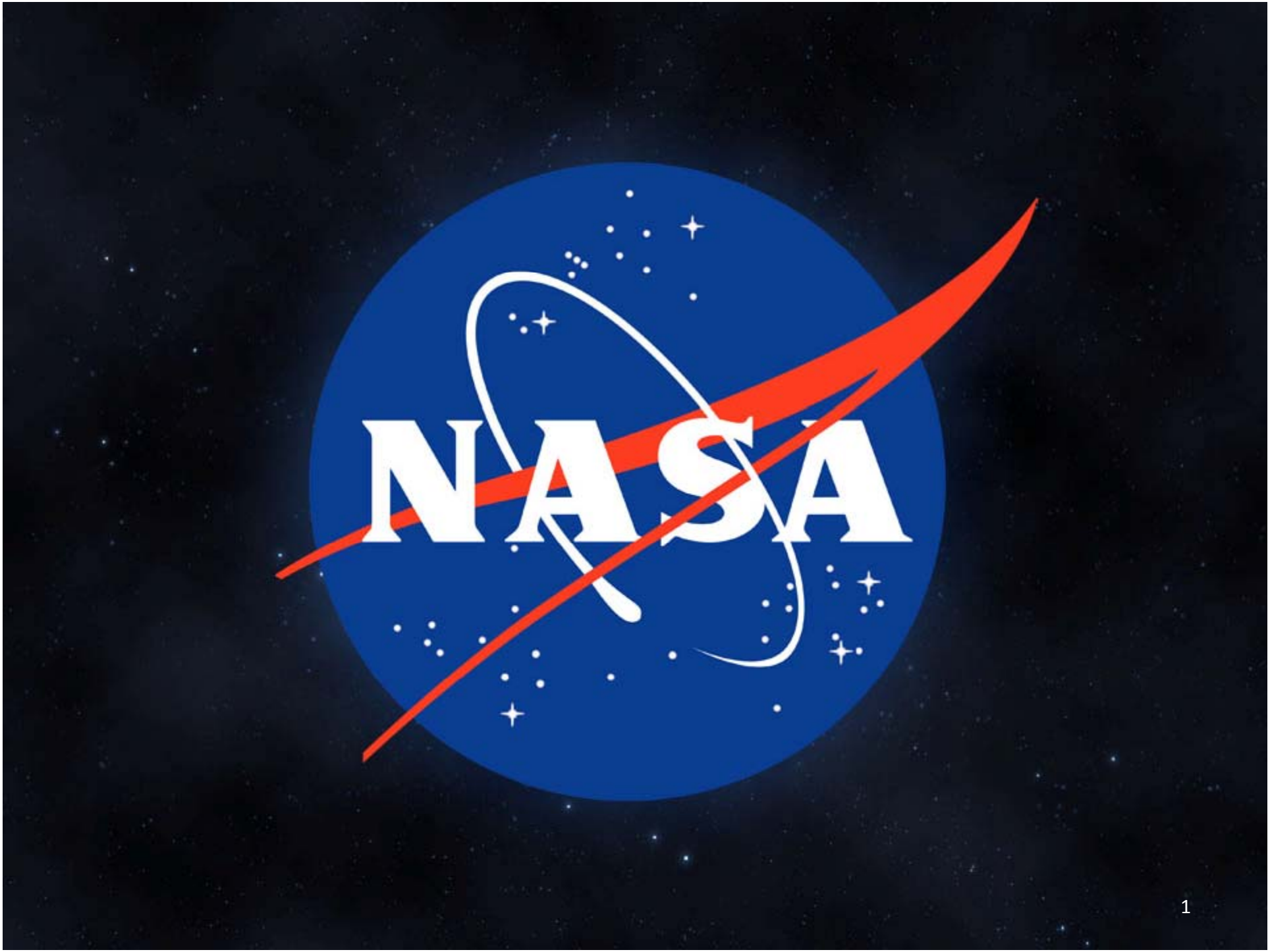
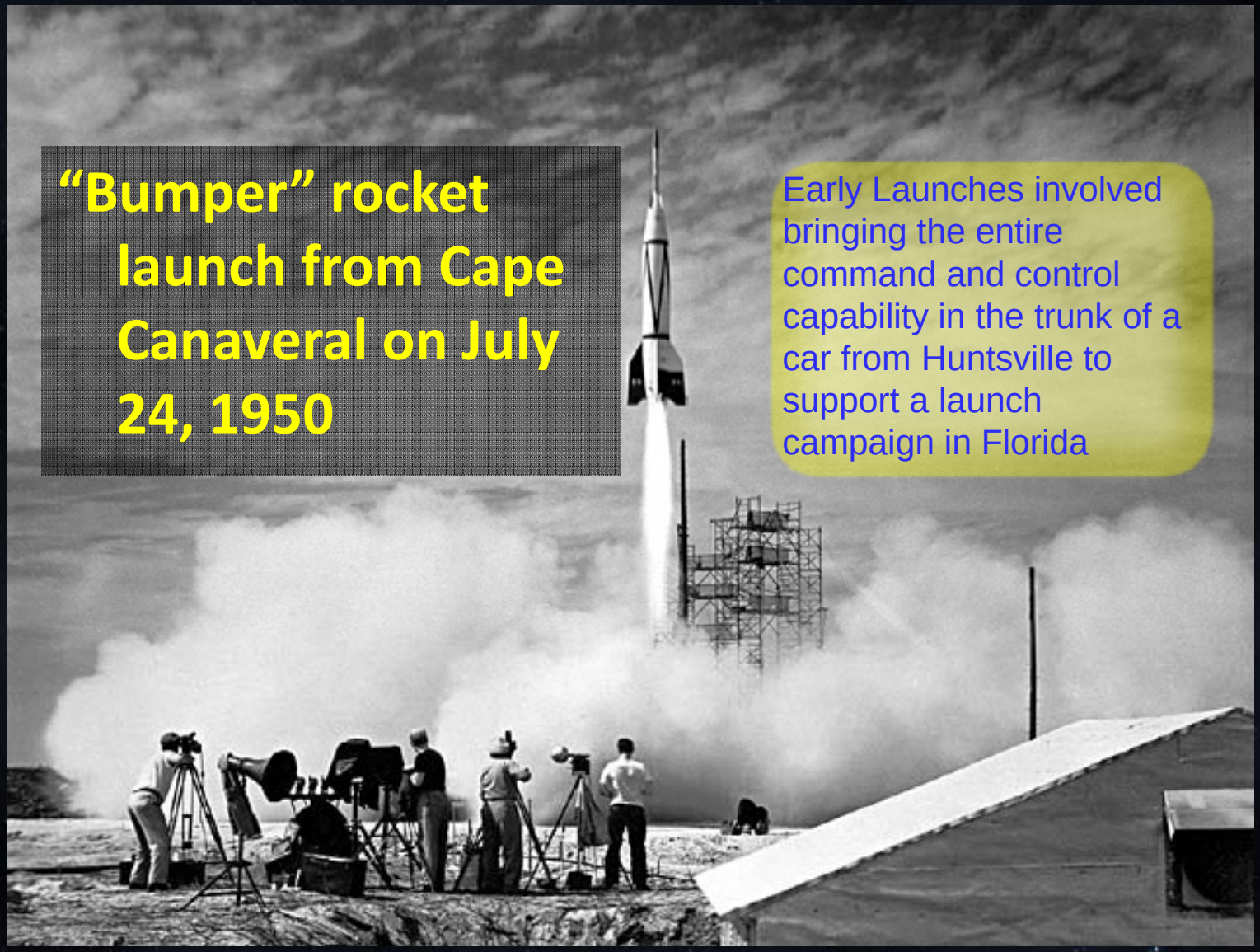

NASA

Kennedy Space Center's Command and Control System

"Toasters to Rocket ships"

