International Civil Aviation Organization

DGP-WG/26-WP/28
13/10/26

**WORKING PAPER**

# DANGEROUS GOODS PANEL (DGP) WORKING GROUP MEETING (DGP-WG/26)

**Centurion, South Africa, 26 to 30 October 2026**

**Agenda Item 4: Managing safety risks posed by the carriage of energy storage devices by air (Ref: Job Card DGP.006)**

## ADJUSTABLE FIRMWARE IN A BATTERY – REGULATORY INTERPRETATION

(Presented by B. Firkins)

**SUMMARY**

This working paper informs the working group of approaches being made to freight forwarders and operators, who are being asked if they are prepared to transport, on aircraft, battery products which have been modified by a firmware adjustment in enable transport under the exceptions provided by Sections II and Sections IB of the lithium sodium ion battery packing instructions.

Action by the DGP-WG is in paragraph 2.

## 1. INTRODUCTION

1.1 In May 2026, a number of operators and freight forwarders received enquiries regarding a letter of interpretation (LoI) and two supporting white papers and whether they would carry batteries and battery powered products which conformed with that LoI.

1.2 A copy of the LoI is provided in Appendix A to this working paper. An accompanying White Paper titled **"**White Paper on ICAO Assessment of Firmware Derated Batteries contained in equipment" is provided in Appendix B to this working paper.

It is stressed that the White Paper titled "**White Paper on ICAO Assessment of Firmware Derated Batteries contained in equipment"** is **not** an ICAO paper.

1.3 An accompanying White Paper on the firmware limit is provided in Appendix C to this working paper.

1.4 An International Air Transport Association (IATA) discussion paper, which has been circulated with the IATA Dangerous Goods Board and the IATA Safety Group in order to develop an understanding of members' appetite for safety risk vs regulatory interpretation, is provided in Appendix D to this working paper.

1.5 The white papers (Appendices B and C) are unsigned, not on letterhead and contain no indication of authorship or organizational ownership. They primarily address and support the regulatory interpretation advanced in Appendix A, while containing limited discussion regarding the transport safety implications of classifying batteries according to adjustable firmware-limited operating characteristics.

1.6 It is noted that Appendix A addresses questions of regulatory interpretation under existing provisions. Questions regarding transport safety were not posed. The work of the United Nations Interim Working Group on Lithium Batteries, being a work a progress regarding battery test standards, would not be expected in a direct response to an interpretation of the current rule set.

1.7 Existing safety controls for the transport of dangerous goods have been developed over many years; with less stringent requirements for goods which present a minimal safety risk. These controls include:

a) UN specification packaging requirements;

b) enhanced marking and labelling;

c) dangerous goods documentation;

d) acceptance and inspection procedures;

e) loading and stowage controls;

f) operator notification processes; and

g) hazard communication to the pilot-in-command.

1.8 The concern arises when dangerous goods are engineered to fall below existing regulatory thresholds in order to benefit from the reduced transport controls. The proposal for adjustable firmware also introduces broader policy considerations regarding normalization of deviance, incremental expansion of the concept to higher-capacity batteries and potential systemic implications for aviation and cargo supply chain risk management.

1.9 The current discussion has arisen from relatively small variances in battery energy ratings. However, if the principle is accepted, DGP may wish to consider whether any practical limits or safeguards should apply to future applications involving larger disparities between physical battery capability and declared transport ratings. Examples include:

a) a mobility aid with a 750 Wh battery with an internal modifiable firmware to permit transport at less than 300 Wh, either in the cabin or in the cargo hold as part of the passenger provisions:

b) an electronic device with an installed battery of 450 Wh, being firmware adjusted to 99 Wh to take advantage of Packing Instruction 967, Section II packaging.

c) a replacement battery for a hybrid-electric powered vehicle, firmware adjustable from 950 Wh to 99 Wh to fall within the limits for Packing Instruction 965, Section IB.

1.10 Unlike a physical battery construction, firmware settings may potentially be updated, modified or replaced during a product's lifecycle. This raises questions regarding the extent to which transport classifications should rely upon software-based limitations that are not readily visible or independently verifiable by operators, regulators or other supply chain participants.

1.11 The issue extends beyond the specific circumstances considered in the original interpretation and may have broader implications for future battery designs.

