Human Systems Engineering for Launch Processing at Kennedy Space Center (KSC)

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Abstract

Launch processing at Kennedy Space Center (KSC) is primarily accomplished by human's users of expensive and specialized equipment. In order to reduce the likelihood of human error, to reduce personal injuries, damage to hardware, and loss of mission, the design process for the hardware needs to include the human's relationship with the hardware. Just as there is electrical, mechanical, and fluids, the human aspect is just as important. The focus of this presentation is to illustrate how KSC accomplishes the inclusion of the human aspect in the design using human centered hardware modeling and engineering. The presentations also explains the current and future plans for research and development for improving our human factors analysis tools and processes.

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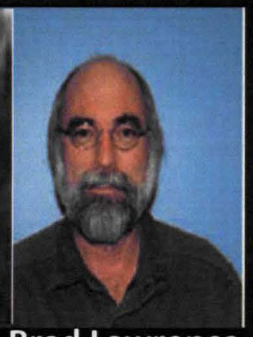
KSC Human Factors

Darcy Miller

Tim Barth
Ph.D.

Donald Tran

Lori Gregg



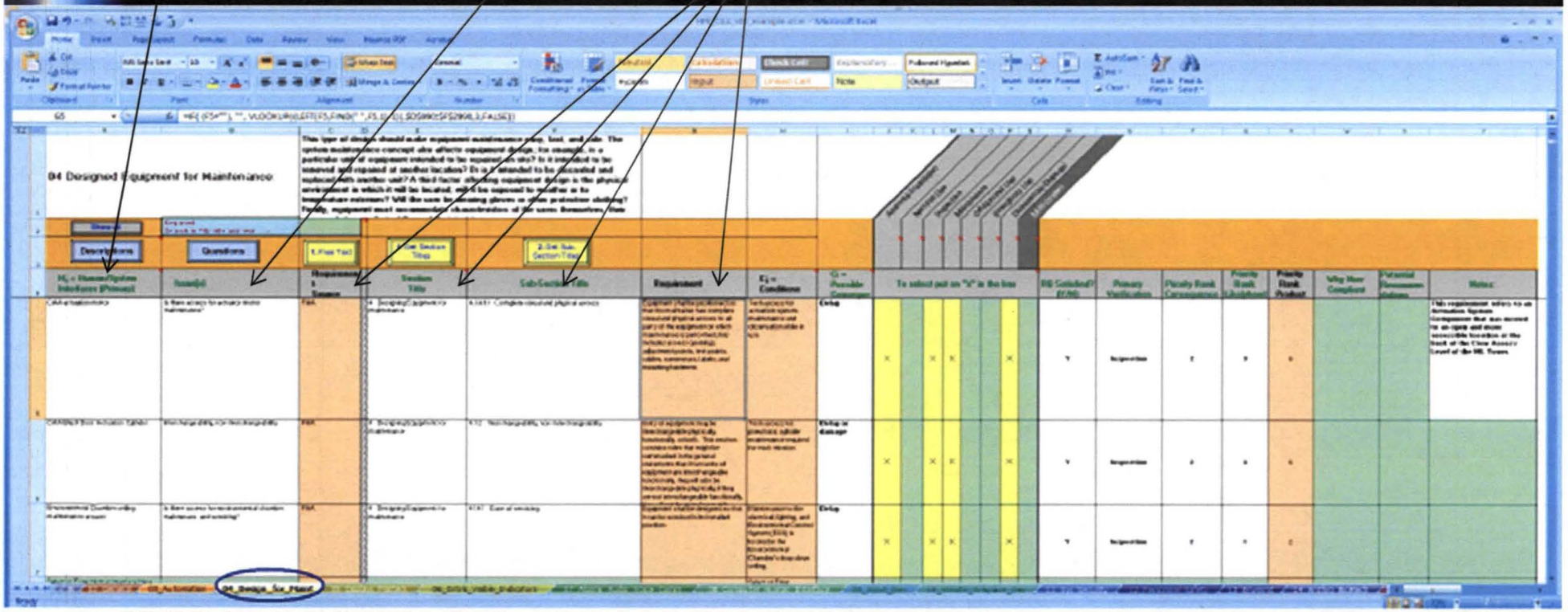
Brad Lawrence

HFEAT

Human/System Interface

Issues

Requirement (Source, Title, Sub Section, and requirement words)

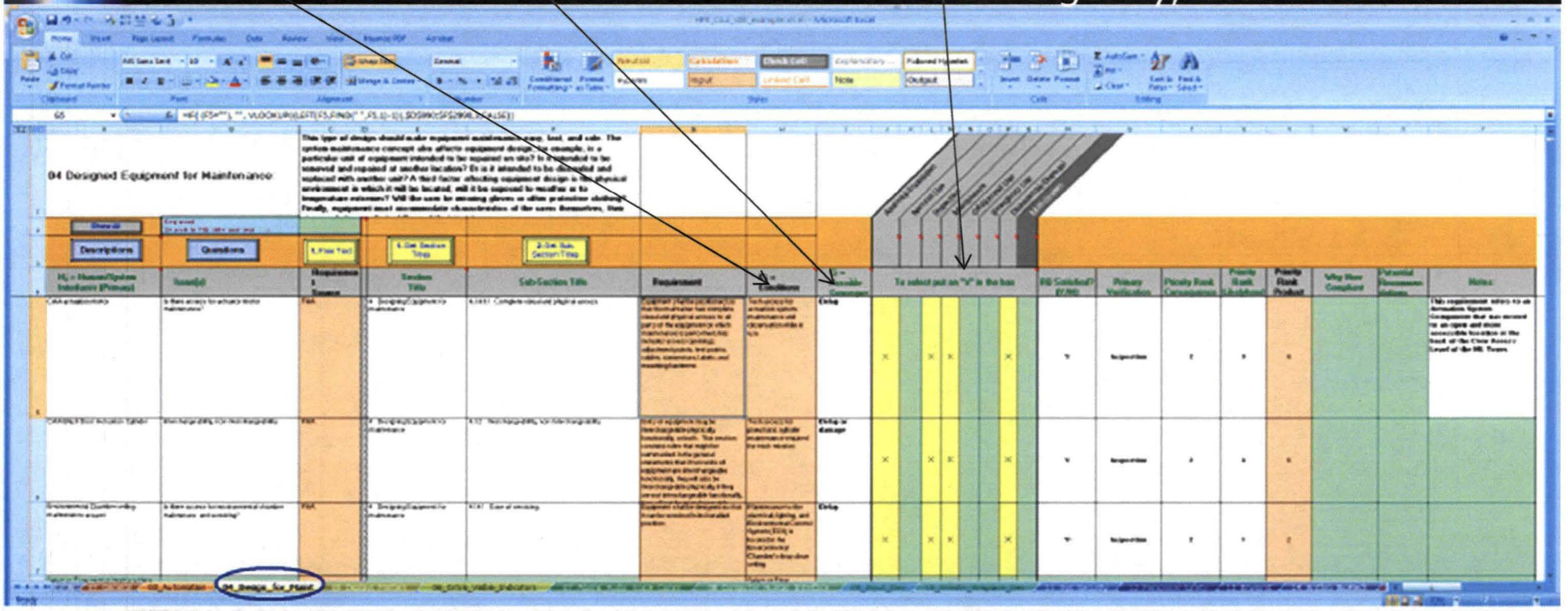


HFEAT

Conditions

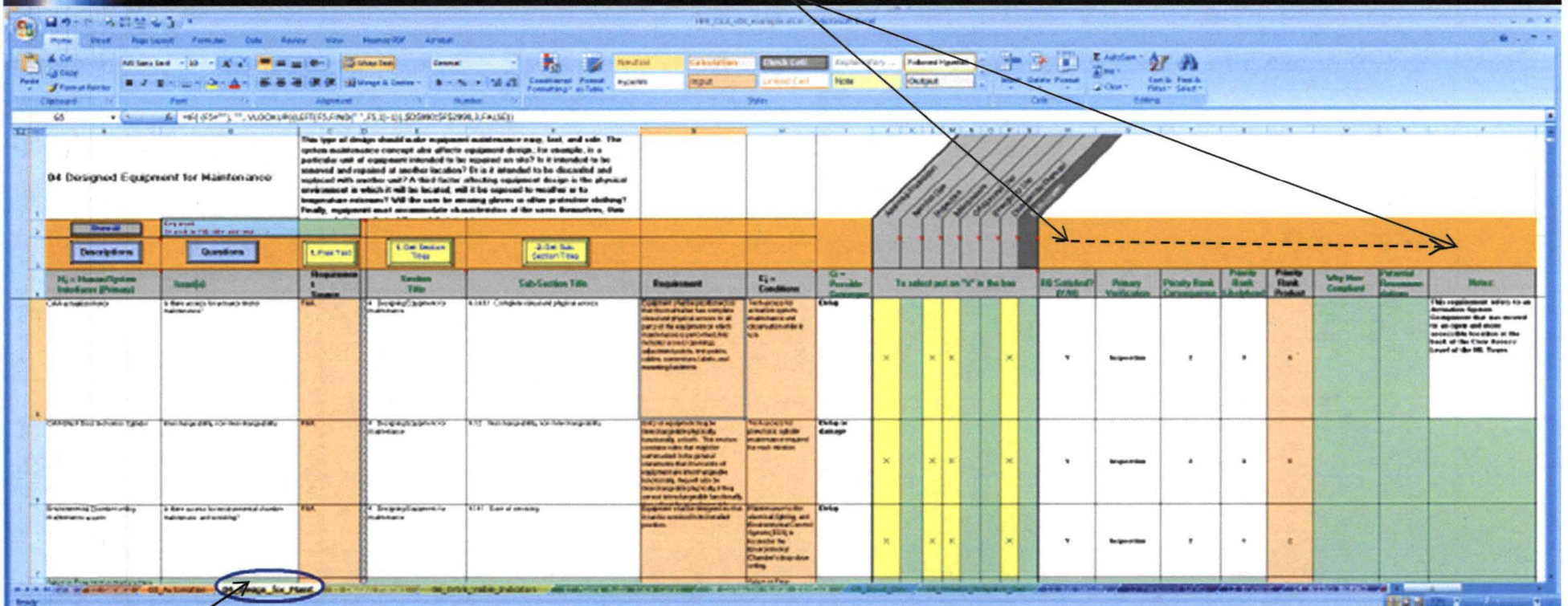
Consequences

Type of processing, Assembly, Nominal, inspection, Emergency, etc.



HFEAT

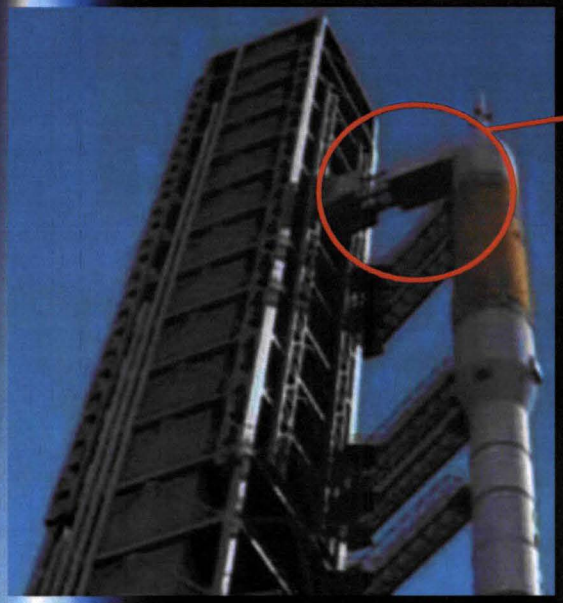
Requirement Satisfied, Verification, Consequence, Likelihood, Priority Rank, Why Non-Compliant, Recommendation, Notes.



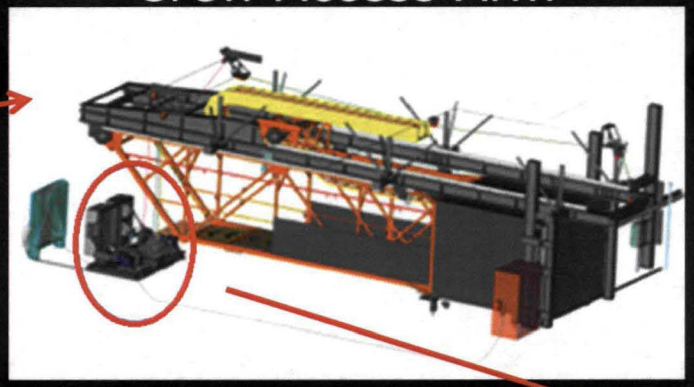
Each Tab is a FAA Chapter: Design equipment for maintenance, Controls and visual indicators, etc.

