

Mainframes and the Moon

The Role Played by IBM Mainframes in the Greatest Technical Achievement in the History of Mankind

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53 Years Ago....

Before we Get Started....

This session focuses on the role of the IBM Mainframe. We are not focusing on:

- The contributions of all of the other providers of information technology that were used in the United States space program through the lunar landing. We look forward to them telling their stories.
- The amazing other computing technologies used onboard the Apollo Command Module or the Lunar Module
- Events (Skylab, Space Shuttle) which occurred after the lunar landing on 20 July 1969.

A big “thank you” to everyone who worked on these mainframes and to Max Campbell at the IBM Archives for his invaluable assistance!

Why is the Manned Space Program Such a Good Story?

- It's a story that combines all of the elements of a great story:
 - Life and death drama
 - Singularity of vision and purpose
 - Engaging, passionate characters
 - Technology (physics, chemistry, electrical engineering, computer science, materials...)
 - Politics, Finance, Management
 - ***Mainframes!***
 - ... and after all the trials and tribulations, a happy ending.



It's a Local Story!

- **With 20,000 contractors and subcontractors, virtually every state in the United States contributed!**
- **Take New York, for example:**
 - IBM Poughkeepsie
 - IBM Kingston
 - IBM Fishkill
 - IBM Endicott
 - IBM Owego
 - USMA, West Point
 - Grumman Aerospace, Bethpage
 - ... and many others

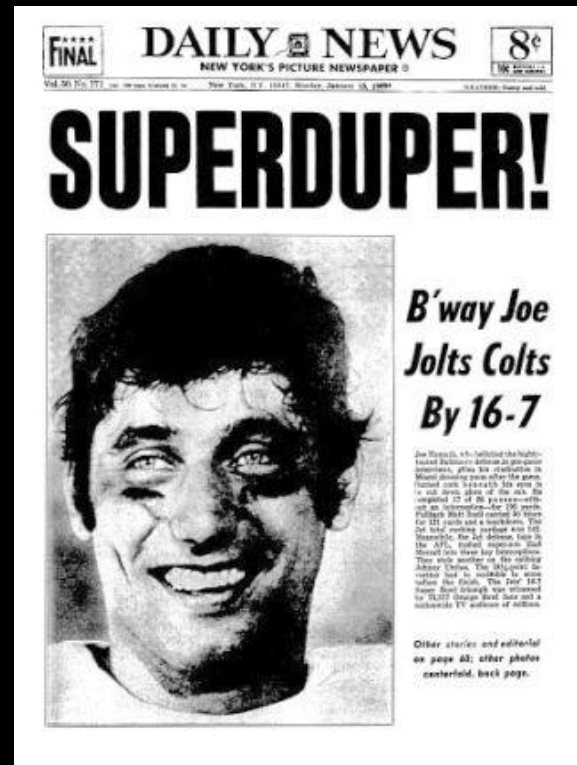


It's a Story about the Times: 1968


1968



It's a Story about the Times: 1969



50
Years of
CICS



Singularity of Vision



President John F. Kennedy's 25 May, 1961 speech before a Joint Session of Congress

“First, I believe that **this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.** No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.”



President John F. Kennedy's 12 September 1962 at Rice University

“**We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard;** because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win, and the others, too. “

The Roots of the Cold War



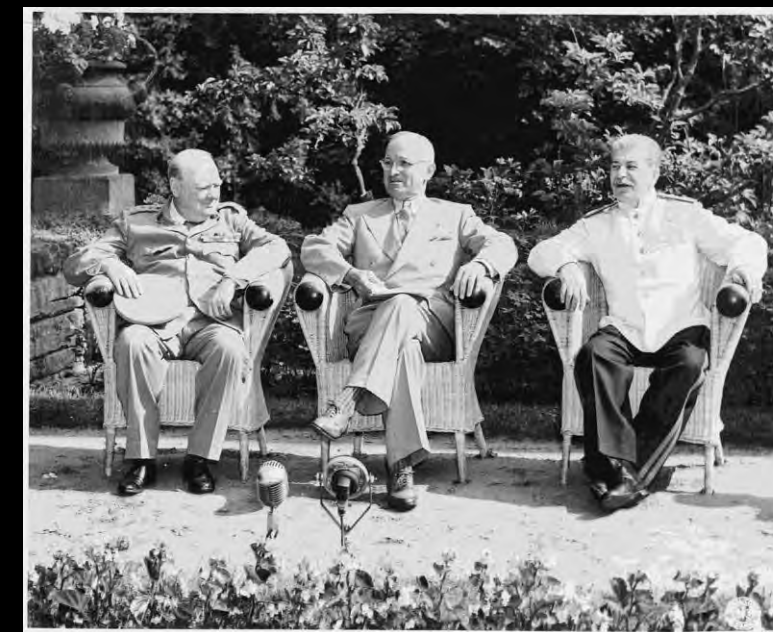
Sputnik: First artificial satellite launch
4 October, 1957



Yuri Gagarin: First human in space
12 April, 1961



Yalta Conference, 4-11 February 1945



Potsdam Conference, 17 July to 2 August

The Stages of the US Space Program Leading up to the Lunar Landing

Project Vanguard

- Goal: Launch a satellite into space
- During a highly publicized launch on 6 December, 1957, the Vanguard rocket rises four feet, sinks back, and explodes
- First satellite into space (Explorer 1), launched on a Juno Rocket on 31 January, 1958

But the Soviet Union had launched Sputnik 1 on 4 October, 1957



Project Mercury

- Goal: One human into earth orbit and return to earth safely.
- Alan Shepard launches for a 15 minute suborbital flight on 5 May, 1961 and John Glenn into an orbital flight on 20 February, 1962

But the Soviet Union had launched Yuri Gagarin into an orbital flight on 12 April, 1961



Project Gemini

- Goal: Prepare for the lunar mission
- Two astronauts flew ten missions to work out maneuvers needed for a lunar landing:
 - Extra-vehicular activity (EVA)
 - Space craft rendezvous and docking
 - Extended duration



Project Apollo

- Three Astronauts on each mission, with 12 manned missions, most notably:
 - Apollo 1: Launch pad fire on 27 January, 1967. Gus Grissom, Ed White, Roger Chaffee perish.
 - Apollo 7: Manned flights resume on 11 Oct., 1968

Apollo 8: First manned flight to the moon in 21 Dec. 1968

Apollo 10: "Dress rehearsal" 18 May

Apollo 11: Success!



