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August 22, 1990

To: *Dennis Webb / DE*
From: M.R.Loree
Subject: MCC Development History

Enclosed is my attempt to document the MCC development history. I compiled this white paper over the last month and hope you enjoy reading it as much as I enjoyed writing it.

Regards,

Ray Loree



MCC DEVELOPMENT HISTORY

AUGUST 1990

Compiled by Ray Loree

The following summary of the engineering history of the MCC was taken primarily from conversations and review comments from NASA and contractor co-workers. Also, extractions were taken from an article titled "The Evolution of the Mission Control Center" by Mike Kearney published in the Proceedings of the IEEE, Volume 75, No. 3, March 1987, and from the FAC Administrative Plan, Attachment F, dated January 10, 1986.

MCC DEVELOPMENT HISTORY

Introduction

The Mission Operations Wing (MOW) of building 30 was built by the Corps of Engineers and a general contractor, ETS-Holken-Galvin. The building ground (electrical ground) was established during construction by connecting the 48 pilings (8 x 6 rectangle with the pilings spaced on 28 foot centers) with heavy copper wire in a large checkerboard pattern before the slab was poured. Radials from the perimeter of this large copper matrix were later connected to the system ground. The system ground or technical ground (used for all computers and subsystems) was made up of several zones of aluminum bars (3/8" x 2) set up on each floor. This bar is mounted under the access floor on block insulator standoffs separating the technical ground from the building ground. Heavy copper runners (4/0) ran from the individual zones to a single ground bar (counterpoise) in room 127A. This bar is commonly called the golden spike. Two 4/0 copper conductors extends from this bar to a solid copper wire buried three feet below the ground and five feet away from the building and stretches around the building perimeter and over to building 48 thereby creating a common ground between the two buildings. Ten foot ground rods are sunk along this wire and connected to it. The building ground radials are attached to this system ground perimeter wire.

The electrical power for the MOW is supplied by building 48 on five buses: A1, A2, B1, B2 and C. The A1 and A2 buses (critical power) are fed from building 48 by motor generators which in turn are powered by either of two commercial substations. The commercial substation sources are backed up by three 1360 kw diesel generators in building 48. The A1 and A2 motor generators are backed by three 350 kw diesel generators making the power for these critical buses very reliable. All critical strings of MCC equipment are driven by the A1 and A2 buses. The B1 and B2 sources is supplied directly from the commercial substations which are backed by the same three 1360 kw diesel generators mentioned above. The 'B' buses drive non-critical system and the air conditioning. Non-redundant commercial power feds the C bus. The MOW when completed had a total of 112,896 square feet. The building was opened for occupancy in July 1964.

Two development contractors (IBM and Philco-Ford) were already working on the MCC systems to go in the new building. In 1962 IBM was awarded the MCC RTCC (Real Time Computer Complex) Contract to do the computers and application programming in the RTCC. In 1963 Philco-Ford WDL (Western Development Laboratories) was awarded a NASA contract for the design, development, implementation, maintenance and operation of the MCC-H (Mission Control Center-Houston). The implementation of this contract required that WDL establish the Philco-Ford Houston Operation (PHO).

MCC Functions

Over the years the MCC has evolved into set of functions grouped into three major systems: the Communications Interface System (CIS), the Data Computation Complex (DCC), and the Display and Control System (DCS). The CIS provides internal communications and connects the MCC systems to the facilities that supply spacecraft communications, primarily NASA Communications (NASCOM) network and the mission simulator. The DCC provides the mainframe computational and display processing and the DCS provides the human interface.

Gemini (MCC Development 1962-66)

The communications system elements consisted of a UNIVAC 490 (the Communications Processor), a Lockheed PCM-102 Ground Station, and some custom hardware called the Master Digital Command System (MDCS). The Gemini Launch Data System (GLDS) at the launch site collected data from the 2.0 kbps lines from the ETR (Eastern Test Range) as well as its own data and sent telemetry to the MCC at 40.8 kbits/s where the PCM Ground Station did the frame sync and decommutation functions. Corpus Christi and Bermuda were the other sites with 2.0 kbps lines for telemetry and commands. The PCM Ground Station drove strip chart recorders, meters on the consoles, and sent the telemetry to the Comm Processor via a special built device built by Philco-Ford called a buffer formatter. The Comm Processor also accepted remote site summary messages (several 100-word/min teletype circuits) and trajectory (2 kbits/s) from the long-line interfaces, and formatted the input data for routing to the Realtime Computer Complex (RTCC). The MDCS accepted command inputs from the operator's consoles and formatted and encoded the commands for shipment to the Comm Processor which routed them across on 2 kbps circuits to CCAFS (Cape Canaveral Air Force Station), Corpus Christi, or the ETR (Eastern Test Range) sites for uplink to the Gemini spacecraft. The other remote sites (called remoted sites) stored their commands and TTY instructions were issued by the MCC as to which stored command to uplink. Also biomedical data was received from the sites from FM/FM lines in FM/FM ground stations which in turn routed the data to strip chart recorders. Additionally, during simulations the Comm Processor would present data from the simulation complex to the rest of the MCC system as if it were real-time data.

Even considering that there were reduced performance requirements in those days, the 490s performed with amazing efficiency. They had 128 kbytes of memory (30-bit words) and 880 Kbyte of flying head drum storage. Their functions would later be performed by a multitude of other processors and custom hardware.

The mainframe processors consisted of five IBM 7094s utilizing customized IBM operating system within the Real Time Computer Complex. The machine which was running the

Mission Operations Computer (MOC) software would process the data from the Comm Processor and perform the telemetry, trajectory, and command functions. A concept of a Dynamic Standby Computer was established. The DSC would process the same inputs with the same software, but the outputs were not used. The operators would compare the results of processes from the two machines (MOC and DSC) to insure that they were synchronized. When the DSC diverged from the MOC due to imperfectly synchronized inputs, they would be resynchronized. Should the MOC fail, the DSC would be brought on-line to become a new MOC within seconds. Using the processing results, the MOC would build display descriptions in a graphics language for transmission to the Display and Control System (DCS).

The DCS element which created video displays and presented them to the operator was the Digital-to-Television (D/TV) subsystem. The MOC data was shipped to the D/TV subsystem across a channel buffer. The D/TV subsystem then used the MOC data to produce 48 channels of displays. The background data consisted of static display elements which were determined pre-mission and did not change with the telemetry processing. They were composed on 35-mm photographic slide film and projected into an optical assembly within the display system. The foreground data elements were the dynamic results of the MOC processing. They would be fed to a Stromberg-Carlson Character Cathode Ray Tube (CRT) device which produced a character/vector display. The Character device used the digital data from the host channel buffer to draw a vector or to select a mask (a stencil in the shape of an alphanumeric character) which was placed between the CRT's electron stream and the phosphor surface. This would produce the video image of that vector or alphanumeric character on the screen. The location of the character on the screen was controlled by the CRT's X-Y deflection coils. The image from the CRT display was optically mixed with the background image from the matching 35-mm photographic slide which automatically selected by an electro-mechanical slide file retrieval system. Partial optical reflection within this assembly allowed a 945-line video camera to view both the static background on the 35-mm slide and the active foreground on the Character CRT. The output of that video camera became the pseudo-digital image of an MCC data display. The black-and-white video was then sent to the Video Switch Matrix to be distributed to the console CRTs. The Video Switch Matrix also distributed NTSC-standard 525-line video (for example, spacecraft video) to the other CRTs throughout the building.

The display subsystem also drove discrete event lights on the consoles and detected operator inputs from push buttons on the console panels. The host data from a Subchannel Data Distributor would feed the Digital Display Driver (DDD) equipment, which in turn drove the 28 volt lamps on the console for indicators, warning, and alarms. Before every mission, the wiring on a hardwired distribution frame

called the CTC (Crossconnect Termination Cabinets) would be reconfigured so that the operators's indicator lights and the push button inputs would take on different meanings based on the changing operations scenarios and the revisions to flight software. Even at this earliest stage of the system evolution, the MCC had to accommodate flight-to-flight reconfiguration of the operator interface as operators gained experience with flight planning and control. The delays associated with these hardwired reconfiguration changes were later to be one of the driving factors in the upgrade to reduce reconfiguration times and maintenance costs.

The Projector Plotter Display (PPD) Equipment is the subsystem which (then and now) produces the large-screen display of the spacecraft position and groundtrack on the world map as well as other launch and landing graphics (energy plots, for example). The same basic system still supports the Space Shuttle program. The PPD receives data from the MOC trajectory processor via a Subchannel Data Distributor, similar to the one which feeds the DDDs. There are 2 PPDs in the MCC (one for each Mission Operation Control Room), each one consisting of seven projectors; one background projector, two spotting projectors, and four scribes. The background projector places the static world map on the screen from a 1-inch square slide. The spotting projector places a symbol from a slide (a symbol representing a spacecraft or target) on the screen, and moves it based on the vehicle's trajectory information as received from the MOC. Under control of the MOC, the scribing projectors use diamond-tipped styli to scratch through a metalized coating on a glass slide (an alphanumeric symbol or an X-Y plot, for example). These scratches allow light to be projected on the screen using 2500 watt xenon lamps and color filters. Usually, several slides are superimposed to make a complete display, requiring critical alignment of the equipment.

Other MCC-unique systems were developed in this timeframe, including the video hardcopy system. If a user needs a printout of his 945-line video display, he presses a hardcopy request button which is associated with a particular CRT on his console. This request is accepted with other operators' requests, and then activates a camera which takes a 35-mm film image of the same video channel that the requesting operator is viewing. The film is automatically processed, printed on paper, and dried in 15 to 20 seconds. The hardcopy equipment operator then places the print into the Pneumatic Tube (P-tube) system and the canister delivers the processed print to the console operator. One automatic function of the video hardcopy system is that if a mission is aborted the system rapid fire hardcopies of 40 specific console monitors. This hardcopying is triggered by any of abort command request toggle switches on either of two designated consoles. These console monitors are selected prior to the mission from the many operator consoles which are in service.

Along with the grounding system, power system, the Voice Intercom Subsystem, the PPD, the Video Hardcopy, SCRs, and

the Pneumatic Tube systems are major Gemini era systems which remain in service in the MCC today. During this timeframe many of the "computer operators" (Computer Sup, Dynamics, Track, etc.) were housed in a glass area in the center of the first floor.

