INTERNATIONAL MULTIDISCIPLINARY LITHIUM BATTERY TRANSPORT COORDINATION MEETING

FIRST MEETING

Atlantic City, 4 to 6 February 2014

SUMMARY OF DISCUSSIONS AND RECOMMENDATIONS

1. INTRODUCTION

1.1 The first ICAO International Multidisciplinary Lithium Battery Transport Coordination Meeting was hosted by the Federal Aviation Administration (FAA) William J. Hughes Technical Center from 4 to 6 February 2014 (see Appendix A for the letter of invitation and Appendix B for the agenda). Representatives from ICAO (dangerous goods and flight operations), the United States Department of Transportation (FAA (flight standards, airworthiness, hazardous materials, technical center) and the Pipeline and Hazardous Materials Safety Administration (PHMSA)), the European Aviation Safety Agency (EASA), the International Coordinating Council of Aerospace Industries Associations (ICCAIA), associations representing battery manufacturers (National Electrical Manufacturers Association (NEMA) and The Rechargeable Battery Association (PRBA)) and experts of the Dangerous Goods Panel (DGP) attended (see Appendix C) and were welcomed by the Director of the FAA Technical Center, Mr. Dennis Filler.

1.2 The meeting consisted of three parts:

a) test demonstrations and presentations;

b) additional considerations;

c) conclusions and development of recommendations.

2. TEST DEMONSTRATIONS AND PRESENTATIONS

2.1 Test demonstrations and observations

Notes.—

1) *The batteries used in the following tests were not packaged as for air transport.*

2) *The cells in the demonstrations were heated into thermal runaway by two methods. For some of the demonstrations, a small alcohol fire was used to heat the cells and*

initiate thermal runaway. This method provides a low-intensity heat source that simulates the temperature that may be found in a suppressed cargo compartment fire and supplies an ignition source for the electrolyte when it vents. The remaining demonstrations used an electric heater to raise the temperature of the cell to the point where thermal runaway is initiated (approximately 190°C for lithium metal batteries).

3) *All tests were recorded and are available at:*

http://www.fire.tc.faa.gov/temp/ICAO/ICAO_Test.zip.

2.1.1 **Different chemistries — lithium metal (123A size), lithium ion (18650 size) and nickel metal hydride (AA size) cells**

a) The fire propagation and pattern was substantially different between the lithium metal and lithium ion cells; the nickel metal hydride cells were non-reactive.

2.1.2 **Same cell chemistry and type (lithium ion 18650 cells), different manufacturers**

a) The fire propagation and pattern was substantially different.

2.1.3 **Same lithium metal cell size (D), different chemistries (lithium manganese dioxide and lithium sulphur dioxide)**

a) The fire propagation and pattern was substantially different between the two chemistries.

b) The lithium manganese dioxide cell exhibited strong thermal runaway and propagated between cells, while the same size cell with sulphur dioxide chemistry exhibited weak thermal runaway and did not propagate between cells.

2.1.4 **Varying sizes of lithium metal "button" cells (2032 and 2450)**

a) The hazardous characteristics of these button cells appeared to be proportionate to the size and significantly less reactive than larger lithium metal cells. When heated, the cells vented by splitting the case into two halves, releasing the electrolyte. The case halves were projected up to twenty feet from the test site.

2.1.5 **Lithium metal D size cell containing "non-flammable" electrolyte (lithium thionyl chloride) tested inside an otherwise empty LD3 shipping container**

a) The cell was induced by heating with a 100 watt cartridge heater into a thermal runaway state. The result was an explosion that dislodged the ceiling of the LD3 and produced significant smoke — all from one single D-cell battery.

2.2 **Full-scale testing of 4800 lithium metal cells**

2.2.1 Following the demonstrations, the group reviewed a video of the full-scale testing of 4800 lithium metal 123A cells (lithium manganese dioxide batteries). The cells were tested in the original, as delivered, shipping cartons in a B727 airframe. Lithium manganese dioxide batteries are the most common consumer type lithium metal batteries in use. Observations of the fire test were as follows:

a) The resulting fire in the lower deck cargo compartment (Class C) could not be controlled with Halon 1301;

b) The test in the Class C compartment had to be halted after approximately nine minutes after the fire would have been detected (approximately 50 per cent of the cells had been consumed by fire) to prevent the loss of the test airframe (B727);

c) The fire test in the Class C cargo hold caused significant smoke propagation into the flight deck within eight to nine minutes of expected fire detection — the main deck cargo compartment was fully obscured by smoke;

d) After the test in the class C cargo hold was halted, an explosion occurred that blew the flight deck door off its hinges, dislodged all of the main deck flooring above the mix bay and dislodged some of the cargo liners in both the Class C and Class E compartments; and

e) The fire test in the Class E cargo hold produced temperatures at the ceiling that exceeded the certification requirements for cargo liners and caused smoke propagation into the flight deck within five minutes of fire detection — the flight deck was fully obscured by smoke. The low ventilation rate and reduced oxygen concentration had little effect in controlling the fire.

2.2.2 An early version of the presentation was given at DGP/24 on 31 October. A copy of the full presentation was given during the Seventh Triennial International Aircraft Fire and Cabin Safety Research Conference in December 2013 and is available on the FAA Fire Safety website:

http://www.fire.tc.faa.gov/2013Conference/files/Battery_Fires_I/WebsterFullScaleTests/WebsterFullScalePres.zip

2.3 **Presentations**

2.3.1 **Safety risk mitigation**

2.3.1.1 A presentation on the ICAO risk mitigation tool was made by the Chief of the ICAO Flight Operations Section (see Appendix D); this included detailed reference to the ICAO *Safety Management Manual (SMM)* (Doc 9859), Chapter 2 — Safety Management Fundamentals. A worksheet on the hazard identification and risk mitigation process was then presented. The outcome of the analysis suggested the transport of lithium metal batteries on passenger aircraft posed an unacceptable risk under the existing circumstances on the basis that the likelihood of an event occurring was remote but that the severity of the consequence of the event would be catastrophic. The worksheet was presented as an example of one tool used in risk identification and mitigation which the group could use and was provided with the caveat that the analysis was the preliminary work of a small team, produced in a short space of time.

2.3.2 Presentations by representatives of the battery industry

2.3.2.1 Representatives of the battery industry made a brief presentation about the proportion of the global market for primary lithium coin cells and cylindrical cells accounted for by Japanese manufacturers and the proportion of shipments made from Japanese companies' manufacturing locations by air; this was estimated at 10 percent (see Appendix E, Annex 2). Later discussion of this information included an estimate that 10 percent of those air shipments from Japanese battery manufacturers travel on passenger aircraft. No data or estimates were provided as to the size of these shipments. The ICAO Secretariat noted that the ICAO Air Navigation Commission (ANC), during its review of the DGP/24 report on lithium batteries, had emphasized the importance of obtaining quantitative data in support of an SMS approach and that in the absence of quantitative data, worst case scenarios must be assumed for the likelihood and severity of an occurrence/exposure. Battery industry representatives noted their continuing efforts to develop additional data to inform ICAO.

2.3.2.2 Battery industry representatives also provided a short presentation on an analysis of the incidents associated with lithium metal batteries identified to the FAA, which showed no incidents since 2011 (see Appendix E, Annex 1).

