



MIT/IL Apollo Guidance Computer Apollo 11 Lunar Mission

A Brief Review

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Preface

Many years ago, I worked for MIT/IL on the Apollo Program. MIT's role in the Apollo space program was guidance and navigation - Doc Draper's strong suit. The primary MIT technology contribution to the Apollo Program was the Apollo Guidance Computer and the associated hardware and software.

The Apollo program was the United States spaceflight effort which landed the first humans on Earth's Moon. Conceived during the Eisenhower administration and conducted by the National Aeronautics and Space Administration (NASA), Apollo began in earnest after President John F. Kennedy's 1961 address to Congress declaring his belief in a national goal of "landing a man on the Moon" by the end of the decade in a competition with the Soviet Union for supremacy in space.

This goal was first accomplished during the Apollo 11 mission on July 20, 1969 when astronauts Neil Armstrong and Buzz Aldrin landed, while Michael Collins remained in lunar orbit. Five subsequent Apollo missions also landed astronauts on the Moon, the last in December 1972. In these six Apollo spaceflights, 12 men walked on the Moon. To this date, these are the only times humans are known to have landed on another celestial body.

The photos and descriptions included in this document are a few photos on the wonderful, yet limited, Apollo Guidance Computer, and a few photos on the Apollo 11 mission - the first man-on-the-moon lunar expedition. I've commented on, and sequenced the photos, in an order for ease of understanding.

The Apollo 11 mission was flown in mid-1969, so you can see how technology has changed in the last 43 years. What was amazing was that the whole Apollo 11 program cost \$25.4 Billion over 10+ years, and united the world in its many peaceful adventures. For all of its challenges, the Apollo program was truly a wondrous American effort.

I dedicate this document to the three Apollo 11 Astronauts, one of whom we just lost:

Neil Alden Armstrong (August 5, 1930 – August 25, 2012) Apollo 11 spacecraft commander

Edwin Eugene "Buzz" Aldrin, Jr. (born January 20, 1930) Apollo 11 lunar module pilot

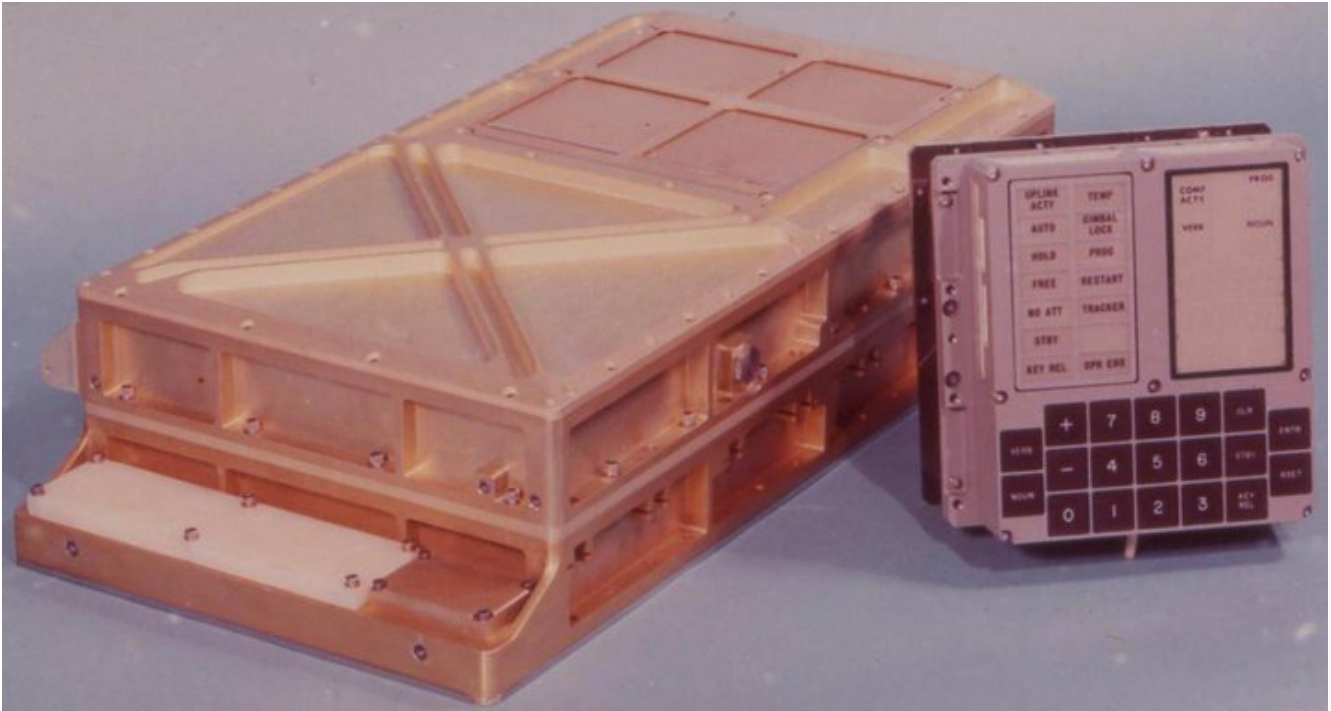
Michael Collins (born October 31, 1930) Apollo 11 command module pilot

As an aside, one has to wonder where the 'American' Big, Hairy, Audacious Goals (BHAGs) are in the 21st century. Today our country acts more like the policeman of the world and peaceful missions and programs like this are unimaginable.

