EASA REGULATORY IMPACT ASSESSMENT

RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

SEPTEMBER 2009

Issue 1

AMENDMENT RECORD

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CONTENTS

ABBREVIATIONS

AAIB	Air Accidents Investigation Branch (UK)
AC	Advisory Circular
AMC	Acceptable Means of Compliance (EASA)
CFR	Code of Federal Regulations (US)
CS	Certification Specification
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration (US)
FAR	Federal Aviation Regulations (US)
JAA	Joint Aviation Authorities
NPA	Notice of Proposed Amendment
RIA	Regulatory Impact Assessment

1 PURPOSE AND INTENDED EFFECT

1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

The requirements for a secured flightdeck door originated from the increased flightdeck access security required by the FAA following the terrorist attacks in September 2001.

Despite its significance in improving aviation security, there is evidence the secured flightdeck door has resulted in several issues. There is a concern that with some locking system designs, the cabin crew may not be able to access the flightdeck in the event of flight crew incapacitation or other emergency situations. Accident experience also shows that having a secured flightdeck door can also result in communication difficulties between the flight crew and cabin crew, especially when the interphone system is not functioning.

Those issues highlight the importance of the reliability of the emergency means for cabin crew to unlock the flightdeck door. There is no requirement or guidance material which addresses the reliability of the flightdeck door locking mechanism or the emergency unlocking mechanism, for example the required availability of the electrical power supply.

The CS-25 requirement applicable to this issue is as follows:

> *25.772 For an aeroplane that has a lockable door installed between the pilot compartment and the passenger compartment: -*
>
> *(c) There must be an emergency means to enable a crewmember to enter the pilot compartment in the event that the flight crew becomes incapacitated.*

This requirement was first introduced in FAR 25 Amendment 25-106 (effective 15 January 2002), and adopted into CS-25 since the Initial Issue (effective 17 October 2003).

All other pertinent requirements are in Appendix 1.

1.2 SCALE OF THE ISSUE

CS-25 Amendment 5 does not specify the required reliability of the emergency flightdeck access system from the cabin.

An in-flight smoke incident to an EMB-190 overhead Edinburgh on 15 January 2009[1] featured a scenario where the power for the emergency unlocking system from the cabin was unavailable because the flight crew had to shut off the main electrical power as part of the 'Electrical System Fire or Smoke' procedure. The cabin crew became concerned that the flight crew might have become incapacitated or that a serious emergency had developed in the flight deck, because they could not establish communication with the flight crew using the interphone system. Due to these concerns, the cabin crew attempted to access the flight deck, but the emergency flightdeck access system did not function due to the loss of main electrical power. Although this incident did not result in injuries or fatalities, and the flight crew were in fact not incapacitated, it raised a concern regarding the reliability of the emergency flightdeck access system.

The safety recommendation issued by the UK AAIB following the EMB-190 incident (Safety Recommendation 2009-020) only recommended Embraer to *"immediately notify all operators, of the Embraer 190 family of aircraft, to inform flight and cabin crew of the functioning of the flight deck access system when the aircraft is supplied only with emergency electrical power".*

Accident/incident experience shows that there have been many communication/coordination difficulties between the flight crew and cabin crew during emergency situations related to the non-functioning of the interphone system[2]. In such situations, the reliability of the emergency flightdeck access system for cabin crew becomes more crucial as it provides a means for

cabin crew to establish direct communication with the flight crew during emergency situations. This issue is significant especially if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power. Accident/incident experience shows that there is a relatively high incidence of the failure of the interphone system resulting from the loss of the aircraft's main electrical power[a].

The incident on the EMB-190 indicated that the design of the emergency flightdeck door unlocking facility might not meet the intent of CS 25.772(c). However, it may be argued that CS 25.772(c) does not explicitly specify that such emergency means should be available at all times, including when the main electrical supplies are not available. There is no guidance material on the subject. In most locking systems, it is possible for the flight crew to unlock the door in the event of a failure of the electrical locking system using a manual override of the door latch; however, this is only operable from the inside of the flightdeck[3]. Such a system would be ineffectual if the flight crew in the flightdeck were to be incapacitated or if the cabin crew could not communicate with the flight crew via the interphone system. If there is an in-flight fire/smoke incident within the flight deck, which could incapacitate the flight crew and at the same time cause or require disconnection of the main electrical supplies, it may be impossible for the cabin crew to assist the flight crew.

