



# Space Systems Pollution Prevention

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Presented By:

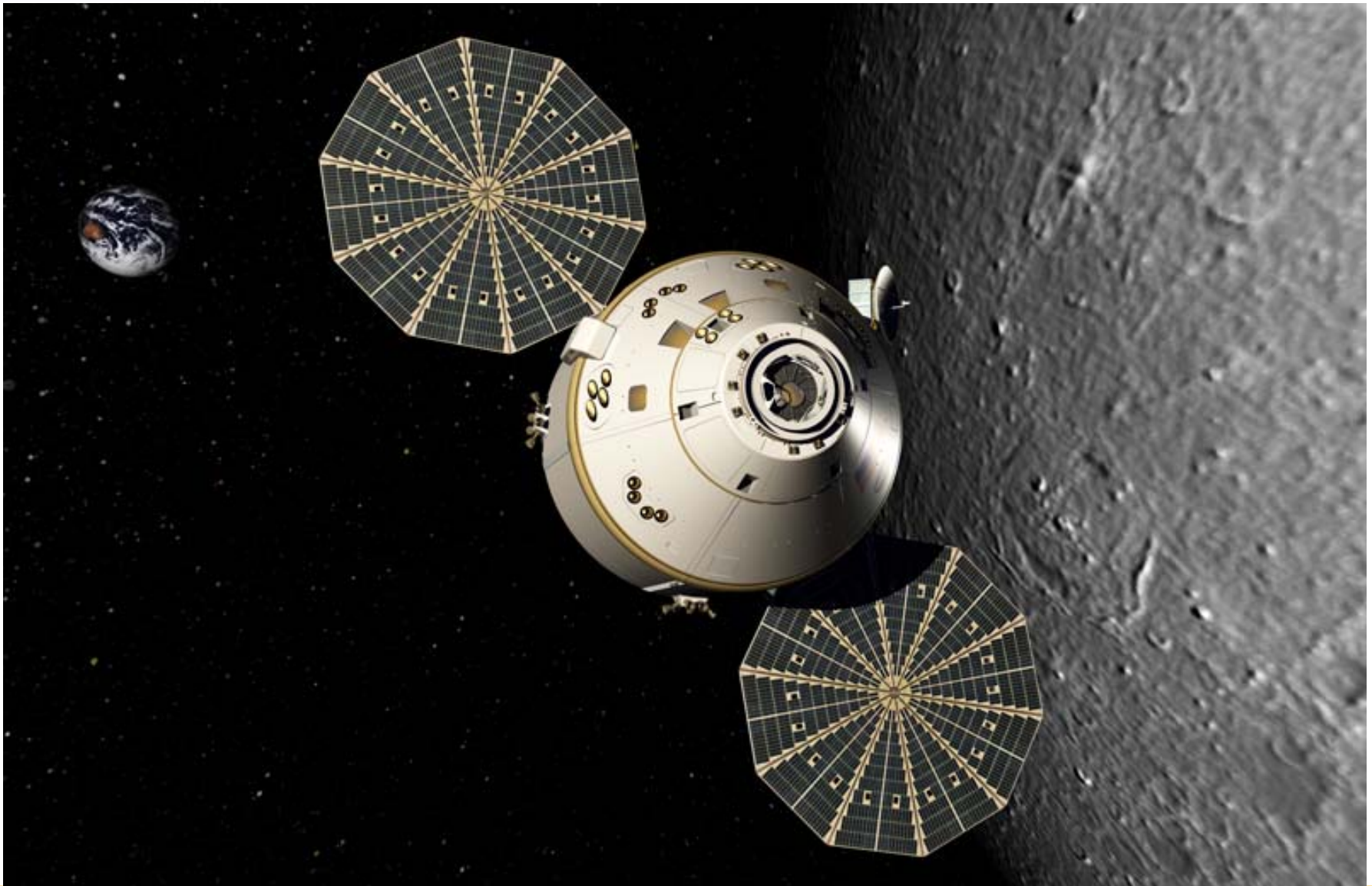
**Dean A. Dunn, PE**

**Orion & Space Exploration Team Chief,  
Launch Vehicle Operations**



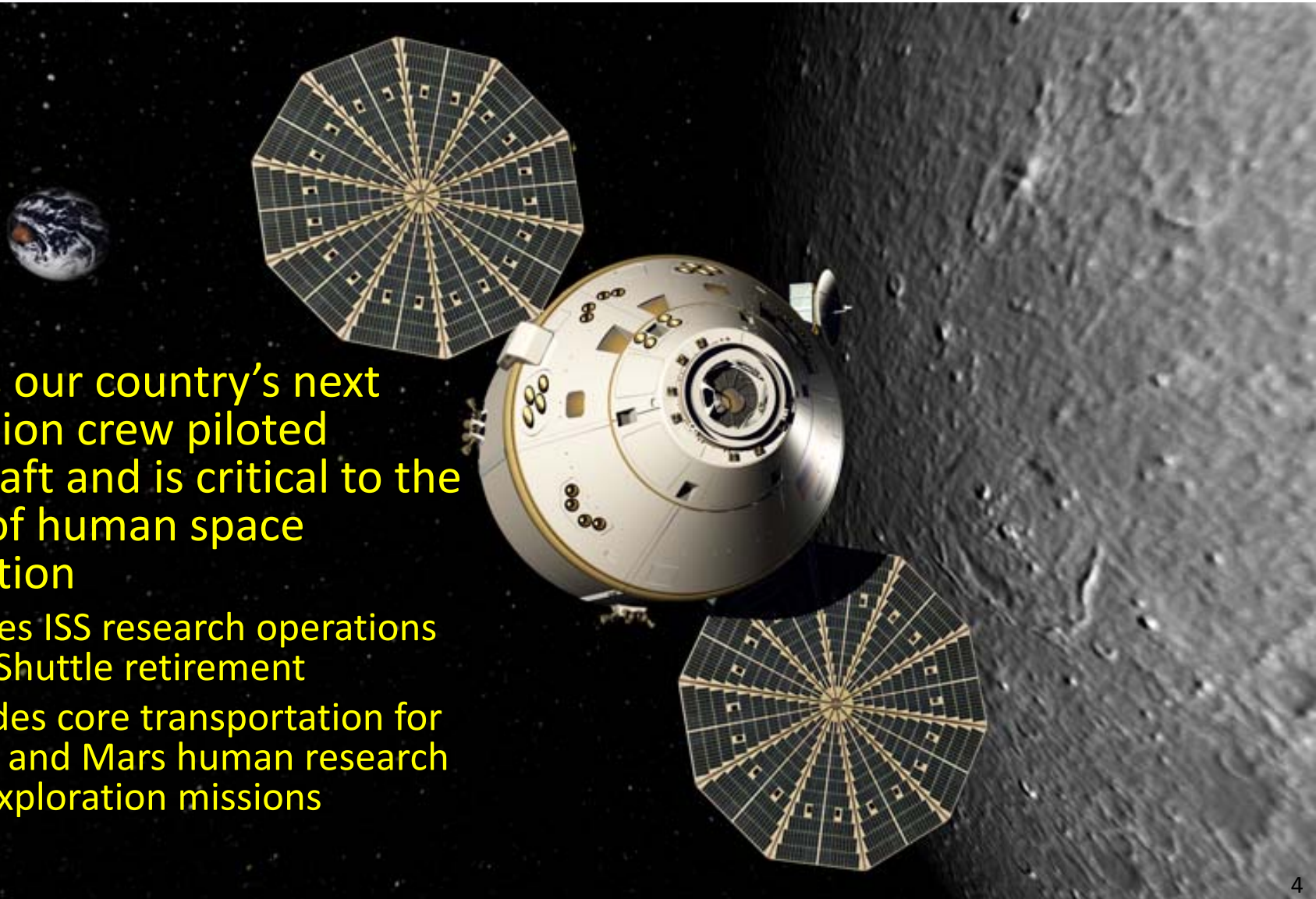
## *Collaborative Relationships/Partnerships*

- **US Space Policies encourage partnership between US agencies**
- **Budgets motivate collaborative efforts**
- **Space Cultures enhance cooperative spirit**
- **NASA demonstrates an exceptional cultivation of cooperative spirit**
  - **Environmental, Sustainment, Energy provide an outstanding baseline for International participation**
- **DoD is very appreciative to have NASA as a partner**
  - **DoD looks forward to continued participation with NASA & International partners in future efforts that benefit all those that participate**



Orion is our country's next generation crew piloted spacecraft and is critical to the future of human space exploration

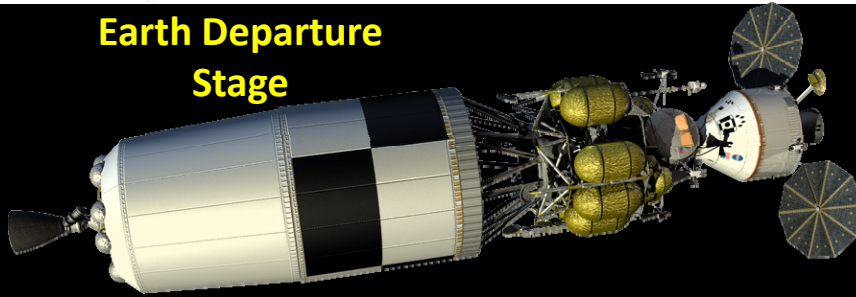
- Enables ISS research operations after Shuttle retirement
- Provides core transportation for Lunar and Mars human research and exploration missions



