Air and Space this Week

Item of the Week

APOLLO NON-CREWED

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Most Americans know about the Apollo Program and its "small step." Many may know something about the Programs that preceded Apollo: Mercury and Gemini. Their launches used boosters derived from military hardware. Apollo was a civilian Program, and there were no military rockets the size of the ones needed to send people to the Moon.

The Saturn missile and Apollo CSM required a lot of engineering, testing, and quality control. Twenty-three launches of various types were required before the first Apollo mission with a crew, Apollo 7, was ready to fly.

NEEDED: VEHICLES TO LAUNCH, FLY TO THE MOON, AND LAND THERE

President Kennedy's charge to land a crew on the Moon and return required the creation of an entire new transportation system, comprising a rocket far larger than any built previously, a spacecraft capable of flying from Earth orbit to lunar orbit and back home, and a spacecraft that could go from lunar orbit to the surface and back. Add to that daunting task the ancillary and supporting equipment and technology, and the management system large enough to handle it all effectively. And don't forget it all had to be done in a few short years!

[JFK had set the goal in a speech delivered to a Joint Session of Congress on May 25, 1971. If "decade" in the speech is taken to mean "10 years," then NASA had until May 25, 1981 to accomplish the mission. If "decade" meant the 1960s, then NASA had until December 31, 1970 to accomplish the mission (1970 is a part of the Sixties just as the New Millenium didn't end until December 31, 2000! Still don't believe count the years from the Year 1. It's Year 1 from January 1, 0000 to December 31, 0001; Year 2 from ditto; and the decade of ten years is not complete until Year 10 is complete!).]

But NASA knew that the American public would take "decade" to mean that it ended on December, 1969, and set their goal accordingly.

I do not desire to recapitulate the 526-page Apollo Program Summary Report JSC-09423 here (!), but I do want to share info about the flight test program for Apollo prior to any crews being launched.

A BASIC DESIGN

Military imperatives during the Korean Conflict and the Cold War of the rest of the 1950s ensured that rocket technologies of all types would develop rapidly. The creation of a civilian Agency, NASA, to handle the manned Space Program changed things somewhat, but many of the same contracting companies that built military rockets were also tapped by NASA to build rockets for Space and Moon exploration, so there was some technological “cross-talk.”

The general procedure followed was to assess the state of the prevailing technology (1961) that would be needed, and estimate which necessary technologies that have to be developed to accomplish the mission. Once the available tools have been identified/developed, then the mission profile plan can be developed. With that, the size and characteristics of the rocket necessary, the characteristics of the Spacecraft and life-support systems can be determined, and a system to land astronauts on the Moon can be developed.

STEP ONE: DEVELOP THE MISSION PROFILE

Three basic mission plans made sense enough to NASA managers for them to be investigated fully: Direct Flight from Earth (DFE); Earth-Orbit Rendezvous (EOR); and Lunar-Orbit Rendezvous (LOR). Each plan had strengths and weaknesses, but the rigidity imposed by NASA treating JFK’s deadline as gospel and by the engineering difficulties that would obviously be encountered in creating really big rockets proved to be decisive in plan selection.

The DFE had the advantage of being the simplest: build a giant rocket that carries everything to the lunar surface and returns. The fatal drawback with the size of the rocket necessary – much larger than the Saturn V that was eventually used, so DFE was almost immediately rejected.

EOR involved launching the Moon rocket in pieces to Earth orbit, and assembling and fueling it there. No too-big-to-build rocket would be needed, however a bunch of smaller-yet-much-bigger-than-any-built-to-date rockets would be needed, and engineers were unsure as to how rendezvous, docking, and assembly in Space would play out. There were too many points of failure in this plan for NASA to stomach.

That left LOR as the only plan left standing, and on July 11, 1962, the base plan was approved. A really large rocket would still be required to launch the spacecraft, its support systems, and a lunar landing vehicle of some sort. Apollo would launch everything to Earth orbit, reconfigure the spacecraft elements for going to the Moon and back, restart the engine and head to the Moon, use the engine again to enter lunar orbit, detach a landing craft that could land and return to lunar orbit, then fire the engine yet again to return home.

The upside of the LOR plan was its relative simplicity in development and overall do-ability, with only one launch required. However, the downside was if anything happened while performing as-yet untried rendezvous and docking at the Moon, the astronauts would be lost in Space without prospect of rescue. Imagine the public outcry! There was no other choice for the otherwise notoriously risk-averse NASA, so they forged ahead, as only NASA could!

I'm going to focus primarily on the "big enough rocket" needed by Apollo. Projects Mercury and Gemini focused on basic spacecraft technology, especially propulsion and life support, and some of the basic skills needed for the Apollo mission profile, such as rendezvous and docking. The Lunar Module that would take astronauts from and back to lunar orbit is another story in its entirety, and was not flight-tested until *Apollos 9* and *10*, so I'll leave that part out, too.

