SABATAIR

Deliverable D6:

Air Transport Operators Generic Safety Risk Assessment Guidance for the Safe Transport of Lithium Battery Consignments as Cargo

Task	**5**	Risk Assessment for the Air Transport of Battery Consignments

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[1] Dissemination level: **PU** = Public, **PP** = Restricted to other programme participants (including the JU), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the JU)

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Executive Summary

Lithium batteries are the preferred energy source to power a wide range of industrial and consumer goods such as mobile phones, laptop computers, cordless tools, e-bikes, electric vehicles and medical devices; stringent international regulations and standards apply to their manufacture, testing and transport. Past events highlighted the specific hazards and associated risks in the carriage of lithium batteries in air transport.

Considering the ubiquitous application of lithium batteries, the Safe Battery by Air (Sabatair) project was funded by the European Commission to provide an additional contribution to enhance safety when transporting lithium batteries on board a cargo aircraft. This guidance document has been developed to assist operators in the creation of their own safety risk assessments and is the result of collaboration with various stakeholders from the battery supply chain.

The purpose of the safety risk assessment is to identify the hazards and evaluate the associated risks, taking into account the operator's activities so that the operator can either eliminate the hazard or take a sensible, proportionate set of measures to mitigate the risks to an acceptable level. A summary of an extensive list of illustrative examples of hazards and the associated potential risks to be considered by the operator, as part of their safety risk assessment, can be found in this document. Although not all the hazards, risks and mitigating measures that are addressed in the document may be relevant for each operator, reviewing the document will certainly contribute to raising the level of awareness of the existence of certain hazards, and may give useful indications of how the associated risks may be mitigated to an acceptable level.

The primary purpose of this document is to provide guidance that operators can use in creating a specific safety risk assessment for lithium batteries when carried as cargo. When identifying specific hazards, evaluating risks and implementing appropriate safety risk controls in their operations, operators should give consideration to a multi-layered risk mitigation strategy. When risk mitigation measures are implemented, it is essential that the risk is not transferred. For example, addressing a solution to the identified problem should not generate or amplify another problem. Operators need to be aware of the complexity of the supply chain. This is particularly important for areas of the world where there is a high risk of counterfeit or poor-quality batteries entering the supply chain.

This safety risk assessment guidance does not focus on or recommend the use of a specific risk assessment model or tool. Whichever model the operator chooses, the capabilities and limitations of the model need to be taken into account, including areas such as ease of use, accessibility, analytical rigour and adaptability. It is important for operators to understand that the safety risk assessment is a living document and therefore it should be kept under constant review and scrutiny to validate its effectiveness. This regular review is paramount to ensure that the assessment is still an accurate reflection of the operator's activities despite any changes that may occur within the workplace.

Chapter I: Introduction

Lithium batteries are classified as Class 9 miscellaneous dangerous goods. Lithium batteries have the potential to go into thermal runaways caused by internal (design and manufacturing deficiencies) and external factors (e.g. short circuits, mishandling, exposure to an external heat source, etc.). The consequences of a lithium battery thermal runaway event may include dangerous heat generation, explosions with releases of fragments, releases of flammable and toxic gases, and the generation of smoke and open flames. Lithium batteries can be considered to be fire ignition sources, while also providing fuel for a fire. Therefore, specific actions need to be taken to address these risks when lithium batteries are carried as cargo in air transport.

Examples of accidents involving cargo aircraft where lithium batteries were involved, but might also have been a contributing factor, are listed below:

- February 7 2006 – DC-8, Philadelphia. A fire started during descent. The aircraft landed safely but was destroyed by the fire. The accident investigation report is available at the following link:

https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0707.pdf

- September 3 2010 – Boeing 747, Dubai. A fire started shortly after take-off. The aircraft crashed during an attempt to return to Dubai. Both flight crew were killed. The accident investigation report is available at the following link:

https://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/40/2010-2010%20-%20Final%20Report%20-%20Boeing%20747-44AF%20-%20N571UP%20-%20Report%2013%202010.pdf

- July 27 2011 – Boeing 747. A fire started shortly after take-off from Incheon, South Korea. The aircraft crashed into the sea. Both flight crew were killed. The accident investigation report is available at the following link:

https://skybrary.aero/bookshelf/books/2143.pdf

The unique hazards from fires involving lithium batteries are not considered within the current aircraft design certification standards. Test evidence has shown (DOT/FAA/TC-16/37 Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments) that the certification requirements for the fire protection systems required by CS 25.855 for Class C cargo compartments may not always have a sufficient level of rigour to protect the aircraft and its occupants from fires involving "high density" shipments of lithium batteries. "High density" means a concentration of lithium batteries which has the potential to overwhelm the cargo compartment fire protection systems in the event of a thermal runaway. The different characteristics of lithium batteries (chemistry, size, design type and state of charge), cargo compartment classifications and loading configurations make it challenging to define a specific quantity limitation applicable to each aircraft type and cargo compartment, ventilation system status and loading configuration.

On 22nd February 2016, the ICAO Council, as a result of safety concerns, adopted the recommendation of the ICAO Air Navigation Commission (ANC) that lithium ion batteries, UN

3480 Lithium Ion Batteries, Packing Instruction 965 (batteries shipped alone), be forbidden for transport on an interim basis as cargo on passenger aircraft, until controls were put in place which established an acceptable level of safety. The prohibition became effective on the 1st April 2016. UN3090 lithium metal batteries, Packing Instruction 968 (batteries shipped alone) were already forbidden for transport on passenger aircraft. The prohibition does not apply to lithium ion batteries packed with equipment or lithium ion batteries contained in equipment, UN 3481, Packing Instruction 966 and Packing Instruction 967 and lithium metal batteries packed with equipment or lithium metal batteries contained in equipment UN3091, Packing Instruction 969 and Packing Instruction 970 respectively.

A performance-based packaging standard was identified as one of the controls to help establish an acceptable level of safety. ICAO appointed SAE International to form a Committee, G-27, with the task to develop such a standard. The draft SAE AS6413 "Performance based package standard for lithium batteries as cargo on aircraft", when officially published, will provide test methods that could be used to demonstrate and document the control of the potential hazards from an event with lithium metal batteries (UN 3090) and lithium ion batteries (UN 3480) when transported as cargo on aircraft. The standard addresses the need to control the hazards which might arise from a failure (thermal runaway) of an individual cell by containing the hazards within the package. Controlling the consequences of a failure within the package is intended to prevent fires that may develop uncontrolled and explosions that may compromise the performance of fire suppression systems currently installed in cargo compartments of large aeroplanes. The same objective can be achieved by showing that a cell/battery design is benign, i.e. the thermal runaway affecting the cell will never propagate to adjacent cells or batteries transported in the same package, regardless of the design of the package itself.

The UN Sub-Committee of Experts on the Transport of Dangerous Goods have established an Informal Working Group - *Hazard-Based System for Classification of Lithium Batteries*, to develop a mechanism to establish greater granularity with respect to the classification of different battery types so that the varying risks posed by different batteries and cell chemistries can be communicated and mitigated appropriately. This may lead to additional UN numbers being assigned to lithium batteries at some point in the future.

This document will assist operators with the identification and evaluation of the risks and available mitigation measures when transporting lithium batteries (UN3090, UN3091, UN3480 and UN3481) as cargo on passenger or cargo aircraft. Additionally, other guidance material is available from ICAO (Doc 10102 AN/540 Guidance for Safe Operations Involving Aeroplane Cargo Compartments) and the IATA Lithium Battery document.

Chapter II: REGULATORY REQUIREMENTS

Lithium batteries are defined as dangerous goods by the United Nations (UN) Recommendations on the Safe Transport of Dangerous Goods for all modes of transport. Together with other requirements, it specifies the manufacturing and testing requirements the batteries must meet.

Each cell or battery must be of a type proven to meet the requirements of each test of the UN Manual of Tests and Criteria, Part III, subsection 38.3 prior to transport (exceptions may apply)[4].

Table 1: UN Manual of Tests and Criteria, Part III, subsection 38.3 tests

Test	Description	Purpose
T1	Altitude simulation	The test simulates air transport under low-pressure conditions.
T2	Thermal test	This test assesses cell and battery seal integrity and internal electrical connections. The test is conducted using rapid and extreme temperature changes.
T3	Vibration	The test simulates vibration during transport.
T4	Shock	The test assesses the robustness of cells and batteries against cumulative shock.
T5	External short circuit	The test simulates an external short circuit.
T6	Impact/crush	These tests simulate mechanical abuse from an impact or crush that may result in an internal short circuit.
T7	Overcharge	This test evaluates the ability of a rechargeable battery or a single cell rechargeable battery to withstand an overcharge condition.
T8	Forced discharge	This test evaluates the ability of a primary or a rechargeable cell to withstand a forced discharge condition.

Cells and batteries must be manufactured under a quality management program. In-house quality management programmes are accepted. Third-party certification is not required (unless required by local national legislation), but the tests must be properly recorded and traceable. A copy of the quality management programme must be made available to the appropriate national authority upon request. For more information on the UN38.3 Test requirements, see the UN Manual of Tests and Criteria Sixth revised edition:

https://www.unece.org/trans/areas-of-work/dangerous-goods/legal-instruments-and-recommendations/un-manual-of-tests-and-criteria/rev6-files.html

From 1 January 2020, manufacturers and subsequent distributors of cells or batteries and equipment powered by cells and batteries manufactured after 30 June 2003 must make available, on request, a lithium battery test summary as required by the UN Manual of Tests and Criteria,

[4] For example, see ICAO special provision A88

Revision and Amend. 1, Part III, sub-section 38.3, paragraph 38.3.5. There is no requirement for paper copies of this test summary to be provided with or to accompany each consignment containing lithium batteries. A web-link may be used to satisfy this requirement.

Table 2 provides details of the information required to be shown in the test summary.

Table 2: Lithium Cell or Battery Test Summary

Lithium cell or battery test summary in accordance with the UN Manual of Tests and Criteria, Part III, sub-section 38.3, paragraph 38.3.5
The following information shall be provided in this test summary: **(a)** Name of cell, battery, or product manufacturer, as applicable; **(b)** Cell, battery, or product manufacturer's contact information to include address, phone number, email address and website for more information; **(c)** Name of the test laboratory to include address, phone number, email address and website for more information; **(d)** A unique test report identification number; **(e)** Date of test report; **(f)** Description of cell or battery to include at a minimum: **(i)** Lithium ion or lithium metal cell or battery; **(ii)** Mass; **(iii)** Watt-hour rating, or lithium content; **(iv)** Physical description of the cell/battery; and **(v)** Model numbers. **(g)** List of tests conducted and results (i.e., pass/fail); **(h)** Reference to assembled battery testing requirements, if applicable (i.e. 38.3.3 (f) and 38.3.3 (g)); **(i)** Reference to the revised edition of the Manual of Tests and Criteria used and to amendments thereto, if any; and **(j)** Signature with name and title of signatory as an indication of the validity of information provided.

The intention of this test summary is to provide more transparency in the supply chain and to assist in verifying that batteries meet the necessary quality standards. Ultimately, it is the responsibility of the shipper to ensure all the regulatory requirements are complied with and this is confirmed by the shipper signing the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air - Dangerous Goods Transport Document / IATA Dangerous Goods Regulations - Shippers Declaration for Dangerous Goods. An operator is not expected to review the test summary as part of the required dangerous goods acceptance check, particularly as they will receive a package prepared for transport and will not be able to view or inspect the batteries inside the package. It should be noted that the safety risk assessment is intended to take a holistic approach, and there is no expectation that this document will be reviewed on a flight-by-flight or shipment-by-shipment basis.

The "Lithium Battery Test Summary" contains information that can be requested by an operator and used as part of accident or incident investigations involving lithium batteries.

Operational requirements in Europe are established by European Commission Regulation (EU) No. 965/2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (Air OPS Regulation). For the transport of dangerous goods, the Air OPS Regulation refers to International Civil Aviation Organization Doc. 9284, Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO TI), which specifies the regulatory requirements that must be met for lithium batteries in air transport, including cargo, mail and passenger baggage.

IATA has produced a comprehensive lithium battery guidance document which is available for use by shippers and operators at the following link -

http://www.iata.org/whatwedo/cargo/dgr/Documents/lithium-battery-shipping-guidelines.pdf

The International Air Transport Association Dangerous Goods Regulations (IATA DGR) reflect all of the regulatory requirements of the ICAO TI. The IATA DGR incorporates additional operational requirements, which provide a harmonized system for operators to accept and transport dangerous goods safely and efficiently[5].

The transport classification for lithium batteries are grouped into two categories based on their chemistry:

- **Lithium metal batteries** are generally considered primary (non-rechargeable) batteries that have lithium metal or lithium compounds as an anode. The most common type of lithium battery used in consumer applications uses metallic lithium as the anode and manganese dioxide as the cathode, with a lithium salt dissolved in an organic solvent. It should be noted that rechargeable lithium metal batteries are also available.
- **Lithium ion batteries** (sometimes abbreviated to Li-ion batteries) are generally considered a type of secondary (rechargeable) battery commonly used in consumer electronics. Also in the definitions for lithium ion batteries are lithium polymer batteries.