Let's Talk About the Mainframes!

Pre-Space Program: IBM SSEC

- **The IBM Selective Sequence Electronic Calculator (SSEC)**
 - Based on the electro-mechanical IBM Automatic Sequence Controlled Calculator (Harvard Mark I).
 - Built at IBM Endicott, installed at 590 Madison Avenue, NYC
 - Electronic and electromechanical design
 - Arithmetic unit: Approximately 12,500 vacuum tubes were used in the arithmetic unit, control, and its eight high-speed registers, which had an access time of less than one millisecond.
 - Control and slow speed registers: Consisted of 21,400 relays with an access time of 20 milliseconds.
 - Calculated position information of the moon and planets; This data was the basis for data used later during the Apollo program



Project Vanguard Computer Center

- Established June 1957, Washington D.C. with a backup in building 701 in Poughkeepsie N.Y.
- Consisted of an IBM 709 in each location
- Supported orbital calculations and tracking data for satellites



IBM 709 Data Processing System

- Vacuum tube technology
- 180 instructions
- Improved version of the IBM 704
- Introduction of the “data-synchronizer units” (we’d call them channels today)
- 32,768 words of 36-bit word magnetic core memory
- Could execute 42,000 addition or subtraction instructions per second
- Could multiply two 36-bit integers at a rate of 5000 per second
- An optional hardware emulator executed 704 programs



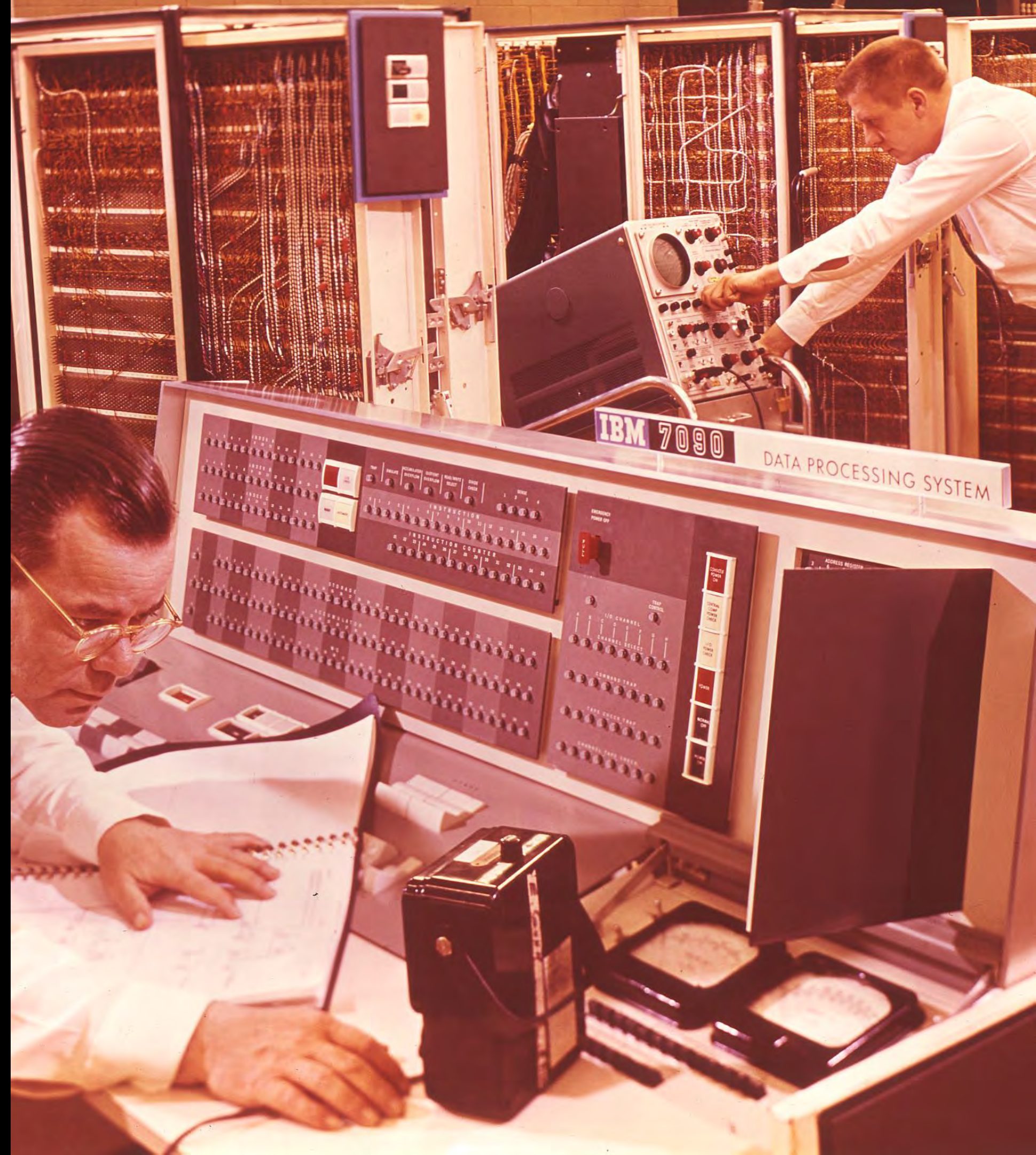
Real Time Computer Center (RTCC): Project Mercury