STEP TWO: BUILD AND TEST A BIG ENOUGH ROCKET

Military rocketry was advancing anyway, as previously mentioned, but the size and weight of a spacecraft(s) that could accomplish the mission, along with the fuel required, was far beyond the lift capacity of any rocket in existence or on the drawing board.

NASA engineers had been thinking about Big Rockets for some time, spurred on by enthusiasts such as Wernher von Braun and his "Paperclip" gang. They knew about how big a Moon rocket would have to be, and knew that it would be better and faster to build a smaller version that would allow more rapid and complete testing of the technologies needed for its larger brother. They called the rockets "Saturn."

A TEST FLIGHT PROGRAM

NASA was extremely busy during the 1960s, even before JFK's speech. Tests using the V-2 and subsequent rocket types were being conducted at White Sands in New Mexico in the early 1950s. Some included test animals, such as Yorick, Able, and Baker.

A slew of 8 "Little Joe" tests and launchings took place in 1959-1961 at Wallops Island in advance of the two Mercury sub-orbital flights, and three more of the Mercury/Redstone system before engineers were confident enough to risk Al Shepard and Gus Grissom. Another test flight, starring Enos the Chimp, was needed to certify the Mercury-Atlas system for the remaining crewed flights of the Mercury Program. The Saturn development program began testing before John Glenn's flight, and Gemini system testing began as soon as Project Mercury was completed. The was considerable interleaving of the launches in the different programs, as shown on the table below, which does not include all of the launches in the planetary exploration program, Pioneers and Mariners.

NASA Manned Space Program Launch Chronology
Showing Interleaving Between Crewed and Test Flights, But Not Planetary Missions

Crewed missions are in bold font
Saturn/Apollo uncrewed missions are in red font

LAUNCH DATE	MISSION	DESCRIPTION
8/21/59	Little Joe 1	Test of Mercury Launch Escape System (failed: pre-launch ignition)
9/9/59	Big Joe	First test of Mercury capsule with Atlas missile
10/4/59	Little Joe 6	Test of Mercury capsule aerodynamics and integrity
11/4/59	Little Joe 1A	Test of MLES in flight with boilerplate capsule
12/4/59	Little Joe 2	MLES test in flight with Sam the Rhesus Monkey

1/21/60	Little Joe 1B	Maximum-Q MLES test with Miss Sam the Rhesus Monkey
11/8/60	Little Joe 5	MLES test at Max-Q with production capsule (failed)
11/21/60	MR-1	First non-crewed test of the Redstone with Mercury Capsule (failed)
12/19/60	MR-1A	First successful test of the Redstone with Capsule
1/31/61	MR-2	HAM the Chimp Leads the Way
3/18/61	Little Joe 5A	Second MLES test with production capsule (failed)
4/28/61	Little Joe 5B	Final, and finally successful, test of the MLES with production capsule
5/5/61	**MR-3**	**Alan Shepard's sub-orbital flight**
7/21/61	**MR-4**	**Gus Grissom's sub-orbital flight**
10/27/61	SA-1	First launch of the Saturn I
11/29/61	MA-5	Enos, the First Chimp in Orbit – test of Mercury/Atlas orbital system
2/20/62	**MA-6**	**John Glenn's first American in orbit flight**
4/25/62	SA-2	Second launch of the Saturn I; Project High Water
5/24/62	**MA-7**	**Scott Carpenter's orbital flight**
10/3/62	**MA-8**	**Wally Schirra's orbital flight**
11/16/62	SA-3	Third launch of the Saturn I; Project High Water II
3/28/63	SA-4	Fourth launch of the Saturn I; Engine-out Capability Test
5/15/63	**MA-9**	**Gordon Cooper's orbital flight**
1/29/64	SA-5	First Block II Saturn launch
4/8/64	Gemini I	Uncrewed test of capsule and heat shield
5/28/64	SA-6	First Apollo capsule (boilerplate) launch
9/18/64	SA-7	Second Apollo capsule (boilerplate) launch
1/19/65	Gemini II	Uncrewed test of capsule and heat shield
1/16/65	SA-9	Third boilerplate launch; Pegasus I micrometeoroid satellite
3/24/65	**Gemini III**	**First crewed Gemini mission; Grissom and Young**
5/25/65	SA-8	Fourth boilerplate launch; Pegasus 2 micrometeoroid satellite
6/3/65	**Gemini IV**	**First Space Walk; McDivitt and White**
7/30/65	SA-10	Fifth boilerplate launch; Pegasus 3 micrometeorite satellite
8/21/65	**Gemini V**	**Week-long flight; first fuel cell use; Cooper and Conrad**
12/4/65	**Gemini VII**	**Two-week flight; Rendezvous w/ Gemini VIA; Borman and Lovell**
12/15/65	**Gemini VI-A**	**Rendezvous with Gemini VII; Schirra and Stafford**
2/26/66	AS-201	First flight of Saturn IB
3/16/66	**Gemini VIII**	**First docking; aborted by thruster malfunction; Armstrong and Scott**
6/3/66	**Gemini IX-A**	**Rendezvous but no docking with ADTA; Stafford and Cernan**
7/5/66	AS-203	First S-IVB stage orbital mission
7/18/66	**Gemini X**	**First use of docked Agena propulsion; Young and Collins**
8/25/66	AS-202	Apollo development flight
9/12/66	**Gemini XI**	**More use of Agena; highest Gemini altitude; Conrad and Gordon**
11/11/66	**Gemini XII**	**More rendezvous and docking; Lovell and Aldrin**
11/9/67	Apollo 4	First launch of entire Saturn V
1/22/68	Apollo 5	First test of Lunar Module in Space
4/4/68	Apollo 6	Final Uncrewed Apollo Test Flight
10/11/68	**Apollo 7**	**First Crewed Apollo mission – Earth Orbit Shakedown Flight**

