Sept. 7 - Apollo command module Boilerplate I was accepted by NASA and delivered to a Space Division laboratory for land and water impact tests.

Nov. 7 - Grumman Aircraft was named by NASA to design and build the LM.

1963

Mar. 12 - Apollo Boilerplate 13, the first flight-rated boilerplate to be completed, was accepted by NASA and shipped to MSFC.

July 23 - Dr. George E. Mueller was named director, NASA's Office of Manned Space Flight.

Oct. 8 - Dr. Joseph Shea, previously with NASA Headquarters, was named Apollo program manager at MSC.

Nov. 7 - The first launch test - a pad-abort test of Boilerplate 6 - was conducted at White Sands.

1964

February - A boost protective cover was added to the launch escape system in order to protect the windows of the CM and the heat shield surfaces from soot from the LES motor.

May 13 - The second test flight of the Apollo program occurred at White Sands when Boilerplate 12 was launched by a Little Joe II vehicle during a high-stress, high-speed abort test. The launch escape system worked as planned, except that one of the three parachutes cut loose. The CM was landed without damage.

May 28 - Apollo command module Boilerplate 13 was placed in orbit from Cape Kennedy following launch by a Saturn I booster. This was the first Apollo vehicle to be placed in orbit, and the third Apollo test flight.

Sept. 18 - Apollo Boilerplate 15 was successfully orbited at Cape Kennedy by a Saturn I two-stage launch vehicle. This was the fourth Apollo test flight.

Dec. 8 - The fifth Apollo test flight occurred at White Sands when Boilerplate 23 was lifted off the pad by a Little Joe II in a high Q abort test.

1965

Feb. 16 - Apollo Boilerplate 16 was launched from Cape Kennedy in a micrometeoroid test. A Pegasus satellite was carried aloft in a modified Apollo SM. All equipment functioned as planned. This was the sixth Apollo test flight.

May 19 - Apollo Boilerplate 22 was launched at White Sands in a planned high-altitude test of the launch escape system. The Little Joe II disintegrated at low altitude, resulting in an unscheduled but successful low-altitude abort test. This was the seventh test flight.

May 25 - The second Pegasus satellite was put into orbit at Cape Kennedy during the Saturn I launch of Apollo Boilerplate 26. This was the eighth Apollo test flight.

June 29 - Apollo Boilerplate 23A was successfully launched at White Sands during a pad abort test. All systems functioned as planned. This was the ninth Apollo test flight, and the fifth abort test. This boilerplate module, previously designated Boilerplate 23, had been launched at White Sands during a high Q test.

July 30 - Apollo Boilerplate 9A was launched at Cape Kennedy and was used to place the third Pegasus satellite into orbit.

Oct. 20 - The first actual Apollo spacecraft, SC 009, was accepted by NASA and subsequently shipped to Cape Kennedy. All previously completed Apollo vehicles had been boilerplate and mockup articles.

Dec. 26 - Apollo SC 009 was mated with the Saturn IB at the Kennedy Space Center.

Dec. 31 - Command modules accepted by NASA by the end of 1965 included 18 mockups, 18 boilerplates, and 2 spacecraft.

1966

Jan. 20 - A power-on tumbling abort test of the launch escape system was conducted at White Sands with the launch of SC 002. This was the sixth and final launch escape test; the LES was then declared qualified.

Feb. 26 - First unmanned flight of Apollo spacecraft (SC 009) was conducted to test command module's ability to withstand entry temperatures, determine adequacy of command module for manned entry from low orbit, test command and service module reaction control engines and test service module engine firing and restart capability. Recovery was in the South Atlantic, 5300 miles downrange, near Ascension Island.

Aug. 25 - Second unmanned test of Apollo spacecraft (SC 011) was conducted to test command module's ability to withstand entry temperatures under high heat load. After three-quarters of an orbit the spacecraft, which reached an altitude of 700 miles, was recovered 260 statute miles from Wake Island.

Oct. - The first Apollo Block II parachute qualification test was conducted at El Centro, Calif.

1967

Jan. 27 - During a manned ground test of an Apollo spacecraft (SC 012) while the vehicle was atop the Saturn IB booster, a flash fire in the command module resulted in the deaths of Astronauts Gus Grissom, Ed White, and Roger Chaffee. NASA immediately established a review board to determine the cause of the fire and the changes which would be necessary to prevent such fires in the future.

Apr. 9 - The review board presented its findings to the NASA administrator. While the exact cause of the fire was not determined conclusively, the board recommended a number of changes, including the elimination of most of the combustible materials in the spacecraft, the protection of wires in the spacecraft, and the installation of a quick-opening hatch. These and other changes were incorporated in later spacecraft.

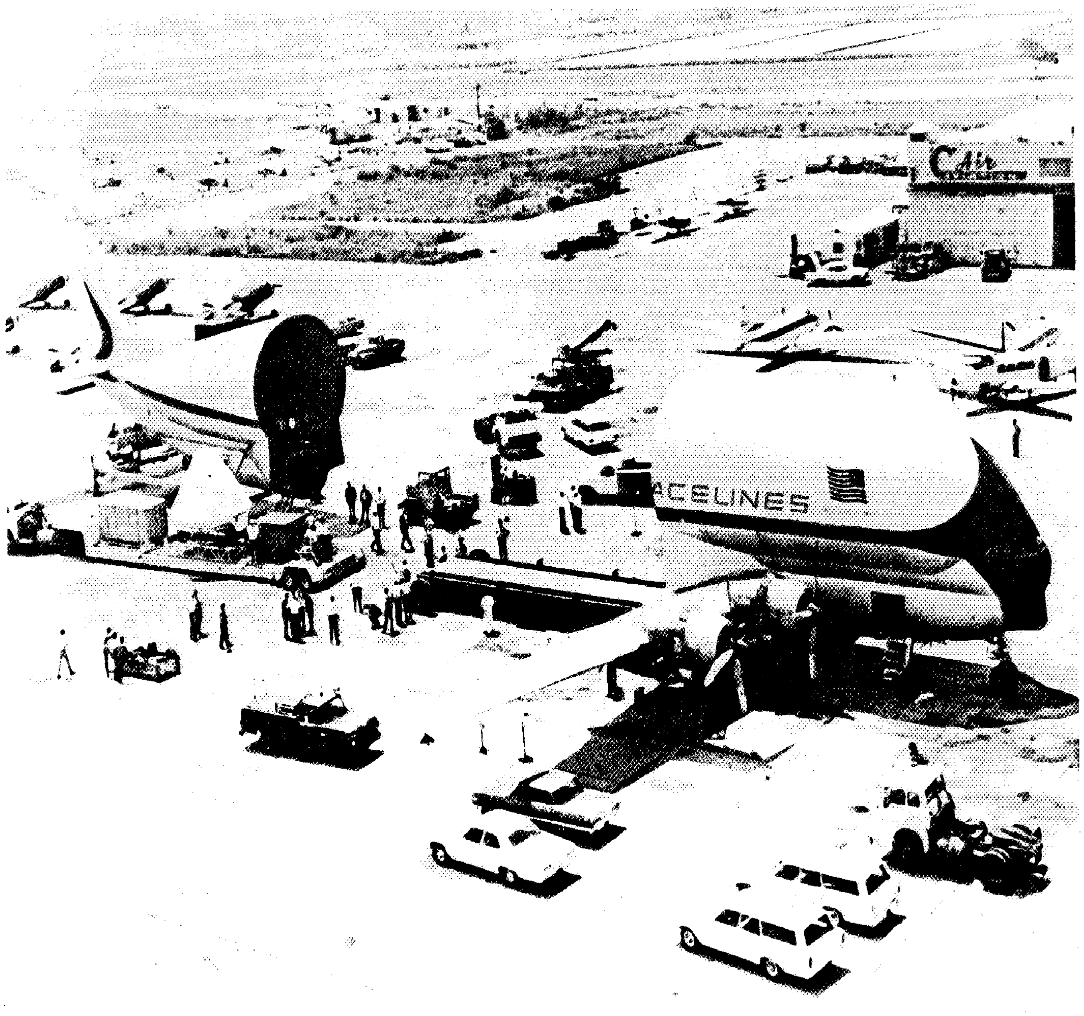
Nov. 9 - The Apollo 4 mission, the first using the Saturn V launch vehicle, was considered. The spacecraft reached an altitude of 11,234 miles, entered the atmosphere at a speed of 24,917 mph, and splashed down in the Pacific six miles from the recovery ship after a flight of eight hours 37 minutes. This flight qualified the heat shield for lunar flight.

1968

Jan 22 - The lunar module was tested during the flight designated Apollo 5. A wrong number in the guidance logic caused immediate shutdown of the descent engine, and led to a series of abnormal events. The LM performed very well, however, and accomplished most of its objectives, including its ability to abort a landing on the moon and to return to the command module during its orbiting lunar flight.

Apr. 4 - Apollo 6, the second test of the Saturn V launch vehicle, although problems developed with the launch vehicle, the spacecraft's accomplishments were impressive. These included the longest single burn in space of the service propulsion engine, proper control of the engine by the guidance and navigation subsystem, and another successful test of the heat shield.

Apr. 29 - NASA announced that next Saturn V/Apollo flight would be manned, and would take place during the latter part of 1968. The next scheduled Apollo flight, designated Apollo 7, will be manned and will use a Saturn IB launch vehicle.



