GODDARD NEWS

GODDARD SPACE FLIGHT CENTER / GREENBELT, MARYLAND

VOLUME III, NUMBER 12 | THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION | DECEMBER 3, 1962

Goddard Works on First Solid State Laser

The optical systems branch, headed by Dr. Henry H. Plotkin, is currently "shedding light"—in the most literal sense of the phrase—on advanced satellite tracking techniques.

Thomas Johnson and H. Dennis Mathews, physicists, and section head S. H. Genatt, all from the astrometrics techniques section, are working with the General Electric Company, missile and space division, to develop the first system to use a solid state laser in the U.S. space program.

The first operational tests of the unique optical tracking system, to be held at Wallops Station, will involve the S-66 polar ionosphere beacon satellite, scheduled for launch into a 1,000 kilometer (600-mile) circular orbit early in 1963.

The heart of the system, the laser (light amplification by stimulated emission of radiation) is a device quite similar in basic operation to the maser microwave amplifier (Goddard News, Nov. 5). Unlike the maser, which must operate at extremely low temperatures in a strong magnetic field, the laser operates at room temperature and requires no magnetic field. This makes it quite practical for field applications.

The operating frequency of the laser in the Goddard system is 4.3 x 10^8 mc., or a wavelength of approximately .7 micron. This wavelength borders on the infrared spectrum, but is still barely visible as dark red light.

Light from a xenon-filled flashlamp lying parallel with a 6-inch synthetic ruby rod inside the laser supplies the light energy. Once each second, the magnetic trigger pickoff from the prism drive motor illuminates the flashlamp. Part of the light from the flashlamp is reflected back and forth inside the rod by the semi-reflective rod ends. This excites the atomic structure of the rod and causes effective absorption of a portion of the light energy.

A few hundred microseconds after the flashlamp fires, the prism reaches a position which produces 100 per cent reflection at one end of the rod. This causes a light "flash" through the rod and discharges all the absorbed light energy as a pulse, from the rod end opposite the prism.

Useful in Tracking

The light pulse passes through a lens system and leaves the laser as a very narrow beam (1/16 degree) with an energy in the Goddard system of one joule. Unlike light from conventional sources, the narrow laser beam retains its energy over a long distance. It is this characteristic which makes the laser potentially useful in satellite tracking.

In the Goddard system, the light beam will be reflected from a special mosaic array of one inch fused silica "cube corners" on board the satellite. A telescope mounted on a movable igor (intercept ground optical recorder) pedestal with the laser and with its axis parallel to the laser beam, focuses the reflected beam onto a photo-multiplier tube. The photo-multiplier converts the light pulses into electrical

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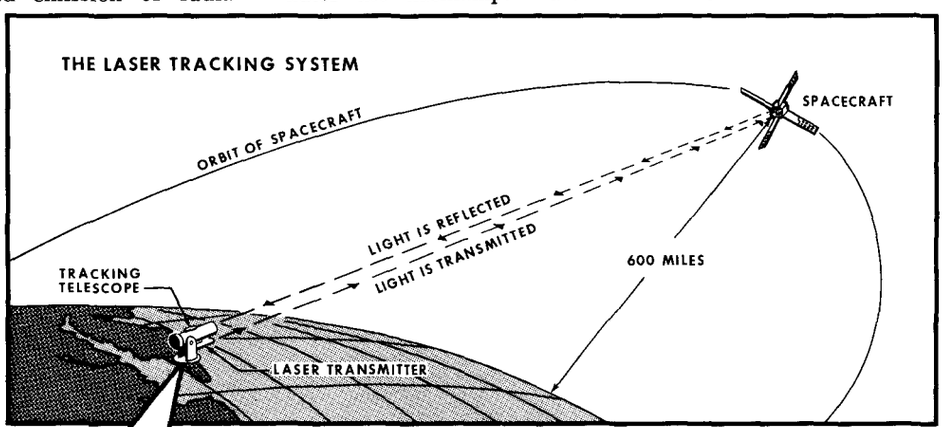
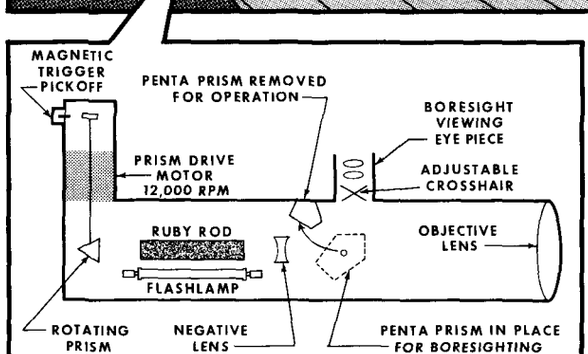




SCHEMATIC REPRESENTATION OF LASER TRANSMITTER

3 Engineers Get Invention Awards

Three Goddard engineers are recipients of awards totalling $850 for inventions under NASA's employee incentive awards program.

They are

- Harold Peake, head of the flight RF systems branch, $100 for a data conversion unit.
- Bill Leavy, aeronautical engineer in the instrumentation branch, $250 for a switching mechanism.
- Stephen Paull, head of the solid state circuits section, flight data systems branch, $500 for a variable frequency magnetic multivibrator.

Peake

Leavy

Paull

The awards bring to six the number of inventions approved for Goddard personnel under the program.

"These contributions provide solutions to scientific and technical problems which are beyond the state of the art," said Leonard Rawicz, Goddard patent counsel. "They also are a significant demonstration of professional merit and add immeasureably to job growth and advancement."

One of the group is receiving his second award. Mr. Paull's variable frequency multivibrator subcarrier oscillator, a forerunner to his present inventions, earned him an earlier $200 award.

About eight additional Goddard inventions presently are being considered under the employee incentive awards act. If a patent application is prepared on an invention, the inventor

(Con't. on Page 8, Col. 2)

Spacecraft Recorder Tests Successful

A new concept in the design of spacecraft recorders has produced impressive results in recent performance tests of a new recorder.

The prototype of the tape recorder for the next joint United Kingdom-U. S. satellite (UK-2), designed and built under Goddard's modularization concept, actually exceeded specifications in several of its tests. For example, the recorder withstood twice the specified vibration level without malfunction.

While many similar units have left the test bench with equally good qualifications, the UK-2 recorder has the unique distinction of being the first unit in any Goddard recorder program to do so on the first try.

"The unit required no redesign or modification of any type," said Jack Peake, head of the flight RF systems branch. "Equal success has been reported in tests of an identical prototype recorder built by Lockheed Electronics, supplier of the flight hardware for UK-2," he said.