When determining the UN number and proper shipping name for lithium batteries, in addition to the battery chemistry, the configuration in which the batteries are prepared for transport is required. The options are for lithium cells or batteries shipped alone, packed with equipment or contained in equipment. There are four UN numbers and six proper shipping names, each with their own packing instruction, available to use for lithium batteries (see

Table 3):

[5] IATA DGR, Introduction, General Philosophy.

Table 3: Lithium Battery Transport Classification

UN Number	Proper Shipping Name	ICAO/IATA Packing Instruction (PI)
UN3480	Lithium ion batteries	965
UN3481	Lithium ion batteries packed with equipment	966
UN3481	Lithium ion batteries contained in equipment	967
UN3090	Lithium metal batteries	968
UN3091	Lithium metal batteries packed with equipment	969
UN3091	Lithium metal batteries contained in equipment	970

Each set of packing instructions provides detailed requirements based on the Watt hour rating for lithium ion cells/batteries, the lithium metal content for lithium metal cells/batteries and the amount/net quantity of batteries per package. Lithium ion batteries (UN3480 only) must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated capacity.

Note: *In the figures shown below (Figures 1-6), Sections I, IA and IB refer to fully regulated dangerous goods. Section II refers to exceptions which may be used to ship lithium batteries.*

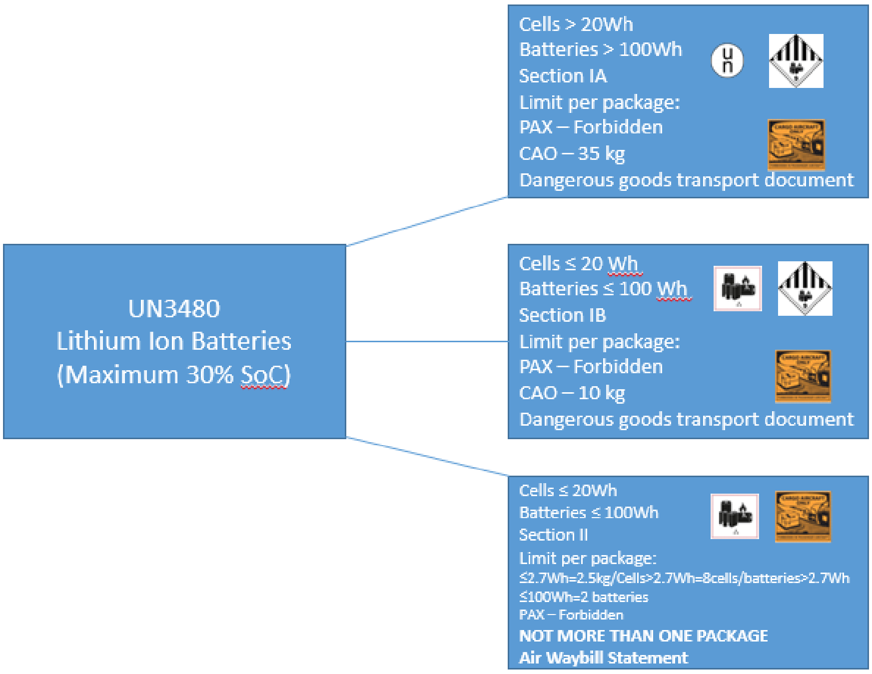

Figure 1: PI965 UN3480 Lithium Ion Batteries

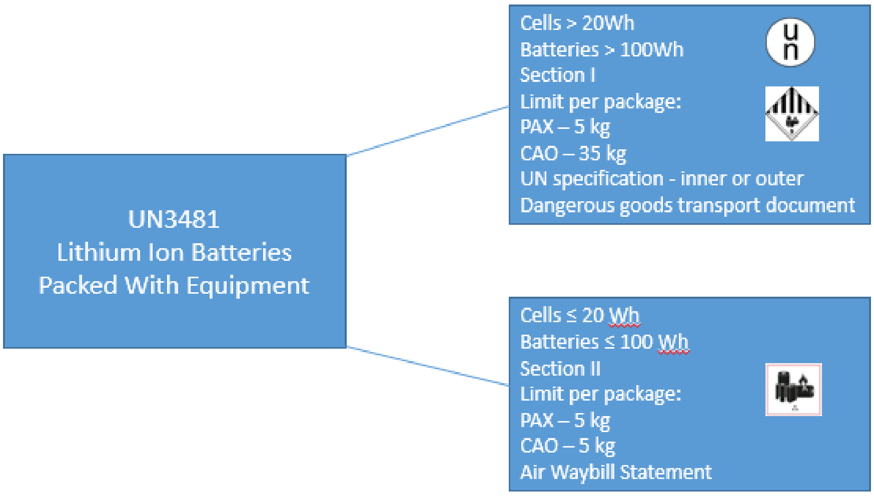

Figure 2: PI966 UN3481 Lithium Ion Batteries Packed with Equipment

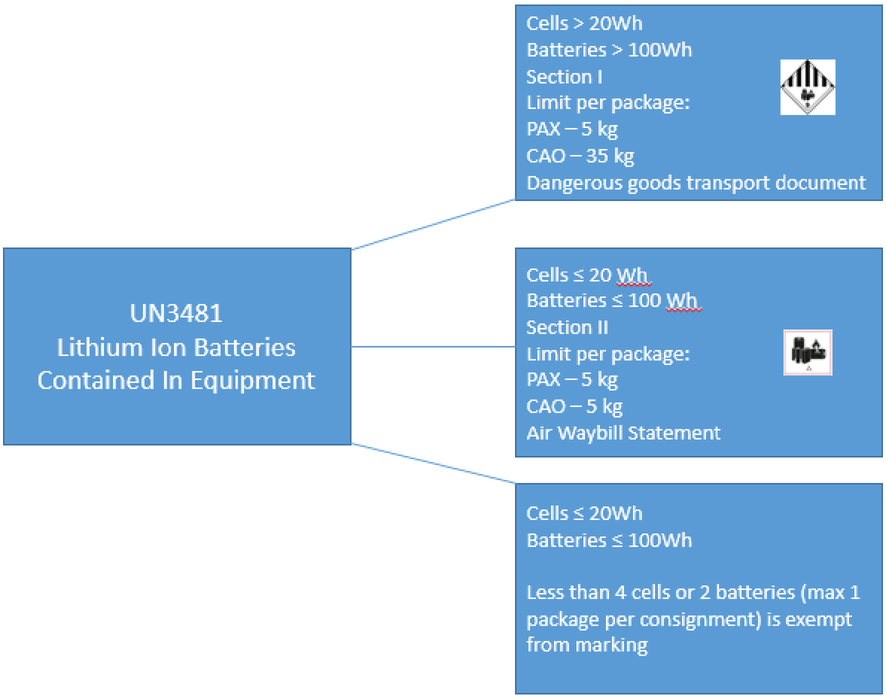

Figure 3: PI967 UN3481 Lithium Ion Batteries Contained in Equipment

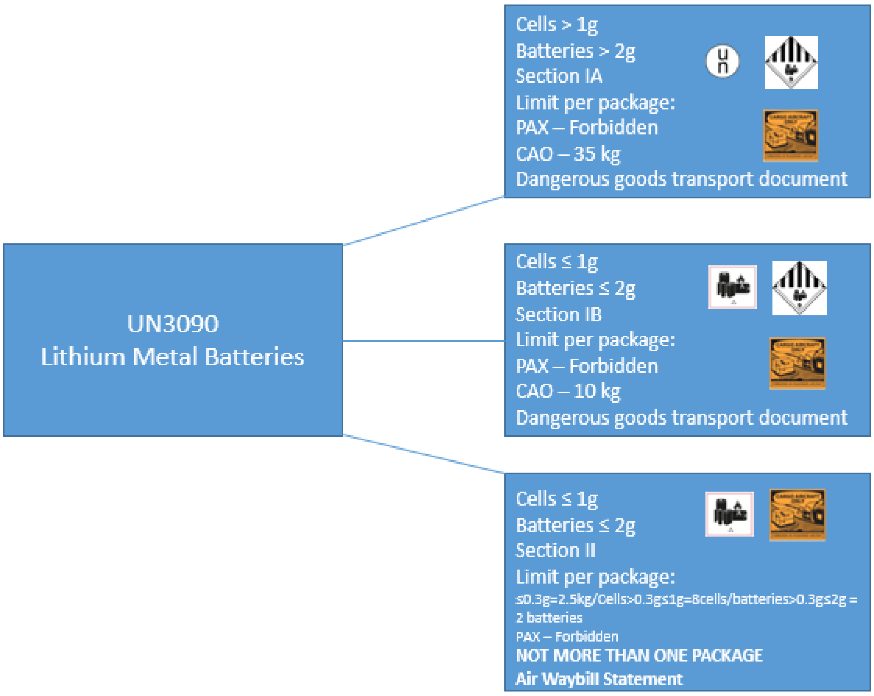

Figure 4: PI968 UN3090 Lithium Metal Batteries

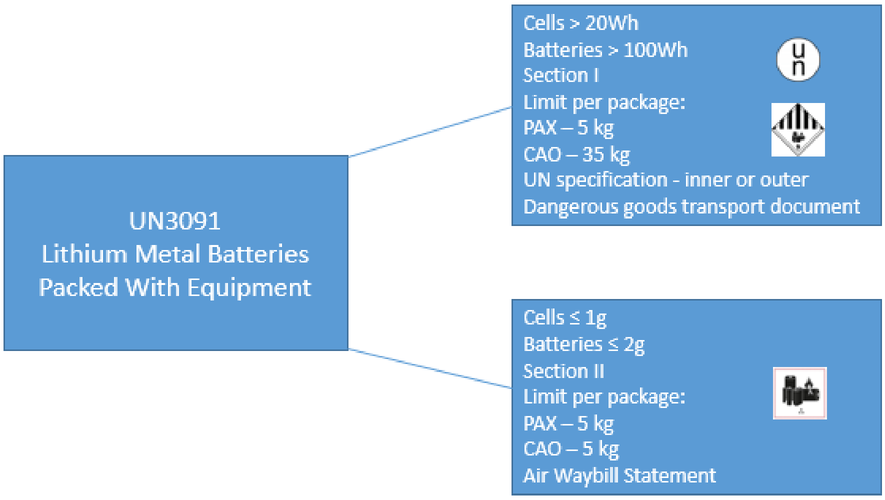

Figure 5: PI969 UN3091 Lithium Batteries Packed with Equipment

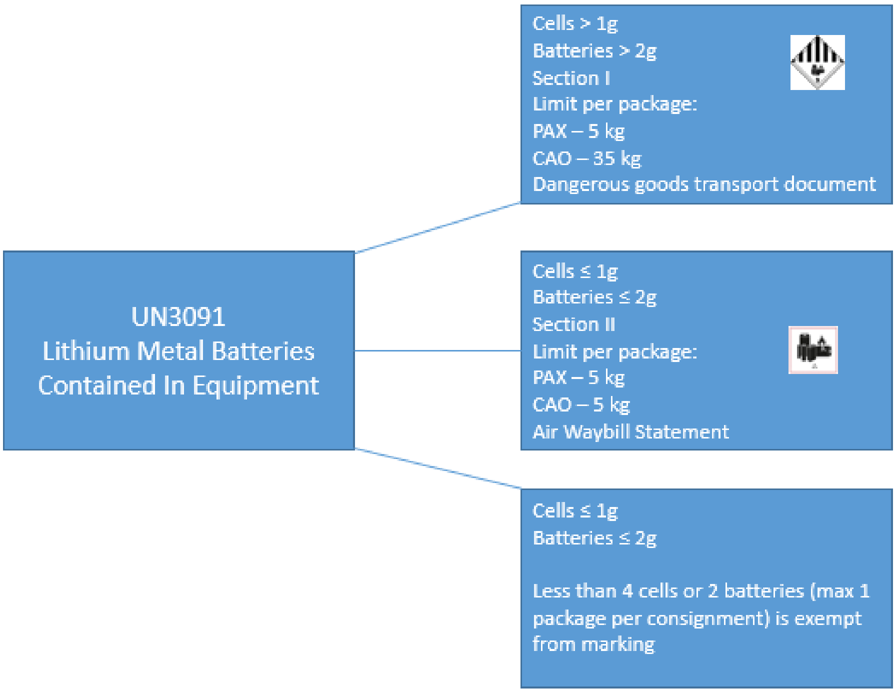

Figure 6: PI970 UN3091 Lithium Metal Batteries Contained in Equipment

Lithium batteries must be tested and manufactured under a quality management programme, classified, packed, marked, labelled and documented in accordance with the ICAO TI to meet the minimum regulatory requirements for carriage by air. States and operators can impose additional restrictions which are more restrictive than the ICAO TI. To ensure that any additional restrictions are visible to the supply chain, these should be published as variations in the ICAO TI and the IATA DGR.

In addition to the requirements referred to above, operators must comply with those regarding acceptance, handling, segregation, loading, notification to the aircraft captain and incident/accident reporting.

Chapter III: SAFETY RISK ASSESSMENT

III.1 Overview of the Safety Risk Assessment

ICAO Annex 6 requires an aircraft operator to conduct a safety risk assessment on the transport of cargo, including the transport of dangerous goods. The document provides specific guidance on the transport of lithium batteries in cargo.

