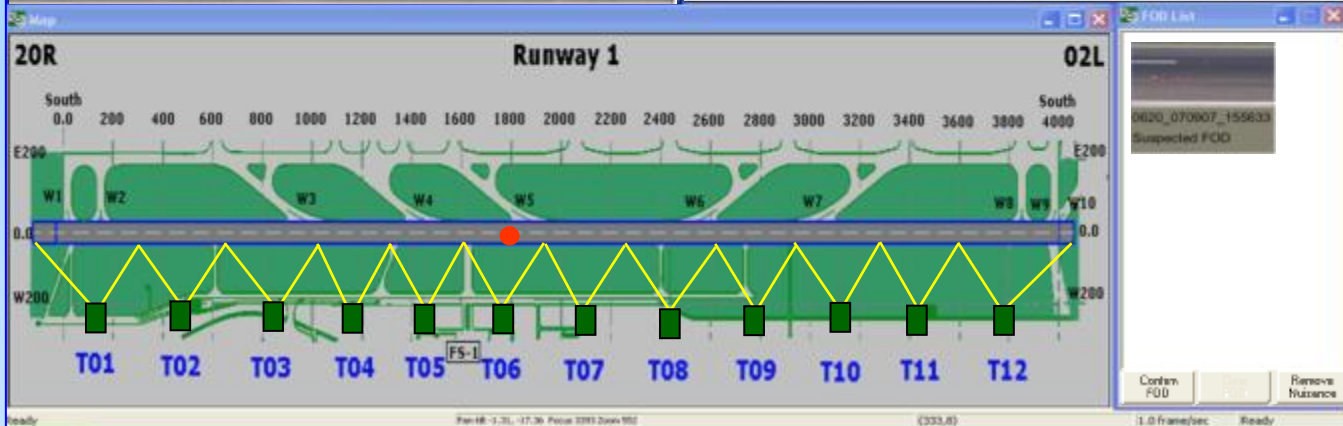


← 2

Detection  
View

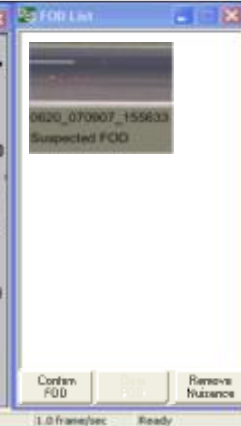
3 →

Digital  
Map



← 4

FOD  
Alarm  
List



# Alert Characteristics

1. Upon detection of an item that is stationary for a minimum of 30 sec. the system provides a visual and audible alert via a console in the control tower (#3).
2. The tower operator has information on a screen that provides location, and an image of the FOD detected.
3. If the alert requires action, coordination between ATC and a field team assures safe and efficient removal.

The FOD detection system at Changi provides ***alerts*** that, when evaluated by airport personnel, can produce an ***alarm***.

It is important to recognize the difference between alerts that call an operator's attention to a FOD object, and an alarm that requires action such as runway closure!

This study has included all alerts produced in 10 months at SIN.

# The Study!

With the cooperation of the Changi Airport Group, and the Assistance of Stratech Ltd, CEAT obtained data records September 2010 – June 2011.

The data set is complete, providing operational review, identification, and action on each object on an alert screen. Multiple objects detected at the same time are identified individually and produce separate alerts.

# Data and Data Management

Data includes:

Detection Time

Date

Camera

Location

Number of items detected

Size

Identification Remarks

Image Reference

# Data and Data Management

All alert data are archived in a data base and were made available in a spreadsheet format.

Images of FOD items are also archived, and all actions taken to view FOD (zoom, etc.) are recorded.

