Effects of Liquid Disinfectants and Ultraviolet-C Germicidal Irradiation on Aircraft Cabin Interior Materials

Federal Aviation Administration

Presented by:

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NIAR-WSU

Wichita State University

Joint Centers of Excellence for Advanced Materials

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JAMS Technical Review

April 19, 2023

Agenda

- Research Team
- Motivation and Approach
- Project Overview
- Phase-I: Chemical Disinfectants of Aircraft Seating Materials
- Phase-II: Chemical Disinfectants of Cabin Interior Materials
- Phase-III: UV-C Disinfectants of Cabin Interior Materials
- Phase-IV: Chemical Disinfectants and UV-C on Cockpit Interior Materials
- Summary & Conclusions

Research Team (Phase I – Phase III)

- **Project Participants (NIAR AVET)**
  - PI: Gerardo Olivares
  - Primary Researchers: Akhil Bhasin, Luis Gomez, Aswini Kona Ravi, Luis Daniel Castillo, Tanat Maichan
  - Additional Researchers: Clayton Ehrstein, Javier Martinez, Irene DeGiacomi, Tareq Siddiqui, Hoolooman Ramdial, Anoushka Raju, Carlos Gatti, Hunter Griffith, Garret McClain
- **FAA Technical Monitor**:
  - Dave Stanley
- **FAA Sponsor**:
  - Jeff Gardlin, Cindy Ashforth
- **Other FAA Personnel**: Ahmet Oztekin
- **Industry Partnerships/Other Collaborations**:
  - SAE Seat Committee, SAE Cabin Interior Committee, Jamco America, Boeing, Aviation Consulting and Engineering Solutions (ACES), Collins Aerospace, AmSafe, SABIC, Lantal Textiles, Schneller, Aero HygenX, Honeywell Aerospace.

Motivation and Approach

- **Motivation & Key Issues**
  - Covid-19 pandemic outbreak.
  - Increased aircraft disinfection procedures enforced by regulatory bodies.
- **Objective & Scope**
  - Evaluate and understand the long-term effects of use of disinfectants on aircraft interiors.
  - Scope of the project extends to liquid and ultraviolet-c disinfection on seating, aircraft cabin and cockpit interior materials.
- **Approach**
  - Identify the commonly used disinfectants for aircraft interior cleaning.
  - Subject the materials to accelerated disinfection tests.
  - Evaluate the effects on mechanical properties, flammability, weight and color.

Project Overview

PHASE-I: Effects of Liquid Disinfectants on Aircraft Seating Materials

- 5 Liquid Disinfectants
- 17 Seating Materials
- Properties:
  - Flammability &
  - Mechanical

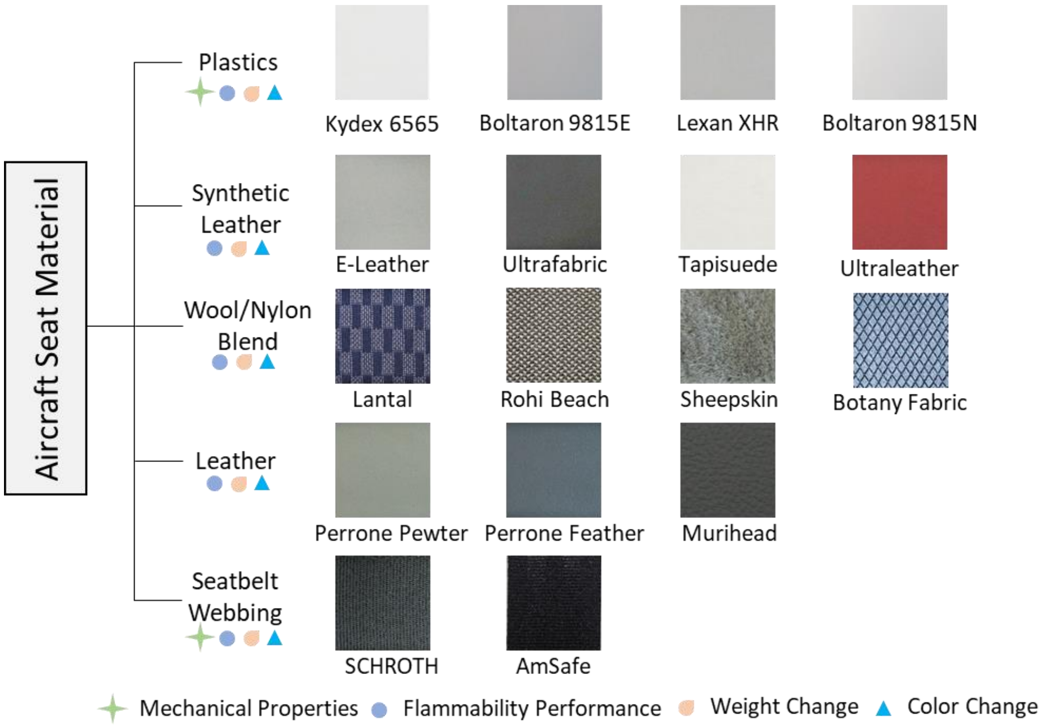
PHASE-II: Effects of Liquid Disinfection on Aircraft Cabin Materials

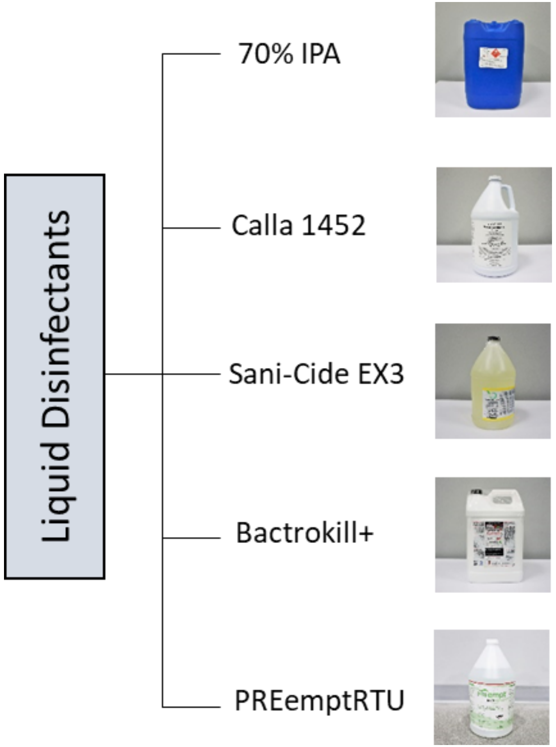
- Cabin Materials: Decorative laminates, floor carpets & honeycomb sandwich panels

PHASE-III: Effects of UV-C Disinfection on Aircraft Seating and Cabin Interior Materials

- 3 Wavelength configurations
- 8 different material types
- Properties:
  - Mechanical

