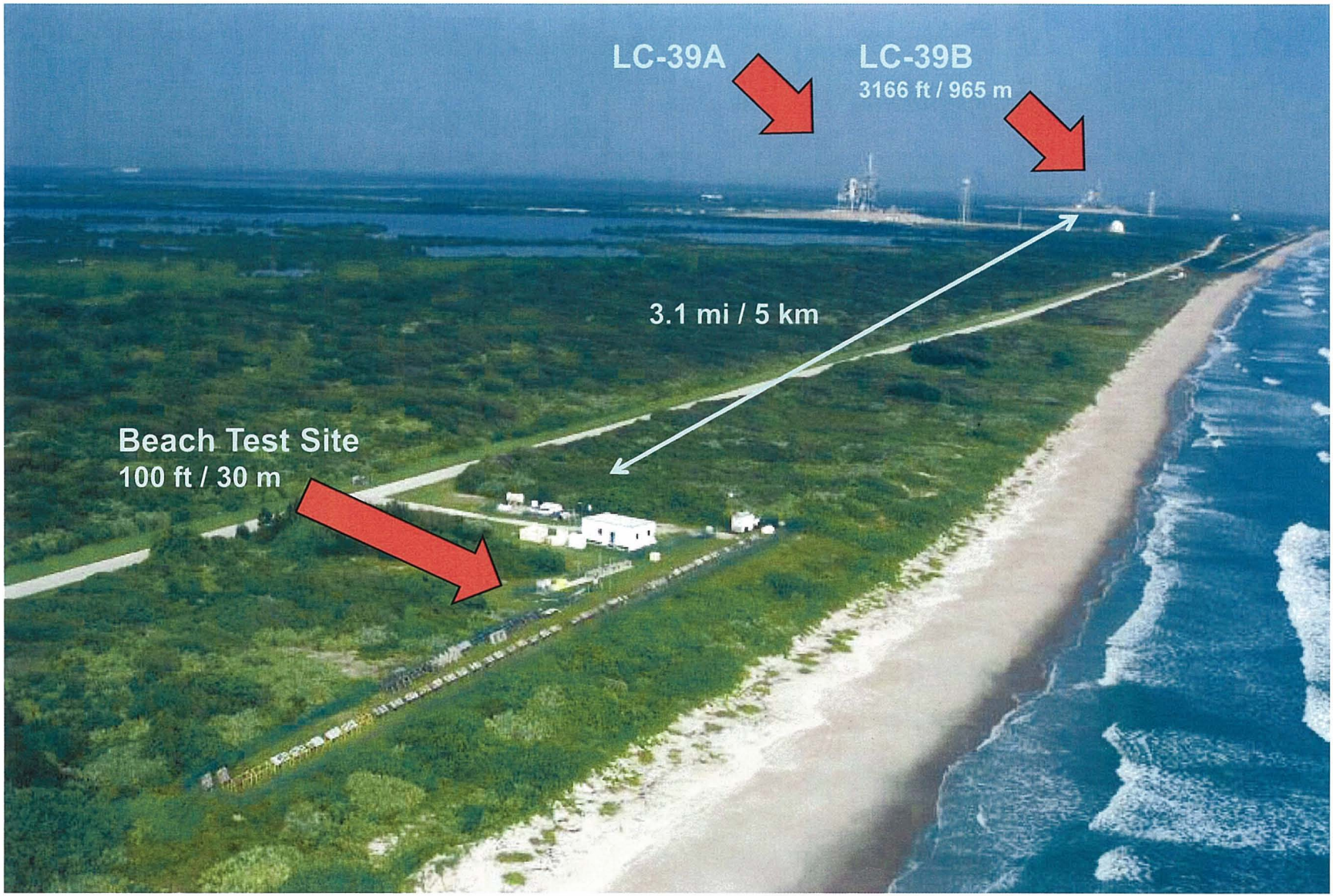
National Aeronautics and Space Administration (NASA)

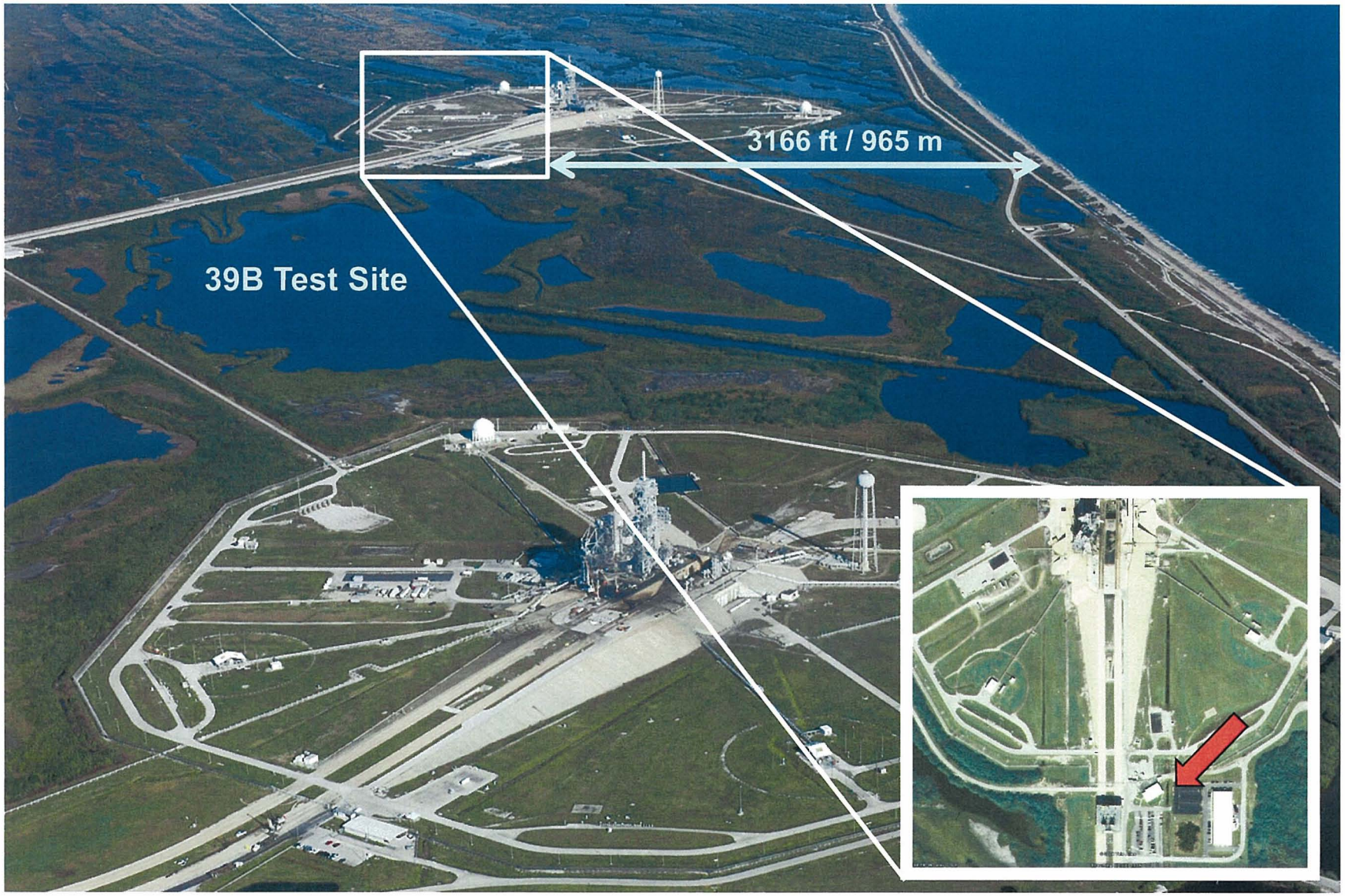
NASA TEERM Hexavalent Chrome Alternatives Projects