- Established in 1960 at Goddard Space Flight Center in Greenbelt, M.D.
- Three IBM 7090s
- Consolidated information from tracking sites and launch control in Cape Canaveral to provide a real-time continually updated aircraft status
- Special-purpose control program/monitor with limited multiprogramming capabilities



IBM 7090 Data Processing System

- **Transistorized version of the IBM 709**
- Six times faster
- Far more reliable
- Half the cost
 - but still \$63K a month in 1960 dollars (\$612K in 2022 dollars)
- **32,768 words of 36-bit magnetic core memory (same as 709)**



RTCC: Project Gemini

- **Had to control two spacecraft at the same time**
- **Five IBM 7094s, partitionable into:**
 - Two mission systems, one b/u
 - One mission, one test/training, one b/u
- **Still has a custom control program/monitor, but commercial off-the-shelf operating system (IBSYS) begins to be used**



IBM 7094 Data Processing System

- **Instruction set increased to 274 instructions**
- **A basic machine operating cycle of 2 microseconds**
- **Double-precision floating-point operations**
- **7094 II**
 - Shorter cycle time
 - Less cycles for multiplications and divisions
 - Memory interleaving



Project Apollo

Apollo Launch Vehicle: Saturn V

- 363' tall, launch weight of 6.5M pounds, capable of lifting 310K lbs. delivered to lower earth orbit, 107K to lunar orbit
- Three stage launch design:
 - 1:(S-IC, Boeing), five F-1 rockets, 2:41 burn of liquid oxygen/kerosene, altitude 36 NM, 50NM downrange, velocity 7.5KFPS
 - 2:(S-II, North American), five J2 rockets, 6:32 burn of liquid oxygen/hydrogen
 - 3:(S-IVB, Douglas), one J2 rocket two burns, one for orbit insertion (2:30), one for trans-lunar injection (6:00)



Apollo Landing Vehicle: Lunar Module

- **Designed and manufactured by Grumman (Bethpage, NY)**
- **Two stage design: Descent and ascent**
- **Dimensions: 23'x31'x31'**
- **Could not be flown in earth's gravity or atmosphere**
- **Flown manually for final lunar descent**
- **Saved the crew of Apollo 13**



Want to See a Lunar Module in Person?

You Can! Visit the Cradle of Aviation Museum in Garden City, Long Island!

- 75 air and spacecraft chronicling over 100 years of aerospace history, focusing on the role of Long Island
- Special exhibits (currently “The Future is Now: Drones!”, “The Arcade Age”, “Pan Am Flying Boats”)
- Planetarium
- Special lectures



