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FogEye UV Sensor System Evaluation: Phase III Report

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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

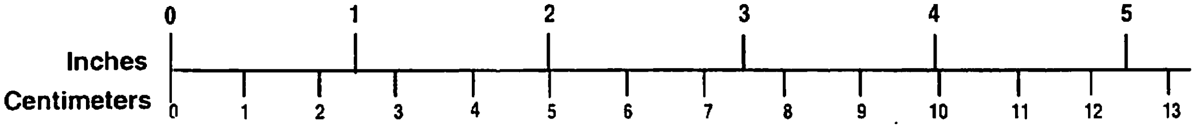
VOLUME (APPROXIMATE)

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)

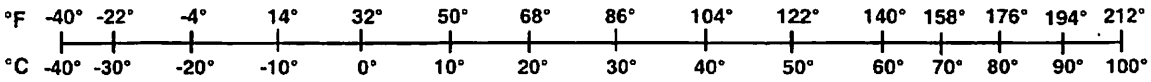
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



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

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PREFACE

FogEye technology offers the potential for operation of electro optical sensors and systems that function "hands-off", over extended distances during varying atmospheric conditions, day and night. The technology has been shown to employ solar blind ultraviolet radiation and special electro optical hardware to achieve immunity to natural background radiation. Solar blind ultraviolet radiation may also have favorable atmospheric transmission properties. A basic FogEye hardware complement consists of a Transmitter, a source of ultraviolet radiation, and a Receiver that accepts this radiation and rejects all of the sun's radiation as well as rejecting man-made sources of non solar blind radiation, but, of course, is sensitive to man-made solar-blind radiation.

Congress has requested the FAA to assess this FogEye technology and evaluate the feasibility of applying it to aviation-related problems. The FAA's Office of Surface Technology Assessment (AND-520) has been assigned responsibility for this investigation and has requested the support of the Department of Transportation Volpe National Transportation Systems Center. (Volpe Center)

The FogEye equipment tested has been provided by Norris Electro Optical Systems.

EXECUTIVE SUMMARY

Control of aircraft and vehicles on airport surface is changing considerably. With the advent of very low visibility operations, down to 300 feet RVR, a concerted effort to preclude runway incursions has been underway for several years. These efforts include ASDE-3 Radar, GPS/GNSS, ASDE-X, and Airport Surface Movement Sensors.

The Federal Aviation Administration (FAA) and the commercial aviation industry seek to develop and evaluate technologies that increase safety and efficiency of airport operations under low visibility conditions. The overall goal of these efforts is to provide commercial aircraft with the technology and operating procedures needed for safely achieving the capacity of clear-weather surface operations during adverse-weather conditions. Sensors based on visible light, such as runway lights, are degraded by sunlight during the day. FogEye technology operates in the solar-blind ultraviolet region of the spectrum and hence operates with the same effectiveness during the day as at night.

Characterization of electro optical emissions from aircraft is essential to the evaluation of this technology. This report presents the results of the FogEye Ultraviolet (UV) Sensor Evaluation for Phase III, which examined camera systems for monitoring runway incursions and to aid pilots during low visibility landings. The test was conducted at Baltimore-Washington International Airport (BWI), and consisted of recording electro optical emissions from aircraft in an operational environment (day/night take-offs and landings).

Data from the evaluation indicates that aircraft landing/approach lights gave off negligible UV light and therefore were difficult to track using the UV Camera. The observation of UV light from some aircraft, primarily foreign showed limited use for possible future applications. It is possible to equip aircraft with UV lights. However, because most of the BWI traffic could not be seen with a UV camera, a UV surveillance sensor would not be effective without requiring installation of new aircraft lights. Such a retrofit would be unlikely under current economic conditions for the airlines.

1. INTRODUCTION

1.1 Background

FogEye is a system that uses solar-blind ultraviolet technology as a means to penetrate fog. The technology can be applied to circumstances requiring navigation or surveillance during low visibility conditions. The FogEye Runway Surveillance sensor is intended to autonomously detect the approximate locations of aircraft on final approach, takeoff and on runways from the UV emissions of aircraft light. UV emissions from an aircraft maybe realized by either augmenting existing navigation lights or by exploiting existing UV emissions. Two or more cameras can locate an aircraft,(angle and range), by triangulation. The goal of Phase 3 is to assess whether aircraft emit enough solar-blind ultraviolet light to permit UV cameras to reliably see aircraft.