During the Gemini era, part of the simulation task was supported in the MCC. GSCATS (Gemini Simulation, Checkout and Test System) was located on the second floor and was used to train remote site flight controllers. Before the remote sites had adequate data communications capability with the MCC, flight controllers were sent to the sites from JSC. Some of the second floor rooms were set up like remote site control rooms to train the remote site flight control teams. The consoles in the simulated remote site control rooms were driven by data from a combination of custom hardware, Lockheed 102 telemetry ground stations, and a commercial/military computer. A UNIVAC 1218 military computer was first used and later upgraded to a UNIVAC 418 commercial computer. Display hardware on the consoles included analog meters, CRT's and event lights.

In March 1965 the MCC-H monitored the Gemini III mission with primary control responsibility resting with the Mission Control Center at Cape Kennedy (MCC-K). Although not all systems were completely tested and operational, the MCC-H came on line in such a manner as to convince NASA that it could control Gemini IV.

In June 1965 PHO, along with NASA and IBM manned the MCC-H to control the Gemini IV with MCC-K as backup. With a successful control of Gemini IV the MCC-H was declared operational and MCC-K was deactivated. The "H" was dropped from the name and Houston became the control center for all manned space flights. While Gemini was being controlled from the third floor, work continued to make the second floor ready to control the Apollo-Saturn 200 missions.

A summary of the Gemini mission supported by the MCC (third floor) follows:

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|---|--|
| <u>Gemini 3</u>
(23 March
1965) | Grissom/Young 3 revolution flight. Control exercised from MCC-K with MCC-H monitoring data and communications. |
| <u>Gemini 4</u>
(3-7 June
1965) | MCC-H assumed prime control responsibility for the 4-day McDivitt/White flight. MCC-H proved that it was operational. The first U.S. EVA was performed on this flight. |
| <u>Gemini 5</u>
(21-29 Aug.
1965) | MCC control of the 8 day Cooper/Conrad flight. |

- Gemini 7
(4-18 Dec.
1965) The Bormann/Lovell 2-week flight which was the target for the first rendezvous (with Gemini Third floor control rooms used for both flights.
- Gemini 6
(15-16 Dec.
1965) The Schirra/Stafford 26 hour flight which accomplished the first space rendezvous (with Gemini 7).
- Gemini 8
(16 Mar.
1966) Armstrong/Scott 7-revolution flight, with first Agena docking; aborted because of failure in Orbital Attitude Maneuvering System.
- Gemini 9
(3-6 June
1966) Stafford/ Cernan 3 day flight, establishing a new EVA record of over 2 hours.
- Gemini 10
(18-21 July
1966) Young/Collins 3 day flight, dual rendezvous with Agenas 8 & 10; two EVAs.
- Gemini 11
(12-15 Sept.
1966) Conrad/Gordon 3-day flight, with 2 EVAs.
- Gemini 12
(11-15 Sept.
1966) Lovell/Aldrin 4-day flight, Completed MCC support of Gemini program. Reconfiguration began to support the Apollo 500 series on the first and third floor.

Apollo (MCC Development 1966-69)

During the Apollo project, the CIS Comm Processor's were upgraded from Univac 490s to 494s. The extra processing power allowed the 494s to perform some of the PCM Ground Station functions and all of the MDCS functions and the new merged system was called the Communication, Command and Telemetry Subsystem (CCATS). The CCATS in the MCC provided the capability of simultaneously performing the functions of digital communication data handling, telemetry data decommutation and distribution and digital command initiation, verification and control. The nucleus of CCATS consisted of three Univac 494 computers. Only television and voice data bypassed CCATS into and out of the MCC. A console called Telemetry Instrumentation Control Console controlled the telemetry flow into and out of CCATS. Possible telemetry input data sources included: ALDS, MILA, Grand Bahama, Antigua, Bermuda, Ascension, Canary Islands, Madrid, Canarvon, Canberra, Guam, Hawaii, Goldstone, Gyamus, Corpus Christi, and the ships Vanguard, Mercury, and the Redstone. Output could include: RTCC (SIB/SIC, SII, IU/S4B, CSM, CMC, LM, LGC, and AGS buffers), PCMGS, and MSFN site telemetry data back to KSC. The PCMGS routed data thru DACS and then via multiple patchboards (configured premission) to the correct SCRs.

Similarly, the DCC processing systems outgrew the IBM 7094s and they were replaced by five model 360/75s. The idea of using a Dynamic Standby Computer which shadowed every operation of the MOC was carried over from the Gemini design. The operating system (OS) of the 360s was modified to support the performance needs of the MCC, and the new OS was dubbed the Realtime Operating System (RTOS) later followed by the Extended Operating System (EOS).

The increasing performance needs were partially due to the increased complexity of the trajectory functions of a lunar mission, but there was also a change in the type of data which were being processed. There was an increased emphasis on mission planning and decision-making support. As the

Apollo support systems were being implemented in the MCC, the Apollo Simulation Checkout and Training System (ASCATS) was being implemented in building 422. This system consisted of a UNIVAC 494 computer, an IBM 360-75 computer, a set of remote site flight control consoles and intercom system, custom telemetry decommutation equipment, and data interfaces to the CSM simulators both at JSC and KSC and the MCC. Simulation software in the IBM 360-75 included math models of the Saturn boosters. After the need to send flight control teams to remote sites had been deleted due to improved data communications with the remote sites, the ASCATS system was relocated to the MCC second floor. This occurred around the Apollo 11 timeframe. The relocated system remained almost intact with the exception of the replicated remote site control room and the separate intercom system. The ASCATS system supported Apollo simulations throughout the Apollo,

Skylab and ASTP missions.

An ALSEP data system was developed in the MCC to support the lunar experiment package deployed by Apollo 12. An operational monitoring and control room was implemented in the MCC second floor utilizing standard consoles, displays and SCRs. The ALSEP data system used a 360-75 (on first deployments, a 360-50 was used) system to decommutate and display the data. Usually the data was taken directly off the two 56 kbps lines from GSFC through two different devices, an ICU (IBM) and a STRU (FAC) which provided the data to the 360. When CCATS was up to perform Apollo operations it also performed the communication functions and interfaced with the 360. The display system included drum recorders, SCRs, terminals, and a high speed printer. The staff support room was located in Room 314. This data system was independent of the MCC Apollo data system because of the requirement to monitor the data all the time not just when there was a flight. The ALSEP data system was deactivated in September 1977 after approximately 8 years of successful support of the five ALSEP packages. The ALSEP lunar transmitters of all five packages were left on as navigational aids for deep space programs. All MCC ALSEP equipment was deactivated.

A summary of the Apollo missions supported by the MCC follows:

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| <u>AS-201</u>
(26 Feb.
1966) | Unmanned, first flight of Saturn 1B and CSM: suborbital; first time for support from the MCC second floor. |
| <u>AS-203</u>
(5 July
1966) | The second unmanned Saturn 1B flight was to test the hydrogen tank. A boilerplate spacecraft was used. Second floor control. |
| <u>AS-202</u>
(25 Aug.
1966) | Third unmanned Saturn 1B with CSM for spacecraft performance study; suborbital; second floor control. |
| NOTE | |
| The AS-201, AS-202, and AS-203 flights were supported with the MCC's Gemini data system. | |
| <u>Apollo 4</u>
(9 Nov.
1966) | Initial flight of Saturn V (AS 501) with CSM and boilerplate LM. Control was from the second floor. This was the first flight CCATS systems were used. |
| <u>AS-205</u>
(27 Jan
1967) | Three astronauts were killed in an Apollo spacecraft fire during a pad test. (Grissom, White, Chaffee) |

- Apollo 5 (22 Jan. 1968) First flight of working LM aboard Saturn 1B (AS-204/LM-1). Unmanned; flight 2 plus days; controlled from the second floor.
- Apollo 6 (4 April 1968) Second flight of Saturn 5 (AS-502) with working CSM boilerplate LM; control from the third floor.
- Apollo 7 (11-22 Oct. 1968) First manned Apollo CSM flight and last use of the Saturn 1B until Skylab/ASTP. (AS-205, Schirra, Eisele, Cunningham). Second floor control.
- Apollo 8 (21-27 Dec. 1968) Second manned Apollo flight and first aboard the Saturn V; lunar fly by; operational LM not carried. This flight and the remaining Apollo flights were controlled from the third floor. (Borman, Lovell, Anders)
- Apollo 9 (3-13 Mar. 1969) First flight with manned LM and first active hard docking between LM and CSM. (McDivitt, Scott, Schweickart)
- Apollo 10 (18-26 May 1969) Lunar orbital mission with LM. Transfer from CSM to LM in lunar orbit and descent to 50,000 feet. Third floor control. (Stafford, Young, Cernan)
- Apollo 11 (16-24 July 1969) First manned lunar landing; EASEP deployed. Third floor used; upon successful completion, the second floor was ordered mothballed. (Armstrong, Aldrin, Collins). "The eagle has landed."
- Apollo 12 (14-24 Nov. 1969) Second lunar landing; ALSEP 1 deployed. no significant discrepancies in any equipment (Conrad, Gordon, Bean).
- Apollo 13 (11-17 Apr 1970) Mission aborted during translunar flight due to failure onboard. Safe landing in 6 days after using LM systems. (Lovell, Swigert, Haise). "Houston we have a problem."
- Apollo 14 (31 Jan-9 Feb. 1971) Fourth manned lunar exploration. ALSEP IV. Several changes to the CSM had been made due to Apollo 13 abort. (Shepard, Rossa, Mitchell)
- Apollo 15 (26 July-7 Aug 1971) First extended lunar exploration (with LRV, TV and extended life support systems) and extensive SIM bay experiments from lunar orbit. ALSEP 2 and P&FS 1. (Scott, Worden, Irwin).

Apollo 16 Second extended lunar exploration with LRV/LCRU.
(16-27 Apr. ALSEP 3 and P&FS 2. (Young, Duke, Mattingly).
1972)

Apollo 17 Last lunar exploration by Apollo program with
(7-19 Dec. LRU/LCRU & ALSEP 5. The first night launch.
1972) (Cernan, Schmitt, Evans)

Skylab/ASTP (MCC Development 1970-76)

The next major change in the MCC systems was replacing the D/TV system with the Digital Television Equipment (DTE). A prototype DTE system was installed in July 1970. The operational DTE system has supported Skylab, the Apollo-Soyuz Test Project, and Space Shuttle missions.