P-301

Apollo spacecraft are shipped to Kennedy Space Center, Fla., by specially converted aircraft from Long Beach Airport

APOLLO BRIEFS

The possibility of a micrometeoroid as big as a cigarette ash striking the command module during an 8-day lunar mission has been computed as 1 in 1230. If a meteoroid did strike the module, it would be at a velocity of 98,500 feet per second. The probability of the command module getting hit is 0.000815. The probability of the command module not getting hit is 0.999185.

* * *

The heat leak from the Apollo cryogenic tanks, which contain hydrogen and oxygen, is so small that if one hydrogen tank containing ice were placed in a room heated to 70 degrees F, a total of 8-1/2 years would be required to melt the ice to water at just above freezing temperature. It would take approximately 4 years more for the water to reach room temperature. The gases in the cryogenic tanks are utilized in the production of electrical power by the Apollo fuel cell system and provide oxygen for the use of the crew.

* * *

When the Apollo spacecraft passes through the Van Allen belts on its way to the moon, the astronauts will be exposed to radiation roughly equivalent to that of a dental X-ray.

* * *

With gravity on the moon only one-sixth as strong as on earth, it is necessary that this difference be related to the Apollo vehicle. A structure 250 feet high and 400 feet long in which cables lift five-sixth of the spacecraft vehicle weight is being used in tests to simulate lunar conditions and their effect on the vehicle.

* * *

The command module panel display includes 24 instruments, 566 switches, 40 event indicators (mechanical), and 71 lights.

* * *

The command module offers 73 cubic feet per man as against the 68 cubic feet per man in a compact car. By comparison, the Mercury spacecraft offered 55 cubic feet for its one traveler and Gemini provided 40 cubic feet per man.

The angular accuracy requirement of midcourse correction of the spacecraft for all thrusting maneuvers is one degree.

* * *

If your car gets 15 miles to a gallon, you could drive 18 million miles or around the world about 400 times on the propellants required for the Apollo/Saturn lunar landing mission. The Saturn V launch vehicle contains 5.6 million pounds of propellant (or 960,000 gallons).

* * *

When the Apollo re-enters the atmosphere it will generate energy equivalent to approximately 86,000 kilowatt hours of electricity - enough to light the city of Los Angeles for about 104 seconds; or the energy generated would lift all the people in the USA 10-3/4 inches off the ground.

* * *

The fully loaded Saturn V launch vehicle with the Apollo spacecraft stands 60 feet higher than the Statue of Liberty on its pedestal and weighs 13 times as much as the statue.

* * *

During its 3.5 second firing, the Apollo spacecraft's solid-fuel launch escape rocket generates the horsepower equivalent of 4,300 automobiles.

* * *

The engines of the Saturn V launch vehicle that will propel the Apollo spacecraft to the moon have combined horsepower equivalent to 543 jet fighters.

* * *

The Apollo environmental control system has 180 parts in contrast to the 8 for the average home window air conditioner. The Apollo environmental control system performs 23 functions compared to 5 for the average home conditioner. There are 23 functions of the environmental control system, which include: air cooling, air heating, humidity control, ventilation to suits, ventilation to cabin, air filtration, CO_2 removal, odor removal, waste management functions, etc.

The 12-foot-high Apollo spacecraft command module contains about fifteen miles of wire, enough to wire 50 two-bedroom homes.

* * *

The astronaut controls and monitors the stabilization and control system by means of two handgrip controllers, 34 switches, and 6 knobs.

* * *

The command system of the acceptance checkout equipment can generate up to 2048 separate stimuli or 128 analog signals, or combinations of both, and route them to spacecraft and other checkout systems at a million bits per second. In contrast, hand-operated commercial teletype generates 45 bits per second and automatically, over voice channel, it generates 2400 bits per second.

* * *

The Apollo command module can sustain a hole as large as 1/4 inch in diameter and still maintain the pressure inside for 15 minutes, which is considered long enough for an astronaut to put on a spacesuit.

* * *

The boost protective cover will protect the command module from temperatures expected to reach 1200 degrees during the launch phase.

* * *

The power of one Saturn V is enough to place in earth orbit all U.S. manned spacecraft previously launched.

* * *

Here is an analogy pertaining to the benefits of the multistage concept as opposed to the single-stage, brute-force method. If a steam locomotive pulling three coal cars carries all three cars along until all fuel is exhausted, the locomotive could travel 500 miles. By dropping off each car as its coal is expended the locomotive could travel 900 miles.

* * *

The F-1's fuel pumps push fuel with the force of 30 diesel locomotives.

Enough liquid oxygen is contained in the first stage tank to fill 54 railroad tank cars.

* * *

The five F-1 engines equal 160,000,000 horse power, about double the amount of potential hydroelectric power that would be available at any given moment if all the moving waters of North America were channeled through turbines.

* * *

The interior of each of the first stage propellant tanks is large enough to accommodate three large moving vans side by side.

* * *

The Saturn V's second stage construction is comparable to that of an eggshell in efficiency, the amount of weight and pressure constrained by a thin wall.

* * *

Total amount of propellant (fuel and oxidizer) in the Saturn V launch vehicle, service module, and lunar module is 5,625,000 pounds.

* * *

The Apollo spacecraft, including the command and service modules and the adapter which housed the lunar module, is 82 feet tall, only 13 feet shorter than the entire Mercury-Atlas space vehicle used in John Glenn's orbital mission.

* * *

The ratio of propellant to payload in Saturn V is 50 to 1.

* * *

The main computer in the command module occupies only one cubic foot.

* * *

While an automobile has less than 3,000 functional parts, the command module has more than 2,000,000 not counting wires and skeletal components.

The command module uses only about 2000 watts of electricity, similar to the amount required by an oven in an electric range.

* * *

The heat shield and its ablator must resist heat twice as great as that encountered by Gemini and Mercury.

* * *

The configuration of Apollo is designed to give it aerodynamic lift so that it is possible to "fly" it during re-entry. The lift-over-drag ratio is about 0.35.

* * *

The honeycomb aluminum used in Apollo's inner crew compartment is 40-percent stronger and 40-percent lighter than ordinary aluminum.

* * *

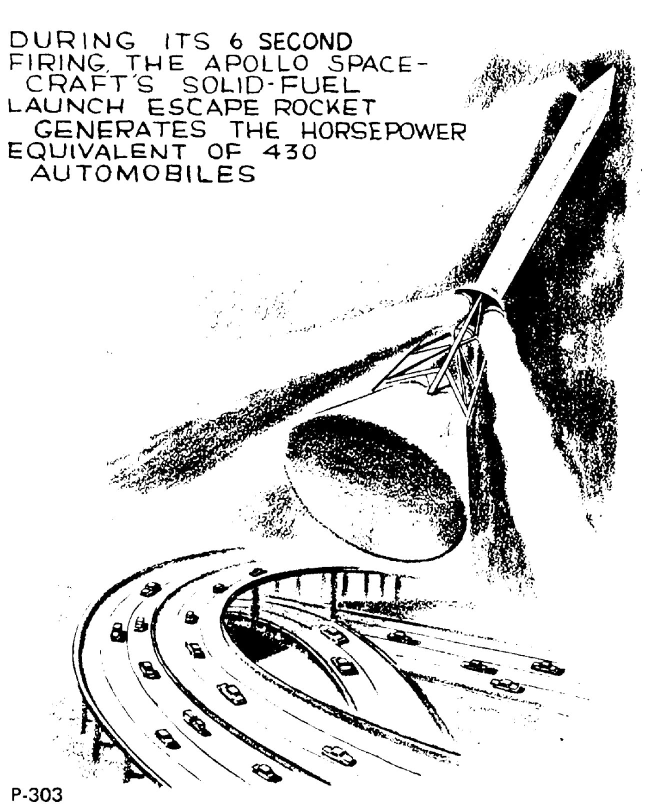
There are 50 engines aboard the Apollo spacecraft: 16 reaction control engines on the service module, 16 reaction control engines on the lunar module, 12 reaction control engines on the command module, the service propulsion engine, the lunar module ascent and descent engines, the launch escape motor, the tower jettison motor, and the pitch control motor. The last three are solid-propellant engines and the other 47 all burn a hypergolic liquid propellant composed of nitrogen tetroxide and hydrazine. A hypergolic propellant is one composed of an oxidizer and a fuel which ignite and burn on contact.