New Approach

Behind the success of this program is a somewhat revolutionary modular design approach conceived by Pleasant Cole, head of the recording techniques section, Charles Rice, Jr., electronic engineer in the section, and Mr. Peake. Mr. Cole presented an invited paper on the subject at the Second International Television Symposium in Montreux, Switzerland, in April. A month later, a similar paper titled "Application of Modularization Concept to Satellite Tape Recoders" was presented at the 1962 National Telemetry Conference in Washington, D. C.

Before modularization was devised, the recorder for each new satellite was designed from "scratch". This approach made somewhat less use of previous experience than was desirable. Many of the same difficulties had to be solved for each recorder development simply because different basic designs were used. Also, the reliability of the recorder was often less than optimum.

The modularization approach, however, is based entirely on previously proved techniques. Each component of the recorder is used because it has been tested separately and found to be the best available. The selected components are then assembled into a basic recorder, using design and fabrication approaches which are tried and proved.

When a new recorder is needed for a different project, the basic recorder design can be easily modified to meet the new requirements. The recording head may be changed, certain tape drive pulleys may be replaced to develop a different tape speed, a new printed circuit card might replace the original.

FINAL INSPECTION of UK-2 flight recorders is made by, left to right, Paul Uber, mechanical engineer, and Lib Rogers, electronic technician, as Pleasant Cole, head of the recording techniques section, observes.

Pitfalls Eliminated

But all the reliability of the basic design remains unchanged. Improvements are incorporated whenever possible, but the pitfalls of designing a totally new recorder are avoided completely. The result: a recorder, like the UK-2, that meets the performance specifications on the first tests.

The validity of Cole's modular approach to spacecraft recorder design is now clearly established, in the opinion of Mr. Peake. "Just as electronics designers use tested, proven components, such as resistors, condensers and transistors, the recorder designer may one day go to his parts' bin for motors, bearings, and heads. Paradoxically, we will achieve better, more reliable recorders in shorter time and for less money."

The UK-2 satellite is scheduled for launch in the summer of 1963. The tape recorder will weigh just 6 pounds and will operate at ¼ inches per second (IPS) to store up to 100 minutes of pulse frequency modulation (PFM) data on 125 feet of ¼-inch wide tape. The data will describe such phenomena as the ozone content of the atmosphere and galactic radio interference noise.

At the proper point in each orbit of the earth, the recorder will be commanded by a signal from a ground station to relay its data to earth. The playback of the 100 minutes of data will take only 2 minutes at the playback speed of 12.5 IPS. The recorder will use ¾ watt of power while recording and 1½ watt during playback. The satellite's central battery supply will power the recorder.

Future Use

The quality of the modular UK-2 recorder design is underlined by its planned use by the Royal Aircraft Establishment the British government for future satellites. Other possible applications outside the field space exploration are anticipated by the British admiralty. The French Centre Nationale d'Etudes Speciales (National Center of Special Studies) also has expressed interest in modularized spacecraft recorders.

The next Goddard application will be in the S-57 satellite, scheduled for launch in the fall of 1963.

Major contributions to the success of the UK-2 recorder project were made by Joseph Conn, structural-design engineer in the mechanical systems branch, in the development of the mechanical isolation system, and by Charles Heerd, model maker, and Carl Walch, machinist, both of the fabrication division's machine shop.

2 Large NASA Contracts Underway

The largest single contract ever awarded by NASA and a larger one under negotiation are new developments in the Project Apollo moon program.

The newly signed contract, worth $319,922,328, is with North American Aviation, Inc., space and information division, Downey, Calif.

The potentially largest contract ever to be awarded by NASA—involving an estimated $350 million—is being negotiated with Grumman Aircraft Engineering Corporation, Bethpage, N. Y.

The North American contract, under direction of Marshall Space Flight Center, is for the development and production of the second stage of the Saturn C-5 Apollo moon rocket. This stage has one million pounds of thrust.

Under the contract, North American will produce nine live flight units, one inert flight stage and several ground test vehicles. The contract will carry work through 1966.

The Grumman contract will call for building Project Apollo's lunar excursion module to provide the roundtrip between the moon and a moon-orbiting mother craft.

The module would look something like the cab of a two-man helicopter, measuring 10 feet in diameter and 15 feet in height on its skid-type legs.

Its legs and touchdown engine assembly also will serve as a gantry during lunar takeoff. The touchdown and takeoff engines will burn storable hypergolic fuel. The touchdown engine can be throttled over a thrust range of from 1,000 up to its maximum of 10,000 pounds.

Goddard, Industry Representatives Review Nimbus Spacecraft Program

More than 250 representatives of government and industry have concluded a three-day review of the Nimbus weather satellite program at Valley Forge, Pa.

Purpose of the meeting was to acquaint top management officials with current progress in the Nimbus program and to inspect the Nimbus spacecraft systems, ground support equipment, and environmental test facilities at the General Electric Company's Valley Forge plant.

"We consider the meeting to have been a very successful one," said Harry Press, Nimbus project manager. "Comments and reports received from those who attended were most favorable."

Program chairman for the opening meeting was W. G. Stroud, chief of the aeronomy and meteorology division. The first portion of the three-day session was devoted to presenting a general resume of the Nimbus program, its organization, progress and significance. The second half was devoted to technical review of Nimbus subsystems and support required during the Nimbus environmental testing program now underway.

In addition to project officials and representatives from all major Nimbus contractors, special guests included Dr. Harry Goett, Eugene Wasielewski, Dr. Michael Vaccaro, and Dr. John Townsend, from Goddard; Morton Stoller, director of the office of applications; Dr. M. Tepper, director, meteorological systems, NASA headquarters; and Dr. F. W. Reichelderfer, chief, U. S. weather bureau.

The meeting was organized by W. B. Huston and members of the Nimbus project staff of the Goddard Nimbus project office.

Schirra Tests Nimbus Filters

What type of filter weather-watching cameras of the second-generation Nimbus meteorological satellite will have may be decided when findings of an experiment conducted by Astronaut Wally Schirra on his recent space flight are evaluated.

Astronaut Schirra took about fifteen pictures over South America and the South Atlantic during his six-orbit flight to test the use of a neutral and yellow filter.

Initial observations of the Schirra pictures indicate that contrast in the picture was poorer with use of the neutral filter, i.e., viewing the earth through white light (no filter). Nearly all visible wave lengths (blue, green, yellow and red) came through the neutral filter, making the contrast of land features, such as mountains, oceans, lakes, clouds, etc., less clear.