Business Operations Branch Management Integration Services Office
Engineering Directorate
Kennedy Space Center, FL

2009 International Workshop on Environment and Alternative Energy
November 10-12
Presenter: Matt Rothgeb
Senior Engineer, ITB Inc.


LC-39A
LC-39B
3166 ft / 965 m
3.1 mi / 5 km
Beach Test Site
100 ft / 30 m

National Aeronautics and Space Administration (NASA)



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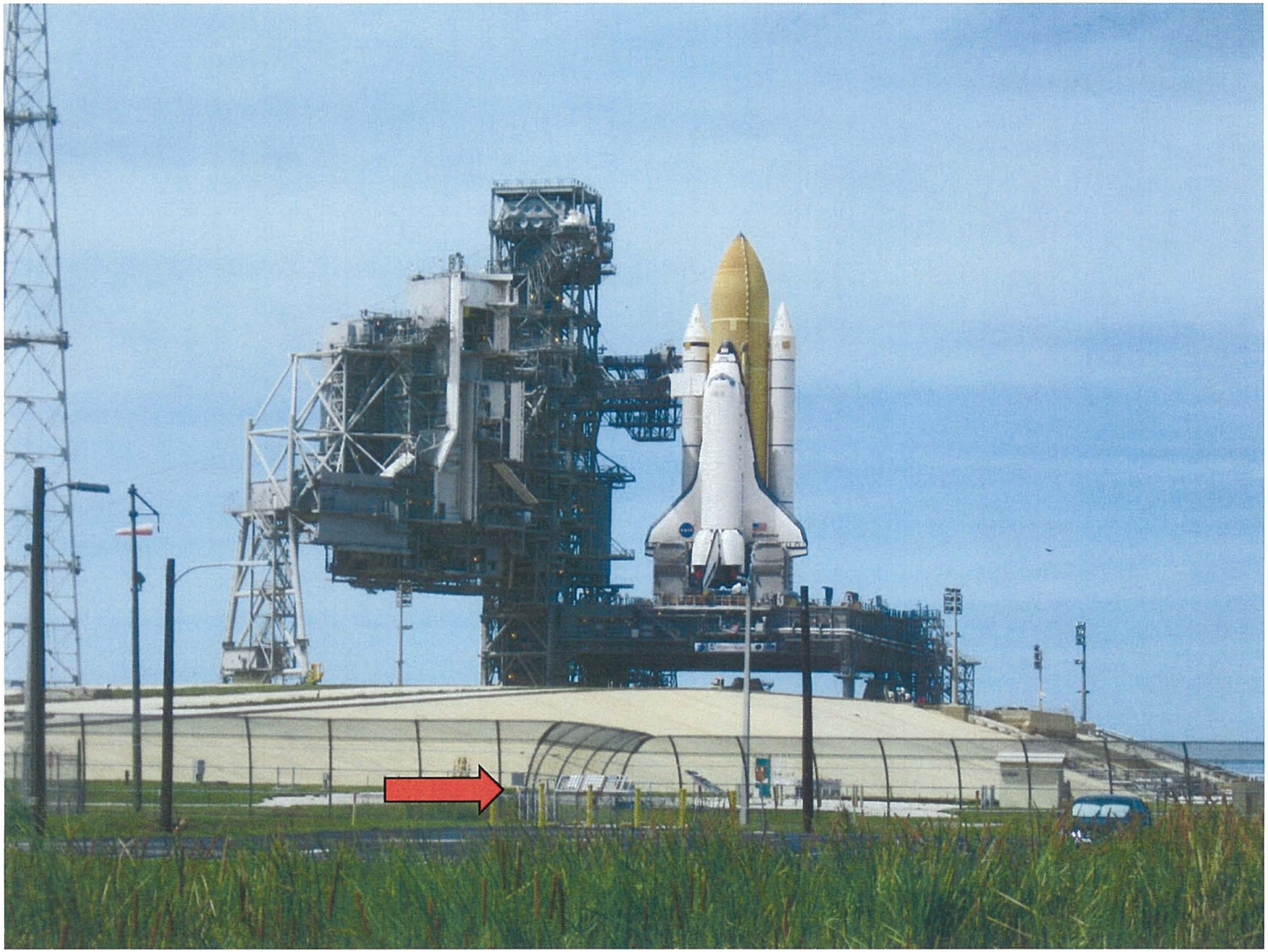


National Aeronautics and Space Administration (NASA)

Non-Chrome Coating Systems for Aerospace Applications (Phase I) (NASA-DoD)

Description:

- Evaluation and testing of non-chromated coating systems as replacements for hexavalent chrome coatings in aircraft and aerospace applications.
- Testing of coating systems to DoD and NASA specifications for corrosion resistance and adhesion.
- Bare corrosion resistance and atmospheric exposure will be focus areas of Phase II Testing.

