Occupational Health Risks from Use of CF_3I as a Halon 1301 Replacement in APU Fire Extinguishing Systems

Britt Weldon, PhD
Boeing Toxicology

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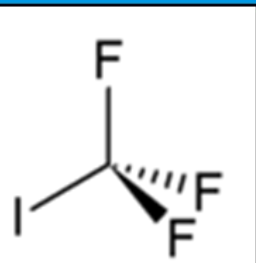
Overview

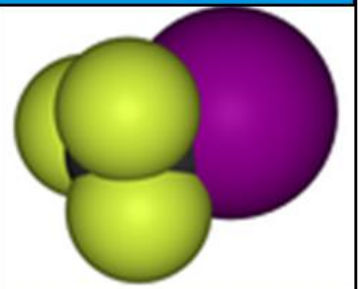
- CF_3I and Halon 1301 replacement
- Human health risk assessment framework
- Risks to workers in and around an APU compartment
- CF_3I toxicity and potential adverse health effect levels
- Potential worker exposure locations
- Dispersion testing at occupationally-relevant locations around aircraft
- Characterization of risks of health effects from CF_3I to workers

Trifluoroiodomethane (CF_3I)

Boeing is evaluating trifluoroiodomethane (CF_3I) as a potential Halon 1301 replacement for use in auxiliary power unit (APU) fire extinguishing systems of commercial aircraft

Trifluoroiodomethane (CF3I)





Properties	
Chemical formula	CF_3I
Molar mass	195.91 g/mol
Appearance	Colorless odorless gas
Density	2.5485 g/cm^3 at -78.5 °C 2.3608 g/cm^3 at -32.5 °C
Melting point	−110 °C (−166 °F; 163 K)
Boiling point	−22.5 °C (−8.5 °F; 250.7 K)
Solubility in water	Slightly
Vapor pressure	541 kPa

Wikipedia: CF3I

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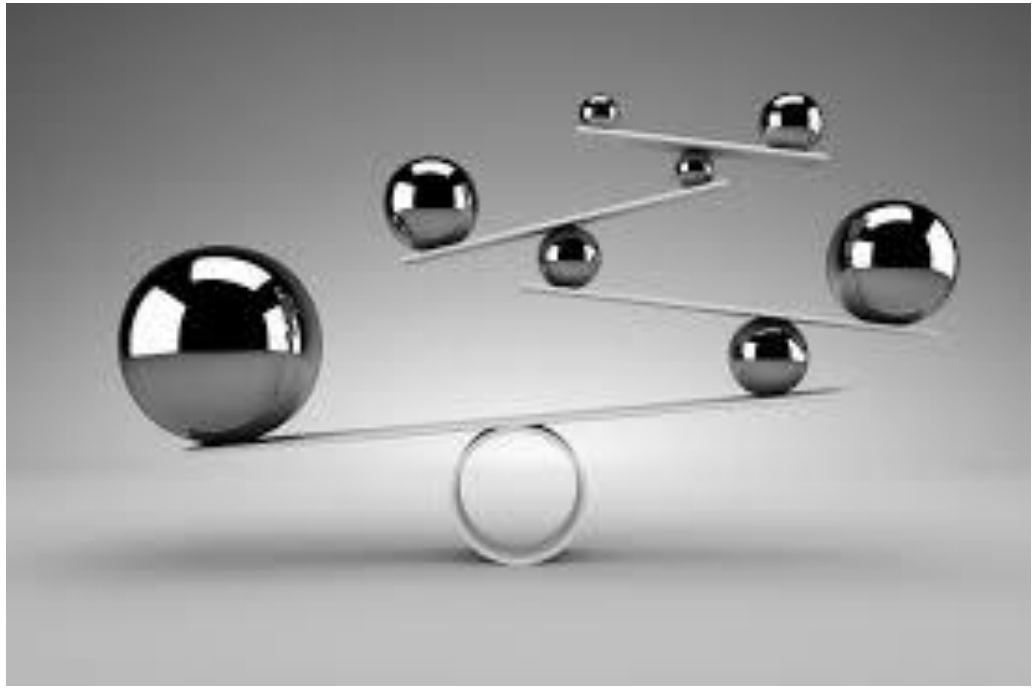
Alternatives Assessment for Halon Replacement

- Identifying a fire extinguishing agent to replace Halon 1301 in APU
- Challenges in balancing:
  - Performance
  - Design compatibility
  - Health and safety
  - Environmental effects
  - Weight/efficiency
  - Availability and cost
  - Material compatibility
  - Regulatory
  - Many more factors…



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Human Health Risk Assessment to Evaluate Health & Safety

Human Health Risk Assessment for Chemical Risks:

A systematic process by which the nature and magnitude of risks to human health from exposure to a chemical(s) are evaluated

Risk assessments characterize risks to inform decision-makers as to whether a risk is able to be sufficiently controlled for the protection of human health

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Human Health Risk Assessment

Risk = Toxicity x Exposure

Risk is a function of both the toxic potential of a chemical (what health effects can it cause and at what dose) and the amount of chemical that a person is exposed to

- If there is no exposure, there is no risk
- If the chemical is not toxic, there is no risk

Most things have some inherent toxicity–

“The dose [exposure] makes the poison” –Paracelsus (1493–1541)

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Are there potential health risks to workers when CF_3I is used in APU applications?

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Occupational Health Risks from Use of CF_3I in APU Systems

Are there potential health risks to workers when CF_3I is used in APU applications?	
Identify population	Who is at risk?
Assess hazards	What adverse health effects can CF_3I cause? At what doses?
Determine potential exposure scenarios	Where might workers be exposed?
Quantify exposure	How much CF_3I might workers be exposed to?
Assess risk	Can workers be exposed to concentrations of CF_3I at levels that may cause adverse health effects?