The interface from the MOC is a byte-serial adapter which drives display definitions across a bus to clusters of DTE. Originally, the system consisted of 10 clusters and each cluster could generate 8 channels of 945-line video displays. The clusters can be switched between the busses of different mainframes, depending on which mainframe is currently the MOC and on which phase of a mission is being supported. Launch, on-orbit operations, and landing phases each have different requirements for displays (and other functions) and the equipment is reallocated frequently. The data rate on each bus is 200 kbytes per second.

The user at a console who wants to request a display does so by selecting a display format number on a rotary switch called the Manual Select Keyboard (MSK). This MSK thumbwheel request is packaged by a Display Computer Input Multiplexer (DCIM) with requests from other users and sent to the host. The MOC retrieves predefined background text and ships the background information to DTE. The MOC calls up the display formatting record to determine the parameters (current results of processing) which will become the active foreground data to DTE once per second, along with the requesting user's identification so that the display subsystem can drive the video to the digital display description, which consists of character words and vector words (start location, direction, length). The use of this display language is a constraint from the D/TV days. It was a design requirement that the newer DTE system would support the same MOC display language as the D/TV Charactron system used because it was not desirable, for many reasons, to rewrite the MOC software just because we were making the transition to a newer hardware technology. This was a common tradeoff which constrained many newer systems to the performance limitations of older systems, and would later have an influence on the MCC Upgrade philosophy.

With these display definitions DTE builds a bit map of the screen (612 pixels per line X 439 lines) which is sent to a location in refresh memory for the DTE channel. There are two separate refresh memories, one for the static background, and one for the dynamic foreground. DTE performs a "logical or" to mix these two images. The video generator reads the pixel map at a video rate and adds composite video synchronization, creating a raster-scan 945-line video signal. The video signal is then routed to the Video Switch Matrix which sends it to the CRT on the requestor's console.

Besides the DCS changes other major changes included implementing a data compression system on the network and the necessary processing changes in the MCC to receive this

compressed telemetry data. A major MCC data storage subsystem was also added called the Mass Data Storage Facility. The MDSF consisted of two Control Data Corporation (CDC) computers, a Cyber 73 and a Cyber 74, a disc drive farm, and CIU. The Cybers were state of the art at that time as were the disc drives. The ICU's provided the interface between the IBM 360-75 selector channel and the Cyber I/O processors. IBM had a 32-bit word length and the Cyber had a 60-bit word length which required reformatting of the messages between the two. Data from the Skylab was processed and stored in the disc drives, processed and dumped to tape. It was also available on near real time reports thru a MDRS (MCC Data Retrieval System) application. It took almost two years to process all the stored data and distribute it. Upon completion, the Cybers were transferred to the Engineering Directorate for the Shuttle information extraction system. During Skylab telemetry data was received and processed to storage through the ADDT system at the rate of 1,785,714 parameters or 12,500,000 bytes of data per hour in the RTCC. At the termination of Skylab 4 on February 8, 1974, ADDT processed 10,178,571,428 parameters of telemetry data to storage for use in the MDRS system by Flight Controllers and scientists. This figures to be 71,250,000,000 bytes of data. 4,500 tapes were used to archive this data. MDRS operated some 776 unique displays which Flight Controllers and scientists used to view the data received by the ADDT system. MDRS serviced some 100 user transactions per hour and handled 670,000 requests for information. 10,000 special data tapes were generated using ADDT for scientists and Flight Controllers.

Several special purpose systems were delivered in this timeframe:

COM (Computer Output Microfilm) equipment-This equipment took computer output tape and converted it directly to a microfilm image. Primary components of the COM were two FR-80 systems. One system had standard COM cameras to produce 35 mm film and standard microfiche. The other system was customized to produce 5 inch color film products for the Earth Resources Aircraft Program (ERAP) and Earth Resources Experiment Program (EREP) projects. Film processors and duplicators were provided for the facility.

MOPS (Mission Operations Planning System) CRT terminal subsystem-This was the first MCC terminal system that was interactive with main frame applications.

Earth Resources Preprocessing Production (PPS)-The system accepted raw earth resources data via CCT obtained from ERAP aircraft and Skylab missions prior to use for data applications purposes. The system accepted various data formats and produced preprocessed data in CCT format for distribution to Principal Investigators (PI's) for final processing. The PPS equipment consisted of 2 DEC PDP 11/45 computer systems that were interfaced with 14 and 28 track instrumentation tape recorders via bit synchronizers and custom buffer hardware. Skylab post mission processing went

on in the MCC for years after Skylab 4 in special data systems like ERPDS (Earth Resources Production Data System).

SEDS (Screwworm Eradication Data System)- accepted NOAA-4 sensor data and used the Earth Resources PPS to process and format the data and output several film products that were used in predicting areas of potential screwworm habitation. MDRS/ADDT were used in this program.

Special video systems were developed for ASTP to standardize colors of Apollo/Soyuz broadcasts (VIRS-vertical interval reference signal). A system called a "digital video synchronizer" which allowed split screen displays between Apollo and MCC signals; and the "automatic color video compensator" which kept the colors between the four Apollo cameras uniform was implemented.

The MCC third floor MOCR and staff support rooms were deactivated after Apollo 17 and remained inactive until the start of Shuttle (May 1973 to April 1979).

A summary of the Skylab/ ASTP flights supported by the MCC (second floor) follow:

- Skylab 1/2 (May 14
22 June
1975) The first Skylab mission primarily oriented to conduct earth resources and biomedical experiments. A solar wing and the meteorite shield was lost. The other solar panel did not deploy. The remaining solar wing and temporary heat shield were manually deployed by astronauts.
First mission supported by MDSF, MOPS, DTE, and Earth resources PPS. The Skylab flights were controlled from the reactivated second floor (79 consoles, 319 cabinets of electronics, 60,000 feet of cable and 120,000 cross connects).
(Conrad Weitz, Kerwin)
- Skylab 3 (28 July-
25 Sept.
1973) Second Skylab mission primarily oriented to conduct earth resources and biomedical experiments. Temporary heat shield replaced.
(Bean, Garriot, Lousma)
- Skylab 4 (16 Nov-
8 Feb .
1974) Third Skylab mission conducted the following experiments: earth resources, biomedical, ATM, and corollary. EVA total on this flight was over 22 hours. Comet Kohoutec observations were made.
(Carr, Pogue, Gibson)
- ASTP (15-24
July
1975) First joint American/Russian earth orbital mission. An Apollo & Soyuz, after being launched from their separate countries, docked together in orbit. Visits were exchanged through a common docking adaptor and scientific experiments were conducted. Last use of the Apollo MCC ground systems. (Stafford, Slayton, Brand) (Leonov, Kubasov)

Skylab
Re-entry
(13 Jul
1979)

Skylab reentry was supported by the MCC with a small group of MOD/MSD personnel, with a special limited data system (PDP 11-45) and voiced commands to the sites.

Space Shuttle (MCC Development 1977-85)

A special ALTDS (Approach and Landing Test Data System) was developed for the upcoming ALT flights while the STS system was still under development. The ALTDS system consisted of a 9.6 kbps line from Edwards AFB to the MCC MDMs and through a special interface box to a UNIVAC 418. Displays were available through the DTE system. An early version of the TPC program was used as part of the software system. The third floor Gemini/Apollo era ROCR (Recovery Operation Control Room) was converted into the primary ALT operations support room. Standard consoles along with SCRs and X-Y plotboards were used to configure the room. The ALTDS was released from ALT support on Nov. 9, 1977. The data system components and floor space was reallocated.

The third floor MOCR and staff support rooms were deactivated between May 1973 and April 1979. In June 1979 all the old DCS equipment was removed from the third floor in preparation for the Shuttle program, Secure ops and the CONIS replacement. The CONIS (Console Interface Subsystem) project provided new console modules in a new layout for all 160 consoles required at this time in the MCC. The new modules interfaced thru a microprocessor housed in the console to Manchester encoded data buses. The buses interfaced with new DCIM, CCIM, and EDD cabinets all of which were placed on the third floor. A CTS (Console Test System) was also provided. This project started in 1977 and was completed in July, 1984. Also during this refurbishment, the second floor FCR consoles were removed and re-painted tan and returned and reinstalled in the room which now had tan carpets and wallpaper. When the new CONIS consoles were in place 85 racks of old interface cabinets were removed and the CTC cabinets were removed from walls of the hall on the second and third floor.

The Communications Interface Subsystem received some major new equipment to support the Space Shuttle program. The TDRSS Network Multiplexer-Demultiplexer system (TN-MDM or just MDM) came on line for STS-3 to set the stage for spacecraft communications in the TDRSS era (first TDRSS satellite was launched on STS-6). The MDM performs the selection of the Shuttle data from the NASCOM Network inputs, which may include data from non-Shuttle missions. It also performs error checking on the raw stream and other data quality monitoring functions. A solid-state matrix communications switch (297 inputs by 297 outputs) called the STS Data Select Switch (SDSS) which operates at data rates up to 16 Mbits/s was developed to handle the data routed by the MDM. The

Network Communications Interface Common (NCIC) also performs some demultiplexing, routing, and data quality monitoring functions. The NCIC routes the real time data to the NIP (Network Interface Processor), onboard recorder data to the DDHE (Dump Data Handling Equipment) and trajectory/radar/site status data directly to the DCC. The NIP is made up of the SKR (the Separator-KG-Recombiner), the NCIU (Network Communication Interface Unit) and the TPC

(Telemetry Processing Computer). The first device to receive data from the NCIC is the SKR. The SKR receives the block of data, separates the unencrypted header from the encrypted data, sends the encrypted data to a Key Generator (KG) subsystem for decryption, receives the decrypted data back from the KG, and recombines the data with the original header. The SKR forwards the blocks of data to the Network Communications Interface Unique (NCIU) which does some network header decommutation, frame-synchronizes the spacecraft data, and passes the data and some header information to the Telemetry Preprocessing Computer (TPC). The TPCs were Interdata 832 computer systems and have the template for the current downlink format (parameter locations within the block) and they identify and pass the data across an interface called the MBI (Multibus Interface) to the MOC. This effectively insulates the MOC from sensitivity to the current downlink format, which may change frequently from one mission phase to the next. Additionally, the onboard Payload Data Interleaver (PDI) places payload data in "windows" in the telemetry stream, and the TPC routes this burst traffic to the PDI Serializer. The PDI Serializer buffers these burst data and produces a serial stream which is sent back to the SDDS/MDM systems for delivery to the local and/or remote payload customers. The TPC also drives selected analog and events to the AED (Analog and Event Distribution) which then drives the strip chart recorders. The NCIC also routes onboard spacecraft recorded data (dump) to the (DDHE) Dump Data Handler Equipment system.