The safety risk assessment is one part of safety risk management, and a key component of the operator Safety Management System (SMS). Managing and mitigating risk is a fundamental principle of an SMS, and therefore it is important that those involved in the application of an SMS in their organisation understand the difference between a hazard and the potential risk represented by that hazard. Operators may wish to have a specific safety risk assessment for lithium batteries or include it in their existing risk assessments for the general carriage of cargo.

For the purposes of this document, the terms ‘hazard’ and ‘risk’ are considered to have the following meanings:

i. **Hazard:** A condition or an object with the potential to cause or contribute to an aircraft incident or accident.
ii. **Risk:** The predicted probability and severity of the consequences or outcomes of a hazard.

Prior to conducting a safety risk assessment, aircraft operators need to identify all the known hazards and any potential hazards in their operations.

III.2 The Purpose of a Safety Risk Assessment

The purpose of the safety risk assessment is to identify the hazards and evaluate the risks taking into account the operator’s activities so that the operator can either consider removing/eliminating the hazard, or taking sensible and proportionate measures to mitigate the risks to an acceptable level. The safety risk assessment should be viewed as a living document that is regularly reviewed and updated, for example, whenever an operational change occurs, such as a new aircraft type entering service, new processes being implemented, a change to regulations, new routes being introduced, a change in the work organisation or following the evaluation of incident data.

Additional guidance on evaluating risks is given in ICAO Doc 10102, ‘Guidance for Safe Operations Involving Aeroplane Cargo Compartments’.

The safety risk assessment should be structured and applied in a way that helps the aircraft operator to:

- Identify the hazards within their activities and evaluate the risks (probability/likelihood) associated with these hazards to determine what measures are required to protect the safety of their employees, passengers and equipment, whilst considering the regulatory requirements;
- Evaluate the risks in order to select/develop appropriate mitigation measures;
- Check whether the measures in place are adequate and working;

- Determine whether further mitigation measures are necessary as a result of the safety risk assessment;
- Demonstrate that all factors in the aircraft operator's activities have been considered, that informed decisions have been made about the risks, and that the measures necessary to reduce risks to an acceptable level have been implemented;
- Ensure that the mitigation measures implemented following the safety risk assessment provide an improvement in the level of protection to the operator that is deemed to be acceptable.

As part of the aircraft operator's safety management system, the safety risk assessment should be routinely evaluated for its effectiveness (for example, through audits).

III.3 Risk Assessment Methodology

This safety risk assessment guidance does not focus on a specific risk assessment model. There are a variety of methodologies available for achieving the same objective. Some examples include:

- Bow-tie Analysis;
- Event Trees;
- Fishbone Diagrams;
- Barrier Based Models:
- Systems Theoretic Process Analysis (STPA)[6];
- Hazard and Operability Study (HAZOP);
- ARMS Event Risk Classification; and
- Safety Issue Risk Assessment.

Whichever model the operator chooses, they should carefully consider the capabilities and limitations that this may have on their assessment capabilities, including areas such as ease of use, accessibility, analytical rigour and adaptability.

For example, "Bow-tie Analysis" is a common risk assessment method used by operators. This method combines hazards into a risk framework to guide risk mitigation. It does, however, require identified hazards, causes and outcomes to be known and entered into the model. The Hazard and Operability Study "HAZOP" method is focussed on hazard identification, risk evaluation and risk mitigation.

Different risk assessment models can be used together. The operator may wish to choose a different risk assessment method from the one used for their other operational activities.

Consideration also needs to be given to the identification of risk inducing conditions, where potential risks are identified, i.e. predictive risk management. Predictive risk management is an attempt to account for hazards and risks that can potentially occur in a given situation.

[6] https://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf

The safety risk assessment should be structured to ensure that all the relevant hazards and risks are addressed.

When a risk is identified, an assessment of the risk should take place to see whether it can be eliminated or mitigated.

The operator may wish to produce a generic safety risk assessment reflecting the common hazards and risks identified. This can be used as a basis for safety risk assessments conducted at multiple locations where the operator conducts activities following the same processes and procedures. The local safety risk assessment should be adapted to take account of any additional hazards not already referenced in the generic safety risk assessment, and should include details of any additional mitigation measures identified.

III.4 Safety Risk Assessment Team

In accordance with the operator's SMS, persons responsible for the SMS must be appointed by the operator. The safety risk assessment should be undertaken by the management of the operator in consultation with those involved in the day-to-day operational environment, including those employees with specific responsibilities and competencies for the handling of dangerous goods and incidents. It is also important to ensure that any conclusions from the safety risk assessment and the risk mitigation measures implemented are provided to the safety risk assessment team and air operator management. Any identified mitigation measures, for example, revised procedures, enhanced training or the use of specified equipment should be communicated and implemented as deemed appropriate.

The safety risk assessment needs to take account of other businesses associated with the operator, such as the use of sub-contractors or other third parties, maintenance staff, ground handling agents, engineers, or staff of wet-lease operators.

III.5 Data Analysis

Analyses of data from internal and external incidents, accidents and occurrence reports, reports of "near miss" accidents, investigation outputs, internal and external audit reports and quality reports can be used as part of the safety risk assessment. This data may help detect risk exposure (hazards and hazard exposure and the changes in both) and help to establish proper risk management.

The free flow of safety data and information is critical to the success of the operator's safety management system. Operators should be encouraged to exchange safety data and information with industry and national competent authorities.

The data needs to be analysed to look for specific trends which may highlight unforeseen risks within the operation, and to avoid complacency if no accidents occur. The absence of accidents is not necessarily an indication that the safety risk assessment is working, and the operator should establish a culture to report "near miss accidents".

Chapter IV: DANGEROUS GOODS TRAINING AND PROCEDURES

All operators must provide training on dangerous goods to their employees, and establish adequate procedures. These must be approved by the competent authority in accordance with the Air OPS, the ICAO TI and Chapter 14 of Annex 6 to the Chicago Convention.

As a minimum, operators who do not hold approvals to transport dangerous goods must provide training that allows staff to recognize undeclared shipments. Undeclared dangerous goods, including lithium batteries, pose a significant risk to flight safety. These may be items that are either unintentionally or incorrectly prepared by the shipper for transport, or by shippers seeking to deliberately hide shipments so as to bypass regulatory requirements (for example by offering forbidden lithium batteries shipped alone to a passenger operator), airline restrictions and/or to avoid dangerous goods surcharges. For undeclared dangerous goods accepted by the operator, there will be an unknown type, quantity and quality of dangerous goods packages loaded as cargo.

The operator must also establish a procedure for when undeclared and/or misdeclared shipments are found. An operator must report any occasion when undeclared or misdeclared dangerous goods are discovered in cargo or mail. Such a report must be made to the appropriate authorities of the state of the operator and the state in which this occurred.

All the mitigating measures used to assist in the detection of undeclared dangerous goods, for example, security screening and cargo documentation reviews, need to be taken into consideration when preparing the risk assessment. These measures are further discussed in Chapter 7 of this document.

IV.1 Occurrence Reporting

Operators must establish procedures to allow the reporting of accidents, incidents and all other occurrences, and should train their staff accordingly. A guilt-free reporting culture must be established to avoid important information being hidden because of the fear of the consequences. The level of reporting should also be established to avoid any unnecessary excessive accumulation of information. Means to discriminate irrelevant information need also to be considered during reporting and data analysis; training on what constitutes relevant information should be given to appropriate employees.

Occurrence reporting is one of the safety tools that enables the management of safety for aviation organisations and states. Experience has shown that accidents are often preceded by safety-related incidents and deficiencies, thereby revealing the existence of safety hazards. Therefore, safety data is an important leading indicator for the detection of potential safety hazards. In addition, whilst the ability to learn from an accident is crucial, purely reactive systems have been found to be of limited use in bringing forward safety improvements.

Reactive safety risk management tends to deal with issues as they arise, whereas proactive safety risk management generally deals with issues before they come up by using reported issues and historical patterns to make decisions on risk mitigation based on anticipation.

The operator must provide clear instructions, information and training for their employees, commensurate with their responsibilities. The competence of the employees should also be assessed on an ongoing basis. Contractors and third-party organisations, who may be employed directly or indirectly by the operator, should also be considered. All relevant persons must be provided with key information from the risk assessment such as:

- Hazards and risks they may face;
- Guidance on detection procedures ;
- Measures in place to deal with those hazards and risks; and
- How to follow any emergency procedures.

The operator's training and procedures should be reviewed on a regular basis.

IV.2 Lithium Battery Emergency Procedures

Emergency procedures are an essential part of an operator's SMS. These procedures should be reviewed not only as part of the operator's SMS, but also as part of the lithium battery safety risk assessment process so as to ensure that all foreseeable situations are considered as part of the organisation's emergency planning.

Specific emergency procedures are required for incidents involving lithium batteries. Operators shall develop such procedures, tailoring them to their operations. Quick and effective actions may help to reduce the consequences of an incident. However, applying an emergency procedure in the wrong manner or applying inappropriate emergency procedures may exacerbate the situation, and result in catastrophic consequences. Employees are more likely to respond to an emergency situation effectively if they:

- Are trained and competent;
- Take part in regular and realistic practice sessions;
- Have clearly agreed, recorded, and rehearsed plans, actions and responsibilities.

Operators should ensure that the above-mentioned points are observed.

Chapter V: IDENTIFY THE HAZARDS

The purpose of this chapter is to identify the hazards posed by lithium batteries.

The hazards that a lithium battery can exhibit can be separated into either non-energetic or energetic categories:

Non-energetic hazards include (flammable) electrolyte leakage and the venting of gases. These can affect the physical and electrical properties of the battery (e.g. loss of capacity, increased impedance, or degradation of battery components). While non-energetic hazards do not directly exhibit an aggressive effect (e.g. heat, fire, thermal runaway or explosion), they have the potential to lead to energetic hazards if not controlled correctly.

Electrolyte leakage can negatively affect human health, and has the potential to create energetic hazards when the electrolyte is flammable. The same applies for the venting of gases. Gases from a lithium battery can be ignited by an external heat source, which can lead to energetic hazards such as thermal runaways. Electrolyte or gas leakage can result from mechanical, thermal or electrical abuse of a cell or battery, or from failure due to internal defaults.

Energetic hazards are directly related to cell/battery thermal runaways. A thermal runaway is a type of uncontrolled positive feedback, where an increase in temperature changes the conditions of the cell/battery such that there are further temperature rises, leading to a destructive result. A thermal runaway can occur in almost any kind of battery chemistry, as long as the rate of heat generation of the battery is larger than the rate of heat dissipation. The severity depends on many factors. It is mainly related to the amount of energy stored in the battery, categorised as the state of charge (SOC) of the battery. A thermal runaway is also affected by the type of chemistry the battery is based on, the heat transfer, and the temperature of the surrounding environment during a thermal event. A substantial hazard that can result from a lithium battery thermal runaway event is the production of a large quantity of flammable gas, which has the potential to collect and ignite, resulting in a significant overpressure/explosive event. The causes for such thermal events are either internal short-circuits, related to internal faults, or external abuse (mechanical, thermal or electrical abuse of a cell or battery).

Thermal abuse is caused by increasing the temperature of the battery until some type of non--energetic failure is achieved which could lead to a thermal runaway, or a thermal runaway is initiated inside the cell/battery. As the thermal robustness of lithium battery chemistries has to be verified to comply with the UN 38.3 tests, the temperature has to exceed 70°C. Electrical abuse includes abuses such as over-charging, over-discharging, external short circuits, fast charging and improper use of the battery that is different from the use intended by the manufacturer. Mechanical abuse occurs when a battery cell is exposed to external or internal structural changes which can lead to shorting circuits between cell electrodes, leading to localized cell heating that propagates to the entire cell, causing a thermal runaway.

Consideration also needs to be given to batteries installed in or packed with equipment when shipped as cargo. Although these packages will contain batteries packed with less density than batteries shipped alone, the provisions for UN3481 allow lithium ion batteries to be shipped at a state of charge up to 100% of the rated capacity.

Passenger baggage may contain items of dangerous goods, such as portable electronic devices containing lithium batteries and toiletry aerosols, such as hairsprays or deodorants. Spare lithium batteries and e-cigarettes are prohibited from checked baggage, and must be carried in carry-on baggage only. Consideration needs to be given in case carry-on baggage is required to be gate checked. Confirmation must be sought from the passenger that no spare batteries or e-cigarettes are contained in checked baggage.

Passengers whose mobility is restricted by either a disability, their health or age, or a temporary mobility problem (e.g. a broken leg) are permitted to travel with battery-powered mobility aids under certain conditions. This permits removed lithium ion batteries up to 300 Wh to be carried in the cabin of a passenger aircraft. There is no limit to the Wh rating for lithium battery powered mobility aids when the battery is not removed from the device. It is important for operators to consider passenger baggage and battery-powered mobility aids when conducting their safety risk assessments.

Undeclared dangerous goods, including lithium batteries, may pose a significant hazard, as these may be manufactured, classified, packed, marked or labelled incorrectly or not at all. It is important for operators to consider the risks posed by undeclared lithium batteries contained in cargo, baggage or mail offered for transport when conducting their safety risk assessments.

provides a non-exhaustive list of potential sources and triggers for thermal runaways in lithium batteries. The batteries offered for transport must be tested for mechanical robustness according to the UN38.3 Tests, but abuses that exceed the tested criteria may result in thermal runaways.

