DANGEROUS GOODS PANEL (DGP)
WORKING GROUP MEETING (DGP-W/23)

Rio de Janeiro, Brazil, 15 to 19 May 2023

Agenda Item 4: Managing safety risks posed by the carriage of lithium batteries by air (Ref: Job Card DGP.003.04)

REPORT OF THE DANGEROUS GOODS PANEL WORKING GROUP ON ENERGY STORAGE DEVICES (DGP-WG/ENERGY STORAGE DEVICES)

(Presented by the DGP-WG/Energy Storage Devices)

SUMMARY

This information paper presents a summary of the activities of the DGP Working Group on Energy Storage Devices (DGP-WG/ Energy Storage Devices).

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1. INTRODUCTION

1.1 The DGP created the working group on energy storage devices to progress the work identified in Air Navigation Commission (ANC) job card DGP.003.03: Mitigating safety risks posed by the carriage of lithium batteries by air. During DGP/28, the panel requested DGP-WG/Energy Storage Devices to conduct of a safety risk assessment on lithium batteries packed with or contained in equipment and vehicles under the guidance of ICAO safety management experts. One consideration the working group was asked to address within a safety risk assessment concerned extending the existing state of charge limit for UN 3480 to UN 3481, particularly for lithium batteries packed with equipment.

1.2 DGP-WG/Energy Storage Devices met during the 2022 DGP Working Group Meeting (DGP-WG/22, Montréal, 21 to 25 November 2022) and twice virtually (23 February 20223 and 5 May 2023). A summary of the discussions at these meetings is provided below.

1.2.1 The DGP-WG/Energy Storage Devices agreed to utilize the bowtie method as a risk assessment tool for its ability to visualize the hazard, the risk, the resulting consequences, and the reactive and proactive controls/measures designed to prevent unwanted outcomes. The working group completed much of the work on the bowtie diagram during in-person meetings during DGP-WG/22 and subsequently during a series of virtual meetings of a task group early in 2023. A copy of the diagram is shown in the appendix to this document.

1.2.2 The draft bowtie developed by the working group as shown in the appendix to this paper identify threats associated with two configurations: 1) lithium batteries packed with equipment damaged at any point prior to loading on aircraft and 2) lithium batteries contained in equipment damaged at any point prior to loading on aircraft. The top event in this bowtie diagram is thermal runaway. The left side of the diagram depicts existing requirements contained in the Technical Instructions and represent the active controls (or barriers) designed to prevent a thermal runaway event. The analysis also identified potential escalation factors that weaken the controls. The right side of the diagram depicts consequences of a thermal runaway event (uncontrollable cargo compartment fire) and recovery controls that mitigate consequences of a thermal runaway. The recovery controls assume traditional commercial air transport operations with larger aircraft and all controls may not be applicable to all aircraft or all operators. Generic escalation factors were included to identify cases in which a recovery control e.g. active fire suppression, depressurization etc. is not present. Unique identifiers for Causal Scenario (CS), Preventative Controls (PC), Escalation Factors (EF), Recovery Controls (RC), and Hazardous Consequence (HC) were added for ease of identification and categorization.

1.2.3 The group next turned its attention to translating this diagram into a safety risk analysis. The goal of any analysis is to produce results that are credible, repeatable, and understandable. A conventional analysis would use a reductionist approach that divides the system into components and analyses them individually. The level of risk in the system is typically defined as a product of severity of an event (e.g. a thermal runaway of lithium batteries in an aircraft cargo compartment) and the likelihood of that event or a specific series of events leading to that outcome. This is used to determine whether the risk is sufficiently controlled. Inputs including incident report data, cargo volumes, and aircraft cargo compartment capability are used to inform such an analysis. Where an identified risk is not sufficiently controlled, additional/redundant controls or barriers are created to prevent or mitigate potential failures. While this is a well-developed process employed for many years, this method of risk assessment poses significant challenges when assessing lithium battery thermal runaway events. While the potential for a catastrophic event involving a fire in a cargo compartment involving lithium batteries is well established, the likelihood of such an event is impossible to predict with any accuracy based only on limited incident reports and cargo transport volumes. Additionally past incidents do not necessarily predict future behaviour as this approach does not reflect changing characteristics of the system.

