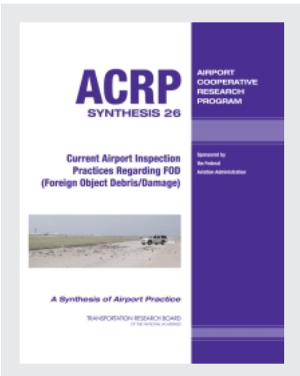

Current Airport Inspection Practices Regarding FOD (Foreign Object Debris/Damage)

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 26

Current Airport Inspection Practices Regarding FOD (Foreign Object Debris/Damage)

A Synthesis of Airport Practice

CONSULTANT

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

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Cover figure: During a B747 departure under takeoff thrust, a 1,000-foot portion of the runway asphalt shoulder pavement failed, creating a significant amount of FOD, causing a 1 hour runway closure, and requiring a sweeper to remove the FOD. Used with permission.

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

In an effort to better control FOD (Foreign Object Debris/Damage) and minimize the hazards associated with FOD on the air operations area, many airports have developed comprehensive FOD management programs, beginning with FOD inspections. In general, FOD inspections range from a simple visual inspection to continuous monitoring technologies. This synthesis report details the components of a comprehensive FOD management program, and compiles current practices, techniques, and lists of tools available for use, or those currently being used by, airports for FOD inspections.

C. Daniel Prather, Prather Airport Solutions, Inc., Murfreesboro, Tennessee, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

CURRENT AIRPORT INSPECTION PRACTICES REGARDING FOD (FOREIGN OBJECT DEBRIS/DAMAGE)

SUMMARY

Foreign Object Debris (FOD) exists in many different forms, comes from many different sources, and can be found anywhere on an airport's air operations area (AOA). FOD can cause damage to aircraft in the form of torn or punctured tires, punctured airframes, nicked turbine or propeller blades, and, in rare instances, even engine failure. FOD can also cause injury to airport employees as debris are propelled by jet blast, prop, or rotor wash. Whether in the form of a fuel cap, luggage tag, concrete chunk, or animal, FOD directly costs the U.S. aviation industry $474 million annually and the global aviation industry $1.26 billion annually. Direct plus indirect costs, such as flight delays, cost the U.S. aviation industry $5.2 billion annually and the global aviation industry $13.9 billion annually. Owing to the propensity of FOD to cause such extensive and costly damage, detecting and removing FOD from an airport's AOA is an extremely critical task for ensuring safety. As stated by E. Miart of Eurocontrol, "Runway safety cannot be understood without addressing FOD."

Historically, airports have conducted regular self-inspections to inspect for, detect, and remove FOD. Specifically, FAA Title 14 Code of Federal Regulations (CFR) Part 139.327 (applicable to U.S. certificated airports) requires that self-inspections be conducted daily. Although the airport operator is inspecting other areas (such as markings, lighting, and safety areas) for compliance during a self-inspection, an emphasis on FOD detection is an important part of every self-inspection. As stressed in Advisory Circular (AC) 150/5210-24, *Airport Foreign Object Debris* (*FOD*) *Management:*

> The presence of FOD on an airport's air operations area (AOA) poses a significant threat to the safety of air travel. FOD has the potential to damage aircraft during critical phases of flight, which can lead to catastrophic loss of life and airframe, and at the very least increased maintenance and operating costs. FOD hazards can be reduced, however, through the implementation of a FOD management program and the effective use of FOD detection and removal equipment.

In conducting regular self-inspections for FOD, airports are adopting a proactive approach. Proactive self-inspections serve to mitigate the hazards associated with FOD and ensure that FOD is detected and removed promptly upon detection. Additionally, reactive self-inspections may be part of a FOD management program. A reactive self-inspection may result from a pilot observing FOD on the runway and subsequently reporting this finding to Air Traffic Control, which then relays the FOD report to the airport operator to ensure its prompt removal. A reactive self-inspection may also be initiated after FOD is observed by Air Traffic Control and reported to the airport operator.

In an effort to better control FOD and minimize the hazards associated with it on the AOA, many airports have developed comprehensive FOD management programs. To provide guidance in this area, AC 150/5210-24 was released by the FAA in 2010. Although specific programs vary based on airport size and an airport's unique needs, these programs typically incorporate training, inspecting, detecting, removal, and documentation. Some airports even employ a FOD manager to promote the program and ensure a process of continuous improvement. This synthesis report details the components of a comprehensive FOD management program.

Owing to the extraordinary annual expense associated with FOD, new technology has been developed to allow airports to continuously inspect for and detect FOD. In 2009, in response

to this new technology, the FAA issued AC 150/5220-24, *Foreign Object Debris Detection Equipment,* addressing the requirements and standards for stationary radar, stationary electro-optical, stationary hybrid radar and electro-optical, and mobile radar. This synthesis report details each of these types of FOD detection systems.

There is currently a wide variety of practices, techniques, and tools that airport operators use to conduct inspections for FOD, including wildlife, on the AOA. These methods range from a simple visual inspection to continuous monitoring technologies. This synthesis reviews and compiles current practices, techniques, and lists of tools available for use or those currently being used by airports for FOD inspections. The report is primarily intended for airport operators, including management and staff responsible for conducting inspections, detecting and removing FOD, documenting FOD, and overseeing a FOD management program, including promoting an awareness of FOD prevention among all personnel.

This synthesis consists primarily of a literature-based review of self-inspection practices and regulations, as well as the current technologies that exist to detect and remove FOD. Sources for the literature review included the FAA, U.S.DOT, relevant studies and articles on self-inspections, FOD detection, prevention technologies, and the producers of FOD detection, removal, and prevention technologies and equipment.

To supplement this literature review, two distinct questionnaires were developed specific to this project. First, 56 airport operators, including domestic, international, and military, were selected to receive a 42-item web-based questionnaire. With a response rate of 89%, valid data were obtained on all components of an airport FOD management program, which are presented in detail in this report. In addition, 20 manufacturers and suppliers of technology and equipment for FOD management programs were surveyed using a 12-item web-based questionnaire. Although only 35% (7) of the manufacturers and suppliers responded, data obtained from manufacturer and supplier websites and product literature, as well as survey responses, provided sufficient information on the various types of equipment and technology available for use by airports in inspecting for, detecting, removing, and documenting FOD.

A summary of the findings from this synthesis, representing 50 airports throughout the United States and internationally, revealed that:

- Almost two-thirds of airports have a FOD management program.
- Most airports conduct inspections for FOD daily, relying on human/visual means.
- Many airports also conduct FOD walks, typically either weekly, monthly, or annually.
- Most airports detect FOD visually, with only some using fixed or mobile systems supporting either continuous or periodic surveillance.
- In addition to manually removing FOD by hand, most airports also utilize mechanized systems (such as power sweepers or vacuum systems) to remove the debris, with some airports relying on jet air blowers to displace FOD. Of the non-mechanized systems, only magnetic bars are used by most airports.
- Although most airports document FOD when it is removed, just over one-quarter of airports use an electronic database for documenting FOD.
- Just over half of airports use FOD letters, notices, and/or bulletins to maintain FOD awareness among airport employees.
- Less than one-fifth of airports employ a FOD manager. At half of the airports, responsibility for the FOD management program is carried out as part of an employee's existing job duties.
- To ensure the quality of their FOD management programs, most airports implement initial and recurrent training, as well as management oversight.
- During reduced visibility and nighttime conditions, only one-third of airports perform more frequent inspections to ensure effective FOD detection and removal. Almost half of airports have not implemented any additional measures during these conditions.
- If resources were available to enhance an existing FOD management program, almost three-quarters of airports would acquire equipment or technology for detection and/or removal.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Foreign Object Debris Defined

Foreign Object Debris (FOD) has been defined by National Aerospace FOD Prevention, Inc. (NAFPI) as "a substance, debris, or article alien to a vehicle or system which would potentially cause damage" (NAFPI n.d., p. 4). By defining FOD so broadly, any material that could possibly be found on the air operations area (AOA) could be defined as FOD. Outside the airport environment, small items such as nails, screws, and aluminum cans would only be considered a minor nuisance; however, if any of these items are ingested by an aircraft engine, they can lead to catastrophic results. Currently the FAA defines FOD as "Any object, live or not, located in an inappropriate location in the airport environment that has the capacity to injure airport or airline personnel and damage aircraft" (FAA 2010a, p. 1). The Australasian Aviation Ground Safety Council (AAGSC) defines FOD as "any object that is left in an area where it could possibly cause damage. Such debris includes, but is not restricted to, metal (e.g., tools, nuts, bolts, and lock wire), wood, stones, pavement fragments, sand, plastic wrapping, and paper" (AAGSC 2003, p. 21). Despite these definitions, at present no standard international definition of FOD exists. The FAA is currently working with the International Civil Aviation Organization (ICAO) to develop a standard definition of FOD for the international aviation community.

Introduction to Foreign Object Debris

FOD may be present on runways, taxiways, aprons, or ramps, and can affect an aircraft in a variety of ways. Because of where FOD is typically located, aircraft can be directly affected during critical phases of flight, such as take-off. Estimates place the worldwide direct costs of FOD, including damages caused by bird strikes, at $1.26 billion annually. Direct plus indirect costs of FOD and bird strikes, such as those costs created by flight delays, cost the global aviation industry $13.9 billion annually. In the United States alone, direct and indirect costs of FOD and bird strikes total $5.2 billion. When considering the direct and indirect costs of FOD not including damages caused by bird strikes, the United States experiences losses of $2.1 billion annually. At the top ten U.S. airports, FOD and bird strikes on runways alone create costs of $28.3 million annually (McCreary 2010). According to McCreary (2010, p. 247),

> Airlines at a 'typical' airport of 300,000 movements per year can expect to spend $12 million per year on the direct and indirect cost of FOD and bird strikes on the runway. For an airport of 400,000 movements the total climbs to just under $16 million per year.

Regardless of how FOD damages are quantified, they represent a significant expense for the aviation industry, both in the United States and globally. In addition to the economic costs of FOD, in extreme cases it can cause aircraft accidents resulting in loss. As Reid (2004, p. 28), explains, "EVERYTHING not nailed down can create big trouble."

	FOD Strikes	Bird Strikes
Total strikes per 10,000 movements	4.0	2.1
Runway strikes per 10,000 movements	2.1	0.7
Damage on the runway per 10,000 movements	1.6	0.1
	FOD Strike Direct Costs	Bird Strike Direct Costs
Average cost per strike	$10,000	$23,000
Average cost per 10,000 movements	$32,000	$47,000
Average cost per tire strike	$2,000	N/A
Average cost per engine strike	$33,000	N/A
	Direct + Indirect Cost of FOD + Bird strikes (in all areas)	Direct + Indirect Cost of FOD + Bird strikes (runway only)
Economic value lost to U.S.	$5.216 billion	$2.675 billion
Economic value lost to EU	$4.347 billion	$2.229 billion
Economic value lost worldwide	$13.910 billion	$7.133 billion

EU = European Union.

Note: Larger airports may experience 300,000 to 500,000 or more movements annually. Large airlines may conduct 600,000 movements annually.
Source: McCreary 2010, pp. 20, 158

Sources of Foreign Object Debris

FOD can be difficult to mitigate because of its unique characteristics. First, it can be generated from a number of sources. According to Advisory Circular (AC) 150/5210-24, *Airport Foreign Object Debris* (*FOD*) *Management,* FOD can be produced by:

- Personnel
- Airport infrastructure (pavements, lights, and signs)
- Environment (wildlife, snow, and ice)
- Equipment operating on the airfield (aircraft, airport operations vehicles, maintenance equipment, fueling trucks, other aircraft servicing equipment, and construction equipment) (FAA 2010a, p. 7).

Construction activities on an airport can be prolific generators of FOD if proper precautions are not implemented. Construction at an airport routinely causes debris, as construction items (e.g., as nails, screws, wood, or stone) can be blown onto the AOA. For this reason, among others, the FAA issued AC 150/5370-2E, *Operational Safety on Airports During Construction.* The AC provides guidance on how to minimize hazards (including FOD) generated by construction activity (FAA 2003). Specifically, the AC recommends adopting a safety plan with FOD control provisions spelled out. Section 3-14 of the AC, Foreign Object Debris Management, explains that:

> Waste and loose materials, commonly referred to as FOD, are capable of causing damage to aircraft landing gears, propellers, and jet engines. Construction contractors must not leave or place FOD on or near active aircraft movement areas. Materials tracked onto these areas must be continuously removed during the construction project. We also recommend that airport operators and construction contractors carefully control and continuously remove waste or loose materials that might attract wildlife (FAA 2003, p. 12).

FOD also has the ability to self-relocate, as debris collects on or near ground support equipment and in and around gate areas it can be picked up and propelled by jet blast or prop wash. FOD can also be relocated from runway and taxiway shoulders or grassy safety areas and propelled onto pavement surfaces by larger aircraft with outboard engines. Furthermore, FOD can be relocated by helicopters as they maneuver over freshly mowed grassy areas or areas with loose dirt. Helicopter rotor wash can also produce FOD, as lightweight equipment may become airborne when subjected to rotor wash (FAA 2010a; McCreary 2010).

> Many foreign nations and agencies, such as ICAO, European nations, and Australia are also conducting research and leading the way in FOD prevention. A ten-year study conducted from 1998–2008 by the Australia Transport Safety Bureau found that of the 398 ground-related aviation accidents/incidents during the study 116 (30%) were FOD related. Of the FOD-related accidents, 25% were caused by aircraft FOD and 19% were caused by misplaced tools and equipment. Highlighting how the long-term effects of FOD can be more detrimental to safety than short-term catastrophic accidents, of the 116 FOD occurrences only one resulted in engine ingestion and failure, and three resulted in a tire blowout. According to the findings, 80% of the FOD occurrences did not adversely affect the safety of the flight in any manner (Australia Transport Safety Bureau 2010).

Types of Foreign Object Debris

Although the FAA definition of FOD includes any item that could be found in the airport environment, some items are more common than others. Indeed, a one year airport study on FOD (FAA 2010a) discovered that nearly two-thirds of foreign objects removed from airfield pavement are composed of metal. Rubber was the next most common category at 18%. Additionally, data released by Delta Airlines in 2005 showed that 45% of the FOD damage sustained by its aircraft engines was caused by aircraft parts, including fasteners (McCreary 2010). Furthermore, according to AC 150/5210-24, typical FOD includes the following (FAA 2010a):

- Aircraft and engine fasteners (nuts, bolts, washers, safety wire, etc.);
- Aircraft parts (fuel caps, landing gear fragments, oil sticks, metal sheets, trapdoors, and tire fragments);
- Mechanics tools;
- Catering supplies;
- Flight line items (nails, personnel badges, pens, pencils, luggage tags, soda cans, etc.);
- Apron items (paper and plastic debris from catering and freight pallets, luggage parts, and debris from ramp equipment);
- Runway and taxiway materials (concrete and asphalt chunks, rubber joint materials, and paint chips);
- Construction debris (pieces of wood, stones, fasteners, and miscellaneous metal objects);
- Plastic and/or polyethylene materials;
- Natural materials (plant fragments, wildlife, and volcanic ash); and
- Contaminants from winter conditions (snow and ice).

> Hartsfield–Jackson Atlanta International Airport is considered to have one of the most effective FOD management programs relying on visual inspections. During 2008–2009, the airport documented the removal of 886 pieces of FOD over the course of 487 days. This equates to 10.6 pieces of FOD for every 10,000 commercial aircraft movements, equivalent to one piece of FOD for every 1,000 commercial aircraft movements. During this period, luggage and passenger equipment represented 46% of the FOD collected, concrete and bitumen 21%, ground vehicles and tools 18%,

whereas aircraft parts represented 1%. FOD that could not be categorized in these categories was categorized as "other" and made up 14% of the FOD collected. A full 83% of FOD during this period was collected on the ramp or on ramp/taxiway connectors.

Source: McCreary 2010, p. 122

In addition to the many types of FOD possible at airports, debris varies greatly in size. As McCreary (2010) explains, large FOD is mostly an issue of safety, whereas small FOD is mostly an issue of cost. Larger FOD includes "metal strips, hinges, thrust reverser parts, flap hardware, hose nozzles, fuel caps, large pieces of pavement, and tire chunks" (McCreary 2010, p. 109). If an aircraft strikes an item of this size, it may result in engine destruction or failure, landing gear collapse, tire failure, damage to aircraft control surfaces, and punctures to the airframe. Smaller FOD includes "pieces of gravel, aircraft fasteners, ice, rivet heads, [and] . . . small nuts and bolts" (McCreary 2010, p. 109). When ingested into an aircraft engine, small FOD can cause nicked, cracked, or broken turbine blades. Small FOD can also create gouges in tires and damage to the airframe.

In a 2004 study conducted by the United Kingdom Civil Aviation Authority (as cited in McCreary 2010), considered the most comprehensive record of runway FOD made publicly available, debris were categorized into 15 clusters by weight. The most common category of FOD (at 10%) was small debris weighing 0.07 to 0.14 ounces and ranging in size from 0.8 to 7.9 in. Examples of such FOD include small bolts, nuts, and aircraft fasteners. The next most common category (at 9%) was heavier objects weighing 5.29 to 7.05 ounces and ranging in size from 2.4 to 15 in. Examples of debris in this category include aircraft pins and nose gear door hinges. The third most common category (also at 9%) included objects weighing 14.10 ounces to 1.1 pounds and ranging in size from 5.5 to 23.6 in. Examples of debris in this category include thrust reverse parts, fuel caps, and small panel covers. Regardless of the size of debris discovered at airports, FOD management programs, according to McCreary (2010), must focus on both small and large categories of FOD.

NATURAL MATERIALS

Of the types of FOD previously mentioned, the category of "natural materials" deserves special attention. Natural materials are typically plant fragments or wildlife. Plant fragments may be in the form of grass clippings as a result of mowing or brush that has found its way onto the pavement. Minimizing FOD in the form of plant fragments can be remedied by choosing to perform activities such as mowing during down times of airport activity and thoroughly performing any necessary clean up after the activity has been completed. However, minimizing FOD in the form of wildlife is not a simple matter.

Of the many types of FOD, wildlife is unique. As stated by MacKinnon (2004, p. 49), "In our enthusiasm to minimize the Foreign Object Damage created by errant aviation hardware, we often forget that FOD also comes in a soft package." This "soft package" in the form of wildlife, represents "between 15% and 33% of the total FOD costs to the aviation industry" (MacKinnon 2004, p. 49). It is estimated that the annual total direct, indirect, and ancillary costs of wildlife-related FOD equal $1.2 billion worldwide (McCreary 2010). Clearly, wildlife FOD makes up a large part of the debris problem at airports and as this threat increases this type of FOD deserves special emphasis. Interestingly, evidence from airports with automated FOD detection technology has shown that there are many more birds on the runway than were previously suspected (McCreary 2010, p. 93). As explained by MacKinnon (2004, p. 51):

> The curtailing of DDT chemical use, successful wildlife conservation policies and laws, the reduction in pressure from hunting and natural predators, the availability of highly processed food in waste disposal facilities, global warming, and increased breeding success have all contributed to the remarkable population increases seen in some North American wildlife populations.

"Wildlife control officers and biologists suggest it is not surprising to find birds sitting on the runway surface. Ground feeding birds such as finches, sparrows, and thrushes often land in non-threatening open areas to eat. Game birds, rails, and crakes are all ground dwelling, and at some airports can be found loitering in grass on the runway edges—presumably because those edge sites offer a combination of sufficient views of the paved surface with some measure of concealment in the grass. For birds such as geese, flocking behavior means they tend to congregate on the ground in open areas. Eating behavior in seagulls and terns means they like hard flat surfaces to break open clams, crabs, and other crustaceans by dropping the shells from height. Crows have been known to drop items on runway and road surfaces as well. Additionally, birds, snakes, mice, and other ground creatures can be attracted to warm paved surfaces, especially at night. Such creatures often attract birds of prey such as owls and raptors, as well as an assortment of foxes, coyotes, and dogs" (McCreary 2010, p. 93).

Living animals are typically targeted by airports as part of their wildlife hazard management program. Using either passive or active techniques, or preferably both, airports can take action to minimize wildlife on an airport. Techniques such as habitat modifications, scare techniques, and fencing may prove quite effective. Although dead animals are quickly categorized as FOD, living animals can represent or even generate FOD at an airport, such as shore birds dropping mussels onto a runway to crack the shells. Whether living or dead, wildlife is not compatible with operations being conducted on the AOA, and the detection and management of living and dead animals on the AOA is one aspect of FOD management that rests with the airport operator. Although wildlife is typically the focal point of a wildlife management plan, it is possible to integrate a FOD management plan with a wildlife management plan. Rather than existing in isolation, these two plans can be complimentary. In essence, the wildlife management plan exists to mitigate aircraft–wildlife incursions and FOD in the form of wildlife. Although this synthesis does consider wildlife as FOD, the report only addresses FOD (including wildlife) and does not refer to wildlife hazard management programs, which is the subject of *ACRP Report 32: Guidebook for Addressing Aircraft/Wildlife Hazards at General Aviation Airports* (2010). Airports may also wish to refer to *Wildlife Hazard Management at Airports: A Manual for Airport Personnel,* published by the FAA in cooperation with the U.S. Department of Agriculture (USDA). Thus, the definition of wildlife for this study is limited to wildlife, whether living or dead, that would be characterized as FOD.

Because pilots are often the first to detect debris in the form of wildlife, it is important for pilots to always report any wildlife FOD accidents/incidents or near misses to the appropriate authorities, whether that is the airport operator, Air Traffic Control (ATC), operations personnel, or a fixed-base operator (FBO) operator/employee. More information on mitigating the presence of wildlife on or near airports may be found in AC 150/5200-33B, *Hazardous Wildlife Attractants on or Near Airports* (FAA 2007a). Although the FAA offers no guidance in this area and these systems are not specifically designed for this purpose, FOD detection technology can also aid the airport operator in preventing cases of wildlife FOD. Some fixed radar-based detection systems have the capability to detect birds and other animals that are present at the airport. When these detections are made, operations personal can remove the wildlife and ATC or the airport operator can inform pilots of any hazards that may exist. In most instances, wildlife as debris can be handled the same as other forms of FOD, in that it is continuously monitored and inspected for, as well as removed and documented according to the airport's FOD management program.

Airports are strongly encouraged by the FAA to voluntarily report wildlife strikes with civil aircraft by means of the FAA Wildlife Strike Reporting Form, which is available online. The FAA estimates that it takes 5 min to complete the 24 items on the form. Reporting strikes ensures that these events will be included in the National Wildlife Strike database, which is currently searchable online. The database includes more than 108,000 records of wildlife strikes occurring between 1990 and 2009 (FAA n.d.). There is room for progress with such reporting, as only 39% of the wildlife strikes at all Part 139 airports were reported between 2004 and 2008 (Dolbeer 2009).

Select Wildlife–FOD Accidents

Watertown, USA, 1975

On June 14, 1975, a NA265 Sabreliner crashed following takeoff after ingesting gulls in both engines. Both wings were torn off, resulting in a significant fire. Three of six people on board were injured and the aircraft was destroyed as a result of the crash and post-crash fire. The city of Watertown, which was sued by the Safeco Insurance Company, was found guilty of failing to warn the pilot of the presence of birds. Judgment for the full value of the destroyed aircraft was entered against the city.

New York, USA, 1995

On June 3, 1995, an Air France Concorde struck Canada geese during its approach and landing at John F. Kennedy International Airport. Two of the four aircraft engines subsequently caught fire and were destroyed. Air France sued the airport operator, the Port Authority of New York and New Jersey, for the $6 million cost of the two engines. After extensive legal costs for both sides, the parties reportedly settled for $5.3 million on the day before the trial. The airport, in this case, was faulted for not warning the flight crew of known Canada geese activity.

Source: MacKinnon 2004, p. 52.

Damage Caused by Foreign Object Debris

In the industry, FOD also refers to Foreign Object Damage. As defined by the NAFPI in this regard, FOD is "any damage attributed to a foreign object that can be expressed in physical or economic terms which may or may not degrade the product's required safety and/or performance characteristics" (NAFPI n.d., p. 4). Damage caused by FOD can result in incidents that range from a nick on an engine fan blade, a cracked windscreen, or, rarely, an aircraft accident. FOD creates the potential for significant losses, whether financially or in human terms. According to E. Gervais of Boeing Aircraft, "jet engines are basically just big vacuum cleaners" (as cited in McCreary 2010, p. 49). Further, McCreary (2010, p. 49) explains that engines are at greatest risk of FOD damage when at "high suck" and "low speed conditions." Thus, the danger of FOD is most pronounced during critical stages of flight, such as takeoff and landing. A 2008 study found that the world's 300 busiest airports deal with more than 60,000 incidents of FOD each year (McCreary 2008). The study estimated that $20 million worth of FOD damage is incurred at each airport annually, as the airports work to prevent, detect, and remove FOD from airport surfaces. Additionally, the average U.S. airline incurs $250,000 worth of maintenance costs from damage caused by FOD for every 10,000 movements performed by the airline. If an aircraft engine is damaged it may require blade burnishing, blade replacement, fan changes, or a complete engine overhaul (Figure 1). If the fuse-

FIGURE 1 Results of engine ingestion of FOD. *Source:* Jim Stephan, Delta Air Lines Corporate Safety, Oct. 25, 2005, FOD/ Wildlife, An Airline's Perspective presentation. [Online]. Available: http://www.fodnews.com/FOD_For_FAA-gif/slide001.htm.

FIGURE 3 Result of tire damage from FOD. *Source:* Jim Stephan, Delta Air Lines Corporate Safety, Oct. 25, 2005, FOD/ Wildlife, An Airline's Perspective presentation. Available: http://www.fodnews.com/FOD_For_FAA-gif/slide001.htm.

lage is damaged, it may require the repair of dents and holes (Figure 2). Tire damage results in the replacement of tires with cuts, loss of pressure, or complete failures (Figure 3). It can be noted, however, that damage from FOD more likely results from debris being thrown by prop wash or jet blast, not necessarily from sucking debris into an engine. As summarized by McCreary (2010, p. 28), "FOD strikes are unlikely to cause a major catastrophe, yet are the most expensive of the four identified runway risks" (the others being incursions, excursions, and birds). Interestingly, FOD strikes that cause actual damage are 5,500 times more likely to occur than even minor damage from an incursion (McCreary 2010).

