

# Affordable Virtual Reality on Next Generation Launch Systems and Products

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## GLOBAL PRODUCT DATA INTEROPERABILITY **S U M M I T** 2018



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# Presentation Outline

Global Product Data Interoperability Summit | 2018

- **Speaker Introduction**
- **NGIS Propulsion Systems Introduction**
- **Virtual Reality (VR) Briefer**
- **VR Development History at NGIS**
- **Affordable VR System Examples**
- **VR Lab at NGIS PS**
- **Successful VR Use Cases and Savings/Benefits**
- **Conclusions**

# Innovation Systems Overview

- Leading Developer and Manufacturer of Innovative, Reliable and Affordable Products for Government and Commercial Customers
  - Launch Vehicles, Rocket Propulsion Systems and Aerospace Structures
  - Tactical Missile Products, Armament Systems and Ammunition
  - Satellites, Space Components and Technical Services
- Approximately 15,000 Employees, Including Nearly 5,000 Engineers and Scientists
- Approximately \$5.0 Billion in Revenues
- Sector Headquarters in Dulles, VA
  - Major Locations in Alabama, Arizona, California, Florida, Maryland, Minnesota, Mississippi, Missouri, Texas, Utah, Virginia, West Virginia
- Formerly Orbital ATK Acquired by Northrop Grumman in June 2018



# Innovation Systems Structure



## Flight Systems Group

- Workforce ~5,800 People
- Divisions
  - Launch Vehicles
  - Propulsion Systems
  - Aerospace Structures
- Major Operations in Arizona, Utah, Virginia, Ohio, Alabama and Mississippi



## Defense Systems Group

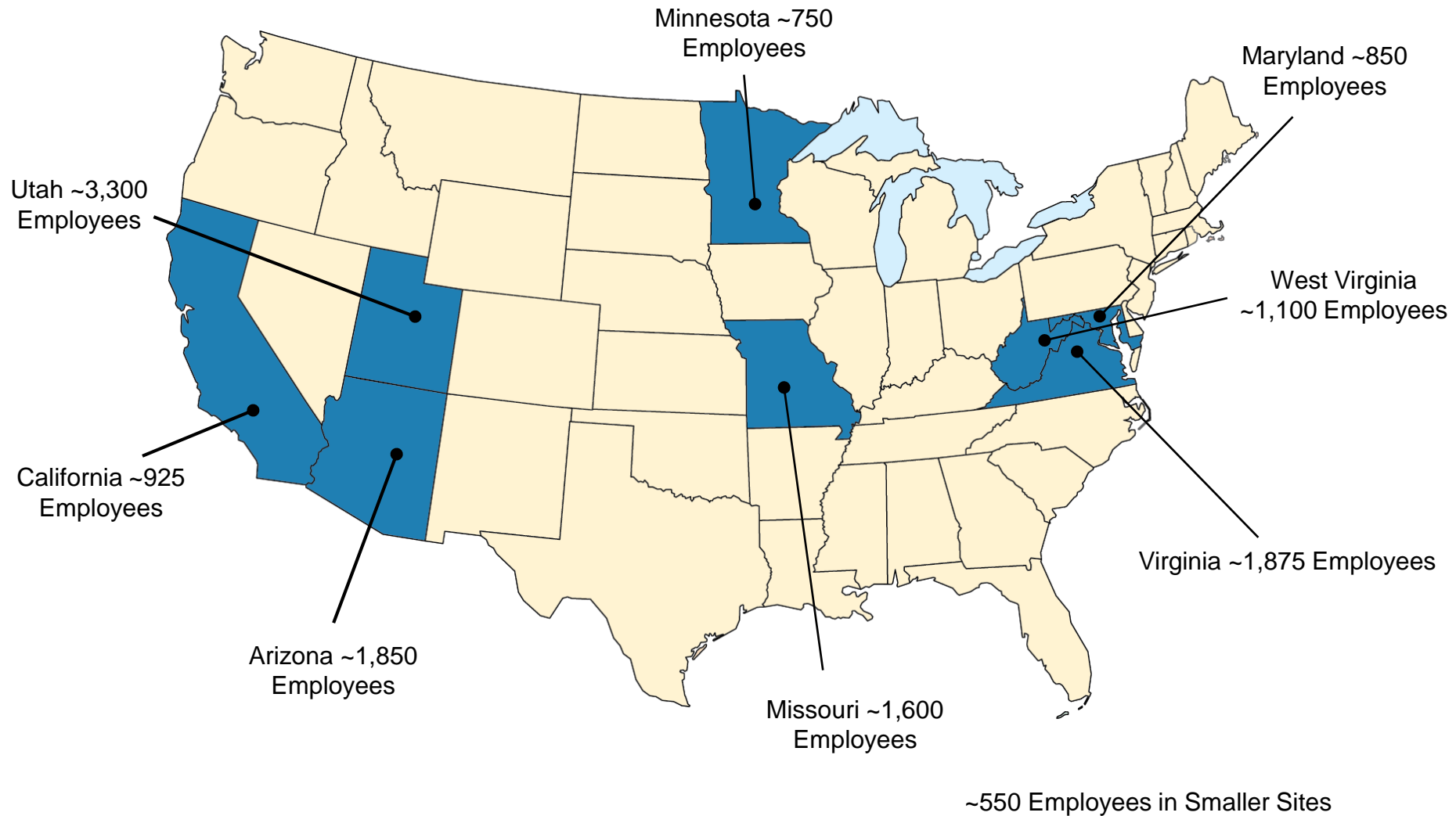
- Workforce ~5,000 People
- Divisions
  - Missile Products
  - Armament Systems
  - Defense Electronics
  - Small Caliber Systems
- Major Operations in Maryland, West Virginia, Virginia, Missouri, Minnesota, Arizona, Texas and California



## Space Systems Group

- Workforce ~3,000 People
- Divisions
  - Satellite Systems
  - Advanced Programs
  - Space Components
  - Technical Services
- Major Operations in Virginia, Maryland, California, Arizona, Texas and Utah

# Major Operating Locations



# Flight Systems Group Structure



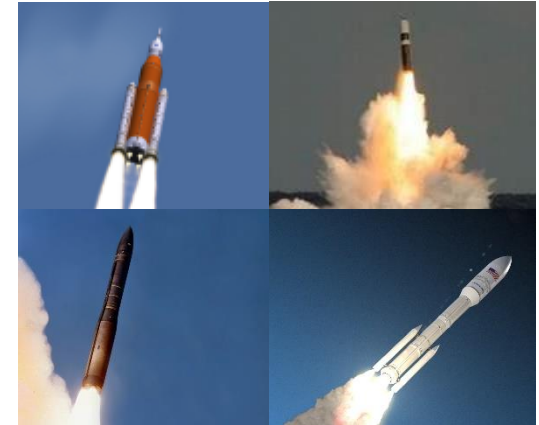
## Aerospace Structures Division

- Workforce ~1,800 People
- Focus areas
  - Commercial aerostructures
  - Military aerostructures
  - Launch vehicle structures
- Facilities in California, Massachusetts, Mississippi, Ohio, and Utah



## Launch Vehicles Division

- Workforce ~1,800 People
- Focus areas
  - Small-class launch vehicles
  - Medium-class launch vehicles
  - Missile defense interceptors
  - Suborbital targets
- Facilities in Alabama, Arizona, California and Virginia

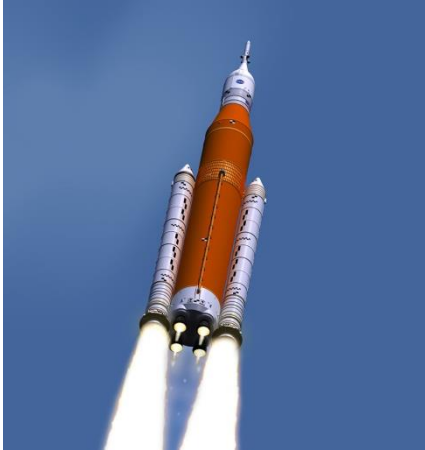


## Propulsion Systems Division

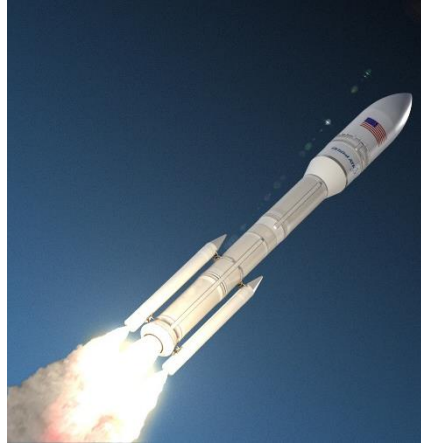
- Workforce ~2,200 People
- Focus areas
  - Large-class vehicle Propulsion Systems
  - Strategic Missile Propulsion Systems
  - Commercial Propulsion
  - Advanced Programs
- Facilities in Alabama, Florida and Utah