Images and videos (e.g. target view and real time zoom views) are archived supporting post-processing

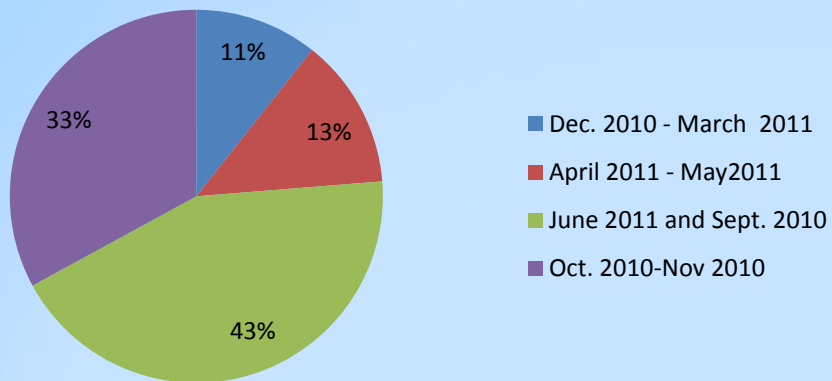
Through 10 months of operation with continuous operation the number alerts identified as FOD objects requiring action averaged about 3 per day, per runway!

Detailed analysis of data on the FOD objects requiring action, help develop a picture of FOD issues at SIN, and support efforts to manage FOD safely.

# Results

Season	Months	Number of Days	% of Total FOD Alerts	# of Alerts Per Day on Both Runways
Northeast Monsoon Season	Dec. 2010 - March 2011	121	24%	3.05
Inter Monsoon Period	April 2011 - May2011	61	15%	3.74
Southwest Monsoon Season	June 2011 and Sept. 2010	30	24%	12.40
Inter Monsoon Period	Oct. 2010-Nov 2010	61	37%	9.43

## Number of FOD Alerts Per Day

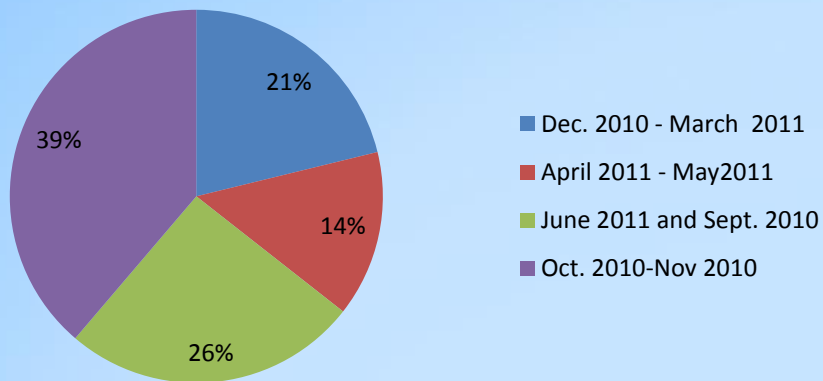


The target alerts varied in number over the period of the study – there was a suggestion of a seasonal pattern.

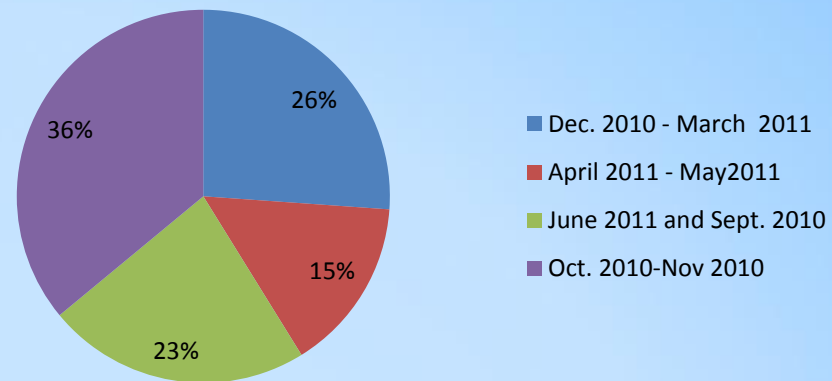
# The number of alerts also differed somewhat by Runway

Season	% of Total FOD Alerts	% of Total Alerts Runway 1	FOD Alerts Per Day Runway 1	% of Total Alerts Runway 2	FOD Alerts Per Day Runway 2
Northeast Monsoon Season	24%	10%	1.2	14%	1.8
Inter Monsoon Period	15%	6%	1.6	8%	2.1
Southwest Monsoon Season	24%	12%	5.9	13%	6.5
Inter Monsoon Period	37%	17%	4.4	20%	5.0