In addition to damages to fixed-wing aircraft, helicopters may also be damaged by FOD. Unlike fixed-wing aircraft, helicopters are less susceptible to catastrophic FOD damage such as engine failures through ingestion, because the engine intake is on top of the helicopter. Even so, FOD-related damage to helicopters can occur over time through the accumulation of dust, sand, and other fine particles passing through the engine. Seventy-five percent of U.S. helicopter accidents in wars in Afghanistan and Iraq this past decade were directly caused by FOD. Historically, helicopters have had significant trouble with regard to FOD when landing in sandy and rocky areas (Fails 1978). Technologies have been developed to prevent sand, dirt, rocks, and other items from being blown into helicopter engines, such as portable helipad mattings that may be placed on landing areas. The U.S. Army is currently testing how successful these items are at minimizing FOD. In addition, helicopters can also cause debris to be dispersed to other areas of the AOA, which requires vigilance by airport operators of helipads and helicopter operating areas (Brower 2004).

Clearly, FOD is a true risk with significant consequences to the aviation industry. Whether a large or small airport, military or civilian, FOD not only impacts safety of operations, but also the bottom line. FOD also inconveniences airline passengers and results in thousands of hours of delayed flights each year. It is therefore extremely important for any airport to be aware of FOD and to have plans in place to detect and remove debris, as well as minimize the frequency of FOD on the AOA.

FIGURE 2 Result of fuselage damage from FOD. *Source:* Jim Stephan, Delta Air Lines Corporate Safety, Oct. 25, 2005, FOD/ Wildlife, An Airline's Perspective presentation. Available: http://www.fodnews.com/FOD_For_FAA-gif/slide001.htm.

Although rare, engine ingestion of FOD has also caused fatal aircraft accidents. A well-publicized accident with FOD as one of the casual factors occurred on July 25, 2000. On this day, Air France Flight 4590 was scheduled to depart from Charles de Gaulle International Airport in Paris, France, bound for New York. During the takeoff roll, the Concorde blew a tire after running over a piece of metal on the runway. Debris from the Concorde's blown tire immediately punctured the underside of the Concorde, which subsequently ruptured a fuel tank. Two of the aircraft's engines lost power as the result of an electrical short caused by fuel rushing out of the ruptured tank. These occurrences resulted in a fire that caused the wing to melt and the plane to crash. A thorough investigation revealed that the accident could be attributed to a small titanium strip that had fallen off a DC-10 that had landed on the runway before the Concorde's departure. This accident resulted in the loss of 113 lives in the aircraft and on the ground, financial losses for the airline, and the eventual grounding of the entire fleet of Concorde aircraft in operation. In December 2010, Continental Airlines and one of its mechanics were found guilty of criminal negligence in the Concorde crash. Even so, legal proceedings were expected to continue.

Source: BEA Accident Reports (2002); "Airline Guilty over Concorde Crash" (2010).

Addressing Foreign Object Debris

To effectively mitigate FOD, airports develop comprehensive management programs. Although the airport operator maintains the responsibility for a FOD management program, airlines, construction companies, and other agencies that have access to the AOA may have their own programs. Regardless of whether a tenant or contractor has a unique FOD management program of their own, their support of the airport's overall FOD management program is encouraged to minimize the risk of FOD in the airport operating environment. Indeed, Chaplain and Reid (2004) promote the concept of an Integrated FOD Team, which includes everyone concerned for the safety of the airport, such as flight crews, office staff, tenants, and visiting contractors and vendors.

Sample Airport Use License Clause

The Licensee shall in exercising its privileges:

a) At all times keep the airside surfaces free of all foreign objects and litter;
b) When directed by the Licensor acting reasonably, remove immediately from the airside surfaces or a portion thereof, its equipment and anything related to its operations;
c) At all times keep the Licensor's facilities in a neat, clean, and orderly condition, free from litter, debris, refuse, petroleum products, or grease that may accumulate thereon as a result of the use of the Licensor's facilities by its passengers or its employees, contractors, or others servicing and operating its aircraft;
d) Require its employees to abide by and comply with the Licensor's AVOP (Airside Vehicle Operator's Permit) Program and shall cooperate with the Licensor in airside safety matters and enforcement of the AVOP Program; and
e) Not engage in or allow any activities which may result in a nuisance or that may cause annoyance to adjoining occupants or any other users of the Airport, the whole as determined by the Licensor, acting reasonably.

(Larrigan 2004, p. 69).

In advising airports on this issue, the FAA issued Cert Alert No. 09-06, *Closing Active Runway for FOD Checks Increases Safe Operation* (2009b). It states, in part:

> The FAA's Office of Safety and Standards has been made aware of instances where some airports have failed to take immediate and positive action following a report of FOD (on or near the runway) from flight crews. In one instance, operations on an active runway continued for several minutes following a report of loose aggregate material (of a size that posed a threat to aircraft operations) on the runway. Stressful situations have added fuel to this debate by fostering opportunities where a controller or pilot reports FOD but operations are continued until someone arrives to clear the debris from the runway. While the temptation to continue operations on a contaminated surface may be strong, particularly during periods of increased traffic movement, airports must never lose sight of the primary goal, which first and foremost is safety of flight.

The manner in which airports accomplish this primary goal of safety of flight may vary, but an effective FOD management program is integral to achieving that goal. The FAA, in AC 150/5210-24, has identified the four main components of a FOD management program (FAA 2010a) as follows:

1. FOD Prevention
   a. Awareness
      i. Program existence and status
      ii. FOD policy and management support
      iii. Safety culture.
   b. Training and education
      i. Audience
      ii. Features
      iii. Training objectives
      iv. Training documentation.
   c. Maintenance programs.
2. FOD Detection
   a. General
   b. FOD risk assessment
   c. FOD detection operations
      i. Inspection areas
      ii. Methods and techniques.
   d. FOD detection equipment.
3. FOD Removal
   a. Background
   b. Equipment characteristics
      i. Mechanical systems
      ii. Non-mechanical systems
      iii. Storage systems.
   c. Performance
      i. Operational standards
      ii. Testing/validation.
   d. Removal operations.
4. FOD Evaluation
   a. Data collection and analysis
      i. Documentation
      ii. Reporting
      iii. Investigation
      iv. Database.
   b. Continuous program improvement.

In addition to the areas spelled out in AC 150/5210-24 (FAA 2010a), other resources are available to airport operators for developing an effective FOD management program. For instance, Dave Larrigan (2004, pp. 70–77) in chapter five of *Make it FOD Free!* suggests the following ten elements of an effective FOD prevention program:

- Management's strong, visible commitment
- Local FOD committees
- Housekeeping performance standards
- Training and awareness
- Selection and maintenance of ground support equipment (GSE) and airfield maintenance equipment
- Spare parts and tools
- Airport construction projects
- Motivating construction crews to understand FOD threats
- Monitoring and inspection
- Seasonal considerations.

Furthermore, Simmons and Stephan (2004, pp. 95–97) suggest the following components of a FOD prevention program:

- Organization
- Policies and procedures
- Vision
- Measurement tools
- Investigations of incidents and accidents
- Feedback procedure
- Establishing goals.

San Antonio International Airport (SAT) has a well-developed FOD prevention program that according to Ryan Rocha, Interim Assistant Aviation Director, cost approximately $10,000 to establish and costs $6,000 per year to maintain. The vision of their program is to "develop and maintain a FOD Prevention Program that addresses and resolves FOD issues and establishes a culture of safety that promotes a zero-tolerance policy for airfield FOD through encouragement, training, collaboration, and commitment." To accomplish this, they first involved stakeholders, including the aviation department, airlines, FBOs, and air cargo. They developed a FOD committee with one representative from each organization, mostly from the manager level. This committee, which meets monthly, sets policy for the FOD program and exhibits management commitment to the FOD program. The FOD Squad is comprised of the members of each organization involved in the FOD program and meets at quarterly FOD squad walks. The FOD prevention program at SAT enhances awareness and participation by developing a new FOD campaign every six months, with a new design to be placed on t-shirts, posters, and stickers. Each campaign has the following components:

- FOD inspections
  - Inspections of each airline gate area, air cargo ramp area, and every FBO area.
  - Conducted by airport operations bi-weekly, with a notice sent to tenants at least 24 h in advance.
  - Surprise inspections conducted twice during every six month campaign.
  - Airlines are given a score per gate that is averaged, with FBOs and cargo airlines given a single score for their entire leasehold. Airlines compete by airline size.
  - Found FOD is photographed, with a score assigned based on the number of pieces found.
    - △ 0 pieces of FOD = 100%
    - △ 1–2 pieces of FOD = 90%
    - △ 3–4 pieces of FOD = 75%
    - △ 5 or more pieces of FOD = 50%.
  - Scores are maintained in a database and tenants have the opportunity to raise scores by participating in FOD committee meetings and FOD squad walks.
- FOD squad walks
  - Scheduled and coordinated by airport operations
  - Lasts one hour
  - Food and beverages are provided
  - Incentives
    - △ Find a gold bucket, earn a gift card
    - △ Turn in a FOD bag and pick either a FOD t-shirt or cap.
  - Group photo after every FOD walk.
- Awards ceremony
  - Six month and annual
  - Awards based on FOD inspection score, FOD squad walk participation, and FOD committee participation
  - First place receives trophy with second place receiving a certificate.

The program at SAT has been successful in preventing the accumulation of FOD, increasing FOD awareness, increasing participation from stakeholders, and increasing communication with stakeholders resulting in cleaner gates, aprons, and airfield areas; in industry recognition; and a proactive approach to a Safety Management System (SMS).

Source: Ryan E. Rocha, San Antonio Airport System, Nov. 18, 2010, San Antonio International Airport FOD Prevention Program Presentation [Online]. Available: http://www.faa.gov/airports/great_lakes/airports_news_events/2010_conference/Media/A-5_FOD_Program.pdf.

Although variation exists in how to best structure a FOD management program, to allow for the most efficient organization of collected data, this report has been organized around the following five main areas:

1. Inspection
2. Detection
3. Removal
4. Documentation
5. Training and Promotion.

OVERVIEW OF STUDY

Scope of Study

The focus of this study was on current airport inspection practices regarding FOD. Airports conduct self-inspections for a variety of purposes, but this study focused solely on those inspections for FOD. In addition, the definition of wildlife for this study is limited to wildlife, whether living or dead, that would be characterized as FOD. Although the synthesis focuses on inspection practices, this study approached FOD from a comprehensive perspective and, as such includes chapters on inspection, detection, removal, documentation, and promotion and awareness. Each chapter not only addresses requirements, but also presents current airport practices and specific technology and equipment available for airports in carrying out each specific component of a FOD management program. Although the majority of airport operators surveyed for this synthesis operate in the United States, and the bulk of pertinent information found through the literature review dealt with FOD in the United States, this report included FOD programs and technologies that exist across the world, in addition to those pursued by the U.S. military.

Study Methodology

To best determine the current state of practice on FOD management at airports, this synthesis was carried out using a comprehensive approach. Information used in this study was acquired through an extensive literature and data review, two surveys, follow-up interviews of survey respondents, contributions from panel members, and the author's professional knowledge of the subject area.

At the outset, a literature and data search was conducted to document regulations for conducting FOD inspections on the U.S. and international levels. Additionally, the literature was reviewed regarding all aspects of FOD management. The search focused on the following: (1) 14 CFR Part 139; (2) relevant state and international regulations on the subject matter; (3) other federal guidance such as CertAlerts and Advisory Circulars; (4) relevant literature in the forms of books, magazines, reports, and surveys conducted on the various aspects of FOD; and (5) examination of current products that exist on the market to prevent, detect, and remove FOD from an airport's surface.

Survey instruments were developed to gather data from a sample of airport operators, as well as the population of manufacturers of technology and equipment considered beneficial for a FOD management program. The first questionnaire, "Airport Survey of Inspection Practices" can be found in Appendix B. This questionnaire, which consisted of 42 items, was designed to solicit perspectives from airport managers and/or operations personnel regarding their current airport inspection practices for FOD. Specifically, the purpose of this questionnaire was to determine the tools (including equipment and technology) and procedures airport personnel are using in carrying out the following components of a FOD management program: inspection, detection, removal, documentation, and promotion and awareness. Also, the questionnaire sought to identify reasons why airports adopted various tools and procedures.

The second questionnaire developed for this synthesis, "Survey of Manufacturers/Suppliers of Airport Inspection Technology and Equipment," can be found in Appendix C. The questionnaire was sent to all manufactures and/or suppliers of equipment and technology considered useful to airports in conducting inspections, as well as detecting, removing, and documenting FOD. The purpose of the questionnaire was to determine the entire spectrum of equipment and technology currently available to airports for carrying out a comprehensive FOD management program. With this information, a continuum of available technology and equipment (depending on the specific component of a FOD management program) was developed. Although the initial effort involved an attempt to determine pricing for the various technology and equipment; typically, manufacturers were reluctant to provide this information. This is the result, in large part, to the very site-specific nature of the technology currently available. Costs vary owing to civil engineering requirements, airfield complexity, and specific airport needs. Thus, airports interested in acquiring equipment or technology for a FOD management program are encouraged to consult with specific manufacturers or suppliers to determine pricing for their intended application.

Great care was taken to ensure that the methodology for the survey implementation was both sound and strategically orchestrated. For instance, to obtain a nationwide representation of airports and manufacturers/suppliers, the FAA's nine regions were utilized. Within each region, an attempt was made to select one airport from each of the following categories: large hub, medium hub, small hub, non-hub, and general aviation (GA). In addition, where possible, two military airports were selected from each of the five U.S. branches of the military, as well as five non-U.S. airports. After revising the sample based on the recommendation of panel members, the study included a total sample size of 56 airports. Because of the relatively small population of manufacturers and suppliers, the entire known population of manufacturers and suppliers was included; 20 companies. The population of manufacturers/suppliers was developed from an Internet search and review of the literature.

To aid in survey distribution and simplify responses, the questionnaires were created in, and distributed by, means of a web-based survey management platform. Once contact information for the 56 participating airports was uploaded, participants were sent an e-mail explaining the purpose of the study and containing a link to the online questionnaire. Once the recipient clicked on the link to access the survey, they were presented with an introduction of the study and a consent request. By clicking "Next," participants were then directed to the first page of the questionnaire. In an effort to reach the desired 80% response rate, multiple contacts were used. Two e-mail follow-ups were sent after the initial invitation e-mail,

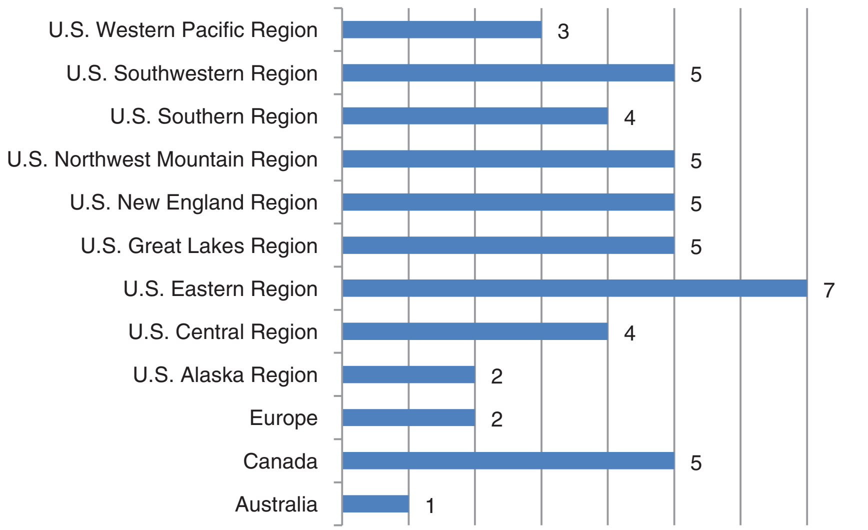

FIGURE 4 Airport respondent self-selected geographic location. *Note:* Two airports did not indicate FAA region or geographic location.

followed by a phone call from the consultant, followed by personal contact by individual panel members as necessary. This effort was sufficient and eventually resulted in an 89% response rate (50 airports).

Participating Airports

Data were collected from 50 airports. Appendix A lists these participating airports and Figure 4 presents the breakdown of respondents by FAA region.

In addition to the wide geographic distribution of respondents, the airports participating in this synthesis were of almost any size. Figure 5 presents the airport respondents by airport category or size.

In addition to categorization by hub size, the questionnaire also determined the size of the responding airports by the number of operations. The airports participating in this synthesis also include a wide range of airports in terms of annual operations. Figure 6 shows airport respondents by annual operations.

Lastly, in a final effort to fully understand the airports participating in the synthesis, participants were asked their airport certification status. Although the majority of participants were larger, Class I airports (as specified by Part 139), other categories (including international) were represented as well. Figure 7 presents airport respondents by certification.

As shown in Figures 4–7, the synthesis collected data from a diverse group of airports. Specifically, participating airports represent all FAA geographic regions and some international

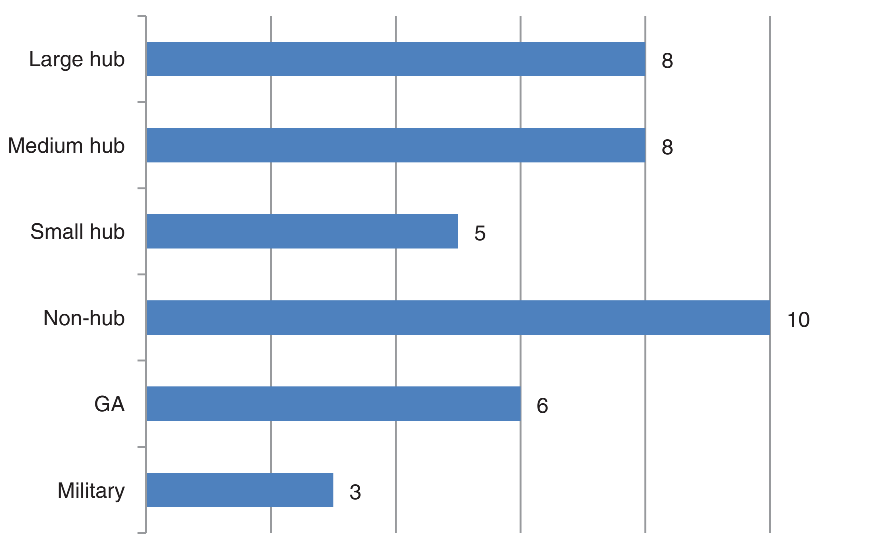

FIGURE 5 Airport respondent self-selected hub size. *Note:* Ten airports did not indicate airport size.

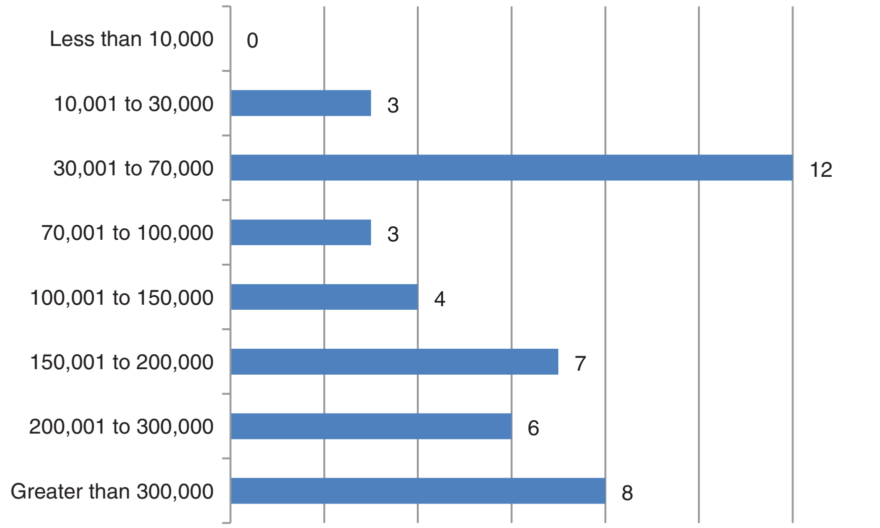

FIGURE 6 Airport respondent self-selected number of operations. *Note:* Seven airports did not indicate classification status.

countries, as well as all hub sizes. Airports vary in size by number of operations and represent all classes of 14 CFR Part 139 (with the exception of Class III), as well as ICAO Annex 14 (ICAO n.d.).

Report Organization

This report has been organized into seven chapters. Chapter one introduced the concept of FOD, provided examples, and detailed the scope and objectives of the project. Chapter two focuses on the methods used to inspect for FOD, as well as current airport practices and technology and equipment available for inspections. Chapter three presents the methods used to detect FOD, as well as current airport practices and technology and equipment available for FOD detection. Chapter four presents the methods used to remove FOD, including both mechanized and non-mechanized systems. In addition, this chapter presents current airport practices, as well as the technology and equipment available for FOD removal. Chapter five presents the methods used to document FOD and analyze data, as well as current airport practices and technology and equipment available for FOD documentation and analysis. Chapter six presents the concepts of training and promotion, and includes current airport practices on this topic. Chapter seven presents concluding thoughts on FOD management and summarizes the major findings of the synthesis. Each chapter generally first presents information gleaned from the literature review, before presenting equipment and technology currently available, followed by current airport practices. There is additional supporting information in the appendices.

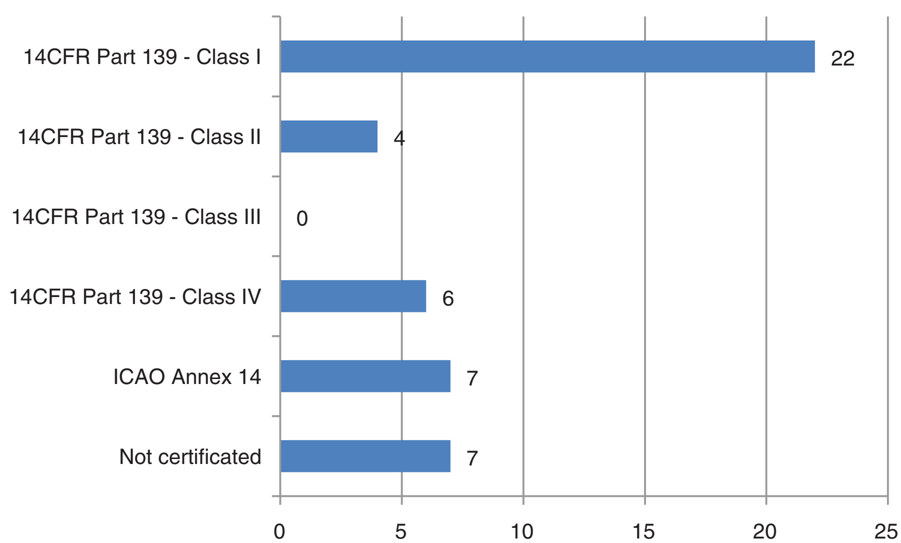

FIGURE 7 Airport respondents by certification. *Note:* Four airports did not indicate certification status.

CHAPTER TWO

INSPECTION

Adequately controlling FOD at any airport begins with a regularly scheduled inspection program. Inspection refers to examining something closely, typically to assess the condition or to discover any shortcomings. In this case, it would be in the form of proactively conducting airfield inspections to monitor for and mitigate any hazards related to FOD. Reactively, this might be in the form of response to FOD as reported by the ATC. With this response, debris can then be removed from the AOA. Whether reactive or proactive, the inspection component is integral to an effective FOD management program.

> Imagine standing on an empty highway at night. It is two miles long and ten lanes across. You are told that someone may or may not have dropped a two inch long, dark colored metal fastener somewhere out here, and your job is to make sure the route is clear before an airplane rolls down the highway. Find the FOD. You have two minutes. . . .
>
> *Source:* McCreary 2010, p. 177

CURRENT REQUIREMENTS AND GUIDELINES

Current inspection requirements for certificated airports in the United States are primarily found within Part 139 (FAA 2004a). Section 327 of Part 139, Self-Inspection Program, spells out that certificated airports are required to conduct daily self-inspections. Specifically, certificated airports are required to conduct daily self-inspections when required by any unusual activity and immediately after an accident or incident. Although U.S. airports typically conduct inspections twice daily, once during daylight hours and once at night, the night inspection is not required and meant to mainly check lighting. The FAA provides guidance in conducting inspections, both within Part 139 and in ACs. For instance, AC 150/5200-18C, Airport Safety Self-Inspection, stresses that the “inspector should continuously check for, and remove any FOD in movement areas, aircraft parking areas, and loading ramps” (FAA 2004b, p. 12).

Although there is no regulatory requirement for GA airports to conduct inspections, it is a recognized best practice for all airports, including the smallest GA airport, to regularly inspect the AOA for FOD, among other items. By conducting daily inspections and having procedures in place for FOD to be reported upon discovery by pilots, especially at non-towered airports that are at times unattended, airports can play an active role in FOD prevention. Whether procedures dictate that observed debris be communicated to the on-call airport representative or the FBO, it is important for sufficient emphasis to be placed on FOD detection and removal to enable removal of debris even during nighttime or weekend hours.

In addition to FAA guidelines for U.S. airports, international airports located outside the United States must also comply with various inspection requirements. For instance, ICAO recommends that airports, by means of ICAO Annex 14, *Aerodrome Design and Operation,* conduct inspections four times daily, or about every 6 h (ICAO n.d.). This standard was actually set by the Provisional ICAO in 1944. At the time, Chicago was the largest airport in the world and the four per day routine required inspecting the runway every 10 to 15 movements. Although the four per day standard has been preserved in Europe and Australia, the United States soon adopted a one per day requirement, which remains in effect (McCreary 2010).

INSPECTION AREAS

A critical aspect of the inspection component of any FOD management program includes knowing the most common areas in which debris are found. These areas vary among airports and, as McCreary (2010, p. 138) explains, these areas are influenced by many factors, including:

- Airport age
- Airline ramp practices
- Aircraft types
- Distance to repair hangars
- Construction activity
- The nearness of buildings
- Aircraft loading practices
- The mix of passenger versus cargo traffic
- Cargo types
- Mix of ground vehicles in use
- Pavement types
- Surface cleaning/sweeping regime
- Weather and the number of winter operations
- Maintenance practices.

