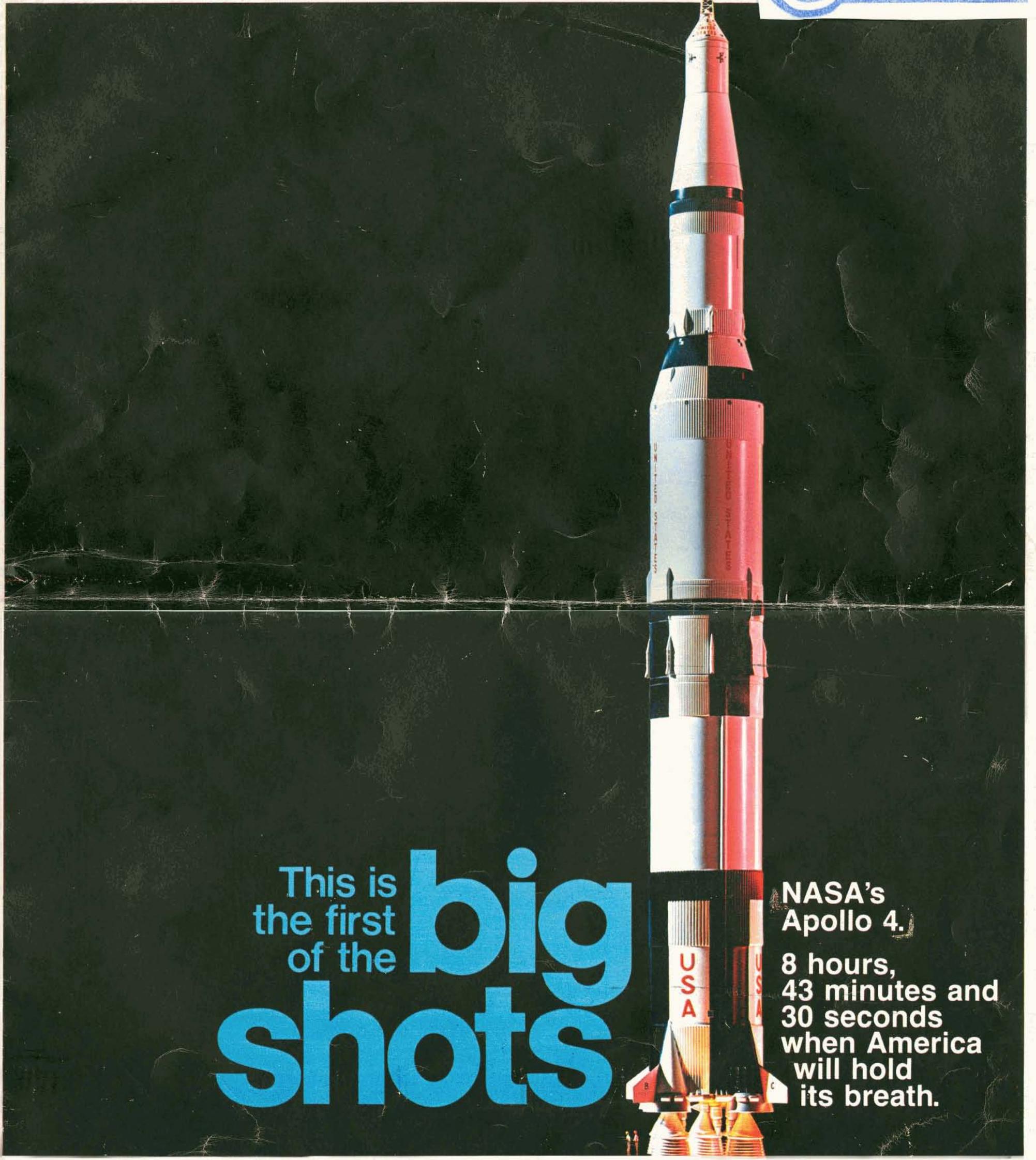


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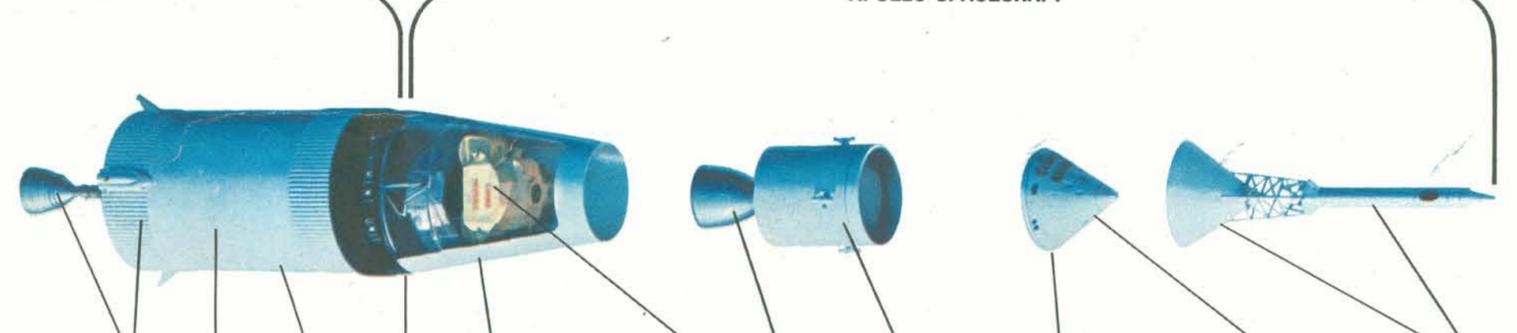
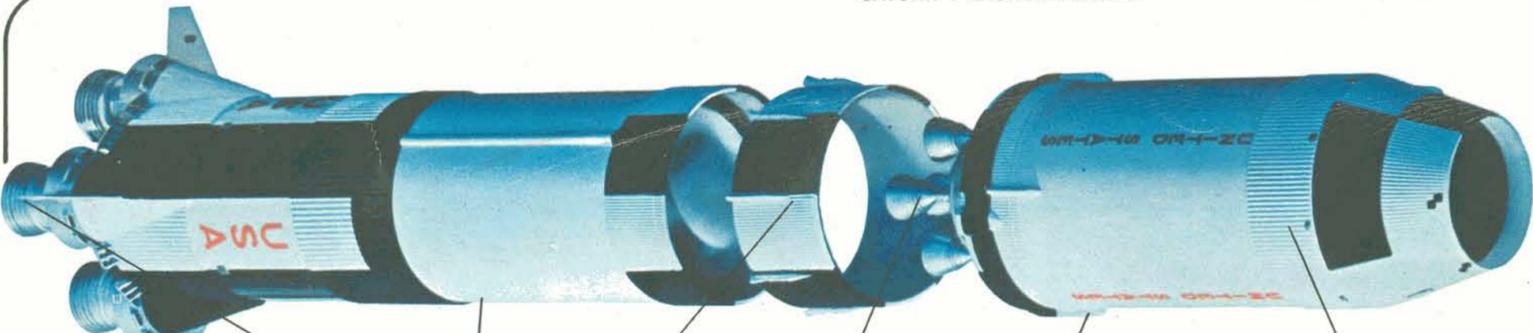
This is  
the first  
of the **big**  
**shots**

NASA's  
Apollo 4.