1.12 As a result, there is value in establishing a common international understanding regarding the extent to which firmware controls may be relied upon for transport classification purpose. Without international alignment, operators, freight forwarders and shippers face uncertainty regarding whether a shipment acceptable in one jurisdiction will be viewed similarly elsewhere.

## 2. ACTION BY THE DGP-WG

2.1 The DGP-WG is invited to seek the views of the DGP and its members on the following question:

> "Is it appropriate for batteries that physically exceed established lithium battery energy thresholds to gain access to reduced regulatory requirements through adjustable firmware-imposed operating limitations, when those thresholds were originally established as the trigger for additional safety-based controls in air transport?"

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# APPENDIX A

# LETTER OF INTERPRETATION (LOI)

U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

June 26, 2025

Frank Lopez
Regulatory Compliance Specialist
Currie Associates
101 Ridge Street Suite I
Glens Falls, NY 12801

Reference No. 25-0021

Dear Mr. Lopez:

This letter is in response to your February 18, 2025 email requesting clarification of the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) applicable to the transportation of lithium ion cells and batteries. Specifically, you ask several questions regarding the use of firmware (*i.e.*, the software that controls the hardware of an electronic device) to limit the nominal energy expressed as the Watt-hour (Wh) rating of a lithium ion cell or battery contained in equipment. You present the following scenarios:

1. A lithium ion cell is capable of exceeding 20 Wh or a lithium ion battery is capable of exceeding 100 Wh, but the cell or battery firmware limits the nominal energy of the cell or battery to 20 Wh or 100 Wh, respectively.
2. A lithium ion cell is capable of exceeding 20 Wh or a lithium ion battery is capable of exceeding 100 Wh and is contained in equipment, but the cell or battery firmware limits the nominal energy of the cell or battery to 20 Wh or 100 Wh, respectively.
3. A lithium ion cell is capable of exceeding 20 Wh or a lithium ion battery is capable of exceeding 100 Wh and is contained in equipment, but the equipment's software limits the nominal energy of the cell or battery to 20 Wh or 100 Wh, respectively.
4. A lithium ion cell is capable of exceeding 20 Wh or a lithium ion battery is capable of exceeding 100 Wh and is contained in equipment, but the cell or battery firmware limits the nominal energy of the cell or battery to 20 Wh or 100 Wh. Furthermore, the cell or battery firmware is designed such that the end user can modify the cell or battery voltage to full capacity, exceeding 20 Wh or 100 Wh, respectively.

We have paraphrased and answered your questions as follows:

Q1. May the lithium ion cell or battery described in Scenario 1 be shipped in accordance with the smaller lithium ion cell and battery provisions in § 173.185(c)?

A1. Yes. The United Nations Manual of Tests and Criteria (UNMTC) (incorporated by reference, see § 171.7), subsection 38.3.2.3, defines nominal energy or Watt-hour rating as "the energy value of a cell or battery determined under specified conditions and declared by the manufacturer..." Firmware that controls the voltage and ultimately the nominal energy is within the design and specified conditions of the lithium ion cell or battery manufacturer. Therefore, the lithium ion cell or battery—as described in Scenario 1—can be considered a smaller lithium ion cell or battery for transportation.

Q2. May the lithium ion cell or battery contained in equipment described in Scenario 2 be shipped in accordance with the smaller lithium ion cell and battery provisions in § 173.185(c)?

A2. Yes. See answer A1. The lithium ion cell or battery contained in equipment—as described in Scenario 2—can be considered a smaller lithium ion cell or battery for transportation.

Q3. May the lithium ion cell or battery contained in equipment described in Scenario 3 be shipped in accordance with the smaller lithium ion cell and battery provisions in § 173.185(c)?

A3. No. In Scenario 3, the software that limits the lithium ion cell or battery nominal energy to 20 Wh or 100 Wh, respectively, is not inherent to the battery itself. Therefore, the lithium ion cell or battery manufacturer's declared nominal energy value for the lithium ion cell or battery must be used when determining the applicability of the small lithium ion cell and battery provisions in § 173.185(c).

Q4. May the lithium ion cell or battery contained in equipment described in Scenario 4 be shipped in accordance with the smaller lithium ion cell and battery provisions in § 173.185(c)?