# Constellation Program



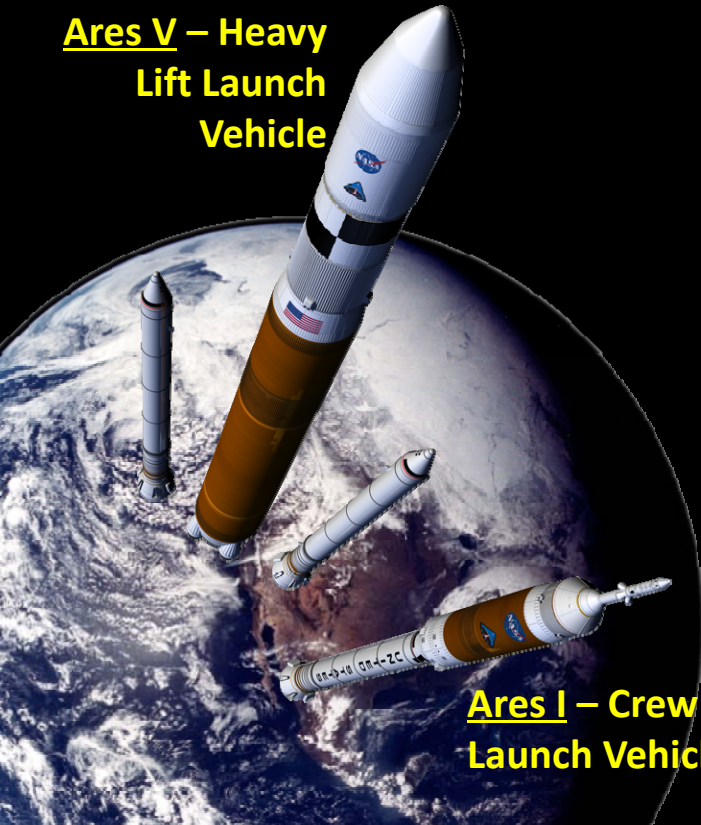
**Earth Departure Stage**



**Lunar Orbit**



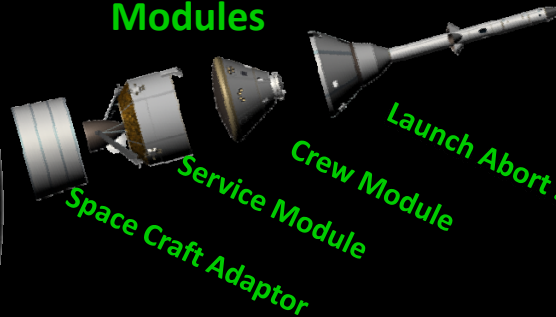
**Ares V – Heavy Lift Launch Vehicle**



**Orion - Crew Exploration Vehicle**



**Orion Functional Modules**



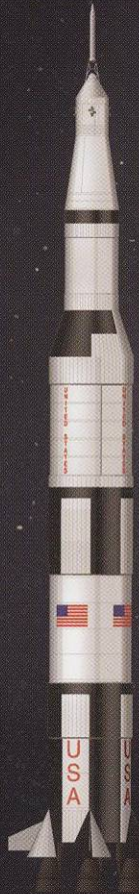
**Ares I – Crew Launch Vehicle**

**Altair - Lunar Lander**

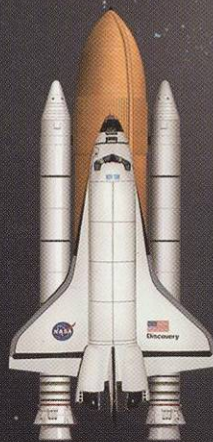




# New vs. Old



Apollo Saturn V



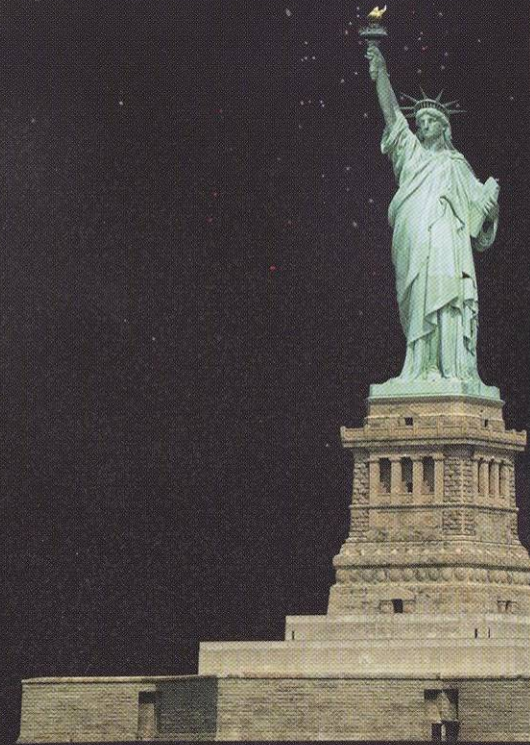
Space Shuttle



Ares I



Ares V



Statue of Liberty  
(Does not launch)

# Primary Work Locations



**~\$7.0B**

- LOCKHEED MARTIN**
- Systems & Design Engineering Support
  - Subcontract Management

- AEROJET**
- Propulsion

- LM GRC**
- SM Liaison Office

- Hamilton Sundstrand**  
A United Technologies Company
- Environmental Control & Life Support
  - Active Thermal Control
  - System Power Management

- Orbital**
- Abort Motor and Jettison Motor
  - Safety & Mission Assurance

- Honeywell**
- Avionics
  - Integrated System Health Management
  - Crew Interface
  - Mission Ground Ops Support

- ATK Elkton**
- Attitude Control Motor

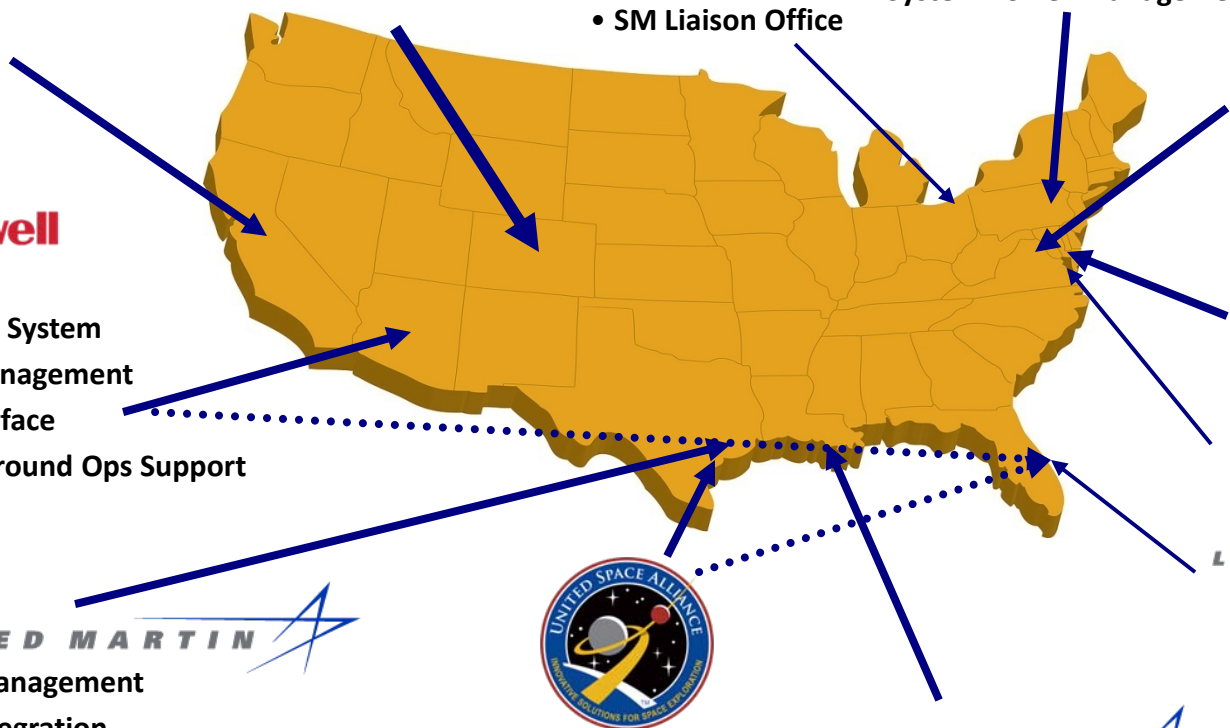
- LM LaRC**
- LAS Liaison Office

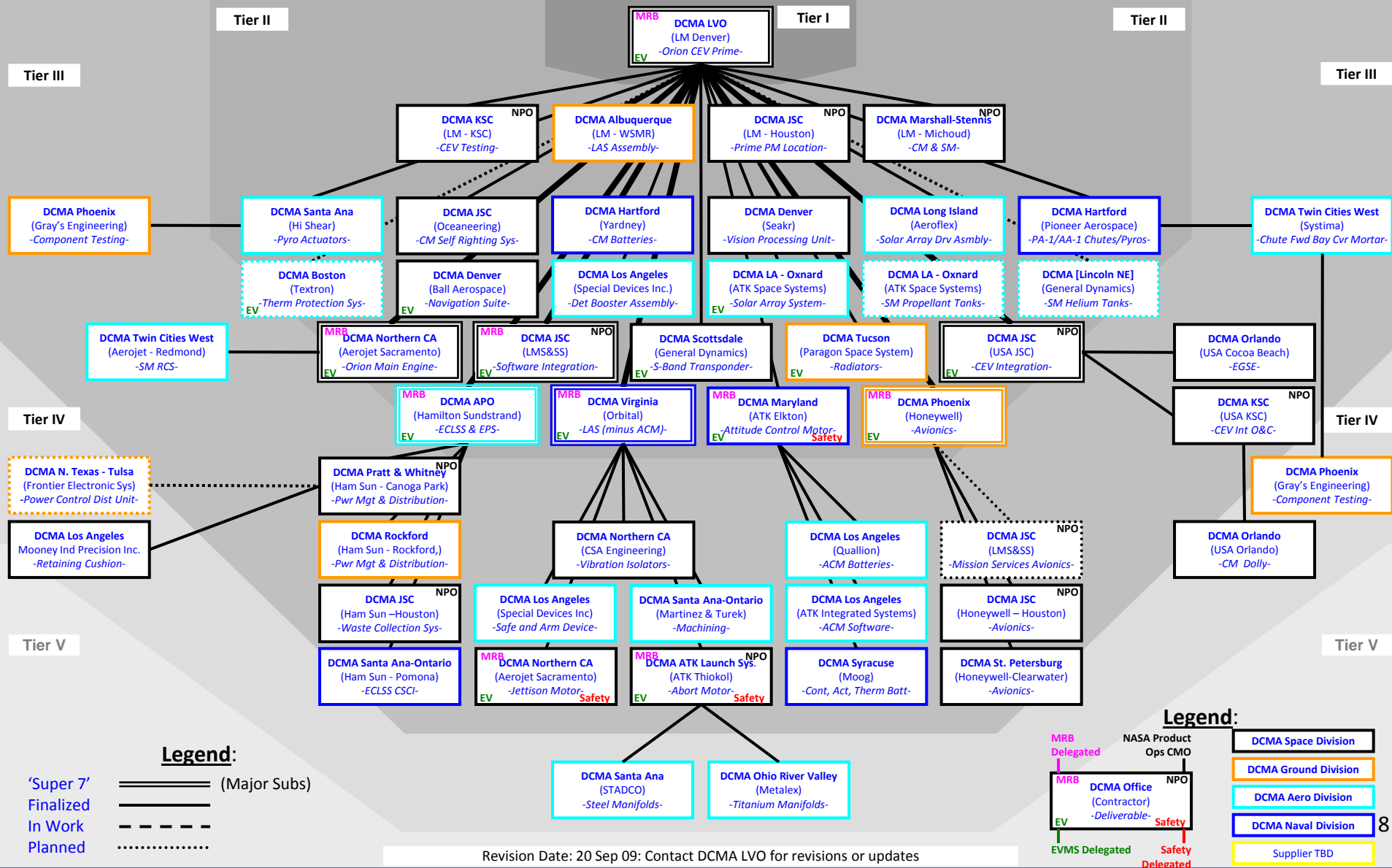
- LOCKHEED MARTIN**
- Program Management
  - Systems Integration
  - Crew Module Development
  - Service Module Development
  - Qualification Test
  - Software Development