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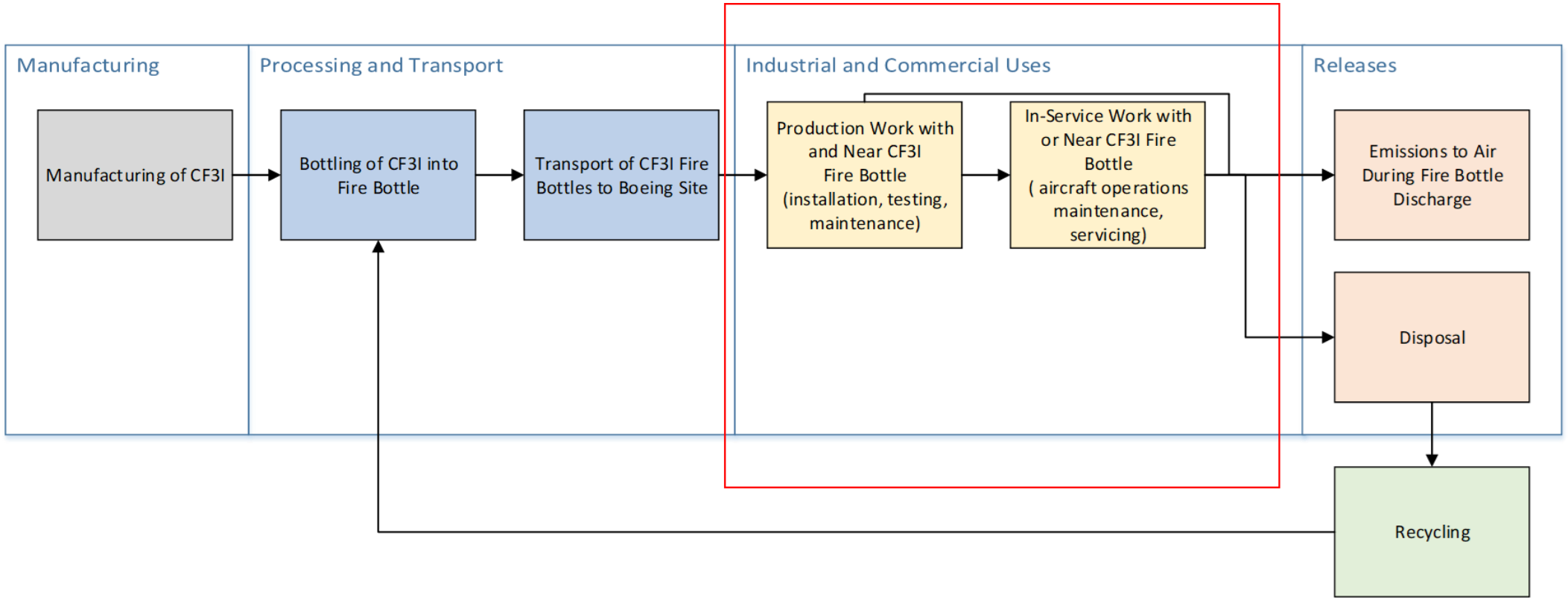
Life Cycle of CF_3I as a Fire Extinguishing Agent

Boeing's assessment focused on workers in the useful life stage of CF_3I's life cycle

- Production environments (e.g., in aircraft manufacturing facilities)
- In-service environments (e.g., airline operations and maintenance of aircraft)



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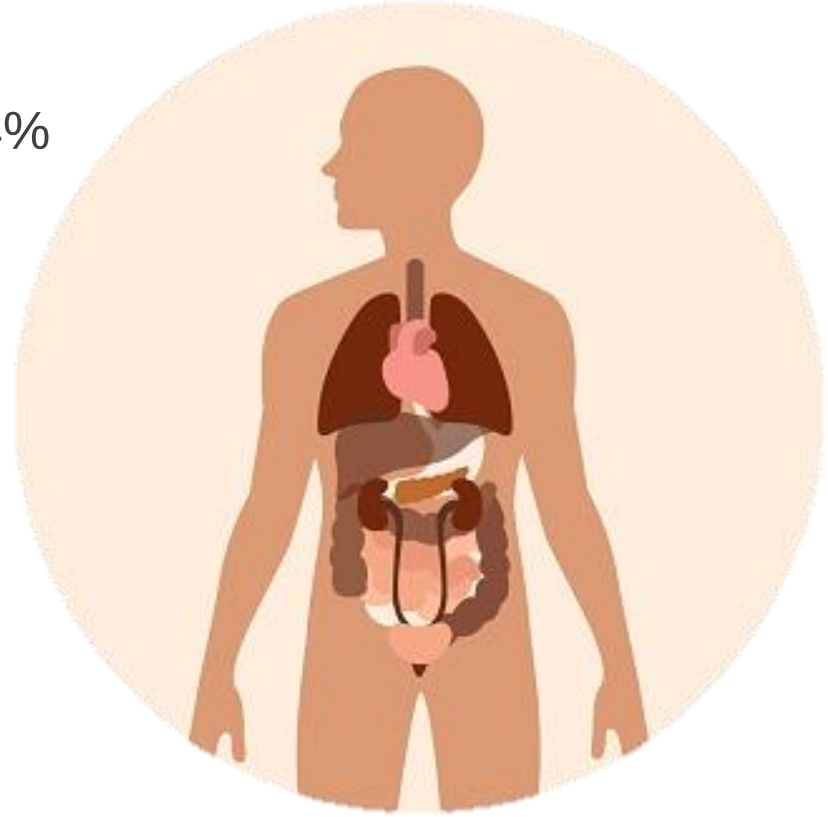
CF_3I Toxicity and Hazard Summary

- Cardiac sensitization- primary health effect of concern from inhalation
  - Key Study: Dodd & Vinegar, 1998
  - Cardiac sensitization test in dogs
  - No observed adverse effect level (NOAEL) identified: 0.2%
  - Lowest observed adverse effect level (LOAEL) identified: 0.4%
- Some potential for respiratory irritation and mutagenicity/carcinogenicity
  - Primarily concerns for non-acute exposures
- Dermal (skin) effects data gap in literature
- Acute hazards



