The Vital Role of the Kennedy Space Center Beachside Atmospheric Corrosion Test Site in Selecting Corrosion Protection Coatings for Increased Sustainability

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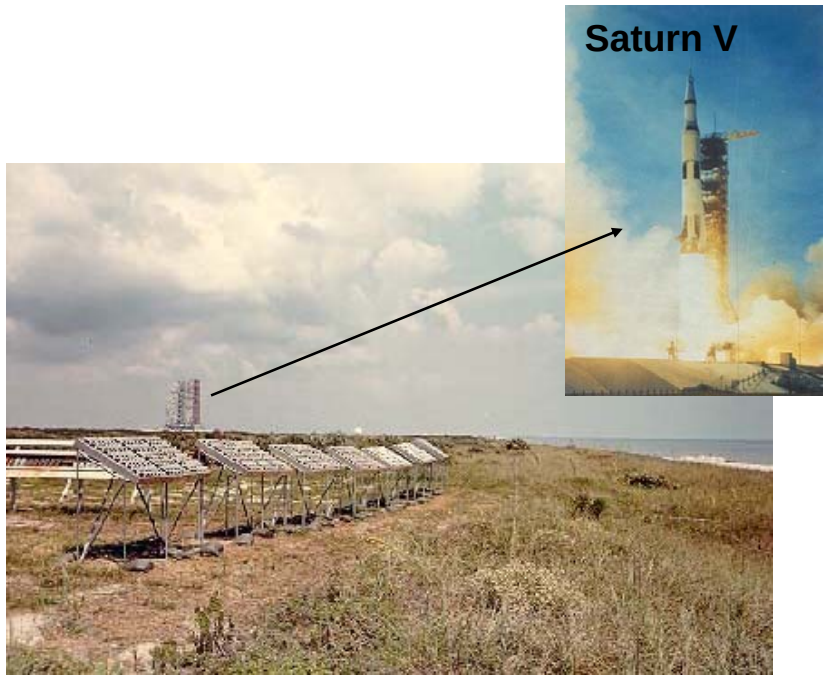
Overview

- History of the Exposure Site
- Environmental Conditions
- Projects and Partnerships

History – Site Establishment

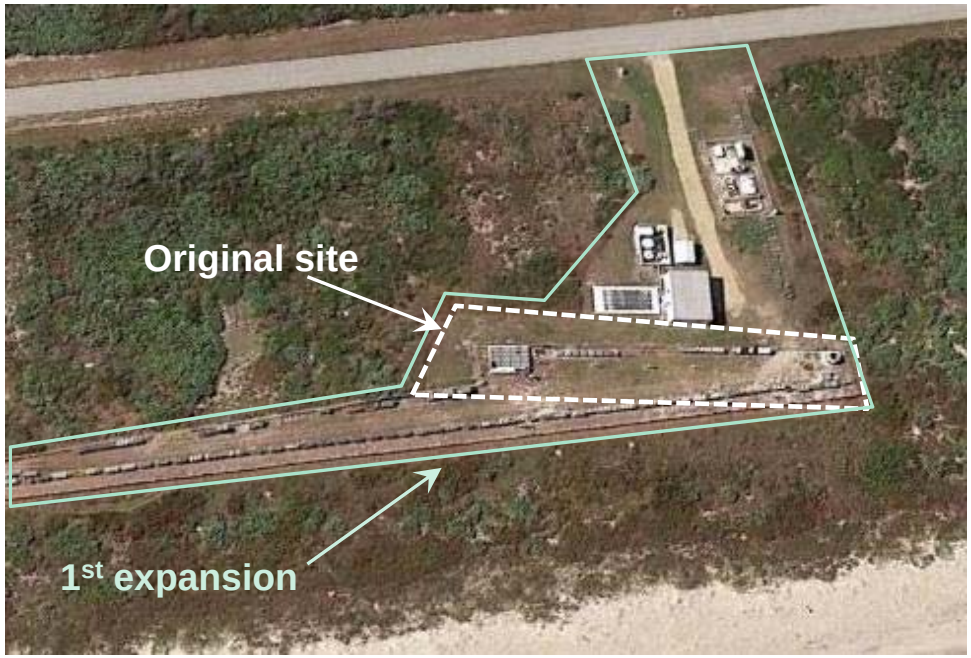
- **1966**: First coatings testing located at the cape side launch pads during the Gemini/Apollo Programs for long-term protective coatings for atmospheric protection of carbon steel.
- **1969**: Beach Corrosion Test Site established with more controlled and cost effective ways to conduct testing on coatings for carbon steel in seacoast launch environment.
- **1981 – 1986:** Coatings resistant to hydrochlroric acid from SRB's for the Space Shuttle Launch Program.