- Operator Interfaces
- Ground Processing
- Mission Flight Planning
- Software Development

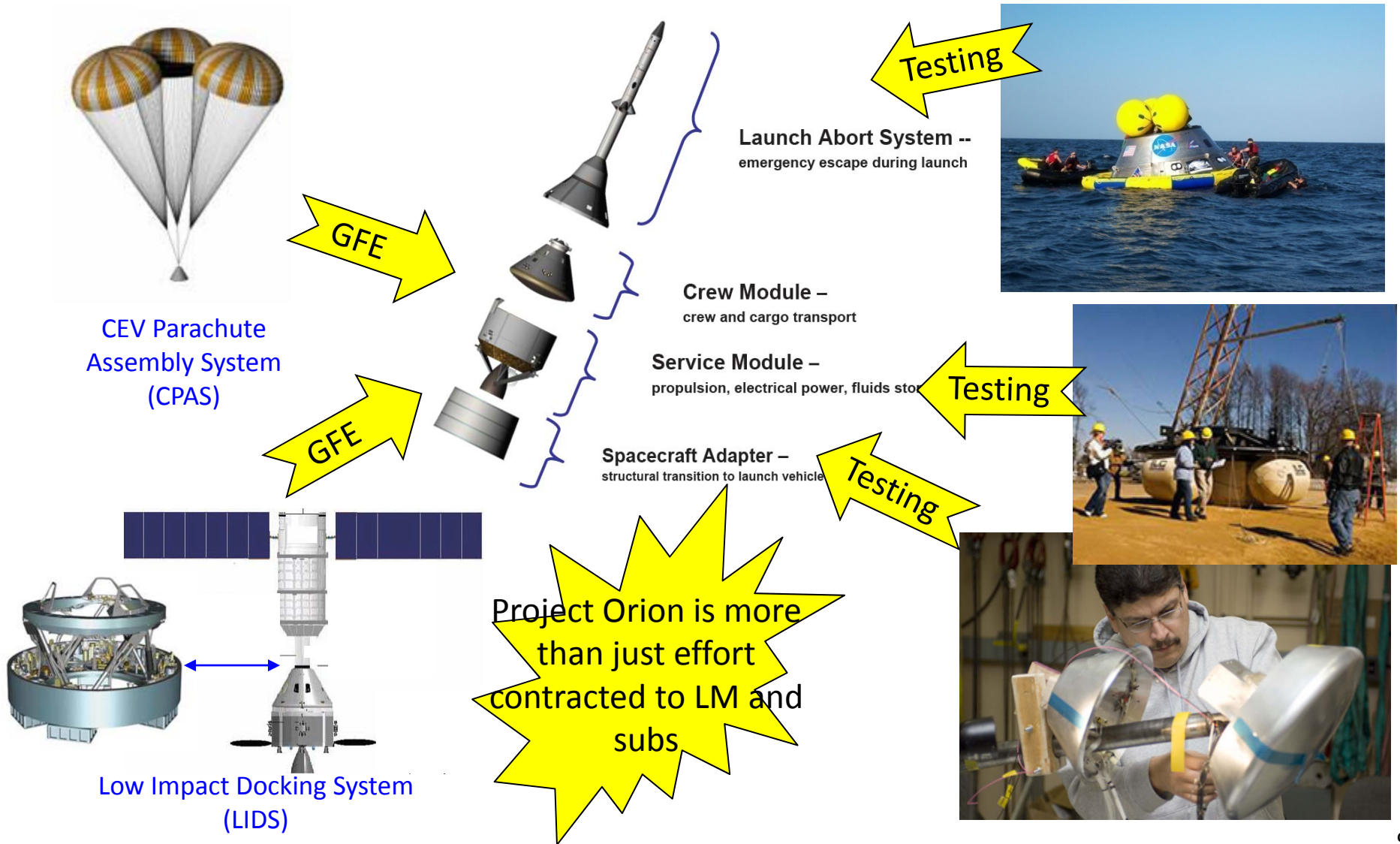
- LOCKHEED MARTIN**
- **Michoud**
  - CM and SM Structures

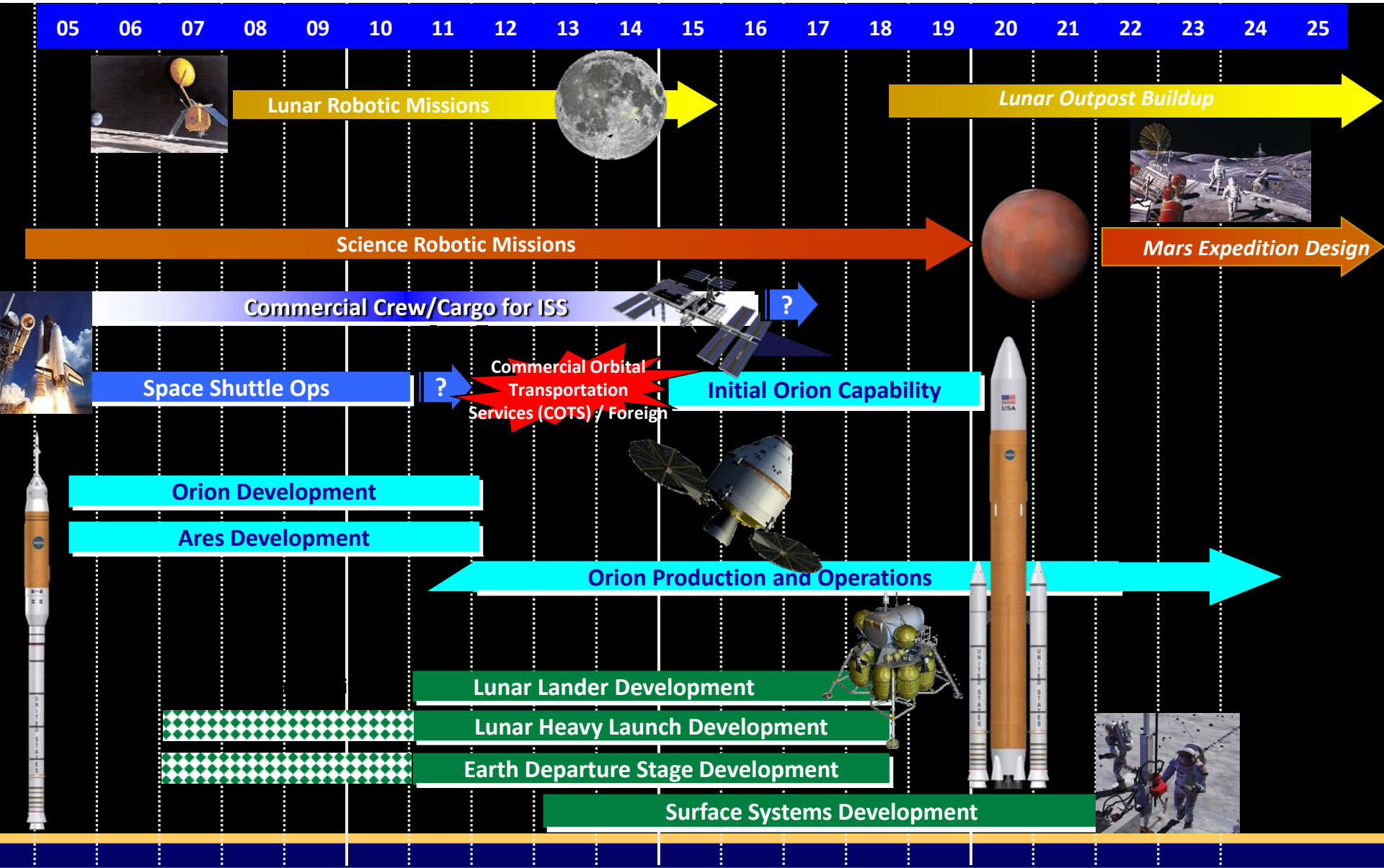
- LOCKHEED MARTIN**
- KSC**
- Final Assembly
  - Checkout
  - Acceptance Test
  - Sustaining Engineering
  - Spacecraft Refurbishment







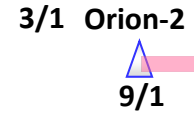
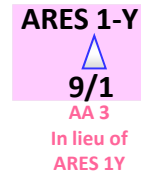
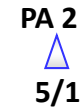
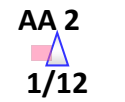
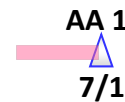
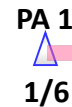
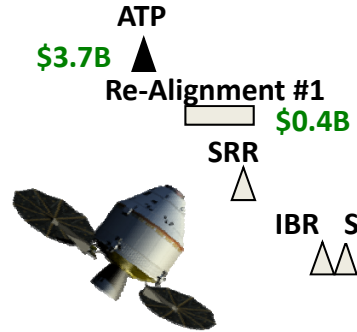




# Major Milestones



FY-2006	FY-2007	FY-2008	FY-2009	FY-2010	FY-2011	FY-2012	FY-2013	FY-2014
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- National Priorities
  - Augustine Panel recommendations under review
- Cost & Schedule
- Technical



# KSC Operations & Checkout



- **Orion completed PDR milestone (10% equivalency)**
  - Many subsystem manufacturing process have been defined
- **Orion heading for CDR (complete 2011)**
  - Many subsystem manufacturing process will be written into stone
  - Influence MRB and ERB process?
  - TRAINING, TRAINING, TRAINING?
- **Lesson Learned from Shuttle**
  - Design Engineers incorporating “Green Engineering” principals/properties in Sub System Designs
    - Incorporation of environmentally friendly alternatives (materials, processes etc)
  - Shuttle Environmental Assurance (SEA) team Template
    - Obsolescent issues, future impacts pending legislation, common problems, alternatives analysis etc
- **GREEN ENGINEERING CHALLENGE - FOCUS ON A “PROGRAM”**
  - \_\_\_\_\_ Green Engineering Summit
  - Location: \_\_\_\_\_ Colorado
  - Date: \_\_\_\_\_ 2010 (before CDR)
  - Showcase a National Program – “FACE ON GREEN ENGINEERING”

- **Purpose:**
  - Integrate pollution prevention into Space systems
- **Objectives:**
  - Enhance system performance
  - Reduce total ownership costs
  - Reduce environmental, safety and occupational health (ESOH) risks / burdens
- **Scope:**
  - Identify, research, demonstrate, validate and implement material substitutions and process improvements
- **Partners: NASA, DoD, International Partners**

- 
- A circular inset image showing a playground with children playing on a blue mat. A chain-link fence is in the foreground, and trees and a yellow structure are in the background.
- **Programs**
    - **Space Lift Launch Coatings**
    - **Hypergolic Rocket Fuels**
      - **Microwave Scrubber**
    - **Range Operations**
      - **Composite Structures**
    - **Internal Ohmic Value Recovery (IVOR)**
    - **Cold Spray Technology**





