Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Aid to Operators for the Expanded Use of Passenger PEDs	**AWB**	23-003	**Issue** :	1
	Date :	29 May 2014		

1. Effectivity

This Airworthiness Bulletin applies to operators that carry passengers in charter and regular public transport operations.

2. Purpose

This Airworthiness Bulletin provides guidance on assessing the suitability of an aircraft for passengers to use portable electronic devices (PEDs) more broadly than the cruise phase of flight. It also provides guidance on establishing operational policy and procedures, and training of pilots and cabin crew.

This Airworthiness Bulletin also provides checklists that can be used to support an application for exemption from Civil Aviation Orders, section 20.16.3, paragraph 9.3, in respect of stowage of small PEDs at all times when seat belts are required to be worn.

3. Background

In January 2013, the US Federal Aviation Administration (FAA) established an Aviation Rulemaking Committee (ARC) to provide a forum for the aviation community and government regulatory groups to review policy and guidance related to PEDs. The ARC was tasked with making recommendations on allowing passengers to operate PEDs outside the cruise phase of flight. In October 2013 the FAA published “Information for Operators” InFO 13010 on the subject of Expanding Use of Passenger Portable Electronic Devices. InFO 13010 does not address the use of mobile telephones on aircraft. In December 2013, the European Aviation Safety Agency published similar guidance.

In February 2014 the FAA published a supplement to InFO 13010 to assist operators to assess the ability of their aircraft to tolerate the low-power RF transmissions likely to be made by passengers’ PEDs. The document is InFO 13010SUP “FAA Aid to Operators for the Expanded Use of Passenger PEDS”. The supplement presents a five-step process to be taken by US operators:

1. Aircraft PED Immunity

2. Analysis and Mitigation

3. Establish Expanded Use

4. Operational Policy & Procedure

5. Pilot & Flight Attendant Training

This Airworthiness Bulletin provides Australian operators with guidance on airworthiness aspects of this process.

4. Recommendations

It is recommended that operators of passenger-carrying services who wish to allow passengers to use PEDs more broadly than the cruise phase of flight should use this Airworthiness Bulletin to assess their aircraft and obtain guidance on what extra phases of flight might be available for passengers to use PEDs.

Operators should be aware that there are other important cabin safety issues that must be successfully considered before final approval can be given to expand the use of passenger PEDs, but this Airworthiness Bulletin does not attempt to cover those other issues.

PED Weight Limitation

CAO 20.16.3, paragraph 9.3, specifies that solid articles must be placed in approved stowage at all times when seat belts are required to be worn. CASA recommends that operators wishing to offer passengers the ability to use PEDs more broadly than the cruise phase of flight should apply to CASA for an exemption against CAO 20.16.3, paragraph 9.3, in respect of PEDs that have a mass of 1 kg or less. If an operator is the holder of such an exemption, any PED that does not exceed this mass may be secured in a passenger's clothing or hands, or in a seat pocket. See Appendix B for analysis supporting 1 kg as the maximum mass of PEDs that are safe not to stow in approved stowage locations but are instead secured. See Appendix A for information on stowage of large items.

Aircraft PED Immunity

There are two mechanisms by which PEDs may interfere with aircraft systems, these are:

a) Front-Door Interference Assessment

   Front-door interference is interference caused by aircraft antennae absorbing electro-magnetic radiation from a PED.

b) Back-Door Interference Assessment

   Back-door interference is interference caused by electro-magnetic radiation from a PED being absorbed by aircraft cables, wires or looms.

Aircraft PED Tolerance to Back-door Interference

Back-door interference is interference caused by electro-magnetic radiation from a PED being absorbed by aircraft cables, wires or looms.

Transmitting PEDs (T-PEDs) are widespread among passengers and crewmembers, take many forms, and have many functions. In many cases the transmitting radio is embedded in a T-PED so that the operation of the radio transmitter is not apparent to the T-PED user. These T-PEDs operate in many frequency bands and with a wide range of transmitted RF power. Common T-PEDs and transmitted RF power include:

Table 1: Common T-PEDs and Associated Power

COMMON T-PEDS AND ASSOCIATED POWER	
Device	**Transmitted RF Power**
Handheld mobile phones	500 mW to 2 W
Wireless RF network transceivers	10 mW to 1 W
Consumer handheld walkie-talkies	500 mW to 5 W
Wireless personal digital assistants	500 mW to 2 W
Handheld amateur radio transmitters	500 mW to 7 W
Automobile keyless entry controllers	50 mW or less
Airline operations handheld radios	1 W to 6 W

The aircraft RF environment produced by T-PEDs differs from the aircraft RF environment associated with High Intensity Radiated Fields (HIRF). The major differences are:

- Transmitting PEDs may operate very close to aircraft systems and wiring, within the aircraft cockpit, cabin, and baggage areas, while HIRF transmitters operate some distance outside the aircraft.
- Aircraft fly through the maximum HIRF RF levels in a few seconds, while the T-PEDs operate within the aircraft over a relatively long time frame.