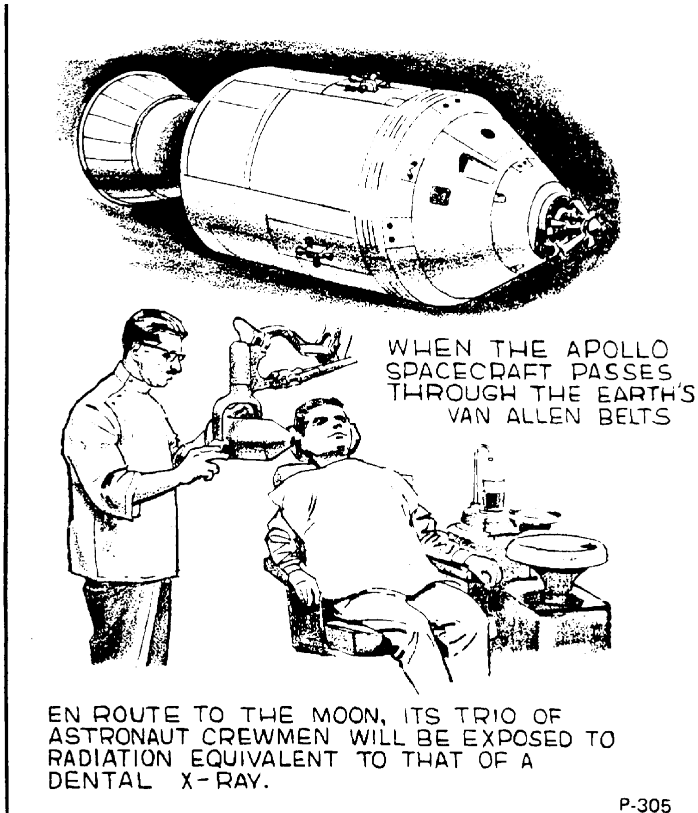
* * *

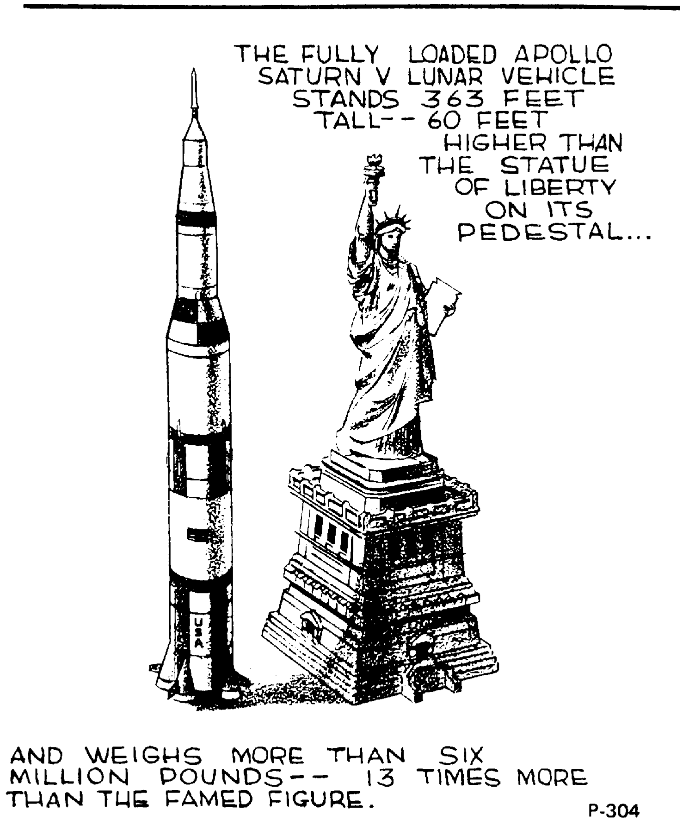
The tanks which hold the cryogenic (ultra-cold) liquid oxygen and liquid hydrogen on the Apollo spacecraft come close to being the only leak-free vessels ever built. If an automobile tire leaked at the same rate that these tanks do, it would take the tire 32,400,000 years to go flat.

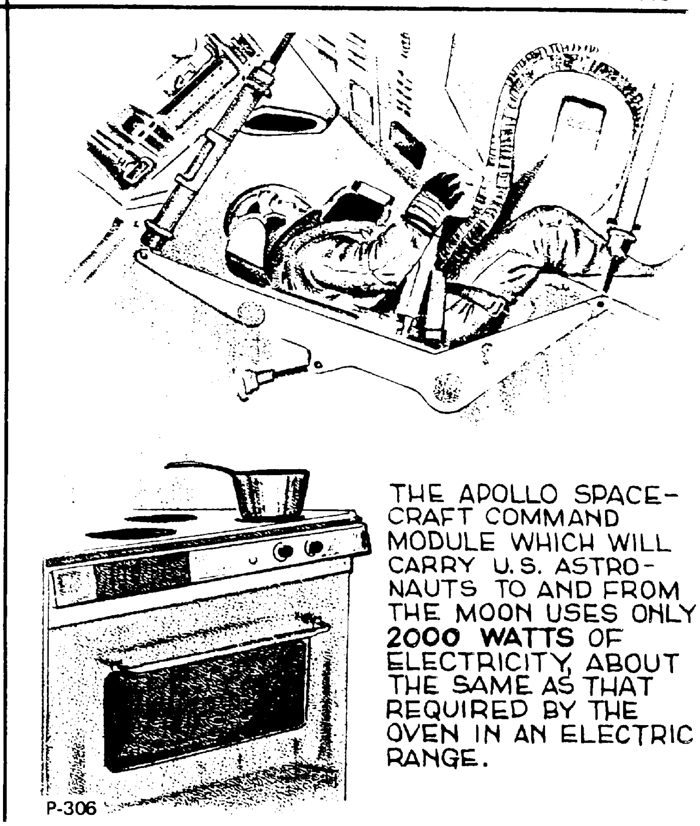
* * *

There are approximately 2-1/2 million solder joints in the Saturn V launch vehicle. If just 1/32 of an inch too much wire were left on each of these joints and an extra drop of solder was used on each of these joints, the excess weight would be equivalent to the payload of the vehicle.

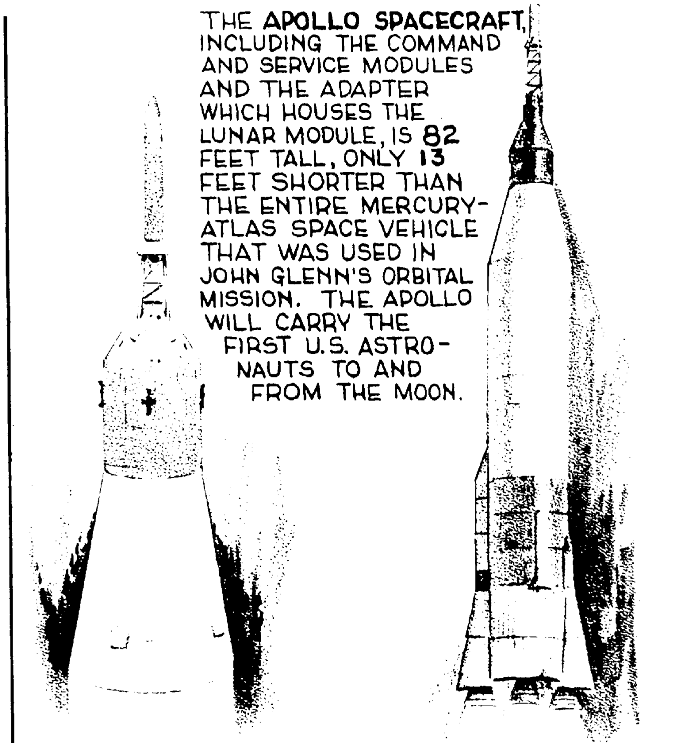

DURING ITS 6 SECOND FIRING THE APOLLO SPACE-CRAFT'S SOLID-FUEL LAUNCH ESCAPE ROCKET GENERATES THE HORSEPOWER EQUIVALENT OF 430 AUTOMOBILES
P-303


WHEN THE APOLLO SPACECRAFT PASSES THROUGH THE EARTH'S VAN ALLEN BELTS
EN ROUTE TO THE MOON, ITS TRIO OF ASTRONAUT CREWMEN WILL BE EXPOSED TO RADIATION EQUIVALENT TO THAT OF A DENTAL X-RAY.
P-305


THE FULLY LOADED APOLLO SATURN V LUNAR VEHICLE STANDS 363 FEET TALL-- 60 FEET HIGHER THAN THE STATUE OF LIBERTY ON ITS PEDESTAL...
USA
AND WEIGHS MORE THAN SIX MILLION POUNDS-- 13 TIMES MORE THAN THE FAMED FIGURE.
P-304


THE APOLLO SPACE-CRAFT COMMAND MODULE WHICH WILL CARRY U.S. ASTRO-NAUTS TO AND FROM THE MOON USES ONLY 2000 WATTS OF ELECTRICITY, ABOUT THE SAME AS THAT REQUIRED BY THE OVEN IN AN ELECTRIC RANGE.
P-306

P-307



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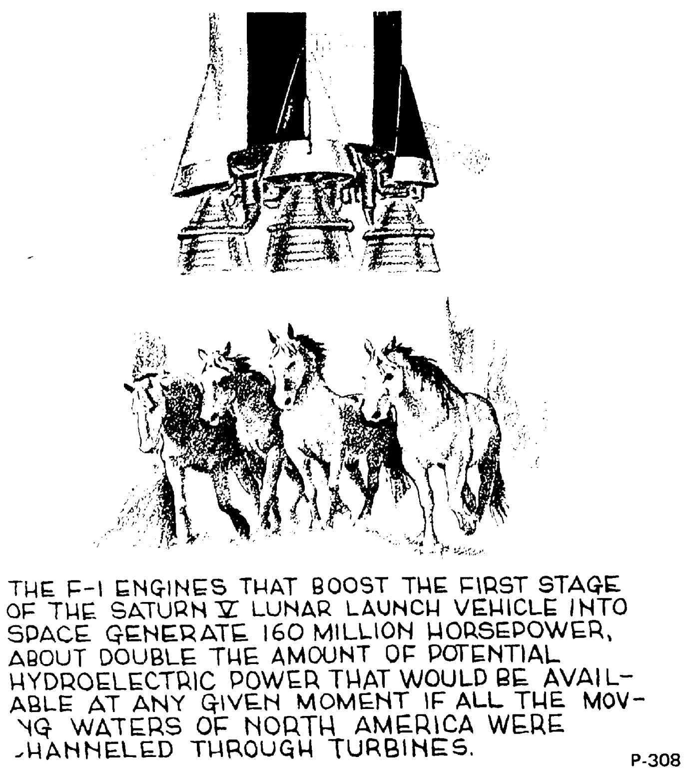