Materials and Disinfectants



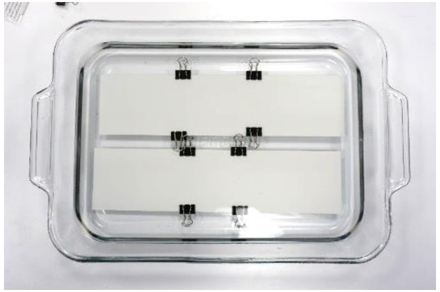


Phase-I

Conditioning Methods

Submersion Method

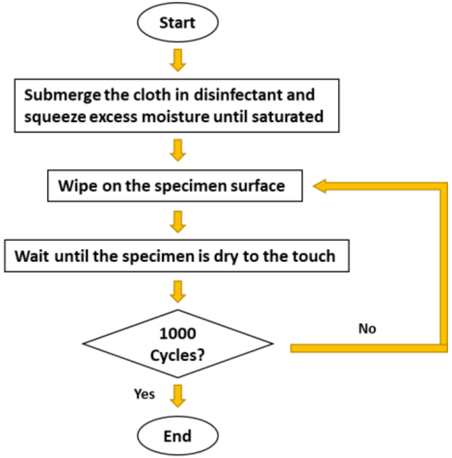
Clamp each specimen with paper clip

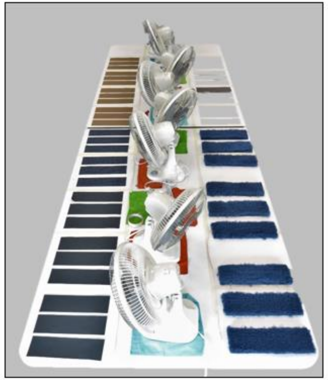


Place them in a tray filled with disinfectant

Cover the tray with vacuum bag

Wiping Method



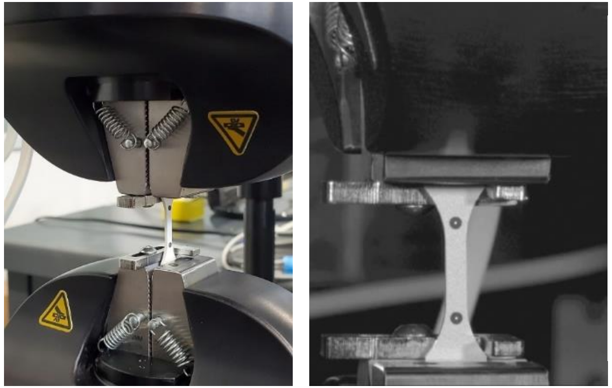


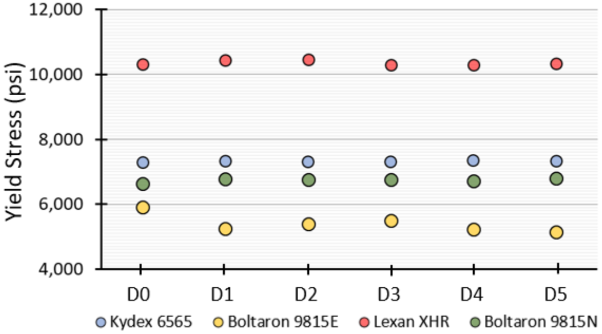
1,000 Cycles

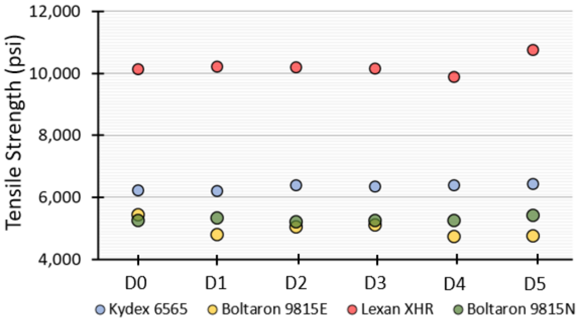
Phase-I

Plastics: Tension Results Summary

Tensile Test Setup







D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

- Mechanical Test Method: Uniaxial tension experiments.
- Test Standard: ASTM D638.
- Test specimens: 4 types of plastic materials; 6 configurations (x120 specimens).

Tension Properties: Statistical Evaluation Summary

Plastic Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Kydex 6565					
Boltaron 9815E					
Lexan XHR					
Boltaron 9815N					

Equivalent to unconditioned specimens

Not equivalent to unconditioned specimens

Equivalent to unconditioned specimens based on reduced testing

Phase-I

Seat Belt Webbing Results: Summary

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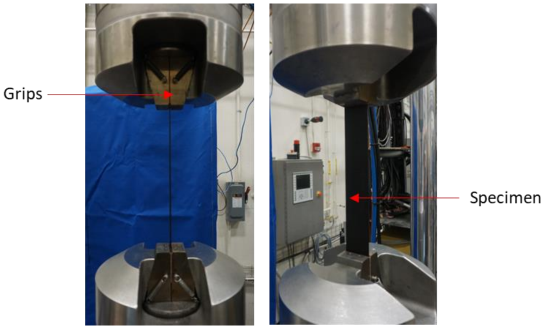
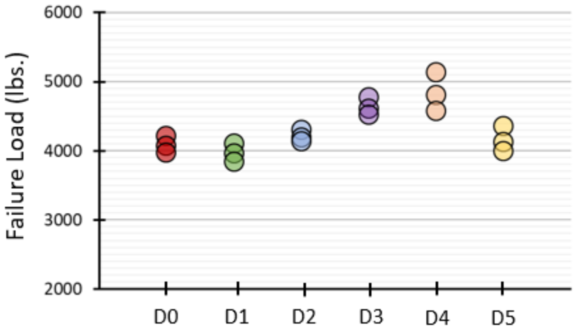
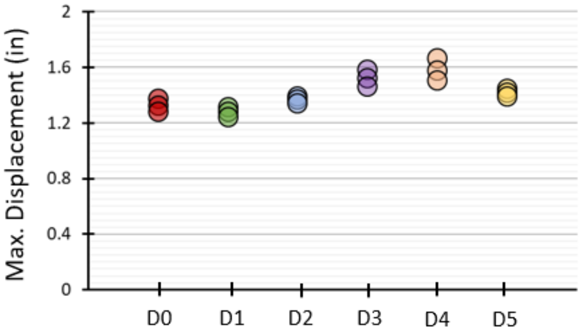
Test Setup



SCHROTH Webbing

- Test Reference: DOT/FAA/TC-15/29.
- Test Specimens: Schroth webbing; 6 configurations (x18 specimens).





D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Failure Load Summary (Seatbelt Webbing)				
Liquid Disinfectant Type				
D1	D2	D3	D4	D5

No Reduction in failure load

Reduction in failure load less than 5%

Phase-I

Flammability Results: Submersion

Test Setup

Video provided by ACES
(speed scaled for presentation)

- Vertical Bunsen burn tests were conducted per Title 14, Code of Federal Regulations (14 CFR) 25.853 Appendix F.
- For seatbelt webbing, 12-second test was conducted;
- For plastics, leather, and fabric materials 60-second test were conducted.

Flammability Results: Submersion Conditioning

Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Plastic	Kydex 6565	[green]	[green]	[green]	[green]	[green]
	Boltaron 9815E	[green]	[green]	[green]	[green]	[green]
	Lexan XHR	[green]	[green]	[green]	[green]	[green]
	Boltaron 9815N	[green]	[green]	[green]	[green]	[green]
Synthetic Leather	E-Leather CL820	[red]	[red]	[red]	[red]	[red]
	Ultrafabric 492-6579FR12	[green]	[red]	[red]	[red]	[red]
	TapiSuede TSFRC0961	[green]	[green]	[green]	[green]	[green]
	Ultraleather ULFRB971-1363	[green]	[red]	[red]	[red]	[red]
Wool/Nylon Blend	Lantal	[green]	[green]	[red]	[red]	[green]
	Rohi Beach	[green]	[red]	[red]	[red]	[red]
	Sheep Skin	[green]	[green]	[red]	[red]	[red]
	Botany Fabric	[green]	[green]	[green]	[red]	[red]
Leather	Pewter BC (Perrone)	[green]	[green]	[green]	[green]	[green]
	Perrone Feather Weight	[green]	[green]	[red]	[red]	[red]
Webbing	SCHROTH	[green hatched]	[green hatched]	[green hatched]	[green hatched]	[green hatched]
	AmSafe Polyester	[green hatched]	[green hatched]	[green hatched]	[green hatched]	[green hatched]

- [green] Increase in avg. burn length less than 50% in comparison to unconditioned specimens
- [red] Increase in avg. burn length greater than 50% in comparison to unconditioned specimens
- [green hatched] Increase in avg. burn length less is less than 6” in comparison to unconditioned specimens

Phase-I

Flammability Results: Wiping

Synthetic Leather (E-leather)

Conditioned with ‘D1’

Pristine Submersion Wiping

Lantal (Nylon/Wool Fabric)

Conditioned with ‘D3’

Pristine Submersion Wiping

Flammability Results: Wiping Conditioning

Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Synthetic Leather	E-Leather CL820	(green)	(green)	(green)	(green)	(green)
	Ultrafabric 492-6579FR12	(grey)	(green)	(green)	(green)	(green)
	Ultraleather ULFRB971-1363	(grey)	(green)	(green)	(green)	(green)
Wool/Nylon Blend	Lantal	(grey)	(grey)	(red)	(green)	(grey)
	Rohi Beach	(grey)	(green)	(red)	(red)	(green)
	Sheep Skin	(grey)	(grey)	(red)	(red)	(red)
	Botany Fabric	(grey)	(grey)	(grey)	(red)	(red)
Leather	Pewter BC (Perrone)	(grey)	(green)	(green)	(green)	(green)
	Perrone Feather Weight	(grey)	(grey)	(green)	(green)	(green)