Most lithium batteries are manufactured with safety mechanisms that help to control energetic and non-energetic hazards. These mechanisms always include safety features to help to vent gases without excessively increasing the internal pressure, and may include thermal fuses to cut the current if a specified high temperature is attained, Current Interrupt Devices (CIDs) when an unsuitable high current is detected, or Temperature Coefficient Devices (PTC) which increase the resistance of a battery with a high detected temperature. Additionally, lithium batteries may have a separator, which, under a high temperature, melts and softens. This closes the microspores in the separator film and restricts the movement of ions between the anode and cathode, thus stopping the chemical reaction and electrical production[7].

[7] SABATAIR D1b – Hazard identification and characterisation

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Table 4: Internal and External Causes for Thermal Runaway in Lithium Batteries

Categories	**Sources**	**Triggers**	**Additional failures**
Poor cell design Manufacturing defects	Internal short circuit Lithium plating Dendrite formation Anode-electrolyte exothermic reactions	High current rate Cell internal heating	

Battery chemistry	Decomposition of SEI Decomposition of electrolyte Uncontrolled intercalation	Exceeding Voltage limits	
Thermal abuse	Plane fumes Fire from dangerous goods Cabin baggage origin fire Plane electrical origin fire Fuel origin fire Uncontrolled ambient temperature	Cell external heating Propagation of fire Melting of safety devices	Capacity loss Increase impedance/resistance Separator shutdown Separator degradation Fuse shutdown Electrolyte leakage Disabled CID, PTC Swelling
Electrical abuse	Improper connection with application Improper personnel handling Improper storage in cargo Airplane movement Improper container Fast charging	Over discharge Overcharge Battery tabs contact SoC beyond safety limits	
Mechanical abuse	Debris from airplane Improper personnel handling Improper storage in cargo Airplane movement Adjustment working systems Improper container	Puncture Drop Vibration	

Chapter VI: EVALUATE THE RISKS

For each hazard identified by following the guidance outlined in Chapter 5, the severity of its consequences or outcomes (risks) needs to be evaluated. At the same time, it needs to be estimated how probable it is that the hazard will occur. When considering the risks, these should be mitigated "to an acceptable level" - This means balancing the acceptable level of risk against the consequences of the measures needed to mitigate the risks (e.g. their cost, time and difficulty). It is not always necessary to take an action if its consequences would be grossly disproportionate to the level of risk. Safety risks are conceptually assessed as acceptable, tolerable or intolerable. Safety risks that are assessed as initially falling into the intolerable region are unacceptable under any circumstances. The probability and/or severity of the consequences of these hazards are of such a magnitude, and the damaging potential of the hazard poses such a threat to safety, that mitigation action is required or activities are stopped[8].

The operator should give consideration to the key stakeholders in the supply chain when conducting the safety risk assessment. These include the packer, shipper, freight forwarder and previous operator (for multi-segment consignments). Each point in the supply chain has a potential for mistakes to be made which could lead to an event affecting aviation safety. These include potential damage to the package, deliberately or unintentionally offering undeclared lithium batteries as cargo without a declaration, and improper classification, marking, labelling or documentation.

The safety risk assessment should only include what the operator could reasonably be expected to know. The operator should:

- Assess all the identified hazards and select all those that may affect the safety of their operation.
- Assess their current processes and procedures (including any mitigation measures) for effectiveness.
- Consider whether the hazard can be eliminated.
- If not, establish new measures to control/mitigate the risks to an acceptable level.
- Establish a system to detect changes and new hazards and risks to evaluate and modify the safety risk assessment.

An extensive list of illustrative examples of hazards and associated potential risks to be considered by the operator as part of their safety risk assessment can be found in the SABATAIR deliverable D5 – Baseline Air Transport Operators Generic Risk Assessment Guidance (See **Annex A**). A summary of this document can be found in

[8] ICAO Doc 10102 AN/540 Guidance for Safe Operations Involving Aeroplane Cargo Compartments

Table 5 below. Although not all the hazards, risks and mitigating measures that are addressed in the document may be relevant for each operator, reviewing the document will certainly contribute to raising the level of awareness of the existence of certain hazards, and may give useful indications of how the associated risks may be mitigated to an acceptable level. While the document is not prescriptive in nature, it provides a set of available options that can be used as a basis by operators to develop their overall risk management strategies and to identify the combination of mitigating measures that are essential to support an effective safety risk assessment.

Table 5: Summary of SABATAIR Risk Assessment for the Air Transport of Battery Consignments Workshop Held in Brussels 6th to 7th June 2019.

Questions	Responses
When designing a cell, does the manufacturer consider the hazards of the chemistry chosen and the potential risks this may pose in the supply chain?	• Batteries are designed for a specific purpose. • Manufacturers only work with the classification system. •Not generally considered for transport but consider final use. • UN 38.3 tests are mandatory. The operator and other stakeholder in the supply chain can request a copy of the UN38.3 Test Summary from the manufacturer or subsequent distributor. • It the batteries are counterfeit, the manufacturer will have no concern for any of the regulatory requirements.
Do cell, battery and device manufacturers consider the implications in transport for the return of batteries/devices containing batteries subject to recalls or warranty returns (whether specifically related to the cell/battery or the device)?	• Really need to know the reason for the recall – Not all reasons for a recall are safety related. For example, a battery that does not charge does not necessarily indicate this is a safety issue. • Consideration needs to be given as to where the batteries are being shipped from and by whom (e.g. members of the public or by companies). • There were comments that the regulations make it clear that batteries recalled for safety reasons are forbidden in air transport
As a mitigation measure to consider for the transport of freshly manufactured cells, a minimum 'wait-and-see' latency period could be defined of at least several days between the conclusion of the formation cycling and carriage by air to allow for the emergence of cell heating, possibly leading to thermal runaway. Is this a practical proposition?	• Having a latency period is standard practice for battery manufacturers, who must operate under a quality management system. • To implement this would require a change in transport regulations. • Currently the UN38.3 Tests are deemed to be sufficient.

UN3480 ithium ion batteries shipped alone must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated capacity. Is there confidence that this requirement is always complied with?	• The signature on the dangerous goods transport document is confirmation that all the applicable transport requirements have been met. • There has to be an element of trust within the supply chain. • If there is an incident with a lithium battery shipment, the regulator would check for compliance with the 30% SoC requirement as part of the investigation. • It was agreed that the risk mitigation document would be considered a living document and could be reviewed if incident data concluded that this was a particular area requiring further risk mitigation measures.
The shipper may not be the packer, for example, a ‘pick and pack’ operation. How would the shipper verify that the packages are packed correctly?	• All tasks prior to handing over to the operator are considered as the responsibility of the shipper. • Traceability of the supply chain for batteries is the responsibility of the shipper. • If roles and responsibilities are contracted out, these should be covered by internal legal documents.
What documents and/or records would you expect to see to verify that the packing and shipping process is full compliance with ICAO/IATA?	• Nothing expected in addition to what is required in the ICAO Technical Instructions. • The new UN38.3 Test Summary Document may be requested by some operators, but there is no expectation for this to be provided for all lithium battery shipments.
If prepared packages are placed in storage prior to shipping, should any considerations be given to the storage conditions?	• No support to change the current process as the UN38.3 and Technical Instructions already mention normal conditions of transport with large temperature range. • High temperatures in certain countries may be taken into consideration, but the storage time in extremes would also need to be taken into account.
What package and documentation checks, if any, would the freight forwarder be expected to conduct prior to handing over lithium battery shipments to the operator/Ground Handling Agent?	• It is expected that anyone offering lithium batteries for transport should do a full check of package labelling and marking as well as documentation check.

	• They should conduct an IATA pre-acceptance dangerous goods check on shipments. Since the freight forwarder my not physically handle shipments, it may only be possible to check documentation.
As part of a booking process, what needs to be considered by the operator as part of their risk assessment process?	• Most operators have a booking process, but the information requested will vary by airline. • Depends on findings of safety risk assessment. • Look for training records – do they have certified staff? • With automated bookings, need to consider generic entries which could be an indicator of hidden/undeclared dangerous goods.
What consideration is given when the origin of the shipment may not be the country at the start of the supply chain (e.g. China-Hong Kong) and how is this assessed?	• Operators should consider lanes that are high risk • How do you identify? Hong Kong may show origin Hong Kong, but is actually China. • The risk assessment should be data driven – dangerous goods origin, incident data etc. • Shared data from airlines would be beneficial via IATA – generic de-identified. • Incidents from ramp and/or warehouse will not be reported by flight crew, so still a gap.
Are additional restrictions imposed by the operator? How are these decisions taken and how is this managed within the operation?	• Accident/incident reports and data is a key trigger for any restrictions. • Concerns over visibility of Section II packages. • Safety letters from aircraft manufacturers. • Driven by airline partners if part of an alliance. • Some operators more risk averse. • A lot is based on perception.
What potential challenges do you envisage with the new requirement for the battery manufacturer or subsequent distributor to provide the UN38.3 Test Summary?	• This a change requested by the battery industry to increase transparency and increase quality. Other parts of the supply chain can also benefit from this new requirement. • The operator has no idea who the cell or battery manufacturer is, therefore, what would be the benefit of the operator requiring the summary document as a blanket policy?

	• The shipper is ultimately responsible for compliance with the UN38.3 Test requirements and they are best positioned to verify the accuracy of the summary document. • The safety risk assessment should be looking at the entire operation and not be focussed on a shipment by shipment basis. • This could form part of the initial approval process.
What challenges are there to increase the detection rate during security screening and how is this process covered in the operator risk assessment?	• There is little engagement as the primary focus is for security screening is the detection of improvised explosive devices and explosives. • Regulators, including ICAO, have a focus on security requirements and not dangerous goods. • Dangerous goods training for security screeners is important and required, but there is resistance to this and not enforced. • Much of the security screening is sub-contracted or conducted by local airport employees – no direct influence by the individual operators. • New technology is available, but this is not mandated and is expensive.
What controls are in place to identify shippers deliberately offering lithium batteries without declaring them (to avoid cost or to enable carriage on an otherwise restricted route/carrier)?	• Tends to be retrospective action. • Can suspend account, but shipper may then use another carrier or change their name. • Can investigate and visit customer premises. • This is reactive. • Reporting is key! • An IATA incident information sharing scheme was agreed at their Annual General Meeting to allow for information sharing of incidents between operators. IATA will provide further details when available.
Is consideration given to mail that may be consolidated and shipped as cargo, potentially with an unknown origin?	• Concerns raised that some Civil Aviation Authorities have no oversight of their Designated Postal Operator. • Tend to be seasonal variations.

	• The route for much of e-commerce, in particular business to customer and reseller hosting sites. • E-commerce presents additional challenges.
How are cultural tolerances to counterfeit goods, in certain parts of the world, considered?	• Maybe the location is unknown – E-commerce is almost borderless. • Could target particular lanes or routes and use incident data to build a picture – Is there an expectation each operator would do this
If Fire Resistant Covers or Fire Containment Covers are just used for lithium battery shipments, what mitigation is used for potential undeclared lithium battery shipments?	• Some operators are moving towards full fleet implementation of Fire-Resistant Containers on certain lanes. • One operator is trialling a Fire Containment bag. • The current standard for Fire Resistant Container covers only class A fires for covers (not Unit Load Devices). • There are potential accessibility requirements if the Unit Load Device is Cargo Aircraft Only (CAO) in position 1 on the aircraft. • What is the certification standard? • Can it be used in a Class C compartment? • Some operators do not use as there is no standard. • Fire Containment Covers can be more susceptible to operational damage. • What does the operator do if there is no equipment available? • Complexity and potential conflict with other aircraft systems. • Unknown implications of using in a Class C cargo compartment (possible delayed fire/smoke detection).

One example of the risks that an operator may need to consider, as part of their safety risk assessment, is identifying the origin of shipments being carried on their aircraft. Operators flying from locations where it is known that there is a higher risk of counterfeit shipments, unbranded, poor quality or undeclared shipments, and/or that have a higher volume of shipments of lithium batteries, should take the associated risks into consideration and ensure that appropriate mitigation measures are implemented. For example: using fire resistant containers/fire containment covers for all cargo, not just for lithium battery packages; making use of enhanced security screening; subjecting shippers to compliance assessments/audits; providing additional training to employees in the local operations; and having an open dialogue with the national competent authority.

Chapter VII: SAFETY RISK MITIGATION

The carriage of dangerous goods must be included in the scope of the operator's Safety Management System. The operator should ensure that safety risks are managed to an acceptable level by implementing appropriate safety risk controls in their operation. Consideration should be given to a multi-layered risk mitigation strategy. When risk mitigation measures are implemented, it is essential that the risk is not transferred, i.e. addressing a solution to the identified problem should not generate or amplify another problem.

VII.1 Cargo Supply Chain

Global air cargo supply chains are extremely complex, with the potential for multiple stakeholders to be involved in the transport of each consignment of lithium batteries. Having traceability and accountability throughout the supply chain is a challenge for all stakeholders involved, as highlighted in Table 6.