1.2 Test Objective and Methodology

The objective of Phase III was to evaluate the operational performance of a FogEye camera for seeing aircraft during airport operations. Rather than study representative aircraft lights under controlled conditions, the decision was made to deploy a solar-blind UV camera to a convenient airport to determine which aircraft could be seen. Four cameras were used to capture the electro magnetic spectrum. The Baltimore Washington Airport (BWI) was selected because of its proximity to the FogEye personnel who provided and operated the test equipment. Two sites were selected, one for viewing landings from near the touchdown point and the other for viewing takeoffs (the second site could also view landing aircraft long after touchdown). See Figure 1. The test schedule permitted the use of both sites during both day and night. The second night session was cancelled because it was felt that no additional information would be gained.

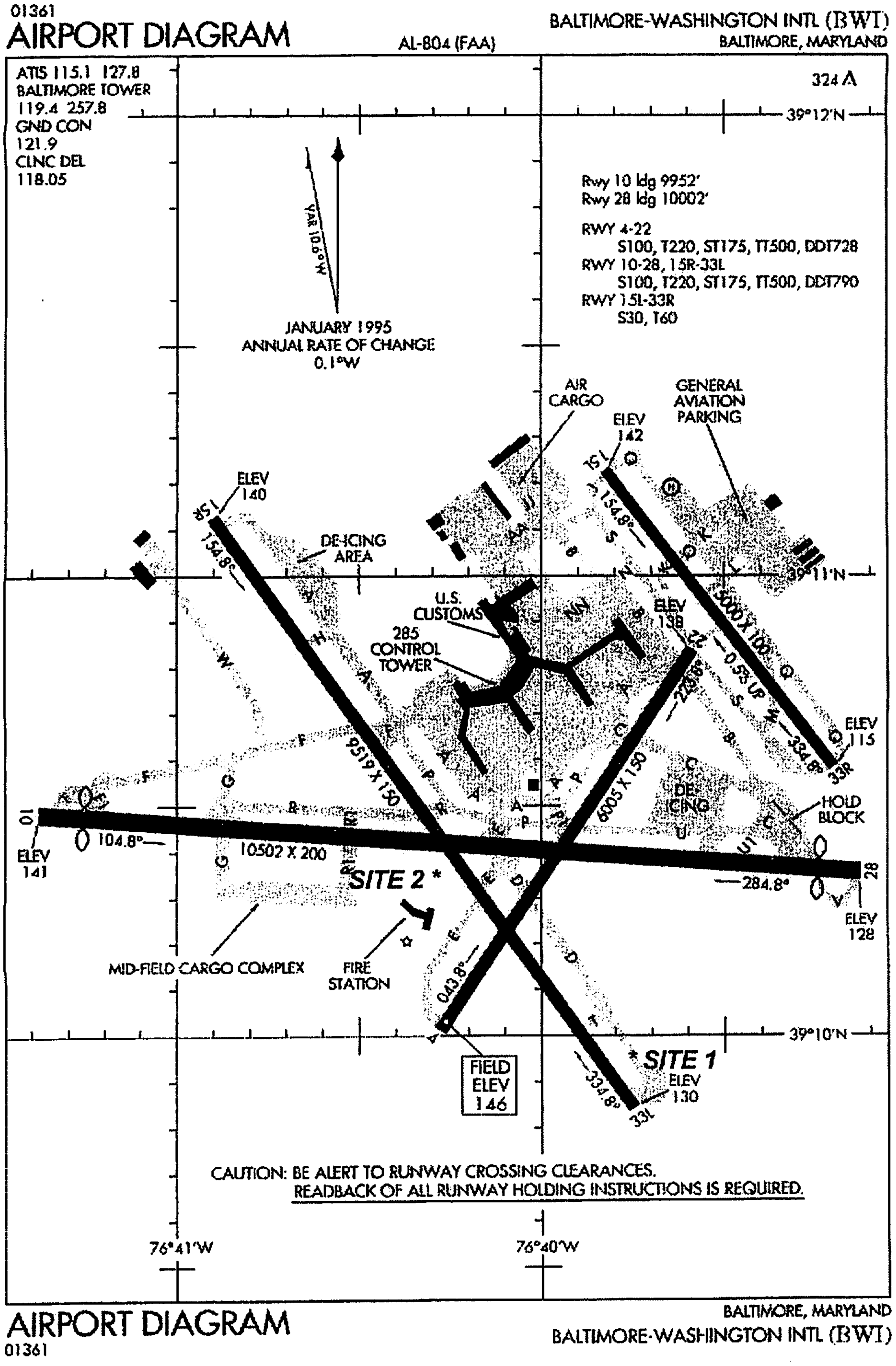

Figure 1 – Baltimore-Washington Intl. (BWI)

