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Corrosion Resistant Coatings for Application on Spent Nuclear Fuel Canisters

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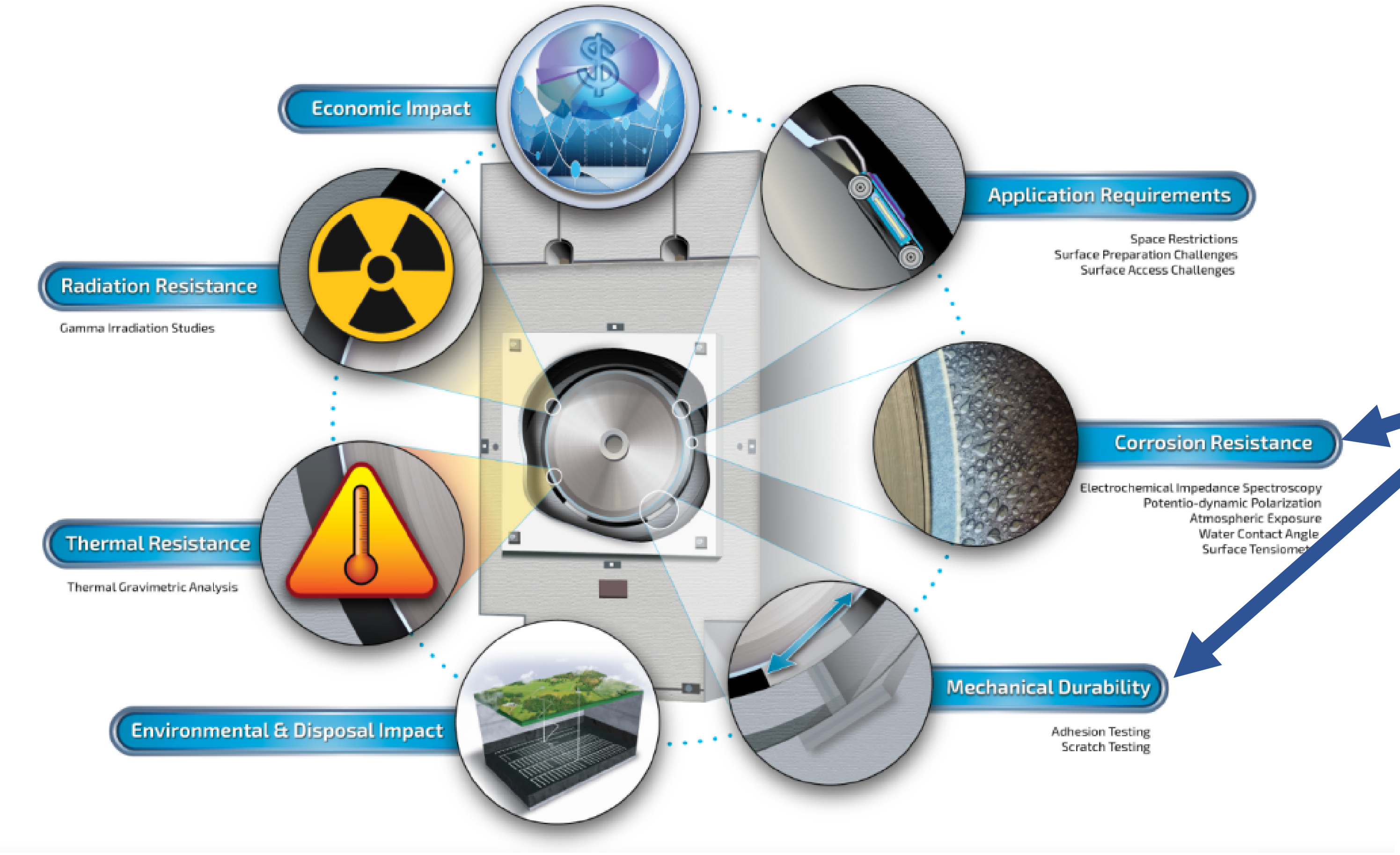
Evaluating Coating Performance



Quickest, most economical way to show differences between coatings, investigate viability

Nomenclature

- VENDOR-YY-VV-CC
  - Example: LUNA-21-01-01 is coupon #1 from first LUNA variant in 2021.

Coatings & Variants

Polymeric (5)

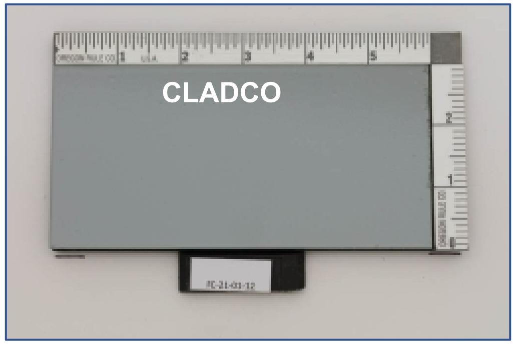
2 variants of Polyetherketoneketone. High temperature thermoplastic with high radiation resistance

3 variants of modified polyimide, polyurea, phenolic resins. Durable, chemically inert and can be loaded with desired additives to increase corrosion and radiation resistance

Ceramic/Organic

With Zn-Rich

2 variants of GENTOO with and without Zn-rich primer to provide a durable ceramic hybrid inorganic/polymer coating with/without galvanic protection



