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FogEye UV Sensor System Performance Characteristics

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0	1	2	3	4	5

Centimeters	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

FogEye UV Sensor System Performance Characteristics

Introduction

The FogEye (Safety Sentry) Emitter/Sensor is an innovative, all weather airport presence detection and runway incursion prevention system. It is very compact and lightweight, completely non-intrusive to aircraft and vehicles operating on the AOA, and requires no additional equipment on aircraft or vehicles. It is a non-contact passive sensor that is integrated into a taxiway or runway light. The sensors operate by detecting interruption of an ultraviolet (UV) beam that extends between a Transmitter and a Receiver that are placed on opposite sides of a taxiway or runway. Interruption of the beam by an aircraft nose wheel is detected and recorded as an "aircraft presence". The UV wavelength (254 nanometers) used is considered "solar blind" that is, it is not affected by direct exposure to sunlight on the receiver.

Detection of aircraft presence on either runways or taxiways is accomplished by placing emitter/sensor at strategic locations along an aircraft's path. The emitter/sensor placements are such that the following aircraft circumstances are detected:

- Aircraft/vehicle position relative to a hold-short line: this position is determined to be either prior to, upon, or beyond the hold short line, i.e. about to enter a runway
- Aircraft/vehicle location along a taxiway/runway surface
- Aircraft exiting a runway

General Operation

The basic FogEye system that enables fog penetration consists of a solar-blind ultraviolet detector and at least one ultraviolet light source. Packaged in with the detector is a digital processor that provides detection logic and communications with additional equipment. The package containing the UV detector and digital processor, along with related equipment, is referred to as the FogEye Receiver. Multiple FogEye units can be setup together to provide additional information, such as direction of travel and velocity.

For the runway intrusion application, the presence of an aircraft is indicated upon detection of the noise wheel of the aircraft and continues until the landing gear passes by the detector. "Master" and "Slave" FogEye units are employed to provide information on direction and velocity.

Figure 1 illustrates the sequence as an aircraft moves through the UV light beam. At time A the nose wheel interrupts the beam, which remains interrupted until time B. Shortly, the landing gear interrupts the beam at time C until time D. An aircraft is present from time A until time D.

Of course, circumstances might occur in which the events show in figure 1 are not so clearly defined. These circumstances can include dispersion of the UV signal due to fog, variation in the speed, including stoppage, of the aircraft and the passage of objects other than aircraft.[1]