The Beginning

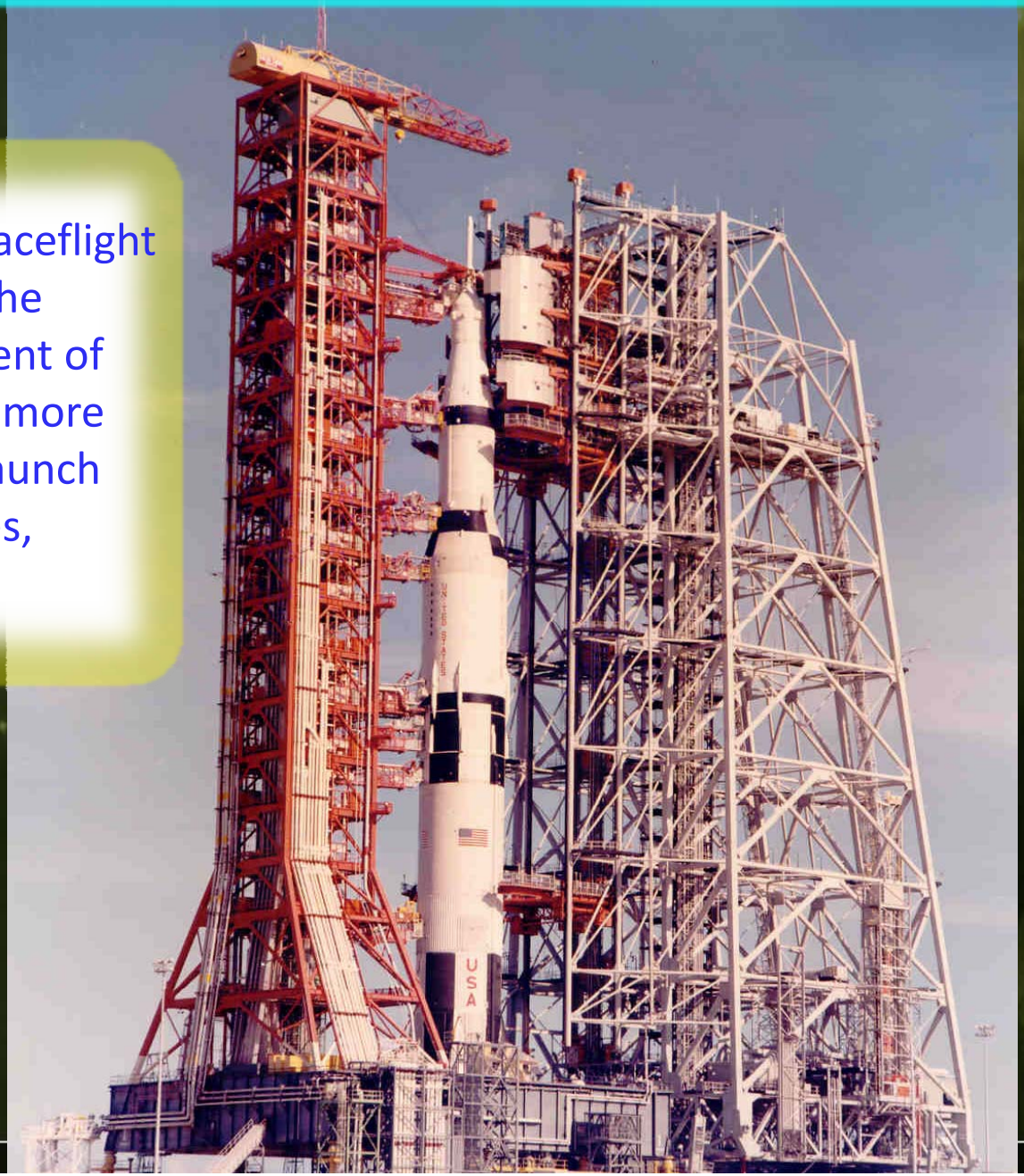


"Bumper" rocket launch from Cape Canaveral on July 24, 1950

Early Launches involved bringing the entire command and control capability in the trunk of a car from Huntsville to support a launch campaign in Florida

Apollo

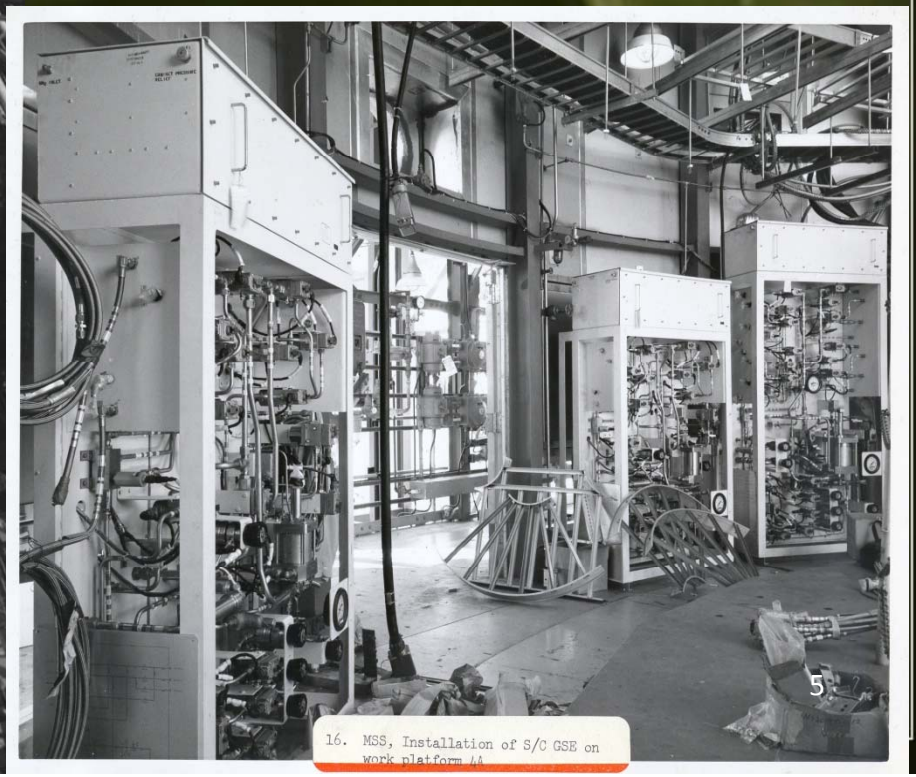
As human spaceflight drove the development of larger and more complex launch vehicles,



1960s

Apollo

The number of actions that needed to be performed for launch increased, while the timing between those actions became more critical thus forcing the development of automated ground processes for the Saturn rocket



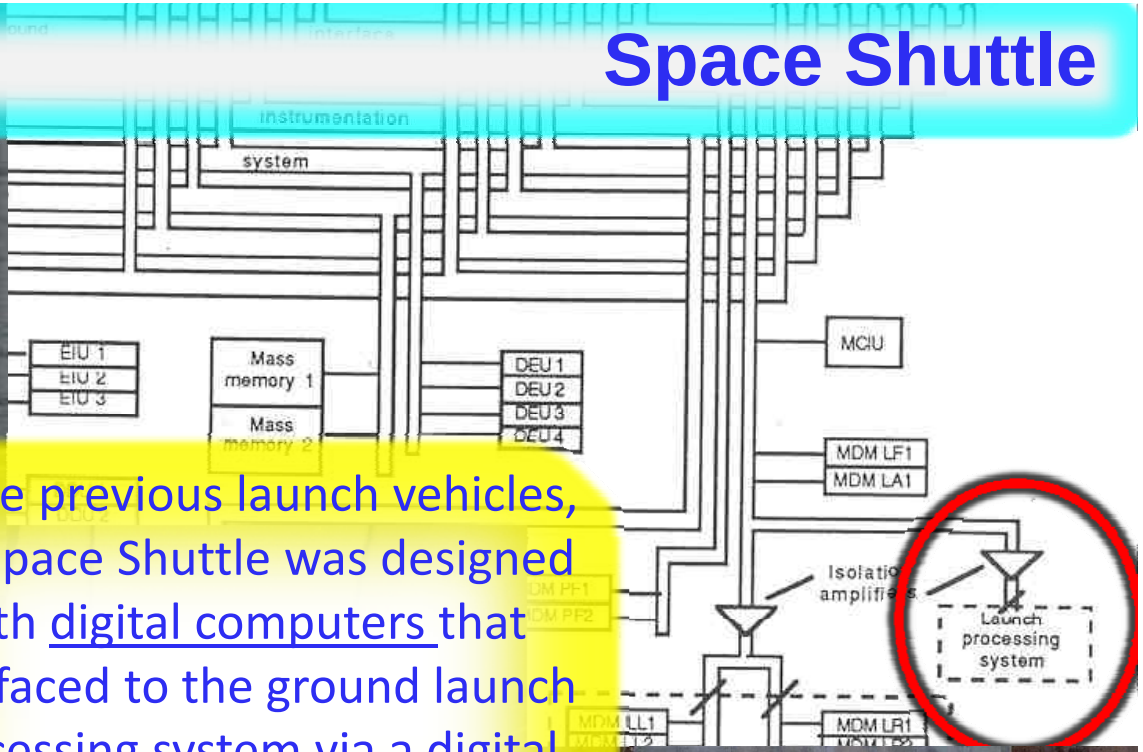
1960s

Apollo

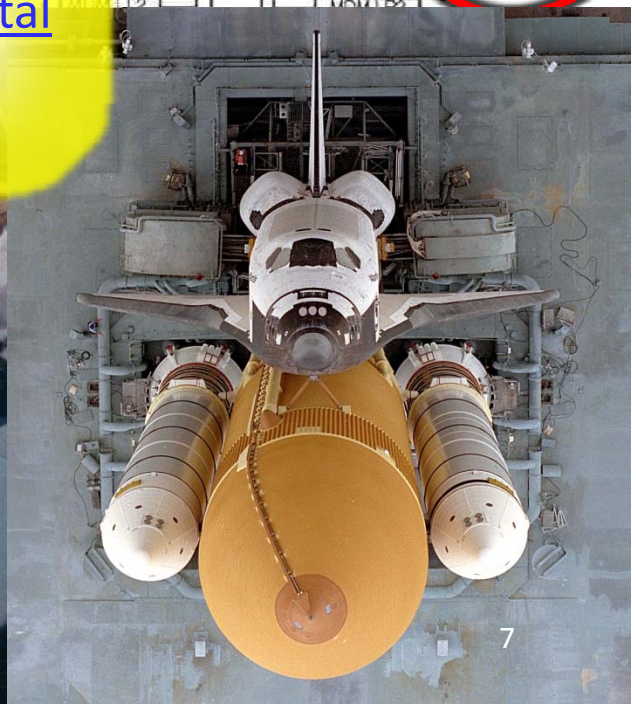
Human launch controllers managed the launch process with a hardware-only system of switches, gauges, lights and dials that required a dedicated human interface to perform every function, throw every switch, and verify every light and gauge until the Apollo vehicle lifted off from the pad

