Stephen Coester added 2 new photos.
· March 22 at 9:33am ·
Another for Space Shuttle interested folks.

Today I'll try to very simply discuss a very complex subject. There are several excellent in-depth discussions of the Space Shuttle Launch Processing System (LPS) you can google for the details.

Twenty years before the advent of desktop computers NASA decided that it needed to get away from the hardwired switches and gauges used to launch Apollo. The system needed to be totally computerized to control all aspects of checkout and launch. LPS was the result with the CCMS or Checkout Control and Monitoring subsystem at its heart. The CCMS is all of those consoles you see in the firing rooms.

KSC was given the task of developing this radical new way of processing and did so in a lab next to the O&C building that previously had been used for Apollo moon landing simulations.

What did this new system mean to the system engineers on the Shuttle? On my jobs on both Apollo-Saturn V and Atlas-Centaur the firing room or blockhouse had individual consoles for each function like propulsion, propellants, pneumatics, etc. Using the knobs, switches and gauges on his specific console the engineer would operated his system.

Not so on the CCMS. In the firing room were twelve consoles each having three computer stations. And all of these stations were identical until loaded with a particular system's software. I had this explained to me my first week and asked where did this software come from so I could control my Main Propulsion System. To my shock I who had never seen a computer was told we system engineers would write that software.

Each of us system engineers then attended GOAL school. GOAL or Ground Oriented Aerospace Language was a new English language based software system that let us write our software with minimum knowledge of ones and zeros.

First we developed displays for the computer screens that schematically showed the system and all of it's valves, instrumentation and other hardware. Then we spent months pouring over the electrical drawings and converting all of that complex logic into code.

Once written, compiled and verified this software would be loaded on one of those CCMS computer stations and we were finally ready to start cycling valves, running automated tests, and launching the Space Shuttle.

Here's an example of what LPS could do. I didn't write this software except some of the MPS part, but helped with the loading criteria. Jimmy Rudolph and Mark Dezendorf get credit for the propellant loading software.

A typical example of the LPS at work can be shown by following the liquid oxygen tank sequence when a Shuttle is on the pad. Only one console is required for this operation. Its task is to transfer some 529,000 liters (140,000 gallons) of a super-cold liquid at minus 181 degrees C (-295 degrees F) one-third of a mile, from the liquid oxygen tank at the edge of the pad to the external tank.

The console operator performs several programs to verify that the system is ready to begin the fill operation. These programs establish that; 1) All exception monitor limits are set to their standby conditions; 2) All system measurements are being reported; and 3) All mechanical valves are cycled to determine their readiness to operate. The LPS does all this without operator intervention, finishing, unless unusual conditions occur, in about ten minutes.

When the verifications are complete, the operator awaits a "go" signal from the lead test conductor. When this signal comes, the operator pushes a single button marked "Fill." The liquid oxygen loading operation begins, and continues automatically until completion. It includes these major steps:
A) A ten-minute chilldown of the storage area and pump. (Liquid oxygen flashes into a gas if it contacts surfaces warmer than minus 181 degrees C. All pipes, pumps, tanks etc., have to be prechilled to prevent an excess amount of gaseous oxygen from forming.)
B). A chilldown of the Shuttle orbiter main engines, through which the liquid passes on its way to the external tank and the oxygen tank itself
C) A slow fill of the oxygen tank, until it is two percent full.
D) A much faster fill of the oxygen tank, until it is 93 percent full.
E) A slower "topping" of the tank to 100 percent.
F) The constant replenishment of the oxygen boiled off and bled off in gaseous form, until about nine minutes before launch.
G) At ignition minus nine minutes, the liquid oxygen tank is sealed, pressurized and ready for launch.

Some 200 computer programs are required to operate all these phases of action. They operate a primary pump or secondary pump, primary fill valve, etc., throughout a complex piping system. While these programs are in process, some 150 measurements are constantly monitored to be certain all temperatures, pressures, etc., are within limits. If a condition is detected which requires immediate corrective action, the program takes that action and notifies the operator. Less immediate problems are called to the operator's attention for his consideration. The operator has the option to alter the sequence of events or take over control, in the unlikely event that he or she should think it necessary.

The loading of liquid oxygen is only one of hundreds of equally complicated, difficult operations performed automatically by the LPS, while operating under stringent safety and performance requirements. The end result is the launch of a Space Shuttle

Also from the fill description:
http://www.spaceacts.com/STARSHIP/seh/lps.html

KSC's Automated Launch Processing System

To maintain the desired launch rate, Space Shuttle vehicles must be assembled, checked out and launched as quickly and inexpensively as safety requirements permit. This pace is made possible by the Launch Processing System, or LPS -- a highly automated, computer- controlled system that oversees the entire checkout and launch process.