2.3.2.3 There was some further discussion regarding the scarcity of statistical data, despite being repeatedly sought by ICAO. The data presented at the meeting only addressed batteries shipped from Japanese manufacturers and could not be usefully extrapolated to other manufacturers or companies which were conducting further shipments by air transport. Additional useful statistics that would assist in making informed, risk-based safety decisions would include the quantities of batteries per shipment by air; the percentage shipped by air versus surface transport; and in the case of battery failure, the percentage of those which fail and the percentage of failed batteries that fail unsafely (i.e. self-combust).

3. ADDITIONAL CONSIDERATIONS

3.1 Passenger versus cargo aircraft

3.1.1 Discussion focused on whether a distinction should be made between passenger and cargo aircraft when transporting lithium metal batteries. Recognizing that the most commonly-used fire suppressant (Halon 1301) on passenger aircraft was ineffective in dealing with fires involving such batteries, there was general agreement that a distinction should be made since different mitigation strategies could be employed on cargo aircraft and that there should be consideration of a further restriction, up to and including a prohibition, on the carriage on a passenger aircraft. It was recognized, however, that transport on cargo aircraft would still need to be addressed, especially for bulk shipments. It was noted that Annex 6 — *Operation of Aircraft* to the ICAO Chicago Convention covers commercial airplanes and that no distinction is made between international passenger and cargo operations.

3.2 Fire suppression requirements

3.2.1 It was also noted that when referencing Annex 6 Standards for extended time operations (applicable to both passenger and cargo aircraft), fire suppression is one critical system contained in FAA and EASA requirements. This implies that when transporting lithium metal batteries, an operator would have to be able to demonstrate an ability to control and protect the aircraft from a fire involving the batteries.

3.3 Performance standard

3.3.1 It was suggested that the multidisciplinary group should consider the development of a performance standard which could be used for transport on cargo aircraft. This could also be utilized as the basis to issue an approval to transport lithium metal batteries or to continue to allow certain lithium metal batteries on passenger aircraft. It was noted that there are two existing packaging performance standards for articles of dangerous goods contained in the Technical Instructions. These are for explosives of Division 1.4 S and chemical oxygen generators in accordance with Packing Instruction 565. A draft flow chart prepared by the FAA Technical Center on a performance-based approach to the conditions of carriage was presented for consideration (see Appendix F). It was suggested that the risk posed by the batteries themselves would dictate the level of mitigation needed; this would then automatically take into account new battery types or chemistries developed in the future. Diverging views were expressed about the distinction made between passenger and cargo aircraft, the types of tests which would be required for the cells or batteries and the difficulty to obtain reproducibility.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Given the information made available through the demonstrations and this multidisciplinary meeting, it became clear to the group that fires in flight involving certain types and quantities of lithium metal batteries have the potential to result in an uncontrolled fire leading to a catastrophic failure of the airframe.

4.2 The multidisciplinary group was advised by ICCAIA that the fire protection capabilities and certification of original equipment manufacturers' (OEM's) airframes and systems were predicated on carriage of general cargo and not the unique hazards associated with the carriage of dangerous goods, including lithium metal batteries. Given the known inability of existing fire suppression and/or starvation systems to extinguish or suppress a lithium metal battery fire, the existing allowance for the carriage of lithium metal batteries could significantly impact the available fire suppression time and could ultimately negate the capability of the systems to prevent a catastrophic failure of the airframe. Given the impact of lithium metal batteries on the certification conditions and operational limitations of existing airframes, the following recommendations were developed:

4.2.1 **Recommendation 1 — Further restrictions on the carriage of lithium metal batteries in commercial passenger carrying operations**

That the carriage of lithium metal batteries as cargo should be further restricted, up to and including a potential ban, on passenger carrying aircraft in commercial air transport. Options for these restrictions should be considered and decided upon by the DGP at its Working Group of the Whole on Lithium Batteries (7 to 11 April 2014) and implemented as soon as possible.

Options include:

Option 1 — Total prohibition on passenger carrying aircraft until such time as the data supporting safe transport is available

Option 2 — Prohibition with an approval provision (guidance to be provided in the *Supplement to the Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284SU))

The specific conditions to support an approval process, where the types, quantities and packaging containing lithium metal batteries would not allow a fire from within the package to propagate beyond the packaging or adversely affect flight safety, would be developed for inclusion in the Supplement to the Technical Instructions. Guidance would be developed no later than the next regular amendment to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284).

Option 3 — Permission to transport certain limited lithium metal batteries based upon a performance-based criteria for packaging such batteries. Performance-based criteria would be developed for inclusion in the Technical Instructions.

Option 4 — Option 3, plus permission to transport very small cells (e.g. button cells). The number and package configuration would be validated based upon a specification (may or may not be fully declared)

4.2.2 **Recommendation 2 — Performance based approach**

That a small multidisciplinary cargo safety group be formed to develop a performance-based approach to the conditions of carriage on passenger aircraft using the draft flow chart prepared by the FAA Technical Center (see Appendix F) as the basis for its deliberations.

4.2.3 **Recommendation 3 — Cargo aircraft**

That risks associated with lithium metal batteries on cargo aircraft be mitigated using the lessons learned in the development of a performance-based approach to controlling the risks associated with the carriage of lithium metal batteries on passenger aircraft, as well as any other potential strategies. A decision on the way forward to be taken during the next DGP working group of the whole meeting in October 2014.

4.2.4 **Recommendation 4 — Multidisciplinary approach to cargo safety**

That a multidisciplinary approach involving all stakeholders be taken as an essential step to advancing the issue of cargo safety.

4.3 There was agreement that the multidisciplinary approach undertaken by the meeting was worthwhile and was likely to lead to greater awareness, understanding and cooperation. Including the airframe manufactures as part of this multidisciplinary meeting highlighted the importance of considering the certified capabilities of aircraft in determining appropriate restrictions on various dangerous goods, including lithium metal batteries. The aircraft manufacturers' certification assumptions for cargo fire protection do not specifically address the risks posed by the carriage of dangerous goods. The approval process for carriage of dangerous goods is not within the scope or control of aircraft manufacturers and there has been an assumption that restrictions placed on dangerous goods by the DGP and State regulatory authorities provide an acceptable level of safety. The process for determining restrictions on dangerous goods, including lithium metal batteries, has been evaluated on a package level and not on whether aircraft fire protection features are capable of controlling fires involving dangerous goods, including lithium metal batteries.

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APPENDIX A

LETTER OF INVITATION

Tel.: +1 (514) 954-8219 ext. 6407

Ref.: AN11/2.12

Name
Title
Address

Dear …,

I wish to inform you that the International Civil Aviation Organization (ICAO) will convene the first International Lithium Battery Transport Coordination Meeting from 4 to 6 February 2014 in Atlantic City, United States. The meeting will be hosted by the Federal Aviation Administration (FAA) William J. Hughes Technical Center. The need for this meeting was determined at the Twenty-Fourth Meeting of the Dangerous Goods Panel (DGP/24) (Montréal, 28 October to 8 November 2013) during discussions on a proposal to forbid the transport of lithium metal batteries by air. An extract from the report of that meeting is provided in Attachment A to this letter.

The purpose of the meeting will be to consider risks and potential mitigation strategies related to the transport of lithium metal batteries by air through input from experts in the fields of safety management, dangerous goods, operations and airworthiness and from representatives of the aircraft and battery manufacturing industries. The report of the meeting will be provided to the Dangerous Goods Panel (DGP) Working Group on Lithium Batteries Meeting (Montréal, 7 to 11 April 2014). The working group will consider its recommendations in determining what amendments to the *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (Doc 9284) are necessary to ensure acceptable levels of safety are maintained.