1970s

Space Shuttle

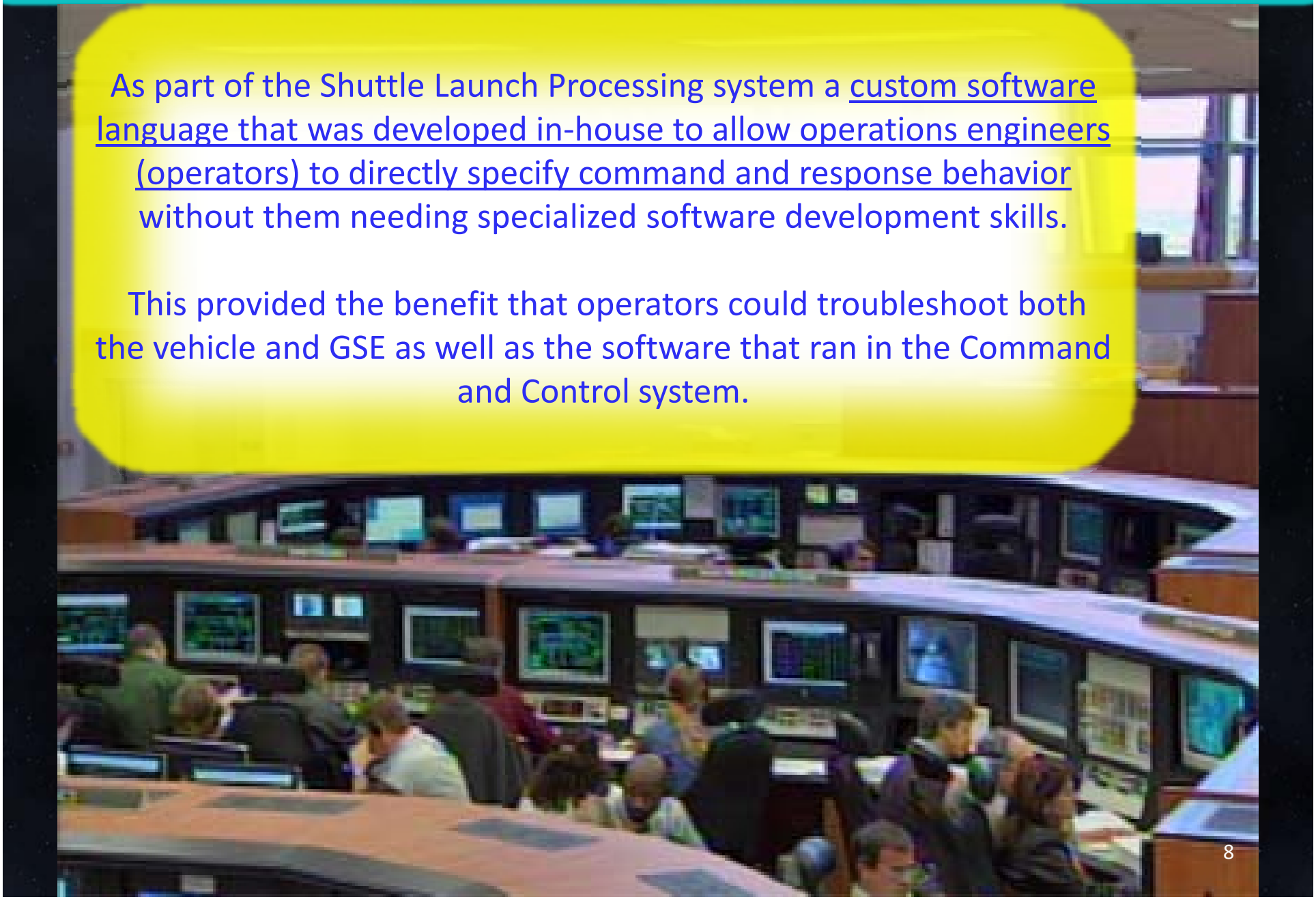


Unlike previous launch vehicles, the Space Shuttle was designed with digital computers that interfaced to the ground launch processing system via a digital launch data bus.



1970s

Space Shuttle

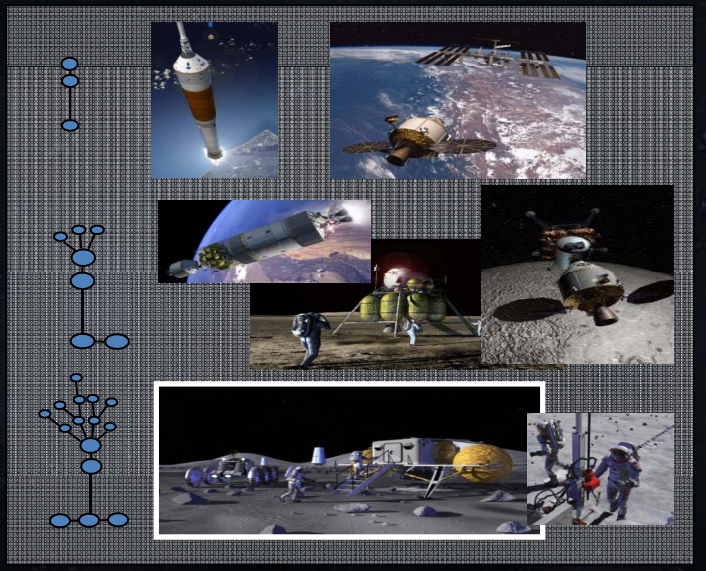


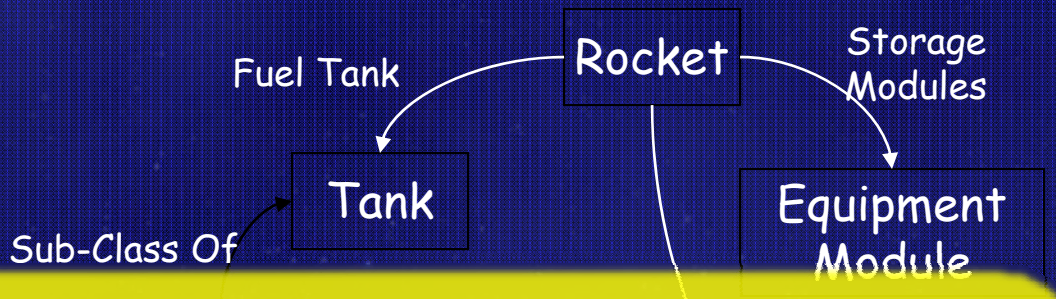
As part of the Shuttle Launch Processing system a custom software language that was developed in-house to allow operations engineers (operators) to directly specify command and response behavior without them needing specialized software development skills.

This provided the benefit that operators could troubleshoot both the vehicle and GSE as well as the software that ran in the Command and Control system.

~2006 - 2010 Constellation/Exploration

With the advent of the Constellation Program NASA KSC determined that a new command and control System would be required for ground processing the fleet of exploration vehicles.





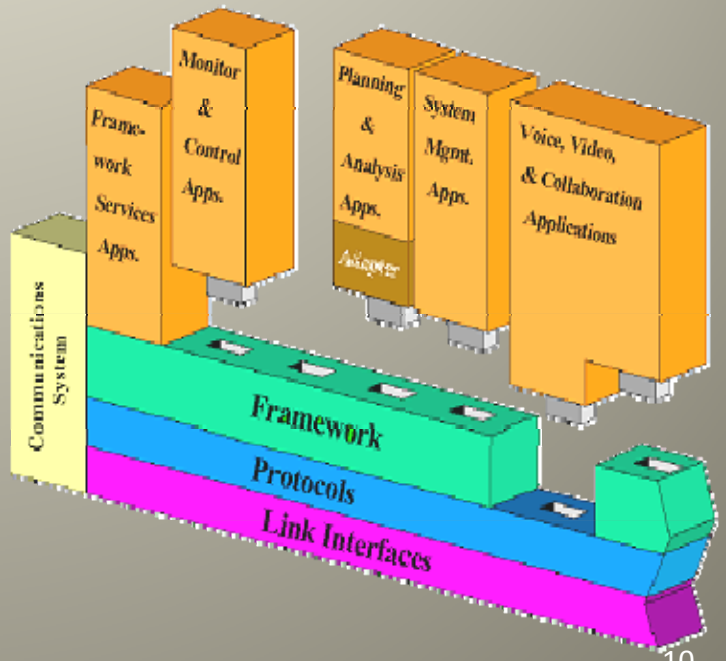
For the first time in thirty years, NASA would not be upgrading an existing command and control, it would be creating a new system from the ground up.

~2006 - 2010

Constellation/Exploration

To support the concept of ground processing a variety of exploration vehicles the design approach of using a "Standards Based Architecture" for a command and control system was chosen.

A Standards Based Architecture maximizes the use of COTS software and developing a minimal amount of "Glue Code" for integrating the commercial products to support the emerging Ground Processing Support requirements.