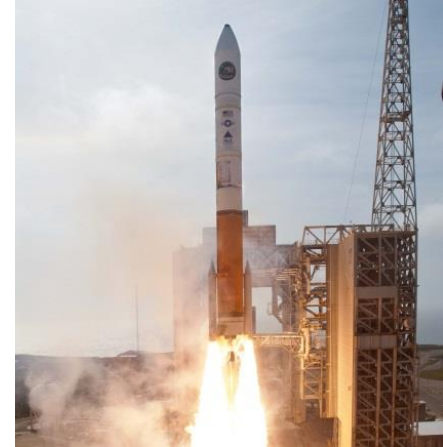
# Propulsion Systems Division Programs



Space Launch System and  
Orion Launch Abort Motor



CASTOR® Motors for OmegaA and  
Antares launch vehicles



GEM motors for Delta, Atlas  
and Vulcan launch vehicles



Trident II (D5)



Orion Motors for Ground-  
Based Midcourse Defense



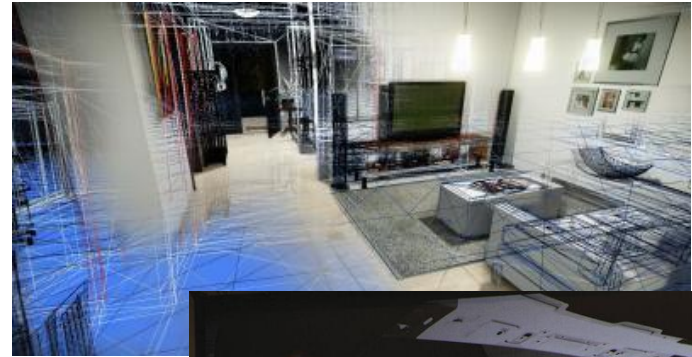
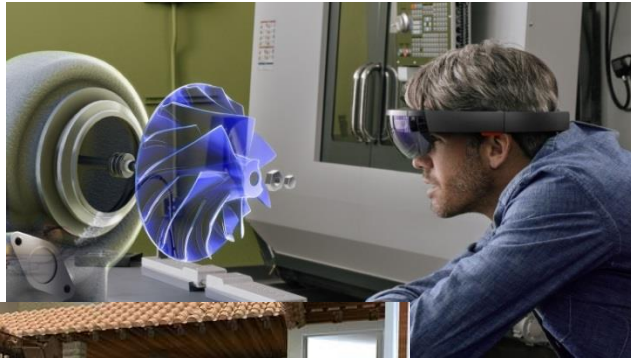
Minuteman III and Ground  
Based Strategic Defense

# What Virtual Reality/Augmented Reality?

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**A three-dimensional computer-generated image or environment that can be interacted with in a seemingly real or physical way.**

- **Virtual Reality (VR)** - Also known as immersive multimedia or computer-simulated reality, completely immerses an individual in a computer-generated environment
- **Augmented Reality (AR)** – Supplements a live direct or indirect view of a physical, real-world environment with computer-generated elements.



*NGIS is using Virtual and Augmented Reality Technologies in the Immersive Visualization Lab*

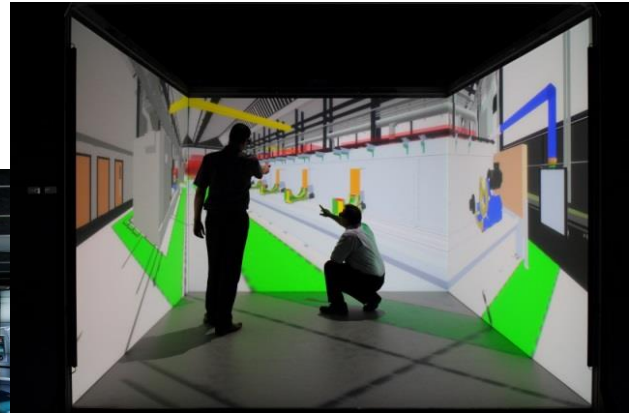
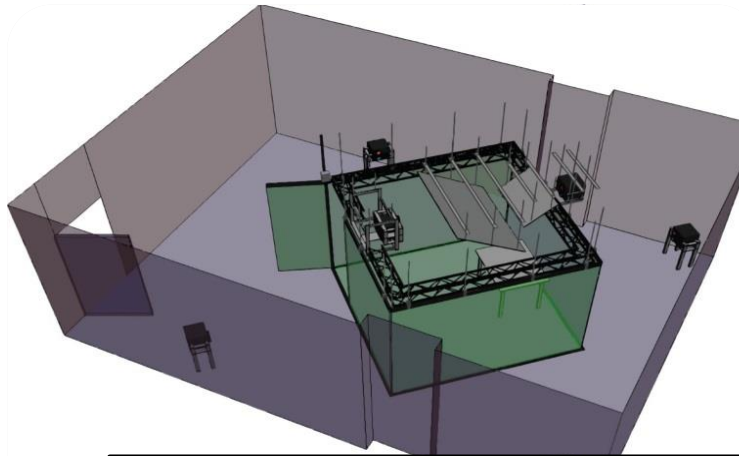


# CAVE

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**CAVE (Cave Automatic Virtual Environment) is a full immersion room that creates “holographic like” images and interaction for a single user.**

- Cube or multisided space where images are displayed by a series of projectors/displays
- Rear projection for walls and floor, 3D glasses and joystick
- Multiple tracking sensors in walls to track users position and orientation
- Computer rendering farm (multiple computers) to generate 3D images
- Dedicated room for CAVE and computer equipment
- Price Tag: \$1M+



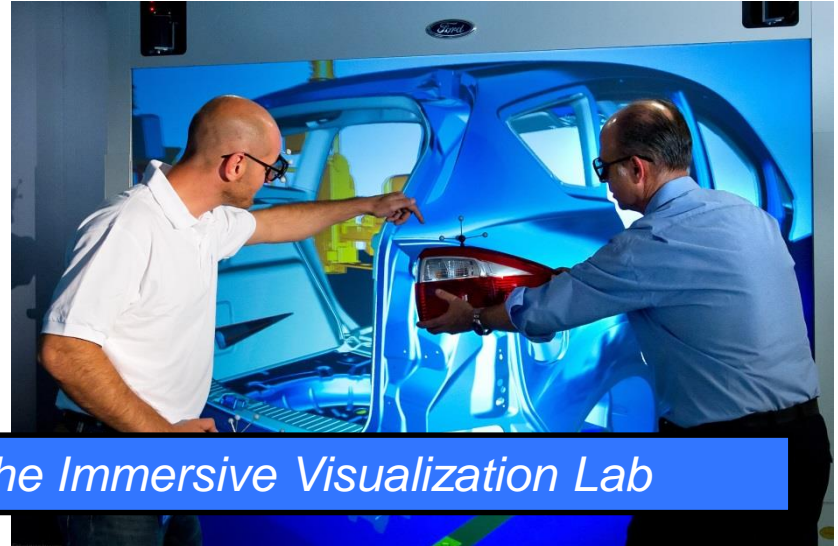
*NGIS has opted not to explore multi-wall CAVEs at this time*

# Powerwall

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## Powerwall - a single wall a full immersion 3D display that creates “holographic like” images and interaction for a single user

- 3D Front/rear screen projection or monitor for a single wall or multi-panel wall
- 3D Powerwall is large enough where user feels immersive effects similar to a CAVE
- Single or multiple rendering computer(s), tracking camera(s), 3D glasses and joystick
- Simple Powerwall (\$25K) – 3D projector or 3D display, single computer with tracking
- Large Powerwall (\$150K) – 3D 4K projector, large screen, multiple computers +tracking
- Price Tag: \$25-\$250K



*NGIS has multiple Powerwalls in the Immersive Visualization Lab*

# Head Mounted Display

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**Head Mounted Displays (HMD) generate a separate image for each eye in a goggle combined with user movement or at goggle motion tracking**