There is no information on the current EASA position on this subject. The JAA Policy Paper on 'Flightcrew Compartment Access Door Design and the Associated Changes in Operational Procedures'[4], contains a non-exhaustive list of additional operational considerations, which included the following relevant points:

- Communication between flight deck/cabin crew and cabin crew/flight deck in normal, abnormal and emergency situations (including flight deck intrusion and pilot incapacitation)
- Procedures in case one flight crew member leaves the flight deck for, health, safety, security or crew rest reasons.

FAA memorandum 01-115-11 of 3 December 2002 provided guidance for the development of systems that satisfy the requirements of FAR 25.772(c). Included was the potential use of an emergency unlock feature that incorporated an appropriate time delay. Nevertheless, the FAA recommended the requirements of FAR 25.772(c) to be addressed by operational procedures, as reflected in the following excerpt from FAA's Final Rule on 14 CFR Part 25 Amendment No. 25-106 and Part 121 Amendment No. 121-288:

> *While not explicitly a current requirement, the FAA has long recognized a need to provide for in-flight flightdeck entry by the cabin crew should a flightcrew member become incapacitated; because the consequences of not providing such access could be catastrophic.*
>
> *A new Sec. 121.313(j) is added to reference the new part 25 standard for the door separating the flightdeck from the passenger compartment. With respect to the requirements of Sec. 25.772(c), which would require systems that would permit entry by flight attendants but not permit entry by other persons, these systems must have a high degree of reliability, and the FAA considers that it may not be practical to develop and install such systems within the compliance time of*

[a] This loss of main electrical supply resulted from the flight crew being required to switch certain power buses off in an emergency or as a result of engine failure or crash impact. A separate rulemaking activity has been proposed to address this subject.

> *this rule[b]. However, operational procedures coupled with simpler, more robust systems could be readily implemented. Procedures could include having a flight attendant occupy a flightdeck seat whenever one pilot must leave the flightdeck[c]. Any system that must be activated by a flightcrew member (either to permit or deny entry) must be operable from the crewmember's duty station. Therefore, Sec. 121.313(j) will require each operator to establish methods to enable a flight attendant to enter the flightdeck in the event that a flightcrew member becomes incapacitated. As with Sec. 25.772(c), these methods are intended to be used under emergency conditions and not for routine access to the flightdeck.*

It is understood that due to the urgent nature of the issue, National Airworthiness Authorities were given guidance by the JAA to "permit and expedite the installation of door design changes, preceding the formal compliance verification with all applicable airworthiness requirements by the NAA"[d]. It is believed that the rushed, deadline-driven installations of a secured flightdeck door have also resulted in the many operational, security and safety issues, as reported in the United States[5,6] and Australia[7].

The significance of this issue depends on the likelihood of an event where all three risks below exist:

- there is an emergency situation which requires crew access from the cabin to the flightdeck, and
- the flight crew are unable to unlock the flightdeck door from the flightdeck by any method available to them, and
- the emergency means for cabin crew to access the flightdeck does not function.

Procedures have been used to prevent incapacitation of all flight crew due to common factors such as food or drink poisoning. There could be other factors such as hypoxia[8], cabin air contamination with noxious fumes or smoke/fire, or windscreen failure (e.g. due to maintenance error[9] or bird impact exceeding the standards provided by the airworthiness requirements[10]). The risk of the incapacitation of all flight crew is considered to be small, but not non-existent (see Appendix 2 for more discussions on flight crew incapacitation). However, there is still a more conceivable risk where one flight crew leaves the flight deck (e.g. to go to the lavatory) and the other flight crew in the flight deck becomes incapacitated. If the emergency means to enter the flightdeck from the cabin does not have a high degree of reliability, the consequences could be catastrophic. Another conceivable risk is where one of the flight crew becomes incapacitated and the other flight crew requires assistance from the cabin crew, but the flight crew is unable to unlock the door from his station for any reason. There have been reports of pilots being locked out of the flight deck[5], with the widely publicised occurrence on a CRJ-100 on a flight from Ottawa to Winnipeg in 26 August 2006[e].