The DDH is a bank of disk drives which receives and processes the data dumped from the recorders on the spacecraft. The data may include segments which are out of sequence and/or reversed, because the recorder on-board may have been played in reverse. It corrects those time-ordering problems and creates a time-contiguous record of the telemetry. It stores up to 24 hours worth of the most recent data on disk for rapid time-ordered playback, rewriting over the oldest data when the disks are full. The time-ordered output of the DDH is transferred to magnetic tape for archival storage before the data is overwritten.

For the DCC in the Shuttle era, the IBM 360/75s were replaced with four 370/168s utilizing the MVS operating system. As described earlier, these computers perform many other functions in addition to the MOC and DSC functions. In 1983, the processing load for engineering analysis required the installation of an IBM 3081 with Multiple Virtual Storage/Extended Architecture (MVS/XA). The other processors in the facility perform software development, vehicle trend analysis, MCC system reconfiguration, mission planning, and many other functions. The IBM 3851 MSS (Mass Storage System) was installed as an alternative to disc drives. This system is still used for development. The remaining 360/75 were used to develop the Shuttle onboard software. FEID's (Flight Equipment Interface Device) were procured and installed in the DCC. A large disc farm was installed. This onboard

software was developed in this facility until 1979 and then moved to the "admin" wing of building 30. One 360-75 was kept until 1982 to back up the new facility called the SPF (Software Production Facility).

In the Display and control System, some new custom design work on the DTE functions produced a functional equivalent to the aging DTE components which would allow expansion. The new clusters are called Display Generation Equipment (DGE) and they boost the number of video displays of the Shuttle data on the consoles from 80 to 104 channels. Once again, the DGE was built to minimize the perturbation on the existing MOC and DTE hardware and software, so the new equipment still responds to the Charactron display language of the Gemini era D/TV equipment. The Voice Intercom Subsystem (VIS) has unique performance capabilities which were implemented for Gemini and the basic system still serves the Shuttle program.

Early in the STS program the DOD identified the need to support classified Shuttle operations in the MCC. In response to this need, implementation of a "control mode" (secure operations) was started in 1979. DAA certification was obtained in May 1983. The development included a secure CIS (MDM, SDSS, NIP, NOM, MBI, AED, PDSS, PDI, SKR, DDHE, etc.). A secure television system was established (VSM, VICI, etc.). The main frame computers could be color changed to support classified operations. The cable trays were separated into red, black and swing. The grounding system for the MCC was modified to support red, swing and black equipment. A subsystem called CMIS (Control and Monitoring Isolation Subsystem) was developed to switch between secure and non-secure ops. The "computer controller" support equipment was relocated to the third floor and in its place on the first floor the DSS (Data System Supervisor) position, the tape library, and the CEF (COMSEC Equipment Facility) was established. The OST (Operations Support Team) area was established on the third floor. Also at this time the CONIS project was completed. The MCC first and third floor were established as a PCZ and card readers were installed in the newly designed lobby which now had its own security office. A visitors center was added to the MOW so that tourists could go to the second floor VIP room to see part of the MCC.

Another major change to the MCC was the JSC POCC (Payload Operations Control Center) which was implemented during 1981-83 time frame to support Spacelab flights. The POCC was complete with it's own CIS, DCC, and DCS. The POCC CIS was made up of the WDDS (Wideband Data Distribution Subsystem), a HRDM (High Rate Demultiplexer), a PDSS (Payload Data Select Switch, the PDRE (POCC Data Recording Equipment) and the DAPS (Data Acquisition Preprocessing Subsystem). The WDDS routed incoming telemetry data to remote users, local users with their own equipment in the MOW, and to the DAPS. The DAPS was made up of 3 Interdata 832s which decommutated the Spacelab Computer data and formatted it for output to the DCC. The POCC portion of the DCC used one of the 370/168 to run a

special POC software program and also to communicate with the MOC which would be supporting an Orbiter and the critical Spacelab systems/interfaces. The DCC passed the data through a "concentrator" to up to 62 intelligent terminals. One of the innovative capabilities of the DCC was the ability of users to define their own computations by using COLD (Computation Offline Definition) application. Although fairly restrictive it did allow user some near real time comp definition capability. The POC function was later moved to MSFC, although some of the equipment remained active in the MCC to support the high rate data.

Additional changes to the MCC during this era included a timing systems upgrade from crystal oscillators to cesium standards. The weather computer (MIDDS) was installed over the lobby on the second floor. The MCC was designated as a National Historical Landmark by the Secretary of Interior on December 24, 1985.

A summary of the Shuttle flights from 1977-85 supported by the MCC follows:

<u>CA-1A</u> (18 Jun 1977)	First manned Captive-Active flight of the Shuttle and the carrier plane. (Haise, Fullerton) The MCC data system which supported this was a Univac 418 and Univac 1218 and used early versions of NIP software.
<u>CA-2A</u> (28 Jun 1977)	Second manned Captive-Active flight of the Shuttle and the carrier plane. (Engle, Truly)
<u>FF-1</u> (12 Aug 1977)	First free flight of the Orbiter (Haise, Fullerton)
<u>FF-2</u> (13 Sept 1977)	Second free flight of the Orbiter (Engle, Truly)
<u>FF-3</u> (23 Sept 1977)	Third free flight of the Orbiter (Haise, Fullerton)
<u>FF-4</u> (12 Oct 1977)	Fourth free flight of the Orbiter (Engle, Truly)
<u>FF-5</u> (26 Oct 1977)	Fifth free flight of Orbiter (Haise, Fullerton)

NOTE

The first STS-1 simulation was successfully supported in March, 1979, and pad pre-launch test

was successfully supported in Nov. 1979.

- STS-1
(12-14
Apr
1981) First orbital flight of the Space Shuttle launched from KSC. Landed at Edwards AFB, Calif. First use of the MCC OFT data system. (Young, Crippen) (FCR-1)
- STS-2
(12-14
Nov
1981) Second orbital flight of the Space Shuttle. Landed at Edwards AFB, Calif. (Engle, Truly) (FCR-1)
- STS-3
(22-30
Mar
1982) Third orbital flight of the Space Shuttle. Landed at Northrup Strip, White Sands, New Mexico. (Fullerton, Lousma) (FCR-1)
- STS-4
(27 Jun
4 Jul
1982) Fourth orbital flight of the Space Shuttle. Landed at Edwards AFB, Calif. (Hartsfield, Mattingly) (FCR-1)
- STS-5
(11-16
Nov
1982) Fifth orbital flight of the Space Shuttle. Landed at the Edwards AFB, Calif. First satellite launched from the Orbiter. (Brand, Overmyer, Lenoir, Allen) (FCR-2)
- STS-6
(4-9
April
1983) Sixth orbital flight of the Space Shuttle. Landed at Edwards AFB, Calif. A TDRS satellite was launched on this mission. (Weitz, Bobko, Peterson, Musgrave) (FCR-2)
- STS-7
(18-24
June
1983) Seventh orbital flight of the Space Shuttle with five crew members, including the first American woman, was completed with a successful landing at Edwards AFB, Calif. In addition to launching 2 communications satellites, the crew deployed a SPAS free flyer with the manipulator arm and obtained the first pictures of the Shuttle in orbit. (Crippen, Ride, Hauck, Fabian, and Thagard) (FCR-2)
- STS-8
(30 Aug.
-5 Sep
1983) Eighth orbital flight of the Space Shuttle with five crew members was completed with a successful landing at Edwards AFB, Calif. The mission marked the first night launch and landing. Satellite INSAT B was deployed, TDRS was tested, and the manipulator arm was tested with a 5000 pound test article. (Truly, Bluford, Brandenstein, Gardner, and Thornton) (FCR-2)

- STS-9
(28 Nov.
-8 Dec
1983) Ninth orbital flight of the Space Shuttle with six crew members was completed with a successful landing at Edwards AFB, Calif. This was the first Spacelab flight and the first use of the JSC POCC. The second floor payload support rooms were full to overflowing with scientists and their equipment from 11 European countries, Japan, Canada, and United States. Experiments were run 24 hours a day as the crew worked in shifts (3 people on 12 hours each). Approximately 720 billion bits of data was processed by the POCC and over 8,800 commands were issued during the flight. The POCC ground support team for the MCC was located in room 210. (Young, Shaw, Parker, Garriot, Lichtenberg and Merbold) (FCR-2)
- 41-B
(3-11
Feb
1984) Tenth orbital flight of the Space Shuttle with five crew members was completed with a successful landing at Kennedy Space Center landing site. Two satellites were deployed and the first untethered spacewalk using the Manned Maneuvering Unit (MMU) was demonstrated. (Gibson, McNair, Stewart, Brand, McCandless) (FCR-2)
- 41-C
(6-13
April
1984) Eleventh orbital flight of the Space Shuttle with five crew members was completed with a successful landing at Edwards AFB, Calif. The Long Duration Exposure Facility (LDEF) was deployed. The MAX SOLAR Max satellite was retrieved (using the RMS, repaired and redeployed. (Crippen, Scobee, Hart Nelson, and Van Hoften) (FCR-2)
- 41-D
(30 Aug
5 Sept
1984) Twelfth orbital flight of the Space Shuttle with six crew members was completed with a successful - landing at Edwards AFB, Calif. SYNCOM IV was deployed using the "frisbee" method, OAST-1 and Telestar were deployed. (Hartsfield, Coats, Resnik, Hawley, Mullane, and Walker) (FCR-1)
- 41-G
(5-13
Oct
1984) Thirteenth orbital flight of Space Shuttle with 7 crew members was completed with a successful landing at Kennedy Space Center landing site. The crew contained a Canadian and two women, one of which was the first American woman to walk in space. Payloads were ERBS, OAST-3, and CANEX. (Crippen, Ride, Sullivan, Leestma, Garneau, Scully-Power) (FCR-2)
- 51-A
(8-16
Nov
1984) Fourteenth orbital flight of Space Shuttle with five crew members was completed with a successful landing at Kennedy Space Center landing site. Retrieval and return of two satellites that had been in a useless orbit and Telsat H and Syncom IV-1 were deployed and placed in geosynchronous

orbit. (Allen, Fisher, Gardner, Hauck and Walker)
(FCR-1)

51-C
(24-27
Jan
1985) Fifteenth orbital flight of the Space Shuttle with five crew members was completed with a successful landing at Kennedy Space Center landing site. This was a DOD mission and all activities were classified. (Mattingly, Shriver, Onizuka, Buchli, and Payton) (FCR-2)

NOTE

This was the first use of the control mode hardware and software which allowed the MCC to support secure classified operations for DOD.

