Apollo 13

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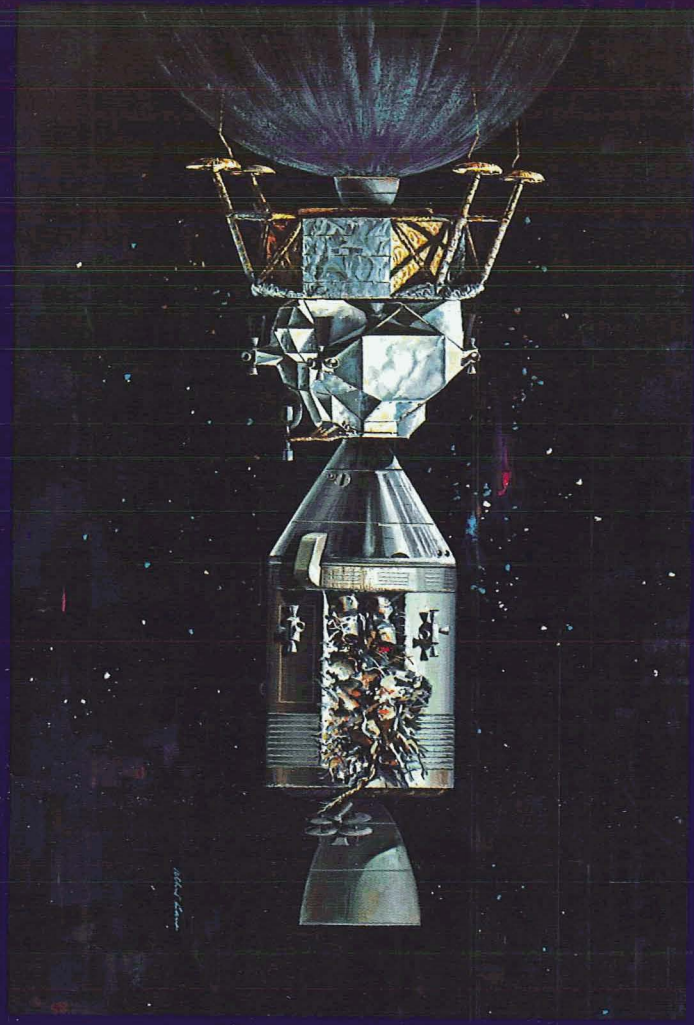


Apollo 13

"Houston,
we've got a
problem."

James A. Lovell, Jr., Apollo 13 Commander.

Fred W. Haise, Jr., Apollo 13 Lunar Module Pilot.

John L. Swigert, Jr., Apollo 13 Command Module Pilot.

SPACECRAFT—*Hey, we've got a problem here.*

Thus, calmly, Command Module Pilot Jack Swigert gave the first intimation of serious trouble for Apollo 13—200,000 miles from Earth.

CAPSULE COMMUNICATOR—*This is Houston; say again, please.*

SC—*Houston, we've had a problem. We've had a Main* B *bus undervolt.*

By "undervolt" Swigert meant a drop in power in one of the Command/Service Module's two main electrical circuits. His report to the ground began the most gripping episode in man's venture into space. One newspaper reporter called it the most public emergency and the most dramatic rescue in the history of exploration.

SC—*And we had a pretty large bang associated with the caution and warning here.*

Lunar Module Pilot Fred Haise was now on the voice channel from the spacecraft to the Mission Control Center at the National Aeronautics and Space Administration's Manned Spacecraft Center in Texas. Commander Jim Lovell would shortly be heard, then again Swigert—the backup crewman who had been thrust onto the first team only two days before launch when doctors feared that Tom Mattingly of the primary crew might come down with German measles.

Equally cool, the men in Mission Control acknowledged the report and began the emergency procedures that grew into an effort by hundreds of ground controllers and thousands of technicians and scientists in NASA contractor plants and on university campuses to solve the most complex and urgent problem yet encountered in space flight.

SC—*We got a Main bus* A *undervolt, now, too. . . Main* B *is reading zip (zero) right now.*

CAPCOM—*We'd like you to attempt to reconnect fuel cell 1 to Main* A *and fuel cell 3 to Main* B.

SC—*Okay, Houston . . . I tried to reset, and fuel cells 1 and 3 are both showing zip on the flows.*

CAPCOM—*We copy.*

SC—*Houston, are you still reading 13?*

CAPCOM—*That's affirmative. We're still reading you. We're still trying to come up with some good ideas here for you.*

SC—*Let me give you some readings . . . Our* O_2 (oxygen) *cryo number 2 tank is reading zero—did you get that?*

CAPCOM—O_2 *quantity number 2 is zero.*

After peaking briefly just before the bang, pressure in one of the two cryogenic (supercold) oxygen tanks, back in the Service Module, had dropped to zero in eight seconds. These oxygen tanks, with the companion cryogenic hydrogen tanks, feed the three fuel cells that generate the spacecraft's electrical current, provide breathing oxygen, and produce water.

Astronauts and flight controllers anxiously monitor consoles during the Apollo 13 mission.

SC—*And it looks to me, looking out the hatch, that we are venting something. We are venting something out into space. It's a gas of some sort.*

Current from the remaining fuel cell dropped slowly.

CAPCOM—*We'd like you to . . . power down until you get an amperage of 10 less amps than what you've got now.*

SC—*It looks like O_2 tank 1 pressure is just a hair over 200.*

CAPCOM—*We confirm that.*

SC—*Does it look like it's still going down?*

CAPCOM—*It's going slowly to zero, and we're starting to think about the* LM *lifeboat.*

SC—*Yes, that's something we're thinking about too.*

Minutes earlier, and only a little more than an hour after Swigert's first report of trouble, had come the laconic announcement to a breathless world:

"Here in Mission Control we are now looking toward an alternate mission, swinging around the Moon and using the Lunar Module power systems, because of the situation that has developed here this evening."

The digital clock above the flight control team showed 57 hours 11 minutes since launch—11:24 p.m. Eastern Standard Time, Monday, April 13. Apollo 13 was 207,000 miles from Earth and moving away at 2,100 miles an hour.

CAPCOM—*We figure we've got about 15 minutes worth of power left in the Command Module. So we want you to start getting over in the* LM *and getting some power on that.*

Three days from home, the spacecraft had electricity for only 15 minutes under normal procedures.

CAPCOM—*We'd like you to start making your way over to the* LM *now.*

SC—*Fred and Jim are in the* LM.

The tunnel into the Lunar Module cabin from the Command Module had remained open after Lovell and Haise went into the LM for a planned check on its instruments earlier in the evening, just before the incident.

SC—*I got* LM *power on.*

CAPCOM—*I have an activation procedure. I'd like you to copy it down.*

Step by step, following instructions from the ground, Haise and Lovell powered up the Lunar Module, which the crew had named Aquarius, and Swigert shut down Odyssey, the Command Module, apparently undamaged, to save its batteries, oxygen, and cooling water in hope they could ultimately be used for reentry and landing.

It was necessary also to maintain the integrity of alignment on the inertial guidance platform. It is this gyroscopic device which "remembers" the spacecraft's position and velocity and thus aids in computing necessary course corrections to stay on the desired trajectory. Swigert drew on battery power to keep the alignment in Odyssey alive, until the alignment in Aquarius could be brought into correspondence with that in Odyssey. It had to be done fast, but it was accomplished.

Lovell remarked later that the transfer of alignment from Odyssey to Aquarius was the first big turning point. Since the optical systems of Aquarius are less sophisticated, and never intended for use in deep space navigation, it would have required movement of the entire spacecraft to get a sighting. Had they lost Odyssey's alignment, the only way to get another alignment would have been to use the Sun and Moon and Earth. The gaseous cloud which had formed around the spacecraft prevented star sightings.

These preliminaries were accomplished, and it was conceded that Apollo 13 had failed as a lunar mission. Success now would be measured by the outcome of the struggle, world-wide, and deep in space, to get three men home alive.

Dressing for launch: foreground to rear, Lovell, Swigert and Haise.

Apollo 13 astronauts move out from transfer van.

Launch of Apollo 13.

Even before launch, Apollo 13 provided a sobering reminder that the problems and dangers of exploring space are beyond anticipation and that engineering genius is not without limitations. Sometimes the problems are minor in the context of Earth-bound activities but major for space flight. One such problem occurred during the launch preparations.

The Apollo 13 prime crew was exposed to rubella, or German measles, while working with Charles M. Duke, Jr., of the backup crew, who developed rubella the weekend before the scheduled launch. Examination of the prime crew revealed that Thomas K. Mattingly II, Command Module Pilot, had no immunity to rubella.

A sick astronaut in space could endanger himself and the mission. As a result, doctors ruled out Mattingly for the Apollo 13 flight.

Plans call for use of the entire backup crew when a member of the prime crew is incapacitated. However, Duke's illness ruled that out. Consequently, a decision was made to substitute backup Command Module Pilot John L. Swigert, Jr., for Mattingly. Swigert was found to be immune to rubella.

The last-minute change presented difficulties because each trio is trained as a team. In a crisis, each man has learned to rely on his companions' reactions. To work Swigert in, the crew engaged in a vigorous and intensive program simulating all flight maneuvers and ensuring unquestioned teamwork.

At 2:13 p.m. EST, Saturday, April 11, 1970, Apollo 13 and its team (James A. Lovell, Commander; Fred W. Haise, Jr., Lunar Module Pilot; and John L. Swigert, Command Module Pilot) were launched from Kennedy Space Center, Florida. A premature cut-off of one engine of the second stage of their Saturn V launch vehicle was compensated for by longer burns of the remaining engines and the engine of the third stage. Apollo 13 achieved Earth orbit at 2:26 p.m. EST.

Apollo 13 and its still attached Saturn V third stage (called the S-IVB) were thoroughly checked while in orbit. At 3:48 p.m., the

Swigert in Odyssey during color telecast of April 12.

astronauts sent their first telecast from space, a five-minute program which included a description of their view of the cloud-covered Eastern United States. S-IVB was re-ignited at 4:48 p.m. EST to give Apollo 13 its final boost toward the Moon. A check of systems after shutdown of the S-IVB showed that all were operating satisfactorily.