8 hours,  
43 minutes and  
30 seconds  
when America  
will hold  
its breath.



**Apollo/Saturn V is the vehicle that America will use to send man to the moon. Apollo is the spacecraft; Saturn V is the launch vehicle. In a short time the complete "stack" will be launched—for the first time. The first stage alone will develop 7,500,000 lbs. of thrust. We have already taken many big steps toward putting man on the moon; the first Apollo/Saturn V test flight, called the Apollo 4 mission, will be a Giant Step. That's why it's the Big Shot.**



**F-1 Engines.** There are five F-1 engines in the first stage, each capable of developing 1.5 million pounds of thrust for a total of 7.5 million. Together, they burn 1,250 gallons of RP-1 fuel and 2,083 gallons of LOX *per second!* Although these engines have been extensively tested over a period of years, this is the first time they will launch a vehicle into space.

**Saturn S-1C (First Stage).** This is the big one. It stands 138 ft. tall, with a 33-ft. diameter, and weighs 307,000 lbs., without propellant. With propellant, the weight jumps to 4,707,000 lbs., more than 3/4ths of the entire Apollo/Saturn V weight. Its job is to push 6.2 million pounds 38 miles through the atmosphere to a terminal speed of almost 6,100 mph. To accomplish this, it will consume 214,000 gallons of special kerosene (RP-1) and 346,400 gallons of liquid oxygen—and do it in 152 seconds.

**Interstage.** Besides connecting the first two stages (as its name implies), the 18-ft.-high interstage contains ullage motors (see glossary) for the second stage, and electronic equipment for the first. It is jettisoned 32 seconds after second-stage ignition.

**J-2 Engines.** There is a cluster of five J-2 engines on the second stage. Together, they develop over a million pounds of thrust. They burn some six minutes, consuming a total of 940,000 lbs. (or 355,100 gallons) of fuel and oxidizer.

**Saturn S-II (Second Stage).** It is a huge structure (81 ft., 7 in. high, 33 ft. across) machined to the tolerance of a fine watch. 90% of its 1,033,000-lb. weight is propellant for its five J-2 engines. The S-II second stage takes over from the first stage at an altitude of about 38 miles, when the vehicle is going some 6,100 mph. It fires about 6 minutes, boosting the vehicle to an altitude of 117 miles above the earth and a speed of 15,300 mph.

**S-II Propellant System.** The second stage is powered by liquid hydrogen (LH<sub>2</sub>) with liquid oxygen (LOX) as an oxidizer—both in huge quantities to stoke the five J-2 engines. In all, there are 267,700 gallons of LH<sub>2</sub> and 87,400 of LOX. The two propellants are carried in a single giant tank with a common bulkhead separating them. Without the common bulkhead there would have to be two tanks, which would mean another 10 feet in length for this stage and another 4 tons of

weight. Its development was no simple matter. Insulation is the critical problem because of the vast difference in temperature between the two liquids—423°F below zero for the LH<sub>2</sub> compared with a relatively balmy 293°F below for the LOX.

**J-2 Engine and Interstage Assembly.** The J-2 engine, powering the third stage, develops a thrust of 200,000 lbs. and can be re-ignited after the first burn. When it's time for the second and third stages to separate, retrorockets on the interstage fire, pushing the second stage away.

**S-IVB Propellant System.** The single J-2 engine of the third stage is powered by 66,900 gallons of liquid hydrogen, with 20,400 gallons of liquid oxygen as an oxidizer.

**Saturn S-IVB (Third Stage).** Height: 58 ft., 7 in. Diameter: 21 ft., 8 in. Weight: 260,000 lbs. (with fuel). The third-stage engine starts burning when the spacecraft is nearly at earth-orbiting altitude—but has a speed of only about 15,300 mph—not enough to sustain an orbit. The third stage burns for 142 seconds, boosting the speed to 17,500 mph. Now the vehicle is in free orbit around the earth; but the third stage's job isn't over. After the second orbit it must re-ignite to push the spacecraft out of a circular earth orbit with a 117-mile altitude, and into an eccentric (egg-shaped) orbit—the farthest point being some 11,400 miles out in space.

**Spacecraft Lunar Module Adapter (SLA).** It houses the Lunar Module (LM) during launch and the early stages of flight. Four panels are separable by mild explosive charges, opening 45 degrees to expose the docking drogue of the LM.

**Instrument Unit (IU).** 3 ft. high, with a 21-ft., 8-in. diameter, the IU weighs about 4,750 lbs. It is the brains of the Saturn V launch vehicle, controlling the firing and jettisoning of the three launch-vehicle stages.

**Lunar Module (LM).** On a lunar flight the LM will carry two astronauts down to the surface of the moon, then back up to rendezvous with the orbiting CSM. The descent engine can provide up to 10,500 lbs. of thrust; the ascent stage develops a 3500-lb. thrust. On Apollo 4 the LM will be a boilerplate (a full-scale, but non-operating, model) since testing the LM is not part of this flight.

**Service Module (SM).** 22 ft. high, with a 12-ft., 10-in. diameter, weighing about 55,000 lbs. The SM contains fuel cells for electrical power, propellant tanks, and systems supporting the CM. Its engines provide the power for all spacecraft maneuvers after translunar injection is completed and the third stage has been jettisoned.

**Service Propulsion System (SPS) Engine.** The Service Module's propulsion engine, with some 22,000 lbs. of thrust, is powered by hypergolic propellants—fuels that ignite on contact with each other. It can be restarted as many as 50 times.

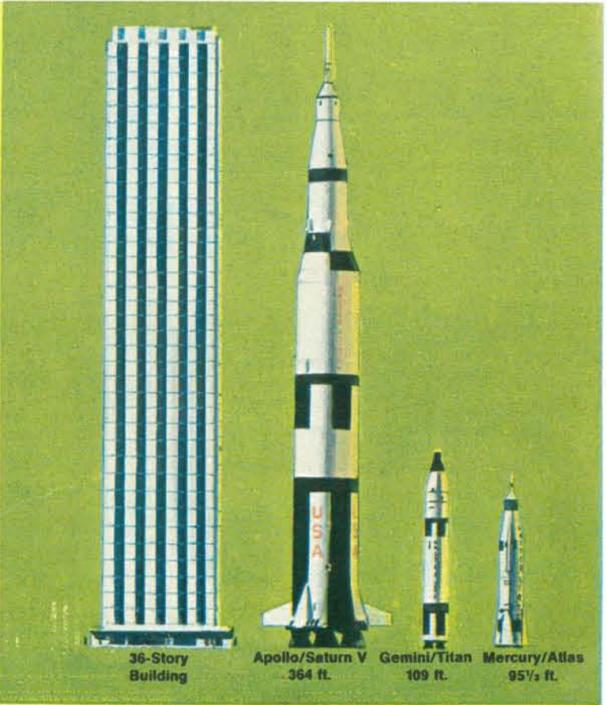
**Ablative Heat Shield.** During re-entry, the temperature on the ablative material of the CM heat shield will probably reach 4500°F. However, it's designed to withstand temperatures in excess of 5000°F. The heat shield is a stainless-steel honeycomb with a special plastic-like ablative material bonded to it. This ablative material burns off during re-entry.