Stakeholders:

- NASA (KSC, MSFC, Boeing, Hill AFB, United Space Alliance, SEA)
- Air Force (Hill AFB, WPAFB AFRL & MLBT)

Benefits:

- Meet EPA and OSHA requirements
- Reduce maintenance cost and government liability associated with continued use of chrome-containing coatings
- Addresses NASA and Air Force requirements on AL alloys 2219, 2195, 6061, 2024 Bare, 2024 Clad, and 7075.

Achievements:

- Completed 3,000 hour salt-spray testing (Hill AFB)
- Completed 2,000 Cyclic Corrosion testing (MSFC)
- Completed Hydrogen Embrittlement testing on Mg-Rich Coatings (Hill AFB).
- Completed Adhesion testing (Hill AFB)
- Completed Filiform Corrosion Testing (KSC)
- Completed Dissimilar Metals testing – (Boeing)
- Began publishing Final Lab Reports (Hill, KSC, Boeing, MSFC)
- Carried best performers into next phase of testing (2008/2009)

Future Plans:

- Complete Final Summary Reporting from Phase I (by May 1, 2009).
- Continue to Next Phase of Testing (See Hex-Chrome Free Coatings for Aerospace Project).

Hex-Chrome Free Systems - Phase I Coating Systems (NASA / DoD)

The coatings involved in Phase I testing:
(Pretreatment / Primer / Topcoat)

- System C: Alodine 1200 / Deft 02-Y-40 / Deft 99-GY-001
- System T: Alodine 5700 / Sicopoxy 577-630 / Deft 03-GY-321
- System N: PreKote / Mg-Rich Primer / Deft 03-GY-321
- System H: Alodine 5700 / Hentzen Primer 05510WEP-X / Deft 03-GY-321
- System D: Boegel AC-131CB / Dupont Corlar 13570S / Deft 03-GY-321
- System S: PreKote / AquaSurTec Crosslinker / AquaSurTec D45

Hex-Chrome Free Systems Phase I
3000 Hour Salt Fog Results

	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only
Coating System	2219-T81	2219-T81	2024-T3	2024-T3	2024-T3 Clad	2024-T3 Clad	7075-T6	7075-T6	6061-T6	6061-T6	2195-T8M4	2195-T8M4
C	C2-1	C3-1	C4-1	C5-1	C6-1	C7-1	C8-1	C9-1	C10-1	C11-1	C12-1	C13-1
	C2-2	C3-2	C4-2	C5-2	C6-2	C7-2	C8-2	C9-2	C10-2	C11-2	C12-2	C13-2
T	T2-1	T3-1	T4-1	T5-1	T6-1	T7-1	T8-1	T9-1	T10-1	T11-1	T12-1	T13-1
	T2-2	T3-2	T4-2	T5-2	T6-2	T7-2	T8-2	T9-2	T10-2	T11-2	T12-2	T13-2
N	N2-1	N3-1	N4-1	N5-1	N6-1	N7-1	N8-1	N9-1	N10-1	N11-1	N12-1	N13-1
	N2-2	N3-2	N4-2	N5-2	N6-2	N7-2	N8-2	N9-2	N10-2	N11-2	N12-2	N13-2
H	H2-1	H3-1	H4-1	H5-1	H6-1	H7-1	H8-1	H9-1	H10-1	H11-1	H12-1	H13-1
	H2-2	H3-2	H4-2	H5-2	H6-2	H7-2	H8-2	H9-2	H10-2	H11-2	H12-2	H13-2
D	D2-1	D3-1	D4-1	D5-1	D6-1	D7-1	D8-1	D9-1	D10-1	D11-1	D12-1	D13-1
	D2-2	D3-2	D4-2	D5-2	D6-2	D7-2	D8-2	D9-2	D10-2	D11-2	D12-2	D13-2
S	S2-1	S3-1	S4-1	S5-1	S6-1	S7-1	S8-1	S9-1	S10-1	S11-1	S12-1	S13-1
	S2-2	S3-2	S4-2	S5-2	S6-2	S7-2	S8-2	S9-2	S10-2	S11-2	S12-2	S13-2

3000 Hrs
< 2500 Hrs
< 2000 Hrs
< 1500 Hrs
< 500 Hrs

Hex-Chrome Free Systems Phase II Draft Test Plan

Potential Alternatives for Phase II –
Considerations - Systems H, N, T, P from Phase I & International

- **Pretreatments:**
  - Alodine 1200 (Control)
  - Iridide 14-2 (Control)
  - Alodine 5200/5700
  - Surtec 650
  - Prekote
  - Metalast TCP-HF
  - METALAST TCP-HF/EPA
  - Alodine 5900T
  - VpCI-440 (Vapor Phase CI)
- **Primers:**
  - Koropon (515X346 / 910x520) (Control)
  - STMK719 Superkoropon (Control)
  - ANAC / Mg Rich XP417-183
  - Hentzen 05510WEP-X / 05511CEH-X
  - Hentzen 16708TEP / 16709CEH (Type I)
  - Hentzen 7176KEP / 16709CEH (Type II)
  - Sicopoxy 577-630
  - Aviox CF Primer (TC) 330312
  - Deft 44GN098 (Waterborne)
  - Deft 02GN084 (High Solid)
  - VpCI-373 (Vapor Phase CI)
  - Lockheed Martin (CF Epoxy Primer)
  - Ecoprime CF
  - Hentzen Epoxzen
- **Topcoats:**
  - MIL-PRF-85285

Hex-Chrome Free Coating Systems for Aerospace Applications (Phase II) (NASA-DoD)

Description:

- Evaluation and testing of coating systems that do not contain hexavalent chrome as replacements for aerospace applications.
- Evaluation of coatings at Beach Test Site and Launch Complex 39B
- Evaluation of non-chrome coatings for electronic housings (bare corrosion resistance and electrical impedance) is a part of this round of testing.

Stakeholders:

- NASA (KSC, MSFC, JSC, MAF, SEA)
- CxP – Ares Upper Stage, Orion
- Air Force, Navy (NAVAIR)

Benefits:

- Meet EPA and OSHA requirements
- Reduce maintenance cost and government liability associated with continued use of hex chrome-containing coatings
- Addresses NASA and Air Force requirements on aluminum alloys 2219, 2195, 2024 Bare, 2024 Clad, and 7075.

