



# MIT January Operational Internship Experience 2011

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# Agenda

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- Background and Introduction
- Systems Engineering
- NASA Organization
- Workforce Core Values
- Human Factors
- Safety
- Lean Engineering
- NASA Now
- Press, Media, and Outreach
- Future of Spaceflight



## JOIE Program

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- 3 week program at KSC
- Allows students to study
  - Operational aspects of spaceflight
  - How design affects operations
  - Systems engineering in practice
- Organized by the Massachusetts Space Grant Consortium, NASA, and ESMD



# The Team



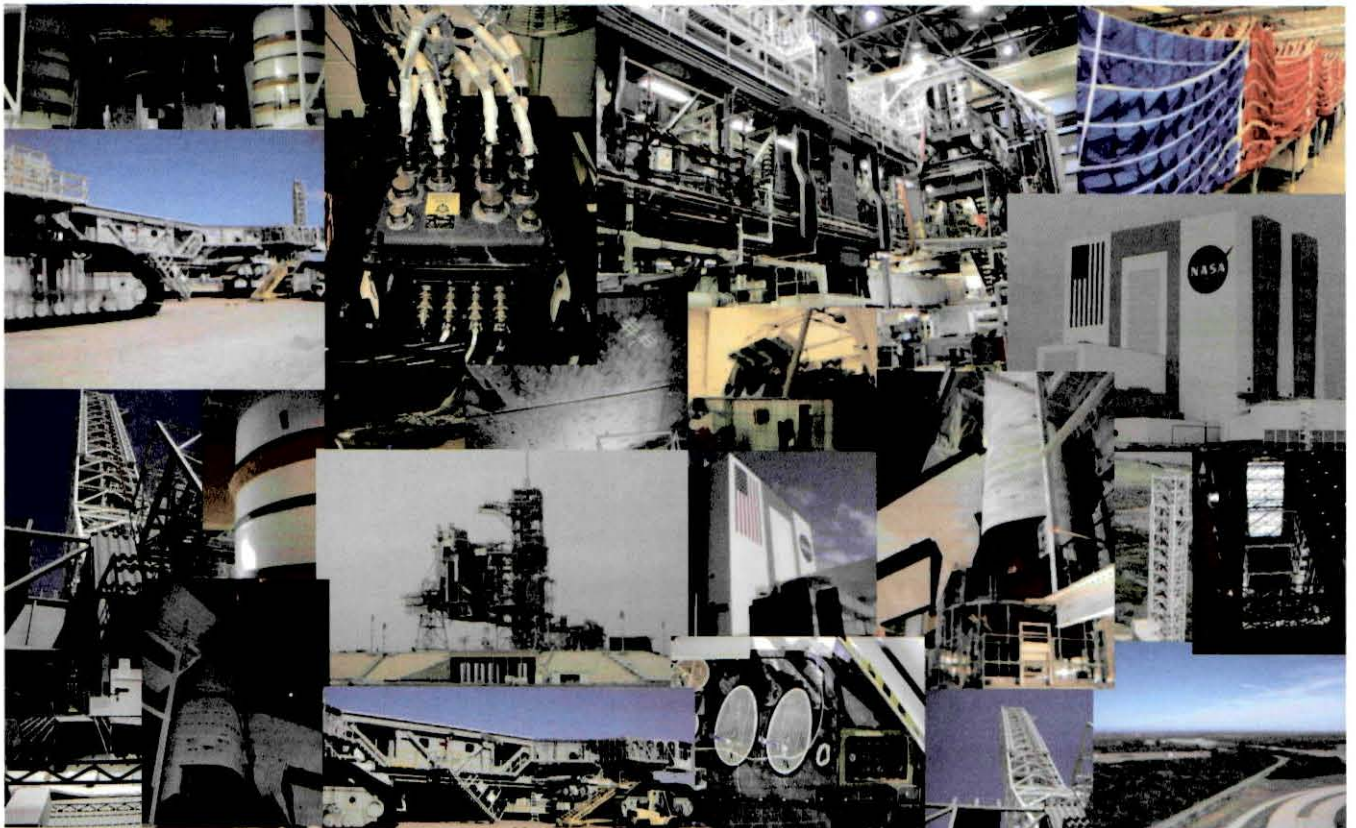
- 7 MIT aerospace engineers, 1 Olin College mechanical engineer
- 4 seniors, 3 juniors, 1 freshman
- Previous internship experiences include JPL, JSC, SpaceX, and Orbital Sciences
- Interest in human factors, design, lean engineering, materials, propulsion, controls and analysis







# Our Experiences



1/25/11

January Operation Internship Experience

5



# CDIO





# SYSTEMS ENGINEERING

1/25/11

January Operation Internship Experience

7



# Systems Engineering

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- Big Picture Approach
  - Integration of diverse systems
  - Optimization through trade-offs
- Iterative
  - Multiple rounds of development and review



# Purpose



“... to ensure safety and mission success,  
increase performance, and reduce cost.”

~ NPR 7123.1

Product Hierarchy &  
Division of Labor

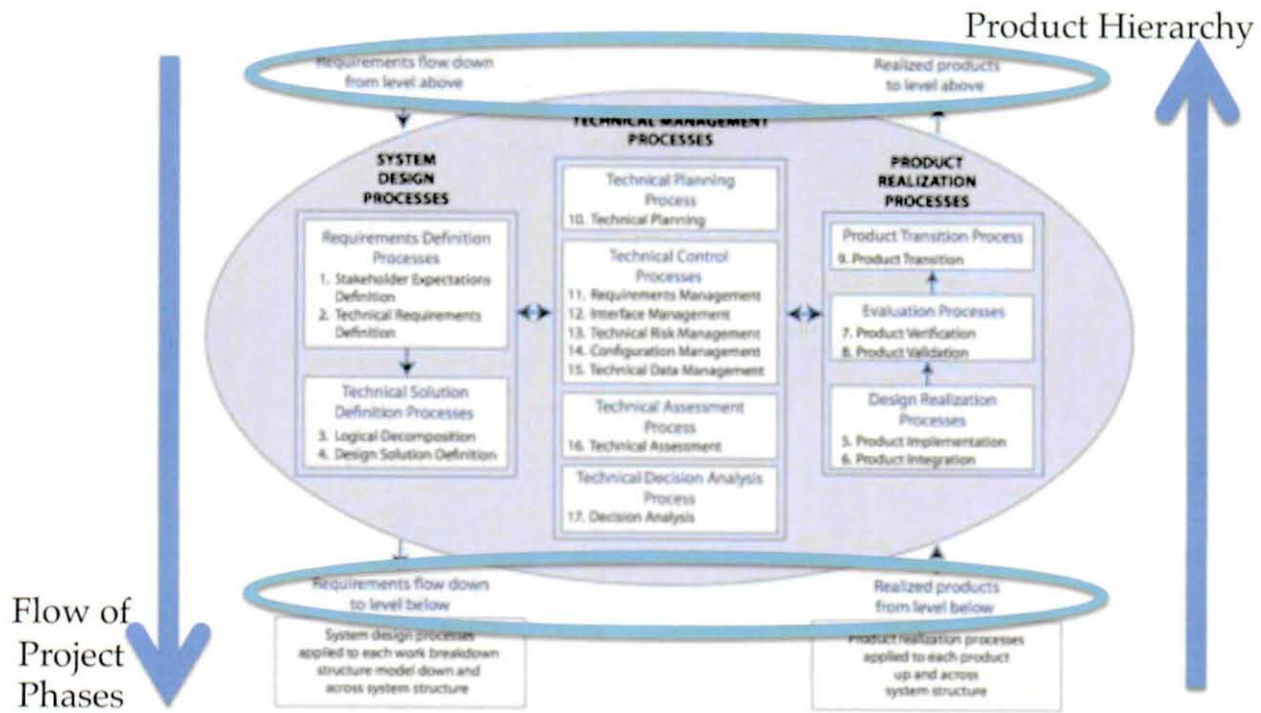
Effectiveness / Cost  
Envelope

Project Phases &  
Approval Mechanisms





# Method: SE Engine

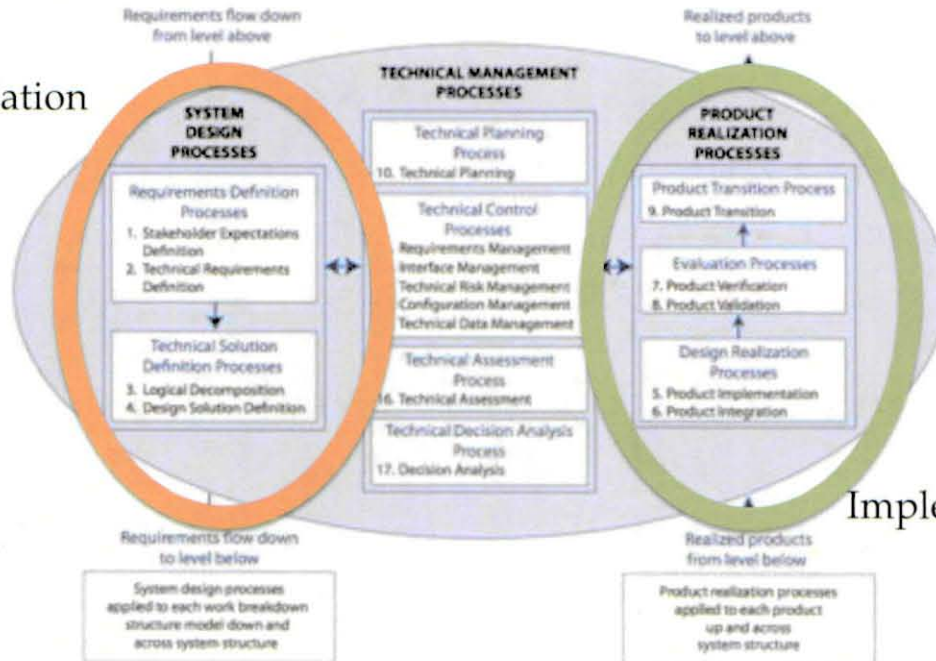




# Method: SE Engine



Formulation



Implementation



## Constellation

- Phase A: Concept & Technology Development
  - Fire & Rescue working with Orion capsule designers
- Phase B: Preliminary Design & Technology Completion
  - Orion capsule mock-ups
  - Constellation Mobile Launcher





# Implementation



## Shuttle Operations

- Phase C: Final Design & Fabrication
  - Manufacturing of Shuttle tiles
- Phase D: System Assembly, Integration & Test, Launch
  - Preparing Atlantis in OPF
- Phase E: Operations & Sustainment
  - ET stringer repairs
- Phase F: Closeout
  - USA Logistics team





## Logistics: Resources and Schedule

- Changes over a project's life-cycle
  - Manufacturers
  - Product demand
- Integration
  - Verification of product
  - Validation of system





## Observations

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- Within each system, designs must be balanced and forward-looking
  - Practicality & safety
  - Saving space vs. maintenance
- Integration of systems facilitated by required interactions between teams
  - Agreements between KSC and other centers
  - Chain of command for different tasks



# CONTRACTORS



# NASA Organization



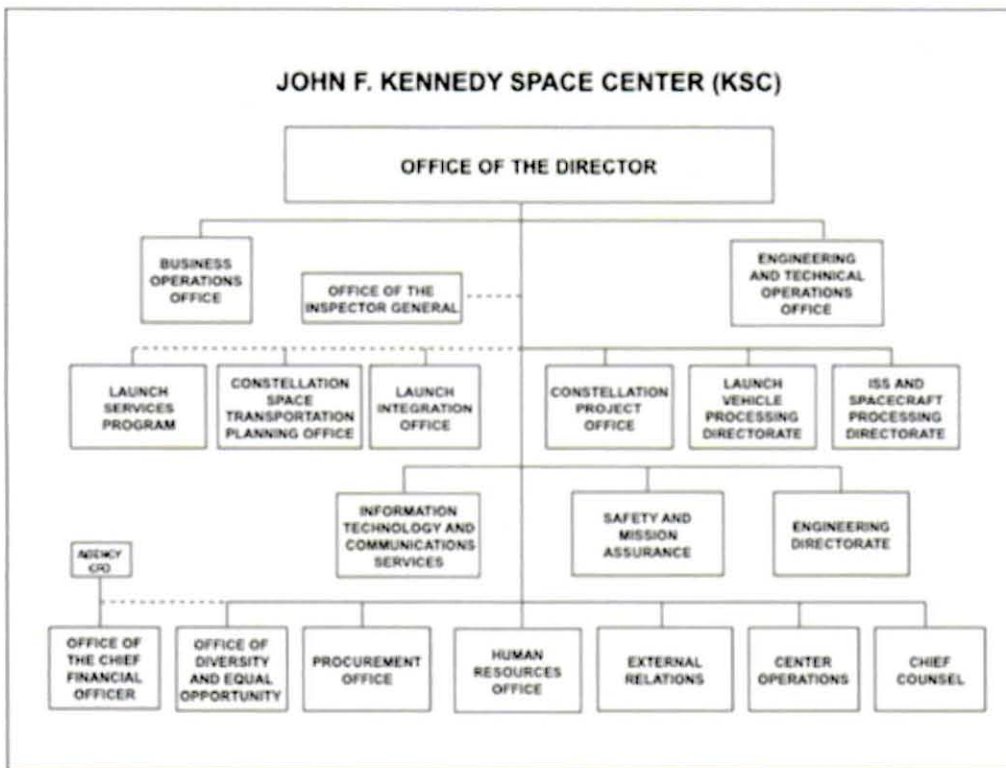
- Bureaucracy
  - Constellation Cancelled
  - Continuing Resolution
- Procedures
  - Documentation
  - Work Approval Process



*Credit: CBC News*



# KSC Organizational Chart



Credit: [www.nasa.gov](http://www.nasa.gov)



# KSC Contractors



Contractor	Role
Analex	Expendable Launch Vehicle (ELV) Integrated Support.
ASRC Aerospace	Arctic Slope Research Corporation (ASRC) Aerospace provides research and engineering services and technical support to KSC.
Boeing	Supports payload processing for the Space Station, Space Shuttle, Expendable Launch Vehicles, and other payload programs.
EG&G Technical Services	Services for the operation and management of complex government installations, and military bases.
Pratt & Whitney Rocketdyne	Powers the Space Shuttle and supplies boosters for Delta II, Atlas V & Delta IV.
Science Applications International Corporation (SAIC)	Innovative applications of technology and expertise.
United Space Alliance (USA)	Prime contractor for NASA's Space Shuttle Program, responsible for the day-to-day operation and management of the U.S. Space Shuttle fleet.
Space Gateway Support (SGS)	Delivers fire and rescue support services for both the Kennedy Space Center and Cape Canaveral Air Force Station

*Credit: [www.nasa.gov](http://www.nasa.gov)*





# United Space Alliance



- Established in 1995 by Boeing and Lockheed Martin
- Sought to reduce Space Shuttle program contractors into one primary contractor
- Space Program Operations Contract (SPOC) in 2006
- Over 70% of repairs and spares for the shuttle fleet go through USA
- NASA Shuttle Logistics Depot



***United Space Alliance***



*Credit: www.nasa.gov*



## ASRC Aerospace



*Credit: www.nasa.gov*

- Vehicle Motion Simulator
- Umbilical Testing
- Cryogenics

- Launch Equipment Test Facility (LETF)
- Quality Assurance
- Rapid Prototyping



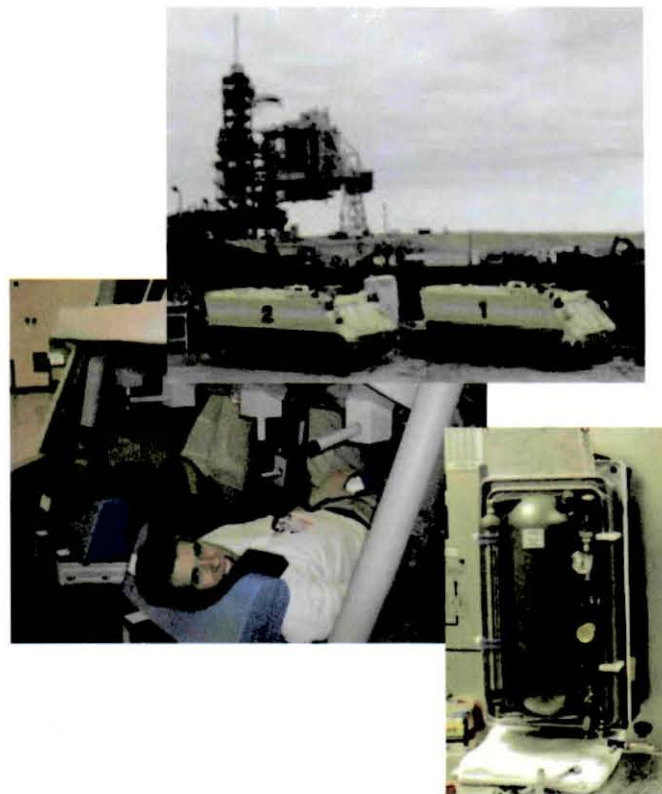
*Credit: www.nasa.gov*



# Space Gateway Support



- Shuttle Program
  - Pad rescue for shuttle
  - M113 armored personnel carriers
- Constellation
  - Orion capsule configuration for rescue
  - Liquid air SCBAs
  - Train Air Force Pararescue





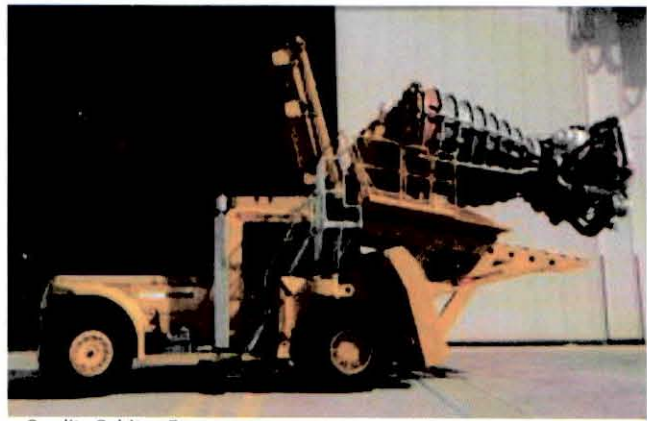
# Pratt & Whitney Rocketdyne



- Space Shuttle Main Engine (SSME) Processing
- SSMEs designed in the late 1970s



*Credit: Wikimedia Commons*



*Credit: Orbiter Forum*





SAIC



- Provides engineering expertise in
  - Systems engineering
  - Logistics
  - Integration
  - Operation
- Focuses on
  - Expendable launch vehicles
  - Consulting for Constellation program







# NASA-Contractor Interaction



**AEROJET**



**LOCKHEED MARTIN**



**SAIC**  
From Science to Solutions



**NORTHROP GRUMMAN**



**Honeywell**



**Raytheon**

**Orbital**

**BOEING**

**ATK**



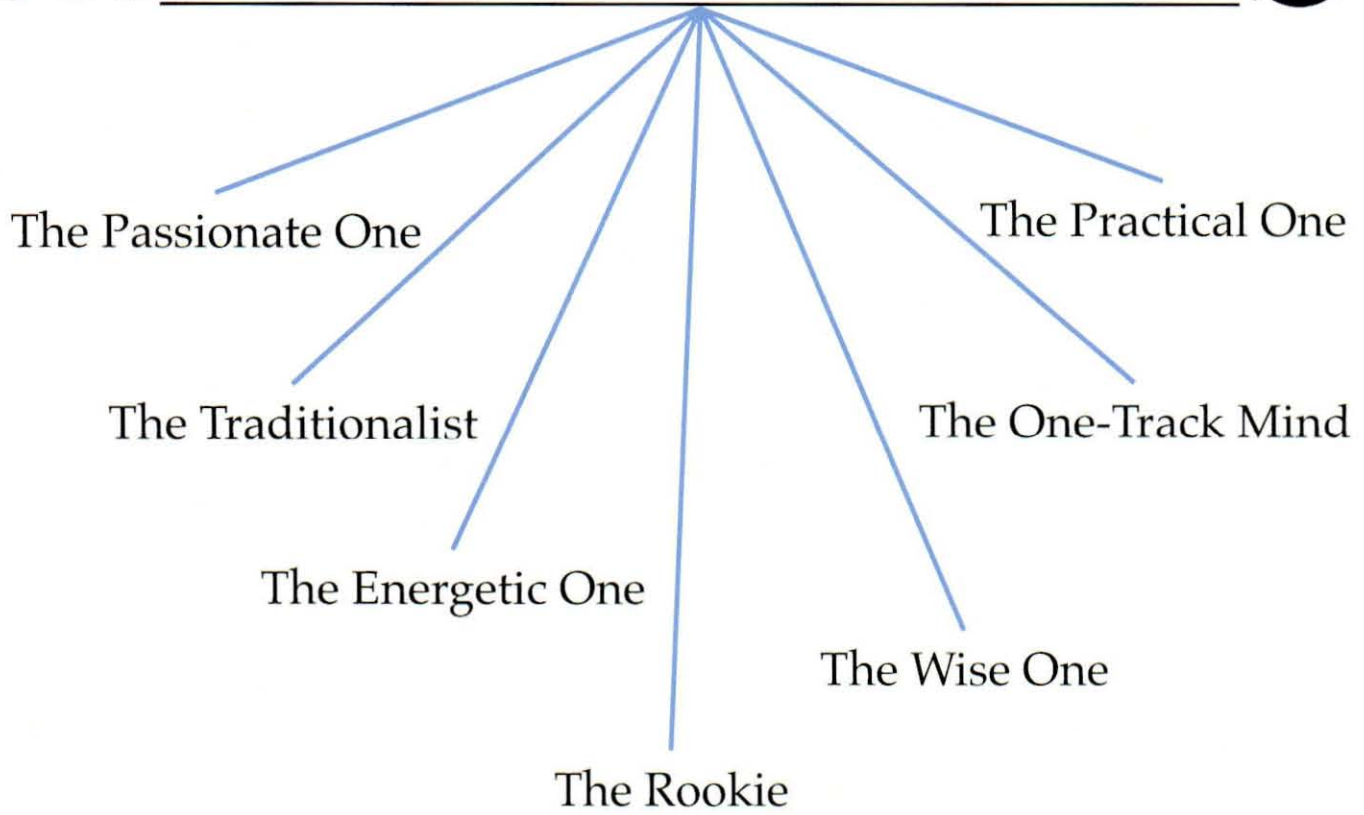
# PEOPLE & CULTURE



- Constraints and interests for a design have all been set by people
- People working together form as important a group as the technical portions
- Workforce, culture, and values are parts of that system

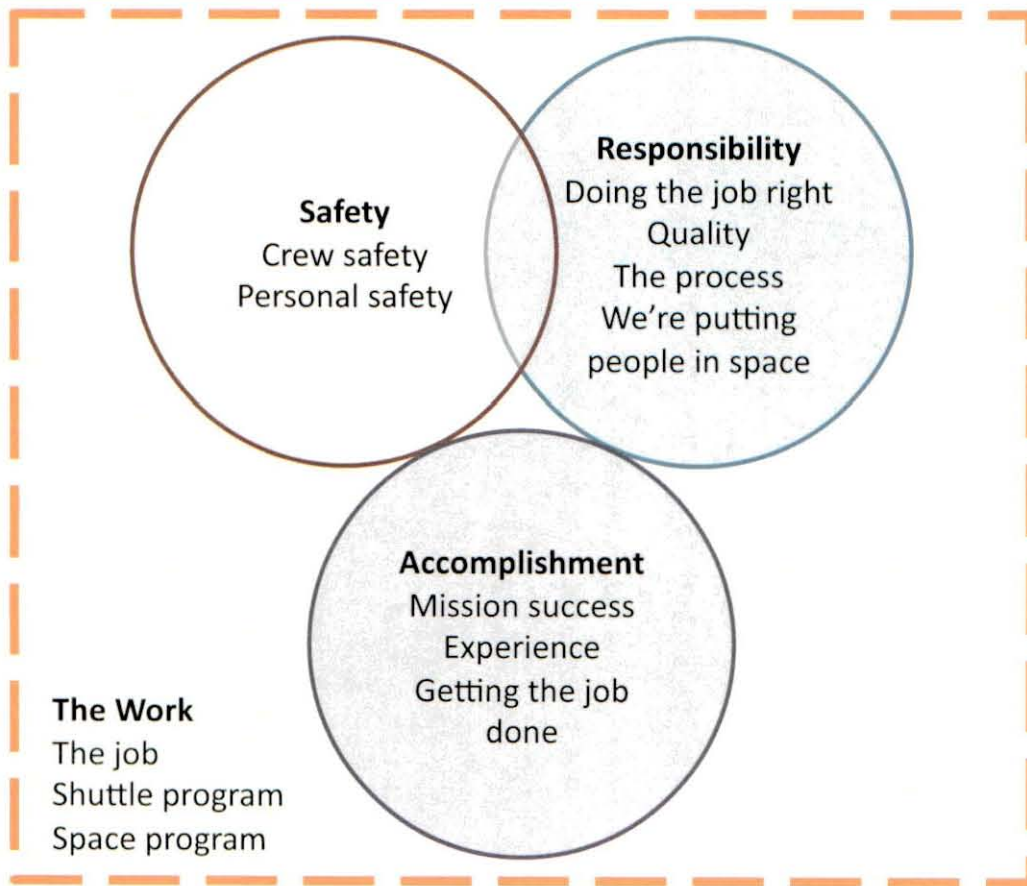


# Types of People





# Values







# HUMAN FACTORS



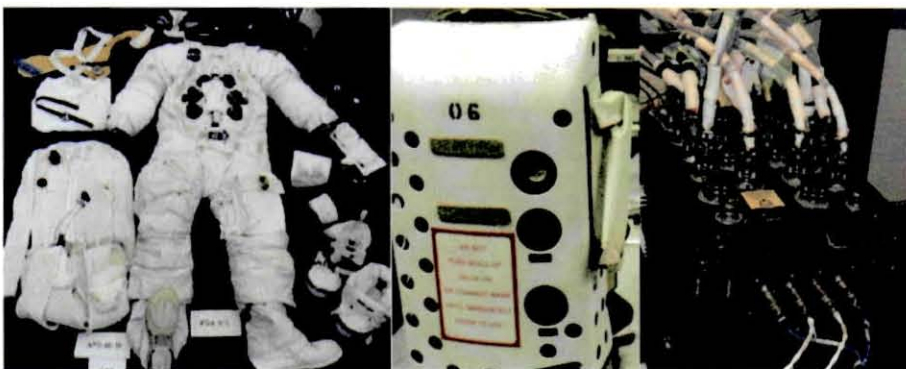
# Human Factors



- Human factors design rules:
  - Safety
  - Ergonomics
  - Work space design
  - Human/robot interaction:  
supervisory control



*Credit: www.nasa.gov*



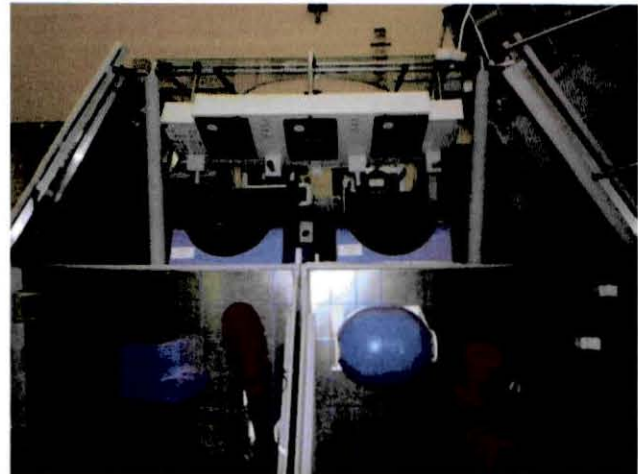
*Credit: www.nasa.gov*



# Human Factors: ORION



- Visual access
- Reach
- Work space
- Technical: ground system to Ares I opening and first stage to upper stage opening



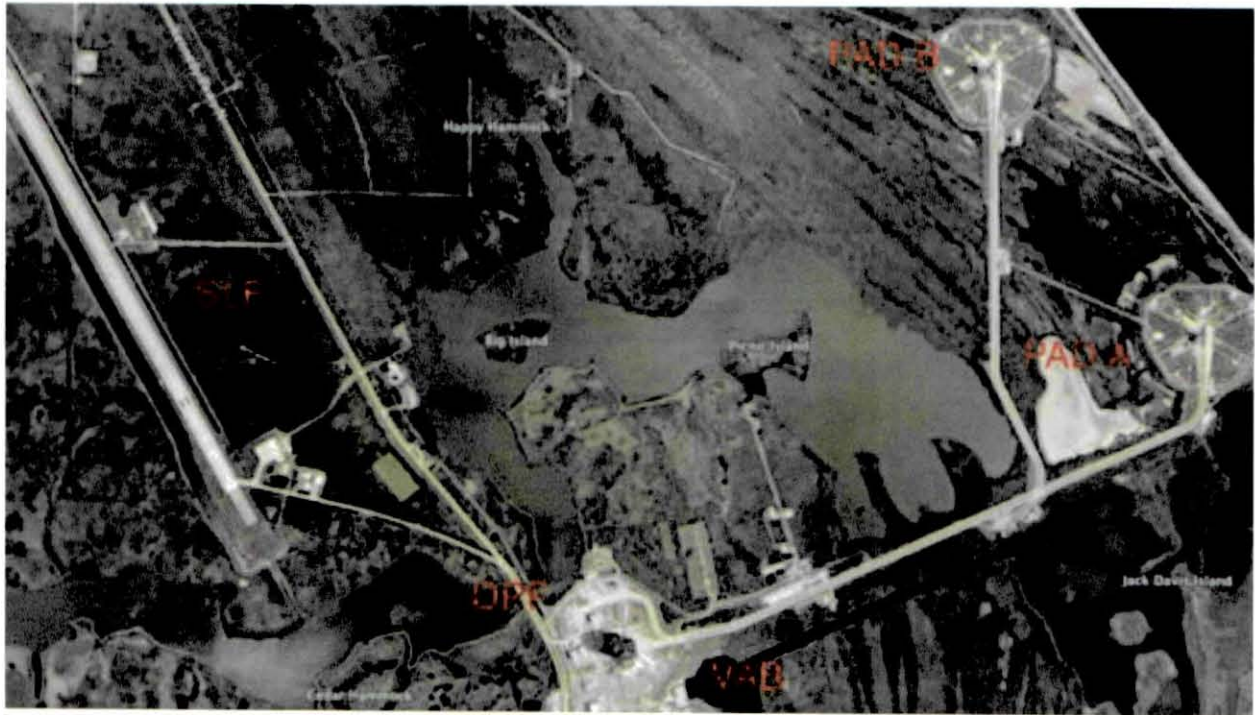


# LAYOUT





# KSC layout



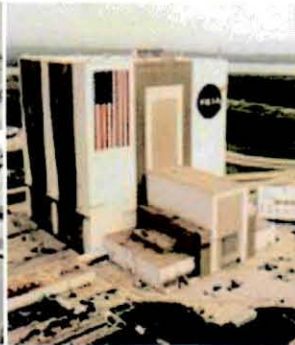
*Credit: Google Maps*



# KSC layout



Operational Processing Facility (OPF)



Vehicle Assembly Facility (VAB)



Mobile Launch Platform (MLP)

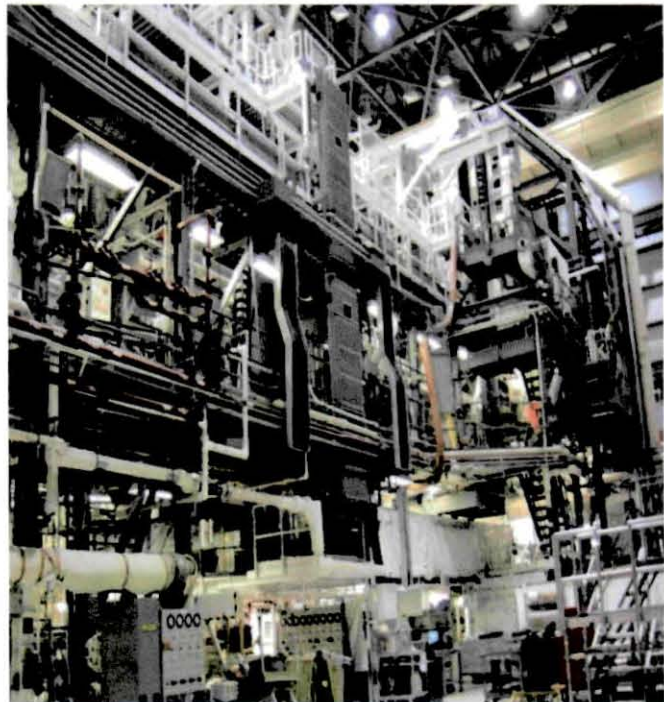


Launch Platform 39-A 39-B



# SAFETY

- Prevention, protection, and handling of hazardous elements
  - Human safety
  - Service equipment
- Communication is key





# Human Safety



- Astronauts
  - Most important payload
  - Familiarize crew with logistics
- Ground / Crew Support
  - Fire Rescue Team
  - Protective equipment







# Service Equipment

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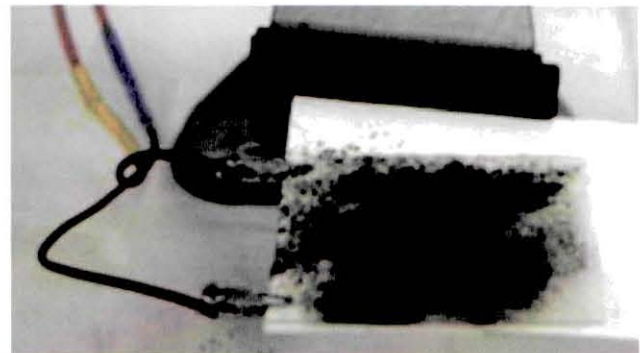


- HAZMAT
- End User Friendly
  - Intuitive
  - Redundancy
- Inspection/Testing
- Maintenance





- Safety motivated research
  - Corrosion Lab
  - Electrostatic and Surface Physics Lab
  - Regolith and Granular Lab



*Credit: www.nasa.gov*



# ACCIDENTS

- Type and severity range
- Always should be a learning experience
- NASA accidents can be very public and high profile



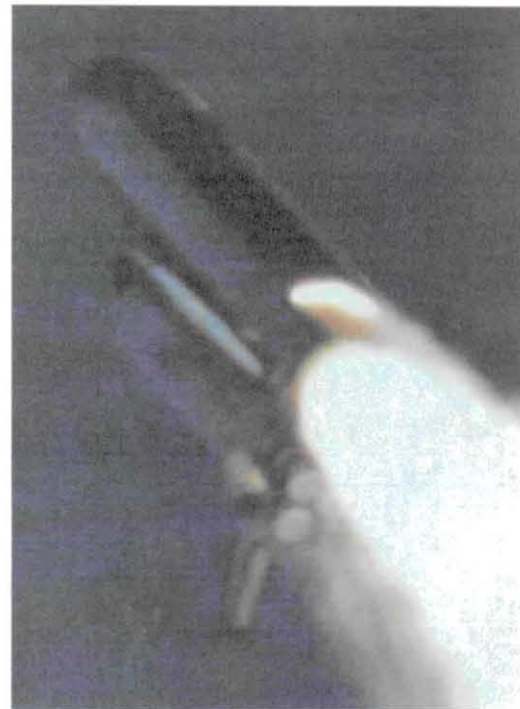
*Credit: Synthstuff.com*



# Challenger



- 25 years ago today
- Result of known SRB joint O-ring issue that was not properly addressed
- NASA management restructured to encourage engineers to speak up about issues
- Many lessons learned



*Credit: <http://loftyambitions.wordpress.com/>*





# Columbia



- Known ET issues
- Impact of these issues not properly addressed
- Cultural issues similar to those encountered with Challenger contributed to lack of data about wing damage



*Credit: www.nasa.gov*



## Lessons Learned

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- RATS cards
- Modifications to shuttle before each return to flight fixed hardware issues
- Safety is a priority



## Lessons Learned

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- Accident Investigation Board Recommendations
  - Fixed Technical Issues
  - Patched organizational issues
- Attrition of recommendations to old ways

“Perhaps most striking is the fact that management – including Shuttle Program Mission Management Team, Mission Evaluation Room, and Flight Director and Mission Control – displayed no interest in understanding a problem and its implications.”  
-Columbia Accident Investigation Board



# LEAN ENGINEERING



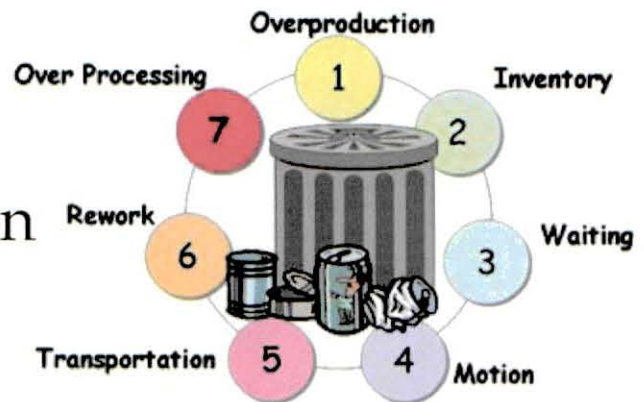
# LEAN Engineering



- Reduced Costs
- More Added Value
- Manufacturing Driven
- Reduced Waste

– 7 Types:

Over production, inventory, waiting, motion, transportation, rework, over processing



Credit: <http://lsspmp.com>

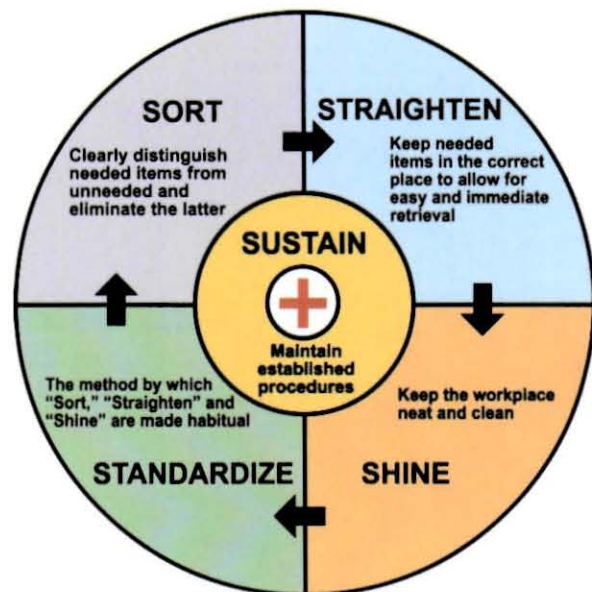




## Places we saw LEAN



- 5S Workplaces:
  - Sorting
  - Straightening
  - Shining
  - Standardizing
  - Sustaining