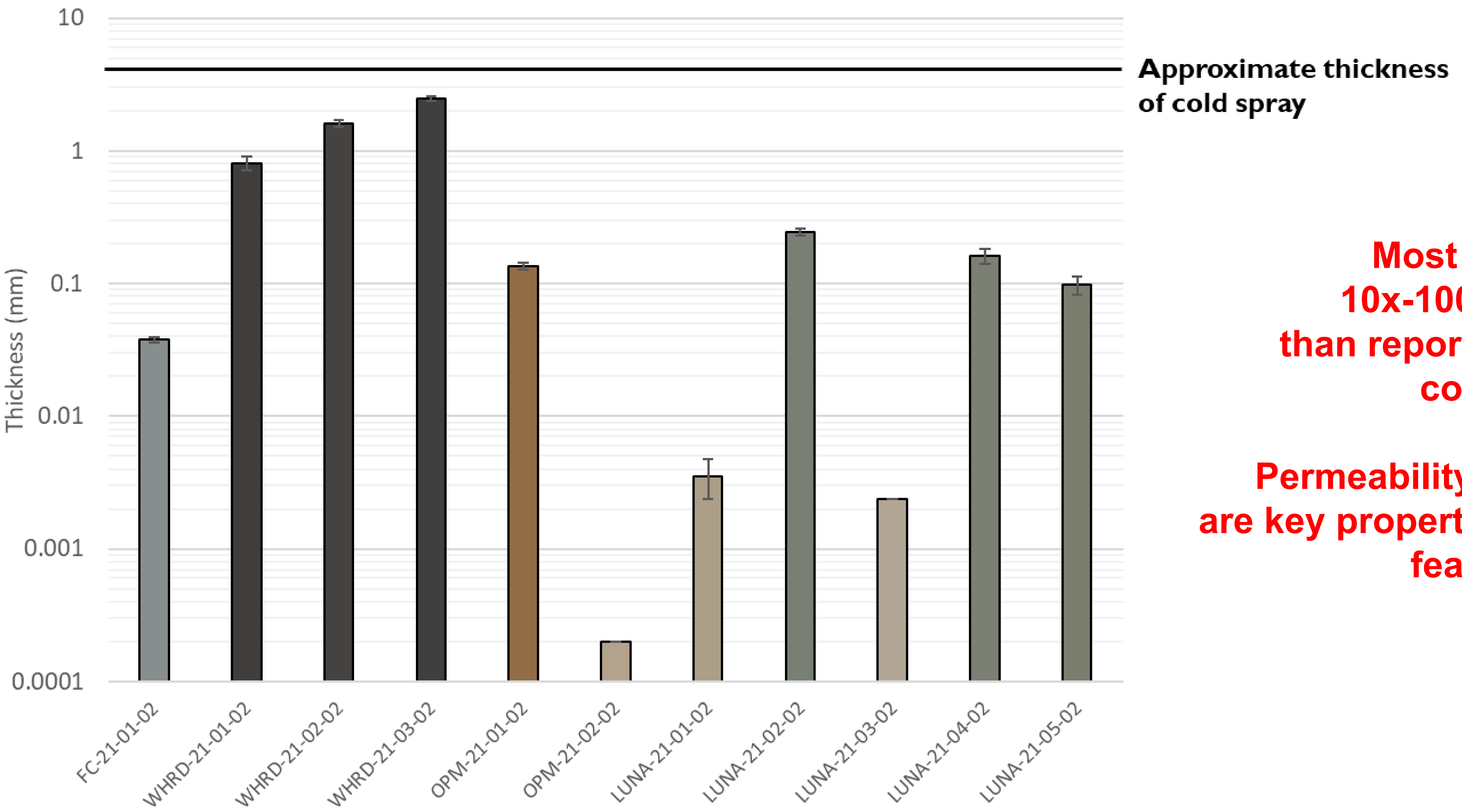
Single component hybrid inorganic/modified polyurethane coating resulting in a quasi-ceramic structure.

COMING FY23

Imidizole Coating

Thiol Coating

Thickness



Most coatings 10x-1000x thinner than reported cold spray coatings

Permeability and durability are key properties to demonstrate feasibility

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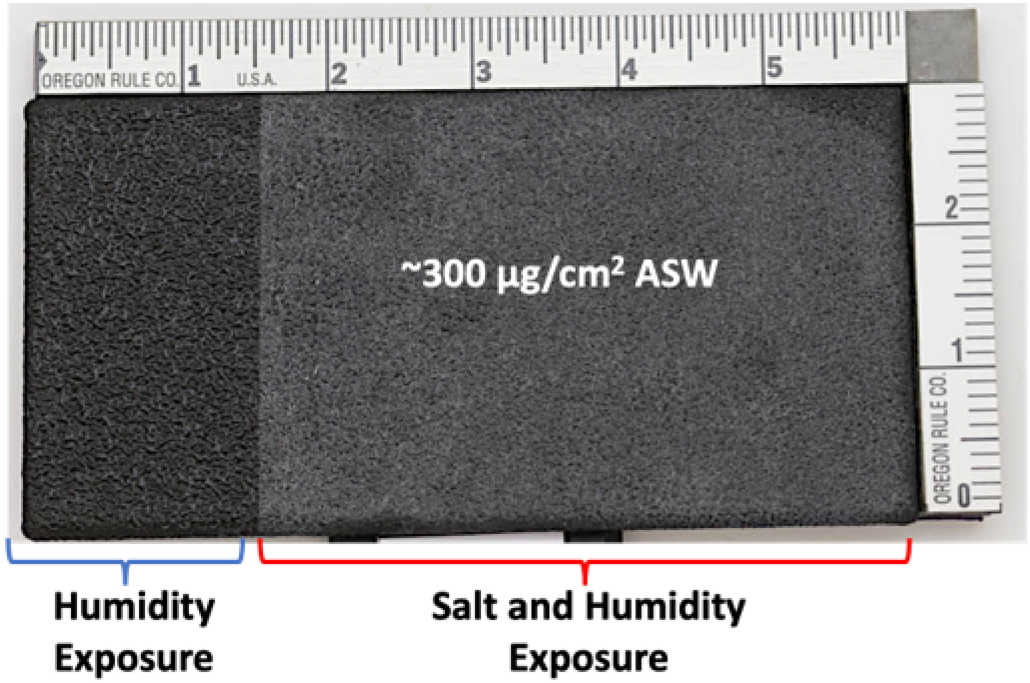
Test Progression

