Early Fire Detection Using Passive and Wireless Temperature Sensing Tags

Presented to: Tenth Triennial International Aircraft Fire and Cabin Safety Research Conference

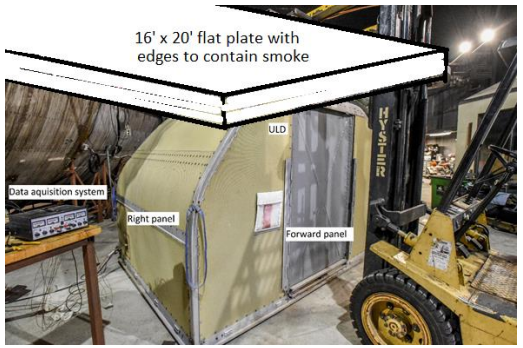
By: Matthew Karp

Date: October 2022

Federal Aviation Administration

Purpose and Goals

- Determine if passive ultra-high frequency (UHF) radio frequency identification (RFID) temperature sensors can detect a fire within a ULD
- Quantify and compare fire detection times for fires originating within a ULD between:
  - Temperature sensors located within a ULD
  - Smoke detectors located on the ceiling of an aircraft cargo compartment
- Demonstrate new use for existing technology to provide cost effective safety improvement for aircraft cargo compartment fire detection



ULD and mockup cargo compartment ceiling

UHF RFID reader – SensThys SensArray Enterprise

Temperature sensing tag – Axon RFM 3200

Background outline

- ULDs
- Accidents with delayed fire detection
- ULD cause fire detection delays
- Currently available ULD fire detection systems
- Very brief cost/benefit of current ULD fire detection systems
- UHF RFID overview
- Very brief cost/benefit of using UHF RFID for ULD fire detection

Unit Loading Device (ULD)

- **Purpose**
  - Secure cargo
  - Quickly load/unload cargo
- **Types of ULDs and materials**
  - All aluminum
  - Aluminum frame and polymer panels
  - *Aluminum frame and fire resistant panels*
  - Enclosed container (top)
  - Palletized load (bottom)

Enclosed fire resistant container (FRC) ULD

Palletized load fire containment cover (FCC) ULD

[1] B. Rogers, ULD Explained, Hong Kong: ULD Care, 2016.

Aircraft fires originating inside ULDs

- Between 2006 and 2011, three catastrophic in-flight cargo aircraft fires originated within a ULD [2]

February 7, 2006
UPS Flight 1307

- Crew fatalities 0/3
- Aircraft destroyed

September 4, 2010
UPS Flight 6

- Crew fatalities 2/2
- Aircraft destroyed

July 28, 2011
Asiana Flight 991

- Crew fatalities 2/2
- Aircraft destroyed

- Between March 3, 2006 and July 13, 2022, there were **98 aviation related incidents** involving lithium batteries on **Cargo aircraft. [3]**

[2] National Transportation Safety Board, "Safety Recommendation A-12 -68 through -70," Washington, D.C., 2012.
[3] https://www.faa.gov/hazmat/resources/lithium_batteries/incidents

ULDs cause fire detection delays

- Significant time delay from start of the fire inside the ULD to detection outside
  - 2.5 – 18.5 minutes from fire inside of ULD to detection outside of ULD
- The growth of the fires after they become detectable can be extremely fast
  - 1.9 to 10.5 minutes from detection outside of ULD to peak heat release outside of ULD
- Concludes that significant damage to an aircraft can occur shortly after becoming a detectable fire
- Longer delays with palletized ULD

Smoke exiting rigid ULD [3]

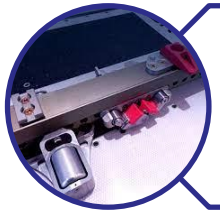
Palletized ULD [3]

[3] National Transportation Safety Board, "Report No. 12-019," Washington D.C., 2012.
[4] T. Wilk, "Smoke Detection Delay Inside a Cargo Container," Federal Aviation Administration (Unpublished), Atlantic City, NJ, 204.
[5] S. Chin, "The Scalability of Smoke Detectors and the Viability of New Detection Methods in Aircraft," Federal Aviation Administration, Atlantic City, NJ, 2019.
[6] J. Wood, "Strategies for Improved Fire Detection Response Times in Aircraft Cargo Compartments," Federal Aviation Administration, Atlantic City, NJ, 2020.