The first and perhaps most critical inspection area on the AOA is the movement area, encompassing both runways and taxiways. The movement area is critical because it is used by each arriving and departing aircraft and hosts the most critical stages of flight; that is, take-offs and landings. As McCreary (2010, p. 121) explains, "While a clean ramp is certainly important, forensic analysis shows that 50% of strikes occur on the runway. . . . [Therefore,] the runway is the key to improved safety and reduced costs." Stated another way, "FOD awareness programs [sic] tend to focus attention on the ramp, where most debris is found, rather than on the runway where most strikes occur" (McCreary 2010, p. 103). One source of FOD on paved surfaces is from cracked, chipped, and broken pavement. Pieces of concrete and asphalt may break loose owing to fatigue, requiring older pavements to undergo more frequent inspections. Broken pieces of pavement can also collect on the edges of ramps, and be carried onto the movement areas by prop wash, jet blast, or the tires of airline or operations equipment or vehicles. By closely monitoring service roads that intersect taxiways, airports can quickly detect and remove FOD from taxiways left by vehicles using the service road. Unpaved shoulders adjacent to pavement, especially if not stabilized, may also generate FOD. Paved shoulders mitigate this concern to a great degree. By inspecting pavement joints, additional sources of FOD can be detected. Turf areas, in the form of safety areas and object-free areas, may collect and retain a large amount of debris, such as paper, cardboard, and plastic. This debris can be blown into areas travelled by aircraft unless collected regularly. Finally, fence lines can collect trash during windy conditions. This debris should be collected before the wind direction changes or increases to avoid debris being blown onto areas travelled by aircraft (FAA 2010a).

The second main portion of the airport to be inspected for FOD includes apron areas (FAA 2010a). By inspecting apron areas, especially at larger airports that offer air carrier service, debris can be detected and removed to prevent damage to aircraft. GA ramps and terminals also accumulate FOD that presents dangers to aircraft. Any areas on the apron upon which ground vehicles operate have the ability to produce FOD.

The third area to be inspected includes areas hosting aircraft servicing operations. Although much of this activity may occur on airport aprons, the FAA differentiates this activity because of its ability to generate substantial FOD, as contrasted with an empty ramp area. As baggage is handled, FOD can be generated in the form of an entire piece of luggage, a wheel, luggage tag, carrying strap, or TSA security tags. Refueling operations can also generate FOD in the form of unsecured fuel caps, ladders, traffic cones, and fuel spills. Likewise, catering activities can generate substantial amounts of FOD. The food provided by catering services often comes in a variety of cardboard and plastic packaging, which, if not properly disposed of, can easily be blown onto the terminal or a movement area. FOD may also collect at both ends of the conveyor, and between the baggage cart and the conveyor belt (FAA 2010a). As McCreary (2010, p. 139) notes, "The ramp is a major source [of FOD], with the gate as the 'dirtiest' source."

Fourth, it is important to regularly inspect air cargo operations for FOD. Air cargo operators deal with substantial amounts of cargo, which can come packaged in a number of ways. All of this packaging creates the potential for blowing debris, especially in the form of plastic wrappers, plastic strapping bands, and cardboard. Continuous surveillance and fencing are two traditional remedies for the FOD problems that may accompany cargo operations (FAA 2010a).

Yet another area to be considered concerns those capital improvement and maintenance projects that can result in FOD. Outside contractors often do not understand the significance of FOD and will not make an effort to prevent FOD if not properly trained by the airport. By educating contractors about FOD and the risks it creates, contractors will be more likely to curb construction debris and regularly clean up the construction site. When planning for projects on the AOA, whether performed in-house or by outside contractors, airports may wish to consider including a means for routinely checking and restricting debris. As previously mentioned, the FAA has issued AC 150/5370-2 to address FOD and other safety-related items during construction projects. The AC encourages airports to hold contractors responsible for complying with the requirements of the airport's FOD management program and any construction safety plans (FAA 2003). In addition, according to the FAA the airport operator should inspect all construction areas for debris on a daily basis, as well as remaining aware of the potential for vehicles to track FOD from construction areas onto the airport's movement areas. Smaller pieces of FOD, such as gravel, can become lodged in the tires of a vehicle, and then become dislodged on a runway or taxiway if the tires of the vehicles travelling between these two areas are not inspected before every trip. Some airports have found it a best practice to require the contractor to follow all vehicles traversing paved areas with a sweeper truck to remove any debris immediately. Another option, in the form of rumble strips, is discussed in chapter four (FAA 2010a).

The final area considered important for FOD inspection includes aircraft maintenance areas. A large number of tools and hardware are typically used in maintenance areas and these items may inadvertently be left on an aircraft or vehicle, which may find its way onto the ramp or taxiway. Within hangars, airlines perform FOD checks as part of daily safety checks, have FOD free verification on work cards, and ensure end-of-shift and task clean-ups. In component areas, there are clean-up days and routine vacuuming and metal pick-up. Line maintenance typically performs worksite analysis and housekeeping, daily safety briefings, and FOD accident investigations. Additionally, visual aids may be used to assist mechanics in this pursuit, specifically checklists, shadow boards (composed of an outline of each tool's proper storage location), or tool trays (FAA 2010a).

INSPECTION TECHNIQUES

There are currently two ACs that provide techniques for conducting inspections for FOD. First, AC 150/5200-18C, *Airport Safety Self Inspection* (FAA 2004b, p. 4) suggests:

> Inspectors should vary the pattern of the inspection. Fixed inspection patterns, while easy to learn, do not provide for an adequate inspection. The use of such fixed inspection patterns can lead to complacency and to the possibility of missing items that are in need of correction. When conducting an inspection on a runway and when there is time to do only one pass on that runway, inspection personnel, whenever practical, should drive towards the direction of landing aircraft with high intensity flashing beacon and headlights on day and night. This practice will enable self-inspection personnel to see approaching aircraft and improve visibility of the vehicle to pilots. However, it is recommended that a runway inspection be done in both directions. Inspection personnel should also drive the stub taxiways between the runway and parallel taxiway as these areas are commonly overlooked.

Although AC 150/5200-18 refers to all types of self-inspections, AC 150/5210-24 refers specifically to FOD inspections. Specifically (FAA 2010a, p. 17):

> The FAA and ICAO require a daily, daylight inspection of aircraft operating areas. Operational areas must be inspected at least once each day, with additional inspections being made in construction areas and immediately after any aircraft or ground vehicle accident or incident or any spill of material which may cause slippery conditions. In addition to performing these inspections at the beginning of the day or shift, personnel in the AOA should practice a clean-as-you-go technique of looking for FOD during their normal shifts in the course of their regular duties. Inspections occurring at night, taking place after the runway is closed or before the runway is opened, also occur frequently. During night time inspections, personnel and vehicles should be equipped with additional lights/lighting systems to better detect FOD.

In addition to these ACs, there are some additional inspection techniques that airports may wish to consider. First, airports may differentiate between proactive inspections and reactive inspections. Proactive inspections are those conducted on a regular basis, whether once per day or every 6 h, to inspect for FOD (as well as other airfield items). Reactive inspections are necessary once FOD has been reported. This involves reacting to a FOD event by responding to the AOA and removing the debris, initiating any corrective action, and documenting the FOD event. All successful FOD management programs use both proactive and reactive inspections.

When conducting a reactive inspection (i.e., responding to a FOD report), it is beneficial to inspect areas in addition to that where debris were reported; FOD may have relocated since it was reported. Likewise, location reports may be inaccurate. If, for example, a rock was reported and that rock was removed, inspection of the surrounding area might reveal a larger spall with additional debris that need removing. If inspection personnel respond to a FOD report and discover nothing, it is important that additional areas (both pavement and non-pavement) be inspected in an attempt to locate the debris. This may mean that a reactive inspection transforms into a proactive inspection, as inspection personnel begin searching for additional FOD that may have not been reported.

Next, although many airports utilize operations personnel to conduct inspections for FOD, some airports also rely on Aircraft Rescue and Fire Fighting (ARFF) personnel, maintenance personnel, and police personnel. At some airports, such as Vancouver International Airport, ARFF personnel may respond to remove debris, because ARFF personnel can often do this more expeditiously than operations personnel who may be inside a terminal building at the time (B. Patterson, personal communication, 2010).

Next, when considering the actual time to conduct an inspection, airports may wish to consider shoulder periods; that is, those lower traffic periods either before or after peak. At many U.S. airports this tends to be around 9:00 a.m. local time. When conducting inspections at night, by focusing on active runways, inspection personnel can then inspect inactive runways before they are used. It may also be helpful to integrate inspections with aircraft arrivals and departures. At Vancouver International Airport, for instance, self-inspections are integrated within aircraft arrivals and departures by filing for two departure slots to allow the inspection personnel the time to sufficiently perform an inspection on the runway. This allows about 3 min per runway, every 6 h (B. Patterson, personal communication, 2010).

Yet another issue when conducting inspections is the type of aircraft using the airport. If only propeller aircraft use the airport, inspection personnel may wish to consider prop wash and focus near the center of pavement areas. Airports serving wide-body jets, on the other hand, may wish to consider the consequences of jet blast and focus inspections on runway and taxiway shoulders, in addition to the center of pavement areas. Airports with jet service that do not have asphalt paved runway shoulders may wish to consider this airfield improvement.

PREVENTION TECHNIQUES

In addition to inspections for debris, proper housekeeping can go a long way in preventing FOD on the front end. As shared by Reid (2004, p. 30), "Almost every FOD incident can be traced back to bad housekeeping." Although this may not be true for wildlife and other natural FOD, it is certainly true for items such as packing material and tools. Therefore, good housekeeping practices are an essential part of FOD prevention techniques. Specifically, as promoted by Reid (2004, pp. 30–31):

- Keep your house and equipment in good repair
  - Equipment that is worn out and broken may leave a part behind, not noticed until someone runs up an engine.
- Watch your "stuff"—materials, packaging, etc.
  - All packing material, binding tapes and wires, string, pieces of cardboard, wood, and plastic must be picked up and disposed of properly. Delivery personnel must

also be attended to, to make certain they leave no debris behind.

- Pretend the Tool Lady/Man is coming to visit
  – By pretending that management or "company" is coming for a visit or inspection personnel are motivated to tidy up. Tool control is of utmost importance and may take many forms, including foam cut-out tool shadow panels in toolboxes, formal checkout procedures, and electronic tracking. A best practice is to take only those tools needed for a job, carry, count, and use them with the same routine, and thoroughly check a work area when finished.
- Parting is the key to avoiding "sweet sorrow"
  – The number of parts, pieces, connectors, caps, and fasteners must be tracked and controlled. Parts control, as with tool control, is critical.
- Track it and tie it down!
  – Prop wash and jet blast turn loose items into flying missiles. Personnel must operate as if someone is about to start an engine by keeping tools, materials, clipboards, and other items secure and in their proper places.
- Write it down and talk it up
  – Personnel should be encouraged to observe, analyze, and communicate with supervisors to ensure that unsafe practices are eliminated and safety is improved.

The European Organization for the Safety of Air Navigation (Eurocontrol) suggests European airports do the following to prevent FOD occurrences (Chadwick et al. 2010, p. 22):

- Clear loose material from land adjacent to the movement areas.
- Wash the tires of visiting vehicles before they are allowed to go airside.
- Maintain all airside vehicles in a good state of repair and cleanliness.
- Provide Foreign Object Bins for use by airport personnel.
- Make sure all airside personnel are properly trained and made aware of foreign object damage.
- Communicate with all stakeholders and actors to maintain awareness of foreign object damage.

CURRENT EQUIPMENT AND TECHNOLOGY AVAILABLE FOR INSPECTION

Inspection Continuum

The equipment and technology available for airports in inspecting for FOD falls along a continuum. This continuum ranges from using a vehicle with a manual checklist to using a vehicle with a GPS/GIS-based inspection and database application. As with all technology, prices vary by the size of the airport and the degree of technology in use. Generally, more technology equates to higher costs, although each airport may wish to evaluate the use of technology in its specific situation as the benefits in efficiency achieved with the adoption of technology may not only enhance employee morale and reduce operational staffing needs, but also improve the rate of debris detected on the airfield. The continuum in Figure 8 has been developed to present the range of options available to airports.

Manual

For most airports, the first line of defense against FOD has been, and continues to be, human observation. To aid the individual with the inspection, manual equipment (such as a vehicle) is often relied on, which typically involves an employee driving a vehicle onto the airport surface for observation and completing a paper-based inspection or FOD checklist. Although this has been an accepted practice for years to meet FAA requirements, some airports have adopted various forms of technology to enhance this process and improve the efficiency of their human observations. Rather than completing a paper-based checklist, airports may implement an electronic checklist, typically loaded onto a PDA (personal digital assistance), tablet personal computer, or notebook computer. This technology allows the individual to elec-

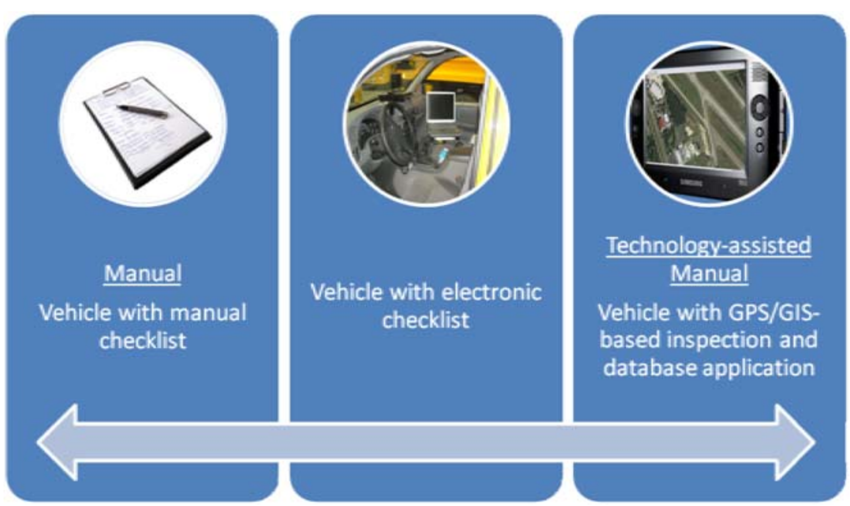

FIGURE 8 Continuum of technology and equipment available for inspection.

tronically complete a daily self-inspection checklist or a FOD reporting form, typically while still in the vehicle. By syncing it with the airport's inspection database records are easily maintained and trend analysis is easily performed.

Technology-assisted Manual

The final step on the continuum involves use of a GPS/GIS-based inspection and database application. This technology provides the user with the ability to pinpoint the exact coordinates of FOD as well as other airfield discrepancies using GPS coordinates, allowing maintenance personnel, for example, to quickly locate discrepancies that were discovered by operations personnel, rather than relying on a written description of where a discrepancy is located. Prior to this technology, for example, edge lights along a runway were numbered and if a light needed attention the light number was forwarded to maintenance for resolution. Many of the GPS/GIS-based platforms overlay the exact location of an item needing attention onto a graphic of the airfield, simplifying the subsequent location of identified items.

CURRENT AIRPORT INSPECTION PRACTICES

Degree of Problem

Of the airports participating in this synthesis, only 18% believed that FOD was not a problem at their airfield. This minority was overshadowed by the 56% who stated that FOD is somewhat a problem, 24% that FOD is a moderate problem, and 2% who noted that FOD is a severe problem at their airfield. By inferring these results to airports nationwide, one can conclude that FOD is clearly a problem of some degree at airports nationwide.

Use of Foreign Object Debris Management Program

Sixty-five percent of the airports participating in this synthesis currently have a FOD management program in place. Among the large hub airports, 75% have a FOD management program in place, whereas only one-third of GA airports have such a program. FOD management programs are typically formal programs with an emphasis on inspection, detection, removal, documentation, and promotion and awareness. Even so, of the 35% of participating airports that do not currently have a FOD management program in place, only 12% have plans to implement such a management program during the next 12 months.

Methods in Use

When queried about the inspection methods an airport currently uses, not one airport answered that they do not inspect for FOD. Thus, all participating airports inspect for FOD using one or more methods. As can be seen in Table 1, on a daily basis, the majority of participating airports utilize a visual inspection process, not including FOD walks. This typically involves an airport employee (generally from either the operations or maintenance department) driving a vehicle down taxiways and runways during a daily airfield inspection, all the while keeping an eye out for debris. On a daily basis, it appears that 26% of participants also use FOD walks to some degree along with their visual inspection method. FOD walks appear to be used by an additional 18% on a weekly basis, an additional 12% use them on a monthly basis, and a further 6% use FOD walks annually. Based on survey responses, a daily FOD walk may only include a ramp area, whereas monthly or annual FOD walks may involve closing a runway. Combined these responses suggest that 62% of participating airports utilize FOD walks on at least an annual basis.

Although not a new concept, FOD walks are becoming a more common method of thoroughly inspecting pavement for debris at airports. With a foundation in the military, FOD walks have been relied on for decades on U.S. aircraft carriers to ensure that a flight deck is free of foreign objects. Indeed, the decks of U.S. aircraft carriers are walked by personnel at least twice daily (McCreary 2010). Although these walks may require closure of pavement, they allow an airport to utilize the assistance of numerous airport employees to thoroughly scan

TABLE 1
FOD INSPECTION METHODS

Method	Daily	Weekly	Monthly	Annually
Human/Visual (not including FOD walks)	89%	6%	0%	0%
Human/Visual (including FOD walks)	26%	18%	12%	6%
Continuous Surveillance Using Technology/Equipment	6%	0%	0%	0%
Periodic Surveillance Using Technology/Equipment	4%	4%	0%	0%
Our Airport Does Not Inspect for FOD	0%	0%	0%	0%

Note: Participants were asked to select all that apply. Thus, percentages may not equal 100% across categories of methods or frequency of inspection.

an entire length of pavement (typically a runway) for any foreign objects in a relaxed setting (i.e., with no aircraft on final approach). A FOD walk is a good way to estimate what has been missed during FOD inspections. Although an airport may hold a FOD walk only once each year, these events can create an esprit de corps among participants. FOD walks, and their use in promotion, are discussed in detail in chapter seven.

> At Whiteman Air Force Base in Missouri, FOD walks are conducted every Tuesday and Thursday. With several multi-billion dollar aircraft operating from Whiteman Air Force Base, including 20 B-2 Stealth Bombers, FOD walks are seen as integral to ensuring flight safety. Because of around-the-clock operations, crew chiefs, maintainers, and other personnel working on the Whiteman flightline all assume responsibility for eliminating FOD to keep aircraft and personnel safe. “FOD is and will always be a dilemma, but it is absolutely one that we keep to a minimum by performing these walks and ensuring we collect even the smallest bits of FOD,” explains Technical Sergeant Kenneth Prenger, 131st Bomb Wing crew chief. Whiteman has discovered that even sweeper trucks may miss some debris; therefore, Airmen and civilian personnel working on the flightline participate in regular FOD walks by lining up side-by-side and walking across the aircraft ramp. According to Whiteman statistics, 363.1 pounds of FOD was collected at the end of the first quarter of 2010. “FOD prevention is everyone’s responsibility,” Sergeant Kelly explains. “We are all one team. If anyone sees FOD, it’s their job to ensure it gets picked up”.
>
> (*Source:* Holston 2010, paragraph 12).

It appears that only 6% of participating airports use any continuous surveillance technology or equipment for detecting FOD, whereas 4% use technology or equipment for periodic surveillance on a daily basis (and an additional 4% on a weekly basis). An in-depth discussion of these various systems is presented in chapter three.

When asked about the frequency of runway closures for non-routine FOD inspection or removal, more than half of respondents (52%) indicated they did not close runways for non-routine FOD inspection removal. This finding supports the need for the 2009 Cert Alert (09-06) that was issued to airports advocating the closure of runways, if necessary, to prevent operations until debris are removed. The findings indicated, however, that almost 30% are forced to close a runway one or more times each month.

> Although almost one-third of participating airports indicated they are forced to close a runway once or more per month as a result of FOD, airports are typically hesitant to close runways (even for a short time) for this purpose. Even though a closure for FOD would often be in the best interest of safety, ATC and the airlines may not support closures of active runways, especially with no advance notice. For this reason, in 2009, the FAA issued a Cert Alert (No. 09-06) indicating that the FAA’s Office of Safety and Standards had been made aware of “instances where some airports have failed to take immediate and positive action following a report of FOD (on or near the runway) from flight crews” (FAA 2009b, paragraph 2). As a result, the Cert Alert reminds airport operators to develop procedures for “affecting immediate runway closures in the presence of certain types of FOD, such as large pieces of metal, large aggregate, large concrete spalling pieces, and any other materials likely to pose a high risk for operators” (FAA 2009b, paragraph 3). To effectively accomplish this, airports may enter into a Letter of Agreement or Memorandum of Understanding with ATC to effect closure when circumstances dictate (Appendix H).
>
> (*Source:* FAA 2009b).

CHAPTER THREE

DETECTION

The second component of a comprehensive FOD management program involves detection. Clearly, if upon inspection there is no debris, then no FOD will be detected, thus eliminating this step. If, however, debris exists on the AOA, it should be detected. Indeed, the most critical aspect of any FOD management program is the actual detection of debris. If FOD that exists is not detected by the airport employee, there will be no opportunity for the subsequent removal or documentation of the debris. Time is perhaps the most crucial aspect of the detection phase of the FOD management program. As seen in the case of the Concorde accident, a piece of FOD can become present on an airport's surface at any time, resulting in a serious accident if not promptly detected and removed. Therefore, it may be insufficient to simply inspect for FOD at certain times of the day. A continuous monitoring system does much to assist the airport in detecting FOD at any point in the day. Even so, several types of inspections exist and, ultimately, the most important objective is the detection of FOD, whether this occurs manually through regular inspections or with automation through continuous monitoring equipment.

Even considering personnel and training costs, manual detection of FOD may be a less expensive detection method than other options. Indeed, manual detection is an important part of any FOD management program, whether or not that program includes the use of FOD detection technology or equipment. Effective manual detection of FOD relies heavily on personnel employed at the airport to regularly monitor their surroundings to detect the presence of debris. This includes personnel performing the daily self-inspection, monitoring of construction activities, working on the terminal or ramps, attending gates, handling baggage, fueling aircraft, piloting aircraft, and controlling air traffic, as well as anyone who works on the AOA. Most commonly, a manual inspection for FOD is carried out by an airport employee (such as an operations employee) as part of a daily self-inspection. As discussed in chapter two, such inspections involve multiple passes of runways and taxiways, usually in a vehicle, with the employee visually inspecting for, and hopefully detecting, any existing debris.

CURRENT EQUIPMENT AND TECHNOLOGY AVAILABLE FOR DETECTION

Detection Equipment and Technology

In addition to manual methods, various forms of technology are currently available to aid the airport operator in detecting FOD; devices that can make the detection of debris much easier for airport operators. Most FOD technology currently being promoted to airports is focused on the detection of FOD. This focus on detection is well-deserved, because with only one or two manual inspections per day at many airports there is considerable opportunity to enhance the ability to detect FOD. Many of the manufacturers of detection technology promote a 95% or better detection rate under all weather conditions with 24/7 operation. This track record is not possible with a manual inspection and detection system.

In addition, some of the FOD detection technology on the market serves multiple purposes. For instance, modern sensors may detect wildlife. FOD detection systems may also to some degree provide surveillance of the AOA. In essence, FOD detection technology is intrusion technology, alerting personnel to foreign objects (including wildlife and possibly personnel) on the AOA. However, the application of these systems for these additional uses has not been approved by the FAA. Therefore, more research will be needed in this area in the future.

In an effort to inform airport operators of the available systems for FOD detection, the FAA has developed AC 150/5220-24, *Foreign Object Debris Detection Equipment.* This AC summarizes the major types of FOD detection systems (FAA 2009a). As seen in Table 2, these include both manual and automated systems.

Detection Continuum

In using these systems identified by the FAA, and based on findings from this synthesis, a continuum was developed showing the degree of automation present in the various types of FOD detection technology and equipment. It can be noted that the continuum is driven by the differing capabilities of the technology (see Figure 9).

Manual Foreign Object Debris Detection

Just as with the inspection stage, the FOD detection stage also has a manual option. Whether proactively, involving an airport employee driving a vehicle on the airfield and detecting FOD during a self-inspection, or reactively, with FOD first being detected by a pilot or ATC, the manual detection of FOD has been in use at airports for decades. Although the human eye may not detect very small debris or have difficulty discerning

TABLE 2
SUMMARY OF FOD DETECTION SYSTEMS

System	Detection Principles	Capability
Human/Visual	Fundamental baseline for the performance of FOD detection systems. Human observation provides detection and human judgment provides the hazard assessment capability to assure safety.	Supports regularly scheduled, periodic condition, and special inspections
Radar	Uses radio transmission data as the primary means to detect FOD on runways and AOA surfaces.	Fixed systems support continuous surveillance; mobile systems supplement human/visual inspections
Electro-optical	Uses video technology and image processing data as the primary means to detect FOD on runways and AOA surfaces.	Supports continuous surveillance
Hybrid	Uses a combination of radar and electro-optical data as the primary means to detect FOD on runways and AOA surfaces.	Supports continuous surveillance

Adapted from AC 150/5220-24 (FAA 2009a).

debris during reduced visibility or minimal contrast conditions, manual detection can be effective with properly trained employees having a keen eye for foreign objects on the airfield. Furthermore, McCreary (2010) presents findings that indicate that there is little debris below a size of 0.8 in. and weight of 0.07 ounces, or 2 cm/2 gram, typically present.

Supplemental Foreign Object Debris Detection

Located between manual and automated detection on the continuum, technology-assisted manual detection can be used to supplement human ability in detecting FOD. Typically in the form of cameras, the effectiveness of inspections can be enhanced by supplementing the visual observation conducted by airport personnel. A camera can be mounted on an inspection vehicle or at a fixed location (typically a terminal building). A camera mounted on an inspection vehicle may be a Forward Looking Infrared to enable more accurate detection of FOD during nighttime and low visibility conditions. Fixed location cameras are manually controlled and may be used to scan the airfield. Cameras are oftentimes most effective once FOD has been reported, as they allow the operator to zoom in on the FOD to verify its location and type, providing additional information to personnel responding to the FOD.