## FOD Alerts - Runway 1

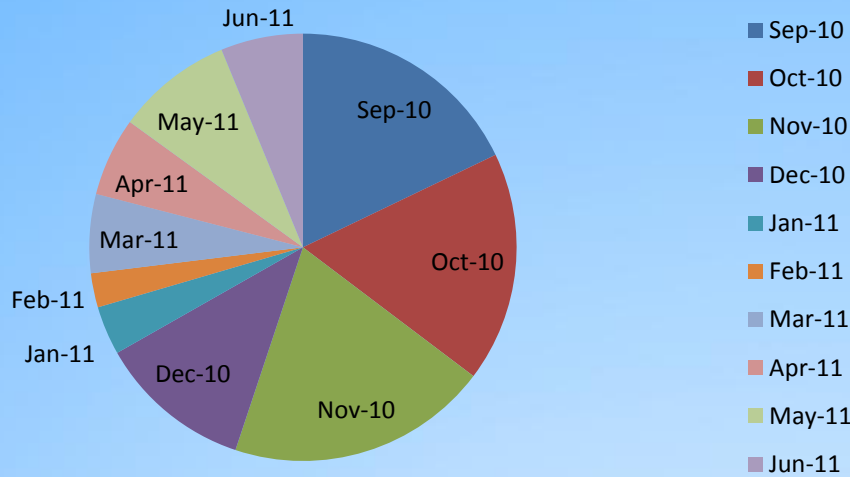


## FOD Alerts - Runway 2



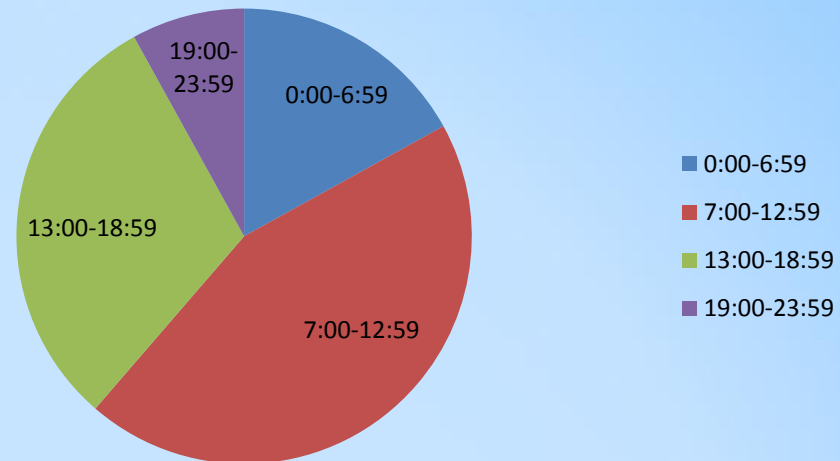
Further analysis suggests monthly and daily differences.

### FOD Alerts by Month



FOD seems to occur when the airport is being used!