ULD fire detection systems

Air sampling smoke detector (ASSD)

Battery powered wireless smoke detector



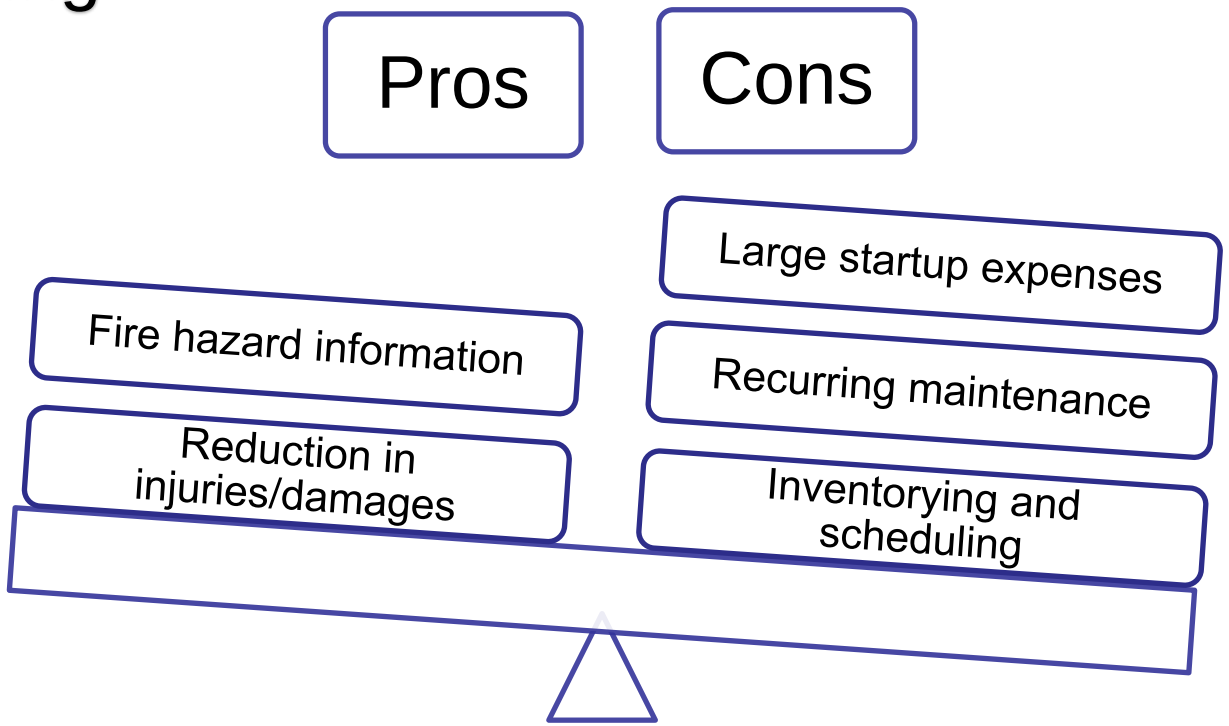
Telair aircraft power drive heat detector

FedEx Express infrared sensor fire detector

[5] S. Chin, "The Scalability of Smoke Detectors and the Viability of New Detection Methods in Aircraft," Federal Aviation Administration, Atlantic City, NJ, 2019.
[6] J. Wood, "Strategies for Improved Fire Detection Response Times in Aircraft Cargo Compartments," Federal Aviation Administration, Atlantic City, NJ, 2020.
[7] Telair, "CONTACT-LESS ULD TEMPERATURE SENSING WARNING SYSTEM," [Online]. Available: https://telair.com/portfolio-item/contact-less-uld-temperature-sensing-warning-system/?nowprocket=1. [Accessed 13 02 2022].
[8] Federal Aviation Administration, "VENTS WITH SMOKE, FIRE, EXTREME HEAT OR EXPLOSION INVOLVING LITHIUM BATTERIES," 30 June 2021. [Online]. Available: https://www.faa.gov/hazmat/resources/lithium_batteries/media/Battery_incident_chart.pdf. [Accessed 6 July 2021].