I am putting the original picture of the site here



History – 1st Expansion

- **1990's**: Environmentally friendlier coatings, zinc-rich primers and inorganic topcoats, silicone ablative coatings
- **1992**: Numerous studies at the site required an expansion to 600 feet parallel to the Atlantic Ocean
- Identified materials, coatings, and maintenance procedures for launch hardware and equipment exposed to the highly corrosive environment at the launch pad
- Results have helped KSC find new materials and processes that increase the safety and reliability of launch structures and ground support equipment



History: Upgrades

Upgrades:

- Weather station
- New permanent building with laboratory and machine shop
- Remote camera system
- New testing capabilities

Concrete:

- Test rebar in concrete
- Electrically connected

Seawater submersion:

- Simulates natural tidal conditions
- Oxygen concentration monitored

Alternating Seawater Spray Test:

- Sprays seawater pumped from the ocean
- Frequency programmable

History: 2nd Expansion

- Site expansion as a result of current demand for additional corrosion testing from NASA and external customers
- 900 total feet of exposure space parallel to the Atlantic Ocean
- 200 feet from the mean high tide line
- Accommodates specialty components

2nd Expansion: Environmental Considerations

Tortoise Protection:

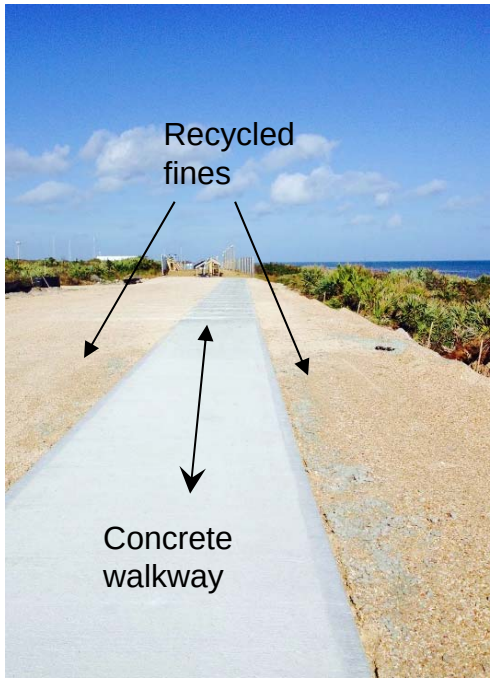
- One successfully relocated

Reuse Materials:

- Reused recycled fines from the Crawlerway rock for the fill and surface of the new section and new driveways

