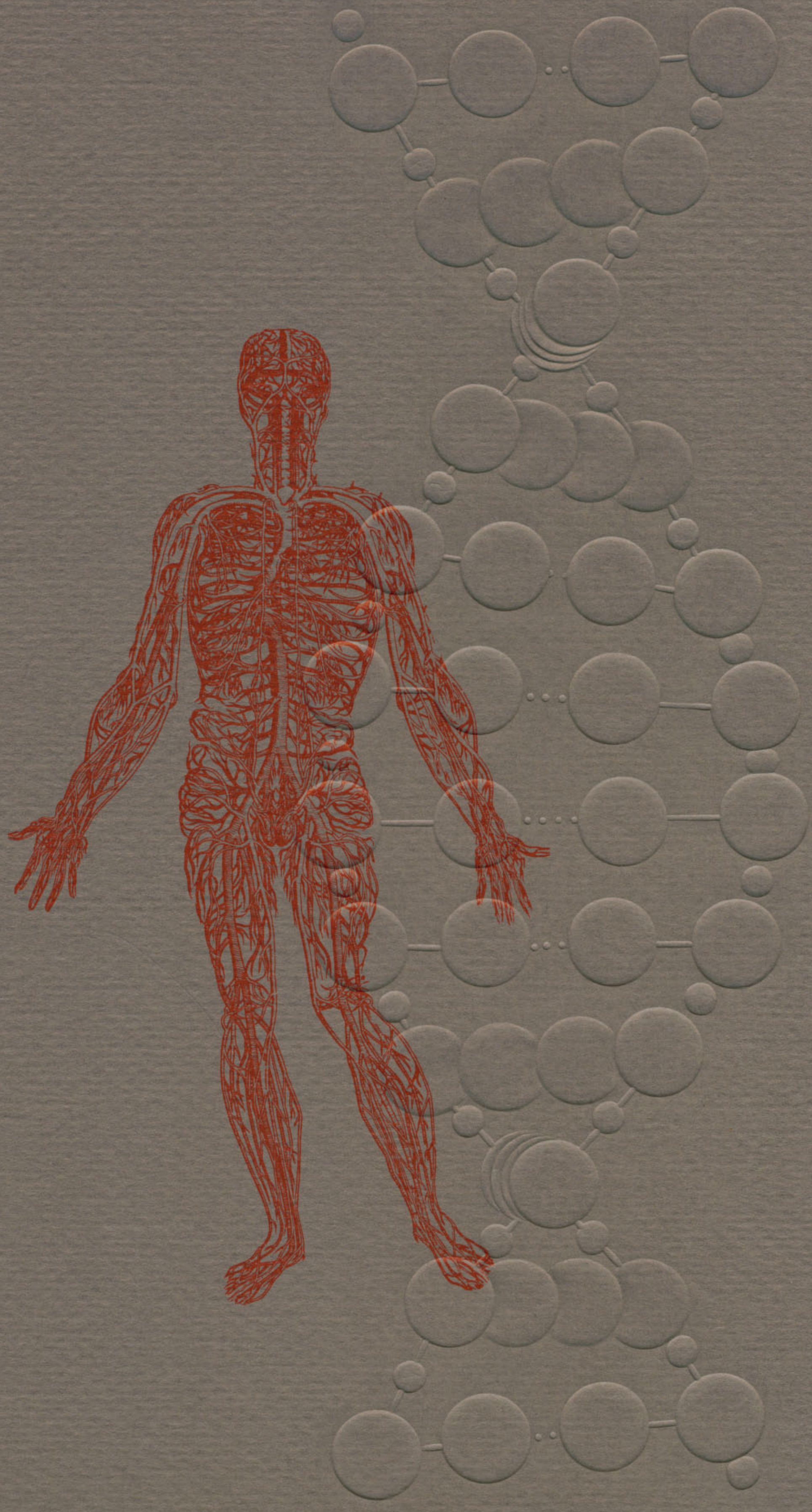

SCIENCE AT THE FAIR

SCIENCE AT THE FAIR

WILLIAM L. LAURENCE, *Editor*

With Prefatory Notes by
ROBERT MOSES, *President*
New York World's Fair 1964-1965 Corporation

and by
PAUL R. SCREVANE, *President of the Council*
The City of New York

UNISPHERE

PEACE THROUGH UNDERSTANDING

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NEW YORK WORLD'S FAIR 1964-1965 CORPORATION

INTERNATIONAL EXPOSITION AT FLUSHING MEADOW PARK

At my request, Mr. William L. Laurence, our top science adviser, has written for our executives a short, understandable piece on Science at the Fair, identifying the pavilions and exhibits featuring science in one way or another and explaining what our sponsors have aimed to show the general public. Next to the great scientists themselves and those who exploit their revelations in basic research and practical implementation come the very few reporters who can make these revelations comprehensible by laymen, the gifted interpreters who can put abstruse terms and formulas in simple English, who take the "expertise" lingo out of thermodynamics, space and inventions. Bill Laurence is the best of this rare breed. He was picked to represent journalists on the spot at Los Alamos, Hiroshima and Nagasaki.

In preparation for Post Fair Flushing Meadow, Mr. Laurence is working on future buildings and exhibits for the new permanent Hall of Science. This little piece is to be read in connection with the previous report on the Post Fair Park and the shorter one on the Hall of Science.

It won't take long to read this piece. It won't require great effort. It will be most rewarding.

Robert Moses, *President*

THE CITY OF NEW YORK
OFFICE OF
THE PRESIDENT OF THE COUNCIL
NEW YORK 7, N. Y.

PAUL R. SCREVANE
PRESIDENT

This book on Science at the New York World's Fair brings home with clarity the impact of the scientific revolution the world is now witnessing.

The pages devoted to the Hall of Science, which will give New York City a permanent museum to meet the needs of an era in which science is playing such an all-important role, are gratifying to me personally, as one who has felt the need for such a museum and has worked with Mayor Wagner for its establishment.

The theme of the Fair—"Peace through Understanding"—has a double thrust: The understanding of people, the social and humanitarian comprehension, must be coupled with an understanding of the physical world, of the universe we live in.

The scientific exhibits at the Hall of Science, the United States Space Park and other pavilions, described in these pages, provide a dramatic illustration of the breath-taking pace of scientific progress during the quarter-century since the last New York World's Fair in 1939. They tell us that we are living in two new ages—the Space Age as well as the Atomic Age, and that we now stand at new frontiers of knowledge that will greatly enrich the life of mankind everywhere.

The present Hall of Science is but a nucleus of what will, in time, grow into a magnificent Science Center, to take its place with Lincoln Center, the Metropolitan Museum, the American Museum of Natural History and our institutions of learning, as part of a great cultural complex unmatched anywhere in the world.

Paul R. Screvane

PAUL R. SCREVANE, *President*

Science at the Fair

Contents

1. *Introduction*

The millions visiting the New York World's Fair of 1964-65 will have a unique opportunity to view many new wonderlands of science of today, tomorrow and the day after.

For moments that will never be forgotten, they will to all intents become actual voyagers through the immensity of interplanetary space. They will see the Apollo space capsule that will take America's astronauts to the moon by 1970, and the giant rocket that will boost them to their destination some 240,000 miles away at a speed of 25,000 miles an hour.

They will watch an awesome rendezvous hundreds of miles in outer space between a ferry space vehicle and an orbiting space station, during which a crew of astronauts sent up from the earth will relieve the crew on the space laboratory. They will be taken on a simulated journey to the moon and then, on arriving at their destination, will step out of their space vehicle for a walk on the lifeless, airless surface of our nearest neighbor in space.

They will be taken on many other breath-taking never-to-be-forgotten journeys in space and time. They will behold the wonders of the infinite and the infinitesimal, the vast cosmic forces that operate in the interior of the sun and other luminous stars and within the infinitesimal nuclei of the atoms of which the sun, the stars and all things living are constituted.

William L Laurence

WILLIAM L. LAURENCE

II. *United States Space Park*

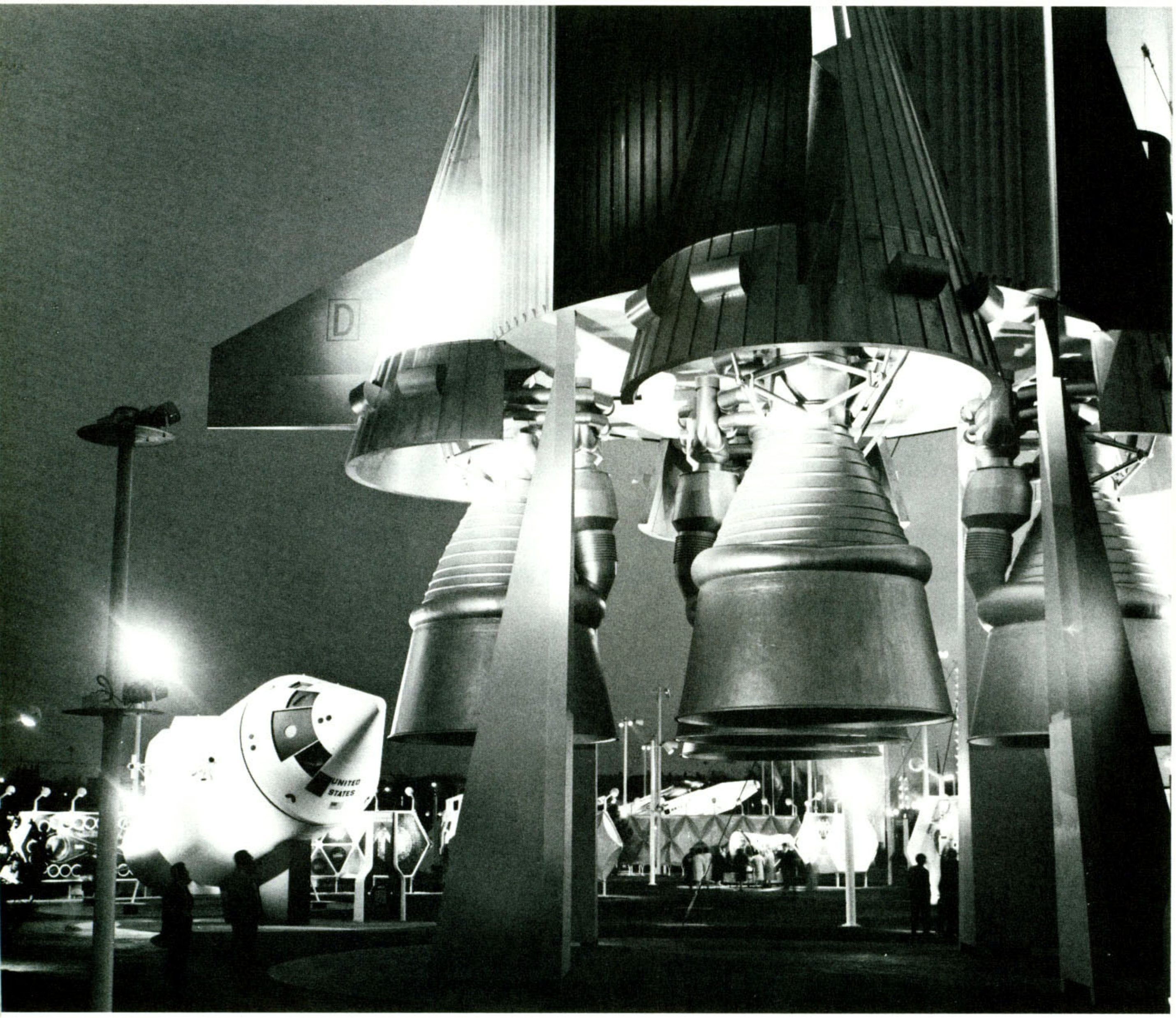


PHOTO BY PETER A. LEAVENS

A major feature of the New York World's Fair is the two-acre United States Space Park which includes, among other space-age hardware, the Aurora 7 that carried Astronaut Scott Carpenter on the second U.S. manned orbital flight.

The Space Park is co-sponsored by the National Aeronautics and Space Administration, the Department of Defense and the World's Fair. It includes the most imposing array of full-scale U.S. rockets and spacecraft ever assembled outside of Cape Kennedy, Florida.

Highlighting the park is a full-scale "boattail" or propulsion section of the massive Saturn V rocket which will send American astronauts to the Moon. The model stands 52 feet tall, measures 33 feet in diameter, and is the bottom section of the 282-foot tall Saturn.