Figure 1

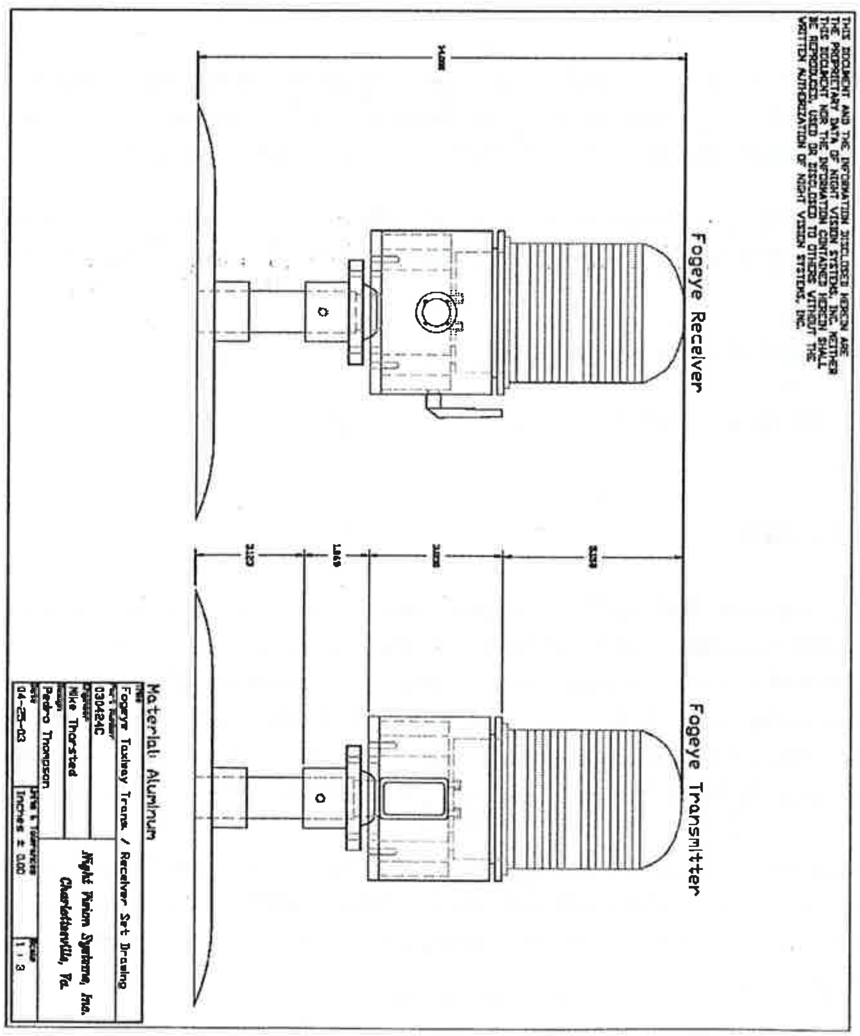

Figure 2

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[1] Zeifler, E. W. "FogEye Safety Sentry Design Aircraft Presence Detection", Sept 2003

Configuration

The FogEye Receiver and Transmitter are installed in Medium Intensity Runway/Taxiway Lights, MI Series FAA Type: L-861, L-861E and L-861T. The Medium Intensity Runway/Taxiway Lights (MIRL) are primarily used on VFR runways, or runways with a non-precision approach. When used in conjunction with medium intensity approach systems, MIRLs allow for precision approaches in up to a half-mile visibility. The Medium Intensity Taxiway Lights (MITL) are used for all taxiways and aprons on airports using either MIRL or High Intensity Runway Lights (HIRL) on the runway. Figures 2 above and 3 below depict the taxiway light with the FogEye Modification. Table 1 lists the transmitter and receiver physical characteristics.