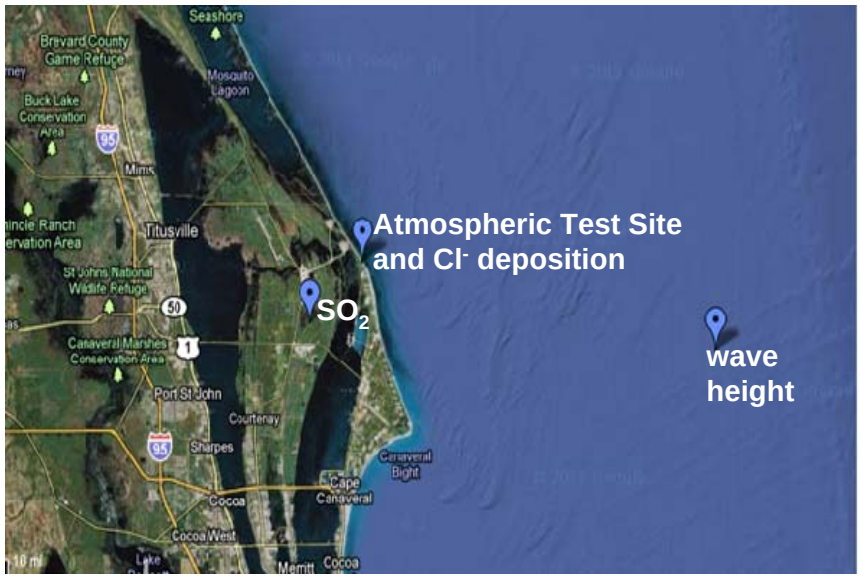
Safety:

- Installed a 6-foot wide sidewalk that spans the entire 900 feet to better secure the racks and stands
- Created a more secure environment for worker safety and stability



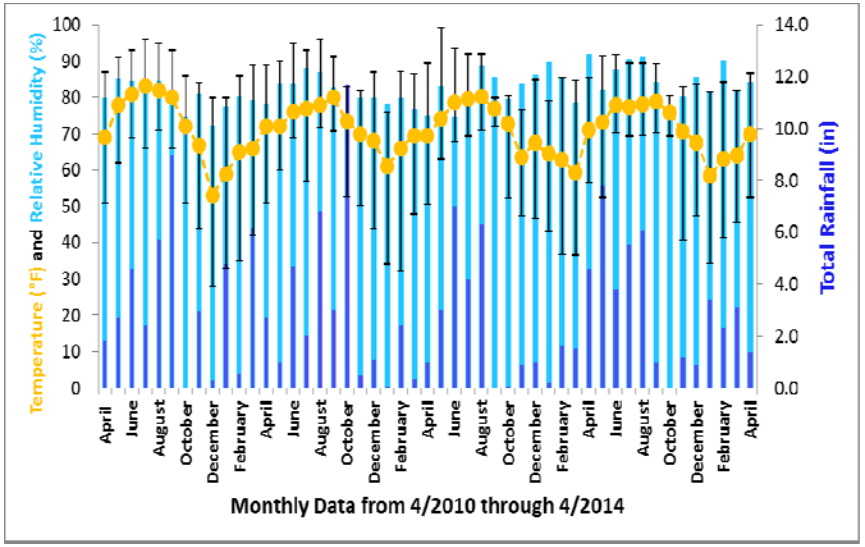
KSC Corrosive Environment

- **Natural Environment**
  - **Ocean salt spray**
  - **Heat**
  - **Humidity**
  - **Sunlight**
- **In addition, when launching:**
  - **Acidic exhaust from Solid Rocket Boosters**
  - **Creates a 70 ton 0.1M HCl vapor cloud during heavy lift vehicle launch**
- **Atmospheric exposure is time consuming, but the gold standard in lifetime prediction.**
- **Thus far, no accelerated test method can satisfactorily correlate to atmospheric exposure.**