Among the spacecraft shown are the Tiros and Nimbus weather satellites; Syncom, Telstar, Relay and Echo communications satellites; Explorers for near-Earth space investigation; the orbiting observatories; Rangers and Surveyors for unmanned lunar exploration, and Mariner II, the world's first successful Venus probe. Also in the group are the Canadian-built Alouette, the British Ariel I, and Discoverer XIV, the first satellite recovered from orbit by aircraft when it reentered the Earth's atmosphere.

Towering over the two-acre exhibit is a Titan II-Gemini launch vehicle and its two-man spacecraft. The Titan II booster, 110 feet high, stands with the Gemini capsule attached on top just as it will be on the launch pad at Cape Kennedy.

Surrounding the Titan II-Gemini are full-scale models of the Apollo Command and Service Modules which will carry American astronauts to the moon, the Lunar Excursion Module, and two-man Gemini spacecraft.

Other full-scale exhibits in the Park are the Atlas-Mercury and Thor-Delta rockets, an X-15 rocket-powered research aircraft and the Agena rocket.

A biosatellite spacecraft illustrates future missions to explore the effects of the space environment on animal and plant tissues.

The NERVA, or Nuclear Engine for Rocket Vehicle Application, is shown in one-quarter scale, and the SNAP-8 (Space Nuclear Auxiliary Power) is represented in one-twelfth scale. A 1/48th scale model of the Titan III C launch vehicle is also shown.

PHOTO BY PETER A. LEAVENS

TITAN LAUNCH VEHICLES

Titan II, a two-stage U.S. Air Force booster, has been chosen by the National Aeronautics and Space Administration to launch the Gemini two-man spacecraft. Its first stage develops about 430,000 pounds of thrust at sea level. The second stage develops about 100,000 pounds of thrust at altitude. Titan II stands 90 feet tall and can place a spacecraft weighing about 7,000 pounds into orbit around the Earth. It is 10 feet in diameter and uses storable liquid propellants that burn on contact with each other. Thus the Gemini launch vehicle can be fueled well ahead of launch and need not be drained if a launch is postponed.

Modifications of Titan II for the Gemini program include development of a malfunction detection system, duplication of vital systems, and increased astronaut control of the vehicle.

A full scale model of Titan II with a Gemini spacecraft mounted on top, 110 feet tall, is on display in the U.S. Space Park.

Titan III is under development as a standard space launch system and part of the National Launch Vehicle Program. It is the first launch system developed by the Air Force from the outset as a space booster. Capable of performing a variety of manned and unmanned space missions in the next decade, Titan III, in its "C" configuration, is a three-stage, 103-foot-tall vehicle developing about 2.5 million pounds of thrust.

Titan III is based on Titan II, modified principally by strapping two large solid-fuel rockets to its sides and adding a liquid-propellant third stage. It will be able to place 5,000 to 25,000-pound payloads in low altitude orbits, 10 tons in a 100-nautical-mile orbit, or 13,000 pounds in a 1,000-nautical-mile orbit.

It will be used to launch the Air Force Manned Orbiting Laboratory (MOL).

PROJECT GEMINI

The next major step after Mercury in the United States manned space flight program is Project Gemini. This project's goals are:

To determine man's performance and behavior during orbital flights for as long as two weeks;

To develop and perfect techniques for orbital rendezvous and docking, the bringing together and coupling of craft in orbit;

To carry out scientific investigations of space that require participation and supervision of men aboard a spacecraft.

The Department of Defense and NASA have agreed on joint arrangements for the planning of experiments, the conduct of flight tests, and the analysis and dissemination of results.

The two-man Gemini spacecraft externally resembles the Mercury spacecraft. It is 1½ feet wider than Mercury at the base and lengthened proportionately. It provides about 50 percent more cabin space than Mercury and weighs about 7,000 pounds. Two men will pilot the Gemini spacecraft.

Gemini components will be outside the crew compartments and arranged in easily removable units, thereby facilitating check-out and maintenance.

Included in Gemini equipment are docking apparatus for coupling with another vehicle in space; a life support system for maintaining pressure, temperature, and atmospheric composition of the crew cabin; instruments to collect, transmit, and record data on conditions of the spacecraft and astronauts; guidance and controls systems operating in conjunction with a computer to aid in navigation, rendezvous with another craft, entering Earth's atmosphere, and landing; radar to aid in rendezvous operations; and a landing and recovery system including a small parachute to stabilize the craft, the paraglider mechanism, landing gear, and recovery aids such as tracking beacons, flashing lights, and two-way voice radios.

Ejection Seats—Gemini will have no escape tower. Instead, each astronaut will have an ejection seat (similar to that used in a fighter aircraft) for escape during launch or for emergencies in the recovery phase.

Adapter Section—The two-piece adapter section is attached to the heat shield at Gemini's base. The adapter section is 7½ feet in diameter at the top, 7½ feet long, and 10 feet in diameter at its base. It weighs about 2,200 pounds. It is made up of the equipment and retrograde modules. As an aid in distinguishing the Gemini parts, the crew section has been designated the re-entry module.

The equipment module contains fuel, fuel cells, oxygen for breath-

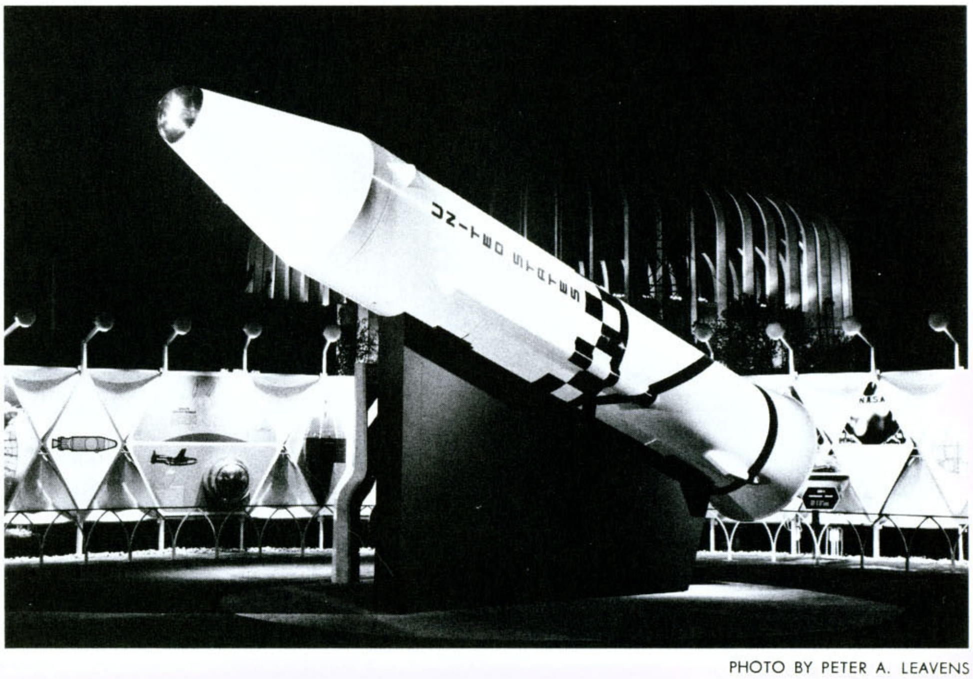


PHOTO BY PETER A. LEAVENS

ing, and a propulsion system for orbital attitude control (orientation) and maneuvers. The retrograde module, sandwiched between the equipment and re-entry modules, contains the braking rockets that decelerate Gemini and enable it to descend from orbit. It also contains a propulsion system to aid in orienting and maneuvering the craft.

The astronauts jettison the equipment module during preparation for return to Earth. They discard the retrograde module just before entry into the atmosphere.

To Land Like An Airplane—Gemini flights will employ parachutes for landing. In later flights the parachutes may be replaced by a 45-foot wide wedge-shaped paraglider.

The paraglider will be part of the equipment of the re-entry module, the only part of Gemini designed to return to Earth. The device, deployed at about 40,000 feet, will enable the astronauts to maneuver the module to any desired landing point within a 20-mile radius.

ORBITAL RENDEZVOUS

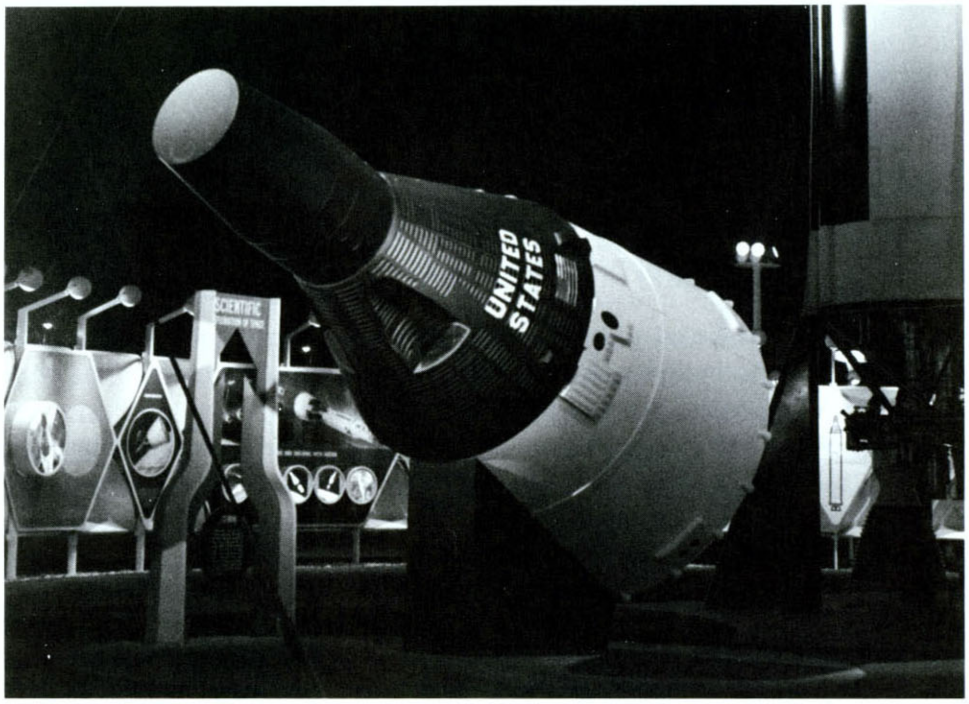
Phase 1—Launch and Insertion Into Orbit—In the Gemini orbital rendezvous mission, an Atlas will first launch an Agena rocket, modified to link up with the Gemini spacecraft, into a near-circular orbit. Ground stations will track Agena and determine the best time to launch Gemini. Later, a Titan II will propel Gemini into an elongated orbit with an altitude generally lower than that of Agena but with apogee (highest altitude) at the same altitude of the Agena orbit.

Because its altitude is lower, Gemini will be able to circle the Earth more quickly than Agena and gradually overtake the rocket. When the two are most favorably located relative to each other, a Gemini rocket will be fired to increase Gemini's speed and to thrust the spacecraft into a circular orbit almost identical with that of Agena.

Phase 2—Closing—As soon as Gemini's radar acquires Agena, the so-called closing phase of rendezvous begins. Radar information is fed into Gemini's computer which tells the pilots which rockets to fire and when and how long they must operate them to keep the craft stabilized and gain on their target. When the two craft are about 20 miles apart, the astronauts are expected to sight Agena and supplement radar information with visual observation. A high-intensity flashing light on Agena will help the astronauts keep their target in sight. By the end of the closing phase, Gemini and Agena will be 10 to 100 feet apart and traveling in the same orbit.

Phase 3—Docking—The final phase of rendezvous is docking, the link-up of the two vehicles. In this phase, much of the sensing, computing, and decision requirements are within the capability of man. Using visual observation, the astronauts will carefully maneuver Gemini into contact with Agena. They are aided by an aiming bar on the Gemini spacecraft and a notch in the rocket's receiving cone.

As they near their target, the astronauts must reduce the relative



velocities between the two craft to less than 1½ miles per hour, although both are whirling around the Earth at about 18,000 miles per hour. Moreover, they must align the conical nose of their craft with the docking socket of the Agena.

They will accomplish this by using the attitude controls to pitch Gemini (move its nose up or down), yaw the craft (turn its nose to the right or left), or roll it around the long axis, as conditions demand.

Docking will be accomplished when the cone-shaped nose of Gemini is gently nudged into the matching slot of the Agena. Coupling of the craft will be automatic, and the astronauts will be able to operate the joined vehicles as a single unit, adding the Agena's propulsion system to that of the Gemini spacecraft.

At the conclusion of their mission, the astronauts will detach Agena and jettison the equipment module. Then, they will turn the spacecraft around, fire the retrorockets to slow down and descend to Earth, and discard the retrograde module.