DESCRIPTION OF THE TEST MISSIONS

EIGHT "LITTLE JOE" MISSIONS AND ONE BIG JOE

STEP THREE: DESIGN AND BUILD A SUITABILE CAPSULE and LIFE SUPPORT SYSTEM

Project Mercury's capsule had to withstand strong aerodynamic forces and the fierce heat of re-entry into the Earth's atmosphere. NASA built a special solid-fuel single-stage booster they named "Little Joe" for eight tests, conducted at Wallops Island, prior to launch of the crewed Mercury flights. NASA also wanted to start matching the Mercury capsule with the Atlas missile and tested the combination during the "Big Joe" flight from the Cape. The Little Joe booster was a cluster of four small rockets encased in a larger cylinder. In cross section, the location of the four rockets resembled a pair of dice showing double twos – "Little Joe" in craps parlance!

Little Joe 1 (8/21/59) was a test of the Mercury Launch Escape System (MLES). It was intended to launch and have the MLES system activate when the booster was hitting maximum aerodynamic stress. The MLES suffered an un-commanded activation a half-hour before the scheduled launch. The MLES pulled the capsule off the booster and, at an altitude of 610 meters, the MLES rocket separated from the capsule. An electrical transient in the MLES system was responsible for the premature firing.

Big Joe (9/9/59) was the first launch of the Mercury capsule (boilerplate) atop an Atlas missile, a combination to be used for the orbital flights on the Mercury schedule (the Redstone did not have enough oomph to reach orbit). The Atlas' outboard booster engines did not separate as planned from the centerline sustainer engine when they ran out of fuel. The mission profile was for a sub-orbital flight, but the extra weight of the outboard boosters caused the splashdown to be about 500 miles shorter than expected, which proved to put more stress on the capsule than planned. The capsule was recovered successfully and withstood all forces and re-entry heat well. There was no need for a follow-on test, so the planned Big Joe II flight was cancelled.

Little Joe 6 (10/4/58) is out-of-sequence for an unknown reason and not well-documented; one source says it was a MELS test, another suggests it was more a capsule aerodynamics and integrity test. In either case, LJ-6 was Little Joe launching an instrumented boilerplate Mercury capsule on a parabola ~37 miles high and ~79 miles downrange. At lot of the attention at the Cape at this time was analyzing the results of the Big Joe test.

Little Joe 1A (11/4/59) was the same high-Q test of the MELS system that failed so pathetically on LJ-1. The pressure-sensing system activated the explosive bolts to separate the capsule from the booster as planned, but the igniter on the escape rocket was supposed to fire at the same time. It didn't at first, and the capsule separated, but at a lower-than-planned speed, making the test a failure.

Little Joe 2 (12/4/59) was another high-Q MELS test, but with SAM a rhesus monkey aboard (USAF **S**chool of **A**viation **M**edicine). MELS worked as planned, the spacecraft was stable under drogue parachute, and SAM did OK. Finally, a success! Al and Gus attended the launch…

Little Joe 1B (1/21/60) was NASA's hope that the third time with the LJ-1 profile would be the charm. The engineering objectives were the same, but this time NASA would also be assessing the effect of a high-Q MELS activation would have on an astronaut. Miss SAM, a rhesus monkey, would be the test animal. The MELS worked as planned, and Miss SAM was unharmed, however, she did experience eye nystagmus during the escape rocket firing and water impact, raising concerns among Mercury doctors that astronauts might be similarly affected and impaired.