**Command Module (CM).** 12 ft. high, with a base diameter of 12 ft., 10 in. Weight about 12,000 lbs. This is "home" for the 3 astronauts on their way to the moon and back. (In the Apollo 4 test, their place will be taken by an electronic device—the Mission Control Programmer.) The CM's small, 94-lb.-thrust Reaction Control engines allow for fine attitude adjustments during earth re-entry.

**Launch Escape System and Boost Protective Cover (LES & BPC).** 34 ft. long, with a 150,000-lb.-thrust launch escape motor, a 33,000-lb.-thrust tower jettison motor and a 3000-lb.-thrust pitch-control motor. The Boost Protective Cover fits over the CM to protect it from the expected 1200°F friction heat during launch. Normally, LES and BPC are jettisoned about 3 minutes, 8 seconds after lift-off. For an abort, the LES would carry the CM up and away from the launch vehicle's path.

## Apollo 4 is an unmanned test. What makes it such a Big Shot?

One thing, of course, is the historic significance of Apollo 4. This is the first time the Apollo/Saturn V will be launched and tested as a complete unit. But just in terms of sheer physical size it is big. In fact, compared with former space vehicles, it's gigantic. Apollo/Saturn V stands 364 feet tall—the size of a 36-story building. Compare that with Gemini/Titan at 109 feet; or with Mercury/Atlas at 95½ feet. The chart on the right gives you a vivid graphic idea of their relative sizes. In fact, Apollo/Saturn V is bigger than any other space vehicle ever fired—including any claimed by the U.S.S.R. Apollo 4 adds up to about 6,200,000 lbs. of weight, with fuel. And a considerable amount of that weight is electronic and mechanical equipment of a complexity never fired into space before. (The Command Module alone contains some 2 million intricate parts.) That's why, as one NASA official put it, Apollo 4 will have to perform about 12 times better than Mercury or Gemini just to get off the launching pad.



	MERCURY	GEMINI	APOLLO
PAYLOAD, LBS			
EARTH ORBITAL	3,500	7,000	250,000
TRANSLUNAR	-	-	94,000
BOOSTER	ATLAS	TITAN II	SATURN V
THRUST, LBS	360,000	430,000	7,500,000

6,200,000 lbs. is over 3000 tons; a good-sized Navy destroyer is only 2200 tons. Which gives you a fair idea of how much weight will have to be lifted off the ground before the Apollo spacecraft can be boosted into orbit, then shot almost 11,400 statute miles out into space and intricately maneuvered during the Apollo 4 flight. To accomplish the most awe-inspiring weight-lifting act in history, Apollo 4 will have a total thrust, counting all, rocket engines, of better than 9 million lbs. The first-stage engines alone develop a thrust of 7.5 million pounds. That's enough to have sent into earth orbit *all* the spacecraft we've ever launched. In the chart, at left, you can see how Saturn V compares with the rockets used in our last two manned programs. All these comparisons are illuminating: payload, overall weight and size, thrust, etc. But what is hard to grasp is the staggering complexity of launching such a mammoth vehicle—especially for the first time. It will truly be one of the greatest technological achievements in our nation's history.

**Apollo/Saturn V has been tested on the ground as much as possible. But a first flight can't be tested; it simply has to be made. In this first Apollo/Saturn V flight there are about 200 other "firsts." Here are a few key ones.**

One of the key firsts is to find out if the Command Module's ablative heat shield can withstand the fearsome heat of re-entry into the earth's atmosphere at the actual earth-return speed of a lunar mission. Nearly 25,000 mph.

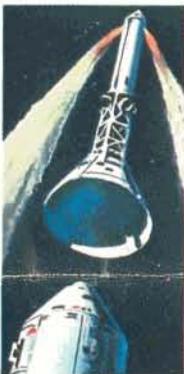


Until now, spacecraft have re-entered from the normal earth-orbiting speed of 17,500 mph. Because of this dramatic difference in re-entry speeds, Apollo's CM heat shield has been designed to weather twice as much heat as Gemini and Mercury did.

*Re-ignition.* The third stage (S-IVB) is powered by a single J-2 engine. It has flown before; but it has had to fire only once during each flight. On a moon-



landing mission, it will have to re-ignite. Apollo 4 will be the first test, in space, of firing the J-2 engine, shutting down, then re-igniting.



*LES Separation.* Approximately three minutes after launch, the Launch Escape System engine will ignite, carrying the Boost Protective Cover away with it. This will be the first test of the system under actual lunar-mission flight conditions.

*Long Firing.* Once Apollo is on the way to the moon, its propulsion will be furnished solely by the Service Propulsion System. On this mission, the SPS will be fired longer than it ever has been in flight—for 24 seconds on its first burn, and 4 minutes, 25 seconds on the second burn. The second burn simulates the firing required to put an Apollo spacecraft into lunar orbit.

*Deep Space.* This will be the first time such a large, sophisticated mass has operated in the violent temperature ranges of deep space. What are the effects? To find out, the spacecraft will be positioned for some 4½ hours with one side constantly facing the sun. It will allow a test of the effect that the extreme heat and cold of space will have on such an intricate mechanism.



*Complex 39.* Before Apollo 4 is ever launched, there will be a first: this

will mark the first use of Kennedy Space Center's Launch Complex 39. The word is "giant" for everything connected with it. Housing Apollo/Saturn V is the biggest building (in volume) in the world. It's so big that if it weren't air-conditioned, there would be rainstorms inside the building. The huge tractor that moves the rocket from the building to the launching pad, three miles away, has eight treads. Each of the 57 links that make up each tread weighs about a ton.



*First Flight of the Saturn S-IC.* The Saturn S-IC first stage, with five F-1 engines, will be launched for the first time—after years of exacting ground tests. Its 7.5 million lbs. of

thrust and nearly 4¾ million lbs. of weight (with fuel) make it the biggest, most powerful single object ever launched by anyone, anywhere on earth.

*Another First—Saturn S-II.* The second stage, Saturn S-II, will also be launched for the first time. With five J-2 engines delivering a total of



1 million lbs. of thrust, this is the biggest, most powerful stage that's powered by liquid hydrogen ever to fly.