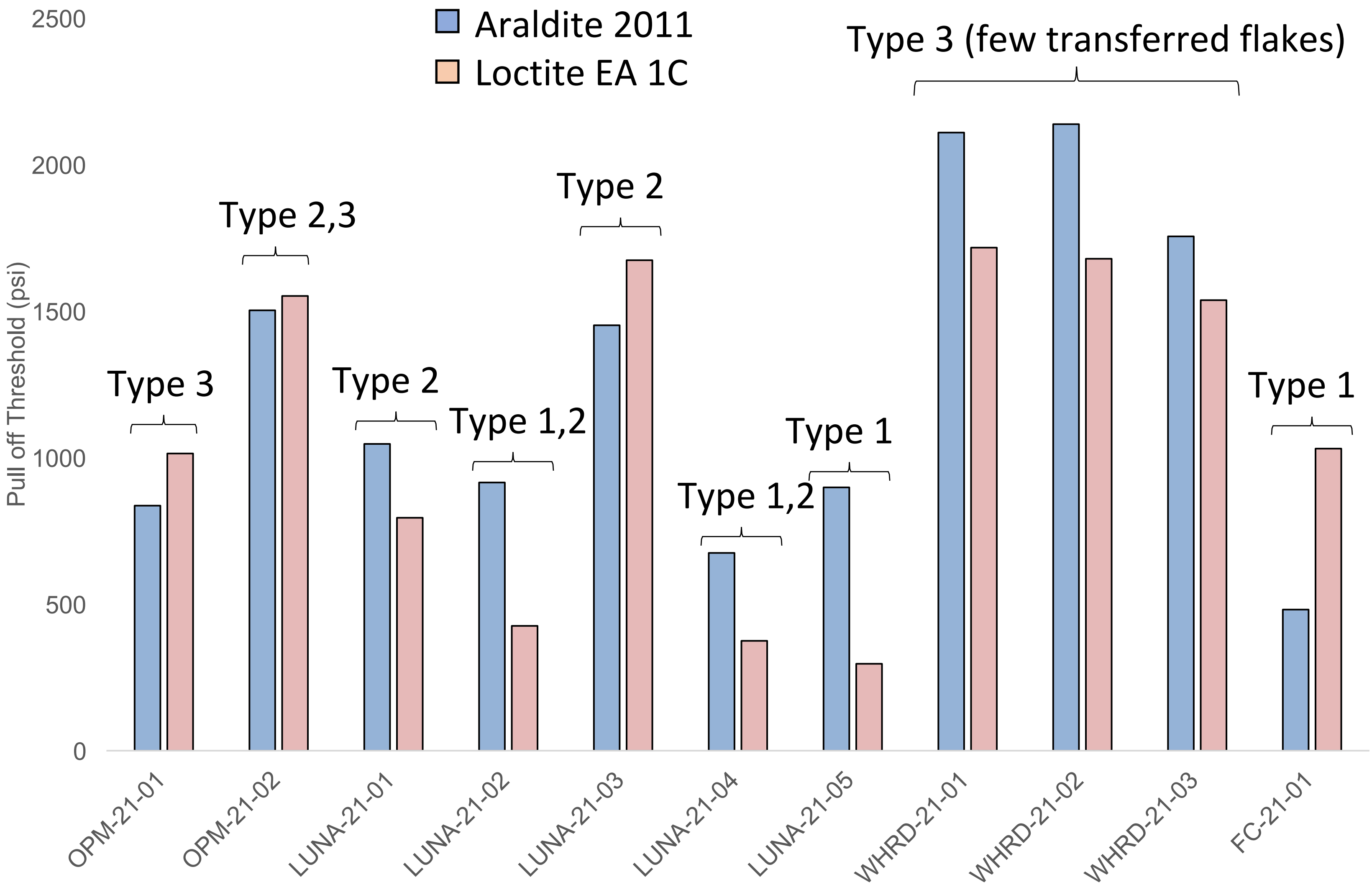
- Baseline Testing
- 30 – Day Environmental Exposure
  - ASW deposited on ¾ of coupon area aged at 76% RH at 40°C.
- 90 – Day Environmental Exposure
  - ASW deposited on ¾ of coupon area aged at 76% RH at 40°C.



Goal: Simulate canister relevant environmental conditions to evaluate effects on coatings and measure changes in performance

Baseline Pull-Off Adhesion

Type 1: Adhesive Failure
Type 2: Cohesive Failure
Type 3: Epoxy Failure



Pre-treatment & epoxy resulting in highest values selected for 30/90 day comparisons