2. TEST CONFIGURATION

2.1 CAMERAS

Figure 2 shows the four cameras used for the evaluation; they were numbered 1 to 4 from left to right:

1. The FogEye camera had two possible lenses, a telephoto lens (shown here) with a 10° field of view and an aperture of f4.5 and a much faster lens with a 30° field of view and an aperture of f1.45. The second lens was used for most of the testing to maximize sensitivity.

2. The black & white telephoto camera had high sensitivity.

3. The color zoom camera was normally operated with the same field of view as the FogEye camera to facilitate comparisons of visible and UV views.

4. The infrared camera (0.9 to 1.7 micron sensitivity) has a telephoto lens.

The UV and visible light cameras were aligned using the target shown in Figure 3, which was illuminated with a UV light (to left). The FogEye camera is also shown in Figure 3.

2.1.1 Data Recording

The four cameras were recorded on four SVHS recorders. Each recorder included a time code so that

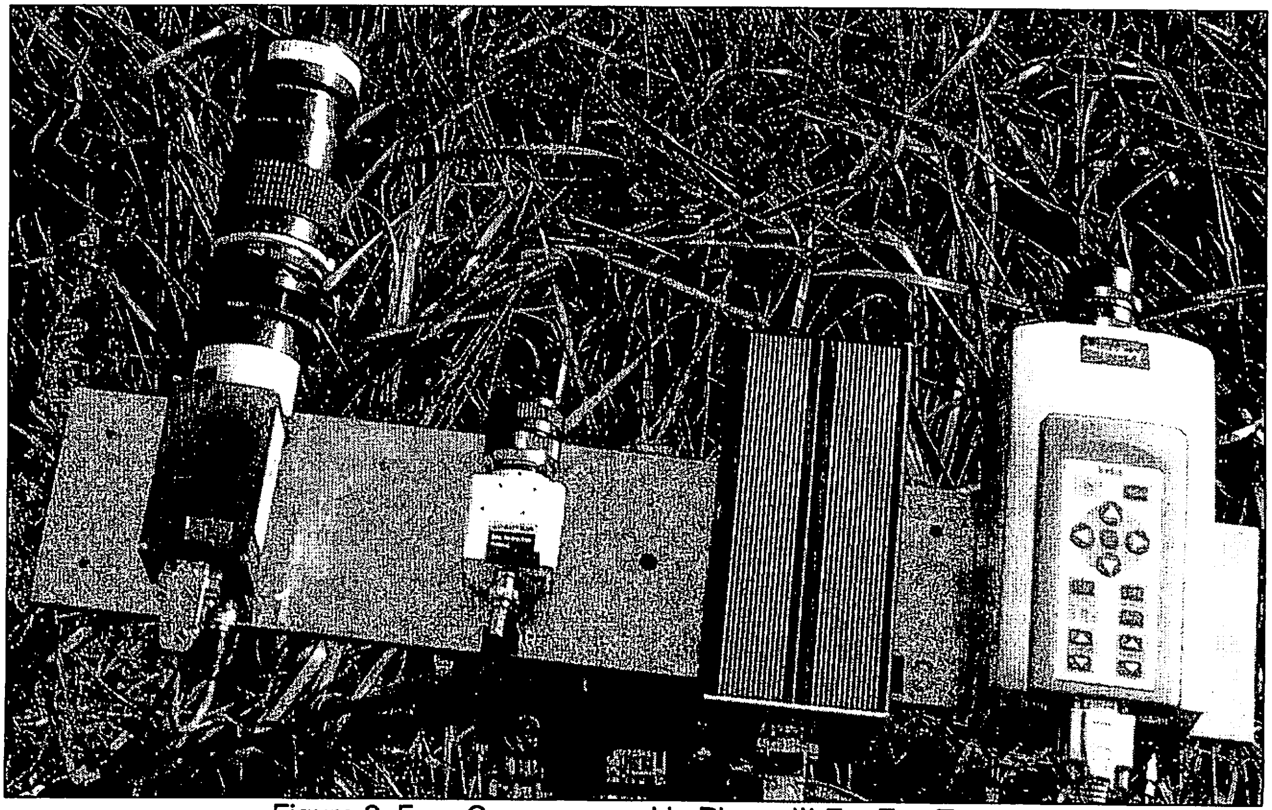

Figure 2. Four Cameras used in Phase III FogEye Test

the pictures recorded at the same time could be compared.