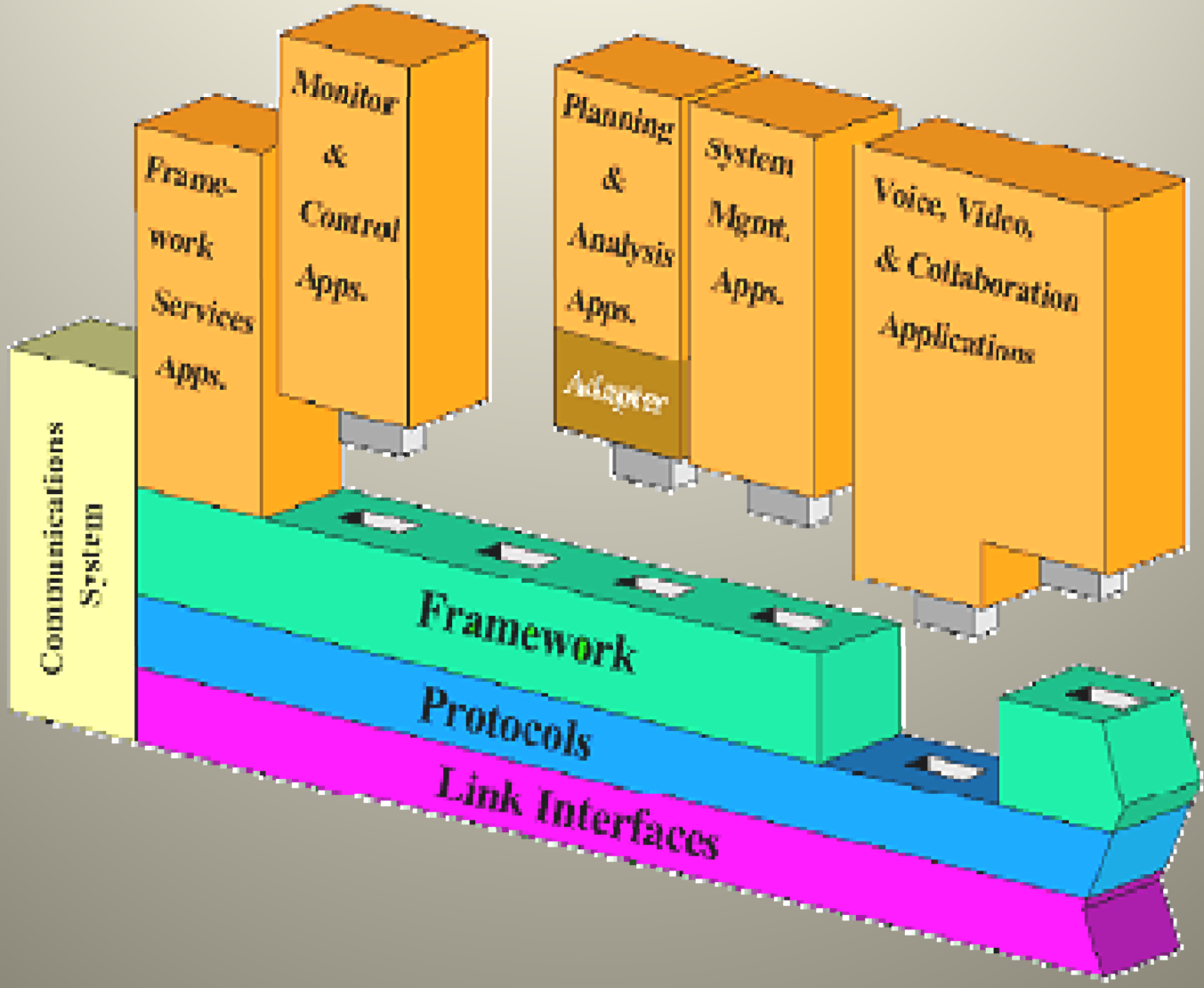


A robust market enabled the “Standards Based Architecture” and “maximized COTS” Approach

Approach for using COTS in the Launch Control System

- Background
  - Decision made to deploy a Standards Based Architecture to support Kennedy Space Center Ground Operations Command and Control Requirements
- Risk
  - Essential ground processing command and requirements not defined in time for initiation of procurements
- Mitigation
  - Develop an architecture that deploys the COTS for best "requirement fit"
    - Allocation of command processing
      - Control room servers and displays for human-in-the-loop, situational awareness requirements
      - Front end, embedded systems, for real-time closed loop control
  - Allocate the emerging ground operation support requirement to the suitable portion of the architecture based on closed-loop performance requirements
- Outcome
  - The Launch Control System architecture and design can accommodate numerous interfaces with a variety of command and control performance requirements
  - *From "Toasters to Rocket Ships"*

LCS- Integration of Commercial Products



~2006 - 2010

Constellation/Exploration

The Launch Control System design effort was based on three major architectural tenets.

First….

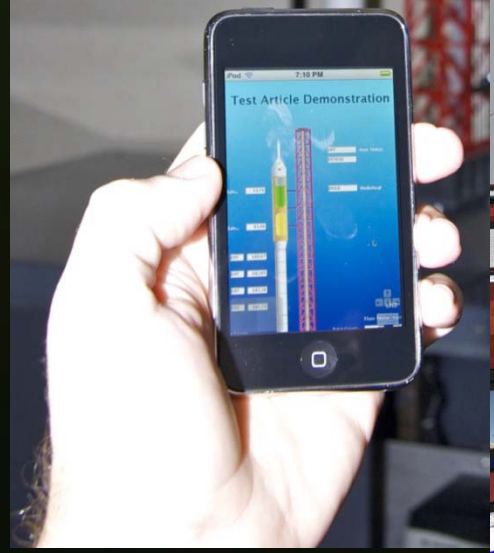
The system had to be sustainable for forty years.

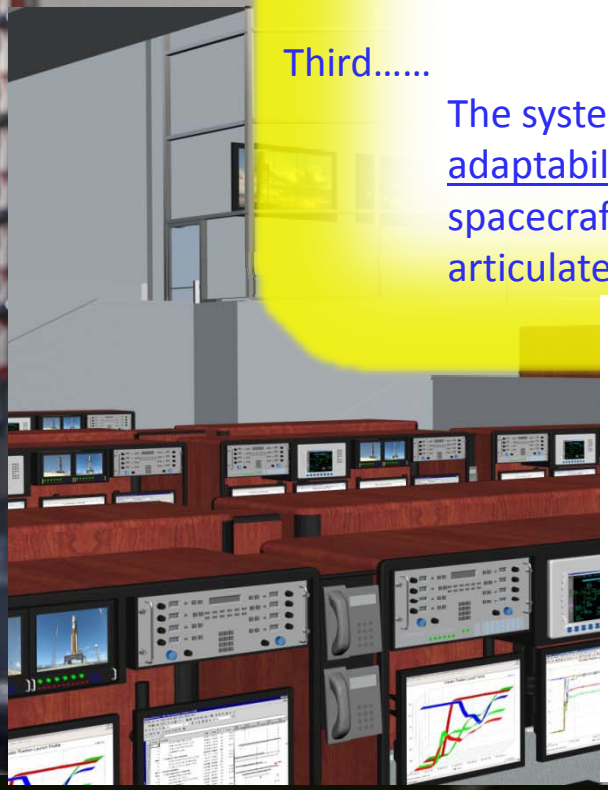
Second….

The system had to be standards-based and not tied to a single vendor.

Third……

The system had to be designed for flexibility and adaptability to support the requirements of future spacecraft and launch vehicles that could not be articulated in the present.

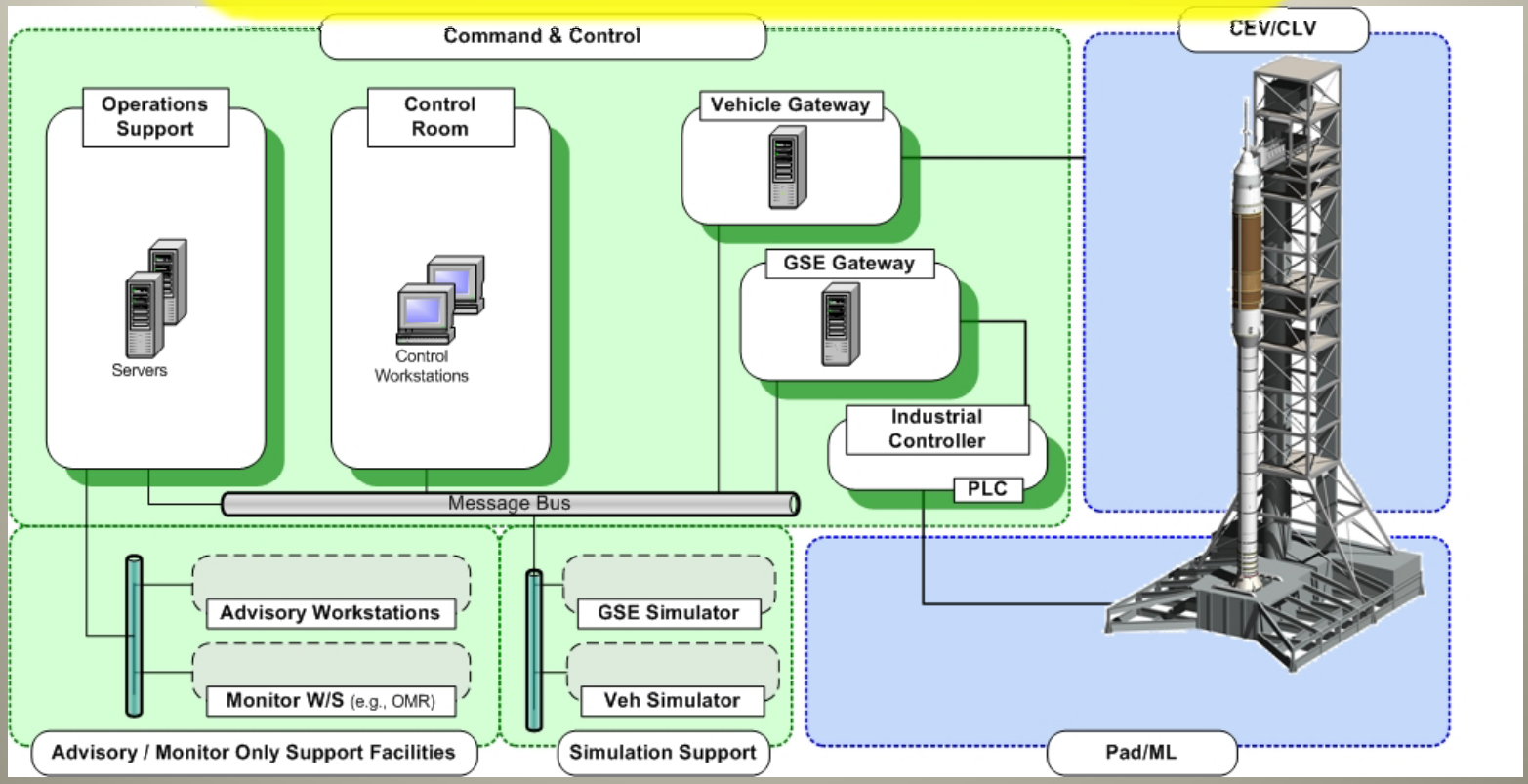




LCS

Launch Control System

The LCS design is based upon the use of mature, industry accepted, hardware and software standards and products for command and control applications.