A4. Yes. See answer A1. The lithium ion cell or battery contained in equipment—as described in Scenario 4—can be considered a smaller lithium ion cell or battery for transportation. However, PHMSA notes that any modification to the lithium ion battery firmware that increases the Wh rating or nominal voltage by 20 percent or more or any modification that represents a change that would lead to failure of any of the tests specified in the UNMTC Section 38.3 (incorporated by reference, *see* § 171.7), constitutes a new lithium battery type that must be tested prior to any further transportation—*see* § 173.185(a)(1) and UNMTC 38.3.2.2. In addition, the lithium ion cell or battery's marked Wh rating must be updated to reflect the new, higher Wh rating before any further transportation in commerce of the lithium ion cell or battery.

Q5. If the lithium ion cell or battery firmware limits the Wh rating of the cell or battery as described in Scenarios 1 through 4, should the cell or battery be marked[1] with the Wh

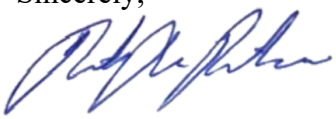
[1] See § 173.185(a)(5).

rating as limited by the firmware or the maximum possible nominal energy for the cell or battery?

A5. For Scenarios 1, 2, and 3, the lithium ion cell or battery must be marked with the Wh rating determined under the manufacturer's specified conditions—*i.e.*, as limited by the lithium ion cell or battery firmware (note – not the device's *software* for Scenario 3). For Scenario 4, the lithium ion battery must be marked with the Wh rating allowed by the currently operative firmware before transportation in commerce or as specified in A4, the new, higher Wh rating for the new lithium battery type before any subsequent transport in commerce. Please note that in each scenario, the lithium battery test summary must indicate the Wh rating appropriate to the cell or battery. For Scenario 4, this could require an update to reflect the higher Wh rating resulting from firmware updates.

I hope this information is helpful. Please contact us if we can be of further assistance.

Sincerely,



Dirk Der Kinderen
Chief, Standards Development Branch
Standards and Rulemaking Division

# APPENDIX B

## WHITE PAPER ON ICAO ASSESSMENT OF FIRMWARE DERATED BATTERIES CONTAINED IN EQUIPMENT

# White Paper on ICAO Assessment of Firmware Derated Batteries contained in equipment

## 1. Summary

The transport of lithium cells and batteries by air is strictly governed to mitigate safety risks, primarily thermal runaway and gas evolution. The baseline for these regulations is established by the International Civil Aviation Organization Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO Technical Instructions). A critical challenge for manufacturers and shippers is ensuring that novel power management designs—such as firmware derated batteries—align with these established provisions. This paper demonstrates that firmware derated single-cell batteries contained in an equipment, when properly configured and tested, fully satisfy the conditions required to be offered for transport under the ICAO Technical Instructions, UN3481 PI 967, Section II.

## 2. Regulatory Framework

Based on an evaluation of the ICAO Technical Instructions (2025-2026 edition) Packaging Instruction (PI) 967, Section II, and associated provisions, a firmware derated single cell battery contained in equipment containing at or below 20 Watt-hours (Wh) of energy that successfully meets all necessary safety, testing, and documentation criteria may be formally offered for air transport.

The packing instruction provision explicitly states that cells and batteries *"may be offered for transport"* provided that each unit meets the provisions of 2;9.3 a) and g), alongside specific capacity and marking limitations:

- **For cells (including single cell batteries):** The Watt-hour rating must not be more than 20 Wh.
- **For batteries:** The Watt-hour rating must not be more than 100 Wh.
- **Marking:** The Watt-hour rating must be marked on the outside of the battery case (except for batteries manufactured before 1 January 2009).

The phrase *"may be offered for transport"* is the key operational directive, indicating that products meeting these precise criteria are legally clear for air shipment without requiring fully regulated Class 9 dangerous goods handling, provided all Section II packing provisions are met.

## 3. Compliance Analysis

To qualify under UN3481 PI 967, Section II, the firmware derated battery must be evaluated against the specific sub-clauses of the ICAO Technical Instructions.

### 3.1. UN Testing Requirements (Provision 2;9.3 a)

- **Requirement:** The cell or battery must meet the requirements of the *UN Manual of Tests and Criteria, Part III, subsection 38.3* (commonly referred to as UN38.3 testing).

- **Compliance:** The firmware derated battery design has been subjected to and successfully meets all requisite UN38.3 testing criteria. It is structurally and electrically validated for transport safety.