The meeting will be conducted in English. Provisional terms of reference are included in Attachment B to this letter. The ICAO focal point will be Mr. Mitch Fox, Chief, Flight Operations Section. Should you require further information, please contact him by email at mfox@icao.int.

I am pleased to extend an invitation for you to attend this meeting. If you wish to attend, please confirm by e-mail to Mrs. Sandra Colapelle at CColapelle@icao.int by 18 January 2014.

I wish to thank you for your support and look forward to your active participation in this worthwhile event.

Yours sincerely,

Nancy J. Graham
Director
Air Navigation Bureau

Enclosures:

A — Extract from the DGP/24 Report
B — Terms of reference

ATTACHMENT A

EXTRACT FROM THE DGP/24 REPORT

5.1 REVIEW OF PROVISIONS FOR THE TRANSPORT OF LITHIUM BATTERIES

5.1.1 LITHIUM BATTERY INFORMATION SESSION

5.1.1.1 A lithium battery information session was held at which representatives from the Federal Aviation Administration (FAA) William J. Hughes Technical Center, two cargo express carriers, and packaging companies were invited to provide information on developments in testing, packaging and fire suppression systems.

5.1.1.2 **FAA Tech Center**

5.1.1.2.1 The FAA Technical Center provided a brief summary of findings from previous tests related to lithium batteries, followed by a report on results from recent full-scale tests undertaken to demonstrate the characteristics of large battery fires in a realistic aircraft environment (B-727). Findings from previous lithium battery tests were summarized as follows:

a) **Thermal runaway.** Lithium batteries were capable of thermal runaway through cell defect, cell damage, heat, rapid discharge, or overcharging resulting in temperatures exceeding 550°C (1100°F) for lithium ion and 760°C (1400°F) for lithium metal. A single cell in thermal runway generates enough heat to cause adjacent cells to go into thermal runaway resulting in propagation from cell to cell and package to package. Thermal runaway results in the release of flammable electrolytes and, in the case of lithium metal, molten burning lithium.

b) **Self ignition.** Lithium ion will generally not self-ignite, but high temperatures can ignite packing materials, which can ignite the electrolyte. Lithium metal can self-ignite and rapidly ignite packaging.

a) **Fire suppression.** Halon 1301 suppresses open flames from lithium-ion cells in thermal runaway but does not stop the propagation from cell-to-cell. Halon 1301 has no effect on lithium metal cells.

5.1.1.2.2 The recent full-scale tests demonstrated the dangers of bulk shipments of lithium metal batteries under realistic conditions which included emergency in-flight air flow. In the main deck Class E cargo compartment, a fire triggered by a cartridge heater simulating a single cell in thermal runaway created conditions that jeopardized the cargo compartment and created smoke in the flight deck. From the first observation of fire, smoke was present in the flight deck in four minutes and the flight deck was completely obscured from smoke in less than six minutes. Testing in a Class C cargo compartment with Halon suppression was terminated because of high temperatures and smoke penetration into the main cargo compartment and flight deck. After the test was terminated, the oxygen levels in the cargo compartment increased, the Halon neared zero, and a single cell in thermal runaway ignited a flash fire in the cargo compartment. The flash fire caused an explosion ultimately resulting in the breach of the main deck floor panels and the flight deck door being blown off its hinges into the flight deck.

5.1.1.2.3 Tests had also shown that the behavior of a burning lithium cell is very dependent on the manufacturer, chemistry, size and design of the cell. Testing on one particular chemistry, although employing a non-flammable electrolyte, resulted in an explosion when thermal runaway was induced by a cartridge heater.

. . .

5.1.2 **LITHIUM METAL BATTERIES (DGP/24-WP/9)**

5.1.2.1 The panel was asked to consider forbidding lithium metal batteries on passenger and cargo aircraft. It was argued that the knowledge that current fire suppression systems in cargo holds had no effect on lithium metal fires and that currently required packagings could not contain a fire made it difficult to justify allowing their carriage as cargo. It was noted that one State and several airlines already banned lithium metal batteries as cargo on their passenger aircraft through State and operator variations. The meeting was reminded of discussions that had taken place earlier that week on safety management systems (SMS) (see paragraph 1.2 of the Report on Agenda Item 1), and it was suggested that continued carriage of lithium metal batteries went against these principles. A basic tenet of SMS was that layered defences against safety risks were necessary in ensuring that single-point failures were rarely consequential. It was suggested that the ineffectiveness of aircraft fire suppression systems on lithium metal fires was a single point of failure which, based on test results, would likely result in a catastrophic event. Continuing to transport lithium metal batteries despite the known risks was argued to be unacceptable.

5.1.2.2 The meeting was reminded of statements made by the Director of the Air Navigation Bureau during the opening of DGP/24 which provided insight into the Secretariat's growing concern with cargo safety and how the mandate of the Dangerous Goods Section would be expanded. Dangerous goods could no longer be thought of in isolation but would need to involve other parts of the aviation system such as operations, airworthiness and security. With that in mind, the Deputy Director, Safety Standardization and Infrastructure (DD/SSI), the Chief of the Flight Operations Section (C/OPS) and operations and airworthiness technical officers from the Air Navigation Bureau were present to provide insight into how other Annexes interacted with Annex 18 and how they might contribute to the panel's decisions. DD/SSI described how quantitative safety performance targets were used to make decisions on adding or amending Standards to Annexes in other aviation segments and urged the DGP to also apply this approach. C/OPS referenced the work that DGP and the Operations Panel (OPSP) had undertaken to introduce dangerous goods requirements in Annex 6 — *Operation of Aircraft* as an example of how interdependent aviation segments were. He suggested that other Annex 6 requirements needed to be taken into account in relation to dangerous goods such as extended diversion time operations (EDTO) and fire suppression capabilities. Annex 8 — *Airworthiness of Aircraft* requirements also needed to be taken into account. A disconnect between Annex 8 and Annex 18 was cited, whereby Annex 8 requires cargo compartment fire suppression systems, including their extinguishing agents, to be designed so as to take into account a sudden and extensive fire such as could be caused by dangerous goods (for aircraft certificated on or after 12 March 2000). It was suggested that since aircraft fire suppression systems could not extinguish a lithium metal battery fire, this requirement could not be met if such items were allowed to be carried as cargo by air.

5.1.2.3 The ensuing discussion highlighted the concerns of those who were in favour of banning lithium metal from transport and those who were not. Although those against the ban did agree that there were risks in transporting lithium batteries, they believed that these risks involved non-compliant and counterfeit batteries and that many if not all reported incidents had involved these types of shipments. It was suggested that a ban would serve only to stop compliant shipments of batteries; non-compliant shipments would continue to be transported, and the number of undeclared batteries would likely increase, therefore increasing the risk to passengers and crew. A ban was seen to be unfair to the majority who did comply with the regulations and would have a negative effect on key industries such as communications, public health and safety. It was suggested that a ban would put the lives of people who depended on batteries to power medical devices such as pacemakers and defibrillators at risk. There was also a concern that the panel would be viewed as indecisive as yet more new rules would be introduced so soon after significant amendments were introduced into the current edition of the Technical Instructions. While appreciating the views expressed by operations, airworthiness and air traffic management experts, one member suggested that the world of air cargo and specifically dangerous goods could not be compared to those areas of aviation because they were closed systems, involving technically qualified staff with no choice but to comply with very strict and exacting requirements. The situation was very different with air cargo, where it was impossible to directly oversee the limitless number of shippers who offered cargo for carriage by air, despite the oversight requirements in Annex 18. The significance of the suggested disconnect between Annex 8 and Annex 18 was also questioned, noting that cargo aircraft did not require fire suppression systems. Did this mean that such aircraft should not be permitted to carry any flammable or explosive dangerous goods at all? It was suggested that the ineffectiveness of the fire suppression system should not be regarded as a potential single point failure, since the packaging was not relied upon as the only barrier against a fire propagating. There were many layers of risk mitigation in place including very stringent testing requirements, the establishment of quality management systems, and other requirements specific to the air mode which were applied to lithium batteries excepted from most of the requirements when transported by other modes. Members against a ban believed that risks would be better addressed through outreach and enforcement. It was suggested that these were lacking in many parts of the world and that efforts needed to be taken in States who were deficient in this area. This would be particularly important were a ban to come into force, because some States might believe that this would lessen the need for oversight. It was believed that even more oversight would be needed if a ban were in place, as the number of undeclared and non-compliant batteries being shipped would likely increase.