The LPS continually monitors the Space Shuttle and its ground components, including its environmental controls and propellant loading equipment. Temperatures, pressures, flow rates, voltages, valve and switch positions and many other critical parameters are monitored several times times each second to see if they are performing as expected. If any reading deviates from normal, the LPS automatically alerts the proper system operator who can then apply human intelligence to the problem.

The checkout and launch process begins with the arrival of Space Shuttle components at Kennedy Space Center. The orbiter, once it has arrived at the Shuttle Landing Facility after a previous mission, is taken to the Orbiter Processing Facility (OPF), where it is refurbished and prepared for its next flight. It is then transferred to the huge Vehicle Assembly Building (VAB) for mating with the solid rocket boosters and the external tank.

The booster segments filled with propellants (shipped from the contractor in Utah) are transferred to the VAB from adjacent checkout and storage facilities. Non-propellant booster components are delivered from a nearby refurbishment facility. The external tank, following delivery from the contractor in Louisiana, is checked out and stored in the VAB. It is the only piece of Shuttle hardware that is not reused.

The mating process begins begins with the stacking of the solid rocket boosters on a mobile launcher platform inside the VAB. The external tank is attached to the boosters, and then the orbiter to the tank. The entire assembly is then carried out to the launch pad by a large tracked vehicle called the crawler-transporter.

The LPS, using digital computers, automatically provides the bulk of the checkout work for the orbiter and much of that for the tank and boosters, reducing the turnaround time between missions and the number of operating personnel involved. It also controls countdown and launch activities. The test engineers operate the LPS through its Checkout, Control and Monitor Subsystem from firing rooms in the Launch Control Center (LCC), the four-story structure located adjacent to the VAB. Two or more Shuttles can be processed simultaneously. During assembly and checkout, the LPS will interface with the solid rocket boosters, external tank, orbiter main engines, and other complex orbiter systems. The LPS also monitors ground support equipment through extensions called hardware interface modules, or HIMS. These modules are located in the OPF, the VAB high bays, the Hypergolic Maintenance Facility in the KSC Industrial Area, the launch pads, the various spacecraft checkout buildings and other sites supporting Shuttle maintenance and checkout. The LPS consists of three major subsystems: Checkout, Control and Monitor; Central Data; and Record and Playback.

Checkout, Control and Monitor Subsystem

The Checkout Control and Monitor Subsystem, or CCMS, consists of operator-manned consoles in the firing rooms, minicomputers, a data transmission system, a data recording area, HIMs, a common data buffer and front-end processors.

Each subsystem operator position in a firing room has its own keyboard and visual display system. The information the human operator needs to make his or her decisions is displayed on computer monitors. Charts and diagrams are shown, pointing out where the unexpected condition exists, and using different colors to indicate the degree of urgency. A red signal means that immediate human attention is needed to prevent possibly serious consequences.

Each group of three keyboards and display systems is considered as one console and operates as a unit. Two consoles, or six operator positions, are usually arranged in a quadrant, or semicircle. All consoles are orchestrated to work together on major tasks through an Integration Console at the front of the firing room. The small computer with each console has an on-line disk storage capacity of five million words to hold all the test procedures to be conducted by that operator and his or her assistants. The checkout and launch functions of each console can be changed, if necessary, by patching and reloading data from the master console.

The master console in the firing room provides the controlling link for transfer of the real-time software from the Central Data Subsystem, or CDS, where it is compiled, to the network of up to 100 parallel minicomputers and microprocessors throughout the LPS. About 40 minicomputers are used during a regular launch.

The number of personnel on duty in a firing room at launch time is less than half of the 450 that were required to launch an Apollo/Saturn vehicle. This reduction in manpower is possible because the LPS monitors thousands of measurements on the Space Shuttle and its ground support equipment, compares them to predefined tolerance levels, and displays only those values that are out of tolerance. This selective process is called the exception monitor capability. In many cases, the LPS computers will automatically react to the exception conditions and perform safing or other related functions without test engineer intervention.

Central Data Subsystem

The Central Data Subsystem, or CDS, consists of two large-scale computers (Honeywell DPS-90/92T) that store test procedures, vehicle processing data, a master program library, historical data, pre- and post-test data analyses, and other related data. These computers make an immense amount of data immediately available to the smaller computers of the CCMS, which have much less storage capacity.

The CDS is located on the second floor of the LCC. In addition to the hundreds of individual data lines, it has two major interfaces. The real-time interface receives the space vehicle and ground support processing data from the CCMS. The video simulation interface provides simulated test data to support the testing of computer programs in the firing rooms without actually having a Space Shuttle to test against.

