

Aircraft **Fire** Protection



Transporting Batteries by Air

Captain John Ransom
Safety Operating Systems



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air safety solutions that **WORK**



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Presentation Objectives

- Describe the prolific growth of battery transportation
- Discuss issues associated with transporting batteries
- Provide a primer on battery hazards



Presentation Objectives (cont.)

Describe methods and technologies to increase safety when transporting batteries



High Energy Devices are Prevalent

What is on your aircraft?

- Passengers carrying multiple devices
- Evolving high-energy technologies being shipped as cargo
- Growing consumer demand



High Energy Devices are Prevalent

On a 737 or A320 – assume each passenger has:

- Watch
- Laptop
- iPhone
- iPad or Tablet

That equates to 500+ lithium batteries



The Battery Market is Growing

Battery energy costs have dropped

- \$3.17/watt hour in 1991
- \$0.12/watt hour in 2014

Bottom Line – Transportation of Batteries and Energy is Increasing



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Frost and Sullivan Report for NAATB

National Alliance for Advanced Technology Batteries

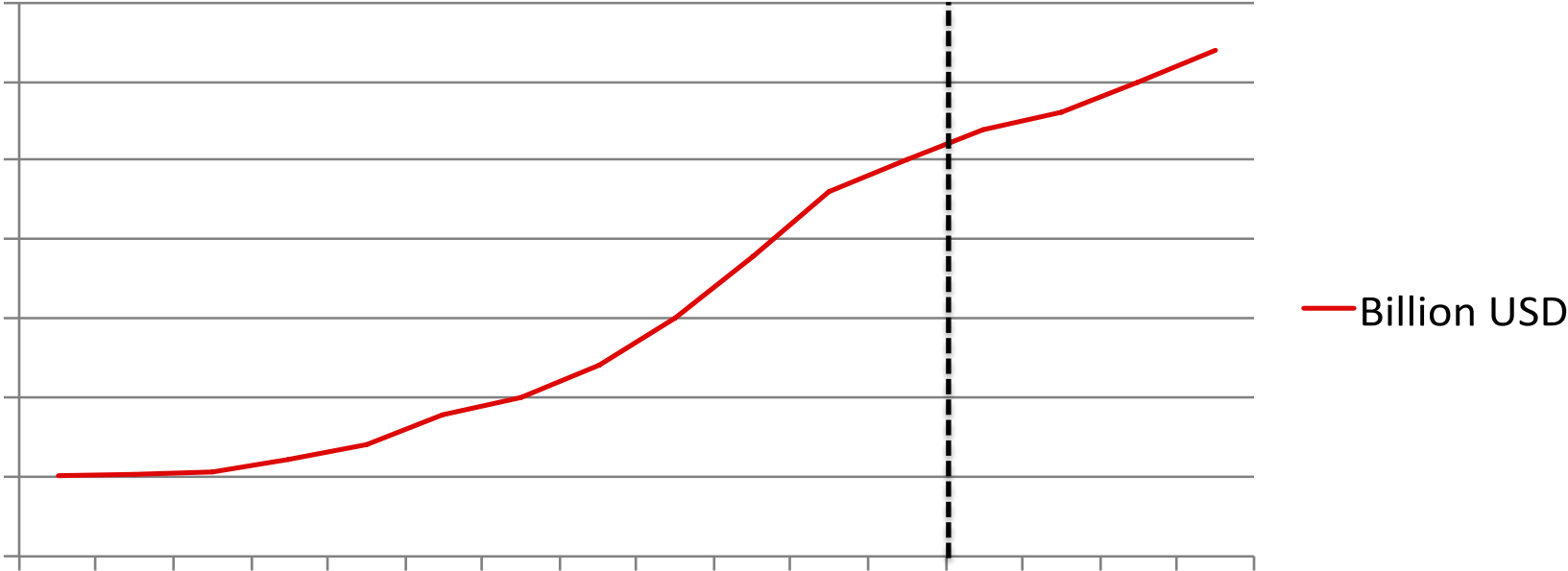
The Battery Market is Growing

- The global lithium-ion market in 2012 was \$11.7 billion
- The large format automobile battery market is expected to double by 2016
- Today 64% of the lithium-ion battery market is in consumer batteries



