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BC 64-3

PROPULSION THE KEY TO MOON TRAVEL

ROCKETDYNE
A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION
6633 CANOGA AVENUE, CANOGA PARK, CALIFORNIA 91304

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PROPULSION

THE KEY TO MOON TRAVEL

ROCKETDYNE
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MOON

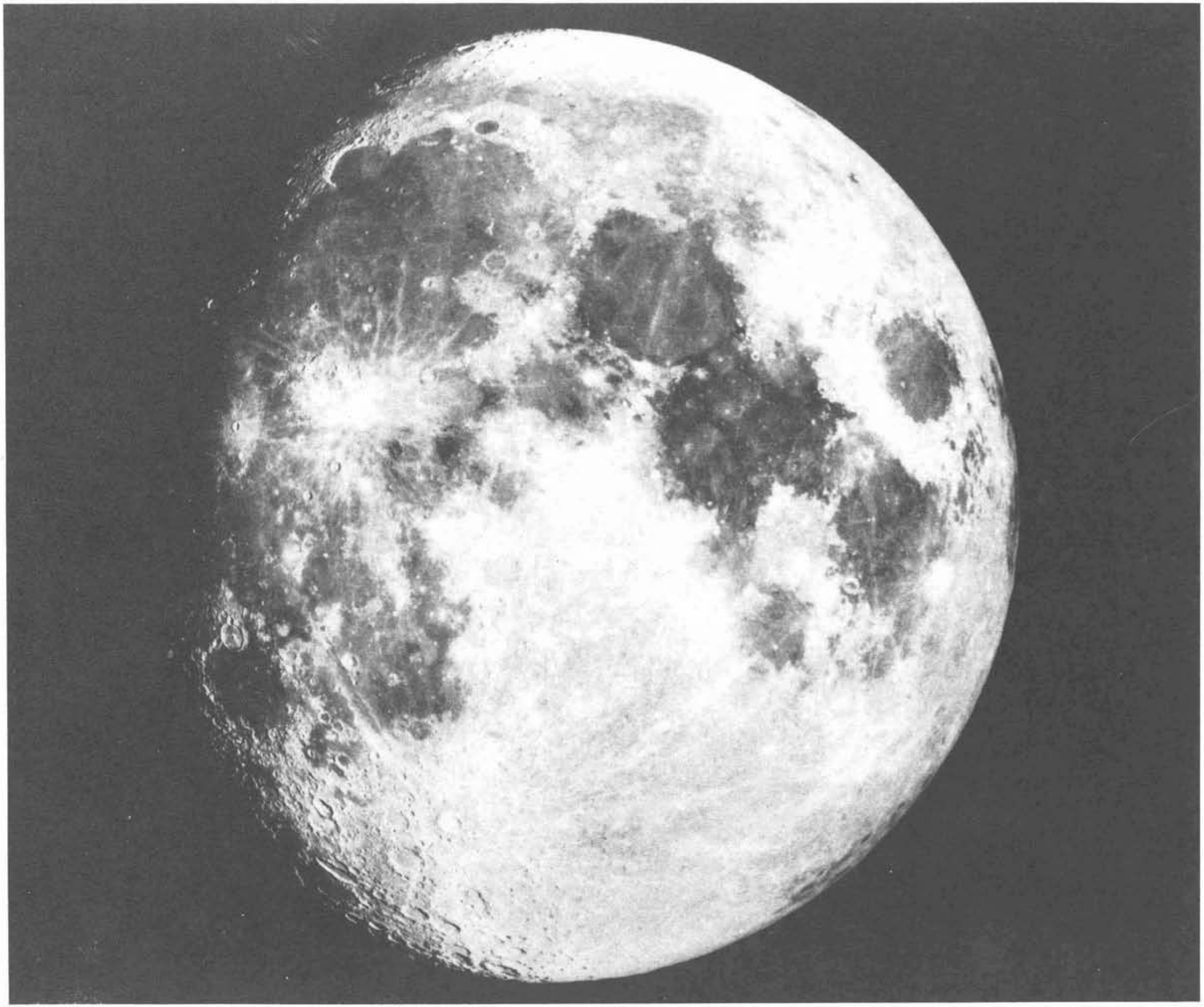
Ranger, Surveyor, Lunar Orbiter, and finally, Apollo--these are the steps that will take us to the Moon.

Ranger will crash-land instruments on the Moon. Surveyor will soft-land about 250 pounds of instruments on the lunar surface. It may be equipped with a drill to sample the lunar surface for chemical and physical analysis. Lunar Orbiter will survey the lunar surface for safe landing areas. There's much to be learned. Some day, soon, man is going to have to survive there.

The Moon presents a special challenge. Unlike the Earth, the Moon--with its lack of atmosphere and accompanying winds and rains to cause erosion--has preserved a record of the solar systems early history.

Technological progress is an element of strength among nations. The race to the Moon has become a major indicator of the technological progress achieved within two competing ideologies.

In addition to adding significantly to man's scientific knowledge, Project Apollo will provide many material benefits--new power sources, new discoveries and technical adhievements, new jobs, new horizons.



SPACE MISSIONS

You are living in what is probably the most exciting time man has ever known. New and amazing information about the universe is being collected with every space probe launched. Almost every scientific discipline is expanding its field of knowledge as a result of the National Space Program.

This year, longer earth orbital flights were planned and attained. Soon the two-man spacecraft, Gemini, will be launched for training of astronauts in rendezvous and docking. The Apollo-Saturn Project of manned flight to the Moon will get underway in about two years with training flights in earth orbit. Following this, a manned circumlunar flight will be made with a landing scheduled by the end of this decade.

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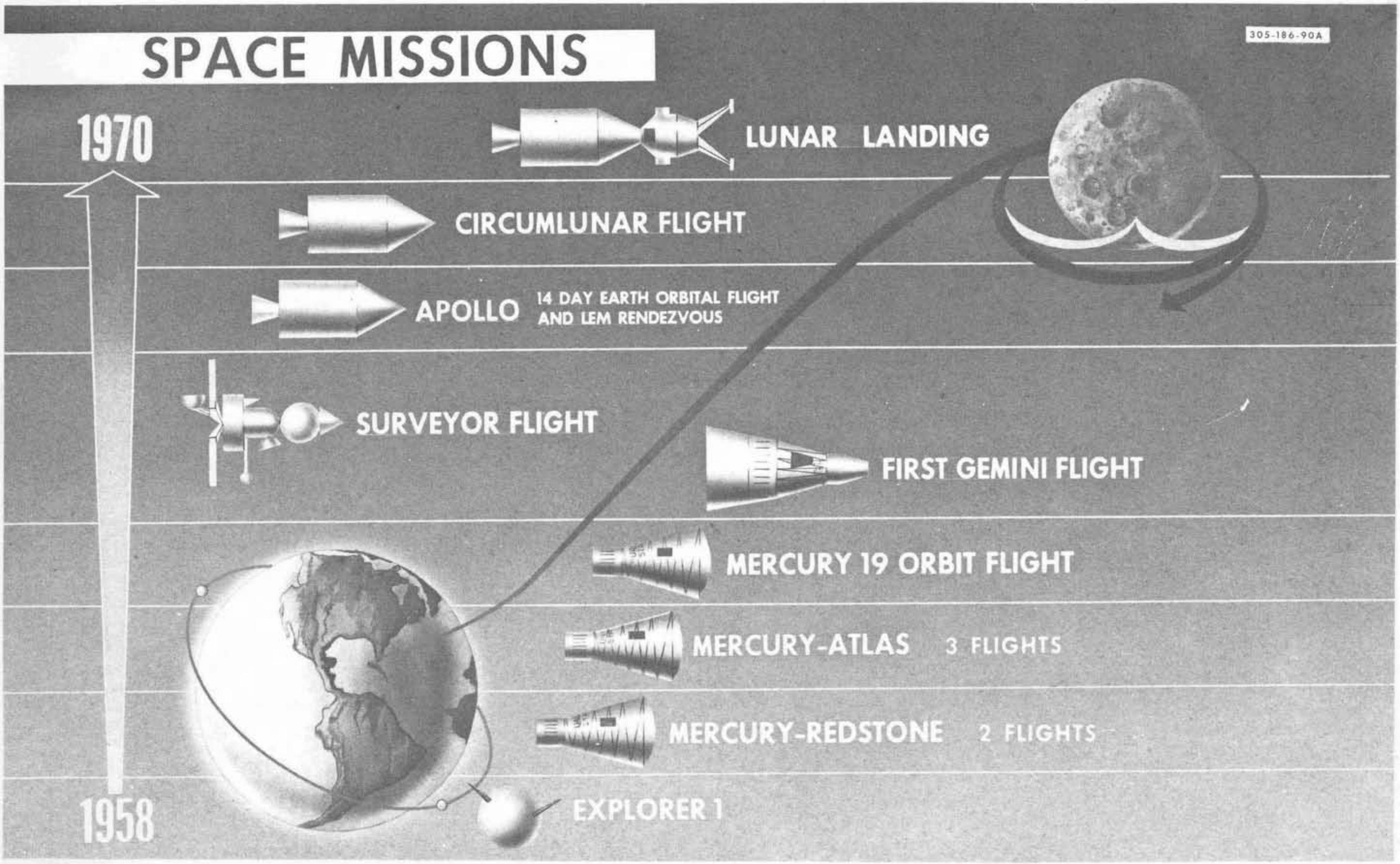

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SATURN CONFIGURATIONS

Now let's look at the vehicles that will have the enormous power needed for the lunar launching. Saturn I, Block II: S-I stage of eight Rocketdyne H-1 engines of 188,000 pounds thrust each and S-IV stage with six engines of 15,000 pounds thrust each.

After initial flights of the Saturn I, it will be uprated to the Saturn IB configuration by substituting S-IVB with one Rocketdyne J-2 engine for the second stage. This new stage has over twice the thrust of the earlier stage. This launch vehicle will be used to place the Apollo "boiler plate" spacecraft and the Lunar Excursion Module, or LEM, in earth orbit for crew training in weightless environment, and rendezvous and docking techniques. In addition, the Saturn IB could launch a lunar logistics system spacecraft.

The Saturn V will provide power for launching the spacecraft. The pad weight of this vehicle is 6 million pounds.

Saturn V will launch 45 tons into lunar orbit trajectory. This vehicle is almost as tall as the Los Angeles City Hall. It would extend the length of the field in Los Angeles Coliseum.

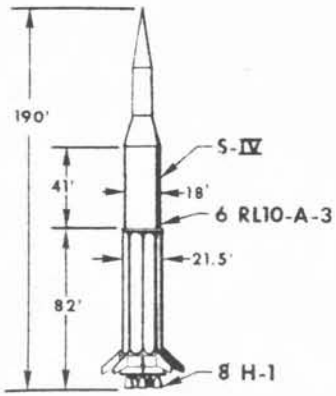
One F-1 engine for the Saturn V develops as much thrust as all eight engines of the Saturn I version. If the Mercury spacecraft, weighing one and one-half tons, is used for comparison, these figures show launch capabilities for low altitude earthorbit:

Saturn I	7 Mercury Spacecraft
Saturn IB	11 Mercury Spacecraft
Saturn V	80 Mercury Spacecraft

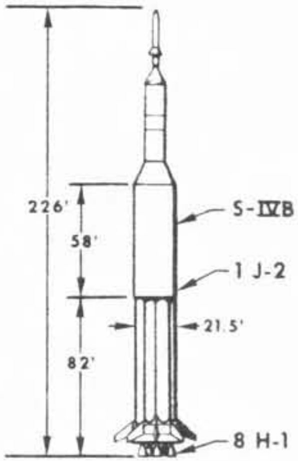
SATURN CONFIGURATIONS

VEHICLE	STAGE	STAGE MFGR	NO. OF ENGINES	ENGINE DESIGNATION	THRUST PER ENGINE 1000 LB	TOTAL NOMINAL THRUST, LB	ENGINE MANUFACTURER	POTENTIAL & PLANNED MISSONS
SATURN I	S-I	CHRYSLER	8	H-1	165 TO 188	1,504,000	R	VEHICLE SYSTEM DEVELOPMENT
	S-IV	DOUGLAS	6	RL 10-A-3	15	90,000	PRATT & WHITNEY	
UPRATED SATURN I	S-I	CHRYSLER	8	H-1	205	1,640,000	R	UNMANNED LUNAR RECONNAISSANCE DEVELOPMENT-EARTH ORBIT SYSTEMS
	S-IVB	DOUGLAS	1	J-2	230	230,000*	R	UNMANNED DEEP SPACE PROBES APOLLO-EARTH ORBIT TRAINING
SATURN V	S-IC	BOEING	5	F-1	1522	7,610,000	R	APOLLO-LUNAR MISSIONS
	S-II	N.A.A., S&ID DIV	5	J-2	230	1,150,000	R	UNMANNED DEEP SPACE PROBES
	S-IVB	DOUGLAS	1	J-2	230	230,000	R	

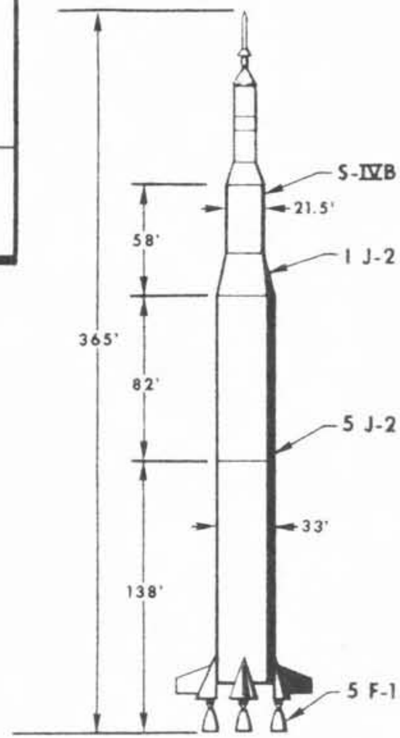
*MAXIMUM THRUST



SATURN I



UPRATED SATURN I



SATURN V

PAYLOAD, LOW ALTITUDE ORBIT ------- 22,500 LB -------------------- 36,000 LB -------------------- 280,000 LB

DIRECT ESCAPE -- 95,000 LB

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TYPICAL MANNED LUNAR MISSION--PROJECT APOLLO

(LUNAR ORBIT RENDEZVOUS)

The Saturn V launch vehicle will be assembled and checked out in the Vertical Assembly Building (VAB). This building, fifty stories high, has four bays, each equipped to assemble and check out one vehicle. The door on the VAB is 450 feet high (the world's tallest door). The missile will be moved to Launch Complex 39 Cape Kennedy, Florida, on a moving platform the size of a baseball diamond.

Pad weight of the Saturn V is six million pounds, or as much as a nuclear submarine or two dozen jet airliners. This weight includes the propellants, the structure, and the Apollo spacecraft.

Spacecraft Characteristics

Spacecraft	Weight	Dimensions
Command Module	10,000 lbs.	154 in. diameter at base 146 in. from base to top
Service Module	50,000 lbs.	154 in. diameter 182 in. long
Lunar Excursion Module (LEM)	30,000 lbs.	120 in. diameter Height 180 in. on four legs
LEM "BUG"		120 in. diameter 102 in. high
LEM "Lander"		Four legs and tank section

Total Apollo Spacecraft: 90,000 lbs.

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The first (S-IC) stage, powered by five F-1 engines rated at 7-1/2 million pounds of thrust, will fire for 151 seconds. During this first stage firing 50 railway tank cars of propellants will be consumed at the rate of 1000 gallons per second. At cutoff the Saturn V vehicle will have reached an altitude of 200,000 feet and a velocity of 7500 feet per second. Immediately after cutoff the S-II ullage rockets are fired and a shaped charge is ignited which peels away the interstage structure between the first (S-IC) and second stages (S-II). Eight 100,000 pound solid propellant retro-rockets are then fired for less than 1 second which causes the first stage to decelerate and separate from the second stage.

Eight 26,000 pound thrust, solid propellant ullage rockets will be fired for 3.8 seconds to settle the propellants to insure proper ignition of the five J-2 engines that power this stage. This stage, with one million pounds total thrust, will fire for 391 seconds to boost the vehicle to an altitude of 99 miles and a speed of 22,000 feet per second. Following cutoff of the five J-2 engines, the S-IVB ullage engines fire followed by four solid propellant retro-rocket motors mounted on the interstage structure, rated at 35,000 pounds each, will fire for 1.5 to 2 seconds and separate the second and third stages.

As the third (S-IVB) stage is separated from the second (S-II) stage, two 1750 pound thrust, liquid propellant (nitrogen tetroxide-monomethyl hydrazine) rocket engines continue to fire to settle the main engine propellants during ignition of the single J-2 engine. The J-2 engine will fire for 160 seconds and injects the third stage with its Apollo spacecraft into an earth orbit at a velocity of 25,565 feet per second. This package then will orbit the earth approximately 1-1/2 times, allowing ample time to accurately determine the orbit and make various other checks in preparation for embarking on a trajectory toward the moon. A second firing of 340 seconds will obtain a velocity of 35,680 feet per second for the lunar trajectory. Attitude control is maintained during the orbit period by two modules mounted 180° apart on the aft portion of the S-IVB stage. Each module contains an aft-facing, 1750 pound thrust ullage motor previously mentioned; two tangentially oriented, 150 pound-thrust motors, and one radially oriented, 150 pound motor. By pulsing the 150 pound chambers in proper combinations and sequences, yaw, pitch and roll control will be maintained during the coast periods.

Shortly after entering the lunar flight trajectory, a four-section fairing adapter is jettisoned from the LEM by shaped charges. When fairings are clear, the Apollo Command and Service Modules are rotated 180 degrees and joined nose to nose with the LEM mounted on the forward section of the S-IVB. The complete Apollo spacecraft is then separated from the S-IVB stage by firing explosive bolts.

Approximately three mid-course corrections are anticipated for a total change in velocity of approximately 200-300 feet per second. The flight to the Moon will require 72 hours.

Before proceeding further, let's examine the remaining Apollo Propulsion System:

	Thrust Chambers	Propellants*
Service Module Engine	22,000 pounds thrust, ablative thrust chamber	NTO/50-50
Service Module Attitude and Maneuvering System	Sixteen 100-pound-thrust, radiation-cooled thrust chambers	NTO/50-50
Command Module Attitude	Twelve 91-pound-thrust, ablative thrust chambers	NTO/MMH
LEM Module Engines		
"Bug" Attitude and Maneuvering	Twelve 100-pound-thrust, radiation-cooled thrust chambers	NTO/50-50
Lunar Ascent	4,000-pound-thrust, ablative thrust chamber	NTO/50-50
Lunar Descent	Throtteable, 10,500 to 1050 pounds thrust	NTO/50-50

*

NTO - Nitrogen tetroxide
MMH - Monomethyl hydrazine
50-50 - 50% Unsymmetrical dimethylhydrazine
50% hydrazine

At the precise moment determined by the guidance system the Service Module engine will be fired for 324 seconds to decelerate the Apollo spacecraft by 3150 feet per second. This deceleration will place the spacecraft into a lunar orbit. Shortly after entering orbit two of the crew will transfer to the LEM.

The LEM will then be separated from the rest of the Apollo vehicle and will be put into an elliptical orbit which passes within 50,000 feet of the lunar surface by firing the descent engine for about 396 seconds. The Apollo Command and Service Modules will remain in an approximately circular lunar orbit with a velocity of 5500 feet per second, while awaiting the return of the LEM module. As the LEM passes the low orbit point of 50,000 feet, the descent engine will then re-ignite and fire for 326 seconds, which will change the velocity 5700 feet per second, and will bring the LEM to a hovering position about 1000 feet above the lunar surface. From this point the astronauts will select their landing site and then maneuver the LEM to the moon's surface by controlling the thrust of the descent engine and use of the attitude control system.

The probable landing area will be in the area west of the Sea of Tranquility. Composition of the lunar surface and knowledge of the lunar environment will have been gained through earlier Surveyor and Prospector flights. Half-way point in this historic flight will now have been reached. In the special protective suits the astronauts will take turns making up to four hour excursions into the nearby lunarscape. It is planned that twenty-four to forty-five hours will be spent on the moon.

After the astronauts have completed their exploration of the lunar surface, they will re-embark in the LEM and at the proper moment to intercept the Apollo modules in lunar orbit they will fire the ascent engine. The "lander" portion of the LEM is used as a launch pad and remains on the moon. The ascent portion of the LEM known as the "bug" accelerates to a 5500 foot per second orbit by firing the ascent engine for about 430 seconds, and then maneuvers to intercept the Apollo Command and Service Modules. The two lunar astronauts will then rejoin their companion in the Command Module for the return passage to earth. The abandoned "bug" remains in lunar orbit.

The return trip to earth, which will require about 76 hours, will be accomplished as follows: The Service Module engine will be fired for 157 seconds which increases the velocity by 3200 feet per second and puts the Apollo into an earth-return trajectory. On arrival at the earth-return corridor, approximately 80 nautical miles above the earth, the Service Module engine is used to accurately position the Apollo for final re-entry into the earth's atmosphere. The Service Module will then be jettisoned and the Command Module maneuvered by its attitude control system to properly orient it for re-entry.

The Command vehicle will use a skip-type re-entry path to keep heat and "g" loads within tolerable limits. This skip-type re-entry path will be controlled by orienting the module by means of the attitude control rockets to provide the lift and drag characteristics which will produce the correct re-entry trajectory. The aerodynamic characteristics of the Command Module (L/D = 0.5) are such that changes in attitude will enable the crew to select any landing site within a ellipse 5000 miles long and 500 miles wide. Current planning calls for a "water" landing.

Final descent will be done by releasing a drogue chute at 25,000 feet, followed by mortar deployment of three large chutes at 15,000 feet which will decelerate the spacecraft to a safe landing velocity.