51-D
(12-19
April
1985) Sixteenth orbital flight of the Space Shuttle with seven crew members was completed with a successful landing at Kennedy Space Center landing site. Syncom IV, Tele Sat 1 and CFES satellites were deployed. U.S. Senator Garn was aboard. (Babko, Williams, Seddon, Hoffman, Griggs, Walker, Garn) (FCR-2)

51-B
(29 Apr
-6 May
1985) Seventeenth orbital flight of Space Shuttle with seven crew members was completed with a successful landing at Edwards AFB, Calif. This was the SL-3 flight and included experiments with 2 monkeys and 24 rats. (Overmyer, Gregory, Lind, Thagard, Thorton, Van den Berg, and Wang) (FCR-1)

51-G
(17-24
Jun
1985) Eighteenth orbital flight of Space Shuttle with seven crew members was completed with a successful landing at Edwards AFB, Calif. Morelos -A, Arabsat-A, and Telestar-3D were deployed. (Brandenstein, Creighton, Lucid, Fabian, Nagel, Baudry, and Al-Saud) (FCR-2)

51-F
(29 Jul
-6 Aug
1985) Nineteenth orbital flight of the Space Shuttle with seven crew members was completed with a successful landing at Edwards AFB, Calif. Spacelab 2 experiments were conducted. (Fullerton, Bridges, Musgrave, England, Heinze, Acton, Bartoe) (FCR-1)

51-I
(27 Aug
-3 Sep
1985) Twentieth orbital flight of the Space Shuttle with five crew members was completed with a successful landing at Edwards AFB, Calif. (Engle, Covey, Van Hoften, Lounge, Fisher) (FCR-2)

51-J
(3-7
Oct
1985) Twenty-first orbital flight of Space Shuttle with five crew members was completed with a successful landing at Kennedy Space Center, Fla landing site. This was a DOD mission and all activities were

classified. (Bobko, Grabe, Hilmers, Stewart, Pailles) (FCR-2)

61-A Twenty-second orbital flight of the Space Shuttle
(30 Oct with eight crew members was completed with a
-6 Nov successful landing at Edwards AFB, Calif. This was
1985) a dedicated Spacelab flight and was supported from
ESA's remote POCC in Germany. (Hartsfield, Nagel,
Buchli, Bluford, Dunbar, Furrer, Messerschmid,
Ockels) (FCR-1)

61-B Twenty-third orbital flight of the Space Shuttle
(26 Nov with seven crew members was completed with a
-3 Dec successful landing at Edwards AFB, Calif. (Shaw,
1985) O'Conner, Cleave, Spring, Ross, Vela, Walker)
(FCR-2)

Space Shuttle (MCC Development 1986-90)

The Shuttle development history has been broken into two periods: 1977-85 and 1985-90. This break point was selected because of the Challenger accident (January, 1986), which caused MOD/MSD management to put the MCCU development on hold to re-examine the budget and future plans. Also during this same time frame, the STSOC contract was awarded. STSOC/MOD was assigned the responsibility for the operations and maintenance of the MCC (rather than the development organization) which caused further re-planning of the MCCU.

As a result of this re-examination, the MOD/MSD management decided to continue with the first step in the MCCU (MCC upgrade) which involved replacing the main frames (10 years old) and the VIS (20 years old) and to stretch out the MCCU Step 2 schedule. (BACKGROUND: The MCC Upgrade project, previously called STARS (Staff Reduction Strategy) and ERRP (Equipment Replacement and Refurbishment Plan), originally started in 1983 as a project to address the replacement of obsolete equipment in the MCC. In parallel with this Flight Control organization was addressing the issues of corporate memory capture and real-time failure analysis tools. Concurrently, other organizational elements were addressing the issue of data system requirements for the evaluation of Shuttle in-flight system performance in order to support Shuttle turn-around requirements. As a result of these study activities an additional study was initiated in the summer of 1983 to evaluate the potential of changing the MCC architecture to a distributive data system in parallel with addressing the obsolescence problem to address all the above mentioned problems. This study resulted in a design concept and a ROM cost being presented to JSC and Headquarters during the FY84 POP budget cycle. The MCCU upgrade was approved as a project with budget starting in FY85. Step 1 called for the mainframe/VIS replacement and Step 2 called for replacing all the consoles (and console interface equipment) with workstations and LANs. An SDR was held in February of 1985. An MOA was signed with the DOD in August, 1985 which called for the DOD sharing in the cost of the upgrade so they could continue to fly classified flights from the MCC.)

In September 1986 part of the first step of the MCCU was completed. The five 370/168s were replaced by 4 new IBM 3083JXs. The first 3083JX was delivered in January of 1986 and the last one was delivered in September 1986. All the mainframe's data input/output devices (2909s) were also replaced at this time with the CICU-A/B. At the same time, MCCU software Delivery 1.2 was accepted by NASA from IBM. This was the first delivery of the software associated with the new computers (3083s). Capabilities included: MVS/XA Checkpoint/Restart, System selectover, IDA above the 16MB line, and applications executing in the MVS/XA environment. The final software delivery associated with this computer replacement, Delivery 1.3, was transitioned to STSOC in April 1987. Capabilities included: RTX retrofit, NRT retention

rehost, CIN connectivity, and NRT format automatic reconfiguration.

During the period from 1986 to 1988, MCCU Step 2 was re-planned and work began on the first delivery. In addition to this work several other noteworthy MCC events occurred. In September 1986 a three story annex to the MOW to store equipment was opened for business called the ESA (Equipment Support Area). In March 1987 the VAFB interface equipment established a secure wide band and black long line interface with the Vandenburg Shuttle launch site. The Air Force decided to shut the launch facility down in the middle of this work (11-86). The project was cleaned up and transitioned to the STSOC in March 1987. In April 1987 the CTE (Communications Test Equipment) was transitioned to STSOC. This equipment was designed to troubleshoot CIS problems and test CIS systems.

In August 1987 a water valve was broken off during a cable pull on the second floor. The second floor area above the MCC Data Computation Complex (DCC) was flooded. The water penetrated the ceiling of the first floor threatening the equipment in the DCC. The simulation in progress was cancelled, the equipment powered down and covered with plastic. A cut off valve was located and stopped the flooding. The building was operational the next morning. (The only time the MCC suffered a major system failure during a flight (more than a couple of minutes) was during STS-5. In November 1982 the A-1 power bus burned in half during STS-5. Some critical equipment (2909s, MDMs, etc.) were all on this bus. Flight controllers were left with voice only for about 1 hour until a workaround was in place.)

In September 1987 the MER was moved from building 45 to the third floor (over the lobby) in the MCC. It was modernized and expanded. The secure communications upgrade was transitioned to STSOC. This task provided secure voice communications between the MCC and other support centers. In October 1987 the CAS (Calibrated Ancillary System) was transitioned to STSOC from the development contractor. This system was built to support a GSFC requirement for calibrated Orbiter data in real time for use in conjunction with payload (PDIS data). The system used MC500s and a local area network and was one of two distributed system operational prototypes for the MCC Upgrade project. The other MCCU prototype was the MITS (MOD IPS TACAN System) which used Masscomp MC500 and gave the users access to trajectory data from the MOC (Mission Operations Computer) and NRT (Near Real Time) data via a LAN. (An early version of MITS was already on the floor when the STSOC transition occurred.)

The TFCR (Transitional Flight Control Room) was established in December 1987 in the MCC room 229. It consisted of prototype workstation housings, phase 1 of the FODS (Fiber Optic Distribution Subsystem) and newly selected MCCU workstations MC5600s (a blanket order was signed in 9-86 with C-3 and then changed to Masscomp in 6-88) connected to the MITS and CAS LANs. An MCCU prototype LAN using the ARTEL

100MBPS equipment was also set up. (During the CONIS project the electronic support cabinets associated with the old technology consoles were also replaced. This allowed removal of 85 old racks of equipment which were in the space that the TFCR occupied. Between 1984 and 1987 ROOM 229 was a maintenance area.) In March 1988 the channel switch FAR was held at this time transitioning the channel switches to the sustaining contractor STSOC. These ten new switches, connected the five new main frames to their peripherals, and provided the higher data rate capabilities that the new computers required plus better isolation.

The first installment of Step 2, Delivery 2.1 FAR was held at this time. Delivery 2.1 consisted of the first version of (WEX) workstation executive, some MITS LAN enhancements, a host based centralized configuration management (CM) program, DTE emulation at the workstation, minor updates to NRT and CCS/C, and user comps study/conversion. The host software except for the CM was transitioned to STSOC.

The first phase of DVIS, the VIS replacement, was set up in the TFCR in June, 1988 to test all aspects of the DVIS engineering. Thirteen keysets were installed on the consoles and paralleled into the VIS. The DVIS keysets were used in addition to the VIS keysets during operations. A formal review was then held and FAC was given the authority to proceed with phase 2. In April, 1989 Phase 1 equipment was removed and sent back to FAC for phase 2 implementation.