Achievements:

- Completed all Phase I Testing (Salt Fog, Cyclic Corrosion, Filiform Corrosion, Hydrogen Embrittlement, Adhesion (Patti Jr.), Dissimilar Metals)
- Three Systems from Phase I, 4 from Navy/DoD Testing and 1 Un-tested will be a part of this Hex-Chrome Free Coatings Project.
- Additionally Coatings (+11 in total) from Ares and AF are a part of the project.
- JTP Draft Completed in October 2008.
- AF Coupons, Ares Coupons, TEERM Coupons and Corrosion Rate Coupons have been placed at test sites at KSC (April 2009)

Future Plans:

- Complete Test Reports for Phase I testing (by May 1, 2009)
- Complete Final JTP for Phase II (by May 1, 2009)
- Begin laboratory testing for Phase II (April / May 2009)

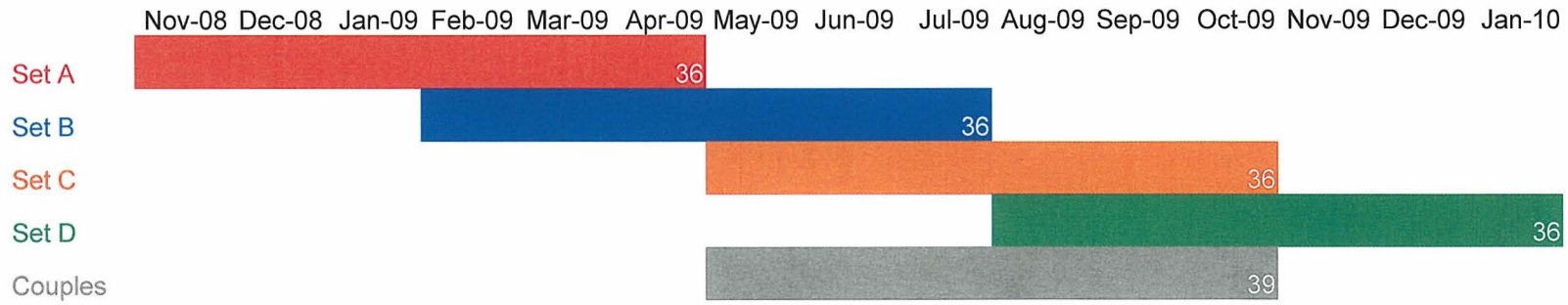
Hex-Chrome Free Systems Phase II Draft Test Plan

- **Repeat some Phase I Testing (2,000+Hrs Salt-Fog, Adhesion) for newly considered systems** (on AA2195, AA2219, AA 2024, AA7075):
  - CorTec - VpCI-440 Pretreat, + VpCI-373 wash primer + Topcoat
  - Lockheed Martin (CF Epoxy Primer) - TBD

- **Primary Phase II Tests:**
  - 18 Month Beach Exposure Testing (AF Round Robin / Mg Rich Only)
  - 15-18 Month Corrosion Rate Testing (Pad + Beach)
  - 6 Month Galvanic Couple Corrosion Rate Testing (Pad + Beach)
  - 15-18 Month – Pad Exposure Testing (All Coating Systems)
  - 6 Month Galvanic Couple Pad Exposure Testing (1-4 Coatings)
  - 168 Hour Bare Corrosion Resistance (Pretreatments)

Concurrent Corrosion Study

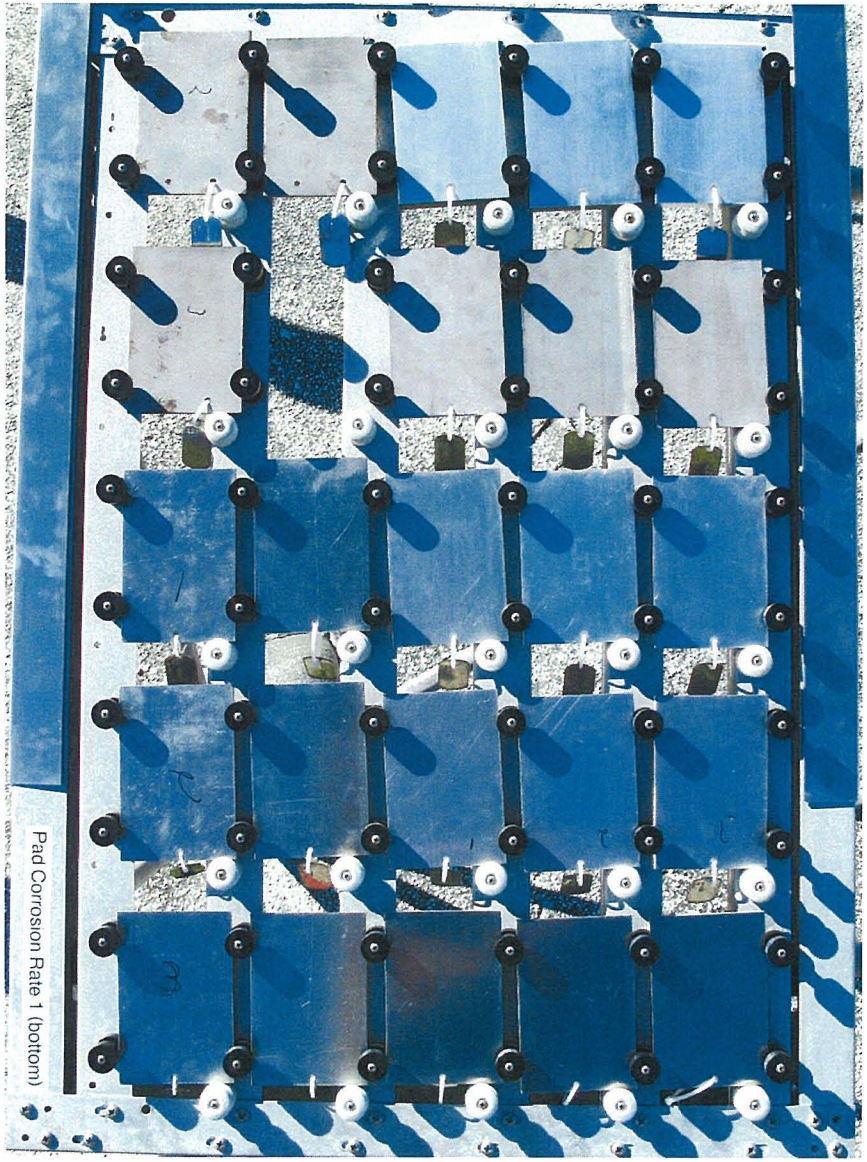
KSC Pad Atmospheric Corrosion Testing Schedule