Gemini Crew May Step Out Into Space—During advanced stages of the Gemini program, its pressure-suited crew may open the hatches and emerge from the spacecraft while in orbit. Moreover, they may push themselves from the craft, and appear to float in space as they speed around the Earth at about 18,000 miles per hour. For this operation, they will be tethered to the craft to insure their return. Gemini will store sufficient oxygen to re-fill its cabin when the astronauts return.

This experiment will help pave the way for future operations in which man can make repairs, assemble orbiting stations, and perform other functions in space.

SATURN PROJECT FACT SHEET

Three heavy space vehicles are being developed by the National Aeronautics and Space Administration under the project name "Saturn." The Saturn project is providing vehicles capable of sending payloads of many tons into Earth orbit, to the Moon and into deep space. The main purpose of the project is manned space exploration, including the landing of men and equipment on the Moon within this decade. The Saturn development program is under the direction of the National Aeronautics and Space Administration.

The smallest vehicle, Saturn I, has a booster developing 1.5 million pounds thrust. This development program was started in late 1958. The initial Saturn I booster with inert upper stages was launched on a perfect flight over the Atlantic Missile Range Oct. 27, 1961. The second, third and fourth launchings, on April 25, and Nov. 16, 1962, March 28, 1963 and Jan. 29, 1964 were likewise successful.

The largest Saturn vehicle, Saturn V, will have a booster of 7.5 million pounds thrust. The program was initiated in January, 1962.

In addition to these two basic Saturn vehicles, the Saturn IB will be used. The IB will consist of the first stage of the Saturn I and the third stage of the Saturn V. The IB will be capable of delivering 16 tons to low Earth orbit, compared to 11 tons for the Saturn I. Both will be used in early phases of the Apollo program, while the Saturn V will be used for the Moon landing.

All Saturn boosters or first stages use as propellants RP-1 (kerosene) and liquid oxygen, whereas all upper stages use the high energy combination of liquid hydrogen and liquid oxygen.

Saturn I consists of two stages, S-I and S-IV. There is a 10-vehicle research and development flight test program. In the first four, only the booster was "live." In the remaining ones, the booster (S-I) and the second stage (S-IV) are live. The first live upper stage launch was made on January 29, 1964, successfully placing in orbit the spent second stage and inert ballast weighing a total of 37,700 pounds. The second live launch was made on May 26, 1964.

The initial Saturn I test rocket weighed about 925,000 pounds when fueled. The later Saturn I, with a live second stage and Apollo payload, weighed 1,130,000 pounds. The vehicle placed a boiler plate Apollo spacecraft into low Earth orbit in preparation for the lunar voyages that will follow. Its Earth orbital capability is about 22,000 pounds.

Following are descriptions of the Saturn I stages:

S-I: The Saturn I first stage or booster, called S-I, is powered by a cluster of eight H-1 engines, each of which produces 188,000 pounds of thrust to give a total of 1,500,000 pounds, or 32,000,000 horsepower. The booster is 21½ feet in diameter and 82 feet in length. Empty weight is slightly less than 100,000 pounds.

The H-1 engine, an advanced and compact offspring of the Jupiter and Thor engine, was selected because of its relative simplicity, early availability, and proven reliability. It burns RP-1 kerosene fuel and liquid oxygen.

S-IV: The second stage of the Saturn I vehicle, known as S-IV, is powered by six RL-10 engines, each having 15,000 pounds thrust. This is the same engine that is used for the Centaur space vehicle.

The S-IV stage is 18 feet in diameter and about 40 feet in length, with propellant capacity of 100,000 pounds. Since this stage uses the super-cold fuel, liquid hydrogen, the design includes many innovations.

The Saturn V consists of three stages, the first stage having 7.5 million pounds thrust—five times more than the Saturn I first stage. The vehicle will be capable of placing about 120 tons in Earth orbit and sending about 45 tons to the vicinity of the Moon. The rocket will weigh more than six million pounds at liftoff.

Following is a description of the Saturn V stages:

S-IC: The Saturn V booster, or S-IC stage, is approximately 138 feet in length and 33 feet in diameter. The basic configuration will be cylindrical, with separate propellant tanks. Suction lines from the forward liquid oxygen tank will pass through tunnels in the fuel tank to the engine. Dry weight of the stage will be about 280,000 pounds, with a propellant capacity of about 4,400,000 pounds.

Structural configuration for the stage propellant tanks will be an all-welded assembly of cylindrical ring segments with dome-shaped bulkheads. Both propellant tanks will include slosh baffles over the full depth of the liquids.

The propulsion system will use five F-1 engines for a total thrust of 7,500,000 pounds. The F-1, under development for NASA, has been static fired at full thrust (1.5 million pounds) for full flight duration (about 2½ minutes). The first production engine is scheduled for delivery in 1964.

S-II: The second, S-II stage will measure about 82 feet long and 33 feet in diameter and have a propellant capacity of 930,0000 pounds. The basic configuration will be cylindrical, with an insulated common bulkhead separating the liquid oxygen tank and forward hydrogen tank.

The propulsion system will use five J-2 engines, providing a total of 1,000,0000 pounds thrust.

Four engines will be placed in a square pattern, with the fifth engine rigidly fixed in the center.

S-IVB: The third stage for the Saturn V configuration will be identified as the S-IVB stage which measures about 21½ feet in diameter and about 58 feet in length. The tankage is sized for about 230,000 pounds of propellant for orbital operations, which includes an allowance for boil-off and power during orbital coast.

One J-2 engine, providing about 200,000 pounds of thrust at altitude, will be gimbaled for pitch and yaw control. Auxiliary propulsion systems provide attitude control during coast.

SATURN V THRUST STRUCTURE

Visitors to the New York World's Fair this year are treated to an upward look at the "business end" of the National Aeronautics and Space Administration's mammoth Saturn V Moon rocket.

A full-size mock-up of the thrust structure of the three-stage rocket's booster, the S-IC stage, rests on four support piers with the five huge F-1 engines 12 feet above the ground.

Fair visitors are able to walk beneath the 52-foot-tall structure and gaze upward into the nozzles of the 10-ton engines, which will give the real Saturn V booster a total thrust of 7.5 million pounds.

A complete booster will be 138 feet tall and 33 feet in diameter. With all three stages assembled and the Apollo spacecraft mounted atop, the Saturn V will tower some 360 feet into the sky.

The Saturn V is being developed as the vehicle which will send the Apollo spacecraft and three astronauts to the Moon before 1970.

At the base of the exhibit is an Apollo Command Module to show visitors how the three astronauts will ride to the Moon, and a Lunar Excursion Module, the vehicle known as the "bug" which will lower two astronauts from lunar orbit to the Moon's surface.

The Command Module, Lunar Excursion Module and a third section, the Service Module, containing instrumentation and a propulsion system, make up the Apollo spacecraft.

APOLLO

Liftoff—The trip to the Moon will start at Cape Kennedy, Fla., when the Saturn V rises from the launch pad. The booster, or S-1C stage, drops away after burning and cutoff. The escape tower is discarded after second stage ignition.

The second stage is also separated after burnout. A partial burn of the single J-2 engine in the third, or S-IVB, stage is necessary to place this stage and the Apollo Spacecraft into a "parking" Earth orbit.

Injection Into Lunar Trajectory—At least 1½ revolutions around the Earth will be required to reach the proper launch "window" (most direct line toward the Moon), to check out the spacecraft, and to determine that everything is ready to commit the spacecraft to the mission. When the decision is made to go, the third stage engine will be ignited again to reach the escape velocity of about 25,000 miles an hour.

Apollo Spacecraft—The Apollo Spacecraft has three major parts. The Command Module carries the crew, plus guidance and control instrumentation. The Command Module will weigh about five tons and measure 12 feet high. The Service Module, containing the primary spacecraft propulsion elements, will weigh about 23 tons and measure 23 feet high. The third element is the Lunar Excursion Module, or "Bug." It will weigh about 15 tons and stand about 20 feet tall. In addition to its scientific instruments, communications, and guidance systems, the Bug will carry two astronauts to and from the lunar surface and the orbiting Command-Service modules.

When the proper Earth-to-Moon trajectory has been established, fairings which have shielded the Bug are released. The Command-Service modules are separated from the Lunar Excursion Module-third stage, and turned 180 degrees, then mated nose-to-nose with the Bug. This will be done by "flying" the Command-Service Module to its re-oriented position through attitude control. After this maneuver the third stage is jettisoned.

The crew makes navigation checks by taking bearings on the Earth, Moon, and stars, and corrects the spacecraft's course, if necessary. The pull of Earth's gravity will slow the vehicle's speed to about 6,500 miles an hour after one day, and 1,500 miles an hour after two days. As the Moon looms nearer, its gravitational pull becomes stronger, and the craft begins to fall toward the Moon, gaining velocity.

Entering Lunar Orbit—A number of mid-course maneuvers may be required to place the spacecraft into position for braking into a precise, circular lunar orbit. Approximately 72 hours after liftoff, the Service Module propulsion unit will ignite, slowing the entire spacecraft into a precise circular orbit about 60 miles above the Moon.

Entering Landing Ellipse and Landing—After preparing the Bug for descent to the lunar surface, the two lunar explorers will transfer to the Bug through the hatch at the connecting point of the two vehicles. Once they are transferred, the Bug will separate from the Command-Service modules, which will remain in lunar orbit.

The Bug's propulsion system will place the two-man ship into a trajectory having the same period as the Command-Service Modules but with a lower perigee of approximately 60,000 feet. This low perigee permits a close examination of the intended landing site. It also enables the Bug and the mother ship to come closely together twice during each orbit. This would be a natural position for rendezvous if for any reason the situation calls for an aborted mission.

After a carefully blended combination of manual control and automatic system operation, retro-maneuver will be executed, bringing the Bug out of lunar orbit. It drops to within 100 feet of the Moon.

The explorers will be aided by maps, reconnaissance data and possibly a previously landed beacon. The Bug can maneuver laterally 1,000 feet to get in the best possible position of lunar touchdown. Descent to the surface is probably the most critical phase of the entire operation. Fortunately, the Bug will be small and will be designed specifically for landing, rather than for both landing and re-entry.

The Bug will have a reasonable amount of glass area so that the landing maneuver can be under visual control of the two astronauts. During the landing maneuver, the Command-Service Module with the one astronaut aboard will always be in line of sight and radio communication with the Bug.

Once lunar touchdown has been completed, and before taking any other action, the two explorers will prepare for re-launching. They will be assisted by the astronaut in the mother ship and information transmitted from Earth.

Lunar Exploration—When the first astronaut steps from the Bug and sets foot on the Moon, it will transcend in significance the moment of discovery of continents or oceans here on Earth. Manned exploration of the Moon is a logical extension of unmanned lunar exploration. Man's judgment and ability to make unscheduled observations make him a valuable means for gathering information. Much of the lunar exploration will be geologic in nature. It will include mapping, photography, observation of surface characteristics, core and surface sampling, seismic measurements, and radiation measurements. The Bug will carry about 200 pounds of equipment for this purpose.

Lunar Liftoff—Once the decision has been made to re-launch the Bug, the crew will fire the launching engine at a precisely determined instant while the mother ship is within line of sight. The landing stage in effect becomes a launch pad, a "Lunar Kennedy," and such items as fuel tanks for landing gear itself will be left on the lunar surface.

Lunar Orbit Rendezvous—At liftoff the Bug's engine propels the module up a trajectory which enables it to rendezvous with the mother ship. During the ascent maneuver, there will be radar and visual contact between the Lunar Excursion Module and the Command-Service Module. A flashing light on the mother ship will aid visual acquisition. When Bug and mother craft are about three miles apart, the Bug will re-orient itself, coming into the correct position for nose-to-nose rendezvous with the mother craft. When the two are joined, the Lunar Excursion Module crew will transfer into the Command Module, and the Bug will be detached and abandoned in lunar orbit.

The Return—After the Command and Service Modules are thoroughly checked out, the Service Module, with a 20,000 pound thrust engine, will provide the propulsion to break out of lunar orbit and onto the proper return trajectory. Mid-course correction is made, if necessary, using the propulsion system in the Service Module.