Example Actuator Motor

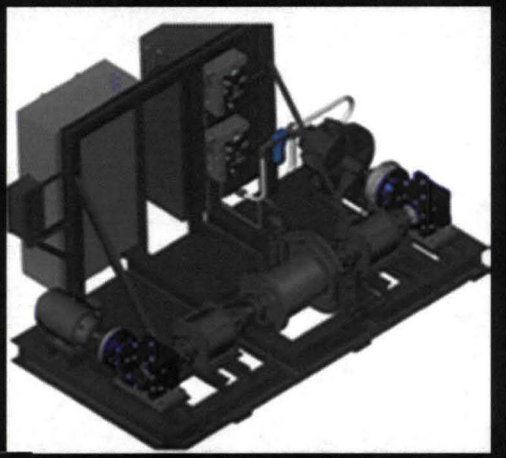
Mobile Launcher



Crew Access Arm



Actuator Motor

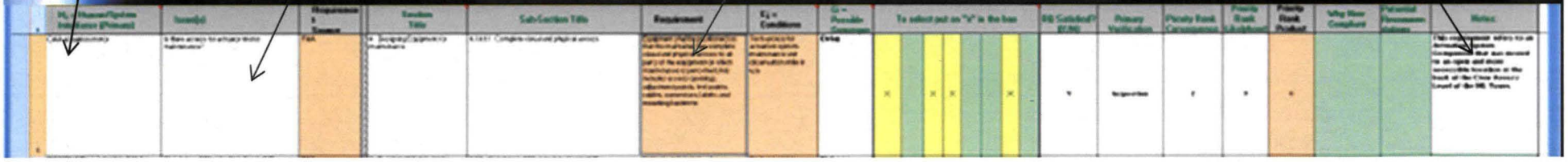


ctuator motor

Complete visual and physical access

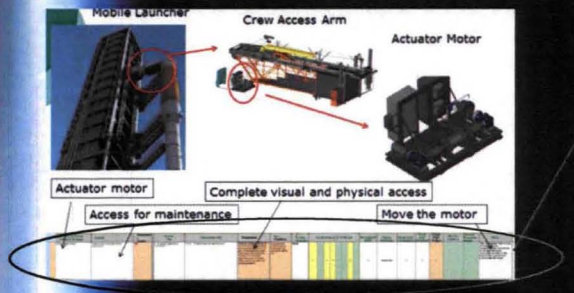
Access for maintenance

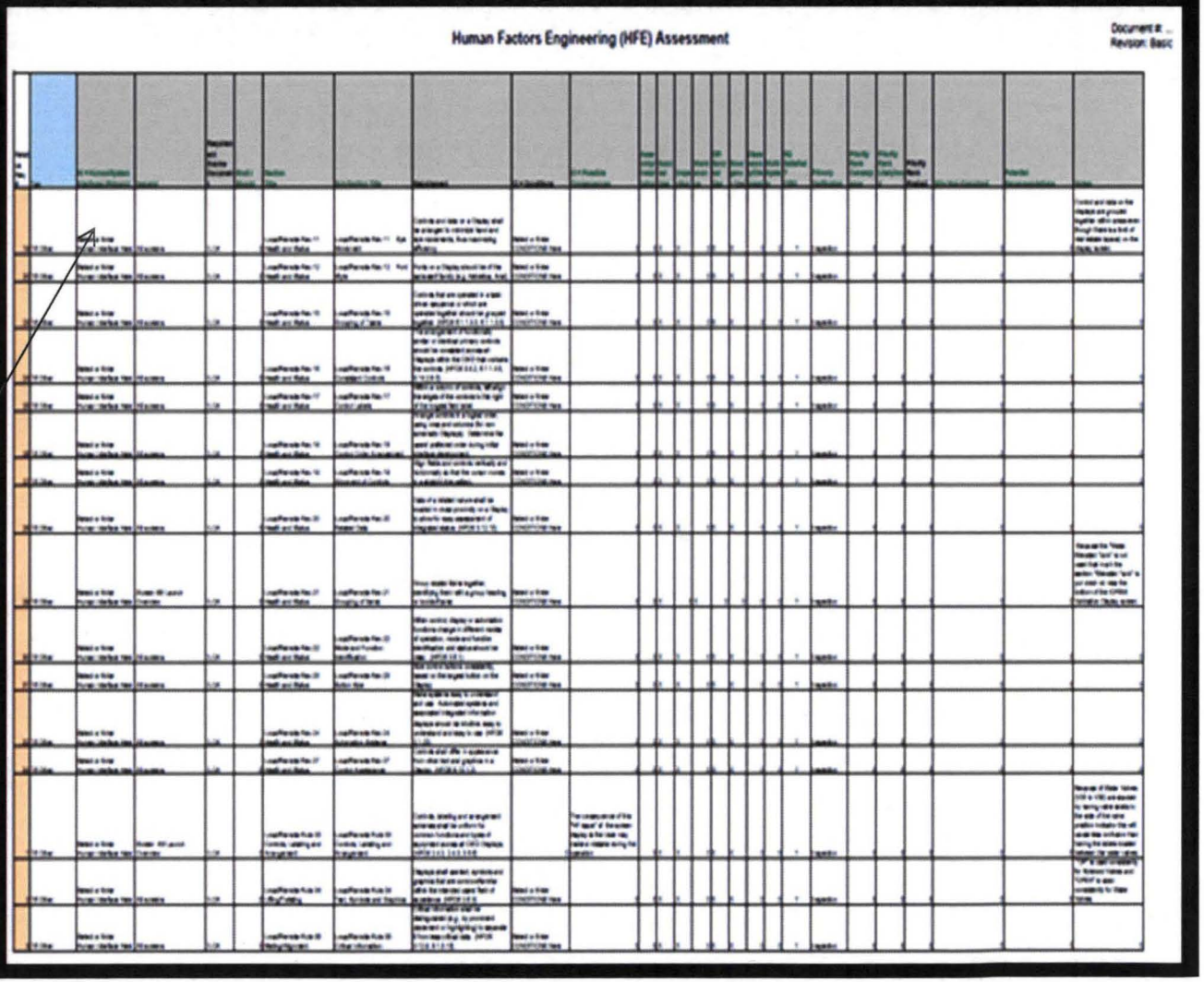
Move the motor



HFEA Report for Crew Access Arm

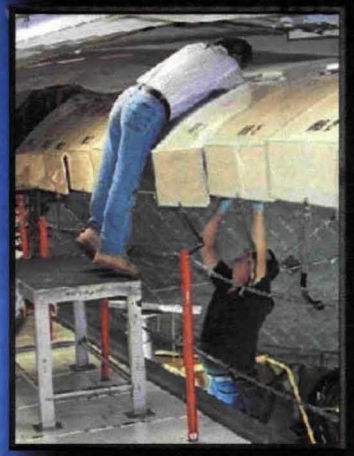
Actuator Motor Issue





KSC Human Engineering Modeling and Performance Laboratory (HEMAP)

Human Systems Engineering Analysis using HEMAP

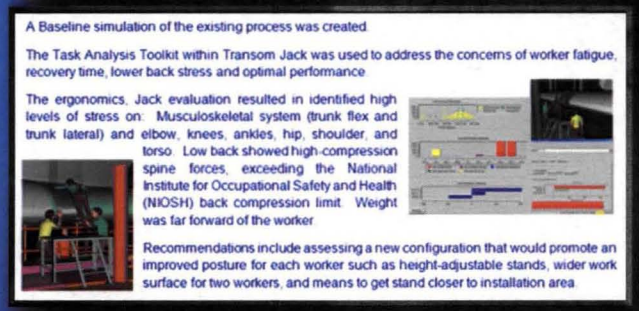


Real Task

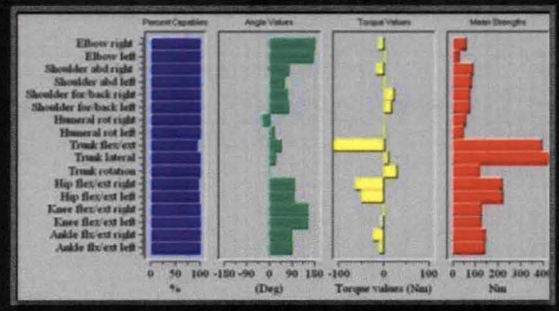
Motion Captured Task (Actual Techs & Biomechanical Data)

Real time Biomechanical Model

CAD and Human Real time Simulations



Human Factors Analyses and Recommendations

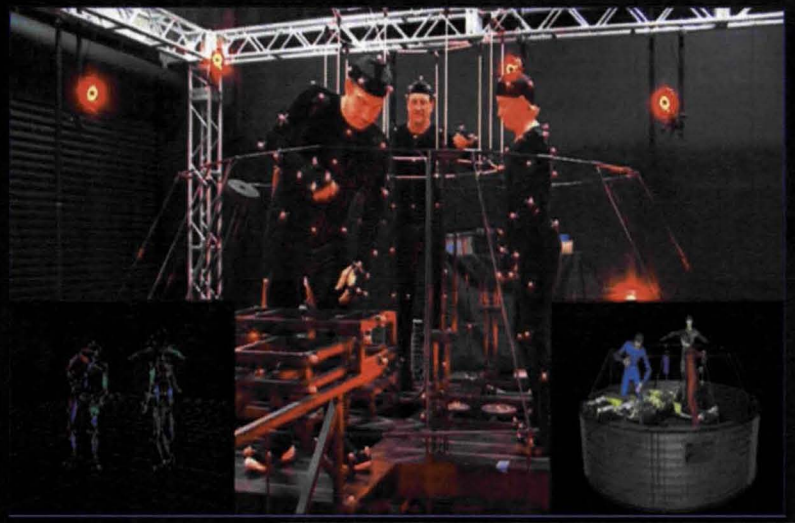


Real time Ergonomic Analysis

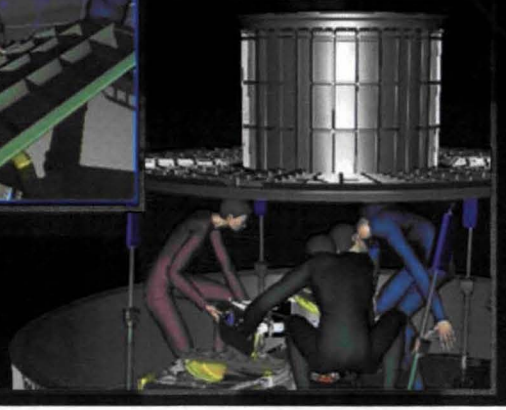
HEMAP supports multiple person/object tracking into live ergonomic analyses

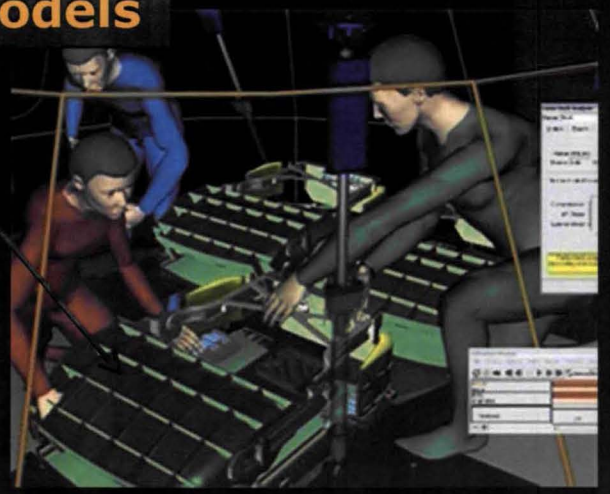
Requirements Compliance through Motion Capture Human Factors Analysis for Proactive Design and Operational Improvements

Motion Capture

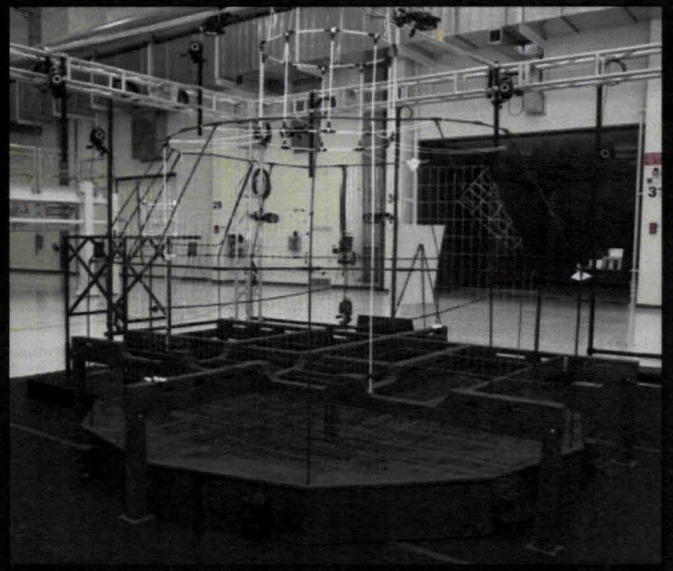


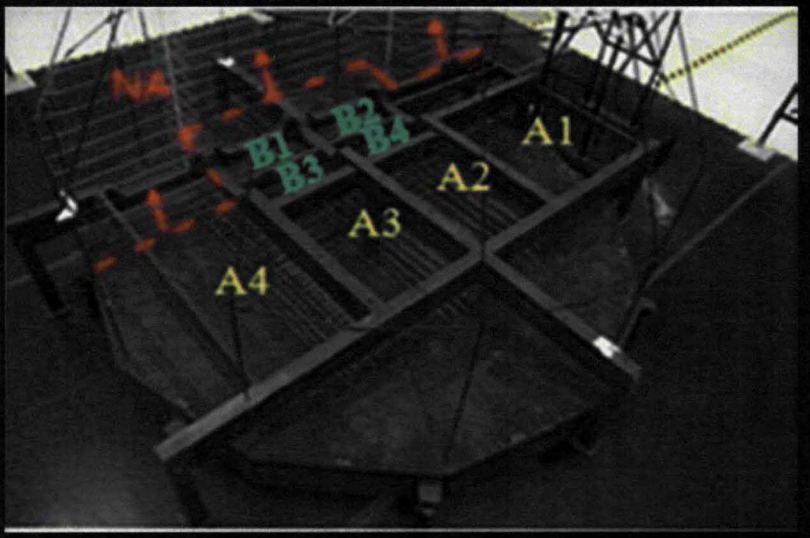
CAD Models with Human Models

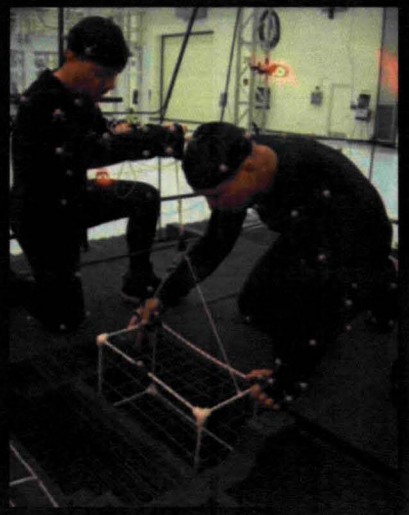


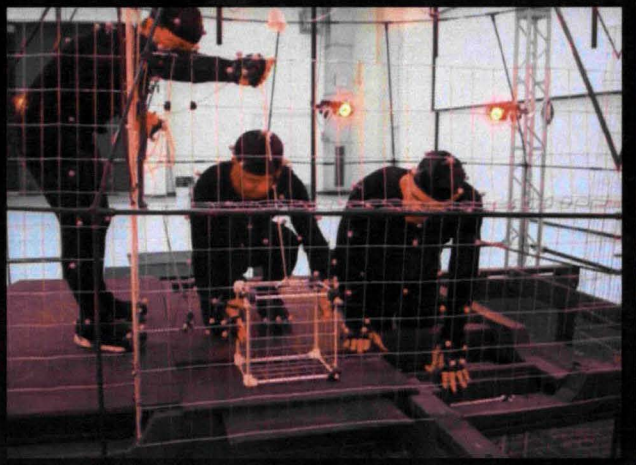


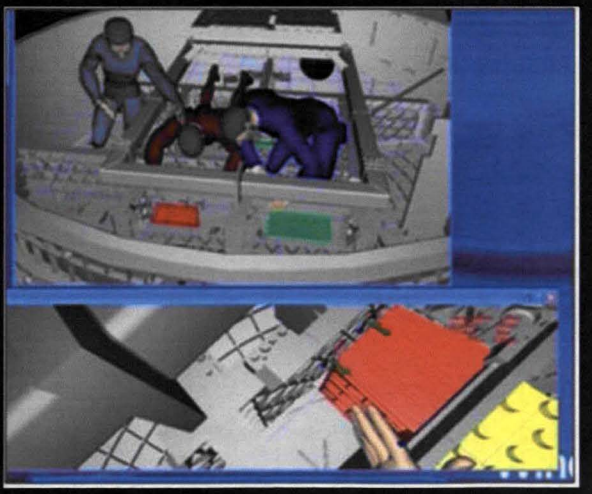
Orion Avionics Box Installation









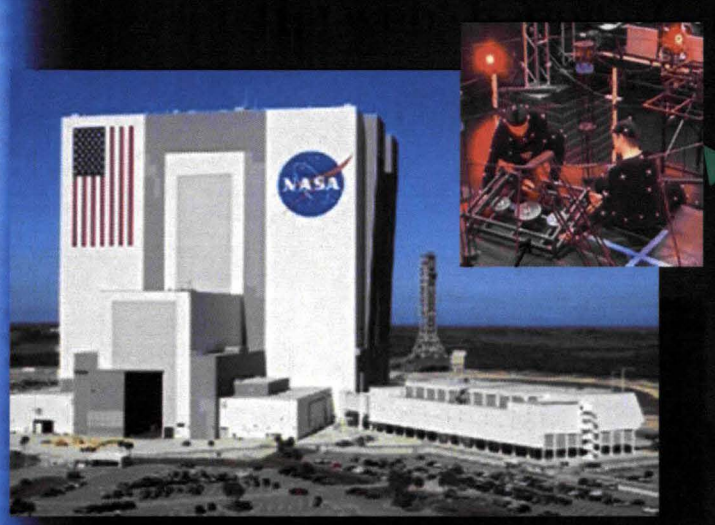


Self-Contained Atmospheric Protective Ensemble SCAPE Suit

Markers placed on SCAPE suits to create actual life size and motion of suits

Interactive Virtual collaboration

- Interactive virtual collaboration of motion capture data among KSC and MSFC
  - The web sharing of motion capture tasks within the shared virtual environment provides real-time ability to update designs based on actual human-system interfaces being evaluated.