Specialized Software will be developed only when no suitable industry/government product is available.

Vehicle & Ground Systems Interfaces

General Characteristics

Design maximizes the use of industrial based process control products and COTS to configure a software communication and data distribution architecture rather than build one from scratch

Launch Control System (LCS)

LCS – provides C&C functionality for vehicle processing.

LCS Hardware Architecture

Control Room Workstation – Windows/Linux platforms providing Thin-Client Displays, Light-Weight Displays, and Application Display Clients

Application/Gateway/Display Servers – Unix/Linux platforms, Mid-Range, multi-processor servers providing Integrated Control Applications, Subsystem Control applications, reactive control, emergency vehicle safing, command processing and telemetry data publication.

Industrial Controllers – embedded control systems to provide closed loop control.

LCS System Software Architecture

Isolation service layers providing common functionality, data logging services, networking services, recording services, commanding services, application framework, display framework and system monitoring and control.

LCS Application Software

Processing Operations Applications for Orion/Ares I.
Processing Operations Applications for LSAM/Ares V.

LCS Simulation System

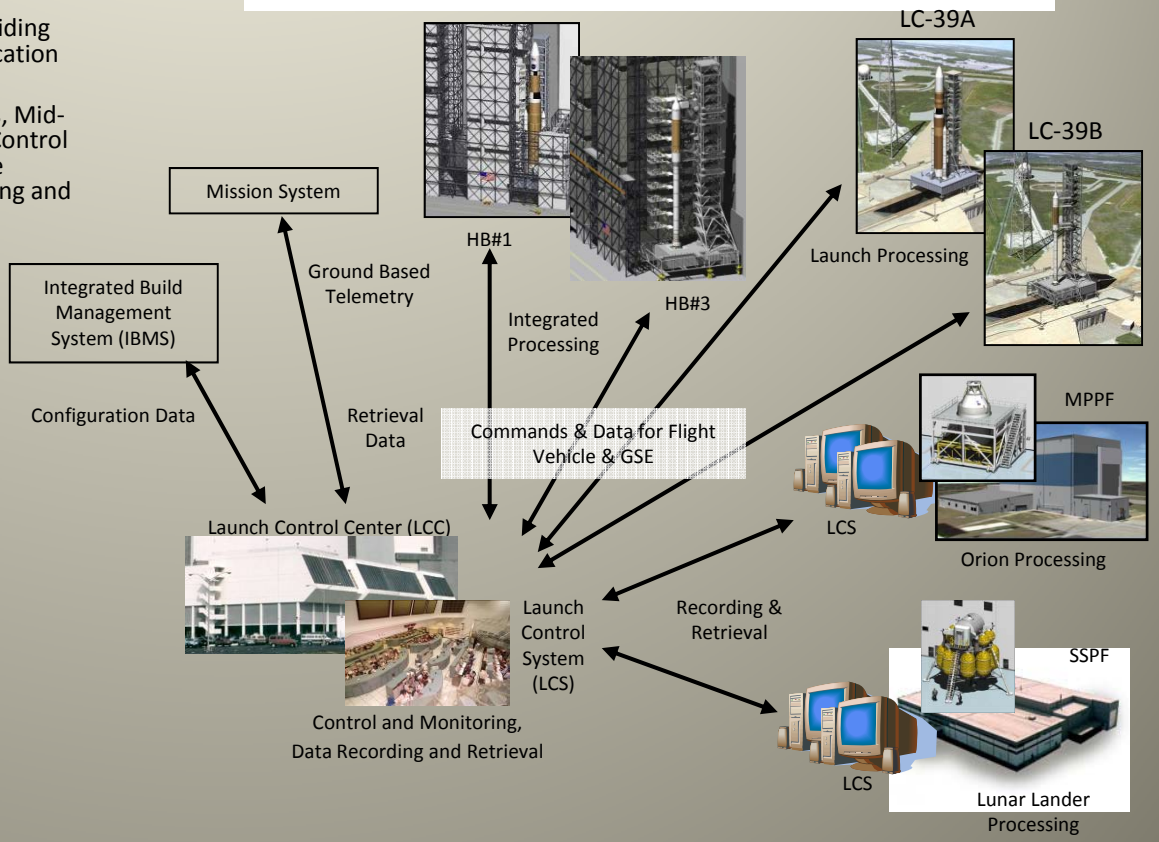
Missing element simulation, training, and testing support

LCC Control Rooms

Firing Room 1 for Launch Vehicle Processing
Firing Room 4 for Crew Exploration Vehicles

Current Initiatives

Requirements allocation and system design.



LCS Implementation To Date

Industry Standard Programmable
Logic Control PLC technology installed to
Interface to the Ground Support Equipment
(Solenoids, Valves, Transducers)

Industry standard
Control Room supervisory
Commercial-off –The shelf control systems installed

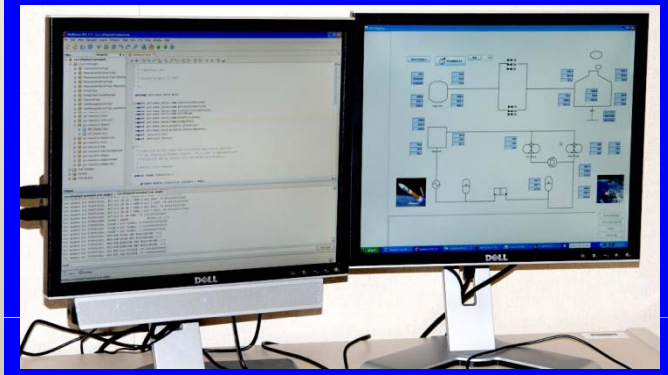
Modern User/Computer Interface
Wireless technology
Standard workstation interfaces
EMI/EMC Hardened

Application Server

IBM P-570 Enterprise Class Server

- Data Distribution – RTI DDS
- Application Scripting Engine – Python
- Prototype Application – LH2 (Script and Tabular based)
- System Monitor and Control – IBM/Tivoli and HP Openview
- High Reliability Availability and Serviceability Technology – IBM Hypervisor and Robust N/W Switches

User Workstation



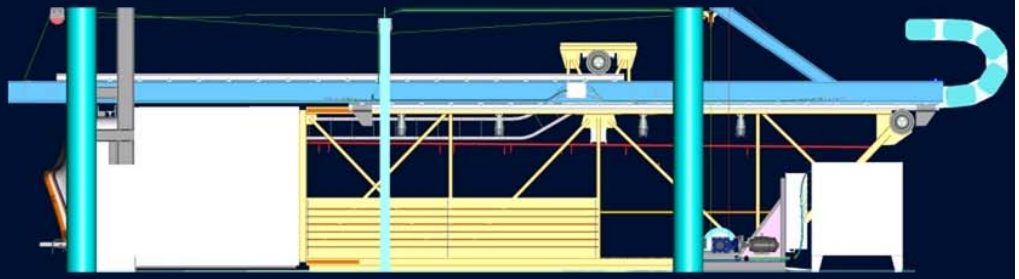
Windows Based Dell Desktop

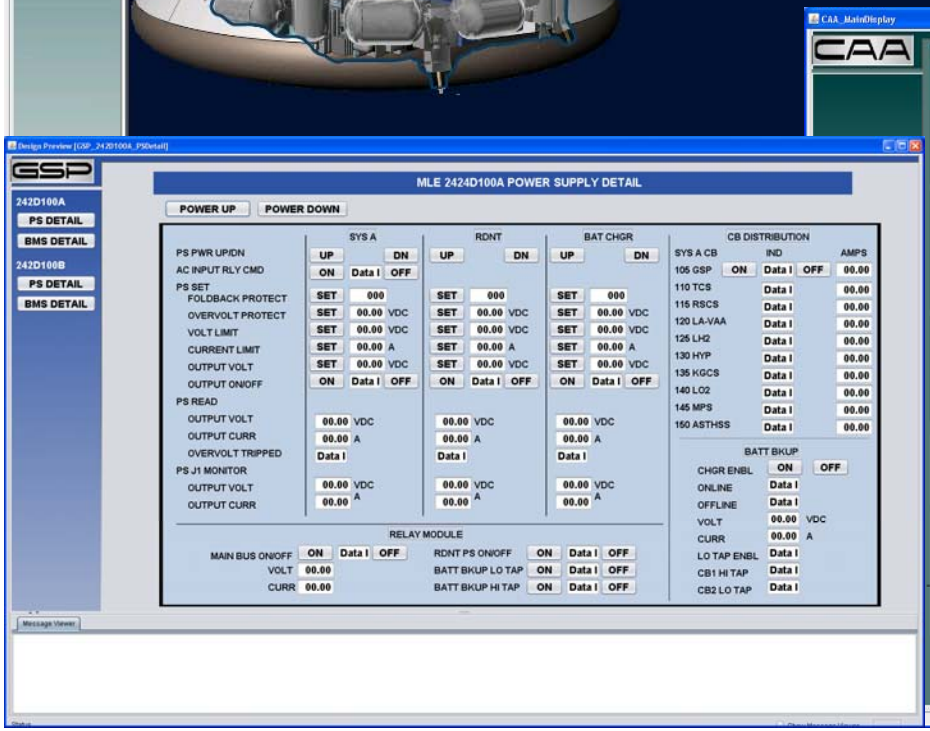
- Data Distribution – RTI DDS
- Display Engine – Java
- Prototype Dispalys – LH2 and PLC
- Health & Status Monitor – Tivoli and HP Openview