Shippers, freight forwarders and operators are not specialists in battery design and manufacturing. This is the responsibility of the battery manufacturer. However, in the majority of scenarios, the battery manufacturer is not the actual shipper, yet the shipper is the party responsible for preparing the shipment in accordance with the regulations, and for signing the Dangerous Goods Transport Document / Shippers Declaration for Dangerous Goods confirming that the batteries meet all of the applicable air transport regulatory requirements.

Operators need to be aware of the complexity of the supply chain. This is particularly important for areas of the world where there is a high risk of counterfeit or poor-quality batteries entering the supply chain.

Consideration also needs to be given to dangerous goods which may be contained in ordinary mail shipments. Currently only 32 of the 192 Designated Postal Operators (DPO) hold the required approval from their Civil Aviation Authority to transport lightly regulated lithium batteries contained in equipment (UN 3481 and UN3091, meeting the provisions of Section II of Packing Instruction 967 and 970; no more than four cells or two batteries may be mailed in any single package[9]). If the operator is carrying mail consigned by a DPO that does not hold an approval from their Civil Aviation Authority to carry lightly regulated lithium batteries, it may be appropriate to ask what policies and procedures they have in place to prevent these entering into the mail. It should also be noted that mail can be consolidated through a freight forwarder, and may be carried as cargo, making it challenging to identify.

Freight forwarders may specialise in consolidating cargo from multiple shippers, or may act on behalf of a single shipper. When conducting a safety risk assessment, it is a critical to verify what controls the freight forwarder has in place to ensure their customer's compliance with the regulatory requirements.

[9] IATA DGR 2.4.2 (d) and (e).

Table 6: Air Cargo Supply Chain Responsibilities for Lithium Battery Consignments

Stakeholder	Responsibility	
	Section I, IA and IB	Section II
Manufacturer	**UN38.3** **Quality Management System** **Make available UN38.3 Test Summary**	**UN38.3** **Quality Management System** **Make available UN38.3 Test Summary**
Shipper	**Shippers Declaration for Dangerous Goods** **Packaging, Marking and Labelling** UN38.3 Quality Management System Make available UN38.3 Test Summary	**Packaging, Marking and Labelling** UN38.3 Quality Management System Make available UN38.3 Test Summary
Freight Forwarder	**Air Waybill** Shippers Declaration for Dangerous Goods UN38.3 Quality Management System	**Air Waybill** UN38.3 Quality Management System
Operator	**Safety Management System** **Acceptance Check** **Handling requirements/segregation** **Notification to Aircraft Captain** Air Waybill IATA Shippers Declaration for Dangerous Goods	**Safety Management System** Air Waybill

VII.2 Operator Cargo Acceptance Responsibilities

For fully regulated lithium batteries and other dangerous goods, the operator is responsible for the following:

- Acceptance
    - Use of a dangerous goods acceptance checklist to show compliance with the regulations;
- Storage
    - segregation of lithium batteries from other flammable dangerous goods;
- Loading
    - Secured from movement;
- Inspection
    - No damaged/leaking packages;
- Provision of information, including emergency response information
    - Notification to the aircraft captain;

- Reporting;
- Retention of records;
- Training.

Prior to accepting a consignment containing lithium batteries or other dangerous goods, the operator should implement clear policies and procedures detailing any additional company restrictions, specific aircraft type restrictions or aircraft routings. These restrictions must be made available both internally and to external customers.

The acceptance of a consignment of fully regulated lithium batteries must be conducted by a suitably trained person with a valid certificate using a dangerous goods checklist .

The acceptance check verifies the documentation, packaging, labelling and marking is in compliance with the ICAO TI and the IATA DGR. There is, however, no requirement to inspect the contents of the package. By signing the Dangerous Goods Transport Document / Shippers Declaration for Dangerous Goods, the shipper is making a legal declaration that the shipment is prepared in full compliance with the regulations.

Analysis of an operator's shipment rejection checklists can be used to identify shippers who may be lacking in competence, and provide an opportunity for the operator to open a dialogue with the customer to improve their compliance, resulting in improved safety.

VII.3 Training

The successful application of regulations concerning the transport of dangerous goods, and the achievement of their objectives, are greatly dependent on the appreciation by all the individuals concerned of the risks involved and on a detailed understanding of the regulations. This can only be achieved by properly planned and maintained initial and recurrent dangerous goods training programmes for all persons concerned in the transport of dangerous goods[10]. The ICAO TI and the IATA DGR require that personnel must be trained in the requirements, commensurate with their responsibilities, for all the key roles in the air cargo supply chain, including shippers, packers, freight forwarders, cargo acceptance staff, security screeners, Designated Postal Operators and aircraft operators. Specific dangerous goods training should be supplemented with additional safety related training, including any safety recommendations identified as part of the operator's safety risk assessment.

VII.4 Security Screening

Security screening using X-ray machines can be an effective way of identifying certain types of undeclared dangerous goods, including lithium batteries. Although the primary role of security staff is to detect any prohibited articles or substances which may be used to commit an act of unlawful interference from being carried out on board an aircraft, there is a requirement for these security screening employees to receive dangerous goods awareness training, including the recognition of undeclared dangerous goods.

[10] IATA DGR 1.5.0.1

Other methods of security screening are permitted, including the use of detection canines, random manual visual inspections and thermal screening with infra-red equipment. Security practices may vary depending on the location, and on local regulatory policies and procedures. Although security screening methods may be an effective way of identifying undeclared dangerous goods, it should be noted that it is not easy to detect undeclared lithium batteries. Operators should carefully consider the effectiveness of security screening mitigation measures as part of their safety risk assessment, paying particular attention to (agency / regulatory) security screening over which they do not have full control.

VII.5 Undeclared/Misdeclared Lithium Batteries

Undeclared dangerous goods pose a significant safety risk to operators, as they will be unaware of the hazards contained in a consignment, and cannot make use of the measures for properly handling dangerous goods. Security screening, cargo documentation reviews and employee training are the minimum mitigation measures the operator should implement to help identify undeclared/misdeclared dangerous goods. Additional mitigation measures the operator may wish to consider include:

- Developing a system for approving / registering known shippers;
- Requiring a specific customer contract for dangerous goods transport;
- Enhancing the screening of advance shipment data, with a particular focus on general air waybill descriptions;
- Using autonomous X-ray screening with pre-defined algorithms to detect lithium batteries;
- Using fire resistant containers/fire containment covers (ref. ETSO-C203) for cargo identified as having a high risk of containing undeclared dangerous goods, either at the shipper or origin level. See ISO 14186:2013(E) and ISO 19281:2016(E) Air Cargo – Fire resistant containers – Design, performance and testing requirements.

VII.6 Package and Packaging

The minimum package and packaging standards and maximum quantities of batteries per package are specified in the relevant ICAO/IATA packing instructions PI's 965 to 970.

Note: *Operators must have procedures in place to prevent the loading of damaged or leaking dangerous goods onto an aircraft.*

VII.7 Aircraft Loading Density

The number of batteries carried per package is limited through the packing instructions in the ICAO TI and the IATA DGR. As with other dangerous goods, excluding radioactive materials, there is no upper limit specified in the regulations for amount of dangerous goods which may be carried on an aircraft or in an aircraft position. The operator may wish to consider implementing specific limits for aircraft loading in an overpack, in consolidations, in a ULD or at the aircraft cargo compartment level, based on which additional mitigation controls are in place.

It is important for operators to consider their route structures and the time needed for an aircraft diversion and landing in the event of an emergency. This consideration is critical for long flight sectors where en-route diversion airports may not be available (for example South Pacific intercontinental flights).

VII.8 Fire Mitigation

Lithium battery thermal events have very different characteristics from events with other classes of dangerous goods (see Chapter 5). Batteries have the potential to produce a great deal of heat energy, violent emissions of gasses, smoke, toxic fumes and the projection of fragments. Due to cell-to-cell propagation during a thermal runaway, there is considerable potential for re-ignition, even after any fire has been extinguished.

VII.9 At Aircraft Level

The requirements applicable to the design of cargo compartments installed on large aeroplanes are described in Annex B. In general, fire protection systems are designed to have a level of performance that is adequate for any fire likely to occur in a compartment. However, the fire protection systems currently available on large aeroplanes may not have a level of performance that is adequate to control fire events involving a large quantity of lithium batteries/cells.

For example, the Halon 1301 fire suppression used in class C cargo compartments is designed to suppress a fire by reducing the heat and energy intensity of the fire, and to prevent a re-ignition of the suppressed fire, allowing the aircraft to land at the nearest suitable airport. Halon has a limited effect on lithium battery fires, as it does not provide any cooling effect, and is ineffective in preventing cell-to-cell propagation during a thermal runaway. Testing conducted by the FAA showed that lithium ion cells in thermal runaways emitted hydrogen gas that can be explosive even in a 5% Halon atmosphere. The pressure and off-gassing from the cells could reduce the Halon concentration at an accelerated rate, thereby causing the loss of fire protection earlier then designed. The ignition of the gases vented by a small number of cells in thermal runaway (the number depends on many factors, such as the chemistry, design, and SOC of the cells, and the size, design, and load factor of the compartment) can cause enough damage to a Class C cargo compartment as to render the Halon suppression system ineffective[11].

When assessing cargo fires involving lithium batteries, the operator should consider a fire originating from a thermal runaway of a battery as having the potential for interaction with packages containing lithium batteries. One consideration to mitigate the risk of fires from other cargo may be to restrict the loading of packages containing lithium batteries to Class C cargo compartments, if available.

VII.9.1 At Unit Load Device Level

An operator may choose to use fire-resistant containers (FRCs) or fire containment covers (FCCs) for shipments containing lithium battery packages.

[11] DOT/FAA/TC-16/37 - Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments

FRCs and FCCs are typically constructed of materials that will pass the oil burner test requirements of Part III of Appendix F[12]. This is in line with the revised CS 25.855, which, for a Class F cargo or baggage compartment not using FCCs, requires a ceiling and sidewall liner constructed of materials that meet the requirements of Part III of Appendix F, which must be separated from the aeroplane structure (except for attachments), while the floor panels must comply with Part I of Appendix F.

If FCCs are used, they should completely surround all the cargo.

The operator should verify the capabilities of any equipment they choose to use in addition to the existing aircraft systems, considering any impact this may have on the aircraft smoke detection and fire suppression capabilities. For example, an FRC or FCC may delay the detection of a fire by containing the effects of any thermal event (smoke or heat).

An FRC is not intended for use in a Class C cargo compartment, since its fire containment capabilities may be redundant with that of the aircraft's fire detection and suppression system, which it could hamper[13]. It should be noted, however, that any mitigation measures, designed to contain the effects of a fire for a prolonged period of time, may create a safer operating environment even if this were to lead to a delayed detection by the aircraft's fire detection systems.

[12] 14 CFR Appendix F to Part 25, Part III - Test Method To Determine Flame Penetration Resistance of Cargo Compartment Liners

[13] ISO 19281:2016(E) Section 1, Note 1.

Chapter VIII: REVIEW AND REVISION

It is important for operators to understand that the safety risk assessment is a living document and that therefore, it should be kept under constant review and scrutiny to validate its effectiveness. There is no mandatory revision period for a safety risk assessment, however, the operator may wish to specify a minimum review period to ensure that the document remains current and valid for their operations, even if the current mitigation measures are working sufficiently well.

As previously mentioned in Chapter 3, the persons responsible for the review and revision of the safety risk assessment must be determined by the operator.

A regular review of the safety risk assessment is paramount to ensure that it is still an accurate reflection of the operator's activities and mitigation measures. Operational working environments are constantly changing. New equipment may be purchased, new routes opened, new customers engaged, and procedural changes may be implemented, each of which could lead to new hazards being introduced that were not previously considered.

The safety risk assessment should be reviewed on a regular basis considering the following elements:

- Have there been any significant changes that may impact the current version of the safety risk assessment?
- Are there any improvements that still need to be made?
- Have employees identified any problem areas?
- Have any lessons been learnt from incidents, accidents or near misses?
- Have any changes in the regulations occurred since the last review?
- Have any operational changes occurred, including changes to aircraft types, since the last review?

GLOSSARY

The following is a list of definitions of commonly used terms in this guidance document.

BAGGAGE. Personal property of passengers or crew carried on an aircraft by agreement with the operator[14].

CARGO. Any property carried on an aircraft other than mail and accompanied baggage[8].

CONSIGNMENT. One or more packages of dangerous goods accepted by an operator from one shipper at one time and at one address, receipted for in one lot and moving to one consignee at one destination address[8].

CONSOLIDATED CONSIGNMENT. A consignment of multi-packages which has been originated by more than one person, each of whom has made an agreement for carriage by air with another person other than a scheduled air carrier. The conditions applied to that agreement may or may not be the same as the conditions applied by the scheduled air carrier for the same carriage[8].

FIRE CONTAINMENT COVER (FCC). A passive device meeting the performance requirements of ETSO-C203 or ISO 14186, used in conjunction with an air cargo pallet and net in order to contain for a rated period a possible cargo fire beneath it[15].

FIRE RESISTANT CONTAINER (FRC). A completely enclosed container, airworthiness approved under applicable general performance criteria, with a demonstrated additional capability to contain a possible cargo fire within it for a rated period[16].