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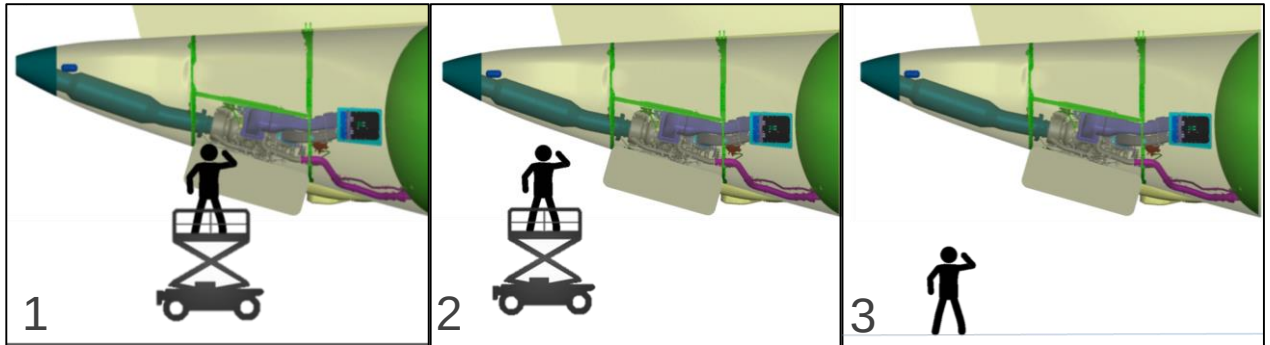
Exposure Scenarios

Occupational exposure to CF_3I from use in APU applications on commercial aircraft.

- Production environments (e.g., in aircraft manufacturing facilities)
- In-service environments (e.g., airline operations and maintenance of aircraft)
- Variety of occupational tasks that may occur in production environments and in-service environments that may result in exposure.

1. Work in or at APU compartment— APU door open, door closed
2. Elevated work near aft of aircraft— APU door open, door closed
3. Ground-level work near aft of aircraft— APU door open, door closed



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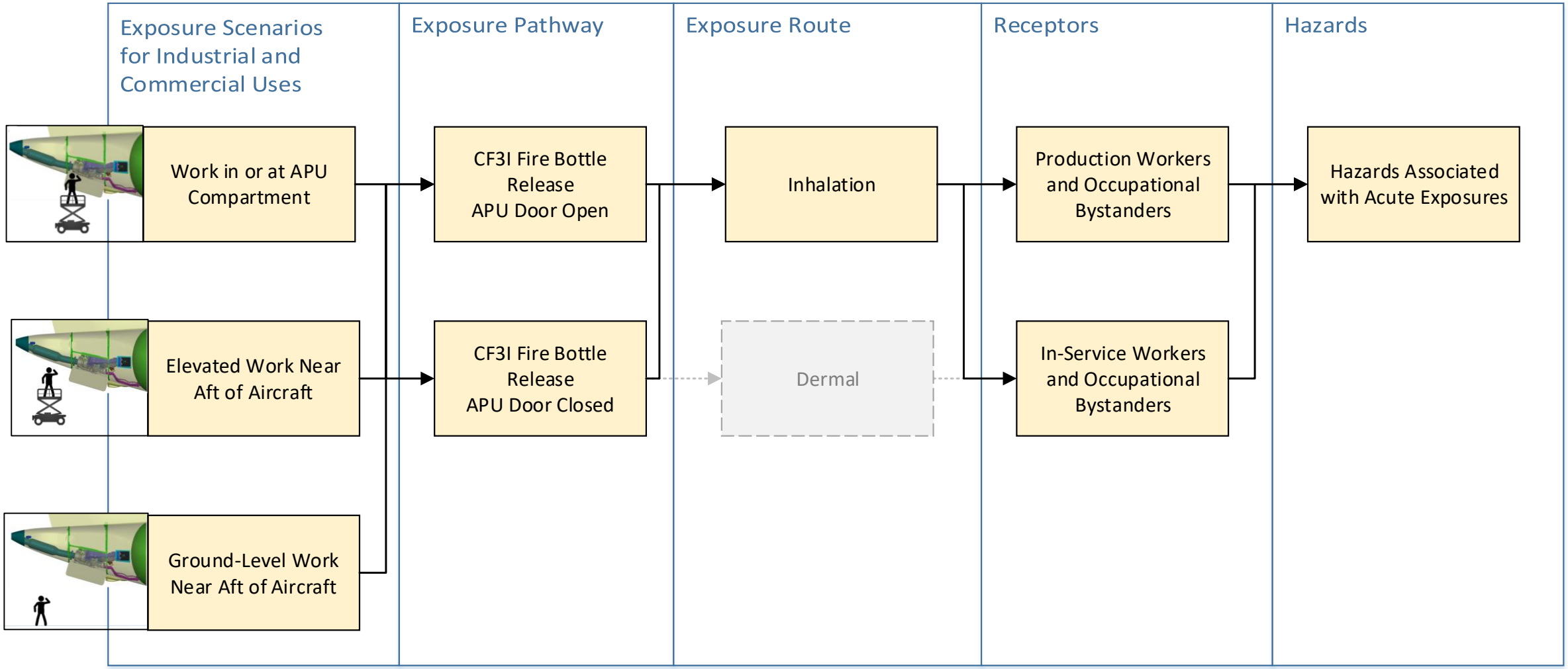
Exposure Scenarios, Pathways, Routes