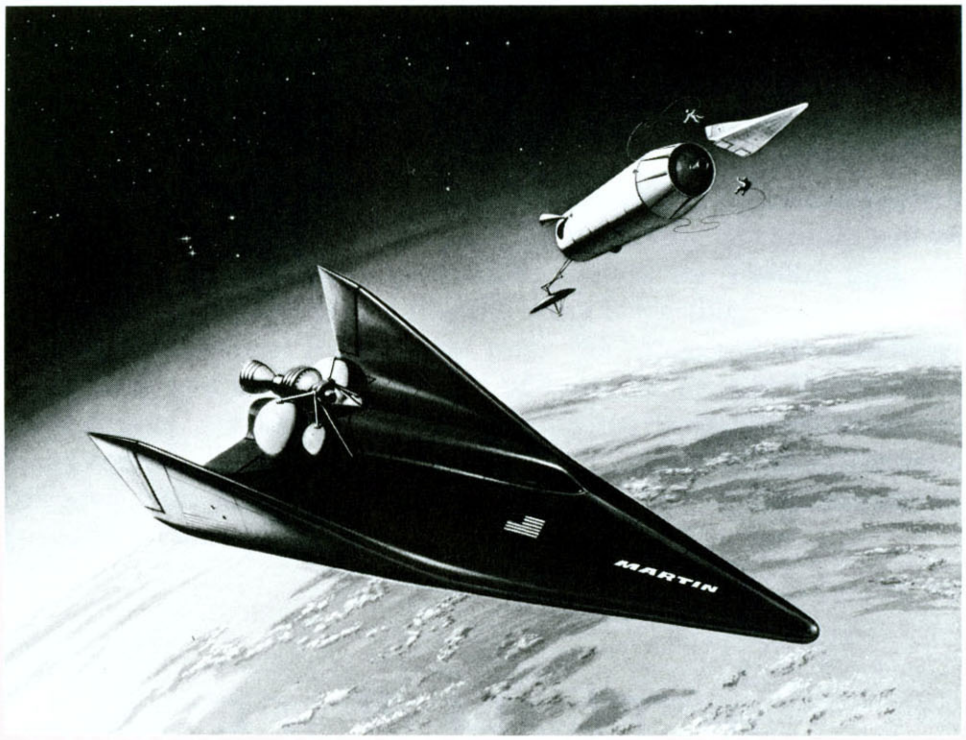
On return to the Earth, a very precise trajectory must be flown to bring the spacecraft into position for a 25,000 mile-per-hour re-entry. Too shallow an approach and the Earth is missed entirely; too steep an approach and the spacecraft plunges directly into the atmosphere. The re-entry corridor is only 40 miles wide, yet must not be missed from a distance of 250,000 miles away. (In comparison, this is like a rifleman with a .22 standing at one end of a football field and hitting a nickel at the other, with both rifleman and nickel moving.)

Just before entering the Earth's atmosphere the Service Module is jettisoned and the five-ton Command Module, containing the three crewmen, turns around, facing its blunt end forward. The angle of attack at re-entry will be about 30 degrees. Heating rates several times those experienced during Project Mercury may be encountered. NASA is hopeful that, by the first Apollo flight, it will be able to overcome the ionization problem and retain spacecraft communication throughout re-entry.

Drogue chutes will be deployed at 50,000 feet. Pressure and friction of the atmosphere slow the module. Final braking of capsule will be by three 85-foot-diameter parachutes, unless the Gemini program proves that a paraglider or a Rogallo wing is feasible.

Radar and optical instruments track the capsule to the predesignated landing area. The astronauts will aim for an area the size of a large airport. A number of sites in the United States plains states are being considered by the Manned Spacecraft Center, which is seeking a flat area with generally good visibility and few of the restrictions posed by a dense population.

III. *The Hall of Science*



RENDEZVOUS IN SPACE

Exhibit by the Martin-Marietta Company in New York City's Hall of Science

The City of New York has appropriated monies to build a permanent Museum of Science and Technology in the Transportation Area of the Fair Site.

In the Great Hall of the building, Martin-Marietta Corporation will provide a majestic ten-minute show in which 400 visitors at a time will be introduced to the story of science and man's search for knowledge. The audience will be engulfed from all sides with light and color and sound in a presentation that will lead from the beginnings of science up to the new experiences that await man in his first step into outer space. It will be climaxed by a demonstration of "*Rendezvous in Space*," employing two full-sized manned orbital space vehicles. The meeting "in space" takes place high above the heads of visitors in the cathedral-like Main Floor. The production includes wide screen motion pictures, directional sound, and animated figures.

SOME OF THE SCIENTIFIC ASPECTS OF A NATIONAL ORBITAL SPACE STATION—(NOSS)

(Martin-Marietta)

The full-scale model of NOSS is based on advanced space vehicles that Martin-Marietta has developed and is still developing. The feasibility is established; such an orbital space station could be built and launched into space within the next decade.

The name NOSS derives from the name of this project, "National Orbital Space Station." The orbital laboratory makes it possible to gather facts that are accessible only to a scientist living in space, and also to gather more precise information about the lethal environment encountered during prolonged periods of space travel.

NOSS is designed for a useful 10-year life in orbit. It completes one orbit of earth every ninety-six minutes (equivalent to a speed of more than 18,000 miles per hour), at an approximate altitude of 350 miles and at an inclination to the equator of 28½ degrees.

Basically, NOSS is a pressurized and double-walled aluminum cylinder, the ends of which are capped with elliptical pressure domes. At the end of the station, but not shown here, is a rendezvous vehicle adapter—a device through which a space ferry or space taxi can put aboard supplies and replacement crews.

At the opposite end, trailing the NOSS laboratory on long booms, are two nuclear power reactors. These shielded reactors provide power for operating the entire space laboratory.

The concept envisions launching the NOSS laboratory vehicle without crew on board. The station could be lifted into its desired orbit by an uprated Titan II, an Intercontinental Ballistic Missile that would be adaptable as a workhorse space booster.

Once NOSS attains the planned orbit, crews and supplies are transported to the space laboratory via smaller "taxi" vehicles—somewhat similar to DYNA-SOAR, a manned controlled space glider for which a modified Titan II has been designated as the booster.

The outer skin of the laboratory is corrugated aluminum, thirty-two thousandths of an inch thick, providing a thermal and meteoritic shield. The aluminum inner skin, fifty-thousandths of an inch thick, provides a constant pressure wall and the structure for the mounting interior equipment. The two walls are separated by insulation, which also encloses a warning system to detect impact of meteorites. This same structure provides protection against excessive radiation.

THE DESIGN OF NOSS. The NOSS space laboratory is the equivalent of a luxury trailer in size. Fully equipped it weighs about 29,000 pounds. It is 41 feet long, 15 feet in diameter, and divided into four separate compartments. Each is capable of supporting internal pressure to minimize the principal hazard to human life in space—an inadvertent loss of life sustaining atmosphere.

Safety and human factors have been given prime consideration, based on extensive knowledge gained in current astronautical missions. Continuous televised viewing of all compartments by any crew man is made possible for the purpose of master warning as well as for monitoring laboratory activities. Duplication of key electrical and mechanical systems is provided. The control system of the interior compartments is selected to minimize human fatigue and encourage well-being. The green floor and blue sky ceiling also provide a reference for the "where's up?" feeling associated with weightlessness.

Escape provisions in NOSS are provided by interlocking rescue hatches at the intersection of the four compartments. The enclosure provides air-lock access to the compartments as well as a supply of emergency space suits, food and equipment to sustain the five man crew for several days, while they await an earth launched rescue vehicle.

Compartment 1 houses engineering test laboratories, containing equipment for a wide variety of tests in zero gravity—commonly referred to as weightlessness. Among its potential uses: tests on structures and materials; observation of the earth and the space around it in greater detail and over longer time periods than ever before; and the recording of these data. Also in this compartment is the environmental control system.

Compartment 2 is, in effect, the space bedroom. It contains sleeping facilities, storage space for the crew's personal belongings, personal toilet equipment, and laundry facilities.

Compartment 3, housing the feeding and recreation and biological laboratories, is the most vital portion of NOSS. Here man becomes not only the experimenter but also the experiment. The importance of man in this vehicle is that his ability to judge, correct, analyze and synthesize data cannot be replaced by tons of complicated electronic equipment. Herein lies the answer to the question: Why send man, instead of a "black box" into space?

Compartment 4 is the station control and maintenance center, where the nerve ends of the station all come together. Here are such things as the guidance and control system panels, and electronic consoles to monitor, test and maintain and repair NOSS equipment. Radiation sensors both inside and outside the laboratory are provided and meteorite impact sensors, beneath the outer hull of the station, connect with electronic monitoring equipment inside the laboratory. An elaborate master warning and intercom network for the crew, and an earth to space communications network are also included, together with the space laboratory's tapes and computers. These store scientific data, which are transmitted back to earth.

LIVING IN A SPACE LABORATORY. At 350 miles above the surface of the earth, five men live and work in a controlled environment.

Temperature inside NOSS is kept at 72 degrees and at a relative humidity varying between 30 and 50 percent. This means that the living conditions in NOSS are considerably more comfortable than in Washington, D.C., or New York City on a muggy summer day.

This atmosphere is circulated through all compartments at a rate suitable to control heat, water vapor, carbon dioxide and oxygen exchange, and to force the elimination of toxic and foreign particles which could accumulate within the space station. Such a highly developed environmental control is calculated to give a healthy atmosphere for the five crewmen for tours of duty of 30 to 90 days. Their working and resting activities are also scheduled for maximum efficiency and minimum fatigue. New crews and fresh supplies are put aboard NOSS at necessary intervals.

The crew's movements are free and unhampered, despite the weightless condition. Crewmen wear normal laboratory working clothes, except for special shoes coated with Velcro, a nylon fabric woven into hundreds of tiny loops designed to adhere to the floor surfaces, which are covered with a rough-woven cloth. This adhesion of shoe to floor resembles the action of a burr caught on clothing, and prevents the crewmen from floating about the cabin in their state of weightlessness. The material is manufactured by the Velcro Corporation-Hartwell Corporation.

To help maintain good physical condition, dual purpose exercise equipment is installed in NOSS. One such device is a treadmill that provides exercise for the crewmen who, while they are using it, also turn generators that replenish the auxiliary battery supplies. A magnetic table is equipped for card games and chess.

The space bedroom is designed for convenience and safety in a weightless environment. Since no more than three of the five crew members are off duty at the same time, only three bunks are provided. Each crewman has a sleeping bag which is clipped to the bunk when in use. Once the bag is snapped into position, the crewman climbs into it and zips himself in. Chairs with special provision for retaining crewmen in a comfortable, weightless position are also provided. These chairs have been developed by Aircraft Mechanics Inc.

The scientific crews that serve on NOSS put themselves through tests that cannot be reproduced on earth. These tests involve problems mainly deriving from the effects of weightlessness on human dexterity, movement, general physiology, and work activities. In this environment bio-medical measurements can be made of metabolic rate, respiratory exchange, blood chemistry, circulation, vision, endocrine balance, neuromuscular reflexes, digestion, and liver and kidney functions.

The space station environment also contributes immeasurably to information on the biological effects of radiation on man.

Data derived from these experiments form a base for man's next step toward wresting more secrets from the universe—such as landing successfully and safely for a prolonged stay on the moon, and making deeper space probes and explorations.

UNITED STATES ATOMIC ENERGY COMMISSION
Oak Ridge, Tennessee

AEC Exhibit at New York World's Fair Will Feature Children's Display

Young visitors at the 1964 World's Fair in New York City will receive special attention in a section of the Atomic Energy Commission's exhibit which introduces the principles of atomic science to the youngsters as they operate interesting new science-educational devices.

This children's section, called "*Atomsville, USA*," is designed to appeal to youngsters between the ages of 7 and 14. The rest of the exhibit, titled "*Radiation and Man*," is also devoted to explaining principles of nuclear science, but for older students and adults. It includes other new educational displays and a large percentage of audience-participation devices.

The AEC exhibit, occupying 3,500 square feet in the Hall of Science, is a part of the Commission's continuing public education effort which includes a program of exhibits for the entire country. The

World's Fair exhibit was designed and fabricated by the Oak Ridge (Tennessee) Institute of Nuclear Studies, the contractor which operates the Commission's national exhibits program under the direction of the AEC's Division of Technical Information.

The "*Atomsville*" exhibit poses a number of questions about atomic energy which are answered when the youngsters press buttons, push levers and otherwise activate various displays.

Adults are able to observe the children in "*Atomsville*" on closed-circuit television or through one-way glass portholes. Photographs can be made through these portholes.

One of the chief displays is a simulated pool-type research reactor to demonstrate the characteristic bluish-white glow from Cerenkov radiation, charged particles passing through the water. Children are invited to manipulate the controls to "operate" the reactor while listening to a tape-recorded explanation of the science involved in terms they can understand. If they bring the simulated reactor up to power too fast, it will "scram" (shutdown), as would a real reactor.

There will be mechanical hands for handling make-believe radioactive materials. This operation teaches the children about shielding for protection from radiation.

Other special devices in the children's exhibit include a control board at which the young visitors may create patterns of different atoms; an atomic model viewed through a small aperture which gives the impression that the viewer is actually inside matter; a "pinball" machine to demonstrate the effect of shooting a neutron into a uranium-235 nucleus; and an "atomic scale" on which a child can read his weight in atoms.