### 3.2. Test Summary Availability (Provision 2;9.3 g)

- **Requirement:** Test summaries confirming the successful completion of the UN38.3 tests (as outlined in 2;9.3 a) must be made available.

- **Compliance:** Comprehensive test reports and summaries are documented and made readily available for the firmware derated battery design, ensuring full transparency for carriers and regulatory inspectors.

### 3.3. Watt-hour Limitation and Calculation

- **Requirement:** For single cells, the energy capacity must not exceed 20 Wh.

- In the case of the subject firmware derated battery, the capacity is electronically and physically limited (derated) via firmware. Using the manufacturer's specified parameters for the product *as offered for transport*, the calculated Watt-hour rating of this single-cell unit is strictly less than 20 Wh.

- The ICAO Technical Instruction mandates that the Watt-hour rating must be marked on the outside of the case specifically for *batteries* (defined as two or more cells electrically connected).

- While the subject item is a single-cell battery—and therefore not strictly bound by the Wh marking requirement intended for multi-cell batteries—the manufacturer has opted to exceed regulatory minimums. The single cell features a clear Watt-hour rating marked directly on the unit, removing any ambiguity for logistics handlers and inspectors.

## 4. Conclusion

The regulatory text is clear: Equipment that meets the enumerated safety and capacity thresholds "may be offered for transport."

The firmware derated battery design complies with UN38.3 testing (2;9.3 a), possesses the required documentation (2;9.3 g), and falls under the 20 Wh limit for cells. Furthermore, it provides transparent Wh marking that exceeds standard requirements. Therefore, based on manufacturer-specified parameters and strict adherence to the ICAO Technical Instructions (2025-2026 edition), **a firmware derated single cell battery contained in Equipment at or below 20 Wh is fully compliant and legally permitted for air transport.**

# APPENDIX C

# ACCOMPANYING WHITE PAPER ON THE FIRMWARE LIMIT

# Leveraging Battery Firmware to Maintain Regulatory Exceptions

## 1. Executive Summary

The global demand for higher energy density in portable electronics is pushing battery and product manufacturers to exceed regulatory energy thresholds for battery transport. This paper proposes a compliant design strategy—limiting nominal energy via battery-resident firmware—to retain access to regulatory exceptions (UN SP 188 / PI967-II IATA) during transport.

## 2. Problem Statement

Under international standards (UN Model Regulations), lithium-ion cells are categorized by their "nominal energy" (Watt-hour rating). The critical thresholds to leverage the transport exceptions is **20Wh for a cell and single cell battery** (and 100Wh for a multi cell battery pack).

Cells and single cell batteries rated at 20Wh or less benefit from significant relief and are considered excepted under the dangerous goods transport regulations, e.g., UN Model Regulation **Special Provision 188** (international ground) and ICAO/IATA **PI967 Section II** (international air).

If a manufacturer produces a cell exceeding 20Wh (e.g., 22Wh) to meet market demands for longer battery life, they lose these exceptions. The shipment becomes a fully regulated Class 9 Dangerous Good. This imposes mandatory requirements such as Hazard Labeling, Shipping Papers, Specialized Training, Carrier Restrictions, etc.

## 3. Impact Analysis

The transition from "Excepted" to "Fully Regulated" status creates challenges in the supply chain:

- **Cost:** Shipping costs can triple due to hazmat surcharges and specialized packaging.
- **Velocity:** Reduced carrier options lead to longer lead times and inability to use standard express logistics networks.
- **Marketability:** Complexity in returns and reverse logistics (e.g., warranty repairs) discourages distributors and end-users from handling the product.

## 4. Proposal: The Firmware-Limited Architecture

To balance high-performance hardware with logistics efficiency, we propose the following design architecture:

- **Hardware:** Manufacture a lithium-ion cell with a physical capacity exceeding 20Wh (e.g., 22Wh).
- **Firmware Control:** Install firmware directly onto the single cell battery that limits the usable voltage and nominal energy to 20Wh.
- **Transport Status:** Ship the device/single cell battery using the firmware-limited rating (≤20Wh) to utilize regulatory exceptions.

**Post-Transport Unlock (Optional):** Allow for end-user modification to unlock full capacity (subject to specific constraints discussed in Section 5).