Liquid hydrogen is considered the most efficient rocket fuel. But it's tricky to handle—and there's a tremendous amount of it in the S-II (more than 267,000 gallons). So this first flight will be an important and impressive milestone in the history of rocketry.

*Welcome Home.* The mission will result, for the first time, in the recovery of a spacecraft that has flown higher (11,400 miles) and faster (almost 25,000 mph) and



re-entered, withstanding more heat, than any other in history.

**Some facts about Apollo/Saturn V aren't exactly technical, but they help you better appreciate the scope of the Apollo program. And they certainly are amazing. In fact, for reasons you'll understand as you read them, they might well be called "Gee Whiz" data.**

We have launched a good many spacecraft since our nation's space program began. Even so, a single Saturn V has enough power to put all of them into an earth orbit at the same time.

There's enough liquid oxygen in just the first stage to fill 34 railroad tank cars. And that stage's fuel pumps work with the force of 30 diesel locomotives.

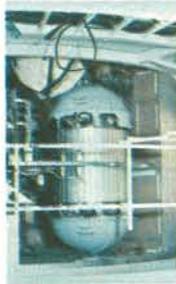
The Boost Protective Cover shields the Command Module from friction heat during launch. That temperature is expected to reach 1200 degrees on the way up—not much less than the amount of heat the Mercury capsule withstood on *re-entry*.

A space vehicle consists of a spacecraft and a launch vehicle, the latter being far and away the larger component. The Apollo 4 spacecraft—Launch Escape System (not shown); Command, Service and Lunar Modules; plus the LM Adapter—is 82 feet high. That's only 13 feet shorter than the whole Mercury/Atlas space vehicle, which was used in John Glenn's historic earth-orbiting mission.



The Apollo Command Module is double the size of the Gemini spacecraft—which was half again bigger than Mercury.

The cryogenic fuel tanks aboard the Service Module are really huge



Thermos bottles. But super-efficient (the vacuum between the inner and outer walls is created by pumps working continuously for 28 days). Three ice cubes placed inside would take 8½ years to melt.

You could drive three big moving vans, side by side, into the Saturn V first stage.



For all the complexity of its electronic systems, the Command Module uses only about 3000 watts of

electricity—about the same as the oven in an electric kitchen range. This power is provided by fuel cells that, in the process of generating electricity, also produce 17 quarts

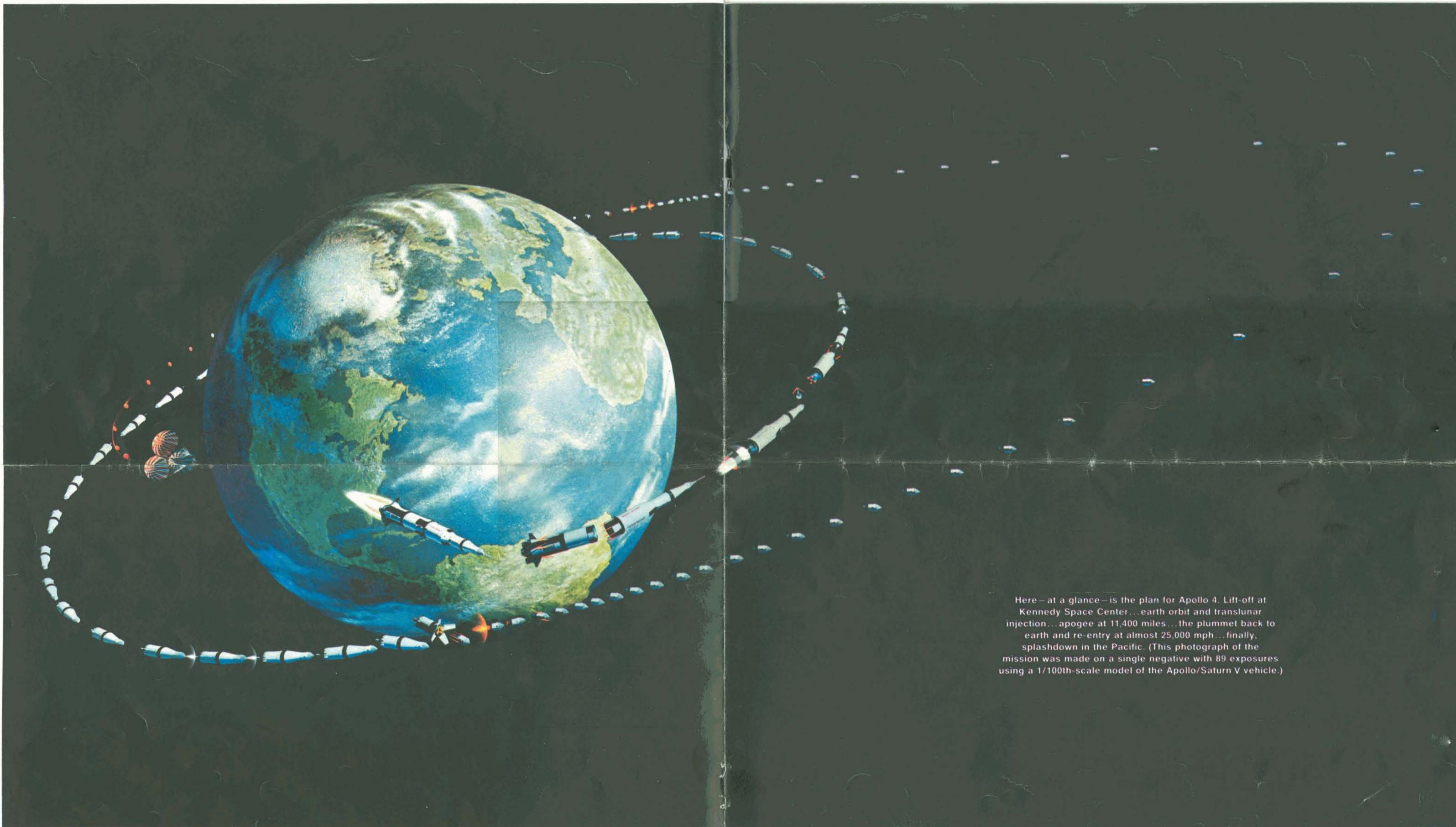
of drinkable water each day. Why three stages? Here's an analogy: A locomotive pulling three coal tenders can go about 500 miles until the coal runs out—if it drags the tenders all the way. If it drops each off, as the tender's coal runs out, the locomotive can go 900 miles.

If you ran all the rivers and streams of America through steam turbines at the same time—you'd get only half the 160 million horsepower that all five of Saturn's F-1 engines generate.



The photo shows a single F-1 engine firing during a captive test.

When the Command Module re-enters the earth's atmosphere, the heat energy generated will be about the same as 2300 kilowatt-hours of electrical energy. That would be enough to light the whole city of Washington, D.C., for 6½ seconds—or to lift all the people in the U.S.A. three feet off the ground. To protect against this incredible heat, there is an ablative shield that, at its thickest point, is only 2½ inches.