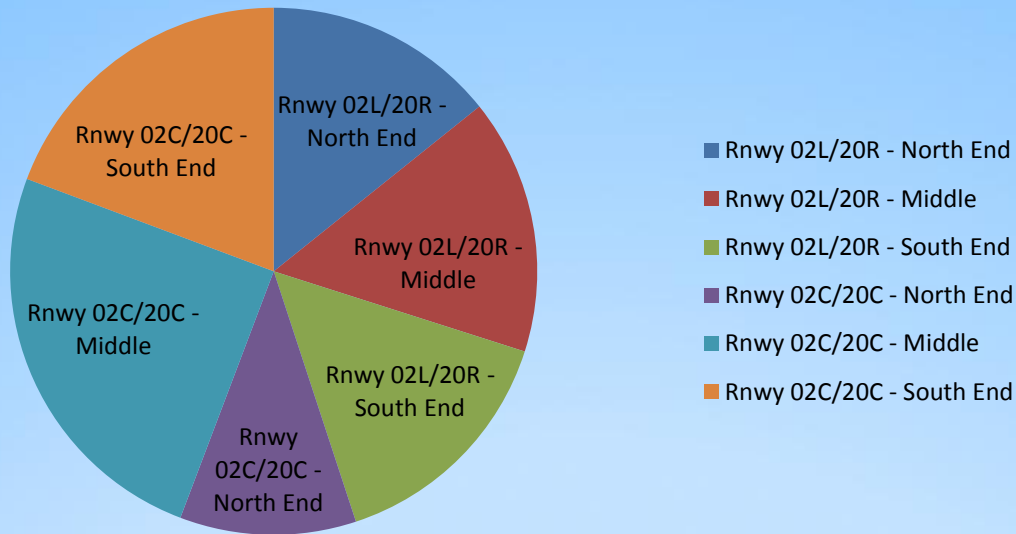
### FOD Alerts by Hour





# We divided the runways into thirds!

## FOD Alerts by Runway and Runway Location



The distribution of FOD alerts is somewhat uneven, with more alerts on the south and middle of Runway 02C/20C.

This analysis has summarized those alerts identified as FOD at Changi!

The sensor system is set to alert to any item on the runway that is stationary for 30 seconds. This means that alerts will be generated for vehicles or aircraft stationary on the runway, and wildlife. Further, the requirement for system sensitivity means the sensors will detect small items on the runway, such as grass or paint flakes, and pebbles.

Evaluating the cause of the alerts, found some interesting results that have relationships to technology and implications for management.

For September 2010 through June 2011 a total of 1,544 FOD alerts were counted, with a total of 2623 alerts for FOD classified as "Other" in the record.

Runway	FOD	Other*
1	694	966
2	850	1657
Total	1544	2623

\* This category includes stationary aircraft and vehicles, grass, and paint flakes or new runway markings such as single skid marks.

The somewhat greater number of alerts for the “other” category did not produce alarms. For example, during normal runway closures vehicles are on the runway. Alerts to these vehicles are produced. As the system has been used procedural changes have been made to reduce these alert types.

Also remember that this technology sees small objects and alerts to objects on the runway for 30 sec. There were many records for grass and small debris that did not present an imminent hazard with removal addressed during normal runway closures that occur throughout the day.

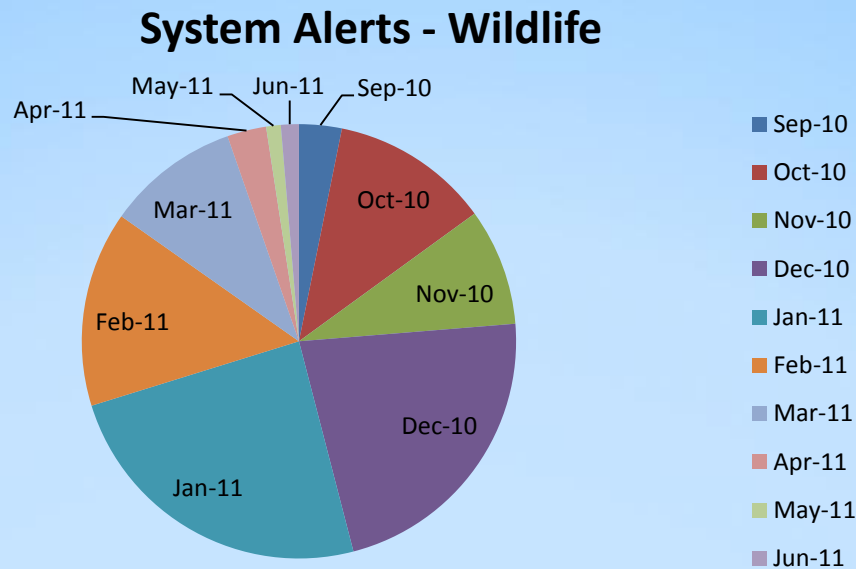
What the system provides is readily interpretable information that can disregard grass cuttings or vehicles while still alerting to more hazardous objects.

Clearly the expected FOD is detected by this system. One finding that I did not expect was the number of alerts produced by wildlife.

One video that was used last year documented the removal of a monitor lizard, and there are videos of eagles feeding and pythons on the runway.

What is more important in this analysis is birds on the runway!