Conceptual Exposure Model of CF_3I exposures in occupational settings

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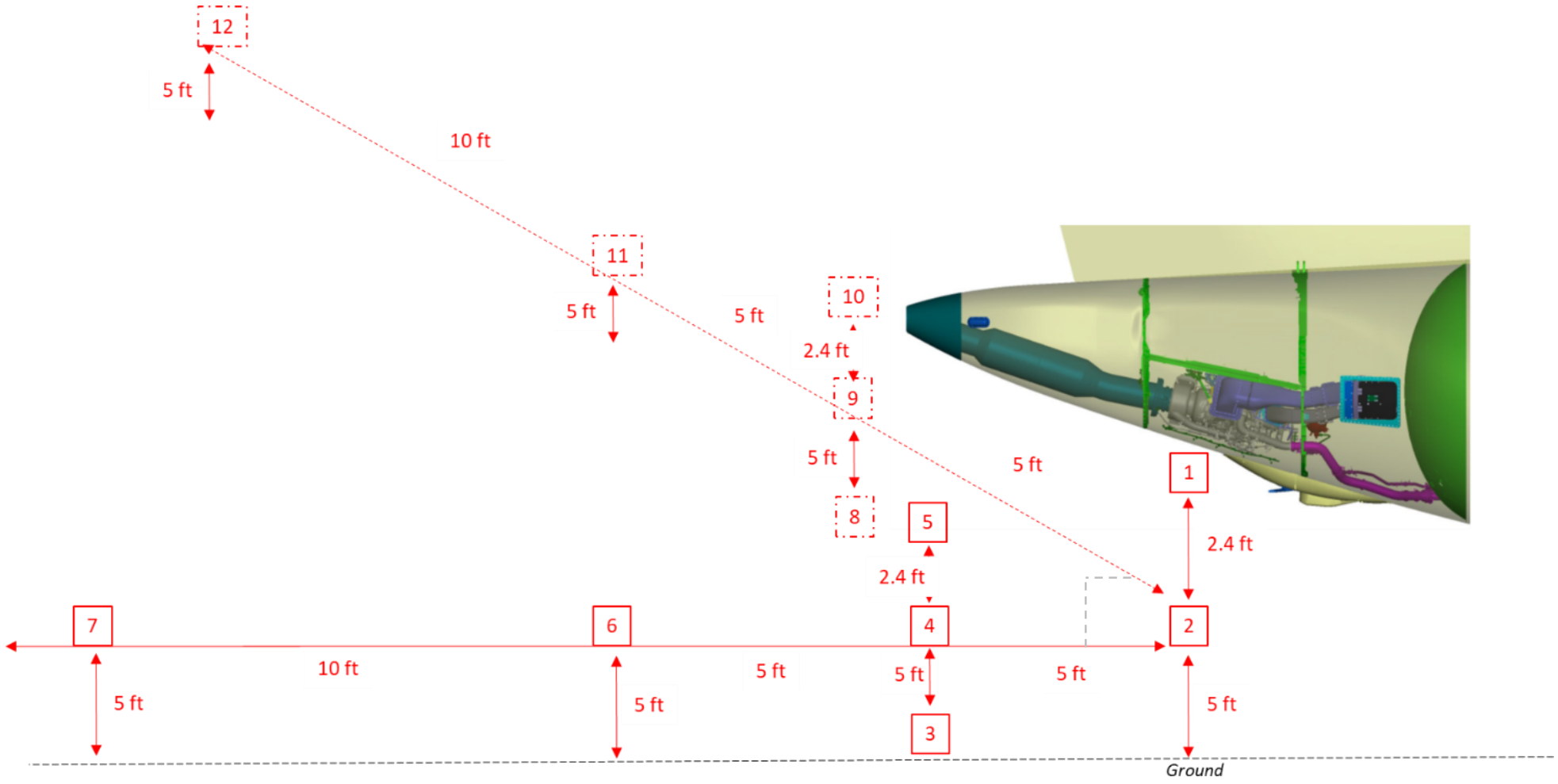
Dispersion Test- Determine Potential Worker Exposure



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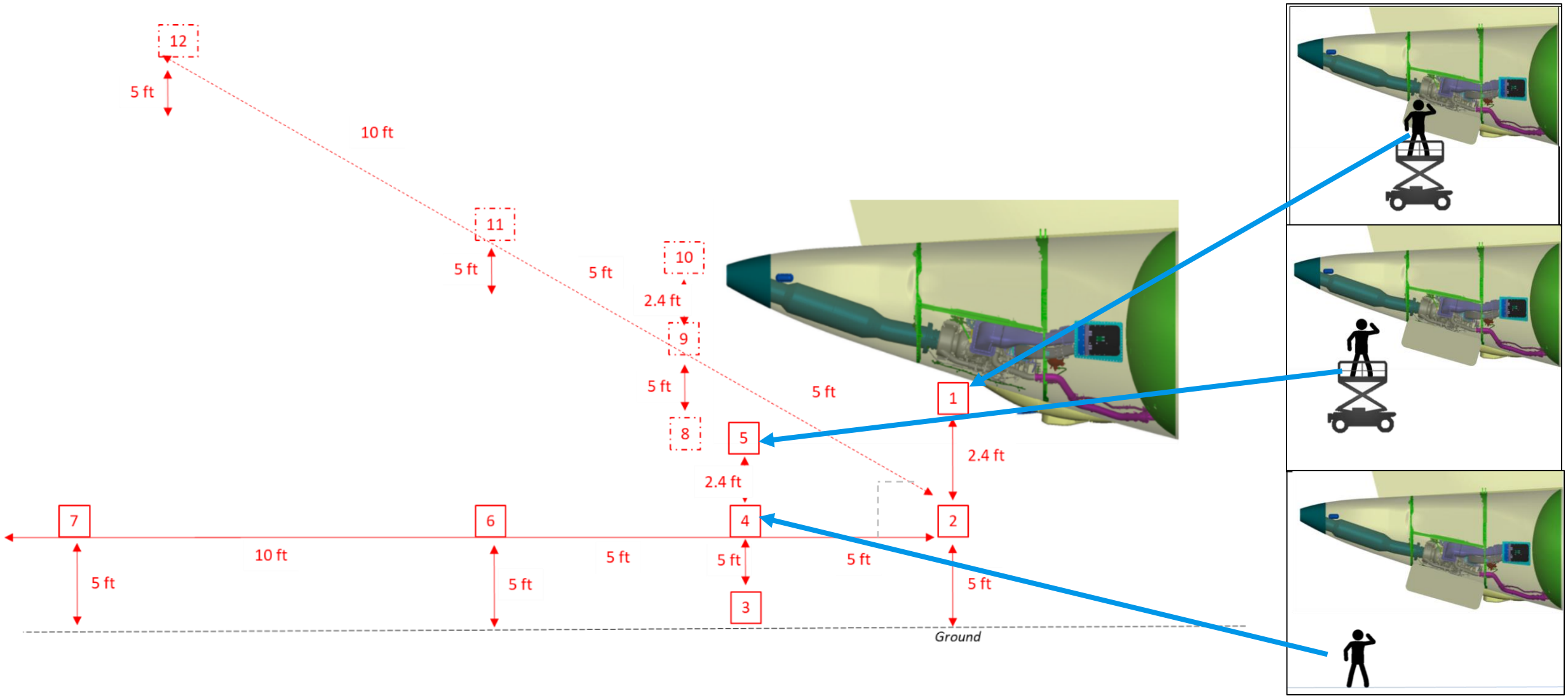