5.1.2.4 Other members supported a ban for the reasons presented with the proposal, but all but one of these members believed the ban should apply to passenger aircraft only. Although they agreed that more needed to be done to mitigate risks on cargo aircraft, a full ban was considered to be too extreme. While the Secretariat’s philosophy in all segments of aviation was not to differentiate between passenger and cargo aircraft, it was acknowledged that there were differences with regards to dangerous goods. Higher quantity limits were permitted on cargo aircraft, and certain substances forbidden on passenger aircraft were permitted on cargo. The member nominated by IFALPA was the one member who supported the proposal as written. He stated that IFALPA’S position was that the requirements for passenger and cargo aircraft should be the same. He also disagreed with an earlier statement which implied that should the fire suppression Standard in Annex 8 be taken literally, there would not be any dangerous goods permitted for transport on cargo aircraft since there were no fire suppression requirements on such aircraft. He noted that depressurization was a method of fire suppression that could meet the Annex 8 requirement. However, tests had shown that although depressurization could suppress a fire involving dangerous goods other than lithium metal batteries, it was not effective on lithium metal battery fires. IFALPA’s position, which he endorsed, was that there was currently no safe way to transport lithium metal batteries and until such time that there was, they should be banned on both passenger and cargo aircraft.

5.1.2.5 Based on the fact there was little support shown for a full ban, a revised proposal was presented to the meeting which would allow lithium metal batteries to be carried on cargo aircraft in accordance with the current requirements and on passenger aircraft with the approval of the States of Origin and the Operator. Some were in favour of this approach, noting that a ban on passenger aircraft had been in effect for almost ten years in one large State. Although there had been logistical problems when the ban was first introduced, these had been effectively dealt with. Representatives from the battery industry stated that its members would likewise adapt to a ban if it were to be enforced internationally.

Those members against even a partial ban believed there were parts of the world that cargo aircraft did not service and therefore there needed to be an allowance for lithium batteries to be transported on passenger aircraft. It was noted that the State that had a ban in place had an extensive cargo aircraft network, something many other parts of the world did not have. The need for replacement batteries for automatic external defibrillators (AEDs) was cited as one example where next day deliveries were often required and for which transport by air would be the only viable mode of transport to meet this need. But others felt that this was an economic argument which was not used in any other areas of aviation safety and should not be used if there were risks to safety. It was noted that the proposal did not ban lithium metal batteries packed with or contained in equipment and that that was done in order to take into account urgent medical needs.

5.1.2.6 All members agreed that non-compliant shipments were a problem and that better oversight and enforcement was needed, but those who supported a ban stressed that even fully compliant shipments posed risks. There was always the possibility of damage to perfectly manufactured and prepared shipments of batteries during transport. The probability of this happening would only increase with the upward trend in numbers of batteries being shipped. It had been cited by industry representatives that billions of batteries were being shipped each year. It was acknowledged that other dangerous goods could result in an aircraft fire, but the number of shipments of other commodities would be substantially lower than that for lithium batteries, making the risk posed correspondingly lower. Testing had shown that the heat from a suppressed fire could ignite lithium metal batteries. The fact that fully compliant lithium metal batteries could serve as fuel for an independent fire was a risk that could not be ignored. Concern was expressed that at some point a catastrophic fire would occur on an aircraft and that action had to be taken. If this resulted in an increase in non-compliance, it was thought this would affect only a small number of shipments and should not deflect the need to address the majority.

5.1.2.7 While there were differences of opinion, most believed that the results of the FAA Technical Center’s full scale testing could not be ignored. Of those against the ban, all but one believed that maintaining the status quo was inappropriate, and that even if a ban on passenger aircraft were implemented, further work was needed to ensure safe transport on cargo aircraft. Developments in fire suppression systems and packaging standards were promising, and it was believed technology was available to establish conditions under which lithium metal batteries could be transported safely. It was recognized that finding a solution would involve a multi-disciplinary approach involving experts from outside the dangerous goods world including operations, airworthiness, battery manufacturing and packaging manufacturing. To that end, an offer was made to host a multidisciplinary meeting on behalf of ICAO at the FAA Technical Center at the beginning of 2014.

5.1.2.8 It became clear that a final decision on the revised proposal which would allow lithium metal batteries to be carried on cargo aircraft in accordance with the current requirements and on passenger aircraft with the approval of the States of Origin and the Operator could not be reached during DGP/24. The revised proposal, although less restrictive than the original, would still have a major impact on industry and some members wished for more time to consult with experts within their States. Others remarked that even if the proposal were agreed in principle, there were several consequential issues that needed to be taken into account, including how to ensure that smaller sized batteries which were not subject to an operator acceptance check did not end up on passenger aircraft. Several panel members wanted to consider options which would not include a ban, such as fully regulating all lithium metal batteries, determining what types and quantities of batteries could be carried without posing an unacceptable risk, and limiting the numbers in a ULD or in a cargo compartment. Some members believed that without urgent action, a catastrophic event was inevitable and that an immediate change to the requirements was necessary. Others believed that a rushed decision would not necessarily be the right one and that every effort was needed to ensure a decision which would result in safe and stable regulations was made. On that basis, the panel agreed to continue work on the subject through correspondence and to schedule a working group in early 2014 at which time a final decision on the proposal to ban lithium metal batteries on passenger aircraft would be made.

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ATTACHMENT B

Terms of Reference
Lithium Metal Battery Coordination Meeting
4 to 6 February 2014
Atlantic City

Goal
At this meeting our primary purpose is to review the air transport of lithium metal batteries in Class C and E aircraft cargo compartments. Any recommendations should provide the international aviation community with an acceptable level of risk and afford the battery industry the least possible burden in implementation.

Organization
This meeting will be comprised of members from States, International Organizations, and relevant related industries whose charter is to provide subject matter expertise on safe shipment by air of lithium metal batteries in Class C and E aircraft cargo compartments.

Objectives
The main objectives are:
- — to provide information, based on areas of expertise, on aircraft fire protection systems and their effects on mitigating the risks of lithium metal batteries via presentations or information.
- — to provide meeting participants with information on the risks lithium metal batteries present in air transport.
- — to become the resource of multidisciplinary knowledge and information on the air transport of lithium metal batteries as cargo in Class C and E cargo compartments.
- — to review, discuss and develop, as needed, draft standards for lithium metal batteries shipped in Class C and E aircraft cargo compartments.
- — to provide recommendations for updated information on the risks associated with the transport of lithium metal batteries and mitigation strategies determined to be appropriate.

Process
Through presentations and discussions including research and data, members of the coordination meeting will look at safe means and possible limitation for the shipment of lithium metal batteries in Class C and E aircraft cargo compartments.

