PROGRESS REPORT ON APOLLO PROGRAM

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It is a great pleasure to be here today and to greet you hardy survivors of the pool party. I will do my best to avoid loud noises and bright colors during my status report. Since the last SETP Symposium, the Apollo Program has been quite busy in a number of different areas. (Figure 1) My problem is to sift through this information and to talk only about those things of most interest to you.

First, to review briefly our hardware, we are talking about two different spacecraft and two different boosters. (Figure 2) The Command Module is that part of the stack which makes the complete round trip to the moon. Attached to it is the Service Module, containing expendables and a 20,000 pound thrust engine for maneuverability. The Lunar Module will be carried on later flights and is the landing vehicle and active rendezvous partner.

The uprated Saturn 1 can put the Command and Service Modules into earth orbit; the Saturn V is required when the Lunar Module is added.

Since the last symposium, we have flown the Command and Service Modules twice and the Lunar Module once, all unmanned.

Apollo 4, the first Saturn V flight, was launched in November 1967. (Figure 3) The Saturn V did a beautiful, i.e. nominal, job of putting the spacecraft into earth parking orbit. After a coast period, the third stage (S-IVB by McDonnell Douglas) was ignited a second time, achieving a highly elliptical orbit. The Service Module engine was then used to trim this orbit to the desired apogee of 9700 miles. On the way back downhill, a second burn along the velocity vector drove the Command Module into the atmosphere at approximately the same speed (36,500 ft/sec) and flight path angle (-7°) as would be experienced during a lunar return.

The spacecraft came through this test in excellent condition, even though it had intentionally been subjected to a thermal gradient across its heat shield which was more severe than the nominal case. Maximum G during reentry was between 7 and 8, measured hypersonic l/d was .37 at a trim angle of 25°, and maximum heat shield surface temperature was 5200°F. All in all, it was a near perfect flight with no surprises.

(Figure 4) This is how the world looks from over 9000 miles up. This is the same view our crews will have prior to entry on the lunar flight and this is the point at which we would like to get a navigational fix, measuring the angle between a landmark and a star. As you can see it is quite likely that no suitable landmarks will be visible, and we shall have to rely on horizon measurements, which are less accurate.

On the other hand, visibility from low orbital altitudes is excellent. (Figure 5) Can you see the A-7 taxiing out for takeoff at NAS Dallas? If not, you'd better lay off the pool parties.

The second Saturn V flight, called Apollo 6 and launched in April, again carried a Command and Service Module into earth orbit. The only difference between this and earlier spacecraft was the addition of a large chunk of iron—a 250 pound side hatch. (Figure 6) Although heavy, this design is a great improvement from the crew's view point, and acted as an excellent thermal and pressure seal during the flight.

Unlike its predecessor, this Saturn V flight was far from uneventful. The first anomaly occurred during the latter part of the first stage burn, when a longitudinal oscillation, or pogo, developed at a frequency of slightly over 5 cycles per second, and with an amplitude of a little over one G, peak to peak.

This oscillation occurred when the natural frequency of the booster, changing as fuel was burned, matched the existing frequency of the propulsion system, causing a jump in amplitude as the two coupled. The longitudinal oscillations induced lateral vibrations in the upper part of the vehicle, causing the launch escape tower to rattle back and forth near its design load limit. Also, the longitudinal frequency of 5 CPS is quite close to the resonant frequency of the human torso (4 CPS). All in all, it would not have been a very smooth ride.

This problem has been fixed, we hope, by the addition of accumulators in the engine liquid oxygen fuel lines, which prevent the propulsion system resonant frequency from coming close to that of the launch vehicle.

After the pogo quieted down, the ride was uneventful until nearly 5 minutes into the second stage burn, when a ruptured flex line caused one of the five J-2 engines to fail. The booster sensed this failure and promptly sent a shut down signal—to the wrong engine. So now the booster was limping along on three out of five, something it was not designed to do.

(Figure 7) Here you can see the pogo and the premature shutdown of two engines. The dotted lines show the nominal burn durations, and the solid, what actually happened. You can see that the second stage compensated for its lowered thrust level by a longer burn, and the third stage continued this compensation. You will also notice that the Saturn V is a comparatively "soft" ride, the maximum of 4.5 G being reached at first stage cutoff. The time-to-climb into orbit is approximately eleven minutes.