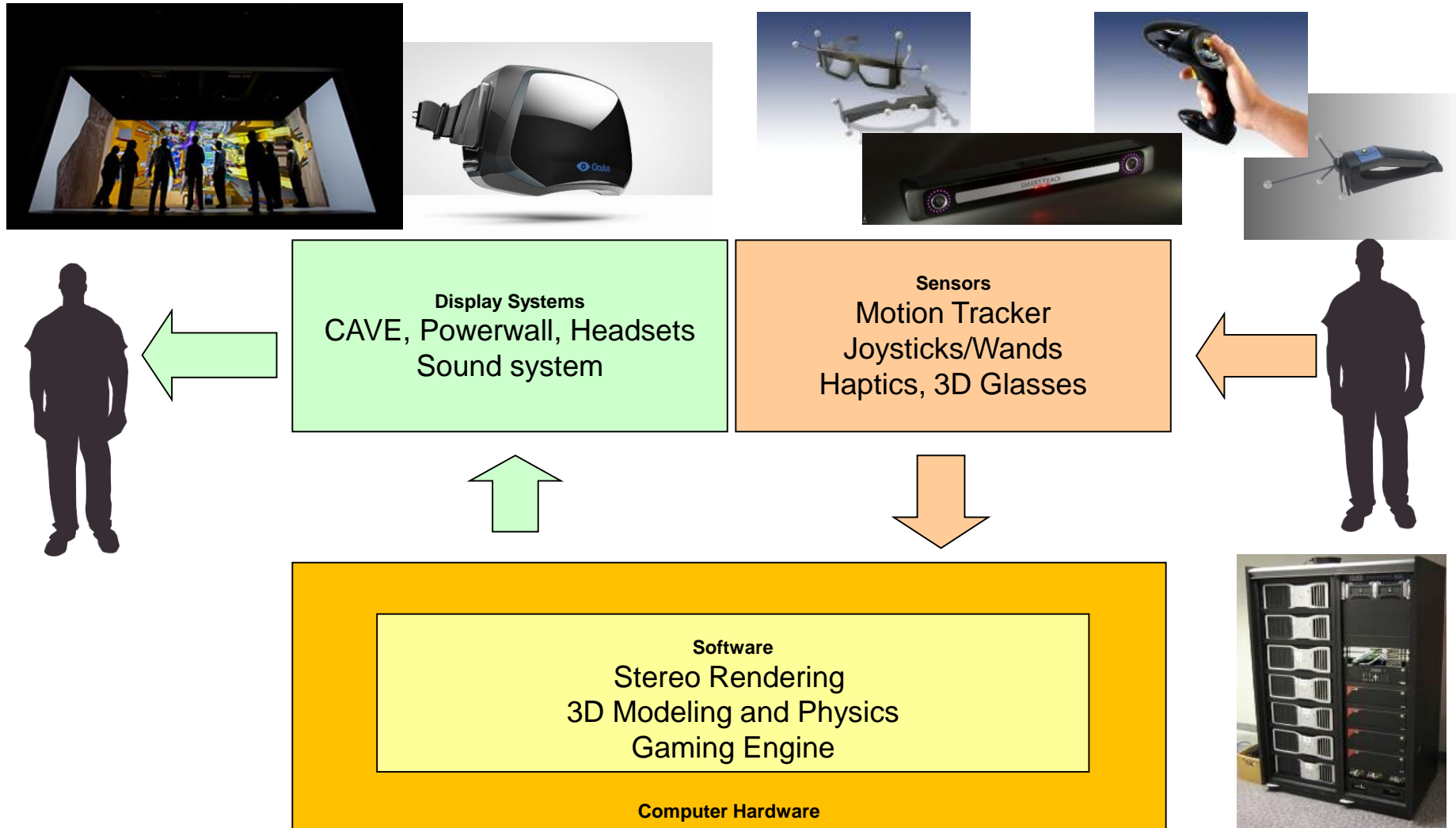
- Display devices attached to the user's head. Dual images - one for each eye
- Gives the user a fully immersive VR experience since the user can only see what is displayed on the HMD display. User is isolated from the outside world.
- An external tracking system follows the movement of the HMD glasses with head movement
- Systems like the HTC Vive HMD allows the user full movement within a 20ft x 20ft box
- Price Tag: \$600-\$5000.



*NGIS is focusing on HMD technologies in the Immersive Visualization Lab*

# Basic Components of Virtual Reality System

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# Brief History of VR at NGIS

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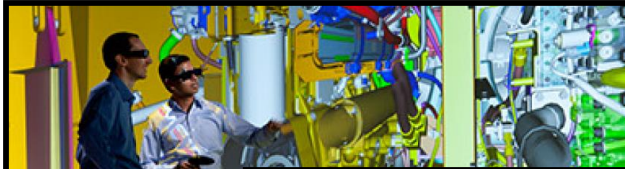
- Over the past 20 years, ATK had developed multiple CAVE systems in conjunction with the DOD and government customers.
  - CAVE systems were expensive, challenging to operate and generally saw limited day to day use. Without proper support, they often “gathered dust”
- In 2015, the GM asked us to explore VR for technician training in mixing solid rocket fuel his goal was to avoid costly training downtime
  - Our challenge: Build a VR proof of concept on a meager \$80K budget
- We benchmarked INL, Caterpillar, FORD, GM, Mechdyne and others to see if we had any hope of turning our \$80K budget into “VR Gold”
  - These companies had all been extremely successful with VR CAVE and all found great value in using VR, but all had better financial support and commitment that us
  - A low end projection display powerwall developed INL for university students who were off site of the national labs, caught our attention. (Price tag: ~\$50K)
- These ideas plus help from others, led us to develop affordable VR
  - Looked to consumer grade LED TV's & projectors (Samsung, Sony...)
  - Also focused on gaming industry HMDs (VIVE, Oculus...)
- All of these technologies have culminated into our current Immersive Visualization Lab which sees daily and weekly use.



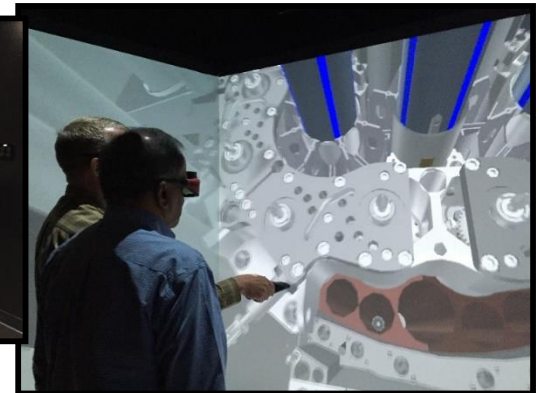
# Leveraging the Experience of Others

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- Caterpillar has been using VR for 15+ years with over 25 VR CAVES installed worldwide.

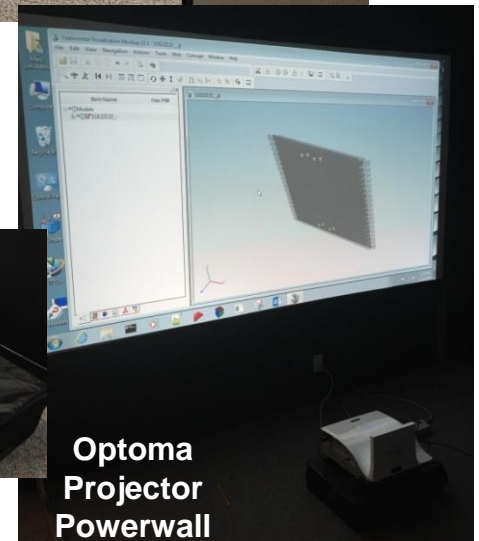
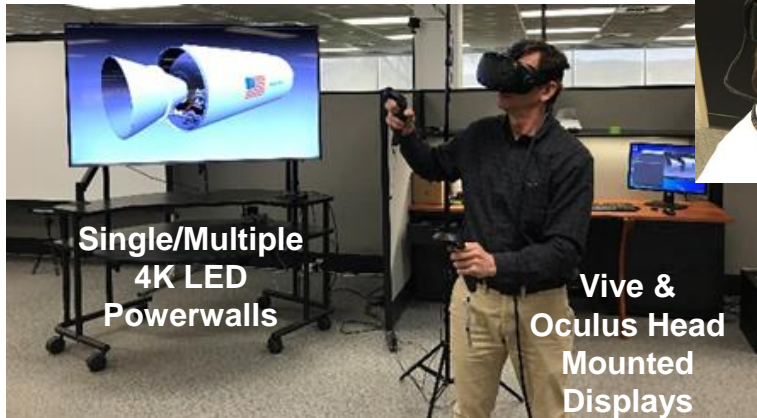
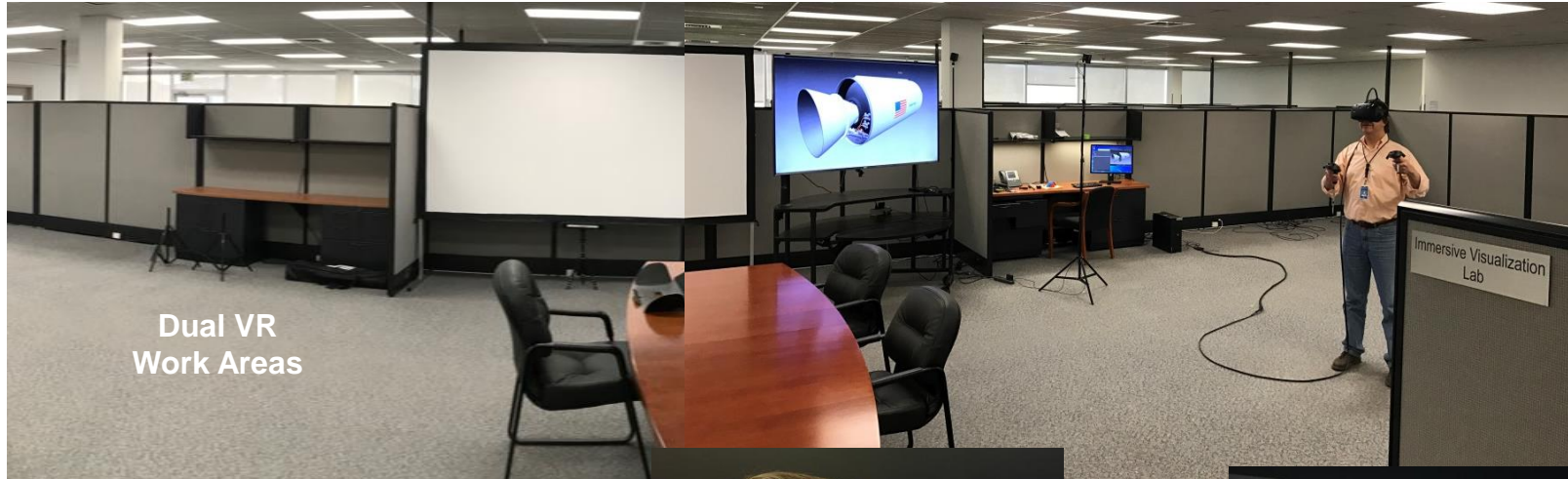