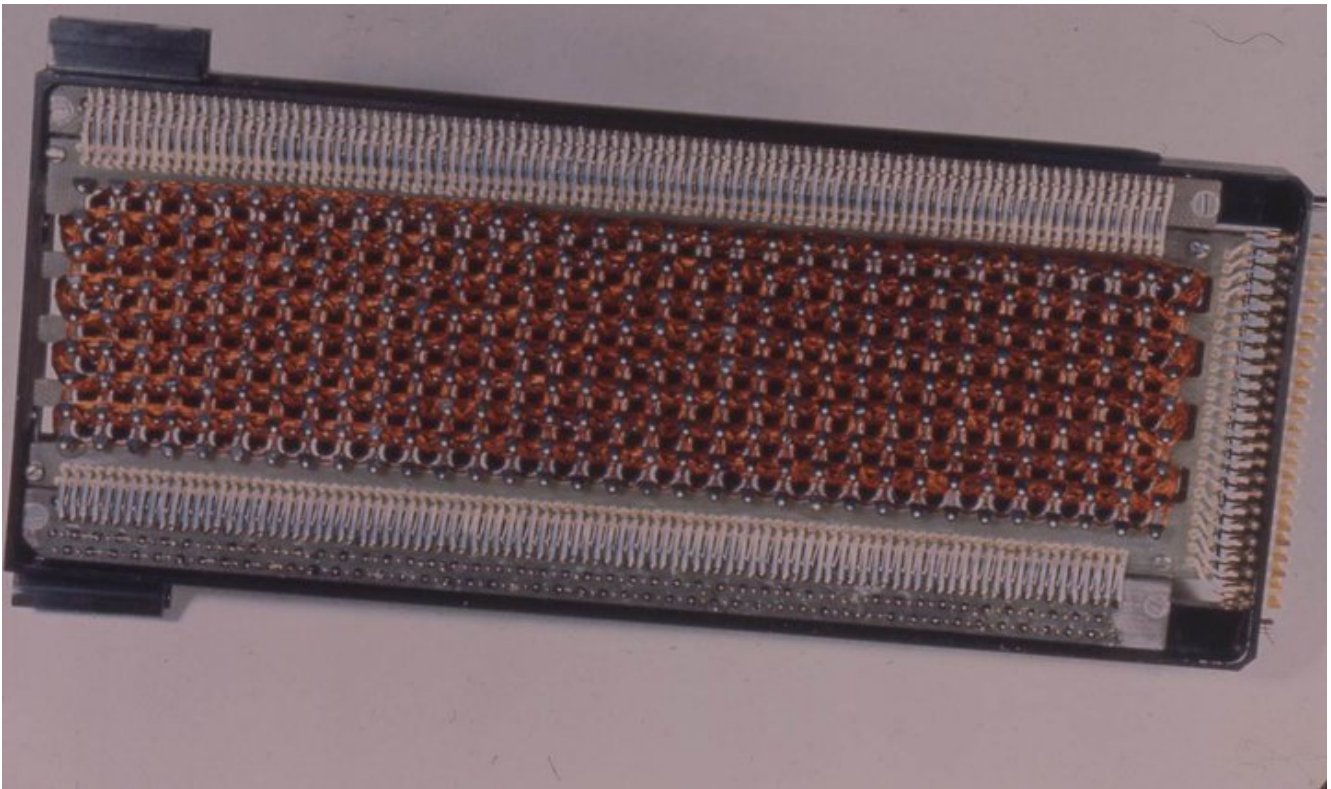
I hope you enjoy this very brief tour through a small part of America's hugely successful Apollo manned space program.

John Sutherland

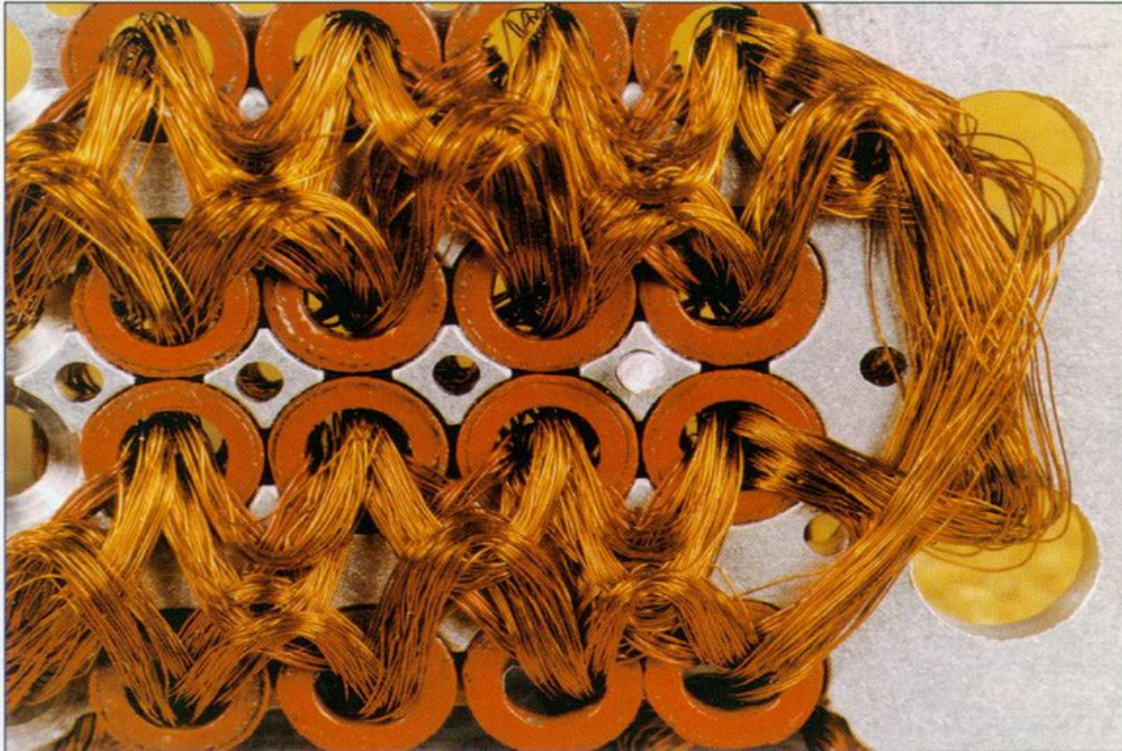
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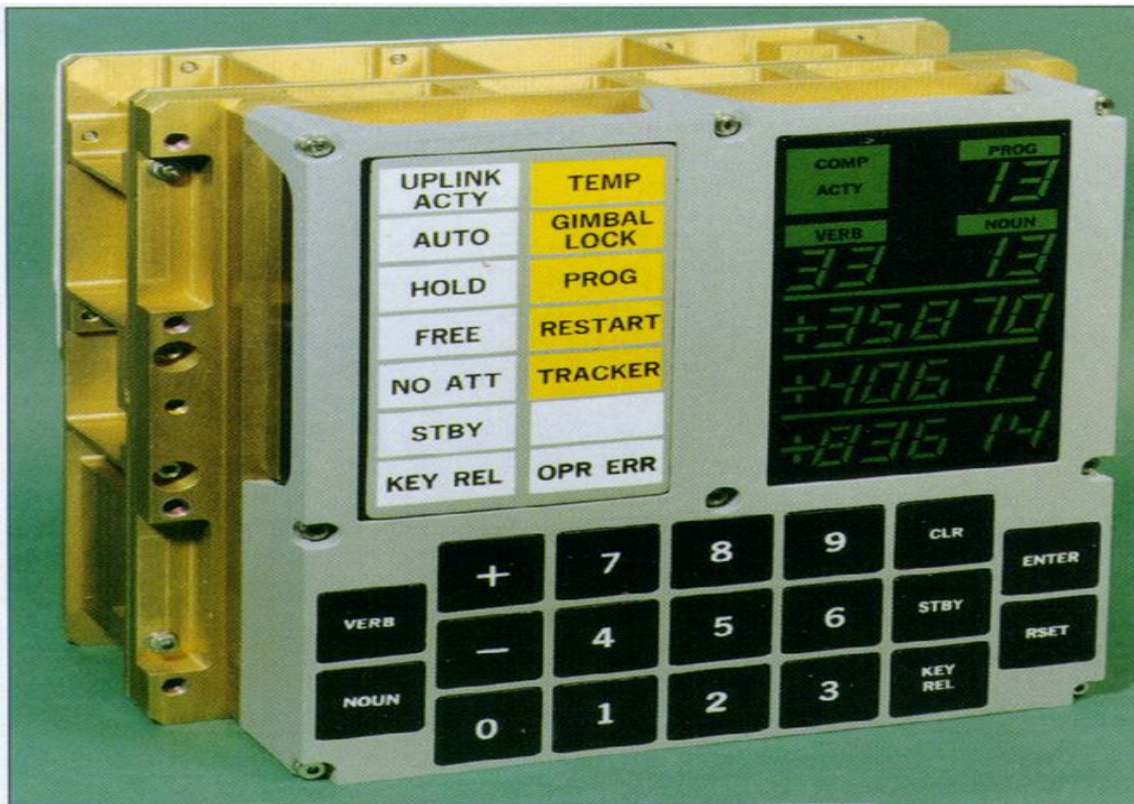
1 - This is an image of the Apollo Guidance Computer (AGC) and the operator Display Keyboard (DSKY) panel used to enter commands into the AGC. The same physical AGC hardware was used on both the Command Module (CM) and the Lunar Module (LM).