1.2.4 Considering these factors, safety management experts at ICAO identified an alternative risk assessment approach known as System Theoretic Process Analysis (STPA) to evaluate the safety of a system. The STPA method follows a series of steps aimed to associate hazards with prioritized losses**Invalid source specified.**[1].

Step 1 (3 parts): Identify losses the analysis aims to prevent, identify system level hazards, identify system level constraints. Losses are anything unacceptable to any stakeholder (e.g. loss of life, loss of aircraft, loss of cargo etc.), system level hazards are a set of conditions that in a worst-case scenario leads to a loss (e.g. cargo compartment fire, damaged batteries loaded onto an aircraft), and system level constraints (e.g. cargo compartment must be protected against fires likely to occur, damaged batteries must be detected, and measures must be taken to prevent loading on the aircraft).

Step 2: Model the control structure that captures the functional relationships and interactions amongst various parts of the system including responsibility and feedback loops. The working group constructed a hierarchical control structure to show how information is sent (e.g. regulations, instructions, commands) and system feedback (e.g. incident reports, documentation).

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

Step 3: Identify unsafe control actions (UCAs) that could lead to the losses identified in step 1. UCAs leading to a hazard take the form of actions that are not taken, actions taken too early, too late, or in the wrong order, and actions in which the duration is too long or not long enough. The goal of this step is to identify unsafe behaviours that should be prevented.

Step 4: Identify why unsafe control actions might occur. In this case which controls actions are improperly executed or not executed that leads to system hazards and losses.

1.2.5 Following completion of Step 4, mitigation measures can be identified and discussed in view of whether measure(s) prevent, reduce, or mitigate UCAs or the occurrence of unsafe causal scenarios that lead to UCAs. In this case the strength of mitigation measures could be ranked based on a hierarchy where controls that prevent the occurrence of UCA through system design are especially powerful, followed by controls that mitigate UCAs, followed by controls that increase detection of UCAs and controls involving additional procedures and training.

2. ACTION BY THE DGP

2.1 The DGP is invited to:

a) review the draft bowtie diagram in the appendix to this paper with the view of finalizing the two threat lines in the draft;

b) discuss and confirm, as appropriate, the consideration of each separate threat line;

c) consider the progress of the DGP-WG/Energy Storage Devices on development of a STPA approach and documentation;

d) discuss a scoring mechanism to quantify the safety risk probability based on the value and effectiveness of each control under the guidance of ICAO safety management experts; and

e) discuss next steps and timelines for drafting a narrative report representing the risk assessment.