The children's exhibit also includes such items as an oscilloscope, a Geiger counter which youngsters may use to check the presence of radiation, an electroscope, a thermal electric display, and a graphic representation of the processes involved in the production of uranium.

The "*Radiation and Man*" section of the AEC exhibit also covers highlights of the basic science of nuclear energy, with emphasis on the effects of radiation on living tissue.

This exhibit includes animated devices that demonstrate such things as how radiation falls off with increasing distances, how radioactivity decays with time, and what happens when a person is X-rayed.

A "*Radiation in Perspective*" display compares the amount of radiation in natural background to which people are exposed all the time with that from watch dials, X-ray machines and other sources.

The "*Radiation and Man*" exhibit includes an electroscope unit which visitors can charge and discharge by various means.

A feature of the exhibit is a motion picture projected from overhead to give a 360-degree image on a horizontal, bowl-shaped screen below. This film shows the tracks of subatomic particles as they appear in cloud chambers, bubble chambers and spark chambers.

There is also a short motion picture on power reactor installations.

THE ATOM

by William L. Laurence

The world of the atom is so fantastic that it requires a complete readjustment in our concepts of space and time.

Atoms are so small that if a drop of water were magnified to the size of the earth the atoms in the drop would be smaller than oranges.

One drop of water is made up of some 6,000 billion billion (6,000,000,000,000,000,000,000) atoms of hydrogen and oxygen, of which 4,000 billion billion are hydrogen atoms.

Yet the atom has a structure analogous to our solar system. In its inconceivably minute center—less than a trillionth of a centimeter in radius—is a relatively gigantic "sun," the atom's nucleus. Around this atomic "sun" revolve tiny "planets" in definite preordained orbits, with the same regularity and obedience to immutable laws as our earth and the other planets revolve around our sun.

The nucleus of the atom is composed of the two fundamental building blocks of the universe, protons and neutrons. Since the two are interchangeable, one into the other, they are known under a common name, the nucleons. When excited, a proton may become a neutron, or a neutron may be transmuted by nature's alchemy into a proton.

On the atomic scale, protons and neutrons have a mass of one atomic unit each. For example, the hydrogen atom, the nucleus of which consists of only one proton, has an atomic mass of one. The helium atom, with a nucleus of two protons and two neutrons, has an atomic mass of four. A twin, or isotope, of hydrogen, known as heavy hydrogen, or deuterium, the nucleus of which consists of one proton and one neutron, has an atomic mass of two, while a third form of hydrogen, named tritium, with a nucleus of one proton and two neutrons, has an atomic mass of three.

An isotope is thus a variant of the same element, in which the number of protons always remains the same, the only difference being the number of neutrons in the nucleus.

The "planets" revolving in their predetermined orbits around the "sun" in the nucleus are the electrons, entities so infinitesimally minute that it would take nearly 2,000 electrons to balance the scale against just one proton or one neutron. It is this bit of almost nothing, the smallest material entity in the universe, that has made possible radio, television, talking motion pictures, the electron microscope, the giant calculating machines that solve in seconds complex mathematical problems that would require years to solve by the most brilliant of human mathematicians, and the thousand and one other automatic devices that have become commonplace in everyday life.

In fact, as its name implies, it is the electron that has made electricity possible, though electricity has been known for more than 2,500 years and has been harnessed for the uses of man for nearly a century before the electron was discovered in 1897. A current of electricity, as we know today, is the flow of electrons in a suitable conductor.

Both the electron and the proton carry a fundamental unit of electric charge. The quantity of the charge in each is exactly the same, differing, however, in sign, the charge in the proton being a charge of positive electricity, whereas the electric charge of the electron is negative. It is the smallest electric charge in nature, the "atom of electricity," one of the fundamental constants of the cosmos.

A fifty-watt electric-light bulb uses up in one second a quantity of electricity equal to the charge carried by three billion billion electrons, that is, three billion billion atoms of electricity.

The neutron is the only normal constituent of the nucleus that does not carry an electric charge. Being electrically neutral, as its name implies, it is the most penetrating particle in nature.

It is this ability of the neutron to penetrate the heavy electrical barrier guarding the nuclei of atoms that has provided man with the key to the atom's nucleus and, in the case of uranium 235, has enabled him to split it in halves. It was the neutron, as we already know, that made possible the atomic age.

NEW DIMENSIONS IN SPACE AND TIME

In the atomic world, and particularly in the nucleus, a millionth of a second is a very long time, a billionth of an inch is something very, very long, and a trillionth of a gram is a mass of great weight.

If there be any doubting Thomases around let them consider Hiroshima and Nagasaki and the Pacific island that was blown off the map, for none of these would have happened were it not for precise measurements in terms of fractions of a millionth of a second and billionths of an inch and trillionths of a gram.

We had better be more at home in these new dimensions, for on our knowledge of them greatly depends the shape of things to come.

The radius of the electron, believe it or not, is one tenth of a trillionth of a centimeter, which is about the smallest length known in nature. Its mass is less than one billionth of a billionth of a billionth of a gram. In that one drop of water mentioned earlier there are 20,000 billion billion electrons, 20,000 billion billion protons and 16,000 billion billion neutrons.

And although the mass of the proton and of the neutron is nearly two thousand times that of the electron (actually 1,838 times) their radius is of about the same order as that of the electron. It would take 600,000 billion billion protons or neutrons to make up the weight of one gram. But it would take more than 1.1 billion billion billion electrons to make up the same quantity.

The Alice-through-the-Looking-Glass world of the atom becomes increasingly fantastic as one enters further into the realm of the nucleus. The radius of the atom is one one-hundred millionth of a centimeter, whereas the radius of the nuclei of the naturally occurring elements ranges from fifteen hundredths of a trillionth of a centimeter for the nucleus of common hydrogen, the first and lightest of the natural elements, to nine tenths of a trillionth of a centimeter for uranium, the last and heaviest of the elements.

This means that the volume occupied by the nucleus is about one-trillionth the volume occupied by the atom as a whole. Which is another way of saying that the atom as a whole consists mostly of empty space, the void in it accounting for 999,999,999,999 parts of the total space occupied by it.

It is this great void that surrounds the forces that could shatter the world of men or "remold it nearer to the Heart's Desire."

Since the matter in the nucleus of the atom occupies but a trillionth of the atom's total space, and since more than 99.98 per cent of the mass of the atom is concentrated in that infinitesimal space of the nucleus, it becomes obvious that the density of matter in the nucleus must be of staggering dimensions.

And, indeed, so it is. The density of matter in the nuclei of atoms is 240 trillion grams per cubic centimeter, as compared with water, the density of which is just one gram per cubic centimeter.

One dime, if its atoms were as densely packed as the protons and neutrons in the nuclei of its silver atoms, would weigh 600 million tons rather than its actual weight of 2.5 grams. At the current rate of 90.5 cents per fine ounce of silver the dime would be worth more than 13 trillion, 32 billion dollars.

The forces within the nucleus holding its particles together are equally staggering. This becomes self-evident when one considers the nature of the electrical charges present.

As everyone knows, like electrical charges repel each other with a force that varies inversely as the square of the distance, the closer the charges the greater the force of repulsion.

Since the distance between the positively charged protons in the nucleus is measured in terms of a tenth of a trillionth of a centimeter, the electrical repulsion force between them, known as the coulomb force, is tremendous. Frederick Soddy, British physicist who won the Nobel Prize for experiments that proved the existence of the atomic twins (isotopes) has calculated that two grams (four-fifths the weight of a dime) of protons placed at the opposite poles of the earth would repel each other with a force of twenty-six tons.

If this force prevailed, all the atoms of the universe, with the exception of the hydrogen atom, which consists of only one proton, would fly apart, transforming the cosmos into one great cloud of hydrogen gas. In fact, the universe of matter, and its great aggregates of stars and galaxies, could never have come into being.

That the universe does exist is therefore absolute proof that there exists within the nuclei of atoms a tremendous force of attraction much greater than the electrical-repulsion force.

As yet we know practically nothing about this force, but we do know that it is by far the greatest in the universe, that it resides within the nucleus of the atoms, and that under certain conditions a small fraction of this force can be harnessed for use either in weapons that could push man back to the cave or as a source of great power that could open the gates to a new Promised Land.

This force is known as the nuclear force. It is the force that holds the universe together, that makes possible the Milky Way and its 100 billion giant suns, of which our sun and its satellites are but an insignificant part, and the millions upon millions of other galaxies, of dimensions of the same order as the Milky Way, in the inconceivable reaches of space.

It is the force that enables the sun to pour out in space every second an amount of energy equal to that of a dozen quadrillion tons of coal, in a process that has been going on for some five billion years, at a rate that will permit it to go on for at least another ten billion years.

And it is a minute portion of that radiance that falls upon our earth and gives it the climate that makes life on it possible.

THE SCIENCE OF SURVIVAL THROUGH KNOWLEDGE AND ADAPTATION

Exhibit of Office of Civilian Defense

The exhibit is intended to encourage people to understand that they can survive the dangers of Radioactive Fallout.

The story line is in three parts. Part I explains the fundamentals of radiation in nature and how civilized man applied his knowledge of it.

Part II is devoted to the Nature of Fallout, its cause and behavior.

Part III shows OCD's programs for protecting our people from fallout and for enabling them to carry on the essentials of existence while fallout is present. The School Shelter Program receives the emphasis.

Section A. **Radiation, an Expression of Energy,** serves to prepare the visitor for the later section on the nature of fallout and how we can defend ourselves from its effects. In addition to graphic representations of sources and behavior of radiant energy, this first section contains a large Wilson Cloud Chamber, permitting a number of people to observe actual cosmic rays as they pass through, or are absorbed by the chamber. Recorded voice explains what is taking place.

Section B. **The Cause and Nature of Fallout** is directly across the aisle from Section A. This area consists of a group of illustrations, graphs and animated models, some representing fallout particles greatly enlarged, the total effect of which is to prepare the viewer to understand the rationale of fallout shelters and to accept their importance to survival in case of a nuclear explosion.

Section C. **Civilization, the Art of Survival** follows Section B. It shows that intelligent men and women always have planned for survival in the event of disaster. In America, we anticipate the tornado with storm cellars; the shipwreck with life boats and a Coast Guard system; fire with thousands of local and volunteer fire departments and with fire escapes; accidents with a highly organized ambulance and hospital system. When major disasters strike, all these, plus the Red Cross, are called into action. Against the hazard of radioactive fallout, man has devised a simple and effective system of shelters which may someday save a hundred-million lives.

Section D. **The Principle of the Shelter.** This explains how knowledge of fallout behavior is applied to protect the people from injury. It shows the design principles that determine selection of material, thickness of material, and how to secure the desired distance from probable radiation sources. Models, graphics, slides, animation, are used here.

Section E. **Protection for 47 million School Children** shows with models, drawings, photographs and a slide film, "The School Shelter Program," and how dual-use facilities in new schools enable the community to provide shelter in times of danger and disaster at almost no additional cost in money or space. It also shows how Government is helping carry out the program.

Section F. **Protecting America's Workers** shows how properly-planned industrial and commercial facilities permit rapid recovery after disaster because, like the schools, plants will serve as shelters for the productive manpower so essential to rapid recovery. Like Section E, this story is told with photographs, designs, models and all other pertinent display techniques.

Section G. **Protection at Home** reminds homeowners that they also can have 24-hour protection against fallout by following instructions to be found in OCD publications.

THE BRAIN IN ACTION

The Upjohn Company

The Upjohn Company's exhibit shows how a thought develops and how the brain reacts, through vision and hearing, to everyday sights and sounds. Electric light signals representing brain "messages" affecting eyes and ears shuttle along metal tubes depicting the nerve pathways. The "messages" produce geometric light patterns in giant aluminum discs, representing the centrencephalic system—the brain's central command post—memory association centers, and other vital areas. The demonstration shows how the brain reacts to a singer's voice, calls up memories of other singers, makes a comparison, and finally commands applause. The 12-foot-high exhibit contains 38 miles of electrical wiring, 30,000 light bulbs.

During life, the brain is always active even during sleep. Sensations are being received and are automatically and unconsciously being acted upon. Fragmentary memories are from time to time being activated in the memory cortices as indicated by the transient patterns appearing there and may flit through consciousness as indicated by the patterns on the central consciousness screen.

Red patterns in the memory cortices indicate visual memories and are accompanied by an image on the screen; green patterns are sound memories and are accompanied by sounds in the sound system.

Our demonstration will consist of tracing the two principal sensations, from the eyes and ears, encountered in attending a concert.