2 - The Apollo Guidance Computer had two types of memory, read-only memory and erasable memory. The read-only memory was used to store the actual computer programs, and the erasable memory was used to receive and send temporary data (e.g. telemetry data). This is a bank of read-only memory.



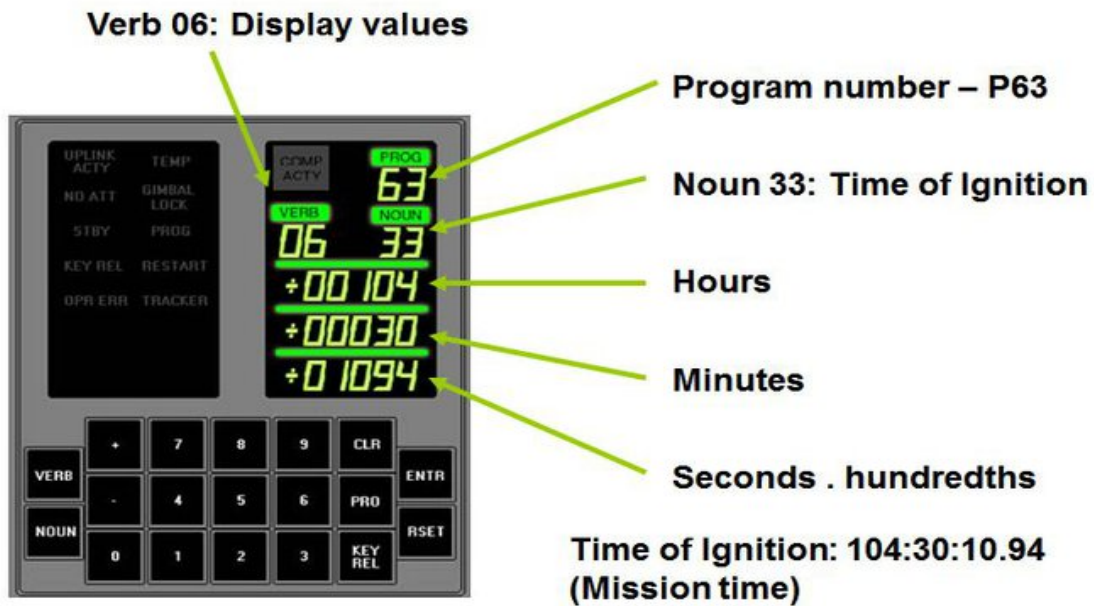
3 - Because of unknown hazards in space, the memory used in the AGC was hard wired magnetic core memory, and the technique used was to convert the software programs into the individual core memory 'donut' state prior to insertion into the actual AGC. This is a close-up of what an already hard wired core memory 'rope' looked like.



4 - This is a close-up view of the astronaut AGC Display Keyboard. The same DSKY was used in both the CM and the LM, and another photo (below, #5) shows a sample of the commands entered. Notice the keyboard number arrangement. This is believed to be the arrangement that help establish the keypad standard we all use today.