HAZARD. A condition or an object with the potential to cause or contribute to an aircraft incident or accident.

LITHIUM BATTERY. "Battery" means two or more cells which are electrically connected together and fitted with devices necessary for use. for example, by its case, terminals, marking and protective devices. A single cell lithium battery is considered a "cell" and must be tested according to the testing requirements for "cells" for the purposes of these Regulations and the provisions of subsection 38.3 of the UN Manual of Tests and Criteria (see also the definition for "lithium cell").

Note:
Units that are commonly referred to as "battery packs", "modules" or "battery assemblies" having the primary function of providing a source of power to another piece of equipment are for the purposes of these Regulations and the provisions of Subsection 38.3 of the UN Manual of Tests and Criteria treated as batteries.

The term "lithium battery" refers to a family of different chemistries, comprising many types of cathodes and electrolytes. For the purposes of the Regulations, they are separated into:

[14] IATA DGR Appendix A – Glossary

[15] ISO 19281:2016(E) Section 3.6.

[16] ISO 19281:2016(E) Section 3.2.

- Lithium metal batteries. These are normally primary (non-rechargeable) batteries that have lithium metal or lithium compounds as an anode. The most common type of lithium cell used in consumer applications uses metallic lithium as the anode and manganese dioxide as the cathode, with a lithium salt dissolved in an organic solvent; and
- Lithium ion batteries (sometimes abbreviated Li-ion batteries) are a type of secondary (rechargeable) battery commonly used in consumer electronics. Also included within lithium ion batteries are lithium polymer batteries[8].

LITHIUM CELL. A single encased electrochemical unit (one positive and one negative electrode) which exhibits a voltage differential across its two terminals. Under these Regulations and the UN Manual of Tests and Criteria, to the extent to which the encased electrochemical unit meets the definition of “cell” herein, it is a “cell”, not a “battery”, regardless of whether the unit is termed a “battery” or a “single cell battery” outside of these Regulations and the UN Manual of Tests and Criteria.

MAIL. Dispatches or correspondence and other items tendered by, and intended for delivery to, postal services in accordance with the rules of the Universal Postal Union (UPU)[8].

NET QUANTITY. Either:

(a) the weight or volume of the dangerous goods contained in a package excluding the weight or volume of any packaging material; or

(b) the weight of an unpackaged article of dangerous goods (e.g. UN 3166)

For the purposes of this definition “dangerous goods” means the substance or article as described by the proper shipping name shown in Table 3-1 of the ICAO TI and Table 4.2 of the IATA DGR, e.g. for “Fire extinguishers”, the net quantity is the weight of the fire extinguisher. For articles packed with equipment or contained in equipment, the net quantity is the net weight of the article, e.g. for “Lithium ion batteries contained in equipment”, the net quantity is the net weight of the lithium ion batteries in the package[8].

OVERPACK. An enclosure used by a single shipper to contain one or more packages and to form one handling unit for convenience of handling and stowage. Dangerous goods packages contained in the overpack must be properly packed, marked, labelled and in proper condition as required by these Regulations. A Unit Load Device is not included in this definition[8].

Note:

Shrink-wrap or banding may be considered an overpack.

PACKAGE. The complete product of the packing operation, consisting of the packaging and its contents prepared for transport[8].

PACKAGING. One or more receptacles and any other components or materials necessary for the receptacles to perform their containment and other safety functions[8].

POST. See Mail.

RISK. The predicted probability and severity of the consequences or outcomes of a hazard.

RISK ASSESSMENT. The process of identifying the hazards, evaluating the risk and implementing proportionate controls to remove or reduce the risks to an acceptable level.

RISK MITIGATION. The process of incorporating defences, preventive controls, or recovery measures to lower the severity and/or likelihood of a hazard's projected consequences[8].

SAFETY. The state in which risks associated with aviation activities related to, or in direct support of, the operation of aircraft, are reduced and controlled to an acceptable level[8].

SAFETY MANAGEMENT SYSTEM (SMS) A systematic approach to managing safety, including the necessary organisational structures, accountability, responsibilities, policies and procedures[8].

THERMAL RUNAWAY – An uncontrolled increase in the temperature of a cell or battery driven by exothermic processes, accompanied by a voltage drop.

UNIT LOAD DEVICE (ULD). Any type of freight container (for radioactive material only), aircraft container, aircraft pallet with a net, or aircraft pallet with a net over an igloo[8].

ANNEXES

Annex A – SABATAIR deliverable D5 – Baseline Air Transport Operators Generic Risk Assessment Guidance

SABATAIR

Deliverable D5:

Baseline of the Air Transport Operators Generic Safety Risk Assessment Guidance for the Safe Transport of Lithium Battery Consignments as Cargo

Task	**5**	Risk assessment for the air transport of battery consignments

Dissemination level[17]	CO	**Due delivery date**	31 December 2018
Nature[18]	R	**Actual delivery date**	12 May 2020

Lead beneficiary	Dangerous Goods Safety Group (UK) Ltd
Contributing beneficiaries	VITO

Document Version	**Date**	**Author**	**Comments**[19]
V0.1	06/05/2020	Khiem Trad (VITO) Paul Horner (DG Safety Group)	Creation
V0.2	12/05/2020	Khiem Trad (VITO)	Review
Final			Final Version

[17] Dissemination level: **PU** = Public, **PP** = Restricted to other programme participants (including the JU), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the JU)

[18] Nature of the deliverable: **R** = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

[19] Creation, modification, final version for evaluation, revised version following evaluation, final

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Executive summary

Lithium batteries are the preferred energy source to power a wide range of industrial and consumer goods such as: mobile phones, laptop computers, cordless tools, e-bikes, electric vehicles and medical devices; stringent international regulations and standards, apply to their manufacture, testing and transport. Passed events highlighted the specific hazards and associated risks of the carriage of lithium batteries in air transport.

Considering the ubiquitous application of lithium batteries, the Safe Battery by Air (Sabatair) project was funded by the European Commission to provide an additional contribution to enhance safety when transporting lithium batteries on board a cargo aircraft. Deliverable D6 of the Sabatair project was the development of a guidance document to assist operators in the creation of their own safety risk assessment. To facilitate the development of the guidance document, a five step approach, as detailed in the introduction, was followed. The outcome from this five step approach is detailed in this document.

Introduction

The constant growth in the volumes of lithium-metal and lithium-ion batteries transported by air, in view of their ubiquitous application in a wide range of electric products, places such an issue prominently in the air safety agenda. Lithium batteries may have been the cause, or contributed to, uncontrolled fires that lead to the loss of three cargo aircrafts between 2006 and 2011. The Sabatair project aims at providing an additional contribution to further handling the underlying technical and operational questions related to the transport of such type of consignments.

The specific objective of the Sabatair project is to propose and evaluate novel and tailored packaging solutions and other operational measures aimed at the safe transportation of both lithium metal and lithium ion batteries on board an aircraft - passenger and cargo alike. The effectiveness of these solutions and measures is currently undergoing validation through a series of desk/modelling studies and experimental tests, representative of the environmental and operating conditions encountered in air transport. The final aim of the project is to develop a risk assessment guideline and enabling tools to support air transport operators in using such solutions and measures in their daily operations.

To develop the risk assessment guideline, a "5 step approach" was proposed:

- Step 1. Analyse and review outputs from Tasks 1-4.
  Develop process mapping for operators carrying lithium batteries from point of accepting a booking, to carrying and offloading the batteries at destination. *(See Mind Map in Annex)*
- Step 2. Develop a questionnaire based on the output from Step 1.
- Step 3. Send the questionnaire to a select group of EU Operators with cargo aircraft only operations.
- Step 4. Summarise and evaluate the feedback from the completed questionnaires.
- Step 5. Hold a 2 day workshop with key stakeholders (operators, ground handling agents, lithium battery expert, aircraft manufacturers and members of the VITO Scientific Committee) to run through the output from Step 4.

This document provides a summary of step 5 and includes details from steps 1-4, all of which will be used as the basis for developing the risk assessment method.

Chapter IX: Pre-workshop Questionnaire

IX.1 Introduction

The workshop was held in Brussels on 6th and 7th of June 2019 and had a twofold objective: (i) to briefly disseminate the project approach and early outcomes; (ii) to seek inputs from the relevant parties – viz. air transport operators, aviation regulators, risk-assessment community, and/or academia - regarding the approaches and guidance that should be provided by the risk assessment.

To prepare for the workshop, participants were requested to complete the following questionnaire with as much information as possible. When completing the questions, the participants were asked to answer from the perspective of the operator.

The questionnaire was divided into six specific areas:

1. Cell/battery manufacturer
2. Shipper (including packer)
3. Freight forwarder
4. Ground handling agent / Operator (ground handling activities)
5. Operator (in flight activities)
6. Aircraft manufacturer

The results of the questionnaire were consolidated to help develop the approach and guidance for the risk assessment

The results of the questionnaire were anonymised and used for the purpose of the workshop only. No specific reference to an individual operator was made in the risk assessment approach and supporting guidance document.

IX.2 Workshop questionnaire

1. Cell/battery manufacturer
When designing a cell, does the manufacturer consider the hazards of the chemistry chosen and the potential risks this may pose in the supply chain? What factors will determine the chemistry? • Cost • Available resources • Performance • Manufacturer capabilities • Other
ICAO/IATA Special Provision A88 states “for pre-production prototypes of lithium batteries or cells, when these prototypes are transported for testing, or low production runs requires

approval by the appropriate authority of the State of origin and the requirements in Packing Instruction 910 of the Supplement to the Technical Instructions are met". As Packing Instruction 910 is not published in the ICAO TI/IATA DGR, manufacturers/shippers must first contact the appropriate authority to request what requirements they must follow as part of the approval process? Would it be beneficial to all in the supply chain to publish PI 910 in the ICAO TI/IATA DGR? What other factors need to be considered when submitting a request for an approval?
UN38.3.4.3 Test T.3 simulates vibration during transport. One of the safety recommendations (SR49&57/2013) from the air accident investigation report of the B747 accident in Dubai in 2010, was for further investigation by manufacturers and/or operators of large cargo aircraft into the vibration and acoustic signatures of the cargo areas for harmonic acoustic vibration resulting from a combination of engine and fuselage vibration. Without this data for each aircraft type, can we be confident that the current UN38.3.4.3 Test T.3 is sufficient for the carriage of lithium batteries in air transport? Who should be responsible for conducting these tests and providing the data? Note: This is a current open item with the ICAO DGP. See DGP/24-WP/69 for further details
Do cell, battery and device manufacturers consider the implications in transport for the return of batteries/devices containing batteries subject to recalls or warranty returns (whether specifically related to the cell/battery or the device)? What challenges does this create for the operator? Consider e-commerce, resellers, passengers etc
Would it be practical to require all positive/negative terminals to be fitted with protective covers to protect against short circuit?
Lithium ion cells undergo a charging process called formation cycling at the end of their manufacture. If an internal fault is present at the time of manufacture, it could be enhanced or catalysed to form an internal short by the formation cycling. In such cases, thermal runaway reactions may occur soon after completion of their formation charging by the battery manufacturer.

As a mitigation measure to consider for the transport of freshly manufactured cells, a minimum 'wait-and-see' latency period could be defined of at least several days between the conclusion of the formation cycling and carriage by air to allow for the emergence of cell heating, possibly leading to thermal runaway. Is this a practical proposition? How would this be managed as part of the risk assessment process? How would the operator know that such a latency period had been followed?

2. Shipper (including packer)
UN3480 Lithium ion batteries must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated capacity. Is there confidence that this requirement is always complied with? What evidence, if any, would be expected by or from the shipper to confirm compliance with this requirement?
When shipping lithium batteries PI965/968, plastic outer packagings are permitted (1H2, 3H2 and 4H2). Is a plastic packaging suitable for use with lithium batteries, as there is the potential for this to melt in the event of thermal runaway, irrespective of its flame retardancy? Should the flammability of the packaging material be considered?
Should any additional thermal isolation or absorbent materials be considered inside the packaging to prevent or extinguish a thermal event, or to absorb gas/electrolyte (Pyrobubbles, mineral wool, phase change materials, vermiculite, active carbon etc)?

Without any regulatory requirement, what incentive would there be for the shipper to use these additional mitigation materials?

The shipper may not be the packer, for example a "pick and pack" operation. How would the shipper verify that the packages are packed correctly?

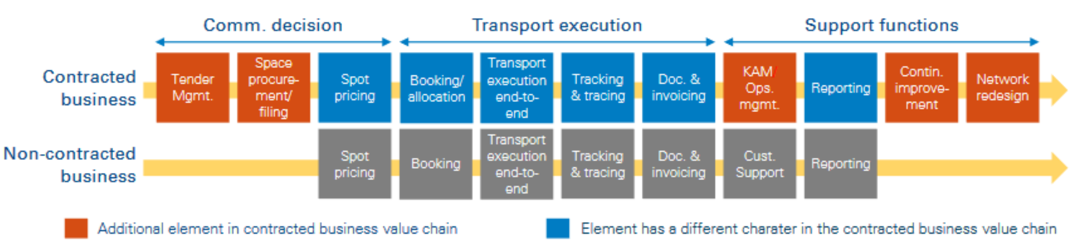
What documents and/or records would you expect to see to verify that the packing and shipping process is in full compliance with ICAO/IATA?