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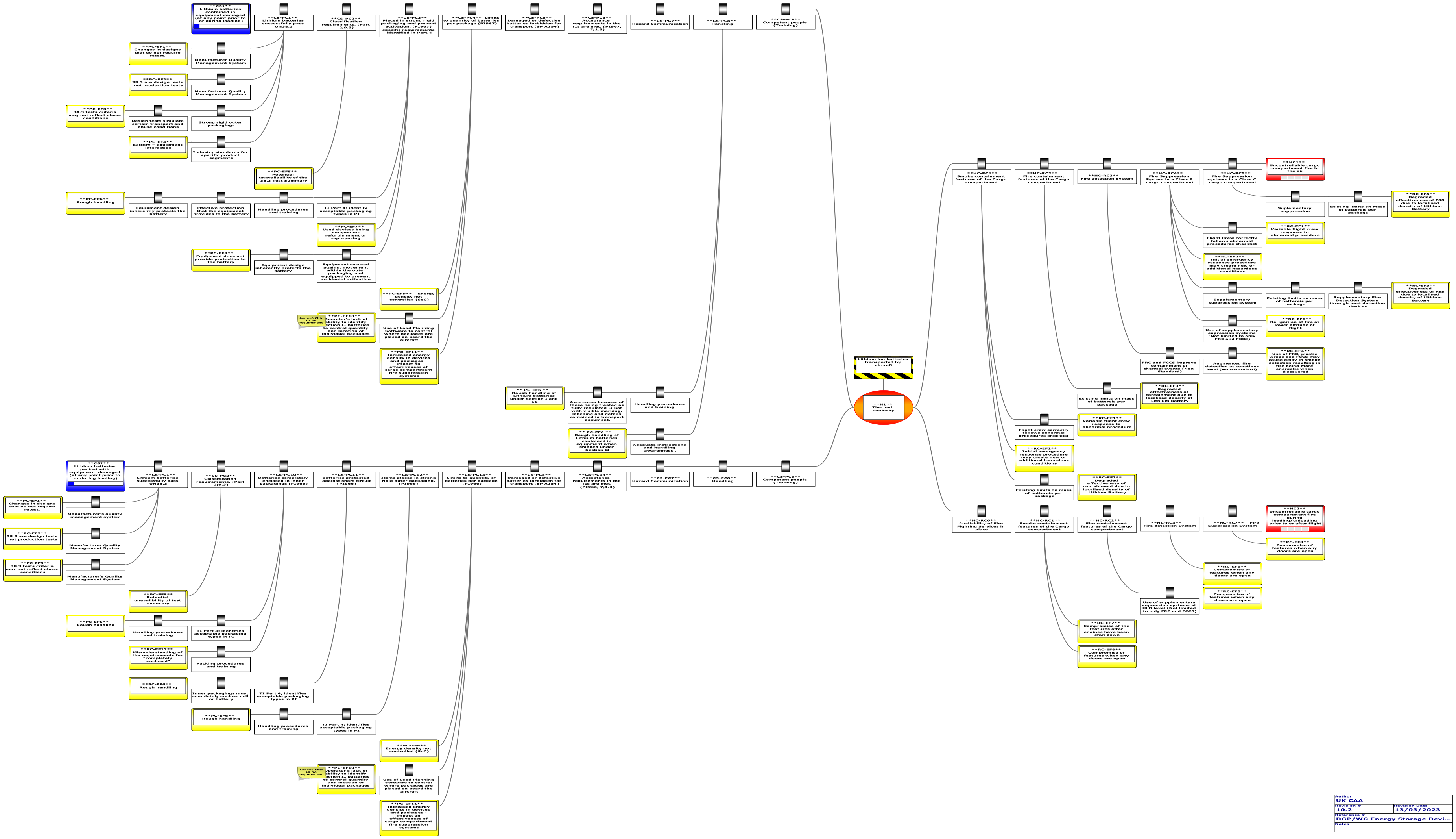
