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ON COMMERCIAL AVIATION SAFETY

WINTER 2002

ISSUE 49

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UNITED KINGDOM FLIGHT SAFETY COMMITTEE

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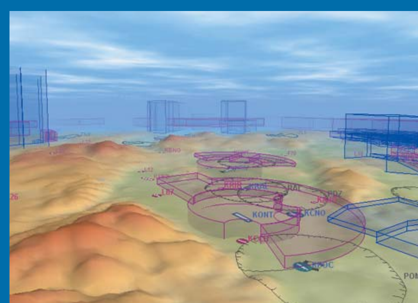

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THE UNITED KINGDOM FLIGHT SAFETY COMMITTEE

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ISSN: 1355-1523 **WINTER 2002** **ON COMMERCIAL AVIATION SAFETY**

__FOCUS__ is a quarterly subscription journal devoted to the promotion of best practises in aviation safety. It includes articles, either original or reprinted from other sources, related to safety issues throughout all areas of air transport operations. Besides providing information on safety related matters, FOCUS aims to promote debate and improve networking within the industry. It must be emphasised that FOCUS is not intended as a substitute for regulatory information or company publications and procedures.

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contents

Reducing the Cost of Ramp Damage

The UKFSC Safety Seminar held on the 4th September 2002 entitled "Ramp Safety Revisited – Chaos or Concerto" looked at the cost of ramp damage, the most common causes and a number of possible solutions to the issues involved. Overall the Seminar is considered to have been a great success. That being so, one would expect to see some changes in behaviour taking place on the ramp, with operators benefiting from reduced ramp damage. I doubt that there has been any change at all and unless each and every air operator, airport and service provider makes a conscious effort to take the initiative to put in place the necessary actions to improve ramp safety, there will be no improvement.

It takes more than some talk at a Seminar to bring about change. If we are serious about reducing aircraft damage we have to change the behaviour of all those who work on the ramp.

The UKFSC Ground Operations Standing Committee is currently investigating what needs to be done to reduce the amount of damage being caused on the ramp. It became clear from their discussions that there is a real need to try to get the industry to accept and adopt the need for a common aircraft turnaround plan. This would enable ramp service providers to give the required services in the same order on every occasion so that proven procedures could be followed by all concerned without one organisation causing hindrance to another.

It is obvious that there is a need for much improved supervision on the ramp to ensure that the tasks are being done safely and correctly. Not having a recognised supervisor for the turnaround means that everybody is doing what they want, when they want and to the standard they believe to be correct. This has led to poor standards of service, poor co-operation and the inevitable reduction in safety and consequent damage to aircraft, estimated to cost the industry many millions of pounds each year.

If we are going to reduce the amount of damage caused to our aircraft, equipment and personnel on the ramp we are all going to have to take a look at the way our personnel are currently behaving on the ramp and make changes. We need to ensure that everybody servicing the aircraft behaves in the correct manner, follows procedures correctly and has the right attitude to their tasks. Above all we need to insist on better supervision.

JAR-OPS regulations make the operators responsible for their contractor safety. This means that they need to be paying more attention to their obligation and to ensure that safety audits of the ramp are carried out more frequently. Shortfalls in performance must be taken up with the service providers and corrective action taken immediately. The sharing of the results of these audit reports between operators could help to provide a more thorough understanding of where the problems lie and to ensure that the corrective action taken is appropriate. For us to be successful in our endeavour to make the ramp a safer and less costly place, we will need the support and co-operation of all those organisations involved in the activities on the ramp.

THE UKFSC HAS THE FOLLOWING OBJECTIVES:

- To pursue the highest standards of aviation safety.
- To constitute a body of experienced aviation safety personnel available for consultation.
- To facilitate the free exchange of aviation safety data.
- To maintain an appropriate liaison with other bodies concerned with aviation safety.
- To provide assistance to operators establishing and maintaining a flight safety organisation.

Winter Operations

by John Dunne, Airclaims

The summer has gone (with some of us wondering if it was ever actually here) and autumn is already with us, all the indications would seem to point towards a bitter winter period throughout Europe. Good news for our children as the prospects of a White Christmas improve, not so good for the grown-ups who'll have to shovel the drive clear though. Our thoughts turn towards that prudent decision to have the central heating serviced at the end of the summer period (you have done that haven't you?) as you retrieve those winter clothes from the wardrobe and put the wellies and shovel into the car boot.

As your domestic winterisation programme is now fully under control it's perhaps an appropriate time to turn our attention to the winterisation programme going on in our airlines and reflect a little whilst we have the luxury of time on our side. We are all well schooled in the discipline of learning, but can you fully recall the details of your winterisation programme? Our checklists are generally structured for those items that we do every day, whilst those once in a blue moon situations are designated as memory items. Maybe this would be a good time to quietly sit down and re-examine and reflect on those procedures before you actually need them.

- What are the effects on performance of ice on the airframe?
- What are the braking performance issues of slush, snow and ice operations?
- How does ATC actually advise us of airfield slush, snow, ice and friction issues and how do we interpret those advisories?
- What are the latest holdover times?
- What fluids and what mix are required for our operation, is there an alternative in case we have to divert away from our usual airfield?
- When we ask for our aircraft to be de-iced are we specific enough – have we requested wing de-icing or did we need and ask for wing and airframe de-icing?
- How do we assess the competency of those staff assigned to de-icing activities?
- Has our Quality department audited all our providers?
- And when we have been successfully de-iced are there restrictions on engine or APU bleed air usage for cabin air?

Cold soaking can be a major "gottcha" for winter operations. Some of the factors affecting wing cold soaking are: amount of fuel remaining in the wing, time spent at high altitude, parking position, exhaust from ground equipment, fuel tank location and time since refuelling. If precipitation falls within a temperature range between –2° and +15°, on cold soaked wings on the ground then clear icing can occur. Icing doesn't have to be symmetrical in form. Clear icing is very difficult to detect visually, particularly in poor weather and lighting conditions – when you perform your pre-departure walk around at night in miserable drizzle on the last sector of a long day how much access do you really have to inspect the wing upper surfaces? Have the turn around slots been altered to accommodate the longer pre-flight inspections and de-icing operations required?

Be vigilant, be thorough, remember, it's not the ice on the wing that will kill you, it's the decision to take-off with the ice on the wing that will kill you.

Vertical Situation Display for Improved Flight Safety and Reduced Operating Costs

Of the more than 200 heavy air transport accidents involving hull loss or fatalities in the past 10 years, more than 50 percent were associated with either controlled flight into terrain (CFIT) or the approach and landing phases of flight (fig. 1). Many of these accidents involved inadequate or loss of vertical situation awareness by flight crews.

To help prevent CFIT and approach and landing accidents, Boeing has created a clear graphical picture of the airplane vertical flight path that enhances the flight crews' overall situation awareness. This vertical situation display (VSD) works in conjunction with the terrain-mapping feature of the terrain awareness and warning system (TAWS) (e.g., the Honeywell enhanced ground proximity warning system) to provide flight crews with an intuitive presentation of the vertical situation relative to the surrounding terrain and the final approach descent path. In addition to terrain alerting, the TAWS provides a lateral, or top-down, view of terrain. The VSD depicts a profile, or side view, of terrain and flight path data.

The VSD is designed to maximize safety while minimizing required changes to airplane hardware and airline flight operations and training. It also capitalizes on airplane design elements common across all Boeing models and can be implemented within the constraints of available space on existing airplane displays.

The VSD will be offered by early 2003 as a customer option on in-production 737s and by retrofit on 737-600/-700/-800/-900 airplanes already in service. Implementation of the system on other Boeing models is under consideration. The value of the VSD can best be understood through a discussion of the following:

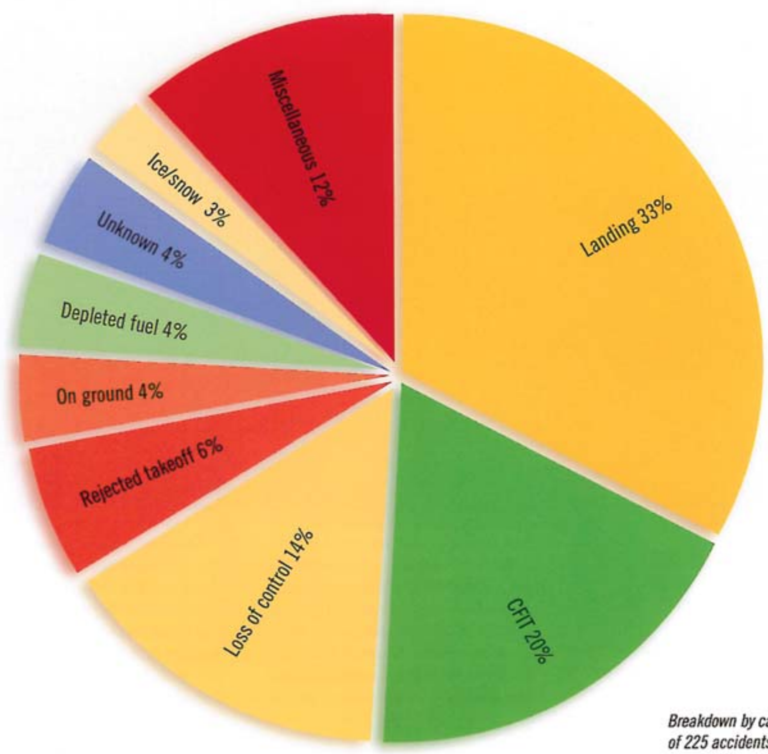
1. Current method for assessing vertical situation.
2. Development of the VSD.
3. Display features.
4. Benefits of the VSD.
5. Implementation on Boeing airplanes.

1. Current Method for Assessing Vertical Situation

Currently, flight crews must assimilate vertical situation information from various sources to create a mental picture of the vertical profile. These sources include barometric and radio altitude readouts, the vertical speed indicator, ground proximity warning systems, terrain depiction systems, and navigation information from the flight management computer (FMC) and navigation charts. Flight crews usually are very effective at integrating this information. However, they can be hard-pressed to formulate and maintain a completely accurate mental model of the vertical profile, especially during time-critical or high-workload situations or during initial training using vertical navigation (VNAV) systems. This makes misinterpretation of the vertical situation more likely.

During the past several years, various options have been investigated to provide vertical situation information on the flight deck. Although many new technologies promise to deliver improved overall situation awareness, significantly enhancing the safety of the worldwide commercial airplane fleet will require cost-effective solutions that are relatively easy to retrofit. Presenting flight crews with a

FIGURE 1 HEAVY AIR TRANSPORT ACCIDENTS INVOLVING FATALITIES AND/OR HULL LOSS



Breakdown by category of 225 accidents from 1987 to 1997

2 FIGURE

side view of the vertical dimension is one such solution - it targets a significant part of the problem yet involves only minor changes to the airplane and airline infrastructure.

2. Development of the VSD

Boeing evaluated various methods of improving vertical situation awareness with the goal of reducing the overall accident rate of the commercial air transport industry. Because the measurement of vertical awareness is subjective and there is no one-to-one correlation between vertical awareness and accident prevention, Boeing decided that measurements of vertical situation awareness alone are insufficient for evaluating the safety of various technologies. Instead, databases - such as those of airline incident reports and accident reports for the past 10 years - were used as one source of evaluation criteria. The incident reports were used to guide the direction of concept development, whereas the accident reports were used to determine the expected effect of specific concepts on the accident rate.

In addition, flight crews flew three types of scenarios in an engineering flight deck simulator that reflected the target accident types (i.e., CFIT and approach and landing). The scenarios involved an approach during which the airplane must descend later than normal to intercept the glideslope, an approach with a steep glideslope, and level flight toward mountainous terrain. Flight crew performance, subjective ratings, and observations were gathered.

Results showed that the VSD was the most effective display format in all three scenarios. The least effective display was a simple three-dimensional (3D) perspective display. The VSD scored high in the areas of early threat recognition, effectiveness when flying steep approaches, and maintenance of a stabilized path.

Based on these results, Boeing chose to pursue further development of the VSD as the most effective and practical option that could be implemented in the near term. This decision was not meant to preclude further developments in 3D perspective displays.

Developing a side-view vertical profile display necessitated refinement of the human interface requirements. Boeing worked with airlines, suppliers, and regulators to ensure efficient development and implementation as well as the

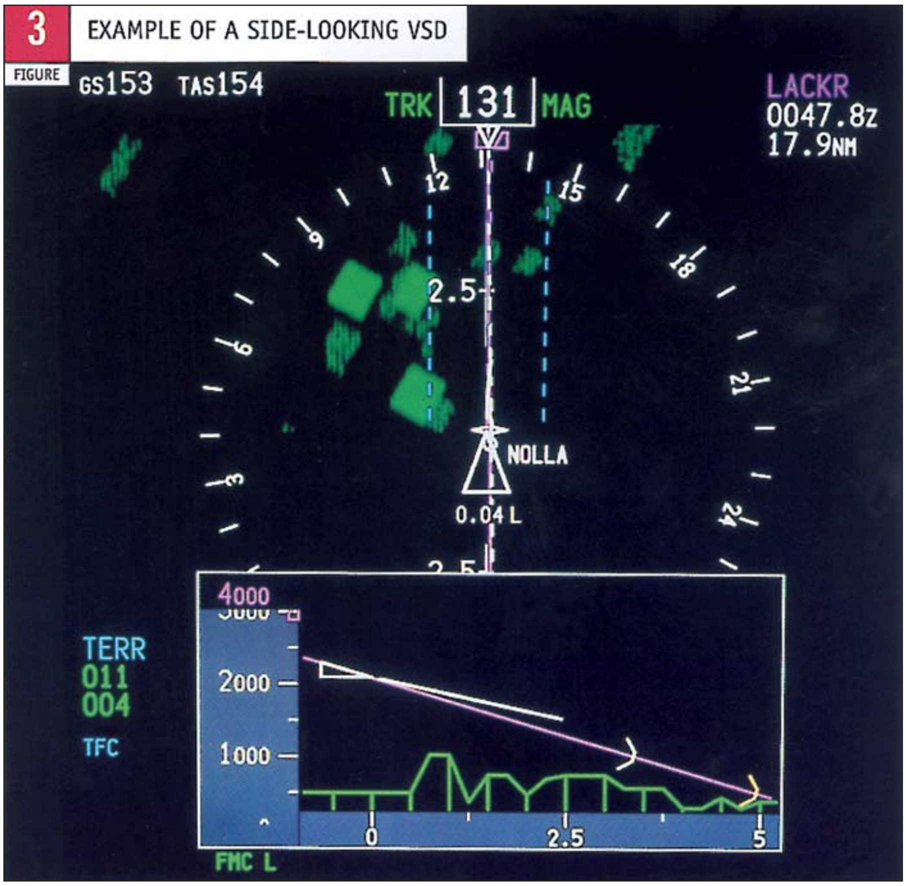


FIGURE 3 EXAMPLE OF A SIDE-LOOKING VSD

establishment and support of an industry standards team. Human interface requirements were refined in the 737 engineering flight deck simulator because the 737 uses various display types and sizes. Boeing wanted to ensure that any VSD design could be implemented on the many sizes of electronic displays used today, including the larger ARINC D-size (8- by 8-in) and the smaller ARINC B-size (6- by 7-in) displays.

3. Display Features

A VSD graphically represents a view of the vertical profile of the airplane. The Boeing VSD depicts a swath that follows the current track of the airplane and therefore is referred to as a track-type VSD. When selected by the flight crew, it appears at the bottom of the navigation display (fig. 2).

Figure 3 shows an example of the Boeing side-looking VSD. The basic features of this VSD include altitude reference and horizontal distance scales, an airplane symbol, a vertical flight path vector, terrain depiction, navigation aids, glideslope depiction, and various information selected by the flight crews and FMC such as the mode control hand (MCP) -selected altitude, minimum decision altitude, and selected vertical speed predictor.

The development of the VSD format involved a thorough human-centered design approach. All the features had to meet basic flight deck philosophies and design guidelines. In addition, because clutter always is a concern, each feature was added only after it was shown to provide a significant benefit in terms of enhancing flight crew awareness. Some of these human-centered design requirements included the following:

- Information had to be consistent with that which already appears on other flight displays.
- Information had to be intuitive and follow standard flight information system and navigation display conventions.
- The display had to use existing symbols to as great a degree as practical.

One issue identified with the track-type VSD was that flight crews wanted additional terrain look-ahead in the direction of a turn. An algorithm was invented that expands the swath in the direction of the turn to give flight crews the desired result.

One guiding philosophy was that the VSD must be intuitive. The swath width actually is dynamic and varies as a function of navigation accuracy requirements and whether or not the airplane is turning. Consequently, the swath is depicted on the lateral display simply with two dashed lines. The information contained between these two lines on the lateral view is the information depicted on the VSD. This results in a display that is more intuitive to flight crews.

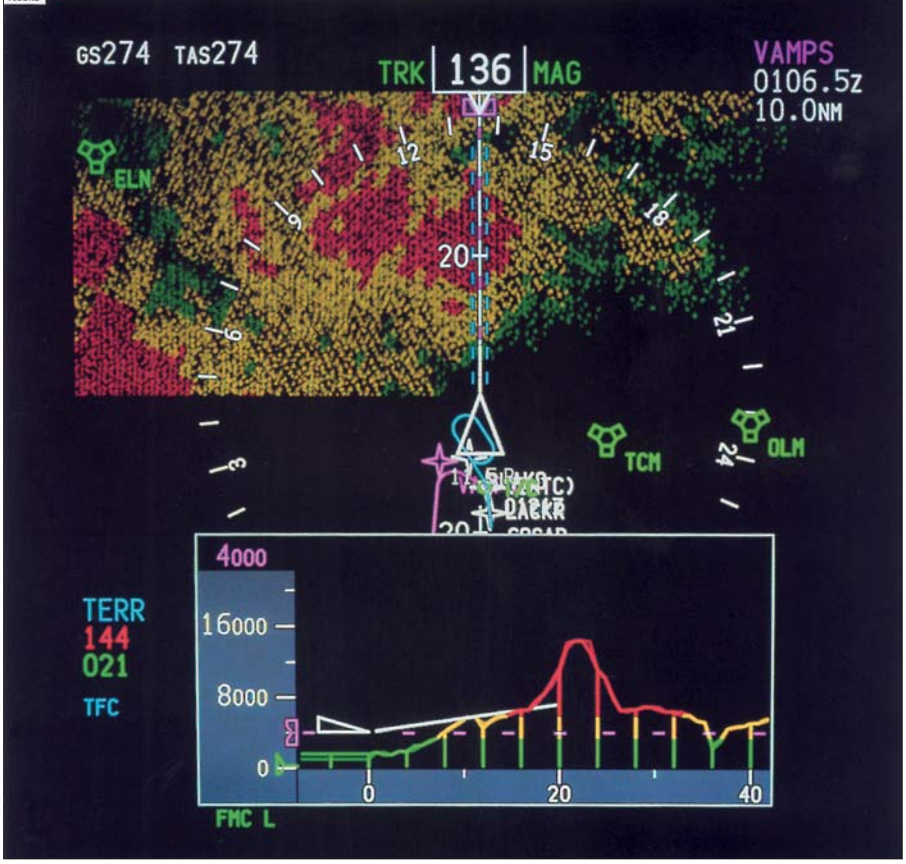
Wherever appropriate, symbols from other displays were incorporated into the VSD. For example, the symbol for MCP-selected altitude is the same shape as the corresponding symbol on the primary flight display altimeter tape.

Although the VSD can be used to assess path stability, path stability is only part of the equation for a stable approach. The other factor is speed stability. To facilitate speed stability, a new symbol was introduced on the VSD. The range-to-target speed symbol is a green dot that shows where excess speed will be dissipated along the vertical flight path vector. If excess speed is not an issue, then the symbol will not appear on the display.

The display remains stable during dynamic conditions. Flight crews should keep in mind that the VSD is a supplementary display and as such is not intended for use as the primary reference during dynamic maneuvers and procedures.

Incorporating the VSD does not require any changes to flight operations procedures, except for the addition of procedures that apply to the VSD in non-normal conditions. Additions to the airplane flight manual describe the features of the VSD. Flight crews' training regarding the VSD only involves written materials.

FIGURE 4 AIRPLANE HEADING INTO TERRAIN BEFORE A CAUTION TERRAIN ALERT IS GENERATED



4. Benefits of the VSD

The main benefit of the VSD is improved safety. The VSD will give flight crews an intuitive view of the vertical situation just as the current map display provides an intuitive depiction of the lateral situation. In conjunction with the other safety features of the flight deck, this increased vertical situation awareness helps prevent CFIT and approach and landing accidents and incidents, thereby further decreasing the already low accident rate of the worldwide commercial airplane fleet.

The VSD depicts terrain information from the TAWS or other onboard sources from another perspective. The TAWS generates a lateral view of the surrounding terrain and provides terrain proximity alerting. The VSD depicts the vertical dimension of the terrain (fig. 4), which will allow crews to recognize possible terrain conflicts more readily, before a TAWS alert is generated.

The VSD also depicts the final approach segment of the intended path of the airplane to the runway (fig. 5) thereby assisting flight crews as they establish the glide path. Terrain alerting from the TAWS is disabled gradually during this phase of flight to eliminate nuisance alerts, but the VSD is available full time.

The VSD also complements the increased use of constant-angle, area navigation, and required navigation performance (RNP) approaches by providing immediate validation of the selected approach path and allowing full-time monitoring of the airplane position relative to the selected glide path. As low-altitude, in-cloud maneuvering becomes commonplace and RNP criteria allow better utilization of restricted airspace, the VSD will serve as an invaluable confirmation of airplane performance.

The VSD will provide additional operational benefits. Earlier recognition of terrain clearance problems facilitates more timely go-arounds and earlier CFIT avoidance. In addition, with improvements in vertical awareness, flight crews have an improved ability to monitor the vertical path. Earlier recognition of unstabilized approaches helps reduce the number of go-arounds and missed approaches. Because many unstabilized approach problems are manifested during the landing phase of flight, earlier recognition also should reduce the number of hard landings, runway overruns, brake fires, and tire failures.

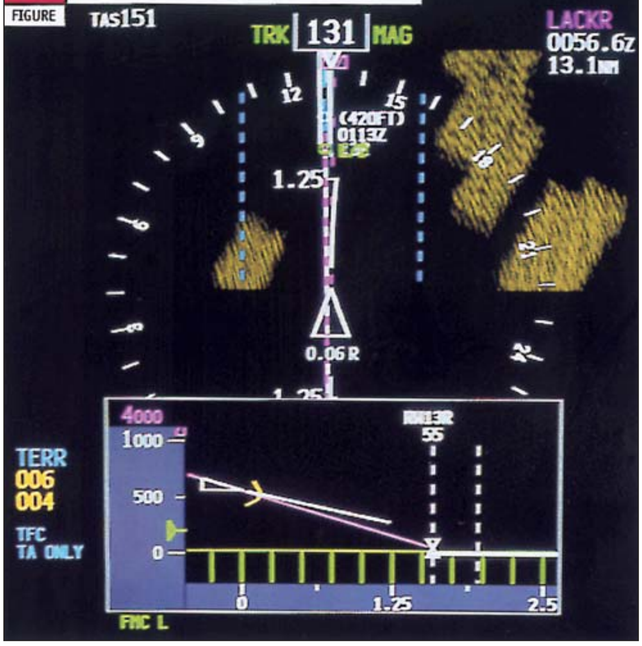


FIGURE 5 FINAL APPROACH AND RUNWAY

This will help reduce airline operating costs by extending the life of the air-frame structure, landing gear system. tires, and brakes and by reducing the airplane maintenance downtime associated with landing problems.

Finally, the intuitive nature of the VSD will allow flight crews to assess the vertical situation quickly, thus reducing overall workload. Crews will have more time during the most critical phases of flight - climb, descent and final approach - to focus on other routine tasks and handle any unusual circumstances they may encounter.

5. Implementation on Boeing Airplanes

The VSD has only recently become a viable option for increasing vertical situation awareness. Three factors precluded an earlier introduction of the technology. The information presented on the VSD must be accurate. Accuracy requires a good terrain database, and that technology has become available only recently for commercial applications. Second, flight crews must have confidence in the accuracy of the position of the airplane relative to physical features. Although most navigation systems are very reliable and robust, the advent of the global positioning system has improved lateral and vertical accuracy of the airplane position.

Finally, as a result of improvements in display technology and computational throughput, the quantity of display symbols is not as limited as it once was.

The VSD was designed for incorporation within the constraints of current production models. Implementation on in-production airplanes requires system changes to the avionics displays, FMC, and TAWS. For the avionics displays, the display system software must be updated. The FMC requires a software up-grade, and new hardware and software are required for the TAWS. In-service airplanes may require additional hardware upgrades to allow full implementation.

The introduction of new, large liquid crystal display screens on Boeing airplanes facilitates implementation of the VSD. The VSD also was designed to be compatible with cathode ray tube-based flight decks. Although Boeing has focused on integrating the VSD into the flight deck, a large portion of the worldwide fleet in the next 5 to 10 years still will use electromechanical instrument flight decks. The VSD can be implemented on these flight decks as a stand-alone display system. These retrofit solutions are in development.

Boeing has developed the VSD so that additional features can be added. One example is the depiction of the vertical profile along the entire planned flight path. Showing the vertical swath along the planned flight path of the airplane, instead of just along the current track, provides several benefits. Not only may this enhance awareness of the vertical mode, but VNAV and lateral navigation concepts also may be simplified for training. Other envisioned enhancements include providing weather and traffic information.

SUMMARY

The VSD is another step on the evolutionary path of flight deck displays. The display is a natural complement to and outgrowth of the lateral moving map introduced into commercial fleets in the 1970s and 1980s. The VSD can have a significant and beneficial effect on commercial air transport safety. By presenting the flight crew with a simple graphical picture of the vertical dimension, vertical situation awareness is enhanced, which potentially can significantly reduce the number of air transport accidents in the worldwide fleet in a realistic time frame. The VSD can be implemented without major airplane hardware changes. The system will be offered by early 2003 as a customer option on in-production 737s and by retrofit on 737-600/-700/-800/-900 airplanes already in service. Implementation of the system on other Boeing models is under consideration.

Improved Understanding Of Human Factors Could Reduce Foreign Object Damage

A U.S. Federal Aviation Administration report provides guidelines for reducing maintenance-related foreign object damage through the application of human factors best practices.

by FSF Editorial Staff

Foreign object damage (FOD) accidents/incidents have resulted in loss of life and destruction of aircraft, as well as flight delays and additional work for aviation maintenance technicians and others. A U.S. Federal Aviation Administration (FAA) report said that one reason for maintenance-related FOD occurrences is the complexity of the aviation-maintenance environment, in which maintenance personnel apply specialized knowledge and skills to conduct controlled procedures in surroundings that include organizational pressures, environmental pressures and work pressures.

[FOD is defined as damage to any part of an aircraft - frequently an engine or a flight control mechanism - that is caused by any extraneous material: the cost of FOD to the worldwide aerospace industry has been estimated to be US$4 billion annually.][1]

Maintenance personnel may not be able to anticipate many of the problems that result from the complexities of the aviation-maintenance system.

"It is critical, therefore, to have an understanding of the human factors of the system and to address those human factors through both proactive [measures], as well as reactive measures," the report said. "Through a grounded understanding of the human factors involved in FOD, the industry can provide the best guidance to eliminate existing FOD problems and prevent future FOD occurrences."

Many FOD-prevention programs emphasise technical procedures but do not consider human factors related to those procedures. Therefore, the FAA Office of Aerospace Medicine conducted a study to identify methods of reducing maintenance-related FOD occurrences by applying human factors best practices.[2]

The report discussed the four causes of most FOD in the maintenance environment - poor housekeeping, deterioration of facilities, improper maintenance and inadequate operational practices. The report also discussed interaction and support of FOD - prevention efforts by management and employees, FOD awareness, FOD training, FOD audits and FOD inspections.

"These factors, taken together, make up the proactive measures that can be used to eliminate and prevent [FOD] in the aviation-maintenance environment," the report said.

The report said that an FOD prevention program should include precise policies and procedures that discuss the following items:

- The importance of FOD prevention and how FOD prevention affects safety, quality, costs and customer satisfaction;

- The goals of the FOD-prevention program and the time required to achieve those goals;

- The standards that will be used to assess the progress of the FOD-prevention program and to compare it with similar programs in other organizations;

- The organization of the FOD-prevention program, including how the program will be managed and what support will be available;

- The FOD-prevention program's policies and procedures, including how those procedures will be disseminated and how improvements in the process will he achieved;
- The methods of communicating the successes or failures of the FOD-prevention program to aviation maintenance technicians and aviation maintenance managers; and
- The methods of investigating FOD incidents and FOD accidents, including how the occurrences will be reported, what data will be collected and how the data will be stored and analyzed.

The report described management support as essential to the success of a FOD-prevention program and said that management support should include adequate funding, appointment of an individual or group with authority to implement the program, support for work to eliminate FOD throughout the aerospace industry and support of a "FOD-prevention culture" throughout the organization.

"The culture of an organization is the collection of beliefs, norms, attitudes, roles, as well as social [practices] and technical practices, that are shared by individuals within an organization," the report said. "A good safety culture focuses on minimizing dangerous and injurious conditions that may affect not only the employees of the organization. A more important result of a good safety culture is improved safety for the public at large…

"The aircraft maintenance technician's attitudes toward FOD will be a reflection of the values and beliefs that management places on FOD prevention or elimination. …Thus, it is incumbent on management to establish and maintain a FOD-prevention culture within the organization."

The report said that all maintenance personnel should receive training in how to prevent FOD, including information about the organization's FOD-prevention procedures; causes and effects of FOD; safe working practices and individual responsibilities; correct storage, shipping and handling of material, components, equipment, personal items and tools; accountability and control of tools, materials and hardware; vigilance for potential sources of FOD; clean-up techniques; and reporting of FOD incidents.

"In addition to the general FOD training required for all employees, contractors and subcontractors, the maintenance technician should receive additional training focused on the technical aspects of FOD prevention." the report said. The additional training may discuss correct methods of cleaning and maintaining fuel filters and disposing of small pieces of maintenance-related material, such as pieces of safety wire.

FOD-prevention training should be required before maintenance personnel work on an aircraft on aircraft subassemblies. Recurrent training also should be required, the report said.

To ensure that all employees develop an awareness of FOD occurrences and the FOD-prevention program, FOD announcements and discussions should be included in meetings, incentive programs should be established to reward individuals or departments for their efforts to reduce FOD, and FOD articles should be published regularly in the company newsletter.

The report said that the FOD-prevention program should include easily recognizable and appropriately sized FOD receptacles throughout the maintenance facilities. Outdoor receptacles should be watertight, and all receptacles should be emptied regularly and should not be permitted to overflow.

"There should be regularly scheduled FOD walks of hangar bays, aircraft ramps and aprons," the report said. "Consideration should be given to using specialized brooms, magnets and vacuum-type machines to clear areas." (Brooms and sweepers should not have metal bristles, which increase the risk of FOD.)

The report recommended several clean-up activities for individual maintenance technicians, including:

- Clean the immediate work area when work is completed, when work "cannot continue," at the end of each shift and before inspection;
- Pick up debris that might migrate to an inaccessible location or to a location where the debris would be out of sight. The report said. "If you see debris, don't walk over it: pick it up and dispose of it properly";
- Do not take food or beverages to the work area; and,
- Return cleaning equipment and tools to the proper storage area.

"The fundamental process to prevent [FOD] is to perform all maintenance tasks "by the book," the report said. "This includes all procedures, from removing excess grease from a component to capping all aircraft ports and disconnected lines with approved material."

The guidelines recommended by the report include the following:

- Protect equipment that is sensitive to FOD. For example, cover engine inlets and exhausts during maintenance that does not require access to the engine area;
- Aircraft undergoing maintenance or modification and the areas surrounding the aircraft should be inspected and cleaned throughout the maintenance/modification process;
- If an item is dropped in a "critical airworthiness area," the item should be removed before further work is performed. If the item is not found, the occurrence should be reported to a supervisor. The item should be accounted for before the aircraft is released for return to service;
- Every assembly step should include an inspection for extraneous material, and FOD inspections should be performed before all final closures;
- Only essential hardware should be taken aboard the aircraft. Tools should be carried and stored in tote trays, sacks or boxes. Tool trays should have lids;
- Before an engine is started, a FOD walk should be conducted in front of the intake area and behind the exhaust area of the engine to ensure that the areas are free of objects that could cause damage;
- "Check aircraft tires for foreign objects";
- Report damage to pavement; and,
- Whenever debris is seen, it should be collected and disposed of properly.

The report said that, whenever possible, the packaging of any item used during maintenance should be in a color that contrasts with the background of the maintenance area. Tools sometimes may be in colors that blend into the background; therefore, tool-control procedures should be implemented. The report said that a written tool inventory should be maintained for each tool-storage area, that personnel should be able to identify all tools and trace them to their assigned storage location and that tools should be transferred from one individual to another only with proper documentation.[3]

The person responsible for the FOD-prevention program should ensure that FOD inspectons and FOD audits are conducted regularly, using checklists to verify compliance with FOD-prevention procedures.

"FOD audits should provide a review of existing conditions, as well as recommendations for improving …debris control," the report said. "The audit results may be used to develop corrective-actions programs and to provide improvements to FOD-training programs."

When a FOD incident or FOD accident occurs, it must be reported promptly and the circumstances must be reviewed to prevent a similar problem in the future. The report recommended that the individual or group responsible for the FOD program conduct an investigation, analyze the resulting data and develop corrective actions.

"Human factors should be an integral part of any investigation of any incident or accident resulting from FOD," the report said. "Whenever possible, investigators of a FOD incident or accident should conduct an on-site examination. This would include walks through the area of concern and interviews with personnel involved and [with] other stakeholders."

The report said that several human factors investigative models have been developed for assessing accidents and incidents in aviation maintenance, including the following:

- Maintenance Error Decision Aid (MEDA), developed by Boeing Commercial Airplanes, is designed to investigate maintenance errors and to reduce or eliminate the errors by redesigning procedures. MEDA is based on three principles: "Mechanics don't intend to make mistakes"; "errors result from a variety of workplace factors, such as unclearly written manuals, poor communication between workers or improperly labeled parts"; and "management can fix the factors that contribute to errors";[4]

- Dirty Dozen, developed by Gordon Dupont in his work with Transport Canada, includes a checklist of aviation human factors issues that can be used for training and situational awareness. The checklist cites 12 errors in aviation maintenance that can affect safety, including lack of communication, complacency, lack of knowledge, distraction, lack of teamwork, fatigue, lack of assertiveness, stress, lack of awareness and "norms" (adopting the behavior of others in the group, even when that behavior is not correct);[5]

- SHEL Model, developed by Elwyn Edwards and modified by Frank Hawkins, describes how the human interacts with the system; SHEL is an acronym for software, hardware, environment and liveware (humans). The SHEL model explains how the liveware interacts with the other three elements, as well as with other human colleagues;[6]

- PEAR Model, developed by Michael Maddox specifically for use in aviation maintenance environments, emphasizes the relationship between individuals and the other elements of the system: PEAR is an acronym for people, environment, actions and resources. The "people" factors include mental capability, physical capability, attitude, training, age and adaptability. "Environment" factors include working conditions such as temperature, noise level and organizational environment. "Actions" factors include the actions that must be taken to complete tasks. "Resources" factors include the tools, computers, information, other people and time that are required for people to perform actions; and,

- Human Factors Analysis and Classification System Maintenance Extension (HFACS-ME), developed by the U.S. Naval Safety Center, is designed to identify human error that contributed to aviation maintenance occurrences and to use the information in the development of strategies to prevent such errors. HFACS-ME classifies human error into four categories - supervisory conditions, maintainer conditions, working conditions and maintainer acts - to study the relationships among latent failures and active failures.

The report said that each organization should have a form to be used in FOD investigations and to help organize data for entry into a FOD database. The form should be designed to collect data to be used in analyzing the cause of the FOD problem, including a description of the occurrence, a description of damage, a report on immediate action taken and recommendations for corrective actions.

By compiling and reviewing the data, the organization can work to identify and to understand the situation that resulted in a FOD occurrence and to implement best practices that will prevent FOD occurrences, the report said.

"Once the problem has been defined and the [investigating] team has an understanding of the system, then they can begin to analyze the information and data in order to identify the root cause of the FOD incident or accident" the report said. "It is possible that an individual -

who intentionally deviated from the safe operating procedures, recommended practices or rules - may have caused the problem. More than likely, however, the investigating team may find weaknesses in equipment design or availability, incorrect or out-of-date operational procedures, or lack of awareness and training deficiencies. They may even find that the root cause goes as far back as the culture of the organization or the lack of management support for FOD-prevention."

A corrective-action plan should be developed by the individual or group responsible for FOD prevention to establish procedures to ensure that the root causes of an FOD incident or FOD accident are identified and are corrected promptly.

A corrective-action plan may include such items as documentation of the processes included in the investigation of the FOD incident or FOD accident; results of the investigation and the root-cause analysis; identification of human factors causes and human factors intervention strategies; evaluation of alternative solutions; and assessments of the economic impact of the solution, of the solutions regulatory compliance and the potential for conflict with other groups or procedures.

If the analysis reveals more than one root cause of the FOD occurrence, separate corrective-action plans should be developed for each cause.

The report cited other analyses of human error in aviation maintenance that have found that errors originate from individual factors or from organizational factors.

The individual factors consisted of the following: physical health, fatigue, time constraints, management pressure, complacency, body size/strength, personal event/stress, workplace distractions, lack of awareness, lack of knowledge, lack of communication skills, and lack of assertiveness.[7]

The organizational factors consisted of the following:

- Hardware/equipment/tools/lack of resources/inadequate staff;
- Design/configuration/parts;
- Maintenance management/leadership/ supervision/company policy;
- Work processes/procedures/ information;
- Error-enforcing conditions/norms/peer pressure;
- Housekeeping;
- Incompatible goals;
- Communication processes;
- Organizational structures/corporate change/union action;
- Training/technical knowledge/ skills;
- Defenses;
- Environment/facility; and,
- Lack of teamwork.[8]

"Not all FOD errors are due to the individual, nor are all FOD incidents or [FOD] accidents attributable to organizational causes," the report said. "In the past, the focus of a FOD investigation was on the problem point or the individual where the active failure occurred. More recently, however, there has been a ... shift in FOD investigations to examine the relevant facts related to the event and to the background causes or latent failures. Employing a structured and systematic approach to the investigation and root-cause analysis will minimize any potential bias toward the individual in the corrective-action plan."

After the FOD error has been categorized, a corrective-action plan can be developed, including human factors intervention strategies. After the plan has been implemented it should be evaluated to determine whether modifying or eliminating the root cause of the FOD has eliminated the immediate cause of the FOD and whether implementation of the plan prevented similar recurrences of FOD.

The report recommended the following guidelines for conducting the evaluation:

- Incorporate the evaluation into other routine proactive FOD-prevention procedures rather than establishing a separate group to evaluate the process;
- Seek opinions from groups rather than individuals. The report said that groups often provide "more valid and creative feedback";
- Computerize all aspects of the evaluation; and,
- Ensure that data-collection procedures are well organized and that the database is designed to allow information to be extracted for analysis.

"The elimination of FOD is a continuous improvement process," the report said. "Lessons learned can help guide and tune future implementation processes, as well as help in developing a business case to expand the [corrective action plan] to other parts of the organization. Finally, the evaluation measures can aid in the development of benchmarks for future comparisons."

[FSF editorial note: This article, except where specifically noted, is based on *Guidelines for the Prevention and Elimination of Foreign Object Damage/Debris (FOD) in the Aviation-Maintenance Environment Through Improved Human Performance.* The report was written by David C. Kraus of Galaxy Scientific and Jean Watson of the Aircraft Maintenance Division of the U.S. Federal Aviation Administration Flight Standards Service. The 34-page report contains figures, tables and appendixes.]

Notes

1. "FOD Defined." FOD News. <www.fodnews.com/fod-defined.html>. June 17, 2002, The estimate of the cost of foreign object damage (FOD) was made by U.S. National Aerospace FOD Prevention Inc. (NAPFI), a nonprofit education organization established in 1985 to work to eliminate FOD.

2. The guidelines relate only to maintenance operations and do not discuss other causes of foreign object damage (FOD), such as bird strikes, animal ingestion, weather-related events, damage from ground-support equipment and airport operational practices. They also do not discuss aircraft tire maintenance.

3. Eri, Eulaine. "Sample Tool-control Ten-point Baseline." *National Aerospace FOD Prevention Newsletter*. May 1998.

4. Boeing Maintenance Error Decision Aid MEDA. Boeing Commercial Airplane Group. 1994.

5. Dupont, Gordon. "The Dirty Dozen Errors in Maintenance." *Human Factors Issues in Aircraft Maintenance and Inspection, Meeting 11 Proceedings*. Washington D.C., U.S.: U.S. Federal Aviation Administration. 1997.

6. Hawkins, F.H. *Human Factors in Flight*. Aldershot, Hampshire, England: Gower Technical Press, 1987.

7. Pakantar Manoj S.; Taylor, James C. "Analyses of Organizational and Individual Factors Leading to Maintenance Errors." Paper no. 2001-01-3005. Society of Automotive Engineers.

8. Ibid.

Further Reading From FSF Publications

FSF Editorial Staff. "Foreign-object Damage Cripples Concorde on Take-off From Paris." *Accident Prevention Volume 59 (April 2002)*.

O'Neill, John F.Jr. "Foreign Object Damage: Elimination Should Be a Priority to Reduce Risks to Personnel and Equipment" *Aviation Mechanics Bulletin* Volume 21 (March-April 1993).

Reprinted with acknowledgement to Flight Safety Foundation, Aviation Mechanics Bulletin, July-August 2002.

Safety Duties Analysed

Lambson Aviation (Knight Air) and Others v. Embraer and Another High Court of Justice, 11 October 2001

Readers will recall the tragic loss in May 1995 of an EMB110 Bandeirante on departure from Leeds-Bradford airport. The crew of the UK-operated aircraft lost control of the aircraft in IMC following the failure of at least one, but possibly both, of the pilots' attitude indicators (AI). Although the incident was some years ago, comment is now appropriate because the operator sought, unsuccessfully, to recover its losses from the aircraft manufacturer (and, initially, the component manufacturer, although this claim was discontinued shortly after the trial started) through the Courts. Judgement was given last year and we follow up on the previous legal adviser's promise in FOCUS Issue 45 to say more about the case.

The case primarily concerned the duty owed by a products manufacturer to an operator when it emerges that equipment proves unreliable in service. This case failed, but in addition, the Court commented on certain flight operations issues - specifically issues relating to aircraft handling under limited panel in IMC - which are likely to be of more interest to this readership.

The background to the litigation was that by the time the subject aircraft was built, the manufacturer recognised that the particular AI fit was unreliable and indeed was not recommended by the component supplier. A Service Bulletin recommending installation of a remote gyro (instead of the original panel-mounted installation) was published in 1982, about two years after the accident aircraft was completed. The operator contended, first, that the airframe manufacturer should never have used the original installation in an aircraft intended for commuter airline use; second, that operators should have been warned of its unsuitability; and third, the Service Bulletin failed to emphasise the seriousness of the failures of the original AI installation.

The following factors were important to the Judge in his decision to reject the claim.

- First, while there was abundant evidence of a problem of unscheduled failures with the original AI fit, this was not a safety problem. While operators had complained about reliability, none had complained from a safety angle and, significantly, none had retrofitted the remote gyro ultimately recommended by the manufacturer as the fix to the problem.
- Second, the AIs were, for maintenance purposes, "on condition" items. It followed that they could fail in service without imperilling the aircraft. Airworthiness regulators accepted this.
- Third, after the accident, the AAIB had not recommended that the SB implementing the new AI fit be made mandatory, nor had the CAA taken that course.

So far as flight operations issues are concerned the flight operations witnesses accepted that, in the event of a soft AI failure, professional instrument-rated pilots should have been able to maintain control of the aircraft. All but one of those witnesses agreed that that should have been the case even if it was a double failure with no standby AI. The Judge concluded that the flight crew had failed to perform to the standard reasonably to be expected, albeit with considerable reluctance given that the crew were not able to explain their conduct in Court. Where the case points up a dilemma is in the recognition - which the Judge shared with the AAIB - of the difficulty of maintaining control of the aircraft on limited panel, particularly in the prevailing weather conditions. Such a task is highly demanding of a pilot's skills and in the case of professional pilots, is neither retrained nor retested after CPL or ATPL initial issue. One may therefore conclude that the prudent operator should consider a programme of recurrent training if, for example, its aircraft are not fitted with a standby AI. However, the AAIB recognised the cost and limitations of such training and clearly took the view that the redundancy afforded by two pilots each with a full set of instruments was more effective protection and so made no recommendation.

Moreover, the manufacturers did not pursue any suggestion that the operator's

training was insufficient; there was no breach of any legal or regulatory requirement in this respect so the Court was not in a position to say that the operator's practices fell short of those reasonably to be expected of any operator. For this reason, it is difficult to draw any conclusion about the training aspect: the Court did not, it appears, hear evidence or argument on the subject, so this cannot be regarded as a definitive conclusion.

What the Court did do was to conclude that the Captain was interpolating, in other words trying to continue using his AI despite knowing that it was not indicating correctly. The Court accepted the experts' evidence that it was axiomatic that if the Captain recognised his AI had failed, he should immediately hand over control to the First Officer. Although not a major factor in his decision, the Judge concluded that the crew did not maximise their ability to deal with the situation and this may have been compounded by the relative inexperience in role of both the Captain and First Officer. That, however, is more a point for the human factors experts than for the lawyers.

Some may ask what difference the flight operations aspects make from a legal perspective. To be brutal, the answer is that in financial terms it made little difference: the operator is liable in any event to its passengers whether the flight crew had discharged their duties or not. On these facts, the operator failed to demonstrate that the manufacturer was in breach of duty, but if the outcome in that part of the case had been different, a failure by the flight crew may mean the difference between the operator's ability to recover indemnity in respect of passenger claims and the hull loss. The difference really lies in the safety of the passengers.

What then, are the conclusions?

First, at the most general level, it is encouraging that the English Courts can deal with complex technical issues and address them, with the right representation and expert evidence, with a high degree of understanding. On occasions in the past this has not been the case.

Second, the central legal point to emerge is that liability in negligence arises where there is a safety issue. It was this, rather than a reliability question, that triggered the manufacturer's duty in tort to the operator and those on board.

Third, it is critical to remember that compliance with a regulatory or certification standard is not necessarily a complete answer to a claim in negligence. Those standards will, however, be taken into account when determining what it is reasonable to require of a manufacturer or operator and thus what burden that party must discharge to avoid a claim of breach of duty. If, therefore, you consider that equipment fit, procedures or whatever do not achieve a high enough level of safety, review and amend them. Do not wait for the regulator to mandate a particular course.

Fourth, the most specific point to emerge is that operators of aircraft of a comparable equipment fit would be advised to ensure that flight crew operating procedures make clear that the handling pilot should hand over control immediately a failure of this nature is recognised.

Finally, no-one should forget that this case only considered civil liability; in the future, in a political environment in which a desire to punish the "guilty" becomes increasingly prevalent, different considerations may come into play.

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This is an expanded version of an article which appeared, under the heading "Manufacturers' Duty Analysed" in Issue 7 of BLG Aviation News. Copies of that and other issues are available on line at www.blg.co/publications.

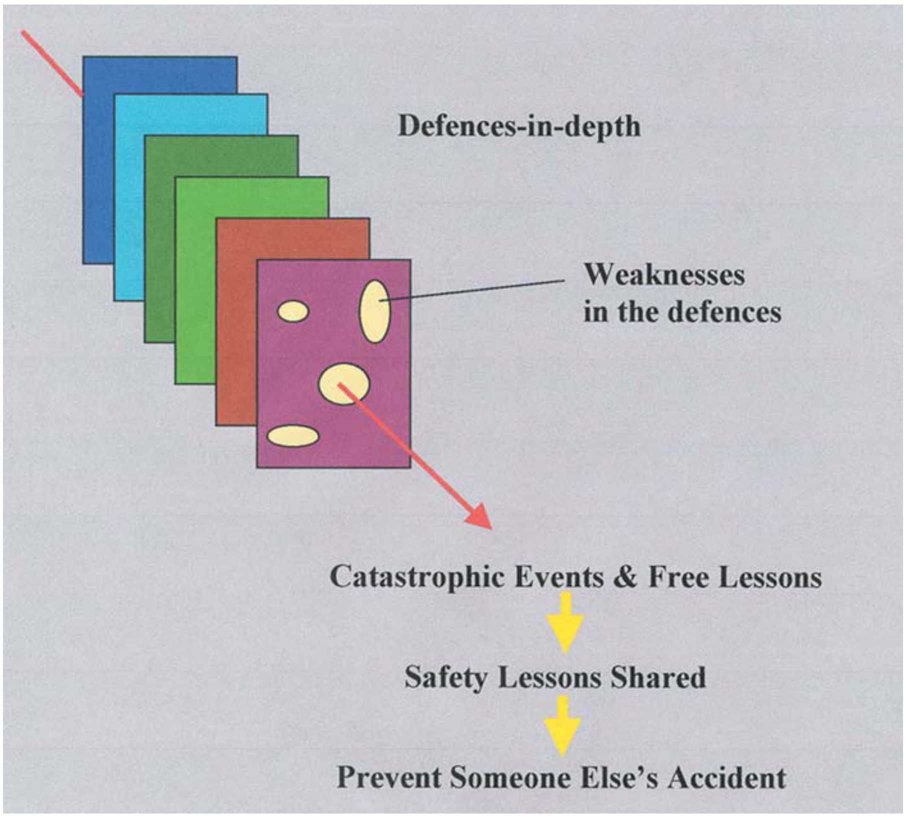
Sharing Safety Lessons

by Capt. John Marshall

Professor James Reason's model of accident and incident causation and investigation has been widely adopted by the aviation industry. The model shows that aviation, in common with other high technology, high-risk industries, has many layers of defence to prevent accidents from occurring. These defensive layers will, however, have weaknesses in them allowing the defences to be breached on occasions (an event). Professor Reason makes these two points:

" The consequences of an event can vary from the catastrophic to the free lesson. All, however, provide crucial learning experiences for the system in question."

"The normal run of operations fortunately offers a fairly large number of free lessons in which a defence or barrier is shown to be deficient without adverse consequences."



Since the early 1950s, starting with the investigation into the De Havilland Comet crash off the island of Elba, aviation has shared the safety lessons learnt from its catastrophic events in the form of accident reports published by bodies such as the UK's AAIB. This approach to flight safety, although undeniably valuable, is reactive in nature.

In recent years, in order to improve a static accident rate, aviation has moved in the direction of pro-active safety management – identifying and mitigating potential safety hazards before an accident occurs. In line with this pro-active approach aviation should also share the safety lessons learnt from its free lessons.

Safety lessons are established, according to Professor Reason's model, by investigating the Active and Latent failures that have caused defensive layers to be breached. Active failures are the errors of front line operators (pilots, air traffic controllers and maintenance engineers in the case of aviation). Latent failures are caused by the policies, decisions and culture that are an everyday part of organisational life, e.g. resource allocation, staff training, documentation provision and management – staff – management communication. The purpose of a safety investigation is categorically not to apportion blame but to establish the root causes of an event thereby establishing the safety lessons.

Airlines have a range of safety tools and other sources of information available to them to help detect and investigate safety events. These include:

1. Air Safety Reports (ASRs)

2. Flight Data Monitoring (FDM)

3. Human Factors Reports (HFRs)

4. Crew interviews

5. Engineering data

6. Quality Audit Reports

Not all reported or detected events will require a full investigation and resources would not permit this anyway. Therefore events should be investigated according to their perceived risk level, bearing in mind that risk is not just a function of the potential severity of the outcome but also a function of the likelihood of it occurring. If a safety event requires investigation then all appropriate sources of information should be used to determine both the Active and Latent failures.
The role of front line operators in the investigative process is clearly very important as they provide much of the initial data on which investigations are founded. They should, therefore, report

safety events with sufficient breadth and detail of information as to allow the safety lessons to be established.

A successful safety information sharing scheme must meet certain requirements, which include:

Confidentiality - Aviation safety information can be sensitive in nature and if used in the wrong way, e.g. punitive action or sensationalist journalism, potentially damaging to the operator or individual from where the information originated. A successful safety information sharing scheme must protect the confidentiality of those involved while at the same time not diluting the safety benefits of the information to be shared.

Workload - Airline Flight Safety departments are often staffed by pilots who discharge their flight safety roles on a part-time basis and as a consequence have a high workload. Therefore a successful safety information sharing scheme must not unduly burden staff with either its administration nor with vast amounts of safety data requiring analysis.

Practical Benefit – The information shared must be of more than just academic interest. Shared safety information should be of practical benefit to the recipient by alerting them to potential safety hazards that they may not have detected themselves thereby helping them to prevent an avoidable accident.

Sharing safety lessons fulfils these requirements. Firstly, confidentiality need not be compromised because the information does not need to be specific to a particular flight or even a particular operator. Secondly, safety lessons do not require the recipient to carry out substantial analysis of data, thereby minimising additional workload. Finally, safety lessons are a readily usable and practical format of information – the recipient decides if the safety lessons are applicable to their operation and then takes appropriate action.

The following is an example of a safety event that should be investigated and the sort of safety lessons that might be ascertained:

An operator's FDM programme detects a GPWS event on a glass-cockpit aircraft during departure from an airport with significant terrain in the vicinity. The crew file an ASR acknowledging a hard GPWS warning while following Flight Management Computer navigation demands on the SID. So far we have little information of practical benefit to other operators. However, if the operator's investigation into the Active and Latent failures determined that the navigation database was incorrect, that the crew had not checked the database tracks and distances prior to departure, the SID had not been monitored with radio navigation data, the departure chart was difficult to interpret, and that the company SOP's were insufficient regarding monitoring and cross-checking FMC navigation, then we start to determine some valuable safety lessons that could help another operator avoid a catastrophic event.

The medium best suited to sharing safety lessons is the Internet in the form of a secure website hosted by a respected aviation body. Such a system is already used by some UK FDM operators and is under development for the UK's Maintenance Error Management System (MEMS) Project. The Internet has the potential to distribute flight safety information securely, efficiently and at reasonable cost on a global scale.

We share safety information to prevent someone else's accident. Apart from any moral justification this makes sound commercial sense. The public perception of airline safety is based on the number of aircraft accidents, not the statistical rate at which they occur. Undoubtedly an airline directly involved in an aircraft accident will suffer a loss of public confidence, at least in the short term. However, if the number of aircraft accidents lowers the public perception of airline safety in general, then the airline industry as a whole will suffer. Therefore, let us share the safety lessons not just from our catastrophic events but from our free lessons as well.

About the Author

I started my aviation career in 1987 as a Flight Dispatcher for Monarch Airlines. The following year Monarch selected me for pilot sponsorship. I rejoined Monarch as a First Officer in 1989 and have remained with them since, latterly as Captain on the A320. I graduated with an MSc in Air Transport Management from City University in May 2002.

Winter Blues

by DASC

Christmas comes but once a year.....and with it mince pies, Christmas cake, snow, ice, Blacktop tannoys, aquaplaning, fog, immersion suits, high sea states etc etc. Unfortunately, Christmas is a bit late to start thinking about it.

Being the consummate professionals that you are, your preparations will have already begun. Here is a checklist to scan through whilst you make your cup of coffee - hopefully it will identify something which you could improve on.

ON THE GROUND

Clothing

Are you scaled for the correct protective clothing? If so, get it issued and wear it. If not, speak to the chain of command to address the problem. DO NOT leave it at home, in the locker room, in clothing stores. Make sure that your waterproofs are readily available. Always wear your waterproofs when it is raining (Sod's law says that the 2 minute job always extends to 20 minutes or more). Wearing bulky gloves inhibits manual dexterity - so leave more time to do a job and tell your supervisor if you cannot complete the task in time.

Check your boots have sufficient tread to maximise traction. HOWEVER tread collects snow, mud and stones, so stick to the hard standing and check that the tread is clean before you get into the cockpit.

Out and about

Get out to the line or HAS site early; if you rush and slip over you defeat the object of running and give the hard pressed manpower manager an extra headache when you reappear in a plaster cast.

When marshalling, stand in a sensible place where the aircrew can see you, even if their view is restricted. Be prepared for the aircraft to skid. If you get to the aircraft parking area and you find that it is slippery - get something done about it before the aircraft moves on it.

Be on the lookout for ice and snow that a taxiing aircraft may blow in your direction.

Blacktop

Are your personnel familiar with the Blacktop plan? They may have signed as having read, but do they actually understand how to implement the procedures? Why not have a briefing giving examples of how to deal with different situations.

THE LINE

Aircraft do not like being out in the wind and rain. Keep them in the hangar or HAS whenever possible. If you have to leave them outside, keep the canopies closed and put the covers on if practicable. Whilst there are fewer squashed bugs on the canopies marks are still caused by de-icing chemicals and dirty water so they still need to be kept scrupulously clean.

Fit chocks correctly. If the wind is forecast to pick up, other measures may be required to secure the aircraft.

Drive slowly; assume you are going to skid when you approach the aircraft.

De-ice with the correct fluid; DO NOT chip ice off an aircraft. How are your stocks of de-icing fluids? Is the de-icing kit serviceable? Do all your NCOs know the techniques for de-icing the aircraft?

Batteries hold their charge less well in low temperatures. How do you ensure that all your ground equipment batteries are fully charged?

Have you had all your fire extinguishers checked recently? The mechanism can freeze in very cold weather.

Remember that rubber seals harden in cold weather and need special care.

Allow extra time to carry out the aircraft inspection; it takes longer when it is cold, wet, windy and dark. Pay particular attention to undercarriage bays, undercarriage microswitches, intakes, tyres, control surfaces, pitot heads and static vents.

Ice on the aircraft is not acceptable for flight - get the aircraft de-iced.

Have a close look at the undercarriage as the aircraft taxies out. Hydraulic seals harden in cold weather and may cause a hydraulic leak which will only become apparent when the system warms up. Make sure the wheels are actually rotating!

FLYING

Supervisors, remember that diversions are sometimes more difficult to come by in poor weather so keep a careful eye on what you have booked. Do not hang on to diversions unnecessarily, other units may be waiting to use them to get a flying state. Keep up to date with the weather situation and do not rely on the met office ringing you to warn you of changes. Brief the met office on your requirements and ask them to keep an eye on areas of concern and inform you as soon as there is a significant change. In allowing flying to take place, are you content that the risk involved due to the weather conditions is worth the prize of going flying at that time?

Aircrew, are you fit to fly or are you pushing it to make up the numbers? Planning to stay below 10,000 ft isn't the solution. If you haven't experienced it yourself let me assure you that a sticky ear or sinus pain is one of the most distracting experiences you can have when you are flying. What are your rules about sickies staying at work to be the auth.....and infect others?

How seriously do you dress to survive? Life in a dinghy in the North Sea at night in the winter is not that pleasant and rescue may not be instantaneous.

Pay extra attention to the met forecast. Consider not only cloud, visibility and surface wind but also the icing risk, precipitation and the trends over the flying period. Know where your nearest suitable diversions are that have more favourable weather and crosswinds. If you experience weather different from that which was forecast - tell someone so others can do something about it.

Know your aircraft's anti-icing system and the limitations on flying in icing conditions. Does your aircraft type have an icing let down technique? If so, revise it.

Is the runway wet? If so, how likely is your aircraft to aquaplane and at what speed? What techniques does your aircraft type require to minimise the risk of aquaplaning?

Make sure that your approach plates are up to date and be familiar with them before the sortie rather than referring to them for the first time in cloud and short of fuel.

When briefing multi-ship formations, include spacing during taxy, poor weather take-offs, stream intervals for the conditions (noting runway spray, cloud base and thickness and radar service available). Does the formation know the technique for a snake climb - even if they expect to have a radar to lock onto the aircraft in front (radars and other electrical gadgets invariably fail in poor weather)? Consider low level aborts into thick cloud and nominate individual levels above safety altitude. Brief the lost leader in cloud drill, making it pertinent for the sortie and do not accept partial knowledge of the drill.

Taxy slowly and well away from obstacles. Expect slippery surfaces anywhere, especially on the runway and taxiway markings and especially after surfaces have been treated with de-icer. If it is too slippery, stop and inform ATC of the problem; if you leave the runway or taxiway it will be your fault not the fault of the Blacktop team, ATC or anyone else. Do not taxy if you cannot see out of the canopy due to mist or ice.

Know the temperatures and pressures that you can expect on engine instruments in cold weather. You may have to wait for oil and hydraulic fluid to warm up.

Standing water and slush affects the take-off and landing performance of an aircraft. Make sure that your calculations for take-off and landing distances, abort speeds etc take the runway condition into account. Know the techniques for taking off and landing on contaminated runways.

Beware of white out when taking off or landing vertically onto snow or when using reverse thrust.

Whilst airborne, keep track of the weather at your recovery airfield and diversions. Recover with sufficient fuel for the procedure required, plus fuel to hold off. Keep accurately to slot times if they are in force. Allow extra time and fuel for larger formations. Make sure that you have a plan on how and when you are going to split for the approach and make sure you give ATC enough notice. If there are several aircraft in the instrument pattern, fly standard pattern speeds to facilitate accurate spacing. Be careful about doing pre-landing checks too early; the fuel penalty incurred by the extra drag from the undercarriage may run you short. Fly the approach accurately so that you are at decision height on speed, on the centreline and on the glidepath so that you stand the best chance of getting in on the first approach in marginal conditions. Are the runway approach lights too bright/dim? One R/T call will get them changed for you.

Once on the ground, remember that it is not over until you have crewed out of the aircraft and it has been put to bed. Aquaplaning, slippery surfaces and the hazards mentioned above still apply on the taxi in. Watch out for airfields that were wet when you departed at dusk as the cold front went through and the temperature has dropped like a stone and those wet surfaces have miraculously changed into icy surfaces. This happened at one particular RAF station some time ago. The temperature drop had gone unnoticed and the taxiways were not treated. As a Tornado from the evening wave taxied in the pilot noticed that he had little control over the aircraft. In order to stop the aircraft, the pilot restarted the engine that had been shut down for the taxy in so that he could use symmetrical thrust reverse to bring the aircraft to a halt. This was done successfully and the pilot reported his predicament to ATC. Some minutes later, the engineering recovery team raced towards the aircraft and narrowly missed colliding with it when they realised that they too had little control of their vehicle!

When it is all over, drive home safely. Manning levels are not helped by RTAs.

Space weather impacts on airline operations

by Captain Bryn Jones, Virgin Atlantic Airways Cosmic Radiation Programme Manager

Recent press coverage regarding exposure to increased levels of radiation while flying at civil aircraft altitudes due to cosmic radiation, has raised the profile of an area of space science, known as "Space Weather", that was previously more likely to be linked only with NASA astronauts and the Space Shuttle. However, the fact that the Earth is immersed in an extremely tenuous bath of high-energy charged particles called cosmic rays (both galactic and solar in origin) is but just one of many physical processes going on in near-Earth space that can have a direct impact on airline operations. Most of the time space weather is of little concern in our everyday lives. However, when the space environment is disturbed by the variable outputs of the Sun, technologies that we depend on both in orbit and on the ground can be affected (See Fig.1). So besides cosmic rays, what are the other Space Weather (SW) phenomena that could have a direct impact on airline operations?

What is Space Weather?

Firstly, what exactly do we mean by the term "Space Weather"? The internationally accepted definition is: "Conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life and health". (From US National Space Weather Strategic Plan, August 1995)

Within this definition we include the effects of Galactic Cosmic Rays (GCRs) that originate from exploding stars outside our solar system but which also affect technological systems, and endanger human life and health because their flux is modulated by solar processes. It is these GCRs that are the primary source of the cosmic radiation at aircraft altitudes.

Also from this definition we can see that the main influence on our SW comes from our Sun and its own "climate-like" variations, which occur on both the short term (hours, days) and the long term (roughly 11-year solar cycle). "Storms" in our SW generally follow severe solar disturbances such as Solar Flares on the photosphere and Coronal Mass Ejections (CMEs) from the outer solar atmosphere. Flares are our solar system's largest explosive events, which can be equivalent to approximately 40 billion Hiroshima-size atomic bombs. They have lifetimes ranging from hours for large gradual events, down to tens of seconds for the most impulsive events. They release ultraviolet, x-ray and radio emissions, which can reach the Earth in 8 minutes, producing a temporary increase in ionisation in the sunlit hemisphere of minutes to hours duration called an "ionospheric disturbance". Large flares, known as Solar Particle Events (SPEs), can release very energetic particles, which then arrive in our atmosphere within 30 minutes. The Earth's magnetic field does offer some protection, but these particles can spiral down the field lines, entering the upper atmosphere in the polar regions where they produce additional ionisation in the ionosphere and increase the radiation at aircraft altitudes. Very energetic and intense events can also lead to increases at lower latitudes.

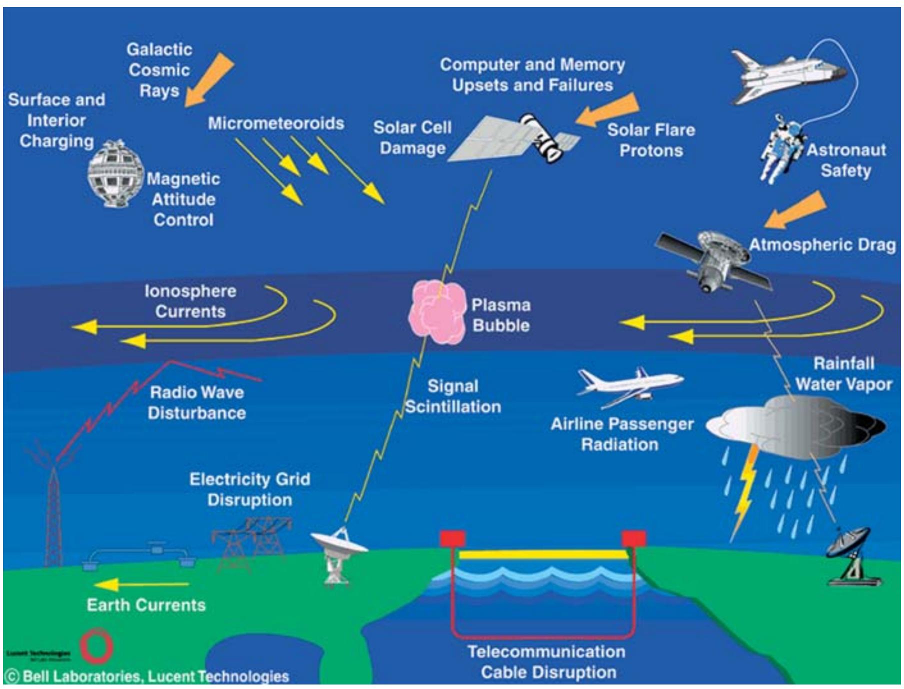


Figure 1. A simple illustration of technolo gical systems affected by Space Weather.

CMEs are huge bubbles of magnetised gas that are ejected from the Sun, at several million miles per hour, over the course of several hours. These explosions of material (equivalent to the mass of Mount Everest!) from the Sun's outer atmosphere can also rapidly shower the Earth with energetic particles and cause severe disturbances in the Solar Wind.

The interplanetary medium (or heliosphere – the region of space dominated by matter from the Sun), once considered to be a perfect vacuum, is now known to be a turbulent region

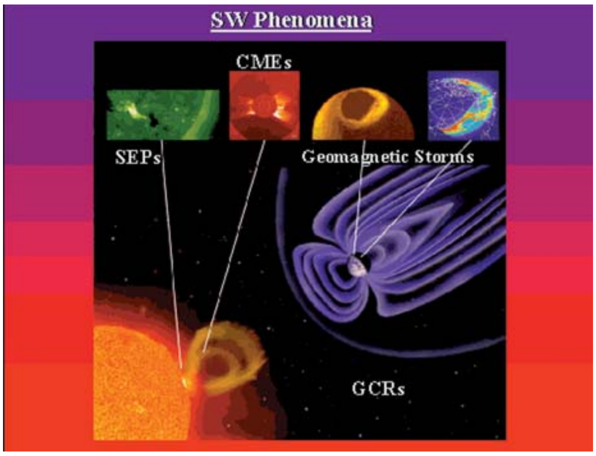


Figure 2. illustration of some Space Weather phenomena

dominated by the solar wind, which flows at approximately 250-1000km/s (about 600,000 to 2,000,000mph). Other characteristics of the solar wind (e.g. density, composition, and magnetic field strength) vary with changing conditions on the Sun. The Earth's magnetic field (similar in shape to the pattern formed when iron filings align around a bar magnet) is influenced by the solar wind, becoming compressed in the sunward direction and stretched out in the downwind direction. This creates the magnetosphere, a complex, teardrop-shaped cavity around Earth. Because the solar wind varies over time scales as short as seconds, the boundary between interplanetary space and this magnetosphere is extremely dynamic.

One to four days after a solar disturbance a slower cloud of solar material and magnetic field reaches the Earth, buffeting the magnetosphere and resulting in a Geomagnetic Storm. The bi-polar magnetic field of the Earth points north but the field contained within the material expelled from the Sun can point in any direction. When the field is orientated in the opposite direction to that of the Earth, that is, when it points south, the two magnetic systems interact and the solar material can enter the Earth's magnetosphere. These interactions can produce very large electrical currents, of up to a million amperes, flowing through the ionosphere and magnetosphere which can change the direction of the Earth's magnetic field at the surface by up to 1 or 2 degrees, mainly in the auroral regions.

Probably the most well known effect of these geomagnetic storms is the aurora borealis (northern lights) and aurora australis (southern lights). They occur when energetic particles, mostly electrons, "rain" down from the magnetosphere during episodes of disturbed space weather. The auroral light is emitted by atmospheric atoms and molecules that become excited by the close passage of the electrons. Aurora begin between 60˚ and 80˚ latitude. As a storm intensifies, the aurora spread toward the equator. During an unusually large storm in 1909, an aurora was visible at Singapore, on the geomagnetic equator. The auroras provide pretty displays, but they are just a visible sign of atmospheric changes that may wreak havoc on technological systems.

What are the Impacts?

Hazards to Humans

The principal SW hazard to humans is exposure to Cosmic Radiation, which is caused primarily by GCRs. These energetic particles start interacting with the significant atmosphere at around 130,000ft causing secondary particles to shower down into the denser atmosphere below. This "particle shower", and the corresponding level of radiation dose, reaches a maximum intensity at around 66,000ft (20km) and then slowly drops off by sea level. Dose rates also increase with increasing latitude reaching a constant level at about 50˚. The dose rate at an altitude of 26,000ft (8 km) in temperate latitudes is typically up to about 3 microSv (μSv) per hour, but near the equator only about 1 to 1.5μSv/hr. At 39,000ft (12km), the values are greater by about a factor of two.

Typically, a London to New York flight in current commercial aircraft accumulates 35-45μSv (5-6μSv/hr); however, the phase of our Sun's activity cycle can give $\pm$ 20% variations in dose from solar minimum to maximum.

Under present international guidelines, the recommended dose limit for aircrew is a 5-year average dose of 20 mSv per year, with no more than 50 mSv in a single year. In the UK an administrative maximum limit of 6mSv has been adopted for record keeping purposes, which is still workable with current flight profiles and annual block hours. However, if future generations of large commercial aircraft are designed for increased range or to utilise the available airspace at higher altitudes, then we can expect to see significant increases in the doses (8μSv/hr at 42,000ft, 10μSv/hr at 51,000ft). (Note: for a pregnant crewmember, starting when she reports her pregnancy to management, her work schedule should be such that the equivalent dose to the child is as low as reasonably achievable and unlikely to exceed 1mSv during the remainder of the pregnancy.)

Figure 3. Example of Space Weather - The Northern Lights or Aurora

The impact of SPEs can also increase the dose. During the SPE of 1956 it has been estimated that the radiation dose received at 40,000ft (12km) on a transatlantic flight would have been approximately 10mSv. Such events are extremely rare, but recent studies of smaller more typical events in September and October 1989 indicate 2mSv for a similar flight.

Medical research is inconclusive, but the chances of developing cancer as a result of cosmic radiation is considered to be very unlikely, as the total career dose is received in low doses per flight, and accumulated slowly over the length of a flying career. It is difficult through epidemiological studies to find causation of cancer due to cosmic radiation as other lifestyle risk factors exist, particularly with aircrew.

Radiation Damage to Avionics

As aircraft avionics continue to use increasingly smaller electronic components, systems are becoming more susceptible to damage from the highly ionising interactions of cosmic rays, solar particles and the secondary particles generated in the atmosphere. The heavier and most energetic particles can deposit enough charge in a small volume of silicon to change the state of a memory cell, a one becoming a zero and vice versa. Thus memories can become corrupted and this could lead to erroneous commands. Such soft errors are referred to as "single event upsets" (SEU). Sometimes a single particle can upset more than one bit to give what are called multiple bit upsets (MBU). Certain devices could be triggered into a state of high current drain, leading to burn-out and hardware failure; such effects are termed single event latch-up or single event burn-out. These deleterious interactions of individual particles are referred to as single event effects (SEE). Satellites incorporating sensitive RAM chips have had upset rates from one per day at quiet times to several hundred per day during SPEs. In-flight measurements of SEU sensitivity in 4Mb SRAM, produced a rate of 1 upset per 200 flight hours, and agreed well with the expected upset rate variations due to changing latitude. Research suggests that 100MB SRAM (i.e., laptop) may suffer upsets every 2hrs at 40,000ft, or 1 upset/minute in 1GB SRAM due to the 1989 SPEs. This problem is expected to increase as more, low power, small feature size electronics are deployed in "more electric" aircraft.

Communication

Many communication systems utilise the ionosphere to reflect radio signals over long distances. Ionospheric storms can affect radio communication at all latitudes. Some radio frequencies are absorbed, while others are reflected, leading to rapidly fluctuating signals and unexpected propagation paths. Solar flare ultraviolet and x-ray bursts, solar energetic particles, or intense aurora can all bring on these conditions. If the effects become especially strong, it can cause a total communications blackout. SPEs produce a particular type of disturbance called Polar Cap Absorption (PCA) that can last for many days. When very energetic particles enter the atmosphere over the polar regions, the enhanced ionisation produced at these low altitudes is particularly effective in absorbing HF radio signals and can render HF communications impossible throughout the polar regions. At a recent SW conference, several US air carriers indicated that they have cancelled trans-polar flights due to such space weather events.

GPS Navigation

There are now plans to use GPS for navigating aircraft so that the separation between aircraft can be reduced, and to position the aircraft on approach. There are also studies in progress on the longer-term goal of landing aircraft by GPS. However, the accuracy of the GPS signal, which must pass through the ionosphere, is obviously affected by any ionospheric variations due to solar and geomagnetic activity. Dual-frequency GPS receivers actually measure the effect of the ionosphere on the GPS signals and can better adjust to, but not irradicate, these difficult circumstances. This is accomplished by using a network of fixed

ground based GPS receivers, separated by a few hundred km, to derive a map of the ionosphere. The map is then transmitted to the aircraft so that the GPS receiver on board can make an accurate ionospheric correction.

On a smaller scale, irregularities in the density of the ionosphere that produce scintillations occur in varying amounts, depending on latitude. For example, the equatorial region, (the latitude zone that spans 15-20˚ either side of the magnetic equator) is the site of some of the greatest ionospheric irregularities, even when magnetic storms do not occur. Seemingly unpredictable episodes of density enhancements in the upper ionosphere can occur there in the evening hours and can cause radio waves to be misdirected. These scintillations make GPS operations difficult.

GPS signals are generally immune to ionospheric changes in response to large infusions of x-rays following a solar flare. However, GPS and all other satellites (including communications) must contend with the detrimental effects the energetic solar particles have on the on-board systems.

Terrestrial Weather

Besides the ionospheric disturbances directly caused by flares and by the auroral particles and currents during magnetic storms, the ionosphere exhibits irregular variations related to the dynamics of the underlying atmosphere. These depend upon the combination of traditional "weather" near the ground, which produces waves in the atmosphere like the waves in the deep ocean, and the winds between the ground and the upper-atmosphere levels that act like a filter to the passage of those waves. While this aspect of space weather may appear to have a non-solar origin, its effects are most pronounced when the upper-atmosphere winds or lower-ionosphere composition is enhanced by the energy inputs from the active Sun.