(green) Increase in avg. burn length less than 50% in comparison to unconditioned specimens

(red) Increase in avg. burn length greater than 50% in comparison to unconditioned specimens

(grey) Normally equivalent results obtained when conditioned using submersion method

Phase-I

Color Change: Summary

Qualitative Color Change: Submersion Conditioning

Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Plastic	Kydex 6565					
	Boltaron 9815E					
	Lexan XHR					
	Boltaron 9815N					
Synthetic Leather	E-Leather CL820					
	Ultrafabric 492-6579FR12					
	TapiSuede TSFRC0961					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					
Webbing	SCHROTH					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Boltaron 9815N (D0) Boltaron 9815N (D4)

Rohi Beach (D0) Rohi Beach (D5)

Perrone Feather Weight (D0) Perrone Feather Weight (D4)

Change in Weight: Wiping Conditioning

Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Synthetic Leather	E-Leather CL820					
	Ultrafabric 492-6579FR12					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					

No change in color/texture Change in color Change in color and texture

Rohi Beach (D0) Rohi Beach (D2)

Lantal (D0) Lantal (D3)

Ultrafabric (D0) Lantal (D3)

Phase-I

Materials and Disinfectants

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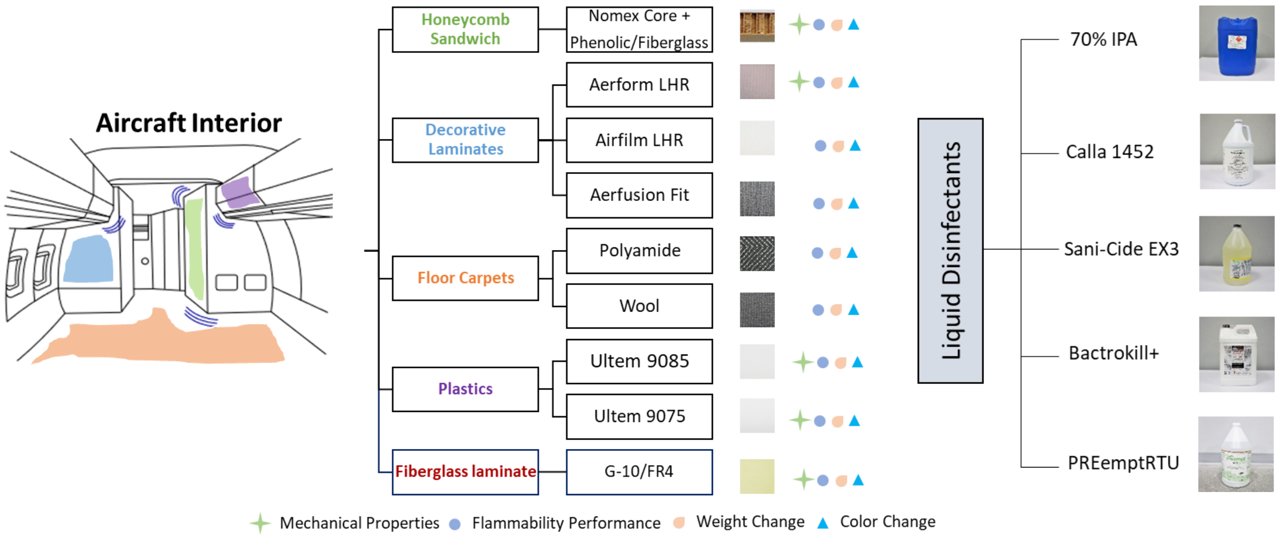
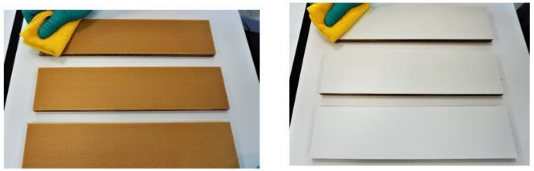
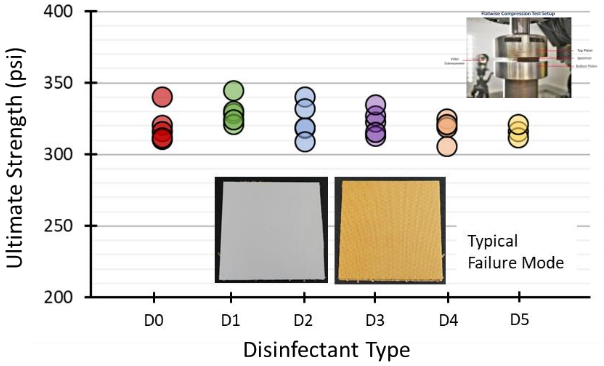


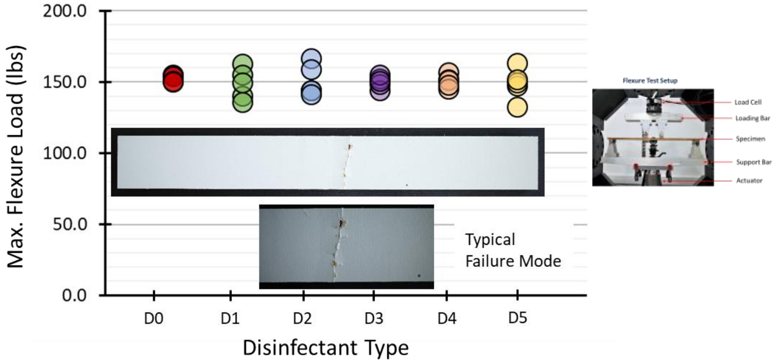

Wiping conditioning for flammability and flatwise compression

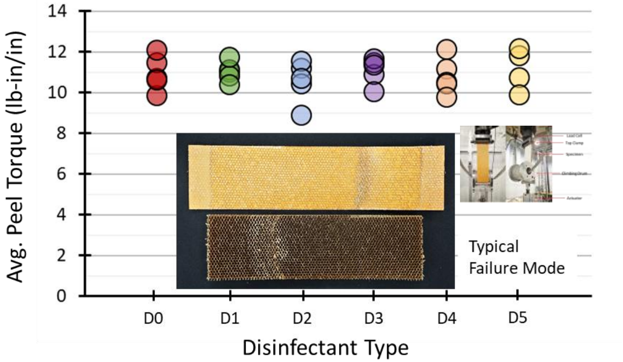

1000 cycles on Face #1

1000 cycles on Face #2

Honeycomb Sandwich Test Summary







Mechanical Properties: Statistical Evaluation Summary

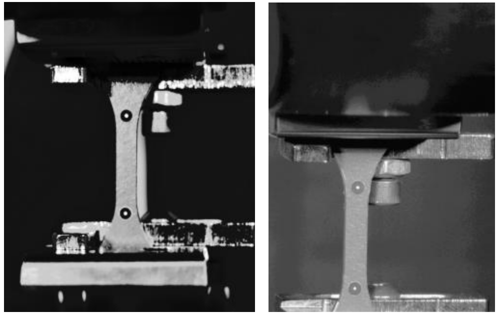
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Compressive Strength					
Average Peel Torque					
Maximum Flexure Load					

(Green hatched cells:) Equivalent to unconditioned specimens based on reduced testing

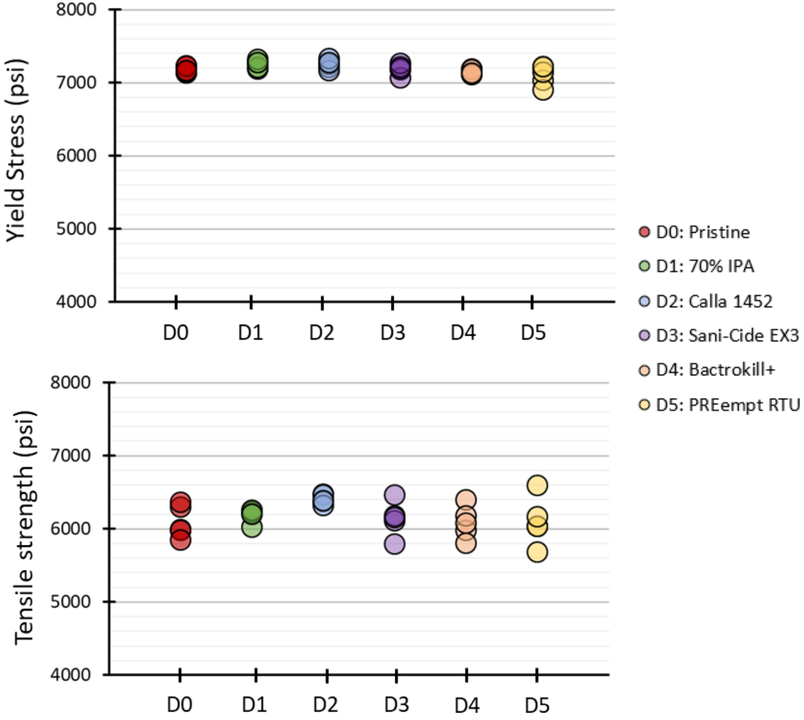
Phase-II

Decorative Laminate Test Summary

Test Setup



Aerform LHR (front and back view)