If you will look behind you, you will see the image of a singer and in the sound system you will hear her voice.

We will now, with the model, indicate what the brain does with the image of the singer and the sound of her song. To see her clearly, the eye has to adjust to the brightness of the light.

If one were in a theatre or a concert hall, as the house lights dim, a stimulus goes up the optic nerve to a visual relay station whence an impulse, indicated by the white lights, returns to the eye and the iris expands. It expands too much, and an impulse traveling to the relay station causes the return impulse to contract the pupil—again it overacts and the pupil gets too small. A third impulse adjusts it correctly.

You will see coded nerve impulses from the eyes travel along the optic nerves. The coded impulses alert the activating center in the mid-brain; go on to the visual cortices; set up a pattern and return to the activating center. The brain now becomes conscious of the singer, as is indicated by her appearance on the consciousness screen.

To adjust the ear to the intensity of the sound, an impulse first travels to a relay station which feeds back an impulse to adjust the muscle that regulates the tension on the ear drums.

After the coded impulses leave the ears, you will see some branch off to the activating center to focus attention on the song. The rest will continue to the auditory cortices where patterns are set up. They then return to the activating center and the brain becomes conscious of the song and you will hear it.

Now that we have seen how both the image of the singer and the sound of the song have been received and processed, let us consider what happens when both processes occur together and how they are united into a single impression and are coordinated with previous experience for the initiation of action and storage as a memory.

When the composite pattern of the singer and the song reach the memory regions of the cerebral cortex, this, for comparison, will bring up memories of previously heard singers.

You now see the impulses starting from both eyes and ears and traversing the course we have already pointed out. But this time when both the auditory and visual patterns are transmitted to the activating system they are fused into a single composite pattern and the brain is conscious not just of a woman and of a song, but of the living impression of the woman singing the song. It is this composite impression that is transmitted to the memory cortex.

The coded impulses are leaving the eyes and ears and follow the same paths as you have seen before, stimulating the activating center where they fuse into one image. You become conscious of a singer and you see her image and hear her voice.

This arouses memories of other singers for comparison as the singer's performance is evaluated. There is something reminiscent of a blues singer; or of a religious song; or of operatic grandeur; or of the deep feeling of a spiritual singer. It was a moving performance, therefore the center of the mid-brain is activated and the motor cortices of the brain which control the muscles then respond by directing the hands to applaud.

THE HUMAN BRAIN

by William L. Laurence

Of all the marvels of living nature, the most marvelous of all is the human brain. Weighing only 50 ounces and occupying a volume of about 1,500 cubic centimeters (about one and a half quarts), it is in actuality a vast world of about ten billion cells, grouped in areas the equivalent of geographical continents, each subdivided into smaller regions in which are hidden life's greatest mysteries and miracles. The whole encompasses one of the glories of creation—the human mind.

The human brain is nature's greatest marvel. It is known to function by means of electrical impulses transmitted to it by the vast network of the nervous system, but the mechanism whereby the brain translates these electrical impulses into thought is one of the great mysteries of all living processes.

The constitution of the brain as a physical entity is so complex that it makes any of the giant electronic computers mere child's toys by comparison. Even a single nerve cell of the brain is composed of infinitely more complex parts than the greatest machine ever made by man. Yet the cerebral cortex of the brain, the seat of the higher mental functions, which constitutes only a small part of the total organ, is composed of ten billion individual nerve cells. Each is a complex protoplasmic unit functioning as an individual living dynamo.

For years students of the nervous system and the brain have been engaged in exploring and mapping the geography of the brain in an effort to localize its infinite functions in human responses, conscious, subconscious and unconscious, involuntary and voluntary. Much progress has been made during the last half century in localizing brain centers controlling such functions as sight, smell, hearing, touch and other sense perceptions. Yet by and large the human brain still remains a vast, unexplored "no-man's land," the greatest mystery of them all, that of the mind itself, still eluding man's most intensive probings. In fact, relatively speaking, the unexplored regions of the brain are greater by far than the still unexplored region of the earth, or, for that matter, of the solar system.

At the annual autumn meeting of the National Academy of Sciences, in 1957, Dr. Wilder Penfield, director of the Montreal Neurological Institute and one of the world's leading authorities on brain function, told a fascinated audience of leading scientists in all fields about his discovery, by stimulating the brain of human patients with tiny electrical currents, of a new area in the cerebral cortex to which until now no function had been assigned. The new "cerebral continent," spread over both hemispheres, covers most of the superior surfaces of the temporal lobes, as well as the lateral and probably the interior surfaces.

In that area, Dr. Penfield told the academy, *"there is hidden away a record of the stream of consciousness. It seems to hold the detail of that stream as laid down during each man's waking conscious hours. Contained in this record are all those things of which the individual was once aware; such detail as a man might hope to remember for a* *few seconds or minutes afterward, but which are largely lost to voluntary recall after that time."*

William James, in 1910, described the "stream of consciousness" as a river forever flowing. Its content was never the same from moment to moment. The record of the stream brought to light by the stimulating electrodes, Dr. Penfield said, *"might better be compared to a wire recorder or to a continuous film strip with sound track."*

When a certain region of the area was stimulated by the electrode the patient would suddenly hear a long forgotten song. *"Definitely,"* the patient testified, *"it was not as though I were imagining the tune to myself. I actually heard it. It is not one of my favorite songs, so I don't know why I heard that song."* Others suddenly relived, as though it was actually happening again, long forgotten episodes of their childhood. Stimulation of the same area, without the patient being aware of it, always brought back the same episode, not as a memory, but as something taking place in the present, though the patient at the same time knew it was something out of the past.

"Many a patient has told me," Dr. Penfield reported, *"that the experience brought back by the electrode is much more real than remembering. And yet he is still aware of the present situation. There is a doubling of consciousness and yet he knows which is the present. A patient may cry out in astonishment that he is hearing and seeing friends he knows are far away."*

Curiously enough, he added, two experiences or strips of time are never activated concurrently. Consequently there is no confusion. *"There seems to be an all-or-nothing organization which inhibits other records from being activated.*

"How is this record of the past stored in the brain?" Dr. Penfield asked. *"One may assume that at the time of the original experience electrical potentials passed through the nerve cells and nerve connections of a recording mechanism in a specific patterned sequence, and that some form of permanent facilitation preserves that sequence so that the record can be played at a later time, in a manner analogous to the replaying of a wire or tape recorder."*

The studies make it evident, Dr. Penfield added, that the temporal cortex yields on stimulation two types of response which are psychical rather than sensory or motor. The two forms are: (1) a flashback of past experience, and (2) a signaling of interpretation of the present experience. The two types of responses, he said, *"would seem to form parts of one subconscious process, the process of comparing present experience with past similar experience."*

Dr. Penfield names the area in the temporal cortex "the area for comparative interpretation" or, more briefly, the "interpretive cortex." This area makes possible the scanning process by which past experiences, however scattered they may have been in time, are selected and made available to the present for the purpose of comparative interpretation.

It is this faculty of comparative interpretation that holds the key to the understanding of how the brain, in the words of Hippocrates, distinguishes *"the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant."*

"This discovery that an electrode can cause the past to flash into consciousness again and provide signals for present interpretation," Dr. Penfield concluded, *"should open a new chapter in the physiology of the brain.*

"There is," he summarized, *"a permanent record of the stream of consciousness within the brain. It is preserved in amazing detail. No man can, by voluntary effort, call this detail back to memory."*

"But, hidden in the areas of the temporal lobes, there is a key to a mechanism that unlocks the past and seems to scan it for the purpose of automatic interpretation of the present. It seems probable, also, that this mechanism serves us as we make conscious comparison of present experience with similar past experience."

THE CHEMICAL MAN

Abbott Laboratories

Chemical man portrays by means of three-dimensional models, microphotography and specially created animated motion pictures the wondrous molecular activity that creates and sustains human life. The fifteen-minute presentation starts with man as a recognizable being, then proceeds down to the cellular and subcellular levels to show how atoms combine to form molecules, and the actions of enzymes, proteins, chromosomes and DNA—the master code for life.

THE ENZYMES MASTER CHEMISTS

by William L. Laurence

Every step in the living process, from bacteria to man, is governed by highly specific chemical catalysts named enzymes. They are biochemical mediators of the body's miraculous chemical factory. They regulate the conversion of all substances required for life and for function. It has been estimated that a single living cell contains 100,000 enzymes to effect the 1,000 to 2,000 chemical reactions the cell is capable of producing at incredible speeds.

All known enzymes are proteins, the most complex biochemical molecules in nature. No enzyme has yet been synthesized by man in the laboratory. They must be extracted by painstaking and slow chemical procedures. As much as three-quarters of the time of a research scientist may be spent in preparing the enzymes he needs to carry out his studies on basic life processes. Moreover, he is limited by ordinary laboratory equipment in the amount of a given enzyme he can prepare. Only a few are now being produced commercially.

Enzymes are very special kinds of proteins. Serving as catalysts, they are responsible for speeding up the thousands of biochemical changes that continually take place in the living organism. They are usually unaffected by the reactions they produce. They may be destroyed, however, by wear, tear or poisoning.

Enzymes, for example, are directly responsible for the digestion of food, the building of tissues, the replacement of used-up blood cells, the conversion of chemical energy into kinetic energy, which, in turn, is responsible for movement and muscular activity. Enzyme action and enzyme control not only play a key role in the development of the human ovum, the germ cell from which all humans have their origin, but also in its fertilization. The ovum is protected by a tough coating of cells cemented together with a substance called hyaluronic acid. The male sperm contains an enzyme, hyaluronidase, capable of penetrating the ovum's protective coating and thus allowing the fertilization of the egg.

Thus without this specific enzyme there would be no creation of life. Without the vast host of other enzymes, the infinite variety of chemical changes in living organisms would not take place.

The rate and direction of the living process—moving, breathing, using and storing energy, the transmission of signals to act and react —all are controlled by the number and efficiency of the various enzymes, each having a very specific and very limited job. Operating in minute concentrations, they carry out extraordinary biochemical feats of far greater complexity than any devised by man.

Each enzyme, it is now believed—though not fully confirmed or understood in all cases—carries out a single step leading to an overall physiological result—the lifting of a finger, for example.

An additional example is the conversion of glucose (sugar) into carbon dioxide and alcohol in yeast cells. Over 20 different chemical reactions are involved in this process, and each is catalyzed by a different enzyme. It works much the same way in the human organism. To illustrate: If a cell in the human body is called upon to convert substance A into substance Z, this is accomplished usually not in a single step but in a series of small steps. Compound A is transformed first into compound B by a specific enzyme. Compound B is then transformed into Compound C by another specific enzyme, and so on. The enzyme for the A to B conversion cannot convert B to C.

In certain hereditary diseases, and in some diseases not clearly inherited but caused by a defect in the body metabolism, it is believed that a particular enzyme is missing because the body's apparatus to synthesize it is defective. Many diseases—some of the anemias, blood disorders and perhaps diabetes—are believed to be probably due to the absence, or reduction in activity, of one or more enzymes.

Investigation of enzyme structure, action and control is expected to bring added insight to a host of biological and medical problems now only partially understood and partially manageable.

Increased knowledge of the mechanism of protein biosynthesis will be applicable not only to hereditary diseases, but in many other areas, including malignant disease, and also in preventing disease. Although it may only be a dream at present, there is even hope that eventually enzymes may help provide the added knowledge that will help to make possible the replacement of worn-out organs, and to produce new and potent anti-virus vaccines in the laboratory.

LIFE IS AN ELECTRON

by William L. Laurence

It is the electron revolving in the outer orbits of the atom that has made possible all the myriads of chemical permutations and combinations between the elements, all the marvelous chemical reactions responsible for the existence of the infinite variety of substances, living and nonliving, natural and artificial, that make up our world. It is, in fact, responsible for life itself.

Without the electron there could be no such vital substances as water (a chemical combination of hydrogen and oxygen) and carbon dioxide (a combination of carbon and oxygen), the two basic compounds that make possible plants and all other forms of life

Without the electron there would be no food or clothing, no hormones, or enzymes, or any other substance essential for the maintenance of the chemical processes that keep the fires of life burning.

The functioning of our central nervous system, including the brain, is an electrical process associated with the production of complex chemicals at the nerve endings. These chemicals, like all the others in the vast labyrinth of life, are created through the mediation of the tiny electrical charges of the electron.

Life, insofar as we are able to fathom it, is an electrical phenomenon mediated by an infinite variety of chemical permutations, and the electron is the vital force behind it all.