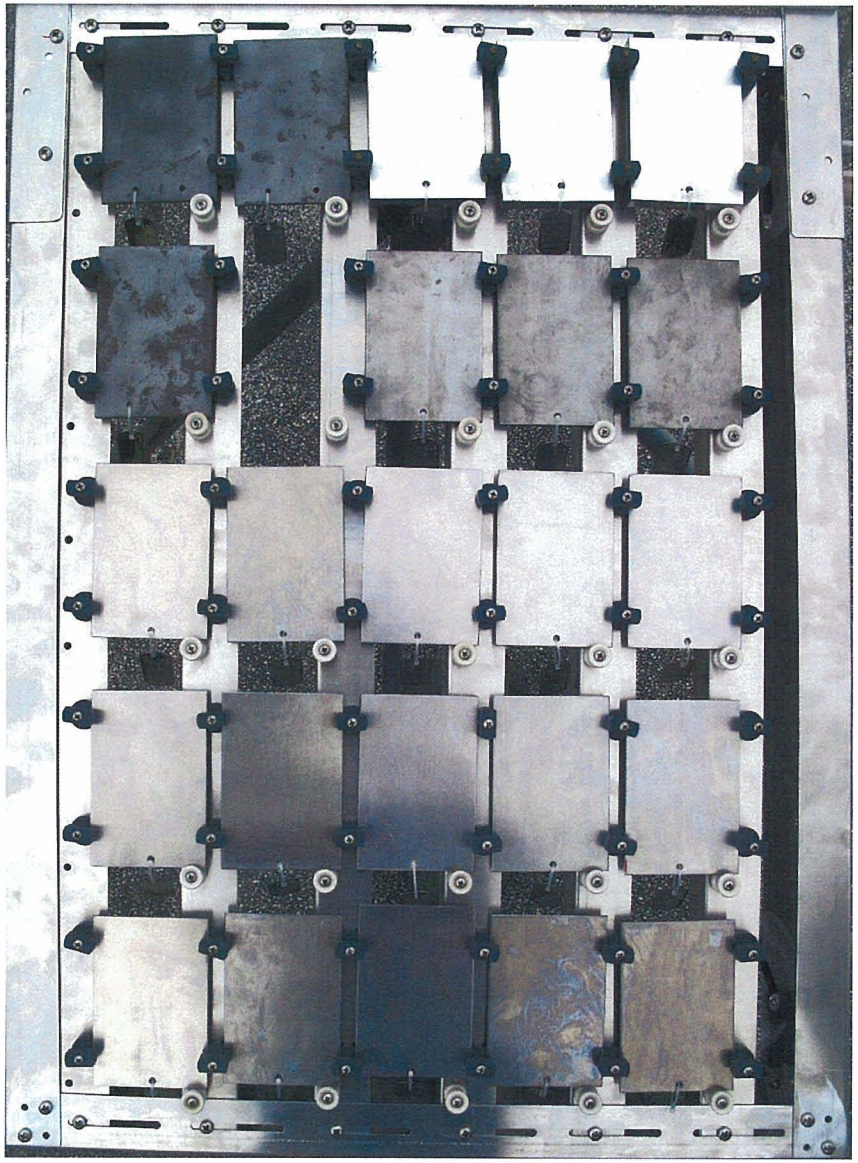


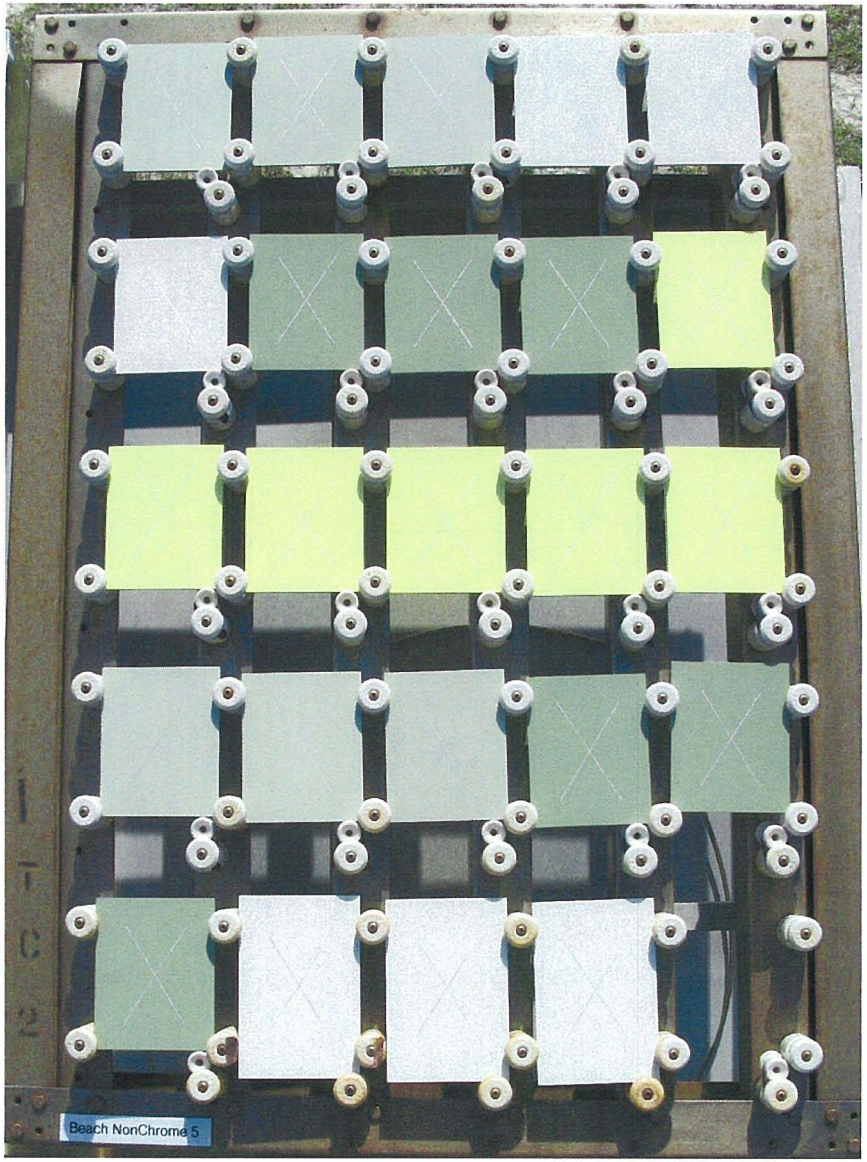
- Aluminum Substrates
  - 2195
  - 2024
  - 2219
  - 2014
  - 6061
  - 7075
  - 7050