[b] According to the Final Rule, "Given the urgency of the situation, such requirements and modifications necessary to meet those requirements should be established by April 2002, such that airplanes operating in the United States, whether foreign or domestic, will have improved flightdeck security by April 9, 2003"

[c] As raised by several operators in Australia[7], on flights with one cabin crew this will result in the cabin being completely unattended.

[d] The Policy Paper stated that "not later than 30th April 2003 the operator shall, in case of a non-compliance exists, have installed a design compliant with the applicable airworthiness requirements."

[e] In this occurrence, the pilot who left the cockpit to use the aft lavatory before landing found himself locked out upon his return after the door locks on the reinforced cockpit doors malfunctioned. The first officer had remained on the flight deck, but was unable to open the door. Crew members were forced to take the door off its hinges to let him back in after the incident, which happened 30min before the scheduled arrival of the aircraft in Winnipeg (Flightglobal.com, 31/08/06)

1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA

The purpose of the NPA is to amend CS-25 to specify the required reliability of the emergency flightdeck access system from the cabin to address the possible risks related to the in-flight incapacitation of the flight crew and the potential communication/coordination problems when the interphone system does not function.

The cabin crew's ability to gain emergency access to the flightdeck needs to be maintained at all times. Some emergency unlocking system designs utilise the aircraft's main electrical power for it to function, resulting in a risk of the cabin crew being unable to access the flightdeck during emergency situations that involve a loss of main electrical power. Since currently the availability of the interphone system is not required to be maintained at all times, this issue will also have the potential to adversely affect the communications/coordinations between the flight crew and cabin crew.

Considering that in some scenarios the consequences of not providing such access could be catastrophic, an amendment to CS-25 may be required.

2 OPTIONS

2.1 THE OPTIONS IDENTIFIED

Two regulatory options are considered in this Regulatory Impact Assessment:

Option 1 – Do Nothing

No amendments to CS-25 to specify the required reliability of the emergency flightdeck access from the cabin would be made.

Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

Amend CS-25 to specify the required reliability of the emergency flightdeck access from the cabin in the AMC for 25.772(c). Further explanation may be necessary including examples of good design practice, such as ensuring the preservation, at all times, of the electrical supply to the emergency flightdeck access system (e.g. using a dedicated battery or a supply from the aircraft hot bus. The proposed amendments to CS-25 are as follows:

> *25.772 For an aeroplane that has a lockable door installed between the pilot compartment and the passenger compartment: -*
>
> *(c) There must be an emergency means to enable a crewmember to enter the pilot compartment in the event that the flight crew becomes incapacitated* ***(See AMC 25.772(c)).***
>
> ***AMC 25.772(c)***
>
> *The applicant must assess all reasonably probable scenarios where the means might be required and to design the systems, including the electrical power supplies, accordingly.*

2.2 THE PREFERRED OPTION SELECTED

See Section 5.3.

3 SECTORS CONCERNED

The NPA is applicable to aeroplanes required to be equipped with an approved flightdeck door that is capable of being locked and unlocked from either pilot's station[f].

The sectors affected by this proposal are crew and aeroplane manufacturers that may bear the costs incurred in material costs, design, testing and certification. There will be a marginal cost to EASA in their oversight of the manufacturers in showing compliance with the regulatory change.