Outputs
The meeting will provide the following results:
- — Recommended changes to the transport requirement for lithium metal batteries to meet determined mitigation strategies.
- — Draft standards, if needed, for lithium metal batteries transported in both Class C and Class E cargo compartments.
- — The risk level this is expected to address so the acceptable level of risk is clear to all in determining what is a tolerable level for air transport.

References
Annex Eight, Airworthiness of Aircraft
Annex 18, Technical Instructions
Annex 6, Operation of Aircraft
Annex 19, Safety Management System
Document 8335
Relevant meeting materials

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APPENDIX B

AGENDA

ICAO BATTERY COORDINATION MEETING

February 4-6, 2014

<u>Tuesday, February 4, 2014</u>

8:30 AM Arrive at FAA Technical Center Security Operations Building for Badging

9:00 AM Introductions and Meeting Logistics

9:45 AM Battery Demos and Discussions (Building 287)

- Metals vs. Others
- Small Button Cells
- Different chemistry same size
- Same type vs. Different manufacturer

11:00 AM Tour Full-Scale Facility

- Fire Resistant Containers (FRC)
- Fire Containment Covers (FCC)
- Cargo Compartment
- Water Mist System
- Packaging

12:00 PM Lunch Break

1:15 PM Presentation on Full-Scale Tests

- Metal Battery Results
- Risk analysis

2:15 PM Discussion

- Ban with exemptions vs. Performance Requirements

5:00 PM Close of Day 1

<u>Wednesday, February 5, 2014</u>

8:30 AM Arrive at FAA Technical Center Security Operations Building for Badging

9:00 AM Discussion: Passenger vs. Freighter

Test Requirements for Exemptions or Performance Requirements

12:00 PM Lunch Break

1:15 PM Continue Discussion

5:00 PM Close of Day 2

<u>Thursday, February 6, 2014</u>

8:30 AM Arrive at FAA Technical Center Security Operations Building for Badging

9:00 AM Develop Recommendations to DGP

12:00 PM Lunch Break

1:15 PM Develop way forward
Any additional discussion/business

5:00 PM Close of Meeting

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APPENDIX C

LIST OF ATTENDEES

STATE/ORGANIZATION	NAME OF ATTENDEE	E-MAIL ADDRESS
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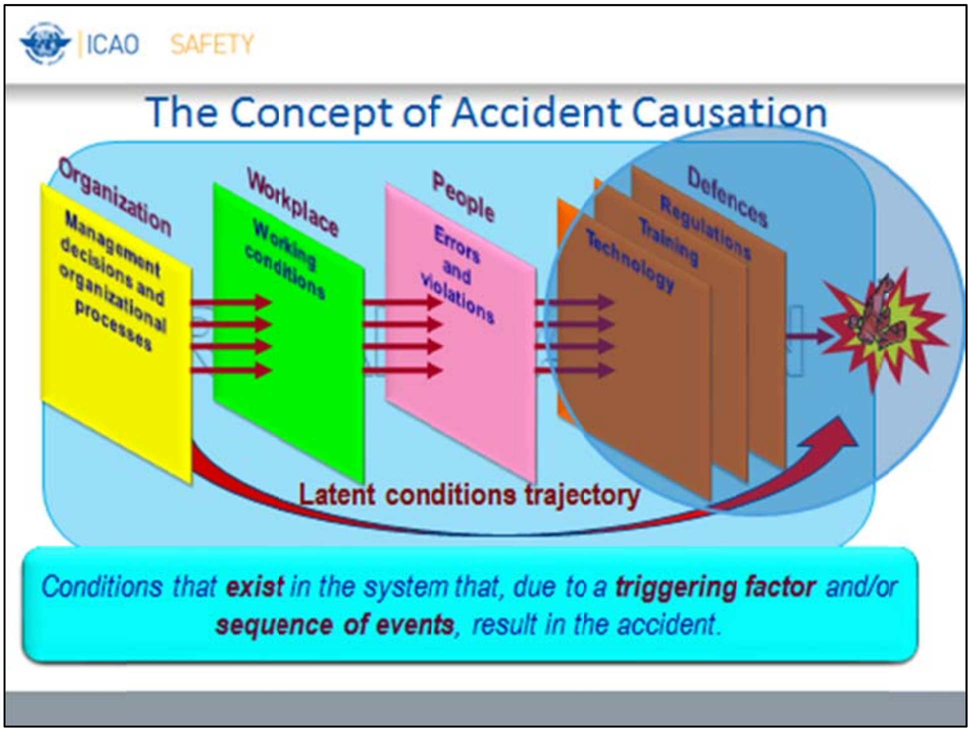
APPENDIX D

ICAO RISK MITIGATIONN PRESENTATION



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SMS Requirements in Annex 19

- "As part of its SSP, each State shall require that the following **service providers** under its authority implement an SMS"

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Service Providers Requiring SMS

- Approved training organizations
  - exposed to safety risks during the provision of services
- Aircraft and helicopter operators
  - authorized to conduct int'l commercial air transport
- Approved maintenance organizations
  - providing services to operators of aeroplanes or helicopters engaged in int'l commercial air transport
- Organizations responsible for type design or manufacture of aircraft
- Air traffic service providers
- Operators of certified aerodromes

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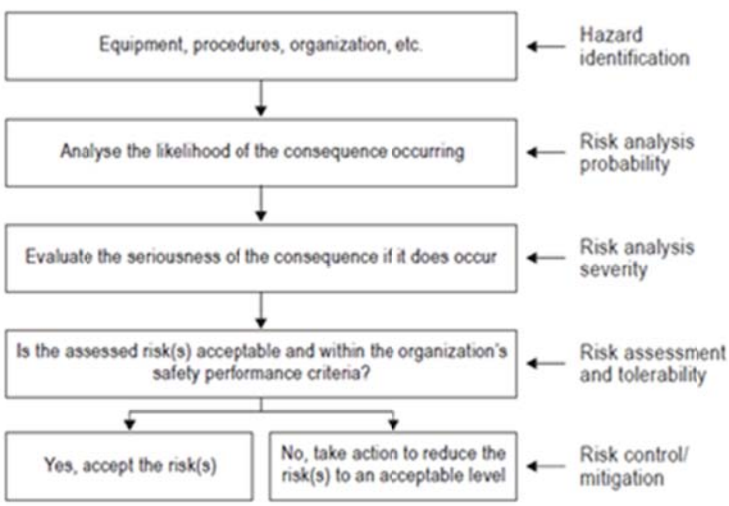
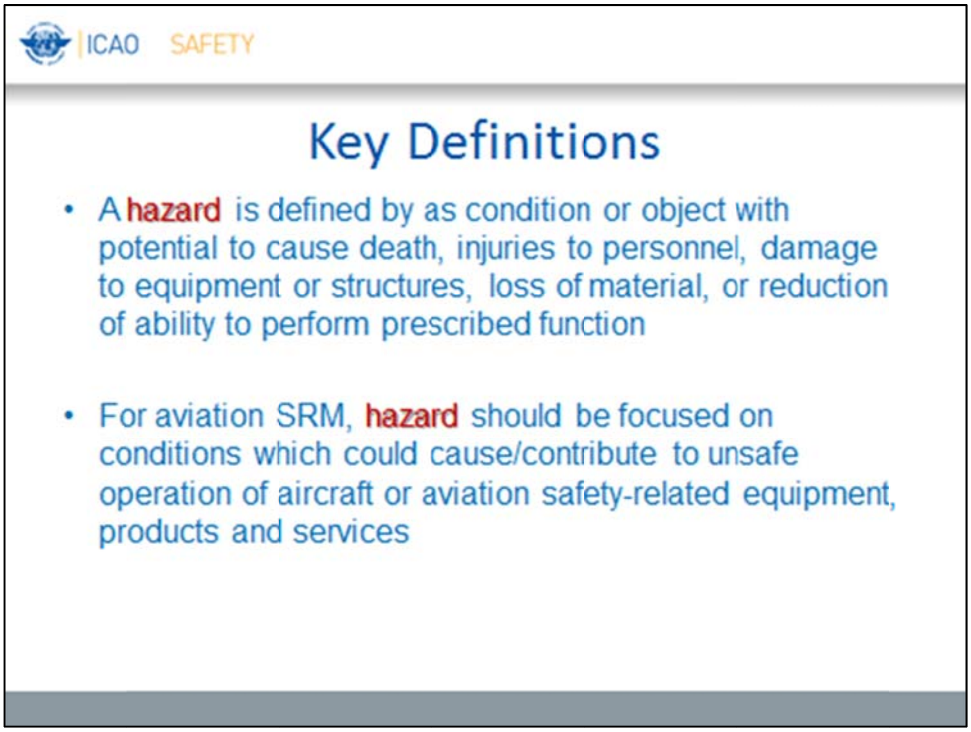
Safety Risk Management Process