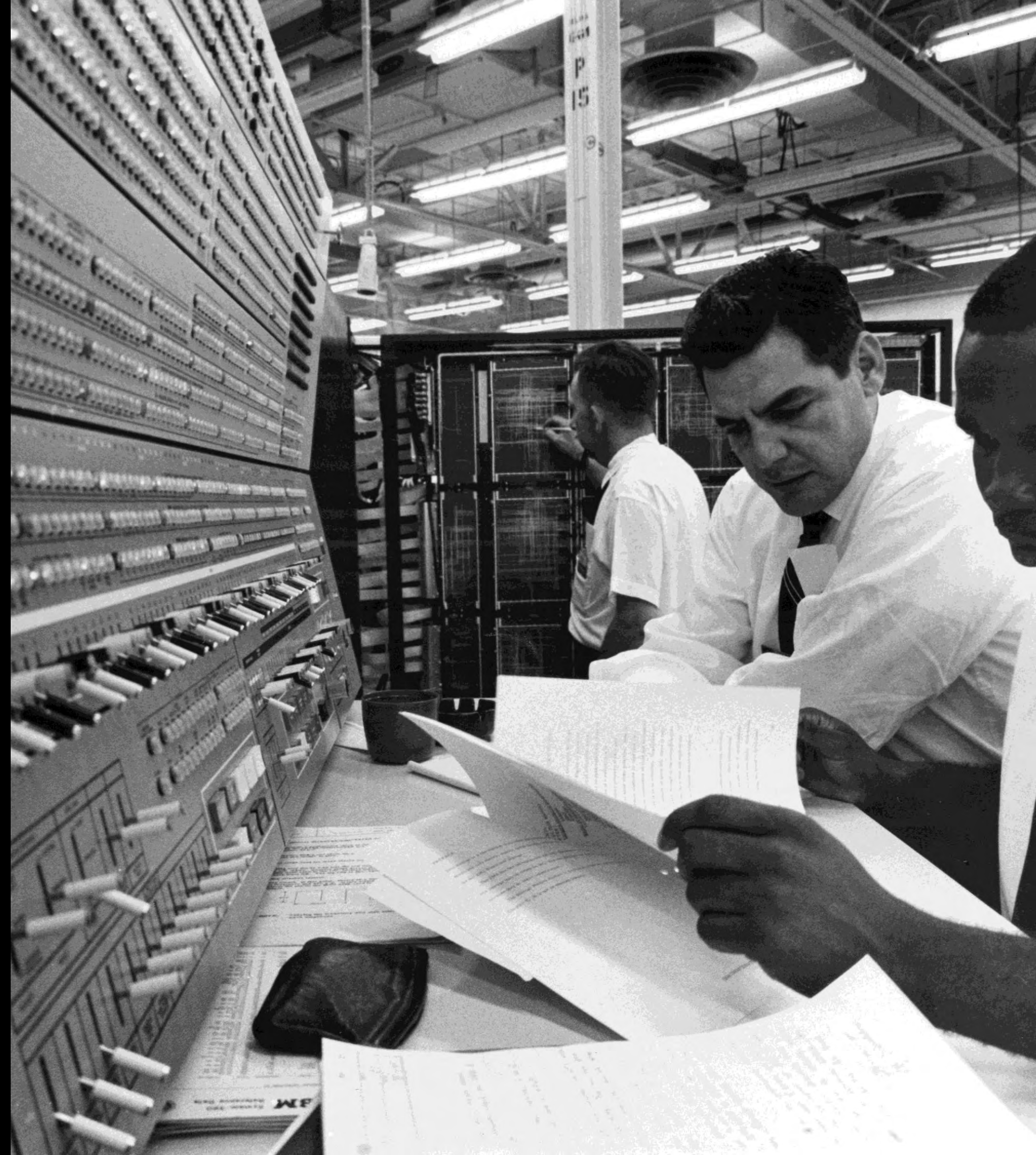
RTCC: Project Apollo

- Transitioned from the five IBM 7094s to five IBM System/360 Model 75Js which were responsible for:
 - Launch systems
 - Management of telemetry data
 - Orbit computation and trajectory determination
 - Mission planning
 - Reentry
- NASA contractors Rockwell and Caterpillar work with IBM to create what is now called IMS to help track the millions of parts needed for the Apollo rockets and spacecraft
- The Apollo Real-Time Operating System (RTOS), a modified version of OS/360 becomes the single operating system to support all Apollo activities



IBM System/360 Model 75J

- **First non-microcoded System/360**
- **Configured with 1M core storage with 750 nanosecond access time**
- **Supported four-way interleaved storage**
- **Purchase price: \$2.5M-\$3.5M (\$24M-\$34M in 2023 dollars)**



RTOS Extensions to OS/360

- **Creation of a new task dispatcher and the concept of tasks which are independent of their creator, run with their own PSW key, and wait for work, which can be queued**
- **Support for a synchronized high resolution (10 micro second) clock and interval timer**
- **Real-time I/O control system for devices supporting a device-independent display format language**
- **Support for IBM 2361 Large Core Storage (4M of additional storage)**
- **Fast swap-over (10 seconds) to backup**
- **Houston Automatic Spooling Priority (HASP) system to control job input and output**



The Iconic Apollo Control Room

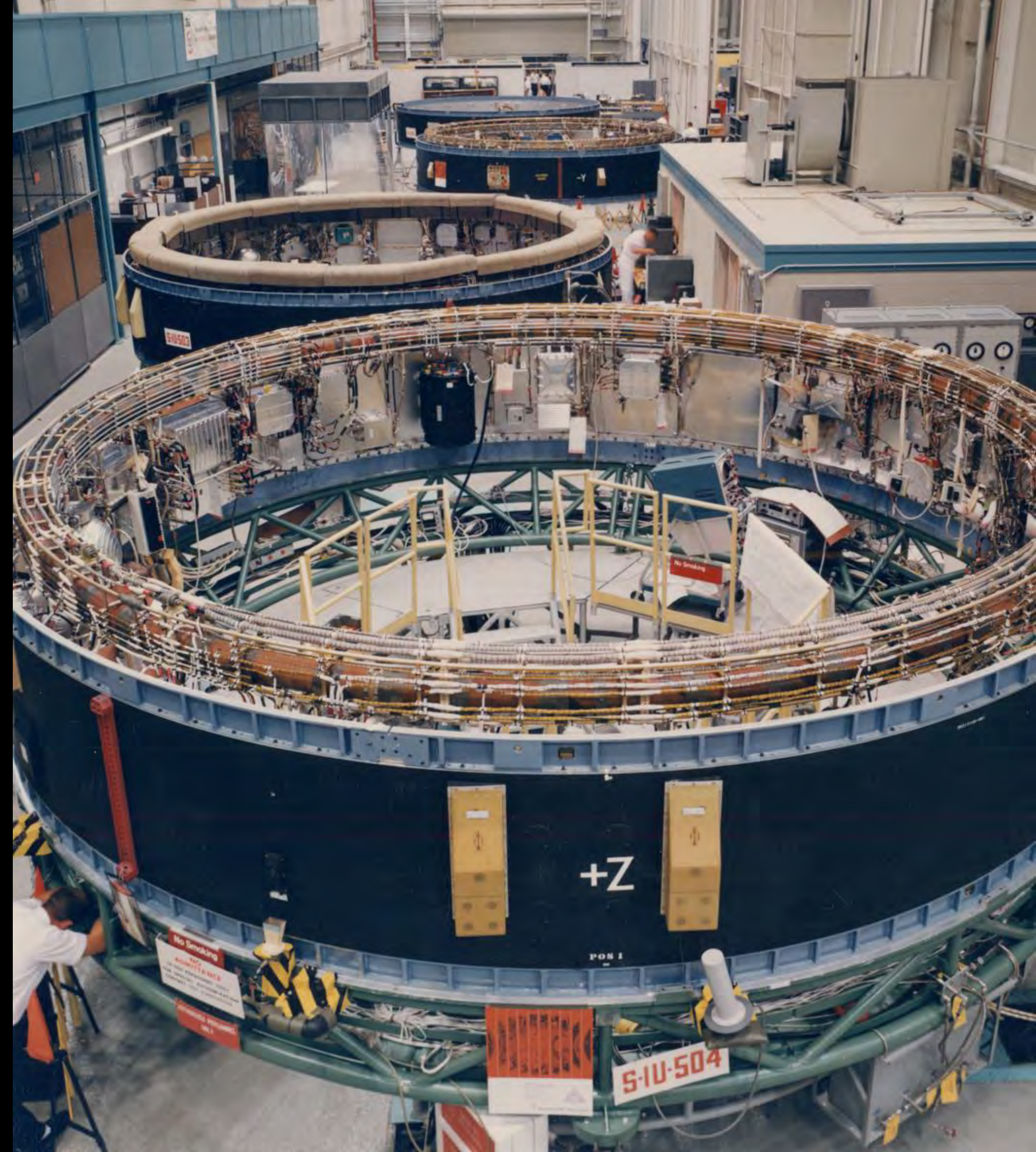
- The display consoles in the Apollo Control room were connected back to the IBM System/360 Model 75 through a 2701 control unit



It's Not a Mainframe but....