In September 1988 the PSS was transitioned to STSOC. This workstation based PNDD (Payload Network Data Driver) software accepted CAS LAN data (Orbiter) and PDIS data (payload), decoded, calibrated and output the data on a Ethernet LAN. Eight payload workstations received, unpacked, and displayed the data.

In October 1988 budget was approved to upgrade the FADS (Flight Analysis and Design Subsystem) which is primarily in the RSOC building, but which has some workstations in the MCC. Budget was also approved for the MPCC (Multi-program Control Center). This subsystem is to use MCCU technology and workstations, with a separate front end to process OMV data. The MPCC is to replace the PSS subsystem. The TSS (tethered satellite) is the first projected user. The MPCC included the capability to uplink payload commands either via the Orbiter or to an independent payload. The first delivery of the MPCC was tied in schedule to the MCCU Delivery 2.5 schedule.

In October 1988 the Delivery 2.3 hardware and the 2.3 host software were transitioned to STSOC. This delivery consisted of 33 workstations, the first implementation of the general purpose (GP) LAN (TFCR only), the first version of the real time (RT) LAN (TFCR workstations plus 9 operational workstations), a major installation of the fiber optic distribution system (FODS), a MITS upgrade, rehost of the SCAP (host and workstations), some CM enhancements, GDR enhancements, major WEX enhancements, the software in the workstation and host to support the LAN, and Data Driver

software to drive the real time LAN.

In July 1989 the final DGE FAR transitioned the last set of DGE equipment to STSOC. This was a reliability replacement of the nine digital television equipment (DTE) clusters with a like number of display generation equipment (DGE) clusters and was made necessary with the stretchout of Step 2. The first set of DGE was installed in April of 1984 as an expansion capability to the display system. In December 1989 the 10 by 20 foot center screens in the second floor FCR and in the third floor FCR were replaced. The new screens are 1/2 inch thick and weigh 2000 pounds each.

In January of 1990 the MSC contract (MCC and SSCC development) was signed by FAC and NASA. The MSC replaced the old FAC and IBM contracts which essentially had been in place since the start of the MCC. (The RTCC Contract for software/computer services had been re-competed as the Ground Based Software contract before Shuttle and IBM won it. The GBS contract ran from 1974 to 1990.) IBM signed a subcontract agreement with MSC (FAC) in June 1990.

In February 1990 the mainframe computers were upgraded to a dyadic capability as 3083KXs and transitioned to STSOC. This upgrade doubled the CPU (8 MIPS to 15.9 MIPS). A custom modification to the computers timing system was required. In

March the OMV project was cancelled. Later in the year it was decided to proceed with the MPCC to support other payloads like TSS, AFE, etc. Also in this timeframe, the DOD announced that it would not fly any more secure flights out of the MCC after STS-38. Planning for phase down of MCC secure ops capability has begun.

In May 1990 construction began on the Space Station Control Center building. RSOC was announced as the OSC (Operations, and sustaining engineering contractor for the SSCC and SSTF).

November 1990(E)

Delivery 2.5 was transitioned to STSOC. This delivery included: six non-secure LANs (two GP, 1 RT, 1 MPCC RT, 1 TFCR RT and 1 TFCR GP), two secure LANS (1 GP and 1 RT), two data drivers to drive the non-secure RT LAN or the TFCR RT LAN, 3 MPDDs to drive the MPCC RT LAN, another major extension of the FODS, 25 new workstations (total of operational workstations is now 65), the first delivery of the MPCC, an updated CM program, a workstation based network manager application, MED/PBI/event processing, enhanced LAN (GP and RT) support from the host including E-mail, checkout software, WEX enhancements, Display Builder/Manager and Comp Builder/Manager enhancements.

December 1990(E)

DVIS was transitioned to STSOC. The delivery included: two CPUs, seventeen racks of equipment and 454 keysets. As a late change, DVIS was modified to support only non-secure

operations. After all DVIS elements are installed, DVIS will replace the Gemini VIS in its entirety. Total replacement should be complete by early 1991.

A summary of the Shuttle missions supported by the MCC from 1986-90 follows:

<p><u>61-C</u> Columbia (12 Jan.-18 Jan. 1986)</p>	<p>The twenty-fourth Space Shuttle flight with a crew of seven was completed with a successful landing at Edwards AFB, CA. (Gibson, Bolden, Chang-Diaz, Hawley, G. Nelson, Cenker, and U.S. Congressman B. Nelson) (FCR-1)</p>
<p><u>51-L</u> Challenger January 28, 1986 ACCIDENT</p>	<p>The twenty-fifth Space Shuttle flight ended in disaster when the Orbiter, and the External Tank exploded at 1 minute and 13 seconds into the flight killing (D. Scobee, M. Smith, E. Onizuka, J. Resnick, R. McNair, C. McAuliffe, and G. Jarvis) (FCR-2)</p>
<p><u>STS-26</u> Discovery (29 Sept.-3 Oct. 1988) RETURN TO FLIGHT</p>	<p>The twenty-sixth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. TDRS-2 was deployed (Hauck, Covey, Lounge, Helmers, Nelson). (FCR-1)</p>
<p><u>STS-27</u> Atlantis (2 Dec.-6 Dec. 1988)</p>	<p>The twenty-seventh Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. This was a DOD mission and all activities were classified (Gibson, Gardner, Shepherd, Ross, Mullane). (FCR-2)</p>
<p><u>STS-29</u> Discovery (13 Mar.- 18 Mar. 1989)</p>	<p>The twenty-eighth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. TDRS-3 was deployed allowing almost complete communications coverage of Shuttle flights (Coats, Blaha, Bagian, Springer, Buchli). (FCR-1)</p>
<p><u>STS-30</u> Atlantis (4 May-8 May 1989)</p>	<p>The twenty-ninth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. Magellan probe was deployed to planet Venus (Walker, Grabe, Thagard, Cleave, Lee). (FCR-1)</p>

STS-28
Columbia
(8 Aug.-13 Aug. 1989)

The thirtieth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. This was a classified DOD flight and the first of Columbia in four years after an extensive upgrade (Shaw, Richards, Brown, Adamson, Leestma). (FCR-2)

STS-34
Atlantis
(18 Oct.-23 Oct. 1989)

The Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. The Galileo probe/orbiter to Jupiter via gravity assists past Venus and Earth (Williams, McCulley, Lucid, Baker, Chang-Diaz). (FCR-1)

STS-33
Discovery
(22 Nov.-27 Nov. 1989)

The Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. This was a classified DOD flight (Gregory, Blaha, Thornton, Musgrave, Carter). (FCR-2)

STS-32
Columbia
(9 Jan.-20 Jan. 1990)

The Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. This flight deployed a communications satellite for the Navy and retrieved the LDEF (Long Duration Exposure Facility) in orbit since 1984 (Brandenstein, Wetherbee, Dunbar, Ivins, Low). (FCR-1)

STS-36
Atlantis
(28 Feb.-4 Mar. 1990)

The thirty-fourth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. This was a classified DOD flight (Creighton, Casper, Mullane, Heilmers, Thuot). (FCR-2)

STS-31
Discovery
(24 Apr.-29 Apr. 1990)

The thirty-fifth Space Shuttle flight with a crew of five was completed with a successful landing at Edwards AFB, CA. The Hubble Space Telescope was deployed on this flight (Shriver, Bolden, Hawley, McCandless, Sullivan). (FCR-1)

APPENDIX A**Summary of MCC Data Systems Changes (Note 1)
1962-1990**

<u>Year</u>	<u>Network</u>	<u>MCC I/O</u>	<u>Main Frames/ DCS (Note 1,2)</u>	<u>Notes</u>
1962-65	Remote(d) sites, FM, TTY, TRAJ lines GLDS (40.8)	FM & PCMGS MDCS, U490 buffer fmtr	7094, D/TV SCRs, PBIs, SDD/DDD, meters DSC	VIS, TV, Ediphor projectors, P-tubes, hardcopy, Milgo Plotter
1966 (APOLLO)	ALDS (40.8) Remote sites	"	"	"
1967-68 (APOLLO)	"	CCATS	360-75 D/TV 360-50	ALSEP DVLP
1969	"	"	"	ALSEP TV scan conv.
1970-71 (APOLLO)	"	"	360-75 DTE	ALSEP SCU, COM
1972-75 (Skylab)	ALDS Data Comp. 7.2 Kbps	"	"	MDSF, MOPS MOPS, COHART, multifunc CIM MDRS, ASP,
1975 (ASTP)	224 Kbps	"	"	ERPDS, SEDS
1976 (ALT)	add GSFC/MCC 224 Kbps	ALTDS	3 370/168s + 2 360s	NIP, ALTDS NCIC, WBS
1977 (ALT)	"	ALTDS NIP	"	New Timing ALSEP end ALTDS end
1978-80	"	NIP	" + 4341-2	MBI, AED, NOM, AGVS TCOS, SWCO
1981-82 (OFT)	GSFC 1 Mbps + White Sands MDMs	"	4 370/168s + 1 360 + 1 4341-2	DDHE, CONIS, CMIS, VICI, CEF, SKR, SDDS (Note 3)

Summary of MCC Data Systems Changes (Continued)
1962-1990

<u>Year</u>	<u>Network</u>	<u>MCC I/O</u>	<u>Main Frames/ DCS (Note 1,2)</u>	<u>Notes</u>
1983 (STS)	" + TDRS	NIP	4 370/168 + 1 3083E + 1 4341-2	POCC (Note 4) CONIS, DAA 4341 end, GE light valve
1984-85	"	"	" + 3 DGE	CONIS, ERRP SDR
1986	"	"	4 3083JX + 3081K CICU A/B Channel Sw	Host Dlv. 1.2 Host Del. 1.3 MITS
1987-88	"	"	"	MITS/CAS/PSS MCCU Del. 2.1 T-FCR
1989	"	"	4 3083KX DGE	MCCU Del. 2.3
1990	"	"	"	MCCU Del. 2.5 DVIS, PPD

NOTES

1. Only changes are shown for the DCS in the above table. The DDDs, PBIs and SCR's are still part of the MOW as of 8-90.
2. The table below provided by J. Abernethy shows a summary of main frame replacement in the MCC.

<u>Operational Date</u>	<u>Machine</u>	<u>MIPS</u>	<u>Replaced</u>	<u>Method of Purchase</u>
1964	7094	.75	1967	Directed Procurement
1967	360/75	1.0	1976	Directed Procurement
1976	370/168	3.1	1986	Competitive CDC/IBM
1986	3083-JX	8.0	1987 Upgrade	Competitive IBM/Amdahl/ Hitachi
1989	3083-KX	15.4	1995 (E)	Competitive

3. All the DOD equipment was installed in 1980-82 including the 4 red TPCs, MBI C & D, NOM, SKR, CMIS, DDHE, AED, CEF, PWDS, etc. The third and first floor were modified to meet DOD PCZ requirements, the lobby was modified and the card readers were installed. Another major facility modification was the Visitor Center which opened in 1981 (?) and gave the visitors direct access to the second floor VIP room. DAA certification was received in 5-83.
4. The Spacelab POCC was moved to MSFC. This system was completed in October 1983 and contained a complete high data rate front end (HRDM, PDSS, 3 preprocessors for the Spacelab ECIO and SCIO computer telemetry), a mainframe POCC specific program and 62 intelligent terminals. The JSC POCC supported Spacelab 1 (STS-9), Spacelab 3 (51-B), Spacelab 2 (SL-2) and German Spacelab (D-1) before the POCC was deactivated. Some of the POCC equipment was left in place in the MCC such as PDRE, PDSS, HRDM, etc.
5. The table below provided by D. Roundtree summarizes some of the MOC telemetry history:

<u>MOC OUTPUT</u>	<u>GEMINI</u>	<u>APOLLO</u>	<u>SKYLAB*</u>	<u>ASTP</u>	<u>SHUTTLE</u>
Input (Total)	821	1590	2290	950	12616
Analog	323	784	?	570	4949
Events	174	120	?	70	7667
Digitals	324	686	?	310	?
Special Comps	90	516	950	310	962
Special Events	few	several	570	85	930
Critical events	-	?	?	?	118
Critical alarms	-	?	?	?	5
Display Output					
DTE	164	408	350	167	925
DDD	500**	1500**	6000**		
DDD Fmts	-	-	225	108	182
THRIFT	-	200	750***	105	-

NOTES:

- * Shuttle numbers from STS-1
- ** Unique TLM Events
- *** MDRS Formats

6. The summary of the MCC history of near real time data capabilities is shown below and was provided by D. Roundtree:
 - a. During Gemini, history tabs were constructed manually
 - original source was low speed (TTY) TLM
 - display consisted of TTY message cut and physically taped in chronological order
 - primary use was at remote sites (MCC had history)

- line from ADDT and same data could output on tape
- calibrated data was output to tape and sent to experimenters
- onboard dumps were special reports
- memory dump compares were performed
- MCC history loads were invented
- archive tapes were built
- special data search modes were available: delta time search, limit search, min-max search, event search and combinations of these
- temporary and permanent limits and comp constants were employed
- data privacy was supported

- e. For ASTP essentially the original THRIFT was used but was called THRIFT II.
- f. For Shuttle OFT an enhanced THRIFT III was used.
- g. For Shuttle OPS NRT (Near Real Time) application was used and continually modified and improved. The NRT data was available to the MITS and MCCU workstations in raw or in formatted form.

APPENDIX B**NASA Management Responsible for the MCC Development**

The Nasa management for the development during the 1962-1990 era was as follows:

<u>Date</u>	<u>Name of Division</u>	<u>Division Chief/Dep</u>	<u>Name of Branches</u>	<u>Branch Chief</u>
12-62	Flight Operations	Kraft	Flt Cntr MCC Facilities Miss. Plan	Kranz T. Roberts H. Kyle Mayer
7-63	Ground Systems Project Office	Vavra H. Kyle	IMCC Design Systems Anal GOSS Unif. RTC Off.	MacAfee Gibson H. Kyle R. Everett
3-64	IMCC Program Office	Clements	Systems Operations Facilities	? ? ?
10-64	Flight Support	Clements	Operations Cmptr Cntr Network	Holt Leech McCown
5-67	Flight Support	Clements Dunseith	Cmptr Cntr System Eng Operations Flight SW	Leech Satterfield Frere Stokes
6-67	Flight Support	Dunseith	Cmptr Cntr System Eng Operations Flight SW	Leech Satterfield Frere Stokes
9-67	Flight Support	Dunseith	System Spt System Eng Operations Flight SW	Miller Satterfield Frere Stokes
1-70	Flight Support	Dunseith	System Spt System Eng Operations Flight SW	Miller Satterfield Sanborn Stokes
7-71	Flight Support	Stokes Satterfield	SIM & Flt SW System Eng Operations Data Proc. Comm Data	Williams, JE Miller Sanborn Dungan Parker

<u>Date</u>	<u>Name of Division</u>	<u>Division Chief/Dep</u>	<u>Name of Branches</u>	<u>Branch Chief</u>
1-73	Flight Support	Stokes Satterfield Miller	SIM & Flt SW System Eng Operations Data Proc. Comm Data	Williams, JE Sanborn Mager Dungan C. Parker
1-74	Ground Data Systems	Stokes Miller	Sw Systems System Eng Operations Data Proc.	Williams, JE Sanborn Mager Stokes/Hall
8-75	Ground Data Systems	Stokes Miller	Sw Systems System Eng Operations Data Proc.	Williams, JE Sanborn Mager Hall
9-76	Ground Data Systems	Stokes Miller	Data Proc. System Eng Operations	Hall Sanborn Mager
4-80	Ground Data Systems	Stokes Miller	Data Proc. System Eng Operations	Hall Smith Mager
7-81	Ground Data Systems	Stokes Hall	Data Proc. System Eng Operations	J. Parker Smith Mager
6-83	Ground Data Systems	Hall Mager	Data Proc. System Eng Operations	J. Parker Smith Vice
1-84	Ground Data Systems	Mager	Data Proc. System Eng Operations	Dixon Smith Loree
10-84	Ground Data Systems	Mager Seyl	Data Proc. System Eng Operations	Cole Loree Mager
3-85	System Development	Mager Seyl	Sys.Support Sim Dvlp. MCC Dvlp	Williams Roundtree Loree

<u>Date</u>	<u>Name of Division</u>	<u>Division Chief/Dep</u>	<u>Name of Branches</u>	<u>Branch Chief</u>
8-88	System Development	Seyl Olasky	Sys.Support Sim Dvlp. MCC Dvlp	Vowell Roundtree Loree
4-89	System Development	Seyl Olasky	Sys/Net Spt Host Dvlp. WKST Dvlp CC Proj Ofc Sim Proj Ofc	Vowell Abernethy Duffin Loree Roundtree
8-90	*Space Shuttle Ground Sys.	Russell Epps	CC Sys. Sim Sys.	Duffin Kane

* During the fall of 1989 and Spring of 1990 there was a JSC center reorganization. The Control Center(s) (MCC/SSCC) and the Simulators (STS/Space Station) development responsibility was transferred to MOD. The Space Shuttle Ground System Division was responsible for the sustaining, operations and development of the MCC and SMS.

APPENDIX C

ACRONYM LIST

ADDT	ALL DATA DUMP TAPE (SITES)
	ALL DATA DIGITAL TAPE (MCC)
AEDS	ANALOG EVENT DISTRIBUTION SYSTEM
AFB	AIR FORCE BASE
AGS	ABORT GUIDANCE COMPUTER
AGVS	AIR/GROUND VOICE SYSTEM
ALDS	APOLLO LAUNCH DATA SYSTEM
ALSEP	APOLLO LUNAR SURFACE EXPERIMENT PACKAGE
ALT	APPROACH AND LANDING TEST
ASCATS	APOLLO SIMULATION, CHECKOUT, AND TEST SYSTEM
ASP	APOLLO SCHEDULING PROGRAM
ASTP	APOLLO SOYUZ TEST PROJECT
BDU	BIOMEDICAL DISPLAY UNIT
CAPS	CREW ACTIVITY PLANNING SYSTEM
CAS	CALIBRATED ANCILLARY SYSTEM
CCAFS	CAPE CANEVEAL AIR FORCE STATION
CCATS	COMMUNICATIONS , COMMAND, AND TRACKING SYSTEM
CCF	CENTRAL COMPUTING FACILITY
CCIM	COMMAND COMPUTER INPUT MULTIPLEXER
CCRF	CONSOLIDATED COMMUNICATIONS RECORDING FACILITY
CCS	CONSOLE COMMUNICATION SYSTEM
CCT	COMPUTER COMPATIBLE TAPE
CEF	COMSEC EQUIPMENT FACILITY
CIN	CENTER INFORMATION NETWORK
CIS	COMMUNICATIONS INTERFACE SYSTEM
CM	CONFIGURATION MANAGEMENT
CMD	COMMAND
CMIS	CONTROL AND MONITORING ISOLATION SUBSYSTEM
CMC	COMMAND MODULE COMPUTER
COLD	COMPUTATION OFFLINE DEFINITION
COM	COMPUTER OUTPUT MICROFILM
COMM	COMMUNICATION
COMSEC	COMMUNICATIONS SECURITY
CONIS	CONSOLE INTERFACE SUBSYSTEM
CPU	CENTRAL PROCESSING UNIT
CRP	CONFIGURATION REQUIREMENTS PROCESSOR
CRT	CATHODE RAY TUBE
CSM	COMMAND AND SERVICE MODULE
CTC	CROSSCONNECT TERMINATION CABINET
CTE	COMMUNICATIONS TEST EQUIPMENT
CTS	CONSOLE TEST SET
DAA	DESIGNATED APPROVAL AUTHORITY
DAC	DIGITAL-ANALOG CONVERSION
DAPS	DATA ACQUISITION PREPROCESSING SYSTEM
DASD	DIRECT ACCESS STORAGE DEVICE
DCC	DATA COMPUTATION COMPLEX
DCIM	DISPLAY COMPUTER INPUT MULTIPLEXER
DCS	DISPLAY AND CONTROL SYSTEM
DDD	DIGITAL DISPLAY DRIVER
DDH	DUMP DATA HANDLER
DDHE	DUMP DATA HANDLING EQUIPMENT
DDHS	DUMP DATA HANDLING SUBSYSTEM
DGE	DIGITAL GENERATION EQUIPMENT
DOD	DEPARTMENT OF DEFENSE
DRK	DISPLAY REQUEST KEYBOARD
DSC	DYNAMIC STANDBY COMPUTER

