



NTSB National Transportation Safety Board

Cargo Heat Release Rate Testing

Joseph Panagiotou

Office of Research & Engineering

Materials Laboratory

Recent Fires in Freighter Aircraft

- UPS, flight 1307, DC-8
 - February 7th 2006 in Philadelphia, PA
 - In-flight fire with emergency landing
 - Total hull loss
 - Undetermined ignition source
- UPS, flight 006, B747-400F (ongoing)
 - September 4th 2010 in Dubai, UAE
 - In-flight fire with crash landing (total hull loss)
- Asiana Cargo, flight 991, B747-400F (ongoing)
 - July 28th 2011 west of Jeju island, South Korea
 - In-flight fire with crash landing (total hull loss)

Issues That Keep Coming Up

- Lithium & lithium-ion batteries in the cargo
 - Fire hazard posed by batteries?
- Fire detection & suppression
- Fire containment
- Fire resistance of cargo liners
 - Characteristics of cargo container fires?

Fire Hazard Potential of Batteries

- Ignition Hazard
- Explosion/overpressure
- Incendiary particles / fire spread
- Energy release rate / total energy
- Hazardous products of combustion
- Propagation in low oxygen environment

Cargo Container Fire Characteristics

- Detectability of the fire
- Container effects (depends on type)
- Size of the fire at detection and growth rate
- Energy release rate and total energy
- Container material flammability
- Cargo flammability