## 5. Feasibility and Regulatory Validation

The success of this proposal relies on whether regulators accept "firmware" as a valid method for determining a battery's rating. Based on the interpretation by the Pipeline and Hazardous Materials Safety Administration (PHMSA) dated June 26, 2025, this approach is **compliant**, provided specific engineering criteria are met.:

### A. Firmware vs. Software: The Critical Distinction

For the proposal to succeed, the energy limitation must be inherent to the battery, not the host device (cannot be exclusively software).

- **Successful Approach (Battery Firmware):** PHMSA confirms that if firmware controls the voltage and nominal energy, the resulting value is considered the "declared" rating by the manufacturer as offered for transportation. A cell or single cell battery capable of >20Wh but limited to 20Wh or less by its own firmware **may be shipped** under the smaller cell provisions. This applies even if the battery is contained within equipment.
- **Failed Approach (Device Software):** If the cell has a rating >20Wh, and the *equipment's* software limits the draw to 20Wh, this **does not qualify** for the exception. The limitation is not inherent to the battery, and the higher physical rating must be used for transport classification.

### B. End-User Unlock Capabilities

A unique advantage of this proposal is the potential for "Unlockable Capacity." PHMSA acknowledges scenarios where firmware is designed to allow the end-user to modify voltage to full capacity later, and has and has [determined/opined] that transport of these "unlockable" batteries under the lower (20Wh) rating is permitted.

### C. Marking and Testing Requirements

To ensure success under this proposal, manufacturers must adhere to the following marking protocols:

- **Marking:** The cell must be marked with the Wh rating determined under the firmware-limited conditions (20Wh), which may appear in addition to the true rated capacity.
- **Test Summary:** The UN 38.3 Test Summary must indicate the Wh rating appropriate to the firmware-limited state.

## 6. Conclusion

This proposal would enable manufacturers to successfully market cells with physical capabilities exceeding 20Wh while leveraging global transport exceptions by embedding energy limits in the battery firmware. This strategy is validated by PHMSA Interpretation 25-0021. To succeed, the energy limit must be controlled by the battery's firmware (not device software), marked according to the limited rating, and supported by a matching UN Test Summary. This approach optimizes initial supply chain costs without compromising safety compliance.

# APPENDIX D

# IATA DISCUSSION PAPER

# Discussion Paper
# Batteries Limited by Firmware

## Executive Summary

Recent industry enquiries have highlighted the emergence of lithium battery designs that utilize firmware controls to limit the declared watt-hour (Wh) rating of a cell or battery for transport purposes. Such designs may allow products that physically contain higher-capacity cells to be offered for transport under regulatory provisions intended for lower-energy batteries.

A regulatory interpretation has been issued by the United States Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA), which, along with supporting papers have been circulated to forwarders and airlines in the aviation industry.

While the interpretation may provide a lawful basis for compliance within the United States regulatory framework, important questions remain regarding the broader safety intent of international dangerous goods regulations, the potential implications for multimodal transport, and the absence of a globally harmonized position.

This paper is intended to explore whether the interpretation remain aligned with the safety objectives that originally informed lithium battery transport thresholds and whether further consideration by international regulatory bodies is warranted.

## Background

Lithium battery transport provisions include a series of thresholds that distinguish between fully regulated dangerous goods and batteries eligible for various regulatory exceptions or reduced regulatory requirements.

These thresholds have historically been based on characteristics such as:

- Cell watt-hour rating;
- Battery watt-hour rating;
- Lithium content;
- Packaging configuration; and
- Quantity limitations.

In recent months, industry stakeholders have been approached regarding products containing batteries whose physical electrochemical capability exceeds a regulatory threshold, but whose operational energy is limited through battery-resident firmware which can be subsequently adjusted.

The central proposition is that a battery capable of exceeding a threshold, such as 20 Wh for a cell or 100 Wh for a battery, may nevertheless be classified and transported based on its firmware-limited operating state if that state is declared by the manufacturer and forms part of the battery design. Once in the hands of the end-user, the battery is adjusted to a higher operational energy rating.

This approach has commercial implications because maintaining eligibility for transport under reduced regulatory provisions significantly reduces packaging, documentation, marking, labelling and transportation costs.

The issue therefore sits at the intersection of regulatory interpretation, technological innovation, commercial efficiency and transport safety.

## The Regulatory Interpretation Question

At its core, the current debate concerns how dangerous goods regulations should interpret "nominal energy" or declared watt-hour rating.