Little Joe 5 (11/8/60) was the first MLES test made with a "production" Mercury capsule rather than a boilerplate test capsule. The escape rocket motor ignited prematurely, 15 seconds after launch, but the capsule did not separate and was destroyed in the resulting crash. There would be two follow-up Little Joe launches in the sequence, but first there were three tests of the Mercury/Redstone combination.

For some reason, there are no entries in the NASA Space Science Data Coordinated Archive for **Little Joes 3**, **4, or 6 or Big Joe.**

OTHER PROJECT MERCURY TEST FLIGHTS

Mercury/Redstone 1 (11/21/60) became known as the "Four-Inch Flight," one of NASA's early ignominious failures. The mission was to test MR-1 and its automatic systems as part of the "man-rating" the MR system. The Redstone ignited, the rocket stirred, then the engine shut down, the escape tower blew (leaving the capsule behind), and the recovery parachutes draped the rocket like a shroud. At least it didn't blow up on the pad. Yet. The gantry had pulled away, and the capsules retrorockets and the self-destruct charges were a cause of considerable concern. Ideas abounded as to how to "safe" the situation, including some rather hare-brained (*e.g.* shooting holes in the Redstone to depressurize it), but Chris Kraft kept his cool and let the oxidizer slowly boil off and let the on-board battery discharge. The lonely, wobbly, Redstone sentinel remained that way overnight before technicians could render the MR-1 safe. Investigation that morning showed that two cables to the booster, control and power, disconnected in the wrong order by 29 msec. The capsule's sensors controlling the capsule separation were set to do that near zero-g conditions, at the top of the rocket's ballistic arch, but they continued to read 1g sitting still, so the capsule did not separate. The firing of the escape rocket activated the parachute sensors, set to fire when lower than 10,000 feet, which they were so they did. What a mess! But it was an important learning opportunity.

Mercury-Redstone 1A (12/18/60) was a repeat of the MR-1 mission. This time the whole system worked nearly perfectly. The only slight deviation was that the speed at booster engine cut-off was all of 80 m/s higher than planned. The rocket and capsule had checked out. Now only one test remained: HAM.

Mercury-Redstone 2 (1/31/61) was a full-up test of the MR system and a check on how a primate could withstand the forces of the flight. A chimpanzee named HAM, for **H**olloman **A**erospace **M**edical Center, got the call. The flight proved to be a shaky dress rehearsal. The thrust control on the booster functioned too well, giving the rocket a higher speed than planned. The booster ran out of fuel a half-second before the controlling mechanism was due to deactivate the abort pressure sensor. The system detected the premature shut-down and activated. The over-thrusting booster, coupled with the boost from the escape rocket, caused the capsule to overfly its expected landing zone by about 140 miles, more than 60 miles from the nearest recovery ship. Poor HAM ended up enduring a peak g-load of 14.7, more than 3g over that planned. The air inlet schnorkel valve malfunctioned during the flight, dropping cabin pressure precipitously, but HAM's suit protected him. It took over two hours for the recovery ships to recover the capsule. HAM appeared to have withstood the flight well, although his post-flight behavior clearly indicated he wanted nothing more to do with a Mercury capsule! OK, Al, the booster was too strong, the capsule leaked air, and it proved to be a bumpy ride. Even the chimp wants no part of it. Ya ready to go?

He was and he did. Gus, too. Both crewed Mercury-Redstone missions (MR-3 and MR-4) were successful, with one serious glitch. The escape hatch on Gus' Liberty Bell 7 capsule blew out prematurely, before the capsule, and Gus, had been secured. Gus had already removed his helmet when the capsule began to sink. The Mercury spacesuit was waterproof when the helmet was on, and there was a rubber dam around the astronaut's neck that was supposed to keep water out, but it didn't. Gus almost drowned like high-altitude balloonist Victor Prather did during a spacesuit test, one day before Al's flight (see item about Prather below in the News: Humans in Space section).

The remaining four Mercury crewed flights all used the Atlas missile to boost them into orbit. But first there had to be a primate test of the Mercury-Atlas system.

Mercury-Atlas 5 (11/29/61) HAM may have wanted no more rocket flights, but Enos the Chimp answered the call. The mission plan called for a three-orbit flight, the same as planned for the first two crewed MA flights. The Atlas booster functioned as planned, placing MA-5 in Earth orbit without problem. However, the attitude control thruster developed an anomaly (caused by a paint chip in its fuel), and the capsule slowly yawed. The automated system would fire thrusters to move the capsule back into proper attitude, but the drift/correct cycle continued, depleting thruster fuel faster than planned. The third orbit was cancelled, and MA-5 splashed down and was recovered about 75 minutes later.