Automated Foreign Object Debris Detection

Automated FOD detection systems can be more expensive than manual methods, but may also prove more effective. In

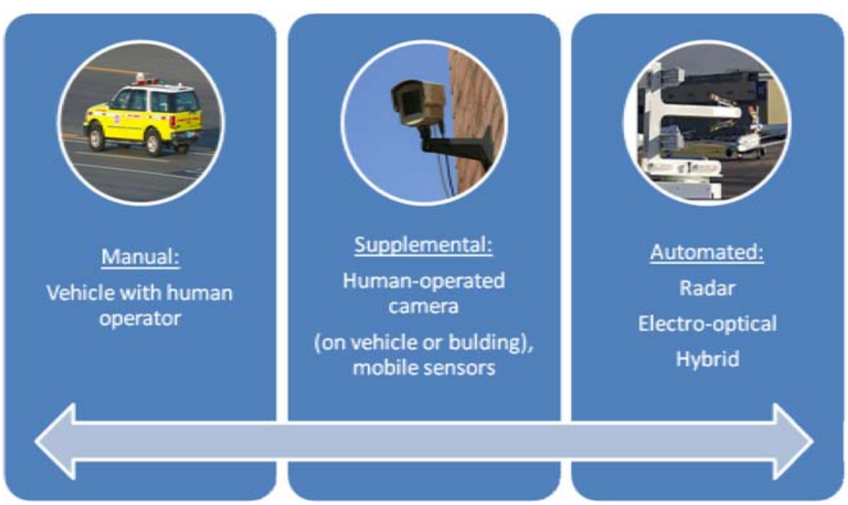

FIGURE 9 Continuum of technology and equipment available for detection.

the report, *Runway Safety,* Insight SRI, a provider of automated detection technology, explains:

> . . . Properly applied, the technologies of automated runway scanning (ARS) represent a major opportunity for both airlines and airports. The opportunity is not only to improve safety, but to improve the bottom line to the tune of millions of dollars. Curiously, it is an opportunity that has been consistently and expensively overlooked for almost a decade (McCreary 2010, p. 23).

Specifically, data from Vancouver International Airport (the first airport in the world to adopt automated detection technology) show that FOD is detected on the runways, on average, once every two days. This, according to McCreary (2010), is a sixtyfold improvement over airports relying only on visual inspections, where debris are typically found once every two months. Therefore, depending on the size of the airport, the degree of the debris problem, and the resources available, automated FOD detection systems may be a valid option.

Rather than being used in isolation, automated systems, such as those offering continuous surveillance, are designed to augment manual detection strategies, such as periodic visual inspections. This is an important supplement, as inspection personnel may only know the status of FOD on a runway 0.5% of the time when solely relying on manual detection of FOD (B. Patterson, personal communication, 2010). It can be noted, however, that these systems are automated, rather than automatic. Although many of these automated systems are continuous, the systems do require human interface to interpret system output.

Although some in the industry (such as McCreary) advocate the adoption of automated FOD detection technologies by airports, the technology remains relatively new and is not currently widely utilized. For instance, in 2005 the first automated runway scanning system was installed at Vancouver International Airport in Canada. Four years later, in 2009, the FAA approved the four technologies then on the market for Airport Improvement Program fund eligibility. By 2010, however, only six airports throughout the world had adopted automated scanning systems (McCreary 2010). As explained by McCreary (2010, p. 31), "Neither the regulators, the airlines, nor the airports have collected the statistics required to make a strong case for automated scanning."

Benefits of Automated FOD Detection

Direct Benefits:

- Detect, find, and identify FOD or other runway hazards
- Improve operational safety
- Reduce airline operating costs
- Reduce airport operating costs
- Provide uniform risk exposure for all movements.

Indirect Benefits:

- Allow airport to actively control their risk profile (same risk applied to all flights)
- Fewer delays means lower carbon emissions
- Reduce total manpower (over time) as systems roll out.

Longer Term Benefits

- Flexible decision making by tower and airport
- New methods to reduce delays and minimize inefficiencies
- Add new network capacity
- Preserve existing airport runway capacity
- Reduce operational variability
- Sustain operational tempo
- Low visibility operations
- Add new airport runway capacity
- Reduce runway closure times
- Improve punctuality and time of entry into the en route system
- Allows for an international, standardized approach to safety and hazard management
- Major improvements in safety data recording and risk management.

Source: McCreary 2010, p. 207

Radar

The first type of automated system utilizes radar, typically in the form of millimeter-wave radar. This technology uses extremely high frequency in the range of 30 to 300 gigahertz (GHz). This band has a wavelength of ten to one millimeter, giving it the name millimeter band or millimeter wave. Currently, there are both fixed and mobile systems that incorporate millimeter-wave radar. A mobile system currently on the market contains radar that incorporates a 78–81 GHz sensor mounted on a reciprocating platform on top of the vehicle that allows the scanning of a field of approximately 80 degrees in front of the vehicle. The antenna tilt is fixed in relation to the vehicle, scanning at the rate of 30 scans per minute and providing a detection distance in front of the vehicle of approximately 650 ft with a detection "cell" of approximately one square yard. The system also features a high-quality GPS that can be calibrated to reach near differential GPS accuracy and a photographic system that is coordinated with the system software to provide images of detected FOD ("FOD Finder" n.d.; Patterson 2008).

A fixed system currently on the market uses a combination of sensor technology and advanced digital signal processing to automate FOD detection. Millimeter-wave radar is used to give uninterrupted coverage of the runway, while object identification is enabled by a powerful day and night camera system cued onto the object automatically. The radar is accurate at distances of up to 0.6 mile. With this radar scanning technology, an entire runway can be covered by just two to three units (Patterson 2008).

Electro-optical Sensors

Yet another type of technology utilizes electro-optical sensors. One system currently on the market using this technology features self-calibrating cameras, automated scene analysis, and configurable scan resolution for different object sizes. These remotely placed electro-optical sensors provide continuous surveillance of the runway surface on a 24/7 basis. Objects can be detected at night without supplemental illumination, although because it is optical the detection capability of the system may be affected by certain types of weather ("Iferret" n.d.; Patterson 2008).

Hybrid

Some technology is considered hybrid in that it utilizes both radar and electro-optical sensors. One product currently on the market is promoted as "dual technology." This product combines a millimeter-wave radar sensor and an optic sensor that scans a portion of the runway and analyzes the data locally to detect foreign objects. In cases of positive detection, the operator receives both an audio and visual alert. With multi-sensor deployment, an airport's runway and taxiway surfaces can be scanned in as little as 30 s. Generally, the sensors that are collocated with runway edge lights are located on every or every other edge light, based on airport requirements ("FODetect" n.d.; Patterson 2008).

Decision Process

Although airports may be hesitant to investigate automated FOD detection technology owing to the cost, it is prudent to consider how automated technology may improve an airport's overall FOD detection capability. As explained by McCreary (2010, pp. 31–32), by comparing findings from automated detection systems and findings from visual runway inspections:

> Unassisted visual runway inspections may find better than 80% of the debris present at the time of inspection, but are in total no more than 3–4% effective in terms of finding and removing all items present on the runway throughout the operational day. This means that airports relying on visual inspections are in fact exposing their airline customers to a relatively high strike risk, and thus to higher operating costs than is otherwise necessary.

In deciding which of the FOD detection systems to acquire, airports are encouraged to consider many different factors affecting the success of the system in their specific airport operating environment. The FAA, through AC 150/5220-24, encourages airport operators to consider the following factors (FAA 2009a):

- Number and type of aircraft operating,
- Number and size of surveillance areas,
- Location of surveillance areas,
- Detection equipment precision and sensitivity,
- Detection equipment maintenance requirements,
- Airport climate, and
- Ability of personnel to respond to alerts and recover FOD from runway surfaces.

These factors, when considered in light of the available resources, will guide airports in (1) deciding if an automated system is appropriate, and, if so, (2) which specific system to acquire.

FOREIGN OBJECT DEBRIS RISK ASSESSMENT

Immediately after FOD has been detected, a decision is made about how to handle it. This involves an assessment of risk, and takes place whether FOD has been detected manually or through automated means. In actual practice, risk assessment in a FOD management program is a two-part process. At the point of FOD detection, an instantaneous, and possibly subconscious, decision process is carried out by the individual detecting the debris in determining how to initially handle the FOD item. In simple terms, just as an individual decides whether to drive, walk, or take a taxi to work, the FOD inspector immediately makes several decisions, including how to move and dispose of the debris, whether certain areas of the AOA need to be closed for further removal or inspection, and how best to document the FOD. As mentioned, in most instances, this form of a risk assessment happens instantaneously, and the inspector may be unaware that a risk-based decision process has been carried out; nonetheless, the process has taken place.

With the Proposed Rule, Safety Management System for Certificated Airports, issued by the FAA in 2010, this process of risk assessment will likely be required at all certificated airports in the near future. Specifically, the proposal would require a certificate holder to establish a Safety Risk Management process to identify hazards and their associated risks within the airport's operations. Under a Safety Risk Management (FAA 2010b), the airport would be required to:

- Identify safety hazards;
- Ensure that mitigations are implemented where appropriate to maintain an acceptable level of safety;
- Provide for regular assessment of safety level achieved;
- Aim to make continuous improvement to the airport's overall level of safety; and
- Establish and maintain a process for formally documenting identified hazards, their associated analyses, and management's acceptance of the associated risks.

A more in-depth discussion of risk assessment is presented in chapter five.

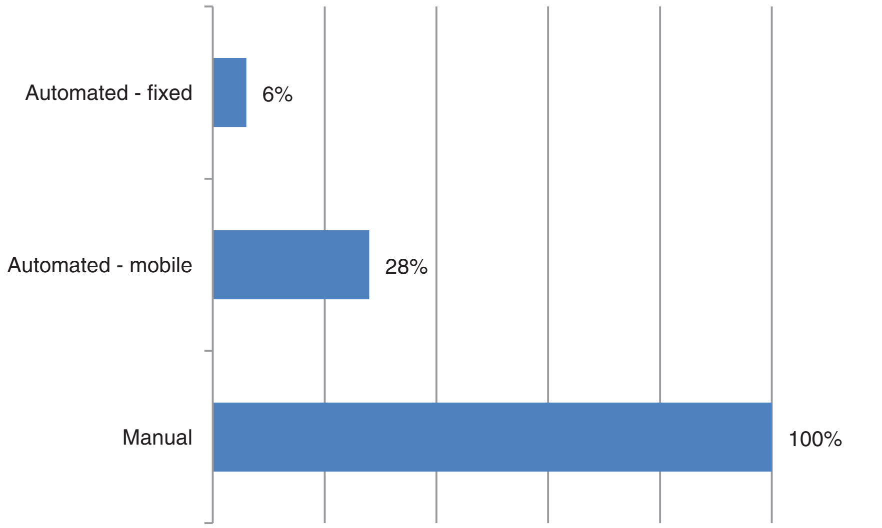

FIGURE 10 Systems in use to detect FOD. *Note:* Participants were asked to select all that apply. Thus, percentages do not total 100%.

CURRENT AIRPORT DETECTION PRACTICES

Systems in Use

When queried as to the type of systems in use to detect FOD at participating airports, 100% of respondents indicated they used a manual system, such as human or visual detection (Figure 10). Clearly, this is the most common method identified by respondents for detecting FOD at airports. At Part 139 airports, daily airfield inspections are required, and during these inspections airport personnel also inspect for, and hopefully detect, any FOD on the airfield. However, some airports have also adopted additional systems to detect FOD. Specifically, 6% of participants use a fixed system to support continuous surveillance. Just over 14% use a mobile system to support periodic surveillance.

Procedures in Place for Foreign Object Debris Detected by Others

Although it remains the airport operator's responsibility to properly detect and remove FOD, oftentimes, owing to the nature of airport operations and the timing of FOD inspections, debris may be detected by someone other than the airport operator, such as a pilot or the ATC. If debris were detected by someone other than the airport operator, participants were queried about the procedures they had in place. As can be seen in Figure 11, 31% of participating airports

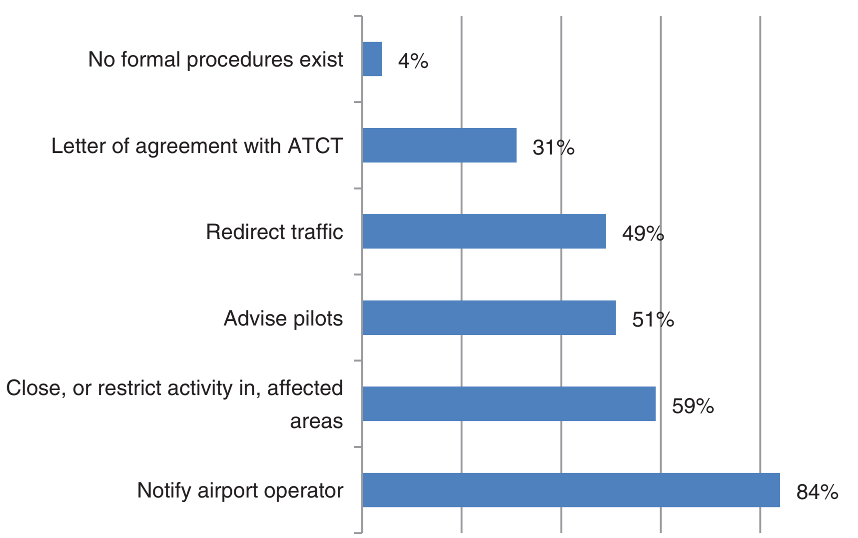

FIGURE 11 Procedures if FOD detected by others. *Note:* Participants were asked to select all that apply. Thus, percentages do not total 100%.

actually have a Letter of Agreement in place with the ATC for these instances. The vast majority (84%) expect the ATC to notify the airport operator if FOD is discovered. At that time the airport would dispatch personnel to immediately remove the debris. Approximately half of the participating airports (1) close, or restrict activity in, affected areas; (2) redirect traffic; and (3) advise pilots. In essence, by ensuring that the airport operator is advised as soon as FOD is discovered, aircraft can be prevented from operating in an area where debris are present until it is properly removed.

Investigation into Detection Technology and Equipment

In an effort to determine the degree of airport interest in technology and equipment for the detection of FOD, participants were asked if they had investigated the various types of technology and equipment available for such detection. Of the airports participating in the synthesis survey, 41% answered in the negative, whereas 33% indicated they had indeed investigated the various options available. Additionally, 27% of respondents had "somewhat" investigated the options available.

Airports Without Technology and Equipment in Use for Detecting Foreign Object Debris

Airports were also asked if they currently use any technology or equipment (such as radar or electro-optical sensors), in addition to the manual system in use, for detecting FOD. The vast majority (96%) answered no. When asked if they had plans to acquire, in the next 24 months, any technology or equipment for detecting FOD, 65% of these same airports indicated they had no plans. However, 27% were unsure, which might indicate some degree of consideration of the various types of technology and equipment on the market today for detecting FOD.

Airports with Technology and Equipment in Use for Detecting Foreign Object Debris

Only two participating airports (4% of respondents) indicated they currently use some sort of technology or equipment for detecting FOD. Both airports utilize systems combining millimetric wave radar with an optical zoom camera system for automated runway FOD detection, location, and alerting. One airport uses a tower-based system, the other a ground-based system. Likely, these results are indicative of airports nationwide; with the vast majority not yet having acquired advanced technology for detecting debris (McCreary 2010).

> Vancouver International Airport, in early 2006, became the first airport in the world to acquire the Tarsier FOD radar detection system from QinetiQ. Airport officials acquired the system with the hope of improving airport safety by accurately detecting FOD between self-inspections. Four Tarsier radar units were installed at Vancouver, one at each end of the north–south parallel runways. A display unit, installed in the operations center, provides the airport operations team with an all-weather, 24/7 runway picture. By providing staff with coordinates of FOD, and by entering these coordinates into a GPS navigation system, operations personnel are able to quickly and accurately locate and retrieve the debris.
>
> *Source:* http://www.defensefile.com/Customisation/News/Civil_Airlines_Airports_and_Services/Runway_Security_and_Safety/QinetiQ_-_Tarsier_FOD_radar_detection_system.asp

CHAPTER FOUR

REMOVAL

Clearly, a critical aspect of any successful FOD management program includes the actual removal of debris from the AOA. This involves removing FOD as expeditiously as possible without undue interference of airport operations, all the while considering the safety of the individual responsible for removing debris.

In developing a FOD removal plan, airports may wish to consider:

- Implementing a policy that conveys whom, when, how, and with what equipment the removal of FOD shall take place.
- The risk assessment process in FOD removal; especially, how this can be complimentary to an SMS plan.
- Implementation with sensitivity to the risk, traffic, and safety of everyone on the airport.

The removal process can range from being fairly simple and straightforward to very complex and dangerous. For example, a luggage tag that finds its way on the apron surface can be immediately removed by the line crew, whereas a piece of metal that finds its way onto the runway, is another situation altogether. Furthermore, wildlife FOD may be removed by personnel different than the personnel that removes other types of debris, as a result of the oftentimes biohazard nature of wildlife FOD. It is the duty of the airport operator to ensure that this part of the process is conducted in the most professional and conscientious way possible, considering aircraft traffic and the location of FOD.

Although each airline or tenant can be asked to keep their area free from FOD, it is ultimately the responsibility of the airport operator to mitigate FOD. To accomplish this, airports may adopt manual, as well as mechanized, equipment removal. The most successful means for removing such debris is with FOD removal equipment. This equipment is available commercially and can be used in conjunction with manual removal methods. At the same time, however, the use of FOD removal equipment may lead to complacency. This may occur because the employee considers the equipment as the primary tool for FOD removal, relying on it too heavily, and becoming less engaged in the FOD removal process (see Figure 12).

CURRENT EQUIPMENT AVAILABLE FOR REMOVAL

Removal Continuum

A number of solutions exist for the removal of FOD—ranging from non-mechanized to mechanized. The continuum in Figure 13 has been developed to present the range of options available to airports.

Non-mechanized FOD Removal

Of the two main types of FOD removal equipment, those categorized as non-mechanized are simply attached to, or towed behind, a vehicle. These non-mechanized units are fairly versatile, with the ability to be attached to a tug, airport operations vehicle, or maintenance truck. Because they are non-mechanized, they are less costly to operate and rarely out of service as a result of mechanical issues.

Tow-behind Friction Mats

Within the non-mechanized category, there are several types of equipment. First, tow-behind friction mats utilize a series of bristle brushes and friction to sweep FOD into sets of capture scoops, which are covered by a retaining mesh to hold the collected debris. Figure 14 shows a tow-behind friction mat.

Magnetic Bars

Magnetic bars are another non-mechanized piece of equipment available to airports for removing FOD. These bars are attached to vehicles and designed to collect metallic debris. With the majority of FOD collected at airports being metal, this piece of equipment is a simple solution to that specific FOD source. To ensure effectiveness, airports utilizing magnetic bars inspect and clean the bars regularly to remove all accumulated metallic debris. If not, once collected, debris may fall off the vehicle and become FOD yet again. Figure 15 shows a magnetic bar attached to the front of a pick-up truck.

FIGURE 12 FOD removed during one FOD walk at Kadena Air Base, Japan. (*Source:* U.S. Air Force photo/Airman 1st Class Jarvie Wallace.)

FIGURE 14 Tow-behind friction mat. *Source:* Sherwin Industries.

Rumble Strips

Rumble strips, or FOD shakers, are the third type of non-mechanical equipment available for FOD removal. This system is comprised of 10- to 15-ft-long devices positioned on the pavement to dislodge FOD from vehicles as they are driven over. Rumble strips can typically be moved as needed. According to Drew Lasseter, Guantanamo Bay Airfield Facility Manager:

> FOD shakers will not remove all FOD from tires. In many cases, it removes FOD, but in just as many cases it loosens it up enough that it becomes likely that the FOD will fly off while on the ramp. FOD shakers are never a substitute for human interaction (Peck 2010).

Additionally, in northern climates, the freeze/thaw cycle may degrade some types of rumble strips, thus creating FOD. Although once quite common, these devices are no longer a widely accepted FOD removal system. A better practice is for the operator to stop a vehicle at a designated checkpoint, perform a visual inspection for debris on the vehicle, and use a hand tool to manually remove debris from tires or undercarriages. Figure 16 shows rumble strips in use on an asphalt road.

Mechanized Foreign Object Debris Removal

Mechanized FOD removal can be more costly for an airport; however, many times the additional expense is justified by the enhanced efficiency provided by a mechanized unit. Proper maintenance is necessary to ensure successful operation with minimal breakdown of equipment.

Power Sweepers

Power sweepers, which include tow-behind bristle trailers, first remove debris from the pavement. A true mechanical broom sweeper can clean the surface of large debris, but dirt

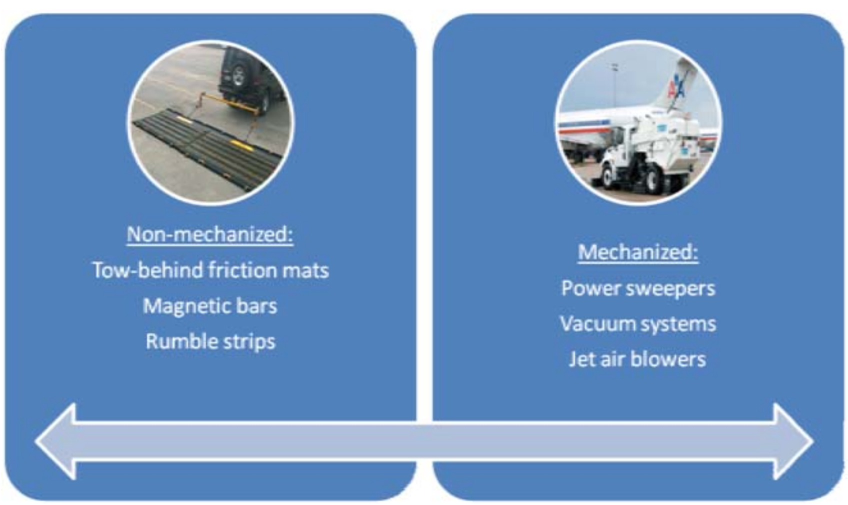

FIGURE 13 Continuum of equipment available for removal.

FIGURE 15 Magnetic bar. *Source:* The F.O.D. Control Corporation.

and fine particulates may be remain on the surface and in pavement cracks. These units are typically used throughout the airfield on pavement surfaces, as well as on ramp areas where ground support equipment is staged. According to AC 150/5210-24, bristles can detach from brooms and become a source of FOD (FAA 2010a). Therefore, metal bristles or spines should not be used for FOD removal purposes. Plastic or combination plastic/metal bristles may be appropriate for airports depending on the equipment manufacturer recommendations. Regardless of the equipment used, a thorough visual check of the pavement should be conducted at the conclusion of the sweeping procedure (FAA 2010a). Figure 17 shows a self-propelled, walk-behind sweeper, while Figure 18 shows a sweeper attached to a tractor. Figure 19 shows a sweeper truck.

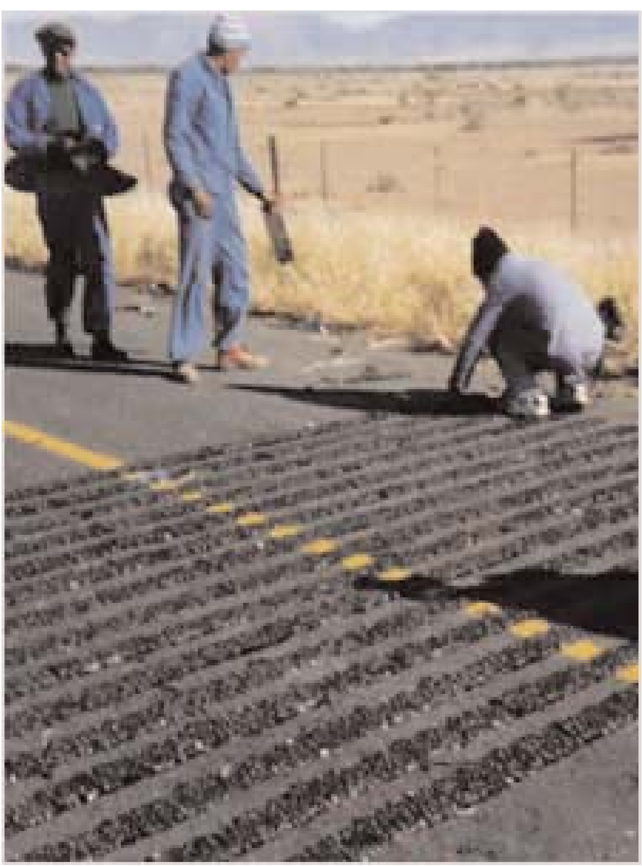

FIGURE 16 Rumble strips. *Source:* A.J. Broom Road Products.

FIGURE 17 Self-propelled, walk-behind sweeper. *Source:* Digital Commons.

FIGURE 18 Sweeper attachment. *Source:* Digital Commons.

FIGURE 19 Sweeper truck. *Source:* Digital Commons.

FIGURE 20 Walk-behind vacuum. *Source:* Mid Carolina Turf and Outdoor Equipment.

Vacuum Systems

Next, vacuum systems rely on air flow as the primary means of removing FOD. Although a unit may only contain a vacuum, which may be walk-behind (Figure 20) or driven (Figure 21), airports often utilize a unit that combines a vacuum system with a mechanical broom and/or a regenerative or recirculating air feature (Figure 22). By utilizing a constantly moving windrow broom to transfer debris over to a suction nozzle at one side of the sweeper, debris are removed by means of a suction tube.

Jet Air Blowers

The final option in using mechanized equipment to remove FOD is with jet air blowers. These systems direct a stream of high velocity air toward the pavement surface. Technically, these systems do not remove FOD, they simply displace it. Although a jet air blower may not contain a debris collection mechanism, it is beneficial to only acquire jet air blowers that incorporate a debris collection mechanism to avoid blowing FOD to other areas. One jet air blower currently on the market is capable of blasting ambient air with speeds of up to 438 mph. The manufacturer states that this is effective in removing ice, dirt, snow, leaves, and other debris (see Figure 23).

FIGURE 21 Vacuum truck. *Source:* Tymco.

FIGURE 22 Vacuum with mechanical broom and regenerative air feature. *Source:* Tymco.

Foreign Object Debris Storage

Lastly, although not categorized as FOD removal equipment, containers for the purpose of storing collected FOD are beneficial for a FOD management program and the final step in the removal process. By ensuring that storage systems or FOD containers are easily seen and visible from all gates for the purpose of gathering debris, as well as marked appropriately and emptied regularly to guard against any overflow, the containers are more likely to be used. The FAA also suggests that airport employees wear "pouches" to collect any debris they might come in contact with while conducting their respective duties. Although five-gallon buckets are common at many airports, the FAA recommends that FOD containers have covers

FIGURE 23 Jet air blower. *Source:* RPM Tech.

or lids to prevent wind or jet- or prop-wash from stirring up or shifting debris inside the container, thus creating more FOD (FAA 2010a). It is helpful to locate FOD containers in all high traffic areas, generally near entry points to the AOA, hangers, maintenance areas, FBO, and at each aircraft gate. If there are multiple containers in visible locations, personnel will be more apt to properly dispose of FOD without being prompted. For hazardous materials, specialized containers, in accordance with appropriate regulations, must be used. Figure 24 shows an example of FOD containers.