## *Space Lift Launch Coatings*

- **Purpose: Demonstration/Validation of Space Lift launch coating systems**
  - **Select environmental friendly coatings - Low/no-volatile organic chemical (VOC), non-hazardous (non-chromate, cadmium free etc), Isocyanate free**
  - **Test coating systems on a “live” launch complex**
  - **Reduce environmental, safety, and occupational health concerns with current systems**
  - **Reduce O&M costs**
  - **Increase coating survivability and performance**

## *NASA Beach Testing*



Test Panels



NASA – Test Facility



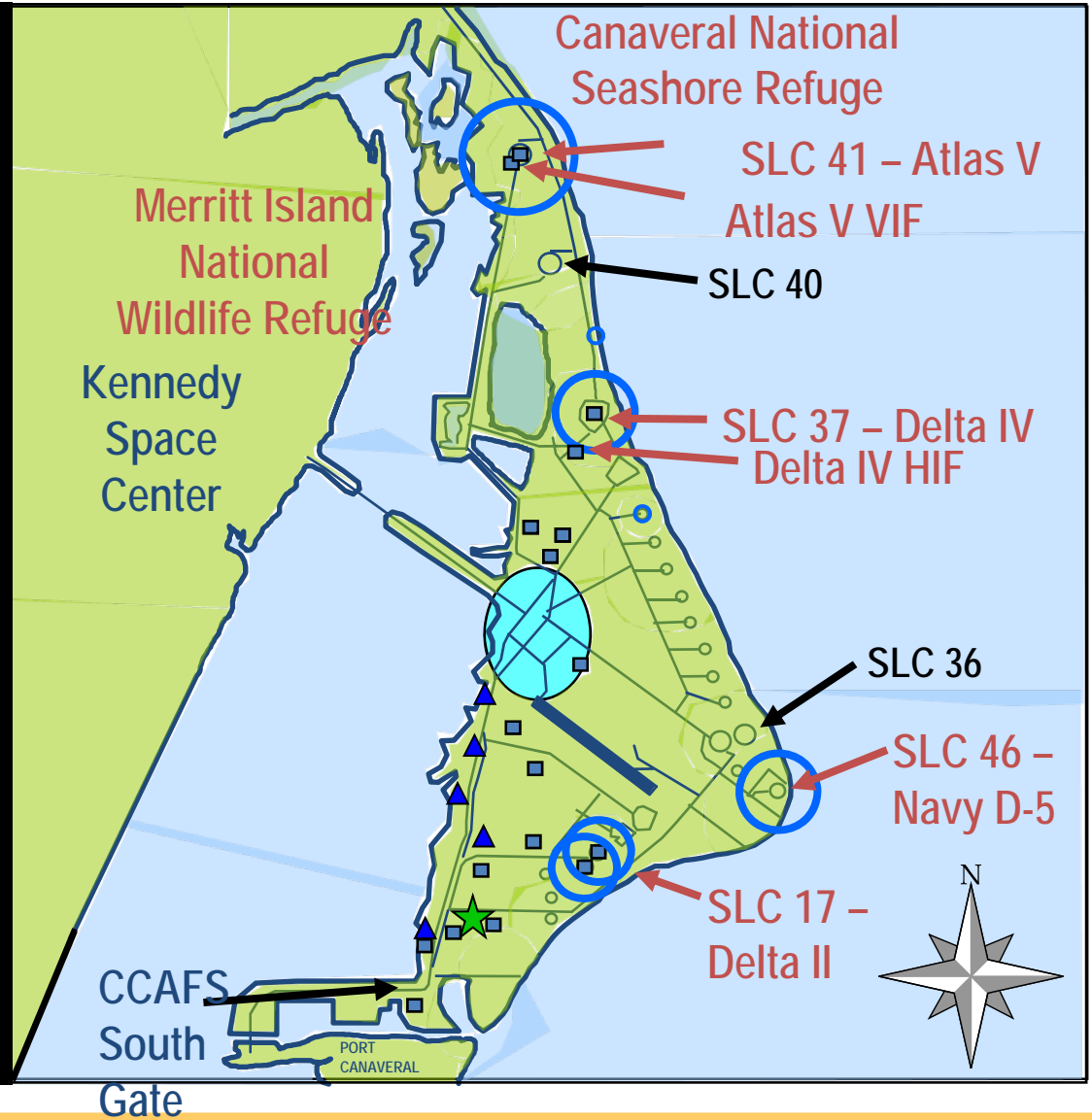
Exposure Racks



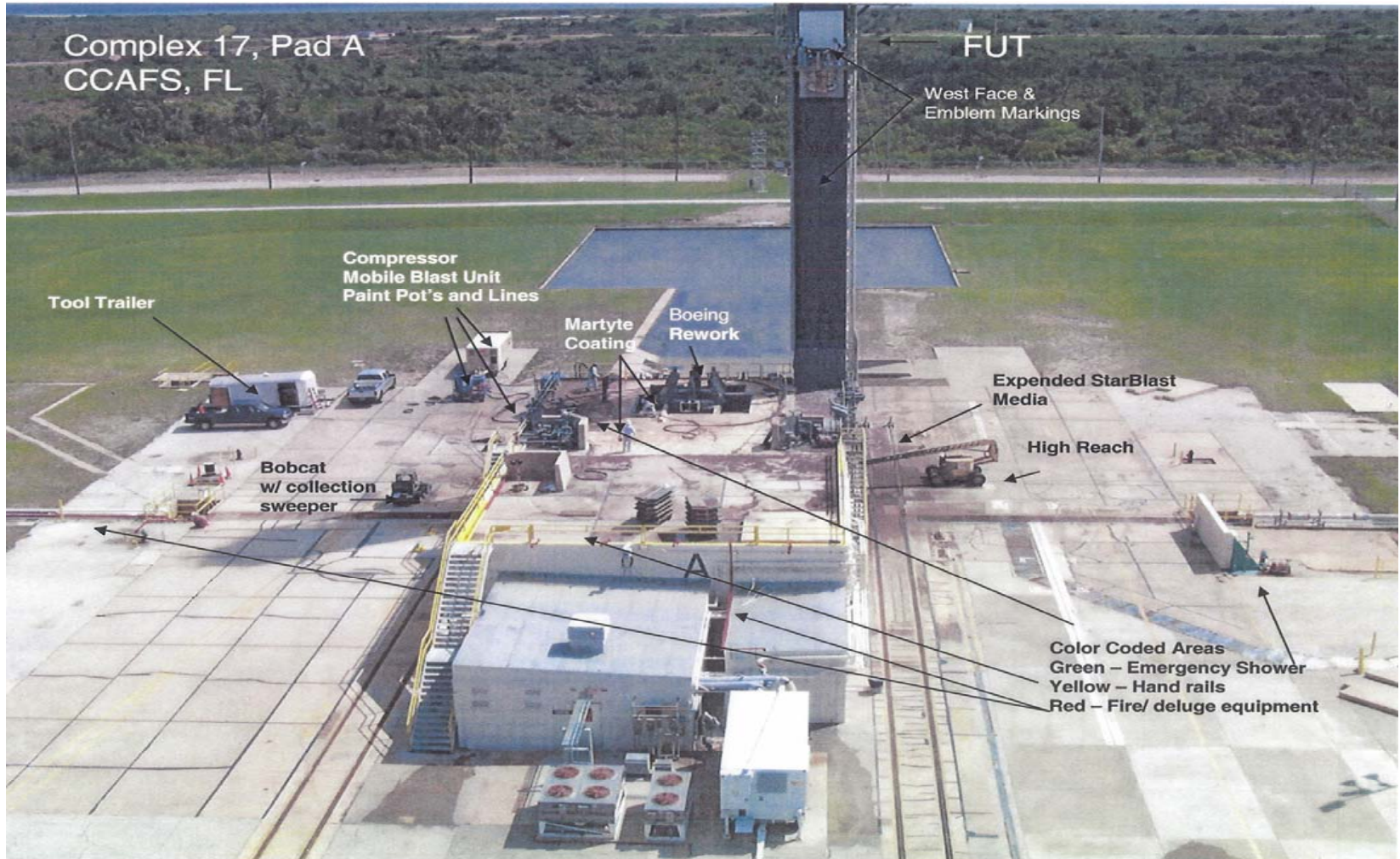
## *Launch Coating*

- **NASA completed Beach Testing on coating systems**
  - **Round 1: Two of three coatings passed 18 month beach corrosion exposure tests**
  - **Round 2: Four additional coatings in testing**
- **All coatings are Environmentally preferable systems (Non-chromate, no/low-VOC systems usable in California/Florida for Space Lift applications)**
- **All coatings passed Hypergolic compatible, High Temperature screening prior to beach test**

- Explosive pre-launch ground hazard areas (QD Arc)
- Post-launch combined Impact Limit Lines (ILL) encompass entire Cape
- Critical Facilities
- ▲ Hazardous material & fuel storage areas
- Wildlife refuge areas
  - Safety buffers
- ★ Planned admin campus
- Industrial area
  - Population center



## Cape Canaveral Testing of Launch Facility Coatings



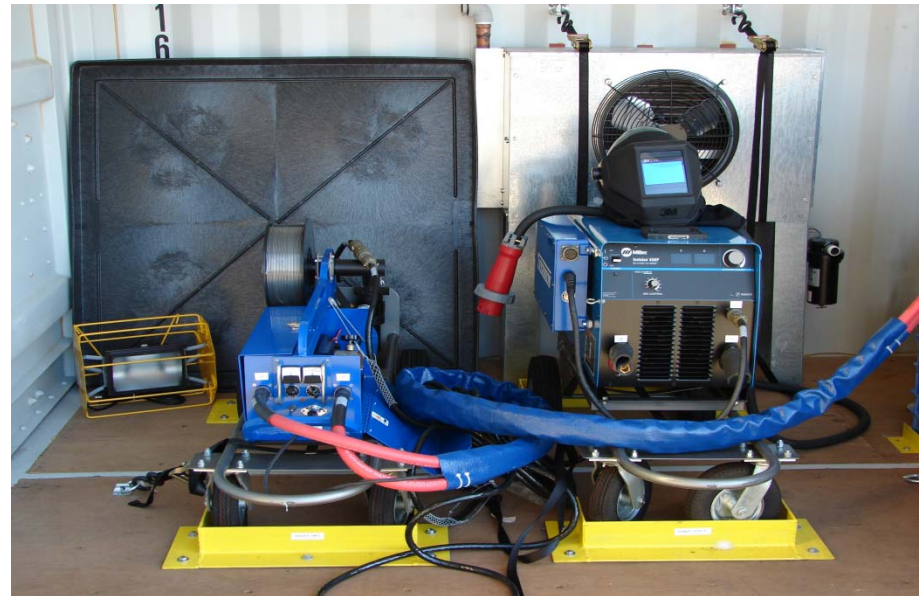
Pad B  
Blast Shield  
Deluge Pit



## Thermal Spray Program



100% Zinc metallize on removable heat shield



# Delta 2 Launch from SLC-17B





## *Thermal Spray Program*

- **Background**
  - Thermal Spray (metallization) Coating Technology identified as a replacement to existing outdated/hazardous coating systems
    - No VOCs, No Particulates, Minimal worker PPE
  - Technology application developed early 1900s. Primary usage are mild strength steels
    - Operator application was cumbersome until late 1990s
    - Manufactures began to redesign and produce compact units increasing system portability and usability
  - Launch program burdened extensively with large re-work/repair and environmental/occupational health burdens of existing coatings
  - Launch Facilities exposed to “Harsh” coastal atmospheric environments causing corrosion failures