The two engine out problems would have given a crew quite a wild ride, for the following reasons. The second stage guidance, designed to handle only one engine failure, responded to the lowered acceleration after the second failure by asking for an excessive nose up condition. Consequently, at the time the third stage took over the guidance task, the booster was too high and too slow. The third stage guidance is programmed first to steer out altitude deviations, and this it did, by reducing pitch angle. Once altitude had been corrected, it found itself with a large negative radial velocity, which it then attempted to steer out by climbing abruptly.

These gyrations also caused errors in the calculation of cut off velocity, so that the third stage finally shut down only slightly low but 160 ft/sec too fast.

(Figure 8) The whole story is shown here, with the dotted line being the nominal. S-II cutoff conditions were 300 ft/sec slow, 3 miles high, at which point the third stage wild ride began. It is interesting to note that the 160 ft/sec overspeed was less than 1% off nominal, yet resulted in an apogee of 198 nautical miles instead of the planned 100 nautical miles. This indicates how sensitive orbital operations can be; maneuvers, especially those during the rendezvous approach, must be very precisely executed. Incidentally, the flex line which caused the engine failure has been replaced by a rigid line.

After orbital insertion the plan was to use the 3rd stage for a second time, to boost apogee to 12,000 miles, and then to use the Service Module engine to drive the spacecraft back into the atmosphere at lunar return velocity.

However, the third major problem of the flight, a broken line to an engine start bottle, prevented the booster from igniting a second time. Therefore, the spacecraft used its own engine as a substitute and burned for 7½ minutes to achieve the 12,000 mile orbit. In so doing, however, its fuel was nearly depleted, so that the burn to speed up for entry was deleted. This change in plan resulted in a velocity of 33,000 ft/sec, 3500 less than planned, but was still a good data point from a thermal viewpoint.

If three men had been on board Apollo 6, they would have been able to accomplish a variety of mission objectives despite three major anomalies, an indication of the flexibility and back-up built into the system.

Our first and only Lunar Module flight took place on January 22, 1968. We called it Apollo 5 and it was a systems test with emphasis on firing the two Lunar Module engines, one used during descent to the lunar surface and one for ascent. The 10,000 pound thrust descent engine is gimballed and throttleable; the 3500 pound thrust ascent stage engine is neither.

(Figure 9) Here we have the mission profile. The first burn of four seconds duration was the result of a premature engine shutdown. The onboard guidance computer had been programmed to expect a rapid thrust build-up; the actual acceleration sensed was slower than the computer's pre-set threshold value. Therefore, it "did its thing" as programmed, and shut off what it thought was a sick engine. Needless to say, this threshold value has been lowered. The flight controllers then shifted to a preplanned alternate mission, and the smooth execution of the remainder of the flight is a tribute to their foresight.

The second descent stage engine burn was 26 seconds at 10% thrust, followed by 7 seconds at max thrust. The third burn was started shortly after the second, and was 26 seconds at 10%, followed by 2 seconds at max thrust.

As the descent stage engine was shutting down, the ascent stage engine was fired, separating the two vehicles. This "fire in the hole" staging technique is used in an abort near the lunar surface. The ascent stage engine was later burned to propellant depletion. The two Lunar Module stages, having no heat shield, burned up when they entered the atmosphere. In general, we were especially pleased with the maturity of the spacecraft hardware on its first flight.

No on-board film was exposed on the LM flight because it would have burned up during entry, but film was taken during the two Saturn V Command Module flights, and I have put together a composite showing the more interesting parts of each.

So that, in a nutshell, is the story of the past year, the year of unmanned testing. I will now give you our "best guess" for the coming year, the year of manned flights. Apollo 7 will be our first manned flight, an open-ended test of the Command and Service Modules launched by an uprated Saturn I. If all systems permit, the flight will continue in earth orbit for ten days. This duration is sufficient to validate the equipment for the lunar trip, which can take up to nine days.