4 IMPACTS

4.1 ALL IDENTIFIED IMPACTS

4.1.1 Safety

Option 1 – Do Nothing

This option would not address the potential risks related to the inability of cabin crew to access the flightdeck using the emergency access system during emergency situations, such as flight crew incapacitation. Scenarios involving loss of the aircraft's main electrical power that affects the functioning of the emergency access system will continue to pose such risks. Based on accident/incident experience the overall risk appears to be relatively small; however the consequences could be catastrophic. The potential crew communication/coordination difficulties during emergency situations related to the non-functioning of the interphone system will not be addressed, which is of special significance if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power[g].

Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

Amending CS-25 would increase safety by minimising the risk of cabin crew being unable to access the flightdeck during emergency situations. The risks related to communication/coordination problems during emergency situations due to the non-functioning of the interphone system, especially if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power, will also be minimised[g].

[f] All passenger carrying aeroplanes of a maximum certificated take-off mass exceeding 45 500 kg or with a maximum passenger seating configuration of more than 60 engaged in the commercial transportation of passengers (OR.OPS.035.SEC)

[g] If the requirements for the power supplies of the interphone, public address and evacuation alert system are amended, as proposed in a separate regulatory action, this issue will be less significant.

4.1.2 Economic

Option 1 – Do Nothing

There will be no costs related to Option 1, other than the possible costs to operators from accidents/incidents that could occur related to the risks identified in this RIA.

Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

The proposed amendment will incur initial design and certification costs, and manufacturing costs particularly to the manufacturers of new type certificate aeroplanes. Depending on the design, operators may bear additional fuel costs due to the increased weight of the system. These costs can be considered relatively minimal. Conversely, the costs to operators from accidents/incidents that could occur related to the risks identified in this RIA may be avoided.

4.1.3 Environmental

No significant environmental impacts have been identified. If the improvements to the emergency flightdeck access system were carried out, an increase of CO_2 emission from each flight may occur should the design solutions result in significant additional weight. The amount of this increase will depend on the additional weight, but at worst it is considered to be relatively small.

4.1.4 Social

No social impacts have been identified.

4.1.5 Other aviation requirements outside EASA scope

No aviation requirements outside the scope of EASA which may be affected by the contents of the NPA have been identified.

4.1.6 Foreign comparable regulatory requirements

ICAO Annex 6 and Annex 8 were reviewed and no text was found in conflict with the content or overall objectives of the NPA.

Since there are no current rulemaking activities within the FAA or Transport Canada regarding this subject, a rule change will introduce differences in the standards.

4.2 ISSUES OF EQUITY AND FAIRNESS

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

5 SUMMARY AND FINAL ASSESSMENT

5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

Option 1 – Do Nothing

This option does not mitigate the risks associated with the inability of cabin crew to access the flightdeck during emergency situations. The level of safety achieved will vary greatly on different aeroplane types since there is no guidance available on the required reliability on the emergency flightdeck access system. Although there will not be any direct costs related to Option 1, there are possible costs to operators from accidents/incidents that could occur related to the risks identified in this RIA.

Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

By incorporating the proposed AMC for 25.772(c), the intent of the requirement can be elaborated further to ensure that design of the emergency flightdeck access means takes into account all reasonably probable scenarios where the means might be required. Considering the possible catastrophic consequences of the inability of the cabin crew to access the flightdeck when required during emergency situations, the costs that may be incurred by this option are considered acceptable.

5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

Aircraft crew and passengers will be positively affected by the improved level of safety related to Option 2. In terms of economic impacts, Option 2 may incur costs to aeroplane manufacturers which consist of material, design, testing and certification costs. There will be a marginal cost to EASA in their oversight of the manufacturers in showing compliance with the regulatory change. Conversely, the costs to the industry from accidents/incidents that could occur related to the risks identified in this RIA may be avoided.

5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION

After due consideration the Agency believes that Option 2 - Rulemaking Action is to be preferred.

Considering the possible catastrophic consequences of the inability of the cabin crew to access the flightdeck when required during emergency situations, the costs that may be incurred by this option are considered acceptable.

Rulemaking as described under Option 2 above is therefore considered to be justified.