Here — at a glance — is the plan for Apollo 4. Lift-off at Kennedy Space Center... earth orbit and translunar injection... apogee at 11,400 miles... the plummet back to earth and re-entry at almost 25,000 mph... finally, splashdown in the Pacific. (This photograph of the mission was made on a single negative with 89 exposures using a 1/100th-scale model of the Apollo/Saturn V vehicle.)

# You can watch the lift-off on TV. Here's what will be happening after that—out where the cameras can't see.

The mission projected here is typical—and accurate as possible. The times given, though, will not necessarily be exact. There are too many variables involved.

For instance, the force of earth's gravity—and its effect on Apollo—will vary slightly, depending on the time of day when the rocket lifts off. And even that tiny change is enough to change the timing of some events pictured here.



**8:38:19**—At approximately 10,000 ft., three main parachutes deploy to lower the CM gently down. Relatively speaking, some 15 minutes before, it re-entered at a speed of 25,000 mph. Now the CM will splash down at about the same speed you would if you jumped off a 12½-ft. platform.



**8:23:06**—400,000 ft. above the earth—about 78 miles. This is considered the effective start of the earth's atmosphere. From here on there will be friction resulting in truly fearsome heat—about 4500°F.



**0:00:00**—Lift-off. The five F-1 engines of the Saturn first stage ignite. There's an 8.8-second delay while they develop their full 7.5-million-lb. thrust. Then the holding arms let go and the 6.2-million-lb. Apollo 4 is on its way.



**0:02:32**—The first stage has been jettisoned. Now, after 8 small ullage rockets fire briefly, the five J-2 engines of the Saturn S-II second stage ignite. 30 seconds later the interstage will break away. Altitude is about 38 miles; speed about 6100 mph.



**0:03:08**—The Launch Escape System is jettisoned. Any abort now can be accomplished by normal CM-SM separation and re-entry.



**8:21:41**—The Command Module and the Service Module separate. Before it enters the atmosphere, the CM has three minutes to reorient itself by means of small Reaction Control engines so the thick part of the heat shield is forward.



**8:19:04**—SPS cutoff. The CSM must now orient itself for clean separation.



**1:38:35**—Apollo completes one orbit and begins its second. Ground Control is constantly plotting speed and position, computing the proper firing time for simulated translunar injection.



**8:14:39**—SPS engine re-ignition. It will fire for about 4½ minutes, longer than it has ever fired in space before. The spacecraft will travel at the true lunar-mission return speed of almost 25,000 mph.



**8:01:09**—The CSM orients itself, by means of small Reaction Control engines; it is now "pointing" toward the earth.



**0:11:10**—Third-stage cutoff. Apollo is now in a circular parking orbit around the earth, about 117 miles high, at a speed of 17,500 mph. The spacecraft is coasting, without propulsion.



**0:08:44**—The single J-2 engine of the Saturn third stage ignites after the second stage is jettisoned. Vehicle speed: about 15,300 mph; altitude: just short of 117 miles.



**3:28:59—8:01:09**—Cold Soak. Immediately after SPS firing, Apollo again orients itself to face the sun for the test of wide-ranging, hostile temperatures on its electronic systems and insulation. It will stay in this attitude past apogee to the next SPS burn, just before re-entry.



## Is Apollo 4 really a Big Shot?

After all, it is unmanned; and it is traveling "only" 11,400 or so miles into space—whereas we have already landed vehicles on the moon while two space vehicles are right now hurtling toward Venus. Is Apollo 4 really all that important?

The answer is a firm, emphatic yes! It's a very big Big Shot indeed—crucial to our country's program of putting a man on the moon in this decade.

For one thing, the launch vehicles that have already sent payloads to the moon—ours and the Russians'—are pygmies compared to Saturn V. But to get man to the moon and back requires a vehicle this size.

Then there's the problem of re-entry. Earth-orbiting speed is around 17,500 mph. So far, every orbiting spacecraft that has re-entered earth's atmosphere has slowed down from that speed and "dropped" back in. But a spacecraft returning from the moon will have to smash into the atmosphere at about 25,000 mph. The difference in heat is awesome.

Apollo 4 will prove that the Command Module's heat shield can take it. To do it, the vehicle will simulate a return from the moon. After orbiting the earth, the third-stage engine will re-fire for about 5½ minutes, long enough to send the Apollo spacecraft about 11,400 miles out.

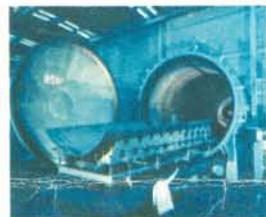
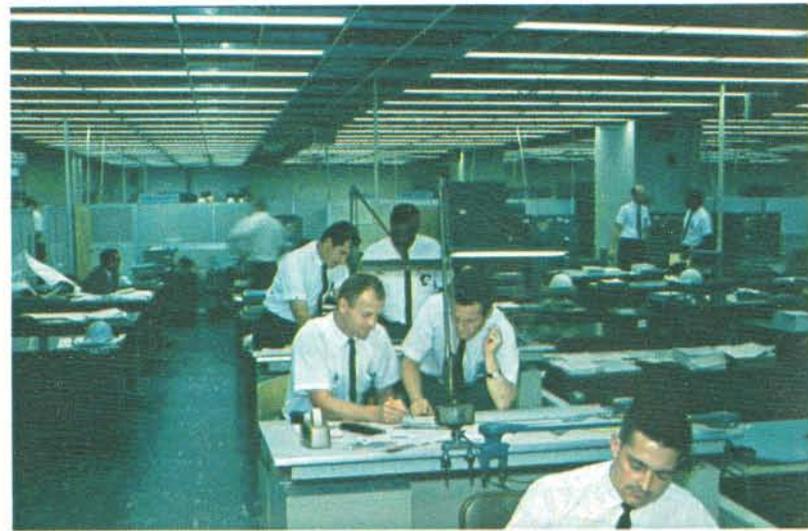
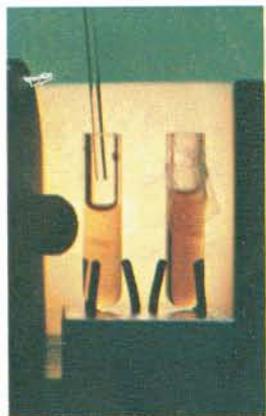
If the third stage burned just 19 seconds longer—and were oriented in a slightly different attitude—Apollo would go clear to the moon. That's what several other vehicles have done—and have never returned to earth. But this mission has a different purpose.

About 8½ minutes before entry into the atmosphere, the Service Module engine will fire for about 4½ minutes. That will boost the vehicle's speed to the true lunar-mission re-entry speed of 36,333 feet per second: almost 25,000 mph. (This simulates the firing that, on a lunar mission, is required to slow Apollo out of its flight path to the moon and inject it into an orbit around the moon. So, in effect, this second SPS firing is still another test of operations on a manned lunar flight.)