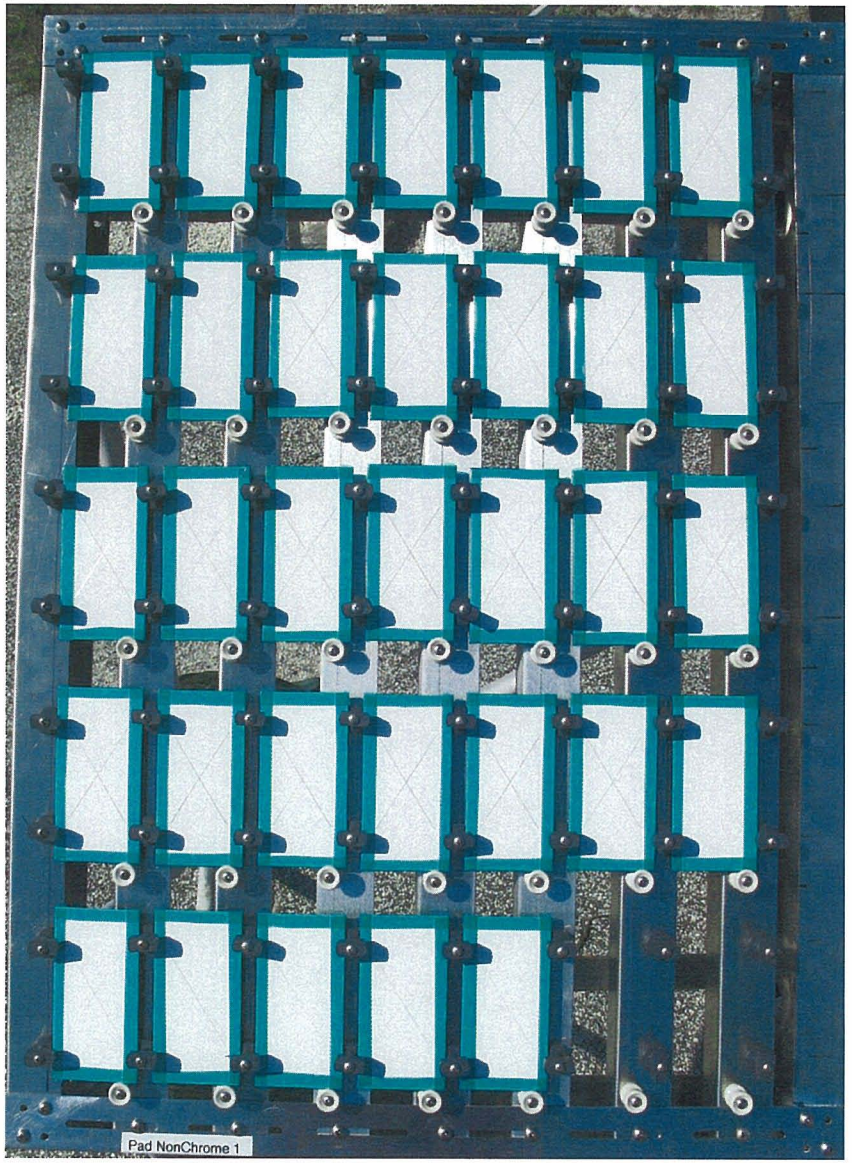
- Steel Substrates:
  - 4340 or D6ac
  - A286
  - 304SS
  - 1080
  - PH17-4

- Couples
  - A286 with 7075/2219/6061/2195
  - 4340 (or D6ac) with 6061/7075/2195/7050
  - 304 SS with 6061/7075/2219/2195/2024


Pad Corrosion Rate 1 (bottom)




Beach NonChrome 5


Pad NonChrome 1

Hex-Chrome Free Systems Phase I & II Project Participants

- **NASA**
  - Orion – Mike Pedley (NASA), David Shindo (NASA)
  - Ares I Upper – Rhonda Libb (NASA)
  - Ares I Lower – John Bailey (USA) / A. Priskos (NASA)
  - Other – Steve Hudson (NASA), Andrew Hodges (Vista)

- **DOD**
  - Air Force
    - AFRL / RXSSO (Chris Joseph)
    - AFRL / CTIO (Bill Culhane)
    - Hill AFB (Wayne Patterson)
  - Navy
    - Craig Matzdorf, Steve Brown (NAVAIR)
  - Army
    - Steven Carr (ARMY)

- **Private Sector / OEMs**
  - Raytheon – Rich Spitzer
  - Lockheed Martin – Steve Deblasio
  - Spirit Aerosystems – Gary Taylor
  - ATK – Robert McBride
  - USA - John Bailey

Life Cycle Corrosion of Space Vehicles

Description:

- To obtain a clear understanding of the lifecycle environment as it pertains to corrosion potential and potential coating repair cycles for space vehicles, beginning with testing at KSC LC-39B. Initial screening tests will focus on characterizing the environment at this location and attempting to simulate this environment in an accelerated laboratory test.
- Additionally testing will be performed on the repair and re-exposure of non-chrome coating systems after exposure and compromise to better understand necessity of maintenance that may be necessary with a fully Hex-Chrome free coating system.
- Later Phases will address in a similar way the other environments that components for CxP and other assets exist in during their lifecycle, from assembly to launch.