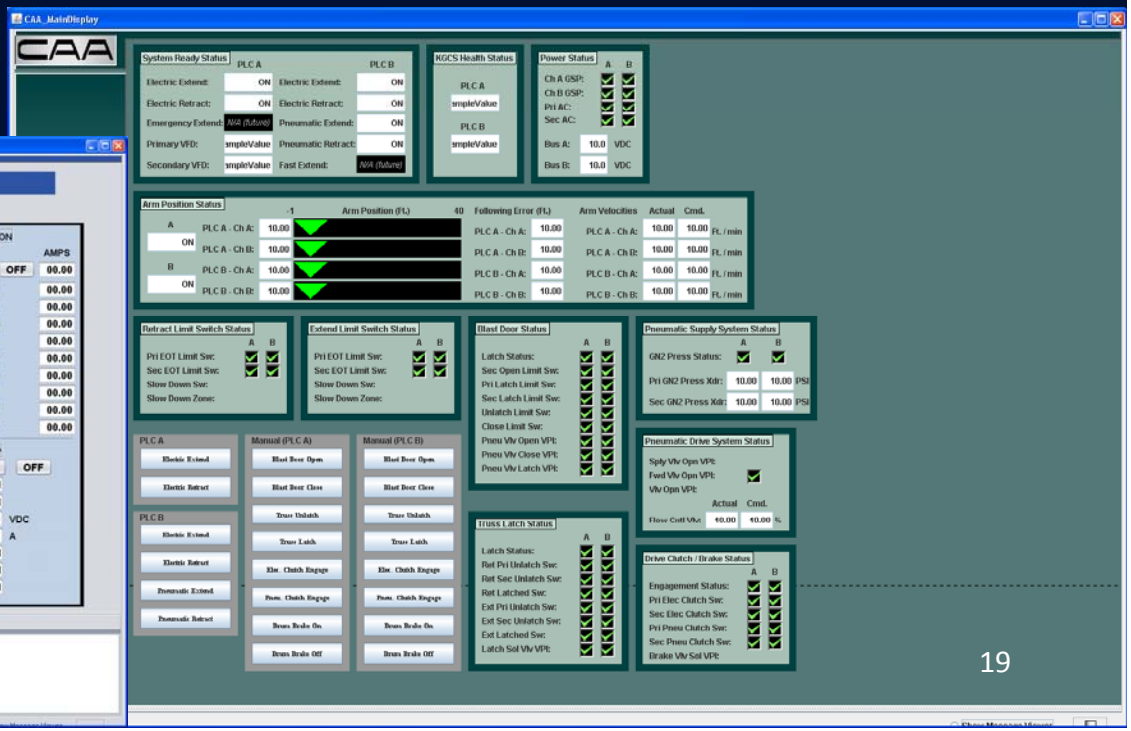
Gateway Interface Server

- PLC/GSE Data Processing – Harris OS Comet
- Telemetry and Command Processing – Harris OS Comet
- Data Distribution – RTI DDS
- Health & Status Monitor – HP Openview

Industry standard display tool technology in use for the command and control of flight and ground systems







2011 and beyond

Future

Enabling Capabilities Catalog

Virtual Customer

Support HLLV* Development & Test

*Heavy Lift Launch Vehicle (HLLV)

Commercial Provided Capability

Government Furnished Enablers

Common Infrastructure (Government Furnished)

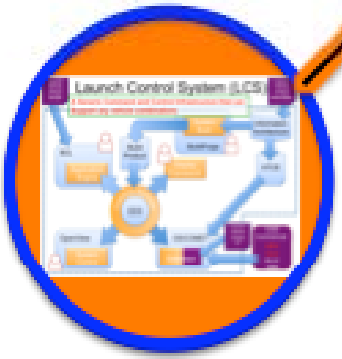
Customer Brings own C&C

Unproven Technology

Payload Launch Experience

Critical Payload Launch Experience

Commercial Provider Maturity



Adapt Launch Control System

Integrated Network Services

Increased Range Capacity & Flexibility

Transitioning from Constellation to 21 Century Launch Complex, Heavy Lift Support, Commercial Crew, etc.

- **Team is working to re-validate the system design in terms of building blocks of capabilities.**
- **Phased in FY11 and FY12 to provide a basic Command and Control capability.**
- **Generic System to support unique development for any customer starting at the end of FY12.**

Command & Control System is being developed to support three Roles:

1)Common Infrastructure for SLS development and test flights.

2)Provide assured access for mission assurance / NASA Insight.

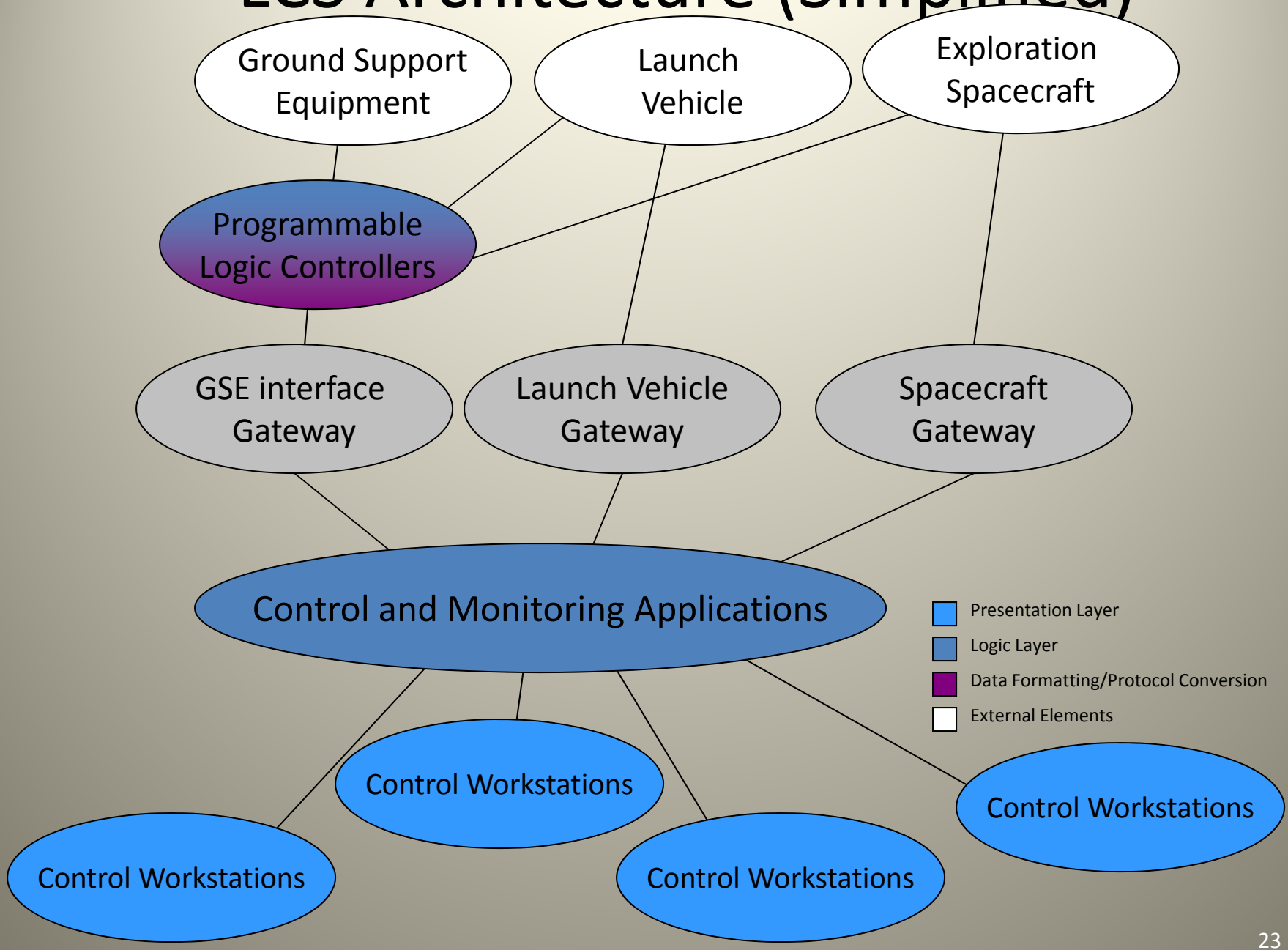
3)Enabling capabilities to compliment commercial provider resources.