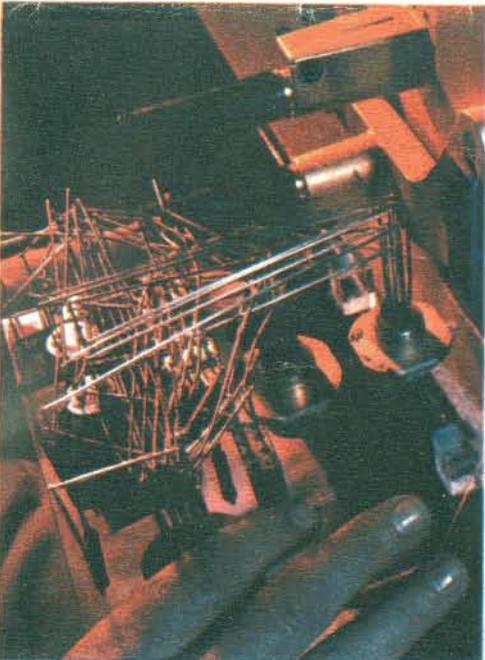
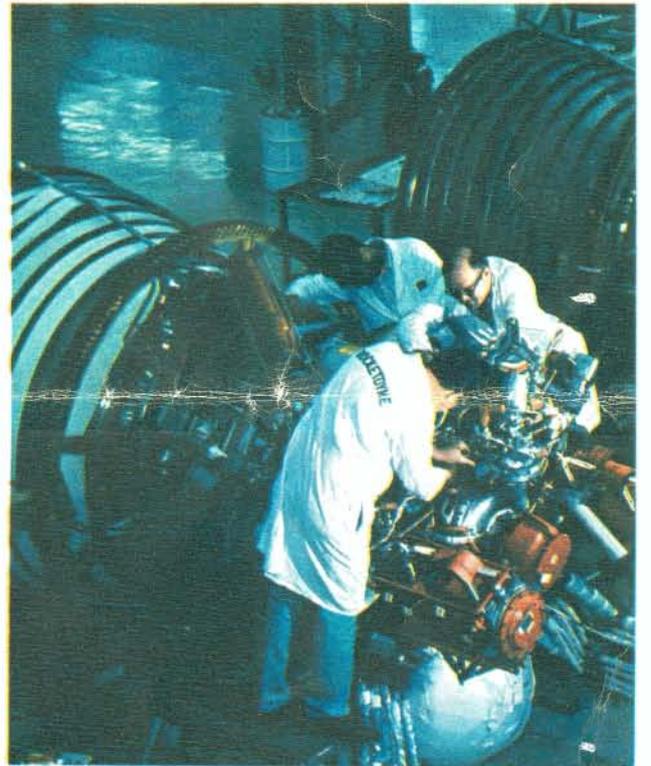
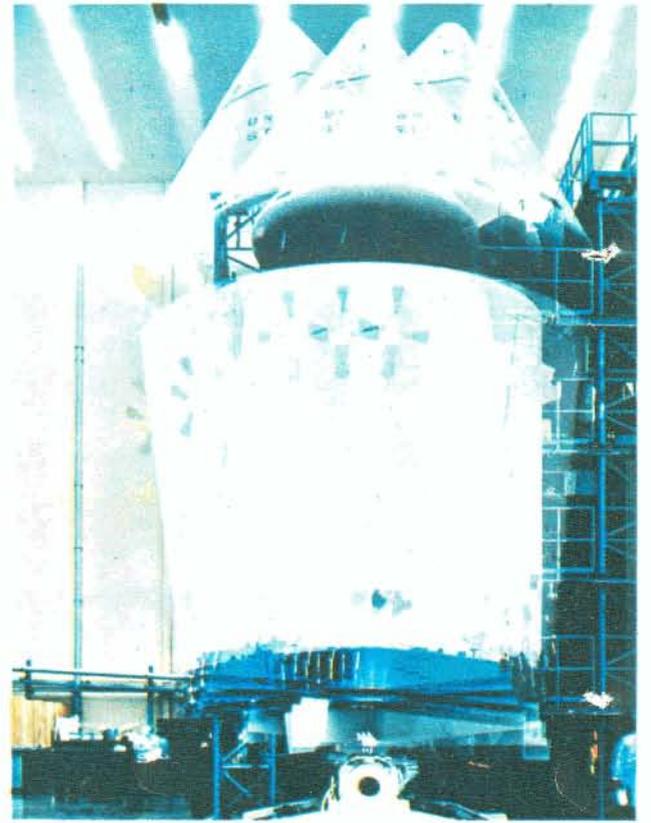
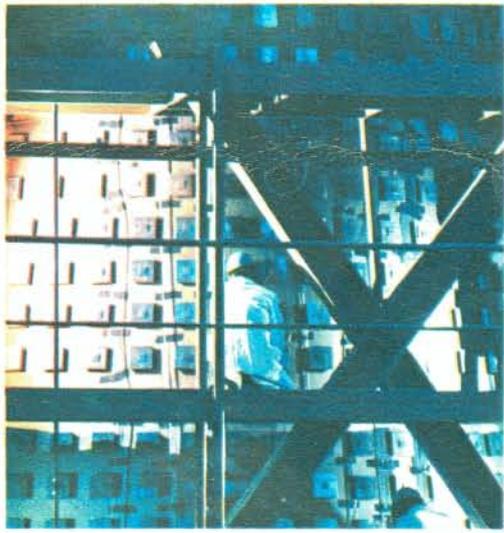
Then the Command Module will separate from the Service Module and orient itself, thick side of the heat shield first, for re-entry—all in a little over 2 minutes.

Apollo/Saturn V is the largest space vehicle ever launched; Apollo 4 is the first launching. At the start, the whole vehicle weighs 6.2 million lbs.; at re-entry, the Command Module part of it will be traveling almost 25,000 mph.

From lift-off to splashdown Apollo 4 is, indeed, a very big Big Shot.

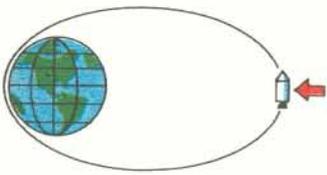


Like any other great achievement, Apollo 4 will have many high points. But the first—and, perhaps, most dramatic—will be lift-off. And like other great moments, it's the result of countless hours, days and months of unremitting labor by thousands of people. Here are just a few of the moments leading to The Moment...



**Ablating Materials**—Special epoxy phenolic (plastic-like) heat-dissipating materials on the surface of a spacecraft that are carried away or vaporized during re-entry.

**Abort**—To cut short an aerospace mission before it has accomplished its objective.



**Apogee**—The point at which a moon or artificial satellite in its orbit is farthest from the earth.

**Attitude**—The position of an aerospace vehicle's axes in relation to some frame of reference, usually the earth's surface.