Record and Playback Subsystem

The primary function of the Record and Playback Subsystem, or RPS, is to record unprocessed Shuttle instrumentation data during tests and launch countdowns. These recordings can then be played back for post-test analysis when firing room personnel wish to troubleshoot Shuttle or LPS problems. In addition, a limited number of selected data signals can be processed for display or evaluation.

The subsystem consists of instrumentation tape recorders, PCM and FM telemetry demultiplexing equipment, direct-write recorders and computers to provide the wide variety of data reduction capabilities necessary to support the launch crew's special needs in problem analysis and isolation. This subsystem also provides certain functions in support of the CCMS and CDS, such as data playback from downrange instrumentation tapes sent to KSC for data analysis by KSC systems engineers.

Altogether, the three subsystems form a highly efficient, automated means of performing what was previously a slow, expensive and labor-intensive process. The LPS greatly increases the performance capability of each test engineer. Automation and computer technology enable each person to do the work for which several people were needed on earlier manned space programs.

System Operations

A typical example of the LPS at work can be shown by following the liquid oxygen tank sequence when a Shuttle is on the pad. Only one console is required for this operation. Its task is to transfer some 529,000 liters (140,000 gallons) of a super-cold liquid at minus 181 degrees C (-295 degrees F) one-third of a mile, from the liquid oxygen tank at the edge of the pad to the external tank.

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The concepts underlying the LPS can be applied to other, similar complex operations in many industrial applications. They can be adapted to operate as a multipurpose module system anywhere that mechanical and electrical systems are used to provide checkout and operational control. The programs are written in a high level language (GOAL, or Ground Operations Aerospace Language) that is adaptable to several different host computers. What began as a means of reducing costs and turnaround time for Space Shuttle launches may ultimately bring reductions in the costs of thousands of factory operations throughout the industrialized world.

Future Checkout System Needs at KSC

Rapid advancements in digital data processing and communications, plus increased launch processing requirements for the Space Shuttle, have led NASA to call for a replacement for the CCMS subsystem of the LPS. At the same time, a new test control and monitor system for the International Space Station and future NASA launch systems will be needed. All of these requirements will be met through a follow on of the CORE Project. This effort takes its name from its goal of creating a generic test, command and control system that can be tailored to the vehicle and spacecraft processing needs of all NASA centers and especially those at KSC. The original Core project has been downsized and rescoped due to the changing requirements of the International Space Station.

Original Core Elements

The Core design was one that took full advantage of state-of-the-art, real-time computers; modern graphic displays; multi-tasking software and communications devices; and advanced design, development and testing capabilities. KSC officials believe that the new approach will greatly increase productivity while reducing operating costs.

A building block approach that allows the system to be upgraded with the latest commercial off-the-shelf hardware and software serves as the basis of the Core design. This methodology allows Core to be adaptable to a wide range of system and testing needs, and to economically sustain a 30-year-plus lifetime.

Core will have interfaces with flight hardware and ground support equipment; a high-speed, high-capacity, real-time network; a large-scale data base subsystem; multiple archival and retrieval subsystems; a software production facility; a high-speed display network subsystem; and a modern display processing subsystem where operators will control and supervise test and checkout operations from high-quality color graphics workstations. Here, they will be able to perform multiple functions at the same time in a multi-tasking environment, while being provided with information on the status of the test proceedings and the condition of the test article.

Each Core firing room will have the capability to support over 100 locally connected computers, and can support multiple tests at the same time. During the tests, up to 50,000 changes in measurements will be monitored every second. If any of these measurements indicate a potentially dangerous condition, the system will respond to the emergency in less than 20 milliseconds.

Shuttle Core Implementation

The CCMS-II is the Core replacement for the current Checkout, Control and Monitor Subsystem of the LPS used to process and launch the Space Shuttle. The CCMS-II will support all functions and operations of the present LPS, including the existing Central Data Subsystem and the Record and Playback Subsystem. The CDS received new computers in 1989.

Eventually, all of the firing rooms in the LCC will be replaced with CCMS-II hardware. However, since the new system will be able to interface with the existing CDS and run existing CCMS application software, minimal modifications will need to be made to these existing resources once the CCMS-II is in place. The new Core system will provide NASA with enhanced processing capabilities, which will help reduce Shuttle ground support and flight hardware processing time.

International Space Station Checkout Implementation

The Test, Control and Monitor System (TCMS) will be the Core implementation designed to control prelaunch testing and checkout for all ground support equipment, flight hardware and software elements, payloads and experiments for Space Station Freedom before launch on the Space Shuttle or future unmanned heavy lift vehicles.The TCMS will be located in the Space Station Processing Facility at KSC. Here it will be able to support simultaneous testing of multiple launch packages or individual items. Processing will be accelerated by the use of computer simulations, which will take the place of components not yet delivered that interface with hardware already at KSC. These simulations will save time, since all equipment will not have to be in place before the testing of some components can begin.