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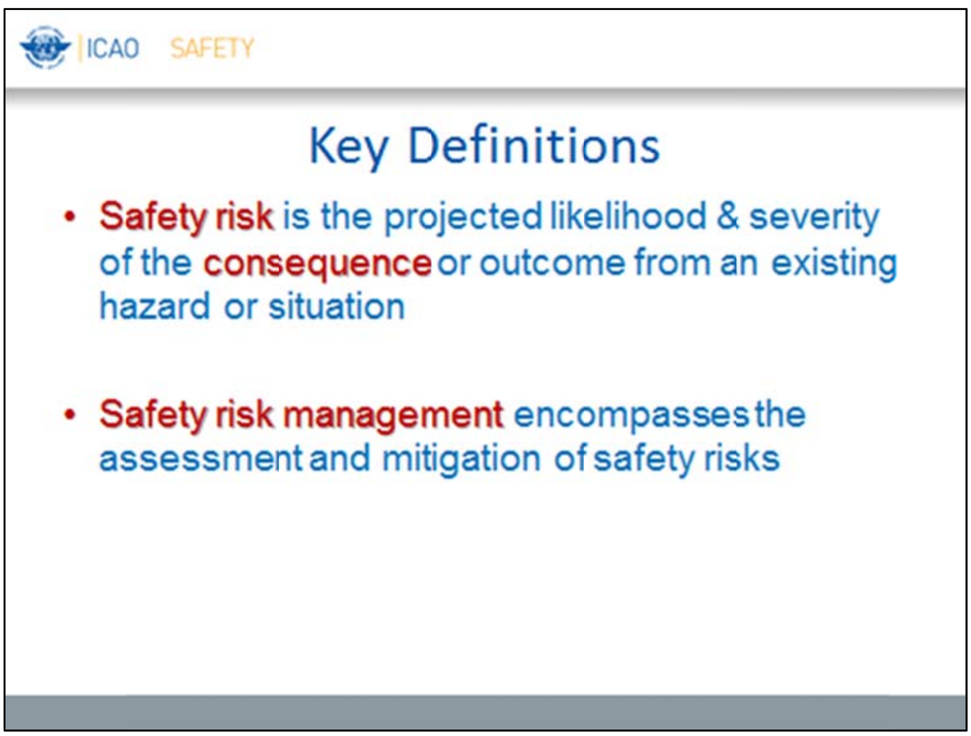
Key Definitions
• A hazard is defined by as condition or object with potential to cause death, injuries to personnel, damage to equipment or structures, loss of material, or reduction of ability to perform prescribed function
• For aviation SRM, hazard should be focused on conditions which could cause/contribute to unsafe operation of aircraft or aviation safety-related equipment, products and services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Key Definitions
• Safety risk is the projected likelihood & severity of the consequence or outcome from an existing hazard or situation
• Safety risk management encompasses the assessment and mitigation of safety risks

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Safety Risk Mitigation Tool

- ICAO developed safety risk mitigation tool
- Example of a safety risk mitigation worksheet
  - Developed in ICAO SMM, 3rd Edition
    - Chapter 2, App 2
- ICAO also developed XLS version
  - To assist in risk assessment & mitigation process

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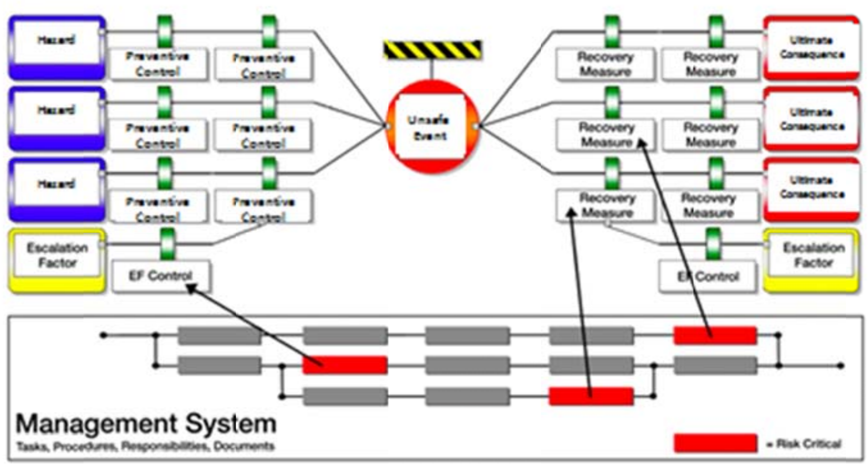
Risk Mitigation Process Overview



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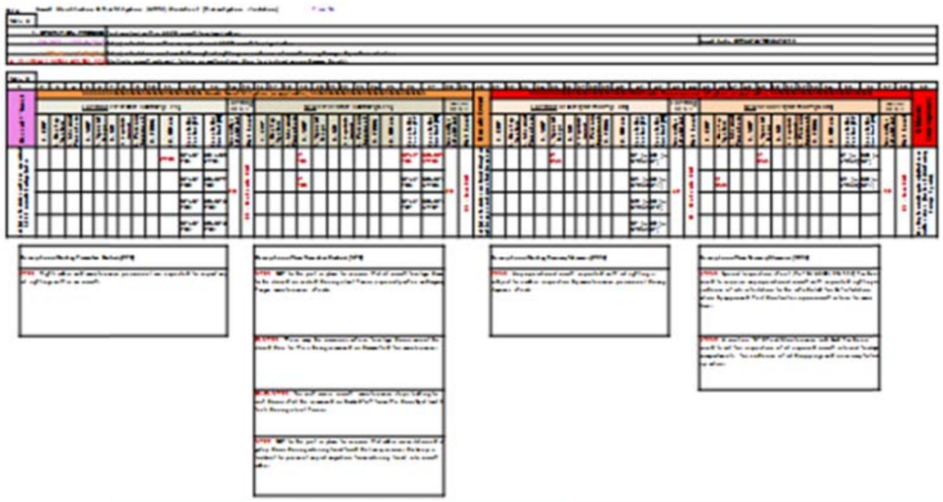
Risk Mitigation Worksheet