At 5:20 p.m. EST, Odyssey separated from the adapter that connected it with the S-IVB. Simultaneously, the four panels that made up the sides of the adapter fell away, exposing Aquarius, the Apollo 13 Lunar Module. The Lunar Module is designed principally for landing two men on the Moon, serving as a shelter and base during the short lunar expedition, and later returning the astronauts to the Command/Service Module, waiting in lunar orbit.

After separating Odyssey from the adapter, the astronauts moved out about 60 feet ahead of S-IVB. Then they turned Odyssey around and docked it nose-to-nose with Aquarius. They backed their craft and the attached Aquarius away from the S-IVB. By 6:14 p.m., they had freed Aquarius and turned their three-module spacecraft around to head for the Moon. Most of the transposition and docking maneuvers were telecast live to Earth in a 72-minute program that began about 5:30 p.m.

Also shown on TV was the maneuver that sent the S-IVB on a separate path to crash on the Moon as a scientific experiment, designed to add to knowledge about the make-up of the Moon. This turned out to be the only successful lunar experiment of Apollo 13.

The path of Apollo 13 was so true that a scheduled course adjustment was cancelled as unnecessary. No major mission event was scheduled until 8:54 p.m., Sunday, when a hybrid transfer was initiated. This rerouted the craft to sweep within 70 miles of the Moon rather than the approximately 115-mile altitude of the earlier course. The change was designed to put Aquarius in the right place at the right time for the desired lunar landing site. The hybrid transfer also meant that Apollo 13 could return to Earth only by another course adjustment. On the earlier course, called a free return trajectory, Apollo could swing around the Moon and return to Earth without using any additional rocket power.

The hybrid transfer, conducted for all the world to see on TV, was so accurate that a scheduled subsequent maneuver was unnecessary.

Another major event on Sunday threw a usually cool and calm astronaut into a mild panic. In the rush to substitute for Mattingly, Swigert forgot to file his Federal Income Tax return.

"How do I apply for an extension?" he asked. Amid laughter from Mission Control, he sought to explain: "Things kinda happened real fast down there and I need an extension. I'm really serious. Would you. . ."

Joe Kerwin, the capsule communicator, was unsympathetic: "You're breaking up the room down here."

Swigert continued: ". . . turn it in?"

Later, Flight Director Glynn Lunney said that American citizens out of the country get a 60-day extension on filing. "I assume this applies," he added.

On Monday evening at 9:15 p.m. EST, Lovell and Haise entered the pressurized Aquarius for the first time. Among other things, Mission Control wanted them to check an Aquarius helium tank that had shown a slightly high pressure on the launch pad. Lovell found that the pressure in the tank was showing the kind of rise expected.

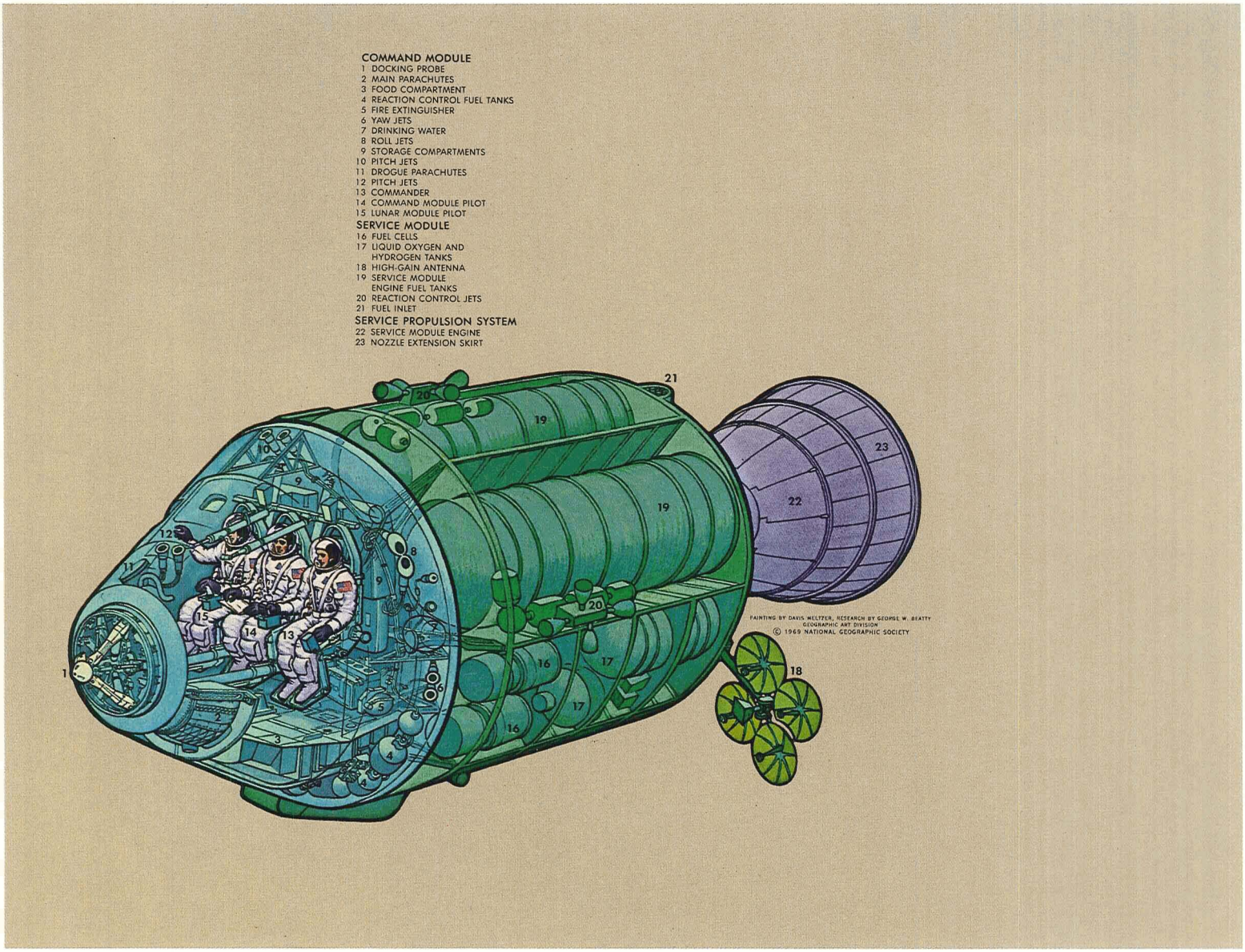
Haise remarked that "One of the nice things for a novice like myself is the ease of moving around in here."

The two spent about an hour inside of Aquarius, telecasting their activities to Earth. The show ended, and all was well.

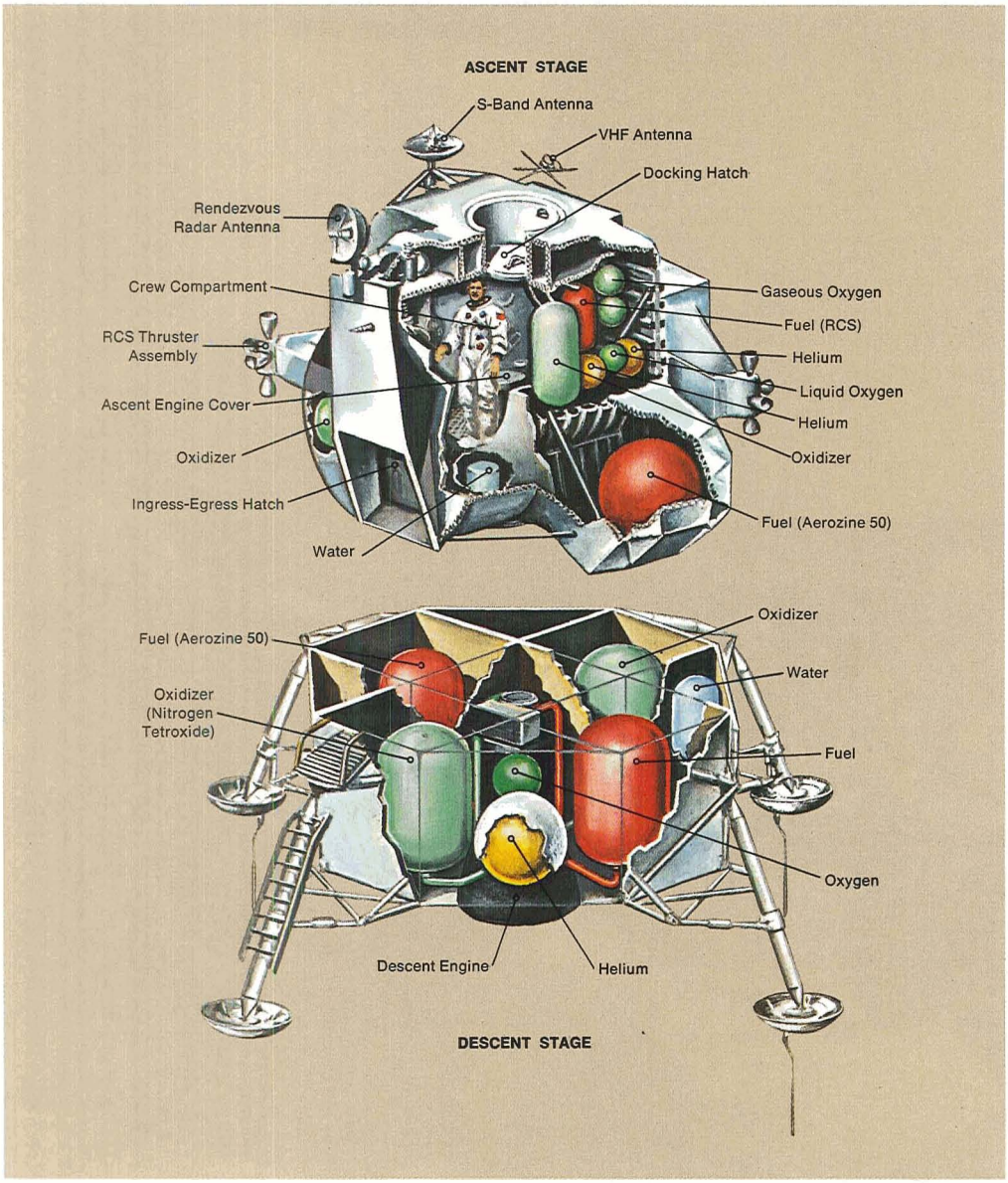
Haise was still in Aquarius. Lovell was in the tunnel between Aquarius and Odyssey, clutching a camera and gingerly making his way among the TV wires. Swigert was in Odyssey. Suddenly, they were startled by a loud bang.