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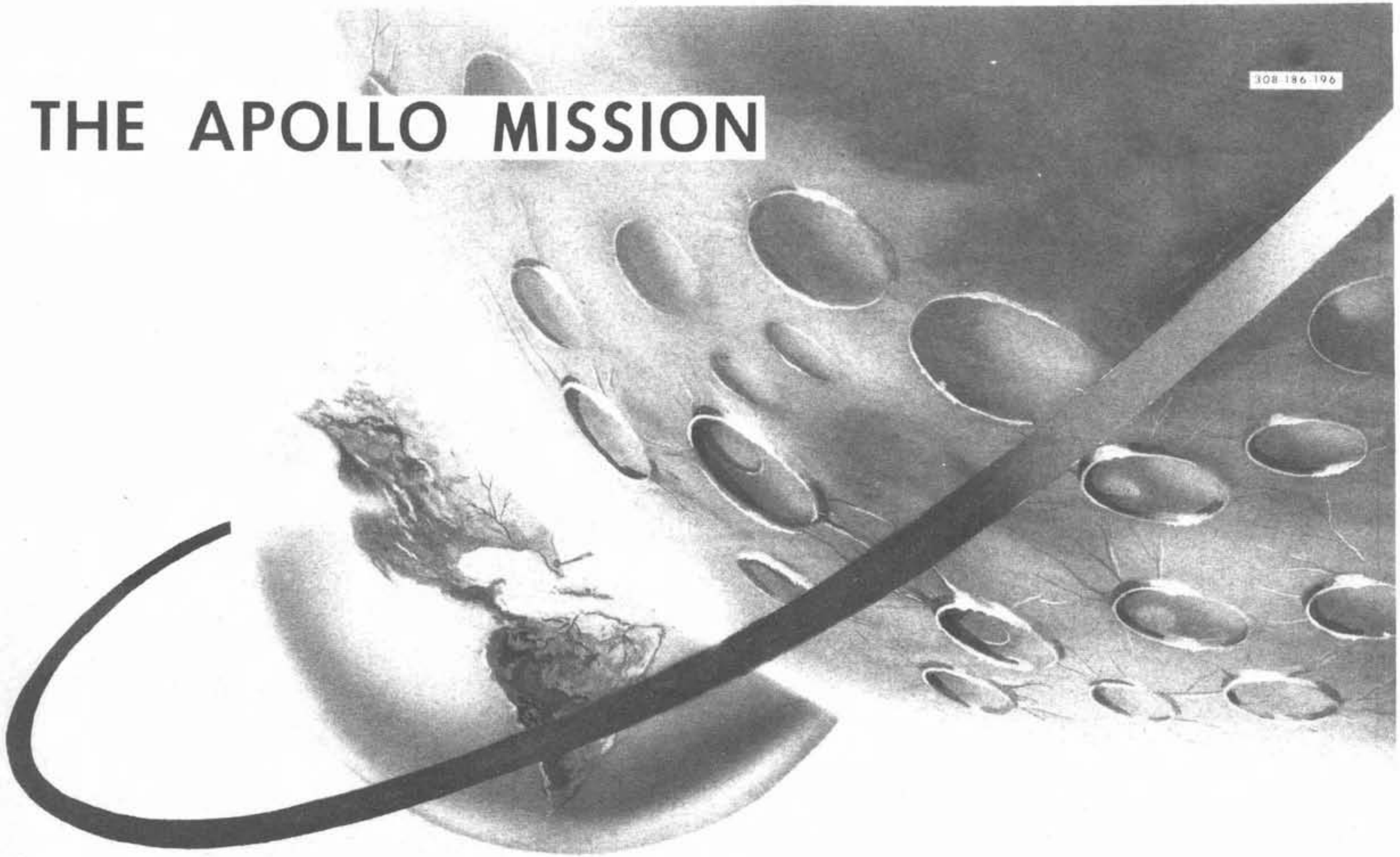
THE APOLLO MISSION



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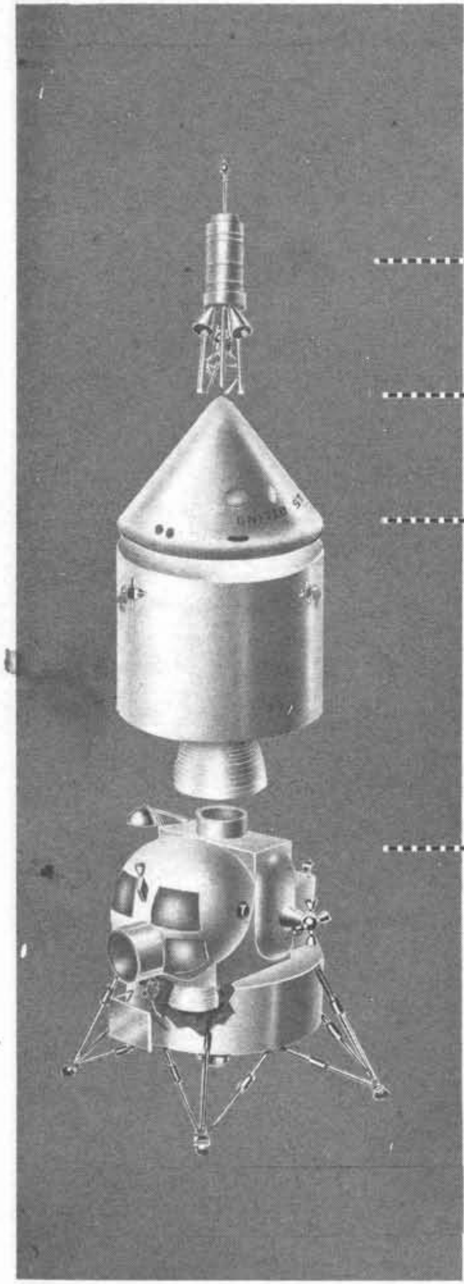
APOLLO

The Saturn V will provide power to make a lunar landing possible. This chart shows the spacecraft which will provide life support for the three-man crew. The Apollo spacecraft consists of three major units: The Command Module, the Service Module and the Lunar Excursion Module composed of the two-man "bug" and the "lander". Propulsion systems include attitude control systems for the Command and Service Modules. The Service Module uses one engine for lunar orbit injection, ejection into earth return trajectory and mid-course corrections. The "bug" has an attitude and maneuvering propulsion system and a lunar take-off engine. The lunar descent engine is a part of the "lander" which will be left on the Moon. Rocketdyne is developing the attitude control system for the Command Module and the descent engine for the Lunar Excursion Module or LEM as it is called. The total weight of these three modules will be 45 tons. The Saturn V launch vehicle must accelerate this weight to over 26,000 mph for the lunar flight.

Note the nozzles of thrust chambers mounted on the sides of the LEM and Service Modules for attitude control.



APOLLO

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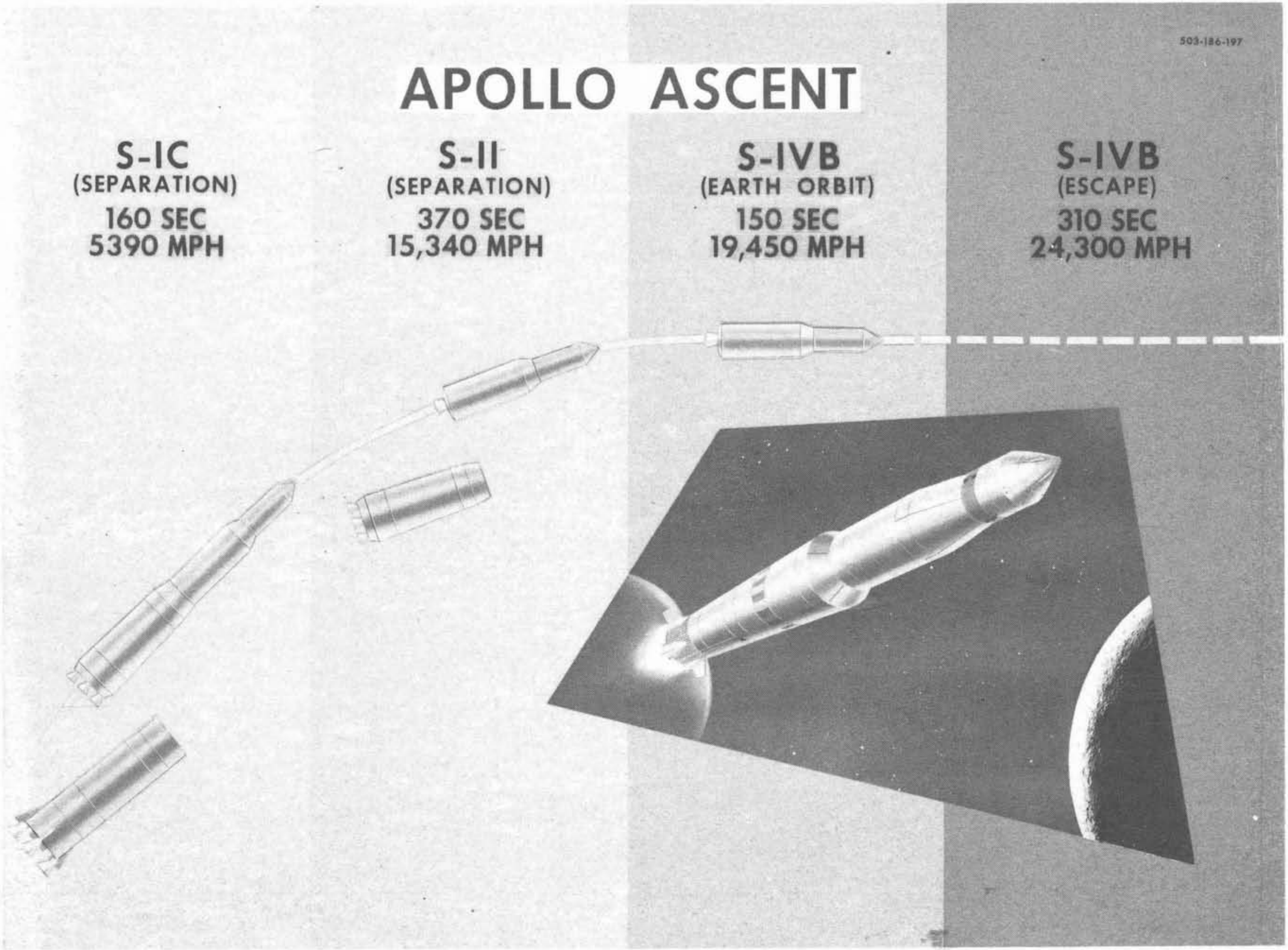
		PROPULSION REQUIREMENTS
LAUNCH ESCAPE SYSTEM		155,000 LB THRUST - ESCAPE 2500 LB THRUST - PITCH 31,650 LB THRUST - JETTISON
COMMAND MODULE		12 - 91 LB THRUST - ATTITUDE
SERVICE MODULE		16-100LB THRUST -ATTITUDE AND MANEUVERING 21,500 LB THRUST MAIN PROPULSION
LUNAR EXCURSION MODULE	"BUG"	16-100 LB THRUST -ATTITUDE AND MANEUVERING 3500 LB THRUST - ASCENT
	"LANDER"	10,500 LB THRUST - DESCENT (THROTTLEABLE)

APOLLO ASCENT

The manned flight to the Moon will be accomplished by the lunar orbit concept. That is, the Apollo spacecraft, including the Lunar Excursion Module or LEM, will be launched by Saturn V to a lunar orbit.

The first stage developing 7-1/2 million pounds thrust will burn for 150 seconds and the second stage will burn 390 seconds. The third stage will burn for 160 seconds, shut-down, coast, and then reignite to run for a total of 400 seconds to impart a velocity of 36,000 feet per second (26,600 mph) required to place the Apollo spacecraft into an earth escape trajectory toward the Moon.

Injected into space are the third (S-IV) stage (now dry) and the Apollo spacecraft still attached to and mounted on top of the S-IVB stage.



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TRANSPOSITION

Shortly after entering the lunar trajectory, shaped charges peel away the fairing, leaving the Apollo in free flight. The spacecraft is then turned by means of the attitude engines to dock, nose-to-nose, with the LEM riding in the forward portion of the third stage. Explosive bolts are then fired to separate the LEM from the third stage which is left behind.

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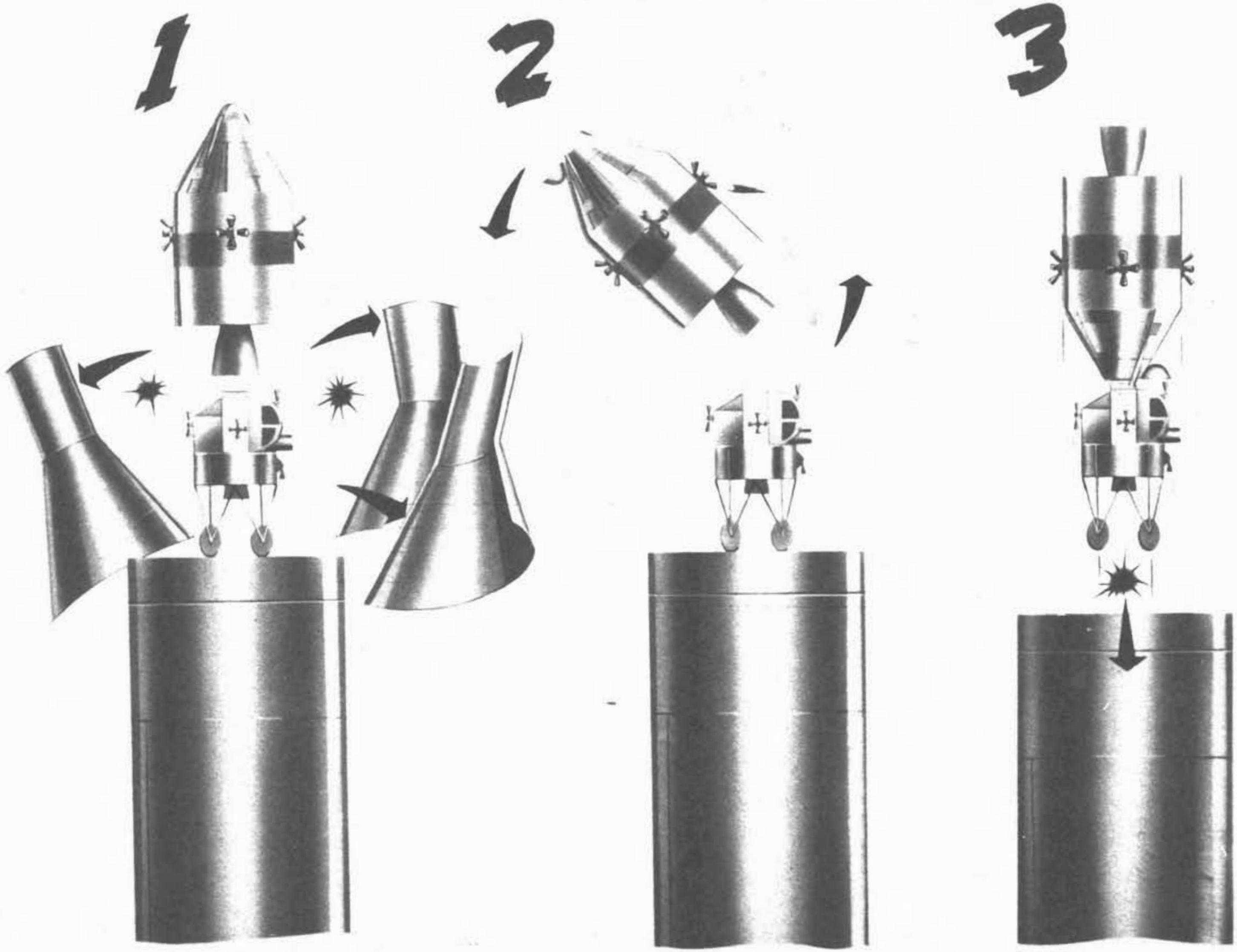
TRANSPOSITION



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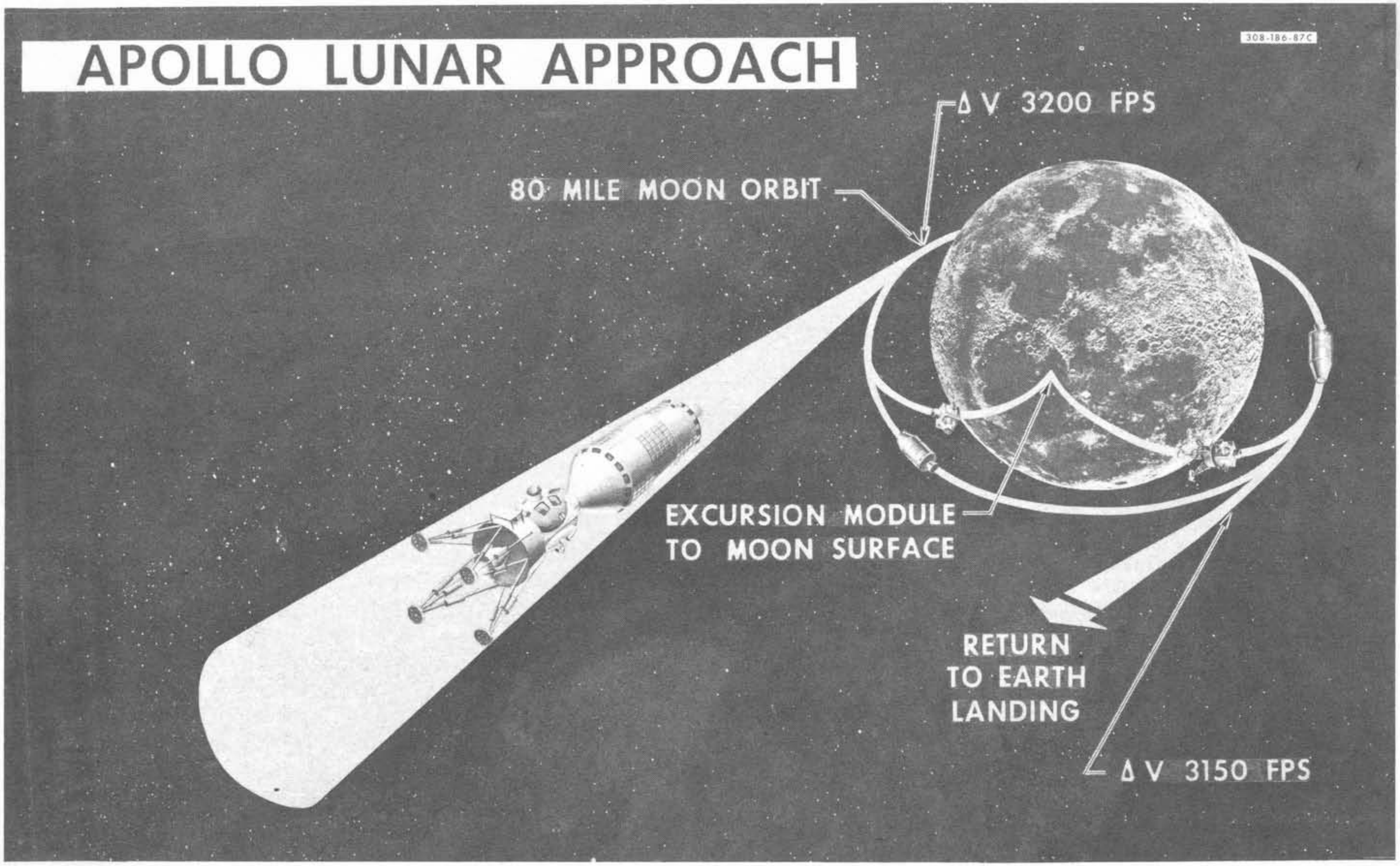
APOLLO LUNAR APPROACH

Two or more midcourse corrections will be supplied by the main engine of the Service Module during the 1-1/2 day flight to the Moon. As the Moon is approached, greater and greater gravitational pull is exerted on the spacecraft. Computers on earth and in the spacecraft determine the moment when the Service Module engine is fired to slow the spacecraft into the lunar orbit at 5500 feet per second.



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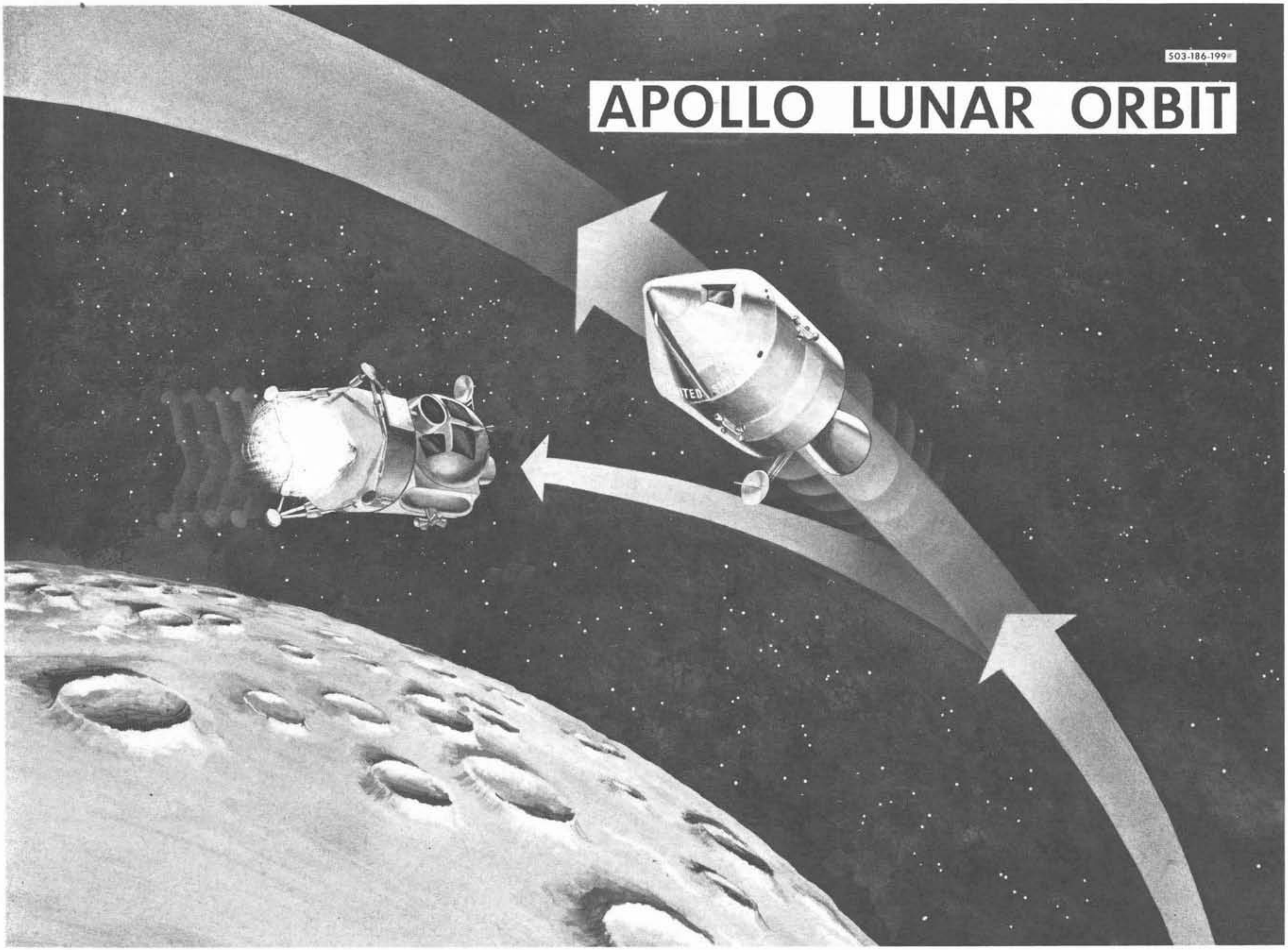
APOLLO LUNAR ORBIT

On approach to the landing site, two of the crew transfer to the LEM and detach from the Command Module. The descent engine will be fired briefly to place the LEM in an elliptical orbit which passes within 50,000 feet of the Moon. The orbit of the LEM passes near the Command Module every two hours so that a rendezvous may be possible in case of an abort.