(Figure 10) This figure shows the flight plan in skeleton form. Among other things, there is a rendezvous–using optical techniques only–with the spent second stage booster. The Service Module engine will also get a work out, with a total of eight different burns. Included are several minimum impulse burns of a fraction of a second duration. These are important because if delicate midcourse corrections are needed during translunar flight, it is preferable to use one short pulse out of the large (20,000 pound thrust) engine rather than hoseing out several minutes of the small RCS thrusters, which produce only 100 pounds thrust and which fire two or four at a time for translation maneuvers. The fuel supplies for the two systems cannot be shared, and there is more "poop" by far available from the Service Module system than from the RCS system. The crew for Apollo 7 will be Wally Schirra, Donn Eisele, and Walt Cunningham. Their flight is now scheduled for mid-October.

The Apollo 8 crew (Frank Borman, Jim Lovell, and Bill Anders) is now also in intensive training. Their mission may be either earth or lunar orbital, depending on the results of Apollo 7. If the flight test data from 7 indicates design problems, or casts doubts on the reliability of any important components, then Apollo 8 will be used in earth orbit to further investigate these problems. If, on the other hand, Apollo 7 turns up "clean as a whistle", then Apollo 8 can use the capability of the Saturn V to fly a lunar orbital mission using the CM and SM only (NOLM). Approximately twenty hours would be spent in lunar orbit. This mission would be useful as a precursor to more complicated lunar flight plans in that it would give us experience in communications and telemetry at lunar distance, plus it would enable our tracking people to refine their model of the lunar gravitational field. It appears from the Lunar Orbiter data that there are local spots of greater density beneath four of the lunar maria, or seas. These cause perturbations to the orbit of any spacecraft flying low over them, and we would like to have more information on this subject prior to a lunar landing. A launch window for Apollo 8 opens the latter part of December.

Following Apollo 8, Jim McDivitt, Dave Scott, and Rusty Schweickart will have an earth orbital flight aboard a Saturn V. Apollo 9 will be the first "all-up" flight and will feature the first manned LM operations. (Figure 11) After the transposition and docking maneuver and LM checkout, McDivitt and Schweickart will separate the LM some 80 miles from the CM and execute a series of rendezvous maneuvers prior to returning to dock. In the event of LM propulsion difficulties, Scott in the CM has the capability to perform "mirror image" maneuvers as he takes over the role of the active rendezvous partner. Apollo 9 will also demonstrate an extravehicular transfer from LM to CM. This mode will be used in the lunar flight in the event of docking difficulties. For this reason, it should be demonstrated to be feasible, under carefully controlled conditions, prior to separating the LM from the CM the first time, since it may have to be used "for real" coming back. Apollo 9 is scheduled for the first quarter of calendar year 1969.

Beyond Apollo 9, our planning is quite flexible. As you in the test business know, grandiose plans can be altered radically by flight test results. Therefore, our intent is to tailor subsequent missions to achieve the goals omitted or not possible during the earlier flights. Hopefully, only a few of these will be required, so that we may achieve Apollo's original mandate–to land Americans on the surface of the moon and to return them safely to earth—by the end of this decade. Time runs short, but I think there is enough left to give us a fair chance of success. Perhaps we can tell you about it at the next symposium!