TESTING THE SATURN I AND SATURN V (AND GEMINI, TOO)

After the MA-5 test flight, the rest of Project Mercury was a "go!" But the four remaining crewed missions were not the only flights on NASA's schedule. After the MR-4 flight, NASA began testing the Saturn I missile, a test program that would extend past the end of Project Gemini. Two non-crewed Gemini test flights were in the mix, too. The idea was that Project Gemini would allow the equipment, flight skills, and procedures needed for the eventual Moon landing to be developed, while the Saturn-Apollo test program would develop the launchers and spacecraft needed for the Moon landing to be developed.

Saturn-Apollo 1 (10/27/61) The Saturn I test program began three months after MR-4 (Grissom) and six months before MA-6 (Glenn). The smaller Saturn was had ten times the thrust of the Juno I rocket that launched *Explorer 1*, the USA's first satellite. The new rocket was large and complex, so NASA decided to test each stage separately, using boilerplate "dummy" stages where necessary. SA-1 was a test of the S-1 first stage, with two dummy stages atop. The booster performed flawlessly.

Saturn-Apollo 2 (4/25/62) was launched after Enos (MA-5) and John Glenn (MA-6), but before the flights of Carpenter and Schirra. It was a test of the new cluster of eight H-1 engines installed in the first stage of the Saturn I. In addition to the new engines, internal baffles were installed in the fuel and oxidizer tanks to minimize sloshing-caused destabilizing weight shifts. Ballast water was being used in the dummy stages in the SA launch series to give them the proper weight. For SA-2, provision was made to explode the booster in order to dump that water at the apex of the SA-2's trajectory, in an experiment called "Project Highwater." The resulting cloud of water/ice would help scientists investigate the nature of the ionosphere and the behavior of ice in Space. Both the H-1 engines and Project Highwater were a success.

Saturn-Apollo 3 (11/16/62) was launched after Schirra's Mercury flight (MA-8), at the height of the Cuban Missile Crisis. SA-3 was another test of the Saturn I's first stage, this time with a full load of fuel aboard. SA-3 was fitted with retro-rockets, to test part of a stage separation system needed later in the Project. A number of engineering tests were made before/during/after the flight. The booster's dummy stages were equipped to explode at the apex of the rocket's trajectory, part two of Project Highwater. This flight was deemed successful, in spite of a few communications, control, and other glitches.

Saturn-Apollo 4 (3/28/63) was the second Saturn test flight sandwiched between the Mercury flights of Schirra (MA-8) and Cooper (MA-9). This time, engineers wanted to test the performance of the Saturn first stage if one of its engines failed, or in this case, was turned off about 100 seconds after launch. The booster performed flawlessly, both before and after one engine went off line. Fuel was properly re-directed to the functioning engines, and the non-firing engine did not cause/suffer additional problems or damage.

Saturn-Apollo 5 (1/29/64) was launched after Gordon Cooper's day-long MA-9 flight finished off Project Mercury. It was the first "Block II" Saturn launches, comprising the already-tested first stage (with larger fuel tanks and new-and-improved H-1 engines) with a live second stage, the S-IV (which would be used as the third stage on a Saturn V). The booster would carry a full fuel load for the first time. This would be the first Saturn orbital mission, and it was generating excitement at both NASA HQ and the White House. JFK would refer to larger-than-the-Russians' size of the Block II Saturn in a speech on November 21, 1963. That's right, the day before he was assassinated. The scheduled launch on 1/27 had to be scrubbed because of an issue with fueling the booster. Two days later, the problem was fixed, the rocket fueled up, and off it went. Everything went perfectly, proving that NASA had rockets as big as the Russians'.

Gemini I (4/8/64) was the first test flight of the production Gemini capsule and heat shield. The Gemini booster, the Titan II, was already in (military) service, but the mating of the two and the Gemini capsule's structural integrity had to be tested. The Titan II performed flawlessly, putting the joined capsule and Titan second stage (as planned) into orbit. It made three orbits then came down over the South Atlantic, exactly as planned. (NSSDC entry)

Saturn-Apollo 6 aka AS-101 (5/28/64) was the first Saturn I launch with a boilerplate Apollo Command Module aboard, rather than the "Jupiter nose cone." It was an additional test of the Saturn I launch vehicle, and a test of how the booster performed with an Apollo-shaped payload. The rocket and its sub-systems worked well, although one of the eight H-1 engines in the first stage shut down 24 seconds early (a good un-planned test). Extensive use of engineering telemetry (even ejecting and recovering cameras take aloft) helped plan upgrades for the Saturn IB and Saturn V rockets being developed. The spacecraft destructively re-entered the Earth's atmosphere on its 50th orbit two days after launch.