- Idaho National Labs shared their VR expertise and helped us get started



# NGIS Propulsion Systems Immersive Visualization Lab

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# Affordable Virtual Reality Systems

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- **Two examples of affordable VR systems**
  - Affordable hardware provides access to more engineers and use cases
  - Both are examples of component based user VR system builds
- **Industrial VR systems are still not turnkey and require significant development**
  - Engineering software suppliers like Siemens, PTC, AutoDesk, ESI, TechVis are working to make VR systems more turnkey and affordable
  - VR system builders and integrators like MechDyn and others can also help

## Stationary VR System with LED Powerwall

- |                             |                 |
|-----------------------------|-----------------|
| • 128GB Workstation         | \$3500          |
| • Graphics Cards P5000      | \$5000          |
| • VIVE Pro HMD              | \$1500          |
| • 75" 4K LED TV             | \$3000          |
| • <u>Stands/Cables/Misc</u> | <u>\$1000</u>   |
| <b>Total:</b>               | <b>\$14,000</b> |
| • VR Software               | \$0-\$25K       |

## Portable VR System

- |                        |               |
|------------------------|---------------|
| • Alienware 17" PCn    | \$1800        |
| • VIVE HMD             | \$900         |
| • 50" 4K LED TV        | \$500         |
| • <u>Stands/CaMisc</u> | <u>\$500</u>  |
| <b>Total:</b>          | <b>\$3700</b> |
| • VR Software          | \$0-\$25K     |



# Virtual Reality Focus Areas

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## What business areas are using/exploring Virtual Reality at NGIS?

- Product Design Review and Verification
- Facilities and Tooling Design and Verification
- Human Factors/Ergonomics
- Manufacturing Operations Training
- Product Field Simulation
- Manufacturing Process and Workflow Simulation
- Product and Brand Marketing
- Recruiting and Education

*Virtual and Augmented Reality Technologies are emerging as new viable forms of visualization with potentially wide industrial use. NGIS is developing several of these use cases*

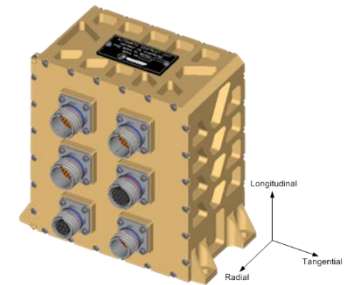
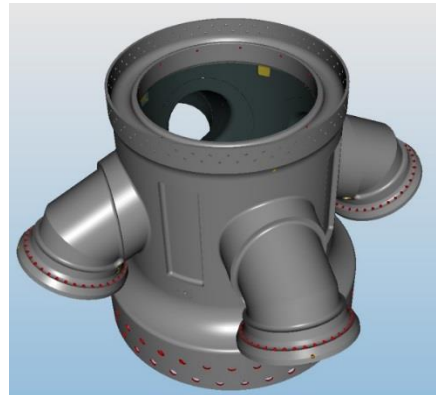
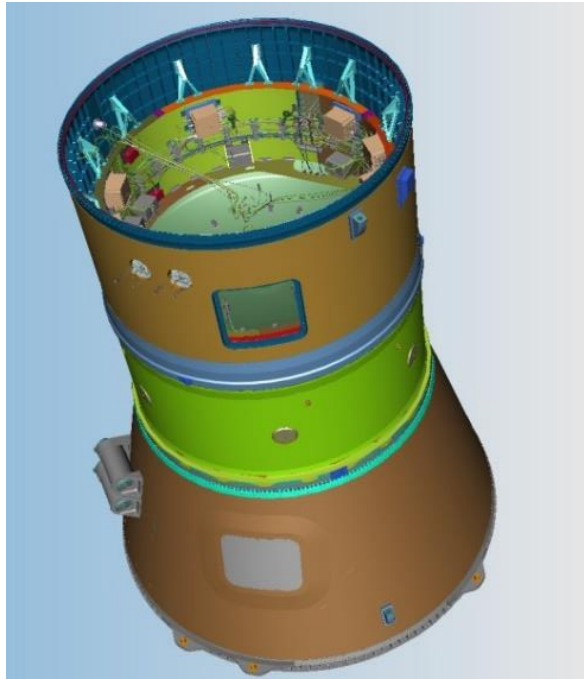
# Product Design Reviews/Verification

## NASA SLS Motor Design

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NGIS is developing new products using VR systems with CAD models.

- Enables full scale product walk thru, fit check, design evaluation
- Provides increased insight for design and customer reviews
- NASA program office has been very supportive of collaborative VR
- Design reviews are a primary use case for VR



*Digital models and VR have replaced a multi-million dollar mockup facility in Clearfield, UT*



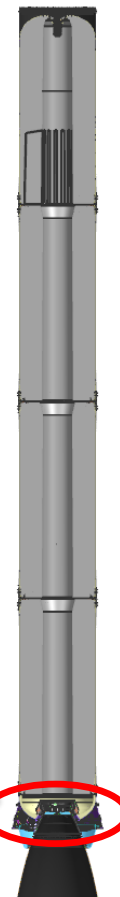
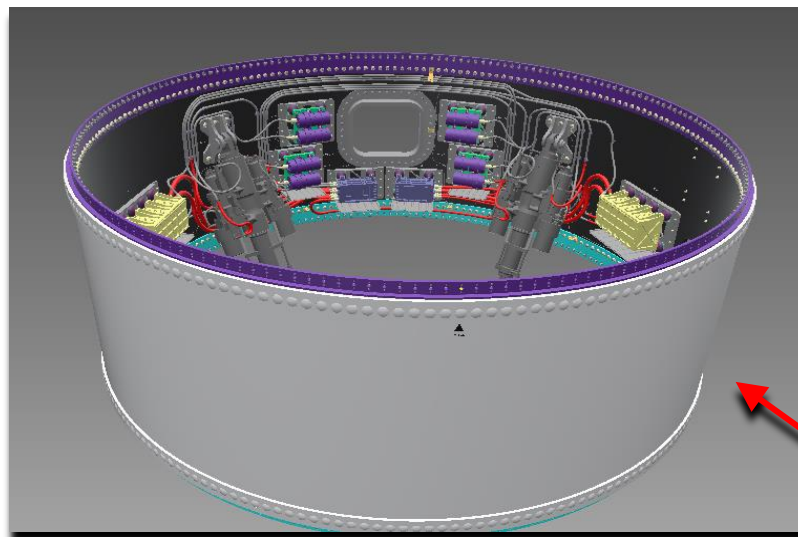
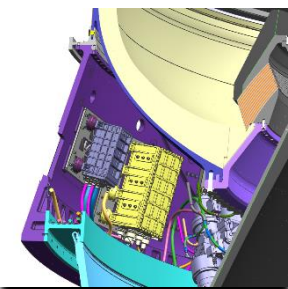
# Product Design Reviews/Verification

## Common Boost System TVC Review

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VR is a key element for the new CBS rocket motor design (C300,C600 & C1200)