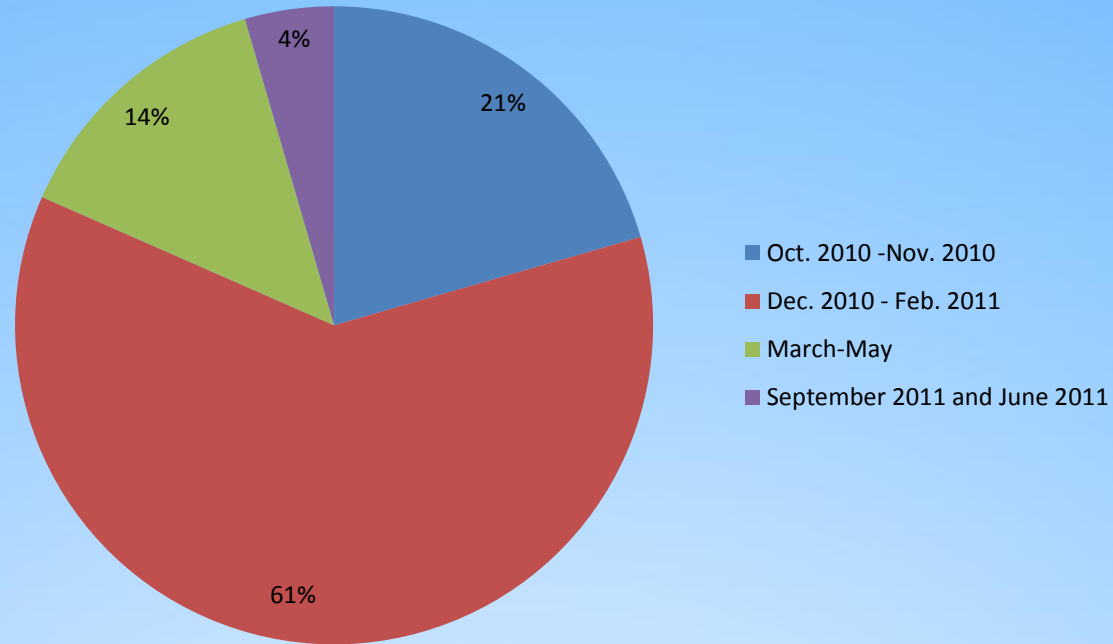
Wildlife management at airports is supported by observations, which are unfortunately limited. These limits are due to the actual time biologists can spend making observations, and limited opportunities to observe wildlife in the most hazardous position, on the runway. The iFerret system at SIN has added a new dimension to wildlife management information. For example, alert numbers show a seasonal trend – almost half in December and January!



Keep in mind that wildlife management at airports is supported by observations, which are limited in scope and timing. These limits are due to the actual time biologists can spend making observations, the fact that organism schedules are not biologist schedules, and observations can be made only during daylight.

The continuous surveillance system at SIN has added a new dimension to wildlife management by providing information on what birds occur when and where on runways.