## *Thermal Spray Program*

- **Background**
  - HQ AF Space Command initiated the evaluation of “thermal spray” technology application to Launch program
  - Sub-scale and laboratory program initiated with support of AF Research Laboratory
    - Developed Test Plans
    - Verified Corrosive Protection properties, Environmental & Health Benefits, Sustainability and Life Cycle costs
  - Developed comprehensive organizational approach to obtain buy-in on technology
  - Sub-scale tests revealed conservative 20 year life in corrosive coastal environments
  - High temperature and hypergolic compatibility testing completed
  - NASA Beach testing complete

## *Field Testing Thermal Spray Coating*

- Field Testing – Demonstration/Validation
  - Joint AFSPC/NASA Dem/Val Test Plan developed and approved
    - Live Launch Facility was approved for testing of coating system
  - Two coatings selected – 100% Zn & Al/Mg
  - Coating exposed to actual launch gases during NASA mission
  - No degradation of metallized coating after launch gas exposure
    - Versus, baseline coating system completely fails and requires replacement prior to next test launch
  - Coating approved for 2<sup>nd</sup> Launch exposure

## *Hypergolic Microwave Scrubber*



## Hypergolic Microwave Scrubber



Hypergolic Storage Facility



Hypergolic Storage tanks

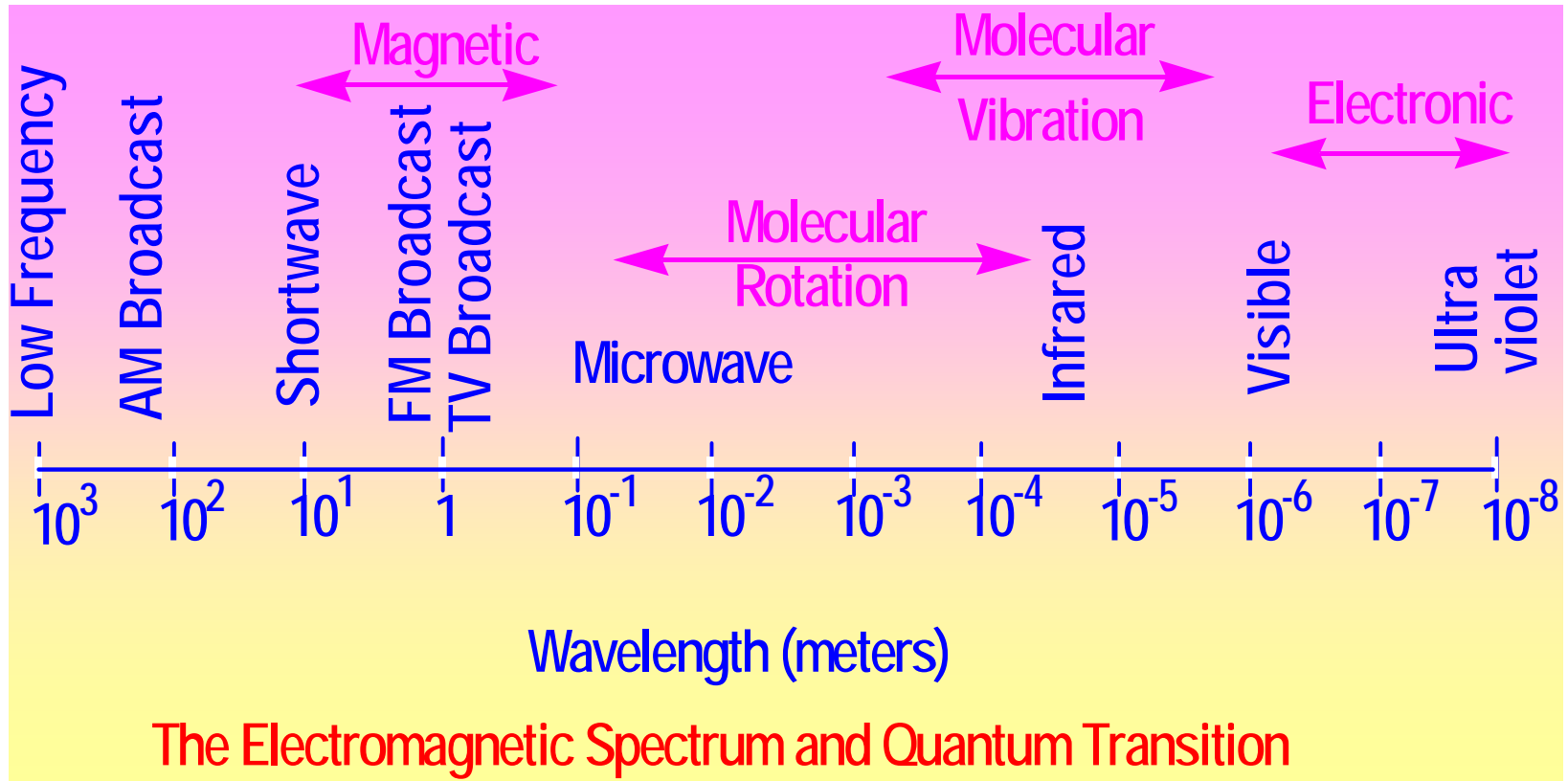


Transfer Operation



Microwave Scrubber

## Microwaves



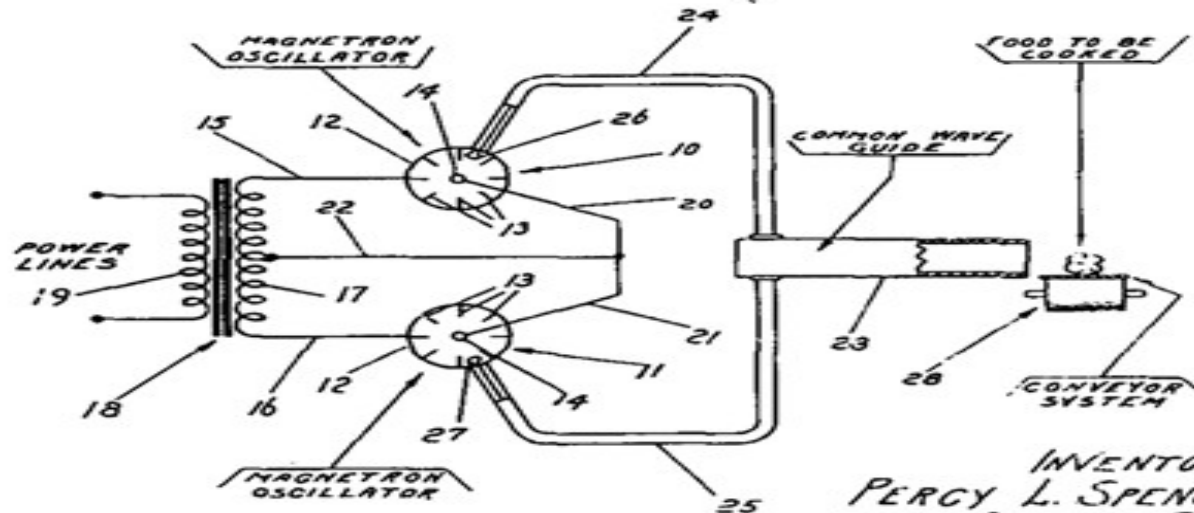
Jan. 24, 1950

P. L. SPENCER

2,495,429

METHOD OF TREATING FOODSTUFFS

Filed Oct. 8, 1945



INVENTOR.  
PERCY L. SPENCER.  
BY *Chas J. [Signature]*  
ATTY.

From Spencer Family Archives

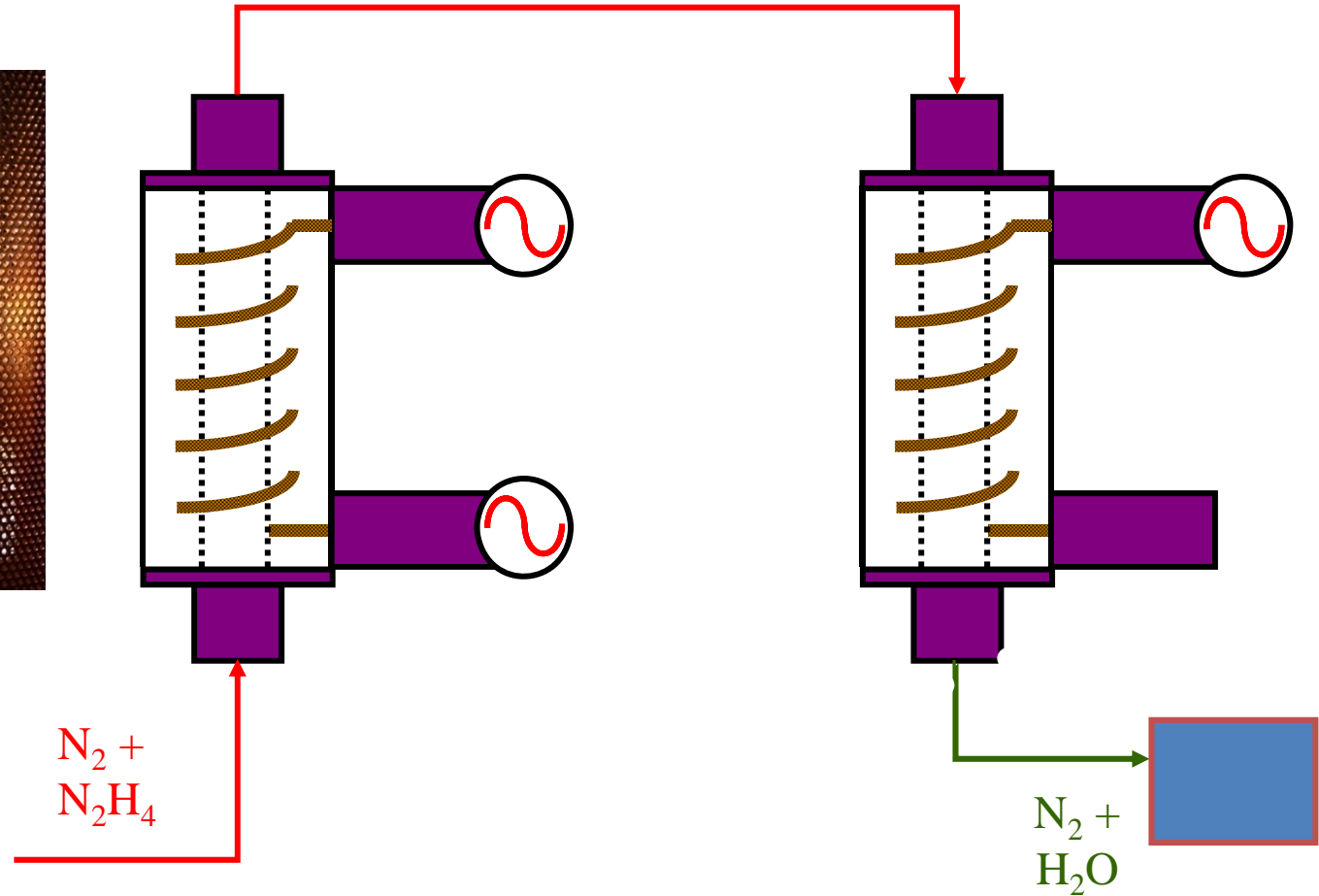
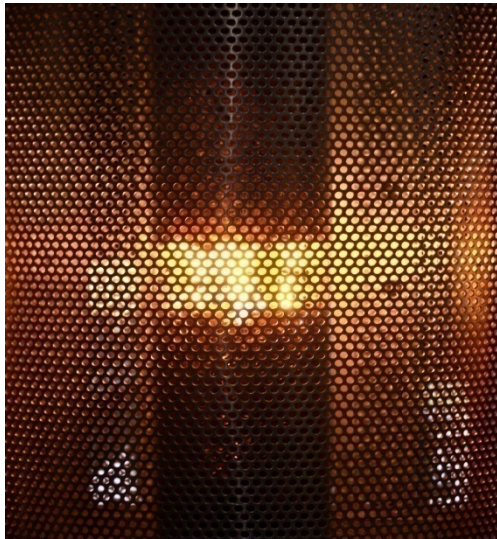


## A Brief History

- 1946: Original patent (P. L. Spencer)
- 1947: First commercial oven
- 1955: Home models
- 1967: Desktop model
- 1975: U.S. sales exceed gas ranges
- 1976: 60% of U.S. households have microwave ovens



## Hydrazine Destruction Apparatus





## Hypergolic Microwave Scrubber

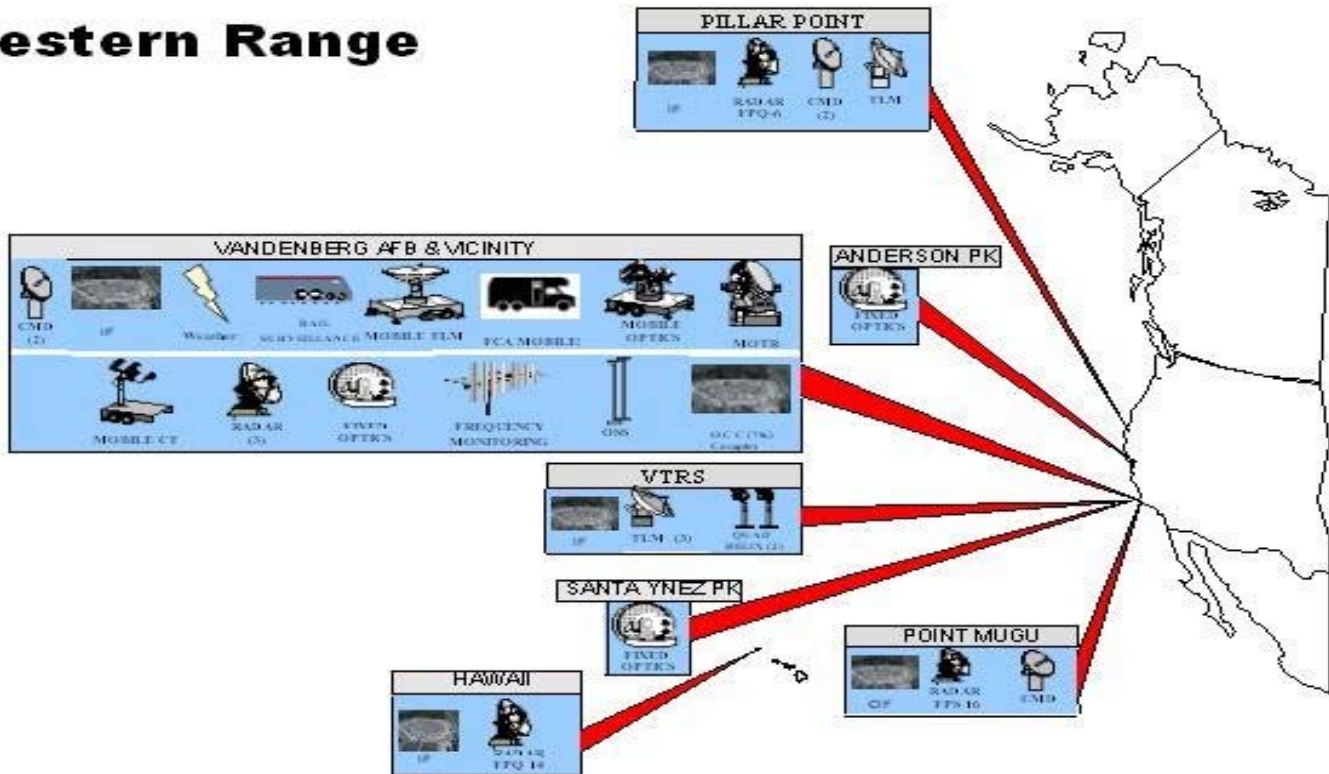


Microwave Scrubber

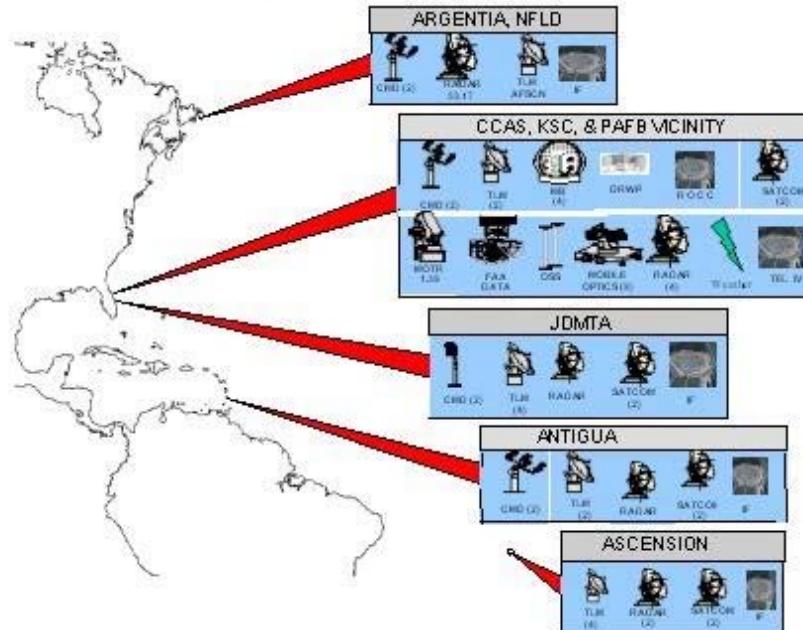
## *Range Operations*



## Western Range



## Eastern Range





# *Containment*



***Eastern Range Metallized Structure***



## Range Operations

# Composites







## ***Composite Benefits***

- Reduced Maintenance/Increased Life Cycle
  - High strength/weight ratio
  - Non-corrosive
  - Electromagnetic improvement (Non-conductive)
- Environmentally Friendly
  - Reduces hazardous waste streams
  - No painting required (Elimination of Chromates, Cadmium, Isocyanates, & VOCs)
- Innovative Designs
  - Tilt-down/freestanding design for Towers
- Easy to Transport/Install
  - 1/3 the weight of steel
  - Utilize the existing foundation

## Composite Range Towers



New composite tower



Current tower corrosion



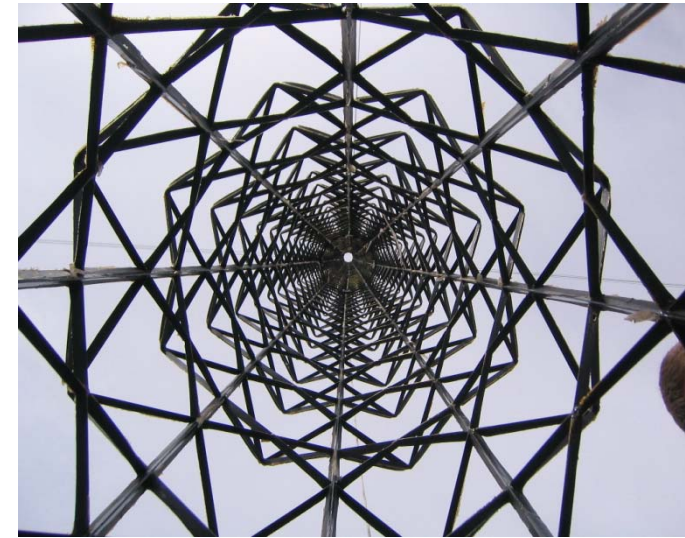


- Tower #60 at Western Range
  - 60-ft Composite Sensor Tower
- Tower #215 at Cape Canaveral
  - 60-ft Composite Sensor Tower
  - No damage to tower during hurricanes Frances and Ivan

## *Instrument Tower*



- Iso Truss
- Tilt-down composite
- SBIR funded composite technology for tower development

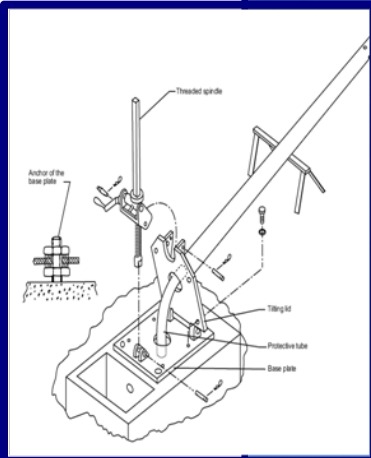
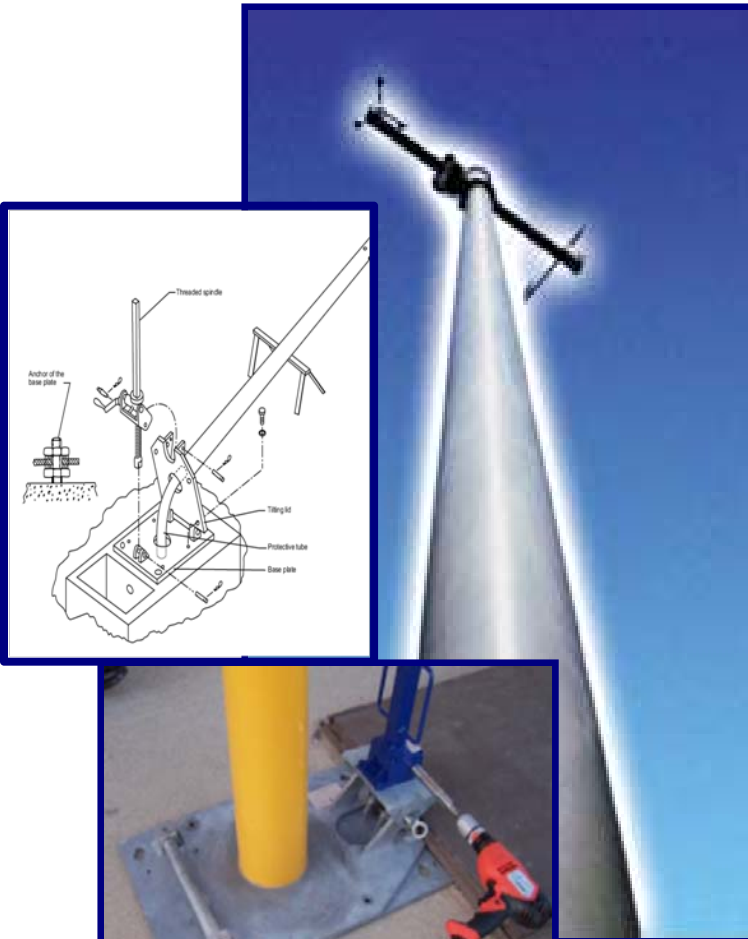


Interior View

## *Proposed Free Standing*

# Proposed Composite Tilt-down Weather Poles

- No Climbing (or man-lift) required
- Safer work environment
- Free-standing (non-guyed)
- Lowering mechanism powered by hand-drill motor
- Rapid lowering for efficient operations



- Proposed Composite Fixed Site Shelter
  - 8 ft. by 10 ft. shelter replacement
  - Lightweight
  - Improved corrosion resistance over metal shelters
  - No paint required

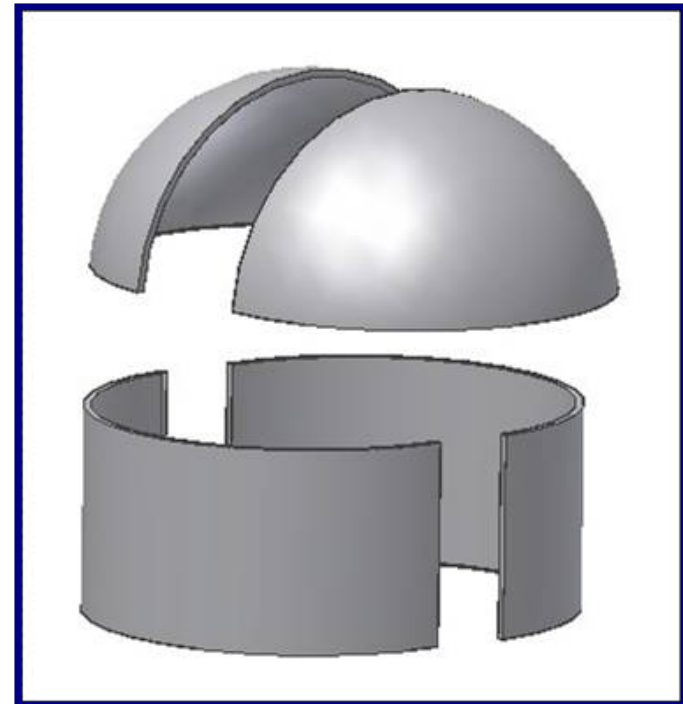


Sever Coastal Corrosion  
of conventional metal shelters

## Composite Radome

### Advanced Composite Radome

- 9-ft functional replacement
- Increased strength to withstand 212 mph winds
- Cost: \$25K vs. \$1.7Mil
- Low Maintenance with no periodic painting required



## *Internal Ohmic Value Recovery (IVOR)*





## *Internal Ohmic Value Recovery (IVOR)*

- Uninterruptible Power Supplies (UPS)
  - Utilize Valve Regulated Lead Acid (VRLA) absorbed mat batteries
  - Single cell – 1000's installed per location such as AF Satellite Control Network Stations at Onizuka and Cheyenne Mtn.
  - Current Battery Life of 5-7 years
- IOVR technology claims to restore capacity and extend useful life through rehydration and insertion of catalyst vent cap
  - Philadelphia Scientific Battery Research & Testing
  - Process catalyst removes excess oxygen
  - Permits negative plate to recharge
  - 12 battery strings under testing

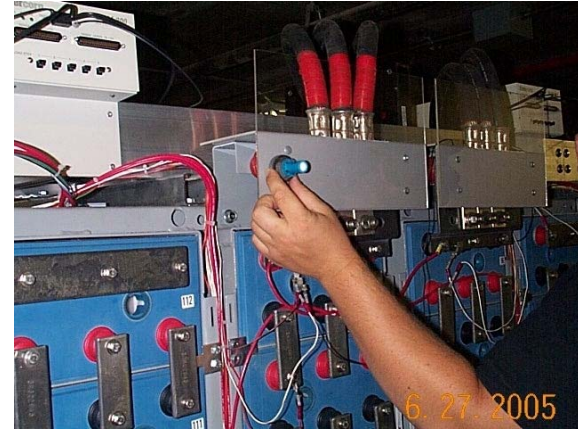
## *Internal Ohmic Value Recovery (IVOR)*

- Existing Battery Condition tested IAW IEEE Standard 1188
  - Internal Ohmic value recorded
  - Replaced cell water lost through off gassing and re-saturating of the mat
  - Perform Insulation Breakdown Test
  - Replace Vent Caps
  - Pressure Test Each Cell
- Install Catalyst Vent Assembly
  - Baseline battery terminal, individual cell voltage & Ohmic values
  - Reconnect Battery String

## Internal Ohmic Value Recovery (IVOR)



Battery String

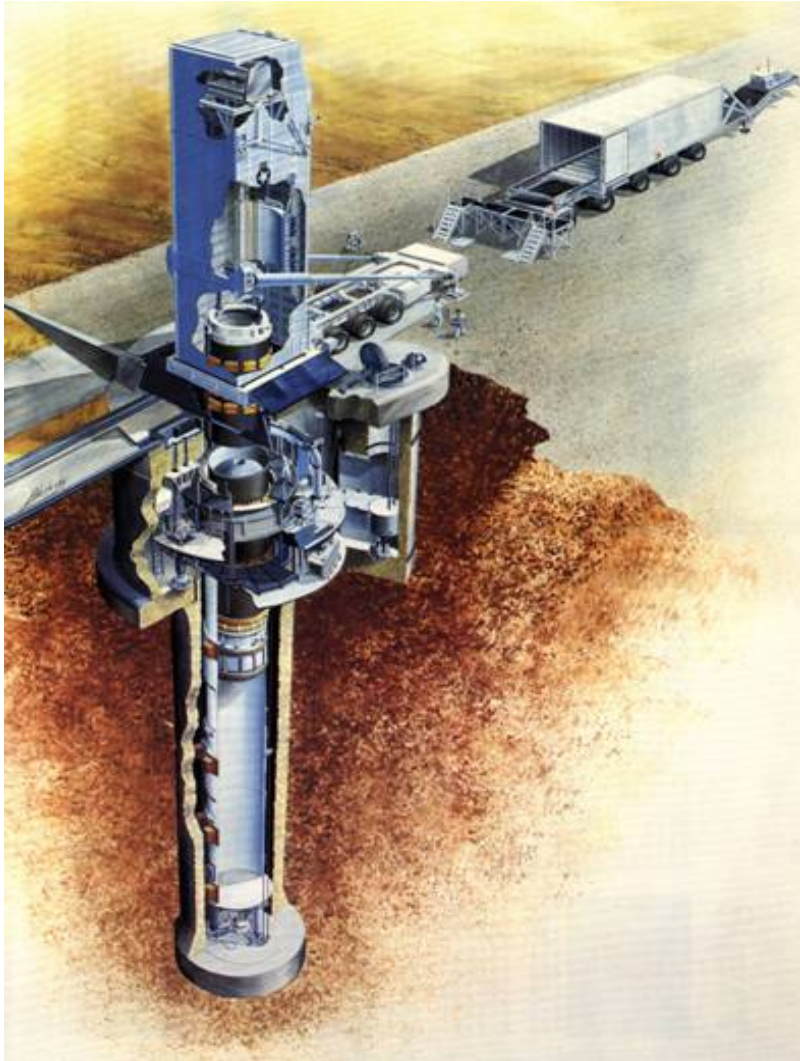


Catalyst cap



Catalyst Cap installation

## Demo/Validation Kinetic Energy - Cold Spray Technology



Test



Exposure





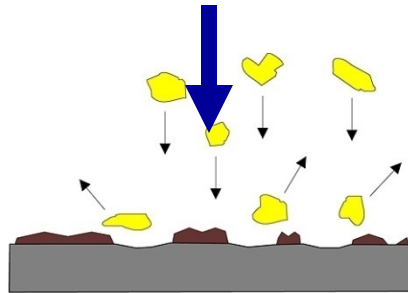
## Gas Dynamic Spray

- Industry referred as “Cold Spray” or “Kinetic Energy”
- Russian systems developed in the mid 1980’s
- Gas media used to accelerate particles to supersonic velocities
- Dual capability – surface preparation & surface coating application in one unit
- Environmentally Friendly – No Chromates, No VOCs, Isocyanate Free
  - Equipment under Review by State of California for “open air” use environmental certification