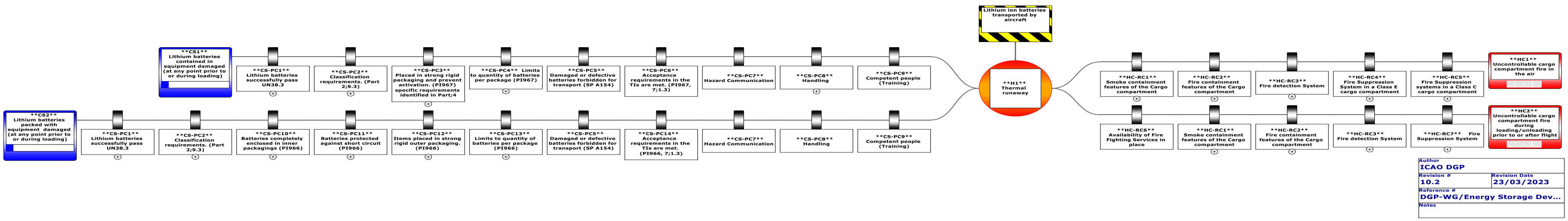
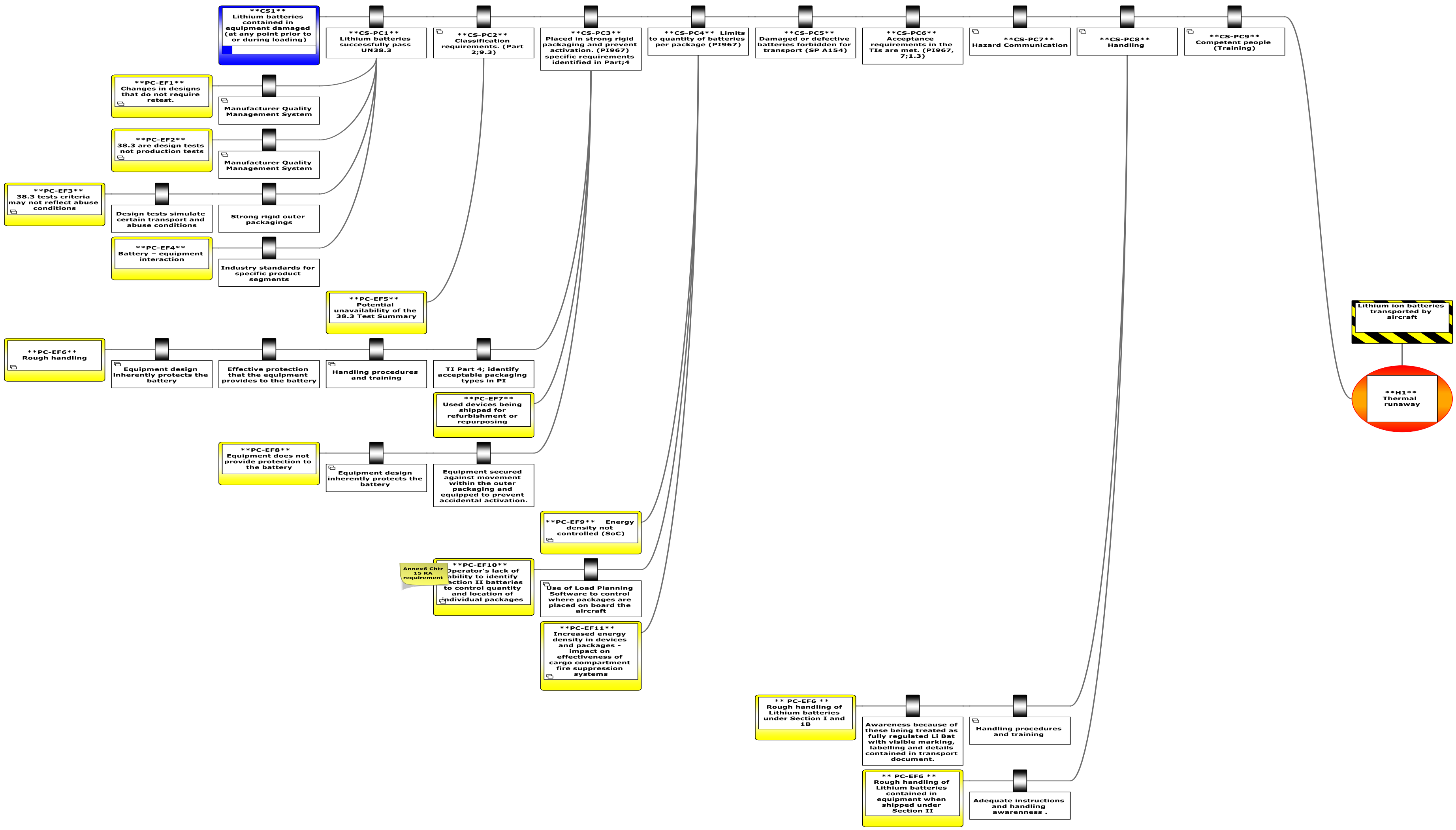
VIEW 1 – Full View