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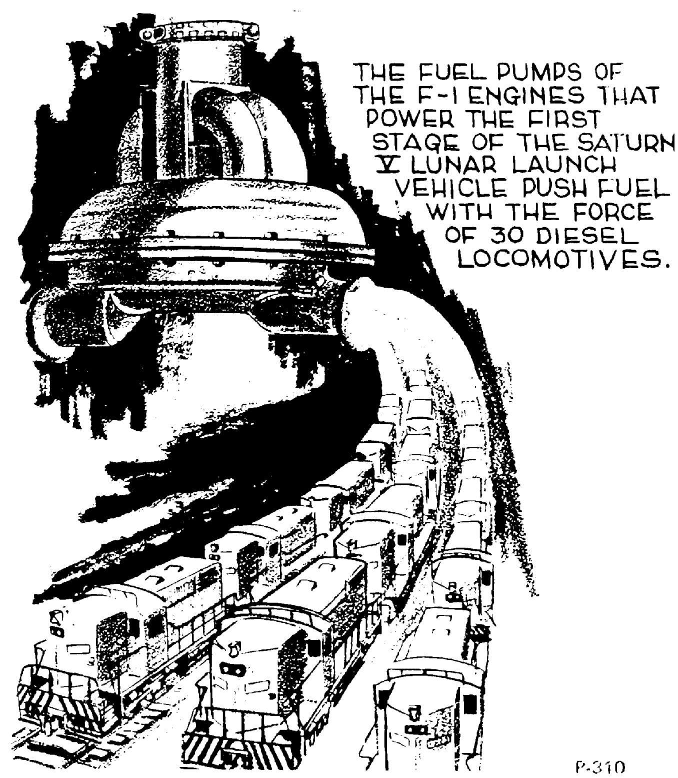

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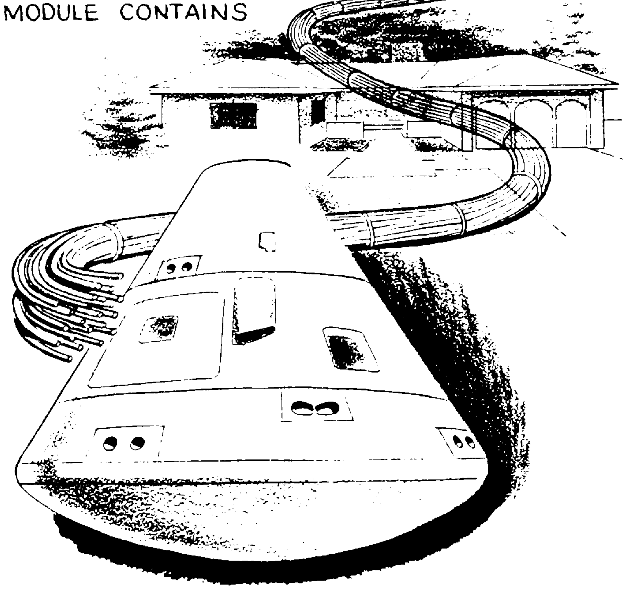
THE 12-FOOT-TALL APOLLO SPACECRAFT COMMAND MODULE CONTAINS



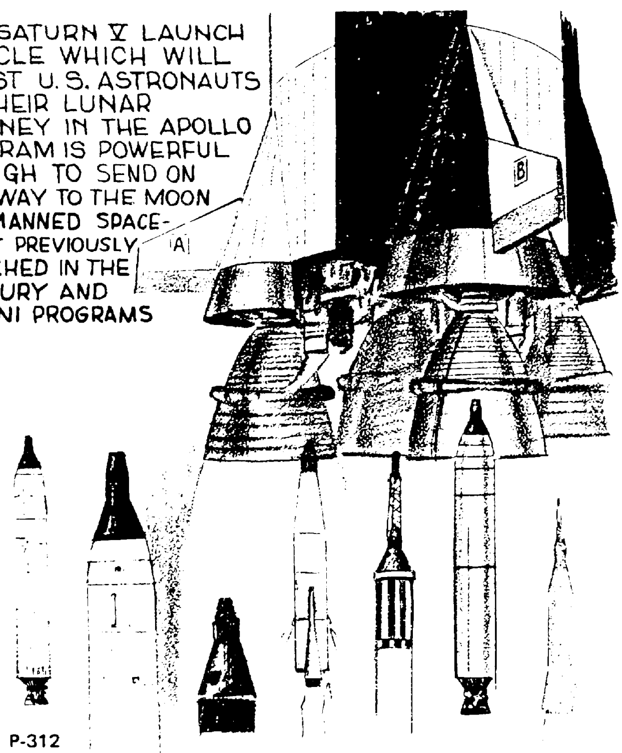
ALMOST 15 MILES OF WIRE, ENOUGH TO WIRE 50 TWO-BEDROOM HOMES

P-311

AT ITS PEAK, MORE THAN 20,000 INDUSTRIAL FIRMS, EMPLOYING MORE THAN 350,000 PERSONS, WERE PRODUCING EQUIPMENT FOR THE U.S. APOLLO/SATURN SPACE PROGRAM UNDER CONTRACTS WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

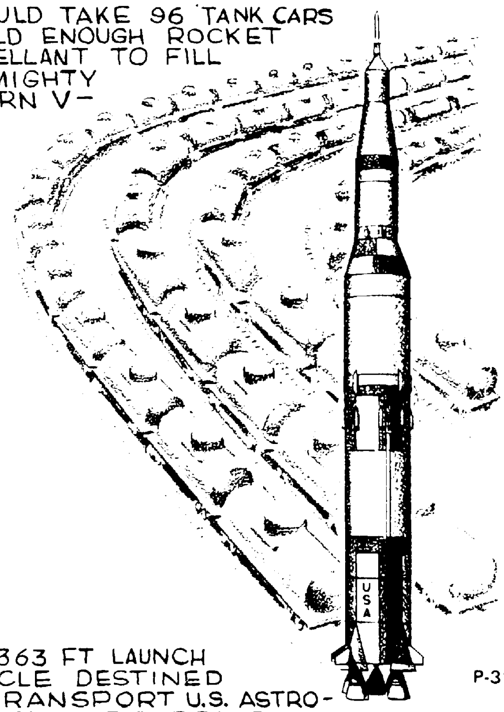
P-313

THE SATURN V LAUNCH VEHICLE WHICH WILL BOOST U.S. ASTRONAUTS ON THEIR LUNAR JOURNEY IN THE APOLLO PROGRAM IS POWERFUL ENOUGH TO SEND ON THE WAY TO THE MOON ALL MANNED SPACECRAFT PREVIOUSLY LAUNCHED IN THE MERCURY AND GEMINI PROGRAMS