DNA

by William L. Laurence

Recent evidence in the field of genetics strongly suggests that the gene is largely, if not exclusively, composed of a basic chemical, one of the most important of life's substances, named DNA (deoxyribonucleic acid). It is a giant molecule, with a molecular weight in the range of 6,000,000 (six million times the weight of the hydrogen atom). A human cell contains about 800,000 molecules of DNA.

Many lines of evidence point to DNA as the major chemical of heredity. It is presumed to act as a controlling code carrying the instructions for all genetic traits. It has been estimated that there is enough DNA in a single human cell to encode the information in 1,000 large textbooks; it is capable of many billions of different combinations. It is present in different forms and varying sizes, though composed of the same basic materials, in all forms of life including bacteria and viruses. It is these differences that determine whether an egg will develop into a fish, a bird, a mouse, an elephant, or a human being, all according to a "genetic code" carried by the DNA.

AMES COMPANY, INC.

This exhibit shows the human body as a chemical factory in which each cell is a laboratory, manufacturing its own particular products and requiring its own special raw materials which it selects from digested foodstuffs. In health, amounts of the various chemicals in the blood and urine remain within a fairly limited range. In disease there is a change in the quantity and perhaps the quality of these substances. Through chemical analysis physicians may uncover unsuspected disorders providing the opportunity for early treatment and recovery.

THE BLOOD. The human body is a complicated chemical factory requiring like any other factory raw materials from which to manufacture its products and power to keep its machinery moving.

Both the raw materials and the energy to use them are derived from the foodstuffs we eat and drink.

In the body every organ, like different buildings in a factory complex, has specialized functions. And like every building in a factory complex it has its own special requirements for raw materials to make its specialized products.

In order to keep the body factory working smoothly, there must be a "transport" system to carry the necessary chemicals to and fro.

The blood-vessels serve as the highways for this system and the blood performs the function of the carrier. Going to and from every organ of the body, the blood carries a myriad of chemicals in solution —raw materials, hormones, waste products, etc.

More specifically the blood:

1. Carries oxygen from lungs to tissues.
2. Carries nutrients absorbed from the gut (sometimes after transformation in the liver) to the tissues.
3. Carries hormones from the endocrine glands to govern the functions of other organs.
4. Carries waste products from organs to kidneys.

In health, when all the various organs are working as they should, their requirements for raw materials and their excretion of waste products run at more or less constant pace. As a consequence, the concentration of all the various chemicals in the blood stream remain within a certain limited range.

However, when disease occurs, certain organs may manufacture more or less than they should of certain chemicals or may even manufacture abnormal products. Or when the kidneys become diseased they may fail to excrete waste products as they should.

Under either set of circumstances the chemicals in the blood become abnormal in quality or quantity.

The nature of the abnormality naturally depends on the nature of the disease and the organs involved. By determining the nature of the abnormality (by chemical analysis of the blood) the physician gains clues as to the nature of the disease—and by measuring the *severity* of the abnormality he can often estimate the *severity* of the disease.

THE KIDNEYS. The kidneys essentially fulfil the function of filtering the blood, removing from it all the waste products which are of no further use to the body.

They also very carefully and selectively drain the blood of just the right amount of salty substances so that the blood itself and the other body fluids retain just the right degree of "saltiness."

To achieve its purpose the kidney receives an exceptionally large blood supply for its size—almost three pints every minute. This means that a volume of blood equal to all that in the body passes through the kidneys every 4-5 minutes.

Each kidney contains about one million tiny filtering units known as nephrons.

Just as with the blood, when the body is healthy, the constituents of the urine will remain within a normal concentration range and will consist only of water, salts and the waste products of the body.

However, when the body becomes diseased, the constituents of the urine may alter.

This may come about in two general ways:

1. When the kidneys themselves are diseased:

- **(a)** They may fail to excrete waste products as they normally should, with the result that these products "pile up" in the blood and poison the tissues.
- **(b)** They may filter out valuable nutrients, predominantly protein, which should be retained in the blood for the nourishment of the tissues.

2. When other body systems are diseased:

- **(a)** Substances which are normally present in the blood (e.g., sugar), and are not normally excreted in the urine, may be formed in excessive amounts. When this happens the concentration in the blood may become so high that the kidney is forced to excrete the excess.
- **(b)** Entirely abnormal substances may be formed in the body which the kidney filters out into the urine.

Again, just as with the blood, certain diseases produce certain characteristic changes in the urine and by determining the nature and degree of these changes (by chemical analysis of the urine) the physician obtains valuable information to help him in his diagnosis.

FACTS ABOUT THE HEART. The human heart is one of the most amazing creations of nature, infinitely more efficient than any man-made machine. It beats at a steady tempo more than 100,000 times a day, 36 million times a year, more than 2.5 billion times in the course of a lifetime of three score and ten. It is a muscle, a living pump, about the size of a man's fist, weighing about three-quarters of a pound, which in a 24-hour period performs work equal to the lifting of one ton 50 feet into the air. Every day it pumps 4,320 gallons of blood through 60,000 miles of blood vessels, a distance equal to two-and-a-half times the earth's circumference, supplying oxygen and nourishment to some 300 trillion cells in the average human body. Yet it is active only one-third of the time, resting between beats about two-thirds of the time.

The normal human heart is such a sturdy organ that it could keep on contracting and relaxing at the same tempo for an estimated hundred years. But the stresses and strains of modern living are resulting in changes in the internal chemical environment in which the heart pulsates, which lead to damage of the arteries feeding the heart and to the impairment of its functioning. As a result diseases of the heart and of the blood vessels have greatly increased during recent times.

AMERICAN CANCER SOCIETY

The American Cancer Society's exhibit is titled "THIS CENTURY'S GREAT LIFE-SAVING ADVANCE AGAINST CANCER." It shows how a scientific technique helped save the lives of thousands of women from uterine cancer. The method, called "Exfoliative Cytology," can distinguish between normal and malignant cells shed by the body.

The exhibit's main objective is to save the lives of many of our women visitors.

Part I explains the meaning of research and its potentialities, by presenting a particularly simple and understandable example: the study of the long-known fact that every tissue, inside or on the surface of the human body, continually sheds, or exfoliates its older cells and grows new ones to replace them. By means of a sequence of photographs, drawings and other two-dimensional graphics, this part tells the dramatic story of Dr. George N. Papanicolaou's life-long study of cell exfoliation, and his discovery in 1928 of a new way to detect certain forms of cancer in their earliest and most curable stage . . . a method that is usually called the "Pap" test, in Dr. Papanicolaou's honor.

Part II looks into the future of the "Pap" test. By means of a sequence of striking color transparencies, it tells of the on-going research into the many possible uses of the "Pap" test for the earlier detection of still other forms of cancer.

Part III illustrates the dramatic results of the discovery of the "Pap" test. A demonstrator, supported by a variety of speaker's aids, such as motion picture sequences, slides and three-dimensional devices, tells of the many lives that are being saved every year thanks to the development of the "Pap" test . . . with particular emphasis on the thousands of women who have, in a sense, saved their own lives because they had "Pap" tests as a routine part of their annual check-ups. The demonstrator urges every woman to do likewise.

PHYSICS OF COLOR

Interchemical Corporation

The theme of the exhibit is the science of color and its power to brighten the world around us. Focal point of the Interchem Color Center is a 14-foot high "Color Tree." At the base of the tree and around the periphery of the exhibit space twelve demonstrations help explain the phenomena of color.

CHEMISTRY AND THE WORLD OF COLOR

General Aniline & Film Corporation

The exhibit is a presentation of basic principles of organic chemistry with emphasis on the ways in which the search for new color components led the research chemist to the creation of thousands of carbon-containing compounds that fill the needs of industry and the consumer in a variety of ways.

The technology of devising specific chemicals which make possible modern high-speed photographic color film are described in visual and audio treatments. The processes by which chemists, "architects of the molecule," synthesize, from simple building blocks, complex dyes, pharmaceuticals, agricultural chemicals and other products better to serve human needs, are shown in easily followed steps.

It is also shown that from this continuing research has recently come a new high point in the progress of organic chemistry. This is the growing understanding of the elaborate chemistry of plant and animal life. The accurate determination of the structure of the DNA molecule, the genetic code of life within the cell's chromosomes, is the most complex organic chemical achievement to date.

HEARING AID INDUSTRY CONFERENCE, INC.

The exhibit, using an enlarged model ear and tape recordings, demonstrates how we can hear, what sound is like with hearing loss and how hearing loss can be corrected. The exhibit shows the development from trumpets to modern, miniature, transistorized hearing aids.

The overall concept of the exhibit is to have people listen to a recorded continuous message via earphones as they examine an enlarged model of the human ear. In addition, tape recordings are incorporated in the exhibit to illustrate various hearing deficiencies.

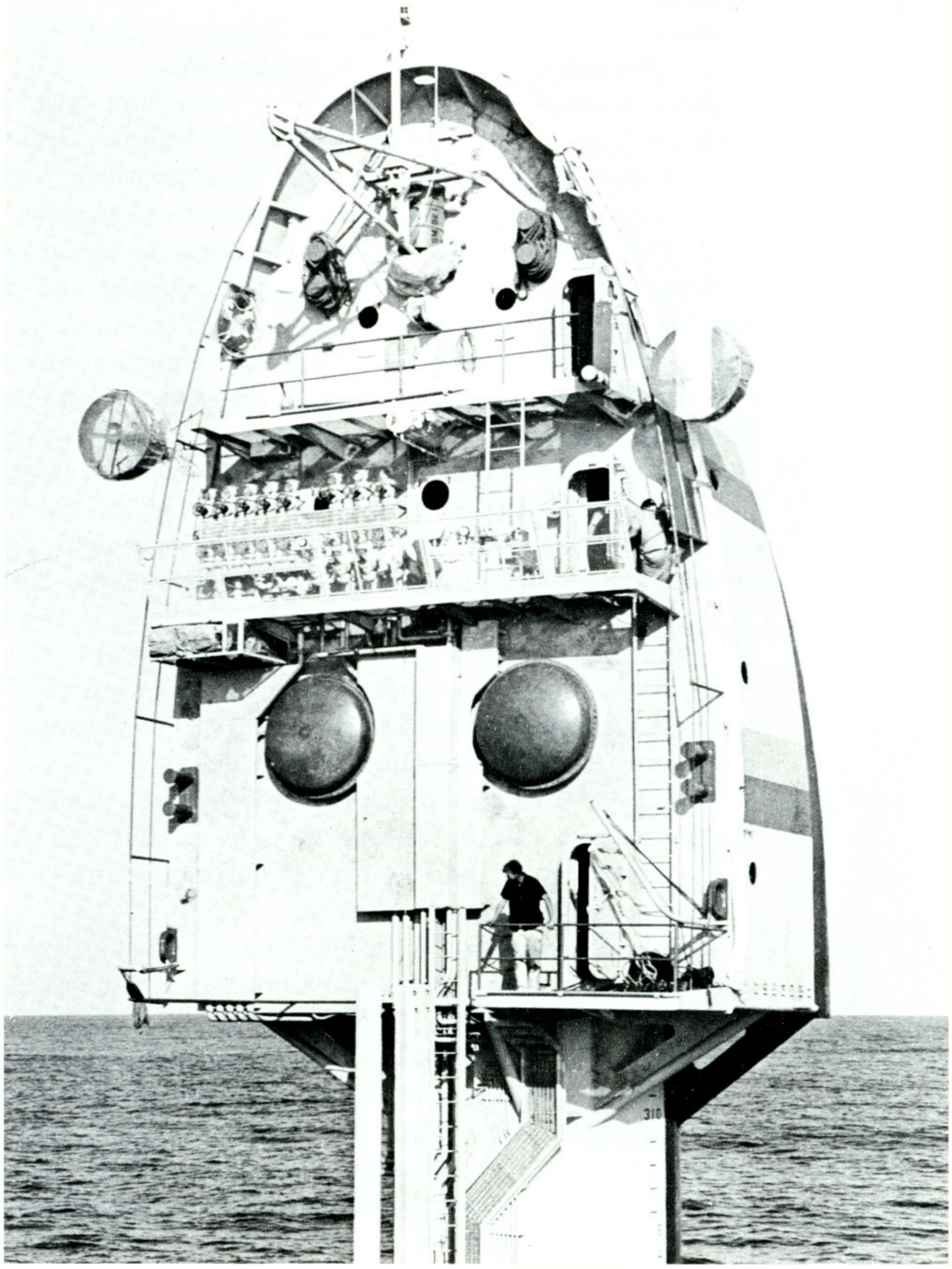
The purpose of this tape recording is to demonstrate to people with normal hearing and border-line hearing the sounds heard by persons with various types of hearing loss. It is inconceivable to a person with normal hearing to be able to understand how words sound to a person with impaired hearing.