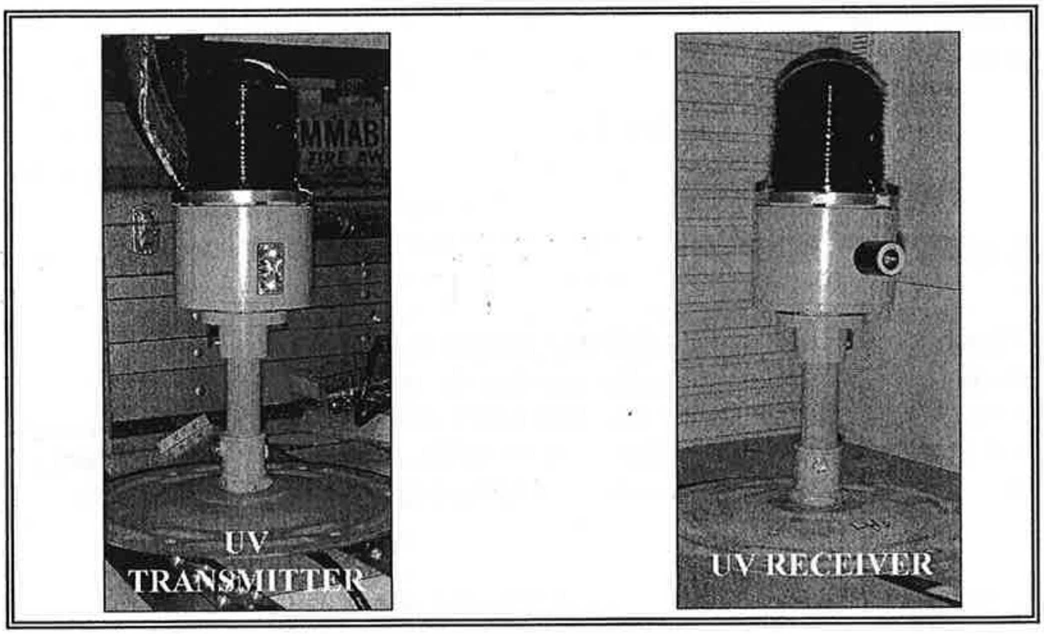

Figure 3

Transmitter	
Power	6.6 to 4.8 Amperes, Current Regulated @ 60Hz, 4.5 Watts
Dimensions	4.7 Inch Diameter x 3.85 Inches High with .21 Inch Protrusion
Assembly Interface	Mates with pole socket/lamp mounting flange on existing airport taxiway edge lights
Wavelength	254 nanometers
Beam Width	12° half width, half power

Receiver	
Power	6.6 to 4.8 Amperes, Current Regulated @ 60Hz, 4.5 Watts
Dimensions	4.7 Inch Diameter x 3.525 Inches High with 1-Inch diameter protrusion and RF Antenna
Assembly Interface	Mates with pole socket/lamp mounting flange on existing airport taxiway edge lights
Communication Message	Aircraft Detection (Relay contact closure indicating presence of aircraft/vehicle)
Wavelength	254 nanometers
Sensitivity	3×10^8 amp/watts
Field of View	1.5^0
Dynamic Range	3×10^5
UV/Visible Isolation	$>10^6$

Table 1

Signal Interfaces

The FogEye System provides for several different interfaces depending on the communication link and the cabinet controller interface desired. The standard FogEye Sensor output message provides presence detection and location. Two pairs used in sequence output presence detection, location, flow of traffic, and average speed for each monitored zone. The FogEye System supports the following electrical communication interfaces:

1) RS-232 (Optional)....................................Hard Wired to system backbone
2) RS-232 (Optional).....................................Wireless Link (range depends on RF devices used)

System Parameters

The operation of the Safety Sentry device is affected by certain values, the parameters of the system. These values can be changed to alter the behavior of the system by modifying the firmware in the digital processor or, when available, via communication with the digital processor. The parameters are described in Table 2 below[2].

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[2] Zeifler, E. W. "FogEye Safety Sentry Design Aircraft Presence Detection", Sept 2003

Table 2

AGC RELATED PARAMETERS	
Desired Signal Level	
Default Value: 3.0 volts	This is the signal level the AGC attempts to maintain when an object has not been detected.
Normal Signal Level Tolerance	
Default Value: 0.1 volts	The AGC will not adjust the detector gain if the signal level is within this amount of the Desired Signal Level.
Fast Signal Level Tolerance	
Default Value: 1.0 volts	The AGC adjusts the detector gain more rapidly if the signal level is outside this amount of the Desired Signal Level.
Time Between Normal AGC Adjustments	
Default Value: 1,502 milliseconds	The internal AGC value is incremented or decremented by one unit (about 0.005 volts) each of these intervals while an object has not been detected and the detector signal level is not within the Normal Signal Level Tolerance of the Desired Signal Level. This value corresponds to about a 20 second time constant when the signal level is within one volt of the desired level.
Time Between Fast AGC Adjustments	
Default Value: 250 milliseconds	The internal AGC value is incremented or decremented by one unit (about 0.005 volts) each of these intervals while an object has not been detected and the detector signal level is not within the Fast Signal Level Tolerance of the Desired Signal Level. This value corresponds to about a 3 second time constant and is used to get close to the desired signal level rapidly and then use the slower adjustment to fine tune the level.
Maximum AGC Value	
Default Value: 3.0 volts	The maximum value of the AGC level.
Minimum AGC Value	
Default Value: 0.0 volts	The minimum value of the AGC level.
Initial AGC Value	
Default Value: 0.75 volts	The initial value of the AGC level when the system is reset