DTE	DIGITAL TELEVISION EQUIPMENT
DVIS	DIGITAL VOICE INTERCOM SYSTEM
EASEP	EARLY ALSEP SCIENTIFIC EXPERIMENTS PACKAGE
ECG	ELECTROCARDIOGRAM
EDD	EVENT DATA DISTRIBUTION
EGSE	EXPERIMENTER GROUND SUPPORT EQUIPMENT
ERAP	EARTH RESOURCES AIRPLANE PROGRAM
EREP	EARTH RESOURCES EXPERIMENT PROGRAM
ERRP	EQUIPMENT REPLACEMENT AND REFURBISHMENT PLAN
ERDS	EARTH RESOURCES DATA SYSTEM
ESA	EUROPEAN SPACE AGENCY
ETR	EASTERN TEST RANGE
EVA	EXTRAVEHICULAR ACTIVITY
FACC	FORD AEROSPACE AND COMMUNICATIONS CORPORATION
FADS	FLIGHT ANALYSIS AND DESIGN SYSTEM
FAR	FINAL ACCEPTANCE REVIEW
FCR	FLIGHT CONTROL ROOM
FEIDS	FLIGHT EQUIPMENT INTERFACE DEVICE
FM	FREQUENCY MODULATION
FODS	FIBER OPTICS DISTRIBUTION SUBSYSTEM
FR SYNC	FRAME SYNCHRONIZATION
FSH	FLIGHT SUPPORT HOST
FSPS	FRAME SYNCHRONIZER PARAMETER SELECTOR
GFE	GOVERNMENT FURNISHED EQUIPMENT
GLDS	GEMINI LAUNCH DATA SYSTEM
GSCATS	GEMINI SIMULATION, CHECKOUT, AND TEST SYSTEM
GSFC	GODDARD SPACE FLIGHT CENTER
GSTDN	GROUND SPACECRAFT TRACKING AND DATA NETWORK
HDRM	HIGH DATA RATE MULTIPLEXER
HDRR	HIGH DATA RATE RECORDER
HDRS	HIGH DATA RATE SWITCH
HWCO	HARDWARE CHECKOUT
IBM	INTERNATIONAL BUSINESS MACHINE CORPORATION
ICU	INTERFACE CONTROL UNIT
IDA	INTERMEDIATE DATA ARRAY
IU	INSTRUMENTATION UNIT
kbps	KILOBITS PER SECOND
KHz	KILOHERTZ
kw	KILOWATTS
KSC	JOHN F. KENNEDY SPACE CENTER
LACIE	LARGE ACREAGE CROP INVENTORY EXPERIMENT
LAN	LOCAL AREA NETWORK
LDEF	LONG DURATION EXPOSURE FACILITY
LGC	LUNAR GUIDANCE COMPUTER
LM	LUNAR MODULE
LRV	LUNAR ROVER VEHICLE
MBI	MULTIBUS INTERFACE
Mbps	MEGABITS PER SECOND
MCC	MISSION CONTROL CENTER
MCCU	MISSION CONTROL CENTER UPGRADE
MDCS	MASTER DIGITAL COMMAND SYSTEM
MDM	MULTIPLEXER/DEMULTIPLEXER
MDSF	MASS DATA STORAGE FACILITY
MED	MANUAL ENTRY DEVICE
MER	MISSION EVALUATION ROOM
MIDDS	METEOROLOGICAL INTERACTIVE DATA DISPLAY SYSTEM
MITS	MOD/IPS/TACAN SUBSYSTEM
MMDB	MASTER MEASUREMENT DATA BASE
MMU	MANNED MANEUVERING UNIT
MOA	MEMORANDUM OF AGREEMENT

M&O	MAINTENANCE AND OPERATIONS
MOC	MISSION OPERATIONS COMPUTER
MOCR	MISSION OPERATIONS CONTROL ROOM
MOD	MISSION OPERATIONS DIRECTORATE
MOPS	MISSION OPERATIONS PLANNING SYSTEM
MOW	MISSION OPERATIONS WING (REFERS TO BLDG 30 AT JSC)
MPAD	MISSION PLANNING AND ANALYSIS DIVISION
MPCC	MULTI-PROGRAM CONTROL CENTER
MPDD	MULTI-PROGRAM DATA DRIVER
MPSR	MULTI-PURPOSE SUPPORT ROOM
MSC	MISSION SUPPORT CONTRACT
MSD	MISSION SUPPORT DIRECTORATE
MSFC	MARSHALL SPACE FLIGHT CENTER
MSFN	MANNED SPACEFLIGHT NETWORK
MSK	MANUAL SELECT KEYBOARD
MSS	MASS STORAGE FACILITY
MTU	MASTER TIMING UNIT
MVS/XA	MULTIPLE VIRTUAL STORAGE EXTENDED ARCHITECTURE
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASCOM	NASA COMMUNICATIONS NETWORK
NCC	NETWORK CONTROL CENTER
NCIC	NETWORK COMMUNICATIONS INTERFACE COMMON
NCIU	NETWORK COMMUNICATIONS INTERFACE UNIQUE
NDD	NETWORK DATA DRIVER
NETCOM	NETWORK COMMUNICATIONS
NIP	NETWORK INTERFACE PROCESSOR
NOM	NETWORK OUTPUT MULTIPLEXER
NRT	NEAR REAL-TIME TELEMETRY
NSS	NETWORK SYSTEM SIMULATOR
NTSC	NATIONAL TELEVISION STANDARDS FOR COLOR
OFT	ORBITAL FLIGHT TEST
OS	OPERATING SYSTEM
OSC	OPERATIONS SUPPORT CONTRACT
OST	OPERATIONS SUPPORT TEAM
PABX	PRIVATE AUTOMATIC EXCHANGE BRANCH
P/B	PLAYBACK
PBI	PUSH-BUTTON INDICATOR
PCM	PULSE-CODE MODULATION
PCZ	PHYSICAL CONTROL ZONE
PCMGS	PCM GROUND STATION
PDD	PROJECTION PLOTTER DISPLAY
PDDS	POCC DATA DISTRIBUTION SUBSYSTEM
PDI	PAYLOAD DATA INTERLEAVER
PDIS	PAYLOAD DATA INTERLEAVER SERIALIZER
PDRE	PAYLOAD DATA RECORDING EQUIPMENT
PDSDD	PLOTTING DISPLAY SUBCHANNEL DATA DISTRIBUTOR
PDSS	POCC DATA SELECT SWITCH
PNDD	PAYLOAD NETWORK DATA DRIVER
POCC	PAYLOAD OPERATIONS CONTROL CENTER
PPD	PROJECTION PLOTTER DISPLAY
PPDS	PROJECTION PLOTTING DISPLAY SYSTEM
PPS	PREPROCESSING PRODUCTION SYSTEM
PSDR	PRELIMINARY SYSTEM DESIGN REVIEW
PSS	PAYLOAD SUPPORT SYSTEM
P-TUBE	PNEUMATIC TUBE
RDCS	RECONFIGURATION DATA COLLECTION SUBSYSTEM
RSOC	ROCKWELL SPACE OPERATIONS COMPANY
RTOS	REALTIME OPERATING SYSTEM
RTCC	REALTIME COMPUTER COMPLEX
RTH	REALTIME HOST

SAC	STATUS AND CONTROL
SCAP	SHUTTLE CONFIGURATION ANALYSIS PROGRAM
SCR	STRIPCHART RECORDER
SCU	SYSTEM CONFIGURATION UNIT
SDD	SUBCHANNEL DATA DISTRIBUTOR
	SYSTEMS DEVELOPMENT DIVISION
SDP	SHUTTLE DATA PROCESSOR
SDPC	SHUTTLE DATA PROCESSING COMPLEX
SDR	SYSTEM DESIGN REVIEW
SDRS	SHUTTLE DATA RECONFIGURATION SYSTEM
SDSS	STS DATA SELECT SWITCH
SEDS	SCREWORM ERADICATION DATA SYSTEM
SERS	SHUTTLE ENHANCED RECONFIGURATION SYSTEM
SKR	SEPARATOR-KG-RECOMBINER
SMEK	SUMMARY MESSAGE ENABLE KEYBOARD
SMS	SHUTTLE MISSION SIMULATOR
SPF	SOFTWARE PRODUCTION FACILITY
SSCC	SPACE STATION CONTROL CENTER
STARS	STAFF REDUCTION STRATEGY
STRU	SIMULATION TRANSMIT/RECEIVE UNIT
STS	SPACE TRANSPORTATION SYSTEM (ORBITER, ET, SRB'S, SPACELAB, IUS & SSUS)
STSOC	STS OPERATIONS CONTRACT
SUTAGS	SHUTTLE UPLINK TEXT AND GRAPHICS HIGH RESOLUTION SCANNER
	SOFTWARE
SW	SOFTWARE CHECKOUT
SWCO	TACTICAL AIR NAVIGATION
TACAN	TEXT AND GRAPHICS SYSTEM
TAGS	TELEMETRY CHECKOUT SYSTEM
TCOS	TRACKING AND DATA RELAY SATELLITE
TDRS	TRANSITION FLIGHT CONTROL ROOM
TFCR	TELEMETRY HISTORY REPORT IN FORMATTED TABULATIONS
THRIFT	TELEMETRY
TLM	TREND MONITORING SYSTEM
TMS	THIRD ORDER POLYNOMIAL DIGITAL ANALOG CONVERTERS
TOPDAC	TELEMETRY PROCESSING COMPUTER
TPC	TRAJECTORY
TRAJ	TETHERED SATELLITE SYSTEM
TSS	TELETYPE
TTY	TELEVISION
TV	ULTRA HIGH FREQUENCY
UHF	UPLINK
U/L	VANDENBERG AIR FORCE BASE
VAFB	VIDEO ISOLATION CHANNEL INDICATOR
VICI	VOICE INTERCOMMUNICATIONS SYSTEM
VIS	VIDEO SELECT MATRIX
VSM	WORKSTATION EXECUTIVE
WEX	WIDEBAND SWITCH
WBS	WIDEBAND DATA DISTRIBUTION SYSTEM
WDDS	