LAUNCH PROCESSING SYSTEM
CONCEPT TO REALITY

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ABSTRACT

The Launch Processing System represents Kennedy Space Center's role in providing a major integrated hardware and software system for the test, checkout and launch of a new space vehicle. Past programs considered the active flight vehicle to ground interfaces as part of the flight systems and therefore the related ground system was provided by the Development Center. This paper addresses the major steps taken to transform the Launch Processing System from a concept to reality with the successful launches of the Shuttle Programs Space Transportation System.

CONCEPT DEFINITION

With the baselining of the Space Shuttle Program, NASA was faced with the technical challenge of processing and launching a new type of space vehicle. In 1972, a task group was formed at KSC to review the checkout requirements of the Shuttle elements and to recommend to Shuttle Management a checkout system which would satisfy all processing requirements and meet the initial April, 1978 launch date.

Initial system sizing was based on a comparative analysis of analog and discrete measurement and stimuli data parameters between Apollo and Shuttle ground and on-board systems (Table I). This 1972 analysis indicated for initial Shuttle and envelopment flights, the total number of parameters (Operational Flight and Development Flight Instrumentation) was approximately the same as Apollo ground and on-board systems.

TABLE I.- COMPARISON BETWEEN APOLLO AND SHUTTLE DATA PARAMETERS IN 1972

APOLLO		SHUTTLE (1972)		
ELEMENTS	PARAMETERS	ELEMENTS	PARAMETERS	
			OFI	DFI
SPACECRAFT	2101	ORBITER	2300	2800
		PAYLOAD	230	—
LAUNCH VEHICLE	3188	SSME SRB/ET	1076	256
GROUND SUPPORT EQUIPMENT	4038	GROUND SUPPORT EQUIPMENT	1787	—
TOTAL	9327	SUB TOTAL	5393	3056
		TOTAL	8449	

To meet the rapid turnaround time requirement of a reusable vehicle as well as to significantly reduce the number of people involved, the entire launch processing activity had to be automated with digital computers. It had to be done in such a way to preserve, from a functional point of view, the test engineers direct control over checkout and launch procedures. Therefore, a highly functional, user-friendly hardware and software interface between the user-engineer and the system was necessary. The system had to be modular to handle the various checkout areas which included not only the integrated vehicle testing and launch, but also the checkout of the individual Shuttle elements; i.e., Orbiter, External Tank, and Solid Rocket Boosters.

Other factors which entered into the review process included such areas as:

1) Use of existing Apollo Checkout Equipment (ACE)

2) Use of newly development systems proposed for use during Orbiter manufacturing phase and the development and operational phase. Examples of these included Unified Test Equipment (UTE) and a Universal Control System (UCS).

3) Development of a new Launch Processing System

4) Phased implementation involving the use of an existing system during the development flight period and a new system for the operational phase.

Based on a thorough examination of all the known factors the decision was made to implement a new concept for the automated checkout and launch of the Space Shuttle.

CONCEPT DEVELOPMENT

In March, 1973, a civil service team was formed at KSC under the Design Engineering Directorate to develop the Launch Processing System (LPS) concept and to provide the systems engineering and integration required to implement the system. By October, 1973, the "LPS Concept Description Document" was released which described an integrated checkout and launch facility capable of controlling the Ground Support Equipment (GSE) and Orbiter thru consoles and interfaces using a distributed processing scheme. The LPS involved two major elements; the Central Data Subsystems (CDS) and the Checkout, Control and Monitor Subsystems (CCMS). The Central Data Subsystem (CDS) would provide:

- o Real time data recording and recall
- o Engineering technical file
- o Work authorization and control
- o Pre/post test data analysis
- o Support software and application program library for the LPS checkout system
- o Simulation for software validation and operator training

The Checkout, Control and Monitor Subsystem (CCMS) involved a modular component, or building block, concept which allowed LPS components to be specified at an early date and then configured in various ways to accommodate the evolving Shuttle program requirements and the different levels of complexity. **Figure 1** depicted the LPS launch support configuration which involved the use of the following modular components:

o Consoles for command and monitor of subsystem functions within an assigned discipline, such as LOX, LH2, GN&C, ECS, Payloads
o Hardware Interface Modules (HIMs) for interfacing with Ground Support Equipment (GSE), such as LOX, LH2, Hazardous Gas Detection, Tail Service Masts
o Front End Processors (FEPs) for receiving data in the LCC and producing a compact computer process oriented measurement list and storing the preprocessed data in the CDBFR
o Common Data Buffer (CDBFR) for providing shared memory for all system data and interconnecting all distributive processors required to transfer data, commands and computer to computer messages
o Processed Data Recorder and Stored Peripheral Area (PDR/SPA) where raw/processed data and commands are logged for near real time or post test analysis
o Timing subsystem, where countdown and real time clock times are generated and controlled