6 REFERENCES

[1] UK Air Accidents Investigation Branch, *AAIB Bulletin No: 1/2009, Ref: EW/C2009/01/03, EMB-190, G-FBEH, 15 January 2009, Overhead Edinburgh*

[2] RGW Cherry & Associates (2009) *Study on CS-25 Cabin Safety Requirements, Report No. 4208/R/000454/KK Issue 4,* prepared for the European Aviation Safety Agency

[3] UK Air Accidents Investigation Branch, *AAIB Bulletin No: 9/2003, Ref: EW/G2003/04/27, Boeing 747-436 G-BNLC, 20 April 2003, Riga FIR, Latvia*

[4] Joint Aviation Authorities, *JAA Policy Paper on Flightcrew Compartment Access Door Design and the associated Changes in Operational Procedures, 20 November 2001*

[5] "Dysfunctional 'Fortress' Doors Have Caused Numerous Safety & Security Problems", Air Safety Week, August 16, 2004

[6] "The Pilots Speak: Case Studies in Dysfunctional Doors", Air Safety Week, August 16, 2004

[7] Australian Transport Safety Bureau (2005) *Operational and flight safety implications of the installation of hardened cockpit security doors in passenger aircraft having a seating capacity of 30 seats or more* ATSB Transport Safety Investigation Report, Aviation Occurrence Report 200504018 – Final. Canberra: ATSB

[8] Hellenic Republic Ministry of Transport & Communications – Air Accident Investigation & Aviation Safety Board (AAIASB), *Aircraft Accident Report 11/2006 – Helios Airways Flight HCY522, Boeing 737-31S at Grammatiko, Hellas on 14 August 2005*

[9] UK Air Accidents Investigation Branch, *Aircraft Accident Report 1/92 – Report on the accident to BAC One-Eleven G-BJRT over Didcot, Oxfordshire on 10 June 1990*

[10] National Transportation Safety Board, *NTSB Identification SEA03FA024, Accident occurred on Horizon Airlines Bombardier DHC-8-401, registration: N409QX on January 08, 2003 in Medford, OR, USA*

Appendix 1 – Other Pertinent Requirements

Operations requirements related to flightdeck door are as follows:

OPS.CAT.519.A Internal doors and curtains - Aeroplanes

(a) Aeroplanes with a maximum passenger seating configuration of more than 19 shall be equipped with a door between the passenger and the cockpit with a placard saying "crew only" and a locking mechanism preventing passengers from opening it.

OR.OPS.035.SEC Cockpit security – Aeroplanes

(a) In all complex motor-powered aeroplanes and in all aeroplanes used in commercial operations, which are equipped with a cockpit door, this door shall be capable of being locked, and means shall be provided by which the cabin crew can discreetly notify the flight crew in the event of suspicious activity or security breaches in the cabin.

(b) All passenger carrying aeroplanes of a maximum certificated take-off mass exceeding 45 500 kg or with a maximum passenger seating configuration of more than 60 engaged in the commercial transportation of passengers, shall be equipped with an approved cockpit door that is capable of being locked and unlocked from either pilot's station and designed to meet the applicable airworthiness requirements.

(c) The cockpit door referred to in subparagraph (b) above shall:

(1) be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorised persons; and

(2) means shall be provided for monitoring from either pilot's station the entire door area outside the cockpit to identify persons requesting entry and to detect suspicious behaviour or potential threat.

ICAO Annex 6 Chapter 13 Section 13.2 states:

13.2 Security of the flight crew compartment
13.2.1
In all aeroplanes which are equipped with a flight crew compartment door, this door shall be capable of being locked, and means shall be provided by which cabin crew can discreetly notify the flight crew in the event of suspicious activity or security breaches in the cabin.

13.2.2
From 1 November 2003, all passenger-carrying aeroplanes of a maximum certificated take-off mass in excess of 45 500 kg or with a passenger seating capacity greater than 60 shall be equipped with an approved flight crew compartment door that is designed to resist penetration by small arms fire and grenade shrapnel, and to resist forcible intrusions by unauthorized persons. This door shall be capable of being locked and unlocked from either pilot's station.