Benefits:

- Increased understanding of the actual environment and level of corrosion protection necessary for CxP vehicles.
- Identification and validation of repair techniques for hex-chrome free coatings that are effective in protecting assets and mitigating risk to mission.

Stakeholders:

- Current = NASA KSC, MSFC
- Current = CTIO, UDRI, ASRC
- Potential = AFSPC / SMC

Funding:

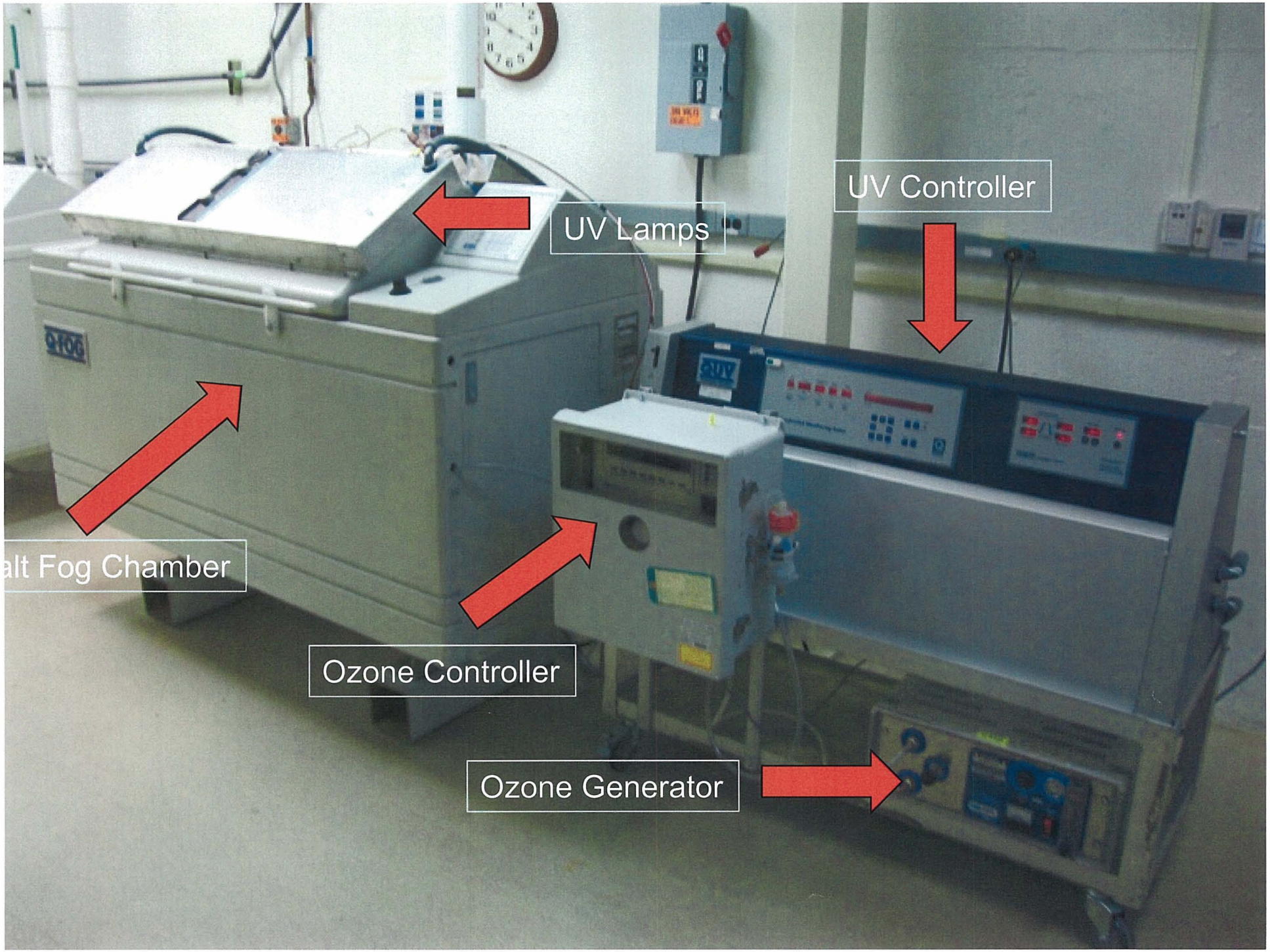
- Estimated total project cost $45K
- Estimated duration- 24 months
- In-Kind contributions from MSFC possible, as well as a potential for discounted rates for testing at UDRI.
- Project development and management covered under core TEERM
- In kind commitments for materials and labor (restoring of test panels) will be sought.

Achievements:

- TEERM engineers assigned to project
- Laboratories at KSC and CTIO have been contacted for support and cost estimates.
- USA SRB has been contacted to discuss resoration process
- Some test panels are already at LC-39B for corrosion rate analysis as part of hex-chrome project.

Future Plans:

- Continue development of current project outline and test plan.


UV Controller
UV Lamps
alt Fog Chamber
Ozone Controller
Ozone Generator

Life Cycle Corrosion of Space Vehicles Laboratory Testing

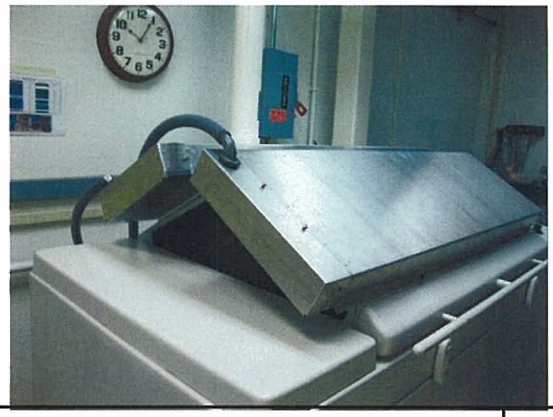
- Factors
  - Temperature
  - Humidity
  - Salt Type
  - Salt Concentration
    - Use XPS to determine ionic species present at LC 39B and Beach
    - ASTM B117 / ASTM D5894
  - Light
    - UV Cabinet
    - Xeon Arc Cabinet
  - Ozone
    - (KSC < 50ppb on average)
    - Affects corrosion in B117 dramatically

- ~~Setup Option 1~~
  - ~~Combination of B117 / Cyclic Cabinets & UV Cabinets~~

- Setup Option 2
  - Modified Cyclic Corrosion Cabinet to include UV + Ozone (UDRI / KSC)