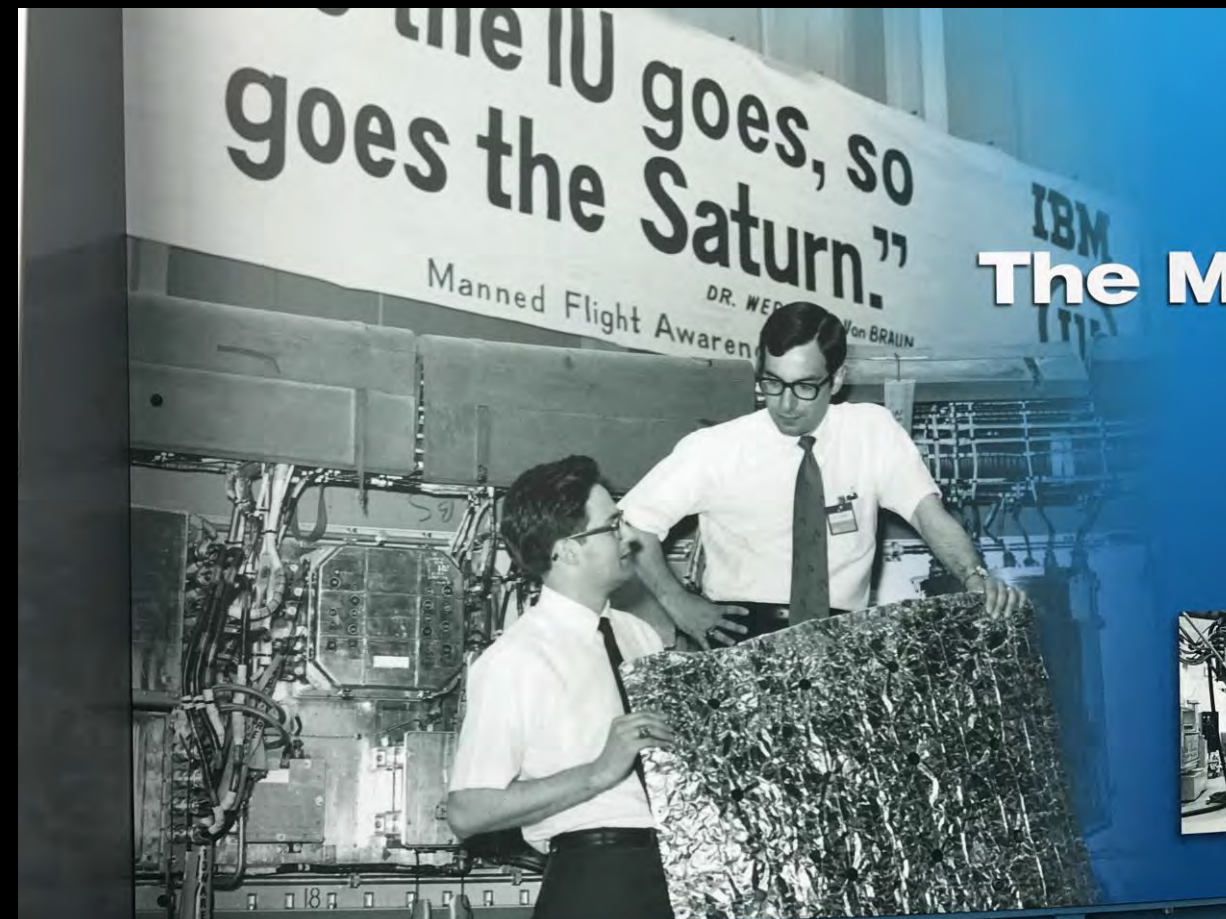
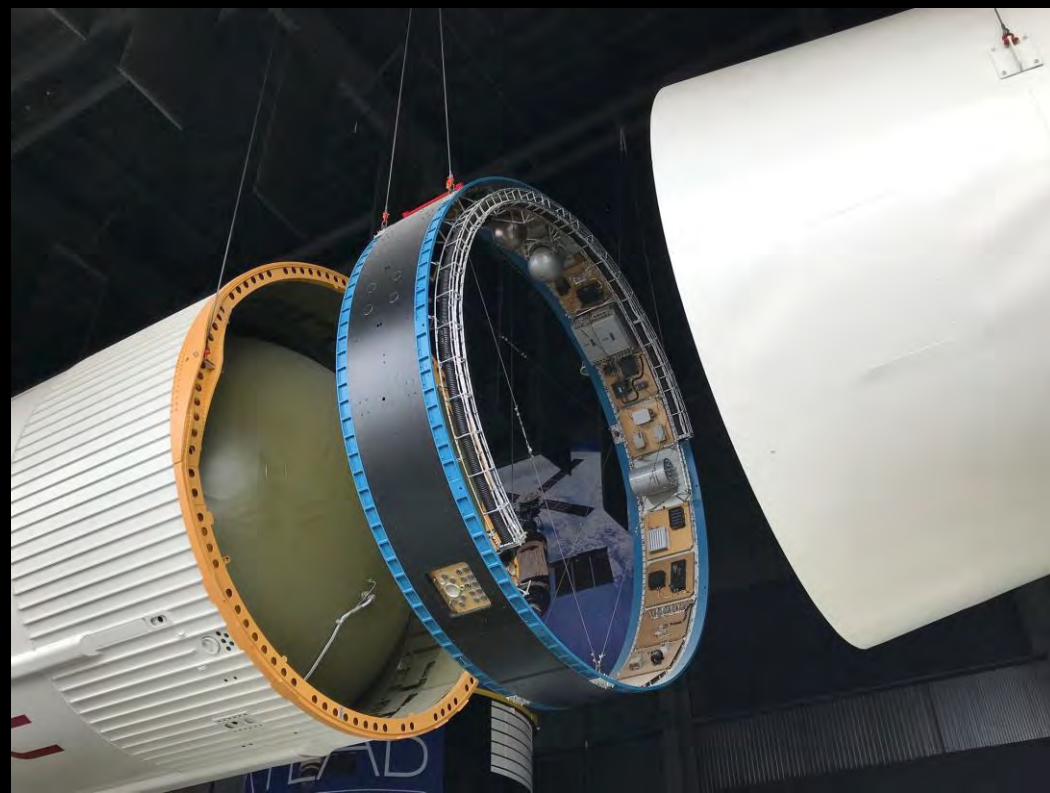
Saturn Instrument Unit