- Full scale walk-thru and visualization provide a unique perspective
- Engineers used VR to assess interfaces and on pad servicing
- Helped customer understand scale and complexity
- Helped identify design several flaws at CDR level before first build

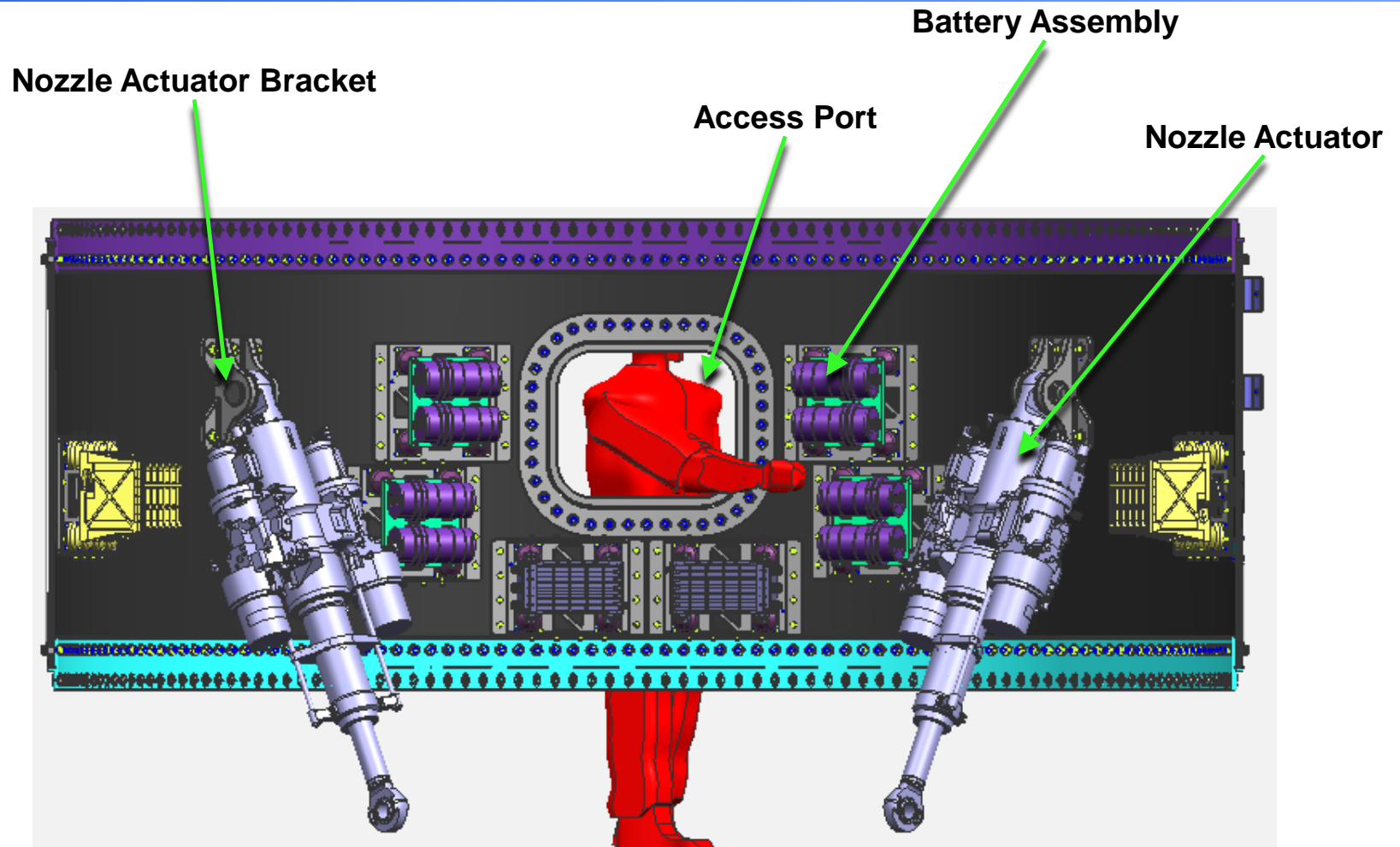


*One VR design review session saved an estimated \$70K in post build ECO's*

# Product Design Reviews/Verification

## CBS C300 TVC Battery Access

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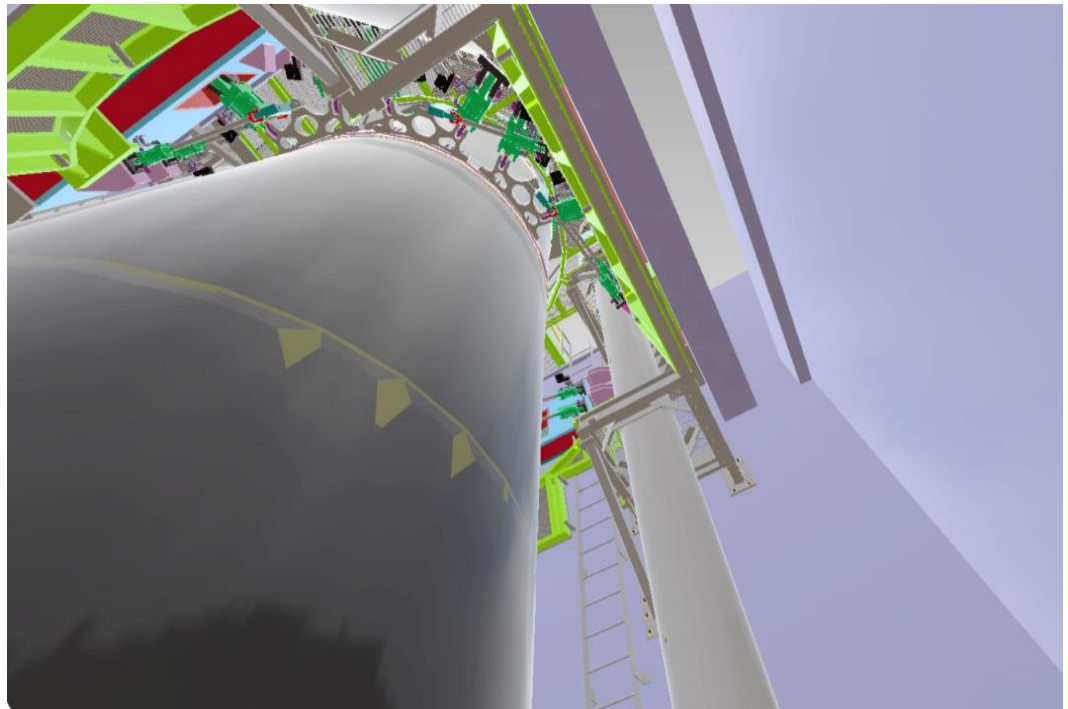
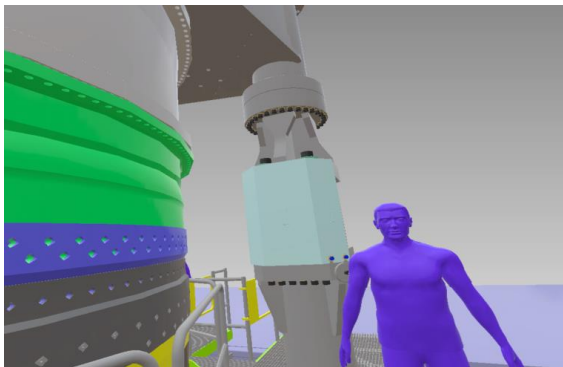
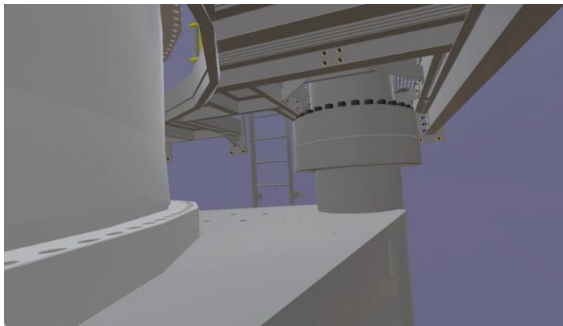
*VR simulation resulted in design changes to facilitate on pad battery access*

# Facility and Tooling Design Reviews

## CBS Large Motor Hydroproof Test Stand

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- NGIS is developing manufacturing and test facilities using VR with large CAD assemblies.
- Design and operations reviews were conducted prior to construction
  - Enables full scale test article/tooling integration, fit checks, walk thru, reach assessment
  - Provides facility/tooling/product verification and change validation



*VR Hydroproof test stand reviews saved thousands in post construction facility mods*