## Seasonal Distribution of Wildlife Alerts

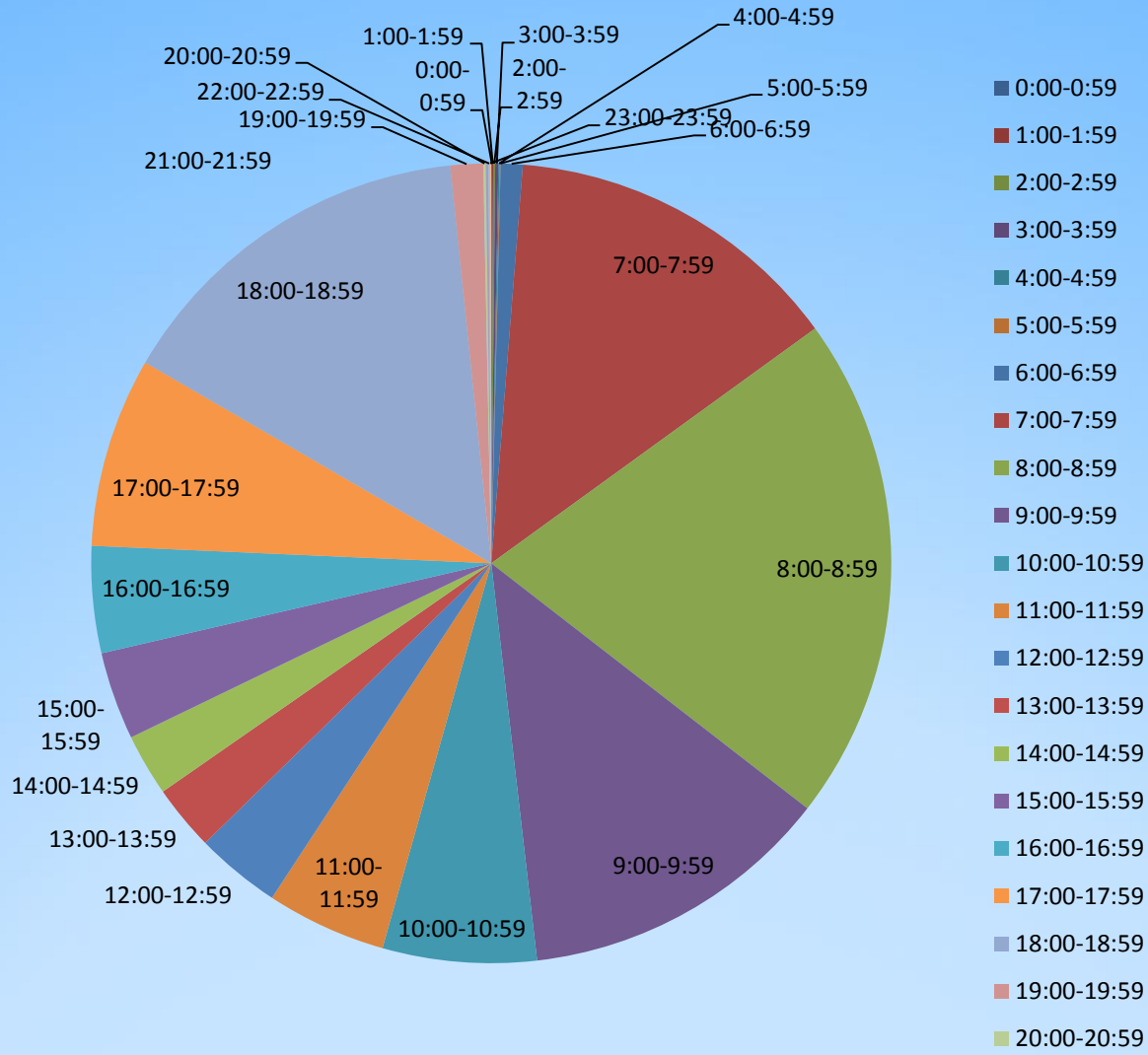


Over 60% of the wildlife alerts occur in three months, December, January, and February – the obvious conclusion is that birds do go south for the winter!

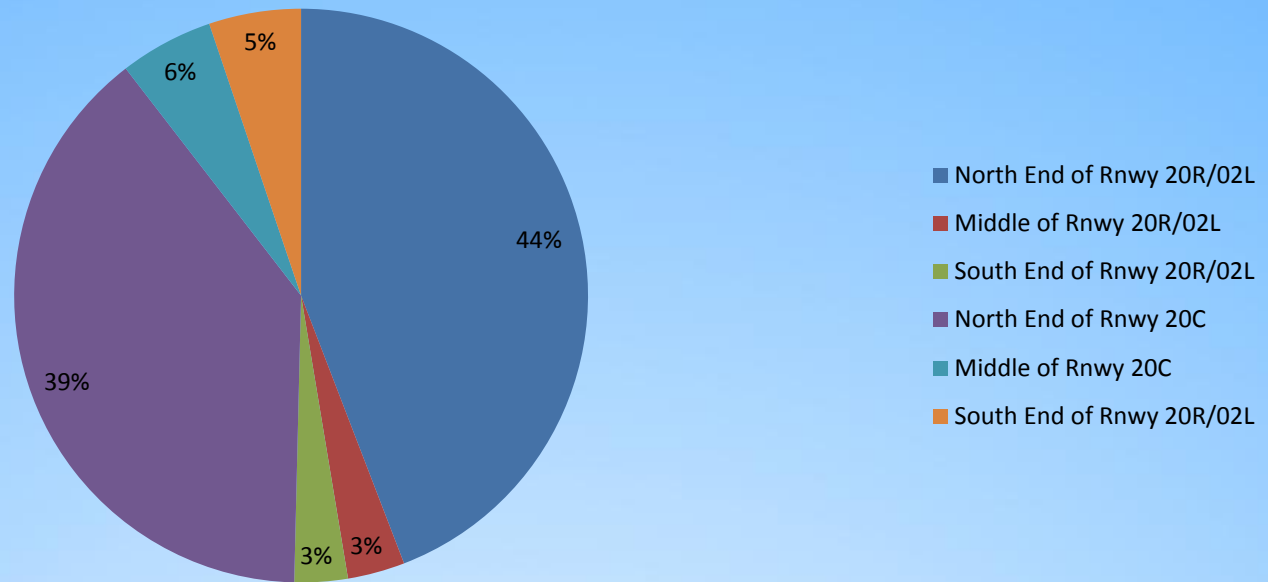
We know that birds on the runway present the most serious hazard to aircraft, so it is important to know when during the typical day do birds use the runway.