- The Saturn Instrument Unit had mainframe reliability characteristics for its mission
- Built by IBM Huntsville, Alabama, with processors made by IBM Owego
- Responsible for aircraft trajectory from before liftoff (“Guidance is Internal”) until established in “parking” orbit
- Saved the Apollo 12 mission when it was struck by lightning during launch causing a complete loss of telemetry
- As designed, continued the launch to orbit (“SCE to AUX”)



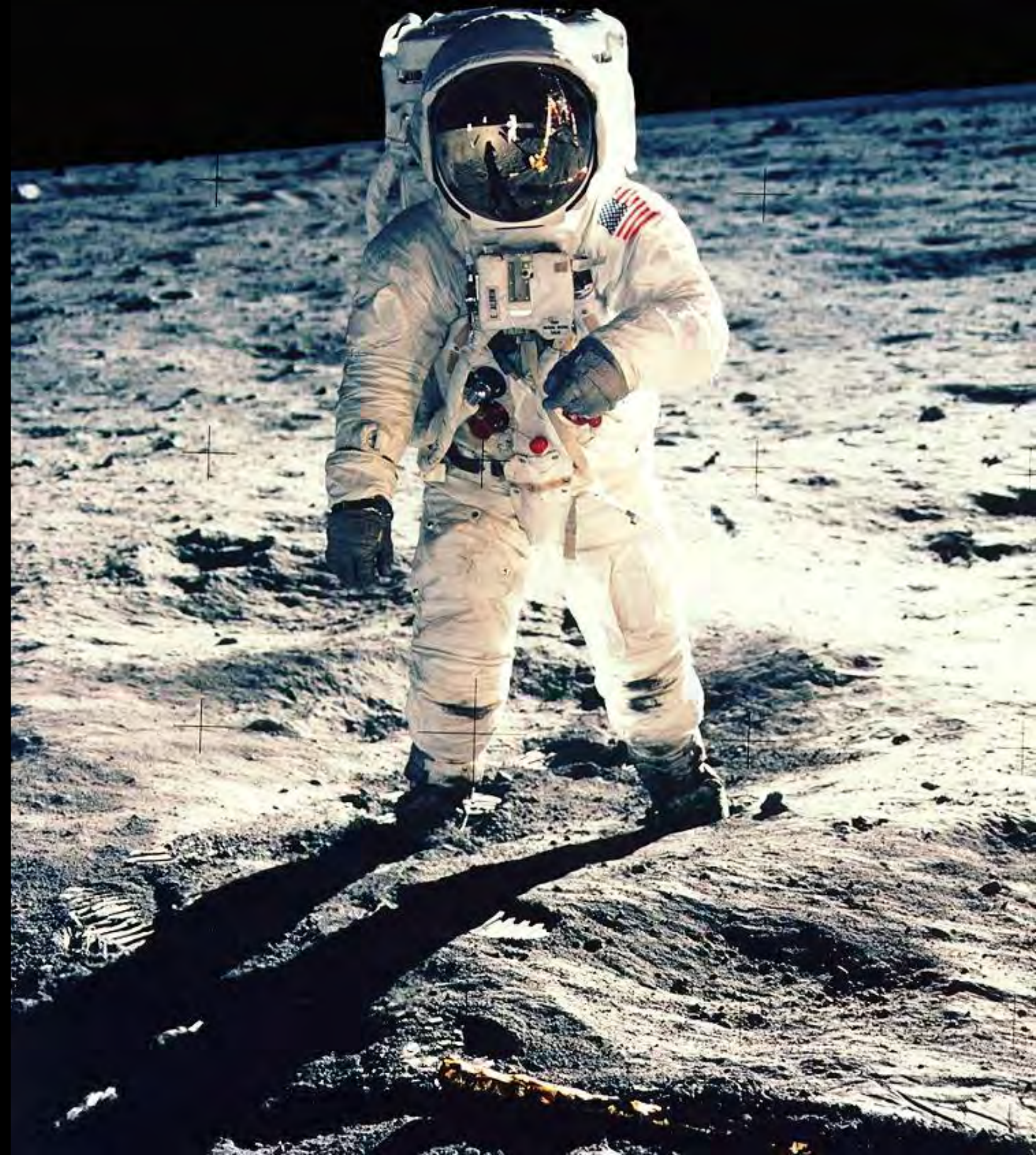
Saturn Instrument Unit...

- SIU is on display at the US Space and Rocket Center in Huntsville, Alabama
- Excellent video on YouTube in the “Smarter Every Day” series: Luke Talley interview
- <https://www.youtube.com/watch?v=dI-JW2UIAG0&>



Which Lead to The Lunar Landing on 20 July 1969

- **Launched on 16 July, 1969 at 13:32 UTC and returned to Earth on 24 July, 1969 17:29 UTC**
- **Commanded by Neil Armstrong, with Buzz Aldrin also in the Lunar Module and Michael Collins remaining in lunar orbit in the Command Module**
- **One lunar EVA lasting 2:31:40 during which 48 pounds of lunar rocks were gathered**
- **Lunar activity was watched by an estimated 20% of the population of Earth**



Where did we go Next?