Cost/benefit of current ULD fire detection

Additional time for emergency landing decision making



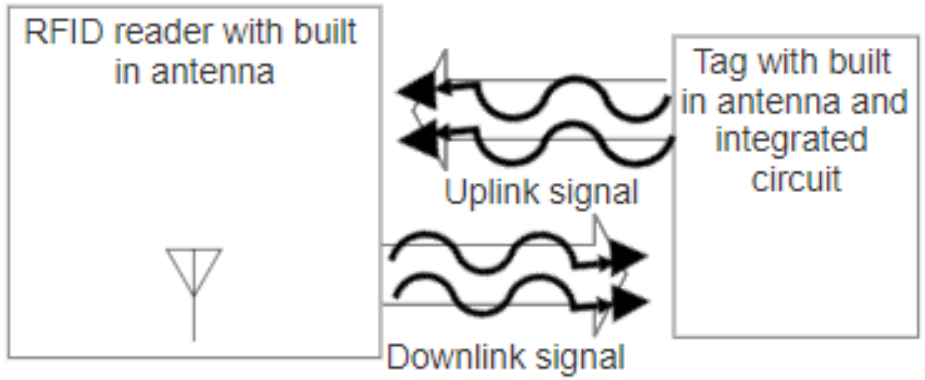
High costs for over one million ULDs currently in use

- Requires regular battery changes (battery powered wireless smoke detector)
- Requires regular maintenance installing and removing tubing (ASSD)

[9] International Air Transport Association, "Unit Load Devices (ULD)," [Online]. Available: https://www.iata.org/en/programs/cargo/unit-load-devices/#:~:text=With%20about%201%20million%20aircraft%20ULDs%20in%20service,aircraft%20parts%20and%20directly%20contribute%20to%20flight%20safety.. [Accessed 14 02 2022].

UHF RFID overview

- **Inexpensive**
- The reader communicates with the tags through electromagnetic radio waves that are transmitted and received through antennas.
  - Can read through composites but not metal
- The integrated circuits (IC) in **passive tags** are powered only by the rectification of the electromagnetic waves received from the reader antenna
- Use backscattered communication to communicate with the reader
- Can collect data from **multiple** tags (~30 reads/second) without a **line of sight** (LOS)
- Possible to sense physical parameters such as gas, **temperature**, moisture, and pressure



UHF RFID basic schematic

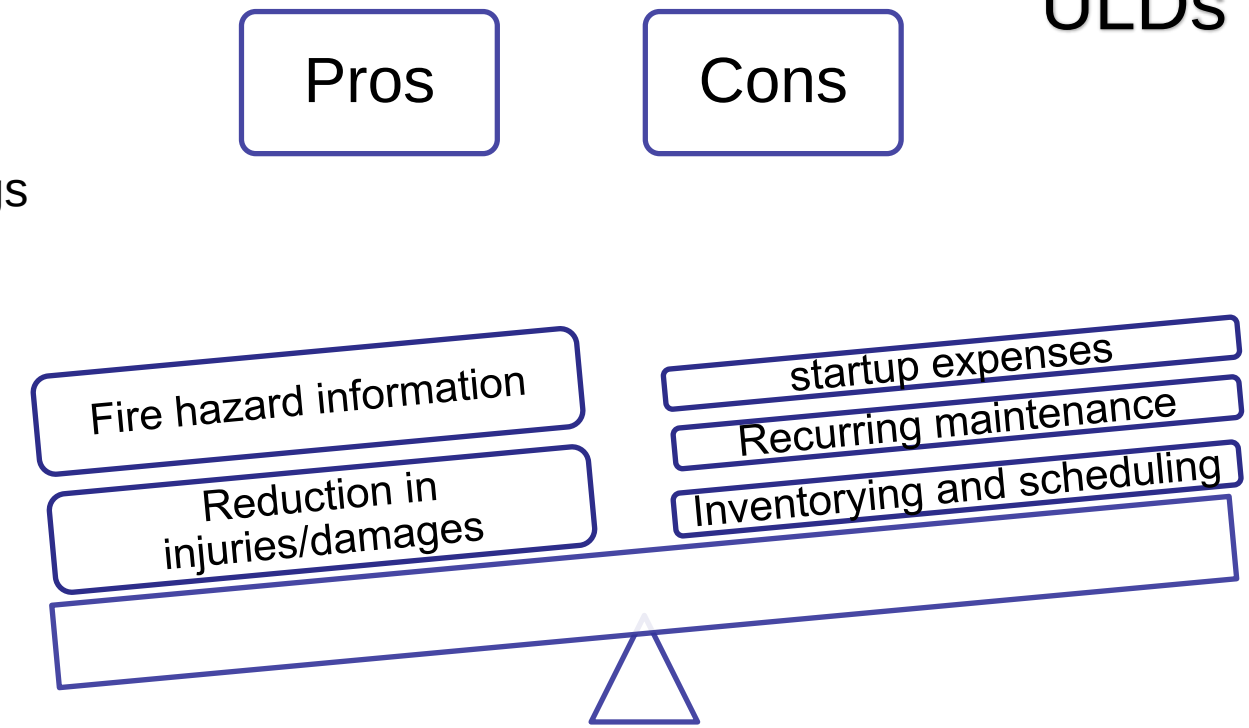
[10] K. Finkenzeller, RFID Handbook Second Edition, West Sussex, England: John Wiley & Sons Ltd., 2003