The yellow filter provided greater contrast in the pictures by shutting out the blue and part of the green portions of the spectrum, which consists of the short wave lengths. Short wave lengths are more susceptible to scattering by smaller dust particles, water vapor, etc., while the lower wave lengths are scattered by larger size particles.

Goddard Speech and Paper Presentations

(Technical presentations approved as of Nov. 27 for period of Dec. 3-16 and late approvals for the past two weeks.)

SPEECHES

John O'Keefe and W. S. Cameron, theoretical div., Central Association of Science and Mathematics Teachers, Inc., St. Louis, Nov. 24. ***"Evidence from the Moon's Surface Features for the Production of Lunar Granites."***

H. E. Frankel, spacecraft systems br., Washington chapter, IES and NAS, Dec. 4. ***"Properties of Materials."***

Edith Reed, astrophysics br., southwest regional meeting, American Chemical society, Dallas, Dec. 6-8. ***"Problems of Analytical Chemistry in Space Research."***

Wilmot Hess, theoretical division, International AEC Symposium on Neutron Detection, Dosimetry and Standardization, Harwell, England, Dec. 10-14. ***"Measurements of the Neutron Flux in Space."***

Carl L. Wagner, Jr., mechanical systems br., American Society of Mechanical Engineers, Wash., D. C., Dec. 13. ***"Structural Design of Ariel One, the First International Satellite."***

Harold E. Evans, mechanical systems br., American Society of Mechanical Engineers, Wash., D. C., Dec. 13. ***"Mechanical Elements for Vacuum Operations."***

TOM JOHNSON, right, adjusts the trigger phase of the laser's magnetic trigger pickoff, while H. Dennis Mathews, left, boresights the laser optical system to assure accurate visual aiming.

Laser Has Unique Tracking Features

(Continued from Page 1)

pulses, and performs initial electrical pulse amplification, thereby "multiplying" the intensity of the incident light.

The distance to the S-66 satellite will be the only parameter measured by the basic system. Accuracy will be about ±50 meters. This range determination will be made by electronically measuring the time between initiation of a light pulse from the laser and reception of the pulse at the photomultiplier.

Three features make the laser system extremely attractive for tracking operations:

- The absence of power-consuming instrumentation on board the satellite.
- The relative electrical and mechanical simplicity of the ground system.
- The extreme "optical" accuracy, unobtainable with other tracking techniques.

However, there are also limitations which must be overcome before the system can become fully operational. Primary among these are daylight operation and satellite acquisition, both of which will be investigated with the S-66 satellite.

During daylight operation, the sunlight entering the receiving telescope at the ground station makes detection of the reflected beam from the satellite difficult. An increase in laser power will be one approach to the solution of this difficulty.

The use of a wide-angle image orthicon system (TV camera) for general location of the satellite is a possible answer to the acquisition problem. Such a system, called radot (real-time automatic digital optical tracking), is now being developed for later experiments with S-66. Electronic data from the system will be fed to a computer which will then aim the laser and photomultiplier telescope at the satellite.

After the radot system becomes operational, the laser system will be aimed by taped prediction data derived from previous radio and optical tracking information. After acquisition, the system will track the satellite automatically.

In addition to range measurement, the radot system will provide a continuous readout of the direction vector to the satellite. Electromechanical transducers will provide X-Y angle data from the radot pedestal which will describe the direction of the satellite from the station.

"The directional data is expected to be accurate to 5 seconds of arc," Mr. Johnson said. "This is quite significant when compared with the 20-minute accuracy now attainable with radio tracking systems."

"In addition to tracking," Mr. Johnson explained, "the laser beams could be extremely useful in satellite telemetry transmission. It has the capacity to carry an almost unlimited amount of information. Operational experience gained with our systems will be applicable to space data transmission as well."

The first technical details of the work were presented on Nov. 8 at Ohio State.

Marshall Center Develops America's Saturn Rockets for Apollo Moon Flights

Special to the Goddard News

HUNTSVILLE, Ala.—NASA's Marshall Space Flight Center in Alabama, while working chiefly on the Apollo moon program, is also providing vital support to the Goddard Space Flight Center's unmanned earth satellite program.

Several Goddard payloads have been launched by rockets provided by Marshall, and others will be in the future.

The satellites, Explorers VII, VIII and XI, were fired into orbit by the Juno II, developed and launched jointly by Marshall and JPL. And in late September the S-27 Topside Sounder satellite was launched from the Pacific Missile Range by a Thor Agena rocket, which system is managed for NASA by Marshall.

Marshall has also supported Goddard in satellite tracking, data acquisition and reduction.

When Saturns I and II, built by Marshall, dumped 95 tons of water in the upper atmosphere as "bonus" experiments earlier this year, they provided Goddard, as well as other government and industrial organizations, with a wealth of data on the physical makeup of that region.

Editor's Note: This is the first in a series of special articles on the activities and responsibilities of NASA's far-flung installations and operations.

Goddard had cooperated with Marshall closely in the planning and conduct of these experiments—including the launching of two small rockets from Wallops as "forerunners" of the big burst.

Develops Saturn Rockets

While all of this work is vital, Marshall's major activity these days relates to the development of the Saturn rockets for manned moon flight.

The Apollo and its eager occupants, when they blast off for the moon late in this decade, will be riding atop a pile of rocket stages composing the largest space vehicle known to this country.

This will be the Saturn C-5, weighing more than six million pounds and turning up 150,000,000 horsepower.

This monstrous rocket will represent the concentrated efforts of more than 6,500 employees at Huntsville, the home of the Saturn family, and many contractors. With a budget of more than $1 billion for fiscal year 1963, Marshall is the largest installation of NASA.

For it is at Marshall that the evolving family of Saturn vehicles, each bigger and more potent than its predecessor, moves from blueprints to assembly floor to test stand in preparation for launches from Cape Canaveral. Marshall Center is the nation's most complete establishment for the development of large rockets. This work is done under the direction of NASA's office of manned space flight, headed by D. Brainerd Holmes.

Orbited First Satellite

Marshall, headed by Dr. Wernher von Braun, had its origin in the army ballistic missile agency. While still a part of the Army, the von Braun team of scientists, engineers, and technicians that later formed the nucleus of the new space agency, orbited America's first artificial earth satellite, Explorer I. The same team also developed the Juno I (Jupiter C) and Juno II space carrier vehicles while still with the Army.

On Sept. 8, 1960, in ceremonies at Huntsville attended by the President and Mrs. George C. Marshall, the new space flight center was officially dedicated and made an integral part of NASA, named in honor of the General of the Army George C. Marshall.