13.2.3
In all aeroplanes which are equipped with a flight crew compartment door in accordance with 13.2.2:

a) this door shall be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorized persons; and
b) means shall be provided for monitoring from either pilot's station the entire door area outside the flight crew compartment to identify persons requesting entry and to detect suspicious behaviour or potential threat.

13.2.4
Recommendation.— All passenger-carrying aeroplanes should be equipped with an approved flight crew compartment door, where practicable, that is designed to resist penetration by small arms fire and grenade shrapnel, and to resist forcible intrusions by unauthorized persons. This door should be capable of being locked and unlocked from either pilot's station.

13.2.5
Recommendation.— In all aeroplanes which are equipped with a flight crew compartment door in accordance with 13.2.4:
a) the door should be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorized persons; and
b) means should be provided for monitoring from either pilot's station the entire door area outside the flight crew compartment to identify persons requesting entry and to detect suspicious behaviour or potential threat.

ICAO Annex 8 Chapter 11 Section 11.3 states:

11.3 Protection of the flight crew compartment
Recommendation.— In all aeroplanes, which are required by Annex 6, Part I, Chapter 13 to have an approved flight crew compartment door, and for which an application for amending the type certificate to include a derivative type design is submitted to the appropriate national authority, consideration should be given to reinforcing the flight crew compartment bulkheads, floors and ceilings so as to resist penetration by small arms fire and grenade shrapnel and to resist forcible intrusions, if these areas are accessible in flight to passengers and cabin crew.

Appendix 2 – In-flight Flight Crew Incapacitation

A study by the Australian Transport Safety Bureau[7] attempted to gain an appreciation of the potential magnitude of the hazard identified in the case of pilot incapacitation in 30 to 59 seat aircraft that included a problematic installation of a hardened cockpit security door.

The study found that in the period January 2000 to July 2005, there had been 43 reports of flight crew incapacitation during the period studied, or an average of about 8 incidents per year. The causes of the pilots' incapacitation varied, but included: the temporary loss of vision as a result of a lightning strike; physical illness, including stomach cramps and nausea; the lodgement of a foreign object in a pilot's eye; and incapacitation as a result of the contamination of the flight compartment. In one instance, both pilots became incapacitated. In many of the reported incidents, a cabin crew member was required to enter the flight compartment to render assistance while the remaining pilot ensured the continued safe conduct of the flight.

The following is the abstract of a study carried out by CAMI[h]:

> *Although it is not known when the first accident due to pilot in-flight medical incapacitation occurred, a recent survey showed that almost one-third of all pilots who responded had experienced an incapacitation requiring another crewmember to take over their duties, with safety of flight significantly threatened in 3% of cases. The importance of in-flight medical incapacitation and impairment can be better understood when it is realized that each in-flight medical incapacitation or impairment could potentially lead to an aircraft accident. We studied in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998. We defined in-flight medical incapacitation as a condition in which a flight crewmember was unable to perform any flight duties and impairment as a condition in which a crewmember could perform limited flight duties, even though performance may have been degraded. We found 39 incapacitations and 11 impairments aboard 47 aircraft during the six-year period. All pilots were males. The average age for incapacitations was 47.0 years (range 25 to 59 years). The average age for impairments was 43.3 years (range 27 to 57 years). The in-flight medical event rate was 0.058 per 100,000 flight hours. The probability that an in-flight medical event would result in an aircraft accident was 0.04. Incapacitations significantly increased with age, with more serious categories in the older age groups. The most frequent categories of incapacitation were loss of consciousness, cardiac, neurological, and gastrointestinal. Safety of flight was seriously impacted in seven of the 47 flights and resulted in two non-fatal accidents.*

[h] DeJohn, C.A., Wolbrink, A.M., and Larcher J.G. (2004) *In-Flight Medical Incapacitation and Impairment of U.S. Airline Pilots: 1993 to 1998, DOT/FAA/AM-04/16.* Oklahoma City: FAA Civil Aerospace Medical Institute