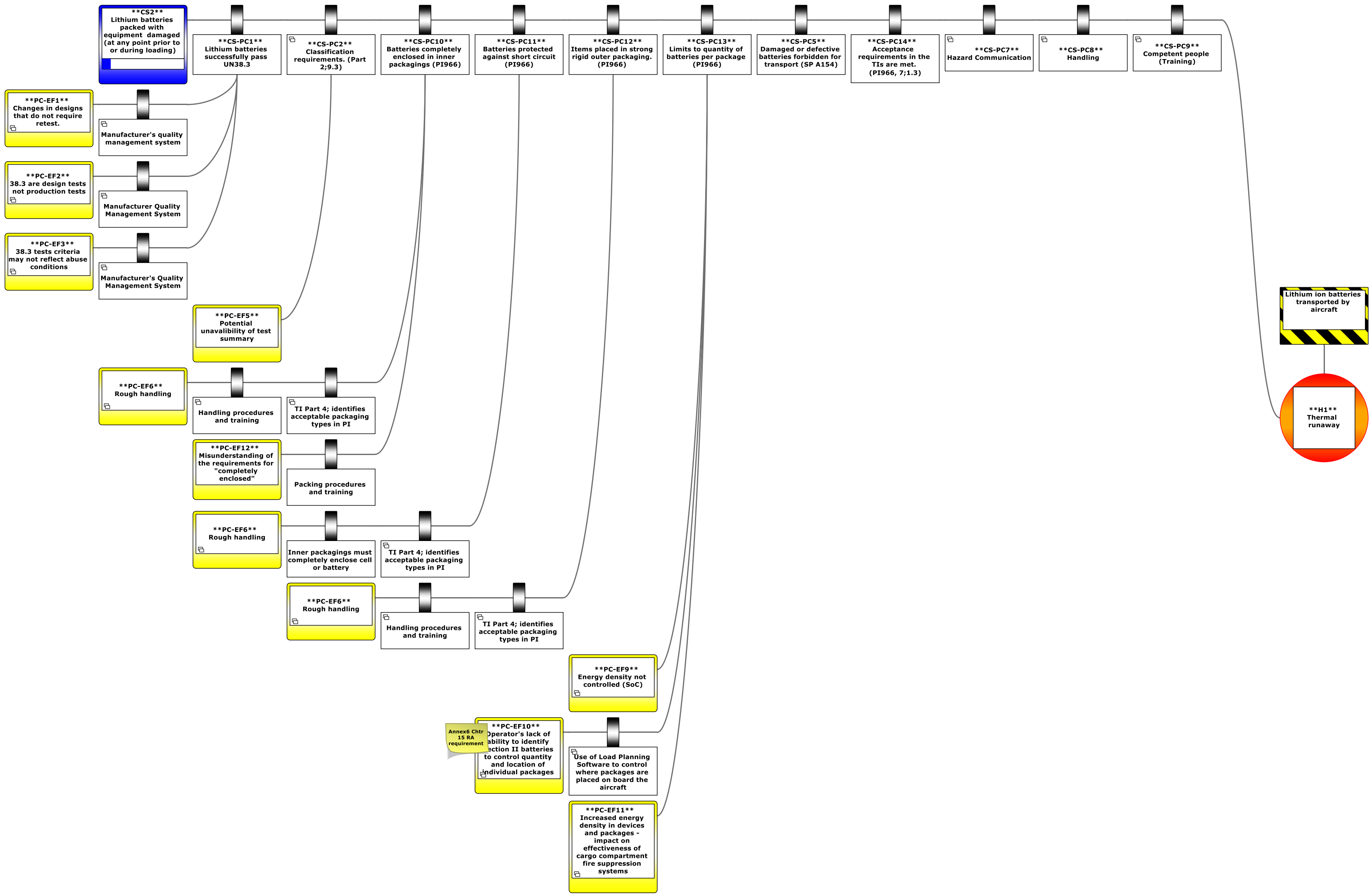
View 2 – Preventative Controls and Recovery Controls