At first, Lovell and Swigert thought that Haise had released a valve, as planned, in Aquarius. But Haise, now back in the CM, and scanning the instrument panel, saw that one of the main electrical systems of Apollo 13 was deteriorating. Just before 10:10 p.m., Swigert radioed the words that drew mankind together in a common concern: "Hey, we've got a problem here."

Diagram of the Apollo spacecraft.



Cutaway view of the Lunar Module.



Mission Control at Houston during the problem-plagued Apollo 13 flight.

When Jim Lovell and Fred Haise, leaving Jack Swigert to batten down crippled Odyssey, moved into Aquarius just before midnight Monday and began powering her up as Apollo 13's lifeboat, the Moon still lay 50,000 miles and 20 hours ahead.

It would be risky to fire the main engine of the Command/Service Module, possibly damaged by an apparent rupture of a high-pressure oxygen tank. The shortest way home—in time—would be to coast on around the Moon and then be pulled automatically back toward Earth.

But on the hybrid trajectory to which the astronauts had maneuvered Sunday evening to facilitate lunar landing in the Fra Mauro Hills, their spacecraft would actually miss the Earth by 250 miles and pass on by, beyond hope of survival.

So a prime concern was to get back on a free-return trajectory that would bring them down in some ocean—almost any ocean—without need for further major maneuvers.

This would have to be accomplished by firing the LM descent engine—an emergency procedure that, by foresight, had been practiced in space by Apollo 9 and by the present crew in simulations at Kennedy Space Center.

Swigert urged combining the free-return maneuver with an extra push to speed the return journey, and doing it soon to cut the drain on the LM's batteries and cooling water:

SPACECRAFT—*The advantage of doing this early is you can do a big burn now in the midcourse and then power the* LM *down. Otherwise, we got to keep the* LM *powered up clear till we get around the Moon.*

But Flight Director Glynn Lunney held off a decision while trajectory planners ran half a dozen alternatives through their computers.

The fastest return would lead to a splashdown in the Pacific about noon Thursday, west of the originally planned recovery area but within steaming distance of the recovery carrier USS Iwo Jima. But this would take a long burn and leave the descent engine little fuel for later course adjustments that might be required.

Fuel could be saved and the return cut short by dropping the Service Module to reduce the dead weight that had to be maneuvered. But a Lunar Module engine had never been used in space to maneuver just the Lunar and Command Modules. And removing the protection that the Service Module gave the Command Module heat shield might expose the shield to damaging cold on the long voyage home.

The next quickest procedure would be landing early Friday morning in the South Atlantic, in range of U.S. planes—but not of ships.

Mission Control chose a two-step abort: an early short burn to reestablish free return, with potential splashdown Friday evening in the Indian Ocean, then a longer burn soon after looping around the Moon to speed the return by 10 hours and shift the target point back to the Mid-Pacific, where the prime recovery forces waited.

The discussion between Spacecraft and Houston continued:

CAPSULE COMMUNICATOR—*We're at this time, water critical in the* LM. *We'd like to use as little as possible. To do this we're going to make a free-return maneuver of 16 feet per second at 61 hours, which is 37 minutes from now. Then we're going to power down the* PGNS (*Primary Guidance and Navigation Section*), *and then at 79 hours we'll go ahead and make another abort maneuver to kick what we got.*

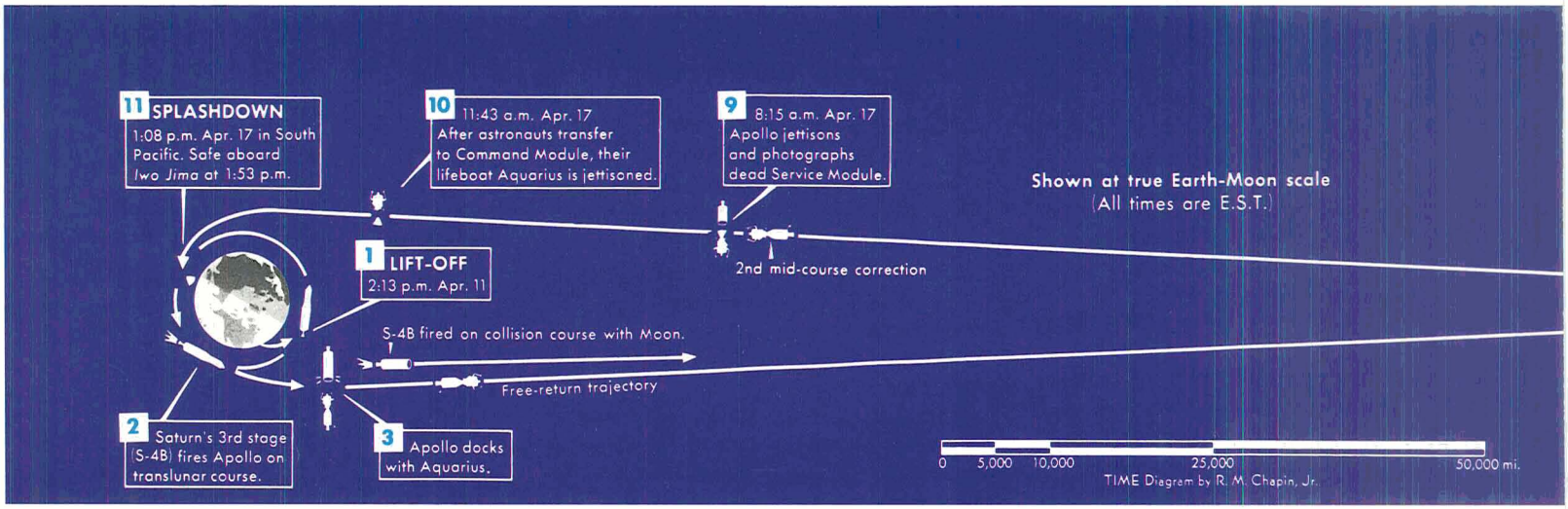
SPACECRAFT—*Could you give us a little more time?*

CAPCOM—*Okay, Jim. We'd like to get a suggested time from you.*

SC—*Let's shoot for an hour if we can. How's that?*

CAPCOM—*Okay, Jim. How about 61 hours and 30 minutes? That's an hour and five from now.*

The Ill-Fated Space Odyssey of Apollo 13.



SC—*Okay, we'll do it. And we want to make sure we can talk back and forth now to make sure we get this burn off right.*

Getting it off right would take not only accurate timing but accurate positioning of the spacecraft.

CAPCOM—*And now we want to ask you a question about alignments, and so forth. We wanted to know if you can see any stars out of the* AOT *(Alignment Optical Telescope).*

SC—*In this attitude that we're pitching around I cannot use the* AOT *to see stars. The Command Module is just radiating too much light into the telescope.*

CAPCOM—*How about using the Service Module to cast a shadow on the Commander's window. If you do that, can you see stars?*

SC—*We tried to do it. The light shines off our quads, which makes it difficult to see stars. We do have the Earth and Moon, if that can be of assistance. Another problem: Right now I'm looking out the right window and it's pretty dark out there, but there are about a thousand or so foam stars out there—left over from the debris. It's hard to discern what's real and what's not.*

Ultimately, Mission Control would come up with a computer solution for lining up the spacecraft by sighting on the Earth, Sun, and Moon through the telescope.

The mission clock now showed 61:28:43, which was 3:42 a.m. EST Tuesday and it was time for the critical burn which would take the spacecraft out of the hybrid trajectory and place it in free return. The engine to be used for this burn was that of the Descent Propulsion System (DPS) of Aquarius. The conversation went like this:

CAPCOM—*Aquarius, you're go for the burn.*

SC—*Master arm's on. One minute.*

SC—*Forty percent.*

CAPCOM—*Aquarius, you're looking good.*

SC—*All shut down.*

And a little later:

CAPCOM—*Aquarius, check your master arm off, please.*

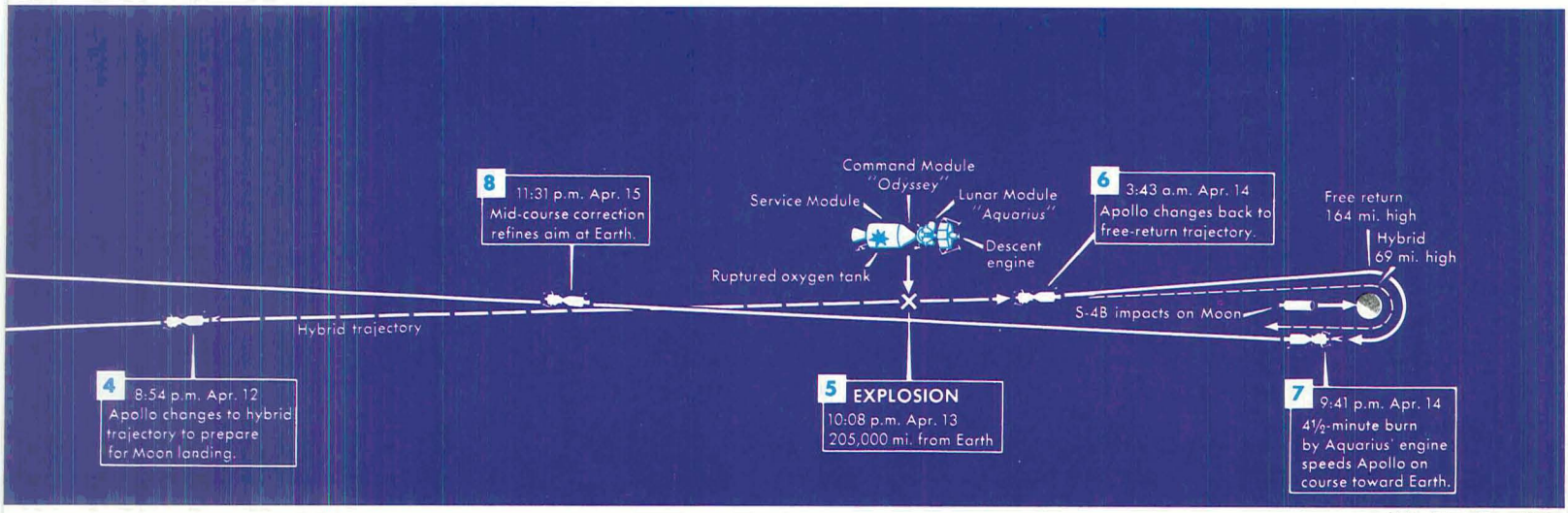
SC—*Okay, Houston, burn's complete. Now we have to talk about powering down.*

The first milestone on the journey home had been passed.