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Dispersion Test Conditions

1. APU door open
2. APU door closed

Test conditions designed to capture worst-case scenario exposure conditions

- No APU compartment ventilation airflow
- Outdoor wind speed < 5 knots
- No precipitation
- Test tailcone low to ground

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Discharge- APU Door Open

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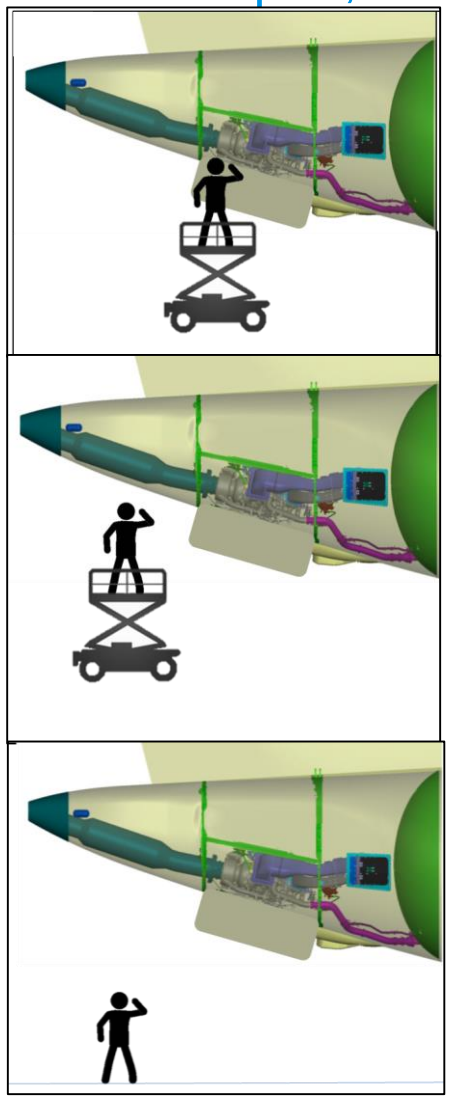
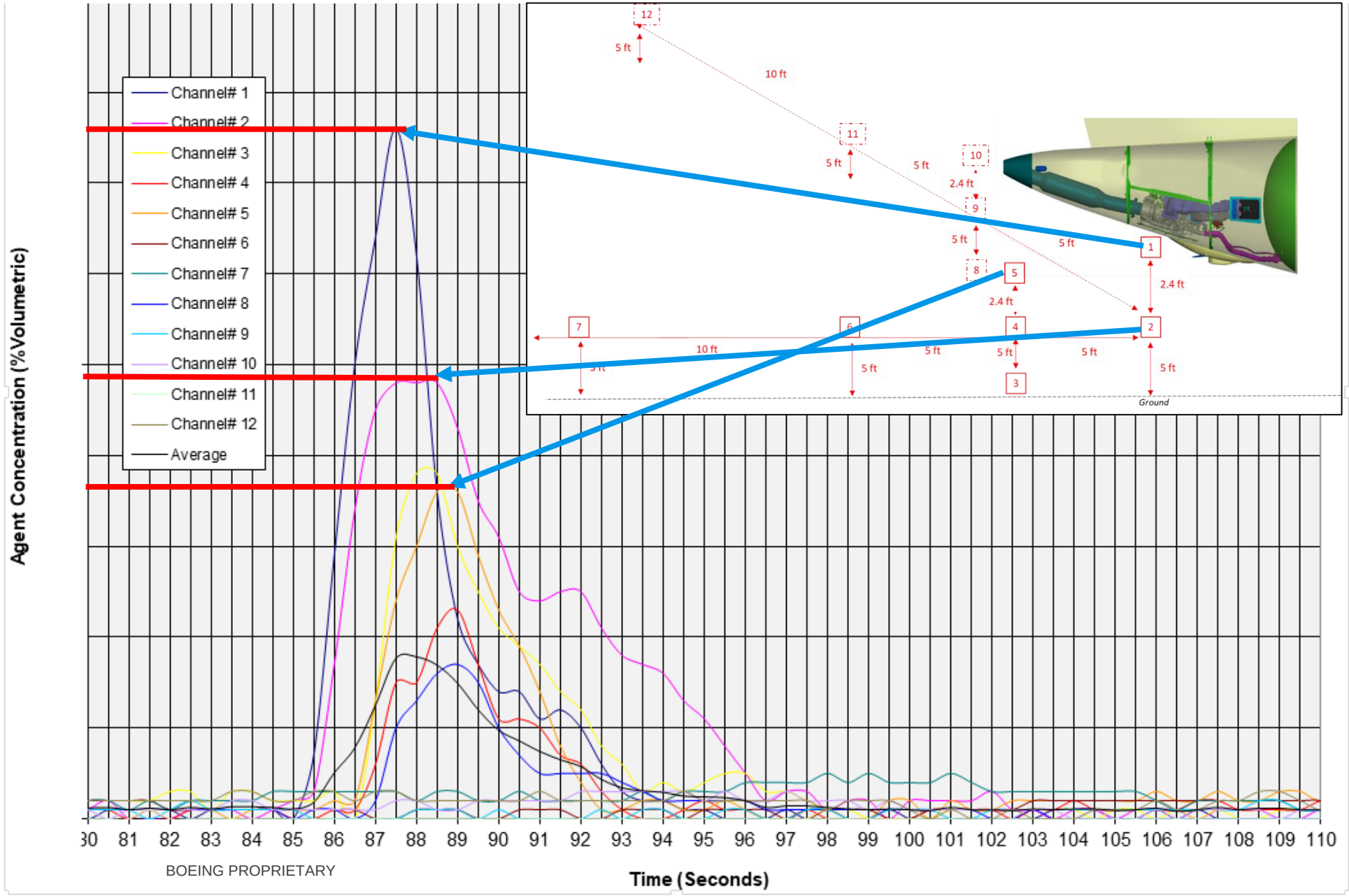
Dispersion Test Run 1