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Content of Worksheets

1. Working Group (Workshop) Instructions
2. Explanatory Notes/ Terminology
3. HIRM (Safety Assessment) Procedure
4. Hazard Identification & Risk Mitigation (HIRM) Worksheet (Table A & B)
5. Severity Table
6. Likelihood Table
7. Risk Index Matrix (Severity x Likelihood)
8. Risk Tolerability Table
9. Defenses (PC/RM) to Risk Index Correlation Guide
10. Safety Risk Mitigation Report (Form)
11. HIRM Master Register
12. Hazards prioritization procedure
13. Example of a completed HIRM

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Steps to Follow

1. Identify the Operation/Process to be analysed
2. Identify the **hazard**
3. Evaluate what is **ultimate consequence** from this hazard
   - possible/ most credible
4. Identify the **unsafe event** (intermediate) which can occur
   - before that ultimate consequence

**Key definitions found in Appendix 2 to Chapter 2 of ICAO SMM*

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Steps to Follow

Once we identified the hazard…

- What are the **Existing Preventive Controls** [E-PC]
  - Regulations
  - Training
  - Procedures
  - etc.
- What are the **Escalation Factor(s)** [EF] that can impede their effectiveness?
  - e.g. Non-compliance with SOPs
- What **Escalation Control(s)** [EC] are in place to prevent the EF from resulting in an unsafe event?
  - e.g. Enhanced surveillance by regulator
- Can **New Preventive Controls** [N-PC] be put in place to prevent an unsafe event?

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Steps to Follow

- If unsafe event occurs…
- What are the **Existing Recovery Measures** [E-RM] to contain it?
  - Back-up systems
  - Checklists
  - etc.
- What are the **Escalation Factor(s)** [EF] that can impede their effectiveness?
- What **Escalation Control(s)** [EC] are in place to prevent the EF from resulting in an ultimate consequence?

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Steps to Follow

- Assess Risk: *Refer to tables in Appendix 2*
  - Probability (likelihood)
    - Table Att-3.
  - Severity
    - Table Att-1.
- Use Risk Index Matrix
  - To obtain alpha-numerical index
  - Table Att-4.
- Asses Risk Tolerability
  - Table Att-5.
- Evaluate the scope of defenses to Risk Index level

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Steps to Follow

- Complete Risk Mitigation Report Form
- Update the organization's Master Hazards Register

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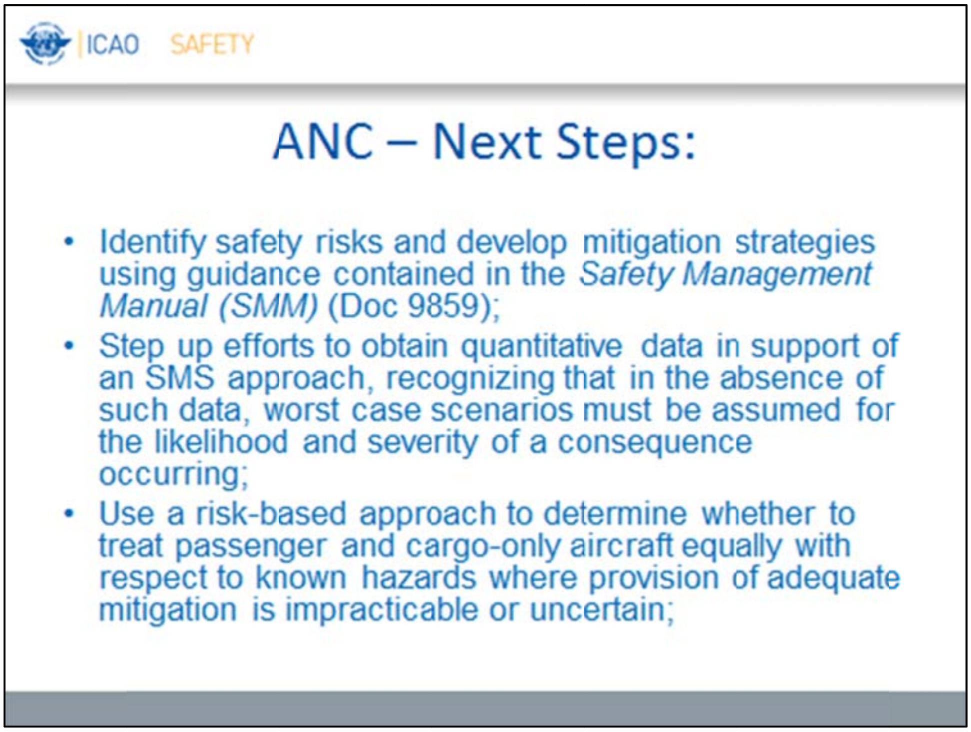
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ANC – Next Steps:
• Identify safety risks and develop mitigation strategies using guidance contained in the *Safety Management Manual (SMM)* (Doc 9859);
• Step up efforts to obtain quantitative data in support of an SMS approach, recognizing that in the absence of such data, worst case scenarios must be assumed for the likelihood and severity of a consequence occurring;
• Use a risk-based approach to determine whether to treat passenger and cargo-only aircraft equally with respect to known hazards where provision of adequate mitigation is impracticable or uncertain;


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European and North Atlantic (EUR/NAT) Office Paris
Middle East (MID) Office Cairo
Eastern and Southern African (ESAF) Office Nairobi
Asia and Pacific (APAC) Office Bangkok
Thank You