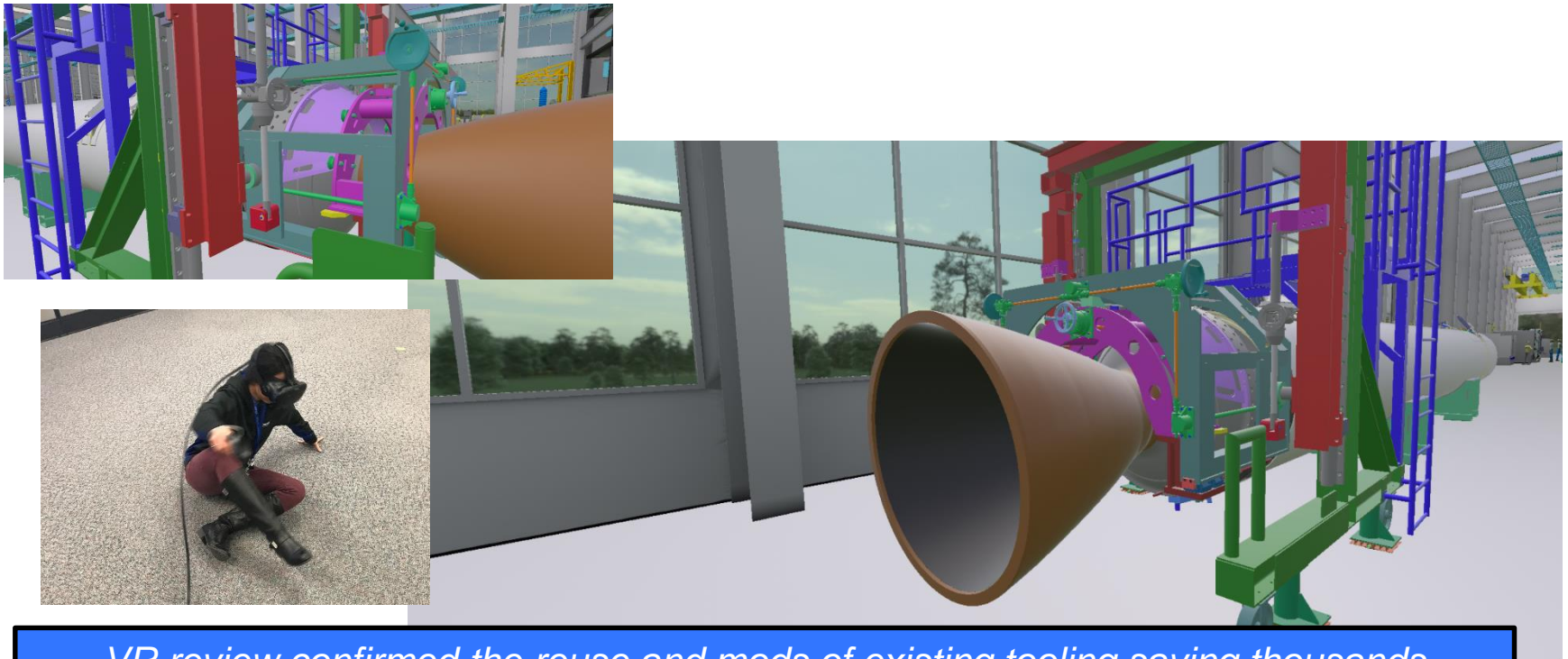
# Tooling Design Reviews

## GEM63/GEM63XL Motor Tooling Early Assessment

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NGIS used CAD tooling from GEM63 motor to assess needs for new GEM36 XL motor

- Reviews included full team (PM's, PE's, Engineers and Technicians)
- Team assessed existing tooling paired with the new XL (eXtended Length) motor
- VR put everyone on the same page. Easier to understand needed changes.



*VR review confirmed the reuse and mods of existing tooling saving thousands*

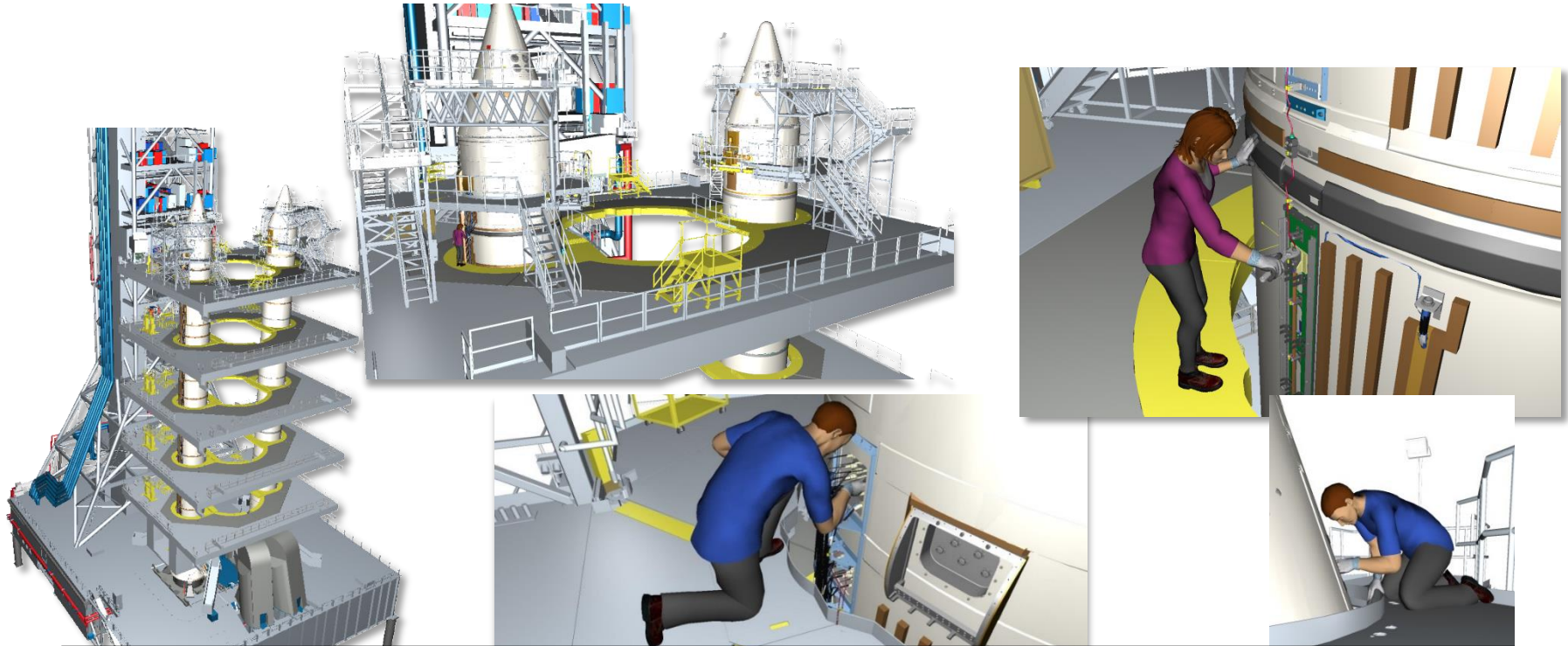
# Human Factors Analysis

## Space Launch System Booster Assembly

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Developed a digital model of the SLS Booster stack and support tower to verify human factors prior to booster build using Siemens Jack and HTC Vive HMD.

- JT models gathered from NASA and multiple NASA contractors used to build the scenario
- Scenario verifies for engineers how technicians can access assembly/maintenance procedures
- VR provides full scale immersion and visual verification



*Digital Models and VR have replaced a million dollar physical mock up facility in Utah.*