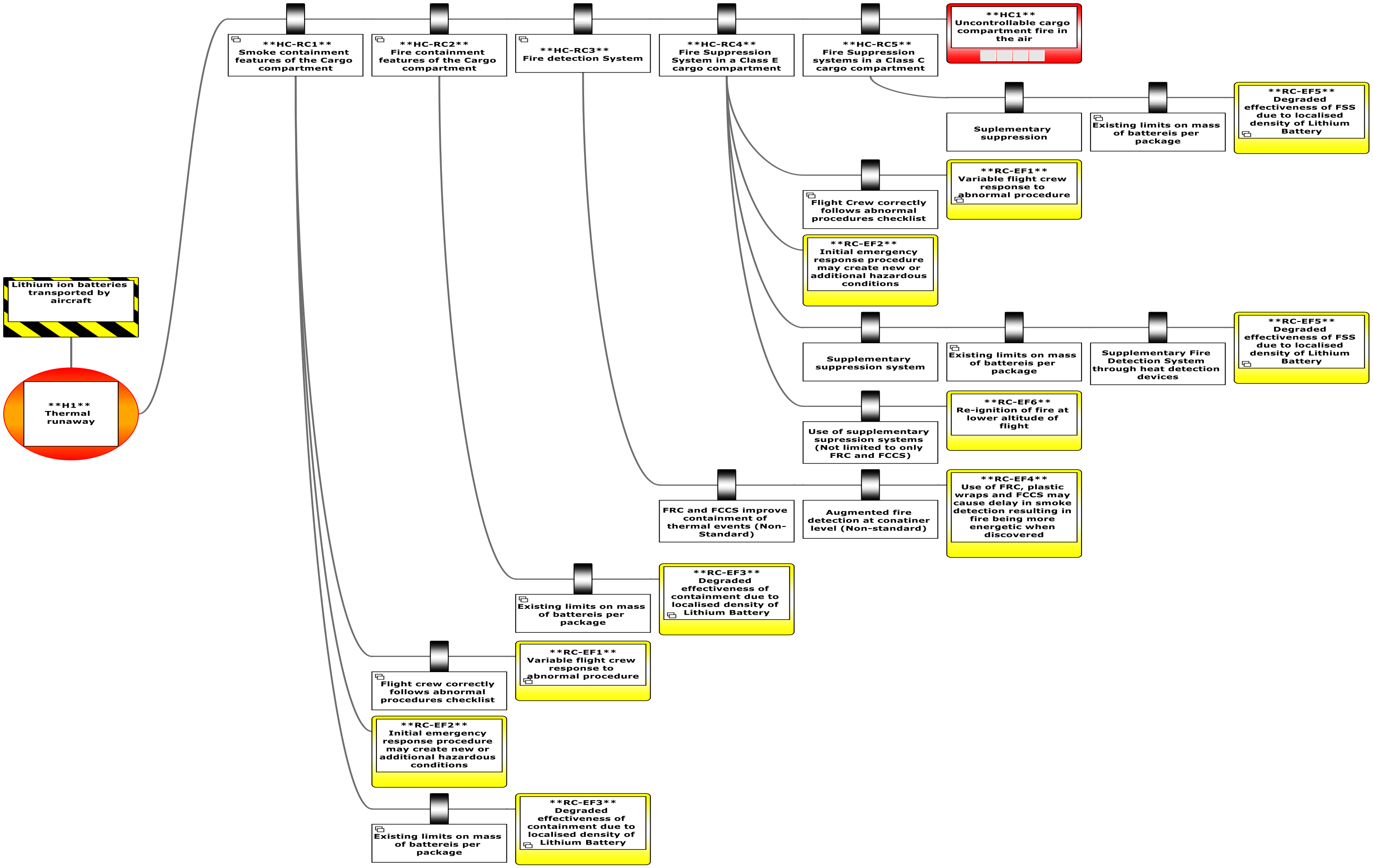
View 3a – Preventative Controls and Escalation Factors (HC1)