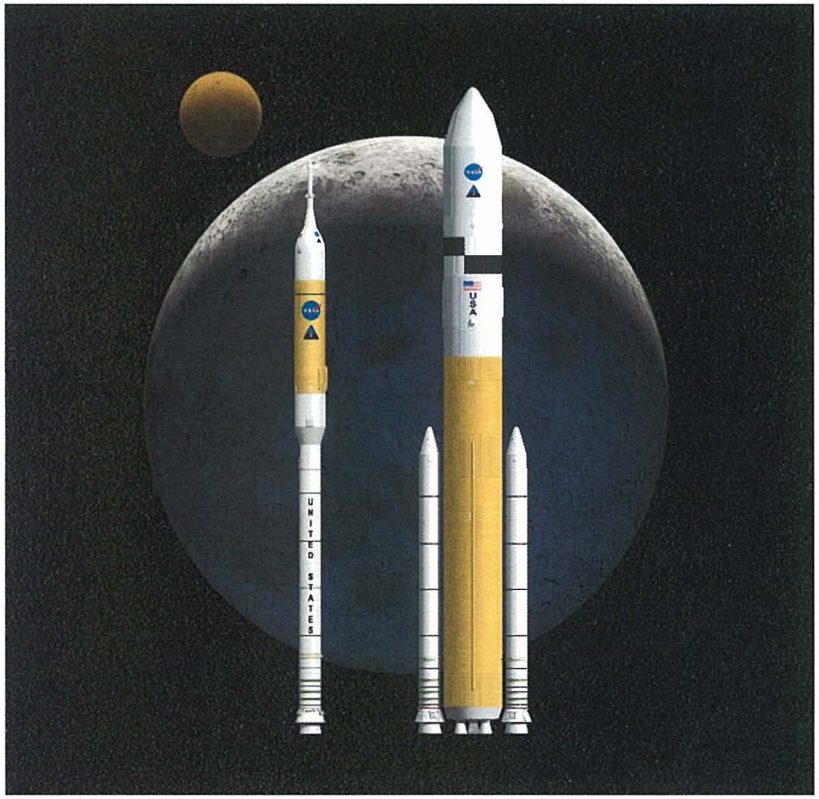
- Initial Screening Tests
  - November 2009.

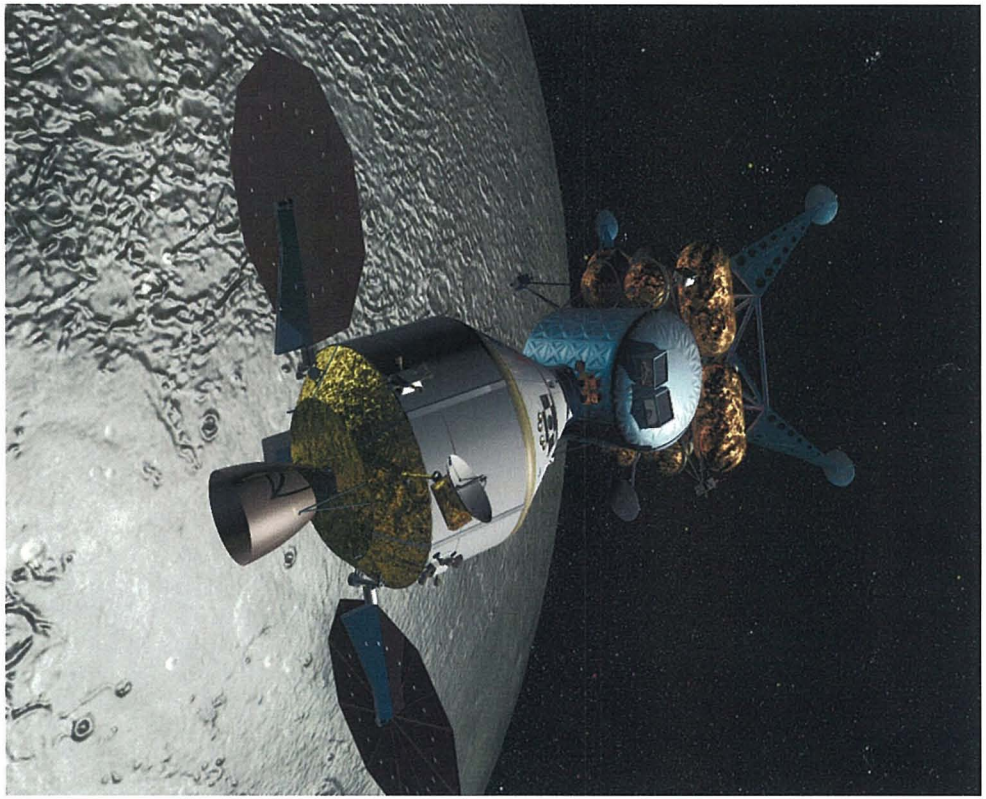
Combined Environment Test chamber and Experimental Design



Setting	UV	Ozone	Salt Mix	Bare			Coated - System 2			Coated - System 7			Bare			Bare			Coated - Control			DATA POINTS
				Hours Exposure			Hours Exposure			Hours Exposure			Hours Exposure			Hours Exposure			Hours Exposure			
				24h	48h	72h	24h	48h	72h	24h	48h	72h	24h	48h	72h	24h	48h	72h	24h	48h	72h	
				Substrate			Substrate			Substrate			Substrate			Substrate			Substrate			
				AL-2024			AL-2024			AL-2024			ST-1010			Ag			AL-2024			
Setting 1	Low	Low	B117 - 5%	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 2	High	Low	B117 - 5%	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 3	Low	High	B117 - 5%	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 4	High	High	B117 - 5%	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 5	Low	Low	KSC (XPS)	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 6	High	Low	KSC (XPS)	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 7	Low	High	KSC (XPS)	4	4	4	4			4			4	4	4	1	1	1	1			36
Setting 8	High	High	KSC (XPS)	4	4	4	4			4			4	4	4	1	1	1	1			36
			Data Points:	32	32	32	32			32			32	32	32	8	8	8	8			**288**
					Total: 96			Total: 32			Total: 32			Total: 96			Total: 24			Total: 8		

Questions?
NASA TEERM Principal Center





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