Cost/benefit of UHF RFID ULD fire detection

Additional time for emergency landing decision making

Reduced costs for over one million ULDs currently in use

- Single reader can read many tags simultaneously
- Does not require line of sight
- Completely passive sensor
- Inexpensive ($2.99/sensor, $500/antenna, $1500/reader)
  - Less in bulk



[9] International Air Transport Association, "Unit Load Devices (ULD)," [Online]. Available: https://www.iata.org/en/programs/cargo/unit-load-devices/#:~:text=With%20about%201%20million%20aircraft%20ULDs%20in%20service,aircraft%20parts%20and%20directly%20contribute%20to%20flight%20safety.. [Accessed 14 02 2022].

Preliminary tests

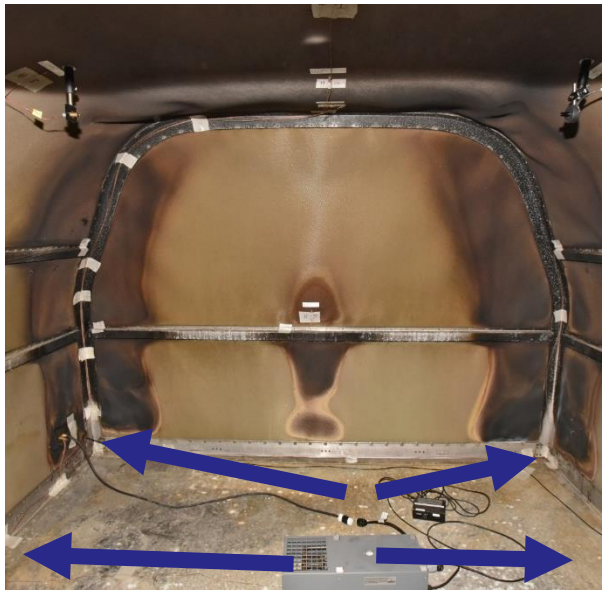
- UHF RFID reader measured temperature rise from a smoke generator with 640 W chimney heaters (6 C/min) through a fire resistant container (FRC) ULD

Enclosed fire resistant container (FRC) ULD

Variables to study

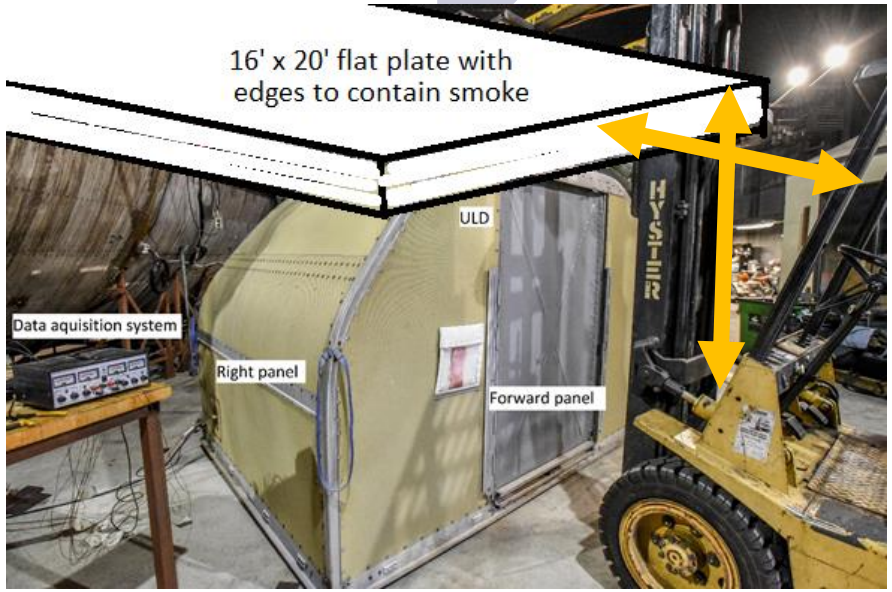
Fire source | **Fire location** | **ULD type** | **Ceiling height**