Refine and Revise:

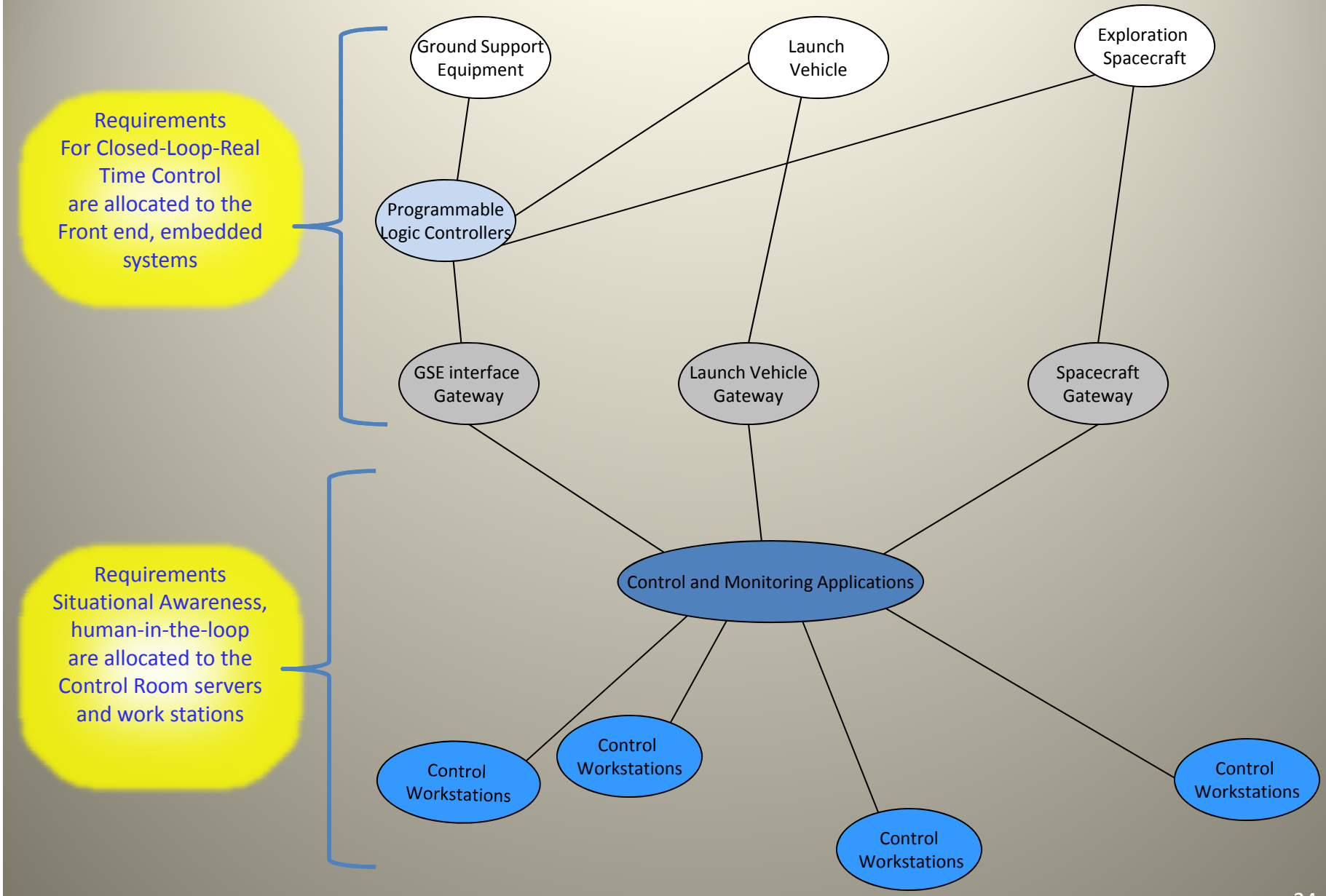
- *Architecture Interfaces*
- *COTS Products*
- *Ground Operations Reqs.*
- *Agility – Rapid Deployment Approach*
- *Hardware deployment*
- *Software capabilities*
- *Maintain CMMI Certification*
- *Provide Flexible Firing Room configuration for variety of customers*

Designing an architecture that can Accommodate Ambiguity

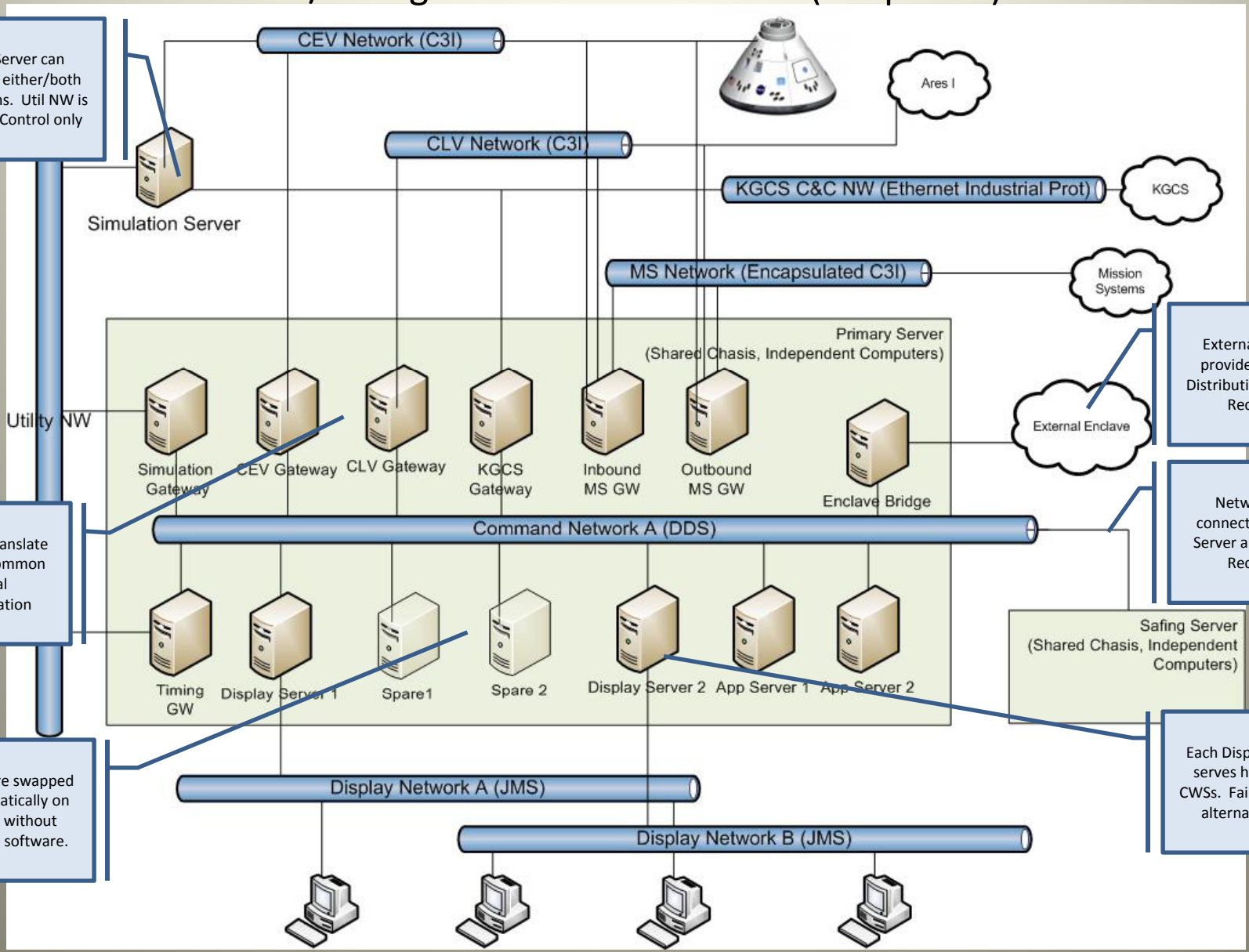
LCS Architecture (Simplified)



Allocation of Control Illustration



LCS / Firing Room Architecture (Simplified)



Sim Server can replace either/both End Items. Util NW is for Sim Control only

Gateways translate to/from a common internal representation

Spares are swapped in automatically on failure, without affecting software.

External Enclave provides Remote Distribution, External Recorder

Network also connects to Safing Server and Internal Recorder

Each Display Server serves half of the CWSs. Failure affects alternate CWS.