P-312

IT WOULD TAKE 96 TANK CARS TO HOLD ENOUGH ROCKET PROPELLANT TO FILL THE MIGHTY SATURN V–



THE 363 FT LAUNCH VEHICLE DESTINED TO TRANSPORT U.S. ASTRONAUTS TO THE SURFACE OF THE MOON

P-314

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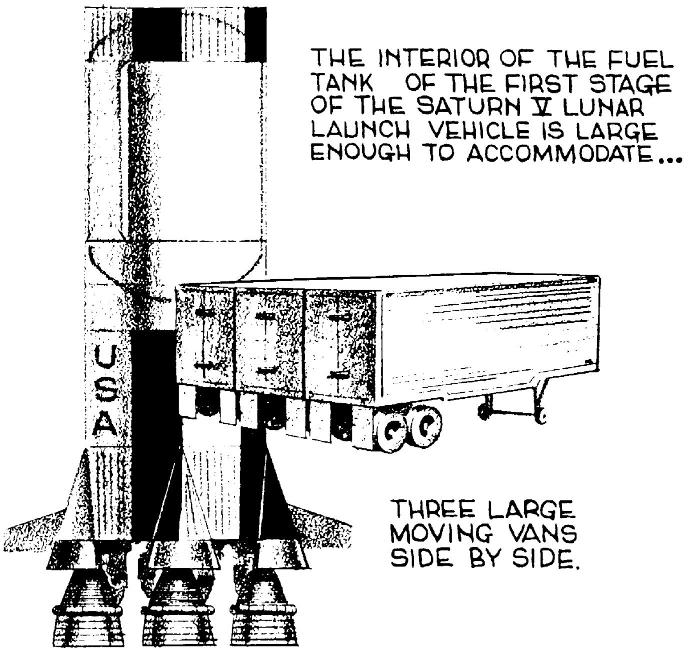
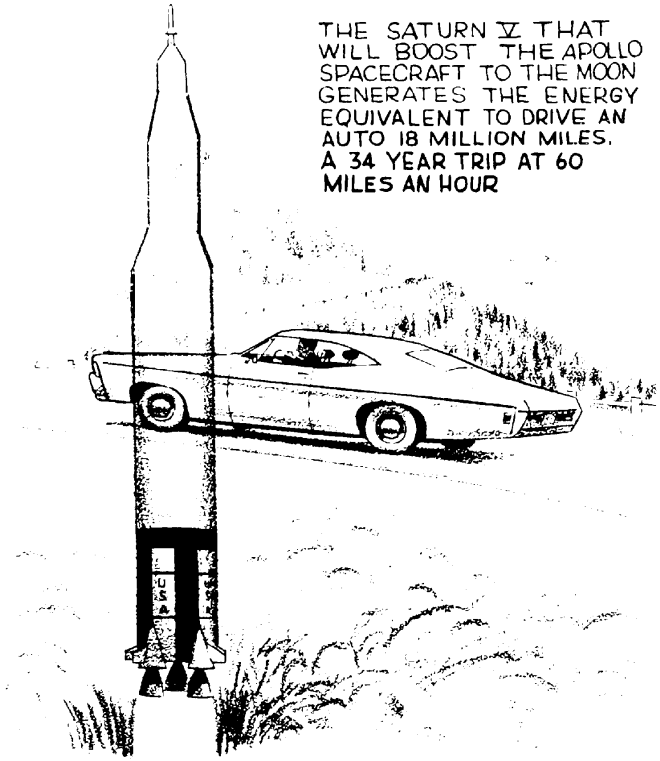
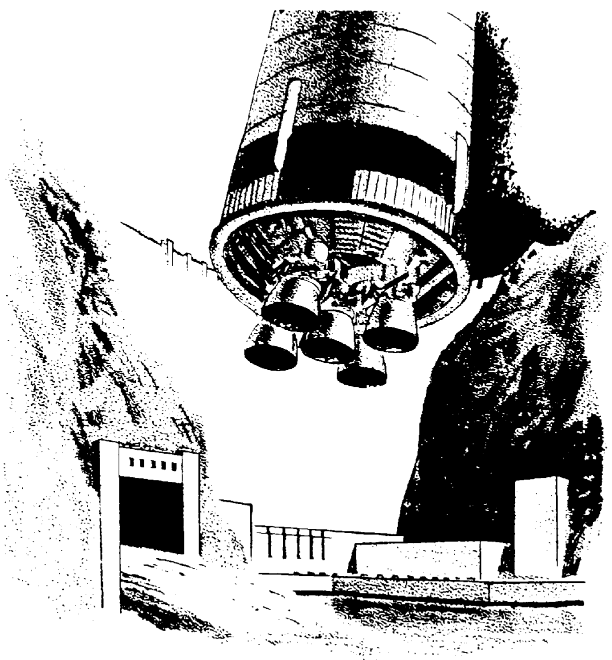


P-315

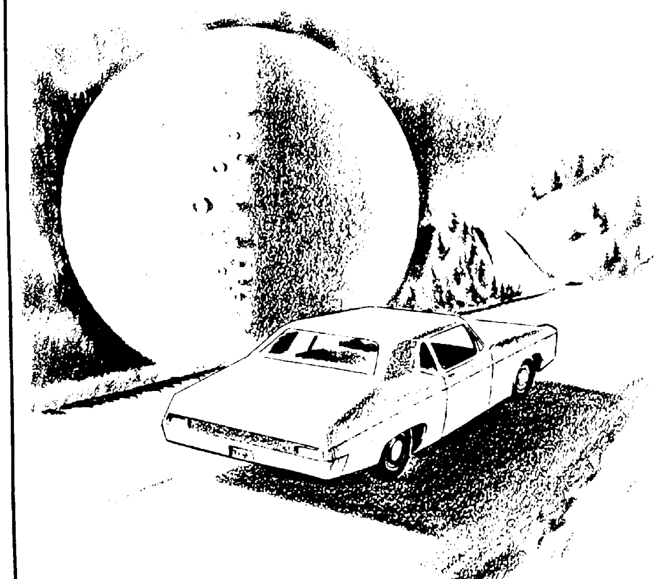


P-317



THE FIVE 225,000-POUND THRUST J-2 ENGINES THAT POWER THE SECOND STAGE OF THE SATURN V LUNAR LAUNCH VEHICLE GENERATE THRUST EQUAL TO ABOUT 95.4 BILLION WATTS, OR THE POWER OF 72 HOOVER DAMS.

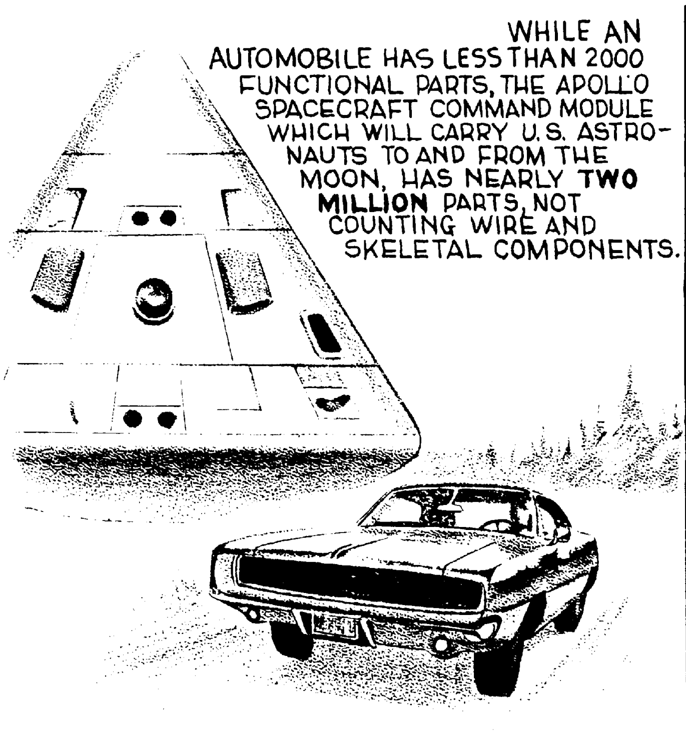
P-316



IF YOUR CAR GETS 15 MILES TO A GALLON, YOU COULD DRIVE 10 MILLION MILES OR AROUND THE WORLD ABOUT 400 TIMES ON THE PROPELLANTS REQUIRED FOR THE APOLLO/SATURN LUNAR LANDING MISSION

P-318

283



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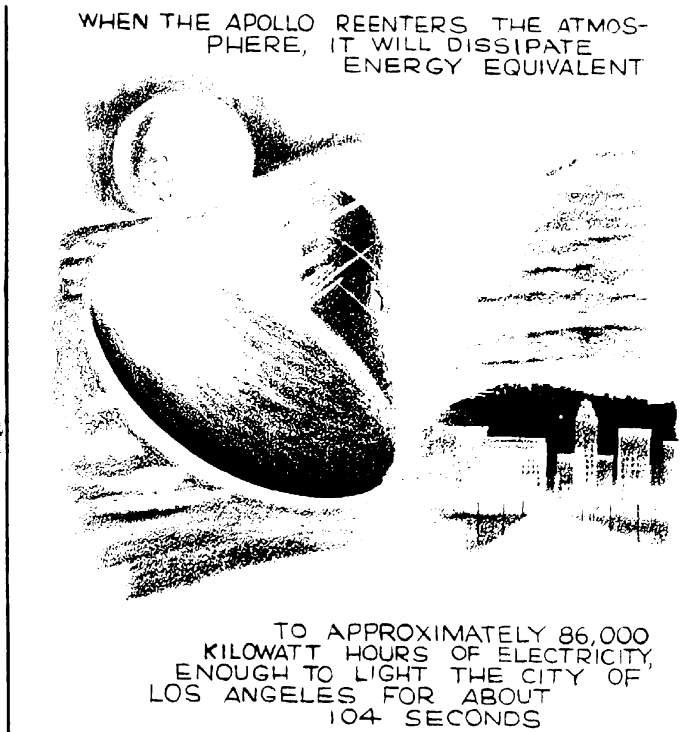
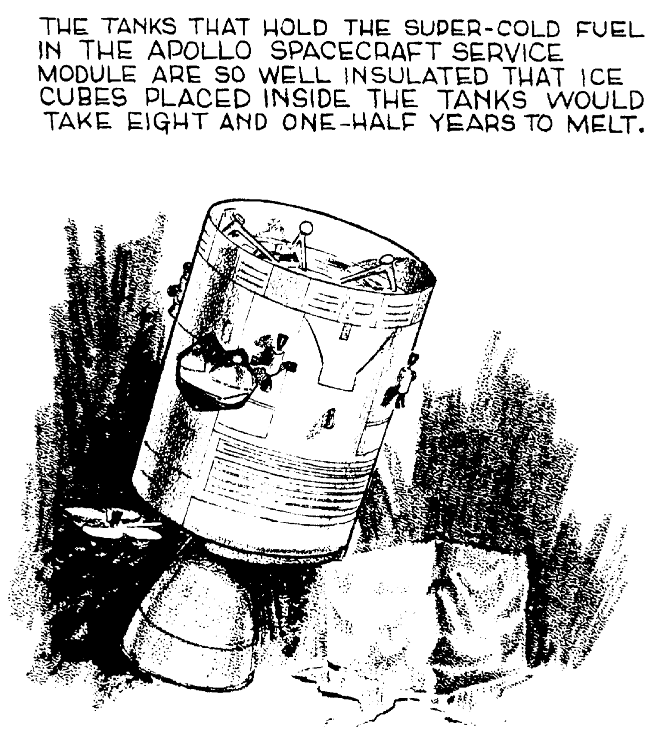