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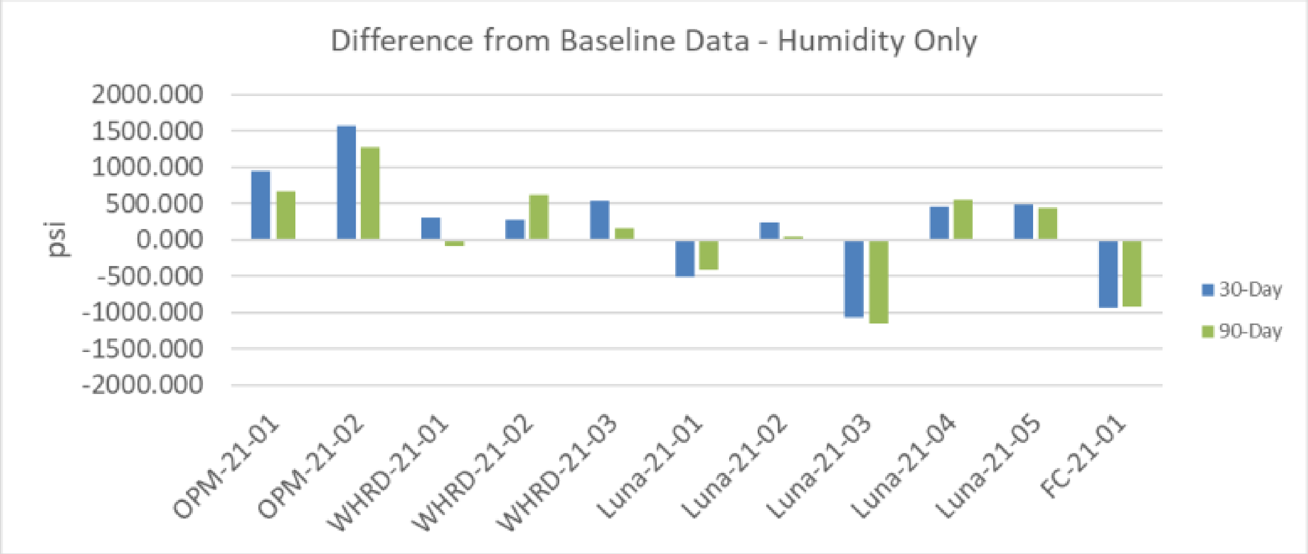
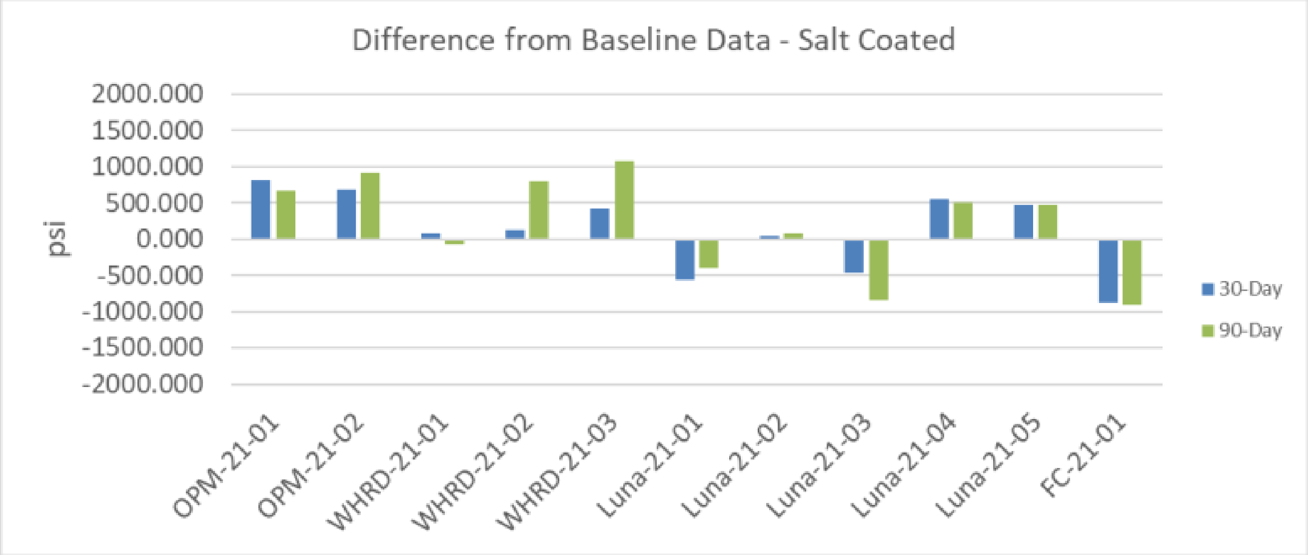
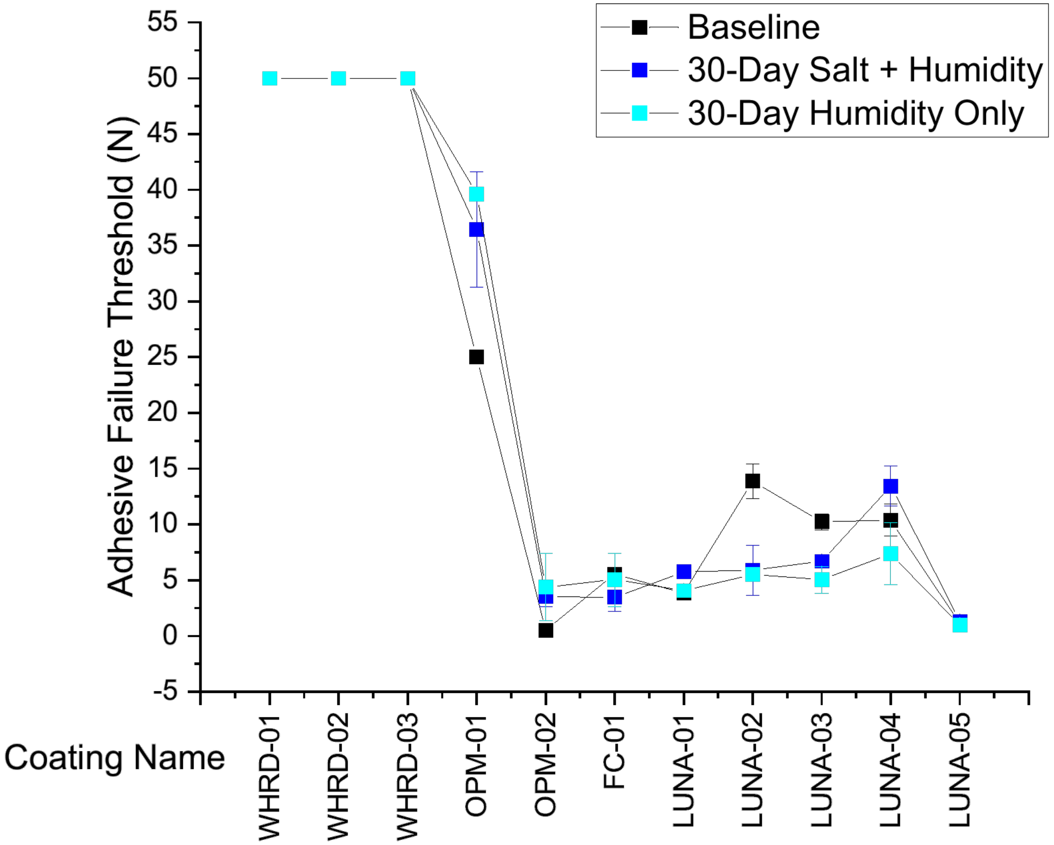
Impact of Environmental Aging