Marshall Center occupies 1,600 acres in the middle of the 40,000-acre Redstone Arsenal reservation, adjoining the city of Huntsville on the north and the Tennessee River on the south. It represents an investment of more than $100 million in property and equipment.

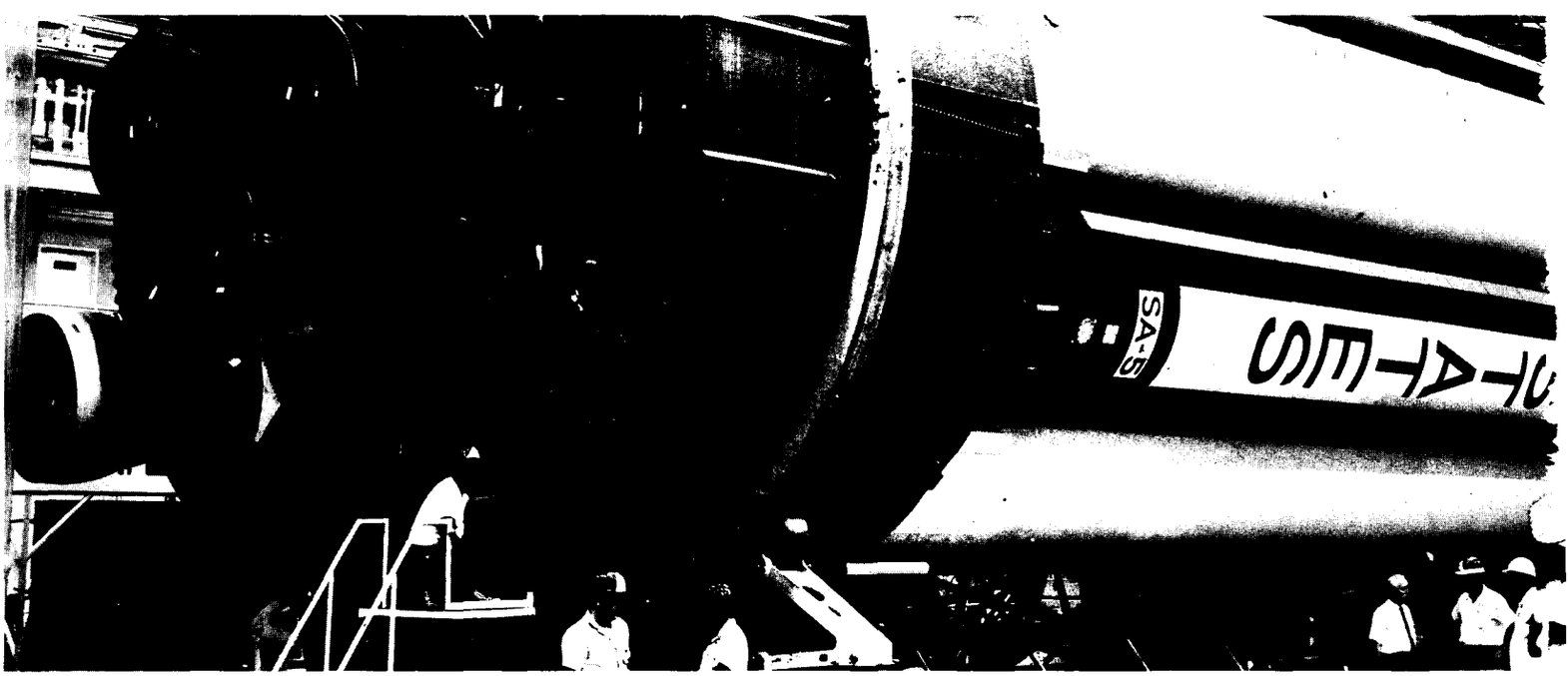
The Center's ten technical divisions are equipped to conceive, design, build and test giant rockets.

The Center's current projects include Saturns C-1, C-IB and C-5, the Thor Agena-B, the Atlas Agena-B, and RIFT (Reactor-In-Flight Test) vehicle. Marshall also manages NASA's engine development projects—H-1, F-1, RL-10 and J-2, all of which are being used or are slated for use in NASA space vehicles. Eighty per cent of the Center's 1962 fiscal budget was spent with private industries and research organizations.

Far-flung Operations

Associated with Marshall in Huntsville are several facilities at other locations. A huge assembly plant for the Saturn vehicle is located in Louisiana. Plant representatives located in the midwest, south and west, provide liaison with the Center's contractors: Marshall personnel are also located at other geographical areas throughout the United States.

NASA recently activated the government-owned Michoud plant at New Orleans for the fabrication of large space vehicle stages. The 846-acre Michoud facility will be the site

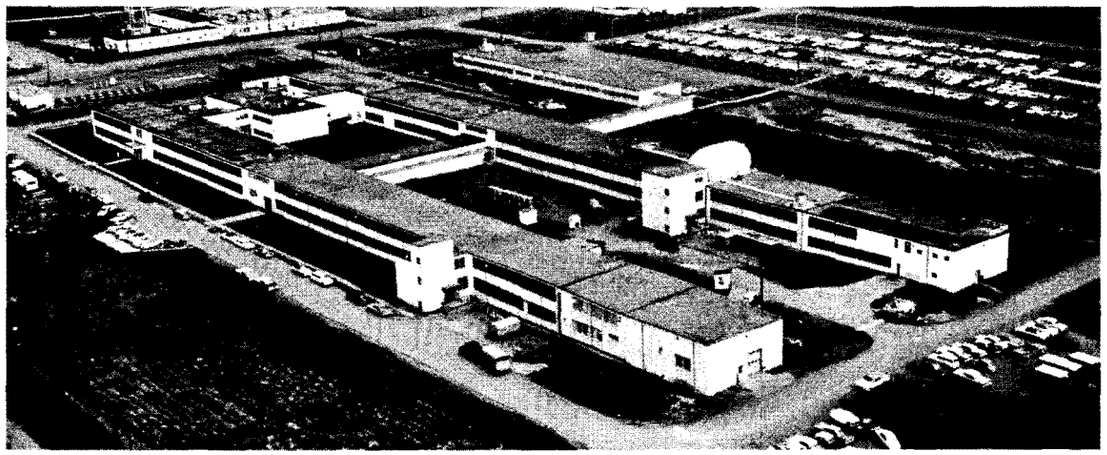


MARSHALL engineers and technicians work on the fifth Saturn flight booster (SA-5). It will be the first Saturn to have tail fins and a "live" uppe

of the production of the Saturn C-1 booster and the Saturn C-5 booster, the latter developing 7.5 million pound thrust. These boosters manufactured at Michoud will be tested by NASA contractors at a static test site about 35 miles from Michoud known as the Mississippi Test Facility. It will cover some 13,500 acres in southwest Mississippi.