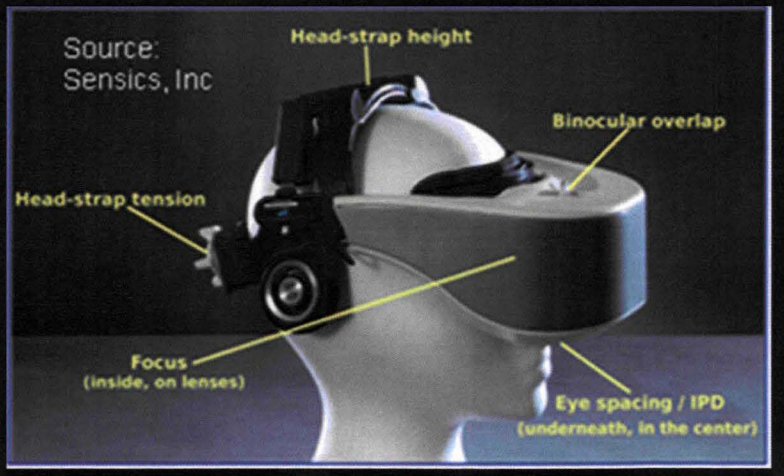
Motion Capture at KSC

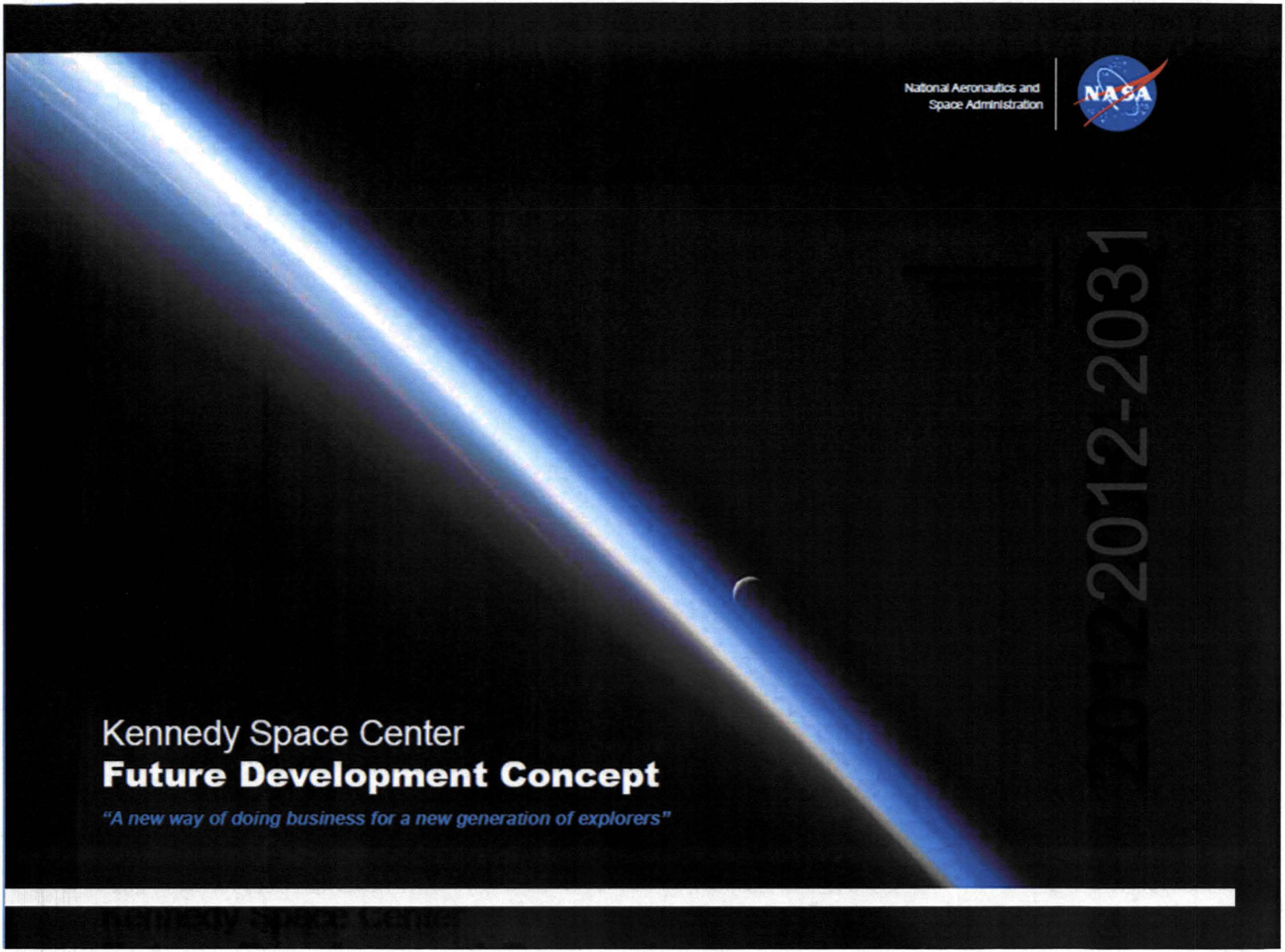
Combined Design Environment

Motion Capture at MSFC

Head-Mounted Displays

- Incorporation of wearable Head-Mounted Displays (HMDs):
  - Negates need for physical mockups.
  - Familiarization/training benefits
  - Collaborative web sharing of models and live motion tracking among NASA centers
  - Immersing the HMD wearers in simple physical mockups




National Aeronautics and
Space Administration
NASA
2012-2031
Kennedy Space Center
Future Development Concept
"A new way of doing business for a new generation of explorers"

Kennedy Space Center
Future Development Concept

Goal 1: Ensure mission success by enabling Government and commercial access to space

Goal 2: Develop, operate, and sustain a robust launch and payload processing complex for all providers

Goal 3: Conduct research and develop technology (R&T) representative of KSC expertise to enable NASA mission success

Goal 4: Provide a flexible, cost-effective institution to enable success

Goal 5: Inspire, engage, and educate through enriching programs, internships, and partnerships

Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

Goal 1: Ensure mission success by enabling Government and commercial access to space

a. Assure successful Government access to space
b. Enable development of routine commercial access to space

Goal 2: Develop, operate, and sustain a robust launch and payload processing complex for all providers

a. Convert the KSC launch and payload processing complex into a multi-user capability
b. Establish plans, processes, and agreements to support multi-user activity

Goal 3: Conduct research and develop technology (R&T) representative of KSC expertise to enable NASA mission success

a. Advance KSC's R&T into relevant uses for KSC, NASA, and the Nation
b. Conduct R&T development to enhance NASA capabilities to explore
c. Perform R&T to enhance surface and launch systems for any

Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

Goal 4: Provide a flexible, cost-effective institution to enable success

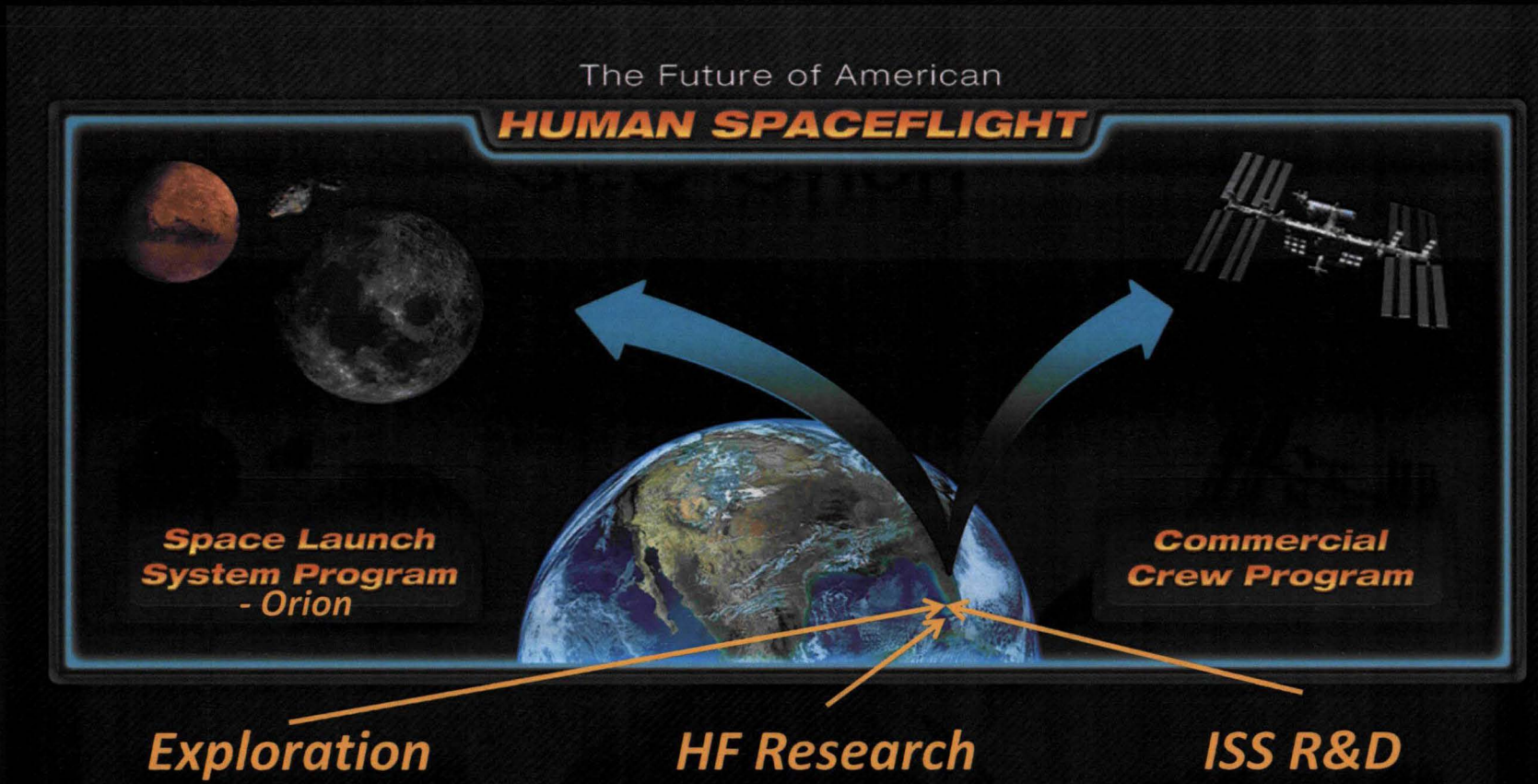
- Align civil service and contractor workforce with NASA and KSC goals and plans
- Continue the transformation of institutional facilities and infrastructure to support future needs
- Continue the transformation of technical capabilities/services required to support future NASA and multi-use programs
- Establish a model sustainability program

Goal 5: Inspire, engage, and educate through enriching programs, internships, and partnerships

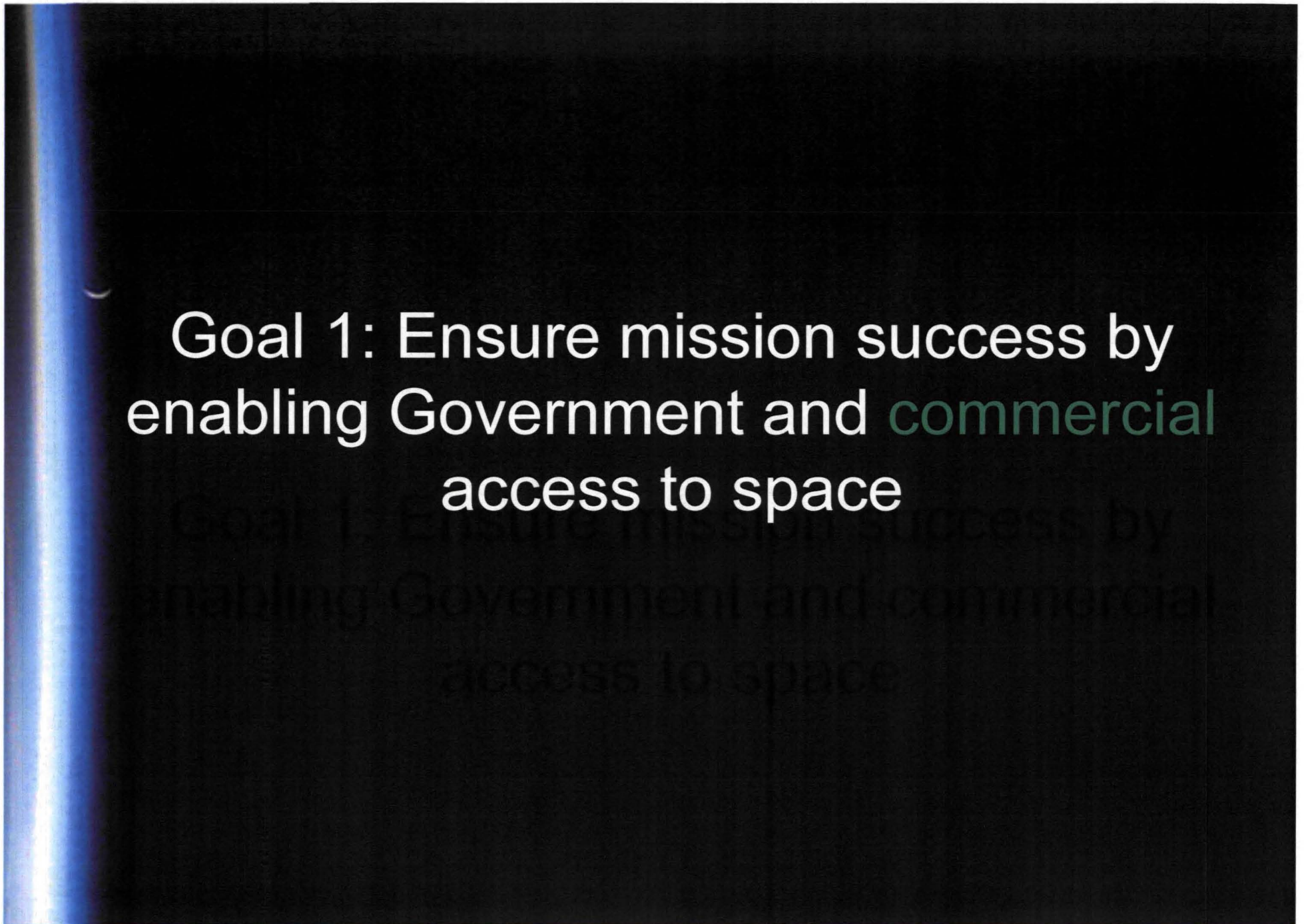
- Assure effective community involvement, partnerships, and STEM awareness
- Increase STEM student opportunities at KSC

Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

HF Research/Commercial Crew/ SLS-Orion



Thanks to Trent.M.Smith@nasa.gov for providing Commercial Crew slides.



Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

Commercial

August 2012, NASA awarded CCiCap:

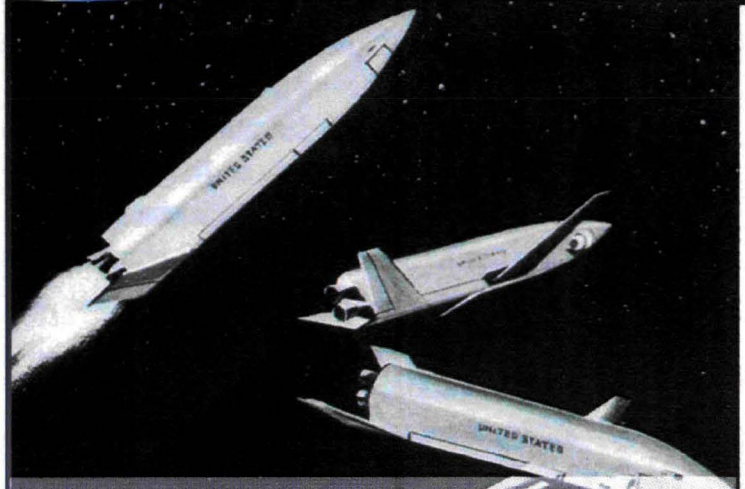
Dream Chaser/Atlas V *Dragon/Falcon 9* *Boeing/Atlas V*

CCiCap: A fully integrated system includes a spacecraft, launch vehicle, ground operations and mission control center.

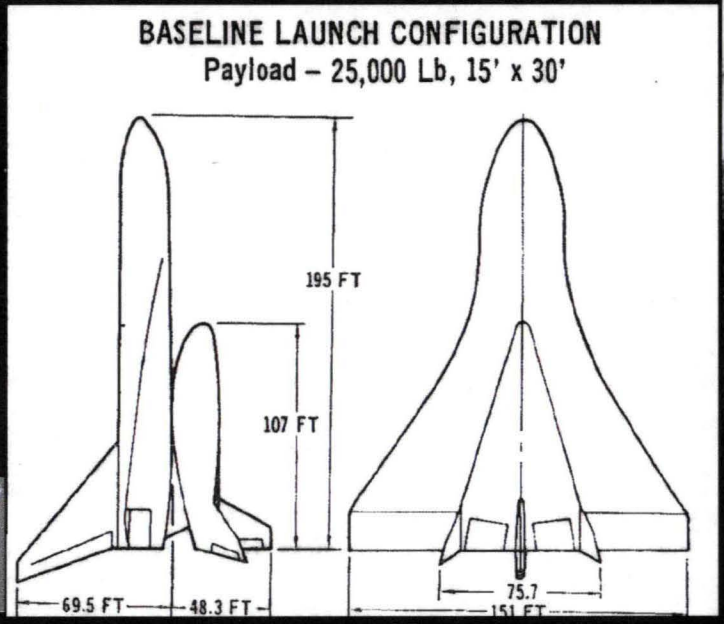
Thanks to Trent.M.Smith@nasa.gov Commercial Crew POC for providing slides.