FIGURE 24 FOD containers. *Source*: San Antonio Airport System.

CURRENT AIRPORT REMOVAL PRACTICES

Common Foreign Object Debris Types

To determine the most common types of debris removed at airports, this synthesis queried the airports. Airports were also asked to indicate the most common types of FOD removed by area. Findings suggest that certain types of FOD (such as plastic and/or polyethylene materials) are generally quite common throughout the airport environment. Other types of FOD (such as flight line items) are most common only in specific areas (such as flight line items on air carrier ramps).

As seen in Table 3, the data can be reduced to the four most common types of FOD removed by area. Movement areas (runways and taxiways) share the first and second most common types of FOD (runway and taxiway materials, and natural materials, respectively). Aircraft parts and debris resulting from winter operations are also commonly found along run-

TABLE 3
FOUR MOST COMMON TYPES OF FOD REMOVED BY AREA

Area	First Most Common	Second Most Common	Third Most Common	Fourth Most Common
Runways	Runway and taxiway materials	Natural materials	Aircraft parts	Winter ops
Taxiways	Runway and taxiway materials	Natural materials	Winter ops	Aircraft parts
Taxi Lanes	Winter ops	Runway and taxiway materials	Apron items (tie) and natural materials (tie)	Aircraft parts (tie) and plastic and/or polyethylene materials (tie)
Air Carrier Ramps	Apron items	Flight line items	Winter ops	Aircraft parts
Cargo Ramps	Apron items	Winter ops	Plastic and/or polyethylene	Aircraft parts (tie) and flight line items (tie)
GA Ramps	Apron items	Winter ops	Flight line items	Plastic and/or polyethylene (tie) and natural materials (tie)
Hangar Areas	Aircraft parts	Winter ops	Mechanic's tools	Apron items (tie) and construction debris (tie) and plastic and/or polyethylene (tie)
Outside Defined Construction Areas	Construction debris	Plastic and/or polyethylene	Apron items	Natural materials
Nonpavement Areas	Plastic and/or polyethylene	Apron items	Natural materials	Construction debris

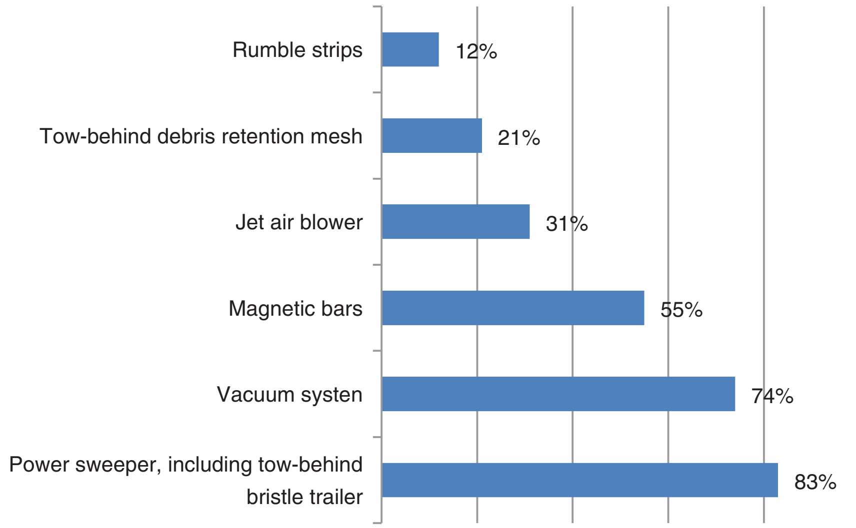

FIGURE 25 Types of FOD removal equipment in use. *Note:* Participants were asked to select all that apply. Thus, percentages do not total 100%.

ways and taxiways. Similarities in FOD types also exist among non-movement areas. For instance, apron items (such as paper debris, luggage parts, and debris from ramp equipment) are the most common type of FOD found on ramps (including air carrier, cargo, and GA). FOD as a result of winter operations (such as ice and snow, vehicle or equipment parts, and broken lights) are also quite common among non-movement areas.

Common Removal Methods

In practice there are only two main methods available to remove FOD from airport surfaces. First, airports typically manually remove debris by physically picking it up, whether by hand or with a shovel or other device. Second, debris can be removed with the use of mechanized equipment, whether by a sweeper, vacuum, magnetic bar, or other piece of equipment. To understand the degree to which airports rely on these various methods of removing FOD, airports were queried as to the methods they use. Fully 100% of participating airports remove FOD manually (or by human means). However, 91.5% also remove FOD mechanically using some sort of equipment designed for such purpose. Furthermore, 15% of participating airports have plans to acquire additional equipment for removing FOD within the next 24 months.

Common Foreign Object Debris Removal Equipment

Those airports using some sort of FOD removal equipment were asked about the specific types in use. Figure 25 reveals that the most common type of equipment in use is the power sweeper. One airport also indicated that they have a dust pan attachment to their sweeper. A vacuum set-up is also quite common, with magnetic bars also used by more than half of participating airports. Less common are jet air blowers, tow-behind retention mesh, and rumble strips.

Based on the most common type of FOD found at an airport, and the area in which each type is found, it is helpful to conduct a risk assessment to determine the hazards presented by the FOD and then adopt tools to mitigate those hazards. For instance, if metal debris are found on runways, the airport may wish to install magnetic bars on all operations and maintenance vehicles. If vegetation is a problem on taxiways, maintenance personnel may need to pay closer attention to mowing practices, and use power weepers and/or vacuum systems after each mowing event.

Of those airports using some type of technology or equipment for removing FOD, 79% indicated that this equipment is very useful at removing FOD. Of those indicating the technology or equipment was very useful, the vast majority (91%) are using a power sweeper. A great number are also using a vacuum system (73%) and magnetic bars (61%). Somewhat less common are jet air blowers (40%) and tow-behind debris retention mesh (21%). Only 21% of participating airports indicate the equipment is somewhat useful, whereas no airports indicated that it was not useful at all.

CHAPTER FIVE

DOCUMENTATION AND ANALYSIS OF DATA

Accurate Data + Thorough Analysis + Effective Action =
Fewer FOD Incidents
(Messenger 2004a, p. 37).

Once FOD is removed, it is essential that it be properly documented, especially debris removed from movement areas. This step may not appear as important as the previously discussed steps of inspection, detection, and removal; however, documentation plays a critical role in the overall process. Without documentation and subsequent analysis of the data, the airport operator or FOD manager has no record of previous FOD events and little idea how to proactively minimize future FOD incidents. Analysis is an important part of this process, so that trends can be revealed and FOD "hot spots" be discovered. Airports can effectively "know their FOD" by properly documenting it. Indeed, the documentation of FOD supports the risk assessment process detailed in chapter three; for without knowing the types of FOD collected and the typical locations from which the FOD is removed it is difficult to understand the risk prevented by FOD at an airport. As Messenger (2004a, p. 38) states, "The purpose of your data is to identify problems and implement lasting solutions." In general terms, the documentation phase consists of the process of writing down on paper, or electronically, and then storing what type of FOD was detected, where it was located, the risk/hazard it presented, and how the situation was dealt with.

DOCUMENTED ITEMS

Documentation is an important component of FOD management, as it provides the airport operator or FOD manager with historical FOD data for the airport. By analyzing past FOD events, the airport operator or FOD manager can take appropriate action to minimize future FOD events and enact best practices. In should be noted, however, that there is no expectation to document FOD removed from apron areas, although airports may weigh the amount of debris collected in containers placed in and around gate areas for the purpose of gauging the severity of the FOD problem. FOD is generally documented when removed from movement areas (runways and taxiways). Through AC 150/5210-24, the FAA recommends the following seven specific items that should be documented in every case of FOD that an airport handles (FAA 2010a):

1. How the FOD object was detected.
2. Date and time of FOD detection and retrieval.
3. Description of FOD retrieved (category, size, and color) and/or image (if available).
4. Location of FOD object (coordinates and reference to the AOA location).
5. Possible source.
6. Name of personnel detecting/investigating FOD item.
7. Airport operations and weather data during the FOD detection event.

Regarding the manner in which FOD is described, it is very effective to also generate categories in which to place documented FOD. According to Morse (2004), 70%–75% of FOD events have historically been categorized as "cause unknown." This makes trend analysis difficult. Thus, Morse (2004, p. 181) proposes that airports allow for the following categories when documenting FOD:

- Internal
- Ice
- Concrete/stone
- Aircraft hardware
- GSE hardware
- Luggage hardware
- Wildlife strikes
- Tool
- Constructional material
- Soft body.

Although documenting FOD may appear simple enough, it does require initiative on the part of the employee handling the FOD event. This is best accomplished by requiring proper documentation as part of the airport's FOD Standard Operating Procedure or policy and conveying this requirement through training and awareness (as discussed in chapter six).

DATABASE

To efficiently record FOD occurrences and allow for trend analysis airports may find it beneficial to develop an actual recording database. Records of individual FOD cases should include the seven items listed previously. As stated in AC 150/5210-24, "These records may be required in the event of a formal investigation of an accident or serious incident, and can also be used to identify any trends, repeats, unusual conditions, etc., in order for corrective action to be initiated"

(FAA 2010a, p. 26). Additionally, however, an airport may choose to include data resulting from audits or inspections and customer or tenant feedback. By maintaining FOD records for at least two years, airports will have valuable information that will help in FOD detection and removal in the future, as well as "ensure traceability of all significant safety-related decisions" (FAA 2010a, p. 26). Some airports advocate that records be maintained for periods longer than two years to allow for historical trend analysis. It is worth noting that the FAA recently initiated efforts to develop a national FOD database, which would work to highlight FOD trends on a national level. Once implemented, the system will operate on a voluntary basis, with airports being encouraged to participate in the database.

ASSESSING PERFORMANCE

To determine the effectiveness of the FOD management program and various FOD prevention techniques that have been adopted as part of that program, airports will find it useful to assess their performance in relation to FOD. As NAFPI (n.d., p. 6) states, "The operational target in any FOD Prevention Program should always be 'zero.' " To determine the degree to which an airport is successful in achieving this target, performance can be assessed. Various methods are available to airports in proving this information, according to NAFPI (n.d., p. 6):

- Visibility charts/statistical graphics derived from audit or incident data. Usually provided on an isochronic schedule; that is, weekly or monthly.
- Trend analysis—Where have you been? Where are you going?
- Report card—A checklist of areas routinely inspected that shows specific problem areas.
- Performance review—A review of worker conformance to standards and expectations.
- Customer comments, concerns, or complaints.

Successful FOD prevention programs incorporate trend analysis on a regular basis. To analyze trends, after the documentation process has been completed, it is critical that the documents be kept for at least 24 calendar months. Trend analysis involves the review of each FOD occurrence at an airport, including how often each type of debris are found, at what locations the majority of the debris are found, what sizes of debris exist, in what weather conditions debris are found, and so on. In reality, trend analysis may be performed on any of the variables recorded during FOD documentation. The purpose of analyzing each FOD occurrence is so that trends may be discovered to assist the FOD manager in improving their inspection, detection, and removal techniques, and possibly to even take steps to eliminate certain types of debris. Airports will benefit from the final steps of documentation and analysis, and the FOD management program will have a longer lasting effect than its short-term goal of immediately removing FOD that has been discovered.

Risk Assessment

As first presented in chapter three, risk assessment in FOD management is a two-part process. The first involves an instantaneous risk assessment, which may take place during the inspection/detection stage, and the other part is a more traditional risk assessment, which may take place during the documentation and analysis stage. The overall process of any risk assessment is much the same and is, according to the FAA, as follows (FAA 2007b):

1. Describe the system
2. Identify the hazards
3. Determine the risk
4. Assess and analyze the risk
5. Treat the risk (i.e., mitigate, monitor, and track).

Risk assessment during and after the documentation stage is one aspect of the trend analysis process. The documentation stage can be very critical to any FOD management program because the strengths and weaknesses of the entire program can be examined. Through documentation, discoveries may be made that reveal where FOD items are generally located, what they are composed of, the time of day and weather conditions that generally accompany these occurrences, and other items. When these items are known, a formal risk assessment involving the five previously mentioned steps of a risk assessment may take place.

The first phase is to describe the system, which entails describing the operating environment in which the hazards will be identified. System description serves as the boundaries for hazard identification. For airports, characteristics of any operational, procedural, conditional, or physical nature are included in the system description (FAA 2010a).

The second phase (identify the hazards), can occur in a variety of ways, and may include the use of a chart. When using a chart, the identifier may list a sampling of common FOD that has been found at the airport, including the hazard, and frequency of the occurrences. For example, a piece of concrete would be classified as having a high expected hazard and a common frequency, whereas a broken runway sign would also have a high expected hazard score, but be deemed uncommon with regard to frequency (FAA 2010a).

The third phase of FOD risk assessment involves determining the risk associated with each piece of debris. In this stage, the actual risk that each piece of FOD presents is determined. For instance, if a small piece of concrete has been identified as a risk, the employee may determine that engine ingestion could be the actual hazard that would threaten an aircraft (FAA 2010a).

The fourth and final phase of a FOD risk assessment process is to assess and analyze the risk. For the purpose of FOD detection, risk has been defined by the FAA as, ". . . the composite of the predicted severity and likelihood of the outcome or effect (harm) of the hazard in the worst credible system state" (FAA 2010b, Appendix 1, p 3). Severity is also considered in the risk matrix and has a different definition than likelihood. The likelihood of each risk occurring was determined in the second phase of the risk assessment. In the fourth stage, the severity or "worst credible potential outcome" is taken into consideration (FAA 2010a). A sample risk matrix is show in Figure 26.

As shown in Figure 26, the likelihood and severity (or consequences) intersect to determine the level of risk. Generally, three levels of risk may be found—low, medium, and high. It is worth noting that several risk matrix charts do include a fourth category, extreme or critical, which ranks above high risks (Stolzer et al. 2008).

High risks are unacceptable in a safety-driven industry such as aviation. A level of medium risk is considered acceptable in many situations, meaning that operations can proceed normally; however, close supervision of the scenario should be maintained. Low risk is the goal of every safety program, and with the proper application of a risk matrix airport operators are most likely to achieve this goal (FAA 2010b).

Finally, after the four phases of risk assessment have been completed, it is vital to treat the risk. At this point the airport operator or other qualified personnel may weigh the options that are presented to them in addressing a particular hazard. In addition, before a FOD management program can be implemented, it is necessary to consider how the program will be funded, who will oversee it, and the implementation schedule. Decisions may have to be made on what to include and what to exclude from the program. It is important for the operator to remain objective during this process and ". . . implement appropriate and cost-effective risk mitigation plans to mitigate hazards" (FAA 2007b, p. 13). When possible, airports may wish to include a diverse group of individuals in making these decisions, as their differing experiences and knowledge base will enrich the development of a risk assessment program (Stolzer et al. 2008, pp. 130–148). For further information on the risk profile of FOD, consult McCreary (2010).

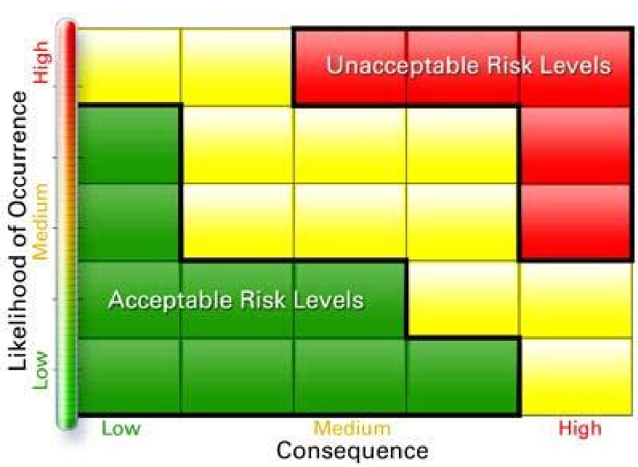

FIGURE 26 Sample risk matrix. *Source:* Mobile Safety Solutions.

IMPROVING FOREIGN OBJECT DEBRIS MANAGEMENT

Perhaps the most important aspect and end goal of the documentation process is improving the entire FOD management program. By properly documenting FOD, airports are able to see how instances of FOD have been handled in the past and where improvements can be made, thus improving the safety performance of the airport. Furthermore, any FOD "hot spots" can be determined, thereby allowing a more focused effort in these areas. Based on data from Vancouver International Airport, McCreary (2010) proposed that FOD hot spots may not exist. However, this may vary among airports, especially if for example an airport has an active FOD generator in the form of a construction site. In any event, it is helpful for the FOD manager to regularly review past findings and evaluate how their FOD management system operates. This may take the form of a Corrective Action Plan, which is based on the root causes of the FOD, and will likely present the steps to be taken to reduce any FOD problems. As Messenger (2004a, p. 45) noted, "Zero FOD is YOUR goal, and sound data coupled with commitment is a key in reaching it."

CURRENT EQUIPMENT AND TECHNOLOGY AVAILABLE FOR DOCUMENTATION

Once FOD is collected and before disposal it needs to be properly documented. As previously discussed, documentation is important for understanding trends and properly incorporating continuous improvement into a FOD management program. Documentation begins with properly recording information once the debris are collected. This can easily be done on a form; however, documentation becomes more complex as an airport begins to analyze debris collected over a certain time period or in a defined location. In this instance, a computer database or FOD-specific software program becomes invaluable.

FIGURE 27 In-vehicle FOD documentation system. *Source:* Paul Khera, Alaska Department of Transportation.

Stand-alone Tools

The simplest form of documentation occurs with a manual system. With a FOD inspection checklist, wildlife reporting form, or other form/checklist, an airport employee with a clipboard and a pen can properly document FOD as it is collected. If a photograph(s) is taken, it can be printed and attached to the paper form. This system allows for a paper trail and can be effective in documenting FOD. However, trend analysis can prove cumbersome, requiring that many previously completed forms be reviewed to uncover trends.

Stand-alone Technology

The incorporation of technology into the documentation process may enhance an airport's efficiency. Various manufacturers currently offer stand-alone technological solutions to FOD documentation. Some of these solutions may be used within a vehicle and allow access to Part 139 inspection checklists, accident reports, operations manuals, and FOD forms by means of a touch-screen tablet PC or notebook computer. They may also contain GPS and GIS capabilities, allowing the inspector to pinpoint exact locations at which FOD is removed. Others mimic a well-developed electronic database, which allows one to enter all required information about a FOD event. Whether obtained from a vendor or developed in-house, once recorded, data can then be analyzed by the variables used to enter the information. In this way, reports can be generated, thereby allowing for investigation, audits, and continuous improvement. Figure 27 shows an in-vehicle FOD documentation system.

Interface with Foreign Object Debris Detection System

Other manufacturers incorporate a documentation software program that interfaces with their FOD detection system. One manufacturer, for instance, has integrated its FOD documentation program with its FOD detection system so that FOD events are not only recorded, but actual images are archived as well. Another manufacturer provides a software toolbox that enables the airport to store, view, and analyze all detection data provided by the system. As a result, trends and patterns can be identified that will allow the airport to improve its overall FOD management program. This same provider's program offers a heat map view, which graphically displays the density of FOD detected by area, overlaid on an airport map or image. This tool can quickly highlight potential problem areas or FOD hot spots, allowing efforts to be focused where they are most needed. Whether the FOD documentation software is included with the FOD detection system or must be acquired separately, airports may wish to consider how well the documentation system integrates with the detection system in use.

Documentation Continuum

Regardless of the degree of FOD documentation at an airport, a number of solutions exist—ranging from fully manual to fully computerized. The continuum in Figure 28 has

FIGURE 28 Continuum of technology and equipment available for FOD documentation.

been developed to present the range of options available to airports.

CURRENT AIRPORT DOCUMENTATION PRACTICES

Documentation of Foreign Object Debris

Documentation of FOD varies by airport. Of the airports participating in this synthesis, 52% reported that they document FOD most times when debris are retrieved or removed. Almost 20% document FOD every time, with 19% documenting sometimes and 10% never. When analyzing the data by airport hub size, it becomes clear that larger airports are more likely to document FOD. Specifically, although FOD is documented most times by 75% of large and medium hub airports and 60% by small hub airports, only 20% of non-hub airports and 33% of GA airports document FOD most times when it is retrieved or removed; furthermore, two-thirds of GA airports never document FOD.

When queried about the manner in which they document FOD, the results were quite comprehensive. More than half of participating airports currently document FOD in the following manner(s):

- Location of FOD (84%)
- Date and time of FOD detection and retrieval (68%)
- Description of FOD retrieved (68%)
- Name of personnel detecting/investigating/removing FOD (61%).

Participating airports also document how the FOD was detected (41%), the possible source of the debris (32%), an image of the object retrieved (23%), airport operations data during the FOD detection event (18%), and weather data during the FOD detection event (9%).

Analysis of Foreign Object Debris

For the purpose of documenting FOD, 64% of participating airports maintain an electronic database. Interestingly, this 64%, to a large extent, represents large hub airports; none of the participating medium hub, non-hub, and GA airports currently maintain an electronic database for FOD documentation. Although 28% of the participating airports do not have an electronic database for this purpose, 9% plan to adopt an electronic FOD documentation database in the near future. For those airports with an electronic database, Figure 29 shows how the data in this database are analyzed. It appears that just as the majority of participating airports document the location, date and time, and description of FOD, these are the same elements most often used in the analysis of FOD incidents. However, although the majority of participating airports also document the name(s) of those personnel who detect and remove the debris, this element is not a common way to analyze data in the database. The manner in which FOD was detected however is.

When asked who analyzes the data in the database, 77% of survey respondents indicated that operations personnel were the most likely candidates. However, other stakeholders also participated in data analysis (as shown in Figure 30).

Similar to the previous question, participants were asked who uses the data stored in the FOD database. It appears that the operations department (87%) and airport management (73%) are the most frequent users (Figure 31).

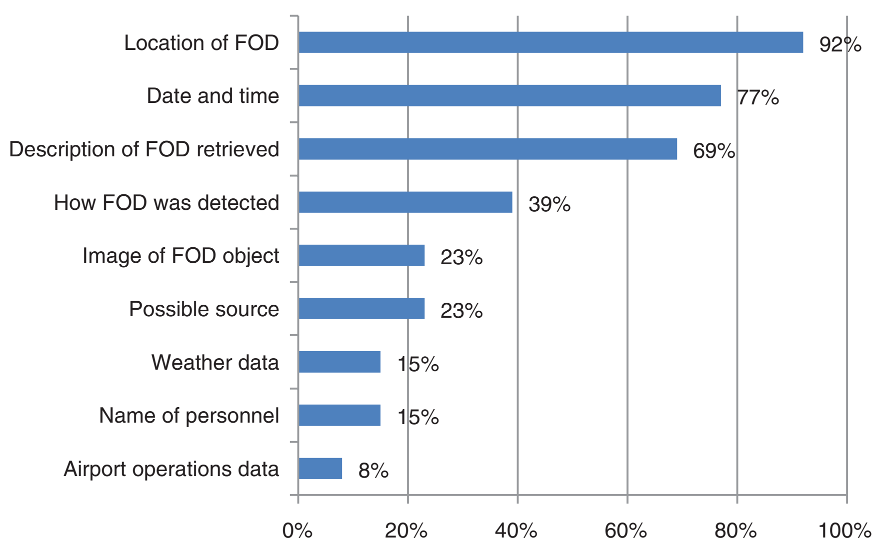

FIGURE 29 FOD analysis by type. *Note:* Participants were able to select all that apply. Thus, percentages do not total 100%.

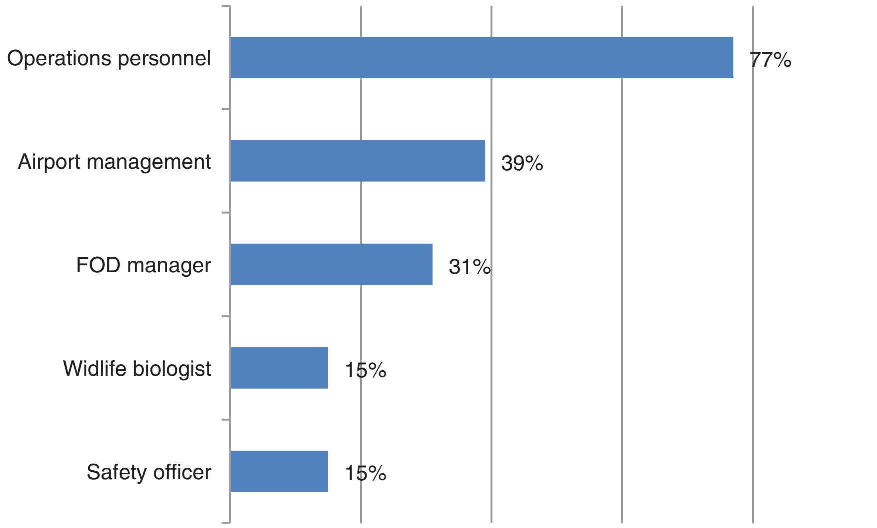

FIGURE 30 FOD analysis by personnel. *Note:* Participants were able to select all that apply. Thus, percentages do not total 100%.

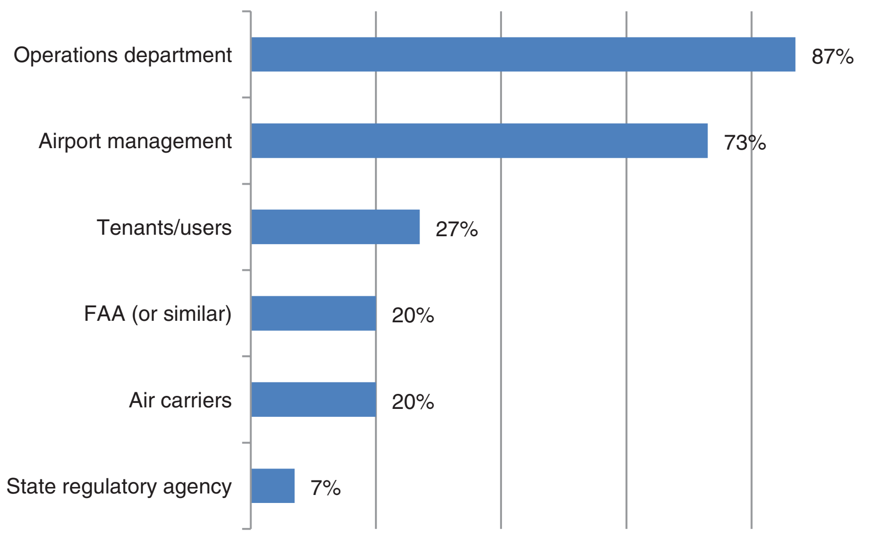

FIGURE 31 Utilization of FOD data. *Note:* Participants were able to select all that apply. Thus, percentages do not total 100%.