Table 2

Dynamic Threshold Related Parameters	
Short Term Signal Averaging Parameter	
Default Value: 4 samples (milliseconds)	This is the time constant for the filtering of the sampled signal values. All computations use the result of this filtered signal value. The values of this parameter can range from one to 64 although values over 8 can result in small, fast moving objects not being detected.
Initial Minimum Average Signal Level	
Default Value: ½ Desired Signal Level (1.5 volts)	The AGC requires time to increase the gain enough when the device is started to provide a minimum detector signal level before valid aircraft presence detection can begin. Once this level is reached, aircraft presence detection will continue even if the signal level falls below this level again.
Time Between Average Signal Level Adjustments	
Default Value: 1,502 milliseconds	The average detector signal value is incremented or decremented by one unit (about 0.005 volts) each of these intervals while an object has not been detected. The average is incremented if the current detector level is above the average and decremented if the current detector level is below the average. This value corresponds to about a 20 second time constant.
Maximum Average Signal Level	
Default Value: 5.0 volts	The maximum value of the computed average signal level.
Minimum Average Signal Level	
Default Value: 1.25 volts	The maximum value of the computed average signal level.
Detection Occurs Signal Level Factor	
Default Value: 6 (37.5%)	Detection occurs when the detector signal level falls below the lower signal level. The internal lower signal level is this value times the average signal level plus 8 all divided by 16 or (factor * avg + 8) / 16. The external signal level is the internal level times 5.0 volts divided by 1,024.

Table 2

Detection Clears Signal Level Factor	
Default Value: 6 (37.5%)	Detection clears when the detector signal level rises above the higher signal level. The internal higher signal level is this value times the average signal level plus 8 all divided by 16 or (factor * avg + 8) / 16. The external signal level is the internal level times 5.0 volts divided by 1,024.
Aircraft Present Timeout	
Default Value: 4 minutes	This value determines how long the "aircraft present" state will be maintained. This is intended to reset the detector if a false detection occurs.
Aircraft Passed Time	
Default Value: 2 minutes	This value determines the maximum time that the "aircraft passed" indicator will be set. The indicator will be reset sooner if another object is detected.
Minimum Time Signal Off	
Default Value: 10 milliseconds	This is the minimum amount of time the detector signal level must be below the lower detection threshold to be considered a valid detection.
Nose Wheel Minimum Time Signal On	
Default Value: 50 milliseconds	This is the minimum amount of time the detector signal level must be above the higher detection threshold to be considered a valid end of detection for the nose wheel.
Landing Gear Minimum Time Signal On	
Default Value: 10 seconds	This is the minimum amount of time the detector signal level must be above the higher detection threshold to be considered a valid end of detection for the landing gear. This relatively longer time allows for multiple landing gear interruptions of the path.
Maximum Time Between Messages	
Default Value: 1 second	A message is transmitted each time a significant event occurs, such as detecting an aircraft. Also, a message will be transmitted if this period goes by without a significant event occurring.

Detection Zone

The FogEye System is designed to operate and provide effective and accurate aircraft/vehicle presence detection for vehicles passing the sensor station at any reasonable (and allowable) speed from stop and go to free flow. There is no inherent upper speed limitation relative to taxiway traffic. Development test achieved speeds up to 45 mph.

The FogEye System provides a typical maximum detection zone in the direction of traffic flow (up/down taxiway) of 250 feet. The zone detection size in the transverse taxiway direction is at least 300 feet. The FogEye detection zone can be selected which covers the entire lane width including some or all of the shoulders. See Figure 4.

Because the FogEye System is based on UV solar blind technology, there is virtually no loss of detection performance due to variation in weather or environmental conditions or visibility conditions.