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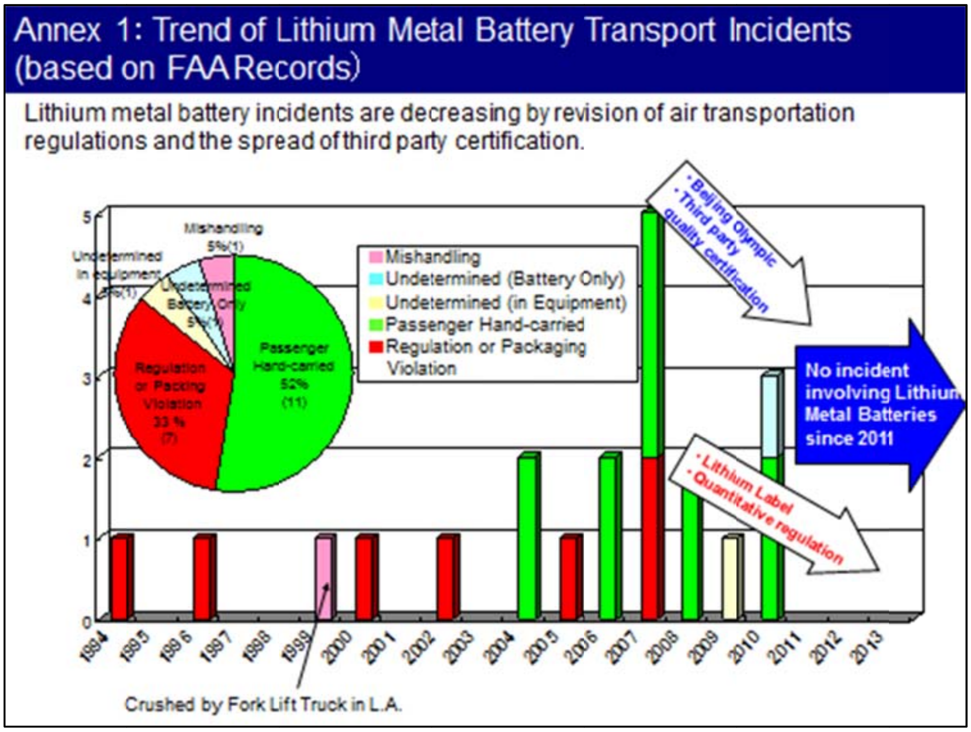
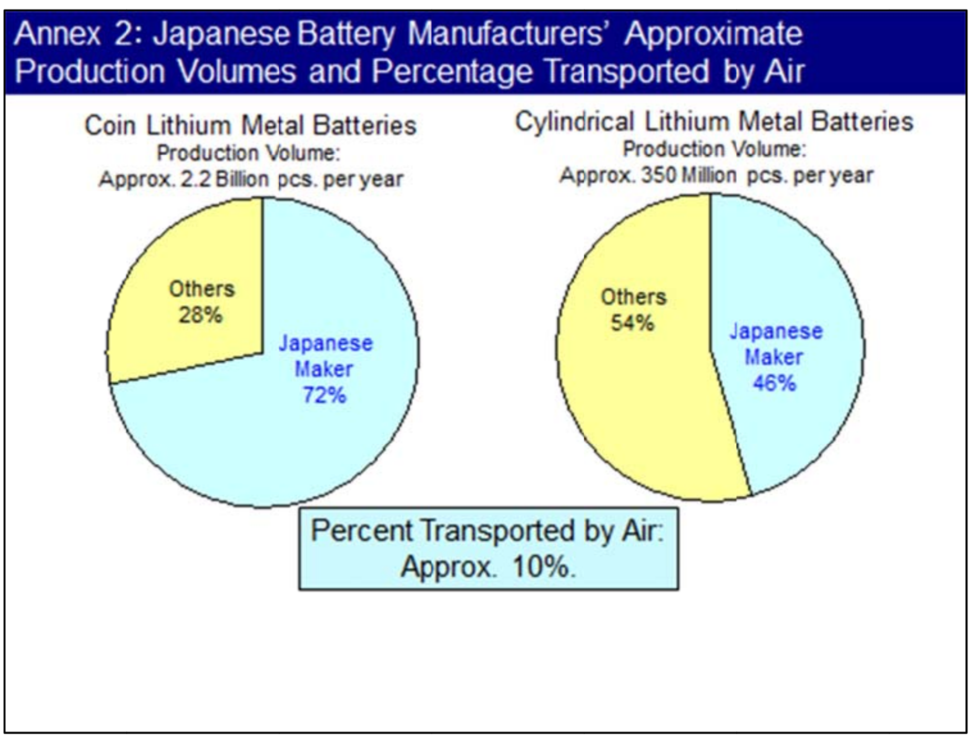
APPENDIX E

BATTERY INDUSTRY PRESENTATIONS





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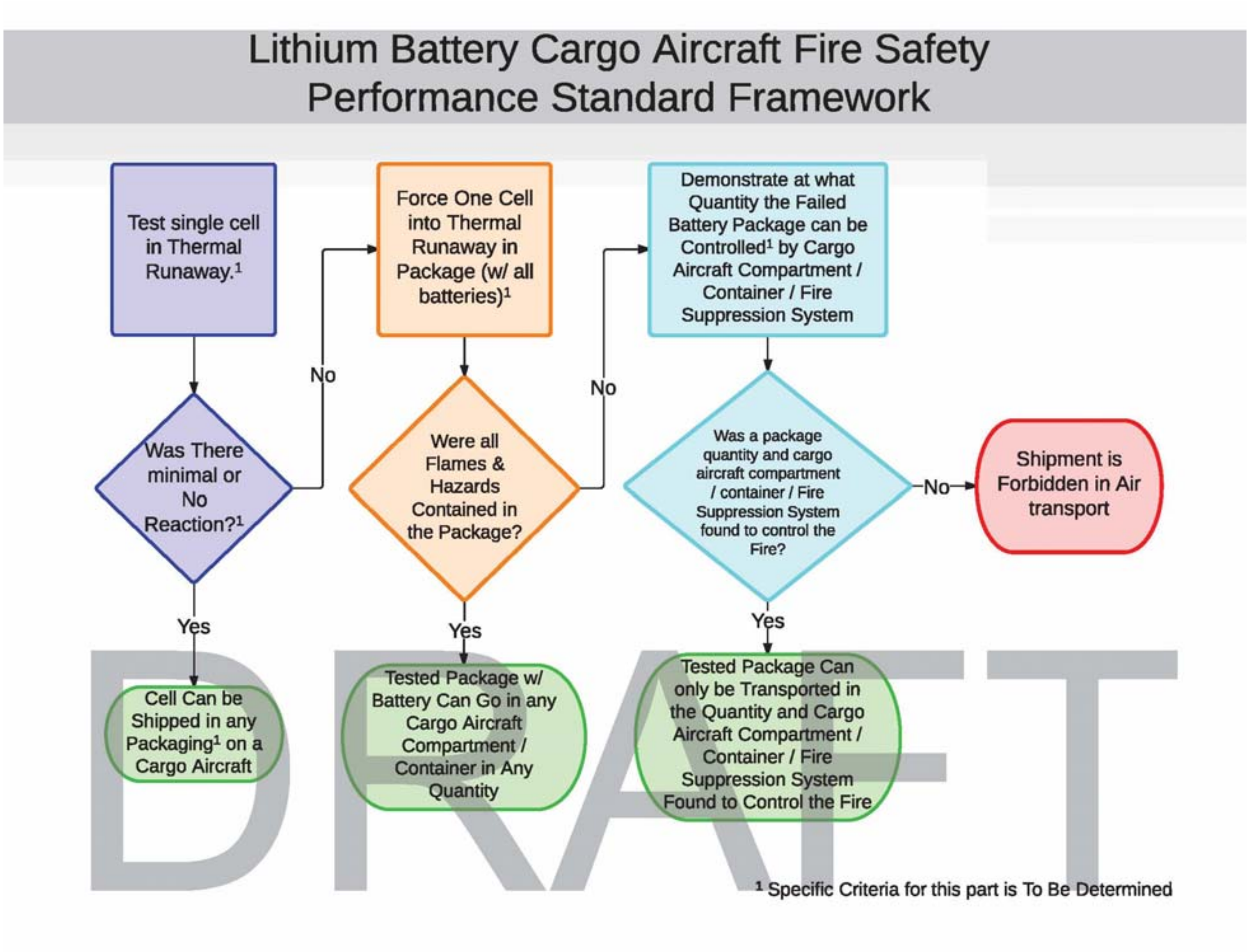
APPENDIX F

DRAFT FLOW CHART ON A PERFORMANCE-BASED APPROACH TO THE CONDITIONS OF CARRIAGE OF LITHIUM BATTERIES


Lithium Battery Cargo Aircraft Fire Safety Performance Standard Framework
Test single cell in Thermal Runaway.1
Was There minimal or No Reaction?1
Yes
No
Cell Can be Shipped in any Packaging1 on a Cargo Aircraft
Force One Cell into Thermal Runaway in Package (w/ all batteries)1
Were all Flames & Hazards Contained in the Package?
Yes
No
Tested Package w/ Battery Can Go in any Cargo Aircraft Compartment / Container in Any Quantity
Demonstrate at what Quantity the Failed Battery Package can be Controlled1 by Cargo Aircraft Compartment / Container / Fire Suppression System
Was a package quantity and cargo aircraft compartment / container / Fire Suppression System found to control the Fire?
Yes
No
Tested Package Can only be Transported in the Quantity and Cargo Aircraft Compartment / Container / Fire Suppression System Found to Control the Fire
Shipment is Forbidden in Air transport
DRAFT
1 Specific Criteria for this part is To Be Determined

— END —