CHAPTER SIX

TRAINING AND PROMOTION

To ensure a successful FOD management program, airports not only need to address the four main areas of inspection, detection, removal, and documentation, but also incorporate a comprehensive training and promotion program. Without adequate training of, and awareness by, all personnel of the airport's FOD management program, employees cannot be expected to (1) understand the consequences of FOD on airport surfaces, and (2) emphasize FOD removal during their daily work. First, however, it is useful to consider the manner in which human factors and culture affect personnel and the training and promotion paradigm.

HUMAN FACTORS

Whether implementing manual inspection and detection methods or relying heavily on automated detection technology, the human interface is still necessary; because of this, human errors can occur. Human errors are defined by ICAO as "the failure of planned actions to achieve their desired goal" (Mason et al. 2001, p. 3). Within the aviation industry, 75% of accidents involve human performance errors (ICAO 2005).

Human factor issues may be broken down into four main categories, which can be characterized in the SHEL model of Software, Hardware, Equipment, and Liveware. Each of these categories is directly affected by human interaction, which is the most flexible and adaptable part of the aviation system; hence, the importance of considering these issues (ICAO 2005). Several steps may be taken by an airport's FOD management team to eliminate and reduce human error issues with regard to FOD. This includes the implementation of disciplined work habits, active FOD promotion, and testing (Mason et al. 2001, p. 5). Awareness and reward programs for successfully executing an airport's FOD program may also help in the human factor issues of motivation and compliancy (Mason et al. 2001, p. 8). Training is especially critical to minimize the impacts of human factor issues on FOD management and Mason recommends that the following topics be taught during training (2001, p. 7):

1. Proper storage,
2. Shipping and handling,
3. Ramp control,
4. Clean-up strategies,
5. Housekeeping,
6. Inspection practices,
7. Accountability, and
8. Reporting.

Over the course of the last several years, the FAA has taken an increased interest in human factor issues across the aviation industry, creating a list of the dirty dozen human factors. These 12 factors, if not guarded against, also can easily negatively affect the FOD process (Cunningham 2007):

1. Lack of communication
2. Complacency
3. Lack of knowledge
4. Distractions
5. Lack of teamwork
6. Fatigue
7. Lack of resources
8. Pressure
9. Lack of assertiveness
10. Stress
11. Lack of awareness
12. Norms.

Although human interaction with FOD inspection and removal equipment is commonplace and may result in human performance issues, visual and manual inspection and removal practices are especially susceptible to human factor problems. As found in the survey of airport operators, the vast majority of airports do not operate FOD detection or removal equipment, and simply rely on visual and manual inspections; therefore, the following human factor issues may be especially important for these operators to consider when performing a visual inspection.

First, visual acuity is especially important to consider, and refers to the clearness of one's vision. Sunglasses, a clean windshield, and an inspection vehicle equipped with adequate external lighting will improve visual acuity. Also of importance is the speed at which an inspection is performed in a vehicle; the faster the vehicle travels, the harder it is for the inspector to scan the entire surface being inspected. Often, ATC asks the inspector to "expedite," and when this occurs it may be best to exit the runway and continue the inspection after the current aircraft operation, rather than driving the runway at excessive speed simply to finish the inspection. One potential remedy to eliminating distractions for the inspector at a towered airport is to have ATC treat the inspector as it would a normal flight, complete with a flight strip, so that a set amount of time can be allocated to the inspector without having to take into account incoming or departing aircraft. The location of the sun is also important, especially during sunrise and sunset. Often, driving away from the sun, especially if is located low on the horizon, will improve vision. The attentiveness of the inspector may be addressed as well, to ensure that there are no outside distractions while performing the inspection. Distractions may be minimized by prohibiting the use of the vehicle AM/FM radio, cell phone, or external music device(s) while on the runway. If airline personnel accompany the inspector, they should be instructed not to talk while the vehicle is on the runway. Pilots are routinely taught how to scan for traffic, and inspection personnel can be taught the same scanning technique, as well as how to rely on peripheral vision. Night, rain, fog, and snow can negatively affect the vision of inspection personnel. In addition, heat can impair the inspector's vision; generating turbulent distortions over pavement and distorting images (Chadwick 2001, p. 41).

CULTURE

Once human factors are addressed, it is important to create a positive culture in which a safe and FOD-free work environment is a top priority. As explained by Larrigan (2004, p. 66), "FOD prevention is not something you teach once; it must be an ongoing, multifaceted program that becomes part of the culture for everyone who operates on the airside of the airport." Developing a positive FOD culture requires, first and foremost, a thorough commitment to FOD prevention by management, including management of the airport, FBO(s), airline(s), other tenants, and contractors. Personnel need to see this commitment and, with an active FOD campaign, this can be ensured. As explained by the FAA (2010a, p. 10):

> An effective FOD management program requires more than the implementation of rules and procedures to be followed. It requires the support of management to establish the attitude, decisions, and methods of operation at the policy-making level that demonstrate the organization's priority to safety.

Additional practices to ensure a positive FOD culture include (Brothers and Simmons 2004, pp. 101–104):

- Emphasis on the individual employee role in safety
- Focus on FOD awareness with efforts such as various FOD campaigns
- Effective training of personnel
- Proper containment of FOD
- Proper equipment and tools
- Regular sweeping schedule
- Tool inventory
- An active FOD committee
- Prohibition on bird and animal feeding on airport grounds
- Debris regularly removed from around ground support equipment
- Regular ramp FOD inspections
- Regular FOD bin cleaning
- Properly stowed aircraft support equipment
- Prevention of personal items from becoming FOD
- Conducting of regular self-audits.

Regardless of the specific practices adopted by an airport to create a positive FOD culture, attention to the airport's culture in relation to FOD is essential.

TRAINING

The first step in promoting an airport's FOD management program is to make certain that all personnel working within the AOA, including terminal ramps and gate areas, receive proper initial training. As stressed by Messenger (2004b, p. 12):

> For many workers FOD training means nap time; a boring video in a darkened room administered by a bored training representative who has no real contact with FOD. It doesn't have to be that way. It *can't* be that way.

Although an abbreviated form of this training can be incorporated into an airport's Security Identification Display Area training program, for employees pursuing airside driving privileges, airports may wish to require the full FOD training program. In essence, airline ramp workers may receive an abbreviated FOD training program, whereas personnel responsible for daily FOD inspections (i.e. operations, maintenance, and/or ARFF) will be fully indoctrinated. This initial training should, according to AC 150/5210-24, focus on the following areas (FAA 2010a):

1. Overview of the FOD management program in place at the airport.
2. Safety of personnel and airline passengers.
3. Causes and principal contributing factors of FOD.
4. The consequences of ignoring FOD and/or the incentives of preventing FOD.
5. General cleanliness and inspection standards for work areas (including the apron and AOA).
6. Proper care, use, and stowage of material and component or equipment items used around aircraft while in maintenance or on airport surfaces.
7. Control of debris in the performance of work assignments.
8. Control over personal items and equipment.
9. Proper control/accountability and care of tools and hardware.
10. Requirements and procedures for regular inspection and cleaning of aircraft and apron areas.
11. How to report FOD incidents or potential incidents.
12. Continuous vigilance for potential courses of hazardous foreign objects.
13. FOD detection procedures, including the proper use of detection technologies.
14. FOD removal procedures.

Similarly, NAFPI promotes the following training subjects (NAFPI n.d., p. 7):

1. Proper storage, shipping, and handling of material, components, and equipment;
2. Techniques to control debris;
3. Housekeeping;
4. Cleaning and inspection of components and assemblies;
5. Accountability/control of tools and hardware;
6. Control of personal items, equipment, and consumables;
7. Care and protection of end items;
8. Quality workmanship ("Clean-As-You-Go," inspection);
9. Flight line, taxiway, and ramp control methods; and
10. How to report FOD incidents or potential incidents.

In addition to initial training, however it may be delivered, it is important to consider recurrent training. Recurrent, oftentimes annual, FOD training is also necessary for a continued focus on FOD prevention by airport personnel. The military is skilled in providing annual FOD refresher training and, although civilian airports may not place as great an emphasis on this, it is helpful to ask, as Messenger (2004b, p. 12) noted, "What should they know in order to make improvements?" The answer to this question will vary among airports, but annual training can be a great time to review details of FOD events during the past year, corrective actions taken or planned, and an overview of upcoming initiatives to better manage FOD at the airport (Messenger 2004b). By incorporating data, photographs, and even examples of FOD retrieved, the training can be effective in gaining personnel support for the FOD program. Ball shares the following "Basic 10" list to teach (2004, p. 129):

- Keep your vehicles free from trash inside and out.
- Always account for your tools when you enter the flight line.
- Use good housekeeping; clean as you go.
- Never pass tools on to the next shift; always turn them in to ensure accountability.
- Immediately report any lost object or tool so you can get help locating it quickly.
- Check your tires at all entry control points before driving into flight-line areas.
- Bag your trash before disposal to prevent it from becoming FOD.
- Call the appropriate person if you see a ramp area that needs to be cleaned with a sweeper.
- Take FOD walks seriously; spend the extra time to pick up everything you see, no matter how small.
- Remember, it takes each and every one of us to form the protective barrier to shield our jets from FOD and keep our people safe.

In addition to these ideas, some considerations are necessary in developing an effective FOD training program. Messenger provides additional suggestions in this regard (2004b, p. 14):

- Determine class size, who will attend, when and where the training will be held, and the duration of training (45 min is a good rule of thumb).
- If possible, use a centrally located training area to reduce travel time, and schedule classes by organization/work center so that classes may be tailored to the type of work performed and particular problems encountered in that area.
- Provide training for all shifts and include all groups that touch the product, visit the work areas, or that may contribute to the generation of FOD.
- Consider requiring all organizations (including tenants and contractors) to attend training.

PROMOTION

Once initial training has been conducted, it is important to promote the FOD management program. Promotion can occur in a variety of ways, but is best accomplished by relying on multiple methods.

Commitment

Just as a commitment by management to FOD prevention is essential in developing a positive FOD culture, management commitment is also essential in successfully promoting FOD prevention. According to Messenger (2004b, p. 9):

> The single most important factor in a successful FOD Prevention Program is the complete commitment and *ongoing* support of your organization's top leadership. Without it, the program is handicapped from the start and will suffer a lack of credibility.

This commitment and support by top leadership requires resources and a concerted effort to maintain awareness of the FOD management program and the dangers of FOD. Otherwise, personnel will likely lose sight of the importance of FOD detection and removal and, if they do not sense it is important to the airport or management, they will likely become a liability to the program, rather than an asset. To develop this commitment by all levels of management and personnel, Chaplain and Reid recommend the following "Ten Commitments" to a FOD campaign (2004, p. 21):

1. Safety—FOD is a primary safety issue.
2. Protect resources—FOD costs the global aviation community several billion dollars annually.
3. Be FOD fighters—Quality people doing quality work.
4. Our customers—They should not have to pay for our carelessness. Neglecting FOD prevention reveals a lack of professionalism, integrity, and maturity.
5. Partnership—Maintain strong relationships with every organization on the airfield.
6. Employees—Flight operations or maintenance, civilian or military; everyone must be involved.

7. Prevention—Demonstrate complete personal commitment to this simple concept: "Clean-as-you-go."
8. Diminishing returns—Minimize equipment or aircraft damaged by FOD and returned for repairs.
9. Perfection—Perfection in a FOD free environment *is* possible.
10. Communication—This is the key to any successful program. Do it well.

Visibility

Effective promotion of any FOD management program requires an emphasis on visibility. This requires regularly "advertising" the importance of FOD prevention to airport personnel (Figure 32). As Messenger (2004b, p. 10) explains, "If you can't *see* 'advertising' for a FOD prevention program in the working environment, it probably isn't reaching the target personnel." It is important for all visual messages to be current, relevant, and dynamic. It is best to regularly change messages to catch the attention of airport personnel.

Various options are available to airports in visibly promoting a FOD management program (Messenger 2004b, pp. 10–11). Some of these options include:

- FOD letters, notices, and bulletins:
  - Whether in the form of a memo, letter to personnel, or a one-page bulletin these written documents can serve to enhance personnel awareness of the importance of FOD prevention.
- T-shirts, caps, or jackets with the FOD logo or mascot:
  - To encourage employee participation in wearing FOD apparel, consider holding a contest in which employees submit designs for a FOD mascot or logo, with the winning design placed on clothing items.
  - Clothing items may be distributed to employees all at once, distributed to tenants finding the most FOD each calendar quarter, used as rewards for employees offering suggestions for innovative FOD prevention, presented to employees signing a FOD commitment pledge, or provided to each employee participating in a FOD walk event.
- FOD banner:
  - This typically involves a large, permanently mounted vinyl sign with a changeable message. It may be mounted above a door, on a hangar wall, or elsewhere.
  - A set individual could be appointed with the task of changing the sign message on a monthly basis.
- Posters:
  - Posters could be mounted in frames or under Plexiglas, rather than simply taped to a wall.
  - Posters need to be relevant to the work being performed in that area and be changed regularly.
  - Although FOD posters are available commercially, this is an opportunity for a design contest, allowing employees to submit poster design ideas.
- Signs:
  - Signs should be used to remind personnel of housekeeping practices to prevent FOD, as well as the importance of FOD prevention. For instance, they may remind personnel to secure loose items, pick up debris when discovered, or check vehicle tires before entering the AOA.
  - Whether placed on a fence at the entrance to the AOA, in airline operations areas, or on the exterior of terminal buildings, signs can serve as an important reminder of FOD prevention practices.
- Shop aids:
  - FOD containers, shop vacuums, work stations, and other shop areas can play a role in FOD prevention.
  - The universally accepted color scheme for FOD is yellow with black letters, and this can be quite effective in promoting FOD awareness.

A sample FOD bulletin appears in Figure 33.

FIGURE 32 FOD sign. *Source:* Indianapolis International Airport.

Awareness

FOD Walk

An innovative way to detect FOD, as well as promote an awareness of FOD prevention, is to organize team events that center around FOD detection. The most widely used such method is commonly referred to as a "FOD Walk" (Figure 34). As previously stated, FOD walks began in the military aboard aircraft carriers and remain the first defense against foreign objects both on aircraft carriers and military installations with aircraft in operation. Many airports have adopted this practice, and although civilian airports do not conduct FOD walks as frequently as the military, it is common for these walks to be held on an annual basis. A FOD walk involves individuals (airport or airline employees, or both) walking side by side along the entire length of a runway. Armed with buckets or trash

FIGURE 33 Sample FOD bulletin.

bags and constantly scanning the pavement, volunteers are asked to pick up any foreign objects, no matter how small. To ensure safety, the runway being inspected is closed, allowing individuals to detect and remove debris in an environment without a sense of urgency. As explained by Technical Sergeant Jeffrey Vergara, 57th Wing FOD prevention NCO and organizer of the 2010 FOD walk at Nellis Air Force Base, Nevada, "By having all of Team Nellis walk the line together, we're able to cover a large amount of space in a short period of time and significantly decrease our chances of missing something that could damage an aircraft" (James 2010, paragraph 4)

FIGURE 34 FOD walk at Kadena Air Base, Japan. (*Source:* U.S. Air Force photo/Airman 1st Class Jarvie Wallace).

Planning is essential for a successful FOD walk. In addition to selecting and promoting a date, as well explaining as the purpose of the walk, certain supplies are provided. As Messenger suggests, personnel need to be properly equipped with the following supplies (2004b, p. 17):

- Heavy duty trash bags,
- A megaphone to communicate with the crowd,
- A large industrial scale to weigh the debris,
- A large flatbed truck to haul away bags of debris,
- Gifts and prizes,
- A photographer to document the event, and
- A stopwatch.

To ensure a successful FOD walk, airport operators endeavor to make the walk as creative and enjoyable an experience as possible. For instance, teams can be created and those teams that detect and remove the most FOD may receive prizes such as t-shirts or gift cards. At Lackland Air Force Base, Texas, the wing vice commander hides a gold-painted bolt on the pavement to be found during the FOD walk. Whoever finds the golden bolt wins their 15 min of fame and thanks from some roaring jet engines (McGloin 2010). In addition, FOD walks can be turned into a form of company picnic, with drinks and food being offered to participants. Additional steps toward teamwork can be taken in having airline personnel or airport tenants join airport inspectors on their daily FOD inspections to provide these individuals with additional insight into the daily application of FOD management.

> Hartsfield–Jackson Atlanta International Airport, the busiest airport in the world, hosts an annual FOD walk. Both airport and airline employees participating in the event are given a singular mission—to search for and pick up any FOD. During the May 2009 event, volunteers (including pilots, administrative assistants, and flight attendants) began arriving by 6:00 a.m. at the north cargo building and boarded buses to be driven to runway 8L/26R. According to Garth Collins, airport senior operations supervisor, "We received a strong showing of support from volunteers who wanted to be a part of this year's FOD Walk. And they did an outstanding job. I was extremely pleased to see practically every career field in Aviation represented during the event." Collins explained that all employees are encouraged to pick up FOD from roadways and ramps during their daily work routine, and to report items detected on the airfield to the Airport's Airside Operations unit (Smith 2009).

Additional Awareness Activities

Effective FOD management programs regularly incorporate various activities to keep personnel engaged with FOD prevention. Many of these activities can be part of a "FOD Week" and prizes can be offered to participants. Messenger

(2004b, pp. 15–16), Larrigan (2004, p. 78), and Brothers and Simmons (2004, p. 105) share the following ideas:

- Adopt a runway
  - Community organizations can be invited to adopt a runway or ramp, and the airport can periodically close that pavement to allow the sponsor to clean the area of debris.
- Committee tours
  - By allowing a FOD committee to hold a meeting as they tour the AOA members may be able to identify problem areas or issues. This knowledge will allow the committee to better formulate strategies to prevent FOD at the airport.
- Incentive program
  - Allows personnel to nominate an employee who has been especially effective at removing or preventing FOD, whereby that employee is rewarded with a gift card or other incentive.
- Caught in the act
  - By rewarding employees on the spot for effective FOD removal/prevention, the motivation to continue being proactive in this regard should persist.
- Cleanest gate award
  - Personnel with the cleanest gate area may be rewarded with the "Cleanest Gate of the Day Award."
- FOD holiday tree
  - Personnel can decorate trees during the holiday season with debris that has been collected during the year.
- FOD poster contest
  - Personnel can submit designs for posters to be displayed around the workplace.
- Guess the number of FOD items in the jar
  - Smaller pieces of FOD can be collected, retained, counted, and placed in a plastic jar. Personnel can then guess the number of items in a jar, while also getting a better idea of the types of FOD collected. Entering individuals into a prize drawing and awarding t-shirts to winners may be appreciated by personnel.
- FOD awareness test
  - A 10 to 15 question multiple-choice test based on the FOD management program or FOD Standard Operating Procedure can be developed.
  - By placing these tests in a central location near a drop-box, personnel can challenge their knowledge and enter to win various prizes.
- FOD inventories
  - By sorting FOD collected from the AOA, an airport can possibly identify the company/personnel responsible for generating the debris and ask them to consider the importance of good housekeeping practices.
- FOD crossword puzzle
  - A crossword puzzle of FOD terms can be developed, with those personnel correctly completing the puzzle eligible to win prizes.

Because most of these activities will require prizes to ensure participation, it is helpful to develop prize guidelines. Messenger (2004b) recommends that most prizes be in the $20 to $30 range, and include items such as gift cards, FOD hats and other clothing items, or a free dinner for two. Grand prize drawings may include a set of FOD control tools, theatre tickets, or tickets to local athletic events. Airports may find it useful to survey personnel to gather additional ideas. In any event, prizes should be advertised when promoting FOD awareness or FOD special events.

In addition, airports may implement promotional tools such as FOD seminars, FOD workshops or conferences, FOD lessons-learned, FOD bulletin boards, safety reporting drop-boxes, and electronic reporting through websites or e-mail. Airports may also find it useful to develop methods to exchange safety-related information with other airport operators.

CURRENT AIRPORT TRAINING, PROMOTION, AND MANAGEMENT PRACTICES

Programs and Practices in Use

When queried about the types of FOD awareness programs and practices currently in use, participating airports shared a wide variety of programs. As seen in Figure 35, the most common method for promoting FOD awareness is through letters, notices, or bulletins. To stay abreast of current best practices, many participating airports also make use of methods to exchange FOD information with other airport operators. However, this method of information exchange is less common among smaller airports. Almost one-third also use FOD bulletin boards, safety reporting drop-boxes, or electronic reporting through websites or e-mail.

Level of Importance

Airports were also queried about the level of importance various groups at the airport place on promoting and supporting FOD awareness, as well as ensuring that debris are discovered and promptly removed. As seen in Figure 36, participating airports indicated that airport operations personnel place the highest importance on FOD awareness. Airport management and airport maintenance personnel also place a high emphasis on FOD awareness. According to participating airports, somewhat less importance is placed on FOD awareness by other groups, such as air carriers, hangar tenants, concessionaires, and FBOs and ground support companies.

Participation

To be successful, a FOD management program requires participation by more than airport operations personnel. To guide the level of involvement by others, airports were asked which tenants play an active part in the FOD management program.

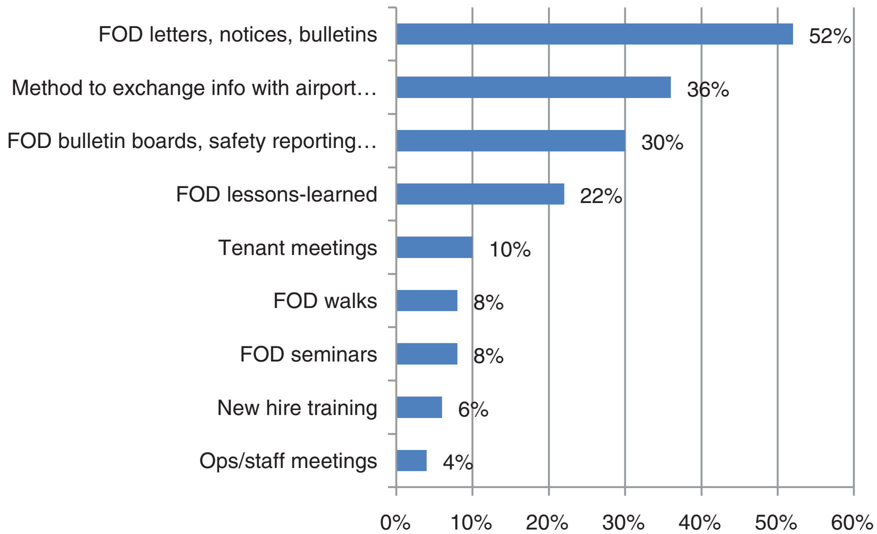

FIGURE 35 FOD awareness programs and practices in use. *Note:* Participants were able to select all that apply. Thus, percentages do not total 100%.

According to participating airports, air carriers and FBOs played the most active role. However, hangar tenants, ground support companies, and military operators also played significant roles, with concessionaires playing a very minor role.

Additional Practices

FOD Manager

Only 17% of participating airports mentioned that they employ a FOD manager with responsibility for the airport's FOD management program. One-half of respondents explained that these FOD management duties are carried out by an employee as part of their existing job responsibilities. One-third of participating airports have no specific person in charge of the airport's FOD management program. Not one respondent indicated that this duty was carried out by an outside consultant. When analyzing responses to this issue by airport hub size, it is common among all airports other than large hubs to have no specific person in charge of the FOD management program. Likewise, it is most common among large hubs to have the FOD management duties carried out by a current employee as part of existing job duties.

Training Program

To determine if airports have a training program for the purpose of increasing employee awareness of the causes and effects of

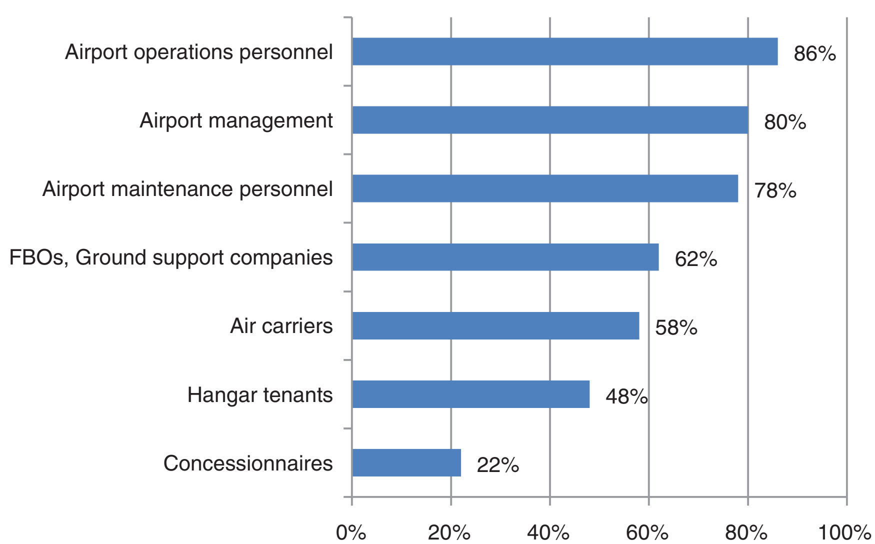

FIGURE 36 Importance placed on FOD awareness programs. *Note:* Participants were able to select all that apply. Thus, percentages do not total 100%.

FOD and promoting active employee participation in eliminating causes of foreign object damage, airports were asked if they currently operate a FOD training program. Almost one-half (47%) of respondents indicated they do have a FOD training program, whereas 53% do not.

Quality Assurance

When queried about the methods used by airports to ensure the quality of a FOD management program, more than three-quarters of participants explained that management oversight was used. More than half also indicated that initial and recurrent training was used. Only 24% relied on equipment, technology, or internal audits to ensure quality.

Adaptations During Low Visibility and Nighttime

Of concern with any FOD management program is the ability of personnel to detect and remove debris during reduced visibility and nighttime conditions. When asked how their airport had adapted its FOD management program to ensure effectiveness during reduced visibility and nighttime conditions, 42% said there had been no adaptation. Of the adaptation that has taken place, the use of more frequent inspections appeared to be the most common (33%).