Sample DSKY Query: Time of Engine Ignition

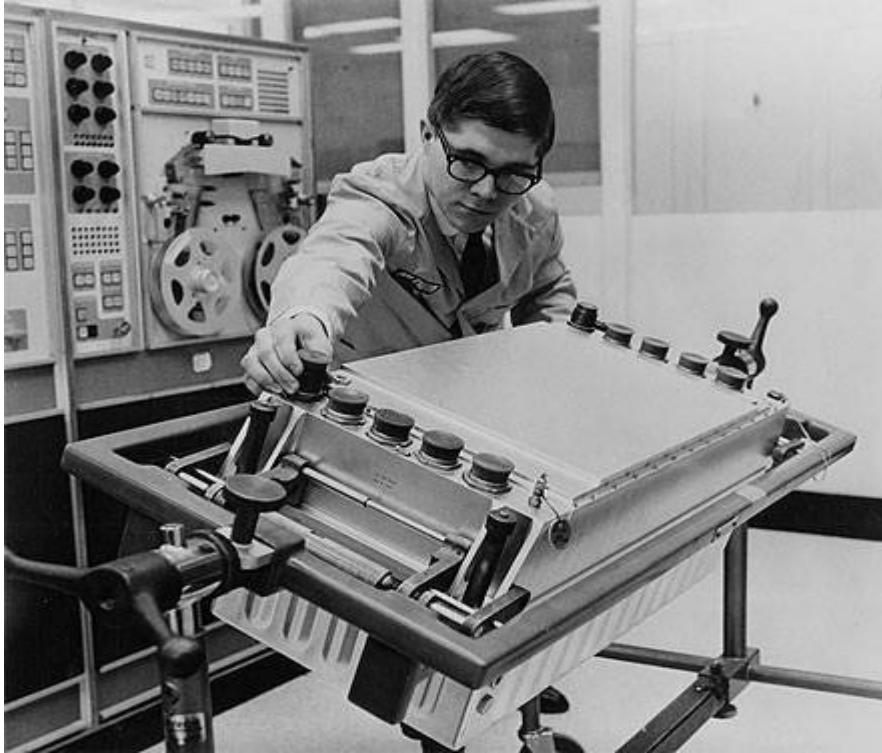
Verb 06, Noun 33: Display Time of Ignition



5 - The AGC DSKY was very primitive by today's standards for data entry, and the image above shows a sample command. The astronaut would enter a command to the AGC as the spacecraft was approaching another transition in the mission. This command is setting up the system for an engine ignition.

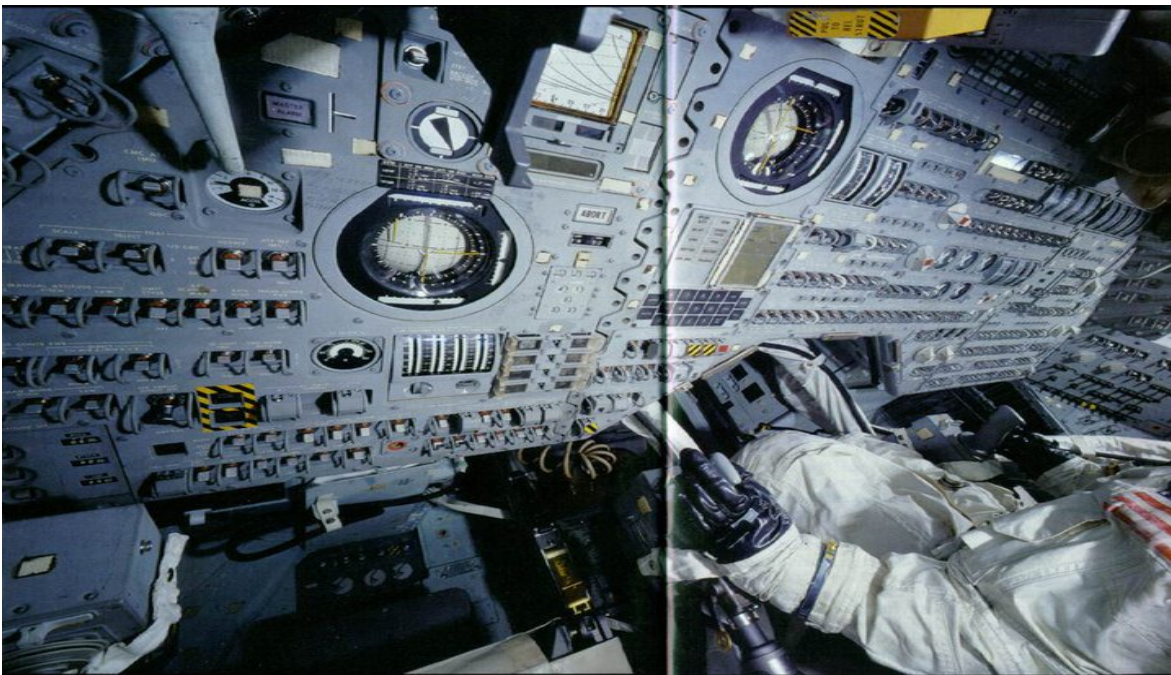
- AGC was “bleeding edge” technology
 - By the end of Apollo, hopelessly outdated!
 - Still, it was all that was needed
- Techniques pioneered in Apollo are still in use today in “modern” computers
- First time a computer required for mission success
- Best thing: The computer never failed!
- In 10 years of Apollo, design was never updated

6 - As primitive as the AGC was, it never failed, and it was never upgraded during the whole ten-year Apollo program. It just worked.



7 - This is the Launch Vehicle Digital Computer (LVDC) and Data Adapter, and as you can see, it was quite a bit physically larger than the AGC.

The LVDC was provided by IBM Federal Systems Division in Huntsville, and it included hybrid circuits similar to the System/360. The system was serial logic and provided triple redundancy. For memory storage, it had 32,768 words of 28-bit word length memory - quite small by today's standards.