The following graph suggests a bimodal distribution of alerts, reflecting more bird use in the morning and afternoon, with small numbers at night.

# Number of Alerts Classified as Wildlife



## Number of Alerts Classified as Wildlife for Each Section of Both Runways



There are also differences between runways, and big differences between ends of the runway!

The actual number of alerts were 9275 wildlife target alerts on Runway 1 and 9135 on Runway 2 during this study.

On first review this may seem extraordinary, producing an alert overload that will challenge operators.

It turns out that this is not the case – let me explain!

Remember the CAG requirements – the detection system must detect multiple objects – this is also a requirement of the FAA Advisory Circular!

Also remember that the Advisory Circular requires reporting of multiple targets that are a minimum distance from each other (e.g. to alert to multiple pieces of a blown tire!)

Finally, birds flock and are social organisms. They hang out together!

What this means is that the total count of targets were in the 1000's, but the number of alert screens was much less!

Two, ten, or hundreds of birds can be reported in the same alert. Considering this system design capability, it is most appropriate to provide a summary of bird target numbers.

Season	Months	Est Number of Birds on Runways per Day
Northeast Monsoon Season	Dec.-March	108.00
Inter Monsoon Period	April-May	12.00
Southwest Monsoon Season	June-Sept.	14.00
Inter Monsoon Period	Oct.-Nov.	62.00
*Data from July and August was not available		

This is a summary that relates wildlife alerts to target numbers providing a good sense of the number of birds using runways.

What is important is that the FOD detection system has provided new information to wildlife managers, and airport operators, that was impossible to obtain before. At SIN it is now possible to know when wildlife hazards are elevated based on continuous observation and detection. This supports better wildlife management.

I mentioned earlier that continuous surveillance technologies were a game changer. In this instance a FOD detection system is providing critical information to wildlife management that was previously unavailable, if not impossible to obtain.

Information on runway wildlife is problematic using existing avian radars, and runway wildlife present the highest risk in the aircraft flight cycle, when it is accelerating for take-off!

Changi has a well developed wildlife management program and recently retained a wildlife hazard expert through ICAO Technical Cooperation Bureau to assist CAG staff in developing measures to deal with wildlife risks. The FOD detection system data is being used to update SIN wildlife management efforts!

## Summary:

For those accustomed to traditional inspection procedures these results may appear extraordinary! They are not!!!

Continuous surveillance for FOD can now provide a real picture of FOD: 1) items typically too small to be regularly observed in normal inspections are detected, 2) continuous surveillance is continuous, and 3) a true picture of FOD, big or small, dangerous or benign is produced.

The critical point I think is the ***alert*** and what it means to improved safety management. At Changi operators now have a better awareness of their airport and can control all FOD more effectively.

Although many alerts are for things like grass, small pebbles, or wildlife, these alerts support overall safety management by alerting airport operations staff to other management needs!

# Conclusions

Continuous FOD surveillance has added a new dimension to FOD management at SIN!

The iFerret system at SIN now alerts airport operations personnel to FOD of all types – 24/7!

The alert system supports rapid analysis of FOD, eliminating false alarms!

The system at SIN has brought about a new understanding of FOD types, location, and hazard.

Continuous surveillance is indeed a game changer, revealing all runway hazards, and contributing to continuous improvement of safety!

Questions?