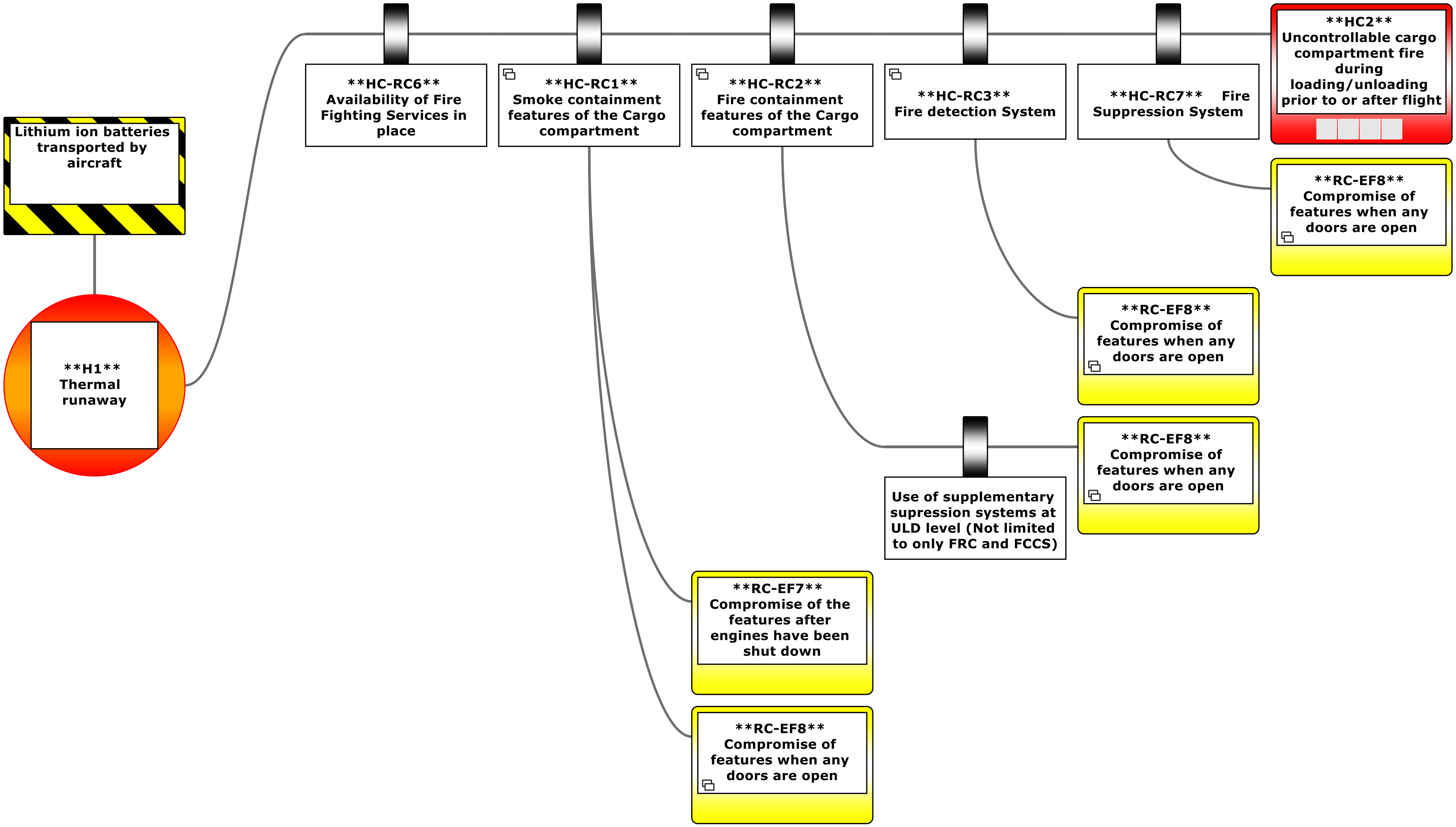
View 3b– Preventative Controls and Escalation Factors (HC2)



View 4a Recovery Controls and Escalation Factors (HC1)



View 4b– Recovery Controls and Escalation Factors (HC2)



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