Other configurations envisioned in the concept document included the following:

- o Maintenance and checkout area
- o ET and SRB "Free Standing" areas

The Application Programs executed in the consoles would be written in a higher order engineering language referred to as GOAL (Ground Oriented Aerospace Language). These programs would provide the required test/operations sequencing, command/control, systems monitoring, displays, interlocks as defined by the test engineers, and hardware constraints. The programs would be written by the user/operator of the particular subsystem being monitored and controlled by the CCMS. The programs would be compiled on the CDS for execution of the subsystem console by the user/operator. The various subsystems could be operated in parallel but independently of each other.

The LPS concept description document was used very successfully by the design team to conduct overall concept design review meetings with users at KSC and with MSFC and JSC personnel. In parallel to these reviews, the design team generated in April, 1974, the LPS Station Set Requirements Document which identified all Shuttle Level II programs and other functional requirements levied upon the LPS.

CONCEPT IMPLEMENTATION

The contractual implementation approach involved the use of four major contracts: (1) System Engineering and Software Development; (2) Minicomputers; (3) CCMS Hardware using GFE'd minicomputers; and (4) Central Data Subsystem Hardware and Software. The phasing of these contracts is shown in **Figure 2**.

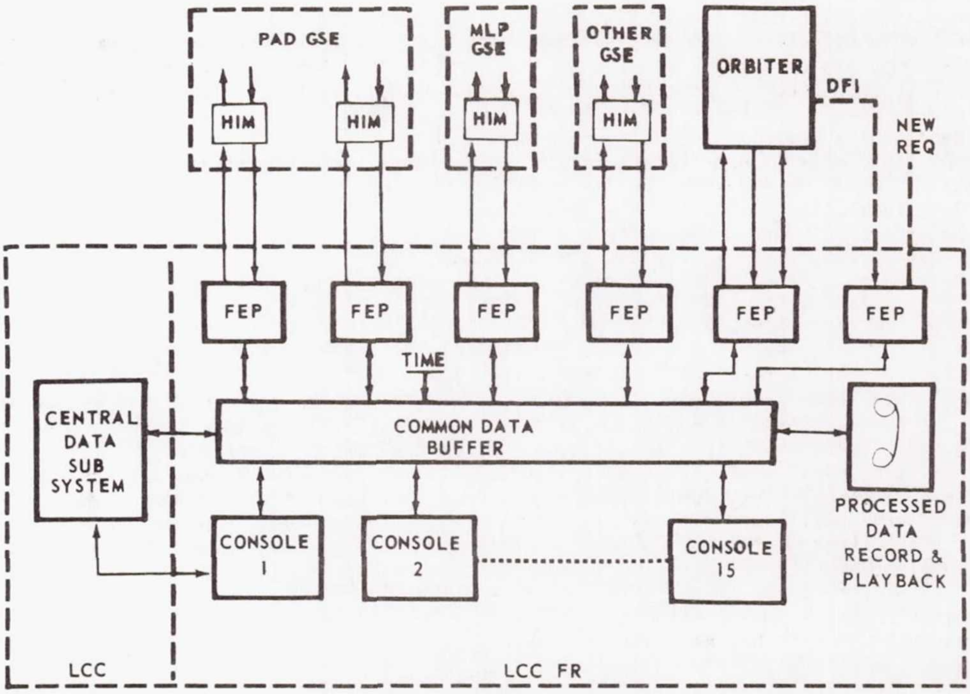

Figure 1.- Launch Support Configuration (Circa 1973).