**Axis** (pl. Axes)—In aircraft terminology, any of three straight lines, the first running through the center of the fuselage lengthwise (X); the second, at right angles to this and parallel to the horizontal airfoils (Y); and the third, perpendicular to the first two axes at their point of intersection (Z).

**Ballistic Trajectory**

—The curved portion of a vehicle's trajectory after the propulsive force is cut off.

**Boilerplate**—A full-size model that has the weight, size and shape of the true item, but not all of its functional features.



**Booster**—(1) a unit that assists the normal propulsive system of a vehicle or other system of a vehicle; (2) the first stage of a multi-stage launch vehicle.

**Burnout**—When combustion (and therefore thrust) ceases in a rocket engine.

**Canard**—A short, stubby, wing-like element located on an aircraft or spacecraft forward of the center of gravity to provide better stability in the atmosphere.

**Capsule**—A small, pressurized cabin with an acceptable environment, usually for containing a man or animal for extremely high-altitude flights, space flight or emergency escape.

**Circular Velocity**—The critical speed at which a satellite will move in a circular orbit; it is an extremely difficult thing to attain because of the accuracy of the control needed.

**Circumlunar**—Trips or missions in which a vehicle will circle the moon.

**Cluster**—Two or more rocket engines bound together so as to function as one propulsive unit.



**CM**—Apollo Command Module.

**Command**—A pulse or signal initiating a step or sequence.

**Cryogenics**—The subject of physical phenomena in the temperature range below about -50 degrees C. More generally, cryogenics (or its synonym, cryogeny) refers to methods of producing very low temperatures.

**CSM**—Apollo Command and Service Modules.

**Deep Space**—Used to refer to space other than that in the vicinity of earth.

**Docking Drogue**—The hollow part of a connector into which a probe part fits.

**Ecliptic**—Plane of the earth's orbit around the sun, used as a reference for other interplanetary orbits;

## What they're talking about:

## a space age glossary.

also the name for the apparent path of the sun through the constellation as projected on the celestial sphere.

**ECS**—Environmental Control System.

**Entry Corridor**—During re-entry, the angular limits of flight that allow safe recovery of a spacecraft.

**Gimballed Motor**—A rocket motor mounted on gimbals; i.e., on a contrivance having two mutually perpendicular axes of rotation, so as to obtain pitching and yawing correction movements.

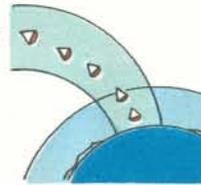
**G & N**—Guidance and Navigation system.

**Glitch**—Originally in electronics jargon, meaning an irregularity in voltage, it has been adopted by aerospace and expanded to mean a fluff, foul-up, mistake, anomaly or interruption of plans, ranking in seriousness somewhere between a heartfelt "Good grief!" and a fairly casual "Oops." The etymology is uncertain. However, glitches generally occur with inanimate things—like computer programs or pieces of machinery; and it is characteristic of glitches that they cannot be traced to, or blamed on, any particular person. Hence, some aerospace people think "glitch" is an acronym for "gremlin-laid-on-hitch."

**Guidance System**—A system which measures and evaluates flight information, correlates this with target data, converts the result into the conditions necessary to achieve the desired flight path, and communicates this data in the form of commands to the flight control system.

**Hypergolic**—Refers to bipropellant combinations which ignite spontaneously upon contact or mixing.

**Inertial Orbit**—The type of orbit described by all celestial bodies. This applies to all satellites and



spacecraft not under propulsive power, their driving force being imparted by their momentum at the instant propulsive power ceases.

**Interface**—Most simply, it is the touching surface of two objects that are joined—like two blocks of wood that are glued together. But it has been personalized in the aerospace industry; people are said to "interface" when they confer.

**Injection**—The process of placing a spacecraft into a calculated orbit.

**Interstage**—Extension of a stage or section that provides a ready means of fitting another stage or section to it.

**Jettison**—Separation of an instrument section or package from the remainder of the rocket vehicle by application of force, internal to the package.

**LES**—Launch Escape System.

**Liquid Hydrogen (LH<sub>2</sub>)**—A liquid rocket fuel that, when oxidized by liquid oxygen, provides about 40% greater thrust than any previously used fuel.

**Liquid Oxygen (LOX)**—Oxygen supercooled and kept under pressure so that its physical state is liquid.

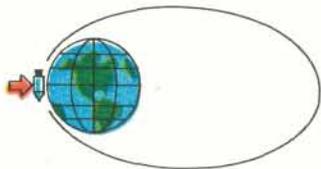
**LM**—Apollo Lunar Module.

**Oxidizer**—In a rocket propellant, a substance such as liquid oxygen or nitric acid that yields oxygen for burning the fuel.

**Parking Orbit**—A self-sustaining orbit achieved when the momentum of the circular velocity of an object equals the force of gravity acting upon that object. With earth orbits, it means



(at about 115 miles altitude) that a spacecraft must be going about 17,500 mph. Once a parking orbit is achieved, no further power is needed to maintain it.



**Perigee**—The point at which a moon or an artificial satellite in its orbit is closest to the earth.

**Pitch**—The rotation of a space vehicle about an axis (Y) that is at once perpendicular to its longitudinal axis and horizontal with respect to the earth.



**RCS**—Reaction Control System.

**Reaction Engine**—An engine or motor that derives thrust by expelling a stream of gases to the rear.



**Re-entry**—The return of a spacecraft that re-enters the atmosphere after flight above it. Technically, of course, the word should be "entry"—since it's entering for the first time; but "re-entry" has come into common usage.

**Retrorocket**—A rocket that gives thrust in a direction opposite to the direction of an object's motion.

**Roll**—The rotation of a space vehicle about its longitudinal (X) axis.



**RP-1 Fuel**—Kerosene-like fuel.

**Scrub**—To cancel out a scheduled launch either before or during countdown.

**SM**—Apollo Service Module.

**SPS**—Service Propulsion System.

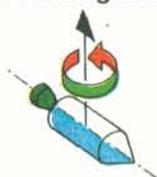
**Step Rocket**—A rocket with two or more stages.

**Telemetry**—A system for taking measurements on the ground or within an aerospace vehicle in flight and transmitting them by radio to another station.

**Time Hack**—Space talk for "What time is it?" But, because of the precision necessary in space talk, a time hack may be expressed in hundredths of a second—or even milliseconds. The hour-minute-second listings on pp. 10-11 of this supplement are time hacks.

**Ullage**—The volume in a closed tank or container above the surface of a stored liquid. Also the ratio of this volume to the total volume of the tank. Ullage does not exist without gravity. So, in space, small rockets must be fired to create ullage—that is, to force the fuel to the bottom of the tank where it can feed into the engines.

**Yaw**—Rotation of a space vehicle about its vertical (Z) axis.



## Space Primer

(How to explain rocketry and space to your children. Or your parents.)