Optical phenomena called "red sprites" and "blue jets" have been observed at altitudes extending from the tops of strong thunderstorms (at around 15-kilometers altitude) to the lower ionosphere (about 95-km altitude). Possibly related to these optical signatures, intense electromagnetic pulses (10,000 times stronger than lightning-related pulses) have been detected over thunderstorm regions by satellites. These observations suggest that there may be a stronger connection between global thunderstorm activity and the ionosphere and upper atmosphere than previously suspected. Interest in their effects will depend on the future use of this region of Earth-space.

A recent NASA-funded Earth Science study supports earlier findings that there may be a relationship between increased cloud cover over the USA and the solar maximum. Previous studies have shown that during the solar maximum, the jet stream in the Northern Hemisphere moves Northward possibly due to the Sun's varying ultraviolet output, which affects the ozone production in the stratosphere. When the ozone absorbs ultraviolet radiation, it warms the stratosphere, which may affect movement of air in the troposphere where clouds form. It is the jet stream, which plays an important role in cloudiness, precipitation and storm formation in the USA. Future studies hope to establish the mechanisms that may link solar variability with terrestrial weather.

National Grid & ATC Ground Facilities

The enhanced currents that flow in the magnetosphere-ionosphere system during geomagnetic storms can affect electric power systems on the ground. These currents cause magnetic field perturbations on the ground that in turn induce other currents in long transmission lines. The slowly varying "DC" part of the currents can be large enough to cause overheating and damage to systems designed for "AC". Disruption of the grid supplies can adversely affect many aspects of our daily lives should a blackout result. However, the reliability of power supplies to critical ATC ground equipment cannot be overstated. The UK National Air Traffic Service (NATS) goes to extensive lengths to ensure they have installed adequate redundancy and

Figure 4. Picture of a red sprite and blue jet over a thunderstorm (courtesy of D. Sentman, Geophysical Institute, University of Alaska at Fairbanks).

backup for failures of the commercial grid supply. They also depend upon the grid operators to notify them when geomagnetic storms threaten the network.

What is the Future?

The need for SW forecasting and reporting has been driven up until now by the needs of the Space Industry. However, it is now realised that there are many other different market sectors that are adversely affected by SW events: power grids, geological prospecting, oil and gas pipelines, railways, defence, risk and insurance, tourism and of course aviation. There are National Space Weather Programmes underway in the USA and Japan, with the European Space Agency (ESA) undertaking extensive work assessing the need for a separate European SW capability. The requirements of the different SW users in Europe are currently being assessed via various ESA or EC funded research programmes and collaborations, and this includes the SW impacts on airline operations.

Initial reports state that with all future technological and operational advancements, the civil aviation industry will begin to see an increasing risk from SW, and will therefore, need to utilise and integrate SW information services into the daily operation. To assess the SW risk correctly an industry-biased educational Outreach Programme is being developed. This should then lead to the identification of relevant expertise within the industry to liase with the SW science community to draw up the requirements of a Space Weather European Network (SWENET). However, one important consideration, is that due to the nature of aviation, any SW network or service would need to be internationally co-ordinated and undergo regulatory (CAA, FAA, ICAO, etc) approval in a similar manner to current terrestrial weather services.

Further Information

The author is currently participating in EU and ESA SW research and can provide further information upon request (contact Captain Bryn Jones on +44 (0)1293 444907 or bryn.jones@fly.virgin.com or jblj@mssl.ucl.ac.uk.)

Some useful websites are:

www.spaceweather.com
- general SW news
www.estec.esa.nl/wmwww/wma/spweather
- ESA SW site
www.sec.noaa.gov
- US Space Environment Center

Hail Damage!

The effect of hail can be somewhat startling. "Storm chasing" is big in the States. It is not common in the airline world. Guidance information strongly advises avoiding storms by considerable margins.

In June 2002 an Airbus A320 entered what appeared to be insignificant high-level cloud. What came out the other side of the cloud was quite unexpected!

At approximately 1650 UTC whilst on the return sector of a flight to Greece the aircraft entered the top of a Cumulonimbus cloud formation. The aircraft suffered considerable damage as a result of hail within the weather system. The crew of this aircraft did not deliberately fly into a storm! The aircraft was in the cruise at 36000ft south east of Prague in the Czech Republic. Visibility was good and both pilots could clearly see the ground and were flying in good visual meteorological conditions.

The aircraft subsequently entered some high-level cirrus cloud. Light turbulence was experienced and the captain elected to switch on the seat belt sign. The level of turbulence increased from light to moderate. The cabin crew were advised to take their seats and as this instruction was carried out the aircraft experienced severe turbulence.

The aircraft's autopilot was doing a reasonable job of controlling the aircraft until the severe turbulence hit. The captain elected to disengage the autopilot and manually set the aircraft attitude in an attempt to stabilise the attitude & speed.

The pilots stated that this was the most severe turbulence they had experienced. The aircraft then entered an intense hail shower. Both main windscreens cracked and crazed over. The hail -storm was over almost as quickly as it started and had quite an effect on the aircraft. The weather radar was selected on as the aircraft entered the cirrus cloud. The radar screen showed some "red" areas. From the Flight data Analysis the aircraft

was in the storm activity for a little over a minute. The flight crew was surprised at the reception inside what appeared to be insignificant high-level cloud. Both pilots had experienced the initial conditions many times in the past with little effect. The crew had a slightly different experience in the cabin. The impression was one of being on a roller coaster ride. The turbulence was the worst the cabin supervisor had experienced. The extremely bumpy ride came out of nowhere and given the smooth outbound sector the crew were not expecting any problems. The CS was in the cabin assisting a customer that had been feeling unwell. The noise was horrendous and the crew considered that the noise was similar to that of the landing gear being lowered.

It would be very easy to speculate about the causes of this incident. It is the honest reporting on the behalf of the crew that is really important and gets the safety message across. It is a dormant evil that inhibits full and free confession, which a professional may make for the good of safety.

So what caused this pounding by hail?

In simple terms the pilots involved did not select the weather radar on prior to entering the high cirrus cloud. They were caught out by what was hidden within! The crew of this aircraft performed extremely well given the circumstances. It is easy to concentrate on what went wrong and lose sight of the safety benefits that come out of the situation!

- The locked flight deck door was not a barrier to good CRM. The crew worked well throughout this incident and the flow of information from the Captain was tremendous.

- The company has a strong support team in place and was in a great position to offer assistance and counselling to both crew and customers.

Worth a read: AIC 72/2001 Effect of thunderstorms and associated Turbulence on aircraft operations.

NATS Led Team Wins Aviation Safety Award

An industry wide team led by National Air Traffic Services has won an award for 'an outstanding contribution to Aviation Safety' from the Guild of Air Traffic Controllers.

Paul Jones, team leader, said that the updated booklet 'Aircraft Emergencies – Considerations for Controllers' represented a huge effort over a short period of time by the team who took on the challenge on top of their 'day jobs'.

Richard Daswson, President of GATCO presented the award to the team at a Gala dinner on the 12th of October at the Botley Park Hotel near Swanwick.

The booklet will shortly be distributed to all UK controllers regardless of whether they work for NATS. The new updated version has been totally rewritten to change the focus, introduce new material including human factors and introduce some general 'rules of thumb'.
The team (pictured left to right – John Dunne Chairman UK Flight Safety Committee, Jane Gothard NATS, Mike Dawson NATS, Paul Jones NATS, Nigel Self British Airways, Susie Foley NATS, and Alan Evans Mytravel) also included Simon Searle GO, Brian Connolly British Airways and Alison MacMaster NATS who were unable to attend the presentation.

Full members

Chairman
Airclaims
John Dunne

Vice-Chairman
flybe. british european
Stuart McKie-Smith

Treasurer
Air 2000
Capt. Martin Pitt

External Affairs Officer
RAeS
Peter Richards

Aer Lingus
Capt. Tom Croke

Aerostructures Hamble
Dr. Marvin Curtiss

AIG Aviation
Jonathan Woodrow

Air Contractors
Capt. Tony Barrett-Jolley

Air Mauritius
Capt. Francois Marion

Air Scandic
Paul Ridgard

Air Seychelles
Capt. Curtis Allcorn

Air Transport Avionics
Colin Buck

ALAE
Dave Morrison

Astraeus Ltd
Capt. Nick Carter

BAA plc
Francis Richards

BAC Express
Capt. Steve Thursfield

BAE SYSTEMS Reg. A/C
Dan Gurney

BALPA
Carolyn Evans

bmi regional
Capt. Steve Saint

British Airways
Steve Hull

British Airways CitiExpress Ltd
Capt. Ed Pooley

British International
Capt. Terry Green

British Mediterranean Airways
Robin Berry

CAA
Dave Lewis - MRPS
Chrys Hadjiantonis - Safety Data Dept.
Brian Synnott - Flight Operations
Alison Thomas - Intl. Services

Cardiff International Airport
Graeme Gamble

CargoLux
Capt. David Martin

Cathay Pacific
Capt. Richard Howell

Channel Express
Rob Trayhurn

CityJet
Capt. Mick O'Connor

Cougar Leasing
Shaun Harborne

DHL Air
Peter Naz

Dragonair
Alex Dawson

Eastern Airways UK Ltd
Capt. Jacqueline Mills

easyJet
Capt. Tim Atkinson

Emerald Airways
Capt. Roley Bevan

European Aviation Air Charter
David Wilkinson

EVA Airways
Alex Reid

Excel Airways
Peter Williams

FlightLine
Capt. Derek Murphy

GAPAN
Capt. Chris Hodgkinson

GATCO
Richard Dawson

Goodrich Control Systems
Keith Joyner

Independent Pilots Association
Capt. Mike Nash

Irish Aviation Authority
Capt. Bob Tweedy

JMC Airlines
Capt. Graham Clarke

LAD (Aviation) Ltd
Steve Flowers

Loganair
Doug Akhurst

London City Airport
Simon Butterworth

London-Manston Airport
Wally Walker

Maersk Air
Capt. Christopher Morley

Manchester Airport plc
Peter Hampson

Middle East Airlines
Capt. Mohammed Aziz

Monarch Airlines
Capt. Gavin Rowden

MyTravel
Capt. Tom Mackle

NATS
Paul Jones

PrivatAir
Capt. Boris Beuc

Ryanair
Capt. Gerry Conway

SBAC
John McCulloch - Secretariat
Vic Lockwood -FR Aviation

Servisair
Eric Nobbs

Shell Aircraft
Cliff Edwards

The Boeing Co.
Edward Berthiaume

Virgin Atlantic Airways
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bmi british midland
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Peter Horner

Bristow Helicopters
Capt. Derek Whatling

Bristow Helicopters Eng.
Richard Tudge

Britannia Airways
Jez Last

Britannia Airways Eng.
Adrian Vaughan

CHC Scotia
Capt. David Bailey

CHC Scotia Eng.
Colin Brown

Eurocypria
Capt. Constantinos Pitsillides

Cyprus Airways
Capt. Spyros Papouis

FLS Aerospace (IRL)
Frank Buggie

FLS Aerospace (UK)
Andrew Hoad

flybe. british european
Stuart McKie-Smith

flybe. british european eng.
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Ford Motor Co. Eng
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GB Airways
Capt. Aaron Cambridge

GB Airways Eng.
Terry Scott

KLM uk
Dean Godfrey

KLM uk Eng.
Andy Beale

Lufthansa Cargo AG
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