Space Shuttle Early Integrated Design

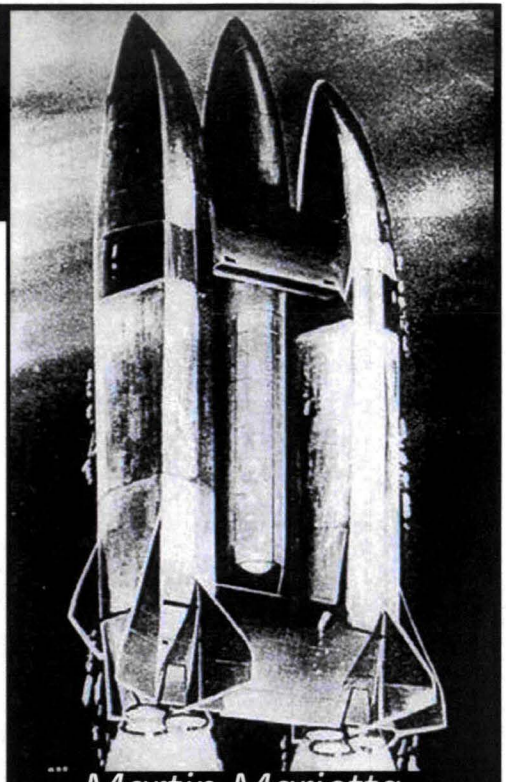
Competition was key



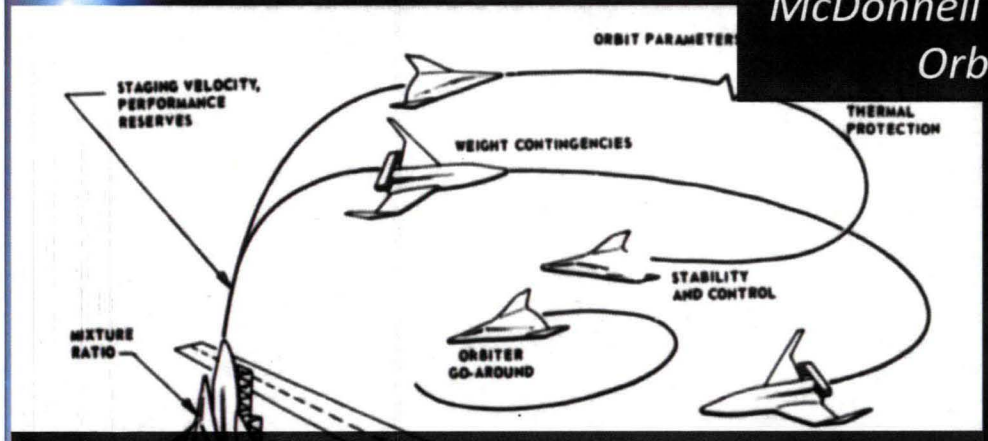
General Dynamics Triamese Design 1969



McDonnell Douglas Two-stage to Orbit Design 1969

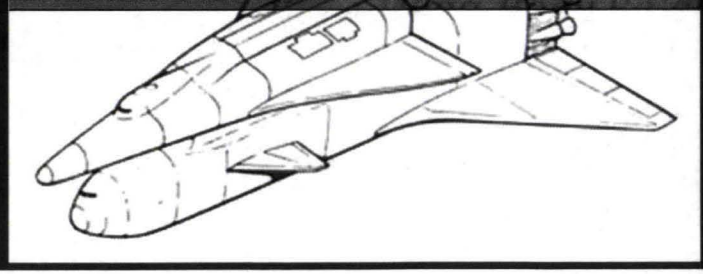


Martin Marietta Catamaran Booster and Wing-Body Re-entry Configuration 1969

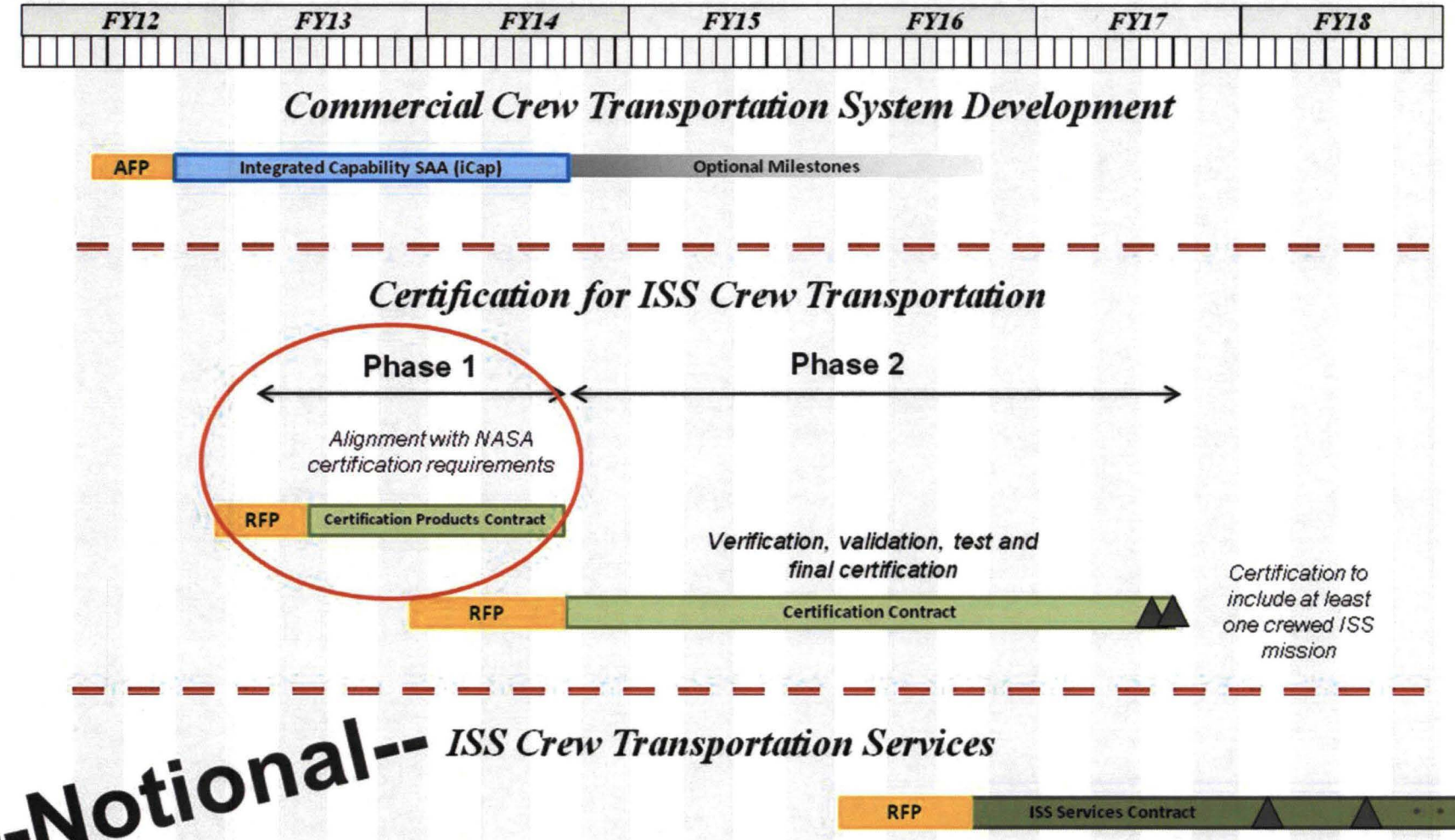


Lockheed Missiles & Space Company Two-stage to Orbit Design 1969

North American Rockwell Corporation Two-stage to Orbit Design 1969



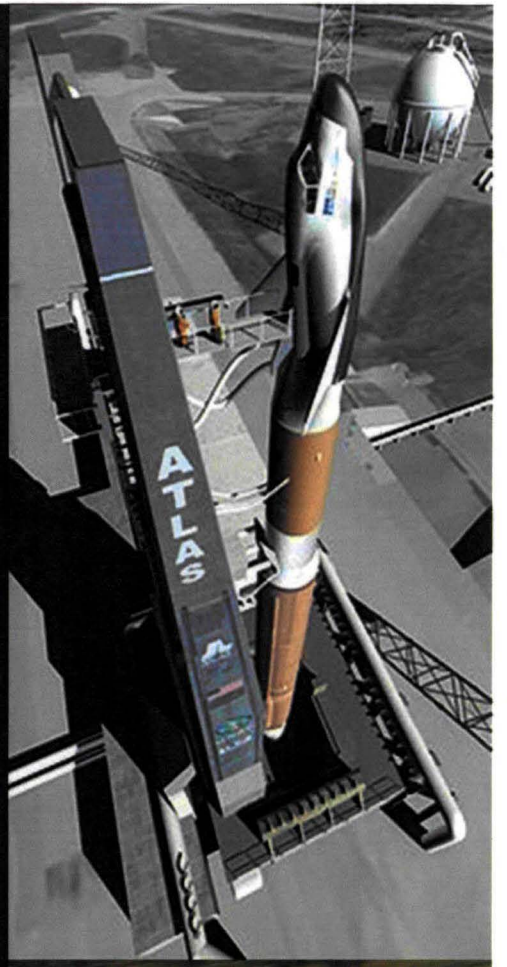
Revised Acquisition Strategy (2012)

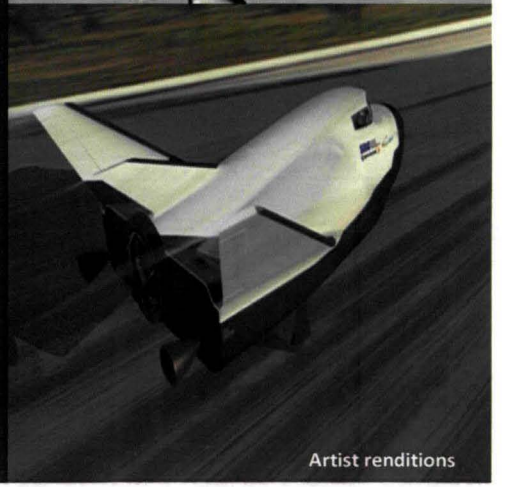


Sierra Nevada Corporation

- Dream Chaser spacecraft is a reusable, piloted, lifting body.
  - Carries up to 7 crew members
  - Utilizes non-toxic propellants
  - **Primary Launch/Landing Site: Florida**
  - Ability to abort to a runway landing
- **Atlas V launch vehicle**

- Testing:
  - Engineering Test Article Flight(s)
  - Wind Tunnel Risk Reduction
  - Spacecraft Subsystem Risk Reduction
  - Main Propulsion Risk Reduction
  - Reaction Control System Risk Reduction





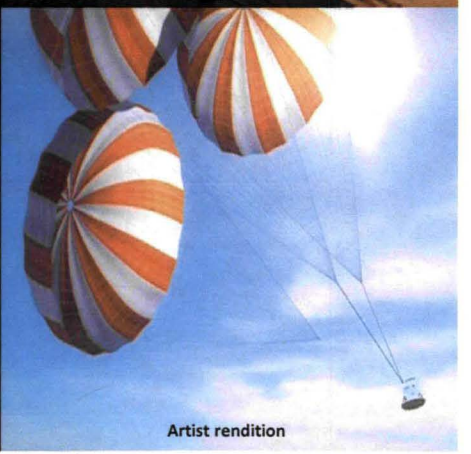
Artist renditions

Space Exploration Technologies Corporation

- Spacecraft uses a crewed version of the SpaceX Dragon capsule
  - Carries up to 7 crew members
  - **Primary Launch Site: Florida**
  - Primary Landing Site: "On land" landing
- **Upgraded Falcon 9 launch vehicle**

- Flight tests:
  - Pad Abort (SLC 40 and last quarter of 2013)
  - In-Flight Abort (SLC 40 and 2nd quarter of 2014)

Picture of Falcon 9 rocket on launch pad in Florida

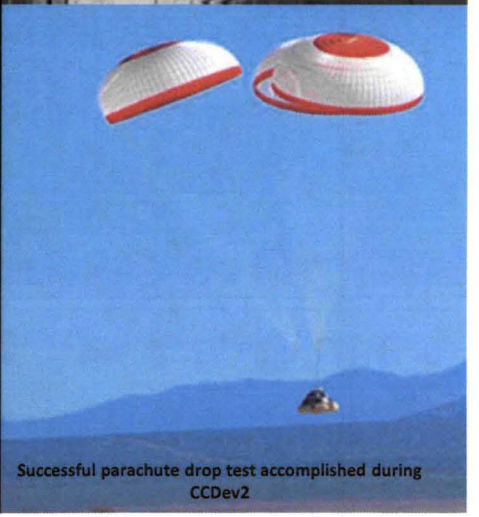

Artist rendition

The Boeing Company

- CST-100 spacecraft is a reusable capsule design
  - Carries up to 7 crew members
  - **Primary Launch Site: Florida**
  - Primary Landing Site: "On Land" landing
- **Atlas V launch vehicle**

- Testing:
  - Integrated Stack Force & Moment Wind Tunnel
  - Dual Engine Centaur Development
  - Orbital Maneuvering & Attitude Control Engine Development
  - Mission Control Center Interface Demonstration
  - Emergency Detection System Standalone
  - Avionics SW Integration Lab Multi-String Demonstration
  - Pilot-in-the-Loop Demonstration

Artist rendition of CST-100 and Atlas V on the launch pad

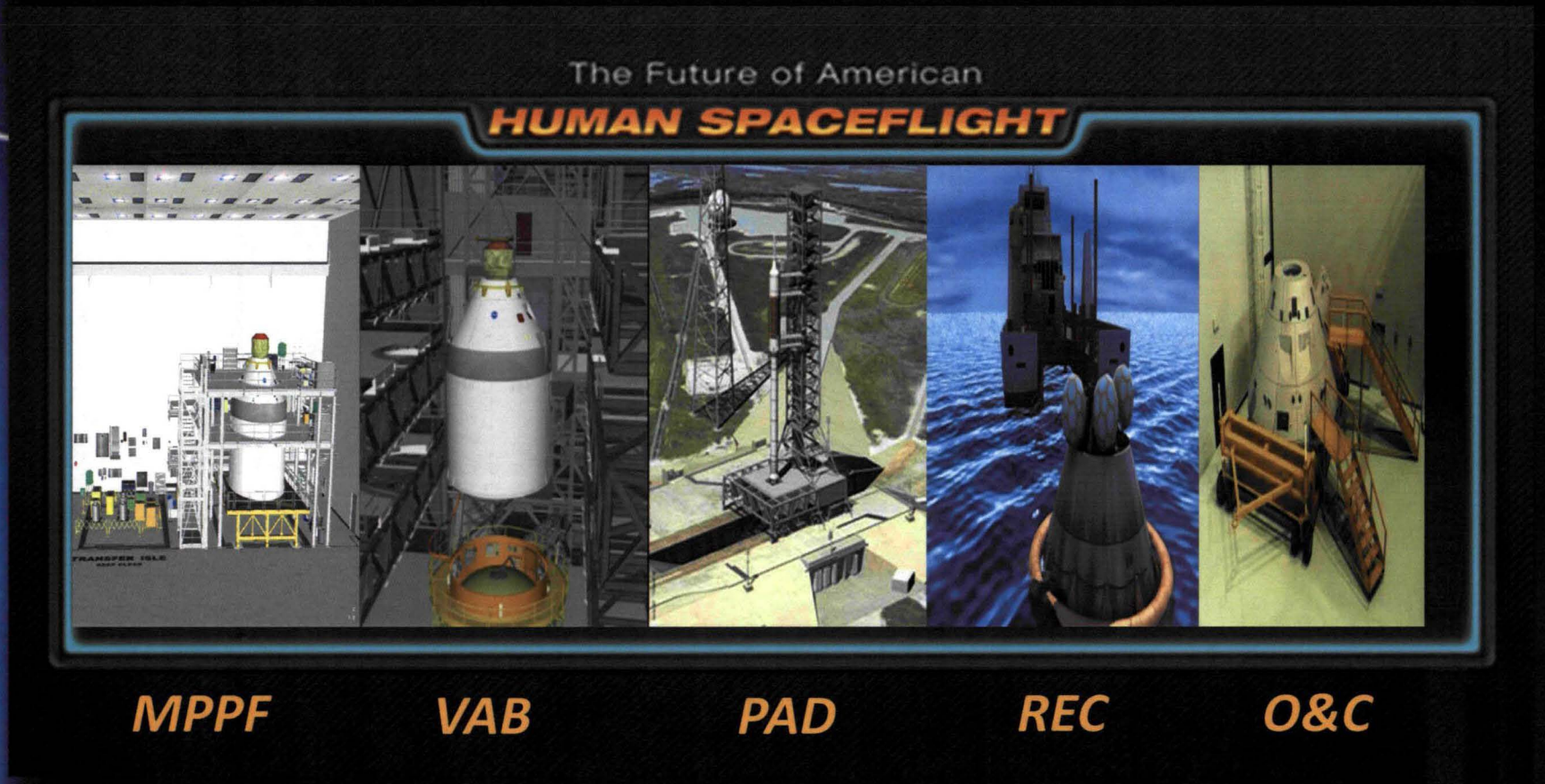


Successful parachute drop test accomplished during CCDev2

Goal 1: Ensure mission success by enabling Government and commercial access to space