P-321



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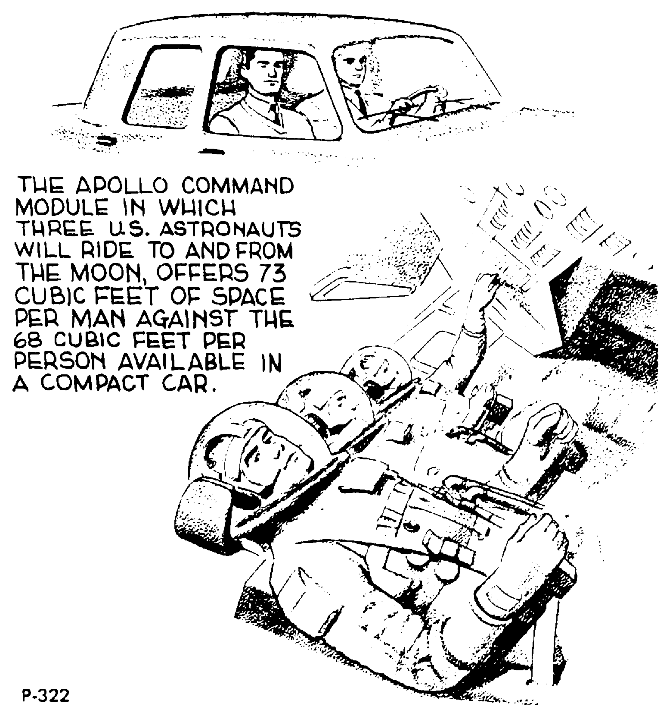

P-322

GLOSSARY

Ablating Materials—Special heat-dissipating materials on the surface of a spacecraft that can be sacrificed (carried away, vaporized) during re-entry.

Ablation—Melting of ablative heat shield materials during re-entry of spacecraft into earth's atmosphere at hypersonic speeds.

Abort—The cutting short of an aerospace mission before it has accomplished its objective.

Accelerometer—An instrument to sense accelerative forces and convert them into corresponding electrical quantities usually for controlling, measuring, indicating, or recording purposes.

Acceptance Test—A test or series of tests to demonstrate that performance is within specified limits.

Acquisition and Tracking Radar—A radar set which searches for, acquires, and tracks an object by means of reflected radio frequency energy from the object, or tracks by means of a radio-frequency signal emitted by the object.

Actuators—Devices which transform an electrical signal into a mechanical motion using hydraulic or pneumatic power.

Adapter Skirt—A flange or extension of a stage or section that provides a ready means of fitting another stage or section to it.

Aerothermodynamic Border—An altitude of about 100 miles in which the atmosphere becomes so rarefied that there is no longer any significant heatgenerating air friction or thermal influence on the skin of fast-moving vehicles.

Airborne Data—Data obtained from space systems during flight.

Ambient—Environmental conditions such as pressure or temperature.

Amorphous—Without definite form; in reference to supercooled liquids and colloidal substances, without real or apparent crystalline form.

Anacoustic Zone—The zone of silence in space; the region above 100 miles altitude where the distance between the rarefied air molecules is greater than the wavelength of sound, and sound waves can no longer be propagated.

Analog Computer—A computing machine that works on the principle of measuring, as distinguished from counting, in which the measurements obtained, as voltages, resistances, etc., are translated into desired data.

Aphelion—Point on an elliptical orbit around sun which is greatest distance from sun. (Earth's aphelion is about 94,500,000 miles from sun.)

Apocynthion—The point at which a satellite (e.g., a spacecraft) in its orbit is farthest from the moon; differs from apolune in that it is an earth-originated orbit.

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

Apolune—The point at which a satellite (e.g., a spacecraft) in its orbit is farthest from the moon; differs from apocynthion in that the orbit is originated from the moon.

Asteroid—One of the many thousands of minor planets which revolve around the sun, mostly between the orbits of Mars and Jupiter.

Astrogation—Navigating in space.

Astronaut—One who flies or navigates through space.

Astronautics—The art or science of designing, building, or operating space vehicles.

Astronics—The science of adapting electronics to aerospace flight.

Astrobiology—A branch of biology concerned with the discovery or study of life on planets.

Astronomical Unit—Mean distance of earth from the sun, equal to 92,907,000 miles.

Astrophysics—Application of laws and principles of physics to all aspects of steller astronomy.

Atmosphere—The envelope of gases which surrounds the earth and certain other planets.

Atmosphere Refraction—Refraction of light from a distant point by the atmosphere, caused by its passing obliquely through varying air densities.

Attenuator—An adjustable resistive network for reducing the amplitude of an electrical signal without introducing appreciable phase or frequency distortion.

Attitude—The position of an aerospace vehicle as determined by the inclination of its axes to some frame of reference; for Apollo, an inertial, space-fixed reference is used.

Axis—Any of three straight lines, the first running through the center of the fuselage lengthwise, the second at right angles to this and parallel to the horizontal airfoils, and the third perpendicular to the first two at their point of intersection (aircraft).

Azimuth—An arc of the horizon measured between a fixed point (e.g., true north) and the vertical circle through the center of an object.

Backout—Reversing the countdown sequence because of the failure of a component in the vehicle or a hold of unacceptable duration.

Ballistic Trajectory—The curved portion of a vehicle trajectory traced after the propulsion force is cut off.

Biatomic Oxygen—The normal oxygen molecule, consisting of two oxygen atoms, which exists in the lower layers of the atmosphere. It constitutes nearly 21 percent of the atmospheric air and is the essential agent in respiration.

Binary Star—Two stars revolving around a common center of gravity.

Bioastronautics—Astronautics considered for its effect on animal or plant life.

Biosphere—That part of the earth and its atmosphere in which animals and plants live.

Bit—A unit of information carried by an identifiable character, which can exist in either of two states - a "one" or a "zero." An abbreviation of binary digit.

Blanketing—When a desired signal is blanketed, or eliminated, from reception by the presence of an overriding, stronger undesired signal.

Bleed-Cycle Operation—Refers specifically to liquid-propellant rocket engines in which a turbopump is driven by hot gases bled from the combustion chamber of the main thrust chamber.

Blip—A spot of light or other indicator on a radar scope (cathode-ray tube).

Blowoff—Separation of an instrument section or package from the remainder of the rocket vehicle by application of an explosive force.

Blow-Out Disc—A mechanism, consisting of a thin metal diaphragm, used as a safety device to relieve excessive gas pressure.

Boilerplate—A full-size mockup that has all of the mechanical characteristics of the true item but none of the functional features.

Booster—An engine that assists the normal propulsive system of a vehicle or other system of a vehicle.

Bootstrap—A self-generating or self-sustaining process.

Boresight Tower—A tower on which there are mounted a visual target and an electrical target (antenna fed from a signal generator); these targets are used for the parallel alignment of the electrical axis of a receiving antenna and the optical axis of a telescope mounted on that antenna.

Braking Ellipses—A series of orbital approaches to a planet's atmosphere to slow a rocket before landing.

Burnout—The point when combustion ceases in a rocket engine.

Burst Diaphragm—Same as a blow-out disc.

Canard—A short, stubby wing-like element affixed to an aircraft or spacecraft to provide better stability.

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

Captive Firing—Test firing of a complete vehicle where all or any part of the propulsion system is operated at full or partial thrust while the missile is restrained in the test stand.

Captive Test—A test conducted while the vehicle is secured to a test stand; primarily intended to verify proper operation of the propulsion and flight control subsystems under full-thrust conditions.

Capture—(1) The act of a central force field capturing a passing or colliding body or particle. (2) Of a central force field, as of a planet: to overcome the velocity or centrifugal force of a passing or colliding body or particle and bring its behavior under control of the force field or integrate the body's mass into the force field.

Cavitation—The rapid formation and collapse of vapor pockets in a flowing liquid under very low pressures; a frequent cause of serious structural damage to rocket components.

C Band—A radio frequency band of 3.9 to 6.2 gigacycles per second.

Celestial Guidance—The guidance of a vehicle by reference to celestial bodies.

Celestial Mechanics—The science that deals primarily with the effect of force as an agent in determining the orbital paths of celestial bodies.

Celestial Sphere—Imaginary sphere of infinite radius, assumed for navigational purposes and center of which coincides with the center of earth.

Center of Mass—Commonly called the center of gravity, it is the point at which all the given mass of a body or bodies may be regarded as being concentrated as far as motion is concerned.

Centrifugal Force—A force which is directed away from the center of rotation.

Centrifuge—A large motor-driven apparatus with a long rotating arm used to produce centrifugal force.

Centripetal Force—A force which is directed toward the center of rotation.

Characteristic Length—In propulsion, the ratio of the chamber volume to its nozzle throat area. A measure of the length of travel available for the combustion of propellants.