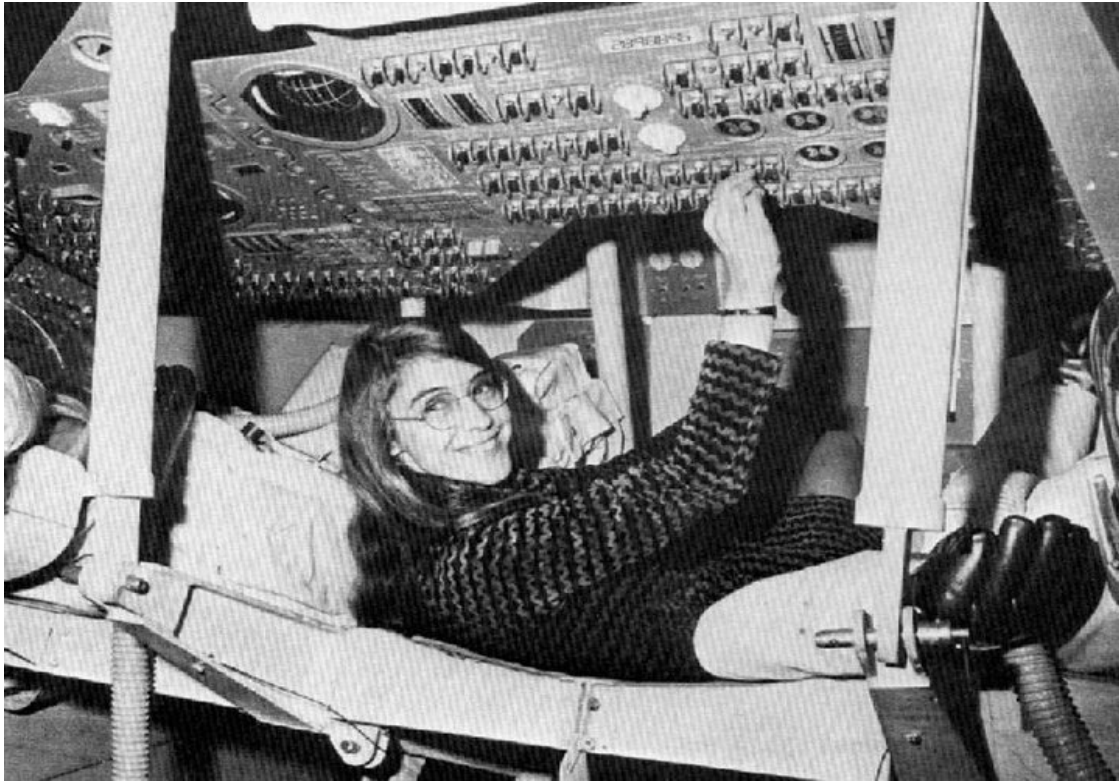
8 - This is the inside of the Command Module, and you can see the guidance computer DSKY panel in the center of the console so that it could be easily accessed by either astronaut. How would you like to sit in one of these cramped seats for hours on end? Our Apollo astronauts were the best we could find.



9 - This is another shot of the AGC DSKY in use.



10 - This is the inside of the Lunar Module, and you can see the AGC DSKY in the lower center near the astronaut's right hand, again placed close to the center of the landing module so that either astronaut could easily access the controls.



11 - At MIT, we had digital/analog simulators for both the Command Module and the Lunar Module. This is inside the CM simulator, and the operator is Margaret Hamilton, Manager, Apollo On-Board Flight Software. The process was to write some specific program, digitally test in on the IBM or Honeywell systems, and then try it in the real-time simulator. Once we felt the program was functional and ready for prime time, we would release the program to Raytheon whose job it was to hard-wire the programs into the rope memory.



12 - For Apollo 11, the big Saturn V loaded up with the Command Module, the Service Module, and the Lunar Module left the Vertical Assembly Building (VAB) on May 20, 1969 for its slow trek to the launch pad. The VAB was so large it had its own weather system inside it.



13 - On May 24, 1969 the three Apollo 11 astronauts, Neil Armstrong, Edwin (Buzz) Aldrin, Michael Collins, are enjoying a break from training.

Michael Collins was the command module pilot for Apollo 11, and while he orbited the Moon, Neil Armstrong and Buzz Aldrin made the first manned landing on the lunar surface.



14 - On July 11, 1969, the Saturn V is on the launch pad and is being prepared for launch. In this photo, you can see the top section of the Command Module (CM), just below it is the Service Module (SM), and in the tapered section below SM is the enclosed Lunar Module (LM). The white boxy structure attached near the top of the Command Module is what I recall as the 'White Room' and it provides the sheltered entry point into the CM for the astronauts. The astronauts first take an elevator to the attachment level, walk down the connecting bridge, and finally climb into the CM.



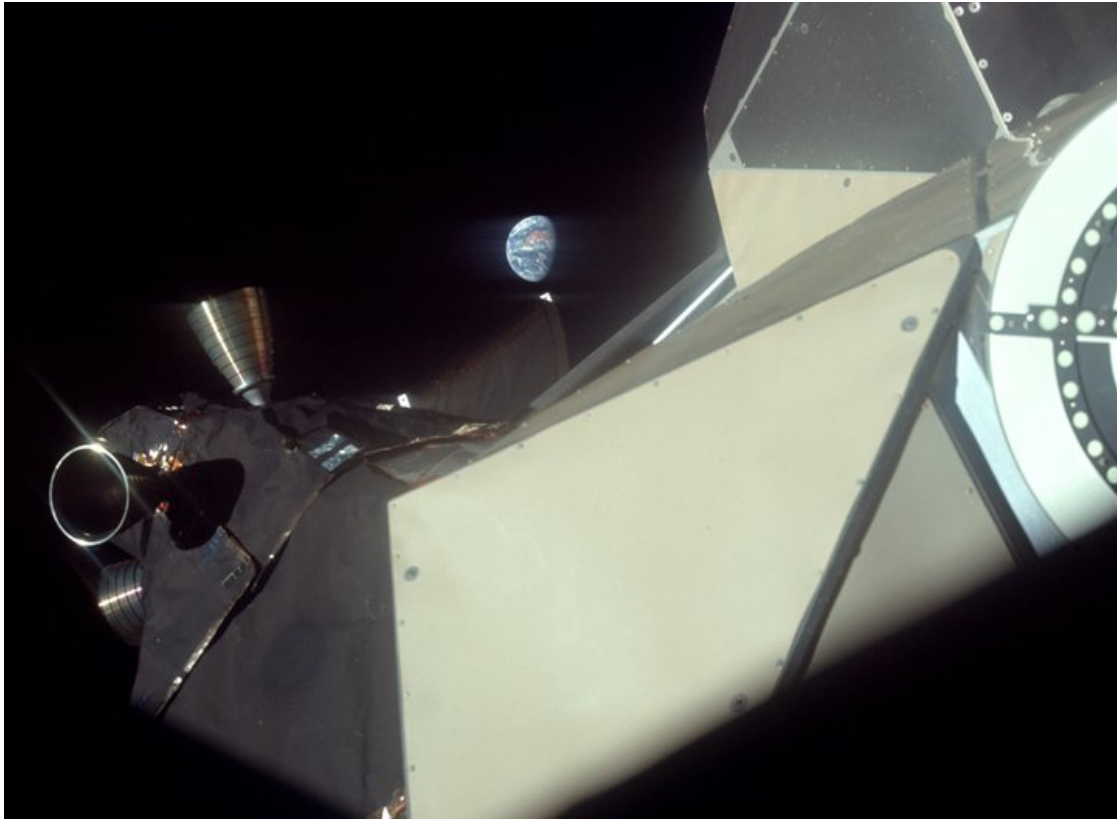
15 - On the morning of July 16, 1969, the Apollo 11 astronauts have a traditional breakfast with chief Astronaut Deke Slayton.