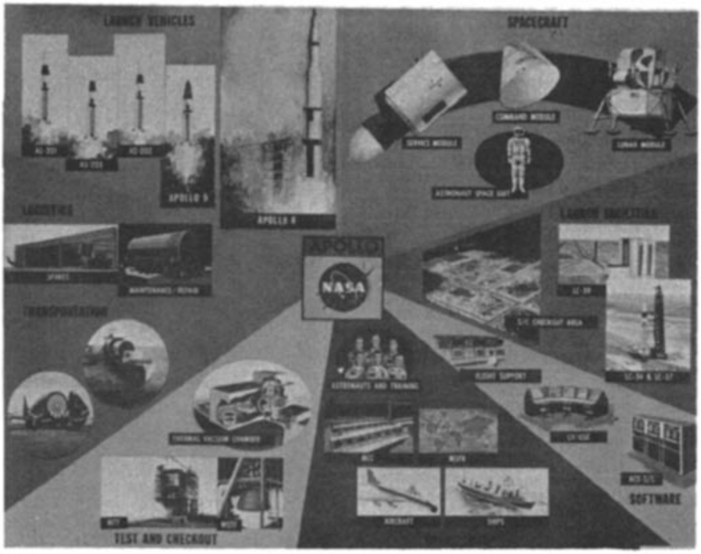


FIGURE 1

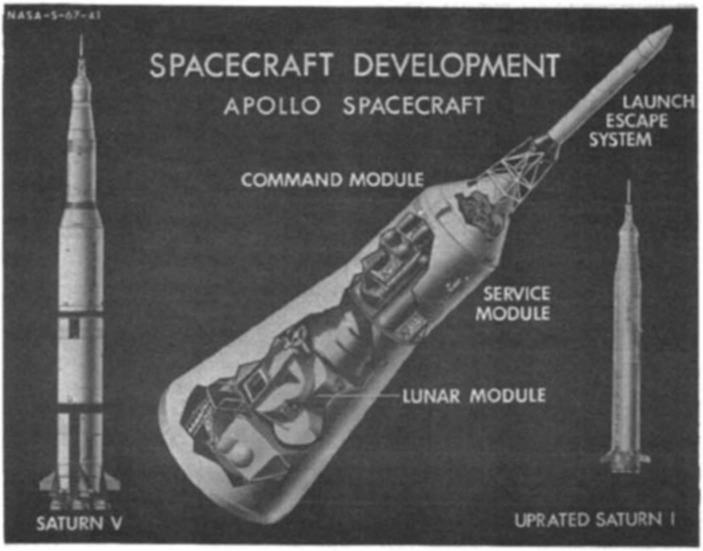


FIGURE 2

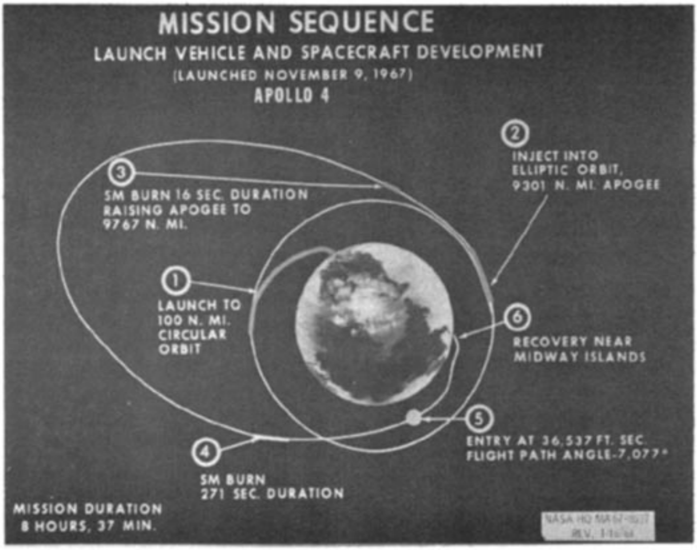


FIGURE 3

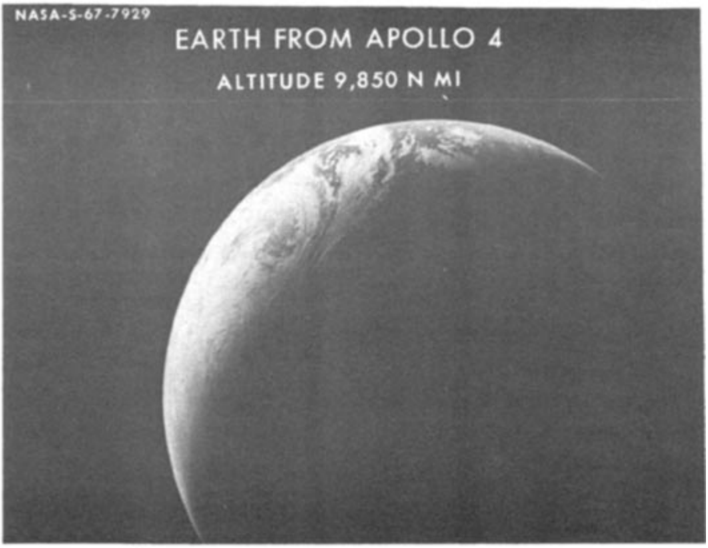


FIGURE 4

FIGURE 5

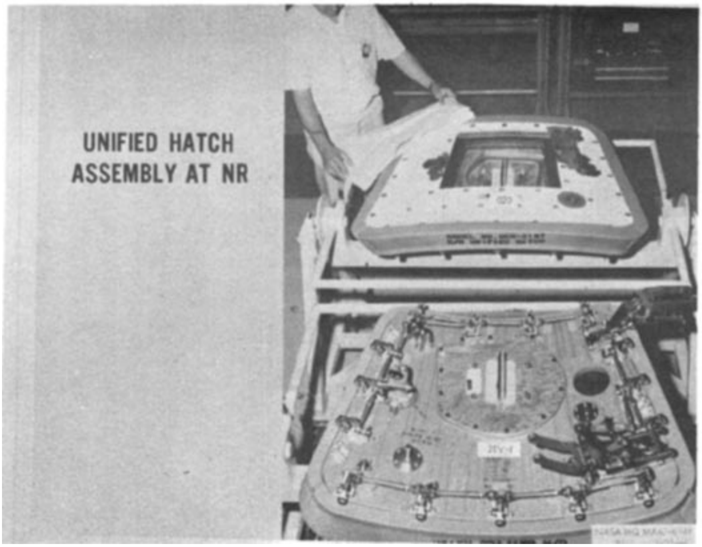


FIGURE 6