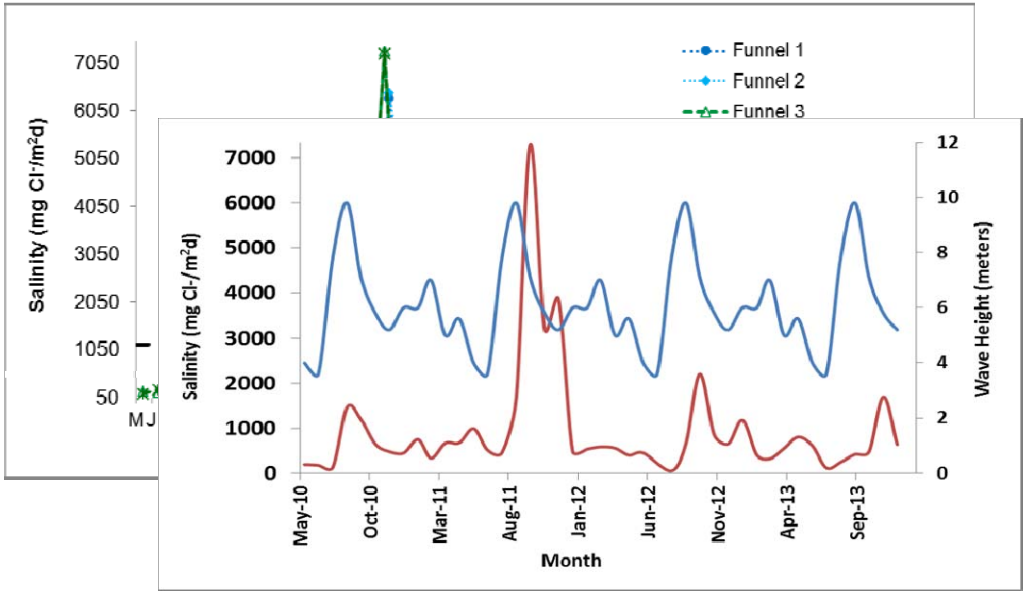


Monitoring Natural Conditions

- **Temperature**
  - **Ambient**
  - **Panel-specific**
- **Relative humidity**
- **Precipitation**

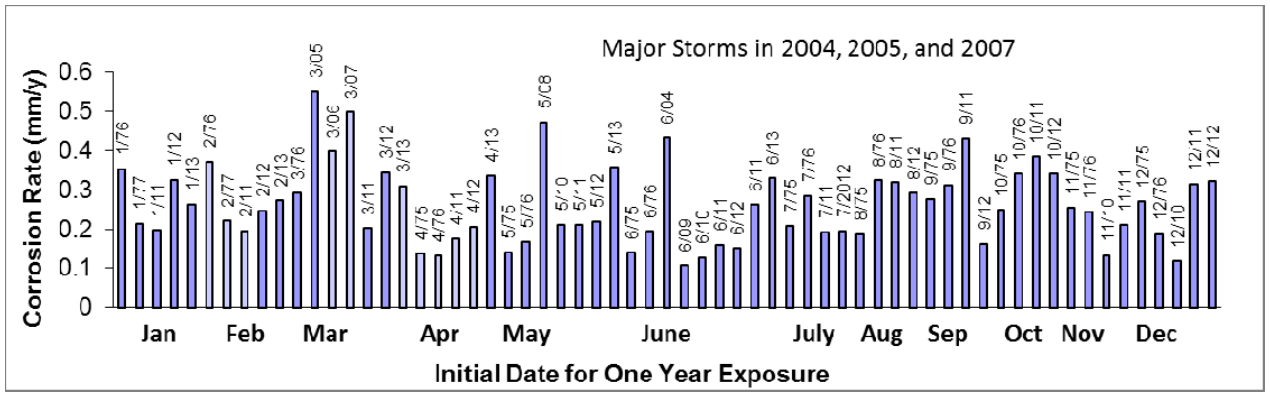


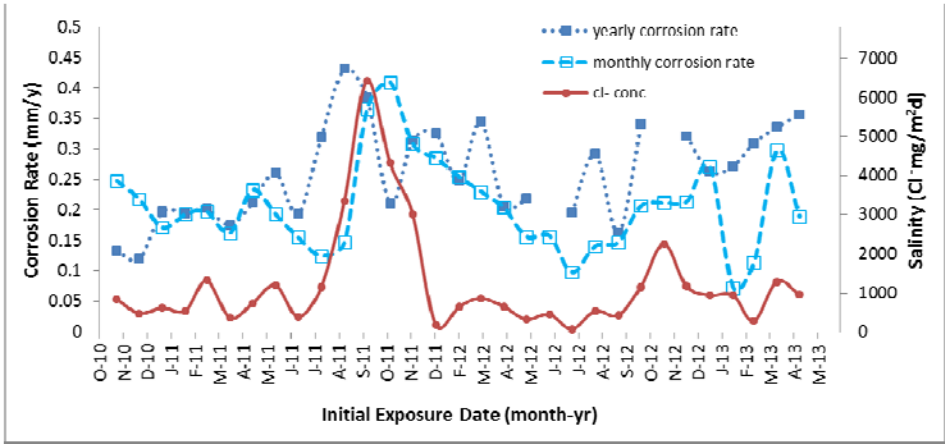
- **Chloride deposition**
- **Sulfur deposition**
  - **NADP FL99**
  - **1-2 mg/m^2-d (very low)**
- **Wave height**
  - **NOAA buoy #41009**
  - **Average over 10 years**