Even without another burn, the spacecraft would return to Earth for a landing in the Indian Ocean. Emergency preparations for the pickup would have to be completed, but that could be done. And there still remained in the flight plan the second critical burn to obtain a quicker trip and landing in the Pacific.

Haise stood watch, while his fellow astronauts tried for some fitful sleep in the chilly Command Module—chilly and dark because its power supply was cut off.

On the ground, possible future maneuvers were tried out in flight simulators at Houston and Kennedy Space Center by their fellow



astronauts: disappointed Ken Mattingly, Apollo 14 Commander Al Shepard, LM Pilot Ed Mitchell, CM Pilot Stu Roosa, Apollo 12's CM Pilot Dick Gordon, Gene Cernan of Apollo 10, Dave Scott of Apollo 9, John Young, Vance Brand, Ron Evans and Joe Engle.

Maneuvers that still remained to be executed were simulated in complete detail. The big burn to get the quicker return and splashdown in the Pacific was simulated: placing the simulated spacecraft in the correct attitude, firing the Aquarius DPS engine, and checking the results by computer. Similarly, the astronauts went through the simulated maneuvers of dropping the Lunar Module, dropping the Service Module and putting the Command Module into the correct attitude for reentry into the atmosphere for safe landing.

Engineers in Downey, Calif., where Odyssey was built, ran emergency problems through computers. A team of 30 at Massachusetts Institute of Technology, where the Apollo guidance system was designed, worked through the night. Ten phone lines were kept open between Mission Control and a room staffed with 70 LM experts at the manufacturer's plant in Bethpage, Long Island.

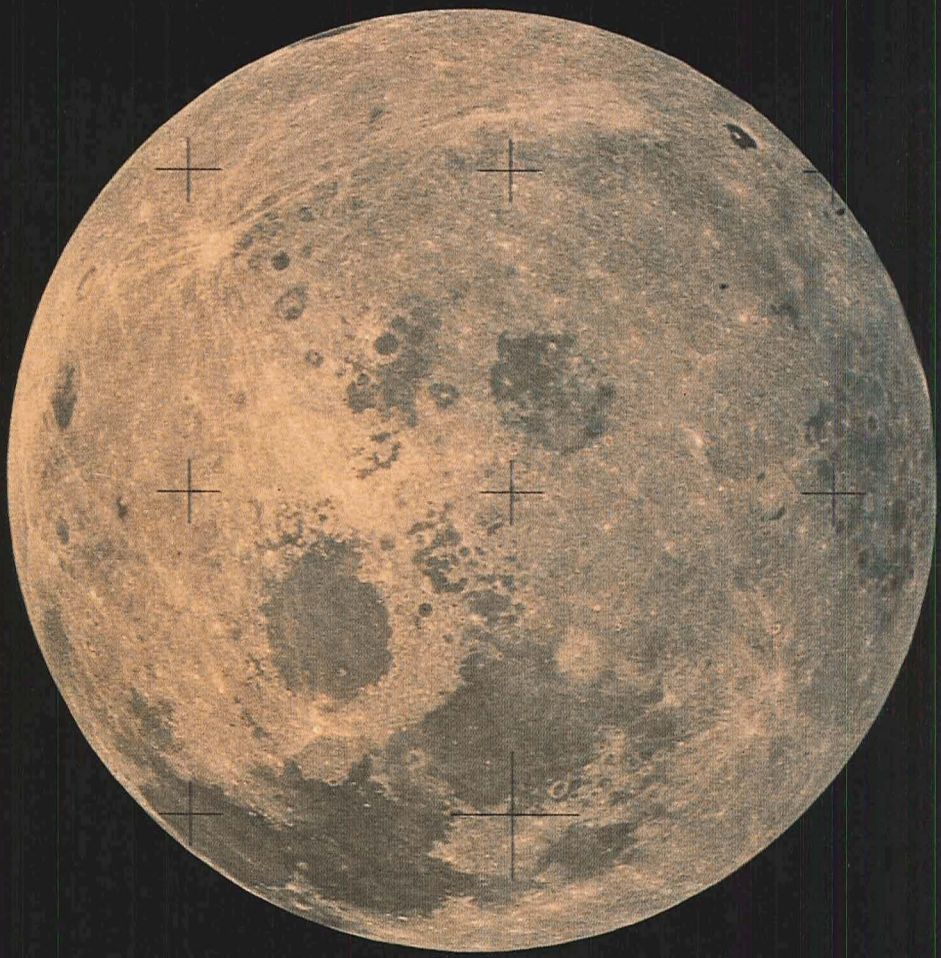
President Nixon cancelled appointments and kept in touch. He was briefed by former astronauts Mike Collins of Apollo 11 and Bill Anders of Apollo 8. He phoned Lovell's and Haise's wives in Houston and Swigert's parents in Denver. He drove out to the Goddard Space Flight Center, in Maryland, primary switching center for NASA's worldwide tracking and communications network.

As the men in Apollo 13 experienced what no men had undergone before, millions followed the developing drama by radio and television in public squares, private homes, schools, offices and factories. Pope Paul, at an audience in St. Peter's Basilica for 10,000 Romans and tourists, said "We cannot forget at this moment the lot of the astronauts of Apollo 13. We hope that at least their lives can be saved." Prolonged applause followed. Prayers were said at Jerusalem's Wailing Wall and on the floor of Chicago's Board of Trade.

On Tuesday, April 14, the U.S. Senate adopted a resolution which urged all businesses and communications media to pause at 9 p.m., their local time, to "permit persons to join in prayer for the safety of the astronauts."

Offers of assistance with ships to aid in the recovery came from many nations. The Associated Press quoted the Russian news agency Tass as saying that four Soviet ships were steaming toward the splashdown area, one of them the Chumikan, a missile tracker equipped with a helicopter. Tass said the Chumikan and fishing trawler No. 8452 were ordered to join the cargo carriers Academician Rykachev and Novopolotsk converging on the Pacific target area.

Premier Aleksei N. Kosygin sent a message saying: "I want to inform you (U.S. Government) the Soviet Government has given orders to all citizens and members of the armed forces to use all necessary means to render assistance in the rescue of the American (Apollo 13) astronauts."



The Moon from Apollo 13.

Italian press reaction was typical of world-wide concern.

Other nations offering assistance included France, Britain, Holland, Italy, Spain, Germany, Brazil and Uruguay.

At 7:21 p.m. Tuesday, the spacecraft swung behind the Moon, lost contact with Earth, and passed 164 miles above the lunar surface. Haise and Swigert, who had never been so close and might never get closer, snapped photos like a couple of tourists. At 7:49 the spacecraft emerged on the other side and was again picked up by tracking stations.

This conversation took place:

SC—*Houston, Aquarius.*

CAPCOM—*Aquarius, Houston.*

SC—*The view out there is fantastic . . . You can see where we're zooming off.*

Apollo 13 was headed homeward.

Moments later the 15-ton spent third stage of the Saturn V launch vehicle crashed into the Moon, as planned.

It occurred at 8:09 p.m. EST, April 14. The S-IVB struck the Moon with a force equivalent to 11½ tons of TNT. It hit 85 miles west northwest of the site where the Apollo 12 astronauts had set up their seismometer. Scientists on Earth said, "the Moon rang like a bell."

Back in November 1969, the Apollo 12 astronauts had sent their Lunar Module crashing into the Moon following their return to the command craft after the lunar landing mission. That Lunar Module struck with a force of one ton of TNT. The shock waves built up to a peak in eight minutes and continued for nearly an hour.

The seismic signals produced by the impact of S-IVB were 20 to 30 times greater and four times longer than those resulting from the LM crash. Peak intensity occurred in 7 minutes.

The information from these two artificial moonquakes led to reconsideration of theories proposed about the lunar interior. Among puzzling features are the rapid build-up to the peak and the prolonged reverberations. Nothing comparable happens when objects strike Earth.

One theory is that the signal is scattered and repropagated in very deep rubble. Another holds that the velocities of seismic waves from these impacts are comparable to measurements of velocities in crystalline rock. So the crystalline material which the astronauts found so abundant on the Moon's surface may extend very deep into the Moon.

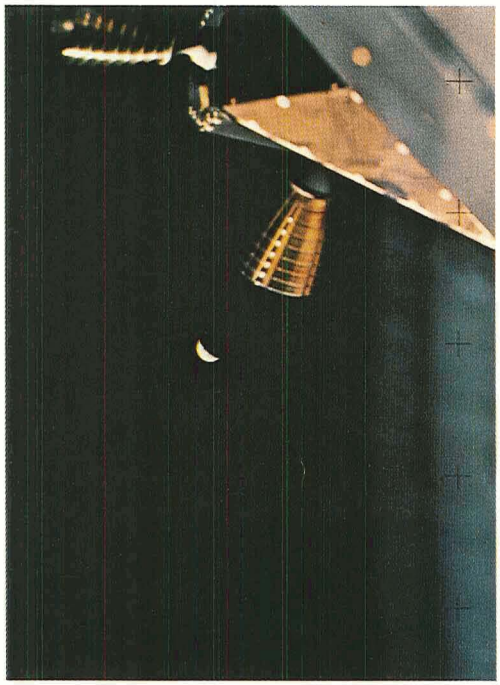
Houston reported the lunar impact of the S-IVB to the spacecraft:

CAPCOM—*By the way, Aquarius, we see the results now from 12's seismometer. Looks like your booster just hit the Moon, and it's rocking a little bit.*

SC—*Well, at least something worked on this flight. . . I'm sure glad we didn't have an* LM *impact, too.*

Time was at hand for the burn, two hours after closest approach to the Moon. The de-

Aquarius points the way to distant Earth. The visible rocket nozzle is part of the Aquarius Reaction Control System.



Flight controllers view prototype of the "do-it-yourself" lithium hydroxide unit that Apollo 13 astronauts constructed following directions from the ground. The apparatus enabled Aquarius to utilize lithium hydroxide canisters from the crippled Odyssey.

scent engine would fire five seconds at 10 percent throttle, 21 seconds at 40 percent, and nearly four minutes at full blast.

This burn would add 585 miles per hour to the velocity of the spacecraft, bringing it to Earth 10 hours sooner, and would make the target for splashdown a spot in the Pacific Ocean south of American Samoa. The carrier Iwo Jima already was enroute to that pinpointed spot.

CAPCOM—*Three minutes—counting down . . . Mark. . .*

SC—*We're burning 40 percent. . .*

CAPCOM—*Looking good at two minutes.*

SC—*Two minutes, Roger. . .*

CAPCOM—*Aquarius, you're go at three minutes. . .*

SC—*Shutdown.*

CAPCOM—*I say that was a good burn.*

SC—*Now we want to power down as soon as possible.*

CAPCOM—*We have a procedure ready. . .*

Aquarius had been designed as a two-man spacecraft and, in the original flight plan, would have been used less than 60 hours. Could her consumables—oxygen, water, batteries—be stretched to keep three men alive nearly 90 hours, from the loss of CSM power the evening before, to just before reentry two and a half days ahead?

After some early false alarms, the outlook by Wednesday morning was reassuring. Plenty of drinking water could be brought over from the Command Module. Oxygen stores showed a margin of 95 hours. With power kept up only on the life-support, telemetry, and communications equipment, except during critical maneuvers, cooling water would last 23 hours beyond reentry, batteries 60 hours—ample to recharge the Command Module's batteries before separation.

One item could be a problem: the cartridges of lithium hydroxide that remove carbon dioxide from the spacecraft atmosphere. The LM's cartridges would last only 50 hours, and the CM's wouldn't fit the LM.

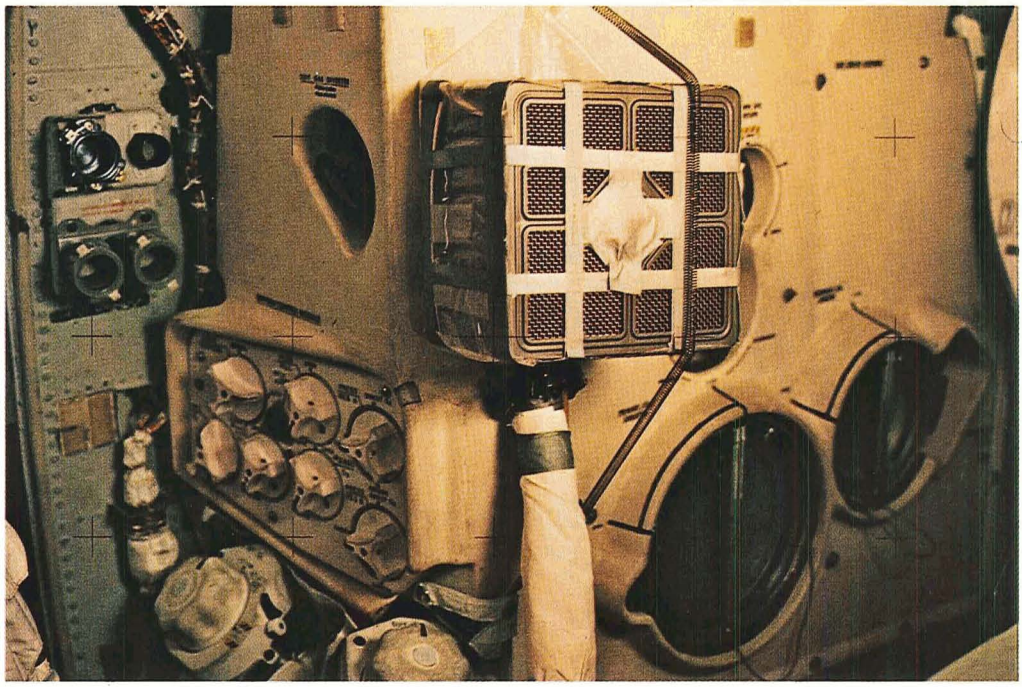
Bob Smylie and Jim Correale, of the Crew Systems Division at Houston, devised a makeshift adapter, and Astronaut Tony England tested the design by putting one together from oral instructions alone. As Mission Control voiced these up to Aquarius, Swigert and Lovell built adapters using cardboard cue cards from unneeded lunar surface procedures, plastic storage bags, and adhesive tape to attach cartridges from the CM to LM hoses that sucked cabin air through them.

CAPCOM—*The next step is to cut a diagonal hole. . .*

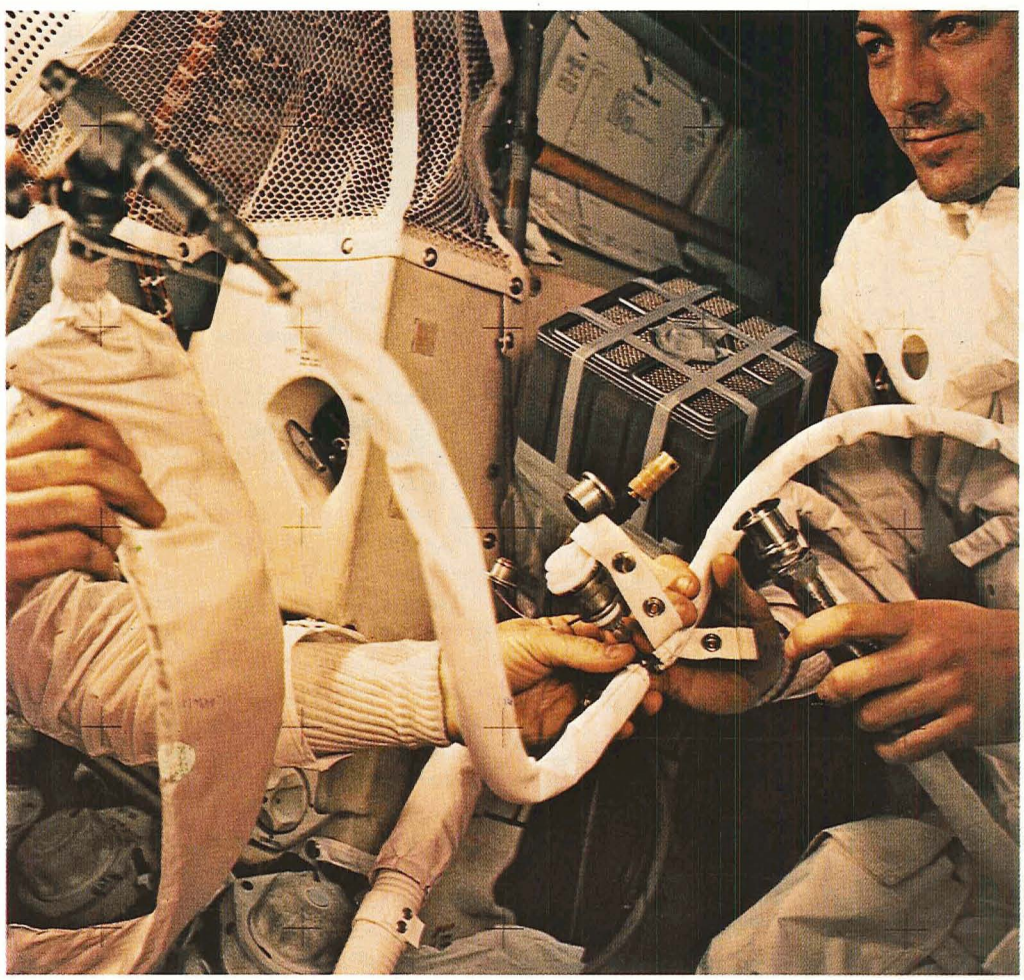
SC—*Okay, our do-it-yourself lithium hydroxide unit is complete.*

Earth stations continued to track the spacecraft. Within four hours after the big burn, just this side of the Moon, their data was showing that, because the automatic guidance system had drifted out of alignment, the re-

The do-it-yourself unit in Aquarius to utilize lithium hydroxide canisters from the crippled Odyssey.



Jury-rigged urine disposal system. Swigert at right.



sults hadn't been as precise as first thought.

By the time Apollo 13 entered Earth's sphere of gravitational influence at 8:38 Wednesday morning, still 216,277 miles from home, the data showed it would miss by 99 miles and sail on in orbit forever. A bigger midcourse correction than ever made before by a returning Apollo lunar mission was scheduled for near midnight. Again safety of the crew depended on Aquarius' descent engine.

The spacecraft was positioned by sighting on the Earth and Sun, a procedure never used previously, but one which had been developed in studies and checked by computers, and which was rechecked while Apollo 13 was enroute from the Moon to the Earth. The engine was fired manually. Lovell and Haise, in their normal LM piloting positions, handled the attitude controls. Swigert, sitting on the ascent engine cover, watched the timer to signal when to start and stop the burn, and Lovell pushed the buttons. Mission Control watched the results.

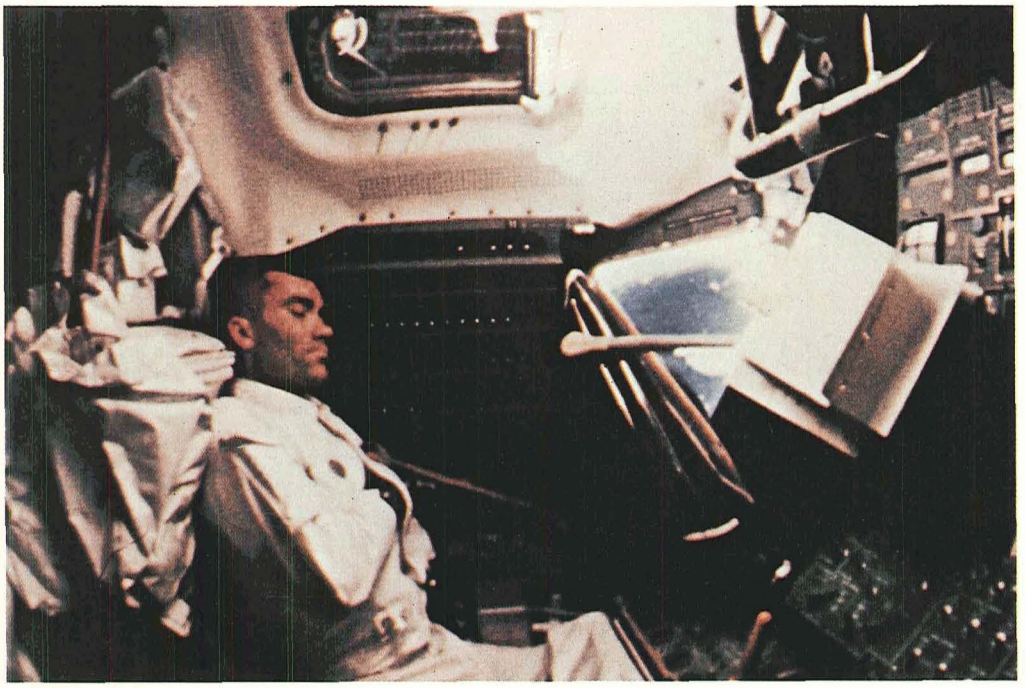
CAPCOM—*Ignition . . . Thrust looks good . . . It shut down . . . Nice work.*

SC—*Let's hope it was.*

Ground trackers could soon report that it was, putting Apollo 13 comfortably within the reentry corridor.

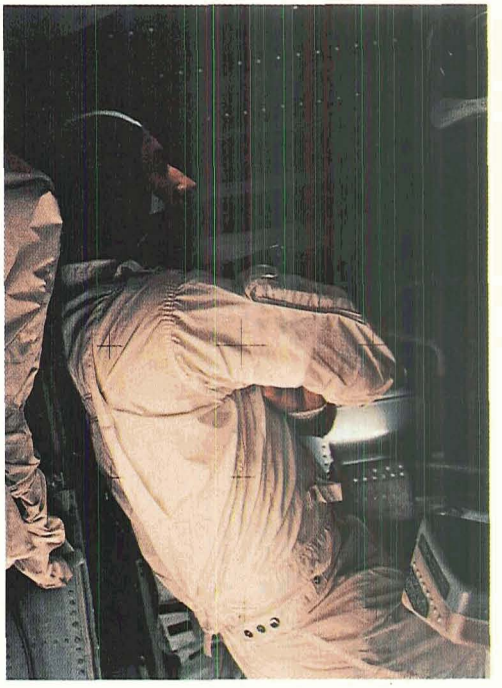
Heat from repeated firing of the descent engine had caused an increased rate of pressure buildup in the LM's supercold helium

Haise sleeps in Aquarius. He restrained his hands so that his arms would not flop about in weightless space environment.



Lovell sleeps in Aquarius.

Lovell's "grand oasis in the vastness of space" beckons to the homebound travelers.



tank, used to pressurize the fuel tanks but no longer needed. Just after noon the tank's burst disc—a relief valve—ruptured, as it was designed to do, and the helium vented into space. The gas had been expected to spew out equally in opposite directions, having no propulsive effect on the spacecraft.

CAPCOM—*See anything?*

SC—*Yeah, I was just about ready to call you. Underneath Quad 4 I noticed a lot of sparklies going out.*

CAPCOM—*Can you hear or feel anything?*

SC—*I sure did . . . I think it changed our* PTC (Passive Thermal Control of the spacecraft by slowly rotating it to distribute the Sun's heat) *. . . I was in right yaw and now I'm in left yaw, at a much faster rate . . . Is that what they call a nonpropulsive vent?*

CAPCOM—*Right. I'd hate to see a propulsive one.*

Thermal control was soon restored by use of bursts from the control thrusters until the slow rate of rotation was readjusted. Switches were thrown to begin recharging the Command Module's reentry batteries from the LM's. And the astronauts of Apollo 13 were allowed the first period of relatively relaxed activity since the accident.

But their physical hardships grew by the hour.

Temperatures in the darkened CM dropped to 38 degrees. Lovell and Haise pulled on their lunar boots, Swigert an extra suit of long underwear. The cabin walls were perspiring, the windows wet and partly frosted over. All food was cold, for there was no hot water in the LM to mix with the dehydrated meals. The men dozed, always leaving one on watch, but real sleep was rare. Deke Slayton, chief astronaut as Director of Flight Crew Operations, told them they could take stay-awake pills during the final hours.

At Mission Control, Gene Kranz's entire team of flight controllers was taken off its regular shifts to work out and rehearse spacecraft separation and entry routines. Astronauts in the simulators proved out every maneuver and crew procedure. Thursday evening Capsule Communicators began hours of reading up check lists to Swigert, then Haise.

CAPCOM—*Next verify . . .*

SC—*I may not sound too clear, because I'm holding a flashlight between my teeth.*

Shortly before 4 o'clock Friday morning, Eastern Standard Time, Lovell and Haise, unable to sleep longer, began powering up Aquarius three hours earlier than planned. The cabin warmed a bit. As they realigned the guidance system, Swigert—watching the time till he could begin reviving dead, cold Odyssey—wryly urged them on:

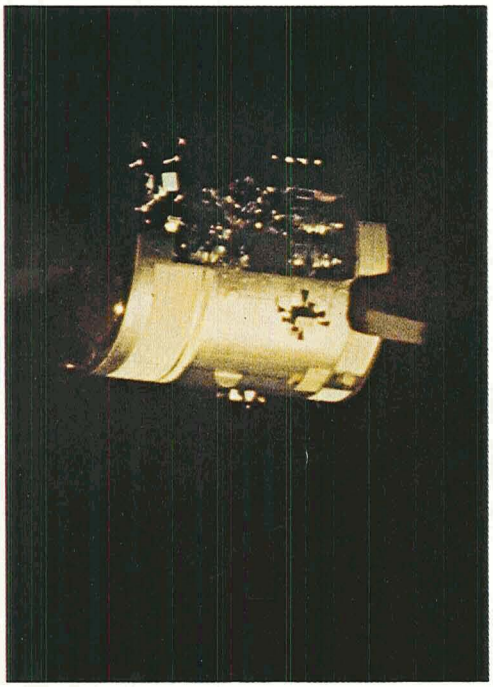
SC—*That Earth is whistling in like a freight train.*

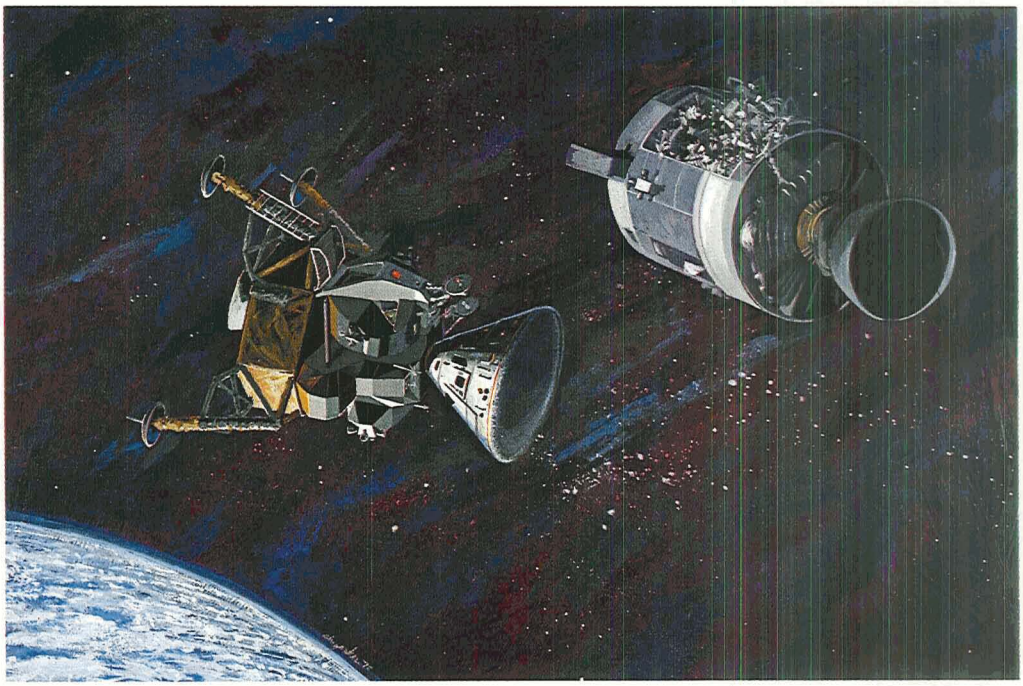
A final course correction with the LM's small reaction-control jets at 7:53 put the

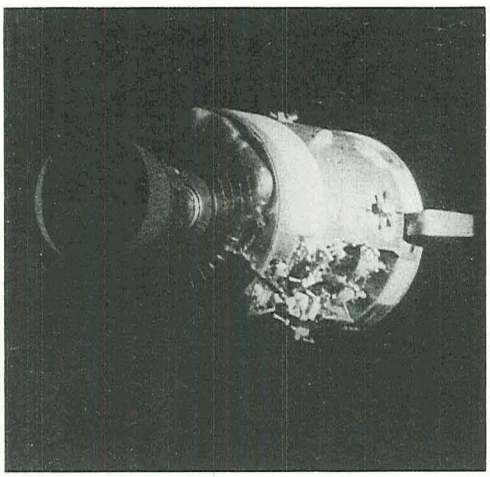
The crippled Service Module drifts away from the Command Module after jettison.