HIRF transmitters are typically very high power transmitters in specific geographic locations outside the aircraft, while T-PEDs may be operated in many locations within the aircraft, including the cabin, cockpit and baggage or cargo compartments.

What methods can be applied to address HIRF, PED and T-PED threats?

- The existing FAA regulations for high intensity radiated fields (HIRF), detailed in the United States Federal Aviation Regulations 23.1308, 25.1317, 27.1317 and 29.1317 were released in 2007. Current HIRF rules apply to systems that have potential failure conditions of Major, Hazardous and Catastrophic.

- The HIRF requirement is based on transmitters located outside the aircraft. Previous HIRF special conditions only applied to systems whose failure or malfunction would prevent continued safe flight and landing of the aircraft. It should be noted, however, that the majority of aircraft certified since 1989, also were certified to the JAA/EASA special conditions, which required compliance to Major, Hazardous and Catastrophic failure conditions, in similar fashion to the existing rule.

- "RTCA/DO-307: Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance" has been released by the RTCA and is referenced by FAA AC 20-164 "Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices". CASA accepts these documents as appropriate guidance material for HIRF-related certification.

Demonstrated aircraft systems PED tolerance to back-door effects show that the installed electrical/electronic systems that perform Required, Major, Hazardous and/or Catastrophic functions are able to perform their intended functions in the presence of RF environment created by T-PEDs, during all non-critical phases of flight. This would allow for operators to treat T-PEDs the same as they would treat non-transmitting PEDs, in accordance with FAA AC 91-21.1B.

Assessment of Aircraft PED Tolerance to Back-door Interference:

RTCA/DO-307 provides guidance that if the aircraft electrical and electronic systems and wiring are separated from potential locations of T-PEDs by 1 metre or more, then RF susceptibility tests on the equipment or systems performed in accordance with RTCA/DO-160E Section 20 Category R, are considered acceptable procedures and test levels for this demonstration. If the aircraft electrical and electronic systems and wiring are separated from potential locations of T-PEDs by less than 1 metre, then RF susceptibility tests on the equipment or systems performed in accordance with RTCA/DO-160E Section 20 Category W, are considered acceptable procedures and test levels for this demonstration. The tests may exclude test frequencies above 8 GHz.

The following table is taken directly from RTCA/DO-307, Section 3, and provides the back-door effects test requirements, based upon system criticality.

Table 2: DO-307 Section 3 Aircraft System RF Radiated Susceptibility Test Recommendations

Classification of system	Distance between T-PED and system LRU > 20 cm	Distance between T-PED and system LRU < 20 cm
Catastrophic	ED-14E / DO-160E, Section 20, Cat. R	ED-14E/DO-160E Section 20, Cat. W, limited to 8 GHz
Hazardous	ED-14E / DO-160E, Section 20, Cat. R	ED-14E / DO-160E, Section 20, Cat. R
Major	ED-14E / DO-160E, Section 20, Cat. R	ED-14E / DO-160E, Section 20, Cat. R
Required by regulation	ED-14E / DO-160E, Section 20, Cat. R	ED-14E / DO-160E, Section 20, Cat. R

Section 3 of RTCA/DO-307 discusses the relationship between HIRF protection requirements and PED tolerance to back-door interference effects. PED tolerance is accomplished by ensuring that all equipment that performs functions that are listed in the “Classification of system” column of the above table have been qualified by test/analysis to the requirements, given in second and third column. Both RTCA/DO-160E and the HIRF User’s Guide[1] provide procedures that can be utilized for these types of tests.

Note that RTCA/DO-160 is currently at version G.

[1] HIRF User's Guide, “Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment” is available in SAE ARP 5583a. http://www.sae.org/technical/standards/ARP5583A

Level of HIRF protection

Follow this process to determine the level of HIRF protection applied to your aircraft:

1. Find the Type Certificate Data Sheet (TCDS) for the make and model of aircraft being assessed.

2. Check the Certification basis for the aircraft make and model.

   Does it include Amendment Nos. 23-57, 25-122, 27-42 or 29-49?

   YES – The aircraft incorporates the necessary HIRF certification levels. No further review is necessary unless the aircraft has been modified or repaired that the possibility exists that it no longer complies with the above amendment.