LCS Software Architecture

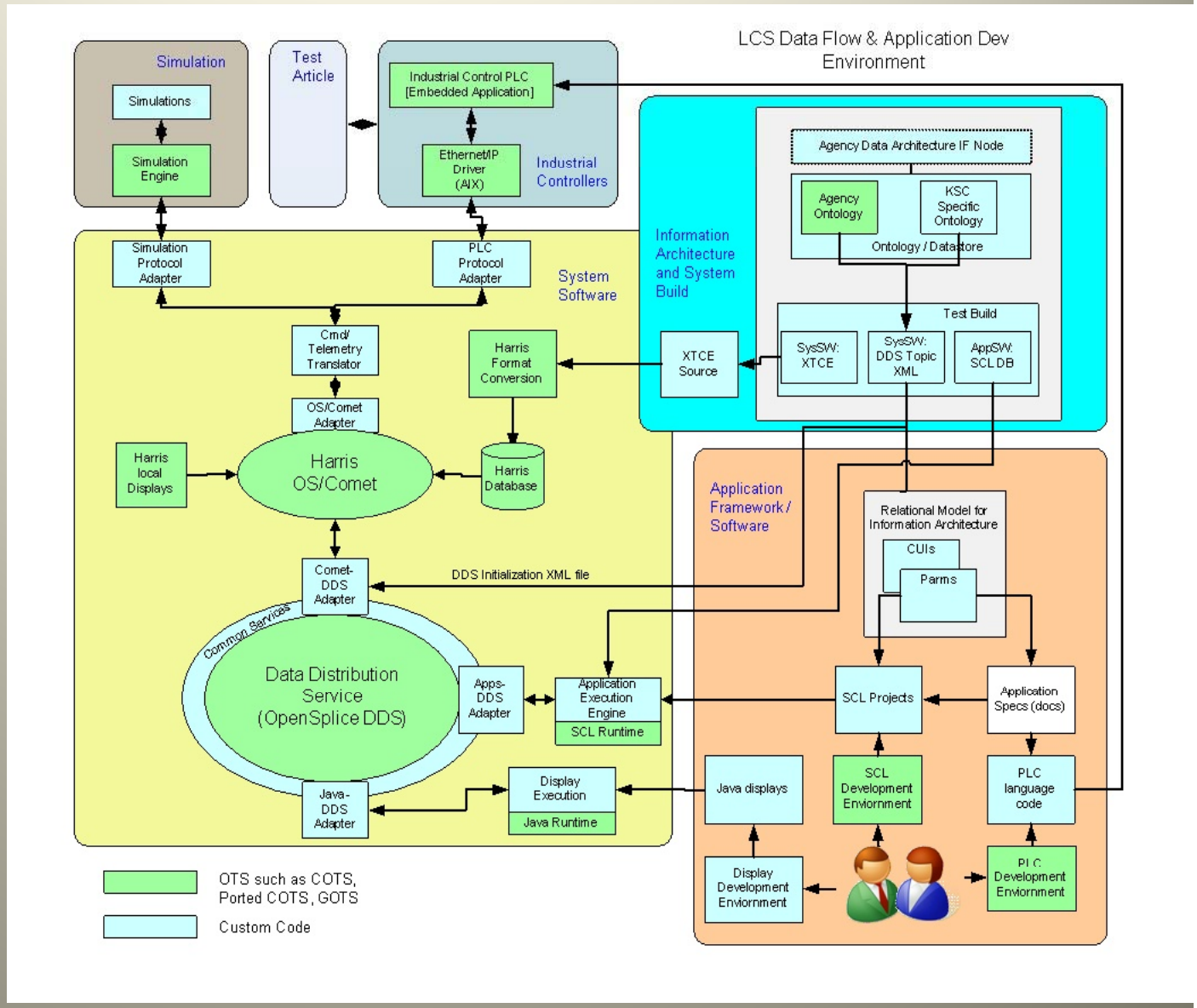
Simulation
- GSE/Veh Shuttle Simulation

Industrial Controllers
- PLC application
- GSE math model

Information Architecture
- Data Ontology
- Build Products

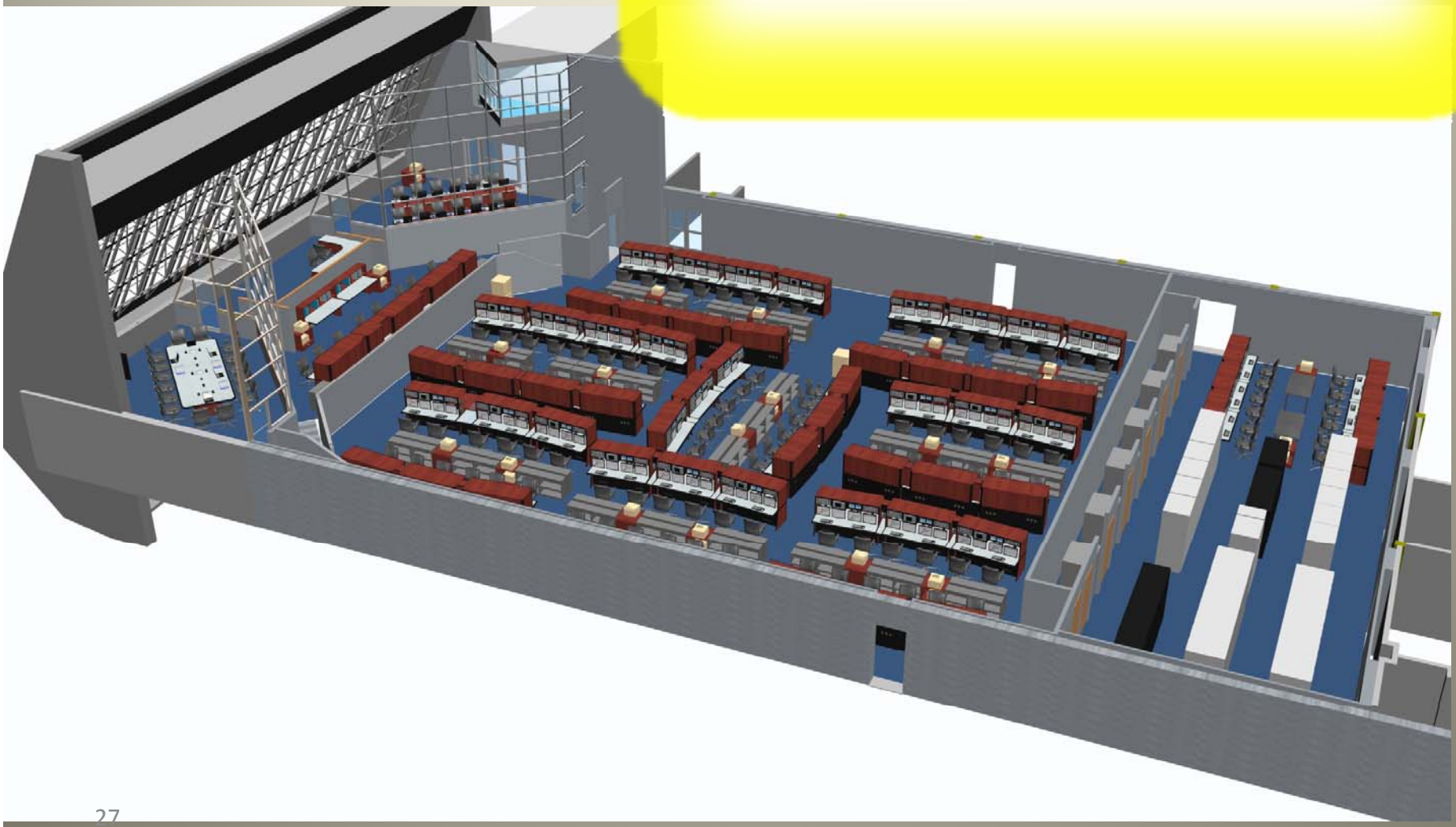
System Software
- Data Distribution
- Isolation layers
- Telemetry processing

Application Framework/Software
- User displays
- Control applications



Kennedy Space Center
Exploration Control Room

Under Construction

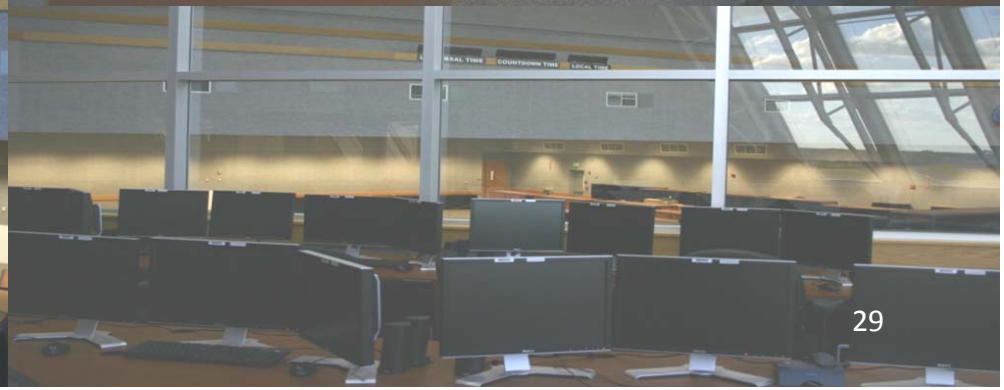


Kennedy Space Center
Exploration Control Room

The new control room is being designed
To support multiple customers with different requirement

Kennedy Space Center
Exploration Control Room

Phase one of the new control room was completed September 2010



Kennedy Space Center
Exploration Control Room

Phase two of the new control room, which includes the main floor layout is scheduled to be completed Spring 2011

Welcome to the Florida Spaceport

Today is Tuesday April 14, 2020

Commercial Crew launch from Pad 39-B to ISS at 8:47 AM **ON TIME**

Mars Communications Satellite launch from Pad 41 at 1:13 PM **ON TIME**

Commercial satellite launch from Pad 37 at 6:35 PM **ON TIME**

Tomorrow April 15, 2020

Space Hotel passenger launch from Pad 39-A at 11:00 AM **ON TIME**

Notice: Use of Virtual Reality sensory implants while traveling on Florida's Spaceport is illegal