Additional Resources

When presented with the possibility of acquiring additional resources for enhancing a FOD management program, more than 70% indicated they would acquire equipment or technology for detection and/or removal. The second and third most common answers, respectively, were more frequent inspections and more effective training of personnel.

Liability

Concerning the liability associated with FOD hazards, one question asked participating airports how many insurance or other claims resulting from FOD had been made at their airport during the past 24 months by air carriers, FBOs, or others. The vast majority (71%) indicated that no claims had been filed, whereas 10% indicated that fewer than five claims had been filed; almost 15% were not sure.

CHAPTER SEVEN

CONCLUSIONS

This study found that a wide variation exists among airports in the practices, techniques, and tools used to conduct inspections for Foreign Object Debris (FOD) and wildlife hazards. Furthermore, there was no readily available synthesis of current airport inspection practices for FOD and wildlife hazards from which airport operators could review and improve their own inspection procedures. This synthesis (1) presents current airport inspection practices regarding FOD, and (2) presents the range of technology and equipment currently available to airports for inspecting, detecting, removing, and documenting FOD.

The following findings and common practices were discovered.

Inspection

- Most airports rely on human/visual inspection for FOD.
- Most airports inspect movement areas (runways and taxiways) more frequently than non-movement areas.

Detection

- Most airports rely on manual detection of FOD by human/visual means, without any type of FOD technology in use.
- Most airports have some type of FOD management program in place.
- Those few airports with some sort of FOD detection technology in use believe that the benefits either exceed or are worthy of the cost.

Removal

- Most airports use both human/visual means and either mechanized or non-mechanized means to remove FOD.
- Of the mechanized means in use, most airports use power sweepers and vacuum systems. Of the non-mechanized means in use, most airports use magnetic bars.
- Of those airports using mechanical means to remove FOD, most believe these means are very useful.
- The most common type of FOD removed on paved movement areas is runway and taxiway materials, including concrete chunks, rubber joint materials, and paint chips.
- The most common type of FOD removed on ramp areas is apron items, including paper and plastic debris, luggage parts, and debris from ramp equipment.

Documentation

- Most airports document FOD most of the time FOD is removed.
- When documenting FOD, most airports record the location of the FOD, the date and time FOD were detected and/or retrieved, a description of the FOD, and the name of personnel investigating and removing the FOD.
- Most airports do not currently utilize an electronic database for documenting FOD.
- Of those airports that do utilize an electronic database, the most common criterion for analysis is location of FOD.

Training, Awareness, and Management

- Most airports utilize FOD letters, notices, and/or bulletins to enhance awareness of their FOD management program.
- According to participating airports, only airport operations personnel, airport maintenance personnel, and airport management place a high level of importance on FOD management.
- At most airports, air carriers (if present) and FBOs play an active part in FOD management.
- At most airports, the FOD management program is handled by someone as part of their existing job duties.
- Most airports do not have a formal FOD training program.
- Most airports ensure the quality of their FOD management program by the use of management oversight.
- If additional resources were made available for FOD management, most airports would acquire equipment/technology for the detection and/or removal of FOD.
- When asked to share thoughts on how FOD management could be improved at their airport, most airports would like to see a better structured FOD management program, as well as the acquisition of technology to aid in FOD detection.

At small, general aviation airports, a FOD management program will typically have a fairly simple structure. At larger, commercial service airports, it may involve many airlines and likely employ a full-time FOD manager. In essence, the FOD management program will be commensurate with the complexity of the airport. Regardless, when a FOD program is developed to meet the unique needs of the airport, damage caused by FOD will be reduced, which benefits not only the airport, but users, tenants, and the entire aviation industry.

In addition to common practices, the following list provides practices that were identified by airports as successful for their FOD Management Program.

Inspection and Detection

- FOD checklist for inspection personnel.
- FOD event/incident form to record specific conditions related to FOD removed (that would later be entered into an electronic FOD database with photo).
- Integration of FOD management with Wildlife Hazard Management Plan and Safety Management System.
- Regular, proactive FOD inspections conducted visually (ICAO standard is four times per day) focusing on both movement and non-movement areas (may be part of a self-inspection as required by Part 139).
- Reactive inspections as FOD is reported by pilots, Air Traffic Control, and others.
- Supplement manual inspections with automated detection technology.

Removal

- FOD containers strategically placed throughout ramp/gate areas.
- Closure of pavement as necessary to prevent aircraft operations on a contaminated surface.
- Proactive removal of FOD with the use of non-mechanized equipment such as tow-behind friction mats and magnetic bars or with the use of mechanized equipment such as power sweepers and vacuum systems.

Documentation and Analysis of Data

- Electronic database with records of FOD removed from movement areas (runways and taxiways).
- Photographs of FOD removed from movement areas (runways and taxiways).
- Regular analysis of data to reveal trends in types of FOD, locations of FOD, and possible generators of FOD, as well as any reductions in FOD removed to gain insight into the effectiveness of the airport's promotion and awareness program.

Training and promotion

- Commitment from management to the FOD management program and the goal of continuous improvement in the area of FOD prevention at the airport.
- Tenant involvement and participation.
- FOD committee, with regular meetings, to establish policy, guidelines, and goals.
- Regular FOD walks, with refreshments and group photos, as well as awards for the most FOD collected or special item(s) found presented at an awards ceremony.
- Promotion and awareness program involving posters, t-shirts, bulletins, banners, and stickers, as well as regular activities to maintain interest and participation in the FOD program, such as contests and clean gate awards.
- Training of personnel, including airline and contractor personnel, of good housekeeping practices and the emphasis on FOD prevention.

Although many questions were answered regarding the manner in which airports manage FOD, additional questions surfaced as well. Below are suggested areas of further research.

- As FOD walks and other proactive FOD mitigation measures began in the military; additional research could be conducted with this population.
- As airports begin acquiring FOD detection technology, follow-up studies could be conducted whereby the experiences of these airports are shared with the community of airports nationwide.
- Research that might lead to a guidebook to assist airports in developing and implementing a FOD management program.
- Uses of FOD detection sensors for additional applications in the airport environment.

ACRONYMS

AAAE	American Association of Airport Executives
AAGSC	Australasian Aviation Ground Safety Council
AC	Advisory Circular
AIP	Airport Improvement Program
AOA	Aircraft Operations Area
ARFF	Aircraft Rescue and Fire Fighting
ARS	Automated Runway Scanning
ATC	Air Traffic Control
AVOP	Airside Vehicle Operator's Permit
CFR	Code of Federal Regulations
FBO	Fixed-base operator
FLIR	Forward Looking Infrared
FOD	Foreign Object Debris
GA	General aviation
GIS	Geographical information system
GPS	Global Positioning System
GSE	Ground support equipment
ICAO	International Civil Aviation Organization
NAFPI	National Aerospace FOD Prevention, Inc.
PC	Personal computer
SAT	San Antonio International Airport
SHEL	Software, Hardware, Equipment, and Liveware

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APPENDIX A

Participating Airports

Airports Council International ICAO Bureau (Montreal)

Albertus (IL) Airport

Bismark (ND) Airport

Bob Hope (CA) Airport

Boston (MA) Logan International Airport

Boulder City Municipal (CO) Airport

Buffalo Niagara (NY) International Airport

Burlington (VT) International Airport

Casper/Natrona County (WY) International Airport

Colorado Springs (CO) Airport

Columbia (MO) Regional Airport

Dallas/Fort (TX) International Airport

Dubuque (IA) Regional Airport

Denver (CO) International Airport

Eielson (AK) Air Force Base

Fitchburg (MA) Municipal Airport

General Mitchell (WI) International Airport

Geneva (Switzerland) International Airport

Groton–New London (CT) Airport

Hartsfield–Jackson Atlanta (GA) International Airport

Hill (UT) Air Force Base

Lambert–St. Louis (MO) International Airport

Los Angeles (CA) International Airport

McClellan–Palomar (CA) Airport

Minneapolis–St. Paul International Airport

Oakland (CA) International Airport

Portland (OR) International Airport

Roanoke (VA) Regional Airport

Savannah/Hilton Head (SC) International Airport

San Antonio (TX) International Airport

Seattle–Tacoma (WA) International Airport

Sioux Falls (SD) Regional Airport

Smyrna/Rutherford County (TN) Airport

Sussex County (DE) Airport

Tampa (FL) International Airport

Toronto Pearson (Ontario, Canada) International Airport

Tweed New Haven Regional (CT) Airport

Vancouver (British Columbia, Canada) International Airport

Victoria (British Columbia, Canada) International Airport

Wichita (KS) Mid-Continent Airport

Will Rogers World (OK) Airport

Zurich (Switzerland) Airport

Note: Eight airports did not indicate.

APPENDIX B

Airport Survey of Inspection Practices Questionnaire

Airport Survey of Inspection Practices (P1)

As an airport operator, you have been selected to participate in an important national synthesis of Current Airport Inspection Practices Regarding Foreign Object Debris (FOD). This project, which is funded by the National Academies as part of the Transportation Research Board's Airport Cooperative Research Program, is designed to gather data regarding the manner by which airports conduct airport inspections for the purpose of detecting, removing, and documenting FOD. Your participation is extremely important as we strive for at least an 80 percent response rate.

Although your responses will remain confidential, the researcher is able to correlate responses to your name and email address for the sole purpose of ensuring the adequacy and integrity of responses. You will not be contacted by the researcher or anyone associated with this project in an attempt to sell goods/services to your airport. Final data will be reported in aggregate and your airport will only be identified as a possible case example of best practices, if you so authorize. Your participation is voluntary. Your decision whether or not to participate will not affect your standing with The National Academies, the Transportation Research Board, or Prather Airport Solutions, Inc. If you choose to participate, you are free to withdraw from the study at any time without consequence or penalty.

The survey should take no more than 15 minutes of your time. By clicking next, you agree to participate in this data gathering effort. If you do not wish to participate in the survey, please close your browser window. Unless you opted out via the email invitation, we may make follow-up emails or calls to you to help clarify a response, to achieve the required 80 percent response rate, or to respond to any questions you may write or have.

Note: For the purposes of this study, the term "FOD" refers to any object, living or not, located in an inappropriate location in the airport environment that has the capacity to injure airport or airline personnel and damage aircraft. The term "FOD Management Program" refers to the activities of inspection, detection, removal, and documentation of FOD at airports.

1. To what degree is Foreign Object Debris (FOD) a problem at your airport?

- ◯ Not a problem
- ◯ Somewhat a problem
- ◯ Moderate problem
- ◯ Severe problem

2. Which of the following methods does your airport use (and how frequently) to inspect for FOD? Select all that apply.

	Daily	Weekly	Monthly	Annually
Human/Visual (not incl FOD walks)	◯	◯	◯	◯
Human/Visual (incl FOD walks)	◯	◯	◯	◯
Continuous surveillance using technology/equipment	◯	◯	◯	◯
Periodic surveillance using technology/equipment	◯	◯	◯	◯
Our airport does not inspect for FOD	◯	◯	◯	◯

Other (please specify)

[ ]

Airport Survey of Inspection Practices (P1)

3. What system(s) does your airport use to detect FOD? Select all that apply.

- ☐ Manual (Human/visual)
- ☐ Fixed (supporting continuous surveillance)
- ☐ Mobile (supporting continuous surveillance)
- ☐ Mobile (supporting periodic surveillance)
- ☐ Other (please specify)

4. What procedures are in place at your airport if FOD is detected by someone other than the airport operator (i.e., pilot report to ATCT)? Select all that apply.

- ☐ Close, or restrict activity in, affected areas
- ☐ Redirect traffic
- ☐ Advise pilots
- ☐ Notify airport operator
- ☐ No formal procedures exist
- ☐ Letter of agreement with ATCT exists
- ☐ Other (please specify)

5. Does your airport have a FOD management program in place?

- ○ Yes
- ○ No

6. Does your airport have plans in the next 12 months to implement a FOD management program?

- ○ Yes
- ○ No
- ○ Not Sure

Airport Survey of Inspection Practices (P1)

7. Has your airport investigated the various types of technology and equipment available for detecting FOD at airports?

- ◯ Yes
- ◯ No
- ◯ Somewhat

8. Does your airport currently use technology/equipment (such as radar and/or electro-optical sensors) for <u>detecting</u> FOD?

- ◯ Yes
- ◯ No

9. Please describe the type of technology/equipment in use at your airport.

10. Comparing the acquisition cost of FOD technology/equipment to the benefits derived, do you feel the benefits:

- ◯ Exceed the cost
- ◯ Are worthy of the cost
- ◯ Do not justify the cost

11. Does your airport have plans to acquire, in the next 24 months, any technology/equipment (such as radar and/or electro-optical sensors) for <u>detecting</u> FOD?

- ◯ Yes
- ◯ No
- ◯ Not sure

12. What method(s) does your airport use to remove FOD? Select all that apply.

- ☐ Human/Manually
- ☐ Mechanically (i..e., magnetic bars, vacuum, sweeper)
- ☐ Other (please specify)

Airport Survey of Inspection Practices (P1)

13. Of the FOD removed at your airport on an annual basis, please specify the most common types of FOD removed by area. (You may select more than one type of FOD per area as long as each type selected contributes to the majority of FOD collected by area, i.e. is most common.)

	Runways	Taxiways	Taxilanes	Air carrier ramps	Cargo ramps	GA ramps	Hangar areas (incl maint)	Outside defined construction areas	Non-pavement areas
Aircraft parts (i.e., nuts, fuel caps, safety wire, tire fragments)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mechanic's tools	☐	☐	☐	☐	☐	☐	☐	☐	☐
Catering supplies	☐	☐	☐	☐	☐	☐	☐	☐	☐
Flight line items (i.e., luggage tags, soda cans, SIDA badges)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Apron items (i.e., paper and plastic debris, luggage parts, debris from ramp equipment)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Runway and taxiway materials (i.e., concrete chunks, rubber joint materials, paint chips)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Construction debris (i.e., pieces of wood, stones, fasteners, nails, hardware)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Plastic and/or polyethylene materials	☐	☐	☐	☐	☐	☐	☐	☐	☐
Natural materials (i.e., plant fragments and wildlife)	☐	☐	☐	☐	☐	☐	☐	☐	☐
FOD as a result of winter operations (i.e., ice and snow, vehicle or equipment parts, broken lights)	☐	☐	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

[ ]

14. Does your airport currently use technology/equipment (such as power sweepers, jet air blowers, magnetic bars, etc.) for <u>removing</u> FOD ?

○ Yes

○ No

Airport Survey of Inspection Practices (P1)

15. Which of the following type(s) of FOD removal technology/equipment is in use at your airport?

- ☐ Power sweeper, including tow-behind bristle trailer
- ☐ Vacuum system
- ☐ Jet air blower
- ☐ Tow-behind debris retention mesh
- ☐ Magnetic bars
- ☐ Rumble strips
- ☐ Other (please specify)

16. How useful is the technology/equipment in use at your airport?

- ○ Very useful
- ○ Somewhat useful
- ○ Not useful

17. Does your airport have plans to acquire, in the next 24 months, any technology/equipment (such as power sweepers, jet air blowers, magnetic bars, etc.) for removing FOD?

- ○ Yes
- ○ No
- ○ Not Sure

18. How often is FOD retrieval/removal documented at your airport?

- ○ Every time FOD is retrieved/removed
- ○ Most times when FOD is retrieved/removed
- ○ Sometimes when FOD is retrieved/removed
- ○ Never

Airport Survey of Inspection Practices (P1)

19. In what manner do you currently document FOD at your airport? Select all that apply.

- [ ] How the FOD was detected
- [ ] Date and time of FOD detection and retrieval
- [ ] Description of FOD retrieved (category, size, color)
- [ ] Location of FOD
- [ ] Possible source
- [ ] Name of personnel detecting/investigating/removing FOD
- [ ] An image of the FOD object retrieved
- [ ] Airport operations data during FOD detection event
- [ ] Weather data during FOD detection event
- [ ] Other (please specify)

20. Does your airport have an electronic database in use for documenting FOD (showing at least the type, location, and source)?

- ◯ Yes
- ◯ No
- ◯ Not currently, but we plan to in the near future

21. How is the data in this database analyzed? Select all that apply.

- [ ] How the FOD was detected
- [ ] Date and time of FOD detection and retrieval
- [ ] Description of FOD retrieved (category, size, color)
- [ ] Location of FOD
- [ ] Possible source
- [ ] Name of personnel detecting/investigating/removing FOD
- [ ] An image of the FOD object retrieved
- [ ] Airport operations data during FOD detection event
- [ ] Weather data during FOD detection event
- [ ] Other (please specify)

Airport Survey of Inspection Practices (P1)

22. Who analyzes the data in the database?

- [ ] Operations personnel
- [ ] FOD manager
- [ ] Airport management
- [ ] Wildlife biologist

Other (please specify)

23. Who utilizes the FOD data gathered? Select all that apply.

- [ ] Operations department
- [ ] Air carriers
- [ ] Tenants/users
- [ ] Airport management
- [ ] State regulatory agency
- [ ] FAA (or similar agency)

24. Which of the following FOD awareness programs/practices are in place at your airport?

- [ ] FOD seminars
- [ ] FOD letters, notices, and/or bulletins
- [ ] FOD lessons-learned
- [ ] FOD bulletins boards, safety reporting drop boxes, and/or electronic reporting through web sites or email
- [ ] Method to exchange safety-related information with other airport operators
- [ ] None
- [ ] Other (please specify)

Airport Survey of Inspection Practices (P1)

25. What level of importance do the following groups at your airport place on promoting and supporting FOD awareness or ensuring FOD is discovered and removed?

	Very high importance	Fairly high importance	Average importance	Little importance	No importance
Airport operations personnel	○	○	○	○	○
Airport maintenance personnel	○	○	○	○	○
Airport management	○	○	○	○	○
Air carriers	○	○	○	○	○
Hangar tenants	○	○	○	○	○
Concessionaires	○	○	○	○	○
FBOs, Ground support companies	○	○	○	○	○

Other (please specify)

26. Which of the following tenants play an active part in the FOD management program at your airport? Select all that apply.

- ☐ Air carriers
- ☐ Hangar tenants
- ☐ Concessionaires
- ☐ FBOs
- ☐ Ground support companies
- ☐ Military
- ☐ Other (please specify)

27. Does your airport employ a FOD manager (an individual responsible for the airport's overall FOD management program)?

- ○ Yes
- ○ No-the airport has no specific person in charge of the FOD management program
- ○ No-this task is carried out as part of someone's existing job duties
- ○ No-this task is handled by an outside consultant

Airport Survey of Inspection Practices (P1)

28. Does your airport have a FOD training program (for the purpose of increasing employee awareness of the causes and effects of foreign object damage and promoting active employee participation in eliminating causes of foreign object damage during performance of daily work routines)?

- ◯ Yes
- ◯ No

29. What is the frequency of runway closures at your airport for non-routine FOD inspection/removal?

- ◯ Once or more per day
- ◯ Once or more per week
- ◯ Once or more per month
- ◯ Our airport does not close runways for non-routine FOD inspection/removal

30. What method(s) does your airport use to ensure the quality of your FOD management program? Select all that apply.

- ☐ Internal audits
- ☐ External audits
- ☐ Initial training
- ☐ Recurrent training
- ☐ Use of equipment/technology
- ☐ Management oversight
- ☐ Other (please specify)

Airport Survey of Inspection Practices (P1)

31. How has your airport adapted its FOD management program to ensure effectiveness even during reduced visibility and nighttime conditions? Select all that apply.

- [ ] No adaptation
- [ ] More frequent inspections
- [ ] More effective training of personnel
- [ ] Acquisition of FLIR or similar technology
- [ ] Acquisition of continuous surveillance technology
- [ ] We do not have a FOD management program
- [ ] Other (please specify)

32. If resources were available, which of the following activities or actions would your airport choose for the purpose of enhancing your FOD management program? Select all that apply.

- [ ] More frequent inspections
- [ ] More effective training of personnel
- [ ] Additional staff
- [ ] Acquisition of equipment/technology for detection and/or removal
- [ ] Acquisition of equipment/technology for documentation
- [ ] Other (please specify)

33. If your airport makes a distinction, please explain how FOD management at your airport is approached differently among movement and non-moment areas. For example, are the frequency of inspections or the technology utilized different for runways than aprons?

Airport Survey of Inspection Practices (P1)

34. During the past 24 months, how many insurance or other claims due to FOD have been made at your airport by your air carriers, FBO, or others?

- None
- Less than 5
- 5-10
- Greater than 10
- Not sure

35. Please share your thoughts in how your airport could enhance its FOD management program, to include inspecting, detecting, removing and documenting FOD.

36. In what region of the world is your airport located?

- U.S. Alaska Region
- U.S. Central Region
- U.S. Eastern Region
- U.S. Great Lakes Region
- U.S. New England Region
- U.S. Northwest Mountain Region
- U.S. Southern Region
- U.S. Southwestern Region
- U.S. Western Pacific Region
- Asia
- Africa
- Canada
- Europe
- South America
- Australia

Airport Survey of Inspection Practices (P1)

37. How is your airport categorized?

- ◯ Large Hub (at least 1% of total U.S. passenger enplanements)
- ◯ Medium Hub (between 0.25 and 1% of total U.S. passenger enplanements)
- ◯ Small Hub (between 0.05 and 0.25% of total U.S. passenger enplanements)
- ◯ Non-Hub (less than 0.05 % but more than 10,000 enplanements)
- ◯ Nonprimary (from 2,500 to 10,000 annual passenger enplanements)
- ◯ General Aviation
- ◯ Military

38. How many annual operations were conducted at your airport for CY2009?

- ◯ Less than 10,000
- ◯ 10,001-30,000
- ◯ 30,001-70,000
- ◯ 70,001-100,000
- ◯ 100,001-150,000
- ◯ 150,001-200,000
- ◯ 200,001-300,000
- ◯ Greater than 300,000

39. In what manner is your airport certificated?

- ◯ 14CFR Part 139 - Class I
- ◯ 14CFR Part 139 - Class II
- ◯ 14CFR Part 139 - Class III
- ◯ 14CFR Part 139 - Class IV
- ◯ ICAO Annex 14
- ◯ Not certificated

40. Do you have a FOD inspection checklist that you would be willing to share? If yes, please email your checklist to dprather@pratherairportsolutions.com

- ◯ Yes
- ◯ No

Airport Survey of Inspection Practices (P1)

41. If you would like to provide any additional information regarding your FOD management program, such as FOD walks or tenant awareness programs, please do so below:

42. Are you willing to allow your airport's name to appear in the final Synthesis Report as a case study or as a participant? If Yes, please provide your contact information in the space below.

- ☐ No
- ☐ Yes: Name, Airport, Email, Phone

Thank you for your time and effort in completing this survey. Your responses regarding airport inspection practices for FOD will provide great insight into this topic and will strengthen the synthesis of information on this topic. If you have any questions regarding the survey, please contact Dr. Daniel Prather at dprather@pratherairportsolutions.com or 615-663-5570. You can mail any documentation that you feel might be helpful to this study to the following address. Thank you.

Dr. C. Daniel Prather, A.A.E.
Prather Airport Solutions, Inc.
425 North Thompson Lane, Ste #38
Murfreesboro, TN 37129

APPENDIX C

Survey of Manufacturer/Suppliers of Airport Inspection Technology and Equipment Questionnaire

Survey of Manufacturers/Suppliers of Airport Inspection Technology and

You have been selected to participate in an important national synthesis of Airport Inspection Practices Regarding FOD/Wildlife Hazards due to your company's products designed to assist airports in carrying out inspections and detecting and removing FOD. This project is funded by the National Academies as part of the Transportation Research Board's Airport Cooperative Research Program. Your participation is extremely important as we strive for at least an 80 percent response rate. Please note that we plan to follow-up with non-respondents to ensure a satisfactory response rate.

We will collect no information with this study that can be personally identified to you. Your company will only be identified as a source of technology/equipment to assist airports in conducting inspections. Your participation is voluntary. Your decision whether or not to participate will not affect your standing with The National Academies, the Transportation Research Board, or Prather Airport Solutions, Inc. If you choose to participate, you are free to withdraw from the study at any time without consequence or penalty.

The survey should take no more than 10 minutes of your time. By clicking "Next," you agree to participate in this data gathering effort. If you do not wish to participate in the survey, please click "Exit this survey" or close your browser window. Unless you opted out via the email invitation, we may make follow-up emails or calls to you to help clarify a response, to achieve the required 80 percent response rate, or to respond to any questions you may write or have.

Note: For the purposes of this study, the term "FOD" refers to any object, living or not, located in an inappropriate location in the airport environment that has the capacity to injure airport or airline personnel and damage aircraft. The term "FOD Management Program" refers to the activities of inspection, detection, removal, and documentation of FOD at airports.

1. For which of the following components of an airport inspection program does your company supply equipment/technology?

- ☐ Inspection
- ☐ Detection
- ☐ Removal
- ☐ Documentation/Data management
- ☐ Training
- ☐ Other (please specify)

2. For which of the following methods does your company supply technology/equipment?

- ☐ Human/Visual (typically in a vehicle)
- ☐ Continuous surveillance
- ☐ Intermittent surveillance
- ☐ Other (please specify)

Survey of Manufacturers/Suppliers of Airport Inspection Technology and

3. For each of the following components of an airport inspection program, specify what technology/equipment your company offers and the price range.

Inspection

Detection

Removal

Documentation

4. What specific benefit(s) to a FOD management program will your product provide?

5. Has a third party verified the performance of your product(s)? If so, please explain.

- [ ] No
- [ ] Yes (please explain)

6. Can you provide client comments to support the performance of your product or technology?

7. For which of the following categories of airports is your product(s) most appropriate?

- [ ] Large hub
- [ ] Medium hub
- [ ] Small hub
- [ ] Non-hub
- [ ] General Aviation
- [ ] Military
- [ ] All of the above
- [ ] None of the above
- [ ] Other (please specify)

Survey of Manufacturers/Suppliers of Airport Inspection Technology and

8. Please specify the percentage of your company's total sales to the following categories of airports:

Large hub

Medium hub

Small hub

Non-hub

General Aviation

Military

Non-U.S.

9. How many years has your company been supplying equipment/technology for airport inspections and/or FOD detection/removal?