   NO – Proceed to step 3.

3. Search the TCDS for HIRF Special Conditions.

   Is there a HIRF Special Condition listed for your make and model?

   YES – Record the number of the Special Condition. Review the Special Condition to ensure it covers electrical and electronic systems. If it does, proceed to step 6. If not, proceed to step 5.

   NO – Proceed to step 4.

4. Is there a HIRF Special Condition applicable to aircraft electrical and electronic systems for your make and model of aircraft?

   YES – Record the number of the Special Condition and return to the TCDS for your make and model. Search the TCDS to verify that the Special Condition is listed for your aircraft. If it is, proceed to step 6. If not, proceed to step 5.

   NO – Proceed to step 5.

5. Is there a HIRF Special Condition applicable to a specific critical electrical or electronic system on your make and model of aircraft?

   YES – Record the number(s) of the Special Condition(s), and the system(s) covered. Proceed to step 6.

   NO – Proceed to step 7.

6. Review your critical aircraft systems to determine if any electrical or electronic system(s) was type-certificated with a Hazard Class (failure condition) of “catastrophic”.

   Does a Special Condition cover your critical system(s)?

   YES – The critical systems are adequately covered for PED tolerance to back-door interference. No further review is necessary unless the aircraft has been modified or repaired that the possibility exists that it no longer complies with the above amendment.

   NO – Proceed to step 7.

7. The critical systems for your aircraft cannot be determined to be PED tolerant to back-door interference based on HIRF certification. Testing and analysis for critical systems (those certified with a catastrophic failure effect) to ensure PED tolerance to back-door interference must be (or have been) accomplished.

A. AIRCRAFT PED IMMUNITY

The following checklists can be used to record the results of assessments of the aircraft's immunity to back-door and front-door interference. The results are used in section B "Analysis and Mitigation". The checklists have been copied from FAA InFO 13010SUP.

A.1 Back-Door Interference Assessment

Back-door interference is interference caused by electro-magnetic radiation from a PED being absorbed by aircraft cables, wires or looms.

Describe HIRF certification basis and/or subsequent PED immunity demonstration. Check if YES. See "Level of HIRF Protection" above for detailed process.

PED Tolerance Qualification		
☐	1. Aircraft that meet RTCA/DO-307 Section 3 *Aircraft system tolerant to intentionally transmitting PEDs, Back-Door Coupling*	No further back-door analysis required.
☐	2. PED tolerance demonstration documented following testing associated with the installation of a wireless local area network – or – similar capability. • At installation, other systems may have received additional testing beyond that of a Hazard Classification of Catastrophic, but the documentation was not required for certification. • Back-door interference tolerance is provided for the frequency ranges tested. Significantly different frequency ranges require additional testing.	No further back-door analysis required.
☐	3. PED tolerance demonstration testing and analysis done using other acceptable methods. Test must be comprehensive and operator must have data to support the testing. • PED testing in support of previous PED use allowance determination, such as WiFi system of cell phone testing done to support in-flight use, may be acceptable. Must be supported by assessment of critical systems in the expanded phase of flight to ensure the previous testing covered these systems. • Back-door interference tolerance is provided for the frequency ranges tested. Significantly different frequency ranges require additional testing.	No further back-door analysis required.

HIRF Qualification		
☐	4. Aircraft type certificated or system installed that meets FAA or EASA HIRF Regulations. (Follow decision flow chart in "Level of HIRF Protection" above.) *Meeting HIRF specifications, Special Conditions (e.g. 25-302-SC), or regulations* • *Catastrophic* systems have been tested at a minimum. • *Operational Required* equipment has not been tested. • At certification, other systems may have received additional testing but the documentation was not required.	No further back-door analysis required.
☐	5. Aircraft Type Certificated or system installed prior to HIRF Regulatory Specifications in effect in 1987. *Aircraft certified prior to 1987 do not have verified RF immunity.* • Compliance to RTCA/DO-307 has not been met. • At certification, other systems may have received additional testing but the documentation was not required.	Back-door tolerance not demonstrated. Additional assessment or test required.

A.2 Front-Door Interference Assessment

Front-door interference is interference caused by aircraft antennae absorbing electro-magnetic radiation from a PED.

The report of the FAA Aviation Rulemaking Committee, Appendix F – Functional Hazard Risk Assessment (FHRA), contains a safety risk assessment for operators to assess the avionics configuration of their fleets, and the failure modes associated with different types of communications and navigation equipment with respect to electromagnetic interference. The FHRA outlines mitigations and controls that the operator needs to adopt to expand PED use into various phases of flight.