Saturn-Apollo 7 aka **AS-102** (9/18/64) was next, a test similar to that of SA-6, but with the escape rocket attached for a jettison test. All test objectives were met successfully, which provided final verification of the Saturn I propulsion, guidance, and structural systems; and the jettison test was successful, too. The boilerplate Command/Service Module (CSM) further showed that it was compatible with the Saturn S-IV stage, as it needed to be for the crewed Apollo missions.

Gemini II (1/19/65) was another test of the Gemini capsule and its heat shield, with a sub-orbital mission profile rather than a plan to orbit like Gemini I. The mission went very well. The automated control system worked as expected, the adapter and retro-rocket sections jettisoned after use as planned, and the heat shield held up to re-entry speeds without damage.

Saturn-Apollo 9 aka **AS-103** (2/16/65) was the third Apollo capsule boilerplate launch. NASA had become more aware of the possible hazard posed to objects in Earth orbit by meteoroids and rocket/satellite debris, so NASA used SA-9 to launch the first of three Pegasus micrometeoroid detectors that were attached to the S-IV upper stage, remaining there after the escape tower then the boilerplate CSM were jettisoned. The Pegasus experiment was folded beneath the CSM and were unfurled after it was gone, unfolding its instrumented "wings" to a span of 96 feet; micrometeoroid impact on the wings would be detected and that info relayed to Earth. The Pegasus detectors also generated data regarding durability of electrical components exposed to Space, and how thermal control systems and coatings fare under Space conditions. I could find no reason why the SA-9 mission launched before SA-8!

The crewed Gemini missions began after the flight of SA-9, but Saturn test flights would continue during and after them. Gemini III launched on 3/24/65 (Grissom and Young). Launches followed about one a month!

Saturn-Apollo 8 aka AS-104 (5/25/65) was a repeat of SA-9, complete with Pegasus 2. Both SA-8 and Pegasus 2 performed as planned.

Gemini IV (6/3/65), which featured the first USA Spacewalk (by Ed White) came next; it was completely successful (OK , one of Ed's gloves drifted away during the walk and is still in orbit).

Saturn-Apollo 10 (7/30/65) was the final test of the Saturn I system; it also carried the third and final Pegasus micrometeorite detector. All systems were "go!" and NASA was getting ready for the upgraded Saturn, the Saturn IB.

The transition between the Saturn I test program and the test program for its successor, Saturn IB caused a seven-month hiatus in Saturn flight test, filled with the next three crewed Gemini missions: Gemini V (8/21/65), Gemini VII (12/4/65), and Gemini VI-A (12/15/65).

Apollo-Saturn AS-201 (2/26/66) was the first flight test of the Saturn IB rocket, in this case paired with the Block I CSM. It was planned as a sub-orbital flight to test the SM propulsion system, the reaction control (thrusters) of both CM and SM, and the CM's heat shield. The Saturn IB had stronger first stage engines, and the S-IV second stage's engines were replaced by a J-2 engine that was stronger than the cluster of six it replaced. The mission objectives included: checking out the Saturn IB propulsion, guidance, and electrical systems; verifying the CSM's heat shield; demonstrate that all component separations worked as planned; and check out the ground-based support facilities needed for launch, mission control, and recovery. All objectives were met, and for the most part, the rocket and spacecraft functioned as planned, especially the Saturn IB's first stage. Only three minor problems kept the mission from perfection; all were easily identified and corrected. The worst was a problem with the SM's engine caused by a leak allowing helium into the oxidizer supply line.

Crewed Gemini flights were next on the schedule: Gemini VIII (Armstrong and Scott) launching on 3/16/66, and Gemini IXA (Stafford and Cernan). Both flights had serious problems; a thruster malfunction on Gemini VIII caused the flight to be aborted and almost lost, and the failure of its target docking vehicle kept a major objective of Gemini IX from being reached.

Apollo-Saturn AS-203 (7/5/66) was the next test in the Saturn program. AS-202 was planned as a test of the Saturn IB with a production capsule aboard, but it wasn't ready in time for AS-202 to make its flight schedule, so AS-203 went ahead of AS-202. The AS-203 objective was to check out the S-IVB improved second/third stage, which used a J-2 engine that burned liquid hydrogen. Liquid hydrogen is difficult to handle and is very, very cold, so engineers wanted to be sure that it "behaved itself" in the second stage, and that it wasn't too cold for the S-IVB variant used for the second stage to re-start, a mission requirement for the Moon shots (the S-IV second stage would provide thrust continuously until its fuel was consumed, while the S-IV third stage would fire to put the rocket and payload into the proper Earth orbit, and then be able to fire again to inject the CSM into a Moon-bound trajectory). The AS-203 mission was completely successful.