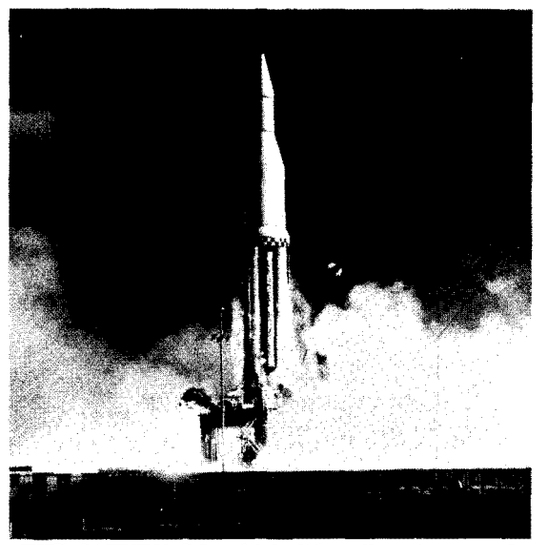
Rockets born at Huntsville were the launch vehicles for many of the Explorer and Pioneer satellites and space probes that have yielded much information about the makeup of the realm beyond earth. The rocketmen at Huntsville gave a major assist in Project Mercury as the developer and launcher of Redstone, the booster that sent astronauts Shepard and Grissom into sub-orbital flights last year, preparing the way for the Glenn and Carpenter three-orbit trips launched by Atlas boosters.

NASA officials say the Saturn C-5 being developed at Huntsville will get us to the moon before 1970. In line with this, the Marshall Center is growing rapidly. New facilities and additions to old ones are going up in almost every direction. In the middle of the Center a new $4-million central laboratory and office facility is under construction. Meantime, temporary office space has been acquired in various off-Center buildings including two former motels and a restaurant.



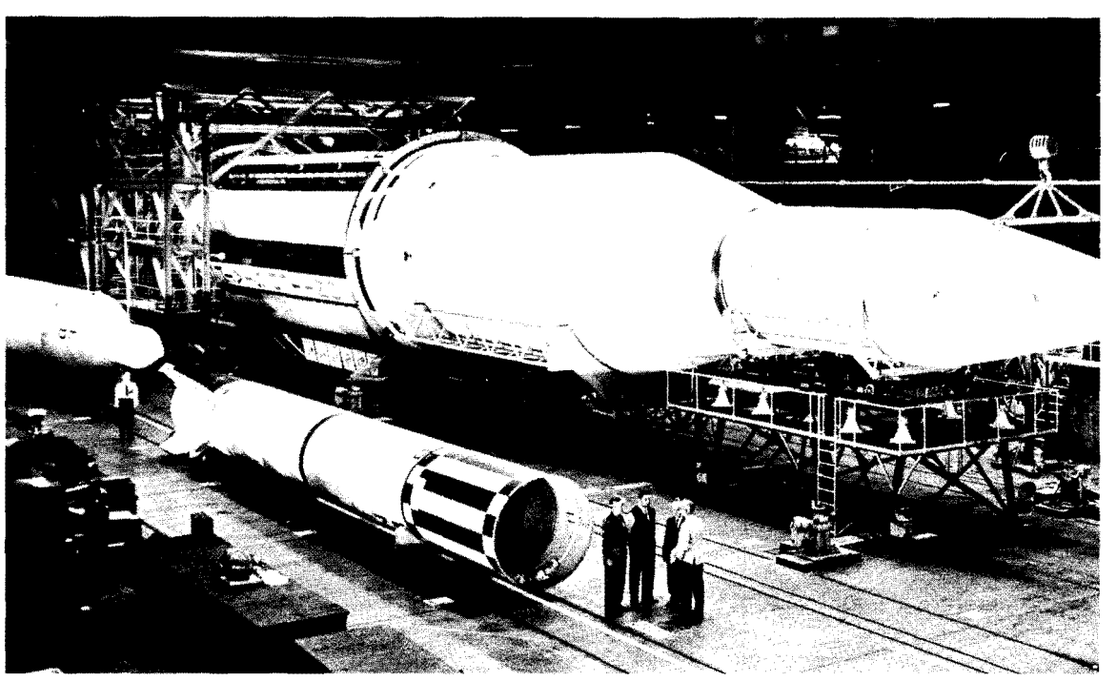
AERIAL VIEW of Marshall shows the major buildings on the 1200-acre installation. The Center develops and launches NASA's booster rockets and conducts related research.

AN ARTIST'S conception shows the three stages of the Saturn C-5 rocket which will carry America's space hopes to the moon.



THE SATURN C-1 vehicle lifts off on its second flight from Cape Canaveral. The vehicle is 162 feet in height, weighs 927,000 pounds, and has 1.3 million pounds of thrust.

r stage. The SA-3 has already been fired.



A SATURN C-1 is seen with the Mercury-Redstone (foreground) and Juno II at Marshall.

Experts Ponder The Mysteries of Planet Jupiter

Approximately 40 astronomers and physicists have concluded a two-day conference sponsored by Goddard's Institute for Space Studies to discuss the properties of the planet Jupiter.

Jupiter's center may be a rocky core approximately the same size as the earth. Surrounding this core is in overlying envelope of hydrogen and helium, probably in liquid and solid form, and an atmosphere of ammonia, methane, hydrogen and helium.

It could be that a large difference developed between Jupiter and the earth because the hydrogen and helium were moved from the vicinity of the earth's orbit at a very early stage by the blasting effects of radiation and particle streams from the sun. Or the condensations leading to Jupiter and the earth could have started in a similar way, but because the primitive earth was nearer the sun, the heat may have caused evaporation and escape of its hydrogen and helium.

Because of the hydrogen that has been retained by Jupiter, the physics and chemistry of the planet are completely alien to those of bodies with which we are more familiar—earth, Mars, Venus, and the moon.

Probes in 70s

Jupiter won't appear very early on a list of space projects, because at current speeds it would take several years for a probe to reach the planet. 1970 is the earliest that we can expect an unmanned exploration by instruments.

In 1955, the work of Dr. B. F. Burke and Dr. F. L. Franklin of Washington's Carnegie Institute led to the discovery that Jupiter is one of the strongest sources of radio waves in the heavens. Since that time the planet has occupied a unique position of interest to radio astronomers. One of the major topics of discussion at the conference was the nature and cause of these radio signals.