Smoldering fire



Interior of ULD

Smoke exiting ULD



Adjustable mock cargo compartment ceiling

Variables to study – fuel source (1 of 4)

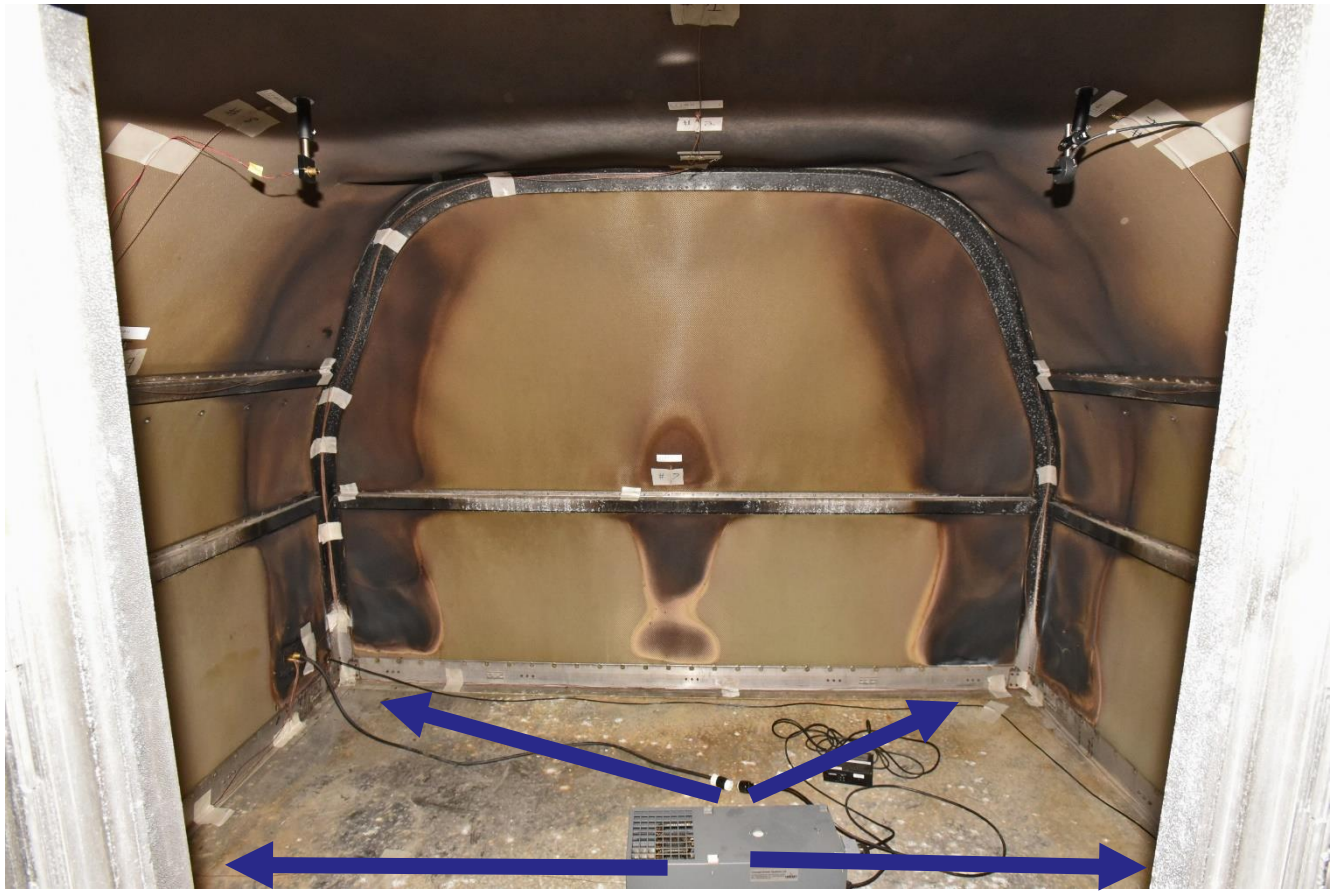
Modified (reduced) FAA standard fire load - shredded paper cardboard boxes