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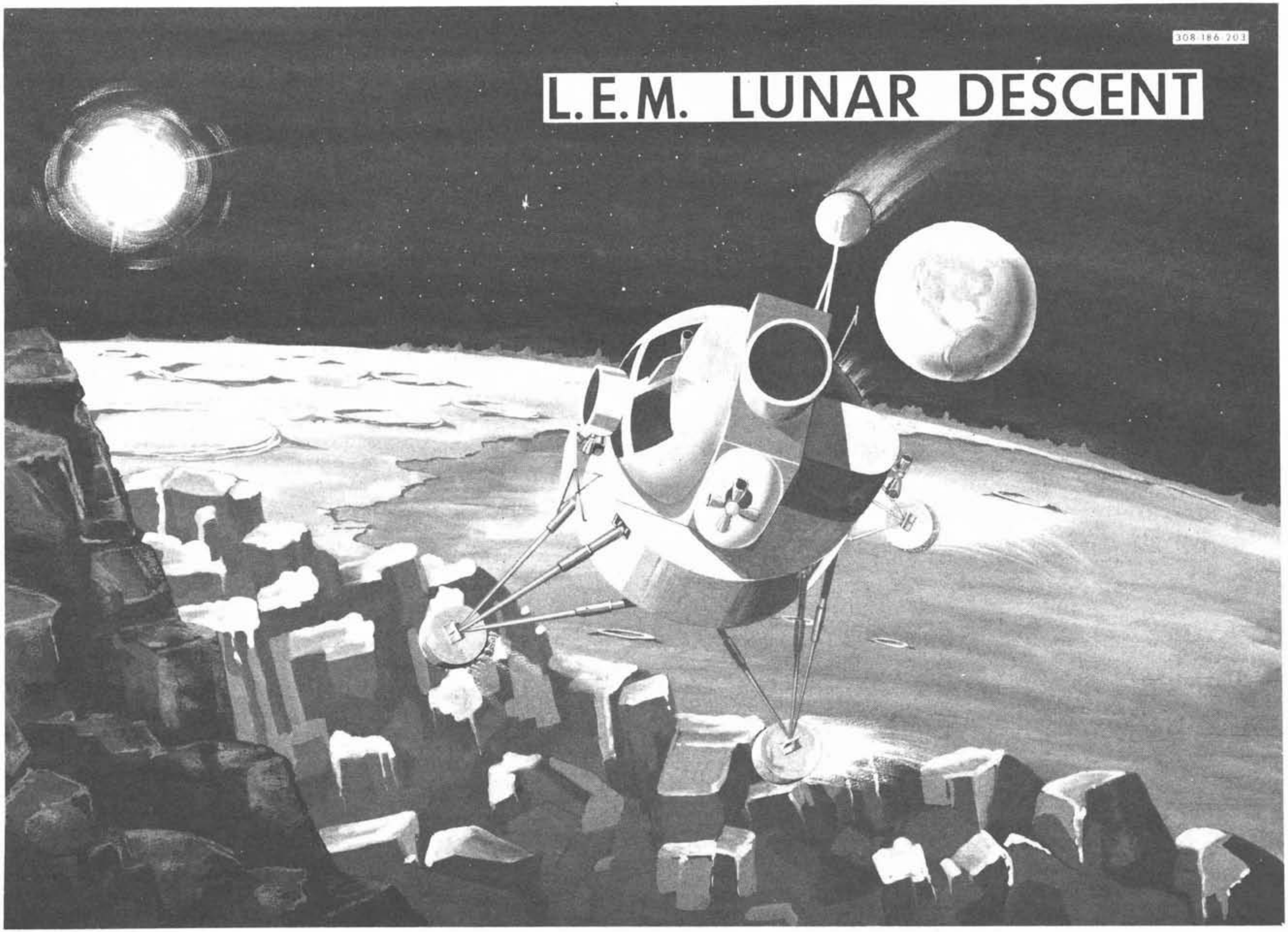
LUNAR DESCENT

At 50,000 feet, the descent engine will be fired and throttled as required to propel the LEM within 1000 feet of the lunar surface. The LEM is then righted to hover over the area to select the final landing site. The LEM may translate up to 1000 feet in selecting the landing site. Immediately after landing, the crew will conduct pre-launch checkouts.



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LEM LUNAR LAUNCH

This chart shows the 4-ton "bug" leaving the Moon after a two day exploration. Note that the 9-ton lander used as a launching pad is left behind.

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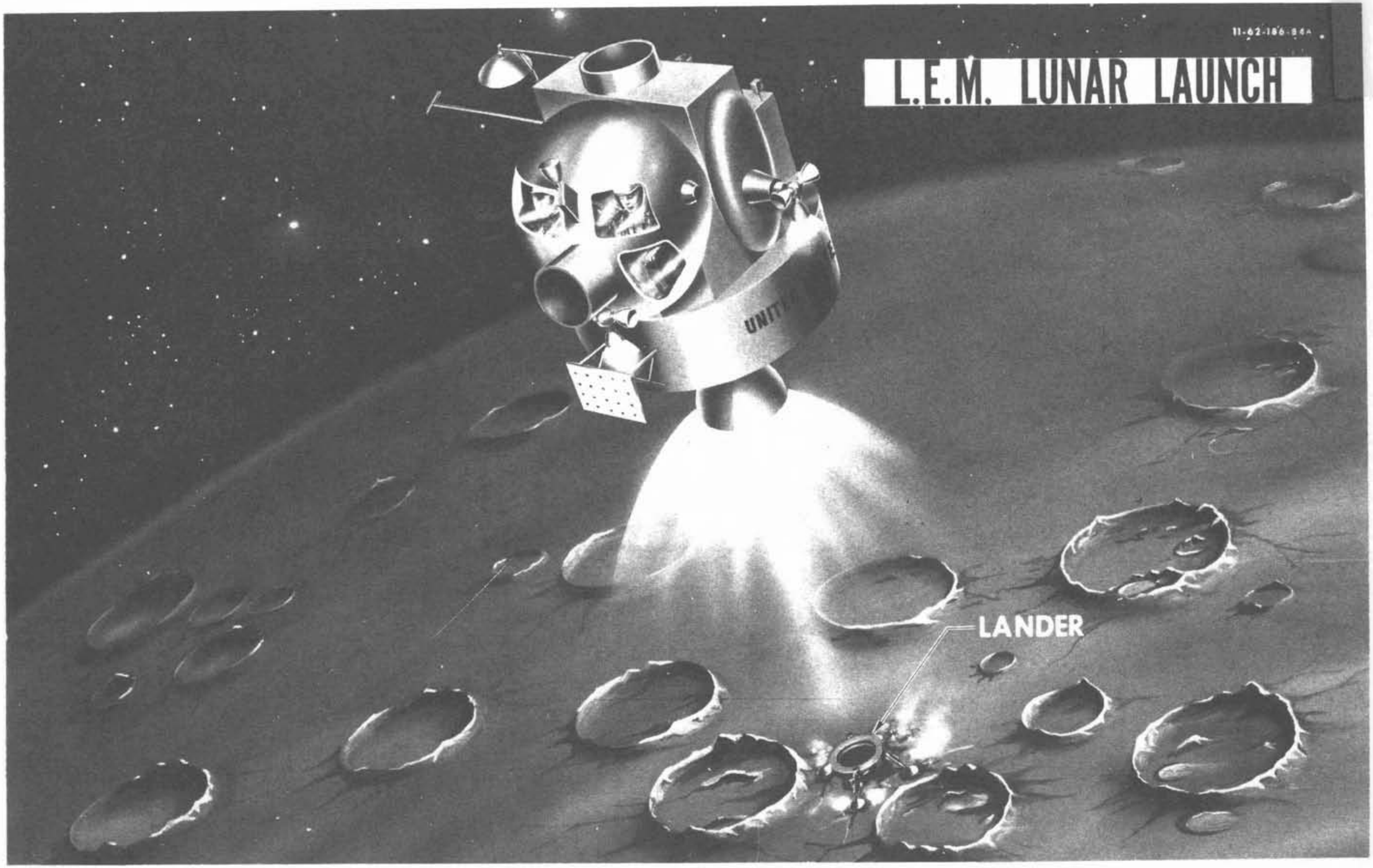

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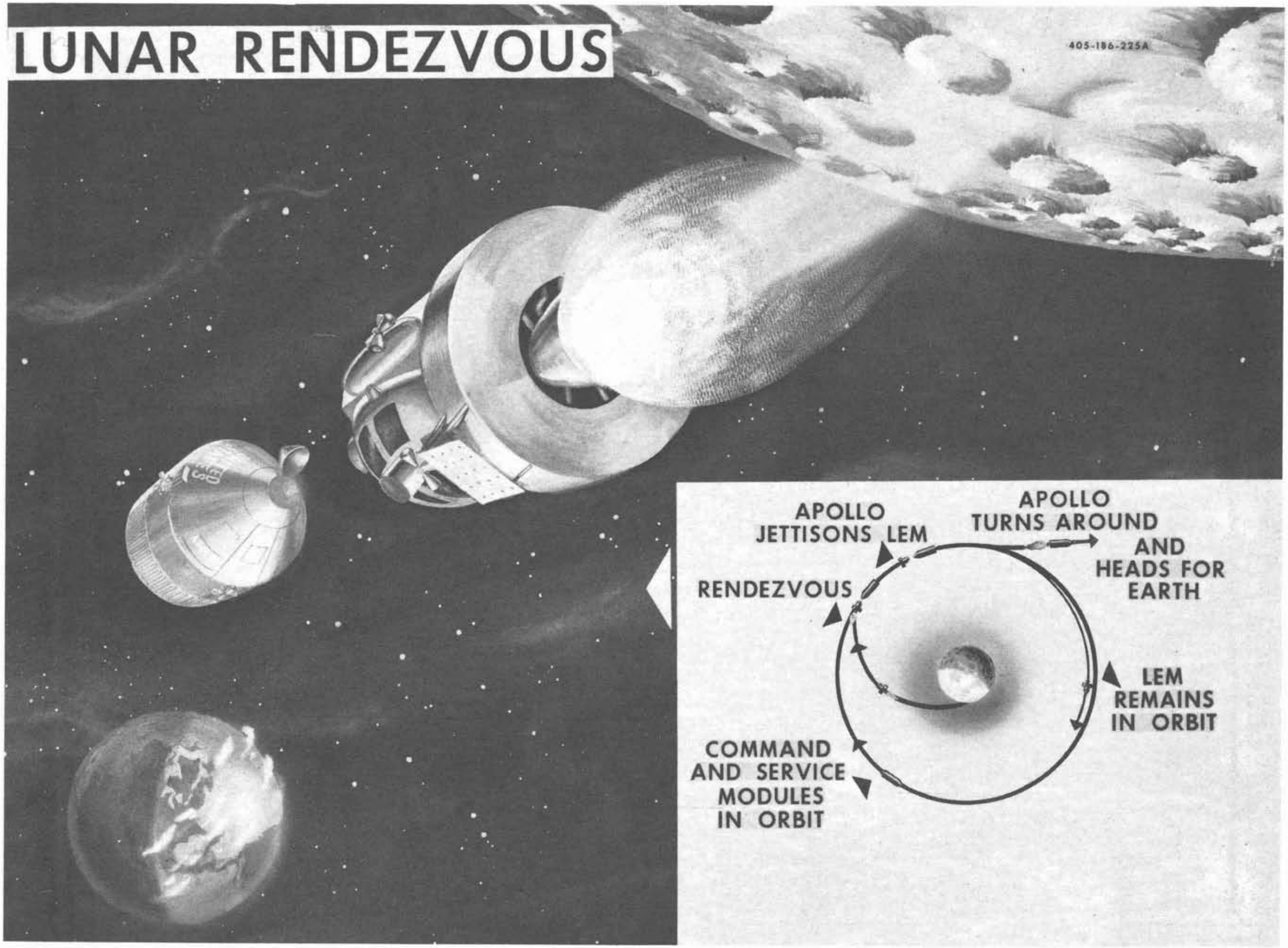
186-84A

LUNAR RENDEZVOUS

The "bug" will rendezvous with the Apollo spacecraft for transfer of the two-man crew to the Command Module, after which the "bug" is discarded. The engine of the Service Module is then fired to inject the Apollo spacecraft into Earth return trajectory. After possible midcourse maneuver and arrival at earth return position, the Service Module is separated.



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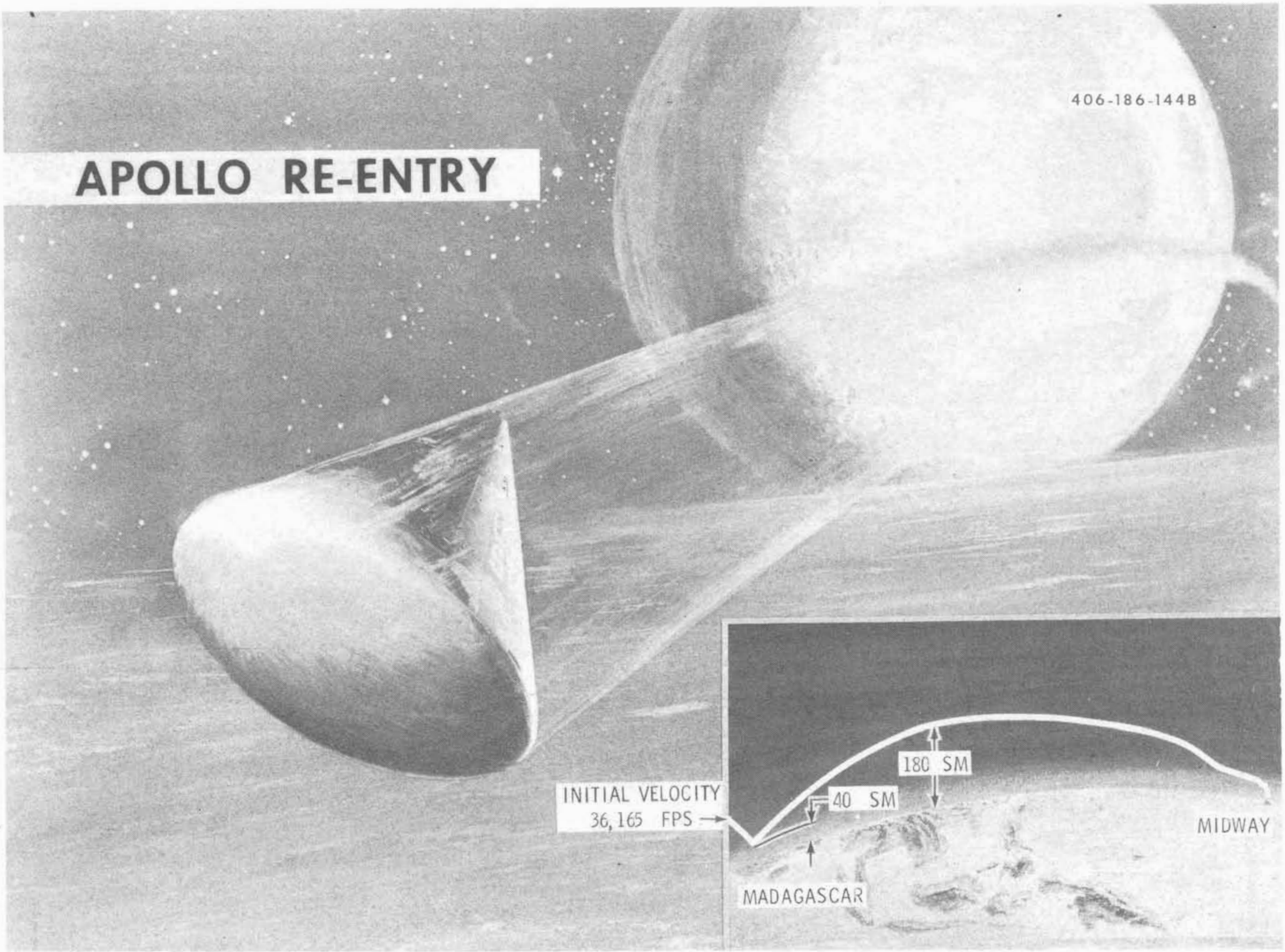
APOLLO RE-ENTRY

Atmospheric braking will be used for return of the Command Module to earth's surface. Attitude engines of the Command Module control the re-entry path so that any landing site within a 5,000 by 500 mile area may be selected. At 25,000 feet, a drogue chute will deploy for slowing the craft. Mortars are used to deploy three chutes at 5,000 feet for lowering the craft to earth.

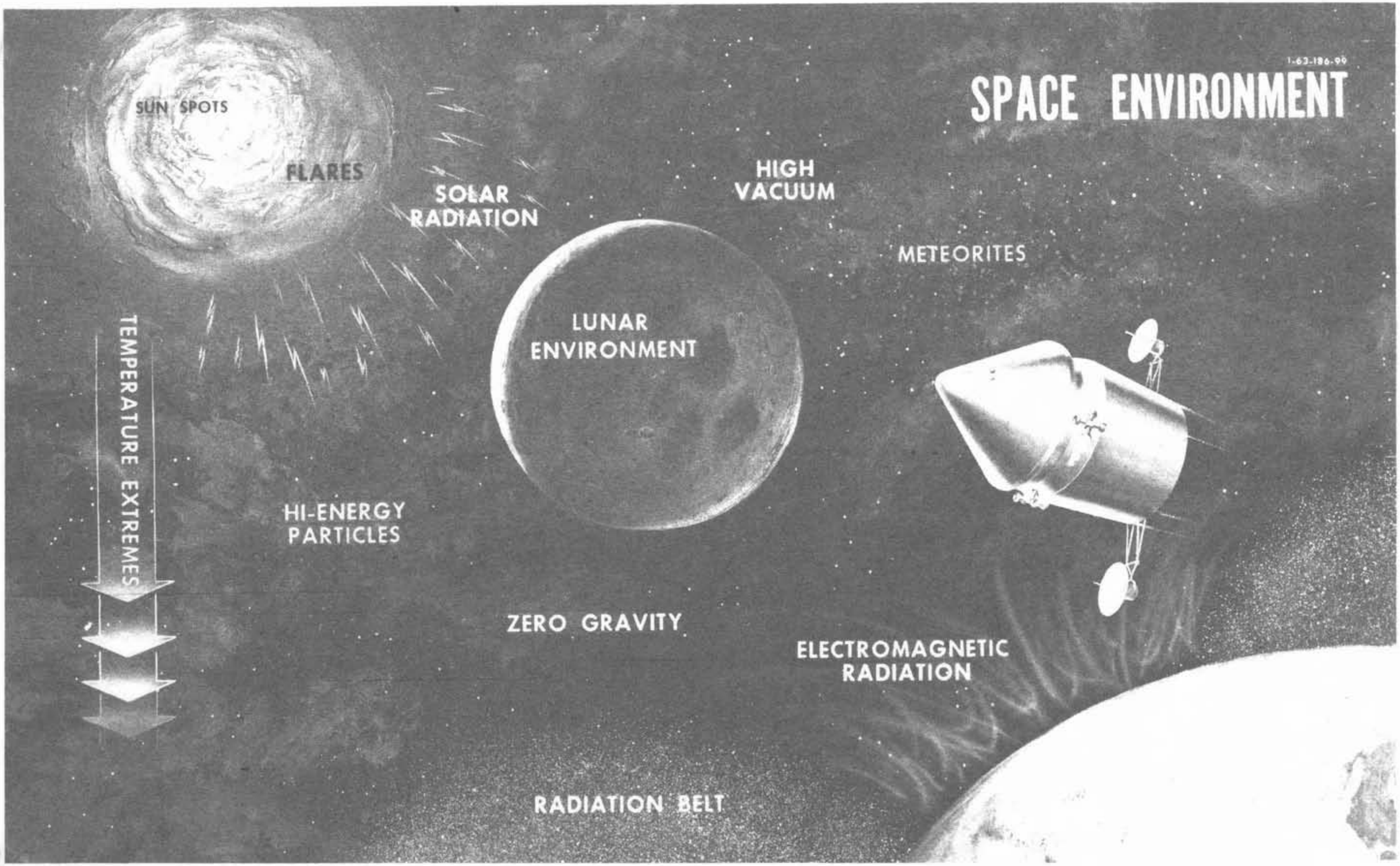

406-186-144B
APOLLO RE-ENTRY
INITIAL VELOCITY
36,165 FPS
40 SM
180 SM
MADAGASCAR
MIDWAY

DEVELOPMENT PROBLEMS POSED BY SPACE ENVIRONMENT

A spacecraft in an earth escape trajectory is exposed to a hostile environment. Design of the spacecraft must take into account the vacuum, the high-velocity meteorites, high-energy particles, temperature extremes, and solar radiation.