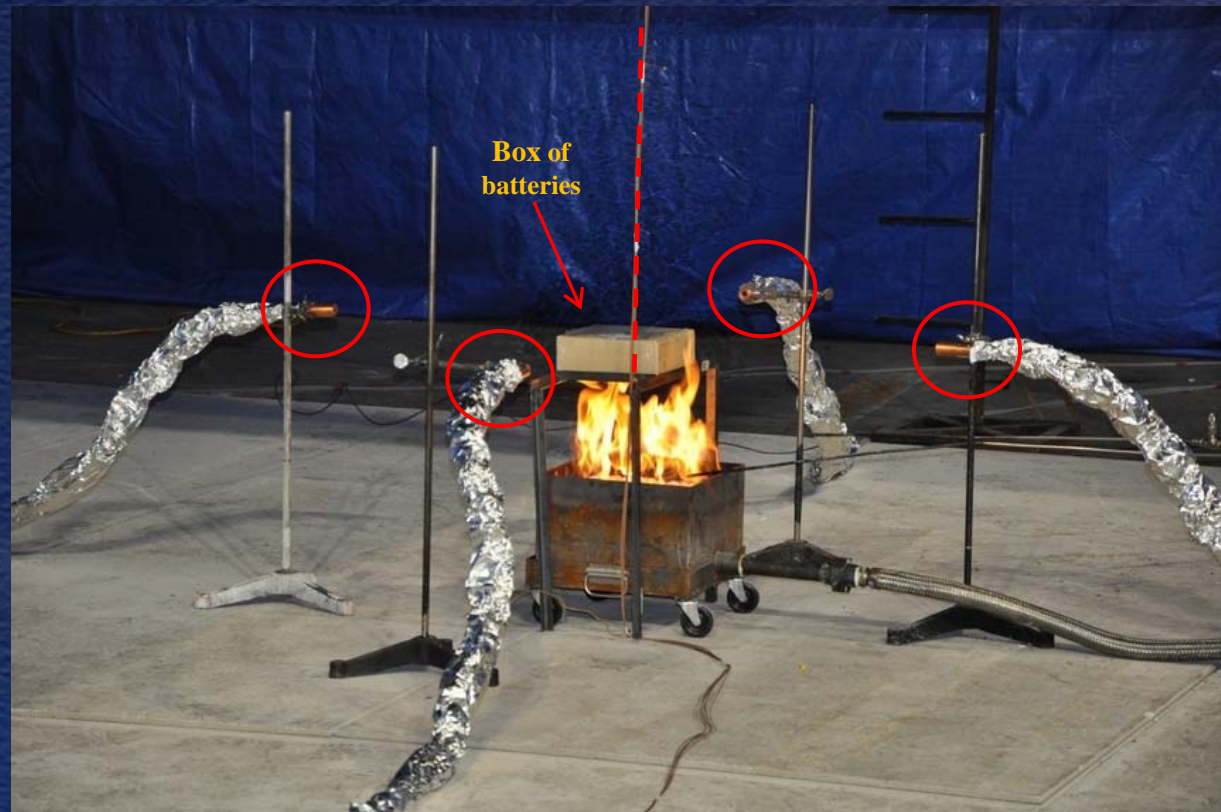
Topics Addressed

- Fire load contribution of lithium and lithium-ion batteries
 - Small scale tests using single battery cells
 - Cone calorimeter (FAATC)
 - Li-ion, Li, Li-PO batteries tested
 - Small scale tests using single boxes of batteries (100ct.)
 - Medium scale oxygen consumption calorimeter hood (BATFE)
 - Li-ion batteries tested
- Burning characteristics of cargo container fires
 - Large scale tests using main cargo deck type containers
 - Large scale oxygen consumption calorimeter hood (BATFE)
 - Rigid A2N (Aluminum/Lexan) construction
 - Collapsible DMZ (FR PP) construction
 - Fire load composed of 77 18" cube cardboard boxes with 2.5lb shredded paper inside

Small Scale Battery Tests

Box of 100 Li-ion batteries subjected to propane burner fire

- Batteries suspended above burner
- Steady burner output of 30kW
- Heat flux gauges
- Thermocouples
- Oxygen consumption calorimetry

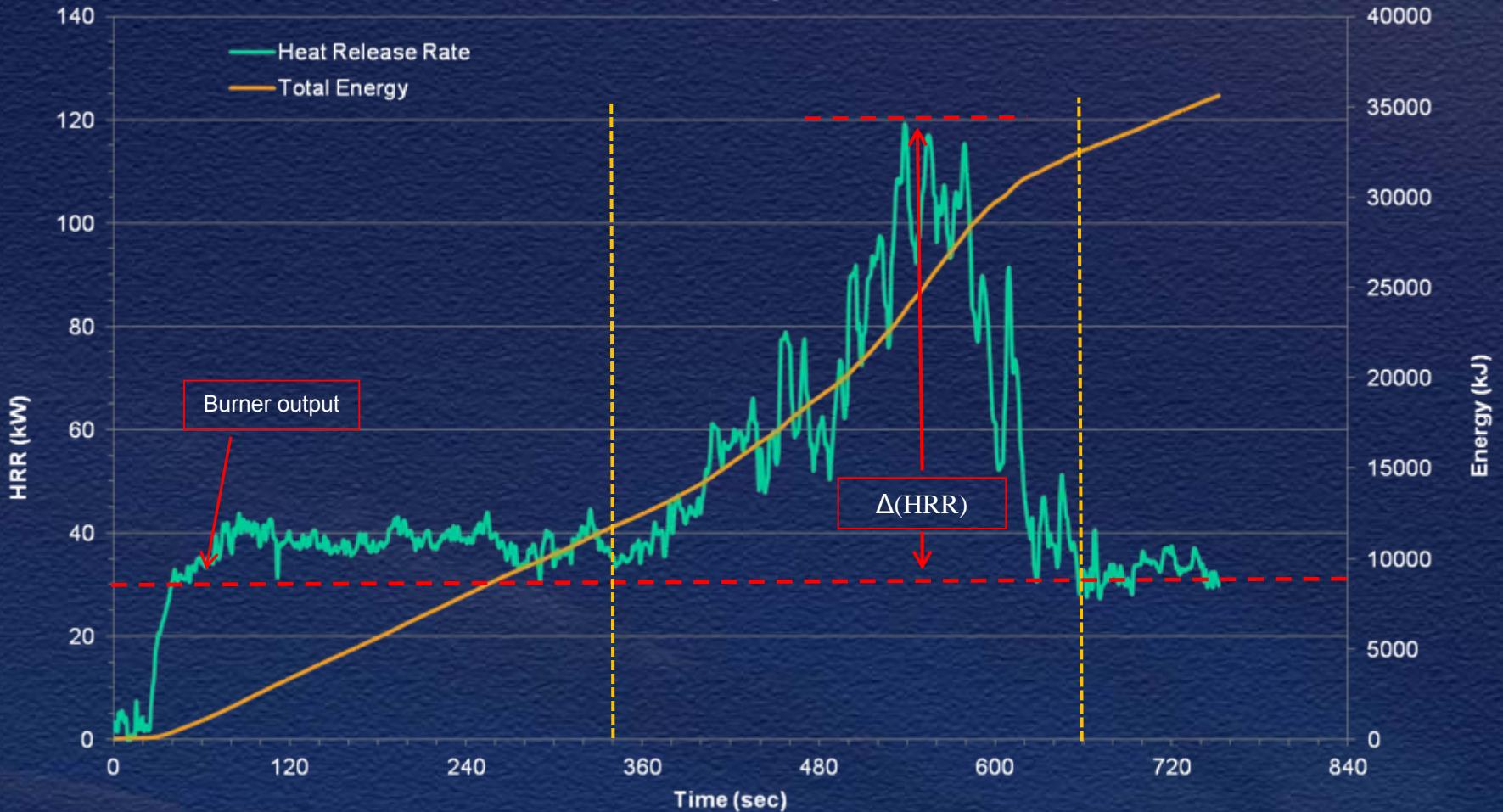


Small Scale Battery Tests (video)



Small Scale Battery Tests

Box of 100 Li-ion Batteries Suspended Over 30kW Burner



Small Scale Battery Tests

- Peak $\Delta(\text{HRR}) \sim 90\text{kW}$ above burner output of 30kW
- Energy contribution from 100 batteries $\sim 11237\text{ kJ}$
 - 112 kJ per battery cell (88 kJ from cone calorimeter testing at FAATC)
- Burning time 320 seconds
- Maximum temperature excursion 12" above box $\sim 250^\circ\text{C}$
- Maximum heat flux excursion 22" from edge of box $\sim 3\text{ kW/m}^2$



Small Scale Battery Tests

Energy Release Rate Comparison



Small Scale Battery Tests

Thermal runaway ignition tests

- 3 x 3 x 2 array of cardboard boxes (18 boxes)
 - 18" cube boxes with 2.5lb shredded paper
 - 1 box of 100 Li-ion batteries
 - 250W cartridge heater
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- Heat release rate
 - Total energy
 - Radiant heat flux
 - Plume temperature
-
- Battery initiated fire scenario
 - Battery contribution



Small Scale Battery Tests



Small Scale Battery Tests



Small Scale Battery Tests

Cardboard Boxes VS Cardboard Boxes and Batteries



Small Scale Battery Tests

- Battery failure spread fire to surrounding combustibles
- Fire load contribution from batteries was minor
- Batteries continued to burn after main fire load was consumed



Large Scale Container Fires



- Rigid A2N type container
- Aluminum / Lexan
- 77 boxes with shredded paper
- Electronic ignition of floor level corner box
- Energy release rate
- Heat flux
- Plume temperature
- Smoke emission and detection time

Large Scale Container Fire (video)



Large Scale Container Fire



Large Scale Container Test

Rigid Cargo Container Test #1 (A2N Al/Lexan)



Large Scale Container Tests



- Collapsible DMZ type container
- FR Polypropylene
- 77 boxes with shredded paper
- Electronic ignition of floor level corner box
- IR camera
- Energy release rate
- Heat flux
- Plume temperature
- Smoke emission and detection time

Large Scale Container Test (video)

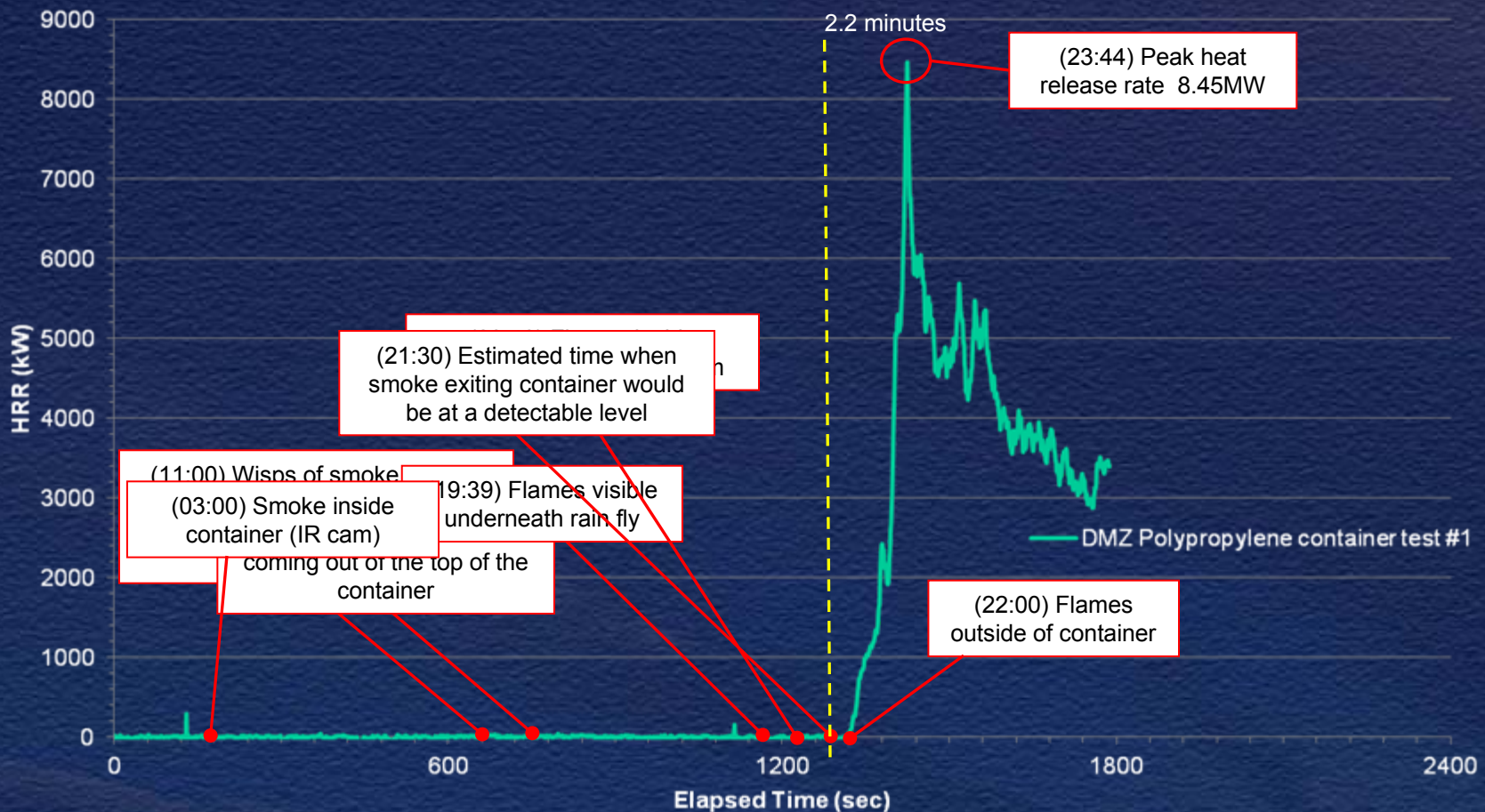


Large Scale Container Test



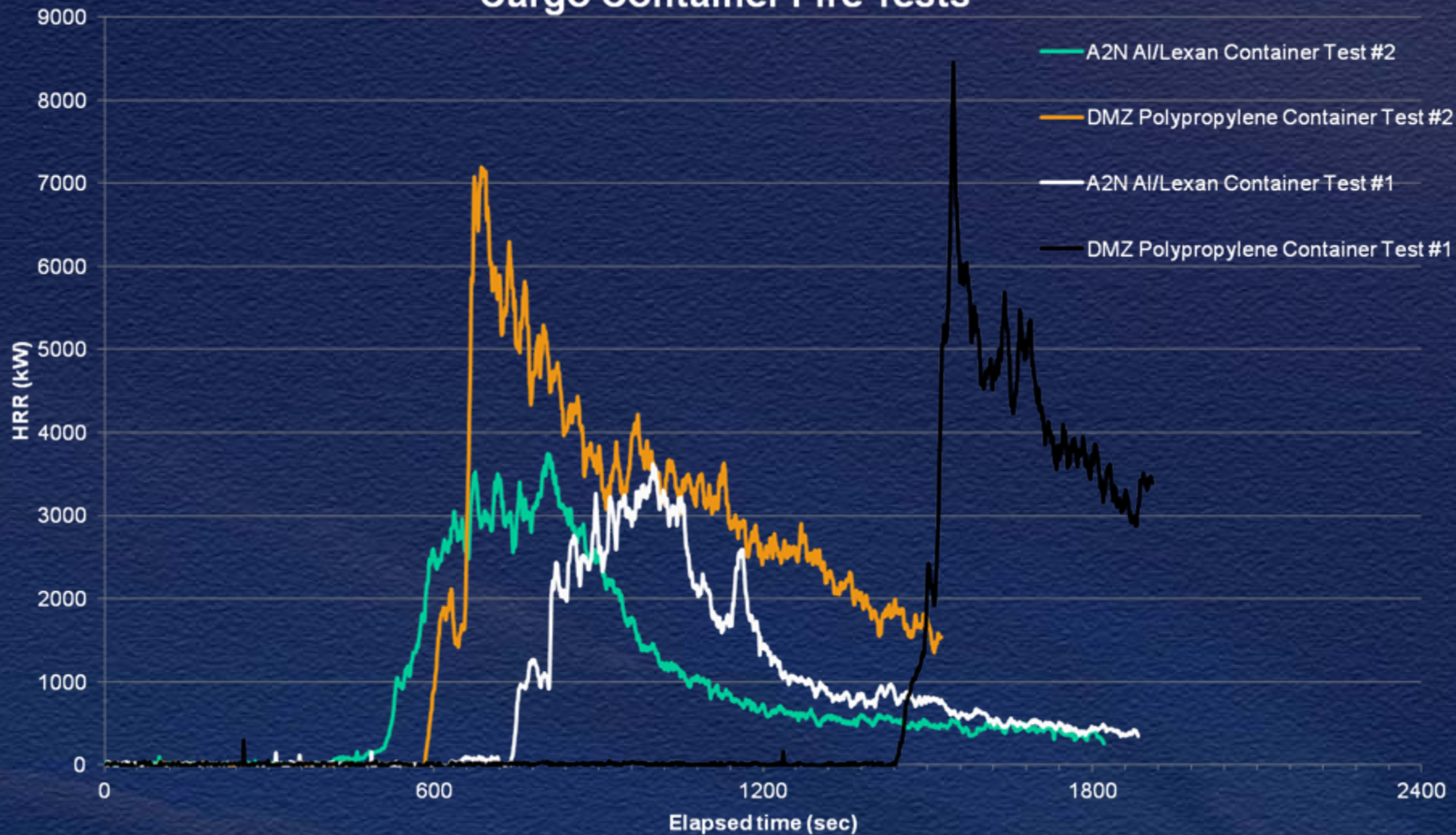
Large Scale Container Tests

Collapsible Cargo Container Test #1 (DMZ FRPP)



Large Scale Container Tests

Cargo Container Fire Tests



Container Fire Test Observations

- Rigid A2N
 - Peak HRR 3.6MW & 3.7MW
 - Time between detectable smoke emission and peak HRR 7.5 minutes & 10.5 minutes
 - Smoke exits through unintentional paths
- Collapsible DMZ
 - Peak HRR 8.45MW & 7.1MW
 - Time between detectable smoke emission and peak HRR 2.2 minutes & 1.9 minutes
 - Construction materials add to fire load
 - Operations/procedures may inadvertently slow detection (rain fly)

Thank you!

This test program was accomplished thanks to the support from the FAA
UPS and ATF.



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