☐	1. Aircraft that meet RTCA/DO-307 Section 4 *Aircraft systems tolerant to unintentional emissions from PEDs, Front-Door Coupling*	No further front-door analysis required.
☐	2. Aircraft system function with Catastrophic, Hazardous or Major failure condition (see risk assessment, "Hazard Class" column) documented to meet the interference path loss requirements of RTCA/DO-307/DO-294. *Documented system tolerance to unintentional emissions from PEDs, Front-Door Coupling*	No further front-door analysis required.
☐	3. Aircraft system function with Catastrophic, Hazardous or Major failure condition (see risk assessment) **NOT** documented to meet the interference path loss requirements of RTCA/DO-307/DO-294.	Must mitigate risk and apply controls. Risk assessment actions required for Catastrophic.

B. ANALYSIS AND MITIGATION

The table below applies the results of the assessment of both front-door and back-door PED tolerance and determines the phases of flight where PEDs can remain ON and be used. Step 1 uses answers to questions in the above section “Level of HIRF Protection”.

STEP 1: Back-Door Tolerance Which questions in “Level of HIRF Protection” are answered YES?		STEP 2: Front-Door Tolerance Which rows in Section 1.2, Front-Door interference, are checked YES?		STEP 3: Acceptable Phases of Flight Tally the results. A “YES” in STEP 1 and a “YES” in STEP 2 mean that this phase of operations is permitted. **Check permitted phases below:**	
A “YES” to any of the Questions 1 – 6 results in a YES, below for all phases of operation:	A “YES” to ONLY Question 7 will require additional assessment or testing for certain phases of operation:	A “YES” to Question 1 or 2 results in a YES, below:	A “YES” to ONLY Question 3 will require risk assessment, and mitigations/controls.		
Yes	Yes	Yes	Yes	**Parked:** Passenger boarding and seating to door close.	☐
Yes	Yes	Yes	Yes	**Taxi Out:** Push back, taxi from gate to (but not including on) the runway.	☐
Yes	No See Note 1	Yes	Yes	**Take-off & Departure:** Take-off transition to climb altitude/or gear-up.	☐
Yes	Yes	Yes	Yes	**Climb:** From transition to climb altitude and/or gear retraction to through 10,000 ft AGL and onto cruise altitude.	☐
Yes	Yes	Yes	Yes	**Cruise:** (currently authorised)	☐
Yes	Yes	Yes	Limited See Note 2	**Descent:** From top of descent through 10,000 ft AGL to IAF and/or flaps.	☐
Yes	No See Note 1	Yes	Limited See Note 2	**Approach:** From IAF to visual reference or landing	☐
Yes	Yes	Yes	Yes	**Landing & Taxi to Gate:** Begins at aircraft touchdown, and concludes when aircraft is parked for passenger unloading.	☐

Note 1: NO

Additional analysis and/or testing of avionics or electrical systems that have major, hazardous or catastrophic failure effects as certified must be done to address back-door PED tolerance.

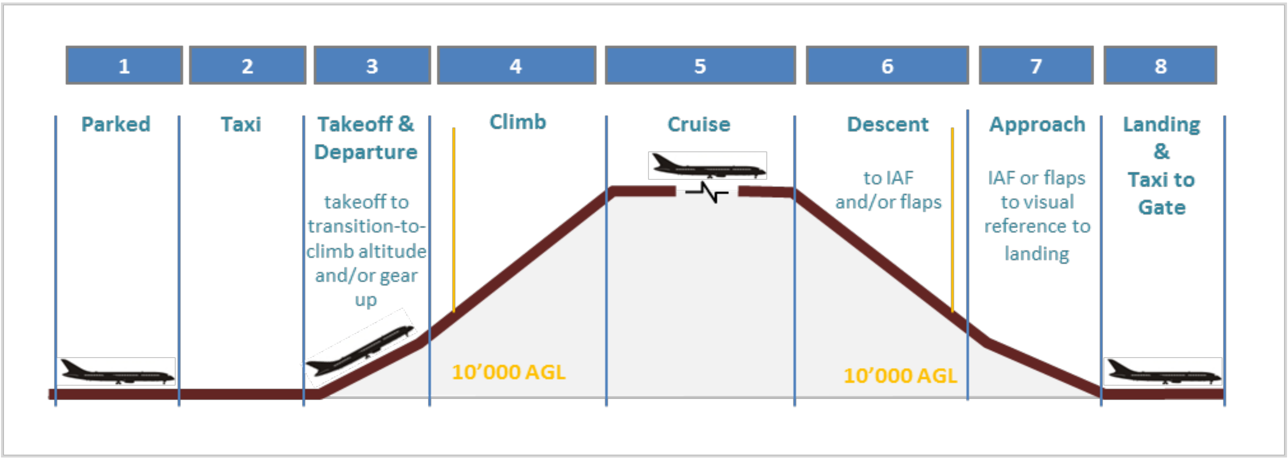
Note2: LIMITED

Examine the report of the FAA Aviation Rulemaking Committee, Appendix F, and specifically the tables starting on page F-37.

1. Reference the ‘Phase of Flight’ column and look for a ‘6’ or ‘7’, ‘Descent’ or ‘Approach’ respectively.

2. Identify the Avionics Systems, the failure modes that have been presented with respect to EMI. Apply the necessary mitigations and controls as indicated, at a minimum for those items with a “Hazard Class” at certification of ‘Catastrophic’, ‘Hazardous’ or ‘Major’.

3. For operations (such as CAT II or CAT III), where the Hazard Classification is ‘Catastrophic’, the listed Mitigations and Controls are mandatory.



C. OPERATIONAL POLICY AND PROCEDURES

The following checklist provides a list of key elements that should be present in an operator's policy and procedures in order to safely implement the expanded use of PEDs.

1.	PED SECURING AND STOWAGE (See also Appendix B) For take-off, landing and other critical phases of flight, the operator has policy and procedure to ensure PEDs are properly secured or stowed.	☐ Complete
2.	RISK MITIGATION: Suspected or Confirmed EMI event Operational procedures exist for a crew to recognize, respond and report transient or intermittent problems and suspected or confirmed EMI events. Note: As a minimum, record the time, effect on aircraft, aircraft location and phase of flight, suspected PED make, model, location, actions taken, and effect of action taken.	☐ Complete
3.	SAFETY PROGRAM DATA COLLECTION AND REPORTING: Operator has policy and procedure related to the reporting of events or anomalies associated with passenger PED use. Reportable items include but are not limited to passenger disruption, suspected or confirmed electromagnetic interference, and smoke or fire from a PED or battery.	☐ Complete

D. PILOT AND FLIGHT ATTENDANT TRAINING PROGRAM

The following provides a key element that should be present in an operator's training program in relation to airworthiness of the aircraft in order to safely implement the expanded use of PEDs. There will also be other training requirements in relation to cabin safety but these are not addressed in this Airworthiness Bulletin.

The operator's training program for pilots and flight attendants should describe how to manage scenarios such as suspected or confirmed electromagnetic interference, smoke or fire from a PED or battery, and other similar scenarios.	☐ Complete

5. References

1. http://www.faa.gov/about/initiatives/ped/
2. https://www.easa.europa.eu/personal-electronic-devices.php
3. RTCA/DO-294 "Guidance on Allowing Transmitting Portable Electronic Devices (T-PEDs) on Aircraft"
4. RTCA/DO-307 "Aircraft Design and Certification for Portable Electronic Devices (PED) Tolerance"
5. FAA Advisory Circulars at http://rgl.faa.gov

6. Enquiries

Enquiries about this Airworthiness Bulletin should be directed to:

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or:

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Appendix A

Securing and Stowing Passenger PEDs

PED – Stowed vs Secured

There is an important distinction that needs to be made between "stowing" and "securing" PEDs. If a PED is to be "stowed", it must be placed into an approved carry-on stowage location. These locations have been designed and certified to comply with the requirements for retention of articles of mass during emergency landings. Approved carry-on stowage locations have specific weight and size limitations. When a PED is "secured", it is restrained by a method which may not have been certified for retention of articles of mass to the emergency landing load limits. The following elements from the PED ARC stowage policy subcommittee identify several considerations for inclusion in an operator's policy for stowing and securing PEDs:

1. Large PEDs (such as full-size laptop computers) must be stowed in an approved carry-on stowage location, and not present an undue hazard in the event of severe turbulence, crash forces or emergency egress. Large PEDs are those the operator has determined have a mass more than 1 kg or are of a size that would impede egress. See Appendix B for analysis supporting 1 kg as the maximum mass of PEDs that are not safely stowed in approved stowage locations.

2. Small PEDs must be stowed or secured at all times when seat belts are required to be worn. Passengers who do not wish to stow their PEDs should be encouraged to secure them on their person, such as in a garment pocket. Passengers may also secure small PEDs by placing them in seat pockets or holding them in their hands. A PED should not be left unsecured on an empty seat.

3. Seat back pockets generally are designed to hold a maximum of 1½ kg. The passenger safety card, magazines, other literature and air sickness bag account for approximately ½ kg. When an operator conducts a safety risk assessment to determine an acceptable weight limit for the seat pocket, these items should be taken into account. As a general "rule of thumb", a small PED and any other personal items placed in the seat back pocket should not exceed a total mass of 1 kg and should not protrude to the point of impeding egress. The FAA provides additional guidance for US air carriers in InFO 09018.

4. PED cords or accessories must not impede emergency egress.

5. PED policy must discourage passengers from getting up from their seats to access the overhead storage bins or other stowage areas at a point in time that would present a hazard to themselves or the passengers around them.

Appendix B

Solid Articles Analysis

Solid articles are required to be stowed at appropriate times as required by CAO 20.16.3 Section 9.3. Operators are proposing to allow passenger to hold certain sized objects during takeoff and landing based on recently revised FAA guidelines. Of particular importance to the analysis is Portable Electronic Devices (PEDs).

The following analysis uses simple techniques and literature reviews to draw conclusions about what may be an appropriate sized object to be hand-held for takeoff and landing based on acceptable injury potential. It is generally regarded that people cannot hold on to any size object during an accident or extreme turbulence due to the effect of their mass, flailing and startle. Therefore, this analysis concentrates on the injury potential of the loose object.

Alexander Radi, a Monash University Doctorate Student, conducted an analysis of human injury potential by Remotely Piloted Aircraft (RPA) for CASA in 2013. The analysis methodology is repurposed here for a solid article (PED) head strike that may occur during an aircraft impact sequence.

The simplified analysis technique contains limitations. Limited orientations of the PED striking the person will be assessed. Additionally only one injury mechanism will be evaluated; the risk of skull fracture resulting from the impact of the PED. Analysis using Transport category design standards will be employed. The results are equally applicable to General Aviation fixed wing and rotorcraft operations due to similar velocities changes used in design standards for Emergency Dynamic Landing conditions.

Recommendations regarding a tolerable mass will be made.

1. Reapplication of Human injury model for small unmanned aircraft impacts

Radi does not consider concussion or neck injuries in the head impact analysis which is a limitation for this purpose as it rules out one measure of incapacitation that is likely to be critical for an evacuation. However the focus on skull fracture is one of numerous appropriate injury measures. These calculations use Blunt Criterion (BC) as adopted by Raymond, et al., (2009) to measure head injury potential, developed for the design of non-lethal munitions. Where the impacting object has a contact area of less than $6cm^2$, it is likely to penetrate the skull rather than suffer compressive fracture. As the impactor moves from a small size (diameter) up to a larger size, the required force/energy to generate a skull fracture increases. Therefore, a flat plate represents the highest energy required to cause injury. The measure is a 50% chance of skull fracture which is an Abbreviated Injury Score (AIS) of 3 and represents an 11% chance of fatality.

Analysis conducted by Radi does not handle small impacting objects (penetrating injuries) which may be associated with an edge-on or corner PED strike. However, it is entirely appropriate for a flat sided strike by using the flat plate extension of the analysis.

For an inelastic collision the Conservation of Momentum and Energy are required. Assuming the PED and Head move together (or at similar speeds) after the collision, a fraction of the impacting object energy is converted into kinetic energy for both objects. The remaining energy is deformational energy, assumed to occur with the head (a PED is rigid and strong particularly edge on). The fractions of kinetic and deformational energy are related to the relative sizes of the impacting and hit objects.

$$p = m_1 V_1 = m_2 V_2$$

$$m_{ped} V_1 = (m_{head} + m_{ped}) V_2 \qquad \text{Equation 1}$$

$$E = E_1 = E_2$$

$$E_{kin1} = E_{kin2} + E_{def}$$

$$\frac{1}{2} m_{ped} V_1^2 = \frac{1}{2} (m_{head} + m_{ped}) V_2^2 + E_{def} \qquad \text{Equation 2}$$

Radi's head injury analysis predicts 76 Joules as the maximum tolerable deformation energy (E_{def}) during an impact with a flat surface (page 16). Similarly, an effective head mass of 6kg will be used. Initial velocity is based on a severe initial impact occurring equivalent to the transport aircraft design standard FAR §25.562(b)(2) 'Emergency Landing Dynamic Conditions' forward impact pulse of 44ft/s (13.4m/s). The resulting head velocity is not required to be known, so the above equations will be resolved for m_{PED}. Rearranging Equation 1 for V_2 and inserting into Equation 2:

$$\frac{1}{2} m_{ped} V_1^2 = \frac{1}{2} (m_{head} + m_{ped}) \left(\frac{m_{ped} V_1}{(m_{head} + m_{ped})} \right)^2 + E_{def}$$