2.1.2 Nature of FogEye Pictures

The FogEye picture of the UV-illuminated target looked much like those form the other cameras. However, when the UV lamp was turned off, the light level dropped to almost zero. The camera gain was increased to the level where single photons showed up as small flashes on the screen.

During the daytime at most a few flashes were seen in each video frame. The camera did, however, efficiently pick up intermittent light from a welding operation on the other side of the airfield.

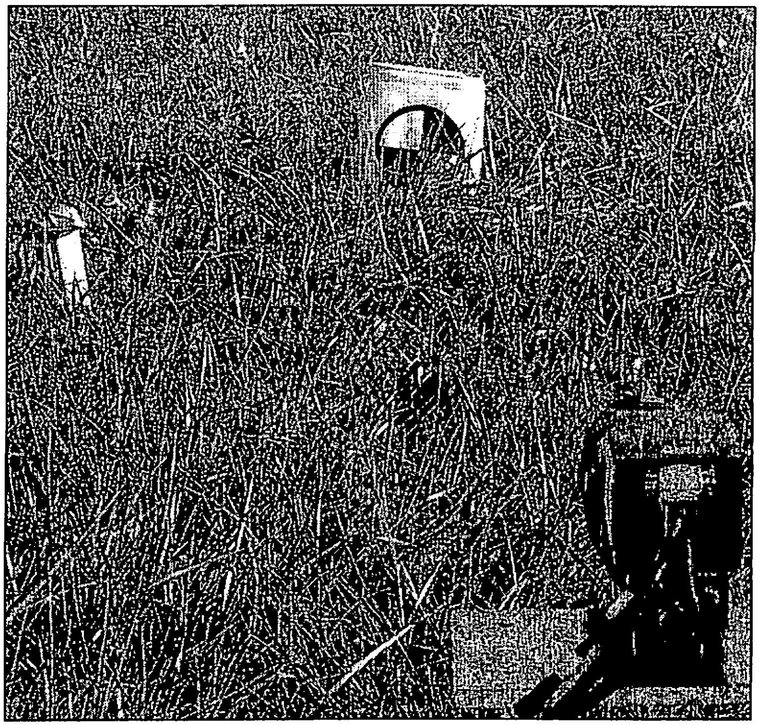

Figure 3. Alignment Target

At night the amount of background light increased significantly. The number of flashes from the horizon sky was perhaps 10 or 100 times that seen during the daytime. Less UV light was seen at higher elevation angles and none was seen from the ground. The horizon UV light was likely caused by outdoor illumination (e.g., fluorescent or high pressure mercury vapor lamps) that scattered from the atmospheric haze. The background light seemed to vary for different azimuth angles.

2.2 TEST SITES

2.2.1 Site 1

The first site (used on 10/22/02) was located near the touchdown point of Runway 33L (see Figure 4). Aircraft could also be viewed on final approach (see Figure 5).

2.2.2 Site 2

The second site (used on 10/23/02) was located near the crossing of Runway 33L (used for landings) and Runway 28 (used for takeoffs). At this location the cameras could be used to view virtually all airport operations. Figure 6 shows a Runway 28 takeoff. Figure 7 shows an aircraft rolling out after a Runway 33L landing. The normal data collection procedure was to scan the camera to follow the aircraft from its initial position at the end of the runway to where it passed the camera location.