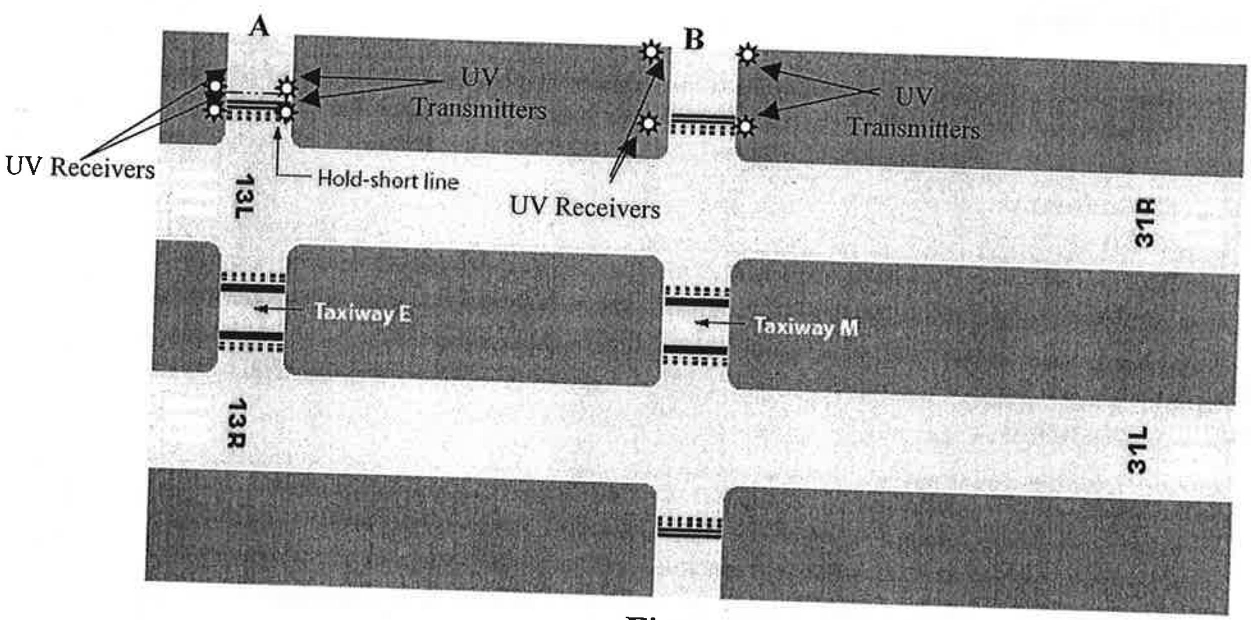

Figure 4

Detection Response

The output of the UV receiver drops quickly when an object interrupts the path between the UV source and the detector. The characteristics of the receiver cause this to be a smooth but not instantaneous drop. Figure 4 depicts the detection of a F-15 taxiing at approximately 20 mph. Other observations showed that the signal dropped nearly to zero in about 17 milliseconds. This corresponds to a time constant of about 5 milliseconds and is in general agreement with the reported time constant of 4 milliseconds[3].