Pull-Off Testing

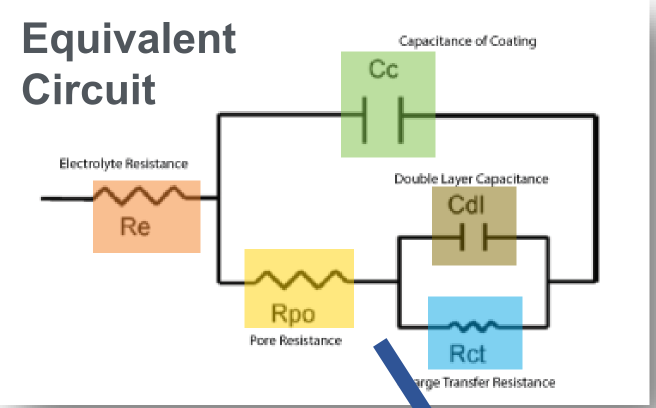




Scratch

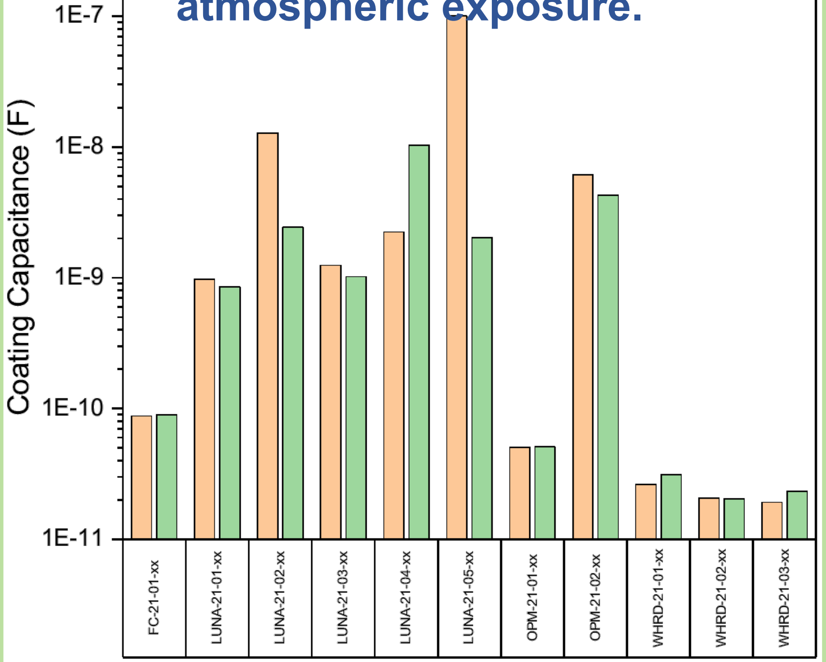


Electrochemical Testing

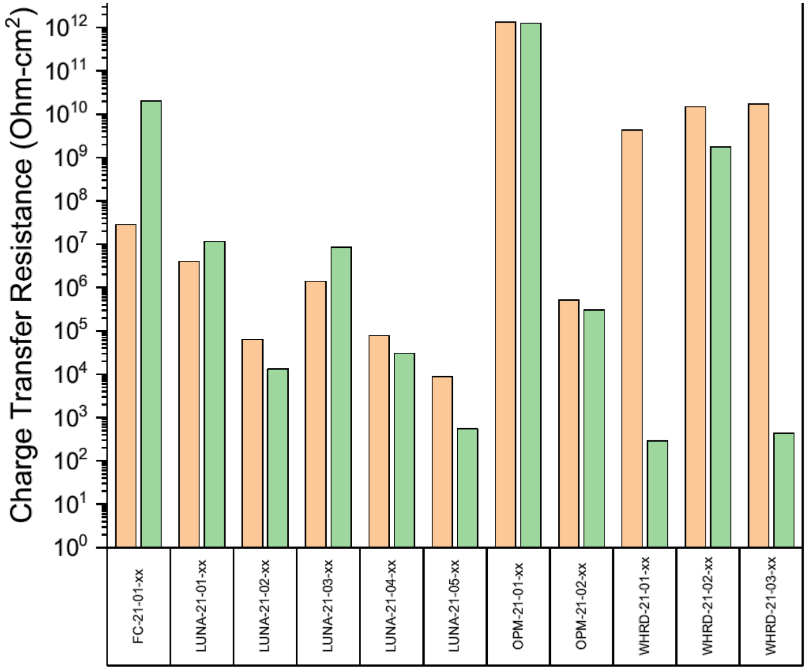


0 Day 30 Day

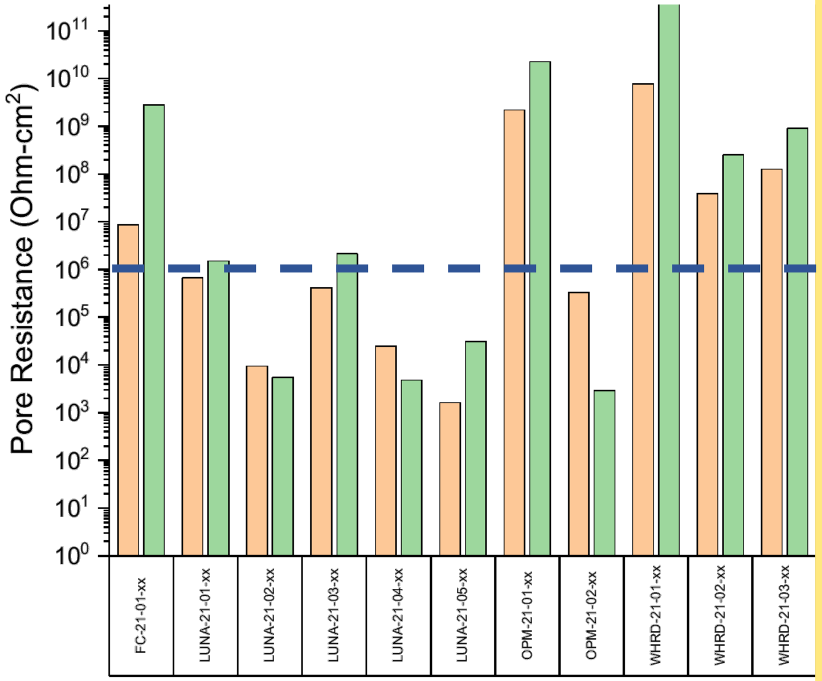
Evaluate changes in water permeability before and after atmospheric exposure.