One set of signals broadcast by Jupiter resembles the radiation emitted by the electrons in Van Allen belts. For this reason, scientists believe that the waves are produced by charged particles on Jupiter, similar to those discovered by Dr. James Van Allen to be circling the earth.

The Jovian radiation belt was first observed through radio astronomy by Dr. Leland Davis Jr. and other scientists at the California Institute of Technology. They measured the shape, polarization, orientation and rotation period of the belt.

Intense Radiation Belt

Reporting on the findings of the Cal Tech group, Dr. David Morris indicated that the Jovian Van Allen belt is several times as intense as the earth's, and is held in place by an extremely strong magnetic field.

The magnetic field captures particles in the upper atmosphere, and as they circle around the lines of magnetic force, the particles give off radiation in the form of radio waves. Their frequency depends on the strength of the magnetic field.

Data presented at the conference by Dr. David B. Chang of the University of California showed that the radiation has frequencies between 3,000 to 10,000 megacycles, corresponding to a wave length of 10 to 30 centimeters, or about one foot. These are known as decimeter waves. From this frequency, Dr. Chang concluded that the magnetic field strength is one gauss. Near the surface of the planet the strength is probably much higher—about 100 gauss. This is a hundred times stronger than the earth's magnetic field in corresponding regions.

Another set of signals emitted by Jupiter is more puzzling than the decimeter radiation. These are radio noise storms—occasional bursts of radio signals with a frequency of 1,000 megacycles and a wave length of ten yards. These are known as decameter waves.

These radio storms are extremely intense. The energy released corresponds to the repeated explosion of hydrogen bombs at the rate of one every second, or an energy release of one million tons of TNT a second. In terms of wind systems, the energy released is equivalent to a hurricane or small cyclone.

Until recently, this radiation was believed to stem from lightning strokes produced by enormous Jovian thunderstorms, but that theory has now been abandoned. Dr. Leona Marshall of New York university noted at the conference that radio waves generated by atmospheric lightning discharges would cover a broad range of frequencies. The decameter waves are confined to a narrow range.

Several new ideas were presented at the conference to replace the old theory on lightning discharges. The participants agreed that the storms must occur in the Jovian ionosphere at high altitudes, and not at the low altitudes which are the seat of weather disturbances.

Professor James Douglas of Yale university told the conference that the Jovian radio emission seems correlated with solar activity. This suggests that the ultimate source of energy may be associated with the solar wind.

Old Theories Pondered

Old ideas about the atmosphere of Jupiter received a thorough working over at the meeting. Dr. Roger M. Gallet, of the National Bureau of Standards, Boulder, Colo., said that previous notions about the Jovian atmosphere cannot be correct because they neglect the changes produced by the condensation of ammonia and water vapor.

Dr. Gallet believes the atmosphere near the surface consists of gaseous ammonia, above which there are ammonia rainstorms, and then a cloud deck of ammonia ice crystals, 30 miles thick. A few miles below the ammonia clouds, there are water clouds, according to Dr. Gallet.

With allowance for the heat released in this condensation, Dr. Gallet calculates a lower temperature and a higher density in the deep atmosphere of the planet than had been believed possible.

He estimates the temperature of the Jovian surface to be 1000 degrees Fahrenheit. This would make Jupiter a relatively warm body.

On earth, there are no forms of life that can exist at this temperature. Moreover, most scientists believe it is extremely unlikely that any recognizable forms could have developed in the alien chemistry of a Jovian atmosphere dominated by ammonia and methane.

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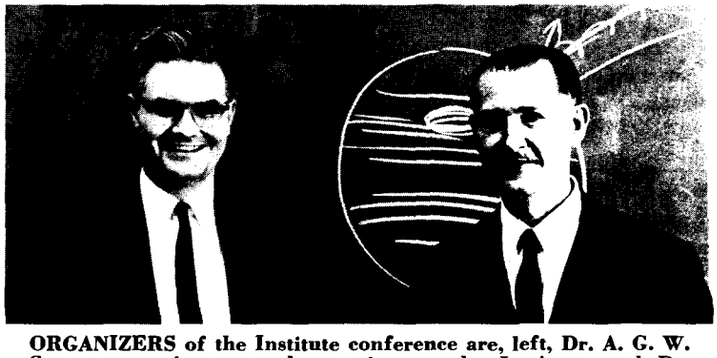
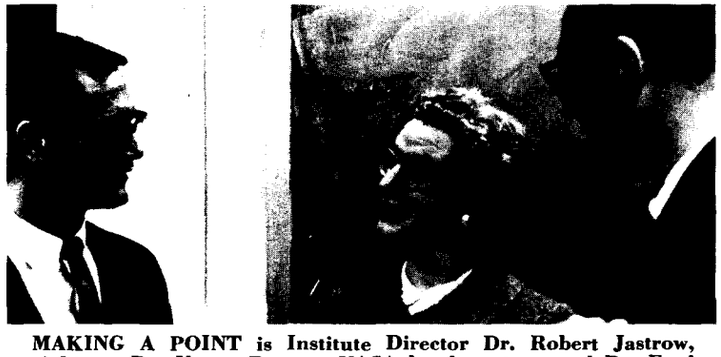


ORGANIZERS of the Institute conference are, left, Dr. A. G. W. Cameron, senior research associate at the Institute, and Dr. Rupert Wildt of the Yale university observatory, along with Dr. Harlan J. Smith also of Yale (not pictured).



MAKING A POINT is Institute Director Dr. Robert Jastrow, right, as Dr. Nancy Roman, NASA headquarters, and Dr. Fred Haddock of the University of Michigan observatory listen.

Goddard Colloquium Speaker Adds to Jupiter Knowledge

How does Jupiter differ from terrestrial type planets?

Jupiter belongs to the group of the "outer" or "giant" planets — Jupiter, Saturn, Uranus, and Neptune. These are much more massive, less dense, and are rotating more rapidly than the "inner" or "terrestrial" planets—Mercury, Venus, Earth, and Mars. It is believed that the giant planets are mainly composed of the light elements, hydrogen and helium, with a small core of stone and iron, while the terrestrial planets consist entirely of rock (silicates) and nickel-iron (as in meteorites), with less than 0.1 per cent of the light gases.

What is the internal structure of Jupiter?