Gemini X (Young and Collins, 7/18/66) came next, before AS-202 could be made ready.

Apollo-Saturn AS-202 (8/25/66) was a repeat of the sub-orbital AS-201 flight, with a few twists. The mission profile called for the SM engine to be fired four separate times (it would have to fire reliably twice on a Moon landing mission), and to further test the CM's heat shield. The booster stages worked perfectly, as did the CSM separation from the rocket. The SM burns worked, too. So did the heat shield, even though it was subjected to strong heating twice, in a planned "skip" maneuver. Parachute deployment and recovery by the *USS Hornet* posed no problems. AS-202 had a lot of telemetry and recording capability, recording the booster separation so well that it has been used in crewed mission documentaries to good effect. AS-202's capsule now resides again on the *Hornet*, now the USS Hornet Museum in Alameda, CA.

Project Gemini closed out with two successful missions: Gemini XI (Conrad and Gordon, launching on 9/12/66) and Gemini XII (Lovell and Aldrin, launching on 11/11/66). It looked like Project Apollo was on schedule to beat JFK's goal by a comfortable margin.

AND THEN DISASTER STRUCK!

Training for the first crewed Apollo mission (AS-204, which the crew had taken to calling *Apollo 1*) had been underway for some time at the close of Project Gemini. The crew had been selected: Mercury and Gemini veteran Gus Grissom would command it, First Spacewalker Ed White would be the "senior pilot," and Space rookie Roger Chaffee rounded out the crew. The projected launch date was February 21, 1967.

NASA's success with crewed missions had been pretty amazing, given the difficulties posed by developing new Space-capable transportation and its infrastructure. There had been a few scares along the way (John Glenn's (not really) loose heat shield and others) and only one really dangerous situation (Gemini 8), but "success had become familiar." On January 27, 1967, the crew entered AS-204 for a simulated launch test. The test program required the capsule to be operating under its own power. Because the capsule had no fuel or thruster propellant aboard, the test was classed as "non-hazardous." However, the crew had complained about there being a lot of flammable material in the capsule.

For no good reason at all, the pad team wanted to make the simulation as real as possible, so they sealed the crew into the capsule (the poorly-designed hatch opened inward and required several minutes to open), and loaded the capsule with pure oxygen, at 15 PSI no less! Maybe they missed the high school demonstration of just how flammable pretty much anything is in pure oxygen at pressure!

The test was marred by a number of minor electrical glitches (sparks, anyone?), and intermittent communications problems. The simulated countdown, seriously behind schedule, was put on a "hold" while radio issues were addressed. Faulty electrical wiring behind a panel caused a spark, which flashed into a big oxygen-rich fire in a few seconds. Five minutes passed before the pad techs could get the hatch open, screams still ringing in their memory; five seconds would have been too long.

I, and all of America, felt like we were punched in the gut when we heard the news. Hard. Really hard. For more on this tragedy, see many other sources, including: https://www.history.com/news/remembering-the-apollo-1-tragedy. In the aftermath, SA-104 was officially renamed "Apollo 1," and the next SA test flight was named Apollo 4, and the Apollo 2 and Apollo 3 names were dropped.

RECOVERY

The Apollo 1 disaster caused a ten-and-a-half-month hiatus in Apollo launches while the capsule was redesigned to be much, much safer. Egad, it makes me sick at my stomach to reflect on this tragedy, even now almost 60 years later.

The pause did give engineers time to complete the Saturn V rocket, Saturn 1's "big brother." They would have needed some time at this juncture, even without the Apollo 1 delay, because the Saturn V was a big step forward, from the five F-1 engines in the first stage, each dwarfing the H-1s used in the Saturn I to many other systems.

Apollo 4 (11/9/67) was the first launch of a complete Saturn V rocket. It was assembled in the new Vehicle Assembly Building and used Launch Complex 39, built specially for the Saturn V. The noise of its F-1s at launch was literally deafening, it knocked off ceiling tiles in the protected blockhouse and almost shattered its observation windows in the face of Walter Cronkite. The F-1s did their job, as did the second stage, lofting the S-IVB third stage and CSM into orbit. The simulated lunar injection burn, restarting the third stage engine, worked as planned, putting the CSM into a highly-elliptical orbit that would allow a high-speed test of the CM heat shield. The CSM separated from the S-IV as planned, and the SM engine fired twice successfully. The rocket and all systems performed satisfactorily. NASA was back!