Evaluate corrosion resistance of coating system



Evaluate resistance to ion transport



Materials vary in corrosion resistance
90-day data is nearly complete

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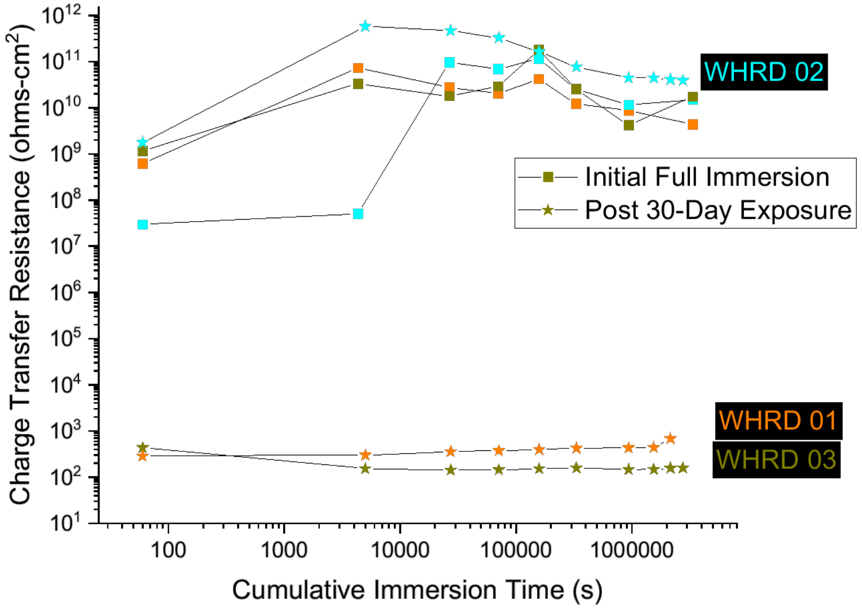
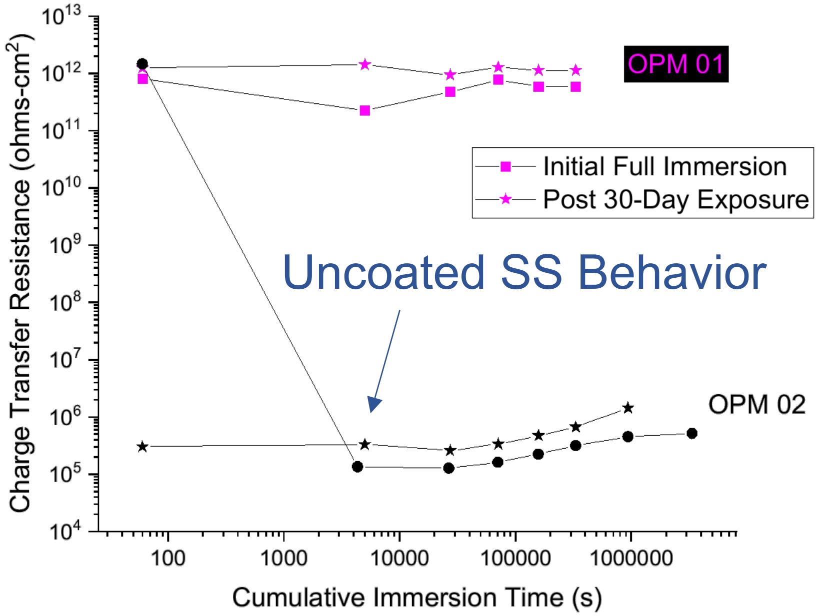
Electrochemical Testing

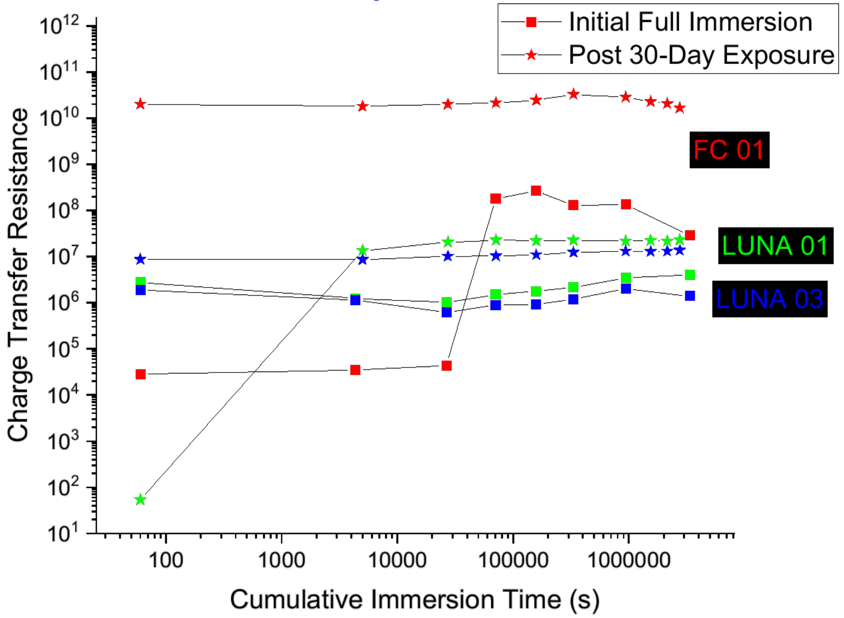
WHRD Comparison



OPM Comparison



Pseudo-Ceramics Comparison



Changes between initial and post-30 day exposure show some materials resist permeation of ions better than others.