Service Module just after jettison shows its seriously damaged side to astronauts.

Separation of the never-flown-before Command Module/Lunar Module configuration from the crippled Service Module.







spacecraft exactly in the center of the corridor in which it should enter the atmosphere.

CAPCOM—*You can jettison the Service Module when you are ready. No big rush, but any time.*

As Aquarius, leading the train of linked modules, pushed gently backward, Swigert fired small explosive devices to sever the SM from the CM. Aquarius then pulled forward to complete the separation. The useless Service Module drifted away from the other two, still joined in a configuration never flown before or practiced in the simulators before the flight.

The three crewmen watched from separate windows and took photographs that might help tell what had happened at the moment when near-disaster struck 82 hours and nearly half a million miles ago.

SC—*Okay, I've got her.*

CAPCOM—*Beautiful, beautiful.*

SC—*And there's one whole side of that spacecraft missing. . . Right by the high-gain antenna the whole panel is blown out, almost from the base to the engine. . . It's really a mess.*

CAPCOM—*Take pictures, but don't make any unnecessary maneuvers.*

SC—*Man, that's unbelievable—looks like a lot of debris is just hanging out of the side near the S-band antenna.*

As Haise began shutting down the LM, this exchange took place between Mission Control and Lovell, the world's most experienced man in space and veteran of four flights:

SC—*Well, I can't say that this week hasn't been filled with excitement.*

CAPCOM—*Well, James, if you can't take any better care of the spacecraft than that, we might not give you another one.*

Time approached to abandon the Apollo 13 lifeboat. Lovell and Haise joined Swigert in the Commnd Module, now fully powered by its own batteries.

SC—*We're ready to proceed with hatch closeup.*

CAPCOM—*Did Jim get the film out of Aquarius?*

SC—*You mean the film we took this morning? Yes, we transferred that.*

Since the CM's jets can control only its attitude, not push or pull, separation would be accomplished by firing pyrotechnics to cut LM loose and simply letting pressure in the closed tunnel between the modules push them apart.

SC—*Can I proceed on and kind of punch off early?*

CAPCOM—*Jack, when you are comfortably ready to punch off, you can go ahead and do it.*

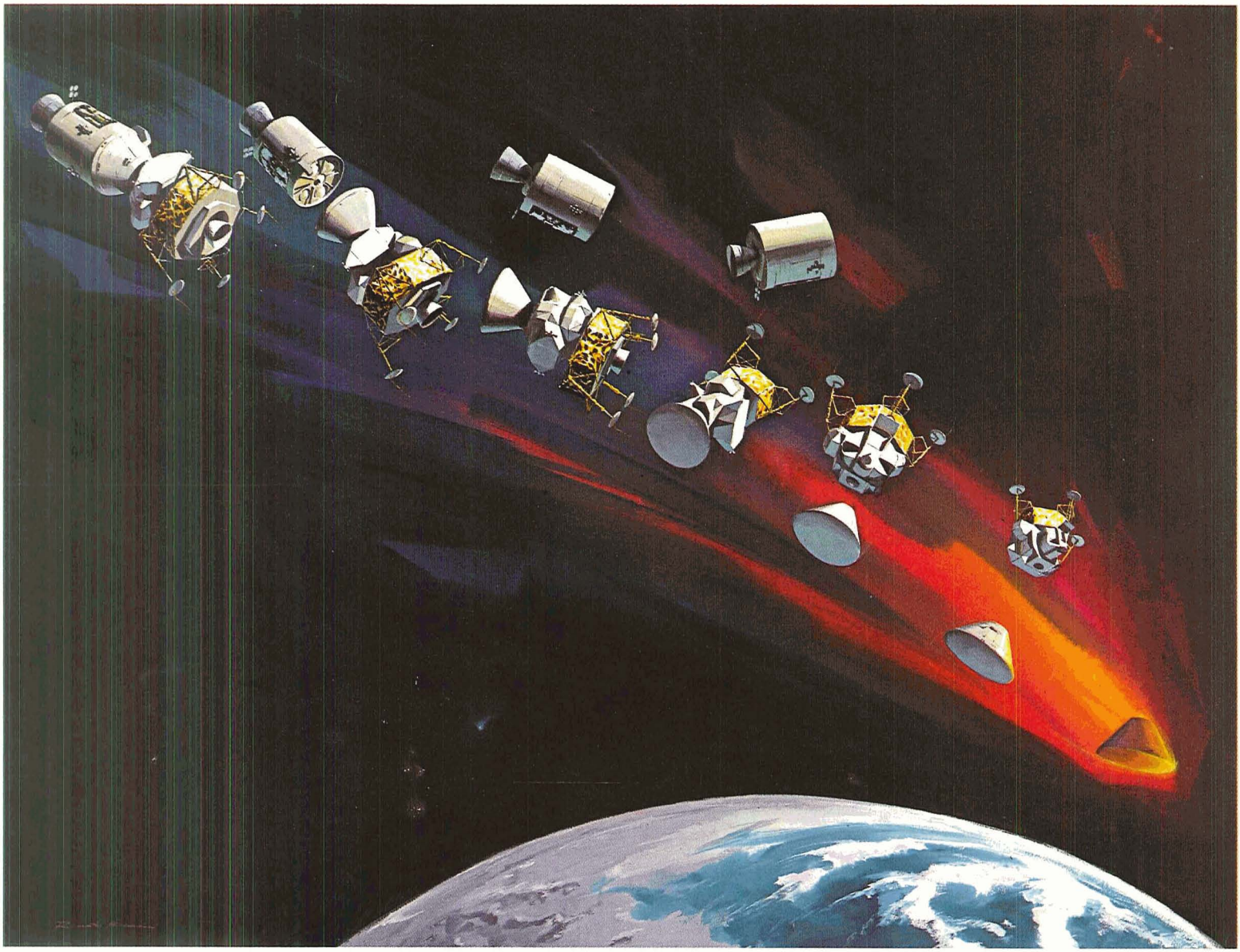
At 11:23 Swigert punched the button.

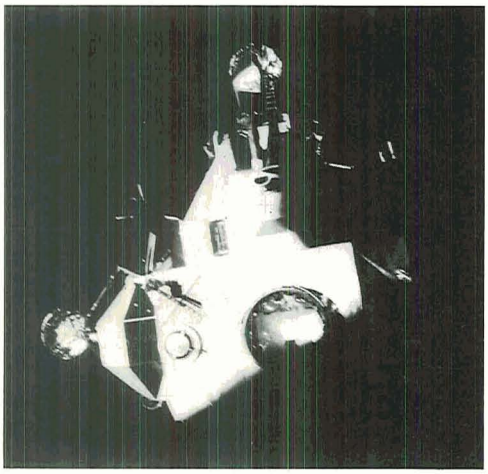
SC—LM *jettison.*

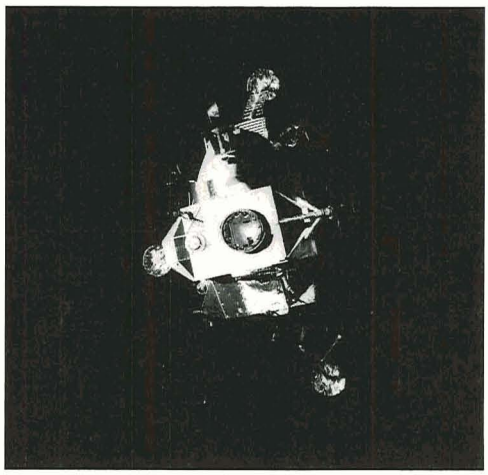
CAPCOM—*Farewell, Aquarius, and we thank you.*

Separation sequence of Aquarius and Odyssey prior to reentry.

"Farewell, Aquarius, and we thank you."







Officials join flight controllers in monitoring Apollo 13 flight. From left: Thomas H. McMullen, Assistant Mission Director; Dale D. Myers, Associate Administrator, Office of Manned Space Flight; Chester M. Lee, Mission Director; and Dr. Rocco Petrone, Apollo Program Director.

Odyssey drifts down through cloudy skies.

SC—*She sure was a great ship.*

The flimsy Aquarius, unshielded for return to Earth, would burn up in the atmosphere.

Six hundred miles southeast of Samoa the carrier USS Iwo Jima awaited Odyssey. Rescue planes patrolled a bath-tub shaped expanse of blue Pacific 390 miles wide and stretching 460 miles uprange and 115 downrange of the target point. The spacecraft's speed rose dramatically as it angled Earthward above the Indian Ocean and across southern Australia: 22,085 feet per second . . . 25,693 . . . 31,141 . . . 34,333 . . . 35,837—more than 24,000 miles an hour—just before the plunge into the atmosphere at 400,000 feet.

CAPCOM—*We've just had one last time around the room and everybody says you're looking great.*

SC—*Thank you.*

For three long minutes no word was heard from the spacecraft as friction with the air raised the heat shield to a fiery glow that blacked out radio communication.