- **The Apollo 11 lunar landing was not the last event in our space travel activities. It was followed by:**
 - 6 additional Apollo missions, which landed 10 more men on the moon
 - The Apollo-Soyuz joint United States and Soviet Union mission
 - Skylab, Spacelab
 - The Space Shuttle



Space Shuttle and IBM Z

- The Space Shuttle program made extensive use of z/OS (IMS, JES3, PL/I, HL Assembler, C++, RACF), z/VM, and Linux on Z (Redhat)
- z/OS was used for mission planning, flight software creation, testing, simulation, and loading and validating software onto the orbiter
- Onboard computing was performed by the IBM-supplied AP-101S General Purpose Computer (GPC)
 - Also used on several military aircraft (B-1, B-52, F-15)
 - Evolved from the S/360 architecture
- See “Space Shuttle Usage of z/OS” (Jan Green, United Space Alliance), SHARE, 14 August 2007, session 8121
<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090001334.pdf>



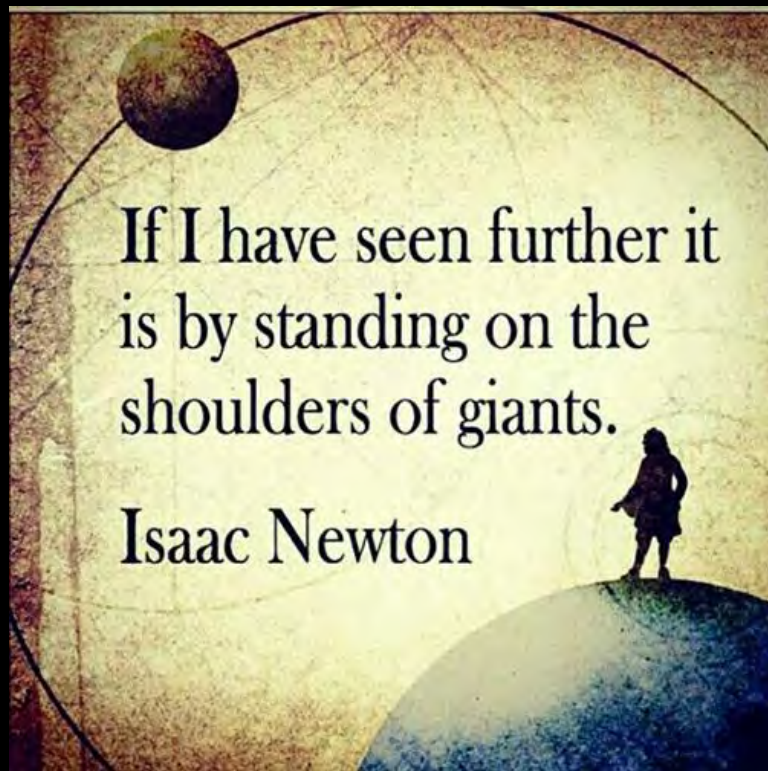
What Happened to the Mainframe?

- **The IBM Mainframe continues to evolve, bring more and more processing power and added reliability and security**
- **The evolution continued through the the IBM System/370, 303X, 308X, IBM 3090, System/390, zSeries (900, 800, 990, and 890), System z9, System z10, zEnterprise System (z196, zEC12, z13, z14, z15, z16)**
- **... and while an operational mainframe never made it to the moon, 37 IBMers were honored when their names were left on the moon during Apollo 15 in recognition of their Apollo efforts**



Where we Stand

Nanos gigantum humeris insidentes



Mainframes and the Moon

The Role Played by IBM Mainframes in the Greatest Technical Achievement in the History of Mankind