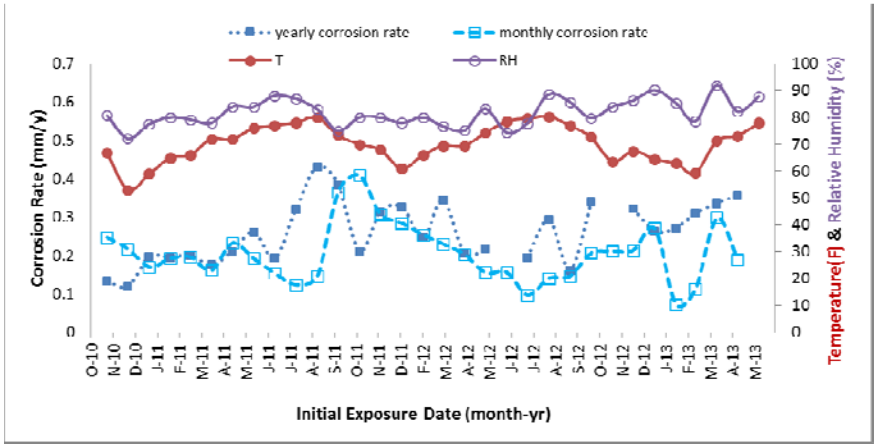


Monitoring Natural Conditions

- **Corrosion Rate**
  - **Weight loss with carbon steel coupons**
  - **Ranges from 0.127 – 0.51mm/y**
  - **Rates vary seasonally and as a function of chloride/precipitation**







Collaborations and Partnerships

- Wide range of organizations
  - Government
  - Military
  - International
  - Industry
  - University
  - Consortium
- Wide range of focus
  - Environmental
  - Aerospace
  - Aviation
  - Energy
  - Coatings
  - Metals
  - Ceramics
  - Polymers
  - Composites
  - Transportation

Collaborations and Partnerships

- **US Government**
  - DoD
    - Army
    - NAVAIR
    - NAVY
    - Marines
    - AFSC
    - Air Force
  - DOT
  - NIST
  - NOAA
- **Industry**
  - Automobile manufacturers
  - Industrial coatings manufacturers
  - Aeospace
    - Commercial
    - OEM
    - Business
  - Metal manufacturers
  - Solar panel manufacturers
- **International**
  - ESA
  - Canadian Govt
  - University (US and International)
  - Coatings manufacturers
  - REACH

- **Path Forward**
  - Support the 21st Century Launch Complex program and Commercial Orbital Transport Services
  - Continue efforts of REACH

Projects: late 90's - Present

NASA-only Projects

- **All exterior coatings used at NASA's Kennedy Space Center are tested at the site**
- **In addition to corrosion protective coatings, items such as metal test panels, launch vehicle components, heat shields, radar support structures, and window frames are tested at the site for corrosion resistance**