Global Lithium Battery Market in (\$US) Billions

Fast Demand of Lithium Batteries in U.S. Billions of Dollars



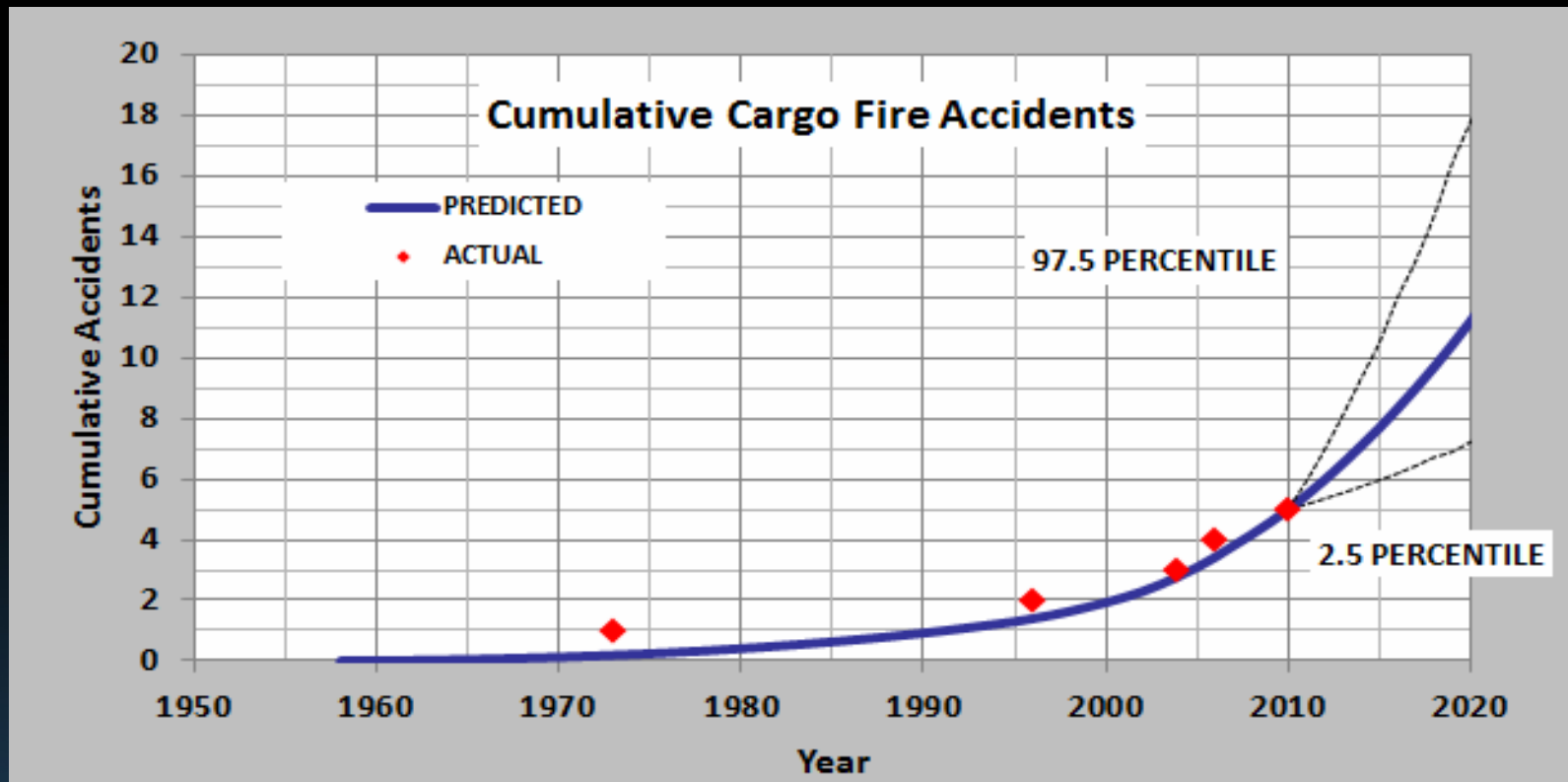
The Issue is Safely Transporting High Energy Shipments by Air



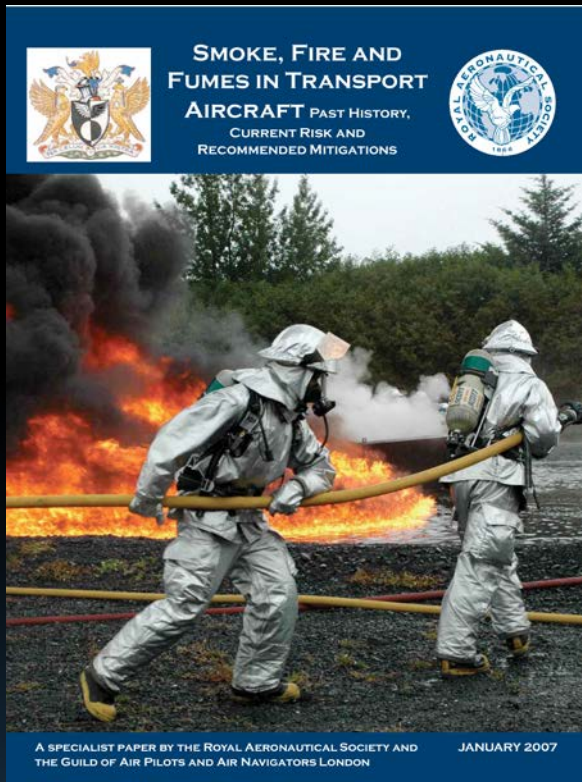
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FAA Study on Cargo Fire Accidents

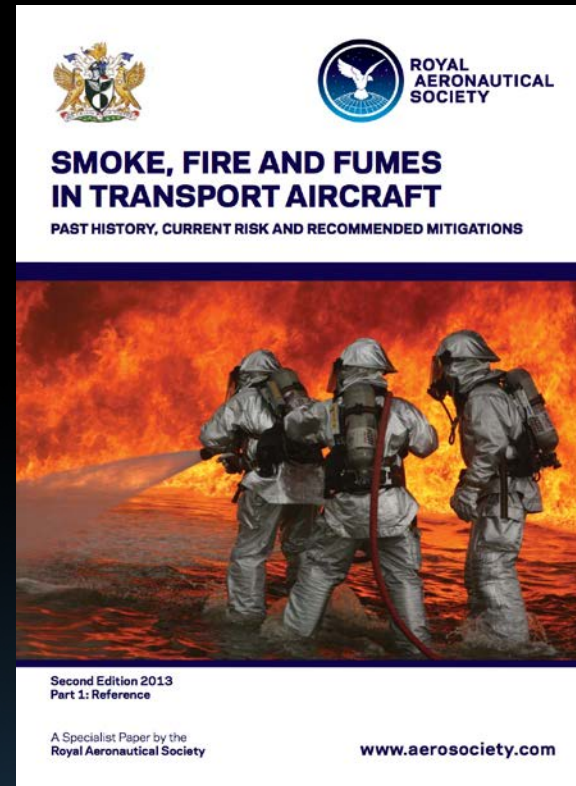
FAA Safety Analysis of U.S. domestic freighters predicts approximately six (6) accidents likely to occur from now to 2021



Where can an Airline or Corporate Operator find guidance to mitigate the risk?



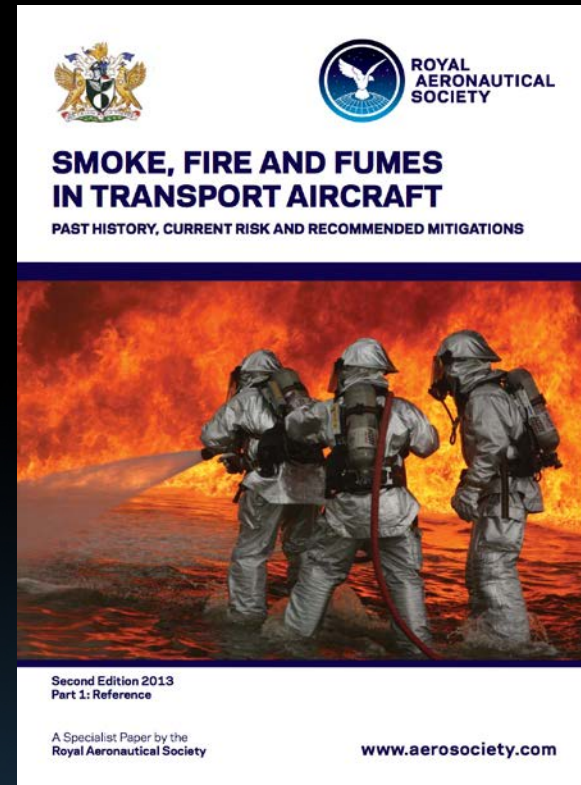
SAFITA 2007



SAFITA 2013

What types of facts can you learn?

- From 1990 to 2010 there have been 18 major accidents involving in-flight fire resulting in 423 fatalities (*Flight Safety Foundation*)
- More than 1,000 in-flight smoke events occur annually – (*IATA*)



SAFITA 2013

A Primer on Lithium Batteries



A Primer on Lithium Batteries

- Lithium-Ion
(rechargeable)
- Lithium Polymer
(rechargeable)
- Lithium Metal
(non-rechargeable)



Main Causes of Failure

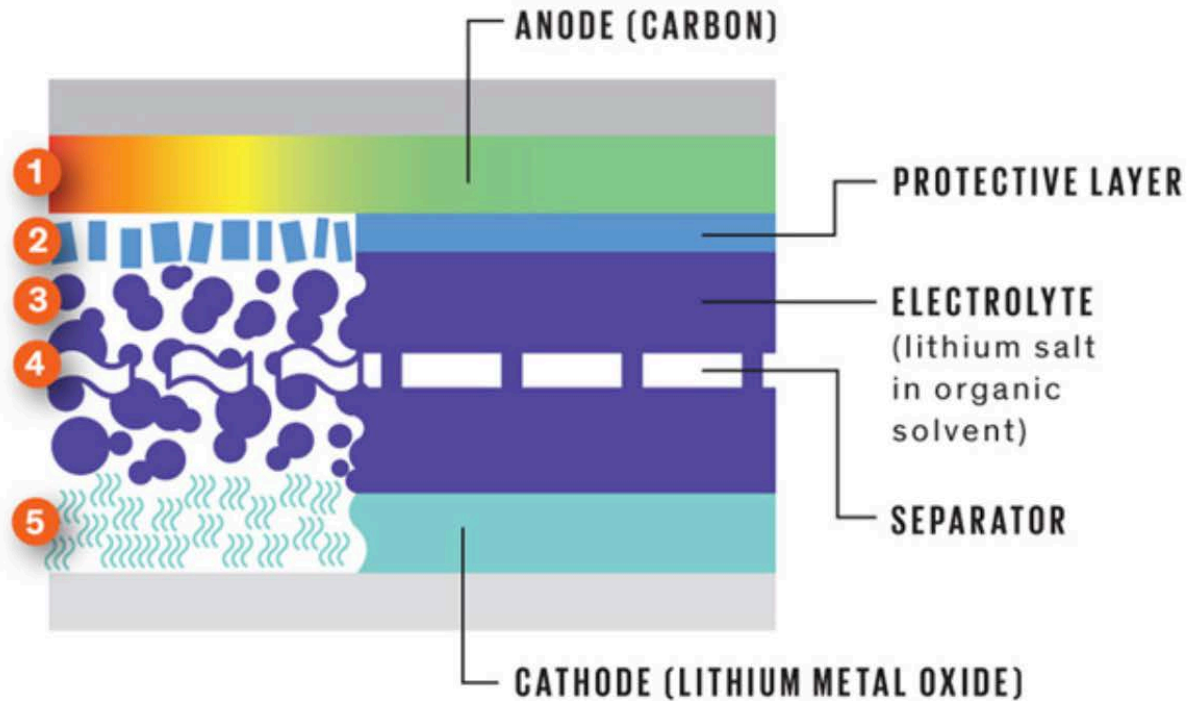
- Short circuits most common cause of fires
- Punctures causing internal short circuit
- Handling also common cause of failure
- Incorrect charging
- Substandard materials or substandard – counterfeit manufacture



Thermal Runaway

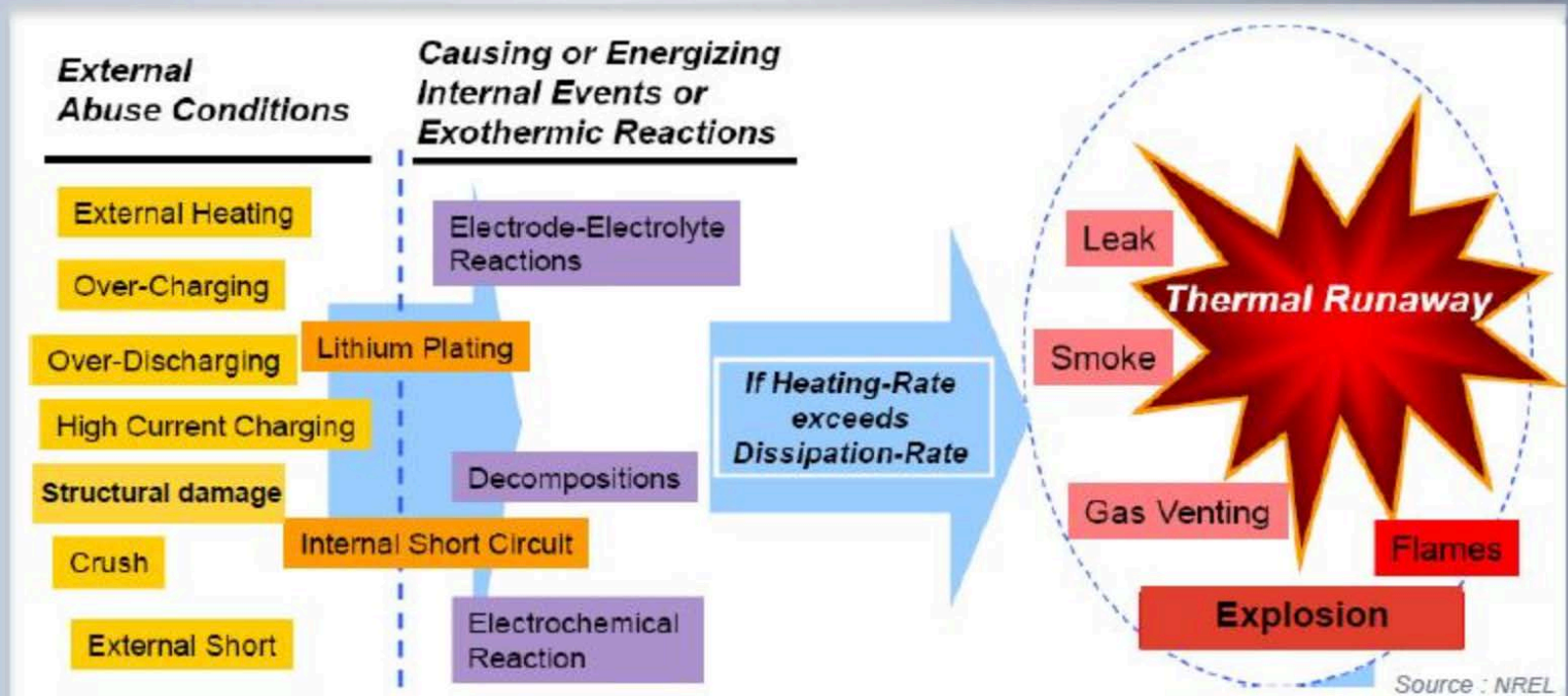
Thermal Runaway in a Lithium-Ion Battery

1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.



Causes

Causes of Thermal runaway



Main contributing factors

- Poor design
- Poor integration
- Poor safety monitoring/protection
- Poor manufacturing quality
- Poor handling/ storage/packing conditions

Defective Batteries and Recalls

- Apple laptops
- Sony laptops
- April 2014 - Three incidents of batteries overheating and "causing partial burns to Vaio computers" have been reported in the last month – Wall Street Journal

Apple's battery recall

A risk of fire prompted Apple Computer to recall 1.8 million batteries used in notebooks sold between October 2003 and August 2006.

Notebook model	Battery model number	Serial number range
12-inch iBook G4	A1061	ZZ338 - ZZ427 3K429 - 3K611 6C519 - 6C552
12-inch Powerbook G4	A1079	ZZ411 - ZZ427 3K428 - 3K611
15-inch PowerBook G4	A1078 and A1148	3K425 - 3K601 6N530 - 6N551 6N601

Source: Apple Computer

iPhones Are Not a Risk.....Are They?



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Phones Are OK.....Right?



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iPad vs. Seat



Lithium Battery Fire



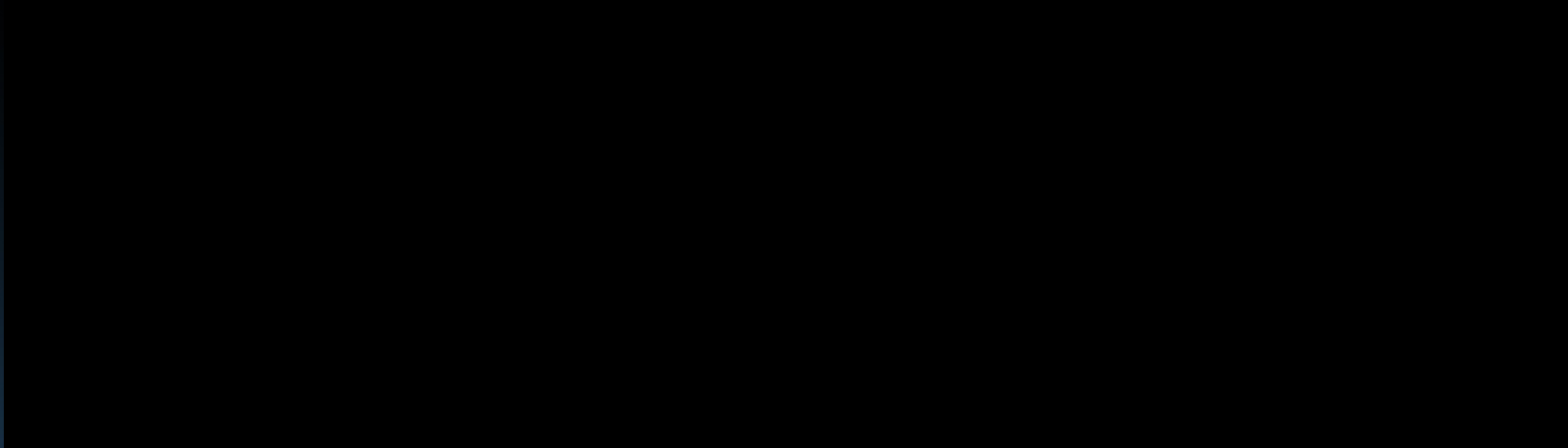
Flammability of Gases



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FAA Extinguishing Laptop Fires



Bulk Battery Test




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Accident Reports Available Online

Inflight Cargo Fire
United Parcel Service Company Flight 1307
McDonnell Douglas DC-8-71F, N748UP,
Philadelphia, Pennsylvania
February 7, 2006




aviation

ACCIDENT REPORT
NTSB/AAR-07/07
PB2007-910408



**National
Transportation
Safety Board**



AAIS Case Reference: 13/2010



AIR ACCIDENT INVESTIGATION SECTOR
FINAL
AIR ACCIDENT INVESTIGATION REPORT

Uncontained Cargo Fire Leading to Loss of Control
Inflight and Uncontrolled Descent Into Terrain

Boeing 747-44F
N571UP
Dubai
United Arab Emirates
03 September 2010

General Civil Aviation Authority
of the
United Arab Emirates


Accident Investigation Sector
General Civil Aviation Authority
United Arab Emirates




ARAIB/AAR1105

Aircraft Accident Investigation Interim Report

Crash Into The Sea After An In-Flight Fire
Asiana Airlines
B747-400F/HL7604
130 km West Of Jeju International Airport
July 28, 2011



September 17, 2012



Aircraft and Railway Accident Investigation Board



Philadelphia, PA – UPS 1307

- February 7, 2006
- DC-8-71F, N748UP
- KATL-KPHL landing at midnight
- Captain, First Officer and Flight Engineer



UPS Flight 1307 – Philadelphia, PA



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UPS Flight 1307 – ULD



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Dubai – UPS Flight 6

- September 3, 2010
- Boeing 747-44AF, N571UP
- Dubai, UAE to Cologne, Germany
- Captain and First Officer



Dubai – UPS Flight 6



Dubai – UPS Flight 6



Asiana 991

- July 28, 2011
- Boeing 747-400F, HL7604
- Incheon, Republic of Korea to Shanghai, China
- Captain and First Officer



Asiana 991



Common Elements

- Situation quickly grew out of control once fire commenced
- Lithium Batteries
- All flights had extremely dense smoke in the cockpit
- Catastrophic situations



The Risk is Growing

- In the past the number of batteries was lower
- In the past the numbers of flights were less
- In the past the numbers of battery events were less
- The likelihood of an battery event is higher than in the past.