One view is that a battery should be classified according to the energy available under the manufacturer's specified operating conditions, including battery management system limitations that form part of the battery's design. A battery manufacturer may intentionally limit a battery comprised of cells that are able to store 300 Wh of energy to 250 wh in order to ensure a longer operational life.

Under this approach, firmware is regarded as an integral component of the battery system rather than an external operational control. Accordingly, a battery whose energy output is limited through firmware may be classified according to that limited rating.

An alternative view is that transport classification should focus on the battery's inherent physical characteristics, including the total electrochemical energy available within the cell or battery irrespective of software or firmware-imposed operating limits.

The concept of an ability to adjust a battery firmware so that it meets a lower threshold for transport and a higher threshold for normal daily use in the home and office is novel. Anecdotally whilst an interpretation has been provided by one regulatory agency; a number of other regulatory authorities approached by IATA have not received a request for an interpretation in their jurisdictions.

However, the key question is not whether an interpretation can be legally supported within a particular jurisdiction or has validity in other jurisdictions, but whether that interpretation reflects the broader safety objectives of the international dangerous goods framework.

## The Aviation Safety Question

The more fundamental issue is whether transport classifications based on adjustable firmware-limited ratings are consistent with the original safety rationale that underpins lithium battery regulations.

Historically, transport provisions were developed in response to concerns regarding:

- Thermal runaway;
- Heat release during failure;
- Fire propagation;
- Gas generation;
- Explosion hazards; and
- Challenges associated with suppressing lithium battery fires during transport.

These hazards arise from the physical characteristics of batteries rather than solely from their intended operating state.

The significance of lithium battery transport thresholds extends beyond classification alone. These thresholds determine the safety measures applied throughout the transport system and form the basis for a layered approach to risk management.

As a basic principle, where dangerous goods exceed specified thresholds, then additional controls are applied, including:

- Use of UN specification packaging;
- Additional marking and hazard communication;
- Dangerous goods documentation requirements;

- Formal acceptance procedures and inspection checks;
- Operational restrictions relating to loading and stowage; and
- Notification of hazardous cargo information to the pilot-in-command.

These measures were developed to ensure that transport personnel are aware of the presence of higher-hazard batteries and that appropriate safeguards are applied throughout the logistics chain.

A lower SoC might reduce the likelihood of a thermal runaway event, however, several questions arise:

- Does firmware limitation materially reduce the consequences of thermal runaway?
- Does it reduce the amount of combustible material present within a battery?
- Does it reduce heat release during catastrophic failure?
- Does it reduce gas generation or propagation risk?
- Should transport classification be based primarily on operational capability or physical inventory of energy-producing materials?

The issue is not about how the original watt-hour rating thresholds were determined or the rate at which technological improvements exceeded those energy capacities. It is about whether firmware-based classification has the effect of avoiding risk mitigation measures that regulators intentionally associated with higher-energy batteries. If the underlying transport hazards remain substantially unchanged, it is necessary to consider whether the resulting reduction in packaging, communication and operational controls remains consistent with the safety objectives of the dangerous goods framework.

## Supply Chain Assurance and Regulatory Oversight

An additional consideration is whether the current regulatory oversight framework is sufficiently robust to support widespread reliance on adjustable firmware-limited battery classifications.

The dangerous goods system places a heavy reliance upon the integrity and compliance by manufacturers, their adherence with the UN Manual of Tests and Criteria, Part III, subsection 38.3 (UN 38.3), diligent shippers, enquiring freight forwarders and effective oversight by competent authorities. In practice, all parties downstream of the manufacturer lack the technical means to independently verify a manufacturer's declared battery characteristics, firmware limitations, test conditions, or subsequent design changes.

Consequently, the safe operation of the system depends upon confidence that:

- Manufacturers accurately declare battery characteristics;
- UN 38.3 testing has been conducted appropriately;
- Test reports and summaries accurately reflect the product being shipped;
- Firmware limitations remain effective throughout the product lifecycle;
- Strong interfaces between the respective parties i the supply chain; and
- Competent authorities are capable of detecting and addressing non-compliance.

A layered system can cater for one or two of these assumptions being weakened. With some notable exceptions, the current cargo supply chain is considered to have poor interfaces between the parties, and a belief that compliance and verification is someone else's responsibility. The aviation industry's confidence in Regulatory Oversight and their upstream and downstream supply chain partners is low.