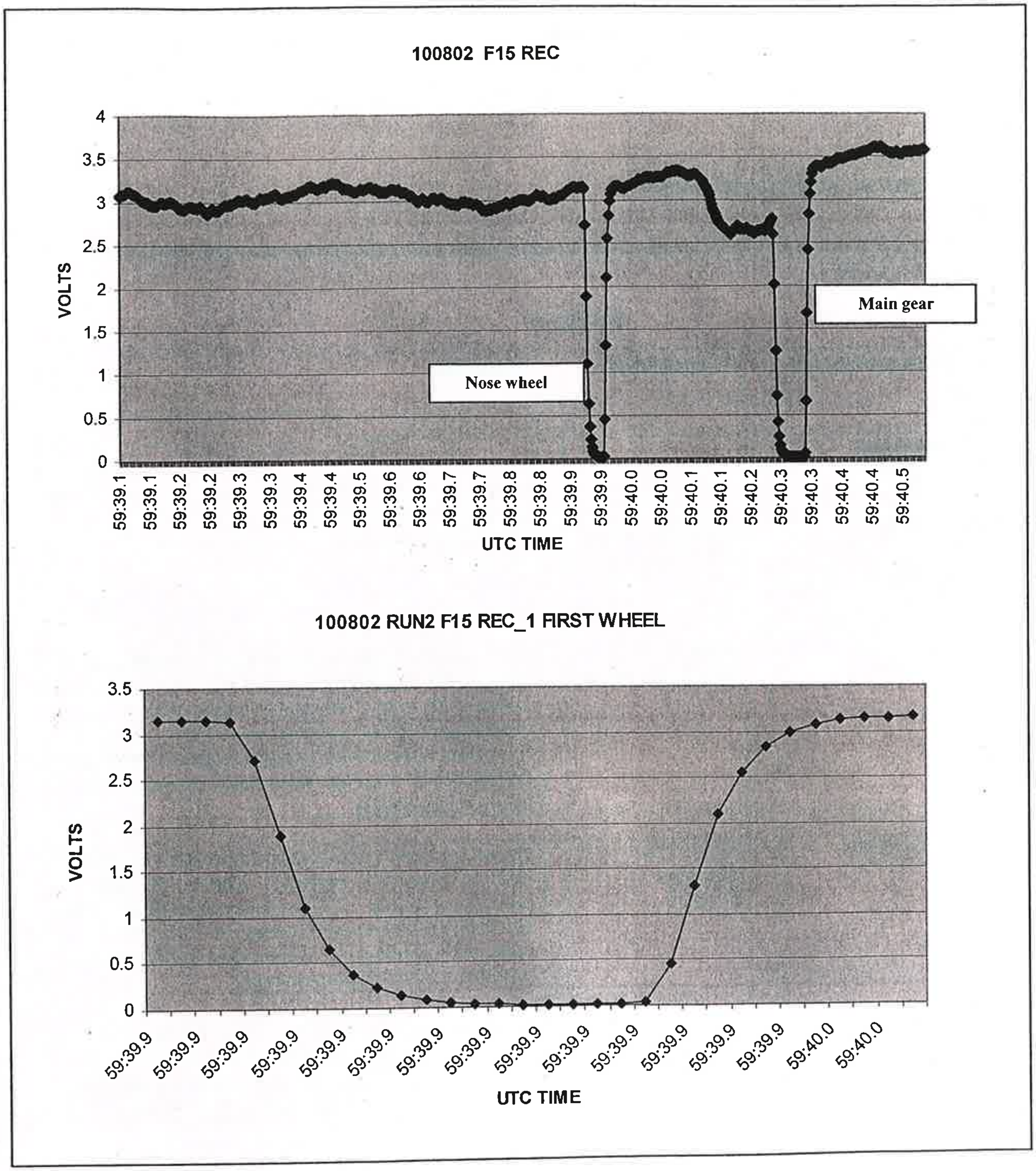

Figure 5

[3] Zeifler, E. W. "FogEye Safety Sentry Design Aircraft Presence Detection", Sept 2003

Probability of Detection

The overall probability of aircraft/vehicle detection for FogEye System is high. This is based on operational testing at Providence International Airport. The probability of detection was determined to be 0.9944, based on 4074 events and 23 system misses.

Measures of Effectiveness

The parameters used to determine the functionality and effectiveness of the sensor are listed in Table 3.

Table 3

Characteristics	Parameter	Results
Operational Effectiveness		
Detection	$P_{detection}$	99.44%
Operational Suitability		
Reliability	Mean Time Between Failure	During initial FogEye installations a power supply failure was caused by a power line over voltage spike of 26 volts. The power supply and subsequent power supplies have been modified to protect against high voltage surges. Thereafter no failures of any type were noted during 3,800 hours of operation.
Maintainability	Mean Time Between Repairs	Based on over 3,800 hours of operation without need to repair, this system is deemed virtually maintenance free. PVD indicates the Mean Time To Replace individual Receiver or Transmitter units is 15 minutes. A Transmitter or Receiver module is a line replaceable unit.
Availability	$\frac{\text{Uptime}}{\text{Uptime+Downtime}}$	Availability was 100 percent when the taxiway power was set at level three, the highest of three settings. The FogEye system power supply has been modified to accept levels one and two.