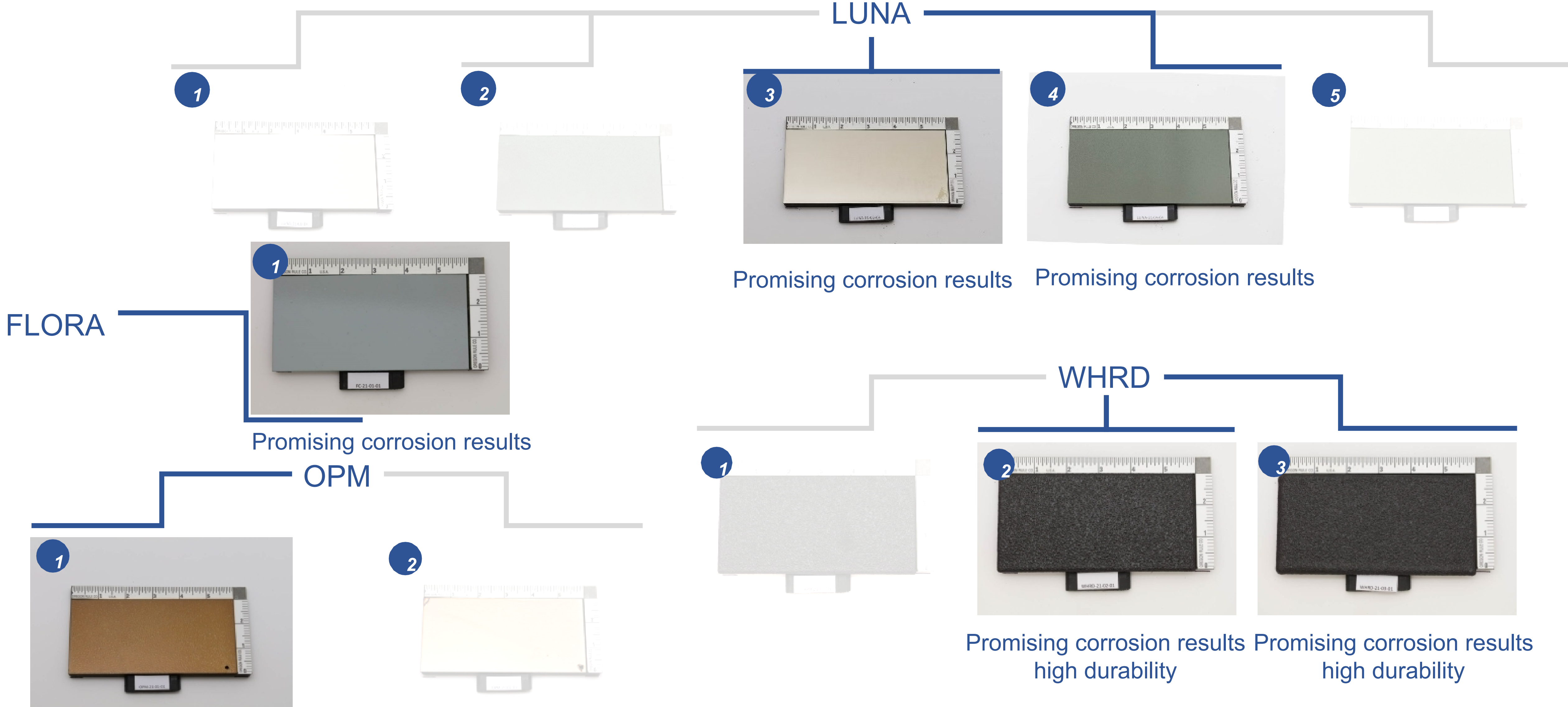
Coating Viability Assessment

Good Performance For This Application

Could Be Improved For This Application

Coating		Initial					Change as a result of exposure					Radiation Exposure	Thermal Exposure
		R_{CT}	R_{PO}	C_C	Adhesion	Scratch	R_{CT}	R_{PO}	C_C	Adhesion	Scratch		
Ceramic/Hybrid Coating	FC-21-01											FY23	FY23
	LUNA-21-01												
	LUNA-21-02*	–	–	–			–	–	–				
	LUNA-21-03												
	LUNA-21-04*	–	–	–			–	–	–				
	LUNA-21-05*	–	–	–			–	–	–				
Polymeric Coating	OPM-21-01												
	OPM-21-02												
	WHRD-21-01												
	WHRD-21-02												
	WHRD-21-03												

Performance Informed Variant Down Selection



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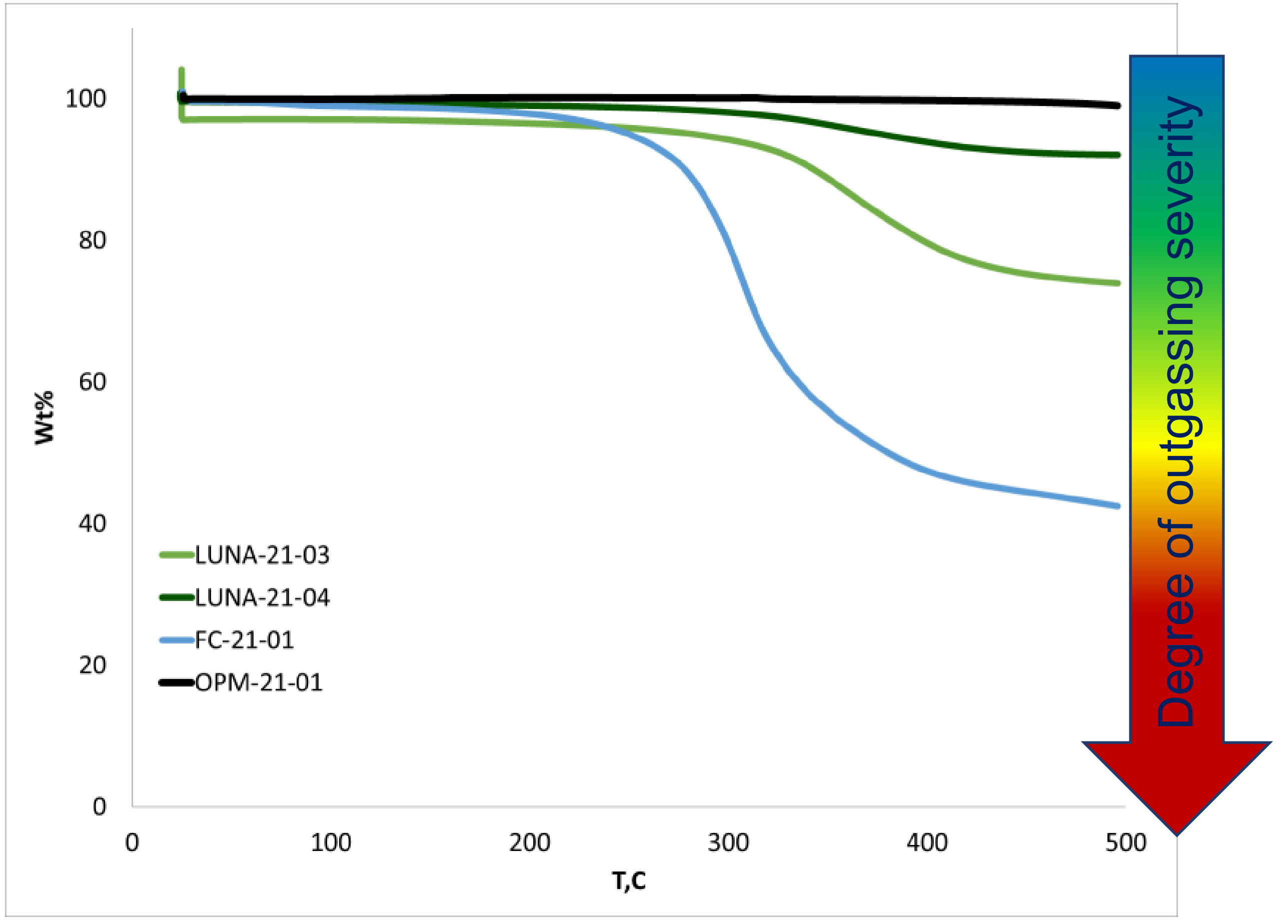
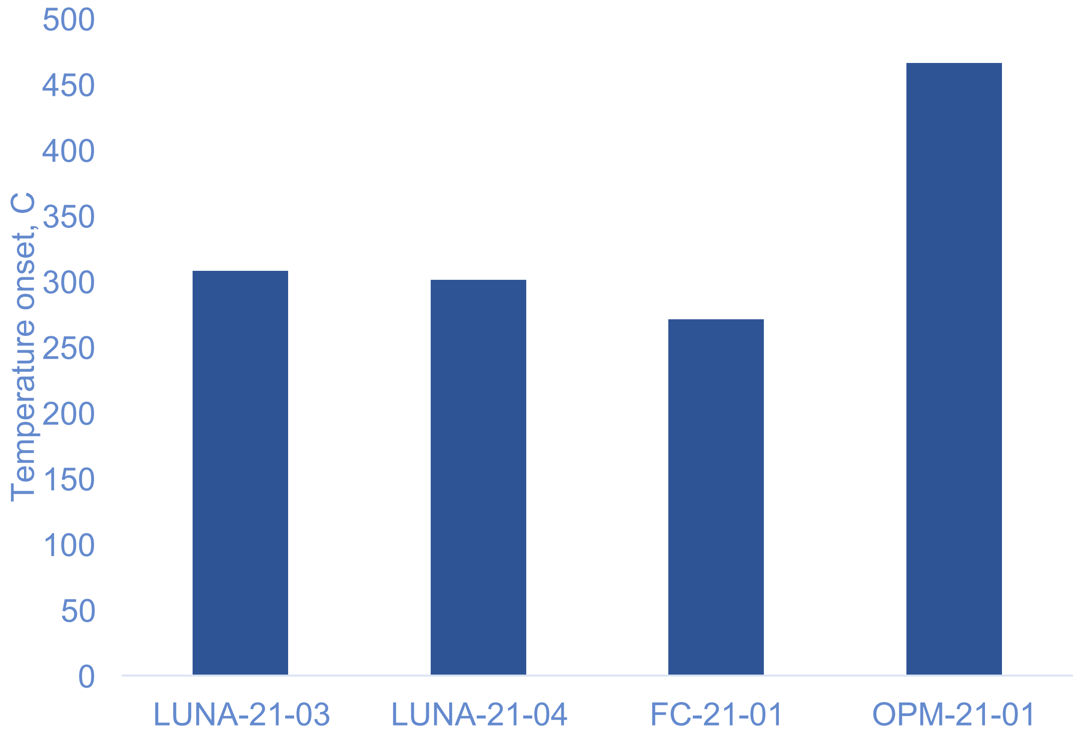
Thermogravimetric Analysis (TGA)