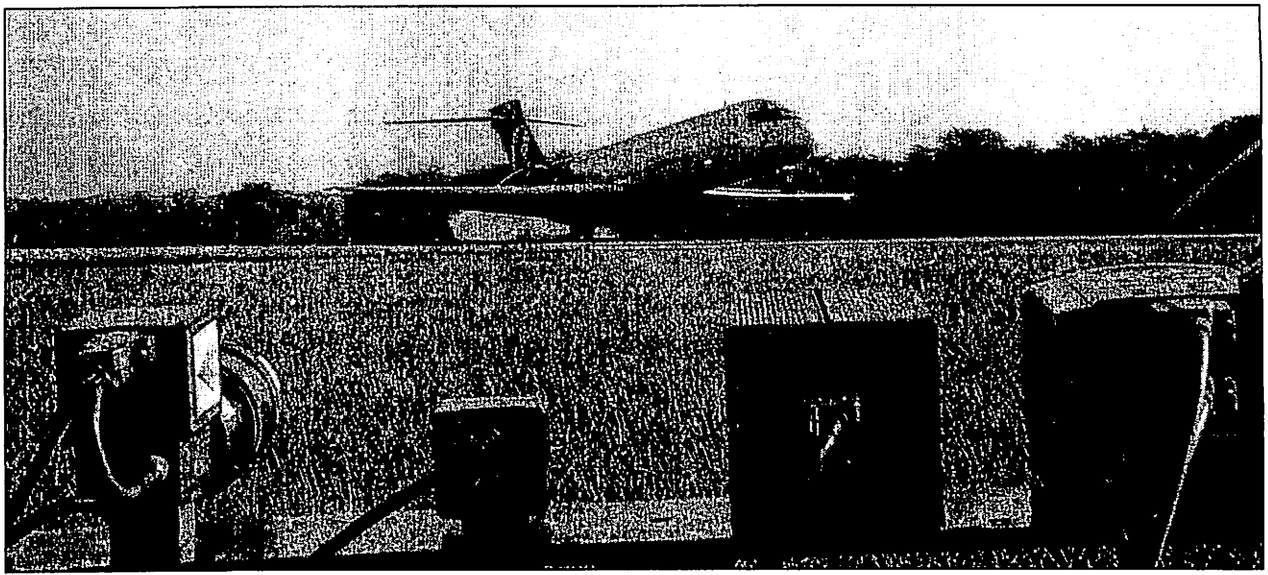
Figure 4. B717 Landing on Runway 33L


Figure 5. B757 on Final Approach to Runway 33L

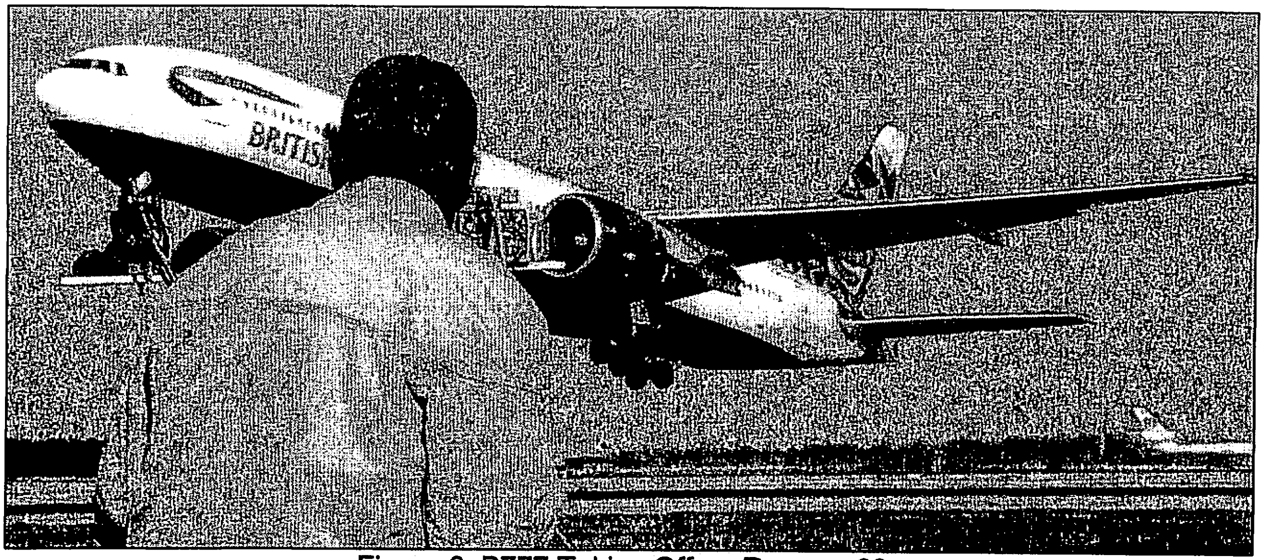

Figure 6. B777 Taking Off on Runway 28.