Self sustained smoldering saw dust in pipe

Smoke generator

Variables to study – fire location (2 of 4)

- Fuel source located in center of ULD and at four corners



Interior of ULD and sensor placement

Variables to study – ULD (3 of 4)

	AAY	AKE (LD3)	No ULD
Internal volume: m^3 (ft^3)	13.9 (492)	4.3 (153)	NA
External dimensions (W x L X H) mm (in)	2,235 (88) x 3,175 (125) x 2,083 (82)	1,534 (60.4) x 2,007 (79) x 1,626 (64)	NA
Aircraft and Deck	Standard Body - Main Deck	Wide Body - Lower Deck	NA

AAY

LD3

[11] Euroasian Cargo Solutions, "ULD Containers," [Online]. Available: https://www.euascargo.com/en/useful-info/uld-containers/ake-dke-mke-qke-rke. [Accessed 08 03 2022].

Variables to Study – ceiling height (4 of 4)

- Two Scenarios
  - ULD height plus 2”
  - ULD height plus 5”

Adjustable mock cargo compartment ceiling

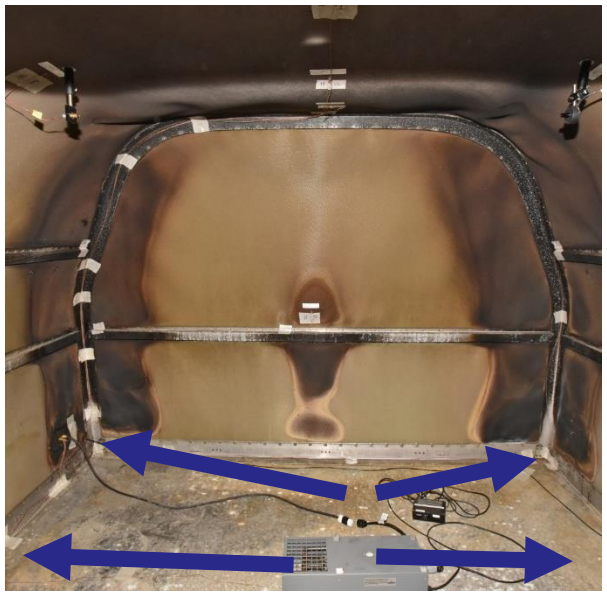
Response variables

ULD fire detection time

Cargo compartment fire detection time

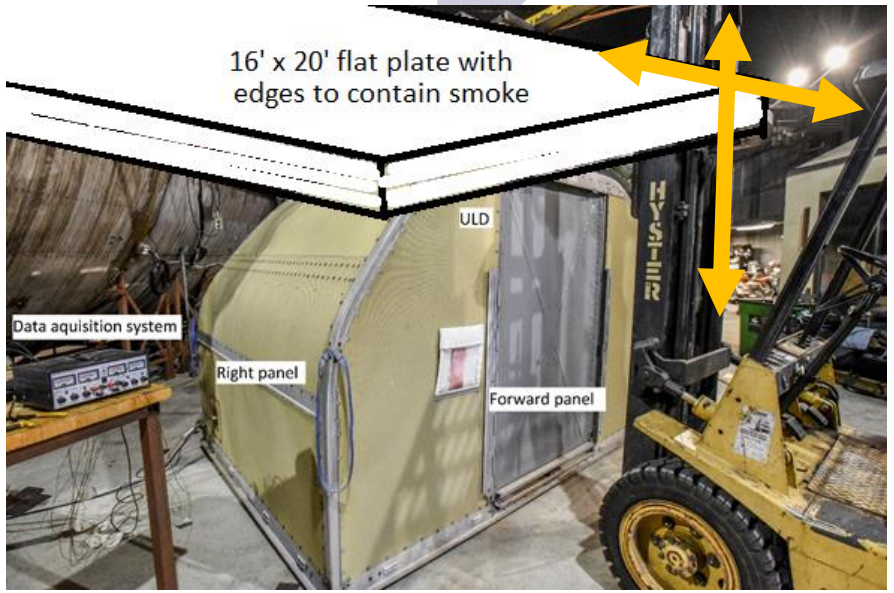
Fire characterization

Smoldering fire



Interior of ULD

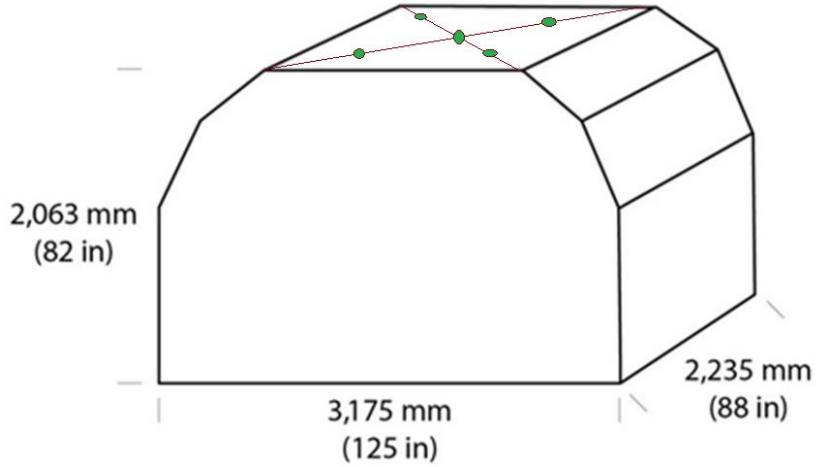
Smoke exiting ULD



Adjustable mock cargo compartment ceiling

Response variables – ULD heat detection time (1 of 3)

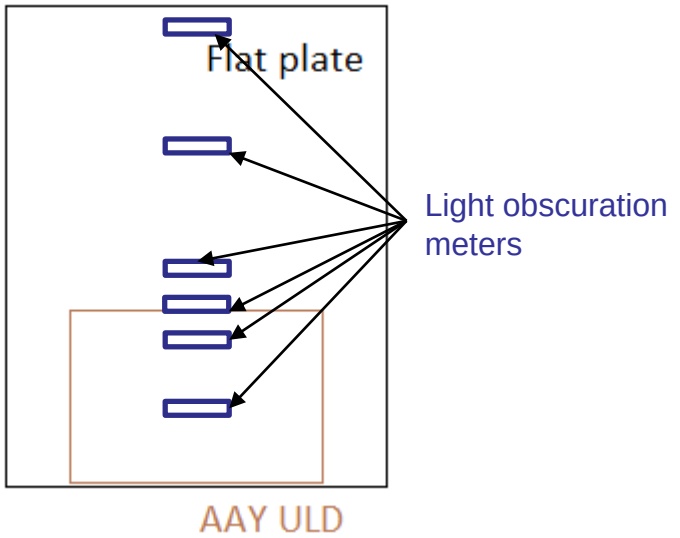
- Five temperature sensing tags and reference thermocouples locations on or near ceiling of ULD
- Measure temperature response within the ULD and on the ULD surface