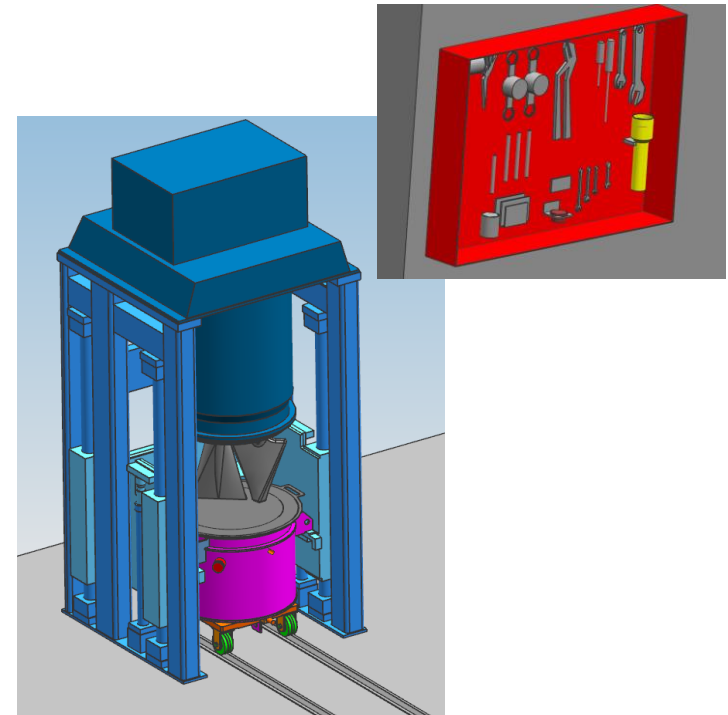
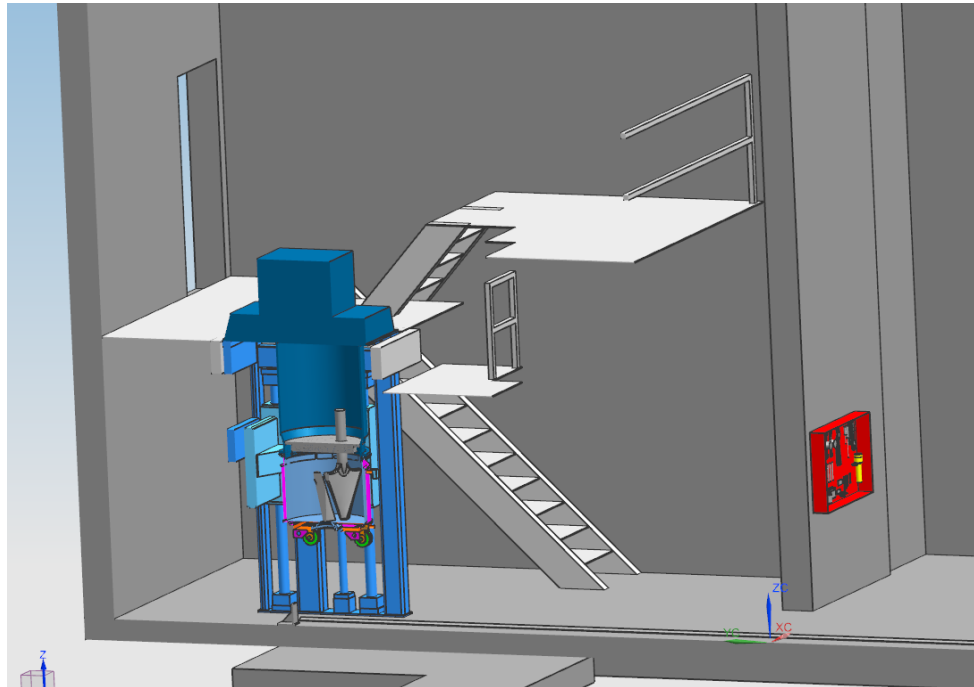
# VR Training Scenario

## Propellant Mix Bowl FOD Inspection

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Mocked up a single simple manufacturing process scenario using NX Models

- Selected the 50 Gallon Mixer FOD Inspection in Building M-34
- Created a storyboard/script for training scenarios
- Used CAD Models of Mixer, Building, Mix Bowl, Cover, Tool Board
- Developed training scenarios for CAVE, 3D Powerwall and HMD



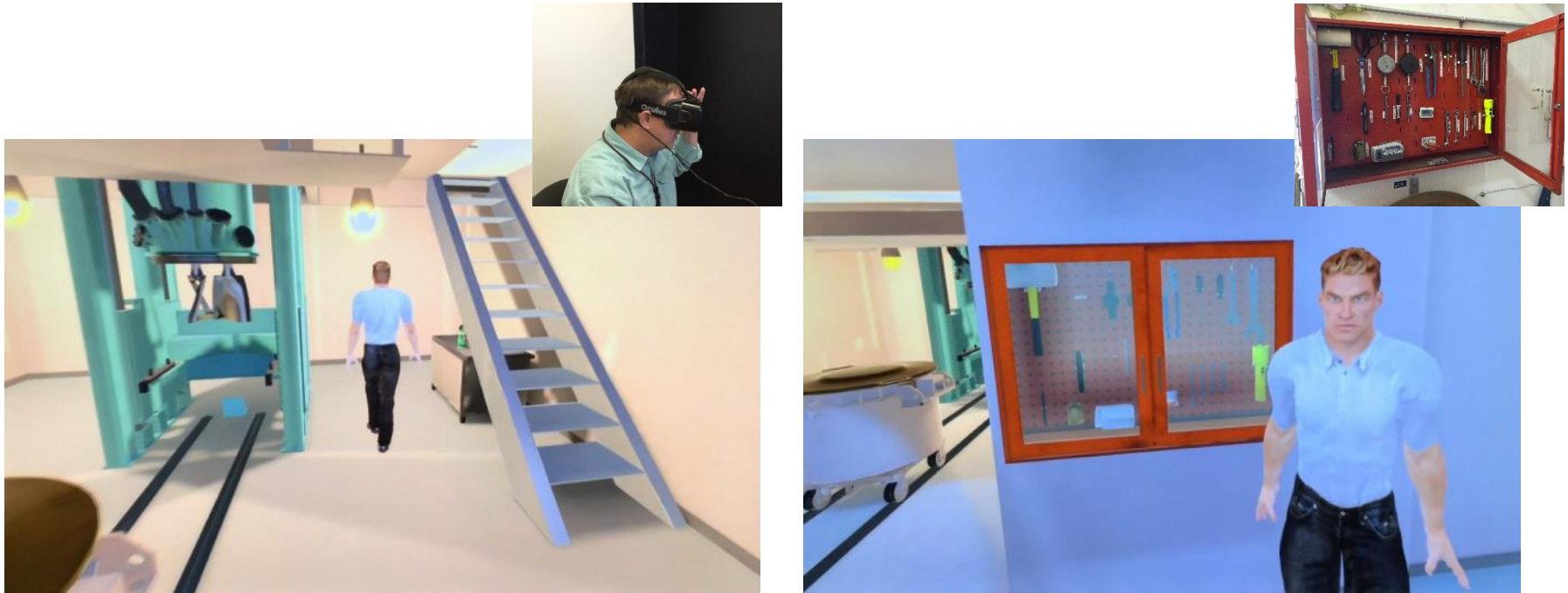
# VR Training Scenario

## Propellant Mix Bowl FOD Inspection

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Created a very simple training scenario for the Oculus Rift HMD

- See it , Do it, format - Trainee is instructed by an avatar then led thru inspection process.
- Scenario demonstrates how trainee might learn to deal with process interruptions
- FOD anomalies were introduced in the scenario to see if trainees recognized them



*POC study showed that VR could save tens of thousands in training downtime.*

# Product Field Simulation

## Switchblade Warhead Customer Demonstration

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- Switchblade provides the warfighter with a lightweight, man-portable, rapidly deployable, munition for use against beyond-line-of-sight (BLOS) targets.
- NGIS developed field performance scenarios to share with customers. Predicted warhead performance data and field scenarios are rendered in a virtual environment.
  - Enables full scale product performance assessment
  - Valuable insight for design and customer reviews