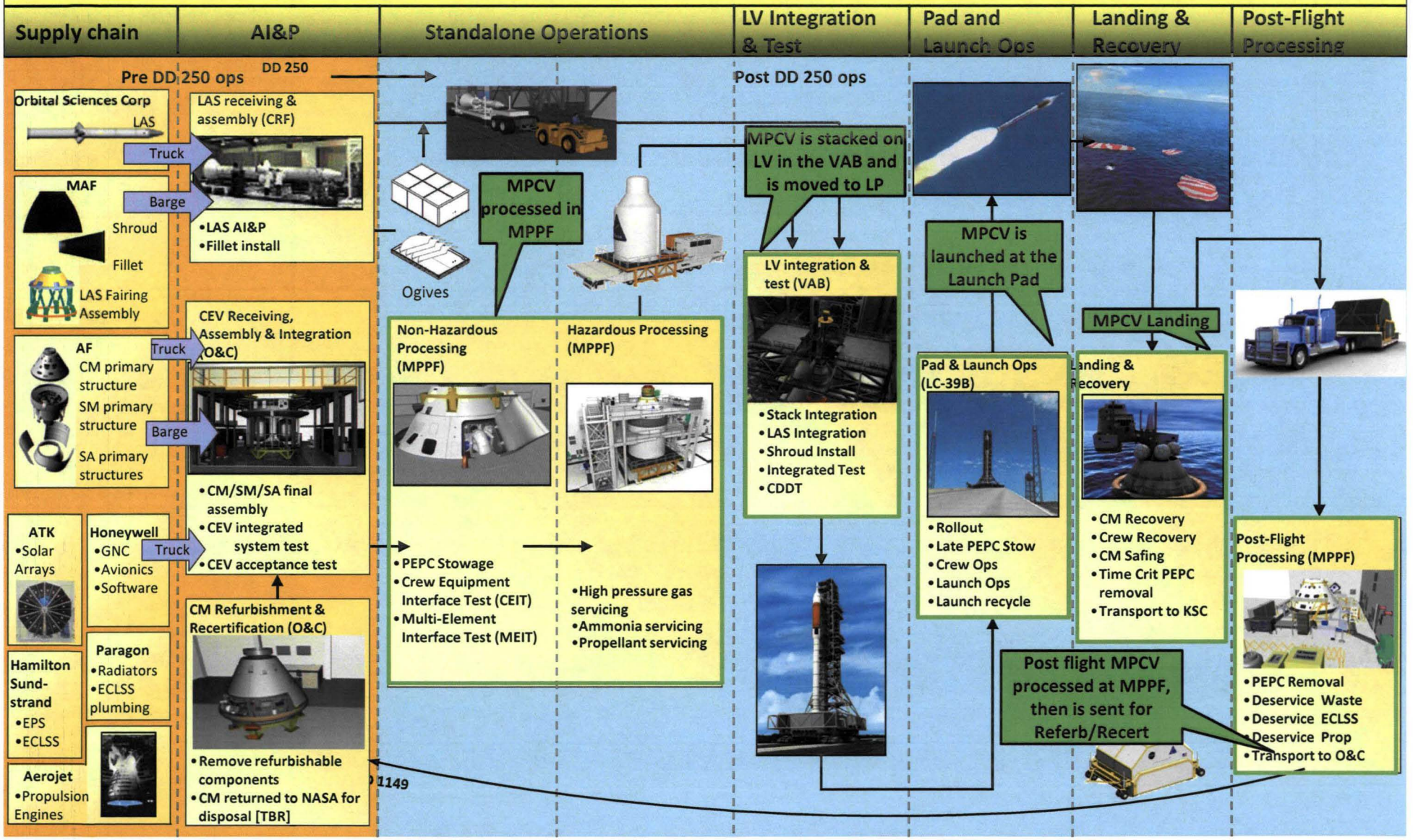
Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

Orion / Multi Purpose Crew Vehicle (MPCV)



Thanks to Gary.F.Letchworth@nasa.gov & Roland.Schlierf-1@nasa.gov for providing MPCV slides.

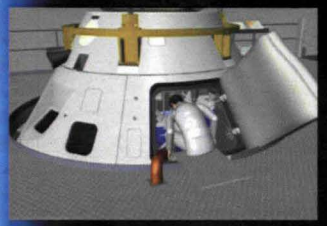
Orion Ground Operations Flow



MPPF – Non-Hazardous Ops

From O&C

To MPPF



Initial Provisions Stowage

-T-0 connection (power, control, data, purge)

-Time critical PEPC fit checks

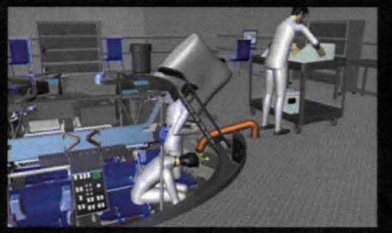
Crew Equipment Interface Testing - CEIT

-Verify flight crew to Orion interfaces

Multi Element Interface Test - MEIT

-Verify Orion interfaces to other flight elements (ISS, Altair, etc.)

-Not for every flow



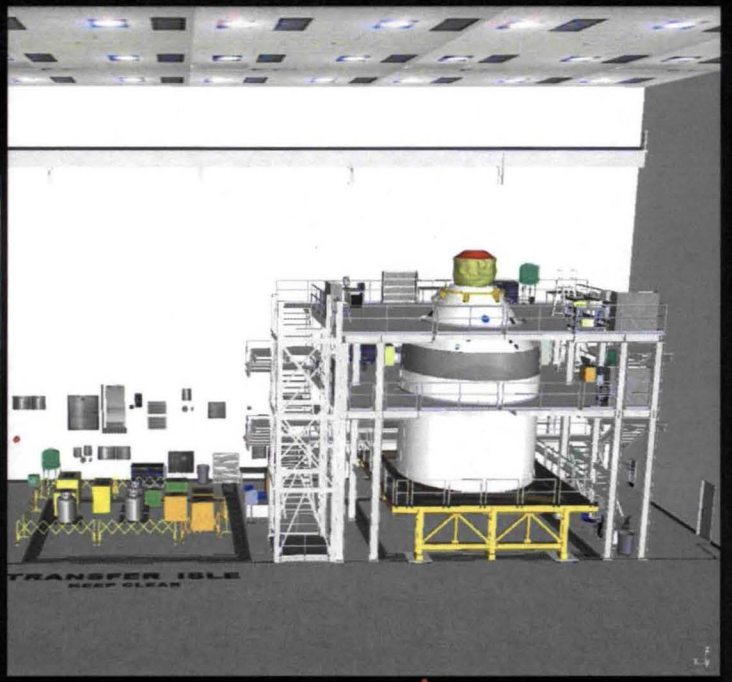
Cargo Stowage and Integration

-PEPC stowage

-Potable water service and sample

MPPF – Hazardous Ops

At MPPF



To VAB

High Pressure Gas Servicing
GO2, GN2, GHe,

Ammonia Servicing
NH3

Hypergolic Servicing
N2O4, MMH, N2H4

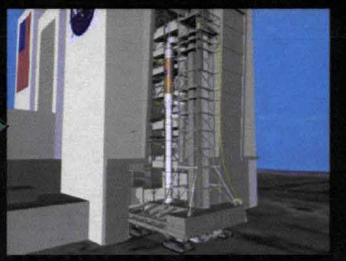
VAB - Launch Vehicle Integration Ops

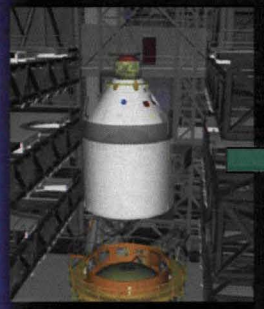
Short Stack From MPPF

LAS from CRF

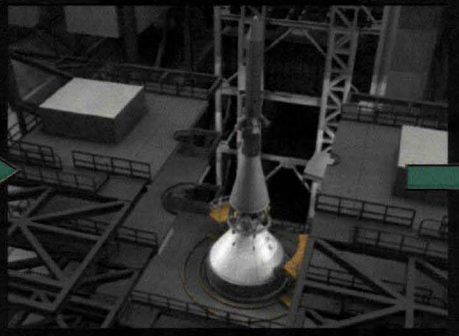
VAB

Rollout to Pad

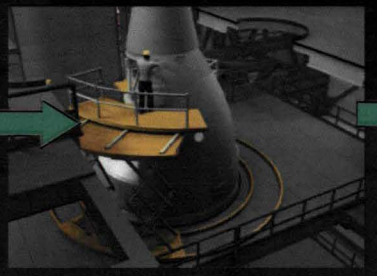




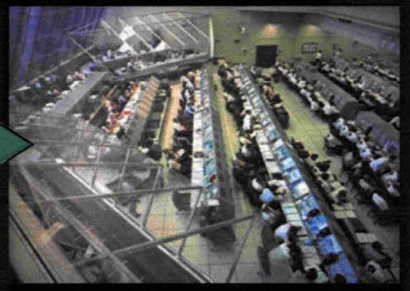
Lift & Mate Short Stack to CLV
- Lift and mechanical mate with the upper stage IU
- Electrical mates
- Connect T-0
- Initiate Purge
- Perform I/F test (powered)



LAS Integration to CM
- Lift and mechanical mate LAS to CM
- LAS to CM Electrical mate
- LAS Interface Test & S&A rotation test (powered)
- Ordnance mate



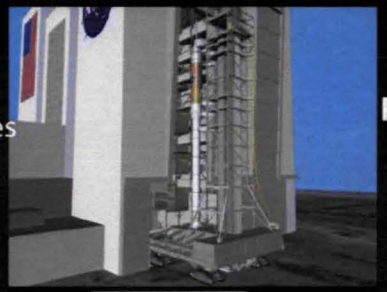
Ogive Installation
- Install Ogive Panels (4)
- Closeout TPS
- Establish internal access (white room)



Integrated Testing
- Vehicle power up & health status
- IVT (including RF testing)
- Potable water sample
- Countdown Demo Test (CDDT)

Pad and Launch Ops

-Rollout to Pad with active purge
-Connect Pad to ML interfaces
-Establish External access (CAA & SM VAA)



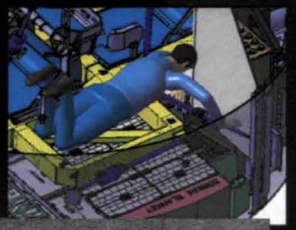
From VAB

LC-39B

Mission Ops

Communications Testing

-Orion Power-up
-Pad IVT
-Comm. End-to-End Testing
  - Uses antennas on LAS



Late Stowage and Final Ordnance

- Late PEPC Stowage
- CM, SM Ordnance Ops
- LAS arm inhibit removals (S&A pins)

Crew Operations

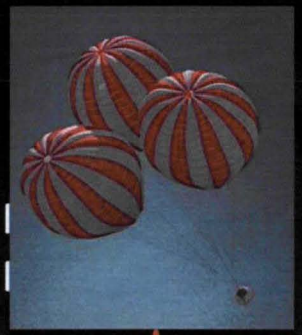
-Crew Ingress
-Hatch Seal Leak Checks
-Cabin Leak Checks
-White Room seal retract
-CAA retract

Launch Readiness Through T-0

- Final countdown and Launch

Landing & Recovery Ops

From Flight Ops



To MPPF

Water Landing

-Location data transmitted to MCC, relayed to recovery crew
-Auto-safing of pyros & fluid systems performed and status provided to MCC
-CM beacon transmits vehicle location to recovery crew

Water Recovery

-Remove CM from water (crew on-board)
-Crew egress after CM secured on ship
-Manual Pyro Safing
-Remove Time Critical PEPC

Transportation

-Install lifting device on CM
-Transfer CM to transporter on dock
-Prepare for over-the-road transportation
  - Transfer CM transporter to trailer
-Transported to MPPF at KSC

Post Flight De-servicing

From Landing Site

MPPF

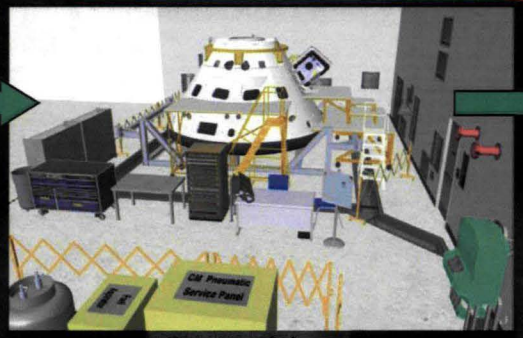
O&C

De-service Preps

Remove CM transporter from over the road trailer
Clean CM & transporter
Move CM transporter in MPPF airlock
Move CM & transporter into High bay for de-servicing

Remove PEPC

- Remove seats
- Remove non-time critical PEPC
- Remove Human Waste
- Flush and Drain Urine system and decontaminate WMS



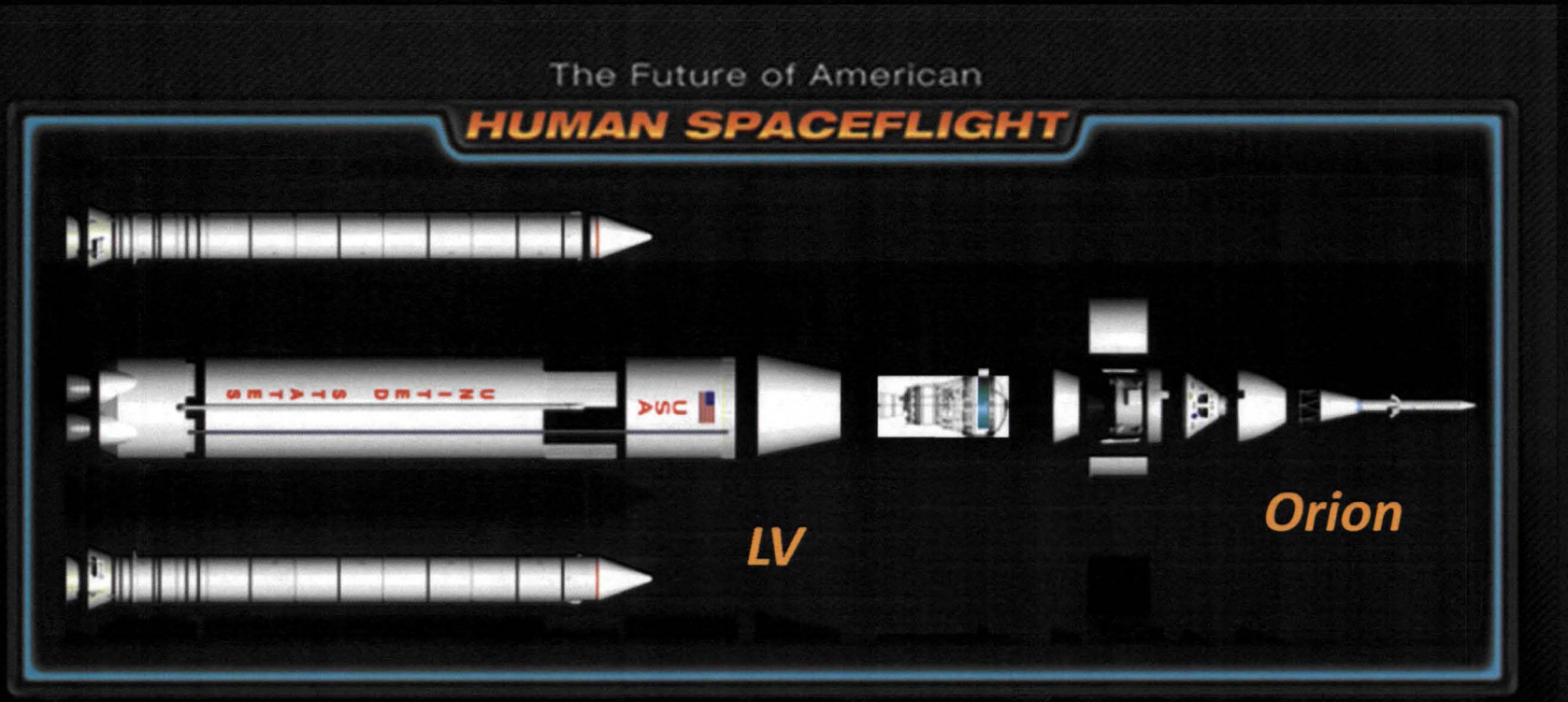
De-servicing

- Data Retrieval if required
- De-service Ammonia system
- De-service ECLSS gases
- Discrete Propulsion system Power-up
- Decontaminate Hydrazine system

Return to O&C

- Move from de-servicing area
- Configure for Transport
- Transport CM and components back to O&C

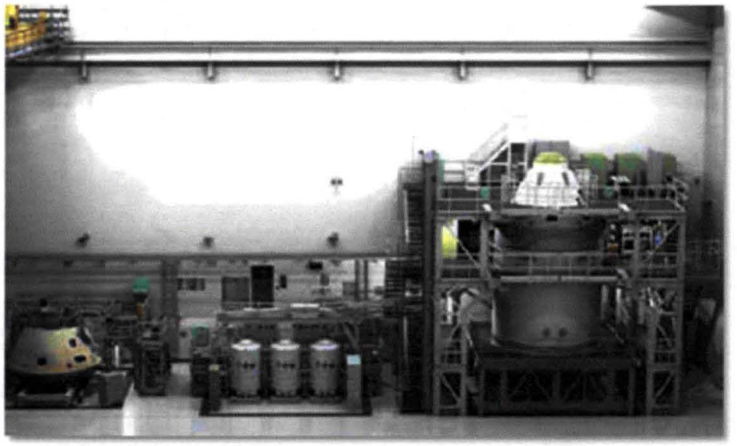
Orion / SLS



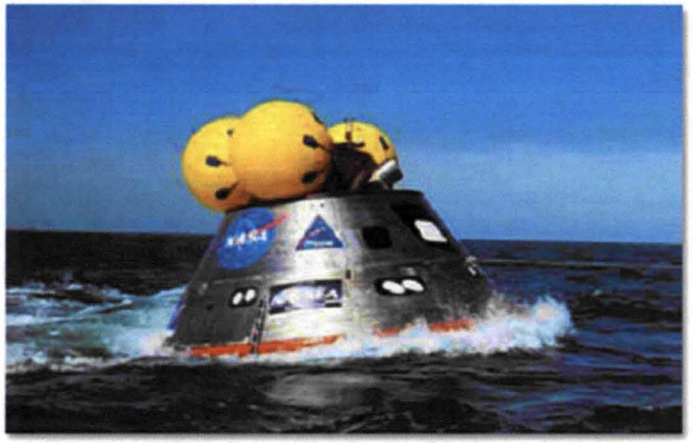
Thanks to for providing slides.