APU door open, 2 Hz





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Discharge- APU Door Closed

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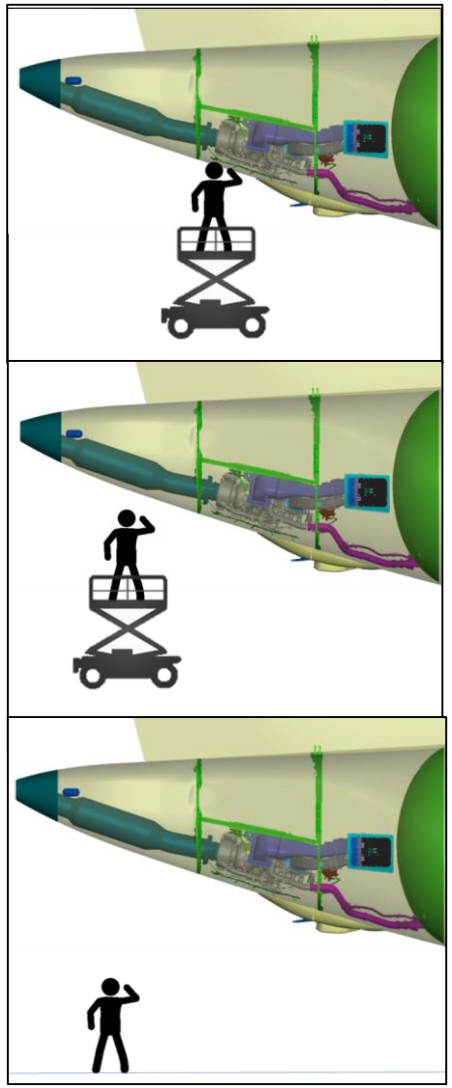
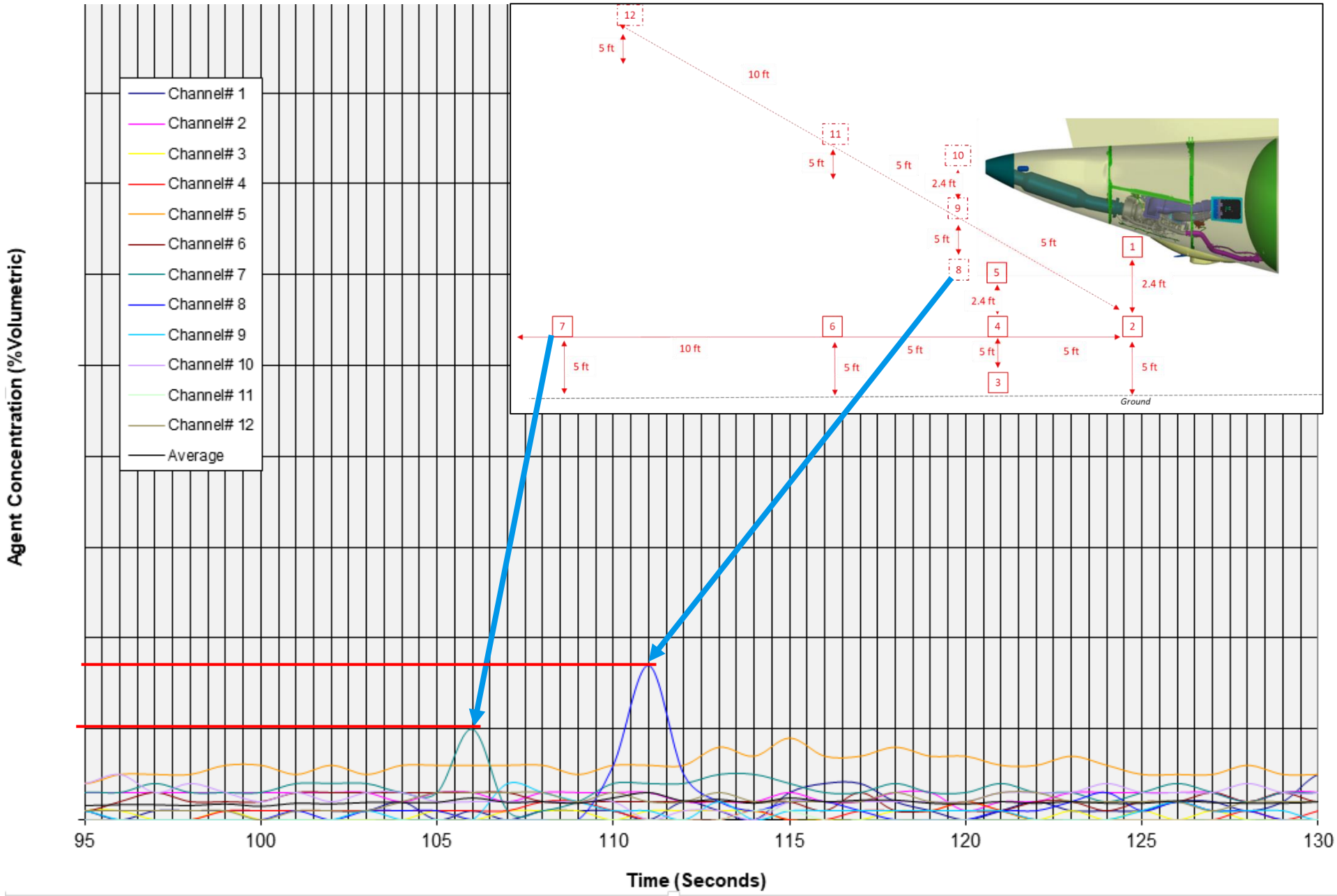
Dispersion Test Run 2

APU door closed,1 Hz





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NFPA 2001 Requirements for CF_3I*- Based on Toxicity

"Not normally occupied spaces" (e.g., APU compartment)	
Condition	**Requirement**
• Personnel may potentially be exposed to the chemical and • System is designed to concentrations above the LOAEL (0.4%)	Limit potential personnel exposure time in accordance with Table 1.5.1.2.1(e)
• Absence of information needed to meet exposure time limits (e.g., concentration not shown in Table 1.5.1.2.1(e)) and • Concentrations exceed the LOAEL (0.4%)	Personnel must be able to escape the area of discharge within 30 seconds

Δ **Table 1.5.1.2.1(e) Time for Safe Human Exposure at Stated Concentrations for FIC-13I1**

FIC-13I1 Concentration		Maximum Permitted Human Exposure Time
vol %	ppm	(min)
0.20	2000	5.00
0.25	2500	5.00
0.30	3000	5.00
0.35	3500	4.30
0.40	4000	0.85
0.45	4500	0.49
0.50	5000	0.35

Notes:
(1) Data derived from the EPA-approved and peer-reviewed PBPK model or its equivalent.
(2) Based on LOAEL of 0.4 percent in dogs.

NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems, 2018

* Requirements summary are adapted from NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems,

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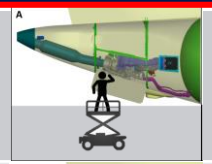
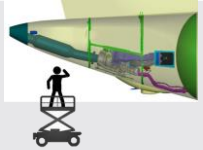
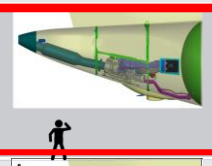
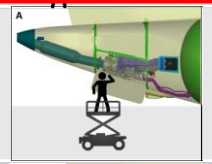
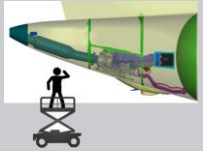
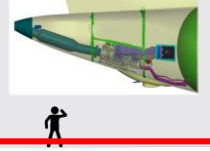
Findings Summary and Assessing Risk

Door Condition	Exposure Scenario	Exposure Scenario Drawing	Conc. >0.2% (NOAEL) for longer than NFPA Allowable Time	Escape Possible in 30 Seconds
Door Open	Work in or at APU compartment		Yes	No*
	Elevated work near aft of aircraft		Yes	No*
	Ground-level work near aft of aircraft		Yes	Yes
Door Closed	Work in or at APU compartment		No	No*
	Elevated work near aft of aircraft		No	No*
	Ground-level work near aft of aircraft		Yes	Yes

* Escape in 30 seconds may be possible, depending on access method (stairs, platform, etc). Worst case assumption is that a scissor lift will not provide 30 second egress).

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Summary

- Boeing is evaluating CF_3I for use in APU
- Evaluation of risks to workers during useful life stage of CF_3I- worker populations
- Cardiac sensitization is the primary health effect of concern
- Measured CF_3I concentrations at various human-relevant locations around APU compartment during discharge
- CF_3I concentrations may exceed toxicity thresholds in some locations very close to APU compartment during discharge with door open
- CF_3I concentrations at ground level generally did not exceed toxicity thresholds
- Ability to escape within 30 seconds possible at ground locations
- Ability to escape within 30 seconds at elevated locations needs to be evaluated in maintenance planning for risk mitigation planning

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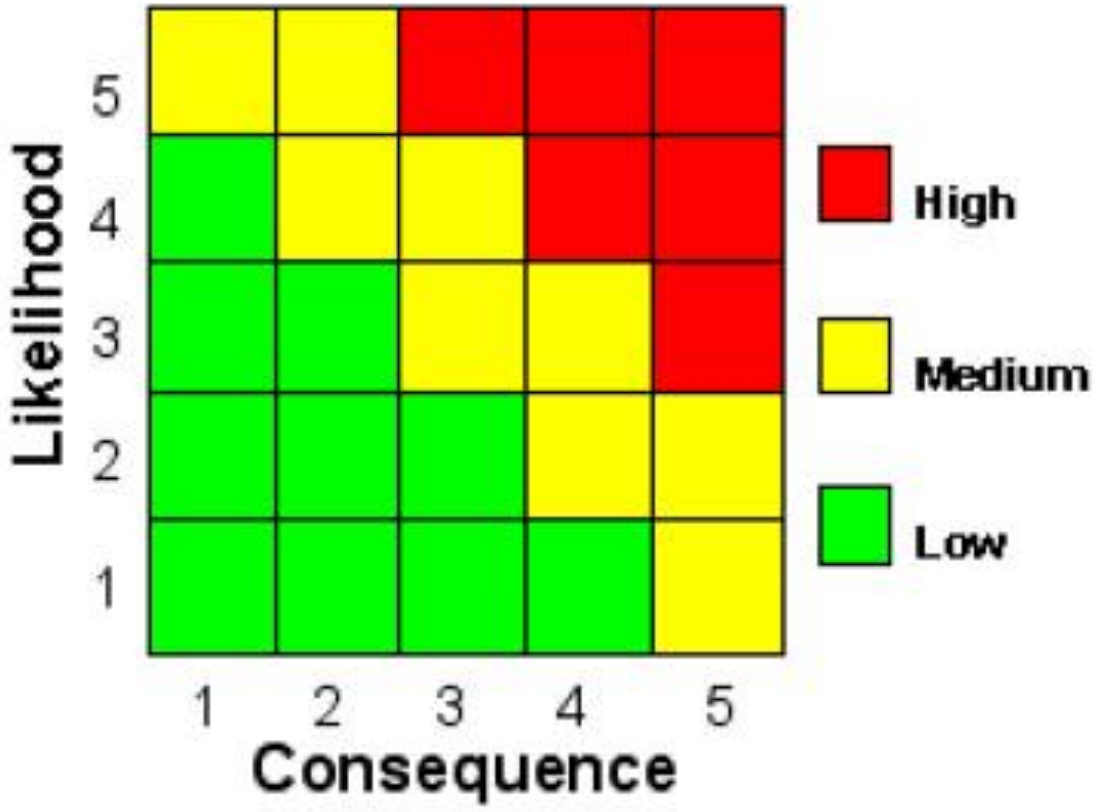
Risk Assessment and Decision-Making

Risk assessment may be used to inform the ‘Consequence’ component of the risk matrix in decision-making



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Dermal Considerations

- Potential dermal exposure in all exposure scenarios
- No dermal toxicity data available for CF3I, risk not assessed
- Liquid CF3I observed streaming from APU compartment door after door closed discharge
- Likelihood of liquid CF3I and dermal exposure in cold environments
  - boiling pt -8.5 F at 1 atm