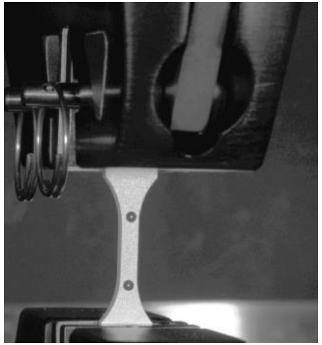
Mechanical Properties: Statistical Evaluation Summary					
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Yield Stress					
Tensile Strength					

Equivalent to unconditioned specimens based on reduced testing

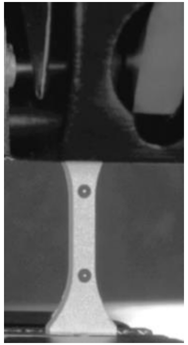
Phase-II

ULTEM 9075 & ULTEM 9085 Test Summary

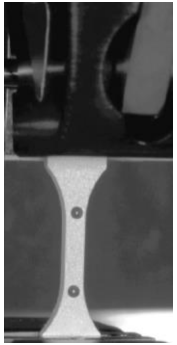
Test Setup



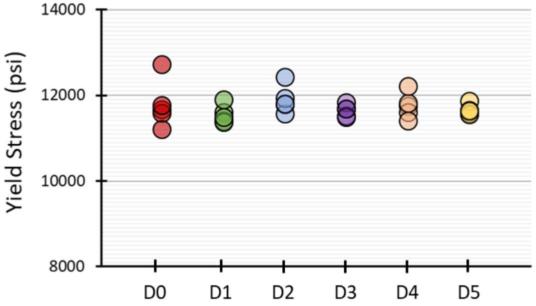
ULTEM 9075

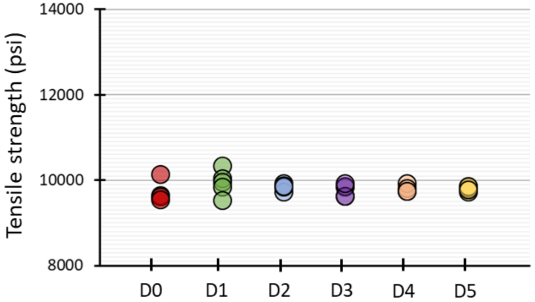


ULTEM 9085

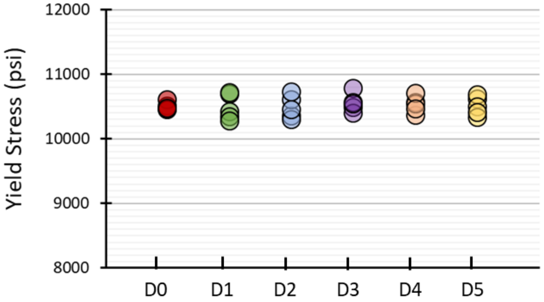


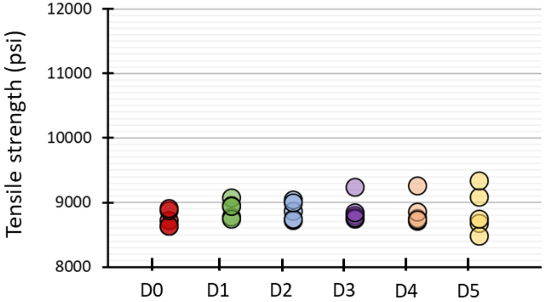
ULTEM 9075





ULTEM 9085





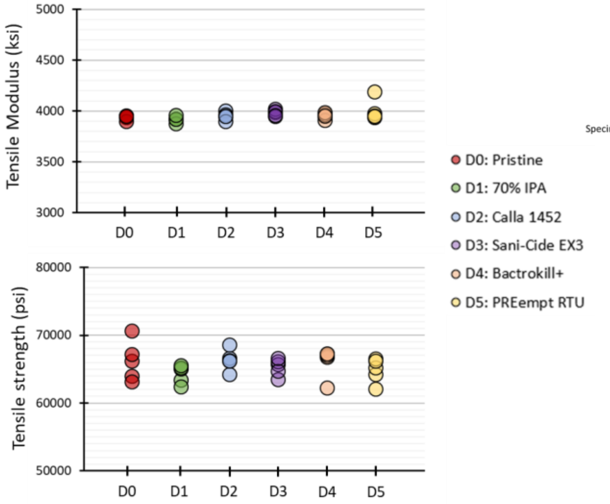
Mechanical Properties: Statistical Evaluation Summary

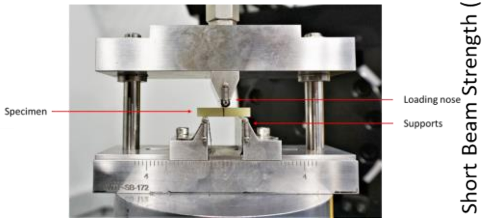
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Yield Stress					
Tensile Strength					

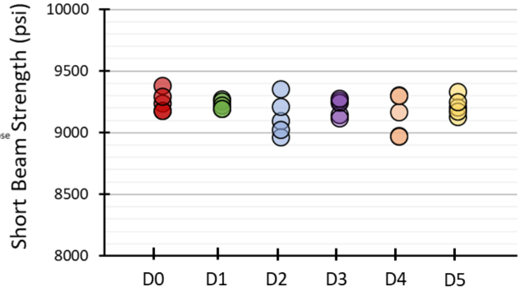
Equivalent to unconditioned specimens based on reduced testing

Phase-II

Fiberglass Laminate Results Summary







Mechanical Properties: Statistical Evaluation Summary

Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Tensile Modulus					
Tensile Strength					
SBS Strength					

Equivalent to unconditioned specimens

Phase-II

Flammability Results

- Vertical Bunsen burn tests were conducted per Title 14, Code of Federal Regulations (14 CFR) 25.853 Appendix F.
- For all selected material types, 60-second test were conducted.

Flammability Results for Cabin Materials: Summary						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Honeycomb Sandwich	Nomex Core + fiberglass/phenolic					
Decorative Laminate	Aerform LHR					
	Aerfilm LHR					
	Aerfusion fit					
Floor Carpet	Polyamide					
	Wool					
ULTEM	ULTEM 9075					
	ULTEM 9085					
Fiberglass	G-10/FR4					

(green) Increase in avg. burn length less than 50% in comparison to unconditioned specimens

Phase-II

Materials and UV-C Disinfection

WICHITA STATE UNIVERSITY

Aircraft Cabin & Seating Interiors

Plastics –

- Kydex 6565
- Boltaron 9815E
- Lexan XHR
- Boltaron 9815N
- Ultem 9075
- Ultem 9085

Honeycomb –

- Nomex core with fiberglass/phenolic resin

Composite –

- Fiberglass (G-10/FR4)