A need to develop solutions to complex issues



Protecting the Flight Deck

(Important facts about cockpit smoke)

“Smoke is the leading defined cause of emergency landings for ETOPS” (*Air Safety Week*)

“The time from first indication of smoke to an out-of-control situation may be very short.”
(*Boeing Aero 14*)

- In-flight smoke events on transport jets are twice as likely as in-flight engine failures
(*ALPA Safety Report*)



The Combination of Two Technologies Greatly Improves Safety

**Full Face
Oxygen Masks**



+

**Emergency Vision
Assurance System
(EVAS)**



Full-Face Oxygen Masks

- Flight crews must be protected not only from smoke, but also from toxic fumes like sulfur dioxide
- Smoke goggles have been found to be ill-fitting for some eyeglass wearers
- Full-Face Masks don quicker, reduce operational complexity and allow a better fit and more effective mask purging



Emergency Vision Assurance System (EVAS)

Pilot vision during a smoke event is essential

The pilot still relies on the oxygen mask for breathing and eye protection

- EVAS represents the last line of defense for the flight crew



Emergency Vision Assurance System (EVAS)



Enhancing Training



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Training Center

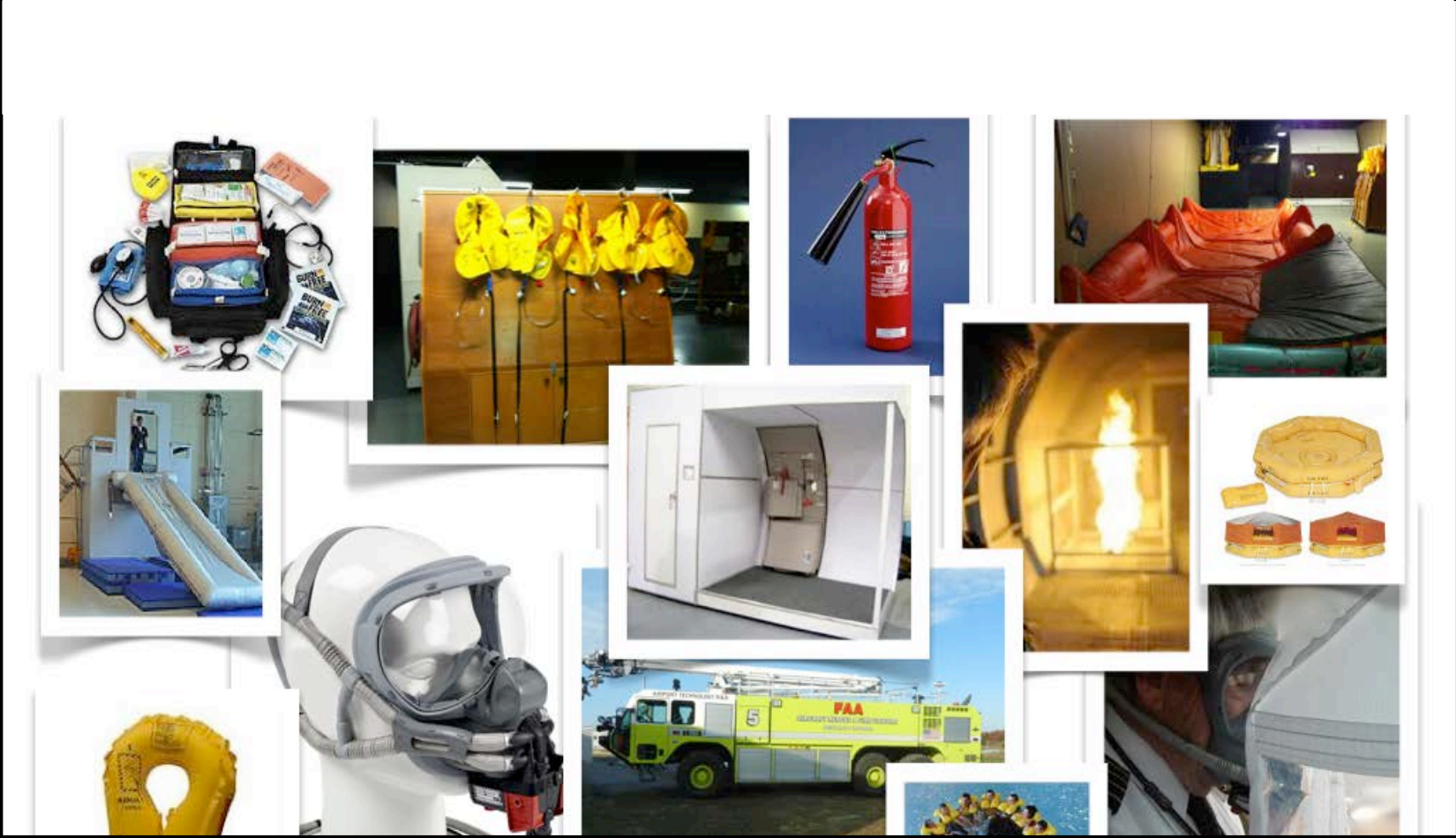
Incorporate Sequence Based Instruction
into **Smoke/Fire/Fumes** Training

“The order in which material is presented can strongly influence what is learned, how fast performance increases, and sometimes even whether the material is learned at all.”

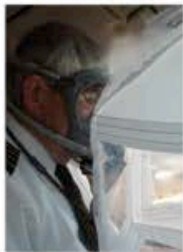
"Sequence learning". *Trends in Cognitive Sciences* 2 (8): 275–81



Combine teaching individual modules



Into a sequence-based learning experience...



————— Inflight Smoke/Fire —————>



Checklist Design

Human Factors Example: Checklist Numbering System

ENGINE FIRE, Severe Damage or Separation

MESSAGE: L or R ENGINE FIRE

AUTOTHROTTLE ARM SWITCH OFF

THRUST LEVER (Affected side) CLOSE

FUEL CONTROL
SWITCH (Affected side) CUT OFF

ENGINE FIRE SWITCH (Affected side) PULL

If Engine Fire Warning light remains illuminated:

ENGINE FIRE SWITCH ROTATE

Rotate to stop and hold for 1 second.