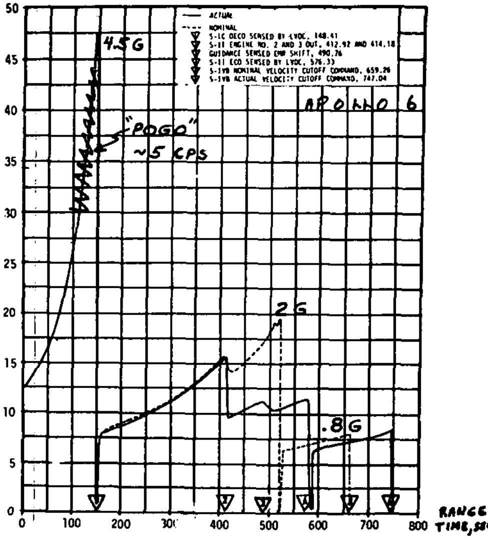


FIGURE 7

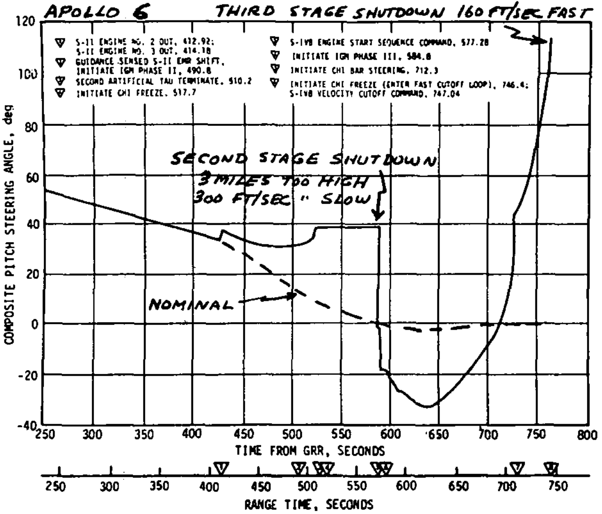
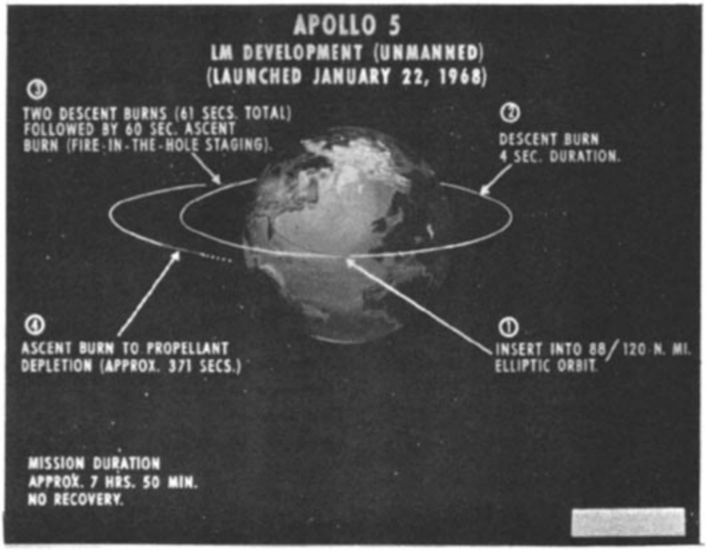


FIGURE 8



APOLLO 5

LM DEVELOPMENT (UNMANNED)

(LAUNCHED JANUARY 22, 1968)

③ TWO DESCENT BURNS (61 SECS. TOTAL) FOLLOWED BY 60 SEC. ASCENT BURN (FIRE-IN-THE-HOLE STAGING).