The following table summarizes the space environment and its effect on propulsion systems:

Zero Gravity	Positive expulsion devices must be used due to the tendency of propellants to separate into globules which float inside the propellant tank.
Solar Radiation	Shielding against solar flares is currently impractical. The Apollo trip will be scheduled when solar activity is not anticipated. A program of orbiting solar observatories is expected to provide data which will make this scheduling possible.
Vacuum	Due to the lack of a cooling medium and the start-stop requirements placed on a space engine, new cooling techniques for thrust chambers are needed. Radiation cooled thrust chambers are under development.
Meteorites	Design of the propulsion system must provide for the possibility of damage by meteorites.
Lunar Environment	Lunar probes are scheduled for determining the composition of the lunar surface. The sunlight side of the Moon reaches about 265 F while the dark side is a minus 240 F.
High-Energy Particles	Electrical and electronic control equipment are effected by these high energy particles.



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FLIGHTS LAUNCHED BY ROCKETDYNE ENGINES

The accomplishments of Rocketdyne propelled vehicles are shown.

Redstone was first flight tested in 1953. This dependable 75,000-pound-thrust engine failed only once in seventy-four flights. It launched the first United States satellite and the first manned-flight with Alan Shepard.

Thor is the current space launch workhorse. Thor launched these spacecraft: Pioneer, Tiros, Anna, and OSO.

Jupiter launched early Explorer Satellites.

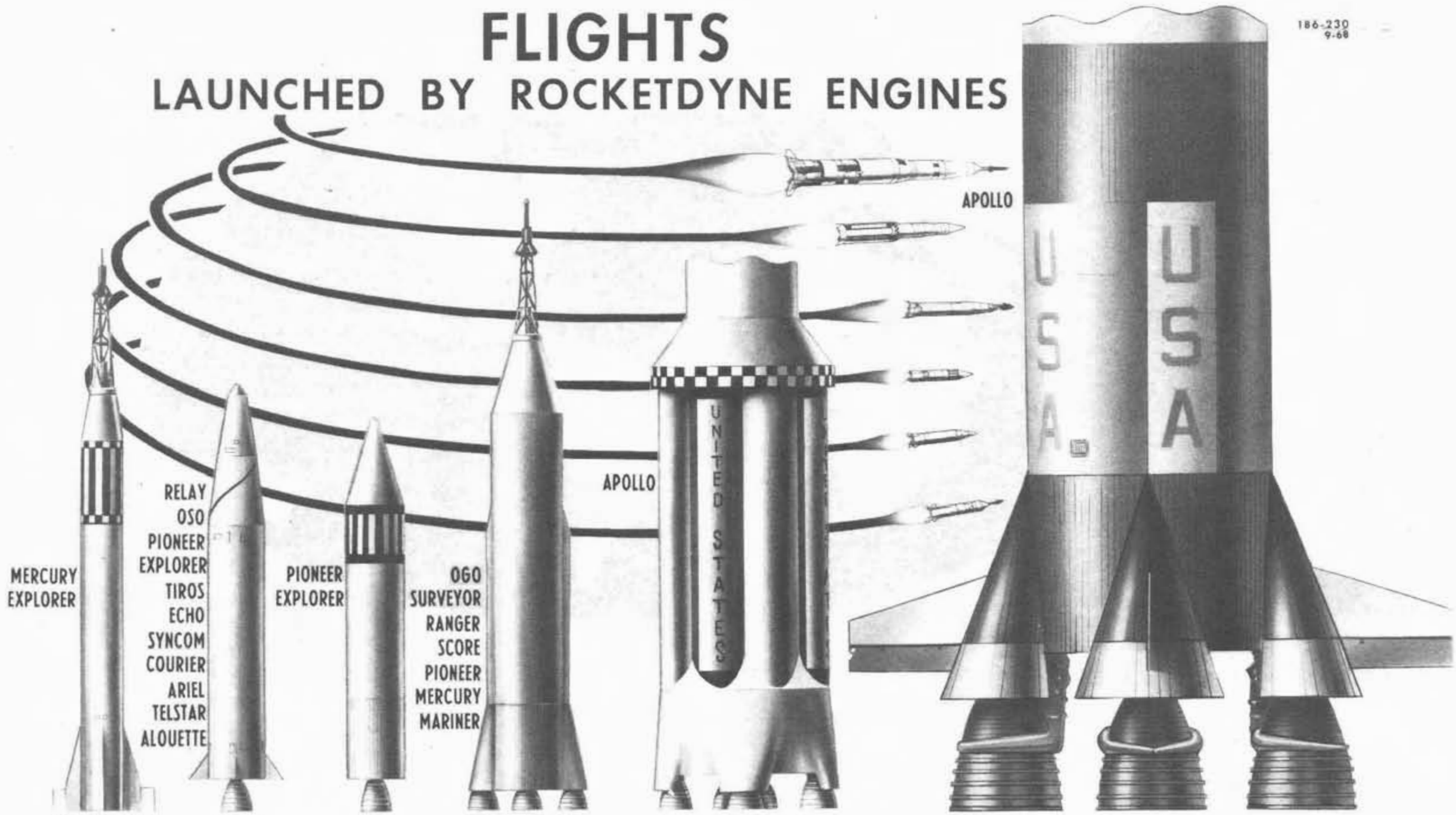
The Atlas Agena is capable of hurling 5000-pounds payload into a 300 nautical mile orbit. This is more than three times the Thor-Agena capability. Achievements include: Pioneer, Mercury, Ranger, and Mariner.

Saturn has had six successful launches. The vehicle is powered by eight H-1 engines, which are simplified, improved versions of earlier booster engines.

Virtually all major space payloads to date have been boosted by Rocketdyne engines.

FLIGHTS
LAUNCHED BY ROCKETDYNE ENGINES

186-230
9-68



	REDSTONE	THOR	JUPITER	ATLAS	SATURN I & IB	SATURN V	TOTAL
SPACE FLIGHTS	12	262	13	142	14	2	445
TOTAL FLIGHTS	75	359	46	367	14	2	863

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ROCKETDYNE BOOSTED LAUNCH VEHICLES

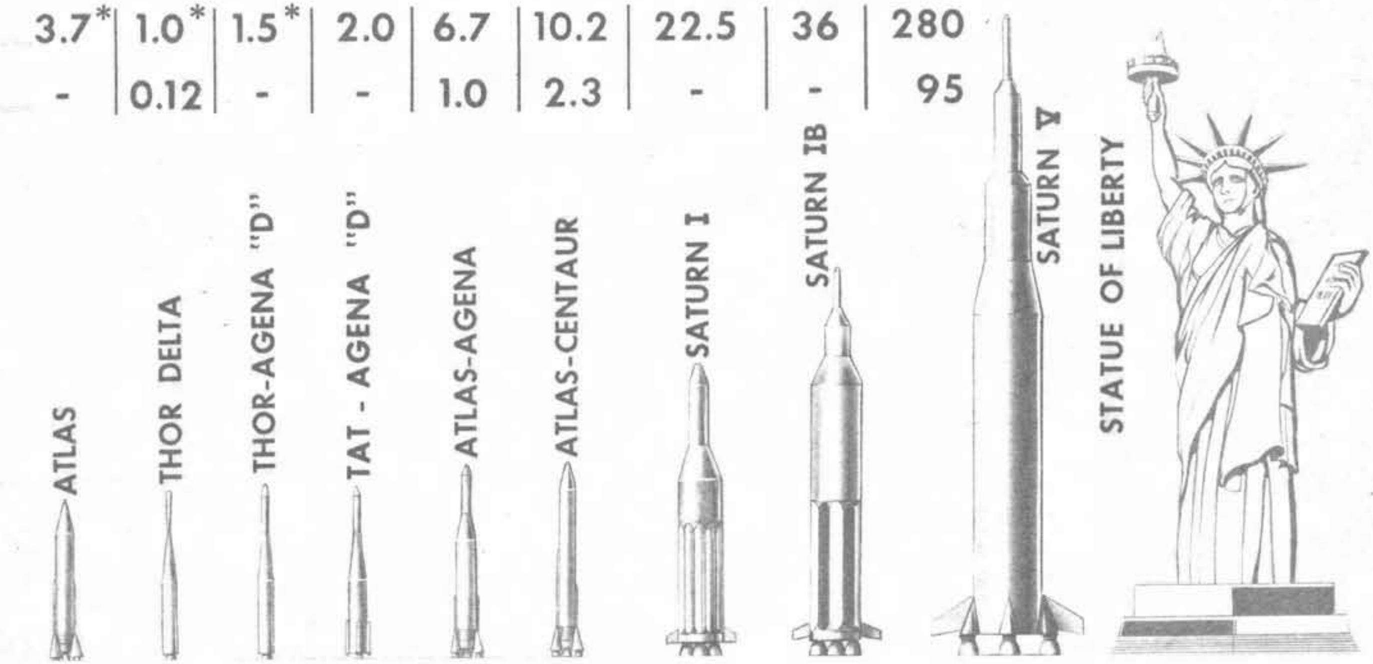
Starting with the Atlas, capable of launching the 3000-pound Mercury spacecraft into orbit with 367,000 pounds of thrust, this line up extends to the Saturn V which will be capable of placing 240,000 pounds into orbit with 7,500,000 pounds of thrust. Saturn I and Saturn IB will be used to develop the Apollo spacecraft.

512-186-160

ROCKETDYNE BOOSTED LAUNCH VEHICLES

PAYLOAD (1000 LBS)	ATLAS	THOR DELTA	THOR-AGENA "D"	TAT - AGENA "D"	ATLAS-AGENA	ATLAS-CENTAUR	SATURN I	SATURN IB	SATURN V
100 N MI	3.7*	1.0*	1.5*	2.0	6.7	10.2	22.5	36	280
ESCAPE	-	0.12	-	-	1.0	2.3	-	-	95

*300 N MI



	ATLAS	THOR DELTA	THOR-AGENA "D"	TAT - AGENA "D"	ATLAS-AGENA	ATLAS-CENTAUR	SATURN I	SATURN IB	SATURN V
L.O. THRUST (1000 LB)	389	170	170	330	389	389	1500	1,640	7600
PADWEIGHT (1000 LB)	260	112	125	138	280	300	1120	1250	6300

ROCKETDYNE

Many of the rocket propulsion systems that will make this voyage possible are being developed by Rocketdyne. In the remainder of this briefing, the capabilities of Rocketdyne will be described which resulted in this division being selected by NASA to develop a major portion of the rocket power systems for the Apollo Mission.

NORTH AMERICAN AVIATION, INC.

Rocketdyne is one of seven divisions of North American Aviation, Incorporated. This division is charged with the development and production of rocket propulsion systems ranging from less than one-tenth pound thrust to the huge one and one-half million pound thrust F-1 engine. Preliminary design is underway for engines developing several million pounds of thrust. Activities include liquid propellant, solid propellant, hybrid, nuclear, and electrical propulsion.

Los Angeles Division is famous for World War II Trainer AT-6 (Navy SNJ), P-51, and B-25. The B-45 was the first jet bomber developed in the U.S. The F-86 fighter was famous in Korea followed by the F-100. Current projects are the Sabreliner, the X-15 rocket research aircraft, and the RS-70.

Space and Information Division produces the air-to-air Hound Dog (GAM-77). Present development includes the Saturn S-II (employing five Rocketdyne J-2 engines), the Apollo spacecraft, and the paraglider for Gemini.

Autonetics produces inertial navigation systems for the Columbus Division A5C, aircraft, ships, Polaris submarines and guidance for Minuteman missiles. Also produced are computer and technical data systems.

Atomics International is developing SNAP (System for Nuclear Auxiliary Power) Models 2, 8, and 10. Nuclear power stations were built at Hallam, Nebraska and Piqua, Ohio. Laboratory and research reactors are located in industry and universities.

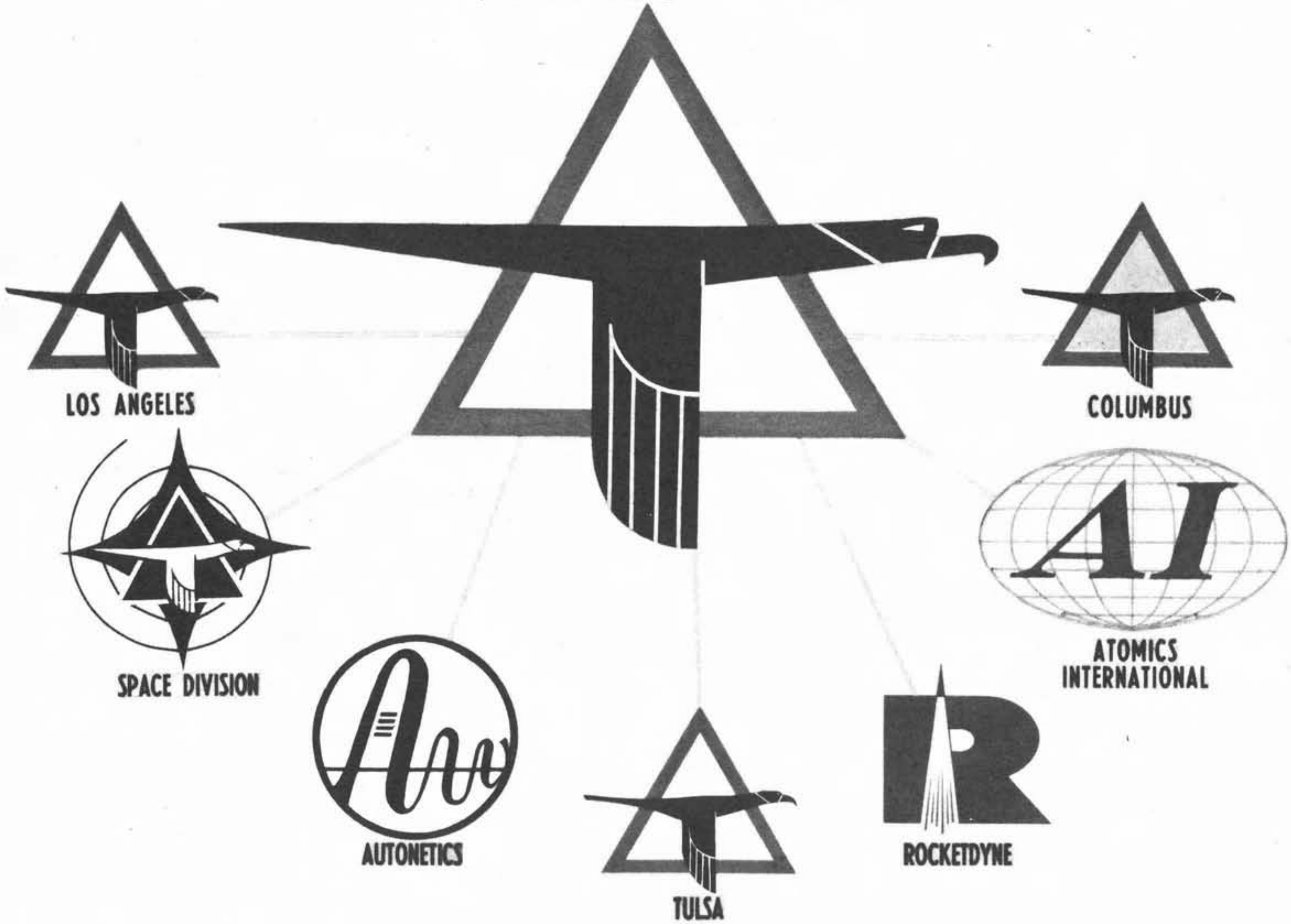
Columbus produces Navy A5C Vigilante, T2J Navy Trainer and Redhead/Roadrunner target drone.

The Science Center conducts basic research on request by the operating divisions and as directed by corporate management.

NORTH AMERICAN ROCKWELL CORPORATION

AEROSPACE AND SYSTEMS GROUP

186-1
11-67



ROCKETDYNE
A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION
6633 CANOGA AVENUE CANOGA PARK CALIFORNIA 91304

ROCKETDYNE OPERATION

The Canoga Park Complex encompasses Engineering, Research and Manufacturing facilities for the Liquid Rocket Division, Nuclionics and Research. The Atlas, Thor, Jupiter, Redstone, and H-1 propulsion systems were developed here. Saturn V engines, J-2 and F-1 are under development. In addition, space engine programs and experimental work on advanced products are in progress. Engine test activities are conducted at the nearby Santa Susana Field Laboratory (SSFL) and at the High Thrust Test Area, Edwards Field Laboratory, California. Research test firings, both liquid and solid, are conducted at SSFL with advanced high energy propellant testing performed at the new Nevada Field Laboratory near Reno, Nevada.

Van Nuys is the location of the Space Engine Operations, and the Ordnance Engines Operation.

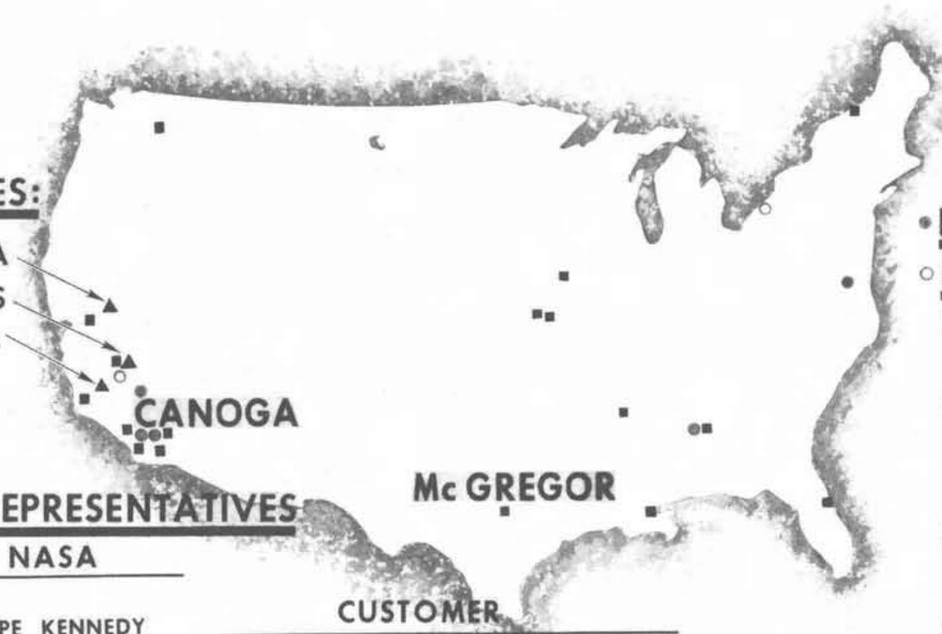
Solid propellant motor engineering, research and manufacture takes place at the Solid Rocket Division near Waco, Texas.

Production and test of Atlas Boosters, P-4 target drone engines, and H-1 engines is accomplished at the Neosho, Missouri plant in support of Liquid Rocket Division.

Company representatives are maintained at indicated locations.

Rocketdyne's total employment is over 18,000.

ROCKETDYNE OPERATION



▲ FIELD LABORATORIES:

NEVADA
EDWARDS
SANTA SUSANA

▪ FIELD REPRESENTATIVES

AFB

NORTON
EDWARDS
VANDENBERG
ARNOLD

NASA

ETR
CAPE KENNEDY
MSFC
HUNTSVILLE
MICHOUD-MISSISSIPPI
TEST FACILITY
NEW ORLEANS
WTR
VANDENBERG AFB

CUSTOMER

MAC
ST. LOUIS
DAC
TULSA
SACRAMENTO
SANTA MONICA
HUNTINGTON BEACH

GD/A
SAN DIEGO
S&ID
DOWNEY
SEAL BEACH
SANTA SUSANA

• REGION AND
○ FIELD OFFICES

EASTERN
WASHINGTON
CENTRAL
• DAYTON
○ CLEVELAND
SOUTHERN
• HUNTSVILLE
SOUTHWESTERN
• HOUSTON
WESTERN
• CANOGA PARK
○ LANCASTER

CANOGA COMPLEX

The four story headquarters building is identified with the Number 1. On three sides of this building are Manufacturing facilities. The Vanowen building in the foreground (Number 3) is the location of Research and Nuclionics.

CANOGA FACILITY

186—102
7-68

1. ROCKETDYNE HEADQUARTERS
2. ENGINEERING
3. LABORATORIES
4. MANUFACTURING
5. WAREHOUSE
6. RESEARCH

TOTAL AREA 1,602,299 SQ FT

ROCKETDYNE
A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION
6633 CANOGA AVENUE CANOGA PARK CALIFORNIA 91304

SANTA SUSANA FIELD LABORATORY

Test firings support both the development and the production programs. The rugged terrain and isolated canyon areas of SSFL, located 10 miles northwest of the Canoga Plant, provide natural protection barriers between test stands. More than two dozen large engine firings have been conducted in a two shift day. The large stands will accommodate up to 1,000,000 pounds of thrust. More powerful engines, such as the F-1, are fired at Edwards, California. Average daily usage is 400 tons of liquid oxygen, 120 tons of liquid nitrogen, and tons of liquid hydrogen. Over 200,000 hot firing tests have been conducted here.

510-186-92D

SSFL TEST AREAS

AREA	UTILIZATION
CANYON	H-1 ENGINE TEST
BOWL	J-2 ENGINE TEST
ALFA	ATLAS ENGINE TEST
BRAVO	F-1 TURBOPUMP TEST
COCA	SATURN S-II TEST
DELTA	J-2 ACCEPTANCE TEST LANCE ENGINE TEST

ROCKETDYNE
A DIVISION OF NORTH AMERICAN AVIATION, INC.