Accelerated UV-C Disinfection

Wavelength Configurations

- 222 nm
- 253.4 nm &
- 280 nm

UV-C Conditioning Setup

222 nm

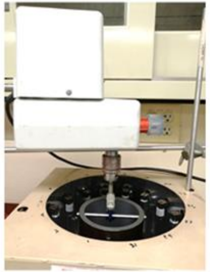
Ushio Care222 Modules

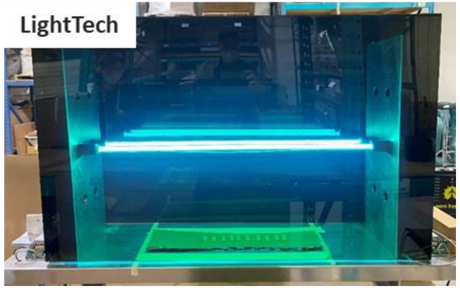
280 nm

Aquisense 24G

253.4 nm

Rayonet Reactor





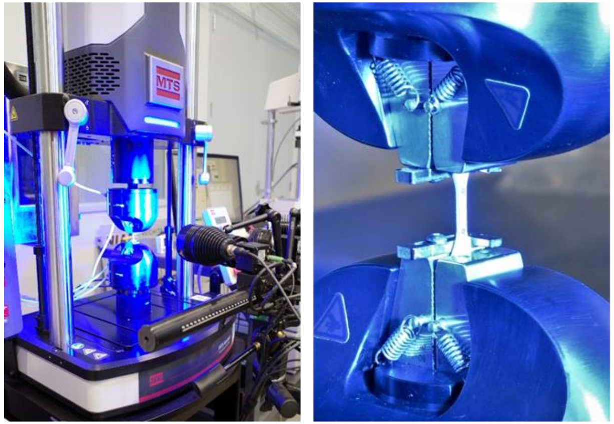
LightTech

UV-C Accelerated Aging Test Parameters					
Wavelength Configuration	Baseline Dose (mJ/cm²)	Average Intensity (mW/cm²)	Cumulative Time (Years)	Cumulative Dosage (mJ/cm²)	Exposure Duration (minutes)
222 nm	3	0.78	One	1095	23.5
			Four	4380	94
			Eight	8760	188
253.4 nm	40	13.2	One	14600	18.4
			Four	58400	73.6
			Eight	116800	147.2
		5.28	One	14600	46
			Four	58400	184
			Eight	116800	368
280 nm	37.5	10.14	One	13687.5	22.5
			Four	54750	90
			Eight	109500	180

Phase-III

Mechanical Tests

Tensile Test Setup

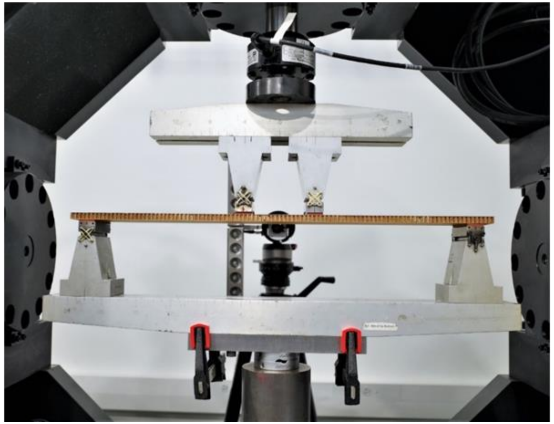


Test Method: Uniaxial tensile experiments

Test Standard: ASTM D638

Test specimens: 6 types of plastic materials (x120 specimens)

Flexure Test Setup

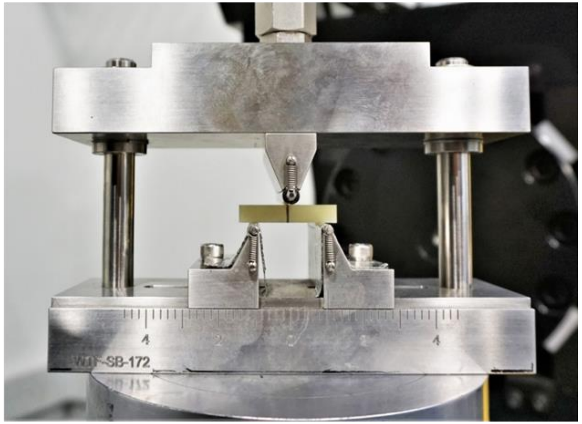


Test Method: Long-beam flexure experiments

Test Standard: ASTM D7249

Test specimens: 1 honeycomb type (x27 specimens)

Short Beam Shear Test Setup



Test Method: Short beam shear

Test Standard: ASTM D2344

Test specimens: 1 fiberglass type (x27 specimens)

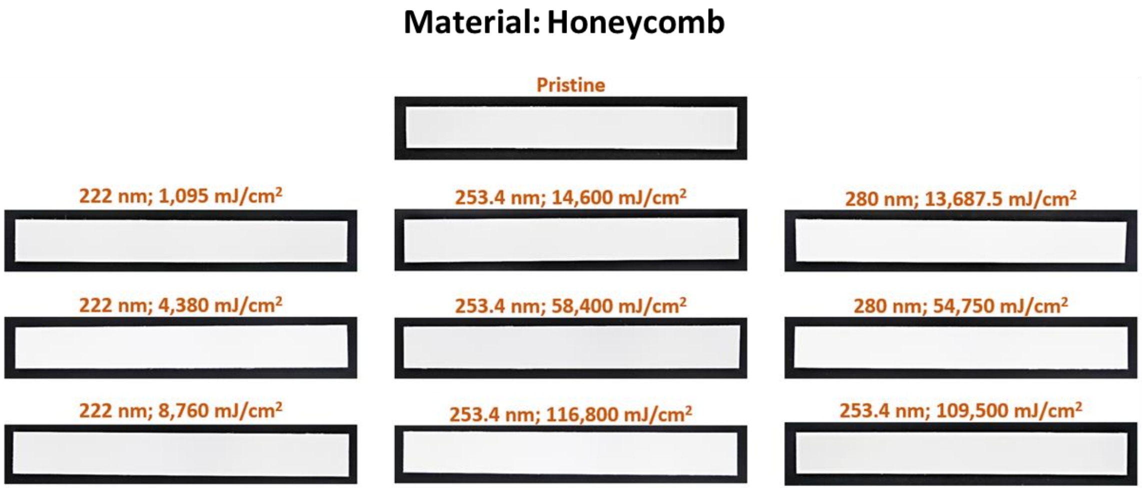
Phase-III

Color Change – Plastics

UV-C Dosage	Kydex 6565	Boltaron 9815E	Lexan XHR	Boltaron 9815N	Ultem™ 9075	Ultem™ 9085
Pristine						
222 nm 4,380 mJ/cm²						
8,760 mJ/cm²						
253.4 nm 14,600 mJ/cm²					N/A	N/A
58,400 mJ/cm²						
116,800 mJ/cm²						
280 nm 14,600 mJ/cm²						
58,400 mJ/cm²						

Phase-III

Color Change – Honeycomb & Fiberglass



Plastic: Yield Stress Summary

Percentage Difference Compared to Pristine Specimens – Yield Stress (Avg.)							
Wavelength Configuration	**Dosage (mJ/cm^2)**	**Kydex 6565**	**Boltaron 9815E**	**Lexan XHR**	**Boltaron 9815N**	**Ultem 9075**	**Ultem 9085**
Avg. Pristine (psi)	**N/A**	7548.1	5521.3	10328.4	6636.3	11776.0	10496.1
222 nm	**4,380**	-4.12	2.16	-4.24	-8.39	4.59	3.69
	8,760	-10.39	1.88	1.25	-9.61	3.87	3.62
253.4 nm	**14,600**	-2.61	2.45	2.10	-3.97	N/A	N/A
	58,400	-5.53	4.06	0.80	3.46	4.65	3.29
	116,800	-5.04	5.54	1.52	-2.15	4.27	6.01
280 nm	**54,750**	-3.90	2.63	1.72	-1.71	4.12	4.39
	109,500	-4.51	3.26	-1.09	-1.90	4.05	4.37

Percentage Difference Compared to Pristine Specimens

- < 5%
- between 5-10%
- > 10%

Phase-III

Plastic: Tensile Strength Summary

Percentage Difference Compared to Pristine Specimens – Tensile Strength (Avg.)							
Wavelength Configuration	Dosage (mJ/cm^2)	Kydex 6565	Boltaron 9815E	Lexan XHR	Boltaron 9815N	Ultem 9075	Ultem 9085
Avg. Pristine (psi)	N/A	6680.5	5180.4	10147.8	5263.5	9722.5	8748.4
222 nm	4,380	-16.49	-9.25	-10.47	-9.66	9.27	4.59
	8,760	-16.55	-6.24	0.04	-12.33	12.22	9.79
253.4 nm	14,600	-4.36	-3.14	-3.72	-2.49	N/A	N/A
	58,400	-13.28	-6.79	0.70	-2.07	-1.65	5.42
	116,800	-19.20	-6.67	-2.18	-7.16	11.11	8.74
280 nm	54,750	-9.12	0.26	-5.21	-6.42	7.78	4.26
	109,500	-9.40	-0.37	-7.09	-6.18	12.89	8.62