$$\frac{1}{2} m_{ped} V_1^2 = \frac{1}{2} \frac{m_{ped}^2 V_1^2}{(m_{head} + m_{ped})} + E_{def}$$

$$\frac{1}{2} m_{ped} (m_{head} + m_{ped}) \, V_1^2 = \frac{1}{2} m_{ped}^2 V_1^2 + (m_{head} + m_{ped}) E_{def}$$

$$\frac{1}{2} m_{ped} m_{head} \, V_1^2 = (m_{head} + m_{ped}) E_{def}$$

$$\frac{1}{2} m_{ped} m_{head} \, V_1^2 - m_{ped} E_{def} = m_{head} E_{def}$$

$$m_{ped} = \frac{m_{head} E_{def}}{\frac{1}{2} m_{head} \, V_1^2 - E_{def}} \qquad \text{Equation 3}$$

After the initial flailing, the occupant is stationary relative to the vehicle (whether or not it is still moving) and an airborne PED strikes the occupant in the back of the head. As per figure 12 of the Radi analysis, a conclusion can be drawn for the critical weight of impactor (i.e. the PED). For a 13.4m/s impact velocity and a flat sided head strike, the critical PED mass is 0.98kg.

The above analysis assumes a direct strike on the occupant after initial flailing by the occupant, i.e. the occupant is at rest with respect to the vehicle and the PED is still at the initial pre-impact velocity. This may be an aggressive assumption. Reasons for a reduced impact velocity/energy include the PED release resistance from the owner's hands or bouncing off seat backs and overhead bins before the head strike. Equation 3 is graphically represented in Figure 1 below for critical mass versus velocity. If an arbitrarily reduced impact velocity of 10m/s is assumed, the critical PED mass rises to 2.04kg.

However, edge and corner PED head strikes will inflict more severe injury (or similar injury at lower weights/velocities).

2. Investigation of Edge and Corner PED head strikes

A review of referenced journals in Radi's report reveals wider application for the BC to different shaped intermediate or heavy projectiles. Whilst the previous equation provides for flat plate impact energy; edge and corner strikes will require less energy to be injurious. However, defining the contact area is problematic. Sturdivan et al.(2004) state where the diameter of the projectile is less than twice the body wall thickness, the diameter of the projectile is used in the BC rather than determining an impact or effective diameter. However, for small projectiles with a non-circular area of contact (A), again an effective diameter (D) is resolved and calculated by:

$$D = 2\sqrt{\frac{A}{\pi}}$$

Equation 4

For the purposes of this analysis, it will be assumed that this criterion can be used for intermediate sized projectiles with small non-circular contact areas. Injury is assumed to occur once the body has been compressed to one wall thickness (T).

For PED edge strikes, a long thin indentation will occur with the contact area being dependent on the depth of penetration. Sturdivan et al.(2004), proposed for a torso impact with a flat plate that the thorax be simplified to a cylinder where the where the curvature of body part is used to calculate the area of contact.

$$A = 2H\sqrt{T(D' - T)}$$

Equation 5

For the purpose of a PED edge contact, the formula can be applied where the height (H) of the flat plate is equal thickness of the PED. Given the length and breadth dimensions of a PED and radius of a human head, it can be conservatively assumed the length of the edge will always exceed the length of the impacting edge.

The Blunt Criterion is:

$$BC = \ln\left(\frac{E}{W^{1/3}TD}\right)$$

Equation. 6

Expanding Equation 6 for kinetic energy and rearranging for determination of critical mass:

$$m = \frac{2W^{1/3}TDe^{BC}}{V^2}$$ Equation. 7

As used in the previous analysis, Raymond et al.(2009) determined a 50% chance of skull fracture is represented by a BC of 1.61. Additionally their values of skin thickness (T) for the head of 0.7cm will be used. Whilst this study looked at temporo-parietal (side of head) impacts, due to a lack of appropriate studies it is assumed to be broadly applicable to occipital (back of head) impacts. From the Radi analysis, the same assumptions of an effective head mass (W) of 6kg, and head diameter (D') of 18cm, will be used. Velocity (V) again will use FAR §25.562(b)(2) forward impact velocity change of 13.4m/s. With respect the dimensions of the PED, the device of most concern is a 'tablet' style computer. Whilst their dimensions vary greatly, a typical thickness of 1.0cm for a 10" tablet will be used. Thinner devices will have a lower critical mass due to reduced contact area but 1cm thickness is typical.

Resolving equations 5, 4 and 7 results in the solutions of an impact area (A) of 6.96cm2, effective projectile diameter (D) of 2.98cm2, and maximum PED mass (m) of 0.21kg.