SSFL COMPONENT TEST LABORATORY

Exhaust gases supplied by the gas generator to drive the turbopump are fuel rich. The plumes seen here burn the mixture as it leaves the stack to remove any safety hazard. Just as parts on an automobile engine are tested, gas generators and turbopumps are hot fired and calibrated before assembly on the engine. The test site in the Santa Susana Mountains includes five Component Test Laboratories. Facilities are available for altitude simulation firing of space engine systems.

T310-186-91A

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310-186-91A

S. S. F. L. COMPONENT TEST LABORATORY

COMPONENTS TEST LABORATORY

CTL — PRIMARY ASSIGNMENT

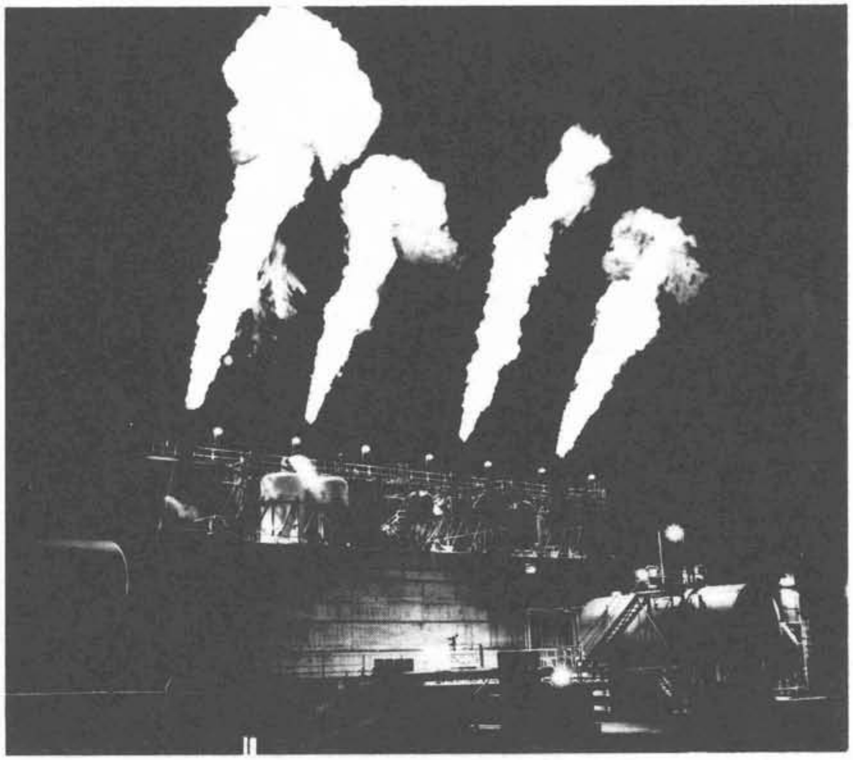
1-------TURBOPUMP DEVELOPMENT

2-------TURBOPUMP AND GAS GENERATOR TESTING

3-------J-2 AND F-1 GAS GENERATOR GEMINI ALTITUDE SIMULATION

4-------SPACE ENGINE TEST

5-------LIQUID HYDROGEN TURBOPUMP TEST



RESEARCH AREA

SOLID PROPULSION RESEARCH

LIQUID PROPULSION RESEARCH

COMBUSTION AND HEAT TRANSFER

ROCKETDYNE
A DIVISION OF NORTH AMERICAN AVIATION, INC.

LIQUID PROPELLANT ROCKET ENGINES

3-62-186-6

THOR

Thor, Thor-Agena or Thor-Delta combinations have launched the greatest number of spacecraft to date. The Agena is an upper-stage with a 15,000 pound thrust engine. The Delta is made up of two upper-stages. Among the space missions boosted by various Thor combinations are: Pioneer--lunar and interplanetary probes; Tiros--meteorological satellites for transmitting TV pictures of cloud formations; OSO--orbiting solar observatory and military surveillance satellites.

ROCKETDYNE
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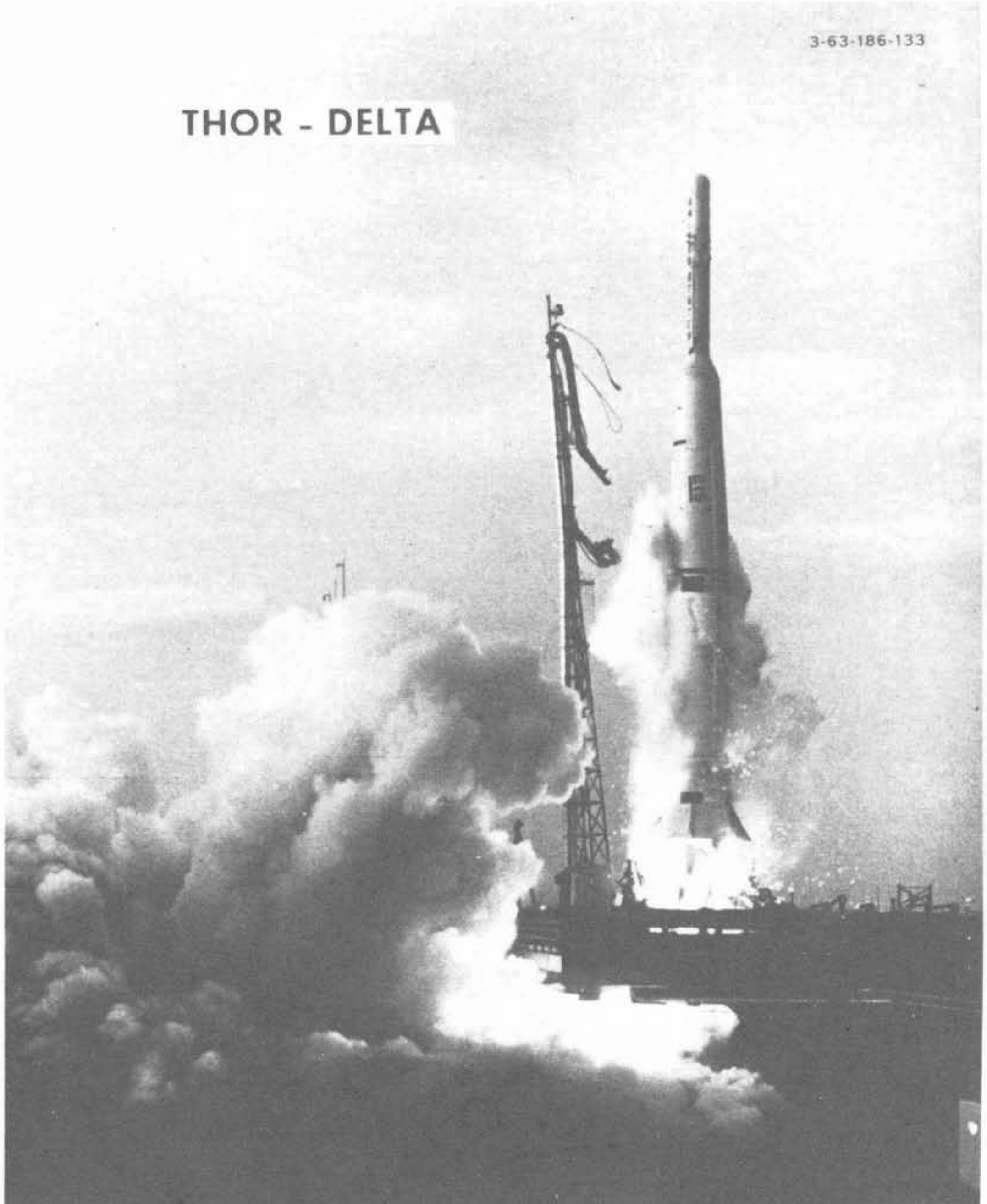
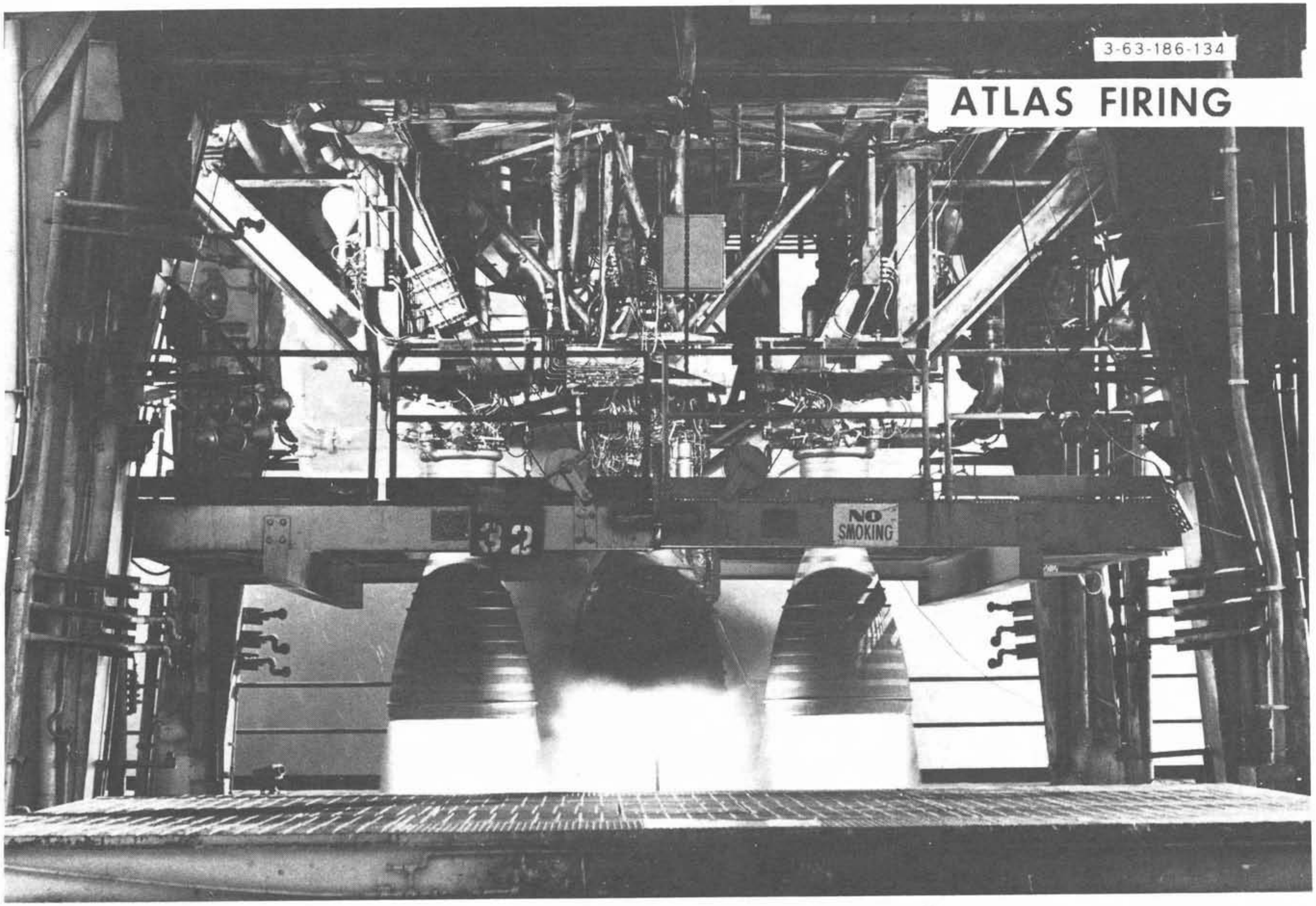

3-63-186-133
THOR - DELTA

ATLAS FIRING

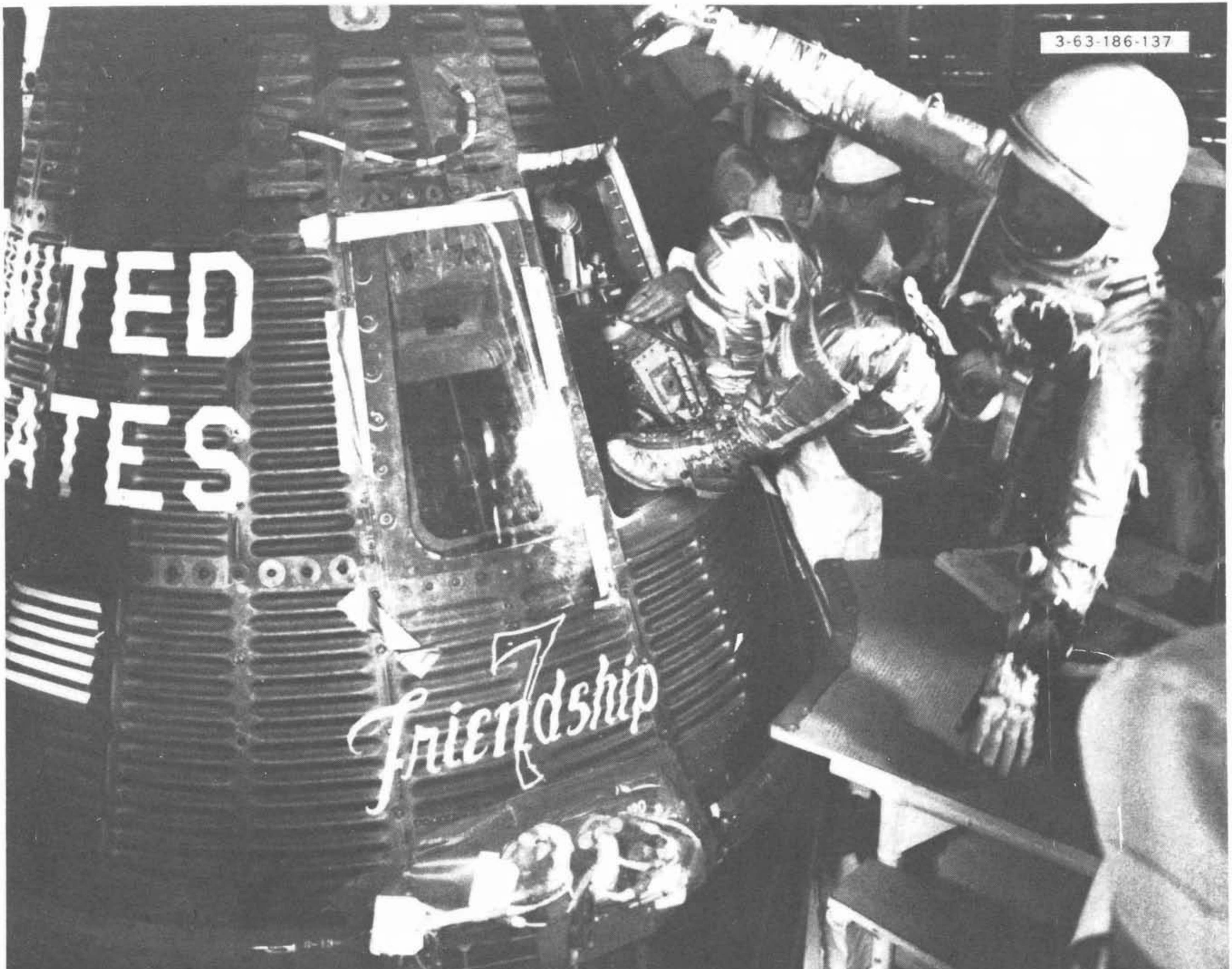
The Atlas was our first operational ICBM. This propulsion system is a one and one-half stage system with five engines: two boosters, a sustainer, and two vernier engines, all igniting for lift off. After about 2 minutes the two boosters are cut off and jettisoned along with the boat-tail fairing. The sustainer continues to burn until cut off at about 5 minutes, the vernier engines continue to burn for a few seconds for final attitude control. The payload is then separated from the tank section and proceeds to the target in a ballistic trajectory. The missile is deployed in silos and horizontal installations at operational site in several states.

The Atlas, as a space launch vehicle, is used for the following payloads; Pioneer--lunar and interplanetary probes; Mercury--manned orbital flights; Ranger--lunar exploration with instrumented package to be landed on the Moon; Mariner--unmanned spacecraft for early interplanetary missions to the vicinity of Mars and Venus.


3-63-186-134
ATLAS FIRING
32
NO SMOKING

FRIENDSHIP 7

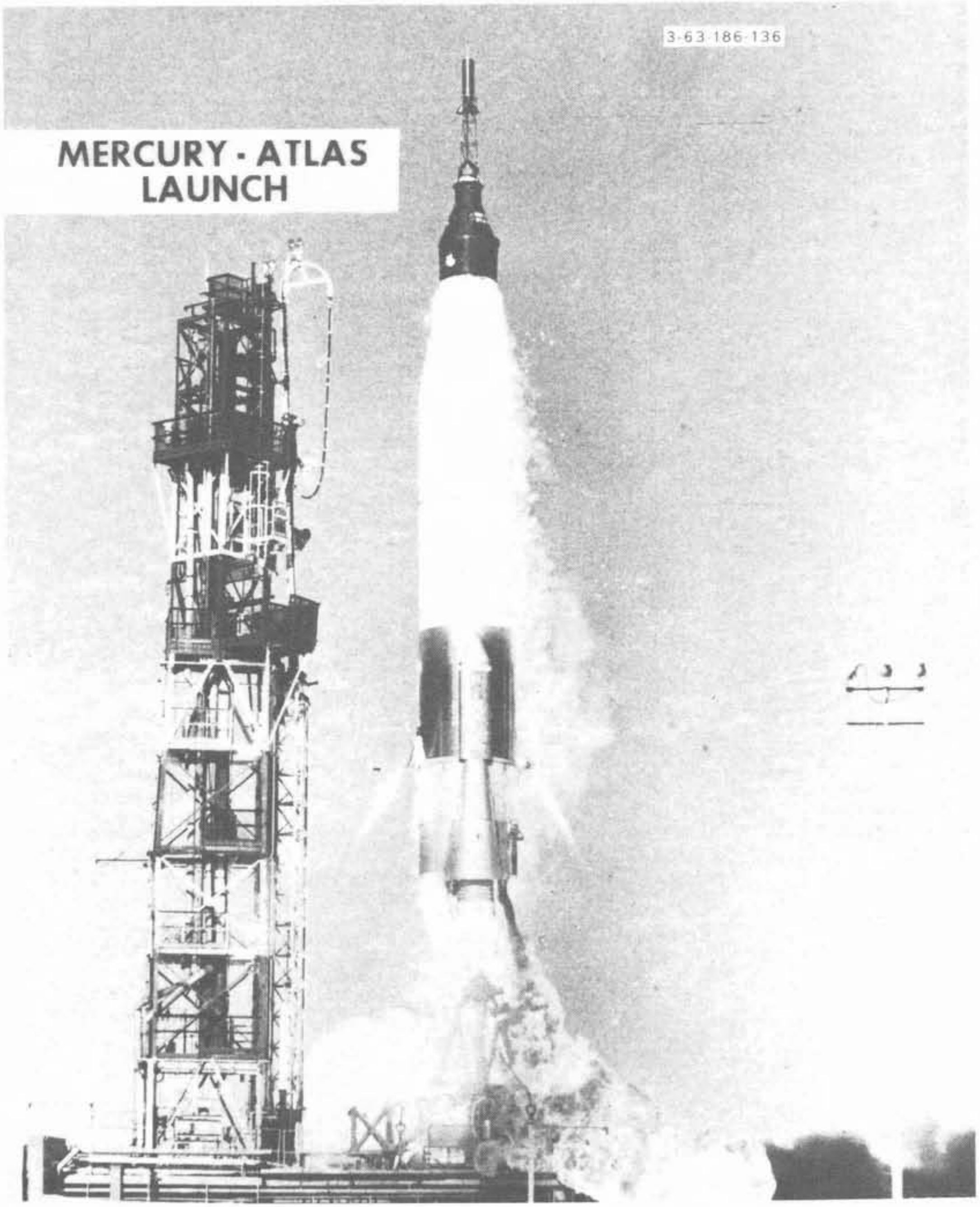
The excitement of this achievement was shared by people the world over. You undoubtedly remember the straight-forward, unrestricted handling of this event. Contrasted with Russian secrecy this milestone became a tribute to democracy in action. John Glenn's flight is a step toward manned flight to the Moon and beyond.


3-63-186-137
ITED
ATES
Friendship 7

MERCURY-ATLAS LAUNCH

The Atlas missile supplied 368,000 pounds of thrust to propel the 3,000 pound Mercury spacecraft manned by John Glenn into an earth orbit. Enormous power will be required to propel a manned spacecraft to the Moon and beyond. Rocketdyne developed the Atlas propulsion system and has under development the giant engines which will make the lunar voyage possible. Preliminary design of huge engines for the voyages beyond the Moon are in progress.

T3-63-186-136

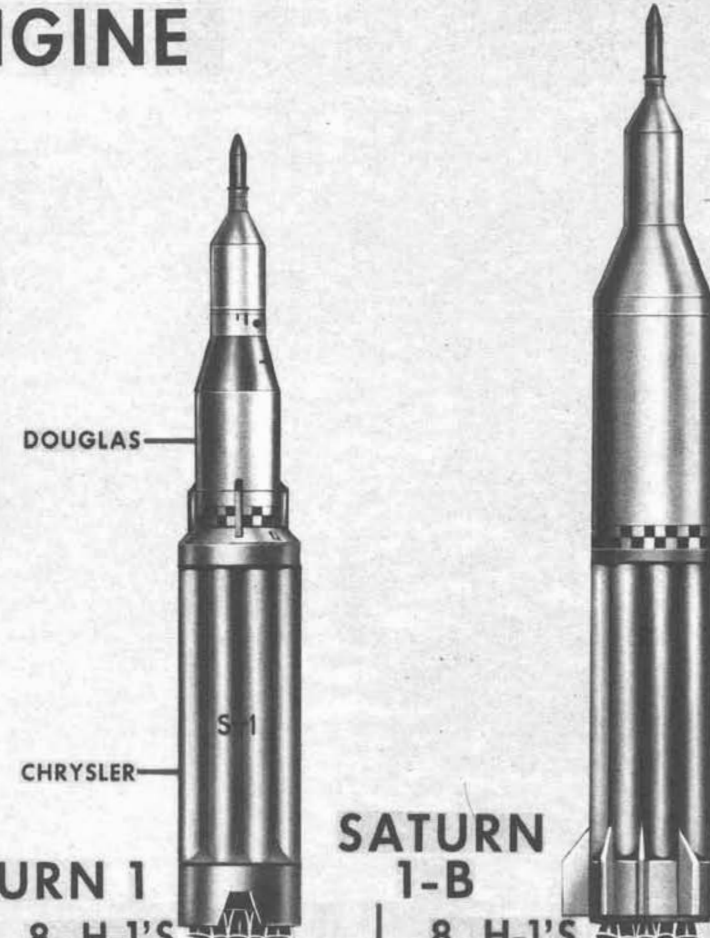

3-63-186-136
MERCURY · ATLAS
LAUNCH

H-1 ENGINE

Experience gained in the development of the Jupiter, Thor, and Atlas propulsion systems led to the development of the H-1 engine. Eight of these engines are used in the S-I stage of Saturn I and IB. A development program is in progress to uprate this engine to 200,000 pounds of thrust.