Percentage Difference Compared to Pristine Specimens

- < 5% (green)
- between 5-10% (yellow)
- > 10% (orange)

Honeycomb & Composite: Test Results

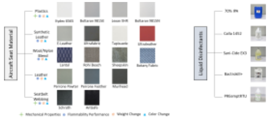
Percentage Difference Compared to Pristine Specimens			
Wavelength Configuration	Dosage (mJ/cm^2)	Honeycomb – Maximum Load	Fiberglass – Short Beam Strength
Avg. Pristine (psi)	N/A	152.4	9250.1
222 nm	1,095	-2.45	-0.91
	4,380	-2.75	-0.16
	8,760	-0.22	-0.75
253.4 nm	14,600	-9.66	-0.56
	58,400	-1.28	-0.80
	116,800	-0.24	-0.23
280 nm	13,687.5	5.52	-2.21
	54,750	-3.47	-0.91
	109,500	-0.74	-0.26

Percentage Difference Compared to Pristine Specimens

- < 5%
- between 5-10%
- > 10%

Phase-III

Project Highlights (Phase I to Phase III)



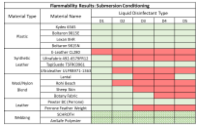
* Phase-I: Identify different materials used in aircraft seat

* Identify different liquid disinfectants being used

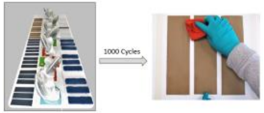
* Condition the specimens with conservative submersion method

* Number of days material conditioned dependent on material type

* Conduct experiments to obtain mechanical, flammability and physical properties of conditioned specimens and unconditioned specimens

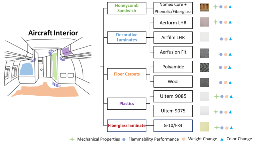


* Evaluate the change in flammability and mechanical properties based on defined criterion



* Condition specimens using wiping method, real world application

*Revaluate change in the flammability properties



*Phase-II: Continue the research effort for materials used in cabin

* Conduct experiments to obtain mechanical, flammability and physical properties of cabin materials

* Phase-III: Evaluate the effects of UV-C irradiation on aircraft interiors.

* Write technical reports and recommended practices for aerospace community

Joint Centers of Excellence for Advanced Materials

Conclusions: Phase I

Effect of Liquid Disinfectants on Aircraft Seat Material				
Material Type	Material Name	Property Type		
		Mechanical	Flammability	Color
Plastic	Kydex 6565			
	Boltaron 9815E			
	Lexan XHR			
	Boltaron 9815N			
Synthetic Leather	E-Leather CL820	N/A		
	Ultrafabric 492-6579FR12	N/A		
	TapiSuede TSFRC0961	N/A		
	Ultraleather ULFRB971-1363	N/A		
Wool/Nylon Blend	Lantal	N/A		
	Rohi Beach	N/A		
	Sheep Skin	N/A		
	Botany Fabric	N/A		
Leather	Pewter BC (Perrone)	N/A		
	Perrone Feather Weight	N/A		
Webbing	SCHROTH			

- Equivalency between conditioned and unconditioned specimen for all liquid disinfectants
- Equivalency not obtained between conditioned and unconditioned specimen for some liquid disinfectants
- Equivalency not obtained between conditioned and unconditioned specimen for all liquid disinfectants

Conclusions: Phase II

Effect of Liquid Disinfectants on Aircraft Cabin Material				
Material Type	Material Name	Property Type		
		Mechanical	Flammability	Color
Honeycomb Sandwich	Nomex Core/phenolic			
Decorative Laminate	Aerform LHR			
	Aerfilm LHR	N/A		
	Aerfusion fit	N/A		
Floor Carpet	Polyamide	N/A		
	Wool	N/A		
ULTEM	ULTEM 9075			
	ULTEM 9085			
Fiberglass	G-10/FR4			

Equivalency between conditioned and unconditioned specimen for all liquid disinfectants

Equivalency not obtained between conditioned and unconditioned specimen for some liquid disinfectants

Equivalency not obtained between conditioned and unconditioned specimen for all liquid disinfectants

Conclusions: Phase III

Effect of UV-C on Aircraft Seat and Cabin Interior Materials			
Material Type	Material Name	Property Type	
		Mechanical	Color
Plastic	Kydex 6565		
	Boltaron 9815E		
	Lexan XHR		
	Boltaron 9815N		
ULTEM	ULTEM 9075		
	ULTEM 9085		
Honeycomb Sandwich	Nomex Core/phenolic		
Fiberglass	G-10/FR4		

No significant changes between conditioned and unconditioned specimen for UV-C wavelength & exposure levels

Significant changes between conditioned and unconditioned specimen for some UV-C wavelength & exposure levels

Significant changes between conditioned and unconditioned specimen for all UV-C wavelength & exposure levels

Technical Reports

- **“Effects of Disinfectants on Aircraft Seating Materials” DOT/FAA/TC-21/18**
  - https://www.tc.faa.gov/its/worldpac/techrpt/tc21-18.pdf
- **“Effects of Disinfectants on Aircraft Cabin Interior Materials” DOT/FAA/TC-22/37**
  - https://www.tc.faa.gov/its/worldpac/techrpt/tc22-37.pdf
- **“Effects of Ultraviolet-C Germicidal Irradiation on Aircraft Cabin Interior Materials” DOT/FAA/TC-23/5**
  - https://www.tc.faa.gov/its/worldpac/techrpt/tc23-5.pdf

Future Work: Effects of UV-C on Kydex 6565

Proposed Materials To Test & Aging Test Conditions			
Material Description	**Material Source**	**Proposed Accelerated Aging Test Conditions**	**Expected Findings**
Kydex 6565*	Spare Material from Phase-III	IUVA test parameters & conditions	To identify if the discrepancy rises from the exposure duration or the Kydex material configuration
Kydex 6565*	IUVA (Boeing)	NIAR test parameters & conditions	To identify if the discrepancy rises from the exposure duration or the Kydex material configuration

*Different Kydex 6565 material grades were used by NIAR and IUVA teams.

Research Team (Phase IV)

- Effects of the use of cleaning and disinfectant chemicals/processes in the mechanical, optical, plastic, and flammability characteristics of aircraft flight deck materials.
- Project Participants
  - PI: Gerardo Olivares Ph.D.
  - Researchers NIAR-WSU: Rebeka Khajehpour, Alyssa Gonzalez, Beth Dalton
  - Students: Austin Mills, Joe Woodard, Michael Self, Hunter Griffith, Anica Tang, Max Chastain, Trey Young, Emily Dalton, Faizen Khan
- FAA Technical Monitor – Cindy Ashforth
- Other FAA Personnel – Jeff Gardlin, Ahmet Oztekin
- Industry Partnerships/Other Collaborators – Airbus, Boeing, Collins Aerospace, De Havilland, Embraer, Garmin, Honeywell, Aero HygenX, Element Labs
- Matching contribution is a mix of funding between Industry and NIAR-WSU

Project Status (Phase IV)

- Phase III (b): Effect of liquid disinfectants and UV-C on cockpit materials (Finished)
  - Anonymize data and compile a summary report of OEM provided test data (Finished)
  - Create test matrix for flight deck materials testing at NIAR ETL (Finished)
  - Make a test plan for flight deck materials testing at NIAR ETL (Finished)
- Phase IV: Cockpit Interiors Technical Approach (Finished)
  - Execution of conditioning and testing at NIAR ETL (Finished)
  - Analysis of test data from the conditioned specimens at NIAR ETL (Finished)
  - Write technical FAA report (Finished)

Materials Selected for Flight Deck

- **Materials and disinfectants were selected from EPA List N, FAA Operator Survey, and feedback from industry partners.**

Plastics:

- Lexan™ 9600
- Poly II acrylic

Coatings:

- C1: Antireflective/ antiglare/ oleophobic coating A
- C2: Oleophobic coating B
- C3: Oleophobic coating C
- C4: Oleophobic coating D
- C5: Antireflective/ antiglare/ conductive/ oleophobic coating A
- C6: Antireflective/ conductive coating

LRUs:

- A1: Air conditioning panel
- A2: Forward panel assy
- A3: Stall warning panel
- A4: Instrument switching

Chemical Disinfectants:

- 70% isopropyl alcohol
- Calla® 1452
- Sani-Side EX3
- PREempt™ RTU
- Bactrokill+
- Pheno D

UV-C:

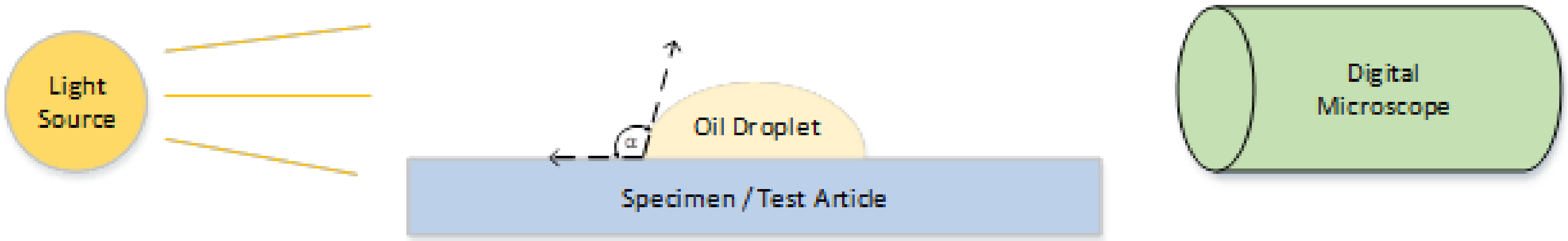
- 222 nm: 4 years (Round 1), and 1 or 8 years (Round 2)
- 254 nm: 4 years (Round 1), and 1 or 8 years (Round 2)
- 280 nm: 4 years (Round 1), and 1 or 8 years (Round 2)

Test Matrix

- In contact angle, a significant change is defined as either a change of 10° in angle compared to the control, or a change from oleophobic (60° ≤ α ≤ 90°) to oleophilic (90° ≤ α).
- For all other test parameters, a significant change is defined as a change of at least 15% as compared to the control specimen.

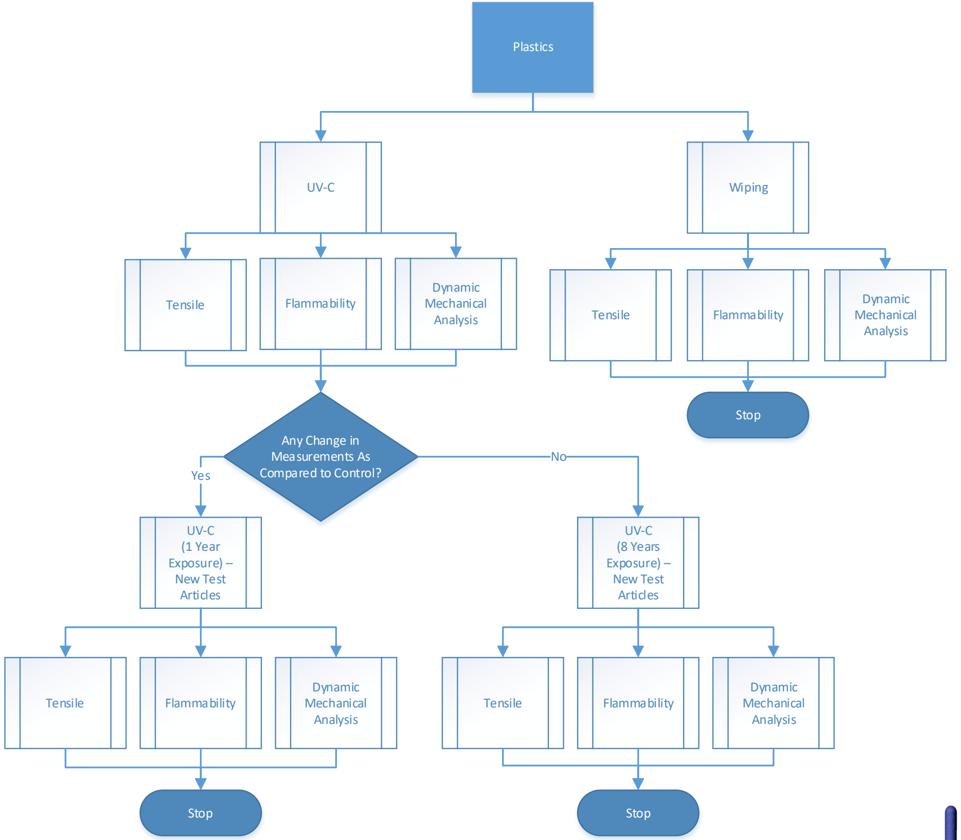
Material	Wipe					UV-C (4 years)			UV-C (1 or 8 years)			Electrostatic Spray	Fog
	70% Isopropyl alcohol	Calla® 1452	Sani-Cide EX3	PREempt™ RTU	Bactrokill+	222 nm	254 nm	280 nm	222 nm	254 nm	280 nm	Calla® 1452	Pheno D
Lexan™ 9600	Weight, Visual, DMA, Flammability, Tensile											N/A	
Poly II Acrylic	Weight, Visual, DMA, Flammability, Tensile												
Coating 1	Weight, Visual, Light Transmission & Haze, Contact Angle												
Coating 2	Weight, Visual, Light Transmission & Haze, Contact Angle												
Coating 3	Weight, Visual, Light Transmission & Haze, Contact Angle												
Coating 4	Weight, Visual, Light Transmission & Haze, Contact Angle												
Coating 5	Weight, Visual, Light Transmission & Haze, Contact Angle												
Coating 6	Weight, Visual, Light Transmission & Haze												
LRUs	Weight, Visual, Functional (mechanical and simulator)					N/A						Weight, Visual, Functional (mechanical and simulator)	

Contact Angle Measurement

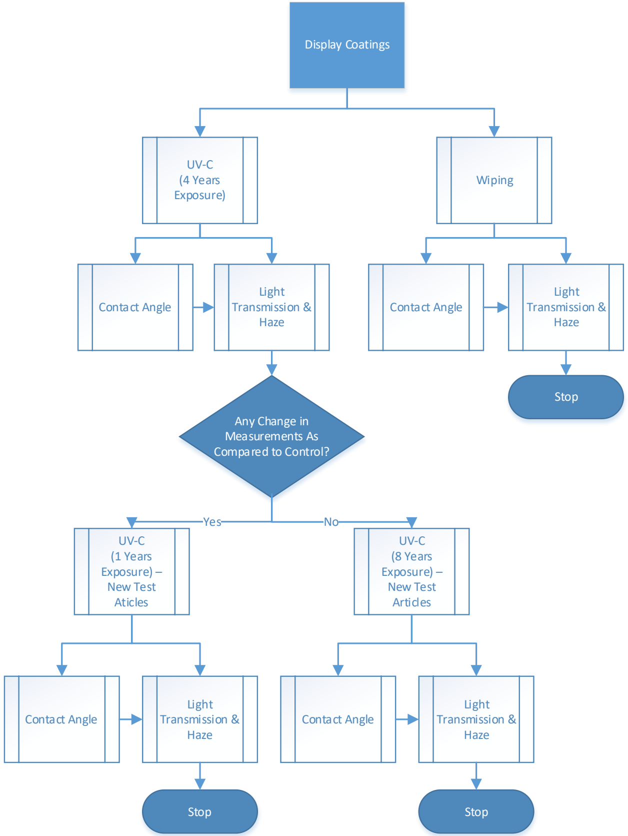


$$f(x) = \begin{cases} 60° < \alpha & \text{Super Oleophobic} \\ 60° \leq \alpha \leq 90° & \text{Oleophobic} \\ 90° \leq \alpha & \text{Oleophillic} \end{cases}$$