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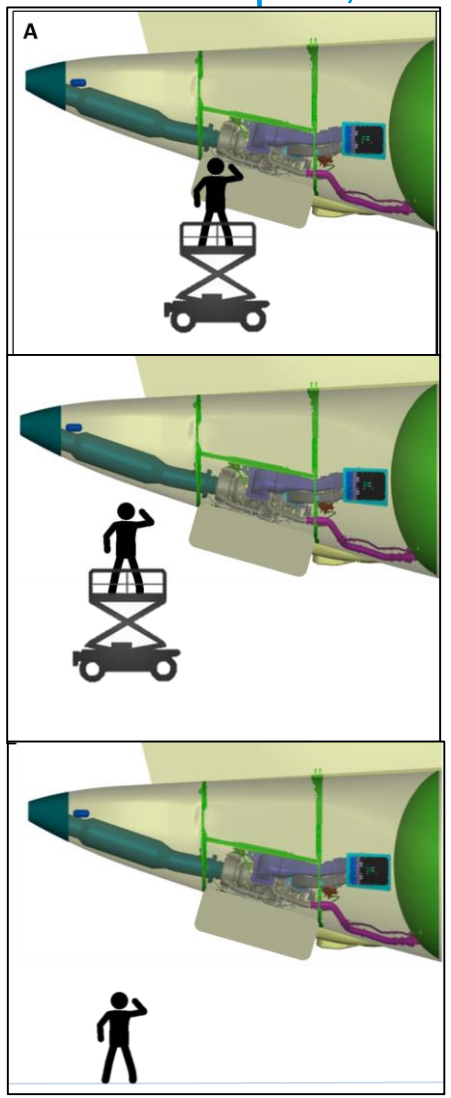
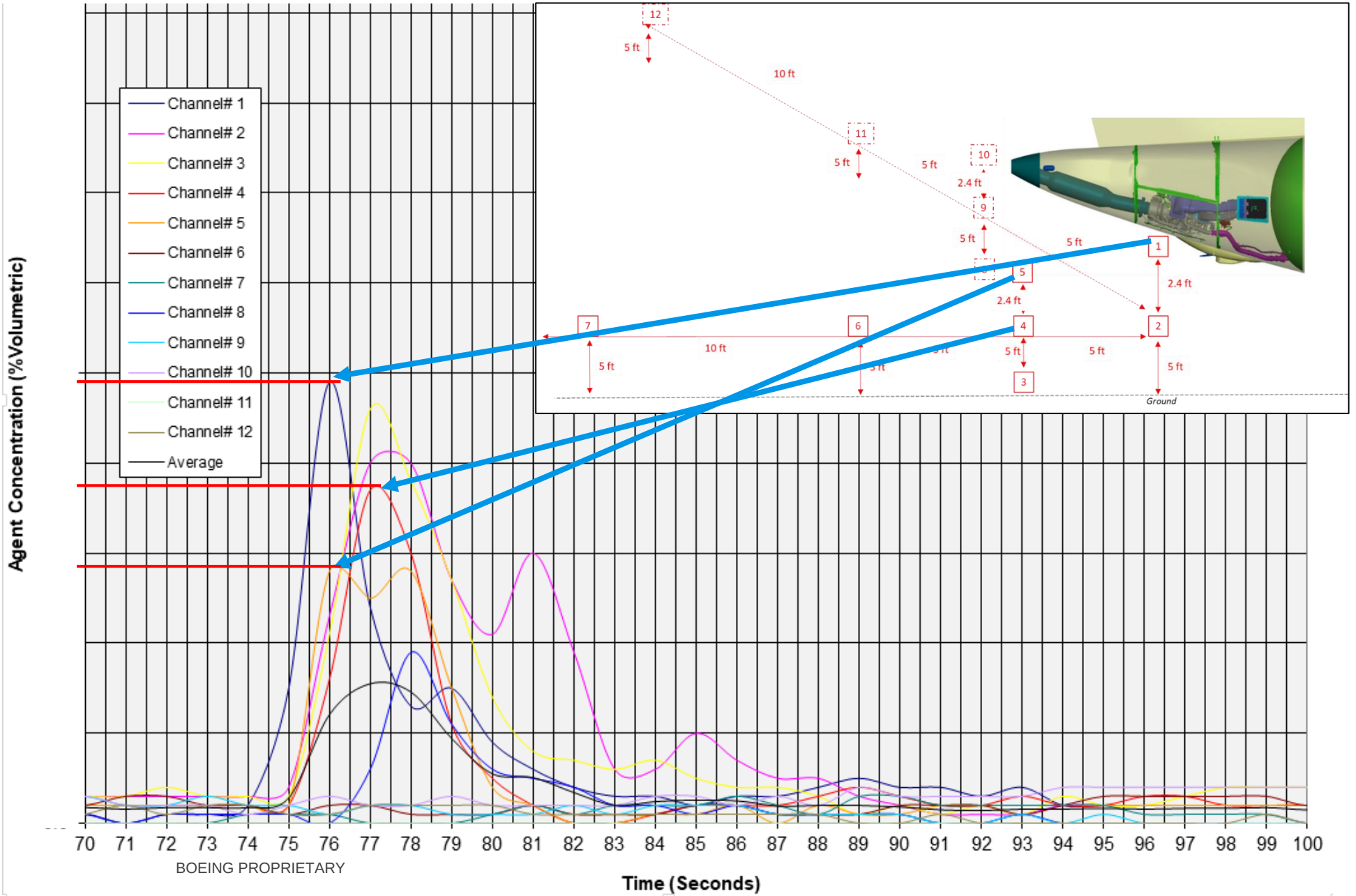
Dispersion Test Run 1

APU door open,1 Hz





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NFPA 2001 Requirements for CF_3I*- Based on Toxicity

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In the absence of information needed to meet exposure time limits (e.g., concentration not shown in Table 1.5.1.2.1(e)) and concentrations exceed the LOAEL (0.4%)	Personnel must be able to escape the area of discharge within 30 seconds
In the absence of information needed to meet exposure time limits (e.g., concentration not shown in Table 1.5.1.2.1(e)) and egress from the site of exposure is expected to take between 30-60 seconds	Agent concentration should not exceed the LOAEL (0.4%)

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