Then:

CAPCOM—*Odyssey . . . Standing by.*

SC—*Okay . . .*

CAPCOM—*Okay, we read you, Jack.*

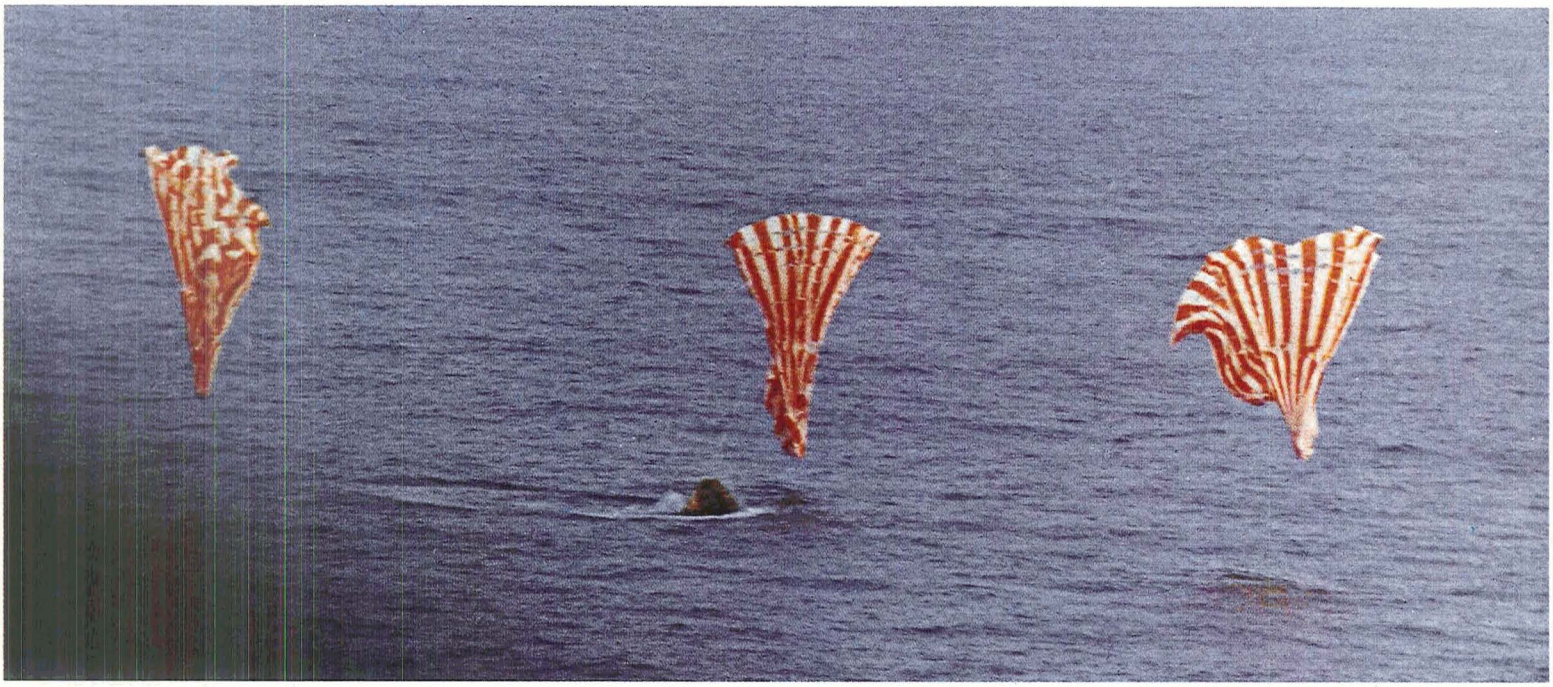
SC—*We got two drogues.*

Odyssey's two small parachutes pulled out its three 85-foot orange-and-white main chutes. Through color TV cameras aboard the Iwo Jima and in a photo helicopter, the world watched the charred spacecraft drift down through broken clouds to a splashdown in moderate seas four miles from the ship at 1:08 p.m., 142 hours 54 minutes 41 seconds after launch.

Swimmers jumped from a helicopter, attached a flotation collar and rubber rafts, and opened the hatch. From the rafts the astronauts, in turn, were hoisted in a basket, shaped like half a bird cage, to the recovery helicopter.

RECOVERY—*I have Astronaut Haise aboard, and his condition is excellent. . .*

Splashdown in the Pacific Ocean.

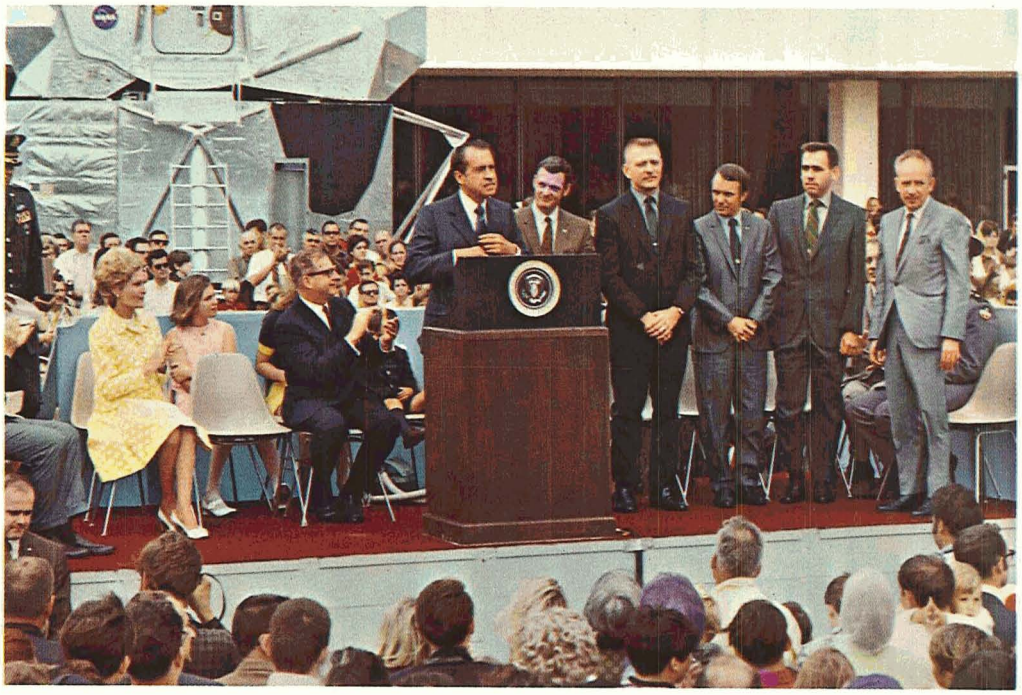


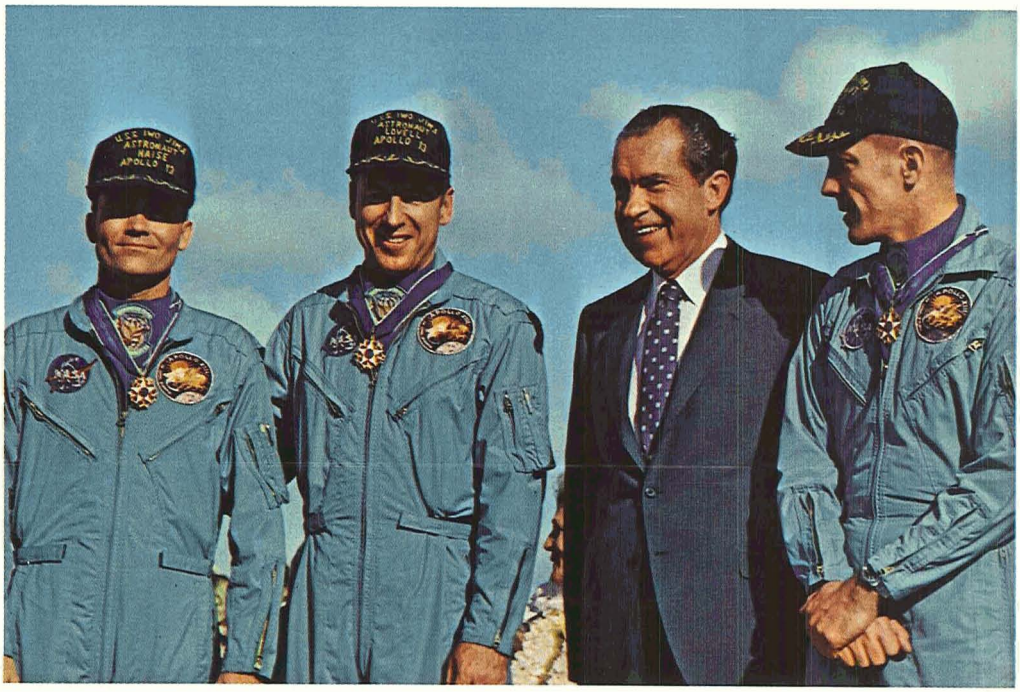
Apollo 13 astronauts wait in life raft for pick up by helicopter.

Mission Control after astronauts are safe on the recovery ship. Lovell, on screen, welcomed by the crew of primary recovery vessel, the USS Iwo Jima.

President Nixon awards Presidential Medal of Freedom to flight directors who helped bring Apollo 13 safely home. Left to right: Flight Directors Glynn S. Lunney, Eugene F. Kranz, Gerald Griffin and Milton L. Windler; Director of Flight Operations Sigurd A. Sjoberg. Seated at left are Mrs. Nixon and Dr. Thomas O. Paine, NASA Administrator.

The astronauts and President Nixon, after ceremonies in which they were awarded the Presidential Medal of Freedom. Left to right: Haise, Lovell, the President and Swigert.





I have Astronaut Swigert on board. He reports he feels fine. . . I have Captain Lovell aboard. He reports he feels fine.

Forty-five minutes from splashdown—the fastest recovery ever—they were safe on Iwo Jima's red-carpeted deck. Microphones had been set up. The admiral and the captain spoke. The ship's chaplain prayed. A band played. But Jim Lovell, Jack Swigert, and Fred Haise were too tired for public speeches.

From the flight deck of the Iwo Jima to American Samoa, to Hawaii and on to Houston, the crew of Apollo 13 travelled on a wave of applause. President Nixon presented the Medal of Freedom to the three astronauts and to Sigurd A. Sjoberg, Director of Flight Operations, and to Flight Directors Glynn S. Lunney, Eugene F. Kranz, Gerald Griffin, and Milton L. Windler.

The President of the United States summarized the reaction of many when he said, "The three astronauts did not reach the Moon, but they reached the hearts of millions of people in America and in the world."

Fiction had turned to fact in the flight of Odyssey and Aquarius. The tension, the agony, and the relief were understated by Jim Lovell: "We do not realize what we have on Earth until we leave it."

But all expressed confidence in America's program of space exploration and planned to ". . . learn from our mistakes and get on with the job."

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