If prepared packages are placed in storage prior to shipping, should any considerations be given to the storage conditions?

What, if any, impact would this have on the operator risk assessment?

A shipper may have a contracted or non-contracted business relationship with their customer(s).

Figure 4: Differences in the contracted and non-contracted transportation value chain



Source: Arthur D. Little

Should these relationships be considered differently when conducting the operator risk assessment?

3. **Freight forwarder**
Are shipments physically handled by the freight forwarder or are these delivered directly to the operator/GHA from the customer of the freight forwarder? Would this type of relationship be assessed differently than shipments being presented directly by the freight forwarder?
What package and documentation checks, if any, would the freight forwarder be expected to conduct prior to handing over lithium battery shipments to the operator/GHA?
Should freight forwarders keep records of shipment rejections, identified either internally as part of a pre-check or by the operator? How could this data be used by the operator as part of their risk assessment process?
A freight forwarder may prepare a consolidation, including consignments from numerous shippers, from numerous locations. The consolidation may also include previous consolidated shipments from other smaller freight forwarders. Is there an expectation that the freight forwarder would have a direct relationship (contracted) with each individual shipper? How will the operator consider this relationship as part of their risk assessment process?

4. **Ground handling agent / Operator (ground handling activities)**
What is the booking process for shipments containing lithium batteries? • Call to customer services • Receipt of consignment into cargo facility • Pre-notification by automated booking system • Other Where does this information come from? • Direct from shipper • Intermediary as part of a consolidated shipment • 3rd party (freight forwarder) • From DG paperwork upon receipt into cargo facility • Other What needs to be considered by the operator as part of their risk assessment process?
Is the origin or shipment considered by the operator when conducting the risk assessment? What consideration is given when the origin of the shipment may not be the country at the start of the supply chain (e.g. China-Hong Kong) and how is this assessed?
It is suggested the operator should consider the battery chemistry when conducting the risk assessment. What would the operator do with this information?
Are additional restrictions imposed by the operator? • No section II • No section IB • No Section IA • Only approved (contracted shippers) • Additional Packing requirements How are these decisions taken and how is this managed within the operation?

Effective 1 Jan 2020, manufacturers and subsequent distributors of cells or batteries manufactured after 30 June 2003 must make available the test summary as specified in the UN Manual of Tests and Criteria, Part III, sub-section 38.3, paragraph 38.3.5.

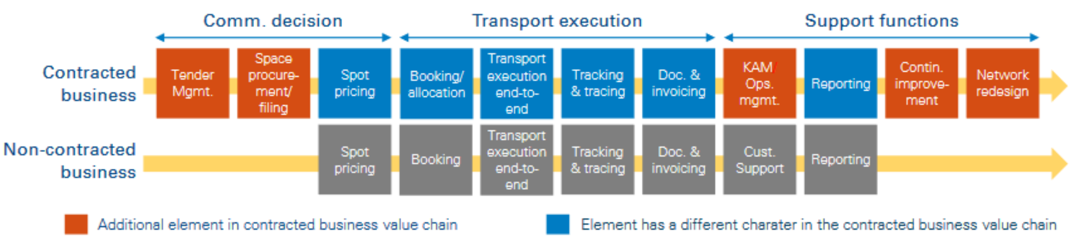
Will this be used by the operator as part of their risk assessment and, if so, how?

What is the expectation of the term "make available"?

What potential challenges do you envisage with this new requirement?

An operator may have a contracted or non-contracted business relationship with their customer(s).

Figure 4: Differences in the contracted and non-contracted transportation value chain



Source: Arthur D. Little

Should these relationships be considered differently when conducting the operator risk assessment?

Is there a longer cut off time for lithium battery shipments to allow for additional check to be conducted prior to loading?

Are commercial departments consulting with the operations team in making these decisions?

What controls are in place to identify shippers deliberately offering lithium batteries without declaring them (to avoid cost or to enable carriage on an otherwise restricted route/carrier)?

Is consideration given to mail that may be consolidated and shipped as cargo, potentially with an unknown origin?

How are cultural tolerances to counterfeit goods, in certain parts of the world, considered? How is this addressed in the operator risk assessment?
What part does security screening play in the detection of undeclared lithium batteries? How is new technology including x-ray with automated algorithms being used? Is there active engagement with the security team to enhance detection of undeclared lithium batteries? What challenges are there to increase the detection rate and how is this process covered in the operator risk assessment?
Is there any engagement with key stakeholders in the supply chain? • Battery manufacturers • Shippers • Freight forwarders • Designated postal operators • Ground handling agents • Others What value does this bring to the operator? How is this considered in the operator risk assessment?
How is the history of shipper compliance, including non-safety related rejections of lithium battery shipments reviewed? What can be learnt from this type of analysis and how does this form part of the risk assessment process?

During the handling process, is there a potential for the package falling from a height in excess of 1.2 metres during the handling process? As this would exceed the packaging test height, what additional measures are implemented to ensure there is no damage to the inner and outer packaging, including the cells/batteries?
Are there any significant conditions of vibration and/or shock encountered when transporting cargo to the aircraft? How would this be assessed and how would this be considered as part of the operator risk assessment?
5. Operator (Load planning/in flight activities)
Are fire containment ULD's or covers used (FCC/FCU)? Are these used for all cargo, or just when lithium batteries are loaded? If just used for lithium battery shipments, what mitigation is used for potential undeclared lithium battery shipments? Are any load limit specified by the manufacture of the equipment?
Is there adequate maintenance of FCUs/FCC's and are loading staff trained and competent in their use? Is this considered as part of the operator risk assessment?
When FCU/FCC are used, what consideration has been given to the possible impact on the aircraft fire/smoke detection system? How is this considered as part of the operator risk assessment?

Are there any loading limits specified per aircraft type and/or per compartment in the aircraft? To include restrictions on: • Number of packages • Net weight • Watt hour rating • Lithium metal content Is consideration given to the potential elevated gas pressure in the cargo compartment in case of a thermal event? Should this be considered as part of the risk assessment process and what factors need to be considered?
When considering inflight emergency procedures, what operational factors are considered? • Route structure • Distance to nearest suitable landing aerodrome • Accessibility of the batteries to the flight crew and their capability to fight an inflight fire
As a class E cargo compartment has no fire suppressions system, has there been any consideration of prohibiting the loading of lithium batteries here? What factors were used when making this decision? How would this be addressed in the operator risk assessment?
Are incident/accident reporting and analysis requirements sufficient? Are these reported to the competent authority and is there analysis of suspicious ad post-accident cells?

Is the competent authority sharing the details with ICAO/EASA? Is there an open reporting culture in all states? Is this data used when conducting the operator risk assessment?

6. Aircraft manufacturer
Are aircraft fire protection features clearly defined and details provided to the operator? Are any specific load limit for dangerous goods, including lithium batteries provided by the aircraft manufacturer?
Are smoke detectors designed using new technology or based on historic certification? Are there persistent false alarms with the fitted devices? Is there any data to support this? What effect can persistent false alarms have on flight crew emergency response and how is this considered as part of the operator risk assessment?
Are smoke detectors supplemented with any visual means to the flight crew? How would this help the flight crew?
Is the use of multi-source sensors considered and feasible (thermal detection)? What benefits, if any, would this bring and how would this be considered in the operator risk assessment?

Chapter X: Workshop overview

At the beginning of the workshop, participants were asked to provide a list of their expectations that the document should address:

- Operators need help
- Guidance needs to be practical
- Need to also consider the supply chain, not just what the operator does
- Assess risks properly
- Real risks are considered – some batteries are more dangerous than others
- Safety of batteries taken into account
- Reality check
- Practical examples
- Practical guideline with appropriate mitigation measures
- Wider/broader context
- Bring in more science
- Bring in something that can be used on a daily basis
- What should be in the risk assessment rather than the method used?
- More clarity / less confusion
- Develop trust – operator – handler
- Proportionate approachLots of confusion regarding mitigation
- Clarity
- Capabilities of the aircraft – insufficient data
- Information sharing
- Where do regulators come in?
- Need statistics/data to be proportionate
- More focus on transparency and traceability

Chapter XI: Specific feedback to each question

Q1- When designing a cell, does the manufacturer consider the hazards of the chemistry chosen and the potential risks this may pose in the supply chain?

- Batteries are designed for a specific purpose.
- Manufacturers only work with the classification system.
- Not generally considered for transport, but consider final use.
- UN 38.3 tests are mandatory, **but not verifiable by the operator**.
- It the batteries are counterfeit, the manufacturer will have no concern for any of the regulatory requirements.

Q3- Packing Instruction 910 is not published in the ICAP TI/IATA DGR, manufacturers/shippers must first contact the appropriate authority to request what requirements they must follow as part of the approval process. Would it be beneficial to all in the supply chain to publish PI 910 in the ICAO TI/IATA DGR?

- There was no agreement during the workshop for PI910 to be published in the IATA DGR. Some States grant approvals without consulting the operator

Q4- Without this data for each aircraft type, can we be confident that the current UN38.3.4.3 Test T.3 is sufficient for the carriage of lithium batteries in air transport?

- The T3 test is standardised and not required per aircraft type. The workshop confirmed this was out of scope for the operator risk assessment

Q5- Do cell, battery and device manufacturers consider the implications in transport for the return of batteries/devices containing batteries subject to recalls or warranty returns (whether specifically related to the cell/battery or the device)?

- Really need to know the reason for the recall – Not all reasons for a recall are safety related. For example, a battery that does not charge do not necessarily indicated this is a safety issue
- Consideration need to be given as to where the batteries are being shipped from and by who (e.g. members of the public)
- There was comments that the regulations make it clear that batteries recalled for safety reasons are forbidden in air transport.

Q6- Would it be practical to require all positive/negative terminals to be fitted with protective covers to protect against short circuit?

- It was agreed in the workshop that the requirement to protect batteries against short circuit is already a regulatory requirement and this proposal should not be in scope of the document.

Q7- As a mitigation measure to consider for the transport of freshly manufactured cells, a minimum 'wait-and-see' latency period could be defined of at least several days between the conclusion of the formation cycling and carriage by air to allow for the emergence of cell heating, possibly leading to thermal runaway. Is this a practical proposition?

- Having a latency period is standard practice for battery manufacturers, who must operate under a quality management system.
- To implement this would require a change in transport regulations.
- Currently the UN38.3 test is deemed to be sufficient.

Q8 - UN3480 lithium ion batteries must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated capacity. Is there confidence that this requirement is always complied with?

- The signature on the Shippers declaration for dangerous goods is confirmation that all of the applicable transport requirements have been met.
- There has to be an element of trust within the supply chain.
- If there is an incident with a lithium battery shipment, the regulator would check compliance with the 30% SoC requirement as part of the investigation.
- It was agreed that the risk mitigation document would be considered a living document and could be reviewed if incident data concluded that this was a particular are requiring further risk mitigation measures.

Q9 & 10 - When shipping lithium batteries PI965/968, plastic outer packagings are permitted (1H2, 3H2 and 4H2). Is a plastic packaging suitable for use with lithium batteries as there is the potential for this to melt in the event of thermal runaway, irrespective of its flame retardancy?

- This should be part of what the regulations permit and cannot be more restrictive.
- SAE G27 committee are already working on a package performance standard.
- Other packaging solutions are already available.

Q11 - The shipper may not be the packer, for example, a 'pick and pack' operation. How would the shipper verify that the packages are packed correctly?

- All tasks prior to handing over to the operator are considered as the responsibility of the shipper.
- Traceability of the supply chain for batteries is the responsibility of the shipper.
- If roles and responsibilities are contracted out, these should be covered by internal legal documents.

Q12 - What documents and/or records would you expect to see to verify that the packing and shipping process is full compliance with ICAO/IATA?

- Nothing expected in addition to what is required in the ICAO Technical Instructions.
- New UN38.3 test summary considered by some operators, but not expected to be required for all lithium battery shipments.

Q13 - If prepared packages are placed in storage prior to shipping, should any considerations be given to the storage conditions?

- No support to change the current process as the UN38.3 and Technical Instructions already mention normal conditions of transport with large temperature range.
- High temperatures in certain countries may be taken into consideration, but the storage time in extremes would also need to be taken into account.

Q14 - A shipper may have a contract or non-contracted business relationship with this customer(s). Should these relationships be considered differently when conducting the operator risk assessment? If yes, how?

- This would provide a higher degree of confidence.
- How deep can you go in the customer relationship?
- This could not be considered on a flight by flight basis.

Q15 - Are shipments physically handled by the freight forwarder or are these delivered directly to the operator/GHA from the customer of the freight forwarder? Would this type of relationship be assessed differently than shipments being presented directly by the freight forwarder?

- No differentiation

Q16 - What package and documentation checks, if any, would the freight forwarder be expected to conduct prior to handing over lithium battery shipments to the operator/GHA?

- It is expected anyone offering lithium batteries for transport to do a full check of package labelling and marking as well as documentary check.
- They should conduct an IATA pre-acceptance DG check on shipments. Since the freight forwarder my not physically handle shipments, it may only be possible to check documentation.