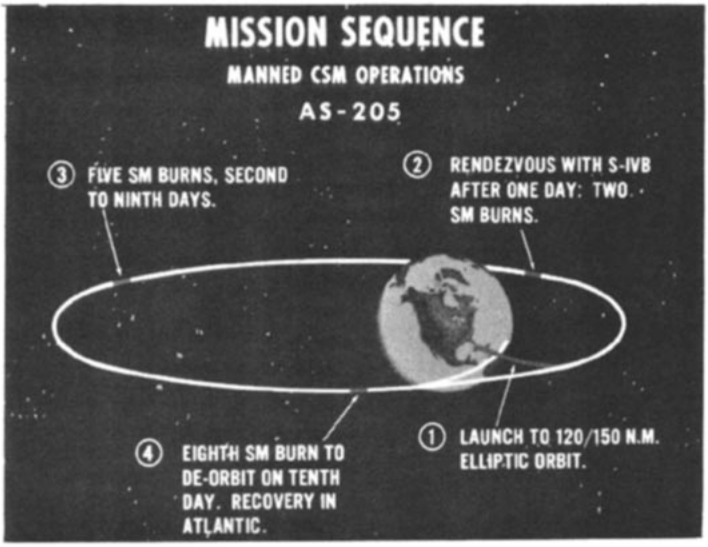
② DESCENT BURN 4 SEC. DURATION.

④ ASCENT BURN TO PROPELLANT DEPLETION (APPROX. 371 SECS.)

① INSERT INTO 88/120 N. MI. ELLIPTIC ORBIT.

MISSION DURATION
APPROX. 7 HRS. 50 MIN.
NO RECOVERY.

FIGURE 9



MISSION SEQUENCE

MANNED CSM OPERATIONS

AS-205

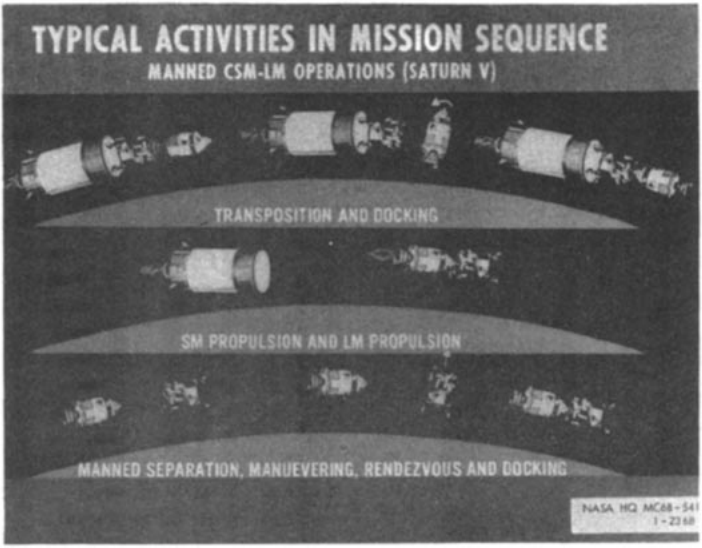
③ FIVE SM BURNS, SECOND TO NINTH DAYS.

② RENDEZVOUS WITH S-IVB AFTER ONE DAY: TWO SM BURNS.

④ EIGHTH SM BURN TO DE-ORBIT ON TENTH DAY. RECOVERY IN ATLANTIC.

① LAUNCH TO 120/150 N.M. ELLIPTIC ORBIT.

FIGURE 10



TYPICAL ACTIVITIES IN MISSION SEQUENCE

MANNED CSM-LM OPERATIONS (SATURN V)

TRANSPOSITION AND DOCKING

SM PROPULSION AND LM PROPULSION

MANNED SEPARATION, MANUEVERING, RENDEZVOUS AND DOCKING

NASA HQ MC68-541
1-23 68

FIGURE 11