After 30 seconds, if Engine Fire Warning light remains illuminated:

ENGINE FIRE
SWITCH ROTATE TO REMAINING BOTTLE

Rotate to stop and hold for 1 second.

If high airframe vibration occurs and continues after engine is shut down:

Without delay, reduce airspeed and descend to a safe altitude which results in an acceptable vibration level. If high vibration returns and further airspeed reduction and descent is not practical, increasing the airspeed may reduce the vibration.

APU (If available) START

(CONTINUED)

ENGINE FIRE or Engine Severe Damage or Separation

N301UP through N315UP

Messages: L ENGINE FIRE R ENGINE FIRE

Condition: One or more of these occur:

- Engine fire warning
- Airframe vibrations with abnormal engine indications
- Engine separation

1 A/T ARM switch OFF

2 Thrust lever (affected side) .Confirm Idle

3 FUEL CONTROL switch
(affected side)Confirm ... CUTOFF

4 Engine fire switch
(affected side)Confirm Pull

5 **If the engine fire warning light is illuminated:**
Engine fire switch. Rotate to the stop and
hold for 1 second

If after 30 seconds the engine fire warning light stays illuminated:

Engine fire switch. Rotate to
the other stop and
hold for 1 second

▼ Continued on next page ▼

Checklist Design

Human Factors Example: Condition and Confirmation Steps

ENGINE FIRE, Severe Damage or Separation

MESSAGE: L or R ENGINE FIRE

AUTOTHROTTLE ARM SWITCH OFF

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(CONTINUED)

ENGINE FIRE or Engine Severe Damage or Separation

N301UP through N315UP

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- Airframe vibrations with abnormal engine indications
- Engine separation

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- 2 Thrust lever (affected side) .Confirm Idle
- 3 FUEL CONTROL switch (affected side)Confirm ... CUTOFF**
- 4 Engine fire switch (affected side)Confirm Pull
- 5 **If the engine fire warning light is illuminated:**
 Engine fire switch. Rotate to the stop and hold for 1 second
If after 30 seconds the engine fire warning light stays illuminated:
 Engine fire switch. Rotate to the other stop and hold for 1 second

▼ Continued on next page ▼

Checklist Design

- CAP 676 Compliant
- No Custodial Steps
- Simplified High-Workload Alternatives



Protecting the Aircraft

New materials,
technologies and
designs are making a
difference



Passenger Aircraft



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Battery Fires Onboard Passenger Aircraft

- An Air France Boeing 777 was over the Atlantic at FL380 when passengers noticed open flames and...
- The hands of a passenger on a Southwest Airlines were flight burned when spare lithium-ion batteries...
- A FedEx pilot was taking the jump seat in the cockpit when a lithium-ion battery...



Battery Fires Onboard Passenger Aircraft

- **WARNING: Do not use fire-resistant burn bags to isolate burning lithium-type batteries.**
- **Transferring a burning appliance into a burn bag may be extremely hazardous. Do not move the device until you are certain the fire is extinguished and the device is cool**

The following information expands upon SAFO 09013.

Safety Alerts for Operators (SAFO) are posted at:

http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safo/

Lithium Battery Fires. Although lithium is a metal, do not treat a fire involving a small number of lithium batteries as a Class D fire. Halon, Halon replacement and/or water fire extinguishers can be used to control fires involving a small number of lithium batteries, such as found in common portable electronic devices (PED) or a laptop computer.

Lithium batteries are capable of ignition and subsequent explosion due to overheating. Overheating may be caused by shorting, rapid discharge or overcharging. Overheating results in thermal runaway, which is a chemical reaction within the battery causing the internal temperature and pressure to rise. The result is the release of flammable electrolyte from the battery and, in the case of disposable lithium batteries, the release of molten burning lithium. Once one battery cell goes into thermal runaway, it produces enough heat to cause adjacent battery cells to also go into thermal runaway. This produces a fire that repeatedly flares up as each battery cell in turn ruptures and releases its contents.

Fighting a fire that contains either disposable or rechargeable lithium battery cells requires extinguishment of the fire and cooling of the remaining cells to stop the thermal runaway. Water is the most effective coolant. Halon, Halon replacement and/or water fire extinguishers should be used for initial knockdown of these fires, followed by immediate dousing with water from any available source.

WARNING: Do not use fire resistant burn bags to isolate burning lithium-type batteries. Transferring a burning appliance into a burn bag may be extremely hazardous. Do not move the device until you are certain the fire is extinguished and the device is cool.

Specific Types of Lithium Batteries

(1) AA Sized Lithium Batteries.

Disposable. Lithium (non-rechargeable) cells are constructed with metallic lithium. Metallic lithium is extremely flammable and cannot be extinguished with the typical hand-held extinguishers found on board transport aircraft. However, the amount of metallic lithium in each AA sized lithium battery is very small and will consume itself in less than one minute. Lithium cells will spray molten lithium as they burn, which can cause severe bodily harm and spread the fire.

Do not treat a fire involving a small number of lithium batteries as a Class D fire.