As before, if some arbitrary energy dissipation is assumed to occur and the velocity is reduced from 13.4m/s to 10m/s, the critical PED mass increases to 0.38kg. The graphical presentation of critical mass versus velocity is given in Figure 1 for a PED edge strike.

Determining the effective diameter for a PED corner strike is problematic for this kind of analysis as the effective diameter is highly dependent on penetration distance. This type of analysis is not appropriate for a highly tapering impactor.

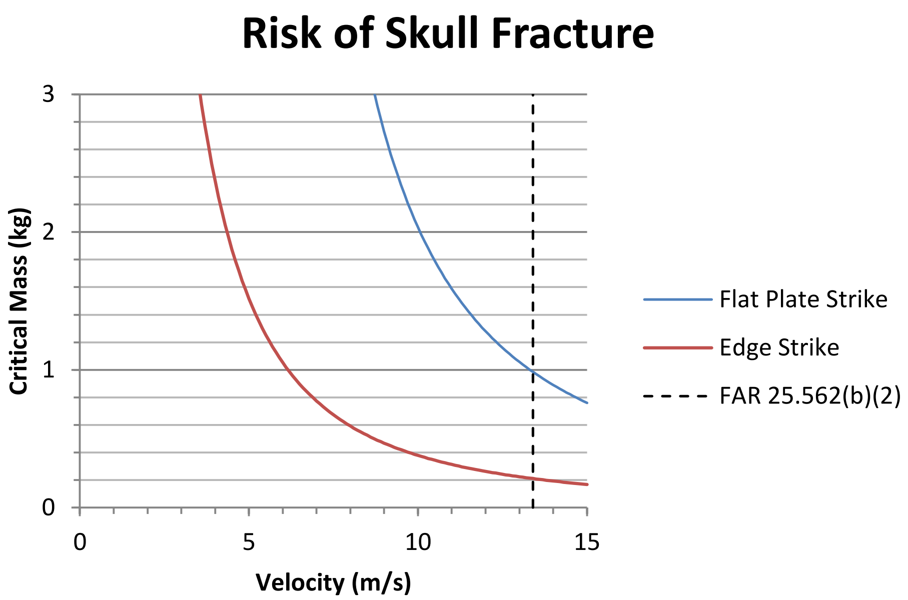

Figure 1 – Graphical representation of Equations 3 and 7

3. QF460 scenario

On 8 November 2013, QF460 on approach to Sydney entered extreme turbulence. The aircraft, after two attempts, diverted to Newcastle. One passenger suffered a minor injury (not hospitalised) due to an iPad2 striking their head reportedly coming from three rows in front. Another passenger was hospitalised after being struck in the head by a laptop falling from an overhead locker. A second passenger was hospitalised by an injury outside the scope of this analysis.

Assuming a turbulence gust of +2.5g applying for the entire period and a 1m fall by the laptop, the velocity of the laptop at the time of striking the passenger's head might be:

$$V_2^2 = V_1^2 + 2as$$

$$= 0^2 + 2 \times (2.5 \times 9.8) \times 1$$

$$V_2 = 7.0 \text{ m/s}$$

Whilst CASA has little details of this incident, it is safe to assume the person didn't suffer a skull fracture given it was reported the injured passengers were only admitted overnight. However for this incident, given a similar laptop mass and slightly lower velocity, the fact that the person was hospitalised goes someway to validating the assumptions of this analysis.

4. Limitations

The following limitations apply to this analysis:

1. Only head injury was assessed. It does not consider neck injury or injury to other body parts.

2. The analysis considers skull fracture as the only injury mechanism. It does not consider concussion or other forms of head injury which may be more critical. Due to lack of data, side of head fracture data has been used.

3. It assumes the PED strikes the passenger with its flat side or edge on. Corner strikes have not been assessed. The analysis assumes a strike perpendicular to the head and not a 'glancing blow'.

4. Assesses the consequences of a direct strike to the head by the PED. A second indirect strike scenario was derived for both assessments using loose assumptions.

5. This analysis only determines the outcome of an injury event. The likelihood of the event occurring is not determined and so does not rationalise the risk.

5. Conclusion

This analysis has shown a 2kg device could be injurious during times of turbulence. This is backed up by service history. A loose 1kg device is injurious with an impact speed of 13.4 m/s which is of similar severity to the aircraft design standard FAR §25.562. Calculations show in a worst case scenario, a 210g PED has the potential to be injurious during an impact sequence.

6. Recommendations

1kg is considered the maximum mass limit for solid articles. This provides protection from PED edge head strike scenarios during turbulence events and is tolerable for flat sided head strikes during accidents equivalent to aircraft ultimate load design standards.

7. References

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