Onset temperatures will advise feasible service temperatures and will be used to design detailed outgassing study



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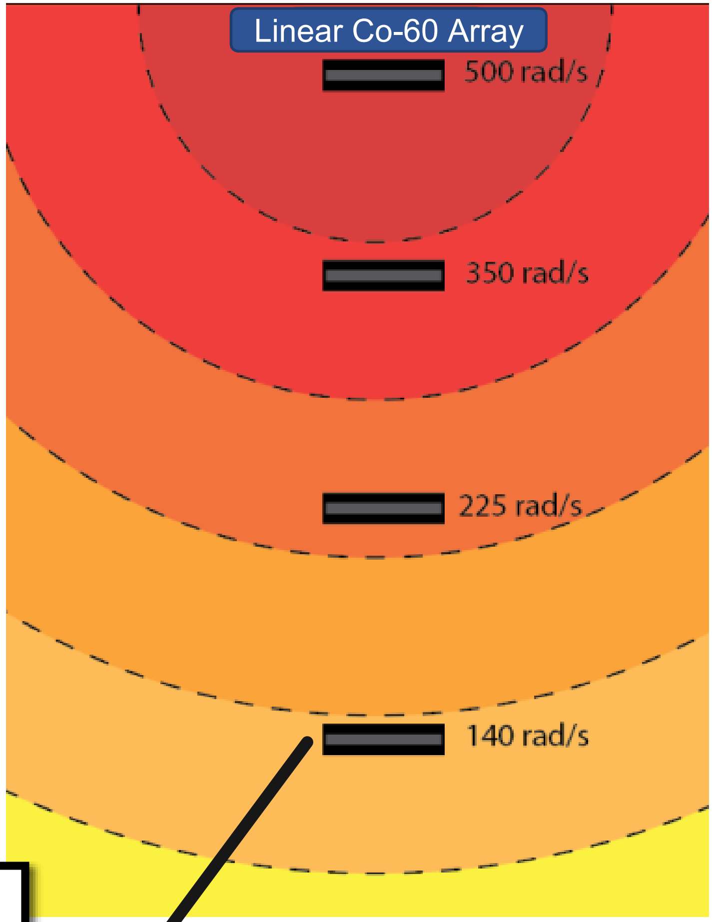
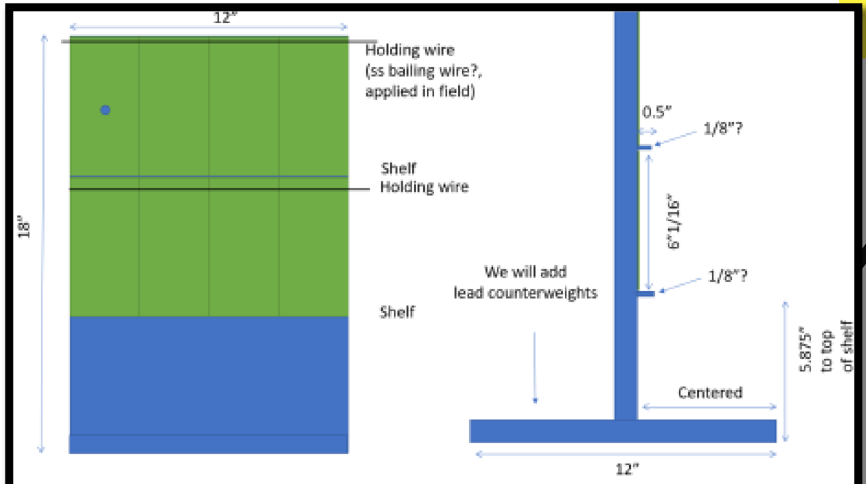
Radiolytic Exposures

- Planned Exposures[1]:

Scenario	Exposure (Mrad)
Ex-situ Prevention (0-300 years)	725
Repair (5-300 years)	495
Repair (first inspection, 20-300 years)	314
Repair (second inspection,40-300 years)	200

- Staggered stand-off distance allows variation of total exposure
  - Stopping half-way through total exposure to check for coating degradation:
    - Hardness
    - Pin-hole Tests
    - Visual Inspection





Floor Stand

[1](Whittman, 2013, Figure 3-10)

Conclusions

- Wide variety of available material types (transparent vs. translucent, thick vs thin, active vs inert, polymer vs ceramic)
- Environmental exposure caused some ± change in most samples
- These changes and overall magnitude of results assisted with first down selection
- 6 variants will proceed to Phase 2 testing (3 ceramics, 3 polymers)
  - Added 2x TDA coatings in Phase 2, but important baseline testing will be performed
- Radiolytic and thermal testing is expected to result in strongest differentiation between coatings and determine which can/cannot be used on DSCs.

Acknowledgments

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