512-178-25

H-1 ENGINE



SATURN 1
8 H-1'S

SATURN 1-B
8 H-1'S

PROPELLANTS.....LOX/RP THRUST.....165,000 TO 188,000 | 200,000 TO 205,000

I_s--NOM (205K) 263 SEC DRY WEIGHT...2025 LB

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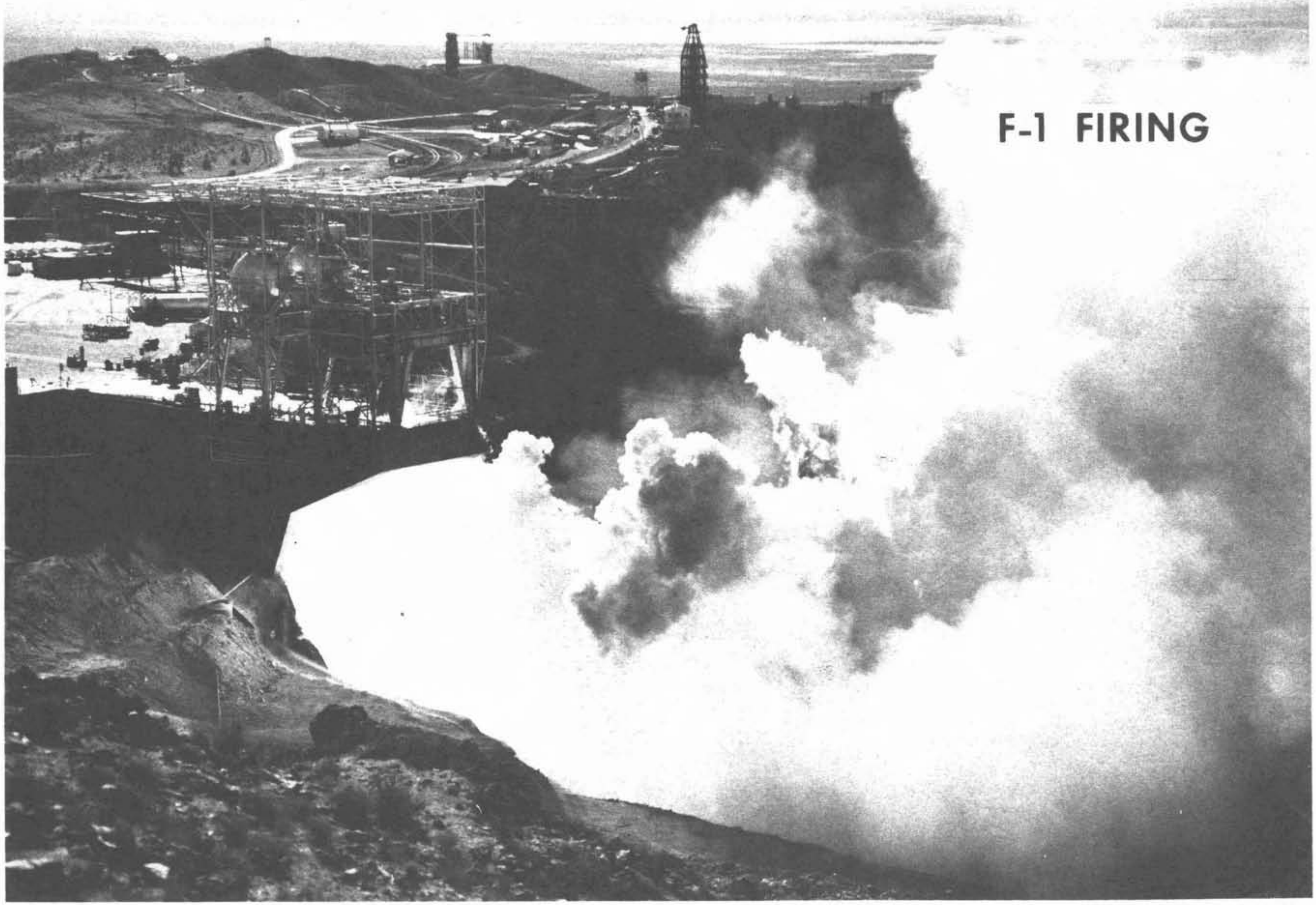
F-1 ENGINE

Five F-1 engines are used in the S-IC booster stage of the Saturn V launch vehicle. The Saturn, you will recall, has been assigned the task of boosting the Apollo spacecraft into a lunar orbit. In supplying one and one-half million pounds thrust for 2-1/2 minutes, each F-1 engine will burn approximately 10 railroad tank cars of propellants. Power generation of this stage is equivalent to that supplied by the operation of 85 Hoover dams. The gas generator, about the size of a street light globe, supplies power equivalent to more than 30 diesel railroad locomotives. The fuel pump is capable of forcing fuel to a height of 1 mile.

3-63-186-140



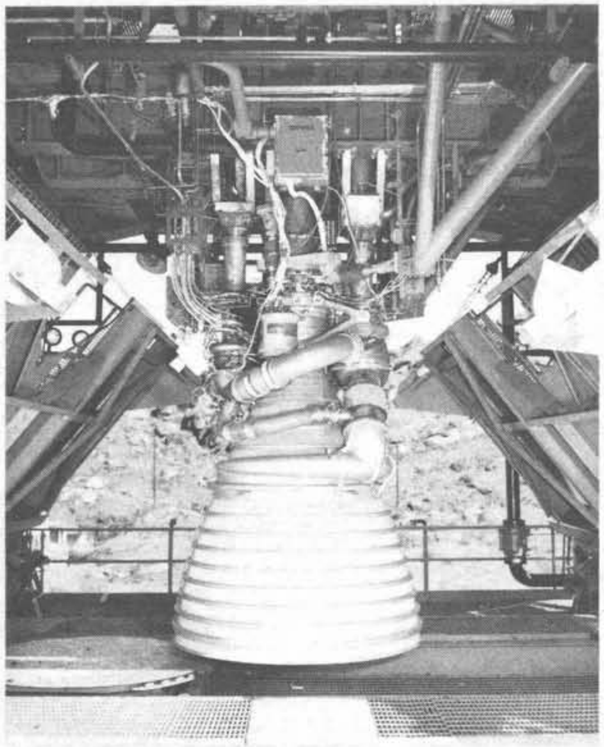
F-1 FIRING

J-2 ENGINE

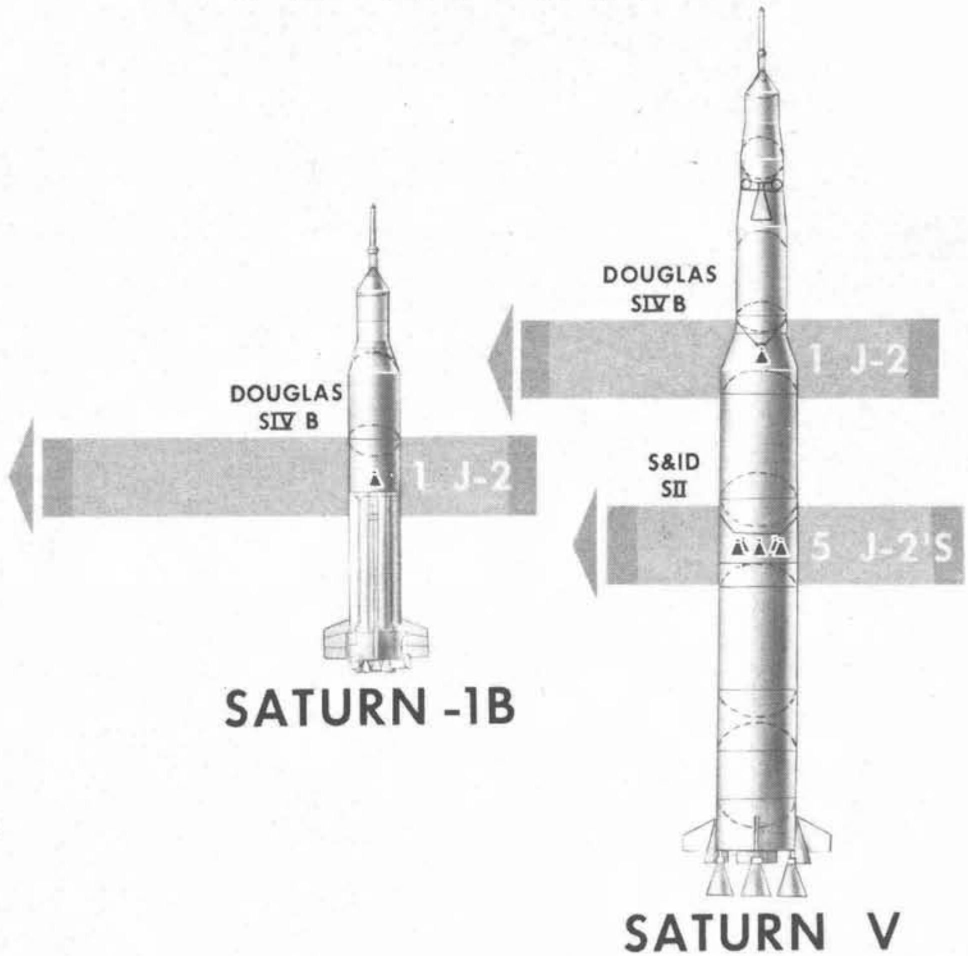
The J-2 engine is a liquid oxygen/liquid hydrogen propellant engine. Through the use of liquid hydrogen, the thrust per pound of propellant per second (specific impulse) is increased by about 40% over kerosene fuel engines. Five of these engines will power the second stage of the Saturn V. One J-2 engine will power the third stage. An important feature of the J-2 will be the capability of multiple restarts in space.

501-178-27C

J-2 ENGINE



PROPELLANTS ________ LOX/H_2
THRUST ________ 200,000 LB
DRY WEIGHT ________ 2600 LB



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ROCKETDYNE LARGE ENGINE PROGRAM

The Apollo mission will be made possible due to the intensive development of highly reliable components which are in turn assembled into reliable engines. This chart shows some of the Rocketdyne engines which have provided the experience that will lead to the successful development of the man-rated F-1 and J-2 engines.

Largest member of Rocketdyne's family is the F-1 rated at 1,500,000 pounds of thrust. The E-1 was a smaller development engine which enabled us to gain experience for the development of F-1.

Atlas engines, you recall, boosted many of the nation's space probes. Several squadrons of Atlas missiles are deployed in the United States.

Eight H-1 engines boost the Saturn I. This simplified engine was developed from experience gained in producing the Atlas, Thor and Jupiter engines.

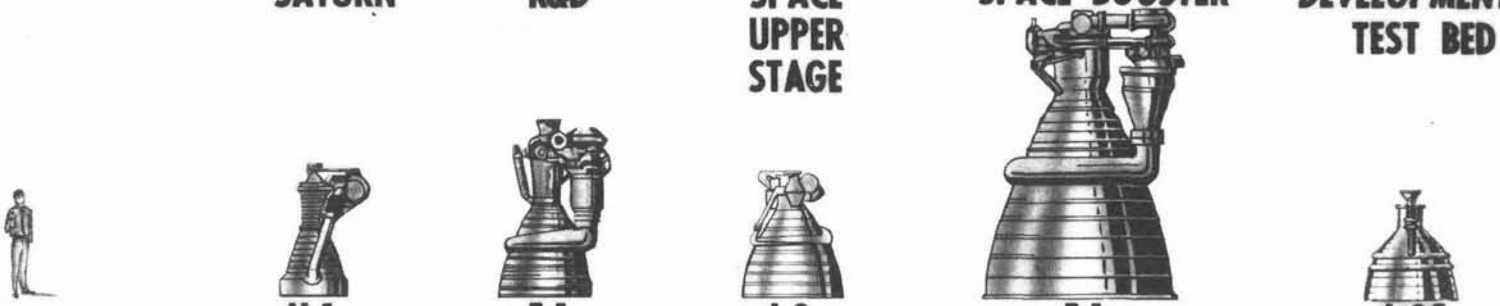
Thor and Jupiter use as space launch vehicles has been mentioned.

The Redstone engine was the first high thrust rocket engine developed in the United States following World War II.

ROCKETDYNE LARGE ENGINE PROGRAMS

186-80
1-68

	REDSTONE	JUPITER	THOR	ATLAS	ATLAS
	75-110	S-3D	MB-3	MA-2-5	MA-3
THRUST , K	78	150	170	*368 – 389	*389
I_s (SEC) NOM	214	245	252	252 B 309 SV	254 B 309 SV
PROPELLANTS	LOX/ALCOHOL	LOX/RP	LOX/RP	LOX/RP	LOX/RP
DESIGN YEAR	1951	1955	1955	1956	1958



	SATURN	R&D	SPACE UPPER STAGE	SPACE BOOSTER	DEVELOPMENTAL TEST BED
	H-1	E-1	J-2	F-1	J-2S
THRUST , K	200–205	400	230	1522	
I_s (NOM)	260–262	254	423 V	264.5	
PROPELLANTS	LOX/RP	LOX/RP	LOX/LH	LOX/RP	LOX/LH_2
DESIGN YEAR	1958	1957	1960	1959	1967

V – VACUUM   B – BOOSTER ONLY   S – SUSTAINER   *WITH VERNIERS

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6633 CANOGA AVENUE CANOGA PARK CALIFORNIA 91304

BASIC CHARACTERISTICS

Both solid and liquid propellant rockets depend upon the combustion process of a fuel and an oxidizer to produce gases which are ejected through the nozzle at high velocity. This flow of gases produces a reactive force called thrust.

In the solid propellant, the oxidizer is normally finely ground crystals of ammonium perchlorate or ammonium nitrate which have been mechanically mixed with a fuel binder (usually a synthetic rubber compound). This mixture is cast or extruded into a grain and cured; a process not unlike the mixing and baking of a cake.

In a typical liquid propellant rocket engine, the fuel and oxidizer are pumped to the injector where they are atomized, then burned in the combustion chamber to produce gases which are ejected through the nozzle. A gas generator is used to supply hot gases to drive the pump turbine. Fuel is circulated through the tubes to regeneratively cool the thrust chamber. There are many variations of this typical engine which employ different propellant and cooling methods.

The solid rocket is simple and does not need the extensive servicing and checkout that liquid rockets normally require. However, once started, they cannot readily be shut down or restarted. Thus far, the liquid rockets have received more development effort and are capable of producing more thrust per pound of propellant burned. Development efforts are underway to produce a very large solid motor in segments. In the Saturn V, solid propellant rockets are used to settle liquid propellants, separate stages and to provide an emergency escape system.

Several yardsticks are used to determine the over-all performance capabilities of a rocket vehicle. The terms most frequently used are: thrust, specific impulse, exhaust velocity, and mass ratio.

Thrust is the reaction experienced by an engine due to the ejection of high velocity gases through the nozzle. Thrust of the booster determines the weight of the vehicle which can be lifted against the pull of gravity.

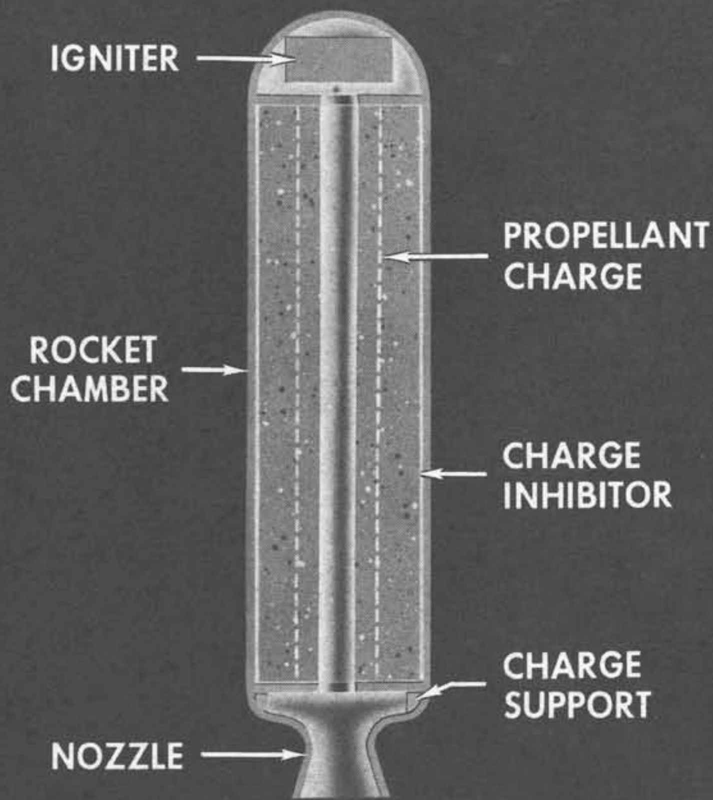
Specific Impulse indicates the amount of thrust that can be derived from each pound of propellant in one second of engine operation. Analogous to miles per gallon for an automobile. It is a measure of propellant and engine efficiencies. An increase in specific impulse reduces the weight of propellant required for a given mission with the resultant weight reduction of the tanks thus permitting an increase in payload.

Exhaust Velocity is the speed in feet per second at which the combustion gases are expelled. Exhaust velocity and mass ratio determine the final attainable velocity of a rocket.

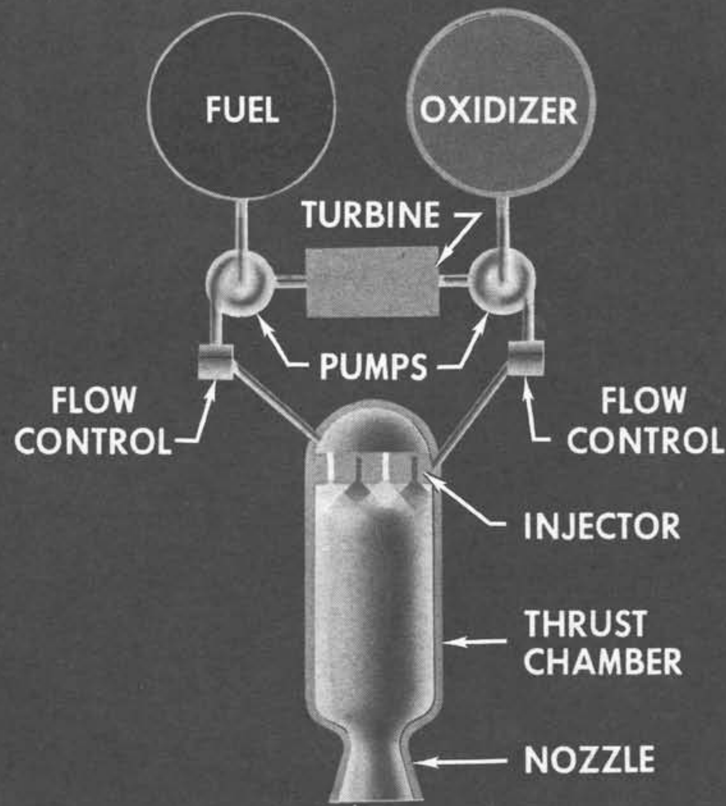
Mass Ratio is the ratio of the total loaded vehicle's mass to its mass when all propellants have been burned.

BASIC CHARACTERISTICS

SOLID-PROPELLANT ROCKET



LIQUID-PROPELLANT ROCKET



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SOLID PROPELLANT ROCKET MOTORS

A solid propellant rocket motor is shown boosting an aircraft to flying speed from a launching platform. This system is called ZEL or Zero Length Launch. At burn-out of the ZEL booster the aircraft has reached a speed of about 270 knots. Solid motors on the Saturn V launch vehicle are used for stage separation and for ullage motors. Ullage motors provide acceleration forces to the upper stages of the vehicle to settle the propellants in the aft portion of the tanks to insure proper propellant feed.