**What is space?** Space is considered to be everything beyond earth's atmosphere. In space, there is an almost total lack of the molecules that make matter. In our atmosphere, "thin" air is really composed of molecules that are (relatively speaking) packed tightly together. In space, there are only a few molecules per cubic foot, compared with millions in a cubic foot of the air we breathe on earth.

**What do you hear and see in space?**

Because there's no air in space, there is no sound. That's because sound depends on air molecules. When you clap your hands, you hear it because molecules are compressed in waves that strike your eardrum. There are no air molecules to compress in space—so no sound. The blue of our sky is caused by the way in which molecules and dust particles disperse light rays. Without them, there is no color; space is black.

**Is it hot or cold in space?** Both—and always in extremes. Again, it is the air on earth that makes for moderate temperatures, dispersing heat so it never gets too hot, retaining heat so it never gets too cold. In space, there is nothing to retain heat, so it is very, very cold. On the other hand, near the sun (or any other star), there's nothing to shield you from the heat. If you took a "sun bath" in space, the side facing the sun would burn up—while the side away from the sun would freeze.

**How does a rocket work?** If you fire a shotgun, a blast goes out the muzzle; at the same time, the stock kicks back into your shoulder. That's because every action has an equal reaction—in the opposite direction. Place the shotgun vertically, muzzle down, pull the trigger and you have a rocket of sorts. The stock (in fact, the whole gun) is moving in the opposite direction from the direction of blast. *Not* because it's pushing *against* anything; that just happens to be a natural law of motion. Blast hard enough and long enough and you can move an awful lot of weight at an awfully high speed. That's what a rocket does.

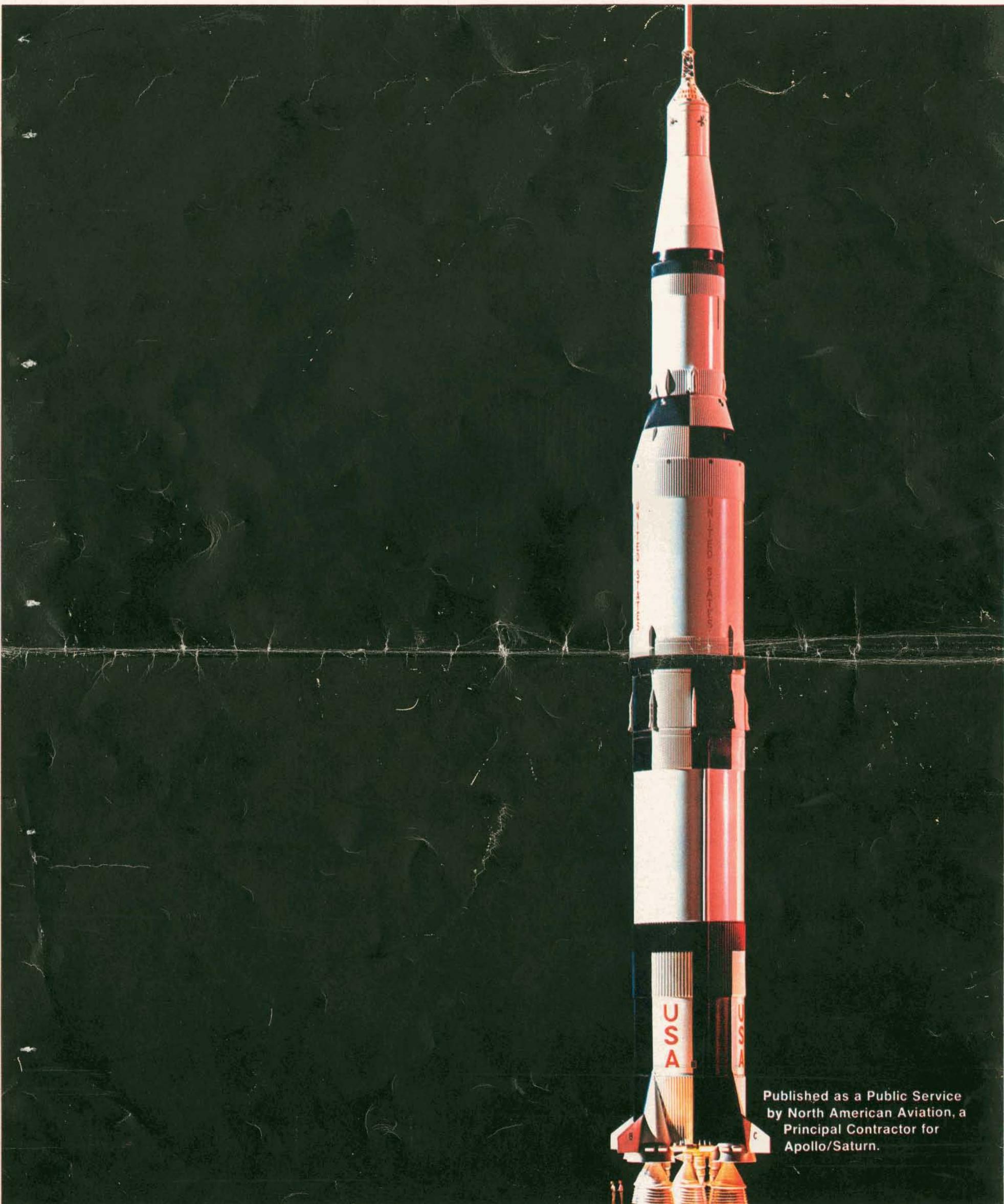
**What keeps a spacecraft "up"?**

In orbit, that is. Think of a weight tied on the end of a long rubber band. Start twirling and the weight will, of course, go around in a circle. It will also rise up until—if you twirl fast enough—its path will be in a circle parallel to the floor. It is "in orbit" around your fingers. Its speed outward balances the pull of the rubber band. The same thing happens with a rocket and earth's gravity—which acts as the rubber band.

**How do you get out of orbit?** There are two answers. Either slow down (in which case you fall back to earth) or speed up—and go out into space. Again, it's like the weight on the rubber band. Twirl fast enough and the band will break, the weight flying off and out. Same goes for a rocket. Increase its speed enough, and it will break the pull of earth's gravity. It will go out of orbit.

**Which way is up?** We can think of a rocket going "up" from the earth without upsetting an astrophysicist too much: that's because the earth is trying to pull it down. But once we escape the earth's gravitation—and until we enter the effective field of some other body's gravitation—there's no longer a "down." So there is no up.

Putting man on the moon is, perhaps, the greatest single test that man's ingenuity, will and technical ability have ever faced. That is the Apollo program. Launching the Apollo/Saturn V vehicle, in the test called "Apollo 4," is the first of the Big Shots in the program. More than 300,000 dedicated scientists, engineers, technicians and craftsmen, from over 20,000 companies, are committing their talents and efforts to the Apollo program. They have made Apollo 4 possible.



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