16 - On July 16, the Kennedy Space Center (KSC) gets ready for the launch. It is worthy of note that there were two command centers, including KSC in Florida, and the Manned Space Center (MSC) in Houston. The roles of the two facilities were bifurcated with KSC managing the launch and MSC managing the rest of the mission.

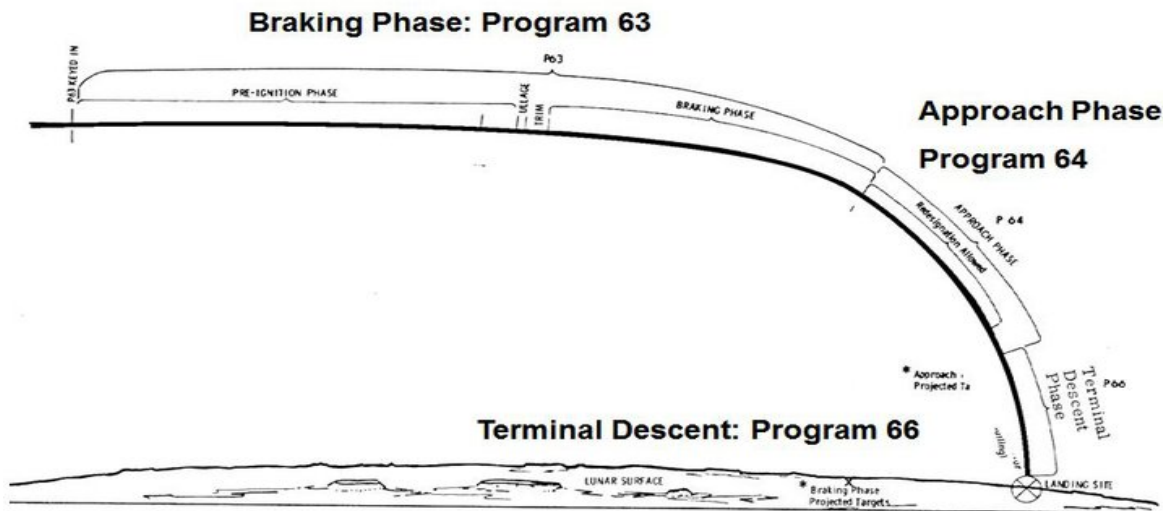


17 - Apollo 11 (AS-506) - with astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr., aboard - was launched from Pad A, Launch Complex 39, KSC, at 9:32 a.m. EDT July 16, 1969.