*VR helped win a multi-million dollar Switchblade warhead contract*



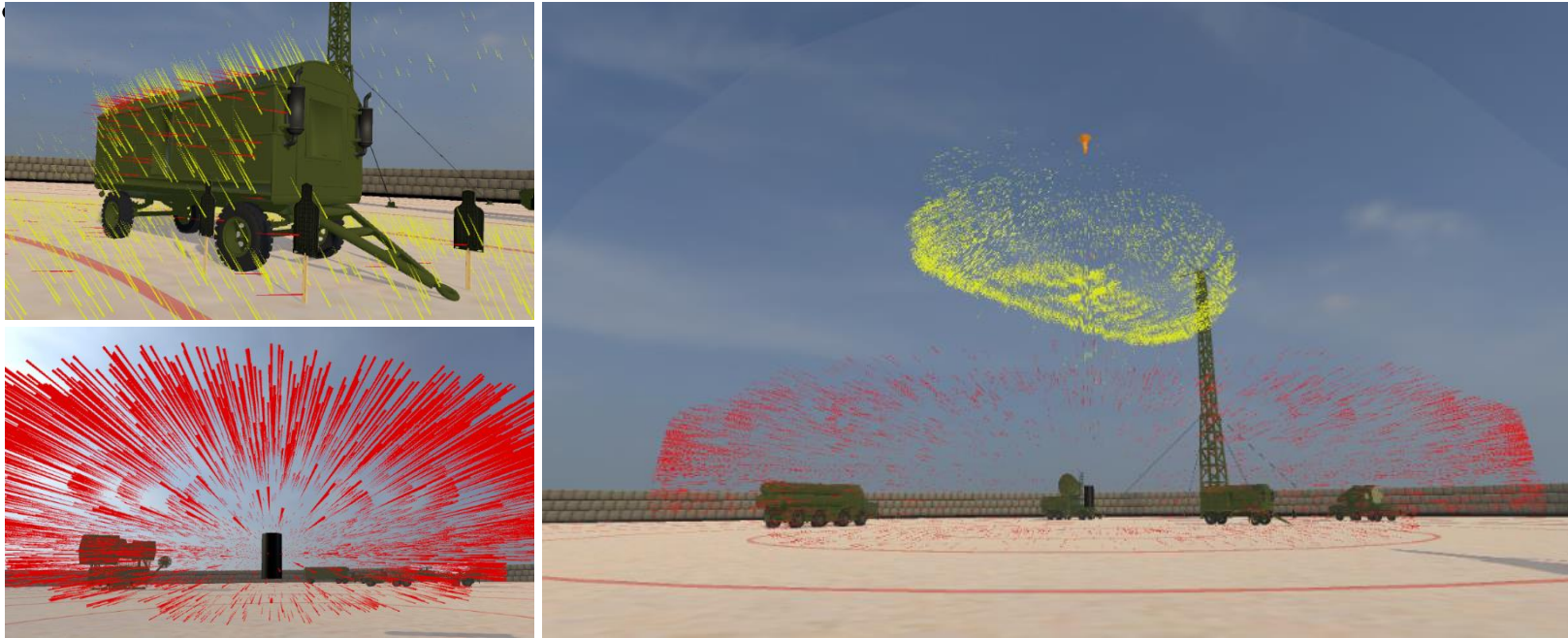
# Product Field Simulation

## Warhead Fragmentation Demonstration (Area Attack Weapon)

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NGIS developed simulated warhead deployment in a virtual combat environment

- Enables interactive visualization of high-speed fragments and blast wave
- Facilitates comparison of combat performance of multiple warheads
- Allows for cost-effective design iterations and customer reviews
- Compare and contrast fragmentation patterns of various warheads



*Significant cost savings over traditional warhead demonstration methodologies*

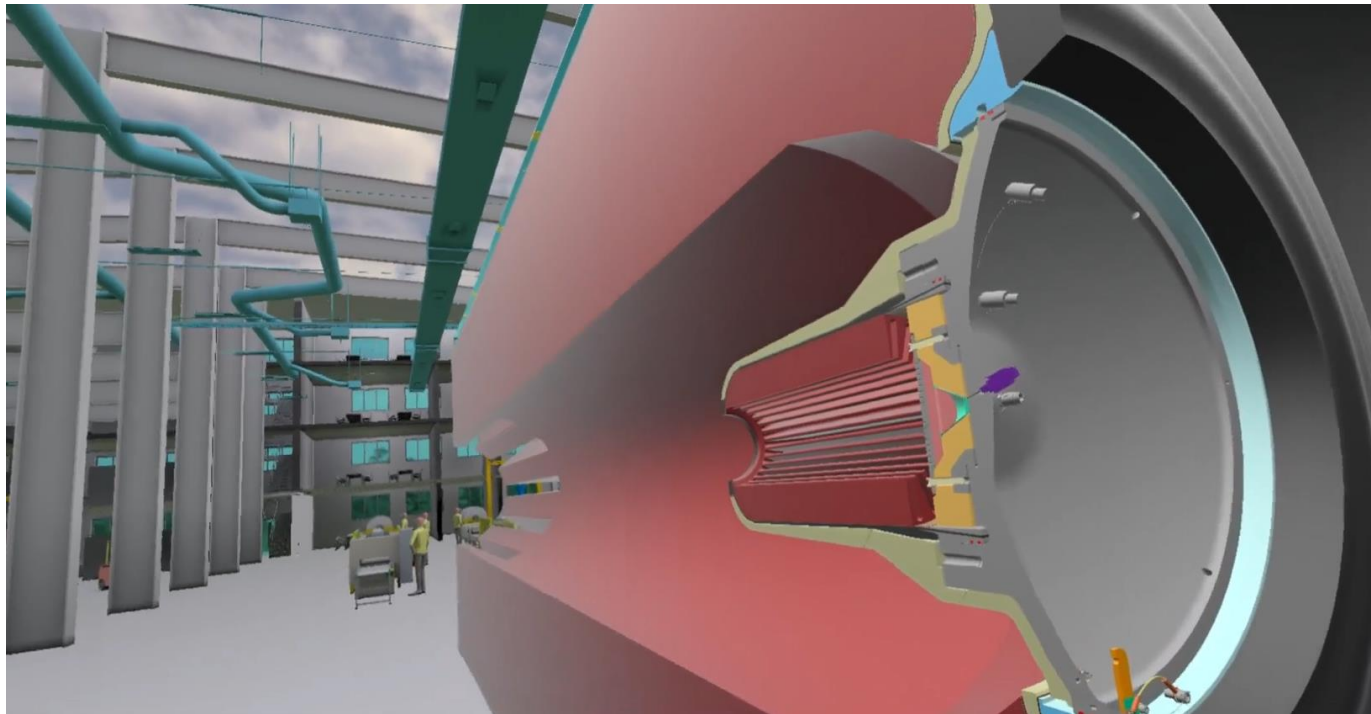
# Process Simulation

## CBS Motor Nozzle Installation

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VR was used to verify nozzle installation procedure and familiarize technicians with process

- CBS Nozzle installation was a new process for process engineers and technicians
- Helped them understand and interact with new hardware early in the design/build phase
- Gave the processing team understanding of the process with full size hardware



*VR nozzle installation helped refine the planning and tooling*



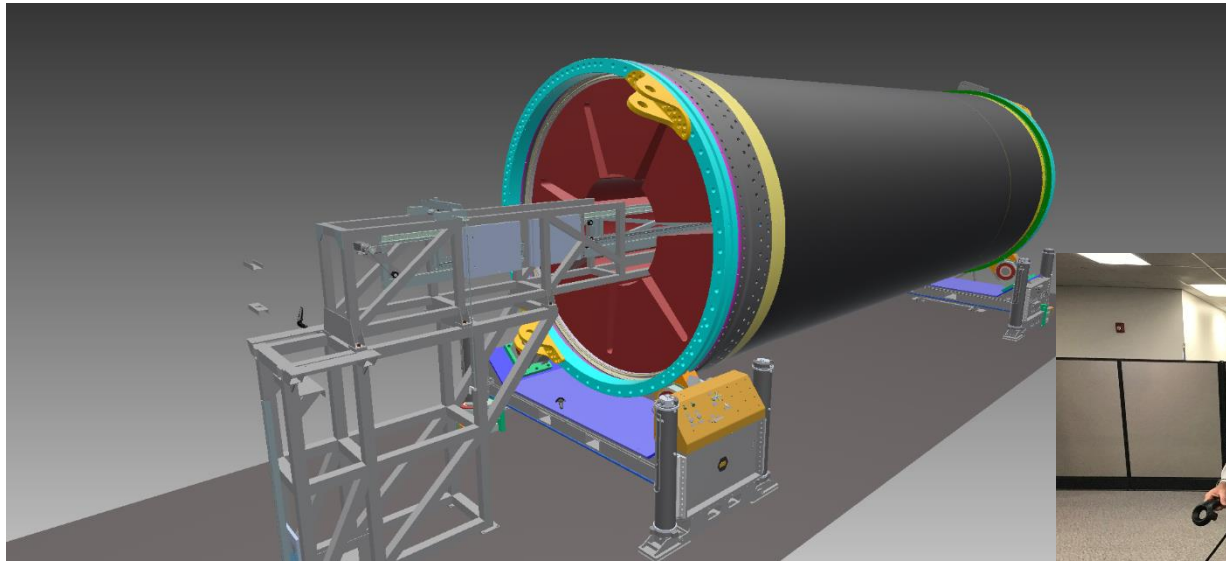
# Manufacturing Process Verification

## Large Motor Propellant Bore X-ray Inspection Verify

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VR was used to verify tool installation and X-ray sensor travel thru a loaded motor

- X-ray technicians interacted VR to get familiar with this new tool and process
- Engineers used it to verify clearances and processing
- Always significant caution and concern working on “live” propellant



*VR Simulation on new rocket motor reduced risk for a first article x-ray inspection*

# Conclusions

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- VR is a promising technology which provides new insights and clarity over traditional training, design and simulation approaches.
- VR has proven very beneficial for design reviews where assemblies with numerous components can be visualized in depth, faster and in full scale.
- VR has been extremely effective with engineers, management and customers in design reviews and product performance scenarios
- The propellant mix bowl scenario successfully showed that 3D VR can provide a training experience that is free from the hazards of live operations.
- VR helps train and condition operators for “what ifs”, hazards and prior anomalous scenarios
- VR provides better immersion and spatial familiarity with product, equipment and facilities than traditional design methods or training materials.
- VR engages customers, engineers and program management to better understand current design, analysis, manufacture and/or training challenges.

*VR promises to change the way we market, design, build and support products*