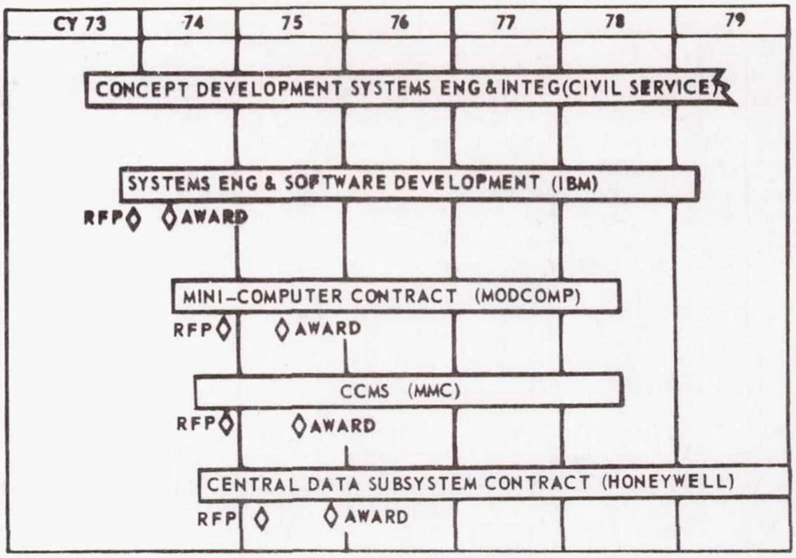

Figure 2.- LPS Contracts.

SYSTEM ENGINEERING AND SOFTWARE DEVELOPMENT

In May, 1974, IBM was selected by NASA to provide the System Engineering and Software Development for the LPS This selection, prior to hardware and computer procurement, allowed a total system design to be put in place for the LPS as contrasted to previous programs where the hardware was selected first and the software was then required to fit a "committed-to" system architectural design. Numerous trade studies were conducted by the government/contractor team to determine the allocations of processing functions. The results of these studies were tested and simulated to predict the effectiveness and performance of each key decision. In parallel to this activity, NASA was performing in-house component design and prototyping of key hardware elements. These included such critical areas as the Common Data Buffers (CDBFR); man-machine interfaces involving keyboards, color CRT's, programmable function panels, hard copy devices, safing panels; data acquisition, transmission and sensors; and distributed computer systems. The CCMS Systems Engineering review and prototype development culminated in selection of a distributive minicomputer network architecture which would support up to 64 minicomputers or microprocessors to share a common 64K-word, high-speed pipeline memory to communicate with each other. These computers perform basically the following functions:

(1) Man-machine interfaces at a console work station.
(2) Interface with Ground Support Equipment to insure commands and monitor and limit check measurements.
(3) Interface with the Orbiter on-board computers via the Launch Data Bus
(4) Interface with the Orbiter command uplink subsystem.
(5) Record transactions in the 64K shared memory.
(6) Provide the capability to retrieve, format and print these prerecorded transactions.

CCMS HARDWARE

In June, 1975, Modular Computer, Inc. was selected to provide commercial mini-computers (MODCOMP 11/45) for the operational systems. In August, 1975, Martin Marietta Corp. (MMC) was selected to provide the design, fabrication, test and installation of the CCMS hardware. By November, 1976 (fifteen months later), the initial set of hardware, "Serial-0", was delivered to KSC to support the operational software development by IBM. By February, 1977, a subset of CCMS hardware and operating software was made available to the system users/operators to support their application program software development using the higher-order language Ground Oriented Aerospace Language (GOAL). Other CCMS sets initially implemented included the following locations:

- o Shuttle Avionics Integration Labs at JSC
- o Hypergolic Maintenance Facility at KSC
- o Launch Control Center Firing Rooms 1 & 2 at KSC
- o KSC's Complex Control Center

CDS HARDWARE AND SOFTWARE

Proceeding in parallel with the CCMS procurement and delivery activities, the fourth major LPS contract was awarded to Honeywell, Inc. for the Central Data Subsystem computers and software support. The initial phase of CDS hardware was delivered in early 1976 and installed in the Launch Control Center. The basic configuration involved two dual 66/80 Honeywell CPU's sharing a megaword of memory. These computers were interfaced to the following primary hardware subsystems:

- o Real-Time Interface (RTIF) used to format CCMS CDBFR data for real time recording on CDS
- o Video Simulation Interface (VSI) used to simulate data into the CCMS in support of CDS modeling of ground and on-board systems
- o Communication Processors for interfacing with CCMS consoles and engineering terminals LPS Application Programs

LPS APPLICATION PROGRAMS

The development of the software required to automate the processes, control mechanisms and testing procedures for checkout and launch of the STS involved the many users of LPS. Each user was responsible for creating, modifying and controlling his software, which included the application programs, test display skeletons, control logic sequences, and Test Control Supervisor (TCS) sequence procedures. The following represents the number of procedures and computer size words used by the user for vehicle and ground test:

User Software	# Procedures	Total Word Size
GOAL Programs	1381	14,230,272
Display Skeletons	563	608,040
Control Logic Sequences	220	13,170
Test Control Supervisors	51	56,890

EVOLVING REQUIREMENTS

From the time that the initial set of hardware was delivered until the launch of STS-1, numerous changes occurred which could have impacted the LPS Operational Readiness Date (ORD) if it had not been for the flexibility and modularity of the system hardware and software architecture. Some of the primary changes were:

- o Growth in vehicle and ground support equipment parameters from initial 1972 estimated of ~14,000 OFI/DFI measurements to 41,000
- o Bulk Memory addition to the consoles
- o TCS Compiler/Loader (GOAL On Board IF)
- o Safing & Biomedical System
- o Monitor Consoles in support Firing Room
- o Huntsville Operating Support Center (HOSC) Interface to MSFC
- o FEP Expansion to handle PCM/GPC formats
- o Orbiter Computational Facility for processing Mass Memory Load Tapes
- o Processing of Non-Standard Data Types
- o Real Time Diagnostics

The Firing Room LPS configuration which supported the launch of STS-1 consisted of 41 minicomputers and 4 microprocessors actively communicating through the Common Data Buffer. An additional 8 CPU's in FR2 were actively connected to the same CDBFR in a data monitoring, engineering support role. The 1973 LPS concept depicted in **Figure 1** had become a reality.

REALITY

The Launch Processing System successfully supported the checkout and launch of the first reusable Space Transportation System in April, 1981. Since this was the first launch, the NASA/IBM engineering team performed post processing analysis of the data processed by the CCMS FR #1 computers during terminal countdown to evaluate system performance. Areas measured included the following:

- o Processed Data Recorders (PDR) FIFO/Logging activity as a measure of computer communication activity across/through the Common Data Buffer (CDBFR). (Excessive logging could result in loss of recorded data)
- o Computer-to-computer (C-C) activity

The PDR FIFO/Logging rate to disk and tape for STS-1 experienced 31K-word pairs in one second during the terminal count against a design limit of 33K-word pair per second. Prior to STS-2, CCMS S/W modifications were incorporated which raised the loss-of-data rate to 58K-word pairs of logging. **Figure 3** provides the highest logging rates and the tape switchover rate for STS-1 thru STS-6.

The maximum number of computer-to-computer (C-C) transactions per second which the CCMS could handle across the CDBFR was determined prior to STS-1 to be 670. This number represented the maximum system load before loss of logged data occurs. **Figure 4** depicts the maximum C-C's per second encountered during STS-1, 2, 3, and 6 terminal counts.

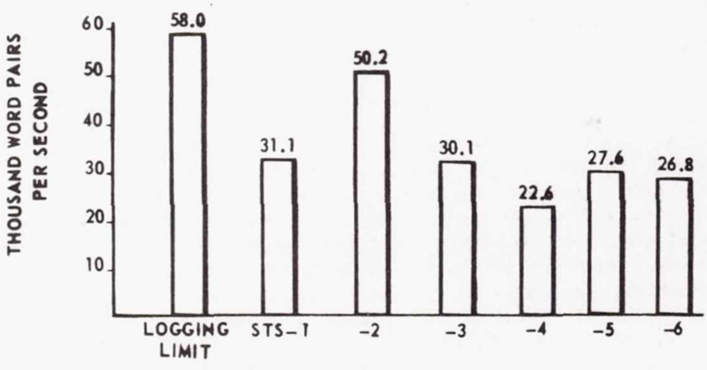

Figure 3.- PDR Logging Rates (Maximum) During STS Terminal Count.

Since the launch of STS-1, a significant number of changes have been incorporated in LPS due to vehicle and/or ground changes. Examples of these are listed below. The changes were implemented without impacting the system architecture which again demonstrated the flexibility and modularity of the hardware and software elements.