GROUND SYSTEMS
Development and Operations

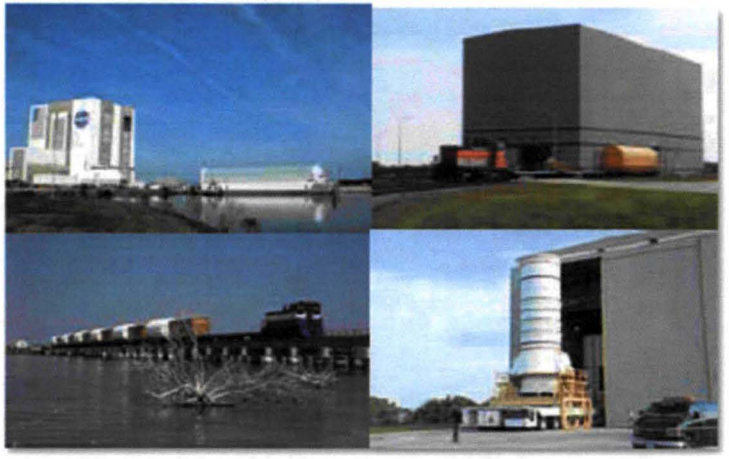
Offline Processing & Infrastructure (OPI)



Spacecraft Offline Processing



Landing & Recovery



Launch Vehicle Offline Processing

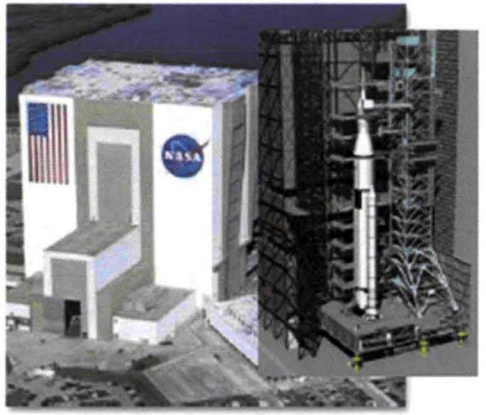
Environmental & Infrastructure

GROUND SYSTEMS
Development and Operations

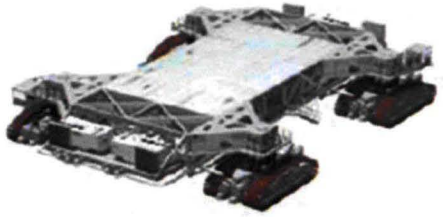
Vehicle Integration & Launch (VIL)

Mobile Launcher – Orion and SLS access and servicing

Pad - LC-39B Launch Operations



VAB – SLS and Orion Integration and Check-out Operations



Crawler Transporter – ML, MLP and Integrated Stack move operations

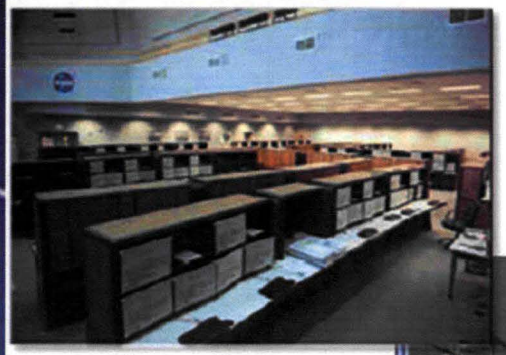
VIL Capabilities

Small Class Vehicle - Planning and Studies*

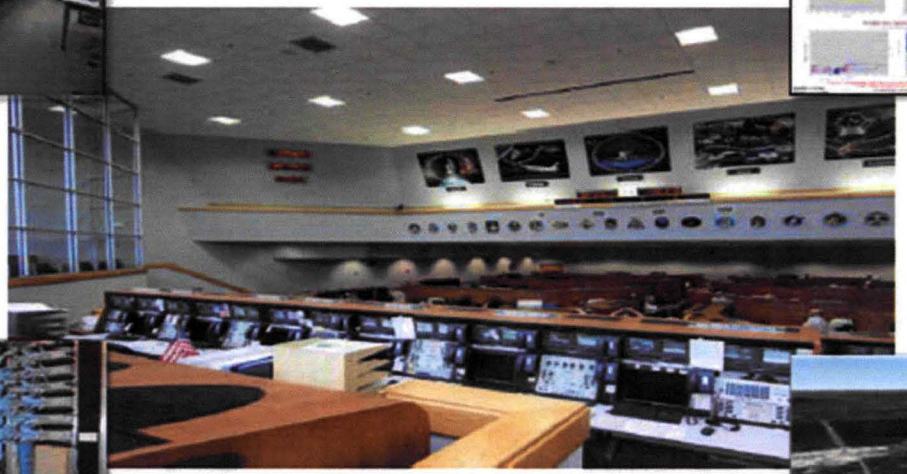
*SCV not included in GSDO SRR/SDR

GROUND SYSTEMS
Development and Operations

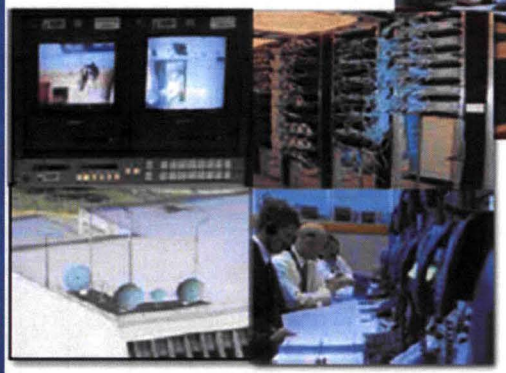
Command Control Communications & Range (C3R)



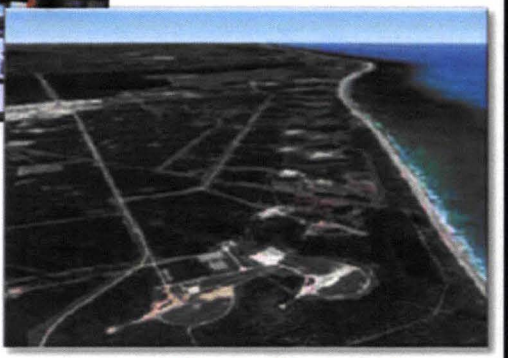
End to End
Command & Control



Advanced Ground Systems
Maintenance (AGSM)*



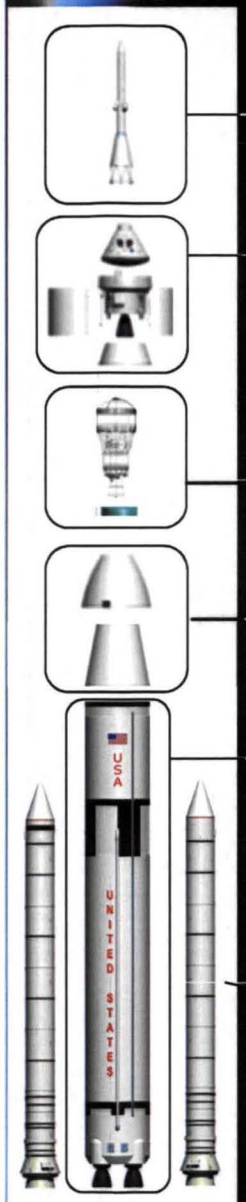
Communications Systems



Range Systems*

C3R Capabilities

Orion/SLS Concept of Operations



Offline Spacecraft Processing

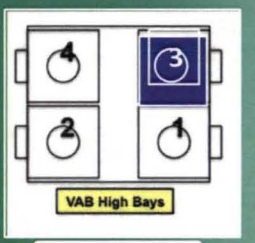
Transport Elements to VAB

CCC & Range

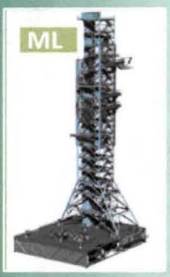
ICPS Processing

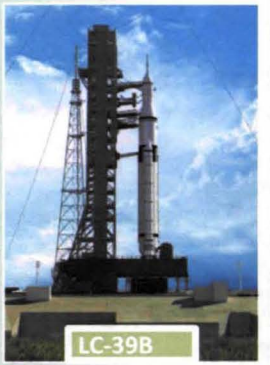
Barge Terminal

Vehicle Integration and Launch



VAB HB 3





Vehicle Integration & Test

CT-2

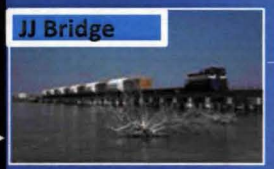
Transport to pad

ARC 8.0 Final JML 9/5/12

Lift-Off

No SRB Recovery

Offline SRB Processing



Railcar to RPSF

Aft/Fwd Skirt and Frustum Refurb and Assembly *(SLS Production Activities)*

Aft Skirt and FWD Assembly Buildup *(SLS Production Activities)*

Landing & Recovery

CM & Crew Recovery

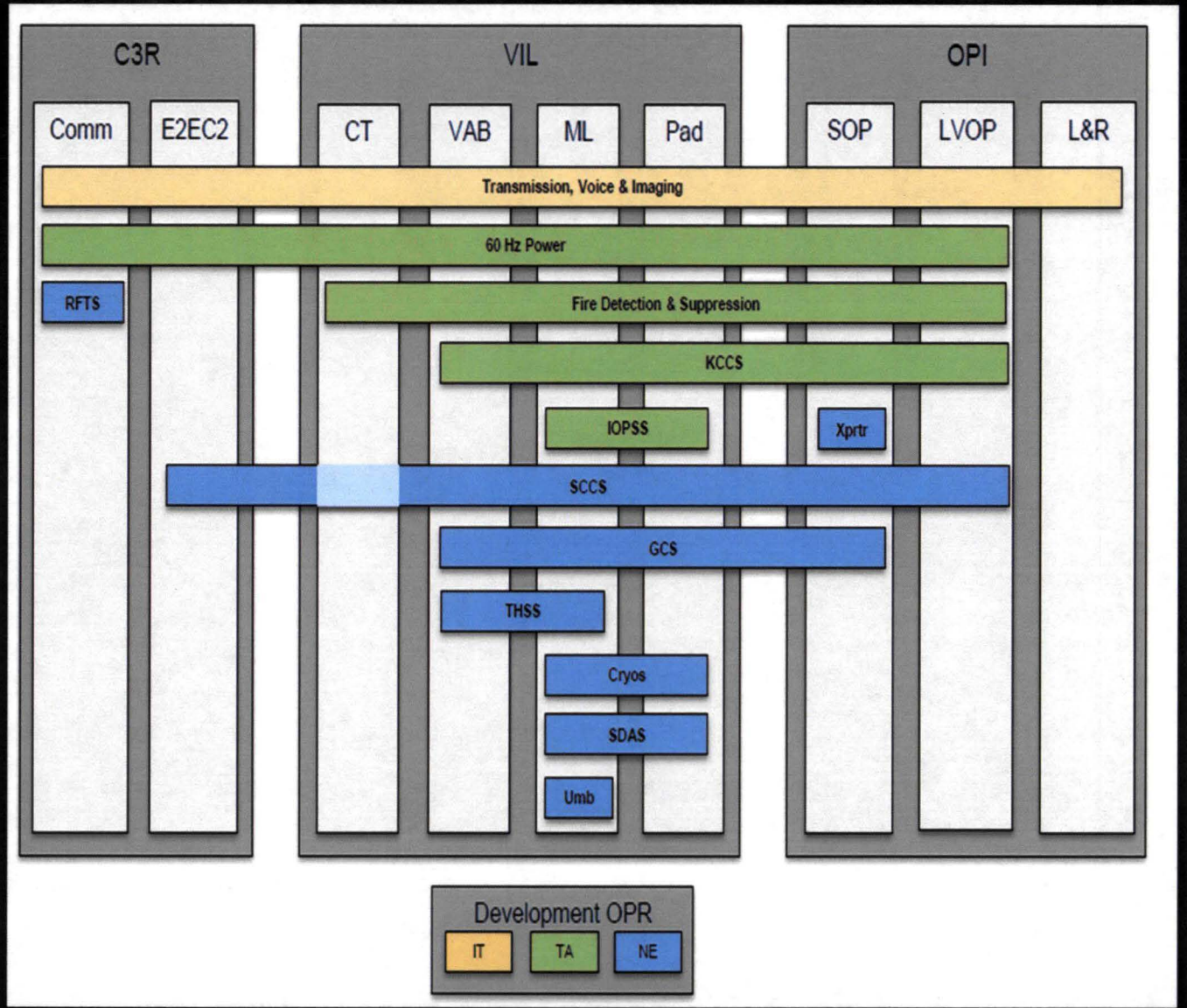
CM Landing

West-coast Recovery & Transport to KSC for Deservicing

Subsystem-EIT-IPT Integration

GSDO MSL has 70 Subsystems identified and some cross multiple EITs/IPTs .