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Backup

The Timeline

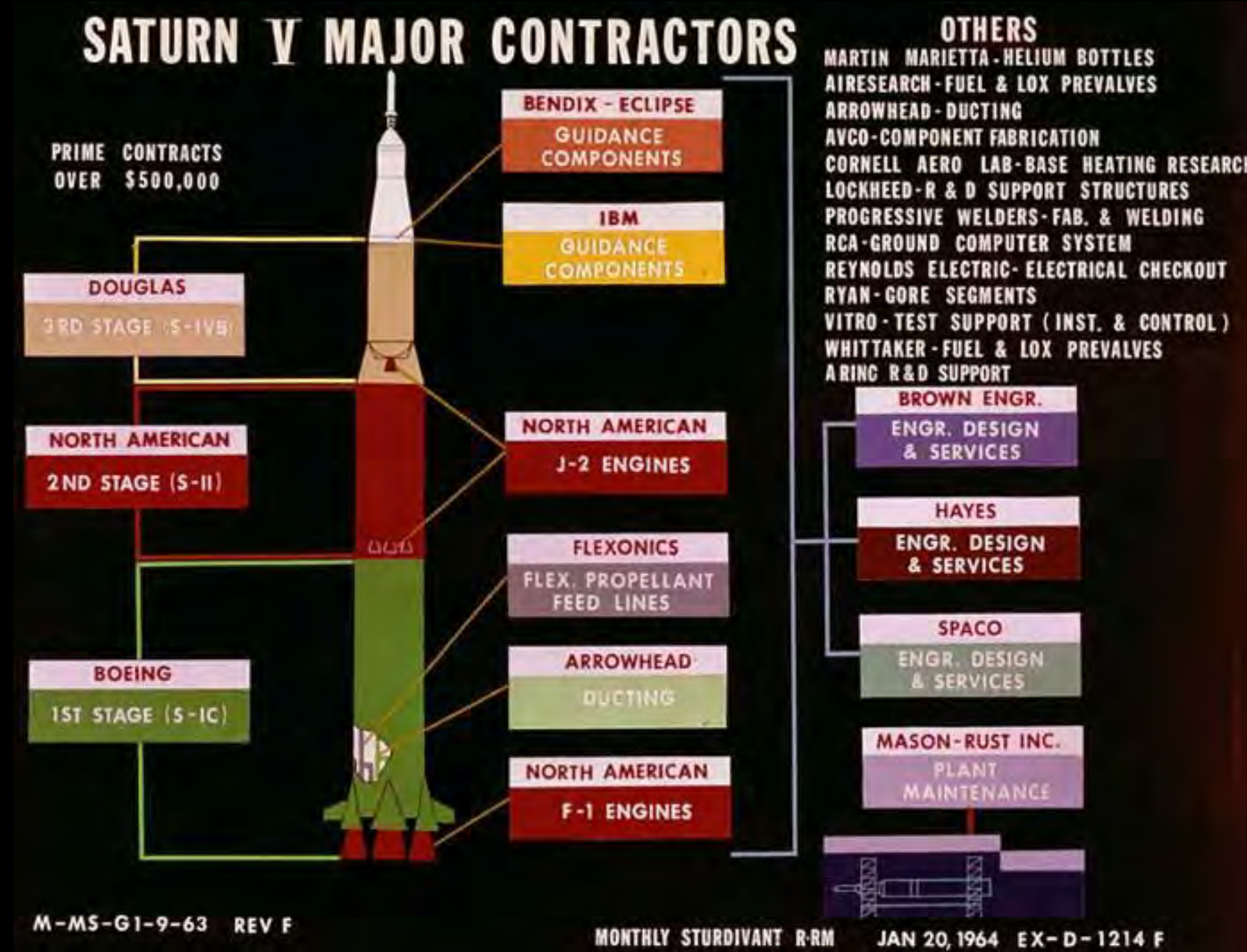
Event Timeline: Early US Space Program

Date	Event
August 7, 1944	IBM presents the Mark I to Harvard University.
January, 1948	IBM Selective Sequential Electronic Calculator enters service. The SSEC is a hybrid mechanical (relay) and electronic (vacuum tube) unit.
October 4, 1957	The Soviet Union launches Sputnik 1, the first man-made satellite in space. It emits beeps for twenty-one (21) days before its batteries are exhausted and continues to orbit the earth until it burns up in the atmosphere on January 4, 1958.
November 3, 1957	Sputnik 2 is launched. On board is the first “space dog”, Laika, who expires, as expected, during the flight.
December 6, 1957	The United States attempts to launch TV3. The Vanguard rocket lifts four feet off the launch pad, sinks back, and explodes. The launch was televised and widely viewed. https://www.youtube.com/watch?v=zVeFkakURXM
January 31, 1958	The United States successfully launches Explorer 1.
March 7, 1958	The launch of Vanguard I succeeds.
April 12, 1961	Cosmonaut Yuri Gagarin becomes the first human in space, orbiting the Earth once in a 108-minute flight.
May 5, 1961	Alan Shepard becomes the first American in space in a 15-minute flight that traversed 496 miles.
May 25, 1961	President Kennedy’s message to a joint session of Congress: “I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.”
September 12, 1962	President Kennedy’s Speech to Rice University: “We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.”

Event Timeline: Manned Apollo Missions

Date	Event
21 February, 1967	Apollo 1, launch pad fire kills all three astronauts: Gus Grissom, Roger Chaffee, and Ed White
4 April, 1968	Apollo 7, first manned orbital mission launches using a Saturn 1B.
21 December, 1968	Apollo 8, first manned flight to the moon launches using the Saturn V and performs 10 lunar orbits.
3 March, 1969	Apollo 9, first manned flight of command service module (CSM) and lunar module (LM) in earth orbit.
18 May, 1969	Apollo 10, lunar landing rehearsal with lunar orbit launches. LM descent to 50,000 feet over lunar surface.
16 July, 1969	Apollo 11, lunar landing mission launches. Lunar landing on 20 July. Two and a half hours spent outside the LM on the moon. Forty-seven pounds of lunar rock returned
14 November, 1969	Apollo 12 launch almost derailed by telemetry loss due to lightning strike. "SCE to AUX" recovery.
11 April, 1970	Apollo 13 launches, mission canceled when SM experiences an explosion and crew uses the LM to provide environmental support to the astronauts that allows them to safely return to earth.
31 January, 1971	Apollo 14 launches.
26 July, 1971	Apollo 15 launches. During the lunar visitation, leaves a canister containing a miniaturized version of a booklet honoring the men and women who worked on the missions. Thirty-seven IBMers are listed.
16 April, 1972	Apollo 16 launches.
7 December, 1972	Apollo 17 launches, the only manned Apollo launched at night.

Saturn Subcontractors



Apollo 13: Engineers Have a Sense of Humor!

North American Rockwell
Space Division
Downey, California

INVOICE NUMBER
70-417

CONVEYED TO

INVOICE DATE	PACKING SLIP(S) NO.	DATE SHIPPED	INVOICE NO.	ITEMS NET FOR SHIPPING WT.
17 April 1970				
BUYER'S ORDER OR CONTRACT NO.	QUOTATION NO.	DATE OF ORDER	SHIPMENT NO.	SHIPMENT DATE
QUANTITY	DESCRIPTION	UNIT PRICE	AMOUNT	
1	400,001 Miles Towing, \$4.00 first mile, \$1.00 each additional mile Toll-free call, last service Battery charge (road call + \$.05 KWH)		\$400,004.00	
2	1 IOM Customer's jump cables		4.05	
3	50 Lbs. Oxygen at \$10.00/lb.		500.00	
4	1 Sleeping accommodations for 2, no TV, air-conditioned, with radio, modified American plan, with view		Prepaid	
5	Additional guest in room at \$8.00/night (1) Check out no later than noon Fri, 4/17/70, accommodations not guaranteed beyond that time		32.00	
6	Water		4.00	
7	Paranitized "trip-tik", including all transfers, baggage handling and gratuities		N/A	
			\$400,540.05	
	20% commercial discount - 2% cash discount (net 30 days)		82,116.01	
	Charges for keeping this invoice confidential		100,000.00	
			\$417,424.04	