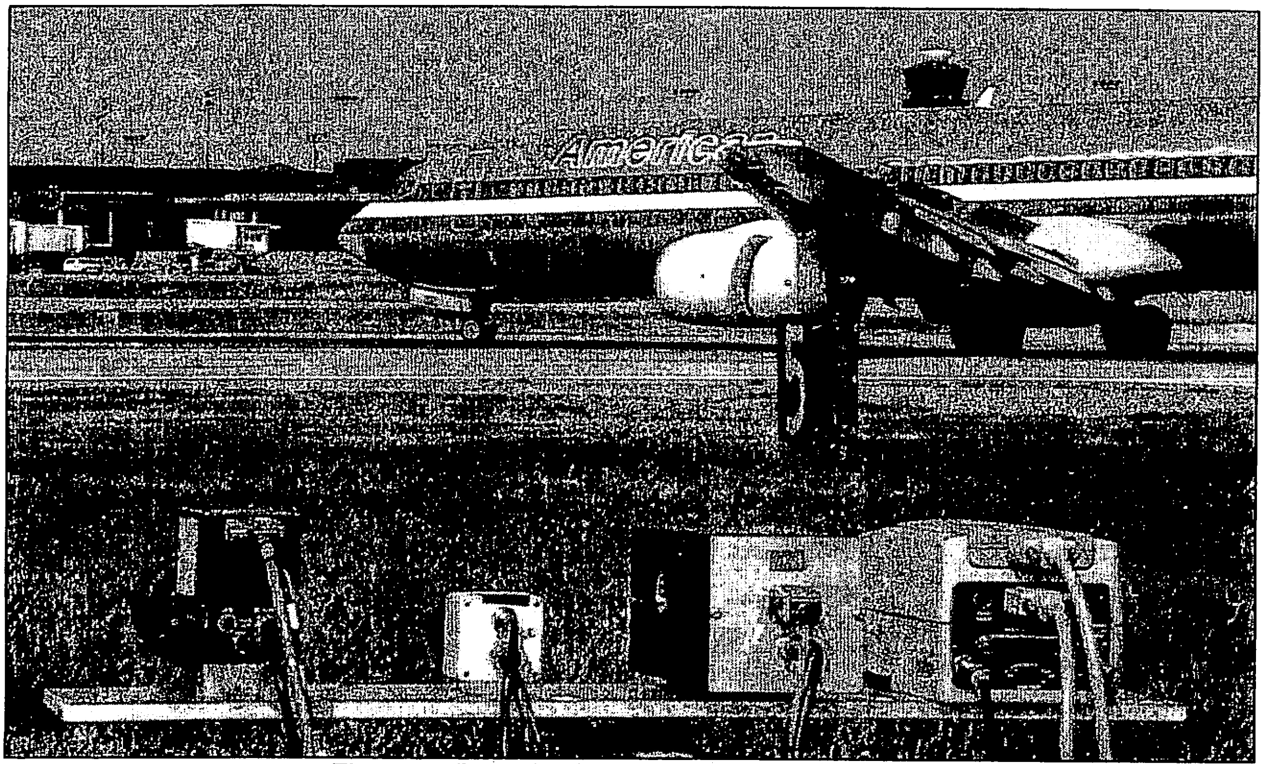

Figure 7. B737 Rolling Out After 33L Landing

3. TEST RESULTS

Out of 134 aircraft events, (takeoff, landing, rollout, taxi, etc..) only a small fraction of the aircraft lights could be seen by the ultraviolet camera. As would be expected, the lights containing ultraviolet were limited to a few aircraft types, which were not those most common at BWI. Four types were observed by the UV camera:

1. A320 operated by US Airways
2. B717 operated by AirTrans.
3. Regional jet operated by Continental Express
4. Beach aircraft operated by UA Airways Express.

Another aircraft operated by FedEx was seen but not clearly identified because of darkness. It appeared to have the wing end plates associated with Airbus aircraft.

Some of the B717 and A320 aircraft did not have their brightest lights illuminated on takeoff and could not be seen in the ultraviolet on departure.

4. CONCLUSIONS

The observation of solar-blind ultraviolet light from some aircraft was not encouraging with regard to possible future applications of FogEye technology. It is entirely possible to equip aircraft with UV lights. However, because most of the BWI traffic could not be seen with a UV camera, a UV surveillance sensor would not be effective without requiring new aircraft lights. Such a retrofit would be unlikely under current economic conditions for the airlines.