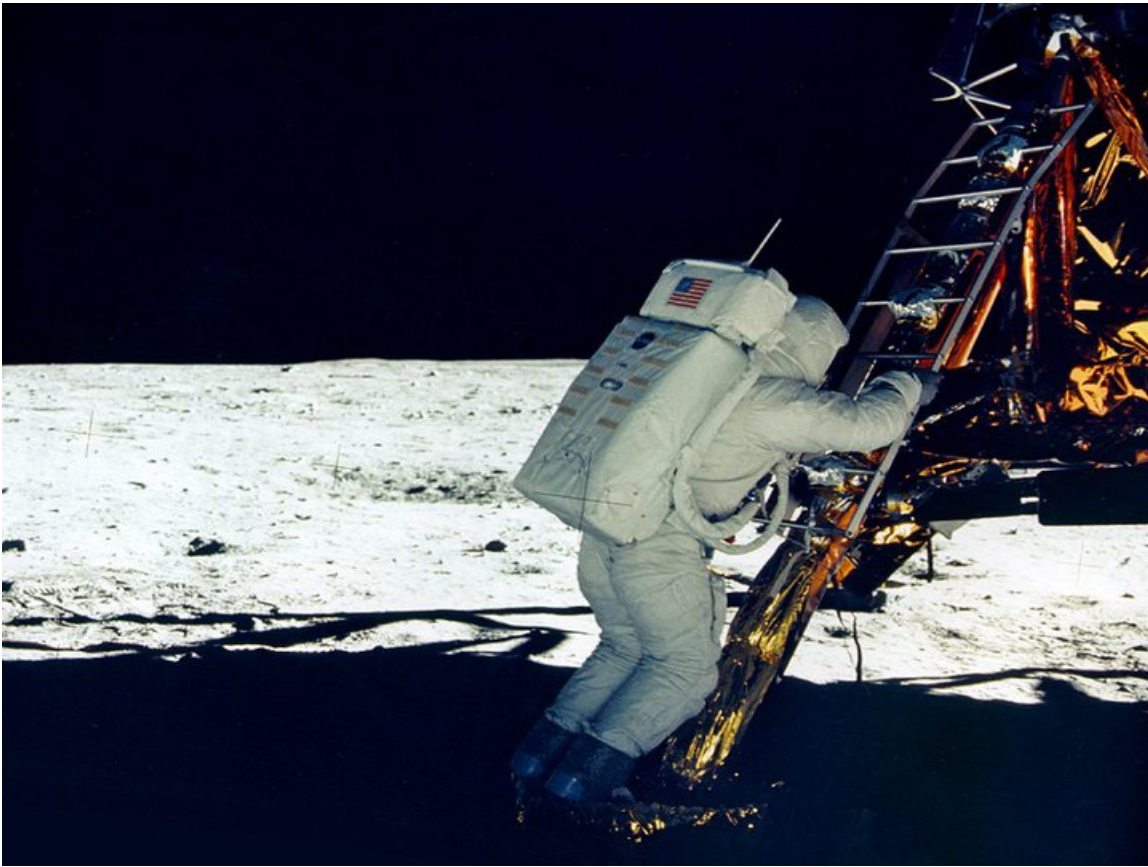


18 - In transit to the moon, one of the Apollo 11 astronauts photographed the planet Earth that they were rapidly leaving behind.

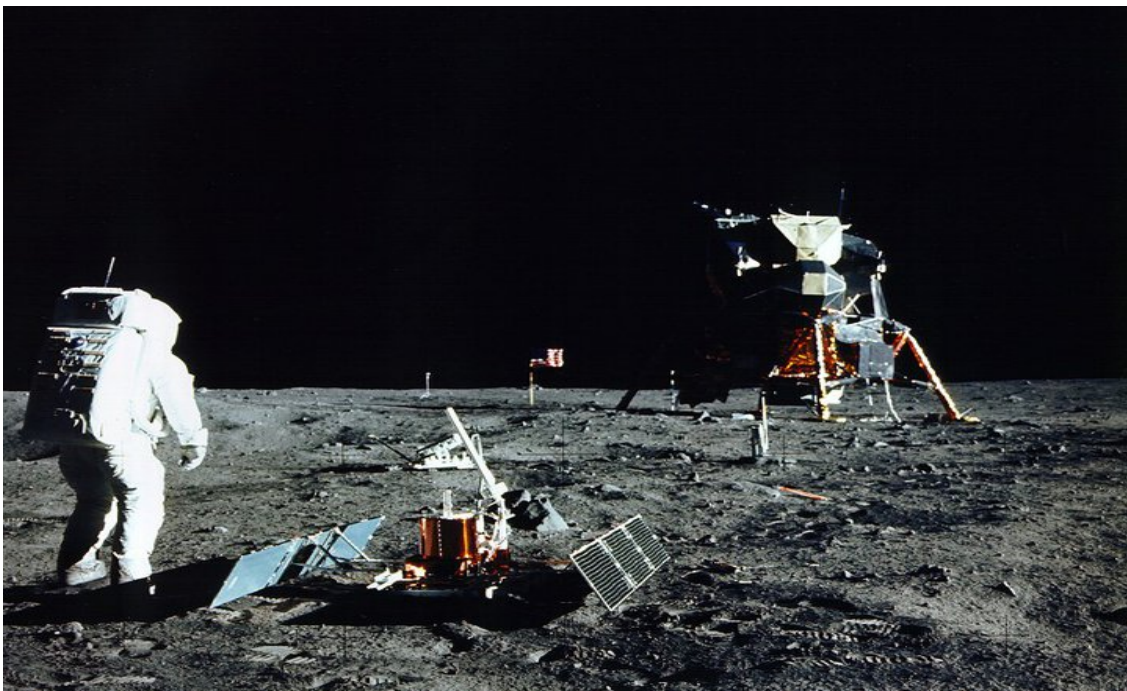
Lunar Module Descent Profile



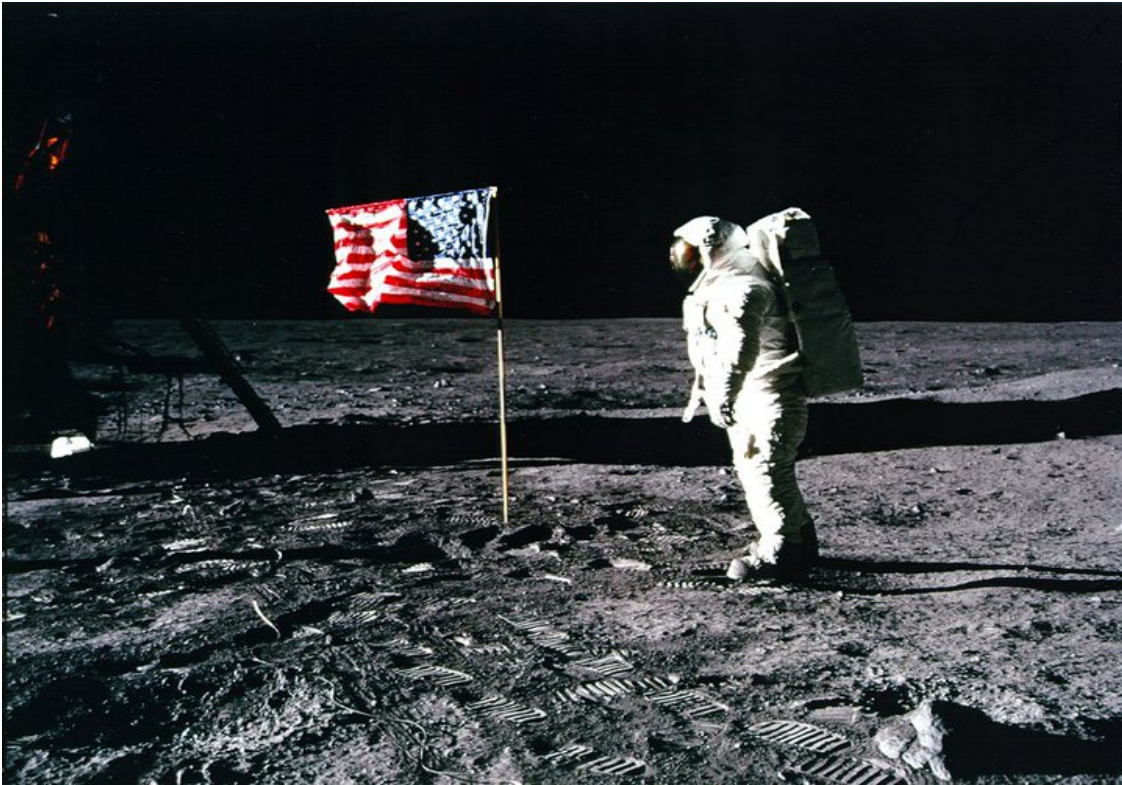
19 - The Apollo 11 three module configuration (the CM, SM, and the LM) went into orbit around the moon, and after the go ahead from MSC, separated the LM and negotiated the transfer of two astronauts from the CM to the LM. The landing crew then proceeded to land the LM on the moon along a trajectory (as depicted above) on July 20, 1969. Thinking back on the earlier images of the DSKY, you can see the 2-digit program numbers indicated in the image above that were fed into the AGC. Kinda neat, huh. There was only one hiccup in the landing when the normal mission sequences were interrupted by priority displays of 1201 and 1202 alarms, giving the astronauts a go/no-go decision to make (to land, or not to land). The decision was made to ignore the alarm and to land. The rest, as they say, is history.