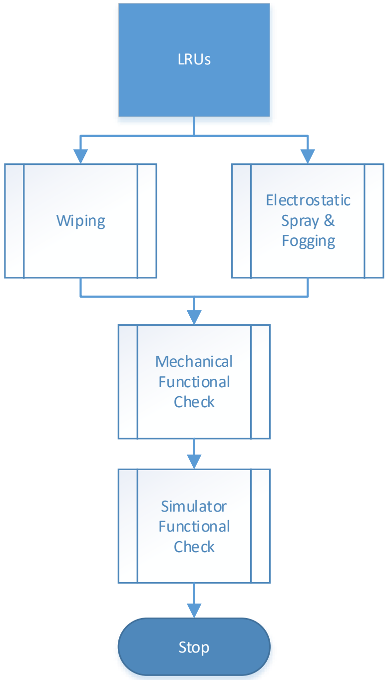
Test Procedure Flow Chart: Plastics



Test Procedure Flow Chart: Coatings



Test Procedure Flow Chart: LRUs



Results: LRUs

Test	Application Method & Disinfectant						
	Wiping x1000					Spray x120	Fog x120
	70% IPA	Calla® 1452	Sani-Cide EX3	PREempt™ RTU	Bactrokill+	Calla®1452	Pheno D
Weight	No Significant Change	No Significant Change	No Significant Change	No Significant Change	No Significant Change	No Significant Change	No Significant Change
Visual	No Significant Change	Visible Residue; Local Discoloration and Oxidation; Label Damage	Visible Residue; Local Discoloration	No Significant Change	Local Discoloration and Oxidation	Visible Residue; Local Discoloration and Oxidation	Visible Residue
Functional (Mechanical Switches)	No Significant Change	Increased Friction on Toggle Switch	Increased Friction on Toggle Switch	No Significant Change	No Significant Change	Increased Friction on DUs Knob	No Significant Change
Functional (Simulator)	Failed Sim Check	Passed Sim Check	Failed Sim Check	Failed Sim Check	Failed Sim Check	Passed Sim Check	Failed Sim Check

Significant Change Detected

No Significant Change Detected

Results: Wiping Coupons

Material Specifications	Wiping x1000				
	IPA (70%)	Calla® 1452	Sani-Cide EX3	PREempt™ RTU	Bactrokill+
Lexan™ 9600	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability
Poly II acrylic (MIL-P-5425)	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability	Tensile DMA Weight Visual Flammability
C1 (Antireflective/ Antiglare/ Oleophobic Coating A)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C5 (Antireflective/ Antiglare/ Conductive/ Oleophobic Coating A)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C2 (Oleophobic Coating B)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C3 (Oleophobic Coating C)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C4 (Oleophobic Coating D)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C6 (Antireflective/ Conductive Coating)	Weight Light Transmission & Haze Visual	Weight Light Transmission & Haze Visual	Weight Light Transmission & Haze Visual	Weight Light Transmission & Haze Visual	Weight Light Transmission & Haze Visual

Significant Change Detected

No Significant Change Detected

Results: UV-C Round 1

Material Specifications	UV-C Exposures		
	Round 1		
	222 nm, 4 year duration	254 nm, 4 year duration	280 nm, 4 year duration
Lexan™ 9600	Tensile	Tensile	Tensile
	DMA	DMA	DMA
	Visual	Visual	Visual
	Flammability	Flammability	Flammability
Poly II acrylic (MIL-P-5425)	Tensile	Tensile	Tensile
	DMA	DMA	DMA
	Visual	Visual	Visual
	flammability	Flammability	Flammability
C1 (Antireflective/ Antiglare/ Oleophobic Coating A)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual
	Contact Angle	Contact Angle	Contact Angle
C5 (Antireflective/ Antiglare/ Conductive/ Oleophobic Coating A)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual
	Contact Angle	Contact Angle	Contact Angle
C2 (Oleophobic Coating B)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual
	Contact Angle	Contact Angle	Contact Angle
C3 (Oleophobic Coating C)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual
	Contact Angle	Contact Angle	Contact Angle
C4 (Oleophobic Coating D)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual
	Contact Angle	Contact Angle	Contact Angle
C6 (Antireflective/ Conductive Coating)	Weight	Weight	Weight
	Light Transmission & Haze	Light Transmission & Haze	Light Transmission & Haze
	Visual	Visual	Visual

Significant Change Detected

No Significant Change Detected

Results: UV-C Round 2

Material Specifications	UV-C Exposures					
	Round 2					
	222 nm, 1 year duration	254 nm, 1 year duration	280 nm, 1 year duration	222 nm, 8 year duration	254 nm, 8 year duration	280 nm, 8 year duration
Lexan™ 9600		Tensile DMA Visual Flammability	**Flammability**	Tensile DMA Visual **Flammability**		Tensile DMA Visual
Poly II acrylic (MIL-P-5425)		**Tensile** DMA Visual Flammability	**Tensile** DMA Visual	**Tensile** DMA Visual Flammability		Flammability
C1 (Antireflective/ Antiglare/ Oleophobic Coating A)				Weight Light Transmission & Haze **Visual** Contact Angle	Weight Light Transmission & Haze **Visual** **Contact Angle**	Weight Light Transmission & Haze Visual Contact Angle
C5 (Antireflective/ Antiglare/ Conductive/ Oleophobic Coating A)				Weight Light Transmission & Haze **Visual** Contact Angle	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle
C2 (Oleophobic Coating B)	Weight **Light Transmission & Haze** Visual Contact Angle				Weight **Light Transmission & Haze** Visual Contact Angle	Weight **Light Transmission & Haze** Visual Contact Angle
C3 (Oleophobic Coating C)	Weight Light Transmission & Haze Visual Contact Angle	Weight Light Transmission & Haze Visual Contact Angle				Weight Light Transmission & Haze Visual Contact Angle
C4 (Oleophobic Coating D)	Weight **Light Transmission & Haze** Visual Contact Angle	Weight **Light Transmission & Haze** Visual Contact Angle	Weight **Light Transmission & Haze** Visual Contact Angle			
C6 (Antireflective/ Conductive Coating)	Weight **Light Transmission & Haze** Visual	Weight **Light Transmission & Haze** Visual				Weight **Light Transmission & Haze** Visual

Significant Change Detected

No Significant Change Detected

Conclusions

Overall

- No change was observed in the weight or the glass transition temperature (T_g) of any conditioned material.
- While nearly all specimens failed flammability per FAR 25.853 Appendix F, these materials (as they are found in the flight deck) fall under a small part exemption and are not required to pass this standard.

UV-C Conditioning

- Lexan™ 9600 had no change in tensile strength as a result of UV-C exposure for any wavelength or exposure duration. Poly II Acrylic had significant changes in tensile strength for all investigated UV-C wavelengths and exposure durations.
- UV-C disinfection of any wavelength or exposure duration did not significantly change the oleophobicity for any coating EXCEPT C1 when exposed to 254 nm for 8 years.
- Most coating configurations had a change in light transmittance and haze when exposed to any UV-C conditioning, EXCEPT C1 & C5 which had no significant change when conditioned at any UV-C wavelength for any exposure duration.
- Most of the UV-C disinfection configurations had no visual changes. Configurations that had visual changes were:
  - Both plastic materials when exposed to 254 nm for a 4 year duration,
  - C1 when exposed to either 222 nm or 254 nm for an 8 year duration, and
  - C5 when exposed to 222 nm for an 8 year duration.

Conclusions

Chemical Disinfectant Conditioning

- For mechanical switch functional checks on LRUs, Calla® 1452 (spray and wipe) and Sani-Cide EX3 (wipe) increased the friction in the switches. None of the other chemical disinfectants caused a change to mechanical functionality of switches.

- For tensile strength of plastics:
  - Calla® 1452 had no effect on the tensile strength of either Lexan™ 9600 or Poly II Acrylic,
  - Bactrokill+ and PREempt™ RTU did not significantly change the tensile strength of Lexan™ 9600, but did for Poly II Acrylic, and
  - 70% IPA and Sani-Cide EX3 caused significant changes in tensile strength for both plastic types.

- There were significant changes to most oleophobic coating configurations. Configurations with NO significant change in olephobicity were:
  - C3 conditioned with any chemical disinfectant,
  - C1 and C2 conditioned with Calla® 1452, C2 and C5 conditioned with PREempt™ RTU, and
  - C2 conditioned with Bactrokill+.

- All coating configurations had a change in light transmittance and haze EXCEPT:
  - C1 conditioned with 70% IPA,
  - C1 conditioned with Bactrokill+, and
  - C5 conditioned with Bactrokill+.

- Wiping with Sani-Cide EX3 and PREempt™ RTU resulted in visual/tactile changes in all plastic and coating materials, while none of the other chemical disinfectants had an effect.

Questions?

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