Rechargeable. Lithium-ion (rechargeable) cells are constructed with a flammable electrolyte and have the same fire hazard as non-rechargeable cells.

Battery Fires Onboard Passenger Aircraft

- Safer alternative to burn bags
- Allows device to be moved from critical or undesirable locations
- Protects firefighter



Cargo Aircraft



Fire Containment Covers (FCC)

- Cover high-energy shipments and unknown palletized freight
- Used from origin to final destination
- FCC requires no additional time
- Demonstrated 1500°F fire containment for 4 hours



FCC Battery Test Conducted by FAA

- FAA fire test with 5,000 lithium-ion batteries conducted March 18, 2014
 - Test duration of 4 hours was obtained with a peak temperature of 1500°F
-
- FAA test with 4,800 lithium metal batteries performed March 25, 2014
 - Test limited to 15 minutes with peak temperature of 3000°F

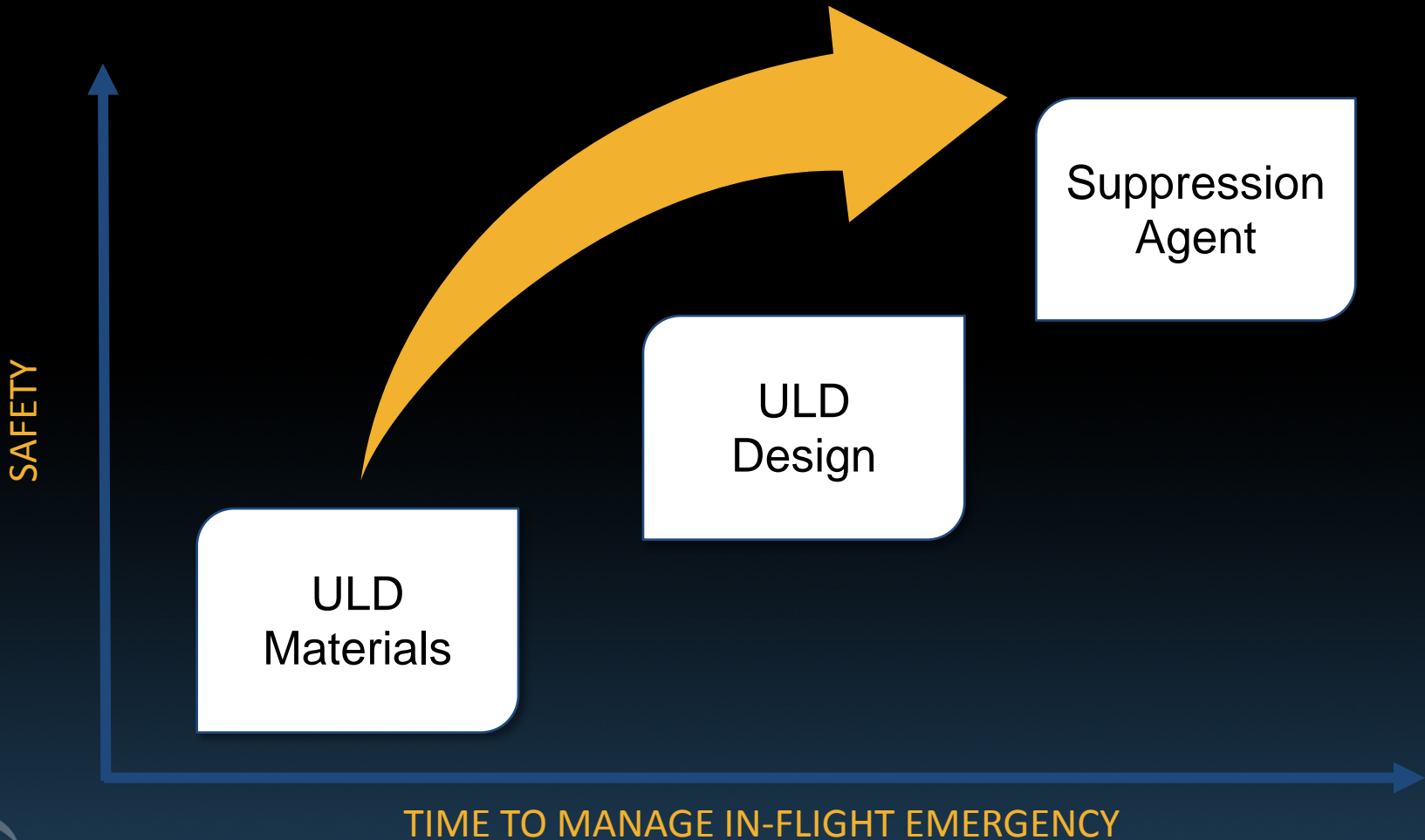


Unit Load Device (ULD)

- UPS Airlines has done extensive research and testing on ULD materials and door designs
- MACROlite material has proven to be lighter weight, more durable and exhibited tremendous fire-resistant properties



Seeking A Solution for Battery Fire Containment



ULD with Suppression

- UPS has applied for an STC
- UPS is multi-modal protection
- Both FedEx and UPS fire suppression systems recognize you have to fight the fire in the container
- Certification testing continues



Final Thoughts...

- A greater level of aviation safety is possible using both existing and developing technologies
- New materials and designs show great promise
- New technology in the area of fire suppression has proven very effective
- In-flight aircraft fires can become survivable events



Questions