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305-186-4A

SOLID PROPELLANT ROCKET MOTORS

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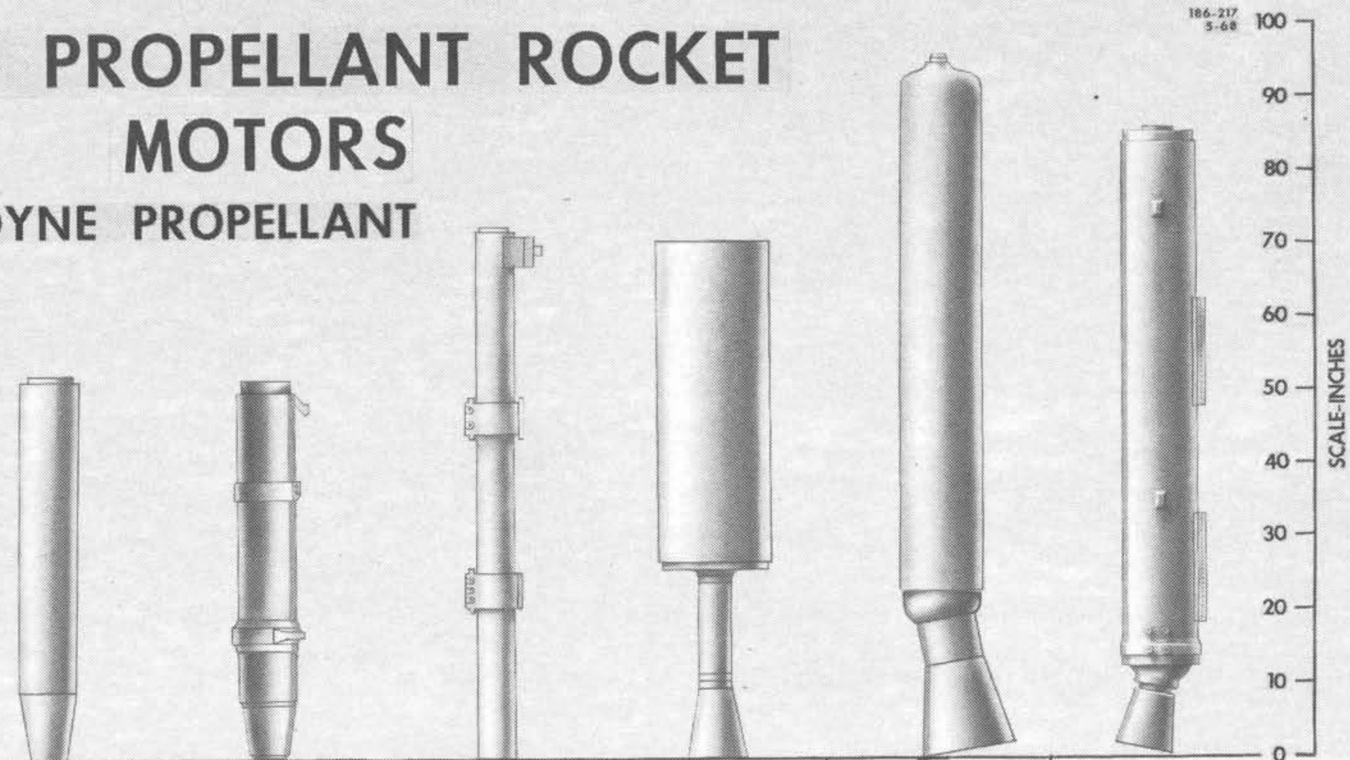
HIGH PERFORMANCE SOLID ROCKETS

Rocketdyne's solid propellant motors includes the group shown. Propulsion for air-to-air missiles makes up most of this group. The propellant formulation for these motors includes Flexadyne, a remarkable fuel-binder developed by Rocketdyne. The physical characteristics of Flexadyne enables the grain to sustain the cold soak of extreme altitudes followed by the aerodynamic heating of a dive without altering its burning characteristics.

T307-186-217

SOLID PROPELLANT ROCKET MOTORS

FLEXADYNE PROPELLANT



IDENTIFICATION	SPARROW III 6b (MK 38-MOD 1,2,3,	SHRIKE (MK 39-MOD 2,3,4,5	SIDEWINDER (MK 36 MOD 2/5)	PHOENIX (MK 47-MOD 0)	S II ULLAGE	ZEL REDHEAD
APPLICATION	USN-USAF F-4B F-4C	USN-USAF ANTI-RADAR A-4	USN-USAF F-8 F4B F-111B	USN F-111B	NASA SATURN V PROPELLANT SETTLING	ARMY MQM-42A SUPERSONIC
STATUS	IN PROD	IN PROD		IN QUAL	IN PROD	IN PROD
DELIVERIES	9500+	6300+	2500+	180+	16	35

ROCKETDYNE
A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION
6633 CANOGA AVENUE CANOGA PARK CALIFORNIA 91304

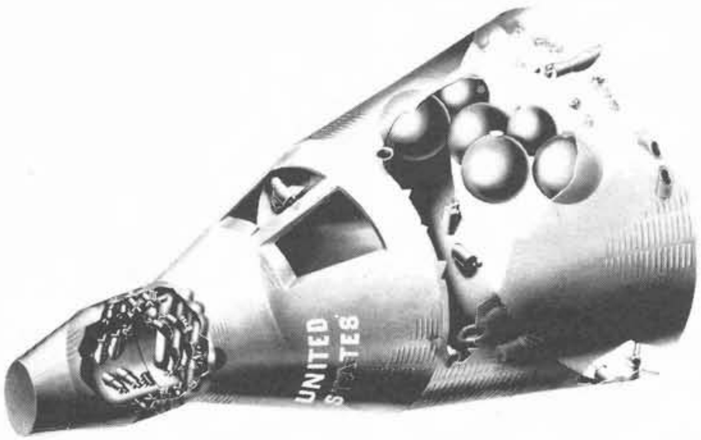
PRODUCT AREAS

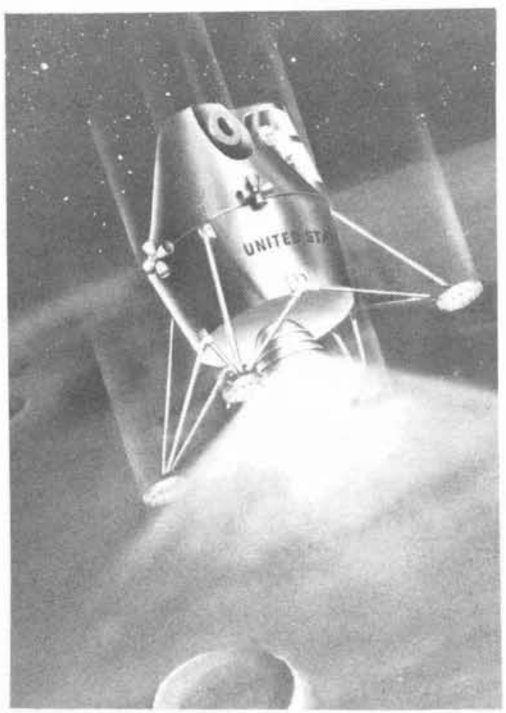
Rocket engines for space vehicles require such features as small, discrete impulse bits; step or continuous throttling; zero "g" operations; extended coast periods with multiple restart capabilities and protection from the hostile environments previously described. Engines with various combinations of the above features provide power needed for orbit injection, escape trajectories, mid-course maneuvering, upper-stage attitude control, re-entry control and lunar descent and ascent.

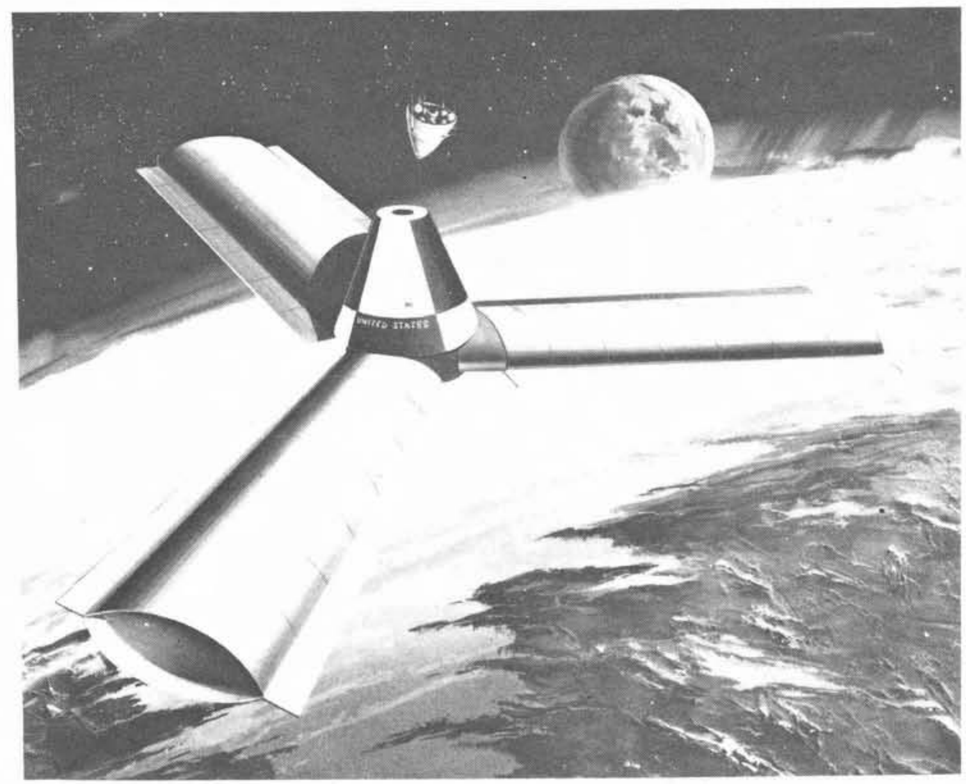
310-188-371

SPACECRAFT ENGINE DIVISION

PRODUCT AREAS







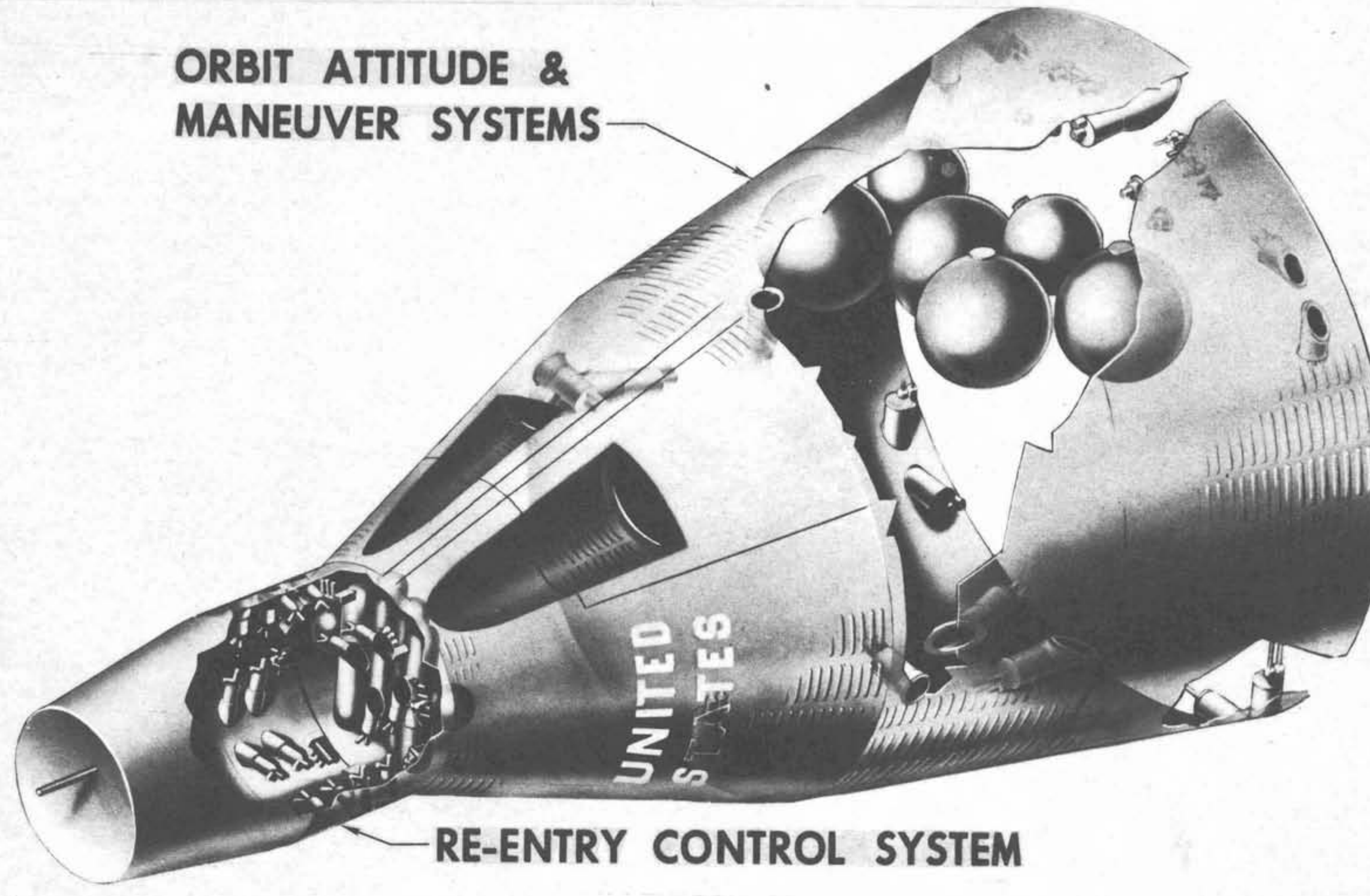
ROCKETDYNE
A DIVISION OF NORTH AMERICAN AVIATION, INC.

GEMINI

Rendezvous and docking techniques required for success of the Apollo mission will be developed in the Gemini program. Two propulsion systems are being supplied by Rocketdyne for the Gemini program. The re-entry module incorporates two complete Attitude Reaction Control Systems, each consisting of eight 25-pound-thrust chambers for controlling the re-entry path. Redundant systems are provided to ensure reliability during the critical portion of this mission. The adapter module, which is jettisoned prior to re-entry, in addition to incorporating the main oxygen supply and electrical system, has the Orbiting Attitude and Maneuvering System for use in rendezvous and docking maneuvers. This propulsion system includes eight 25-pound-thrust chambers for attitude control, six 100-pound-thrust chambers for lateral and vertical movement and two 85-pound-thrust chambers for retro-firing. Propellants are nitrogen tetroxide and monomethyl hydrazine.

PROJECT GEMINI

603-310-381C



RESEARCH---PRESENT AND FUTURE

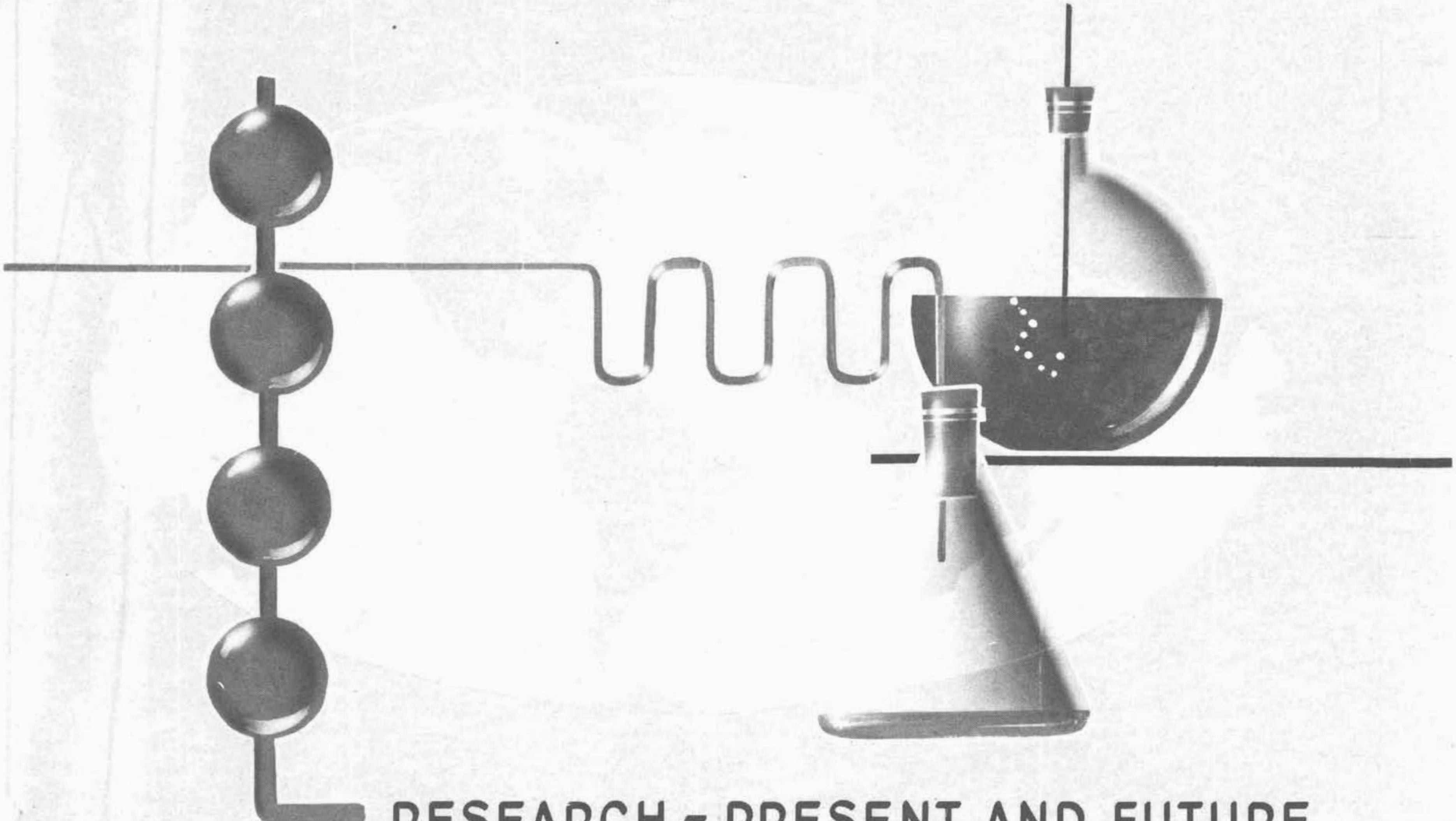
Rocketdyne utilizes the strength of its Research Organization to solve the problems of rocket engine development. This strength lies in its professional personnel and its research facilities. Many of our research scientists enjoy an industry wide reputation in their special fields.

The requirement for more powerful engines places demands on research to develop higher performance propellants, metals which retain their strength at high temperatures and materials for highly specialized applications.

Each component of a rocket engine is expected to meet the stringent requirements of its own operating conditions as well as the rigorous environment of space. Equipment in the materials laboratory is capable of simulating the conditions for space flight enabling our scientists to conduct studies of material behavior under these extreme conditions.

The extremes of operating environment for a rocket engine are: propellants at -423°F adjacent to a 7000°F flame, the thermal and physical shocks of starting an engine, corrosive propellants, the space environment of a vacuum, extreme cold, and the radiation of the sun. The materials laboratory has equipment for testing and evaluating materials under the extremes just stated. The materials group conducts a never ending search for metals to stand up under the rigors of space travel, methods of shaping and joining these metals, and research into the secrets of high strength exhibited by certain metals under extremes of heat, cold and pressure.

ROCKETDYNE

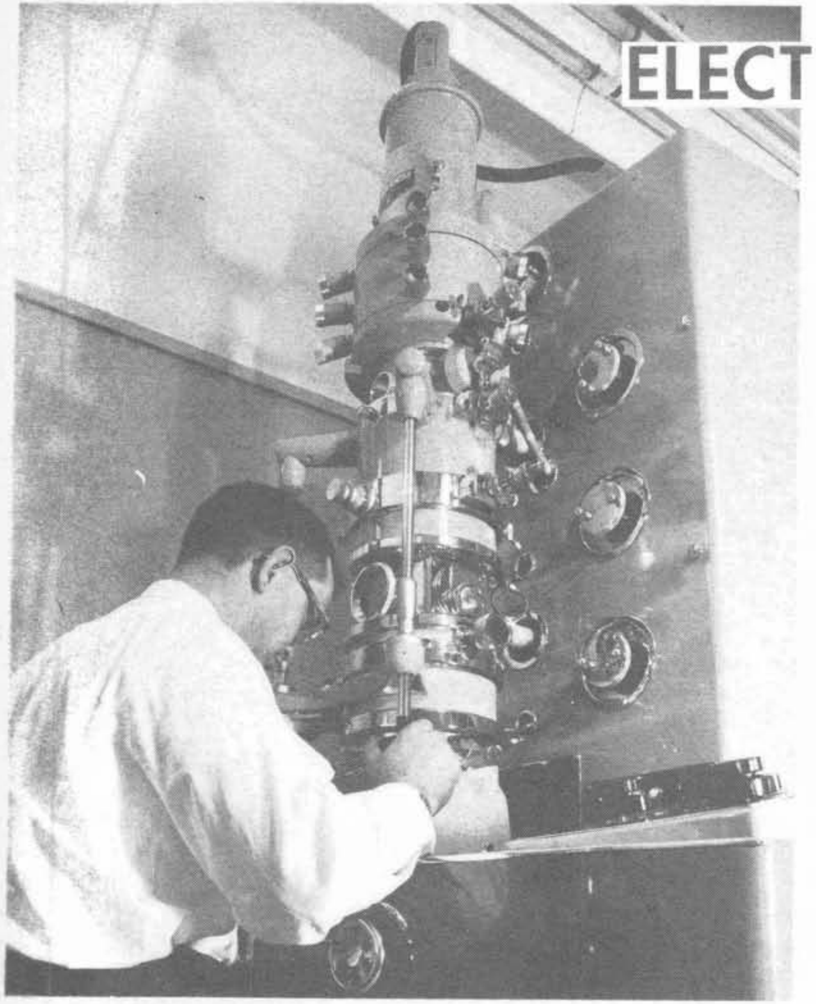


RESEARCH - PRESENT AND FUTURE

11—62—186—83

ELECTRON MICROSCOPY

The size of a particle which can be seen by the eye through a microscope is limited by the wave lengths of light. The electron microscope is a device which makes use of an electron beam to trace a magnified image on a coated plate which can then be viewed. Similarly an electron beam traces pictures on your TV screen. Since the electron is the smallest known particle of matter, extremely high magnification is possible. Thin metal foil samples may be examined for dislocations. Examination of these tiny building blocks provides metallurgists with knowledge leading to the development of higher strength metals required for advanced rocket engine systems.