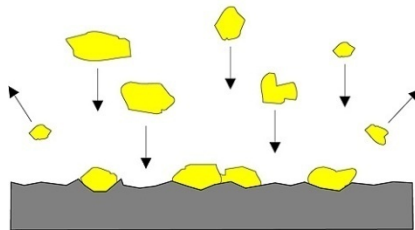
## Gas Dynamic Spray

### Stages of Process

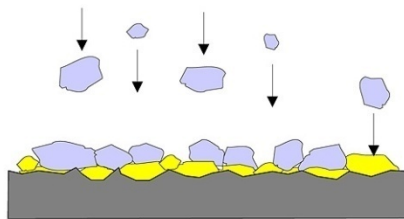
Supersonic Flow



Surface Cleaning and Activation



Formation of a Coating Substrate



Formation and densification of the layers by flow of high-velocity particles

## Cold Spray Demonstration



# Cold Spray Demonstration



## Missile Launch Equipment Cover





# Cold Spray Demonstration



## Cold Spray Demo – Launch Equipment Cover



Cold Spray unit completed both surface prep & coating application

## *NASA DoD Joint Efforts*

Launch coating  
test facilities

Laser Coating Removal  
System

Green Rocket Propellants

Launch coating  
containment system

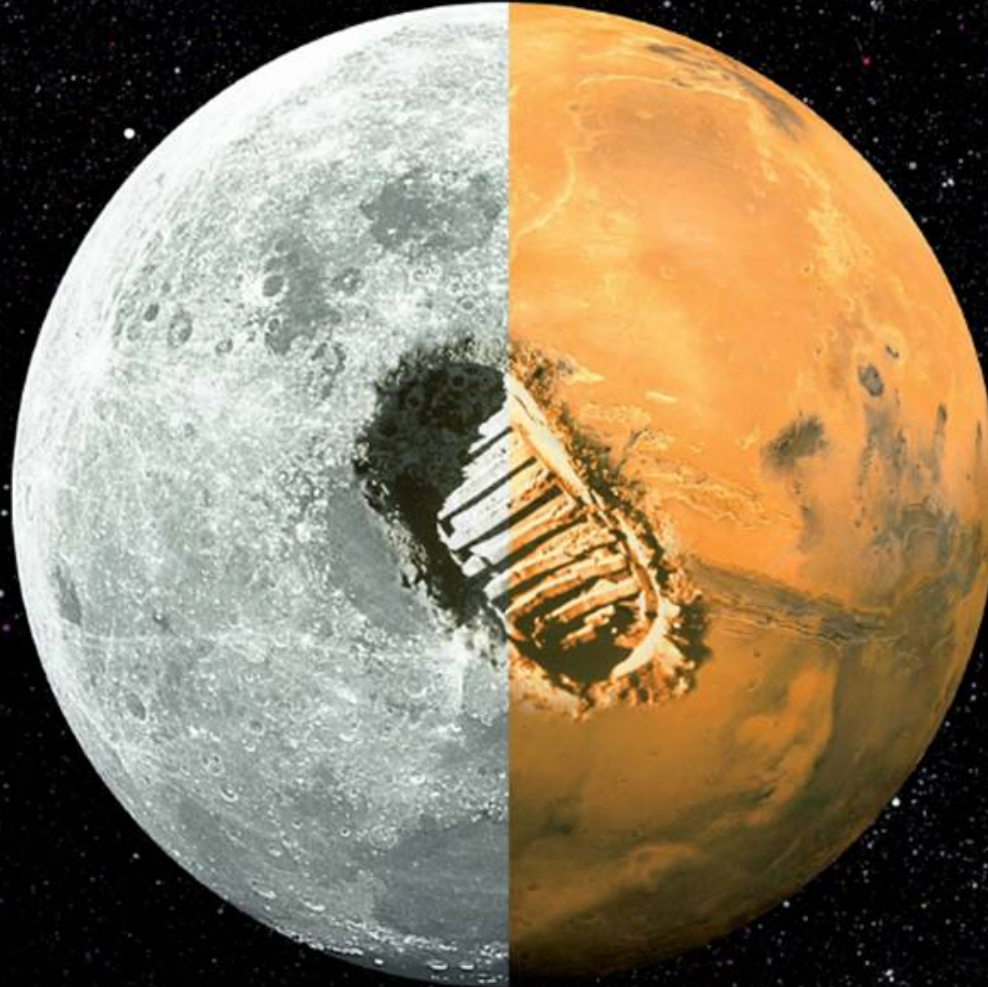
Isocyanides elimination

Lead Free Solder

Teflon reformulation



Step into the future.



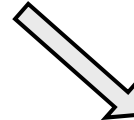
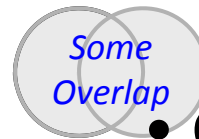
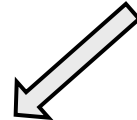
# Questions?



# Back Up



## Two Separate Delegations



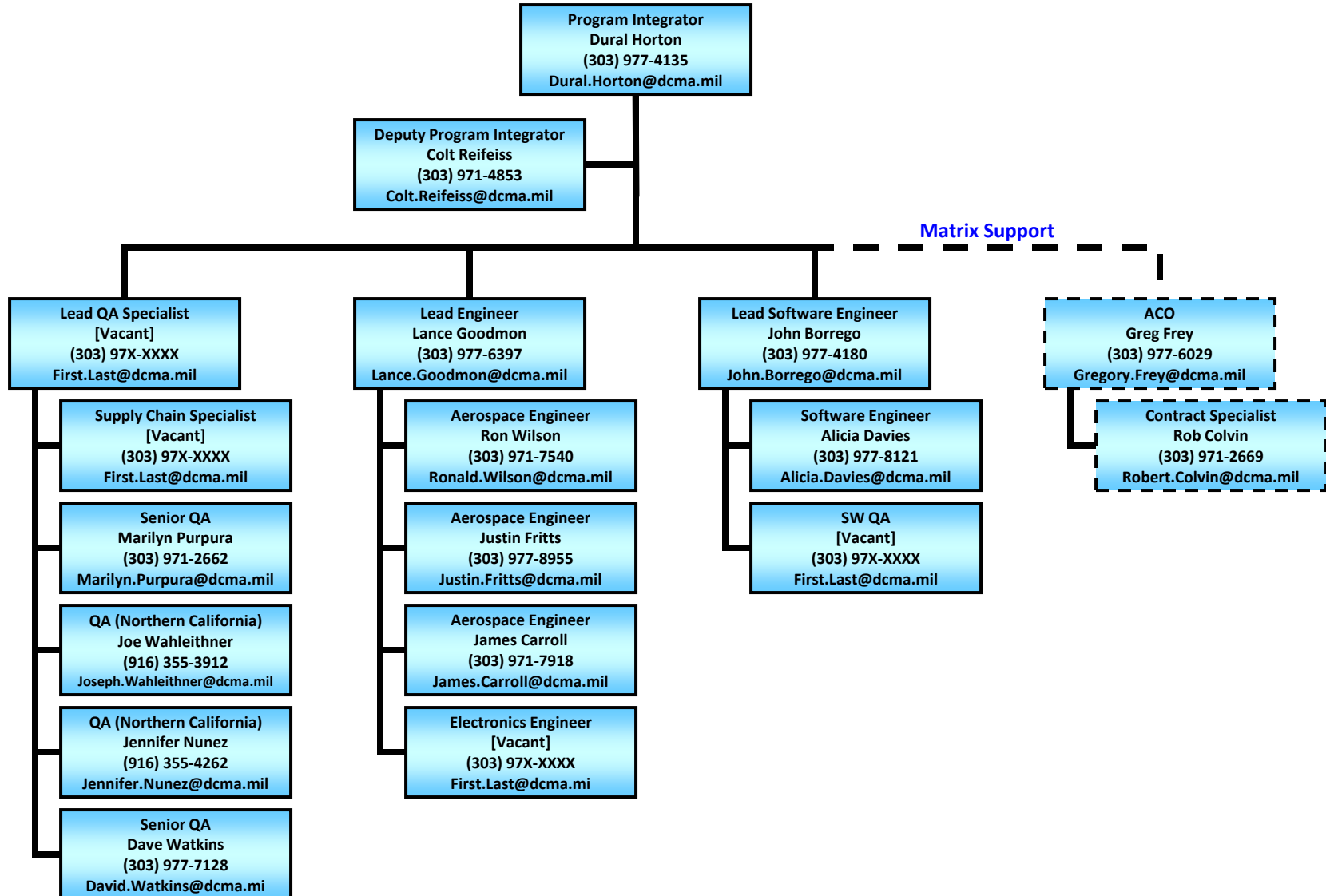
### Product Assurance

- Customer
  - Orion Safety & Mission Assurance
- Quality (Product) Surveillance
  - Document Reviews
  - Product Assurance
    - Design / Dev Eng Assessments
    - Government Mandatory Inspection Points (GMIPs)
  - Record Reviews
  - Quality System Audits
  - Limited MRB Authority
  - Safety (Explosives)
    - Indemnification

### Contract Admin / EVMS

- Customer
  - PCO
  - COTR
  - PP&C
- Business System Surveillance
  - Purchasing, Estimating, Accounting, Compensation, Subcontract Consent
- EVMS Surveillance
  - System Acceptance
  - System Surveillance
  - Project Surveillance
  - IBR Support
- Cost / Schedule / Performance Surveillance
  - FAR 42.302(a)(40)





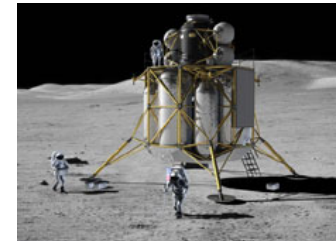
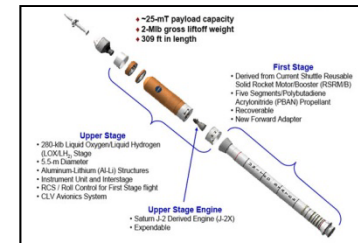


- Orion is a good technical approach for the requirements.
- Concerns:
  - Orion recurring costs high; Alternate Option - Smaller and lighter Four-person Orion could reduce operational costs:
    - Redesign of this magnitude would likely result in over a year of additional development time and a significant increase in cost,
  - Ares I behind schedule; Alternate Option – Promote commercial launch capability:
    - Possibly cheaper and quicker
    - Supplement or replace Orion / Ares I?



- Preliminary Design Review (PDR): Aug 31-Sep 1
- Working Communications and Tracking (C&T) contract mod and incorporating architecture into IMS
- Synchronizing Cost, Schedule, and Technical baseline in preparation of the CCO24 Integrated Baseline Review (IBR)
- Developing Requirements Baseline to begin Design Analysis Cycle 4 (DAC-4) on 1 Oct
  - Getting Ares I Loads Analysis
  - Working NTE Proposal for numerous post-PDR requirements changes
- Pad Abort 1 (PA-1):
  - Likely slipping to early April
    - Quallion Battery failure impacting Critical Path

- **Ares I:**
  - 1<sup>st</sup> Stage Thrust Oscillation Issue addressed
  - Issues with 5 segment test at ATK Thiokol
  - Ares 1-X scheduled for Oct 09.
  - PA-1 Apr 09.
- **Ares V:**
  - Growing in payload capacity and size:
    - Five to six 1<sup>st</sup> stage engines
    - Wider, taller
- **Altair:**
  - Conceptual Design Contracts let
  - Procurement on hold pending Augustine Panel
- **EVA:**
  - Prime Contract let to Oceaneering





# AFSPC & NASA Launch Coatings



Depaint with Blast Recovery System (BRS)



GE Ablative Application



Metallization