Characteristic Velocity—Sum of all velocities that have to be obtained or overcome for purposes of braking by a rocket intended for a particular journey.

Checkout—A sequence of operational and calibrational tests to determine the condition and status of a system.

Chemical Fuel—(1) A fuel that depends on an oxidizer for combustion or for development of thrust, such as liquid or solid rocket fuel, jet fuel, or internal-combustion-engine fuel. Distinguished from nuclear fuel. (2) An exotic fuel that uses special chemicals.

Chemosphere—A stratum of the atmosphere marked for its photochemical activity. (By some meteorologists, the chemosphere is considered to be an extension of the stratosphere.)

Chuffing—The characteristic of some rockets to burn intermittently and with an irregular puffing noise.

Circular Velocity—Critical velocity at which a satellite will move in a circular orbit, it is extremely difficult to attain because of the accuracy of control needed.

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

Cislunar Space—Space between the earth and the orbit of the moon.

Closed Ecological System—A system that provides for the metabolism of the body in a spacecraft cabin by means of a cycle in which exhaled carbon dioxide, urine, and other waste matter are converted chemically or by photosynthesis into oxygen and food.

Closed Loop—Automatic control units linked together with a process to form an endless chain.

Closed Respiratory Gas System—A completely self-contained system within a sealed cabin, capsule, or spacecraft that will provide adequate oxygen for breathing, maintain adequate cabin pressure, and absorb the exhaled carbon dioxide and water vapor.

Cloud Chamber—The path of subatomic particles are made visible in this kind of chamber by depositing a "cloud" of water particles on them.

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

Comet—A loose body of gases and solid matter revolving around the sun.

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

Companion Body—A nose cone, last-stage rocket, or other body that orbits along with an earth satellite.

Comparator—An electronic processing instrument that compares one set of data with another.

Condensation Trail (Contrails or Vapor Trails)—A visible cloud streak, usually brilliantly white in color, which trails behind a vehicle in flight under certain conditions; caused by the formation of water droplets or sometimes ice crystals due to sudden compression, then expansive cooling, of the air through which the vehicle passes, and of introduction of water vapors through condensation of certain fuels.

Console—Term applied to a grouping of controls, indicators, and similar electrical or mechanical equipment.

Constellation—Any one of the arbitrary groups of fixed stars, some 90 of which are now recognized. A division of the heavens in terms of any one of these groups.

Control Rocket—A rocket used to guide, accelerate, or decelerate a launch vehicle or spacecraft.

Control System—A system that serves to maintain attitude stability during forward flight and to correct deflections.

Controlled Leakage System—A system that provides for the body's metabolism in an aircraft or spacecraft cabin by a controlled escape of carbon dioxide and other waste.

Converter—A unit that changes the language of information from one form to another.

Coriolis Effect—The deflection of a body in motion due to the earth's rotation, diverting horizontal motions to the right in the northern hemisphere and to the left in the southern hemisphere.

Corpuscular Cosmic Rays—Primary cosmic rays from outer space which consist of particles, mainly atomic nuclei (protons) of hydrogen and helium, positively charged and possessing extremely high kinetic energy.

Corpuscular Radiations—Consisting of a flux of small particles.

Cosmic Rays—Extremely fast particles continually entering the upper atmosphere from interstellar space; atomic nuclei which have very great energies because of their enormous velocities; potentially dangerous to life during extended exposure.

Creep—The property of a metal which allows it to be permanently deformed when subjected to a stress.

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

Cyclic Testing—Repeated testing of an object at regular intervals to be assured of its reliability.

Damping—Restraining.

Data Link Equipment—Electronic equipment that coordinates data collection, reduction, and analysis.

Deadband—In a control system, the range of values through which the measure can be varied without initiating an effective response.

Declination—In astronomy and celestial navigation, the angular distance of a celestial body from the celestial equator measured through 90 degrees and named "north" or "south" as the body is north or south of its celestial equator measured on an hour circle.

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

Delta V (ΔV)—Velocity change

Destruct—The deliberate action of detonating or otherwise destroying a missile or other vehicle after launch.

Dielectrically Heated—Heating while producing power (i.e., the fuel cell).

Diffusion Process—The exchange of molecules in gas mixtures or solutions across a border line between two or more different concentrations.

Digital Computer—A computer in which quantities are represented numerically and which can be used to solve complex problems.

Doppler Drift—The drift of a vehicle as determined through use of Doppler's (German mathematician Christian Doppler) principle by means of radar.

Doppler Effect—The apparent change in frequency of vibrations, as of sound, light, or radar, when the observed and observer are in motion relative to one another.

Doppler Principle—A principle of physics that, as the distance between a source of constant vibrations and an observer diminishes or increases, the frequencies appear to be greater or less.

Doppler Shift—A shift of a luminous body's line in a spectrum toward the red, indicating an increase in distance.

Dosimeter—An instrument that measures the amount of exposure to nuclear or X-ray radiation; also called an intensitometer or dosage meter.

Down-Link—The part of a communication system that receives, processes, and displays data from a spacecraft.

Drag—The aerodynamic force in a direction opposite to that of flight and due to the resistance of the body to motion in air.

Drift Error—A change in the output of an instrument over a period of time, usually caused by random wander or by a condition of the environment.

Drogue—The hollow (female) part of a connector into which a probe (male) part fits.

Dry-Fuel Rocket—A rocket that uses a mixture of fast-burning power. Used especially as a booster rocket.

Dual Thrust—A rocket thrust derived from two propellant grains using the same propulsion section of a missile.

Dual Thrust Motor—A solid rocket motor built to obtain dual thrust.

Earth-Fixed Reference—An oriented system using some earth phenomena for positioning.

Eccentric—Of an orbit, deviating from the line of a circle so as to form an ellipse.

Ecliptic—Plane of the earth's orbit around the sun, used as a reference for other interplanetary orbits; also the name for the apparent path of the sun through the constellations as projected on the celestial sphere.

Ecosphere—The great circle on the celestial sphere which describes the apparent path of the sun in the course of the year.

Effective Atmosphere—That part of the atmosphere which effectively influences a particular process of motion.

Effective Exhaust Velocity—The velocity of an exhaust stream after the effects of friction, heat transfer, non-axially directed flow, and other conditions have reduced it.

Effector—The mechanical means of maneuvering a vehicle during flight: an aerodynamic surface, a gimbaled motor, or an auxiliary jet.

Electrojet—Current sheet or stream moving in an ionized layer in the upper atmosphere of a planet.

Electrolyte—A substance in which the conduction of electricity is accompanied by chemical action; the paste which forms the conducting medium between the electrodes of a dry cell, storage cell, or electrolytic capacitor.

Emissivity—The relative power of a surface or a material composing a surface to emit heat by radiation.

Entry Corridor—The final flight path of the spacecraft before and during earth re-entry.

Ephemeris—A publication giving the computed places of the celestial bodies for each day of the year, or for other regular intervals.

Escape Orbit—One of various paths that a body or particles escaping from a central force field must follow in order to escape.

Escape Velocity—The speed a body must attain to overcome a gravitational field, such as that of earth; the velocity of escape at the earth's surface is 36,700 feet per second.

Event Timer—An instrument that times an event and records time taken to perform the cycle or event; can record several events simultaneously.

Exerciser—A machine that simulates the strains and vibrations to which a missile is subjected, and used to test for structural integrity.

Exhaust Stream—The stream of gaseous, atomic, or radiant particles that emit from the nozzle of a rocket or other reaction engine.

Exosphere—The outermost fringe or layer of the atmosphere, where collisions between molecular particles are so rare that only the force of gravity will return escaping molecules to the upper atmosphere.

Exotic Fuel—Unusual fuel combinations for aircraft and rocket use.

Explosive Bolts—Bolts surrounded with an explosive charge which can be activated by an electrical impulse.

Explosive Bridge Wire—Wire which heats to a high temperature and burns, thus igniting a charge.

Extension Skirt—Adapter used to connect elements of the spacecraft.

Extravehicular—Indicates that an element, such as an antenna, is located outside the vehicle.

Fairing—A piece, part, or structure having a smooth, streamlined outline, used to cover a nonstreamlined object or to smooth a junction.

Fallaway Section—Any section of a rocket vehicle that is cast off and falls away from the vehicle in flight.

Final Trim—Action that adjusts a vehicle to the exact direction programmed for its flight.

Flash Point—The temperature at which the vapor of a fuel or oil will flash or ignite momentarily.

Float Bag—A collar located around the spacecraft used to keep the spacecraft upright in the water and prevent sinking.

Free-Flight Rocket—A rocket without electronic control or guidance.

Free-Flight Trajectory—The part of a ballistic missile's trajectory that begins with thrust cutoff and ends at re-entry.

Free Gyro—Sometimes referred to as space reference gyro in that the free gyro will maintain its orientation with respect to the stars rather than with respect to the earth.

Frequency Spectrum—The area encompassed by frequencies, from very low to very high, in terms of cycles (vibration) in a unit of time.

Free-Return Trajectory—A return to earth without power; this trajectory would be used in the event of a failure of the spacecraft propulsion system.

Fuel Cell—An electrochemical generator in which the chemical energy from the reaction of air (oxygen) and a fuel is converted directly into electricity.

