

Hazard Assessment of Portable Electronic Devices in Aviation

By Dr. Yi Ji, Witawat Daungjaiboon, Dr. Denice Durrant | UL Standards & Engagement



Abstract

This report presents a comprehensive hazard assessment of seven representative portable electronic device (PED) categories, analyzing risk levels and likelihood across five critical dimensions: manufacturing defects, state of charge, abnormal environmental conditions, safety control failures, and thermal runaway. Data-driven insights highlight high-risk devices such as power banks and e-cigarettes, which account for the majority of TR events and recalls. Recommendations include mandatory certification for high-risk devices, capacity limitations, enhanced passenger education, and proactive regulatory measures to mitigate risks and improve aviation safety.

Highlights:

High-Risk PEDs Identified - Power banks and e-cigarettes (vapes) pose the greatest aviation risks, accounting for most thermal runaway events and recalls. Flammable cartridges in vapes significantly elevate fire and explosion hazards.

State-of-Charge Concerns - High-capacity devices such as laptops, power banks, and CPAP machines are often fully charged before flights, increasing the potential for hazardous energy release under abnormal conditions.

Environmental Stressors Challenge Safety - Reduced cabin pressure, extreme cargo temperatures, and mechanical stresses can compromise even well-designed PEDs, especially as batteries age.



Introduction

Portable electronic devices (PEDs) have become ubiquitous in modern travel, with passengers frequently carrying multiple PEDs on board aircraft. The widespread use of lithium-ion batteries in these devices has raised significant safety concerns due to their potential to trigger thermal runaway (TR) events, such as overheating, smoke, swelling, fire, or explosion. In the confined environment of an aircraft, these risks are further aggravated.

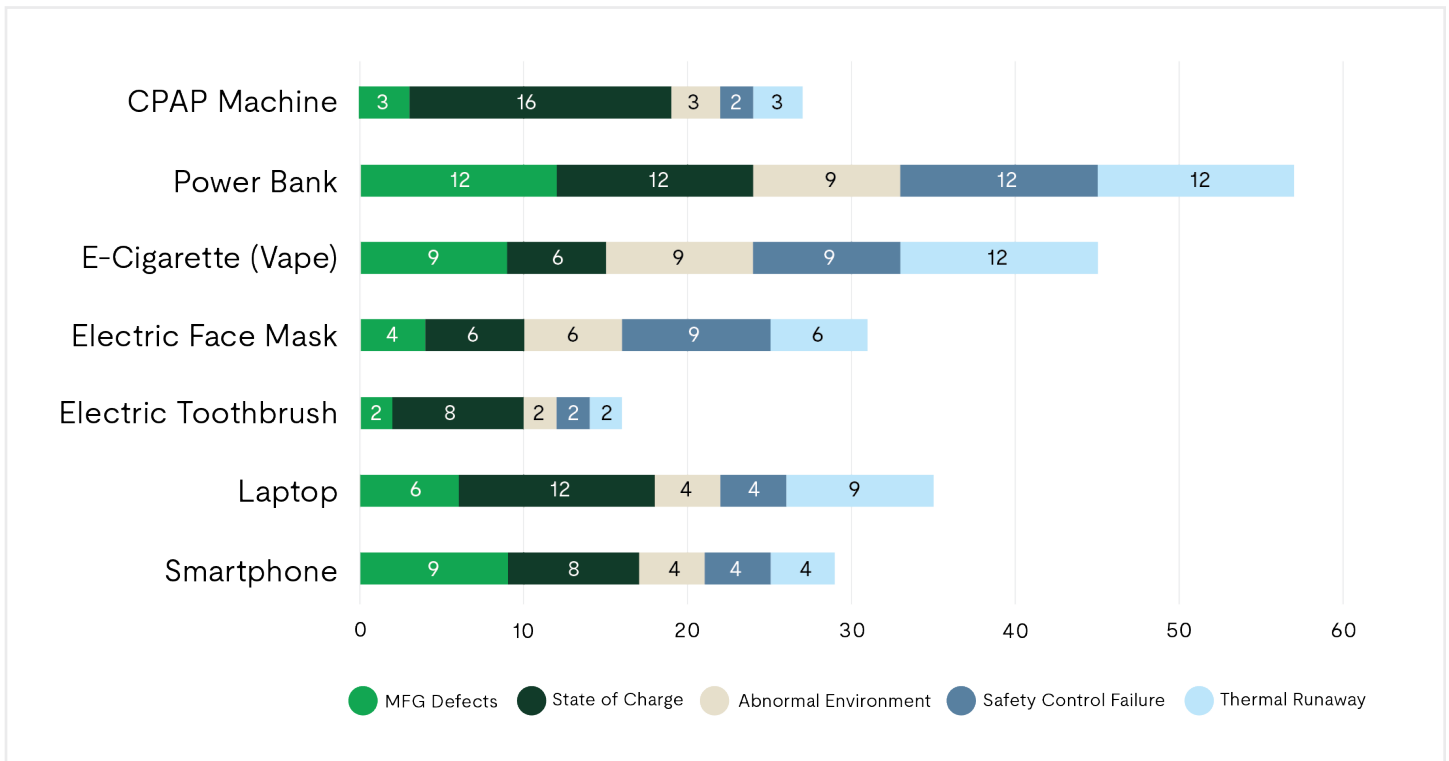
This report aims to assess the hazards associated with PEDs in aviation, focusing on devices powered by lithium-ion batteries. Seven representative PEDs were selected for evaluation: a) smartphones (widely used PEDs), b) laptops (high-energy and widely used PEDs), c) electric toothbrushes (small PEDs), d)