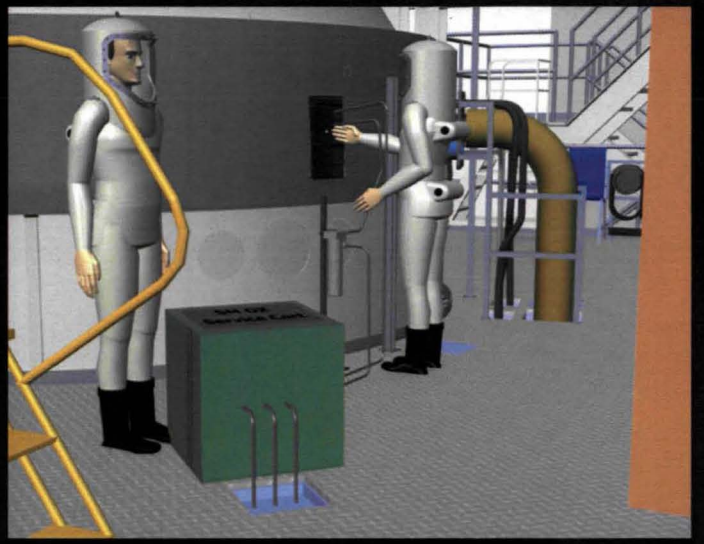
Crosscutting Subsystems will be designed end to end per the Institutional design processes

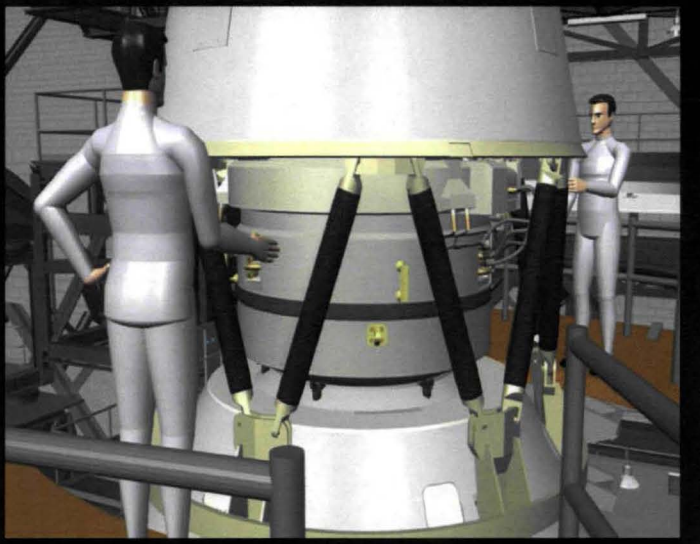


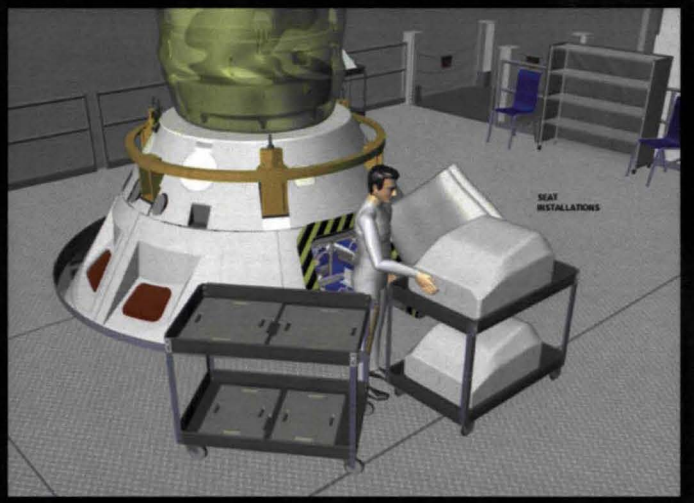
Current GSE Human Systems Engineering Analysis Directions

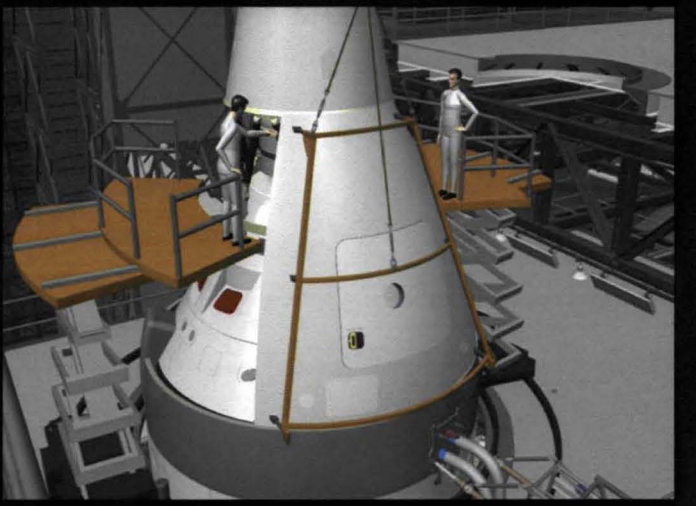
- Orion Handing and Access
- Crew Access Arm Ingress/Egress
- Installing/Removing the GSE side umbilical plates
- CAA Basement
- SLS Access Locations
- ICPS SCAPE Operations
- LAS
- VAB CAA interference issue with the TMLs
- Core stage Linear Shaped Charge
- Aligning/installing Core Stage to SRB
- ICPS Sling Removal