- Less than 1year
- 1 to 3 years
- 4 to 5 years
- 6 to 7 years
- 8 to 9 years
- 10 or more years

10. Please share a case study of an airport utilizing your product(s).

11. Please provide any additional information that you feel might be helpful to us.

Survey of Manufacturers/Suppliers of Airport Inspection Technology and

12. In which of the following FAA regions is your company located (headquartered)?

- ◯ Alaska
- ◯ Central
- ◯ Eastern
- ◯ Great Lakes
- ◯ New England
- ◯ Northwest Mountain
- ◯ Southern
- ◯ Southwestern
- ◯ Western Pacific
- ◯ Non-US

Thank you for your time and effort in completing this survey. Your responses regarding the equipment/technology available for airports will provide great insight into this topic and will strengthen the synthesis of information on this topic. If you have any questions regarding the survey, please contact Dr. Daniel Prather at dprather@pratherairportsolutions.com or 615-663-5570. You can mail any documentation that you feel might be helpful to this study to the following address. Thank you.

Dr. C. Daniel Prather, A.A.E.
Prather Airport Solutions, Inc.
425 North Thompson Lane, Ste #38
Murfreesboro, TN 37129

APPENDIX D

Sample FOD and Damage Prevention Standard Operating Procedure (Courtesy of Wichita Airport Authority)

WICHITA AIRPORT AUTHORITY

STANDARD OPERATING PROCEDURE #26 EFFECTIVE DATE: 8/13/2008

FOREIGN OBJECT DEBRIS AND DAMAGE PREVENTION

PURPOSE

WAA Standard Operating Procedure #26 has been developed by the Wichita Airport Authority (WAA) for the purpose of providing procedural guidance for methods of reducing Foreign Object Debris (FOD) on aircraft operating areas of Mid-Continent Airport.

The WAA will alter or amend these procedures, as it deems appropriate or necessary, with or without notice, in the interest of safety and security.

SUPPLEMENTAL DOCUMENTS:

WAA Standard Operating Procedure #5 Mid-Continent AOA Operating Procedures.

FAA Advisory Circular, AC 150/5380-5 (current edition) Debris Hazards at Civil Airports

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Effective Date: 8/13/08

WICHITA AIRPORT AUTHORITY

STANDARD OPERATING PROCEDURE #26

WICHITA AIRPORT AUTHORITY

FOREIGN OBJECT DEBRIS & DAMAGE PREVENTION

Approved By:

WICHITA AIRPORT AUTHORITY

Victor D. White, Director of Airports	9/22/08 Date

WICHITA AIRPORT AUTHORITY

STANDARD OPERATING PROCEDURE #26 EFFECTIVE DATE: 8/13/2008

FOREIGN OBJECT DEBRIS AND DAMAGE PREVENTION

Section 1. DEBRIS HAZARDS

1.1. Airport debris hazards, or Foreign Object Debris (FOD) are, in general, any object that does not belong on airport apron, ramp, taxiway, runway, safety area or other area on which aircraft operate on or adjacent to.

More specifically FOD is any object or material with a potential for causing damage to an aircraft, either by engine ingestion, damage to or erosion of a propeller, puncturing or cutting a tire, or causing any other damage to any portion of an aircraft.

Loose FOD can also be blown at high velocity by aircraft prop wash and jet blast, endangering personnel and damaging aircraft, vehicles and structures.

1.2. Materials causing FOD may come from many sources, including, but not limited to:

Pavement distress, causing loose gravel and debris

Lightning strikes causing pavement cratering and debris

Rocks and gravel carried on to pavement by vehicle tires

Loose / lost screws, fasteners, parts, tools from aircraft or vehicles

Luggage tags, clips, zippers, straps and fasteners

Mower operations throwing grass and debris onto adjacent pavement areas

Sand and abrasive materials used for ice mitigation

Contractor debris from construction and maintenance projects

Beverage and food containers

Wind blown trash

Chemicals used for rubber removal

Clothing and uniform items including hats, gloves, ID badges and marshalling wands,

Wildlife

WICHITA AIRPORT AUTHORITY

STANDARD OPERATING PROCEDURE #26 EFFECTIVE DATE: 8/13/2008

FOREIGN OBJECT DEBRIS AND DAMAGE PREVENTION

Section 2. WAA REGULATORY STANDARDS

Reference:

WAA Standard Operating Procedure #5 Mid-Continent AOA Operating Procedures.

Section 8 (SOP #5) FOD CONTROL

8.1. Each person issued a WAA Security Access and Identification Media, is responsible if aware of a potential FOD issue, to either correct it or report it so it may be corrected.

8.2. Each contractor, company, tenant, department or work location supervisor, is directly responsible for FOD control during normal operations, maintenance, or construction activity on or adjacent to the AOA.

8.3. Where an access or haul route crosses an active movement area a contractor shall have positioned at the crossing a sweeper and operator available to immediately remove FOD from the pavement.

8.4. Where an access or haul route crosses an active and paved movement area under conditions of mud in the construction area which may not readily sweep off the paved movement area surface, a contract shall, in addition to a sweeper, position a water truck or pressure washer to assist in washing the contaminated pavement surface area.

8.5. Any paved movement area, taxiway or runway, used as a haul route, crossed or transitioned by contractor vehicles shall be swept, pressure washer or otherwise cleaned of all materials, including, but not limited to, loose dirt, mud, debris before the area is opened to aircraft traffic.

8.6. All construction and work sites shall be kept free of loose trash and debris.

8.7. Trash containers must be covered.

8.8. Trucks hauling loose materials must have the material securely covered.

8.9. If it becomes necessary for the WAA to clean, sweep, wash and/or otherwise remove FOD from a contractor construction area or haul route, the service will be billed to the contractor.

Section 3. TRAINING

3.1. All persons who are authorized WAA I.D. Media access to aircraft operating areas of the Airport by the WAA are required to complete both initial and recurring training that includes awareness of / and responsibilities for FOD issues.

WICHITA AIRPORT AUTHORITY

STANDARD OPERATING PROCEDURE #26 EFFECTIVE DATE: 8/13/2008

FOREIGN OBJECT DEBRIS AND DAMAGE PREVENTION

Section 4. INSPECTION

4.1. Aircraft movement and operating areas are inspected for safety discrepancies, including FOD:

a) Twice daily;

b) After any event such as construction, maintenance, severe weather or accident.

4.2. Multi-vehicle / multi-pass / slow pass inspections are conducted of aircraft movement areas weekly.

Section 5. SWEEPER CLEAN UP

5.1. Aircraft ramp and apron areas are power vacuum swept weekly.

5.2. Post winter event cleanup of sand used for ice mitigation is conducted as soon as conditions permit.

Section 6. FOD CONTAINERS

6.1. WAA vehicles which access aircraft ramp, movement and operating areas are provided with brooms, shovels and suitable containers to facilitate clean up of FOD observed.

6.2. Airport tenants are encouraged to provide marked FOD containers in their leased areas to encourage and facilitate FOD clean up by employees. WAA will assist in providing such containers upon request.

Section 7. LEASED AREAS

7.1. Each tenant of the Airport is responsible for control of potential FOD materials, such as packing materials, trash, and other debris originating from, or generated by their operation or facility.

7.2. FOD clean up of leased areas of aircraft ramps and aprons is the responsibility of the tenant.

7.3. Contracted sweeper services of WAA sweeper equipment is available for leased tenant areas, where accessible by sweeper equipment.

APPENDIX E

Sample FOD Program and Inspection Guidance (Courtesy of San Antonio Airport System)

SAN ANTONIO AIRPORT SYSTEM

AIRPORT OPERATIONS

FOD Program and Inspection Guidance Document

Purpose:

The FOD Prevention Program is part of the SAT Safety Management System (SMS) Program. The program is focused on developing a proactive approach to FOD prevention and reduction at SAT.

SAT FOD Committee:

The SAT FOD Committee is comprised of stakeholders from the Aviation Department, airlines, cargo carriers, and FBOs. FOD reduction is the primary objective of the group and is accomplished during monthly meetings focused on planning activities to rid the AOA of FOD. Quarterly FOD walks, bi-weekly FOD inspections, as well as bi-annual and annual award ceremonies are the crux of the committees' efforts.

Inspection Frequency:

Inspections should be conducted once every two weeks. A full inspection of all the airline, cargo, and FBO leasehold areas usually takes approximately 5–6 hours when conducted by a single inspector. Using two inspectors will increase efficiency and typically decrease the total inspection time to between 4 and 5 hours.

Equipment Needed for Inspection:

- Clipboard with FOD Program Scoring Form (found on database)
- Camera
- Dry Erase Board and Pen
- Hearing Protection
- Reflective Safety Vest
- Golf Cart (optional)

Conducting the Inspection and Use of Inspection Form:

Approximately 24 hours or more before the inspection, send the FOD Inspection Notification Form, which is part of the FOD Prevention Program Database (located on the OPS 204 flash drive), to all of the individuals listed on the FOD Prevention Program e-mail distribution list. Print the notification form, scan the form on the OPAG multifunction device and e-mail it to yourself in PDF format. Then forward that e-mail to the FOD e-mail distribution contact list. This step should be omitted when performing an unannounced FOD inspection. One unannounced inspection should occur quarterly as part of each new FOD Campaign.

Inspections should be conducted of all of the FBO aircraft ramp areas, airline gate areas, and air cargo aircraft parking areas. Do not focus on areas where aircraft do not normally park or traverse. Remind the tenant to keep those areas outside of where aircraft typically operate clean and free of FOD, but do not count items found in these areas against them for their inspection score. During the inspection, primarily look for items that could be potentially hazardous to aircraft. These items include metal, hard plastic, plastic binding straps, and large items (gloves, hats, etc.). Do not count small pieces of paper, stickers, and any FOD blowing across the ramp against the tenant on their score. Pay particular attention to pavement joints as small pieces of metal/plastic will fall into these cracks.

Take a blank "FOD Inspection Form" (attached as Appendix A) with you to record the scores that each tenant receives. The Excel file of this form is saved on the OPS 204 flash drive. Each passenger airline gets a score for each gate and each cargo airline and FBO gets a single score for their entire leasehold area. These scores assigned are determined based on the number of pieces of FOD found in each gate (for passenger airlines) and ramp (for FBOs and cargo airlines). The scoring rubric is on the reverse:

Prior to starting your inspection of the leasehold, try to contact the management or ground crew of the tenant to let them know you are going to be conducting the inspection and ask if any tenant representatives would like to accompany you. The tenant representatives can pick up FOD during your inspection

TABLE E1
SCORING RUBRIC

Number of Pieces of FOD Discovered	Score
0	100%
1–2	90%
3–4	75%
+5	50%

and any FOD they find and remove before you do does not count against their score (see Table E1). No notification is needed on an unannounced inspection.

After inspecting an airline gate or leasehold, take a picture of all of the FOD that was found at that location by placing the FOD on the dry erase board and annotating the applicable gate or leasehold at the bottom of the board. These pictures can be used if any airline requests to know exactly what was found at their location.

After Inspection Procedure:

Once the inspection is complete, enter all of the recorded scores into the FOD Prevention Program database. When all the scores have been entered, send out the new "Leader Board" by selecting "Ranking Reports," then "Rankings All" in the FOD database located on the 204 flash drive. Print the "Rankings All" page, scan that page on the OPAG multifunction device and e-mail it to yourself in PDF format. Also, transfer all of the pictures from the camera onto the OPS 204 flash drive. Save these pictures in a new folder that is titled with the date of the inspection. E-mail a copy of each picture along with the updated "Leader Board" to the respective airline, cargo carrier, or FBO.

Overall FOD Program Scoring Process:

There are currently three separate areas from which the Leader Board scores are derived:

1. The scores from the FOD Inspections, as seen above. These scores are annotated in the FOD database located on the 204 flash drive under "Add a FOD Inspection," and by selecting "Regular Inspection" in the "Type of Inspection" drop-down menu.
2. The second area covers attendance points for participation in scheduled FOD walks. The Scoring System for FOD squad walks is: Every airline, cargo carrier, or FBO that sends at least one participant receives a score of 100%. For every additional person that participates from the airline, cargo carrier, or FBO, one additional percentage point is added to their score of 100%. Consequently, a tenant that sends two people will receive a score of 101%, a tenant that sends three people will receive a score of 102%, and so on. Other participating tenants can designate their points to an airline, cargo carrier, or FBO. These scores are annotated in the FOD database located on the 204 flash drive under, "Add a FOD Inspection," and by selecting "FOD Walk Credits" in the "Type of Inspection" drop-down menu.
3. The third area covers attendance points for monthly FOD meetings. The scoring system for FOD meetings is: One percentage bonus point to the final score for a representative from an airline, cargo carrier, or FBO. No additional points are awarded for more than one representative attending the meeting. These scores are annotated in the FOD Database located on the 204 flash drive under "The Attendance Bonus Form" tab.

APPENDIX F

Sample FOD Walk Guidance (Courtesy of San Antonio Airport System)

SAN ANTONIO AIRPORT SYSTEM

AIRPORT OPERATIONS

FOD Prevention Program—FOD Squad Walk Guidance Document

Purpose:

The purpose of this guidance document is to provide guidance in the planning, execution, and post-event activities required when conducting an official FOD Squad Walk as part of the San Antonio International Airport FOD Prevention Program.

Planning: (See Appendix A—FOD walk preparations and assignment list)

<u>At Least Two Weeks Before the FOD Squad Walk:</u> Select a date for the event.

- Make a list of all Ops personnel on duty for the FOD Squad Walk. Ask for volunteers or assign them tasks/responsibilities. (See example of the checklist "FOD Walk Preparations," Appendix A.)
- Decide if food and drink items will be provided and by whom: Ops or contact a tenant for donation.
- Contact Continental Airlines and Airport Parking Facilities to see if a shuttle bus from each is available on the selected date to transport people from the terminals to the FOD Squad Walk location.
- Once the date has been set, with Continental and Airport Parking shuttle buses confirmed, have the Operations' Administrative Assistant make the flyers for the FOD Squad Walk. Make sure the following items are included in the flyer:
  - Date and time of the event
  - The current FOD campaign logo
  - Pick-up locations and times for Terminals A and B. The typical pick-up locations for Terminal A is Gate A1 (personnel exit the terminal at the baggage make-up area to walk to the gate) and Terminal B is Gate B7 (personnel meet north of the gate)
  - What food and drinks will be provided (if any, and by which tenant, if donated)
  - FOD Squad T-shirts and/or other giveaways will be provided to the attendees
  - Latex gloves, garbage bags, ear plugs, and reflective vests will be provided.
- Once the flyers are made, distribute them via e-mail to all Aviation Department employees and to the FOD Committee e-mail distribution list.
- If food or drinks are provided by Airport Operations, make sure that they are ordered and the method of payment has been determined.
- Purchase three $20 gift certificates from a local restaurant for Golden FOD Piece finders as awards.
- Ensure that we currently have enough of the following items in-stock:
  - Latex gloves
  - Ear plugs
  - Heavy-duty garbage bags
  - Cups and napkins (if food and drinks are going to be provided)

If we have less than 40 of each of these items, speak to the Ops Manager to see if more need to be ordered before the FOD Walk. If so, order the equipment immediately to ensure availability before the FOD Squad Walk date.

<u>Day Before the FOD Squad Walk:</u> Check the weather for the day of the FOD Squad Walk. If there is a high probability of severe weather, send out an e-mail to all of the members of the FOD Committee e-mail distribution list and the Aviation Department stating that the FOD Squad Walk has been postponed due to inclement weather.

- Contact Continental Airlines and Airport Parking to confirm the shuttle buses are still available to transport participants to the event site. If only one is available, coordinate pick up times at both terminals, about five minutes apart. If neither is available, postpone the FOD Squad Walk for a later date.

- Contact the tenant or vendors who are providing food or drinks and confirm the orders and their pick-up times on the morning of the event.
- Determine the area on the airfield where the event will be conducted. The area should be large enough and with enough debris to occupy a group of approximately 30 people for about 30 to 40 minutes. It typically takes about 30 minutes for the participants to walk about 2,000 to 2,500 feet. This is about the length of the grass area between the Taxiway Delta and Runway 3/21 intersection to Taxiway Quebec and Runway 3/21 intersection. Once the event location is determined, issue any NOTAMs that are required.
- Make two Sign-In Sheets for each pick up location. The participants can begin signing in while waiting for shuttle transport at the terminals.
- Load Vehicle #1953 (Suburban) or alternate vehicle with all of the items below that you will need for the FOD Squad Walk the next day. If the golf cart is needed, ensure the battery is charged.
  - FOD Squad T-shirts (ensure a variety of sizes) or other giveaway items
  - Four Golden FOD Pieces (Hide 3; 1 is to show the participants what they are looking for)
  - Heavy-duty trash bags
  - Safety vests for FOD Squad Walk participants
  - OPS safety vests for OPS personnel
  - Ear plugs
  - Latex gloves
  - Orange traffic cones for use in barricading any taxiways
  - Two megaphones (check both to ensure they are working and the batteries are not low/dead)
  - Collapsible table, to be used for food and drink distribution and/or for T-shirt/giveaways
  - Napkins (if food is provided or if the occasion requires them)
  - Cups (if drinks are provided)
  - Video camera and two still cameras (with charged batteries)
  - Two coolers
  - Bottles of water

<u>Morning Before the Event Begins:</u>

- Fill the coolers with ice and insert the water. Leave room in the coolers if other beverages are going to be added.
- Load the coolers (with bottled water).
- Pick up food and beverages from the FBO, or if from a vendor, ensure that payment for these items is addressed.

<u>Immediately Before:</u> (20 to 30 minutes prior to the start):

- Proceed to the event site to set up the table and refreshments (if provided).
- Close and barricade/cone off the taxiway.
- Station escorts in Terminals A and B by the pick-up locations to direct the participants out of the terminal to the shuttle bus. There should be at least one person at Terminal A (by Baggage Make Up area to walk participants to Gate A1 for pick-up) and one person at Terminal B (north of Gate B7). These individuals will ride on the shuttle bus to the event. Ensure that at least one of them has a radio and a Nextel. Also ensure that they have the sign-in sheets so that people can start signing in while they are traveling to the site.
- Place the Golden FOD Pieces at the event site. Ensure that they are placed closer to the end of the walking site and that their location is noted so that they can be found by OPS personnel if they are not found by the participants.
- Drive an overflow vehicle to transport extra participants if the shuttle bus should become full. This overflow vehicle will need to stay close to the shuttle bus while it is picking up the participants at each terminal.

<u>During the FOD Squad Walk:</u>

- Direct all of the participants once they are on-site and be the primary event controller/director for the event (Ops 204).
- Hand out the safety vests, latex gloves, ear protectors, and garbage bags.
- Drive the vehicle beside the participants while they are walking. This vehicle needs to have a cooler with water.
- Monitor the participants to ensure they do not stray from the designated site.
- Take pictures and video of the walkers.

<u>Immediately After the Participants Are Finished Walking:</u>

OPS 204 will address the participants with the megaphone regarding these items:

- Award gift certificates to the finders of the Golden FOD Pieces.
- Take the group photo of the participants.
- Collect the equipment (vests, filled garbage bags, used gloves, etc).
- Distribute FOD T-shirts or other giveaways.
- Load the vehicle with the FOD-filled garbage bags for proper disposal.
- Escorts to ride shuttle buses back to the terminals with the participants. Escort parking shuttle off the AOA.
- If a NOTAM was issued, remove the cones, cancel the NOTAM, notify ATCT and open the taxiway.

Execution (for the Primary Event Controller/Director):

- Once the participants arrive at the site, speak to them as soon as possible to provide them direction on the time-line of events for the FOD Squad Walk. If food and drinks are provided, let them eat and drink for approximately 5 to 10 minutes before doing the walk.

- Once you are ready to start the walk, have the people responsible for handing out the latex gloves and garbage bags hand out those items.
- Once that is completed, form the participants into a line while ensuring that OPS personnel are stationed along the edges of the participant line to act as safety monitors and ensure that no one goes outside of the designated walking area.
- Approximately 10 to 15 minutes before the scheduled end to the event, stop the walk and position the participants to have a group picture taken. Place the finders of the Golden FOD Pieces in front.
- After the group picture, have the participants return the reflective vests, deposit their trash and gloves in the designated receptacle, pick-up their T-shirt or other give-away, and board the shuttle buses.
- Once the shuttle buses with all of the participants have left, inspect the area for FAR Part 139 compliance to ensure it is safe for aircraft use. If the area is safe and a NOTAM was issued, cancel the NOTAM, remove the barricades/cones, and open the area.

Post-Event:

- Unload all of the equipment and place it back in the storage room.
- Enter the scores into the FOD Prevention Program database for the airlines, cargo carriers, and FBOs that participated in the FOD Squad Walk. Other participating tenants can designate their points to an airline, cargo carrier, or FBO.
  - The Scoring System—Every airline, cargo carrier, or FBO that sent at least one participant receives a score of 100%. For every additional person that participated from the airline, cargo carrier, or FBO, one additional percentage point is added to their score of 100%. Consequently, a tenant that sends two people will receive a score of 101%, a tenant that sends three people will receive a score of 102%, etc.
- Once the scores have been entered, send an updated FOD Prevention Program Leader Board to all of the airlines, cargo carriers, and FBOs.

APPENDIX G

Sample FOD Inspection Form
(Courtesy of San Antonio Airport System)

Number of Pieces of FOD Discovered	Score
0	100%
1–2	90%
3–4	75%
+ 5	50%

AIRLINE, FBO AND CARGO FOD INSPECTION REPORT

Inspection Date: ____________________ **Inspected By:** ____________________ **Data Entered By:** ____________________

Airline	Time	Note picture number and FOD Amount by Gate Number									
Southwest		A3		A4		A5		A6		A7	
Frontier		A2									
Delta		A10		A12		A13					
Mexicana		A11									
Air Tran		A14									
United		A15		A16							
Continental		B3		B5		B7		B8			
US Airways		A9									
American		B2		B4		B6					

FBO	Time	Picture number, FOD Amount and Score
Millionaire		
Landmark		
Nayak		
Signature		

Cargo	Time	Picture number, FOD Amount and score
UPS		
FedEx		
DHL		

APPENDIX H

Sample Letter of Agreement for Unplanned Runway Closures (Courtesy of Chicago Department of Aviation)

CHICAGO O'HARE ATCT AND CHICAGO DEPARTMENT OF AVIATION

LETTER OF AGREEMENT

Effective Date: November 20, 2008

Subject: Unplanned Runway Closures

1. **Pupose:** To delineate the responsibilities of O'Hare ATCT and the City of Chicago Department of Aviation (DOA) necessary when an event causes the unplanned closure of a runway at Chicago O'Hare International Airport.

2. **Background:** FOD, runway or equipment damage, etc., and braking action reports have caused unplanned runway closures at O'Hare. When braking action advisories are in effect the DOA will activate "Continuous Runway Monitoring Procedures" (CRMP). When two "Poor" or a "NIL" braking action PIREP's are received the DOA will need to do a runway assessment as soon as possible.

3. **SCOPE:** This agreement outlines procedures between O'Hare ATCT and City of Chicago DOA whenever an unplanned runway closure occurs.

4. **Responsibilities:**

   a. O'Hare ATCT:

      i. Upon receiving a PIREP of "NIL" braking action or FOD on a runway suspend further aircraft operations on that runway until City of Chicago DOA advises the runway is open.

      ii. Notify City of Chicago DOA whenever a PIREP of "NIL" braking action or FOD on a runway.

   b. City of Chicago DOA

      i. Close affected runway(s).

      ii. Check the runway(s) for FOD or perform a runway assessment when two "Poor" or a single "NIL" braking action report is received.

      iii. Open the closed runway(s) once corrective action has been taken and the runway is acceptable for aircraft use.

5. **Runway Inspections:**

   a. When a runway inspection is required without delay the City of Chicago DOA will request a "Critical Runway Inspection." When this type of inspection is requested O'Hare ATCT will stop all departures that have not begun takeoff roll on that runway. Aircraft within two miles of the runway will be allowed to land. City of Chicago DOA will only request a "Critical Runway Inspection" under extreme or unusual circumstances and understands significant delays will result. *Note: The full length and width of the runway will be inspected.*

b. When a runway inspection is required with minimal delay the City of Chicago DOA will request a "Priority Runway Inspection." When this type of inspection is requested O'Hare ATCT will stop all departures that have not been cleared for takeoff on that runway. Aircraft inside the arrival fix will be allowed to land. City of Chicago DOA understands that significant delays may result. *Note: The full length and width of the runway will be inspected.*

c. A "Normal Runway Inspection" will be made in conjunction with normal operations. *Note: This inspection will usually include the full length and width of the runway.*

d. O'Hare ATCT will expect a DOA request for a runway assessment after the second "Poor" braking action report. If after the DOA runway assessment the runway remains open for aircraft use, O'Hare ATCT and DOA will closely coordinate runway closures for snow removal.

S.H. Kuywahak
for William J. Mumper
District Manager
Orchard Hub

Richard Rodriguez
Commissioner of Aviation
Chicago Department of Aviation

APPENDIX I

Listing of Equipment and Technology for FOD Management

INSPECTION

Air Boss
http://www.fodfinder.com/pages/airboss.html
Eagle Integrated Solutions
http://www.eagleintegrated.net/
FODetect by XSight Systems
http://www.xsightsys.com/fodetect.htm
Fod Finder
http://www.fodfinder.com/pages/fodfinder.html
i-Air by Nuebert Aero Corp
http://www.airportnac.com/AviationGIS.aspx
i-Ferret by Stratech Systems
http://www.stratechsystems.com/iv_iferret.asp
Atlas Inspection Technologies
http://www.atlas-inspection.com/foreign-object-retrieval-tools.html

DETECTION

FODetect by XSight Systems
http://www.xsightsys.com/fodetect.htm
Fod Finder
http://www.fodfinder.com/pages/fodfinder.html
i-Ferret by Stratech Systems
http://www.stratechsystems.com/iv_iferret.asp
Tarsier by QinetiQ
http://www.qinetiq.com/home_tarsier.html
Trex FOD Finder
http://www.trexenterprises.com/fodfinderSite/pages/fodfinder.html

REMOVAL

Sweepers

FOD Boss by F.O.D. Control Corp
http://www.fodcontrol.com/fod_boss.html
Various sweepers by Tymco
http://www.tymco.com/sweepers/index.htm
Various sweepers by Wayne
http://www.waynesweepers.com/

Magnetic

Power Bar by F.O.D. Control Corporation
http://www.fodcontrol.com/powerbar.html
Myslik, Inc.
http://www.wezulwebdesign.com/myslikinc/airportuse/airportuse.html
Magnets, Inc.
http://www.airportfodmagnets.com/4_fod.html

DOCUMENTATION

Although some airports have developed an in-house documentation system, most suppliers of FOD detection technology have also developed an integrated FOD detection software program to be used with their detection technology.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation