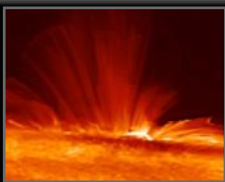


National Aeronautics and Space Administration



# Cutting More Than Metal: Breaking the Development Cycle

**AIAA Propulsion and Energy Forum 2014**  
*July 28-30, 2014*



# marshall

**Christopher Singer,**  
*Director of Engineering*

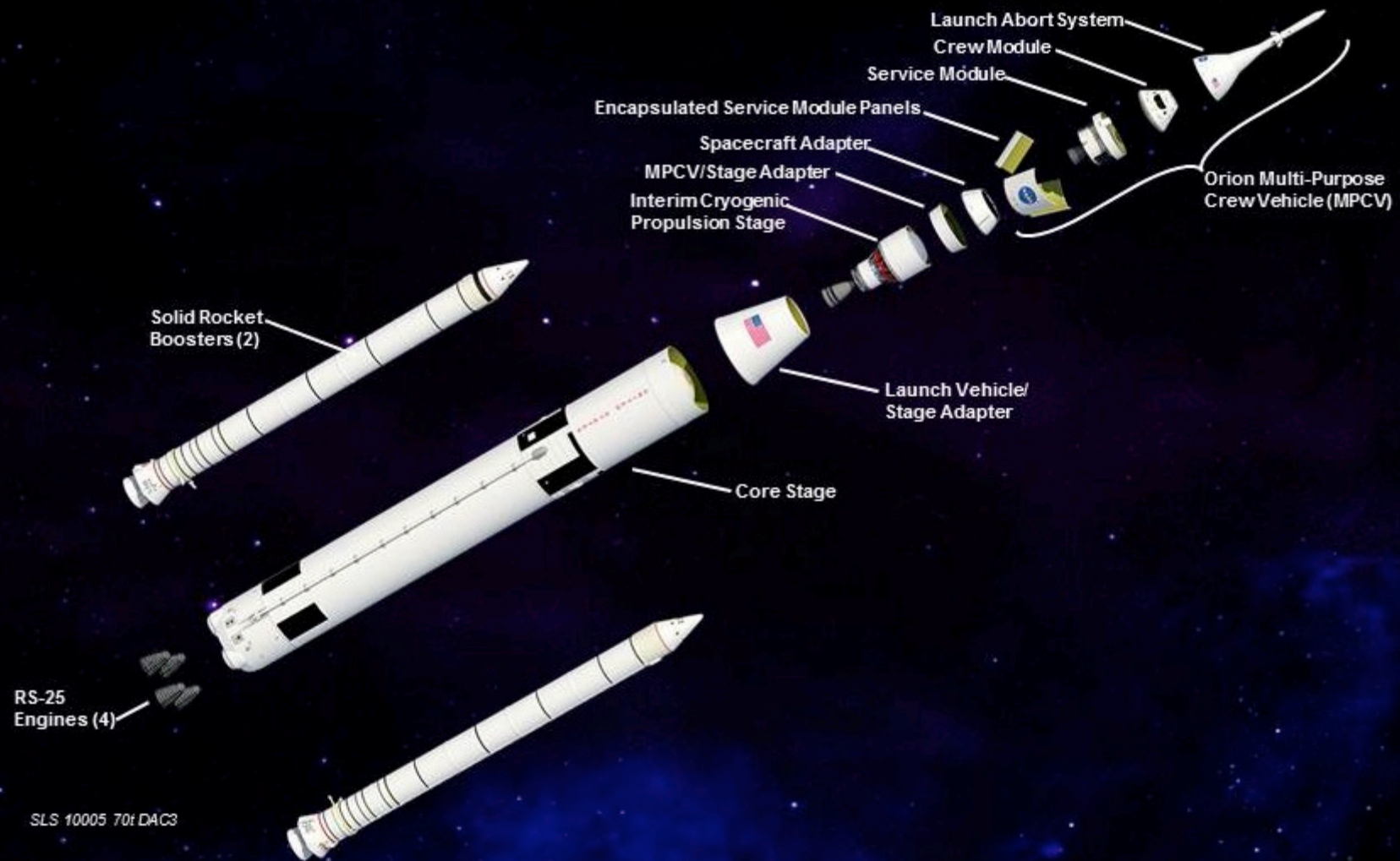
**Jay Onken,**  
*Deputy Chief Engineer, Space Launch System*

# Learning from the Past, Not Living by it

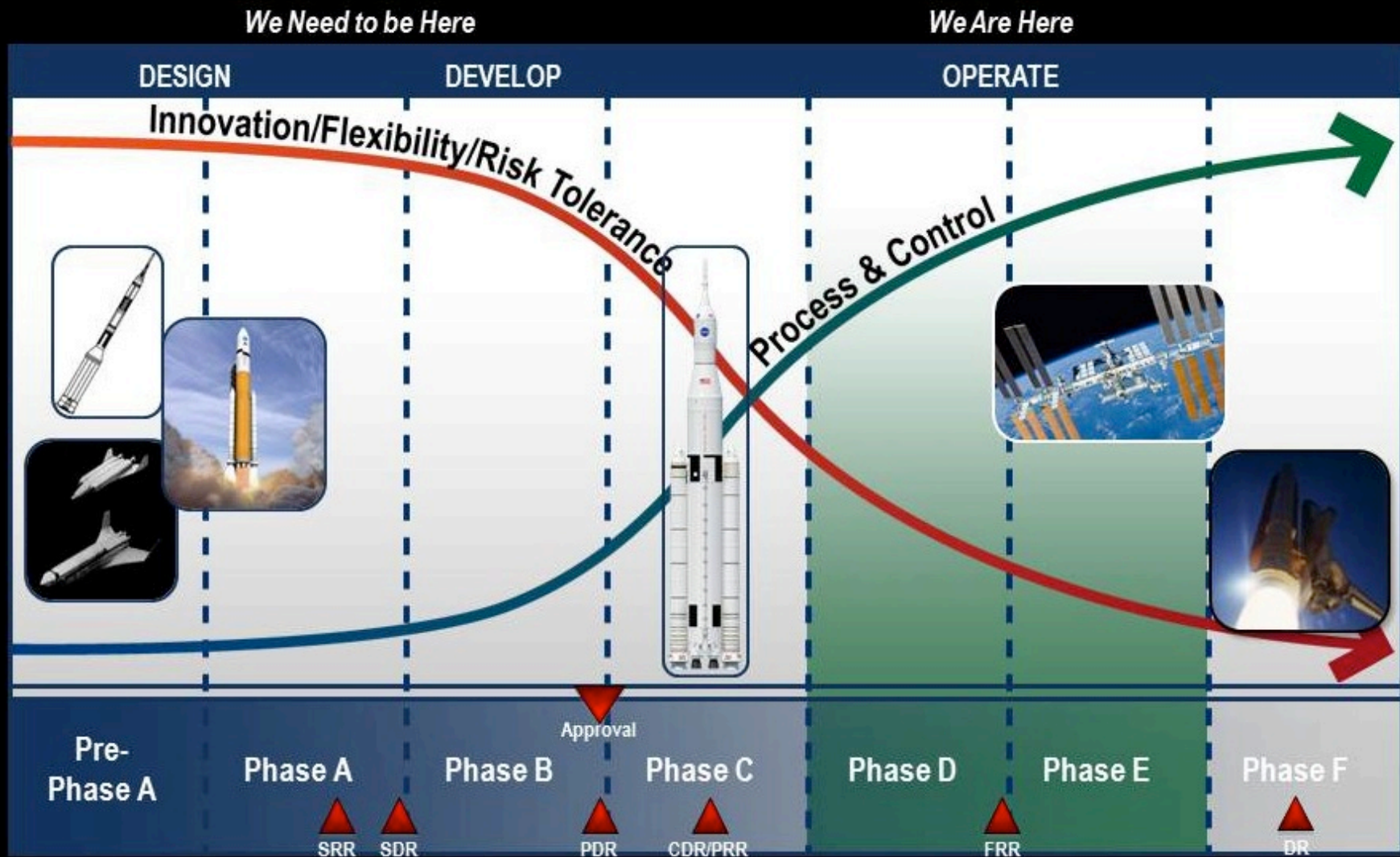




# Capability for a New Era of Space Exploration



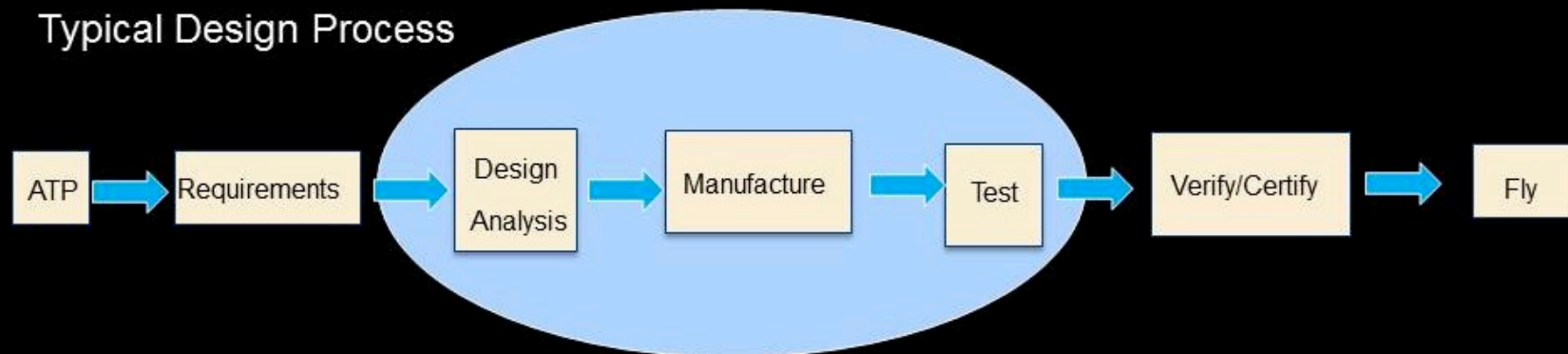
# Development Culture vs. Operational Culture



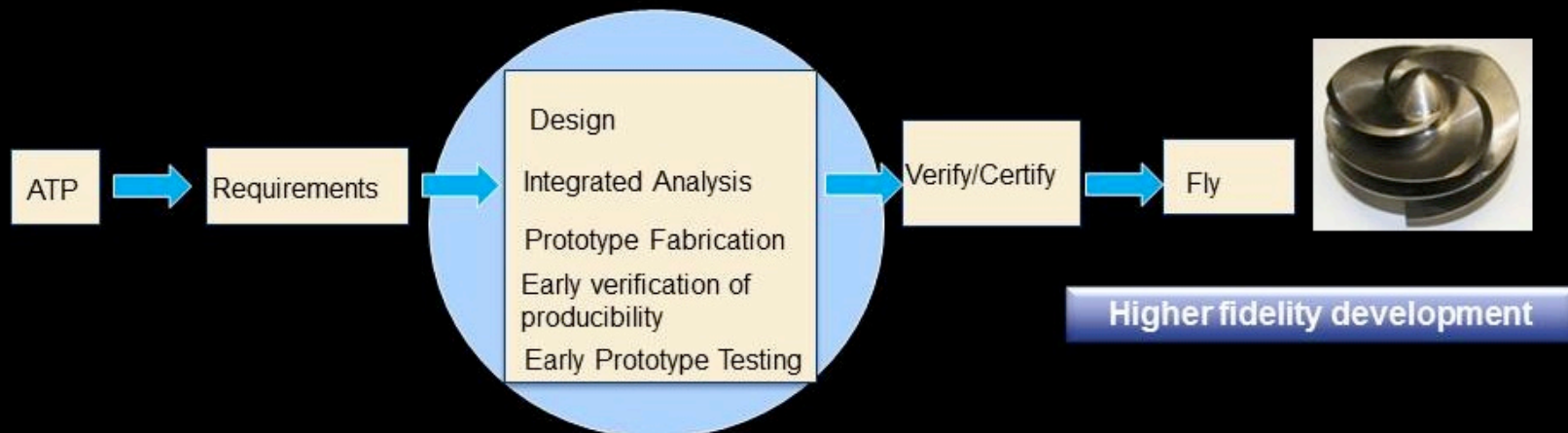


# Changing the Design Process

## Typical Design Process



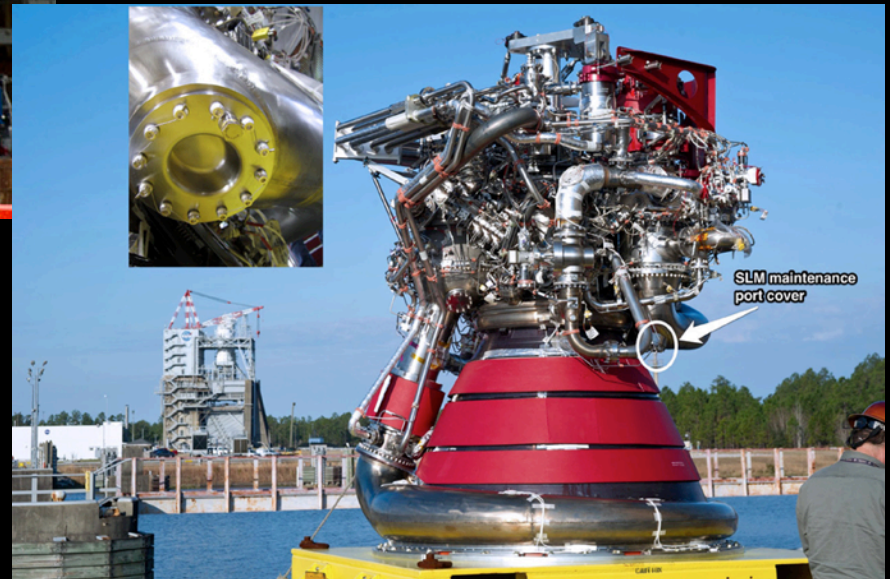
## Evolved Design Process, Enabled by New Technologies



# Additive Manufacturing



3-D printed rocket injector for hot fire test



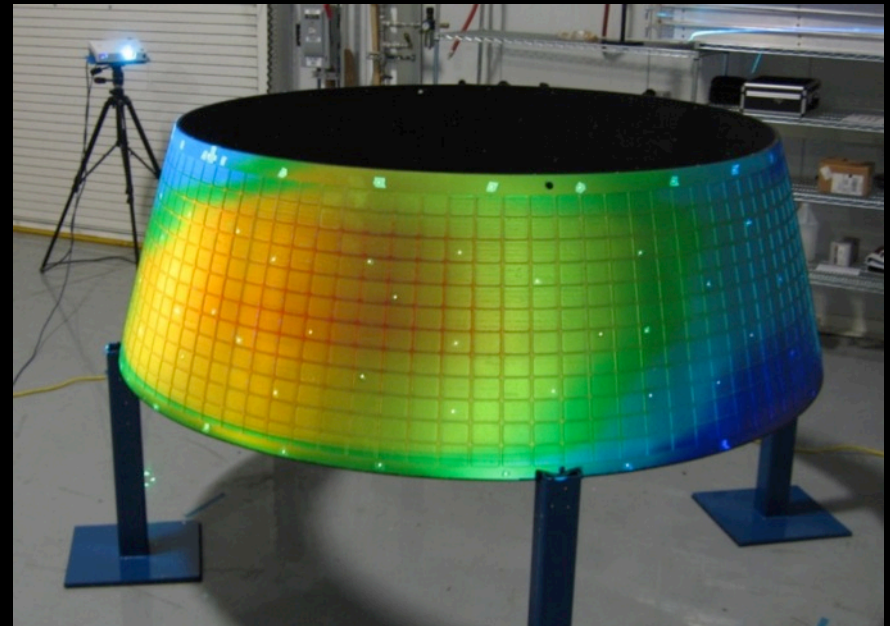
SLM Exhaust Port Cover for J-2X  
(inset and position on engine)



# Structured Light Scanning



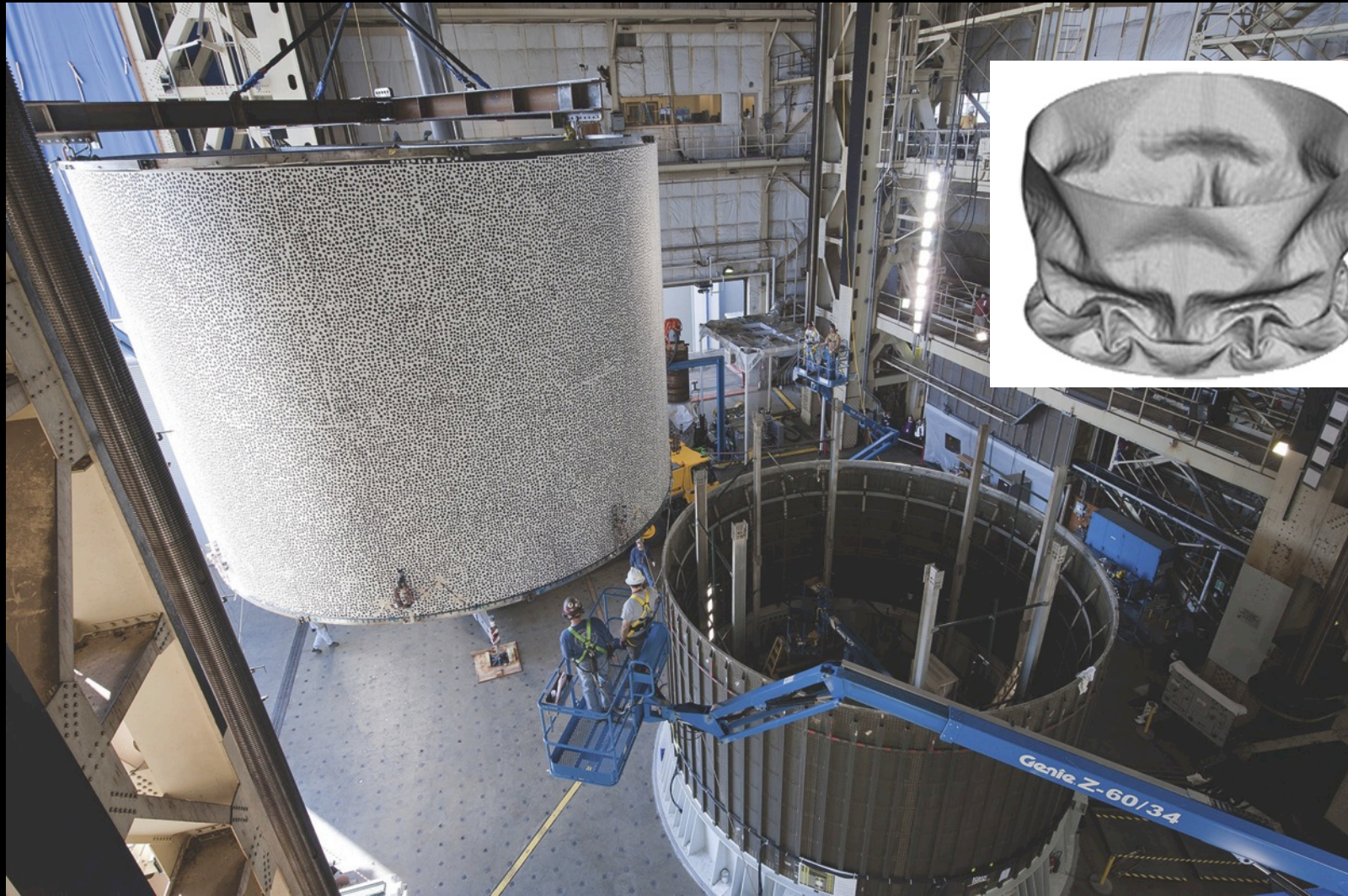
Training and implementing technique with industry.



J-2X nozzle extension showing deformity data projected onto part.

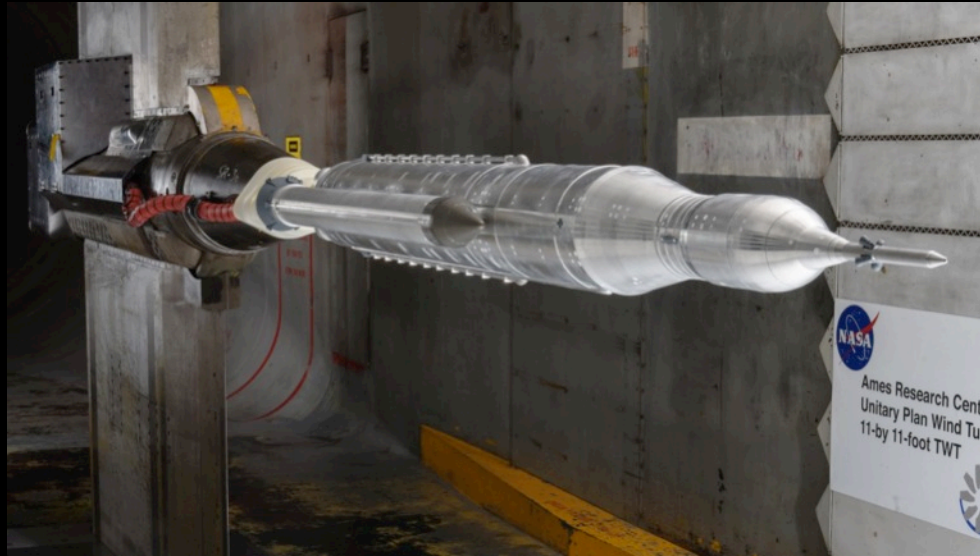


# Shell Buckling Knockdown Factor Testing





# Wind Tunnel, Adaptive Algorithm Testing



3-D printed rocket injector for hot fire test

F/A-18 tests for SLS flight control



# Hardware in the Loop Testing



Workers set up SLS avionics in SITF



Test engineer runs avionics flight simulation in SITF.



# Core Stage Manufacturing

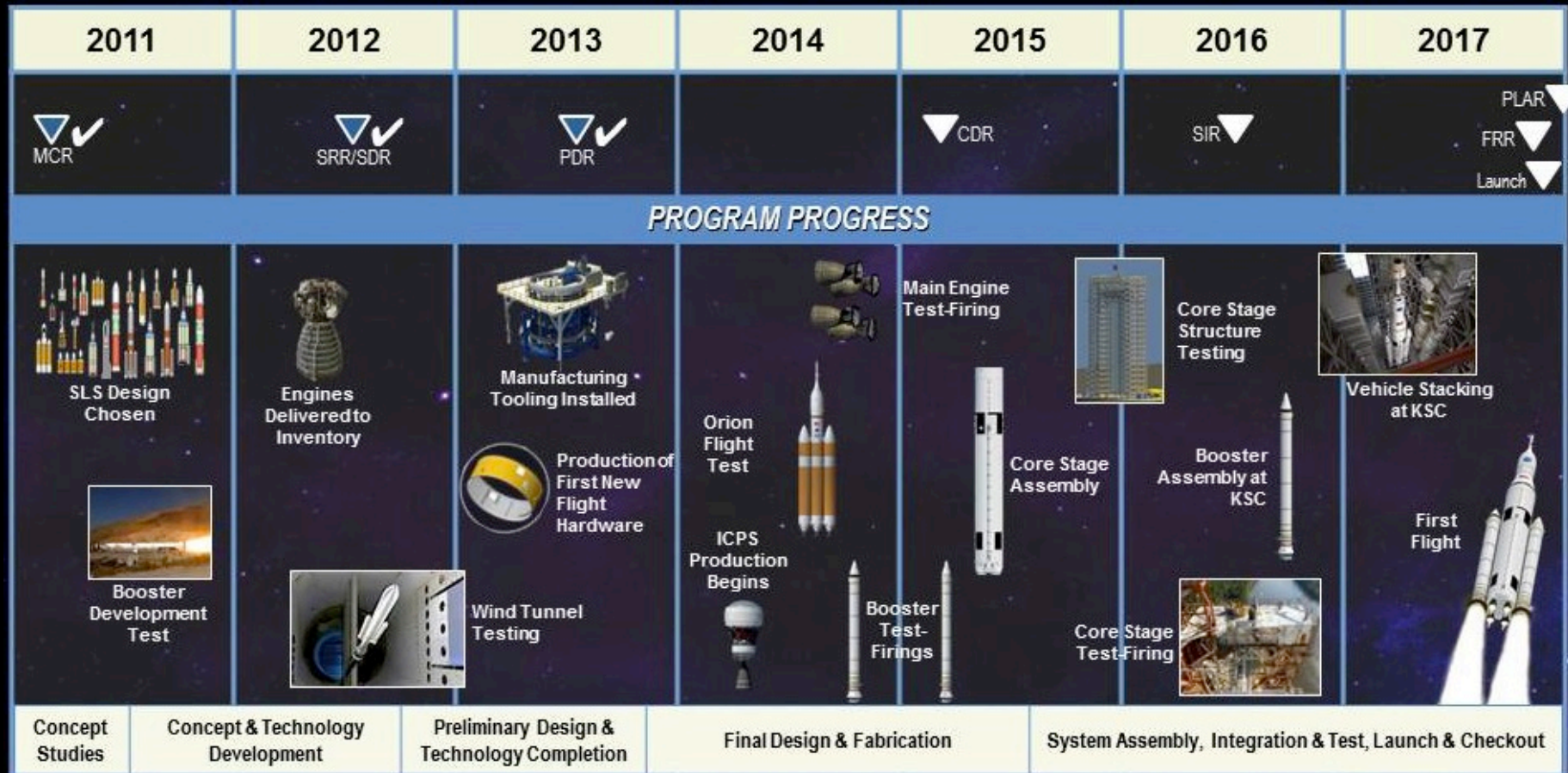


First Core Stage confidence barrel section at MAF



First Core Stage confidence dome section at MAF

# Path to First Flight



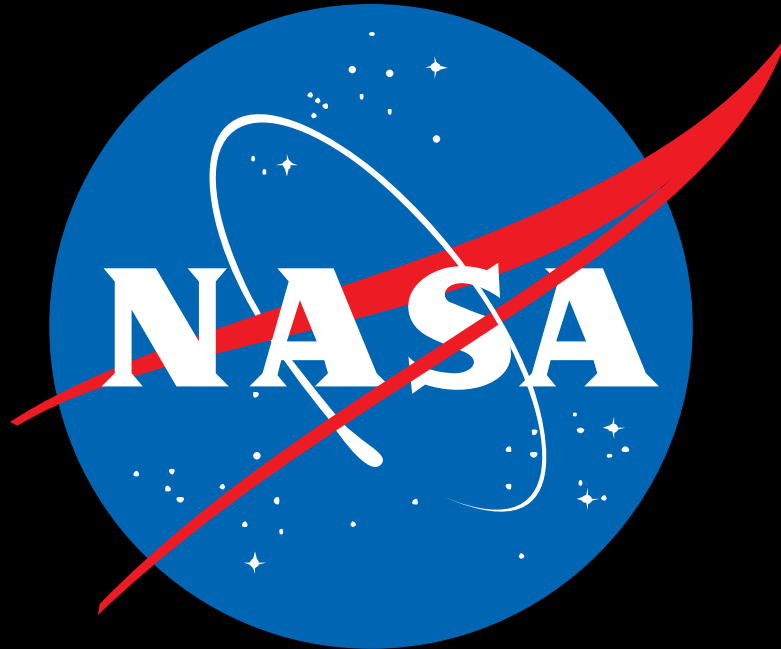


# Results



# Questions?

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



# Explorers Heart: Courage, Passion, Curiosity



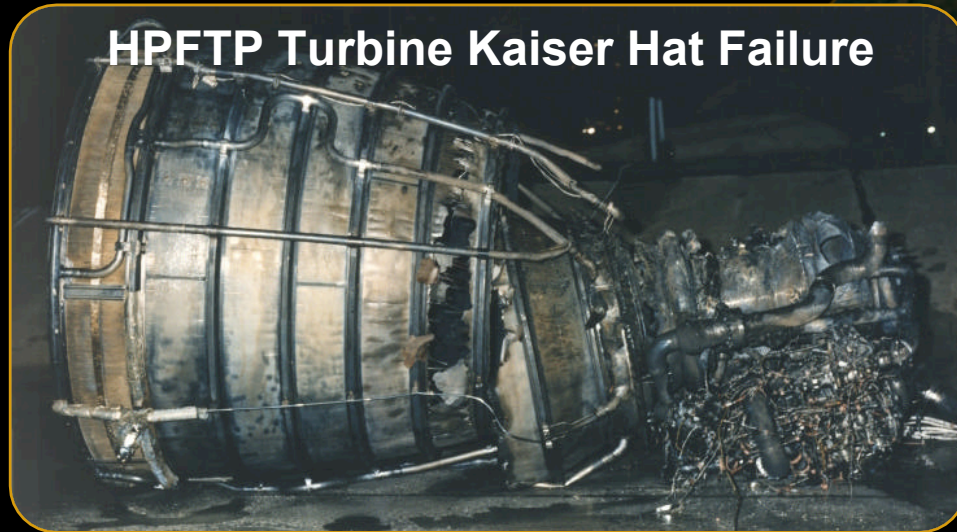
Tragedy triggers our opposing desire to control uncertainty

# New Technologies Will Never Entirely Replace Testing

A-3 Test Stand in Background,  
Engine and Photographers in  
Foreground

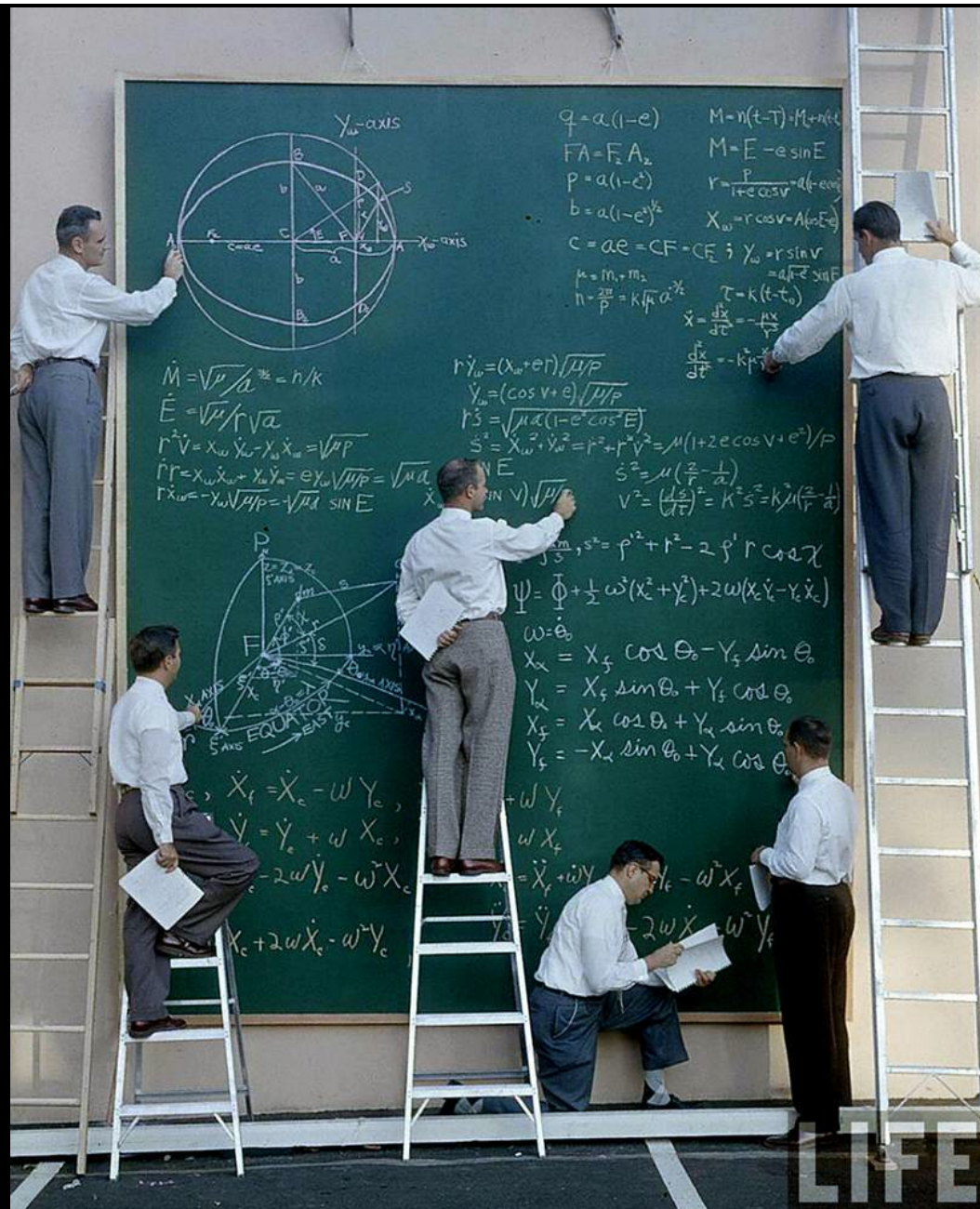


**HPFTP Turbine Kaiser Hat Failure**



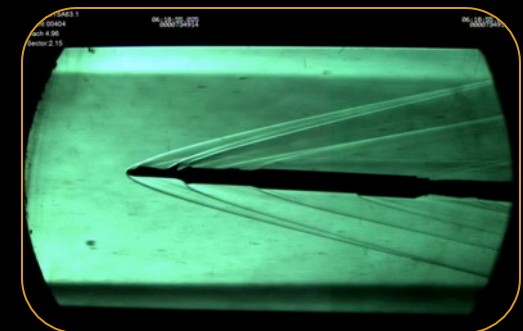
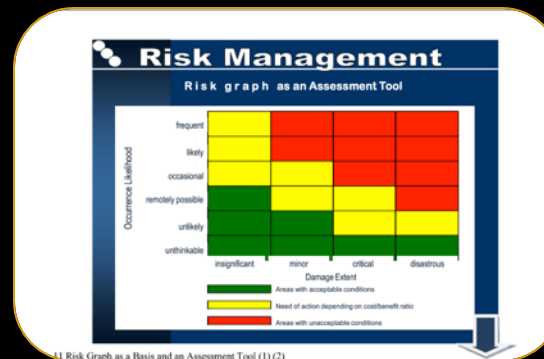
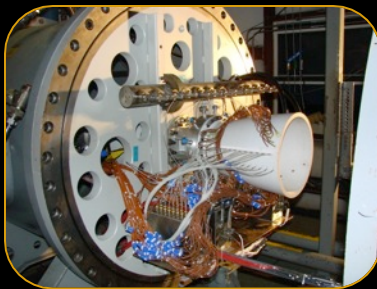
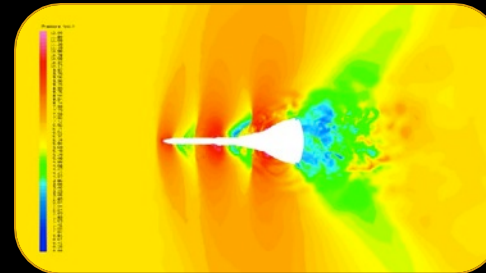
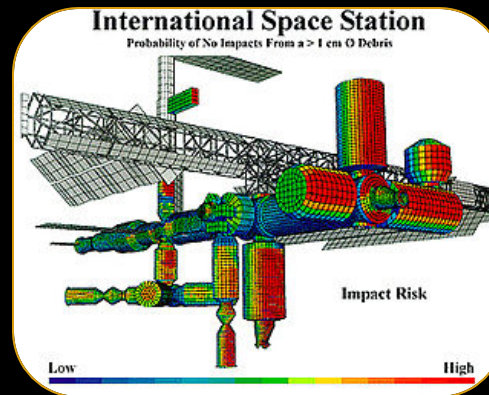
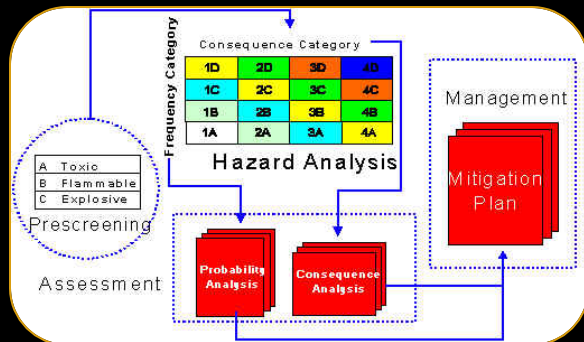
SSME 2013 In the Spillway  
Downstream of the Flame Detector  
Immediately After Test 901-364





**NASA Before PowerPoint**  
**The physics are the same. How we communicate has changed.**

# Tools and Techniques to Manage Risk





# NASA Programs are Tied to Administration Cycles



*Direction and Redirection Come Every 4 to 8 Years*

# Inspiration for Generations

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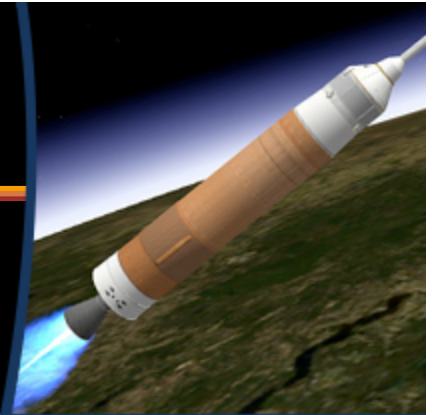


# Ares Development Team Observations

*We made incredible progress despite many obstacles*

- Growing constraints, hurdles, and attitudes in an attempt to finish something ... anything
  - Decisions take too long and are unsupported
  - “Death” by meetings and PowerPoint
  - Proliferation of Ineffective Working Groups,: All voices are equal and no one is in charge
  - One-chance development philosophy (no block upgrade or early testing strategy)
  - Technical is disconnected from Cost & Schedule (Engineering vs. Project);
  - Subsystem stovepipes (everybody for themselves)
  - Pounding issues flat

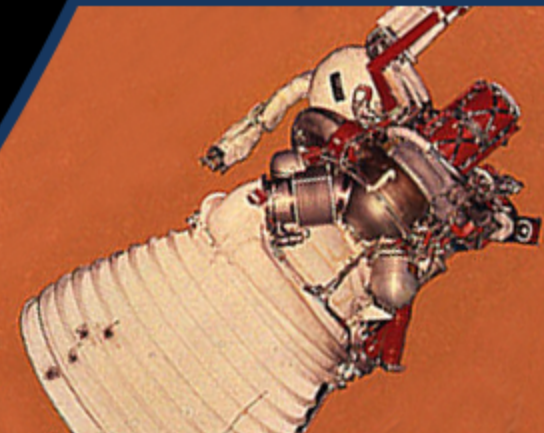
***Uncertainty Can Help Feed Innovation***



J-2X Operation



J-2X Development



J-2X Design

3D models are carried through all phases of the product life cycle.

## More Automation

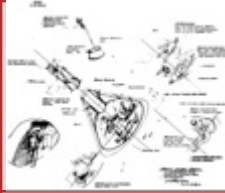
### Past

### Present

### Future

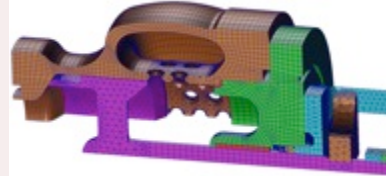
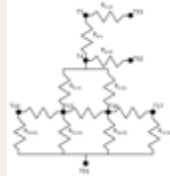
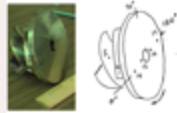
### What is changing?

#### Design



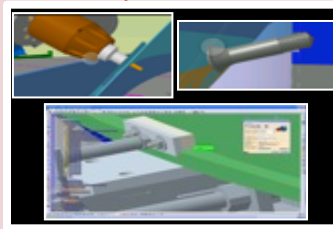
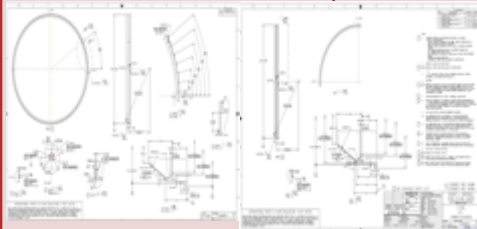
Design is becoming more integrated with manufacturing, shortening the product life cycle and reducing overall cost. Minimizes re-design, re-work.

#### Analysis



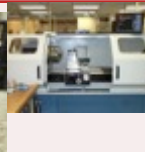
Computers are getting faster, memory is getting cheaper, leading to higher resolution analytical models. Analytical models are becoming more fully integrated.

#### Producibility, Modeling and Simulations



The transition from paper drawings to 3D design models and associated modeling and simulations have enabled advanced producibility analysis with great savings. We are also working towards using annotated models in place of drawings.

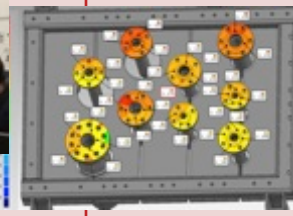
#### Manufacturing



Transitioning from manual processes to full automation, CNC milling, additive processes.

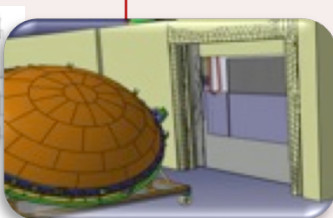
#### Inspection and Test

Label	ActualX	ActualY	ActualZ	I
C_DEVICEPOS001				
M_PLANE001	0.3453	-0.0139	0	0
M_CIRCLE001_I	0	0	0	0
M_LINE001	5.6373	0.7553	0	0
C_COORDSYS001	0	0	0	0
C_ALIGNMENT001				
M_POINT001	33.7529	37.5856	6.728	0
M_POINT002	65.2972	-6.3056	6.725	0
M_POINT003	65.4994	-11.345	-18.992	0
M_POINT004	53.406	-38.724	6.727	0
M_POINT005	24.651	7.4137	6.4737	0
M_POINT006	35.9245	-7.5393	7.7253	0
M_POINT007	48.788	-9.374	94.8761	0
M_POINT008	47.4436	-13.478	130.66	0
C_DEVICEPOS002				
M_POINT009	-22.913	36.1752	73.1477	0
M_POINT010	-26.865	-35.413	96.133	0
M_POINT011	-32.774	37.0945	120.437	0
C_DEVICEPOS003				
M_POINT012	-30.539	-32.851	73.3956	0
M_POINT013	-30.62	-36.053	96.2763	0



Transitioning from discrete measurements to structured light scanning, more full inspection coverage and the ability to compare "as built" directly to "as designed" models, reducing inspection time and increasing fidelity.

#### Logistics and Operations



Using 3D virtual simulations in addition to drawings to reduce cost and schedule by evaluating interfaces during the initial design phase. Simulations can significantly increase efficiency and preparedness for operations.