- Corrosion Resistant Tubing for Space Shuttle Launch Sites
- Chloride Rinse Additive Study
- Electrochemical Evaluation of Alloys for Spaceport Design
- Multisensor for Corrosion Prediction
- Nanoscale Admixtures to Prevent the Corrosion of Rebar in Concrete
- Corrosion Testing of Airplane Wing Structures
- Liquid Applied Coatings for Imbedded Rebar
- NASA (UB) - Two Hour Salt Spray Exposure of Strike Plate (Internal Angular) Part No. 1110ND051
- VAB Roof Remediation Support
- Hex Chrome Alternative Coating Testing
- VAB Siding Coatings Testing
- LC-39 Cryogenic Storage Tank Corrosion Control and Mitigation
- Coatings Support for Exploration and Spaceport Design
- Laser Depainting Study
- Launch Coating Operations Support (NASA and CCAFS)
- Self Cleaning Coatings
- AR7 Coating Replacement
- Polyimide Based Powder Coatings
- In-Situ Phosphatization for KSC Coatings and Corrosion Preventative Compounds
- TEERM and AFSPC Program Support
- Smart Coating Project
- Sintering Methods for Building a Lunar Launch Pad
- Environmentally Friendly Coating Technologies
- Low Volatile Organic Low Volatile Organic Compound (VOC) Topcoats for Thermal Spray Coatings
- AR-7 Replacement
- Refractory Materials Development, Test and Analysis Support
- Continuous Flow Sintering System for Lunar Surface Stabilization
- New Organic Zinc Rich Primer for Launch Structures
- Hexavalent Chrome Alternatives for Aerospace
- Demonstration/Validation of Environmentally-preferable Coatings for Launch Facilities
- GSDO Program Hexavalent Chrome Alternatives
- Environmentally Friendly Corrosion Preventative Compounds
- New Accelerated Test Method for Corrosion Protective Coatings
- Implementation of environmentally friendly corrosion preventative compounds into KSC ground processing use
- Environmentally friendly post treatment/coating extender for improved asset sustainability for CPCs

Projects: late 90's - Present
Partnerships or Outside Customers:

- **Projects are part of collaborations or directly-contracted work**

- Naval Research Laboratory Support
- Army Research Lab/CTC Coupon Project
- Electrochemical Evaluation of Coatings (Private company)
- Effects of Chlorine Dioxide on Metals (Private company)
- Corrosion Resistance of Friction Stirred Welded Stainless Steel (Naval Research and Lehigh University)
- Powder Coating Evaluation (Private company)
- DoD Cost of Corrosion Study
- Naval Facility Support
- Rebar Corrosion (Private company)
- Fluorescing Coating Study (Private company)
- Weapons Group Coating Study (Private company)
- Chromate Coating Replacement for Aircraft Alloys (NAVAIR)
- Boeing (UB) – Evaluation of Corrosion Mitigation Techniques for Flight and other Critical Hardware using Citric Acid Passivation and Perfluorinated Polyether Grease
- Depainting Technology for Structural Steel (AFSPC and NASA)
- Polyurethane Replacement Coatings (AFSPC and NASA)
- NASA AP2 Program Support (NASA and US Air Force)
- Evaluation of USMC Hatch Covers
- US Army Vehicle Coating Study
- NAVAIR Support for Non-Chrome Coatings
- NAVAIR / China Lake
- Army Research Laboratory Coatings and Corrosion Research
- Validation of Citric Acid as an Alternative to Nitric Acid for Passivation of Stainless Steel (NASA and DoD)
- U.S. Army Research Laboratory Coastal Atmospheric Exposure of Army Research Laboratory (ARL) Coated Panels
- U.S. Army Research Laboratory Transparent Armor
- Gulfstream Jet Corrosion Study
- NTPEP Panel Exposure
- Solar Panel Evaluation
- Launch Coatings, Phase 2 for AFSPC
- Lockheed Martin Aeronautics Coating Study
- Paint Manufacturer - Based Non-Chrome Coating Study
- AFSPC Launch Coating Support- Eastern Range Coatings
- Magnesium Coating Study

Summary

- NASA Beachside Atmospheric Exposure Test Site has evolved into a world-class test facility
- Dynamic capabilities and personnel to accommodate the changing needs of a multitude of users

Acknowledgements