G or G Force—Force exerted upon an object by gravity or by reaction to acceleration or deceleration, as in a change of direction: one G is the measure of the gravitational pull required to move a body at the rate of about 32.16 feet per second.

Galaxy—(1) The group of several billion suns, stars, star clusters, nebulae, etc., to which the earth's sun belongs; (2) any of several similar groups of stars forming isolated units in the universe.

Gamma Radiation—Electromagnetic radiation, similar to X rays, originating from the nucleus and having a high degree of penetration.

Gas Chromatograph—An oscillating filter-photometer that separates and analyzes gasses.

Geocentric—Relating to or measured from the center of the earth: having, or relating to, the earth as a center.

Geodetic—Pertaining to or determined by that branch of mathematics which determines the exact positions of points and the figures and areas of large portions of the earth's surface, or the shape and size of the earth and the variations of terrestrial gravity.

Geophysical Constant—A quantity that expresses a fixed value for a law or magnitude that applies to the physics of the earth.

Geophysics—The physics of the earth, or science treating of the agencies which modify the earth.

Gimbal—Mechanical frame containing two mutually perpendicular intersecting axes of rotation (bearing and/or shafts).

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

Glycol—Ethylene glycol, a coolant mixed with water in varying proportions, depending on rate of cooling desired.

Grain—The body of a solid propellant used in a rocket, fashioned to a particular size and shape so as to burn smoothly without severe surges or detonations.

Gravitation—Force of attraction that exists between all particles of matter everywhere in the universe.

Gravity—That force which tends to pull bodies toward the center of mass; that is, to give bodies weight.

Gravity Anomalies—Deviations between theoretical gravity and actual gravity due to local topographic and geologic conditions.

Gravity Simulation—Use of centripetal force to simulate weight reaction in a condition of free fall.

Ground Trace—The theoretical mark traced on the surface of the earth by a flying object or satellite as it passes over the surface.

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.

Guidance Tapes—Magnetic or paper tapes that are placed in the computer and on which there previously has been entered information needed in guidance.

Gyro-Compassing—Use of gyro with axle pointed due north in directional guidance.

Gyroscope—A device consisting of a wheel so mounted that its spinning axis is free to rotate about either of two other axes perpendicular to itself and to each other; once set in rotation, its axle will maintain a constant direction, even when the earth is turning under, when its axle is pointed due north, it may be used as a gyro compass.

Heat Exchanger—A device for transferring heat from one substance to another, as by regenerative cooling.

Heat Sink—A contrivance for the absorption or transfer of heat away from a critical part or parts, as in a nose cone where friction-induced heat may be conducted to a special metal for absorption.

Heaviside—Kennelly Layer—Region of the ionosphere that reflects certain radio waves back to earth.

Heliocentric—Measured from the center of the sun.

Honeycomb Sandwich—A type of construction in which the space between the upper and lower surfaces is occupied by a strengthening material of a structure resembling a honeycomb mesh.

Horizon Photometer—An instrument to determine the distinction between the sky and the horizon; thus, measures light by means of monitoring the infrared emanations.

Hydrosphere—The aqueous (watery) envelope of a planet.

Hydrostatic Effects—The pressures exerted by a column of liquid (water, blood, etc.) under normal gravitational conditions on the surface of the earth or in a gravitational field during an acceleration.

Hyperacoustic Zone—The region in the upper atmosphere between 60 and 100 miles where the distance between the rarefied air molecules roughly equals the wave length of sound, so that sound is transmitted with less volume than at lower levels. Above this zone, sound waves cannot be propagated.

Hyperbola—A conic section made by a place intersecting a cone of revolution at an angle smaller than that of a parabola.

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

Hypersonic—Speeds faster than Mach 5 or five times the speed of sound.

Hypoxia—Oxygen deficiency in the blood cells or tissues of the body in such a degree as to cause psychological and physiological disturbances.

Ice Frost—A thickness of ice that gathers on the outside of a rocket vehicle over surfaces supercooled by liquid oxygen or hydrogen inside the vehicle.

Incidence Angle—The angle between earth and the path of a vehicle.

Inertia—The tendency of an object to remain put or if moving to continue on in the same direction.

Inertial Guidance—A sophisticated automatic navigation system using gyroscopic devices, etc., for high-speed vehicles. It absorbs and interprets such data as speed, position, etc., and automatically adjusts the vehicle to a predetermined flight path. Essentially, it knows where it's going and where it is by knowing where it came from and how it got there. It does not give out any signal so it cannot be detected by radar or jammed.

Inertial Orbit—The type of orbit described by all celestial bodies, according to Kepler's laws of celestial motion. This applies to all satellites and spacecraft provided they are not under any type of propulsive power, their driving force being imparted by the momentum at the instant propulsive power ceases.

Inertial Space—An assumed stationary frame of reference. A non-rotating set of coordinates in space relative to which the trajectory of a space vehicle is calculated.

Injection—The process of injecting a spacecraft into a calculated orbit.

Integrating Accelerometer—A mechanical and electrical device which measures the forces of acceleration along the longitudinal axis, records the velocity, and measures the distance traveled.

Intergalactic Space—That part of space conceived as having its lower limit at the upper limit of interstellar space, and extending to the limits of space.

Interior Ballistics—That branch of ballistics concerned with behavior, motion, appearance, or modification of a rocket when acted upon by ignition and burning of a propellant. Sometimes called "internal ballistics." In rocketry, interior ballistics deals with the missile's behavior in reaction to gas pressures inside the rocket, escapements, shift in the center of gravity as propellants are consumed, etc.

Interleaver—The act of combining computer data to produce, from several sources, a single result.

Interplanetary Space—That part of space conceived, from the standpoint of the earth, to have its lower limit at the upper limit of translunar space, and extending to beyond the limits of the solar system several billion miles.

Interstellar Flight—Flight between stars; strictly, flight between orbits around the stars.

Interstellar Space—That part of space conceived, from the standpoint of the earth, to have its lower limit at the upper limit of interplanetary space, and extending to the lower limits of intergalactic space.

Inverter—A device that changes dc current to ac, or vice versa.

Ion Engine—A type of engine in which the thrust to propel the missile or spacecraft is obtained from a stream of ionized atomic particles, generated by atomic fusion, fission or solar energy.

Ionic Conduction Path—That part of the vehicle where radio communication is not possible due to the ionization of the air - the transmitting medium. The ions interfere with the radio frequency signal.

Ionization—Formation of electrically charged particles; can be produced by high-energy radiation, such as light or ultra-violet rays, or by collision or particles in thermal agitation.

Ionized Layers—Layers of increased ionization within the ionosphere. Believed to be caused by solar radiation. Responsible for absorption and reflection of radio waves and important in connection with communication and tracking of satellites and other space vehicles.

Ionosphere—An outer belt of the earth's atmosphere in which radiations from the sun ionize, or excite electrically, the atoms and molecules of the atmospheric gases. The height of the ionosphere varies with the time of day and the season, but its lower limit is generally considered to lie between 25 and 50 miles. It is divided into several layers with respect to radiation and reflective properties. A characteristic phenomenon is its reflection of certain radio waves.

Iostatic—Under equal pressure from every side.

Isothermal Region—The stratosphere considered as a region of uniform temperature.

Jet Steering—The use of fixed or movable jets on a space vehicle, ballistic missile, or sounding rocket to steer it along a desired trajectory, during both propelled flight (main engines) and after thrust cutoff.

Kelvin Scale—(After Baron Kelvin, English physicist and inventor.) A temperature scale that uses centigrade degrees but makes the zero degree signify absolute zero.

Keplerian Trajectory—Elliptical orbits described by celestial bodies (and satellites) according to Kepler's first law of celestial motion.

Kepler's Law—The three laws of planetary motion discovered by Kepler:
(1) The orbit of every planet about the sun is an ellipse, the sun occupying one focus. (2) A line from each planet to the sun sweeps over equal area in equal times. (3) The squares of the times required for the different planets to complete their orbits are proportional to the cubes of their mean distances from the sun.

Leveled Thrust—A rocket power plant equipped with a programmer or engine control unit that maintains the output at a relatively constant thrust.

Lift-Drag Ratio—The ratio of lift to drag, obtained by dividing the lift by the drag or the lift coefficient by the drag coefficient.

Light Year—Distance traveled in one year by light, which covers 186,284 miles in one second; equal to 5,880,000,000,000 miles.

Linear Explosive Charge—The shaping of a charge; shaping the explosive pattern of charge to achieve an explosive profile.

Liquified Gases—These are gases which have been converted to liquids under certain pressure and temperature conditions.

Liquid Hydrogen (LH_2)—A liquid rocket fuel that develops a specific impulse, when oxidized by liquid oxygen, ranging between 317 and 364 seconds depending upon the mixture ratio. Hydrogen gas becomes liquid at 423 degrees below zero.

Liquid Oxygen (LOX)—Oxygen supercooled and kept under pressure so that its physical state is liquid. Oxygen gas becomes liquid at 279 degrees below zero.

Loxing—Vernacular term for the task of loading liquid oxygen into fuel tanks of a missile from a ground supply.

Lunar Base—A projected installation on the surface of the moon for use as a base in scientific or military operations.

Lunar Gravity—The attraction of particles and masses towards the gravitational center of the moon.