20 - Neil Armstrong was the first man on the moon, and Buzz Aldrin (above) was number two. This photo of Aldrin is much better than the grainy TV image we have all seen of Armstrong's first step, and that is why I included it.



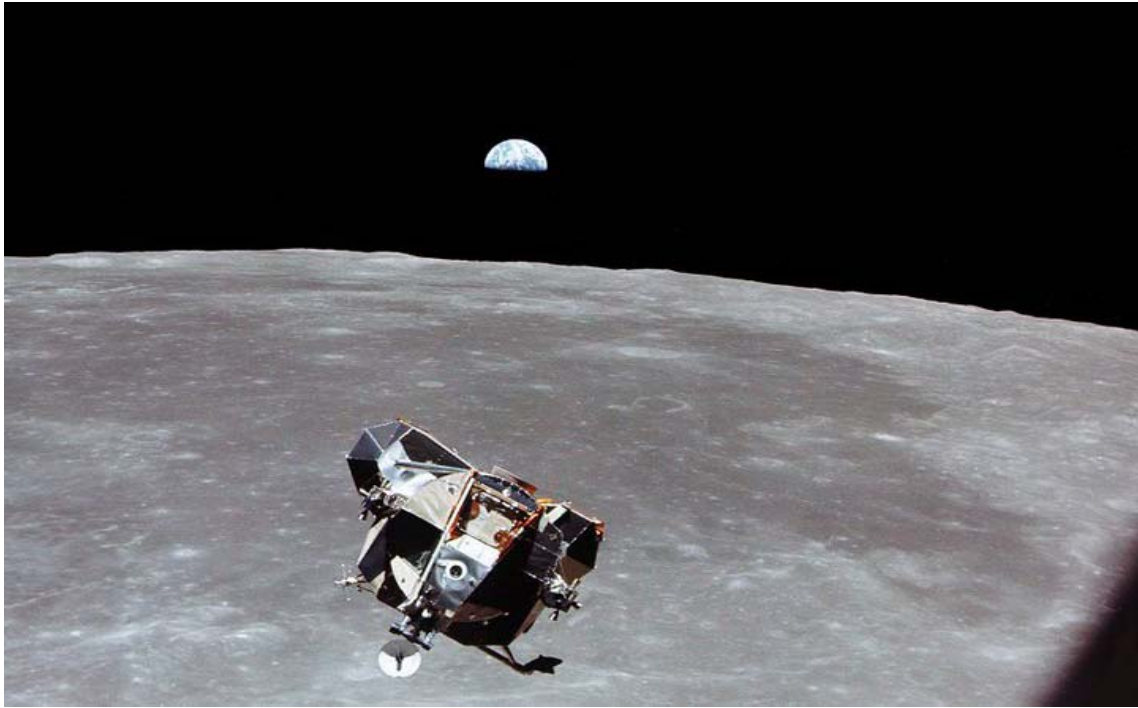
21 - In this photo, Aldrin assembled a seismic experiment. Aside from bringing back a load of moon rocks, the astronauts performed several important experiments while on the lunar surface.



22 - After the American flag is planted, Buzz Aldrin salutes it. With no wind on the moon, the extended flag was held out with a rod.



23 - After the first EVA, Neil Armstrong is clearly tired but also quite stoked by the event.



24 - At the end of the lunar excursion, the LM had to return to the Command/Service Module (CSM) for the return flight home. The Eagle lifted off from the moon at 1:54 p.m. EDT July 21, having spent 21 hours 36 minutes on the lunar surface. It docked with the CSM at 5:35 p.m. and the crew, with the lunar samples and film, transferred to the CSM. The LM ascent stage was jettisoned into lunar orbit. The crew then rested and prepared for the return trip to the earth.

This is the photo taken during its ascent of the LM and its approach to the CM. Mother Earth is in the background... a long way off.



25 - On July 21, the news of the lunar landing hits the streets.



26 - At 12:15 p.m. EDT July 24 the Apollo 11's command module Columbia splashed down in the mid-Pacific, about 24 kilometers from the recovery ship U.S.S. Hornet. Following decontamination procedures at the point of splashdown, the astronauts were carried by helicopter to the Hornet where they entered a mobile quarantine facility to begin a period of observation under strict quarantine conditions. The CM was recovered and removed to the quarantine facility. Sample containers and film were flown to Houston.



27 - Upon learning of the successful recovery of the splashed down Command Module, Mission Control celebrated wildly (as did we all at MIT and around the world).



28 - The astronauts received the biggest celebration ever in New York City. A great tribute to a hugely successful mission.

Final Comments

Thanks for reviewing my memory and history of the MIT Apollo Guidance Computer and the Apollo 11 Lunar Mission. I was motivated to compile this document after learning that Neil Armstrong had passed. I wanted for all of us to remember the 'good old days' of 1969.

MIT has provided a forty year interview of some of the Apollo managers at MIT/IL, and if you are interested in reading their comments, you will find them here: <http://web.mit.edu/newsoffice/2009/apollo-vign-0717.html>

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