- o Console Memory Margins Requiring GOAL Rewrite
- o DOD Payload Security
- o Launch Data Bus FEP

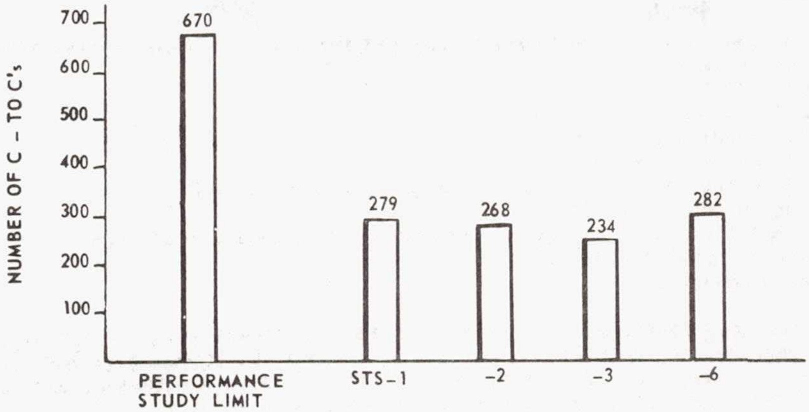

Figure 4.- Maximum C-to-C in a Second During STS Terminal Count.

- o Application Program Growth Affect Disk Sizing
- o Payload FEP addition
- o Data Bank Restructure
- o Engineering Support Assembly Data Display Rates
- o Format changes affecting FEP memory sizing

OPERATIONAL ASSESSMENT

In January, 1981, KSC initiated a 9-month study which addressed the required performance of all LPS elements during the Shuttle operational era. An indepth analysis of all off-line and on-line LPS processes required to support vehicle testing, checkout, launch and landing was conducted. Significant recommendations which are resulting in system changes today are as follows:

- o Restructure Data Bank to make it less sensitive to vehicle changes or mission-to-mission changes
- o Restructure Test Configured Identification (TCID) Build and Load processes to allow easier changes and on-line mods
- o Enhance software build processes to improve quality and documentation of outputs
- o Add equipment which allows Firing Room Sets to be split to perform multiple tasks
- o Add capability to conduct STS element (off-line) tests from the Software Production Facility (FR2) to off-load FR1 & 3 integrated tests and launch activities
- o Enhance O&M functions to reduce system down-time and reconfiguration times

As the Space Transportation System moves into its operational phase, KSC has reviewed the LPS for any potential hardware areas which could affect system performance. This review has included available memory margins, maintainability/spares availability, etc. Two areas are currently under review; the first, memory margins in the console minicomputers and second, the repair problems associated with the console 128K extended bulk memory. The console CPU main memory is limited by design to only 64K words with only 100 unused words (<1%). One major software upgrade to the GOAL executive has been performed which yielded 1300 additional locations. Subsequent changes have reduced the margin to the current figure and another software modification to reclaim additional memory is not advised. To offset the potential risk of exceeding current CPU capacity, KSC has developed an emulator (with up to 2M words of executable main memory) which can replace a Modcomp 11/45 and its associated bulk memory in any console configuration and support all required functions without requiring all CPU's in a particular set to be upgraded at the same time. With the availability of this capability in October, 1984, the Launch Processing System will be capable of supporting the Space Transportation System well into the 1990's.

OPERATIONAL SYSTEMS

Today, twelve LPS systems are operational with two additional planned for the future. The sets are located not only at KSC but also on the Eastern Test Range (ETR) in support of DOD payload processing, at JSC in support of Orbiter avionics to ground interface testing, and at Vandenberg Air Force Base in support of Shuttle and DOD payload testing, checkout and launch from the West Coast. Capabilities are being added which allow data communcation between individual CCMS sets, such as a

VAFB set and a KSC Firing Room set. The CCMS sets have been optimized for the functions which they are required to support. The distributive minicomputers and microprocessors connected to a CDBFR vary from two in the Air Force's Orbiter Functional Simulator to as many as forty-five in a full-up Firing Room. The operational software is modular and can support all CCMS sets without requiring individual releases.

SUMMARY

Through the dedicated and competent efforts of a NASA civil service and contractor team, the Launch Processing System has been brought from concept to operational support. The Launch Processing System is a very integral and key element of the Space Transportation System. LPS is supporting the Shuttle processing very successfully and shall continue in its support role as processing timelines are reduced to achieve the Shuttle Operational Era goals. It's demonstrated flexibility and modularity will allow it to continue to be adapted to unforeseen and changing program requirements. As we move toward the future, the distributive computer architecture employed in LPS will serve as a cornerstone for evaluating other systems as they are conceived and become a reality.

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