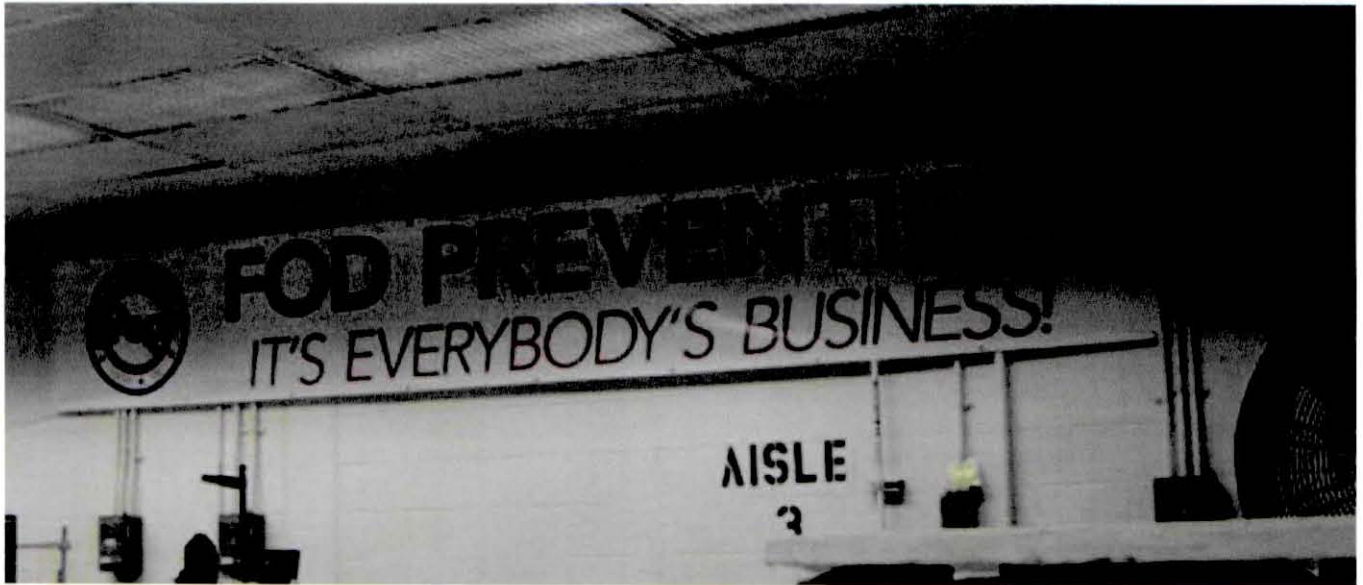


*Credit: Beyondlean.wordpress.com*

- Many offices, labs and contractors use this already



## Places we saw LEAN

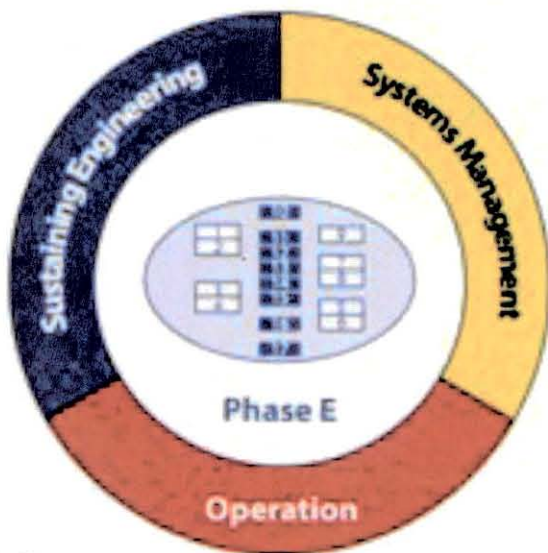




# OPERATION



# Shuttle Operations and Sustainment

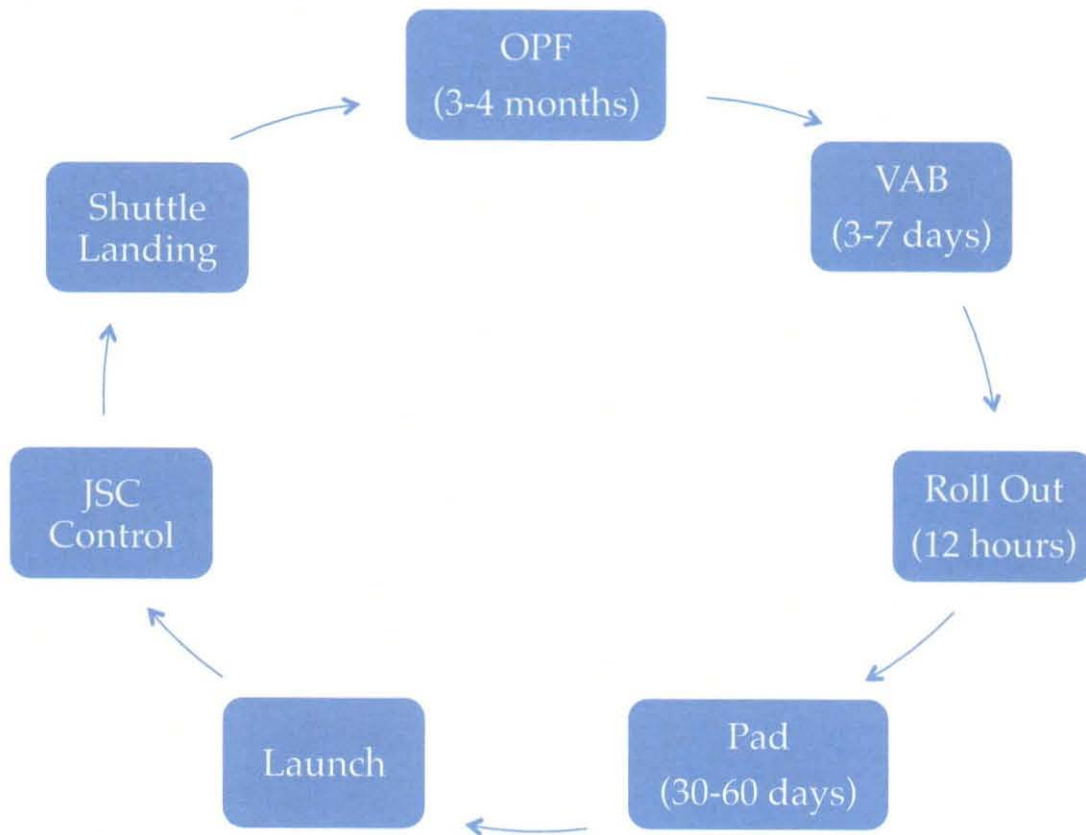


*Credit: www.nasa.gov*

- Spares and refurbishment for reusable parts
- Orbiter tiles require replacement/refurbishment
- SRBs require cleaning and refueling
- Parachutes require cleaning and repacking



# KSC Shuttle Operations







## Closeout of the Shuttle Program

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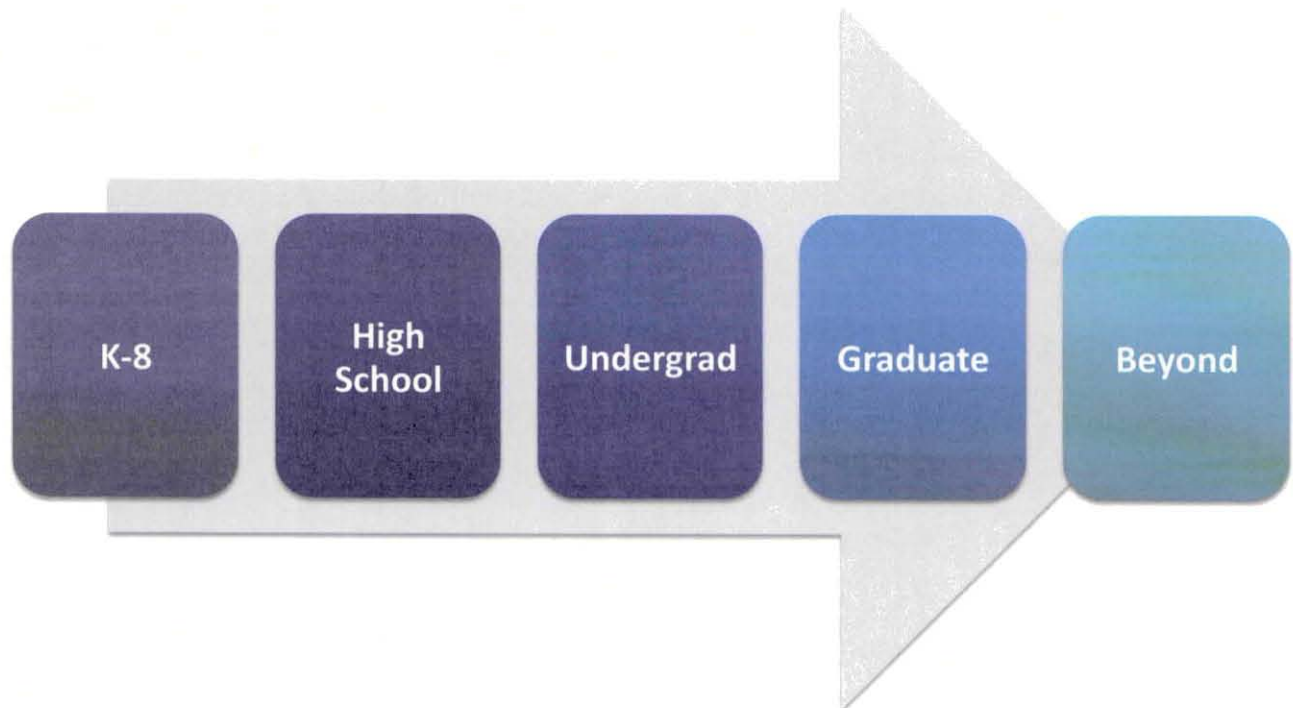
- Plan final flights
- Dispose of hazardous materials, determine the future for ground facilities, etc.
- Top to bottom analyses of program elements
- Data / information requires analysis and archiving
- Workforce reduction
- Rehire issues



# EDUCATION



# Education Programs





# Education Programs

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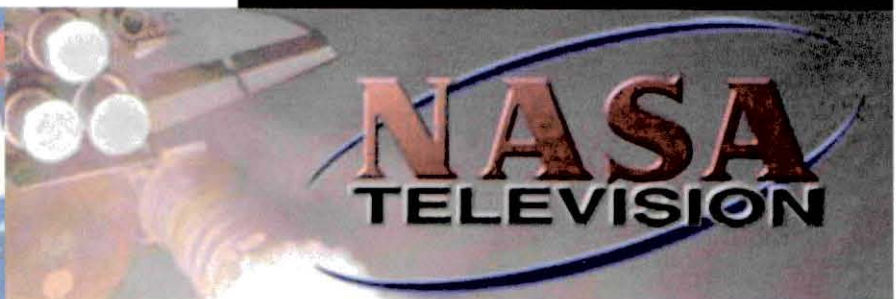
- K-8
  - EarthKam
  - Fly your face in space
  - Send your name to Mars
  - Pluto Pals
- High School
  - FIRST Robotics
  - Space Settlement Design Contest
  - MyNASA
  - NASA Facebook
- Undergraduate
  - Internships (SURE, Space Grant, etc)
  - Future of Flight competition
  - Lunabotics Mining Competition
  - NASA Academy
- Graduate
  - Graduate Student Research Program
  - UARC STI Graduate Student Summer Internship Project
  - PhD mentors



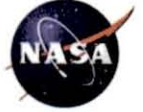
# Beyond



- NASA TV
- Launches
- Astronaut Tweets
- NASA iPod applications



*Credit: www.nasa.gov*



# PRESS

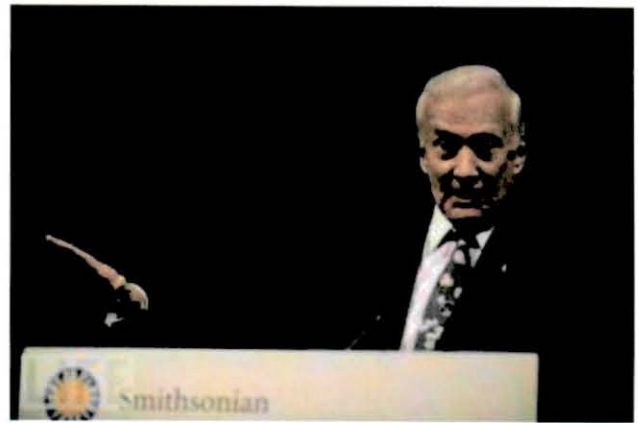


- NASA TV
- Mobile satellite uplink trucks
- Manned flights have most attention
- Historically has not approached networks
  - Missed opportunity to educate public
- Challenges in advertising



*Credit: Wunderground.com*

- Convey NASA to public
- Translate policy and policy implications
- Promotions beyond Florida area
  - Extend NASA speakers program
  - Creative marketing



*Credit: www.nasa.gov*



# NASA Spinoffs



- |                                      |  |  |
|--------------------------------------|--|--|
| Light-emitting diodes (LEDs)         | Portable cordless vacuums                | Athletic shoe design                           |
| Infrared ear thermometers            | Environmental and agricultural resources | Athletic shoe manufacture                      |
| Ventricular assist device            | Water purification                       | Freeze-dried food                              |
| Artificial limbs                     | Solar energy                             | Insulation (mylar)                             |
| Transportation                       | Pollution remediation                    | Water purification technology                  |
| Aircraft anti-icing systems          | Computer technology                      | Surface enhancement coatings                   |
| Highway safety                       | Structural analysis software             | Digital signal-processing for CAT scans & MRIs |
| Improved radial tires                | Remotely controlled ovens                | Vacuum metallizing techniques                  |
| Chemical detection                   | Industrial productivity                  | Cordless power tools                           |
| Public safety                        | Powdered lubricants                      | Cool suits                                     |
| Video enhancing and analysis systems | Improved mine safety                     |  |
| Fire-resistant reinforcement         | Food safety                              |  |
| Firefighting equipment               | Kidney dialysis machines                 |  |
| Consumer, home, and recreation       | CAT Scanner                              |  |
| Tempur foam                          | Cardiovascular conditioner machine       |  |
| Enriched baby food                   | Cook/chill concept                       |  |





# FUTURE

- Space Shuttle retirement
- Constellation
- ISS requires resupply and maintenance:  
Foreign and commercial options
  - Soyuz: \$56 million per seat
  - SpaceX
  - Orbital Sciences



*Credit: www.nasa.gov*



- Use commercial industry to service the ISS in a more profitable and efficient manner
- Cargo and crew transportation capabilities
- Funding once reach milestones (performance objectives) with ISS
- Access to all NASA archives, experts, and experience





## Orbital Sciences

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- 150 major space and rocket missions in 7 years
- Focus on satellites and space systems, launch vehicles, and advanced space programs
- Clear market focus, product line breadth, technical excellence and cost efficiency
- Moderate use of contractors





## Taurus II & Cygnus



- Taurus II is medium class launch vehicle
- Cygnus is advanced maneuvering spacecraft
- COTS demo in the second half of 2011
- 8 pressurized cargo missions from late 2011 or early 2012 through 2015
- \$40-45 million



*Credit: www.nasa.gov*



SpaceX



- Reduce the cost and increase the reliability of space access by a factor of ten
- Simplicity, low cost, and reliability can go hand in hand
- Eliminate traditional layers of management internally and sub-contractors externally
- Design for reuse
- Limited use of contractors

**SPACEX**



## Falcon 9 & Dragon



- Falcon 9- launch vehicle
- Dragon- pressurized capsule with unpressurized trunk
- COTS Demo 1 success
- Next steps: integrated launch abort system and crew accommodations
- COTS Demo 2 and 3
- \$50 million



*Credit: www.nasa.gov*



## SE in the Commercial Industry

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- Contracts and the make/buy dilemma (capability and budget considerations)
- Budget, risk, and performance optimization
- CDIO execution must emphasize the connection between design and operation
- Few failures to learn from thus far



# NASA and Commercial Industry

- Man-rating (i.e.: LETF)
- Facilities available with the end of the Shuttle program
  - space vehicle processing and launch facilities
  - off-line processing facilities
  - payload processing facilities
- Advantages and disadvantages of using NASA facilities







## Acknowledgements

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- Helen Kane
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- Everyone who spent time with us, showed us around, regaled us with stories from Shuttle and Apollo, entertained us, and gave us design and career advice