## Confidence in Compliance Verification

The discussion also raises broader questions regarding the effectiveness of international compliance and enforcement systems.

While many battery manufacturers maintain high standards of compliance, there remains ongoing concern throughout the transport industry regarding undeclared dangerous goods, inaccurate declarations, counterfeit testing documentation and inconsistent regulatory oversight across jurisdictions.

The introduction of firmware-dependent classifications further increases the complexity of compliance verification.

Historically, watt-hour ratings have largely reflected the physical and electrical characteristics of the battery itself. Adjustable firmware-limited classifications introduce a new dimension whereby transport eligibility may depend upon software-controlled operating parameters that are not readily visible or verifiable during transport, especially in the cases of return logistics involving defective products or e-commerce distribution by secondary retailers.

The challenge is not whether compliance can be achieved by responsible manufacturers. There is comfort with responsible large-scale global product manufacturers who understand the threats to global reputational risk that might arise,. The question is whether authorities and supply chain participants possess practical mechanisms to consistently verify and enforce compliance across a rapidly expanding global battery manufacturing sector.

## Normalisation of Deviance and Incremental Expansion

A further policy consideration is the potential for normalisation of deviance. In high-consequence industries, normalisation of deviance occurs when an exception, accommodation or reinterpretation that initially appears minor gradually becomes accepted practice and ultimately shifts the boundaries of what is considered acceptable.

In the current context, stakeholders may view the difference between a 20 Wh cell and a higher energy 22 Wh cell as relatively insignificant. However, the principle of adjustable-firmware being an accepted and established principle, becomes more significant than the specific example under discussion.

Once it is accepted that transport classification can be based upon firmware-limited capability rather than physical capability, similar arguments will be advanced for progressively larger batteries. Questions have already been put to IATA regarding batteries physically designed to be charged to and operated in excess of 100 Wh but being firmware-limited purely for and during transportation to remain below the regulatory threshold of 100 Wh.

The concern is less about a specific 20 Wh versus 22 Wh debate and more about the precedent that is being established for future applications.

Without clear internationally agreed boundaries, there is potential for a significant and rapid expansion of the concept beyond the circumstances originally contemplated by regulators.

## Systemic Risk Considerations

From a safety management perspective, it is also necessary to consider the consequences of being wrong. If a firmware-limited battery genuinely presents a hazard equivalent to a lower-capacity battery, then the regulatory outcome may be appropriate.

However, if the hazard during thermal runaway is more closely related to the battery's physical construction, material inventory, or maximum potential energy than its firmware-limited operating condition, then the regulatory classification may underestimate the actual risk present within the transport system.

The issue becomes more significant as the scale of battery deployments increases and as larger-capacity batteries enter global transport networks.

A key objective of dangerous goods regulation is to ensure that protective measures remain commensurate with the hazard being transported. As a result, any shift from physically-based thresholds towards adjustable firmware-based classifications should be accompanied by confidence that the resulting safety outcomes are equivalent or superior to those intended by the existing framework.

## The International Dimension

A further consideration is the absence of a harmonised international position.

Interpretations issued by one national authority may influence regulators elsewhere, but they do not automatically establish global consensus. This is particularly relevant in a multimodal transport environment where batteries may move internationally by air, road, rail and sea under different legal frameworks and under the jurisdiction of multiple competent authorities. Equally important is whether a State's domestic legislation also concurs with the interpretation.

The consequences of a particular interpretation may therefore extend well beyond aviation. For example, transport exceptions available under one mode may also influence how batteries are identified, declared, marked and handled throughout the broader supply chain.

Without international alignment, operators, freight forwarders and shippers may face uncertainty regarding whether a shipment acceptable in one jurisdiction will be viewed similarly elsewhere.

## Summary

The issue extends beyond the interpretation of regulatory text. It raises questions concerning supply chain assurance, the effectiveness of compliance oversight, the practical ability of regulators and industry to verify firmware-dependent classifications (especially when able to be adjusted), and the potential for incremental expansion of such interpretations into increasingly higher-capacity batteries. While innovation should not be discouraged, there may be value in establishing an internationally harmonised position that considers not only regulatory permissibility, but also the underlying safety intent, verification challenges and long-term implications for the dangerous goods transport system.

"The dangerous goods framework deliberately links higher battery energy to progressively stronger transport risk controls. Firmware limitation potentially disconnects those controls from the physical hazard they were intended to manage."