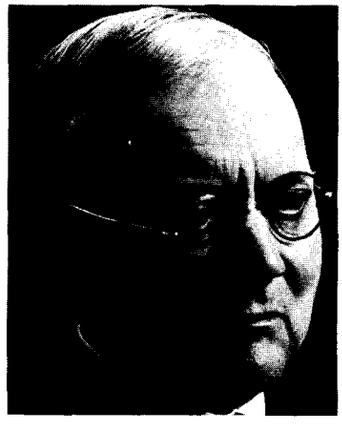
From its observed characteristics it is fairly certain that the bulk of Jupiter's mass is hydrogen (with some admixture of other elements), compressed into solid state by gravitation. At a pressure of some ten million atmospheres, the solid hydrogen may have a temperature of 400 - 10,000 degrees Kelvin and remain solid.

Could Jupiter be gaseous throughout?

If gaseous, it should consist of elements heavier than hydrogen, say nitrogen. With the given mass and radius, the internal temperature of the gas-ball would then be half-a-million degrees. Heat flow by convection, however, would then keep the surface of Jupiter at a temperature of several thousand degrees, making it a little sun. This is certainly not the case. Also, the oblateness would have been by 25 per cent less than observed. A gaseous state of Jupiter's interior is absolutely out of the question. The solid-hydrogen model is the only alternative.

What new data have come to light about the composition of the atmosphere of Jupiter?

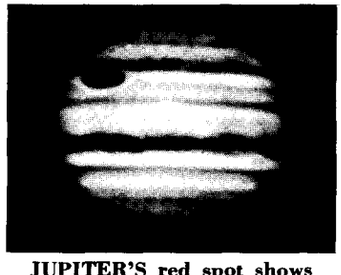
The gaseous envelope of Jupiter contains about 0.1 per cent of its mass and reaches to a depth of a few hundred miles. Only the top of this envelope is observable, bounded by the apparent "surface" representing clouds of ammonia crystals, at a temperature of 156° K (—117° C). Spectroscopically small amounts of ammonia and methane have been observed above the clouds, and recently molecular hydrogen has been detected, equivalent to a layer of 5-8 km at atmospheric pressure and room temperature. Helium, if present, is not observable spectroscopically.



It has been generally accepted that hydrogen is the main constituent of the atmosphere, as it is undoubtedly in the interior.

However, new data are at variance with this concept. A stellar occultation by Jupiter, observed at Mount Wilson, indicated a rate of variation of atmospheric density with altitude which is compatible with a mean molecular weight of 4, or that of helium, and not of 2, that of hydrogen. The result depends on a careful calculation of the radiative equilibrium temperature of the upper atmosphere of Jupiter.

Also, the observed scattering of sunlight by the atmosphere of Jupiter cannot be accounted for by the amount of hydrogen present, which is short by a factor of 3 to 4. The unaccounted-for scattering would require the presence of huge amounts of helium, otherwise unobservable, and this is in accord with the estimate of molecular weight.



JUPITER'S red spot shows up on this 200-inch photograph.

Dr. Opik has been a research professor at the University of Maryland department of physics and astronomy since 1956. He was born in Estonia, studied at Moscow Imperial university and received his Ph.D. from the University of Estonia. He has authored many scientific articles and is a member of numerous honorary and professional societies. Prior to coming to the U. S., he was an astronomer at Armagh observatory in Northern Ireland. He spoke at the weekly Goddard colloquim Friday. An interpretation of his talk, "Composition and Origin of Jupiter," is presented here.

Does Jupiter radiate heat of its own?

Yes, although much less than suggested in the past century when Jupiter was sometimes incorrectly regarded as a little sun. To solar heat absorbed by the planet's surface, Jupiter adds almost twice as much from its own store.

Could the source of Jupiter's heat be of a volcanic nature?

On earth, volcanism is not a source, but a consequence of the flow of internal heat outwards. If volcanism exists on Jupiter, it also can only be a consequence of the internal turnover of heat.

Could Jupiter's famous red spot be of a volcanic nature?

The permanence of the red spot, which sometimes is white, i.e., covered by the white ammonia clouds, and sometimes dark and red, opening up into the depths of Jupiter's atmosphere, observed for three centuries since telescopic means became of sufficient power, would imply that it is anchored in the solid surface, several hundred miles deep under the cloud level. Its depth, however, is small compared to its horizontal extent of more than 10,000 miles. Its base (invisible) may be a kind of island floating on the liquid-solid surface of the hydrogen kernel. Over decades, upward currents generating the white ammonia clouds alternate with downward currents in which the clouds melt away. This purely meteorological phenomenon could account for the variable appearance of the spot. True volcanic activity is highly improbable. Besides the spot is not immovable but over decades may move forward or backward several revolutions.

Jupiter Facts

Diameter—88,640 miles (11 times the earth's)
Size—larger than all other planets combined
Period of revolution—about 12 years
Period of rotation—9 hrs. 50 minutes (giving Jupiter the shortest day of any planet)
Density — 1.34 times that of water.
Surface gravity—2.64 times the earth's (a man who weighs 150 pounds on earth would weigh 396 pounds on Jupiter.)

Hydrogen and helium are well mixed in the nebulae, stars, and intersteller material of our universe. How is it possible that in Jupiter the two elements became separated, and that the heavier element, helium, stayed at the top in the atmosphere while the lighter hydrogen went to the bottom?

One trivial suggestion is that originally hydrogen prevailed in Jupiter's atmosphere but was lost to space through "gas-kinetic escape" or "evaporation" of this lighter constituent. This process can be treated numerically and turns out to be inadequate by factors of the order of billions or trillions. This suggestion is thus of no practical value.

The explanation is to be sought in the mode of origin of Jupiter. After the sun had condensed, a solar nebula occupying the space of the present solar system stayed behind. The planets condensed out of this flat, rotating nebula which contained gas and dust. The dust prevented solar radiation from reaching far into the nebula, which becamely extremely cold. At Jupiter's distance the temperature may have been 4° K (—269° C). At this temperature, hydrogen condensed into crystals of hydrogen snow, whereas helium remained gas. By a "snowball" process the hydrogen (as well as the stony and iron dust) was swept into one solid-hydrogen body, the planet Jupiter (warming up but now kept in a solid state by pressure) while helium stayed behind for some time in interplanetary space and was later on collected by Jupiter on top of its solid-hydrogen core, to form its atmosphere.

(Con't. on Page 8, Col. 3)

Great!

Goddard Begins Recruiting Drive

Goddard has started an urgent recruiting program to help speed the U. S. space program.

The Center has immediate openings for up to 200 engineers and scientists with degrees in electronics, physics and mathematics, according to Dr. Harry J. Goett, Goddard director.

Telephone number for Washington area residents who wish information is 982-5652. Engineers and scientists living in the Baltimore area can call 474-9000, extension 5651 (collect) to arrange an interview.

Qualified applicants living outside the Washington-Baltimore area should send resumes to the personnel director.

Starting salaries for graduate engineers and scientists range from $7,125 to $12,845.

Goddard Coming Events

Lectures: Goddard colloquium lectures:

3 p.m. Dec. 7 Bldg. 3 auditorium — Dr. Ishtiaq Rasool, Institute for Space Studies, "Atmospheres of Mars and Venus."

3 p.m. Dec. 14 Bldg. 3 auditorium — Prof. Derek Tidman, Univ. of Md. Institute of Fluid Dynamics, "Structure of Plasma Shock Waves and Solar Radio Noise."

Society for Experimental Stress Analysis, 8 p.m. Dec. 5, Materials Testing Conference room, National Bureau of Standards—Dr. A. E. Seigel, Naval Ordnance Laboratory, "The Use of Gun-like Devices to Obtain Serodynamic Characteristics of High Speed Models in the Laboratory."

Misc: Goddard Astronomy Club, 12 noon Dec. 5 Room 124, Bldg. 1.

"Booster" Tetanus shots every Tues. & Fri. during December, 1-2 p.m. Room 33, Bldg. 1, health unit.

Goddard Wives Club, 8 p.m. Dec. 12, cafeteria conference room, Christmas social meeting. Call Mrs. Turney, 772-2227, prior to Dec. 11 to be put on security list.

Goddard Employees Welfare Assn. Christmas collection boxes for needy, bldgs. 1, 2, 3, 5, 6, and 7. Contributions until Dec. 19.

To include items in the Coming Events column, please call ext. 4141 or 4142.

Employees to Give Christmas Boxes

Needy families in Prince Georges County will have additional food, gifts and toys again this Christmas under the annual program sponsored by the Goddard Employees Welfare association.

Contributions from Goddard employees may be placed in special boxes in the lobbies of buildings 1, 2, 3, 5, 6, and 7 prior to Dec. 19. The boxes then will be delivered to the County's Volunteer Christmas bureau for proper distribution.

Principal items sought include foods, packaged in cans or glass, new or used toys in good condition, and clothes. Gifts should not be wrapped so that the client can select the desired items.

The Christmas bureau plan of giving eliminates the disadvantages of giving directly to families. The latter approach has resulted in duplication, misdirected charity, and embarrassment to parents in the eyes of their children. Bureau giving allows the mother to select the items she wants.

Goddard Librarian Authors Pamphlet

A brief history of the Goddard library is described in a new pamphlet written by John Weaver, Goddard librarian.

The pamphlet traces the origin of the library, its growth and expansion, and facilities and services it provides. It points out that the library's collection now numbers about 10,000 books, 900 current subscriptions and 150 journal backfile titles, giving emphasis to the physical sciences, especially physics, astronomy, mathematics, and electronics.

The pamphlet is available in the library.

(ENGINEERS, from Page 1)

is automatically submitted for an award under the NASA incentive awards program.

Under the program, a minimum award of $50 is made for each approved invention and a greater amount is made depending upon the merits of the invention. When the patent application is filed, the invention is simultaneously made available for licensing by industry.

(JUPITER, from Page 6)

Dr. Harold C. Urey, Nobel Prize-winning chemist at the University of California, is "exceedingly skeptical" about the possibilty of life on Jupiter. "Speculation is so far removed from the observable facts that it's useless to talk about life on Jupiter until we get more evidence," Dr. Urey asserted.

He said that there are so many factors involved in the creation of life that he still is constantly amazed that it exists on our own earth.

Solid Hydrogen Surface

So little is known about this strange planet that it is not even clear whether it has a surface. The base of the Jovian atmosphere may blend imperceptibly into a gaseous and then a liquid region of gradually increasing density. The consensus of the conference discussion, however, was that there is in fact a surface of solid hydrogen, several hundred miles below the clouds.

The interior of the planet was discussed by Dr. Wendell C. DeMarcus, a University of Kentucky physicist, who is widely known for his work on the structure of Jupiter in collaboration with Dr. Wildt. Dr. DeMarcus presented calculations which indicate that Jupiter's main volume consists of 80 per cent hydrogen, solidified under the tremendous forces of the planet's gravity. The remainder is made up of helium and a much smaller amount of heavier elements.

(SPEAKER, from Page 7)

What is your theory of Jupiter's comet families?

Comets of Jupiter's family are those short-period ones which have their aphelia (greatest distances from sun) near Jupiter's orbit and which move inside this orbit. The origin of this family is practically beyond dispute and, thus, no longer a matter for personal controversial opinions. The existence of these comets is completely explained by celestial mechanics, through gravitational capture of nonperiodic comets when they happen to pass near Jupiter in a certain definite manner. Jupiter alters the orbits of these comets, forcing them henceforth to move in small short-period orbits around the sun.

The very large proportion of hydrogen in the composition of Jupiter reduces its mean density to 1.33, only slightly greater than that of water, and four times less dense than the mean density of the earth.

If hydrogen is responsible for 80 per cent of Jupiter's mass, there will be no fundamental difference between the deep interior and the outer layers, except that the terrific pressure near the center will compress the hydrogen gas so much that it will start to behave like a metal. Speakers agreed that Jupiter's center probably is comprised primarily of metallic hydrogen.

Interior Temperatures

Until recently, the temperature of Jupiter's interior had been believed to be near absolute zero. This conclusion was based on the assumption that Jupiter's center is comprised solely of metallic hydrogen. The metal is an excellent conductor of heat which would rapidly lower the temperature of the interior. However, scientists now are convinced there is a sprinkling of other elements besides hydrogen in the core, and their effect is to reduce greatly the amount of heat that would percolate through the interior to the surface. An impure substance is not a good conductor.

Dr. George Field of Princeton university observatory estimates the temperature in the deep interior at 2,000 to 20,000 degrees Fahrenheit. This is an important result because it provides a reasonable explanation for the strong Jovian magnetic field. Magnetic fields are believed to be maintained by the motion of a metallic core, simulating the action of an electric generator. For the cored to flow, a high temperature is essential.

A highlight of the conference was the presentation of a new theory for Jupiter's most remarkable feature: the mysterious Great Red Spot.

Dr. Raymond Hide, a British physicist who recently joined the Massachusetts Institute of Technology, believes the Red Spot is the top of a huge column of gas that remains stationary above a huge mountain or deep depression on the surface of the planet. Dr. Hide has been able to reproduce the stationary column in laboratory experiments with rotating fluids.