electric face masks (emerging PEDs), e) e-cigarettes or vapes (emerging PEDs), f) power banks (high-energy storage devices), and g) continuous positive airway pressure (CPAP) machines (high-energy medical devices).

The hazard assessment of PEDs in aviation is based on risk level and likelihood across five aspects: manufacturing (MFG) defects, state of charge (SOC), abnormal environmental conditions, safety control failure, and thermal runaway.

Insights from this analysis are intended to enhance safety awareness among aviation personnel and travelers, providing actionable recommendations to stakeholders, and reducing PED-related incidents in aviation.

Visual Summary



WHITE PAPER

Device	Smartphone	Laptop	Electric Toothbrush	Electric Face Mask	E-Cigarette Vape	Power Bank	CPAP Machine
Battery	Li-ion/Li-polymer	Li-ion/Li-polymer	Li-ion/Li-polymer	Li-ion/Li-polymer	High-Rate Li-ion	Li-ion/Li-polymer	Li-ion (e.g., LFP)
Capacity	1,500-5,000 mAh (10-20 Wh)	4,000-9,000 mAh (40-100 Wh)	300-800 mAh (2-3 Wh)	800-3,000 mAh (7-20 Wh)	650-4,000 mAh (2-15 Wh)	5,000-30,000 mAh (20-110 Wh)	20,000-40,000 mAh*
Voltage	3.7-4.5 V	7.6-15 V	3.2-3.7 V	3.7-5 V	3.7 V	3.7-12 V	12-24 V
Form	Slim pouch cell	Cylindrical cell pack or pouch cell	Small cylindrical pr pouch cell	Flat pouch or small cell	Cylindrical cell (e.g. 18650, 21700) or pouch cell	Cylindrical/Flat pack (Prismatic)	Pack (External)
Charging Rate	0.5-2C	0.5-1C	0.1-0.3C	0.3-1C	0.5-1C	0.5-2C	0.2-0.5C
Discharging Rate	<0.5C	<1C	1-2C bursts (motor pulses)	0.5-2C	1-20C bursts	Depends on devices connected	<0.1C
Cycle Life	500-800 cycles	300-1,000 cycles	300-800 cycles	300-500 cycles	200-500 cycles	300-700 cycles	300-5,000 cycles
Design Focus	Slim design, high energy density, long standby, fast charge	High energy & power, thermal safety	Waterproof, vibration-stable, compact	Lightweight, gentle use	High discharge, user replaceable	High capacity, portability, multi-device use	Medical-grade operational reliability
Safety	BMS, thermal sensors, software-based power control and battery aging monitoring, overcurrent cutoff, ingress protection (IP rating)	Smart BMS, thermal sensors, battery aging monitoring with firmware-based control, cell balancing, charge rate limiting, passive venting	Ingress protection (IP rating), current limiting	Thermal shutoff, timer auto-stop	Warnings against misuse, venting, protection against overheating, overcharging, and short circuits by microcontrollers and PCBs	Auto shutoff, overvoltage protection, short-circuit protection (fuses or circuit breakers)	IEC/FDA-compliant designs (FAA approved for in-flight use)

Table 1. Comparison of Batteries and Their Designs in PEDs

*CPAP machine: power bank 300-600 Wh; machine 30-100Wh

	Smartphone		Laptop		Electric Toothbrush		Electric Face Mask		E-Cigarette (Vape)		Power Bank		CPAP Machine	
	Risk Level	Likelihood	Risk Level	Likelihood	Risk Level	Likelihood	Risk Level	Likelihood	Risk Level	Likelihood	Risk Level	Likelihood	Risk Level	Likelihood
MFG Defects	Serious	Likely	Serious	Possible	Minor	Possible	Moderate	Possible	Serious	Likely	Serious	Very Likely	Serious	Unlikely
SOC	Moderate	Very Likely	Serious	Very Likely	Moderate	Very Likely	Moderate	Likely	Moderate	Likely	Catastrophic	Likely	Catastrophic	Very Likely
Abnormal Environment	Moderate	Possible	Moderate	Possible	Minor	Possible	Serious	Possible	Serious	Likely	Serious	Likely	Serious	Unlikely
Safety Control Failure	Moderate	Possible	Moderate	Possible	Minor	Possible	Serious	Likely	Serious	Likely	Catastrophic	Likely	Moderate	Unlikely
Thermal Runaway	Moderate	Possible	Serious	Likely	Minor	Possible	Serious	Possible	Catastrophic	Likely	Catastrophic	Likely	Serious	Unlikely

Table 2. Safety Hazard Assessment of Representative PEDs in Aviation

Discussion

Part 1. Safety Hazard Assessment in Terms of PED Risk Levels and Likelihoods

Table 1 outlines the fundamental properties of selected PEDs, including battery type and configuration; electrochemical characteristics such as capacity, voltage, charging and discharging rates, and cycle life; as well as design focus and integrated safety measures. This section provides a detailed explanation of the risk levels and likelihoods presented in Table 2, analyzed from five perspectives: manufacturing defects, state of charge, abnormal environmental conditions, safety control failure, and thermal runaway.

Manufacturing Defects

Power banks account for 36% of recalls involving PEDs used in aviation, while e-cigarettes (vapes) represent 9% of such recalls. Our analysis draws on consumer product recall data from the U.S. Consumer Product Safety Commission (CPSC)¹, Health Canada², the European Commission Safety Gate Rapid Alert System³, and the OECD Global Recalls portal⁴, all accessed via UL Standards & Engagement's Open Data for Safety Incidents portal⁵. We filtered records with common PED keywords (e.g., power banks, laptops, smartphones, vapes, CPAP machines, smart rings, cameras, and drones) and used a machine learning technique (topic modeling) to group similar recalls and highlight recurring defects (battery failures, overheating, and charging faults). This suggests a high likelihood of manufacturing defects in power banks and a notable probability for e-cigarettes (vapes). For other PEDs, manufacturing defects remain a possibility.

CPAP machines, which are regulated by the FDA and/or IEC standards and approved by the FAA for in-flight use, show a lower likelihood of manufacturing defects.

In aviation, the risk associated with manufacturing defects is a cumulative effect of factors, such as state of charge, exposure to abnormal environmental conditions, and failure of safety controls.

State of Charge

The risk level associated with SOC in PEDs is primarily determined by their battery capacity: moderate for devices under 5,000 mAh; serious for those up to 10,000 mAh; and catastrophic for capacities exceeding 10,000 mAh. The likelihood of risk is influenced by traveler behaviors, particularly charging habits prior to, or during air travel. Passengers are very likely to fully charge commonly used devices such as smartphones, laptops, electric toothbrushes, and CPAP machines. In contrast, electric face masks, e-cigarettes (vapes), and power banks, are often partially or fully charged, depending on usage patterns and travel duration. These behaviors increase the probability of high-energy devices being active or environmentally abused during flight, thereby elevating the overall risk profile.

Abnormal Environmental Conditions

The primary environmental stressors that can lead to abnormal behavior or failure of PEDs during air travel include altitude-related low pressure, abnormal temperatures, and mechanical abuses such as vibration and shock.

Even in pressurized cabins, the ambient pressure at cruising altitude typically simulates conditions at 6,000–8,000 feet above sea level. This reduced pressure can lead to battery swelling or electrolyte leakage, particularly in lithium-ion cells. Such effects

¹ U.S. Consumer Product Safety Commission (CPSC) — Recall Database. <https://www.cpsc.gov/Recalls>

² Health Canada — Consumer Product Recalls and Advisories. <https://recalls-rappels.canada.ca/en>

³ European Commission — Safety Gate Rapid Alert System. <https://ec.europa.eu/safety-gate>

⁴ OECD — Global Recalls Portal. <https://globalrecalls.oecd.org>

⁵ UL Standards & Engagement — Open Data for Safety Incidents. <https://opendata.ul.org/> (accessed Jul 21, 2025)

are more pronounced in devices with aging batteries, substandard battery design, or manufacturing defects.

Temperature-controlled cargo holds are typically maintained between 32–75°F (0–24°C). When animals are transported, the temperature may be increased to 64–75°F (18–24°C) to ensure their safety. In contrast, standard cargo holds can experience a much wider temperature range, from -40–80°F (-40–27°C). If PEDs are stored in these areas, they may be exposed to abnormal temperatures, which can affect their performance and reliability.

Aircraft operations involve continuous vibration and occasional shocks during takeoff, taxiing, turbulence, and landing. These mechanical abuses can damage internal battery components or circuitry, especially in devices with fragile or poorly secured battery assemblies. Safety can be improved through compliance with crush, impact, shock, and vibration tests.

Note that batteries transported by aircraft are required to undergo UN 38.3 testing, which includes altitude simulation, thermal, vibration, shock, and impact/crush testing. While UN 38.3 is primarily intended to validate that a battery or device is suitable for bulk (cargo) transport, devices carried by passengers have also likely undergone these tests by the manufacturer. The primary safety concerns center on battery aging and are further exacerbated under abnormal environmental conditions. These concerns include whether failures due to aging can be effectively detected, and whether product stability is maintained after aging when exposed to such abnormal conditions.

Electric toothbrushes, which are permitted in both carry-on and checked baggage by the TSA, typically have low-capacity batteries and are often validated through vibration testing. The products also can be considered battery enclosures designed to isolate hazardous batteries in the event of a failure. Therefore, the associated risk from abnormal environmental conditions is considered minor. Aged electric toothbrushes may be exposed to abnormal temperatures when stored in the cargo hold.

While smartphones and laptops may overheat when left on tray tables in direct sunlight, the greater concern arises when PEDs are stored in checked baggage, where they are inaccessible during flight. According to a ULSE Insights survey of U.S. passengers, 38% admitted to placing lithium-ion powered devices in their checked luggage, and 27% did the same with power banks⁶. In addition to altitude-related low pressure and mechanical abuse, aged PEDs stored in the cargo hold are likely to experience temperature variations, depending on the aircraft type, flight duration, and external conditions.

For products without a battery management system (BMS), battery aging may go unnoticed and such devices could be brought onto airplanes. This is especially concerning for e-cigarettes (or vapes), which use compact, high-discharge-rate lithium-ion batteries that accelerate aging through frequent high-power demands. E-cigarettes (or vapes), typically carried in carry-on baggage, are particularly susceptible to thermal runaway if the batteries are aged and exposed to heat.

E-cigarettes (vapes) are also vulnerable to mechanical failure under conditions of vibration or pressure, making their overall risk level serious, especially given their battery type and documented incidents. Without effective battery-aging detection, the associated risk profile and vulnerabilities are significantly amplified under such conditions. Electric face masks generally use small batteries, which may be of lower quality in inexpensive models. If they are stored in checked luggage, they could possibly be exposed to temperature extremes and pressure variations, potentially leading to battery damage or swelling. As such, their risk level is considered moderate, heavily depending on build quality and storage conditions.

CPAP machines are typically carried in the cabin due to their medical use, making them less susceptible to abnormal environmental conditions. While they may include high-capacity power banks, these are usually in pack format, which offers greater resistance to mechanical damage compared to cylindrical or pouch cells.

⁶ Lithium-Ion Battery Incidents in Aviation: 2024 Data Review, ULSE Inc. ulse.org/wp-content/uploads/2025/06/TRIP-Report-May-2025-Final.pdf (accessed Jan 21, 2026)

Safety Control Failure

Portable electronic devices such as smartphones, laptops, and electric toothbrushes, which adhere to established safety standards and/or incorporate BMS, thermal sensors, and battery-aging monitoring, are generally less prone to failures in safety controls. And such failures, if they occur, are typically detected and addressed promptly.

In contrast, PEDs such as electric face masks, e-cigarettes (vapes), and power banks often lack sophisticated real-time safety controls or alarms to detect and respond to safety failures. Notably, e-cigarettes (vapes) contain flammable cartridges or nicotine (e-juice) ports, which further elevate the risk of fire or explosion if battery safety controls fail. Power banks, with their high capacity, represent a significant hazard under abnormal aviation conditions. If their safety mechanisms fail or are absent, the last barrier against catastrophic thermal events is lost.

CPAP machines and their power banks, which are subject to FDA and/or IEC regulations and are FAA-

approved for in-flight use, also demonstrate a high level of safety reliability. However, since any failure in these systems may go undetected during flight, the overall risk level is considered moderate.

The analysis from UL Standards & Engagement’s Thermal Runaway Incident Program (TRIP)⁷ reveals a significant increase in thermal runaway occurrences associated with lithium-ion batteries in global aviation operations from 2016 to 2024. Figure 1 shows the top four PEDs causing thermal runaway incidents in aviation. The noticeable dip in TR incidents in aviation during 2020 can likely be attributed to the global impact of the COVID-19 pandemic. In 2020, international air traffic dropped sharply due to lockdowns, travel restrictions, and a significant decline in passenger demand. With fewer flights, there were naturally fewer opportunities for incidents involving lithium-ion batteries.

The overall risk level of a TR event depends on several factors, including the battery’s SOC, the effectiveness of safety controls, and the design of the device. For example, in the case of smartphones,

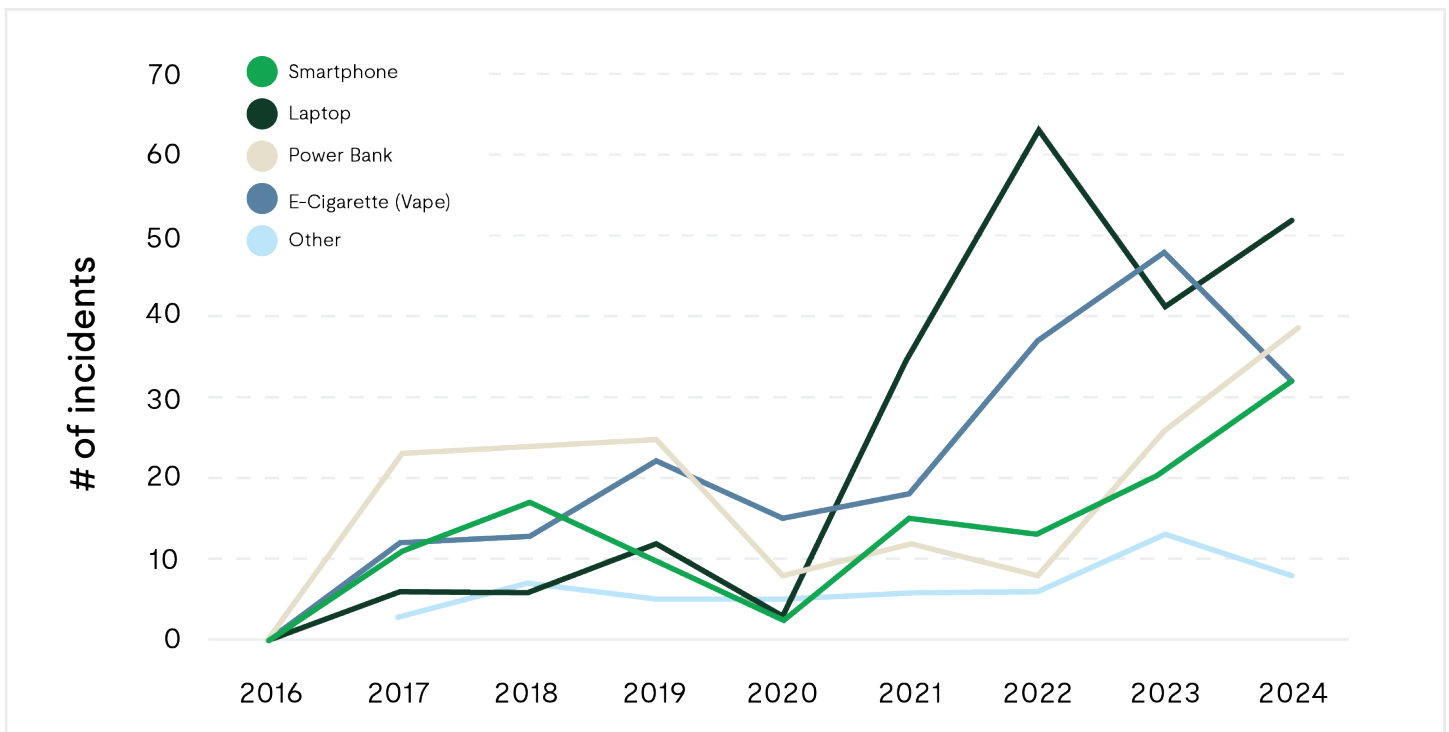


Figure 1. Thermal Runaway Incidents of Portable Electronic Devices in Aviation

⁷ Thermal Runaway Incident Program (TRIP), ULSE Inc. myTripPortal - Thermal Runaway Incident Program (accessed Feb 17, 2026)

both the risk of safety control failure and the risk associated with SOC are considered moderate, leading to an overall moderate TR risk rating. The same logic is applied to other PEDs when evaluating the risk level of a TR event. This risk of e-cigarettes (vapes), however, is exacerbated by the presence of flammable cartridges or nicotine (e-juice) ports, which can intensify the severity of a thermal runaway event.

Laptops and e-cigarettes (vapes) are the most frequently identified PEDs involved in TR events in aviation. In 2024, vapes, while carried by only 10% of passengers, were still the leading cause of thermal runaway incidents, responsible for 28% of the reported total⁶. And smartphones and power banks have been linked to fewer than 50 incidents annually. Considering that nearly every traveler carries a smartphone (81% of passengers brought one on board in 2024⁶), while only a portion carry other PEDs, the relative likelihood of a smartphone causing a TR event is significantly lower. Power banks show “likely” TR events because, although 29% of passengers bring them onboard, they account for

19% of the incidents in the TRIP database in 2024⁶. In particular, there has been a continuous increasing trend in TR events related to power banks since 2022, rising from eight incidents per year to 49 incidents per year.

Between 2016 and 2024, only one TR incident was attributed to a medical device, indicating that medical devices (such as CPAP machines) pose a minimal risk. TR events involving other PEDs, including electric face masks and electric toothbrushes, have remained below 15 incidents per year, suggesting a “possible” likelihood of occurrence.

Our analysis of TRIP⁷ reports from 2016 to 2024 shows approximately 70% of incidents display thermal runaway characteristics including swelling, smoke, heat, fire, and explosion across various PEDs (shown in Figure 2). For smartphones, e-cigarettes (vapes), power banks, and other PEDs, heat and fire are the most common manifestations of TR. Notably, swelling is a frequently observed symptom in laptop-related TR events.

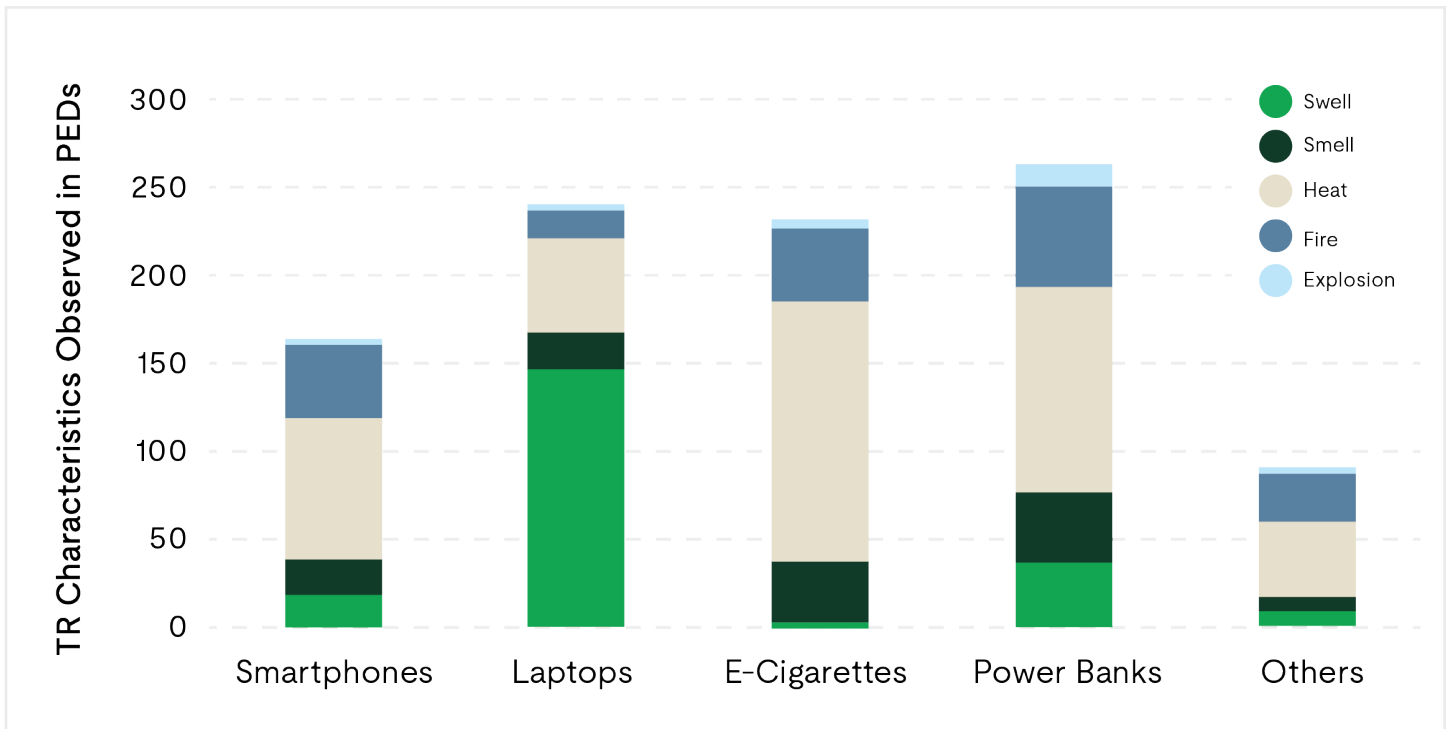


Figure 2. Thermal Runaway Characteristics Observed in Portable Electronic Devices

⁶ Lithium-Ion Battery Incidents in Aviation: 2024 Data Review, ULSE Inc. ulse.org/wp-content/uploads/2025/06/TRIP-Report-May-2025-Final.pdf (accessed Jan 21, 2026)

⁷ Thermal Runaway Incident Program (TRIP), ULSE Inc. [myTripPortal - Thermal Runaway Incident Program](https://myTripPortal.com) (accessed Feb 17, 2026)

Part 2. Determining Risk Rating from Five Perspectives

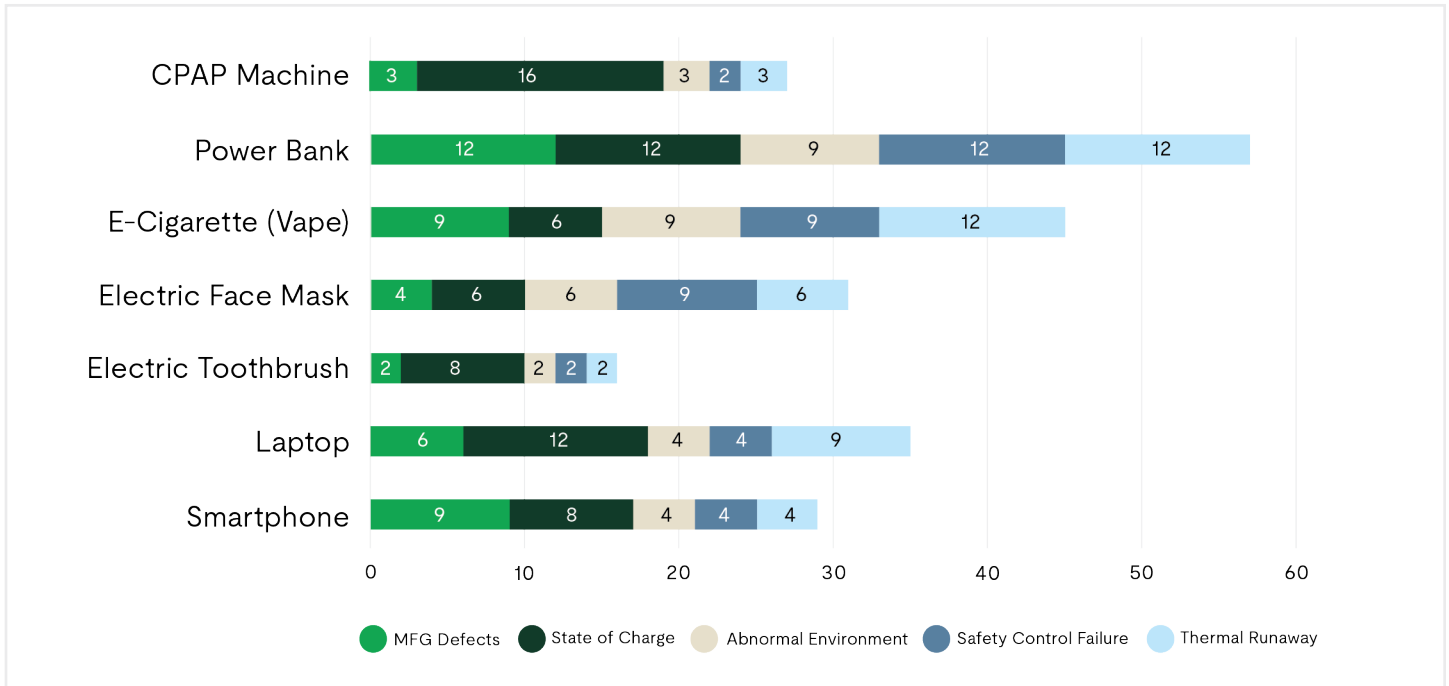


Figure 3. Overall Risk Rating of Representative Portable Electronic Devices in Aviation

Risk rating is calculated based on evaluated risk level and likelihood.

Risk Rating = Risk Level × Likelihood

- Risk levels range from 1 to 4:
Minor (1), Moderate (2), Serious (3), Catastrophic (4)
- Likelihood ranges from 1 to 4:
Unlikely (1), Possible (2), Likely (3), Very Likely (4)

Risk Rating Categories:

- High-Risk (40–60)
- Medium-Risk (20-39)
- Low-Risk (19 and below)

The risk rating of PEDs in aviation is shown in Figure 3. Based on this scale, power banks and e-cigarettes (vapes) fall into the High-Risk category. Smartphones, laptops, electric face masks, and CPAP machines are considered Medium-Risk products, while electric toothbrushes are classified as Low-Risk PEDs.

Note: The risk rating of each perspective ranges from 1 to 16; Risk Rating = Risk Level (1–4) × Likelihood (1–4). The overall risk rating is the sum of risk ratings from each perspective. Higher scores indicate a greater potential risk in that category for that type of PED.

Among the seven representative PEDs evaluated, power banks and e-cigarettes (vapes) are shown as the highest-risk devices in aviation. They account for the majority of thermal events and recalls reported in recent years. E-cigarettes (vapes) present a unique risk due to the presence of flammable cartridges or nicotine (e-juice) ports, which significantly elevate the chance of fire or explosion in the thermal runaway event.

State of Charge (SOC) — the available capacity of a battery expressed as a percentage of its rated capacity — is a growing concern, particularly for high-capacity devices. Laptops, power banks, and CPAP machines frequently exceed 500 mAh and are often fully or nearly fully charged by passengers before flights. The potential energy stored in these PEDs can become hazardous if they experience malfunctions during flight, are stored improperly, or are exposed to abnormal conditions.

Recommendations

Require Certified Electronic Smoking Devices and Power Banks for Air Travel

Airlines and regulatory bodies should consider requiring that High-Risk devices, such as electronic smoking devices and power banks, be certified to meet aviation safety standards.

As of June 28, 2025, China has implemented stricter regulations on power banks for air travel, enforced by the Civil Aviation Administration of China (CAAC). Only power banks with a valid China Compulsory Certification (3C) mark are allowed on domestic flights⁸.

Environmental stressors can lead to abnormal behavior or failure of PEDs during air travel. Ensuring devices are certified under these conditions confirms they have undergone rigorous testing for electrical safety, battery integrity, and environmental resilience under typical aviation conditions. This approach enhances passenger safety and reduces the risk of onboard incidents caused by non-compliant devices.

Electronic Smoking Device Safety Check

Aviation authorities should consider verifying that passengers have taken effective measures to prevent accidental activation of the heating element in electronic smoking devices, or to mitigate risks in the event of thermal runaway. Effective deactivation measures include, but are not limited to, removing the battery from the electronic smoking device, separating the battery from the heating coil⁹, and removing any flammable cartridges from the device. For some disposable e-cigarettes or vapes, such as disposable vape pens, where deactivation measures are impractical or are very difficult, the battery containment enclosure can be designed and verified to prevent propagation during thermal runaway events or ignition of any flammable mixture inside. This is equally important for other electronic smoking devices.

Limit the Number or Total Capacity of High-Energy Devices Allowed Onboard

Regulations may consider placing limits on either the number of PEDs or the total allowable energy capacity (measured in Watt-hour Ampere, WhA) that passengers may bring onboard.

Currently, PEDs rated less than 100 Wh are permitted in both carry-on and checked baggage without restrictions on quantity or cumulative energy capacity. PEDs 101–160 Wh require airline approval and are limited to two spare batteries per traveler, carried in carry-on baggage only¹⁰. However, additional guidance is needed for PEDs with batteries in the 50–100 Wh range. Specifically, limits on the number of such devices and their cumulative energy (also referred to as SOC) should be considered. This would help mitigate the cumulative risk posed by multiple high-capacity batteries in the cabin or cargo hold.



⁸ Civil Aviation Administration: Passengers are prohibited from carrying power banks without 3C certification and those that have been recalled on domestic flights. https://www.caac.gov.cn/XWZX/MHYW/202506/t20250626_227805.html (accessed July 28, 2025)

⁹ PackSafe - Electronic Cigarettes, Vaping Devices. Federal Aviation Administration. <https://www.faa.gov/hazmat/packsafe/e-cigarettes-vaping> (accessed July 25, 2025)

¹⁰ PackSafe - Batteries Carried by Airline Passengers, Federal Aviation Administration. <https://www.faa.gov/hazmat/packsafe/resources/airline-passengers-batteries> (accessed July 28, 2025)