Apollo 5 (1/22/68) was the first of two planned tests of the two-stage Lunar Module in Earth orbit without crew. The Saturn IB launch vehicle put the S-IVB second stage and LM into Earth orbit, a second S-IVB burn put it in a highly-elliptical orbit. The LM's descent engine was fired several times at different throttle settings, followed by a simulated landing abort with the ascent stage engine firing while the descent stage engine was running. A second, longer burn of the ascent stage engine depleted its fuel as planned; both parts of the LM were left to orbital decay. All systems checked out OK and there was only one minor firing glitch caused by "overly-conservative" control software. This flight was so successful that the second planned LM test flight was cancelled. LM-2, the second operational Lunar Module built, was earmarked for that now-cancelled flight, and is now on display at the Smithsonian National Air and Space Museum.

Apollo 6 (4/4/68) was the final non-crewed test flight of the Saturn-Apollo system, basically a repeat of Apollo 4. The booster did not perform as well as the one did on Apollo 4; the first stage suffered pogo oscillations, so called because the vibration resembled the motion of a pogo stick, and the second stage shut down earlier than planned. In spite of these problems, Saturn V and Apollo were deemed "ready to fly," and no further non-crewed test flights were needed.

All that remained were four crewed test flights!

Apollo 7 (10/11/68, Schirra, Eisele, and Cunningham) was an Earth-orbit test of the CMS, it did not carry a Lunar Module, even though the CM was a Block II model, equipped with the hardware necessary to dock with an LM. Since it was only going to Earth orbit, it was launched with a Saturn IB rocket. For more info about this mission and its commander, see here.

Apollo 8 (12/21/68, Borman, Lovell, and Anders) was supposed to be a crewed version of Apollo 5, an Earth-orbit test of the LM. However, the LM was not ready, and rather than delay the program, it was decided to have Apollo 8 fly Apollo 9's mission plan, a trip to the Moon, insertion into lunar orbit, and back. They did so with considerable success.

Apollo 9 (3/3/69, McDivitt, Scott, and Schweickart) flew the Earth orbit test of the LM beautifully, also using a Saturn IB booster. It's the subject of a previous Item of the Week.

Apollo 10 (5/18/69, Stafford, Cernan, and Young) flew the entire Apollo Moon landing sequence, except for the landing itself. Its success paved the way for Apollo 11's famous landing on July 20, 1969. For more information about Stafford and Apollo 10, see here.

CODA

Project Apollo, and its precursors Mercury and Gemini, are arguably the largest and most consequential civilian project ever attempted. Whole new technologies had to be developed and tested, and whole new management processes had to be created to handle the massive effort of many thousands of people in hundreds of different organizations. The Apollo astronauts, especially Neil Armstrong, got the attention their accomplishments deserved.

But remember this.

The astronauts were in a position to succeed because there had been so much effort by so many talented people over that magical decade. It truly was a team effort, and NASA management had found a way to make everyone feel like their contribution to this Great Effort was important. An anecdote from before the Moon landings is proof. Recall that the time of the Apollo crewed missions was also a time of social, political, and civil rights unrest. A reporter, looking for a negative angle to use, asked a Black NASA janitor his opinion of the Apollo effort, hoping for a negative response. What they got was, "Of course I'm in favor of Project Apollo, and I'm proud to be a part of it, because ***WE*** are going to the Moon!"

There is a reason that NASA is often named the best Federal Agency to work for.

And the tangible, semi-tangible, and intangible benefits of Apollo are still coming in to this day! Just see the Spin-offs and Tech Transfer sections of Air and Space this Week!

REFERENCES

Many of the supporting references were linked to within the body of the Item above.

There a many other resources dealing with the crewed Apollo missions; I wanted to present the backstory a bit. A good place to start is NASA's History Division: https://www.nasa.gov/history!

Project Mercury and Little Joe

This New Ocean: A History of Project Mercury: https://www.nasa.gov/wp-content/uploads/2023/02/sp-4201.pdf

Project Mercury: A Chronology, NASA SP-4001: https://www.nasa.gov/history/SP-4001/cover.htm

Little Joe: https://en.wikipedia.org/wiki/Little_Joe_(rocket)

Saturn Test Flight Program

Chrysler Corporation's Space Division prepared a manual for the Saturn I and NASA's Launch Complex 37B, where the SA-series rockets were launched; see: https://ntrs.nasa.gov/api/citations/19650013517/downloads/19650013517.pdf

SA-1 Fact Sheet: https://www.spaceline.org/cape-canaveral-rocket-missile-program/saturn-ib-fact-sheet

General Saturn and Apollo Information

NASA: The Apollo Program: https://www.nasa.gov/the-apollo-program

NASA: Saturn Apollo Program: https://en.wikipedia.org/wiki/Saturn_I_SA-2

NASM: Looking Closer at the Saturn V: https://airandspace.si.edu/stories/editorial/looking-closer-saturn-v

Chaikin, Andrew, 1994, *A Man on the Moon: The Voyages of the Apollo Astronauts*, ISBN 0-670-81446-6

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