- Used to determine heat detection times and optimal sensor placement



ULD temperature sensor placement

Response variables – cargo compartment smoke detection time (2 of 3)

- Six light obscuration meters along mockup cargo compartment ceiling
  - (2.3mW 670nm laser and silicon diode light sensor)
- Measure ceiling jet flow
- Used to determine smoke detection times and characterize jet flow exiting an ULD



Light obscuration meter placement on mockup cargo compartment ceiling

Response variables – fire parameters (3 of 3)

- Thermocouples at fuel source
- Six additional thermocouples along mockup cargo compartment ceiling
- One light obscuration meter within ULD
- Video
- Used to characterize fuel source and acquire additional fire detection data points

Smoldering fire

Summary

- Determine if passive temperature sensors can detect a fire within a ULD
- Compare fire detection times for passive temperature sensors located within a ULD and smoke detectors located on a mockup cargo compartment ceiling for fires originating within a ULD
- Variables to study
  - ULD type
  - Fuel source
  - Fuel source location
  - Cargo compartment ceiling height
- Response variables
  - Temperature of smoke at the ceiling of ULD
  - Light obscuration of smoke that escapes the ULD at the cargo compartment ceiling
  - Fire characteristics

Questions and Answers

- **Matthew Karp**
- **FAA E211**
- **Matthew.Karp@faa.gov**
- **609-485-4538**