Orion Handing and Access

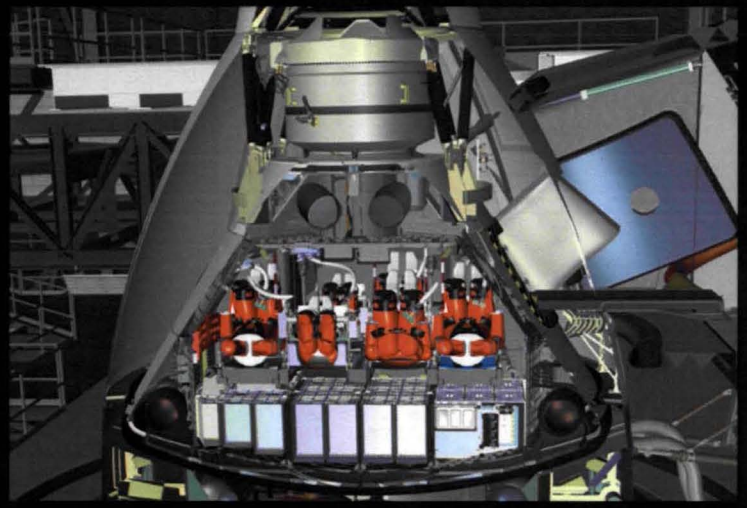


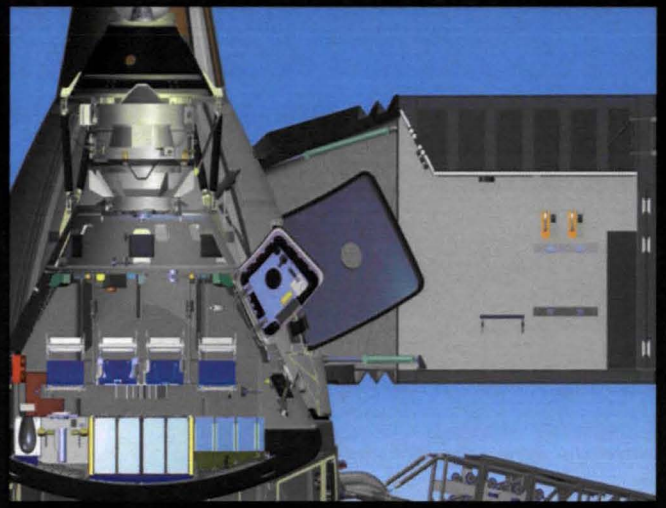


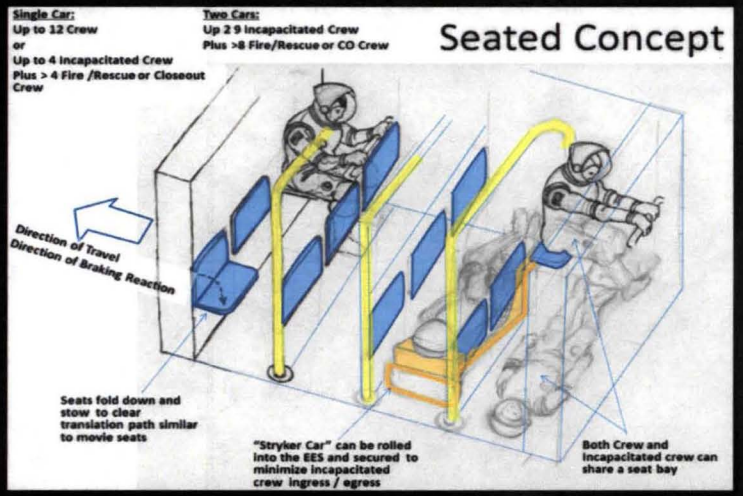


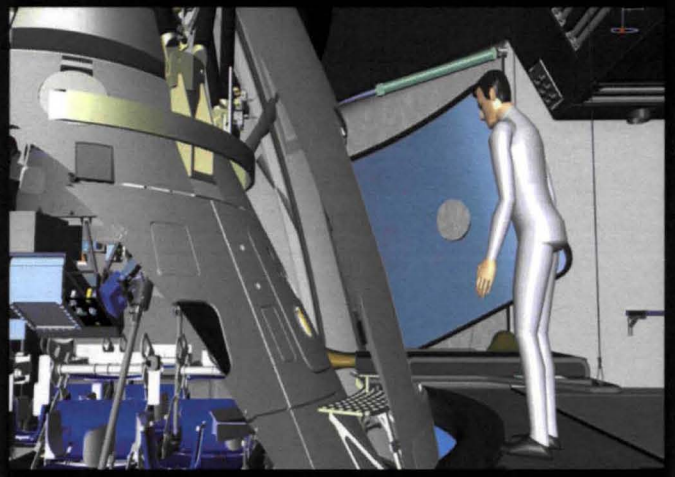


Crew Access Arm Ingress/Egress

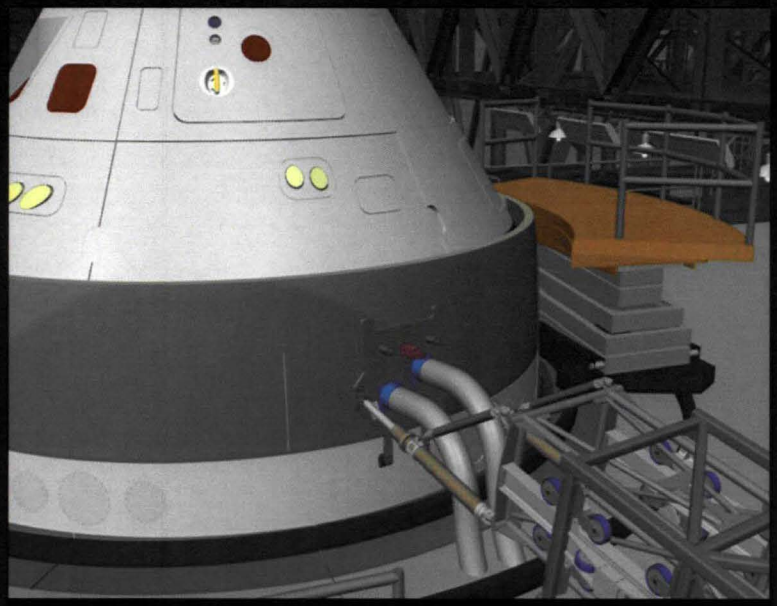


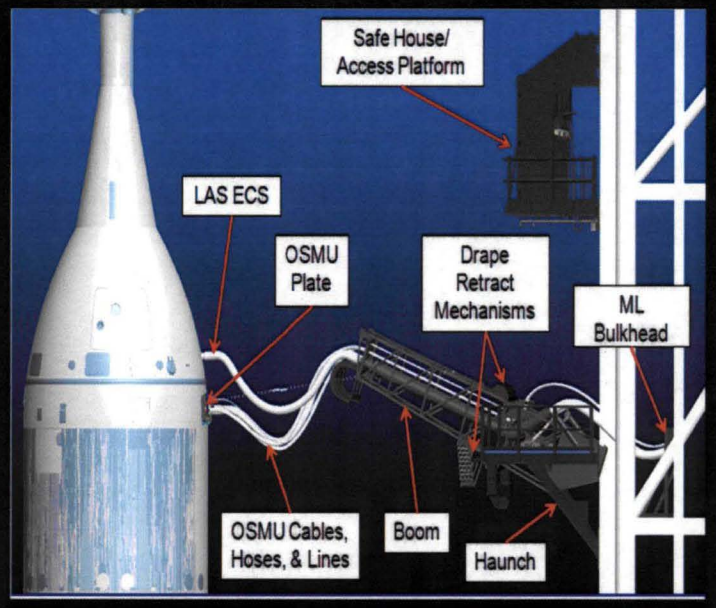




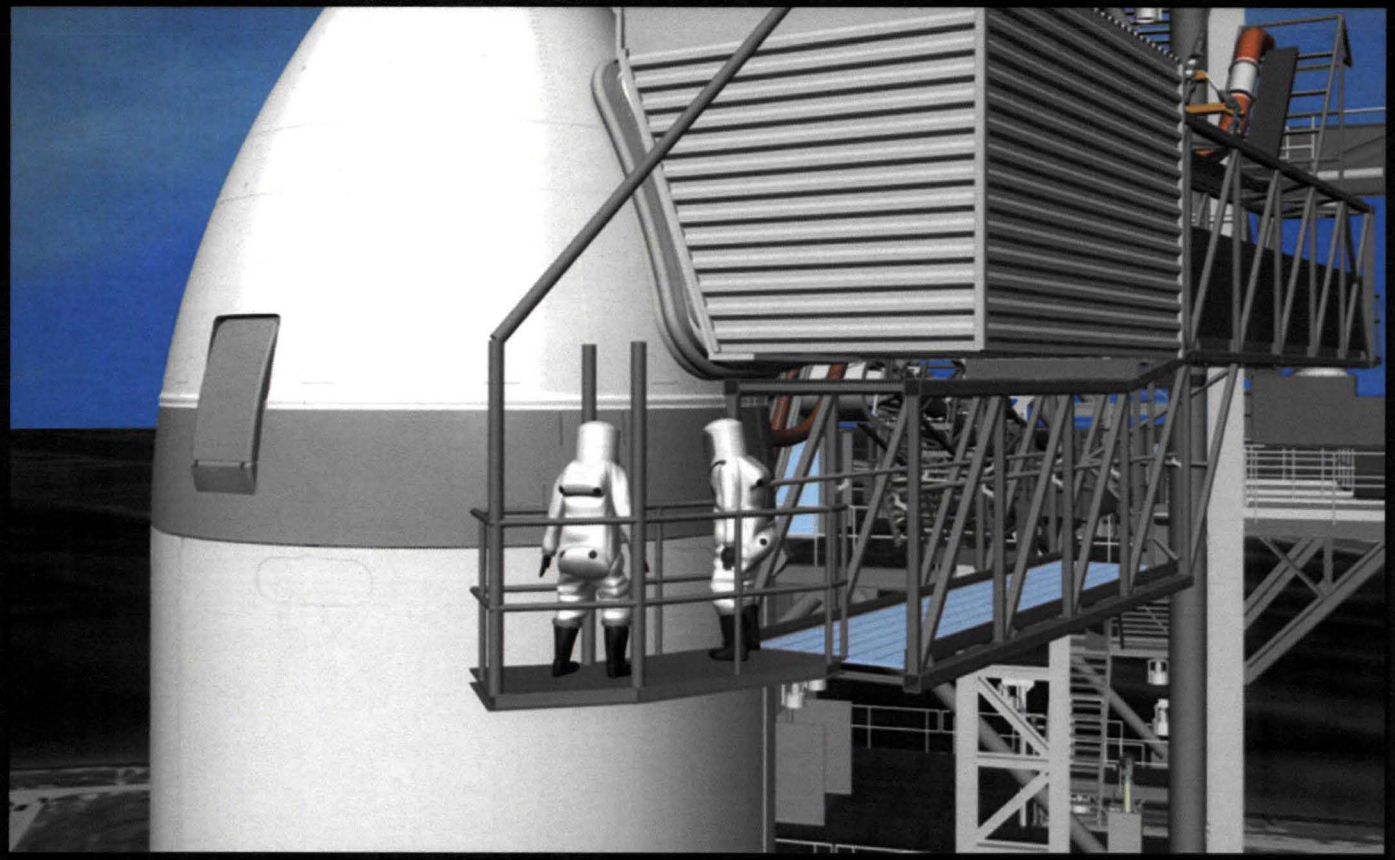


Installing/Removing the GSE side umbilical plates

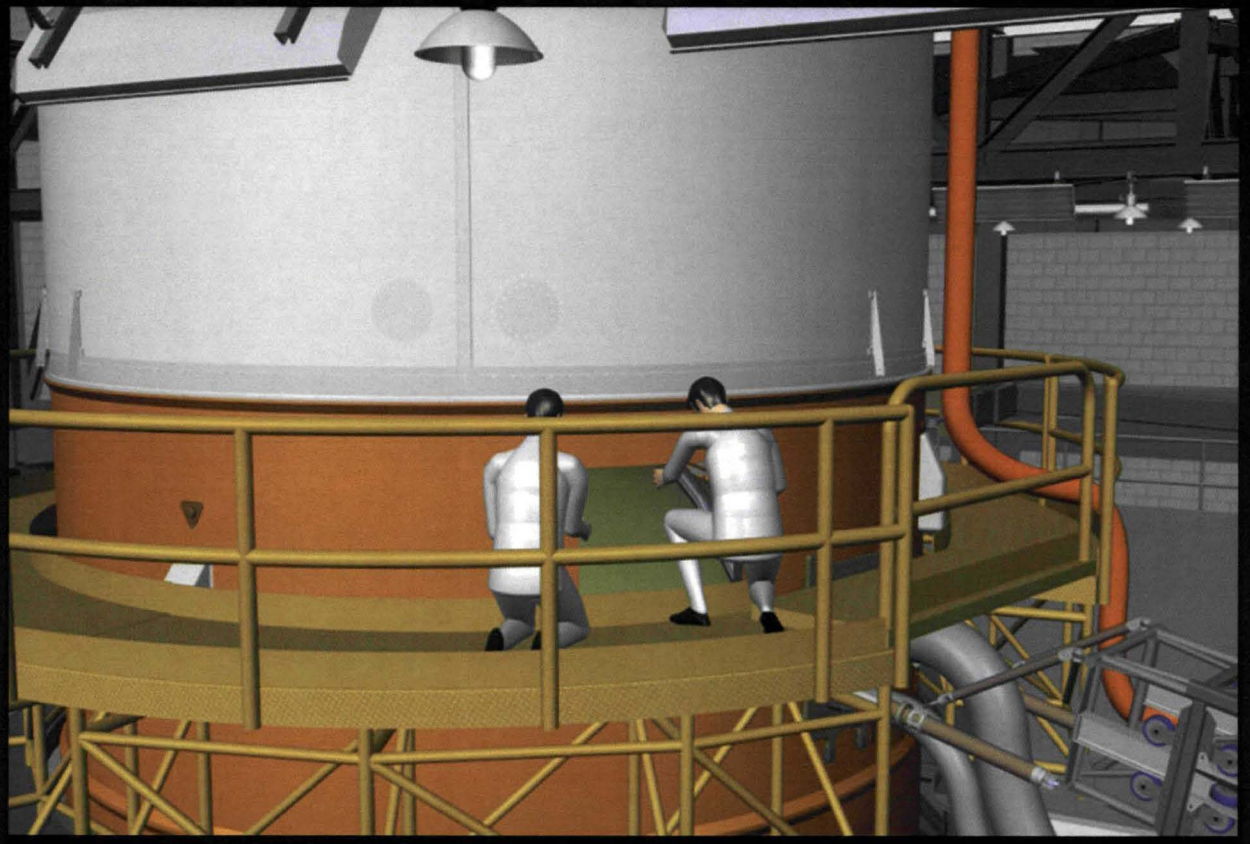




CAA Basement

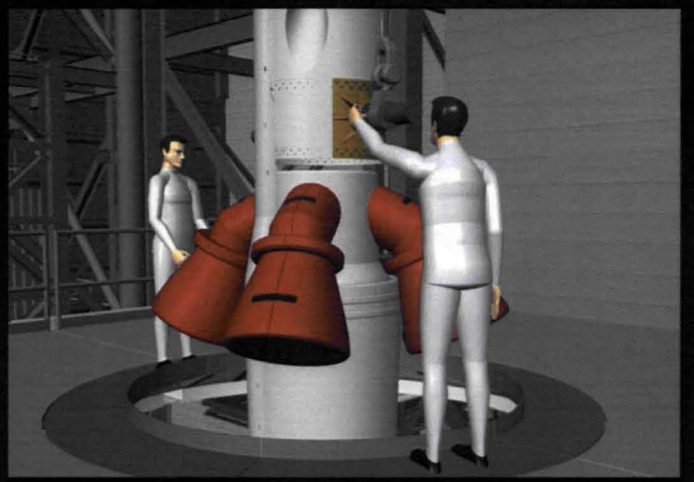


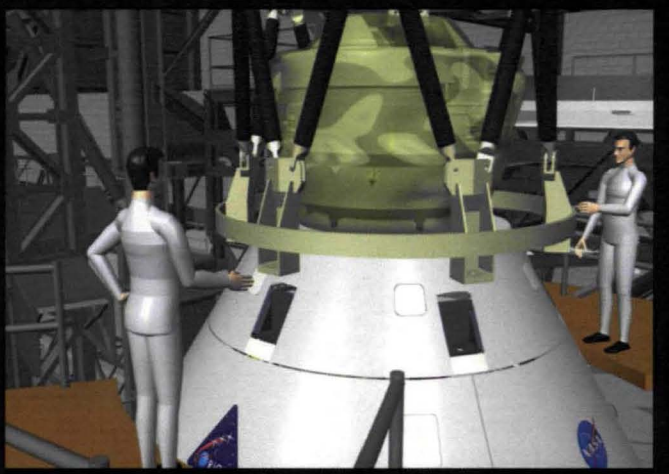
SLS Access Locations

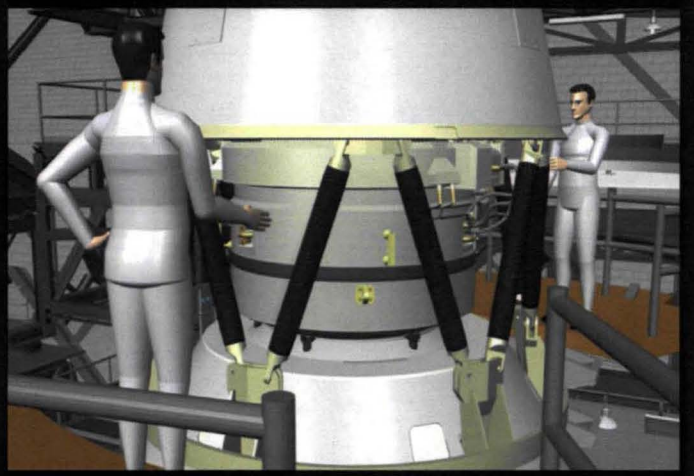


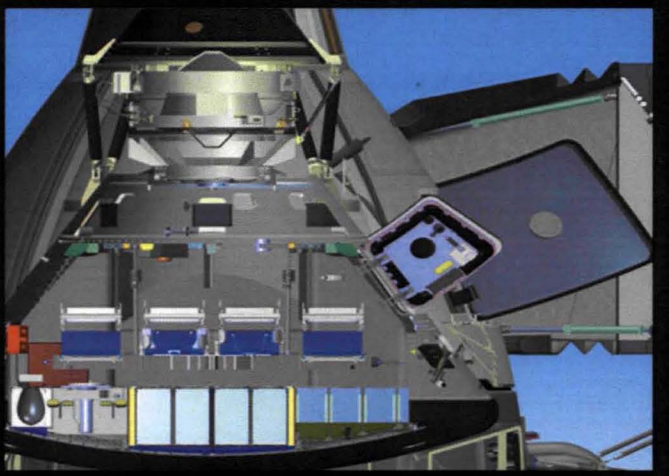
ICPS SCAPE Operations

LAS









Goal 2: Develop, operate, and sustain a robust launch and payload processing complex for all providers

a. Convert the KSC launch and payload processing complex into a multi-user capability

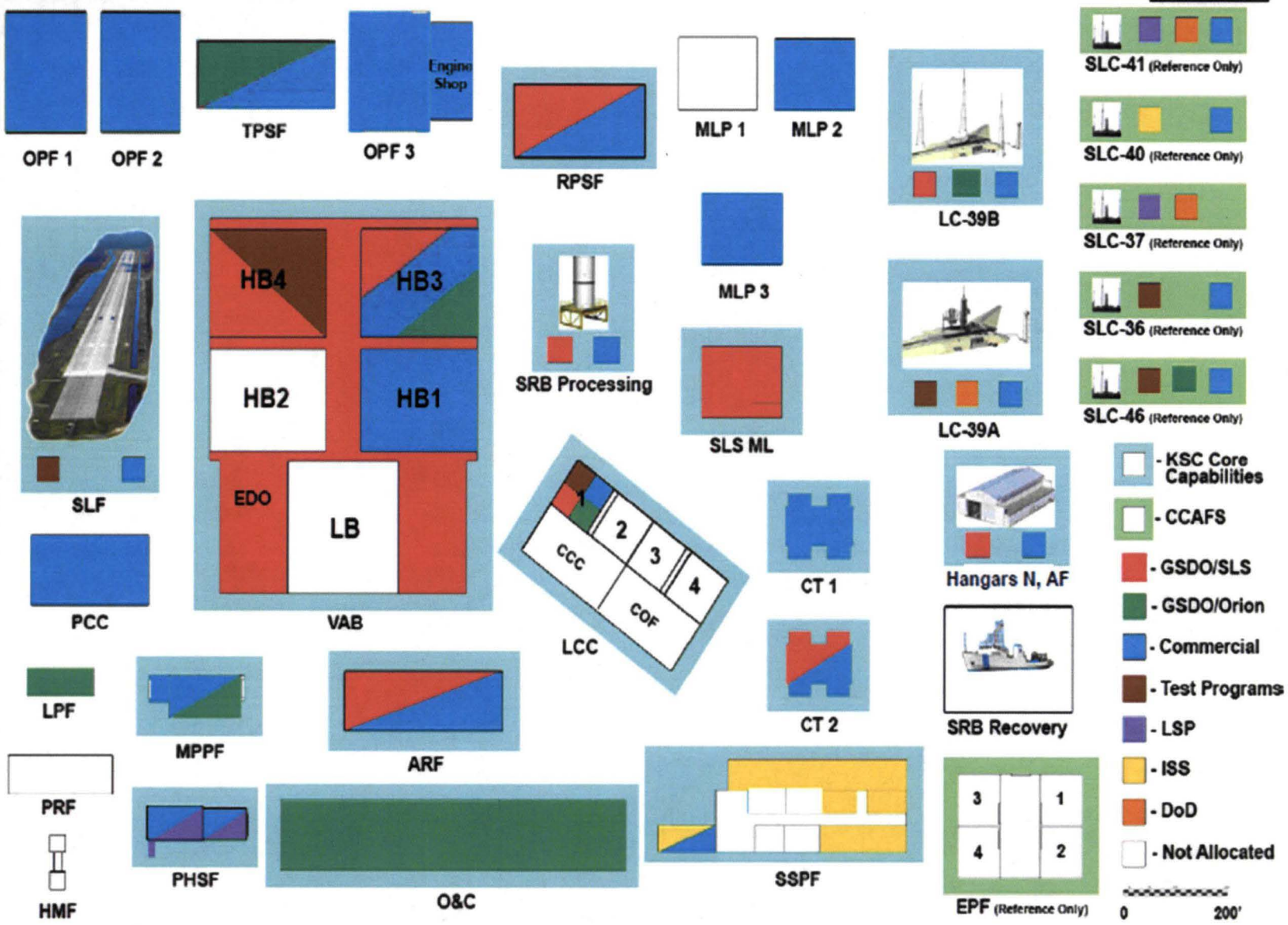
Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

GROUND SYSTEMS
Development and Operations

ARC 7.0 Final Point of Departure Review

Final PoD Integrated Program Architectures (PA) View - 1

ARC 7.0 Final
RPC 3/15/12



Architectures include programs and institutional capabilities; SLS/Orion assets are limited to single string.

Goal 3: Conduct research and develop technology (R&T) representative of KSC expertise to enable NASA mission success

Reference: Kennedy Space Center Future Development Concept, A New Way of Doing Business for a New Generation of Explorers (2012-2031)

KSC HF Research Directions

- *3D CAD-Human and Hardware Collaborative Engineering* is a study to compare the effectiveness of using a 3D CAD/collaborative environment versus existing methods used in Design Engineering for hardware developed for human operators.

- *Primitive Motions for Developing Human Hardware Models* is the development of the "Primitive Motions" library based on motion capture of actual humans. These motions can then be used by modelers to infuse the human motions into CAD models to verify human factors requirements.

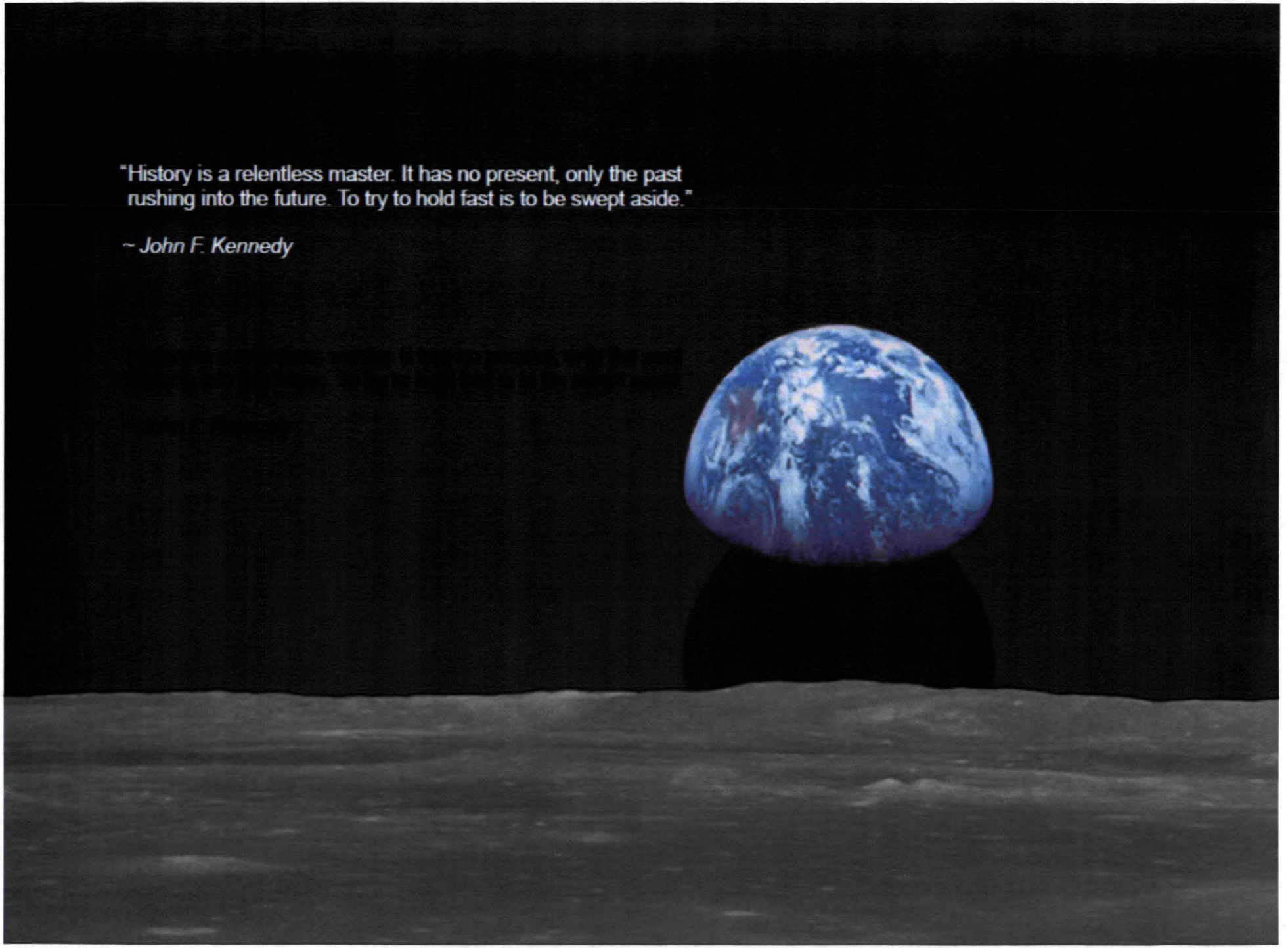
- *Collaborative Human Immersive Virtual Environment (CHIVE)* is the development of a collaborative human immersive virtual environment for CAD developers, Engineers, Technicians, partners, and program integration entities. The CHIVE will have the ability to connect multiple NASA centers and partners simultaneously to promote optimal concurrent engineering collaborations.

KSC HF Research Directions

- ***Human-In-Loop Performance Modeling & Cognitive Simulation Integration*** is the development of human performance models that integrate cognitive with biomechanical data and validated natural human motions and tendencies.

- ***Virtual Mentor Training*** is the development and study of a virtual mentor trainer.

- ***Virtual Environments for Long Duration Missions***: It is well known that one of the greatest challenges to overcome in long duration missions is the psychological factor. To counteract the loneliness of long missions, virtual scenarios will be developed of common daily activities.


"History is a relentless master. It has no present, only the past
rushing into the future. To try to hold fast is to be swept aside."
~ John F. Kennedy

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- Katrine Stelges, Brad A. Lawrence. Human Engineering Modeling and Performance: Capturing Humans and Opportunities. Copyright © 2012 by United Space Alliance, LLC Kennedy Space Center, FL; USA
- Damon B. Stambolian, Brad A. Lawrence, Katrine S. Stelges, Marie-Jeanne O. Steady Ndiaye USA KSC, Ridgwell, Robert E. Mills, Gena Henderson, Donald Tran and Tim Barth, NASA Engineering and Safety Center (NESC). Human Modeling for Ground Processing Human Factors Engineering Analysis. IEEEACpaper#1075
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