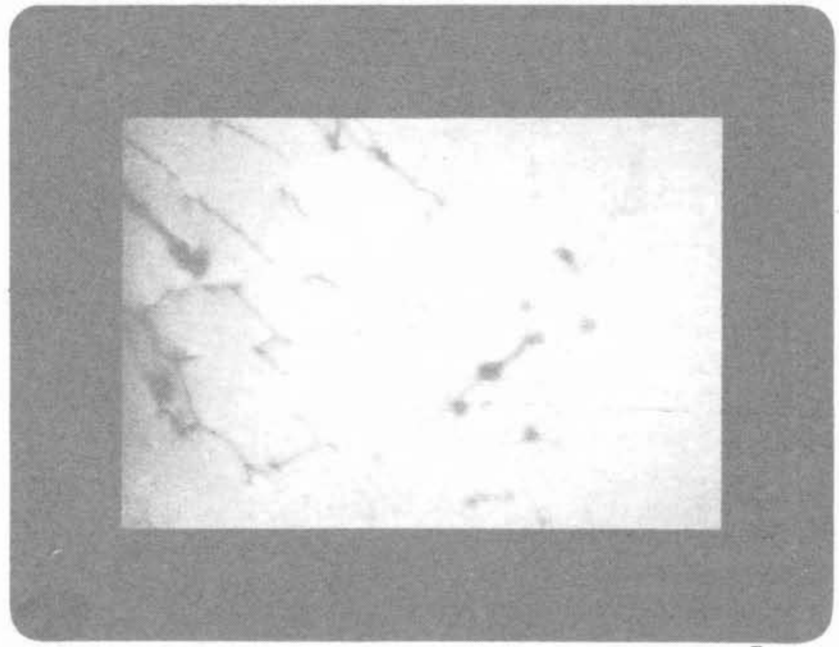
ELECTRON MICROSCOPE

ELECTRON MICROSCOPY

REFRACTORY METALS FLOW & FRACTURE PHENOMENON

THIN FOIL TRANSMISSION MICROSCOPY

- 1.6×10^{-6} THICK TANTALUM FOIL
- 100,000 x MAGNIFICATION
- ATOMIC SIZE DISLOCATION MOVEMENT

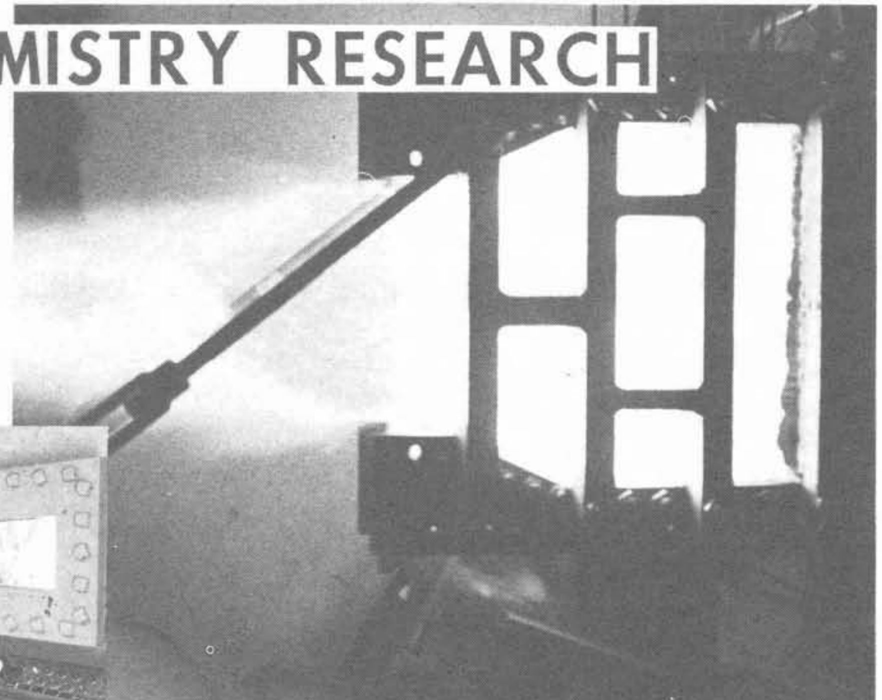


7-62-186-65

ENGINEERING CHEMISTRY RESEARCH

Combustion studies are conducted with the aid of two-dimensional, transparent thrust chambers which provide data records through high-speed instrumentation and permit visualization of the combustion process through high-speed photography. Advanced design concepts and unique propellant combinations are tested as an adjunct to research and development programs.

ENGINEERING CHEMISTRY RESEARCH



COMBUSTION STUDIES

- PROPELLANT MIXING
- INJECTOR PATTERNS
- FLAME FRONT CHARACTERISTICS

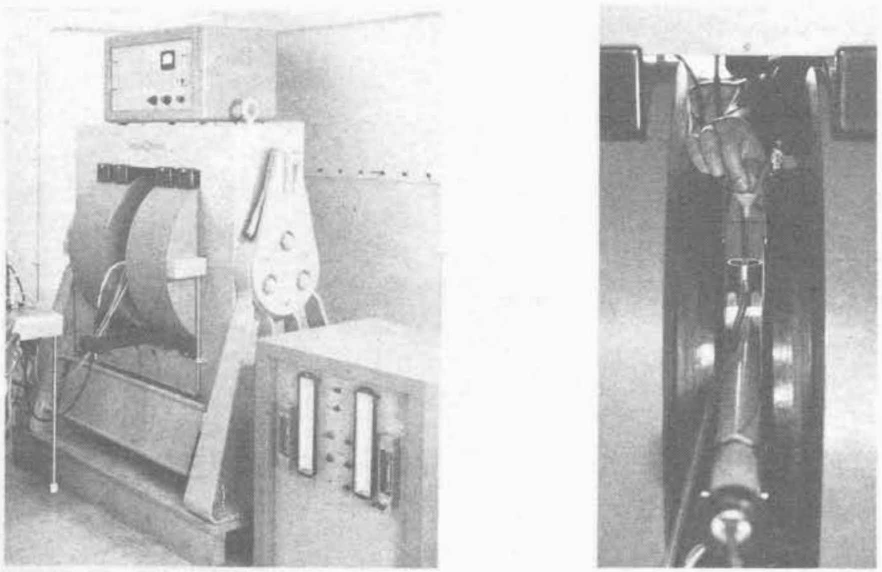
7-62-186-57

SPECTROMETRY

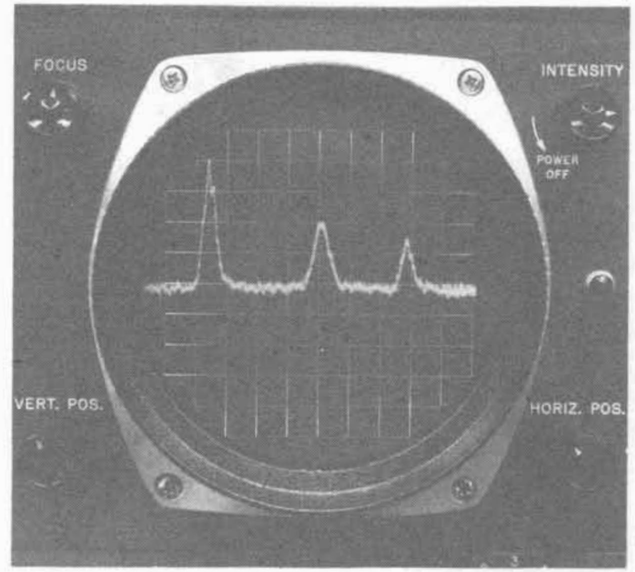
A shock tube located in this laboratory is used to stage combustion processes under controlled conditions. Use of this device enables one to arrest complex reactions and study the products. This tool makes it possible to prepare samples from various stages of a combustion process. Various analytical techniques are utilized to study these products; one of these is spectrometry.

Astronomy, the oldest science, makes use of a prism to break up the light from a star into its various spectra; this is one type of spectrometry. Through spectrometry helium was discovered in the spectra of the sun before it was isolated on earth. Most atoms interact in a characteristic manner with various forms of electromagnetic radiation: infrared, ultraviolet and radio frequencies. Knowledge of these characteristics are used for identification of elements of complex compounds and their atomic structure through spectrometry. Through use of the nuclear magnetic resonance spectrometer, atomic and molecular arrangement of a select group of compounds may be determined. This tool is often used to examine the products of combustion staged in the shock tube. Newly synthesized chemicals may be examined so that their potential as a propellant may be characterized.

SPECTROMETRY



NUCLEAR MAGNETIC RESONANCE SPECTROMETER



- MASS
- INFRA-RED
- ULTRA VIOLET AND VISIBLE

C_2H_6O

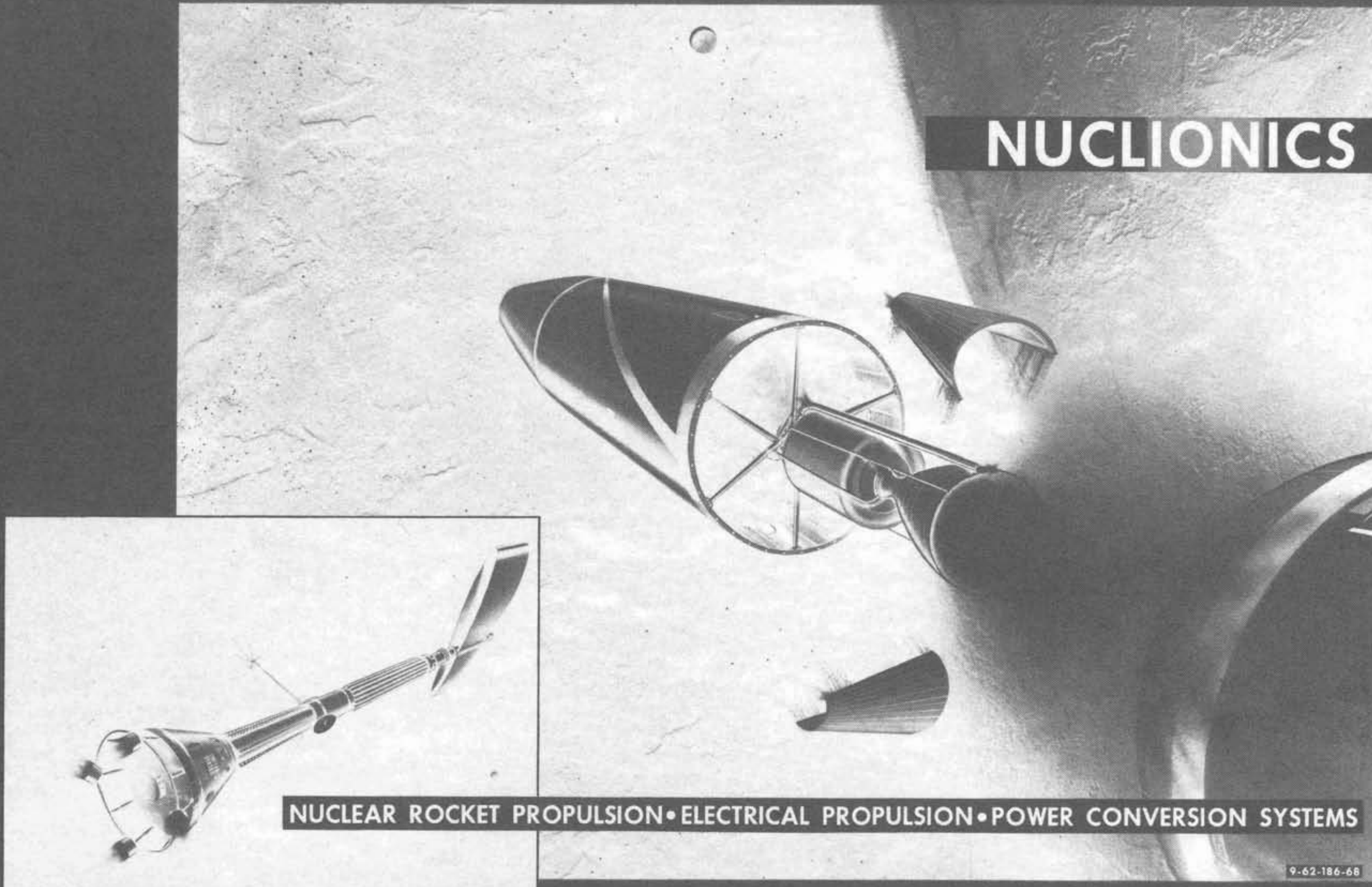
$CH_3\text{-}CH_2\text{-}OH$ = ETHYL ALCOHOL

$CH_3\text{-}O\text{-}CH_3$ = DIMETHYL ETHER

9-62-186-72

NUCLIONICS

Use of nuclear engines as upper-stages for Saturn booster will permit delivery of heavier payloads, approximately twice that possible with chemical stages. The anticipated nuclear engine performance will be more than double that of chemical engines in the thrust per pound of propellant per second. Nuclear engines will be required for manned planetary exploration. In addition, use of a nuclear second stage for the Saturn V vehicle for Project Apollo is under study. It should be noted that the fission of one pound of uranium is equivalent to the combustion of over one million pounds of hydrogen and oxygen. This amount of energy would produce about 160 KW of electric power for one year.


NUCLIONICS
NUCLEAR ROCKET PROPULSION • ELECTRICAL PROPULSION • POWER CONVERSION SYSTEMS
9-62-186-68

NUCLEAR ROCKET ENGINE

The control rods of the nuclear reactor are actuated to preheat a portion of (in this instance) hydrogen (a very light-weight propellant). Some heated hydrogen is then bled off to drive the turbine. Spinning of the turbine pumps liquid hydrogen through the reactor where energy is absorbed, thus super heating the hydrogen gas for very high velocity discharge through the nozzle to produce thrust. A portion of the heated hydrogen is continually bleed off for turbine drive to sustain operation. The engine is controlled through sensors in the reactor actuating the control rods as required. This method attains a very high specific impulse but its use is restricted due to contaminated exhaust products.

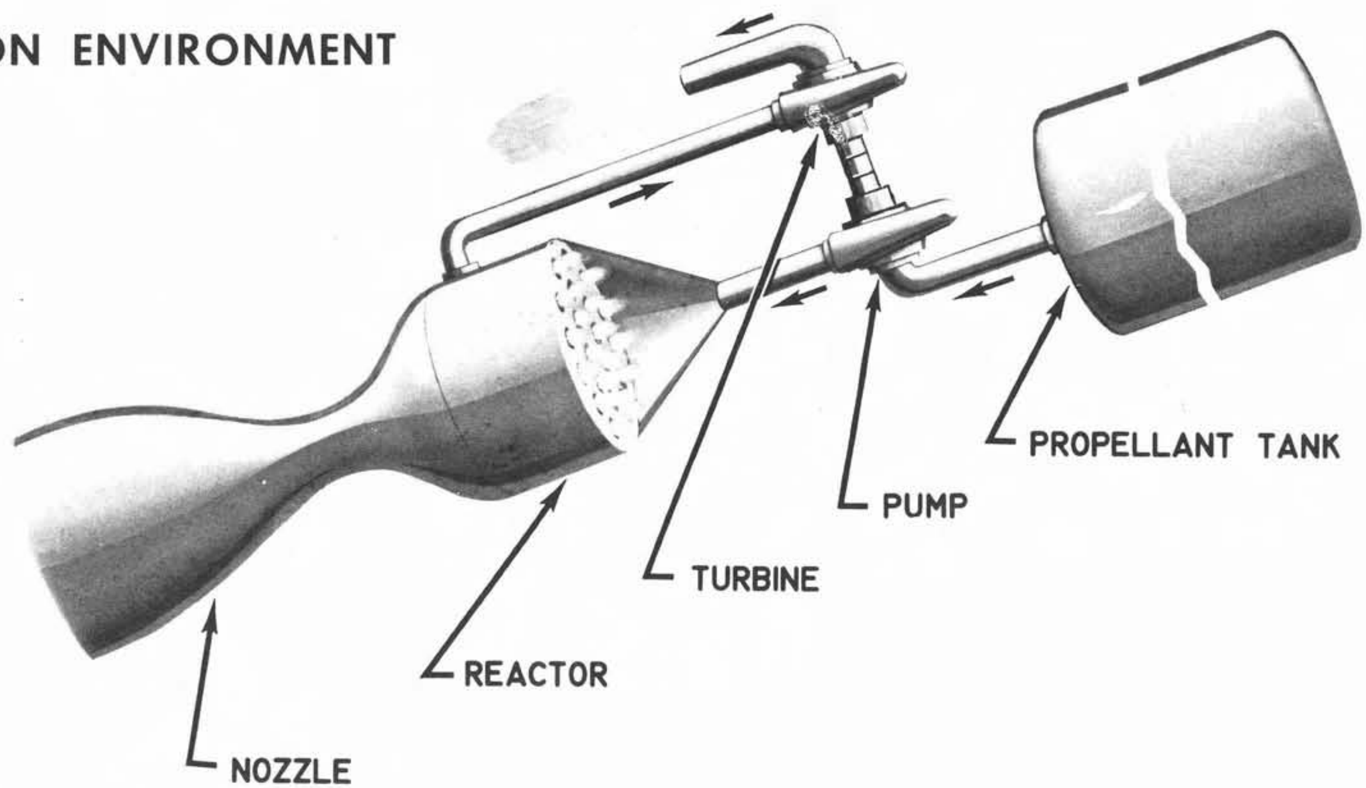
ROCKETDYNE
A DIVISION OF NORTH AMERICAN AVIATION, INC.

NUCLEAR ROCKET ENGINE

407-200-130A

CHARACTERISTICS

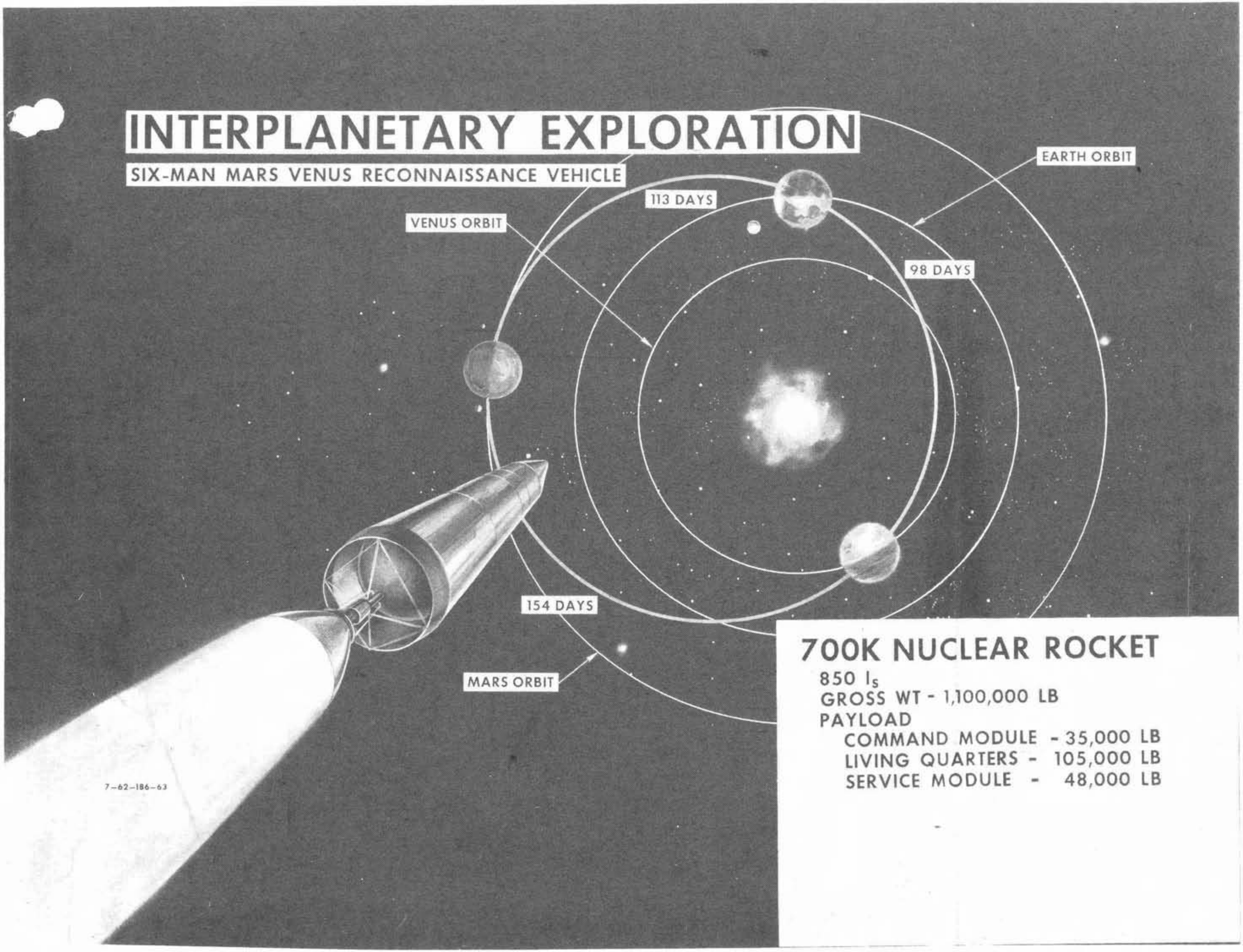
- SPECIFIC IMPULSE 700-1200 SEC
- SINGLE PROPELLANT
- REACTOR HEAT SOURCE
- RADIATION ENVIRONMENT



INTERPLANETARY EXPLORATION AND SUMMARY

Visualized here is a six man reconnaissance of Mars and Venus in one trip, a Crocco mission named for Prof. Luigi Crocco of Princeton. A nuclear rocket engine of 700,000 pounds thrust is proposed for this trip. One hundred thirteen days of travel to Mars, 154 days on to Venus and 98 days to return to Earth (365 days total). This adventure is being considered for the early seventies. A Crocco mission profile uses the mutual attraction of the planets, the spacecraft and the sun to complete a trip with a minimum expenditure of energy. Propulsion would be required as the spacecraft passes near the planets to make minor corrections for freefall flight toward the next body and return. Due to the excessive cost of this program and the very short time spent in the vicinity of the planets, this type of voyage may not be used. Nuclear rocket engines, however, will be required for planetary exploration.

SUMMARY --- Some of Rocketdyne's products have been shown and discussed. The coming Saturn launch of the Apollo spacecraft for the lunar landing has been depicted. Now we would like to close with this chart of the next step in space. Thank you.


INTERPLANETARY EXPLORATION
SIX-MAN MARS VENUS RECONNAISSANCE VEHICLE
EARTH ORBIT
113 DAYS
VENUS ORBIT
98 DAYS
154 DAYS
MARS ORBIT
700K NUCLEAR ROCKET
850 I_s
GROSS WT - 1,100,000 LB
PAYLOAD
COMMAND MODULE - 35,000 LB
LIVING QUARTERS - 105,000 LB
SERVICE MODULE - 48,000 LB
7-62-186-63

ROCKETDYNE

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