Q17 - Should freight forwarders keep records of shipment rejections, identified either internally as part of a pre-check or by the operator?

- This is something that should be considered by the regulators and not an area the operator can control.

Q19 – As part of a booking process, what needs to be considered by the operator as part of their risk assessment process?

- This is an area with some room for improvement.
- Most operators have a booking process, but the information requested will vary by airline.
- Depends on findings of safety risk assessment.
- Look for training records – do they have certified staff?
- With automated bookings, need to consider generic entries which could be an indicator of hidden/undeclared dangerous goods.

Q20 - What consideration is given when the origin of the shipment may not be the country at the start of the supply chain (e.g. China-Hong Kong) and how is this assessed?

- Operators should consider lanes that are high risk
- How do you identify? HKG may show origin HKG, but is actually China.
- The risk assessment should be data driven – DG origin, incident data etc.
- Shared data from airlines would be beneficial via IATA – generic de-identified.
- Incidents from ramp and/or warehouse will not be reported by flight crew, so still a gap.

Q21 - Are additional restrictions imposed by the operator? How are these decisions taken and how is this managed within the operation?

- Accident/incident reports and data is a key trigger for any restrictions.
- Concerns over visibility of Section II packages.
- Safety letters from aircraft manufacturers.
- Driver by airline partners if part of an alliance.

- Some operators more risk averse.
- A lot is based on perception.

Q22- It is suggested that the operator should consider the battery chemistry when conducting the risk assessment. What would the operator do with this information?

- This is not possible
- So complex
- Cannot take the cell chemistry alone when conducting a safety risk assessment
- There are as many chemistries as manufacturers
- The FAA SAFO making this recommendation was published prior to the prohibition of lithium ion batteries on passenger aircraft. This is now outdated and not valid
- Operators should be referring to standards and not chemistry
- **It was agreed during the workshop that the battery chemistry was out of scope of the operator risk assessment**

Q23 - What potential challenges do you envisage with this new requirement?

- This a change requested by the battery industry to increase transparency and increase quality. Other parts of the supply chain can also benefit from this new requirement.
- The operator has no idea who the cell or battery manufacturer is, therefore what would be the benefit of the operator requiring the summary document as a blanket policy?
- The shipper is ultimately responsible for compliance with the UN38.3 and they are best positioned to verify with the summary document.
- The safety risk assessment should be looking at the entire operation and not be focussed on a shipment by shipment basis.
- This could form part of the initial approval process.

Q26 - What challenges are there to increase the detection rate during security screening and how is this process covered in the operator risk assessment?

- There is little engagement as the primary focus is for IEDs and explosives
- Regulatory, including ICAO, ha a focus on security requirements and not DG.
- DG training is important and required, but there is resistance to this and not enforced.
- Much of the security screening is sub-contracted or conducted by local airport employees – no direct influence by the individual operators.
- New technology is available, but this is not mandated and is expensive.

Q27 - What controls are in place to identify shippers deliberately offering lithium batteries without declaring them (to avoid cost or to enable carriage on an otherwise restricted route/carrier)?

- Tends to be retrospective action.
- Can suspend account, but shipper may then use another carrier.
- Can investigate and visit customer premises.
- This is reactive.
- Reporting is key!
- An IATA bulleting was agreed at their AGM to allow for information sharing of incidents. IATA will provide further details when available.

Q28 - Is consideration given to mail that may be consolidated and shipped as cargo, potentially with an unknown origin?

- Concerns raised that some CAA's have no oversight of their DPO.
- Tends to be seasonal variations.
- The route for much of ecommerce, in particular business to customer and reseller hosting sites.
- E-commerce presents additional challenges.

Q29 - How are cultural tolerances to counterfeit goods, in certain parts of the world, considered?

- Maybe the location is unknown – Ecommerce is almost borderless.
- Could target particular lanes or routes and use incident data to build a picture – Is there an expectation each operator would do this?

Q30 - Is there any engagement with key stakeholders in the supply chain and what value does this bring?

- Yes with the shipper and forwarder or General Sales Agent (GSA).
- Information provided through website.
- Through customer contracts.

Q32 - During the handling process, is there a potential for the package falling from a height in excess of 1.2 metres during the handling process? As this would exceed the packaging test height, what additional measures are implemented to ensure there is no damage to the inner and outer packaging, including the cells/batteries?

- This is not specifically addressed.
- Is an extremely rare event.
- There are controls in place and dropped packages would be checked.

Q33 - Are there any significant conditions of vibration and/or shock encountered when transporting cargo to the aircraft? How would this be assessed and how would this be considered as part of the operator risk assessment?

- This was discussed in some detail but it was agreed that it was not practical for the operator to be expected to consider this as part of their safety risk assessment.

Q34 – If FRCs are just used for lithium battery shipments, what mitigation is used for potential undeclared lithium battery shipments?

- Some operators are moving towards full fleet implementation of FRCs on certain lanes.
- One operator is trialling a FC bag.
- The current standard for FRC covers only class A fires for covers (not ULD).
- There are potential accessibility requirements if the ULD is CAO in position 1 on the aircraft.
- What is the certification standard?
- Can it be used in a Class C compartment?
- Some operators do not use as there is no standard.
- These can be more susceptible to operational damage.
- What does the operator do if there is no equipment available?
- Complexity and potential conflict with other aircraft systems.
- Unknown implications of using in a Class C cargo compartment.

Q35 - Are any load limits specified by the manufacture of the equipment?

- Only address Class A fires.
- The flight time is covered in the safety risk assessment – If only operating in the EU the risk rating is very different to operating an ETOPS flight over 7 hours.
- Need to work with probabilities.
- Can operators determine cargo routing to avoid long flights – not really practical.
- Fire containment covers can enable burning for hours. What if no warnings have been activated on the aircraft?
- Should not compromise aircraft systems already in place.
- Check what you are using does not make the situation worse – What do we assume?
- Decision is left with the operator without any specification of aircraft limitations from the manufacturers.

Q42 - Is there an open reporting culture in all states?

- There is no requirement to inform ICAO of all incidents – therefore no global database of incidents.
- What do ICAO do with data if they are notified of incidents?

Mind Map Identifying the Supply Chain Process for Lithium Batteries by Air

To identify the processes that need to be considered as part of the operator safety risk assessment, a mind map was developed and includes the following key stages of the supply chain:

- Cell/Battery Manufacturer
- Packer
- Shipper
- Freight Forwarder
- Ground Handling Agent
- Operator
- Aircraft Manufacturer

PDF

Annex A_Step
1_Risk assessment fo

Annex B – Cargo Compartment Design

This Annex reflects the requirements set out in EASA CS-25 Amendment 24 (Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes) and the content of ICAO document Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods (Doc 9481) (red book).

Cargo Compartment Classification

All cargo compartments must be properly classified in accordance with CS 25.857 and meet the requirements of CS 25.857 pertaining to the particular class involved (see CS 25.855 (a)). In order to establish appropriate requirements for fire protection, a system for the classification of cargo or baggage compartments was developed and adopted for large aeroplanes.

Classes A, B, and C were initially established; Classes D, E, and F were added later. Class D has been eliminated from the CS-25 Specifications (by Amdt 3). The classification is based on the means by which a fire can be detected and the means available to control the fire.

a. A Class A compartment (see CS 25.857(a)) is one that is located so close to the station of a crew member that the crew member would discover the presence of a fire immediately. In addition, each part of the compartment is easily accessible so that the crew member could quickly extinguish a fire with a portable fire extinguisher. A Class A compartment is not required to have a liner.

b. A Class B compartment (see CS 25.857(b)) is one that is more remote than a Class A compartment and must, therefore, incorporate a fire or smoke detection system to give warning at the pilot or flight engineer station. Because a fire would not be detected and extinguished as quickly as in a Class A compartment, a Class B compartment must have a liner in accordance with CS 25.855 (b). In flight, a crew member must have sufficient access to a Class B compartment to reach any part of the compartment by hand or with the contents of a hand extinguisher when standing at any one access point, without stepping into the compartment. There are means to ensure that, while the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent will enter areas occupied by the crew or passengers.

c. A Class C compartment (see CS 25.857(c)) differs from a Class B compartment in that it is not required to be accessible in flight and must, therefore, have a built-in fire-extinguishing system to suppress or control any fire. A Class C compartment must have a liner and a fire or smoke detection system in accordance with CS 25.855 (b) and CS 25.857(c)(1). There must also be means to exclude hazardous quantities of extinguishing agent and products of combustion from occupied areas (see CS 25.857(c)(3)).

d. A Class E compartment (see CS 25.857(e)) is found on an all-cargo aeroplane. Typically, a Class E compartment is the entire cabin of an all-cargo aeroplane; however, other compartments of such aeroplanes may be also classified as Class E compartments. Shutting off the ventilating airflow to or within the compartment controls a fire in a Class E compartment. A Class E compartment must have a liner (see CS 25.855 (b)) and a fire or smoke detection system installed in accordance with CS 25.857(e)(2). It is not required to have a built-in fire suppression system.

e. A Class F compartment (see CS 25.857 (f)) is one in which there are means to control or extinguish a fire without requiring a crew member to enter the compartment. Allowing access by a crew member in the presence of a fire warning is not envisioned. Class F compartments that include a built-in fire extinguisher/suppression system or require the use of acceptable fire containment covers (FCCs) would meet these requirements. A Class F compartment must have a fire or smoke detection system installed in accordance with CS 25.857(f)(1). Unless there are other means of containing a fire and protecting critical systems and structures, a Class F compartment must have a liner meeting the requirements of part III of Appendix F, or other approved equivalent methods (see CS 25.855 (b)). It is not envisaged that lower deck cargo compartments be approved as Class F cargo compartments. The Class F cargo compartment was introduced as a practicable and safe alternative to the previous practice of providing large Class B cargo compartments. These latter compartments were limited to the main deck for accessibility reasons. Lower deck cargo compartments in aircraft carrying passengers need to comply with the Class C cargo compartment requirements of CS 25.857(c).

Fire Protection Features

Based on the class of the compartment, fire protection features must be provided. These features may include liners, fire or smoke detection systems, handheld fire extinguishers, and built-in fire suppression systems.

The primary purpose of a liner is to prevent a fire originating in a cargo compartment from spreading to other parts of the aeroplane before it can be brought under control. The liner must have sufficient fire integrity to prevent flames from burning through the liner before the fire can be brought under control, and before the heat from the fire is sufficiently dissipated. For example, for Class B compartments, it is assumed that the fire will be quickly extinguished. Therefore, the liner does not need to be qualified to the requirements of Part III of Appendix F. For Class C cargo compartments, the fire might have grown larger prior to being suppressed, and therefore, better protection is needed to prevent damage to surrounding systems and structure.

As stated in Part III of Appendix F of CS-25, in addition to the basic liner material, the term "liner" includes any design feature, such as a joint or fastener that would affect the capability of the liner to safely contain a fire. It should be noted that the liner is frequently used to perform the secondary functions of containing discharged extinguishing agents and controlling the flow of oxygen into the compartment. If other means, such as compartment walls, are not capable of performing those functions, the liner must be sufficiently airtight to perform them.

The adequacy of the capacity of the “built-in system” is understood to mean that there is a sufficient quantity of agent to combat the fire anywhere where baggage and cargo is placed within the cargo compartment for the time duration required to land and evacuate the aeroplane. Current built-in cargo fire-extinguishing systems utilise Halon 1301 as the fire-extinguishing agent. Protection is afforded as long as the minimum concentration levels in the cargo compartment do not drop below three per cent by volume. The time for which a suppression system will maintain the minimum required concentration levels should be identified as a certificate limitation.

The designer of the product should work with the aircraft owner and the competent authority providing operational approval to ensure that the cargo fire-extinguishing system provides the required protection time (i.e., by proper sizing of the cargo fire-extinguishing system) for the specific route structure. The competent authority may insist on some holding time to allow for weather and other possible delays, and may specify the speeds and altitudes used to calculate aeroplane diversion times based on one-engine-out considerations.

The competent authority providing operational approval for the aeroplane determines the maximum allowable time, following the discovery of a fire or other emergency situation, required to divert the aeroplane to an alternate landing site. In the past, for some cases, the maximum allowable time was calculated by adding a 15 minute allowance for holding and/or approach and landing to the actual time required to reach the alternate landing site under specific operating conditions. With the issuance of this AMC, an allowance of 15 minutes for approach and landing must be considered, and the certification data must include analysis and/or data taken after landing after a time period which allows for the complete evacuation of all occupants.

Procedures and Limitations

Any operational limitations or procedures necessary to ensure the effectiveness of the fire protection system for cargo and baggage compartments should be clearly defined in the Aeroplane Flight Manual (AFM). This should include such items as any changes to the ventilation system to prevent the entrance of smoke or gases into occupied areas, the use of handheld fire extinguishers, the use of protective breathing equipment, the use of protective clothing, and the use of the FCCs. The certification engineers should work closely with the Agency to ensure that additional training necessary for crew members assigned to combat fires is adequately addressed. Any time limit for a cargo or baggage compartment fire protection system, or other conditions or procedures related to combatting a fire in a compartment, should be clearly defined in the AFM.