Launching the Space Shuttle

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Agenda

- Background
- Engineering
- Operations
- Human Factors
KSC Shuttle Infrastructure

Facilities
- Kennedy Space Center: 140,000 Acres
- Vehicle Assembly Building: 8 Acre Footprint, 525’ Tall
- Three Orbiter Processing Facilities: 30,000 SF Each
- Launch Pads A&B: Fuel/Oxidizer Tank Capacity of 1.8 M Gal
- Shuttle Landing Facility: 15,000’ Runway, 300’ Wide
- Operations Support Building: 200,000 SF Office Space

Support
- 300 Generators, 60 UPS Units, 156 Substations
- 30,000 Tons of Air Conditioning
- Over 52 Cranes, 217 Hoists, and 55 Elevators
- 100 miles of Water Distribution Lines
- 441 Pieces of Heavy Equipment
- 270 Miles of Fiber Optic Cable
- Over 900 Fiber Optic Transmitters and 900 Fiber Optic Receivers
- LC-39 TV System Includes 166 Cameras, 9 Video Recorders, and Over 7770 Monitors
- 142,000 Line Items in Inventory
- 10,000 Issues Per Month
Standard Work Flow
Shuttle Processing Team

- Space Flight Operations Contractor – United Space Alliance
- Responsible for processing Orbiter, External Tank (ET), Solid Rocket Boosters (SRB) and Re-usable Solid Rocket Motors (RSRM)
- Responsible for facility and Ground Support Equipment (GSE) maintenance
- Additional support provided by development and institutional contractors

NASA Shuttle Processing Director is the designated Technical Manager for:

- Management of NASA shuttle support at KSC
- Disposition of technical issues for KSC equipment
- Validating contractor processes meet NASA requirements

NASA Launch Director is responsible for:

- Management of launch count, landing and recovery operations
NASA Shuttle Processing Responsibilities

**Engineering**
- Approve
  - Non conformance to Program Requirements
  - New/Changed Requirements
  - Implementation Procedures
  - NASA Managed Activities
- Analyze Test Data
- Observe Critical Procedures / Tasks
- Audit Requirements Implementation
- Assess Contractor Metrics

**Operations Integration**
- Lead NASA Managed Activities / Approve Procedures
- Lead Vehicle Flow Planning
- Approve Requirements
- Observe Critical Integrated Procedures / Tasks
- Observe Day-to-Day Operations
- Assess Contractor Metrics
- Manifest (Flight Schedule) Development
Orbiter Processing Facility (OPF) Operations
Orbiter Processing Facility (OPF)

- Operations
  - Initial access and safing
  - Post-flight hardware problem resolution
  - Thermal Protection System maintenance, replacement and repair
  - Space Shuttle Main Engine (SSME) removal and installation
  - Payload bay operations
    - Down mission payload removal
    - Mission kit reconfiguration
    - Up mission horizontal payload configuration and installation
  - Orbiter modifications
  - Orbiter sub-system design requirement re-verification
  - Orbiter preparation for roll over to VAB (Vertical Operations)
Vehicle Assembly Building (VAB) Operations
Vehicle Assembly Building (VAB)

- **Operations**
  - Perform External Tank (ET) checkout
  - Solid Rocket Booster stacking requires approximately three weeks
  - ET mate and closeout requires approximately two weeks
  - Orbiter mate requires approximately one week
  - Test interfaces between Shuttle elements
  - Perform structural closeout
Launch Pads 39A and 39B

- Operations
  - Pad processing takes approximately 4 weeks
  - Payload transfer from payload canister to Payload Change-out Room (PCR) to Orbiter
  - Shuttle/Pad system validation
  - Simulated launch count with astronauts
  - Final preparations to vehicle for launch countdown
Launch Processing System (LPS) / Control Room

- Description
  - Automated and computer controlled Shuttle launch and checkout system
    - Customized hardware for Shuttle
    - Custom language used for application software
  - Linked to orbiter, External Tank, and Solid Rocket Booster, and Ground Support Equipment at all processing locations

- Operations Support
  - Automated checkout of Shuttle and associated Ground Support Equipment during preparation for launch
  - Problem resolution and data reduction
Engineering Approach

- **Engineering Requirements** – Demonstrate the “as built ready to launch shuttle” is the same “as designed and certified”
  - Development / design organizations establish requirements implemented at KSC
  - Requirements dictate hardware / software performance and limitations in ground tests and inspections
  - Verified by review of documents used to assemble, inspect and test
  - Periodic management reviews certify readiness

- **Launch Count Requirements**
  - Requirements documented in engineering drawings, NASA Program documents and Launch Commit Criteria
  - Acceptable limits for the system performance and the configuration of the hardware and software

- **System Engineers develop procedures and software to implement requirements**
  - Approximately 500 requirements with approximately 2000 associated measurements
  - Launch count procedures: Approximately 20 documents totaling 5000 pages
  - Approximately 500 software programs
Launch Team Structure

Mission Management Team
- NASA JSC Flight
- NASA & Contractor Project Managers

Launch Director
- Range
- Payload
- Contractor Test Conductors
- NASA Test Director

Engineering Support
- Safety
- NASA & Contractor Senior Engineers
- NASA KSC Integration Engineering

System Engineers
- NASA and Contractor System Engineers
Shuttle Launch Operations Summary

- Activate and test flight and ground systems (16 hrs)
- No work hold (4 hrs)
- Load fuel cell cryogenics (8 hrs)
  - No work hold (4 hrs)
  - Activate and test remaining shuttle systems (12 hrs)
- Time critical stowage and service structure disconnects (12 hrs)
- ET propellant load preps (5 hrs)
  - No work hold (2 hrs)
  - ET Load (3 hrs)
  - No work hold (3 hrs)
  - Terminal count (4 hrs)

Operations Sequenced to:

- Provide orderly closeout of vehicle and launch accessories
- Activate and verify systems meet requirements
- Minimize hazards to personnel and equipment
- Scheduled hold time to allow work to catch up

72 hours
Shuttle Launch – Terminal Count Phase

- T-3 hrs
  - Crew ingress
  - Communications tests
  - Crew cabin closeout and integrity test
  - Guidance systems initialization

- T-20 min
  - 10 minute hold
  - Orbiter computers sequencing initialized

- T-9 min
  - 45 minute hold
  - Final poll of management, operations, engineering, weather, range safety and flight teams

- T-7 min
  - Retract crew access arm

- T-4 min
  - Automated test of orbiter flight controls

- T-2:55
  - Pressurize ET oxygen tank

- T-1:57
  - Pressurize ET hydrogen tank

- T-0:31
  - Activate SRB systems
  - Initiate Orbiter sequencer

- T-0:10
  - Final automated “Go” to orbiter computers
  - Verification of critical ground system activation
Launch Count - Controls

The Ground Launch Sequencer (GLS) is the software supervisor of critical command sequencing and measurement verification for terminal launch countdown.

- Issues or delegates all ground initiated commands to the Shuttle and Ground Support Equipment (GSE) from T-9 min
- Initiates critical activities performed by software at other firing room system consoles
- Monitors all measurements whose violation require immediate reaction
- Monitors all measurements associated with GLS issued commands
- Performs critical safing
- Controls ground and onboard clocks – sets liftoff time
Human Factors

- Automation vs. Manual Control
- Responsibility
- Teamwork Dynamics
  - Decision making process
  - Communication
  - “Launch Fever”