The circular appliqué panels placed on the back wall of the exhibit surrounding this model of the ear show the variety of methods which can be used to correct hearing loss. This includes treatment by surgery, drugs, and the application of the right type electronic hearing aids.

To the left of this area is a concave curved wall which shows the various component parts and function of a modern transistorized hearing aid. This section is also devoted to the story of the power source used in a hearing aid.

To the left of this section is an identical curved wall devoted to case histories of people who have had hearing problems and had these problems corrected by use of hearing aids.

The wall facing the exhibit is used to show the various devices and methods used to detect a hearing loss. Some of these methods include the person himself determining that he has a hearing problem by noticing that other people seem to mumble, or he has difficulty hearing the television set, or a mother may have difficulty hearing her child cry. The external portion of this unit shows a variety of hearing aids and a history of the industry dating back from the first, or early, hearing trumpets and carried right on through the modern hearing aid.



The oceans, which occupy more than 300 million cubic miles and cover nearly three-quarters of the earth's surface, always have fascinated and challenged people of all nations. Over the years, man has sailed over and through the farthest seas, yet little is known scientifically about the aqueous part of his environment. Only recently have scientists intensified their study of the sea.

As the human population of the world continues to rise, the oceans increasingly will serve mankind. As the agricultural and mineral supplies of the land threaten to become inadequate, the almost limitless potential of the sea will be harnessed to meet growing needs for metals, chemicals, medicine, food, water, and energy. The research and development talents of chemists and chemical engineers will be concentrated more and more on the sea, to unlock more secrets of the earth and to use more fully the ocean's resources.

The theme of the ACS exhibit is presented on a tall pylon constructed in such a way as to conceal the building column. Below this theme structure, a glowing blue globe of the world, five feet in diameter, rotates slowly. Land areas are shown in opaque white and the principal oceanographic centers of the world are indicated.

Behind the theme center is a large enclosed and ceiled room, or theater, with artistic treatment on the exterior to make it resemble the ocean as seen from below. The visitor entering this ocean enclosure has the illusion that he is actually entering an underwater world to learn something of its chemical secrets. Overhead speakers at the entrance transmit actual ocean noises, and interior lighting is subdued.

Spotlighted on a platform in the middle of the theater is a model of an undersea research vehicle or research equipment. Five display centers, or stages, are placed around the sides of the theater to present various aspects of chemical research in the sea. In the soft lighting of the room, these scenes glow with luminous paint bathed in ultraviolet light. Backlighted color transparencies also are used. The five stages, each of which has a brief recorded story in addition to the visual presentation, presents information as follows:

History of Chemical Study of the Sea. From the recovery of salt by evaporation in Old Testament days to modern recovery of bromine and magnesium, a brief history is outlined along with a description of studies of salt-water corrosion.

Natural Phenomena of the Sea. Chemists follow, by means of radioactive isotopes, the water cycle from the ocean through evaporation and rain back to the ocean. Also shown is the ocean's part in controlling atmospheric carbon dioxide and in cleansing the air and the land.

Chemical Challenges of the Sea. The chemical studies of the International Geophysical Year; investigation of the oxygen and nitrogen cycles in the sea; and research on such seaborne organic substances as amino acids, vitamins, proteins, and various metabolites are among the topics to be outlined.

The Chemical Potential of the Sea. Vast deposits of manganese on the ocean bed, supplies of all elements in solution, and undersea stores of petroleum and sulfur are described along with novel methods proposed for their recovery.

Future Contributions of the Sea. Continuing research and development efforts are beginning to provide feasible methods for recovery of pure water from the ocean, and chemical methods may be applied to organized "farming" of the sea.

IV. *Other Pavilions*

GENERAL ELECTRIC PAVILION

The Cosmic Powerhouse

by William L. Laurence

In the General Electric Pavilion a journey to the interior of the sun and billions of other luminous suns in our own galaxy of the Milky Way, and in other billions of galaxies in the infinitude of space, constitutes a most spectacular, awe-inspiring experience in which for a few eternal moments dwellers on earth are privileged to witness the cosmic powerhouse that provides the universe with its inexhaustible energy.

They see an actual demonstration, shown for the first time in public in this country, of the fundamental process in the interior of the sun that made it possible for life in all its multifarious forms to originate on this earth, and which is responsible for the continued existence of all living things, plants, animals and man. And it is this very same process that holds out the possibility of the existence of living things, similar to those on earth, on other planets nourished by the life-giving light and heat from other suns similar to ours.

For it is the light and heat poured down by the sun in inexhaustible quantities that make life on earth possible. Without them the earth, the oceans and the atmosphere surrounding them would be one vast frozen lifeless mass in a great void of eternal night.

It is this very basic cosmic process by which the sun and all other suns in the vastness of space produce their light and heat, as well as other forms of radiation, such as ultraviolet rays and X-rays, that visitors to the General Electric Pavilion see in actual operation on this earth. It will be one of the momentous experiences of a lifetime, once its true significance and the promise it holds for the future of all mankind on this planet are fully realized.

This cosmic process is known as fusion, or more technically as thermonuclear fusion, which, as the term implies, is the fusion of two or more nuclei of an element, under the influence of enormous temperatures, into the nucleus of a heavier element.

In the sun, and in other stars of the same family, the process consists of the fusion of four nuclei of atoms of hydrogen, the lightest element in nature, into the nucleus of an atom of helium, which has an atomic mass 0.7 percent less than the total mass of the original four hydrogen nuclei. It is this small amount of matter that is converted into an enormous amount of energy, in accordance with the famous Einstein formula, which revealed that one gram of matter, two-fifths the weight of a dime, is the equivalent of 25 million kilowatt-hours of energy, or more than the total output of Grand Coulee in twelve hours.

In the interior of the sun, a mass of 600,000,000 tons of the light variety of hydrogen is fused into 596,000,000 tons of helium every second, which means that 4,000,000 tons of the sun's mass are converted every second into light and heat and other forms of radiant energy. Since one ton equals one million grams, and since one gram is the equivalent of 25,000,000 kilowatt-hours of energy, this means that the sun generates every second into space an energy of 100 billion

billion kilowatt-hours. Only two-billionths of this unimaginable quantity of energy is received on earth, just enough for the maintenance of life on this planet.

Since the nuclei of hydrogen consist of elementary particles, named protons, which carry positive electrical charges, they would under ordinary conditions, such as exist on earth, repel each other with tremendous force. As stated earlier, it has been calculated that two grams of protons placed at the opposite poles of the earth would repel each other with a force of twenty-six tons.

To overcome these repulsive forces, enormous temperatures are required. In the interior of the sun, and in the billions of other luminous stars of the sun's family, the thermonuclear fusion of the hydrogen nuclei takes place at a temperature of 20,000,000 to 30,000,000 degrees Centigrade generated under the enormous pressure equal to that of a hundred billion atmospheres. The sun's supply of hydrogen is so vast that it will continue to convert 4,000,000 tons of its mass into energy every second for a period estimated to last ten billion years.

During the past several years the Atomic Energy Commission has been engaged in a multi-million dollar program, known as Project Sherwood, to duplicate on earth the fusion process in the interior of the sun, that, if successful, would supply mankind with a virtually limitless source of energy. Similar programs are going on in Britain and Russia, and considerable progress in this great venture, one of the greatest ever undertaken, has been reported in recent months in all these countries, and particularly in the United States, though the ultimate goal is still some decades away.

It is the latest progress along these lines that is being demonstrated at the General Electric exhibit at the New York World's Fair. Here, for the first time in the United States, visitors see the actual fusion of hydrogen nuclei at a temperature of more than 20,000,000 degrees Centigrade. The thermonuclear fusion reaction lasts only a fraction of a second and the number of hydrogen nuclei fused is very small, far from sufficient to produce energy on a practical scale, but it marks the creation on earth of a miniature sun, offering a glimpse of the future in which man, a twentieth century version of Apollo, will harness the sun to his industrial chariot, to provide undreamed of abundance for all mankind everywhere.

Because the process of fusion of ordinary light hydrogen in the sun requires a cycle taking millions of years, it is not possible to use the light variety of hydrogen under terrestrial conditions, in which the reaction must be completed in terms of seconds. The type of hydrogen that can be used on earth is the variety of double weight hydrogen, named deuterium, or of triple-weight hydrogen, named tritium. Deuterium is present in enormous amounts in the world's oceans, lakes and rivers. Tritium does not exist in nature but it can be made artificially out of the light element, lithium. Because of its great abundance, deuterium is expected to be the fuel of the future.

The seemingly insurmountable difficulty in the way of creating a miniature sun on earth is the requirement of enormously high temperature. Even if such a temperature could be achieved, no material exists on earth that would not be instantly vaporized at a temperature above 6,000 degrees Centigrade. This means that no material vessel could be made to contain hydrogen gas at the temperature required to produce fusion.

Since no material container is possible, scientists have invented a container called a "magnetic bottle," which consists of extremely powerful magnetic lines of force in which the electrically charged nuclei of the heavy hydrogen gas are confined and squeezed into a very narrow beam. Thus surrounded by a powerful magnetic wall, the electrical particles can be raised to an enormously high temperature by means of extremely powerful electrical charges, the greater the charge the higher the temperature.

The magnetic bottle takes advantage of the fact that a gas in a tube subjected to an electrical discharge will be broken up, even at moderate temperatures, into its electrically charged components, negative electrons and positive protons, or ions. Such an electrified gas, known as a plasma, and described as the fourth state of matter (neither solid, nor liquid, nor gas) can therefore be subjected to electromagnetic forces. Feeding an electric current into this fourth state of matter raises its temperature to any degree desired, the greater the amount of the current fed into it the higher the temperature.

The magnetic lines of force surrounding them prevent the electrically charged hydrogen nuclei from crossing them and thus from striking the walls of the vessel, which therefore remains cold despite the fact that the plasma within it is at a temperature of many millions of degrees. Instead of going across the magnetic lines of force, the electrically charged nuclei are forced to travel in spirals inside them without approaching the walls of the material container.

The fusion of the nuclei of one kilogram (2.2 pounds) of deuterium would yield a total of 75,000,000 kilowatt hours. A typical swimming pool of 12,000 to 18,000 gallons of water, which contains about 2 to 3 gallons of deuterium, would supply the power requirements of a city of one million population for an entire year. A pitcher of water has enough deuterium in it to provide electricity for a typical home for an entire year.

The fusion apparatus at the General Electric Pavilion consists of a quartz tube 6 inches in diameter and three feet long, which contains the positively charged hydrogen nuclei. A gigantic battery of 72 capacitor units stores up in 30 seconds an energy of 100,000 joules at 60,000 volts. When the capacitors are discharged they release a tremendous electrical current of one million amperes. This creates a magnetic bottle of the enormous magnitude of 100,000 gauss, a magnetic field 200,000 times as great as the magnetic field of the earth.

The entire reaction takes place in six millionths of a second, during which an electrical energy of 30 billion watts is generated. In that infinitesimal fraction of a second this enormous electric charge raises the deuterium nuclei to a temperature of more than 100,000,000 degrees Fahrenheit. At this temperature, a million to ten million nuclei of hydrogen are fused together, half of them creating nuclei of helium of atomic mass three, and a free neutron, while the other half produces nuclei of tritium (triple weight hydrogen) and a free proton. At the same time one kilowatt of electrical energy is liberated.

During the Fair, the reaction is repeated every six minutes for twelve hours a day, seven days of the week. Those watching see a tremendous flash accompanied with a loud bang, signifying the birth cry of a new age, which, in the course of two decades or so, will open for mankind a source of electrical energy great enough to last for billions of years, with the oceans of the world serving as an inexhaustible reservoir of fuel for a new industrial civilization.

BELL SYSTEM EXHIBIT

The Bell System Exhibit is composed of two major elements; the ride in the floating wing, and a series of live demonstrations, displays, and audience participation games in the Exhibit Hall located in the lower level of the Pavilion.

THE RIDE. The Ride is a new departure in theatrical presentation. Seated in two rows of moving chairs, visitors are transported past a series of scenes and stages. Each person has a separate sound system built right into the chair, and each one sees every scene in its entirety.

Theatrical techniques include three dimensional stage settings, film technique that is three dimensional in nature, and front and rear projections of still and motion pictures.

THE EXHIBIT HALL. The displays, demonstrations and games in the Exhibit Hall are designed to tell the story of how the Bell System, through science and technology, has in the past and will continue to make communicating easier and better for everyone, everywhere.

The following describes the major areas of the Exhibit:

Creatures and Man Area. This display consists of a series of light boxes and copy blocks—pictures of creatures of land, sea and air—as well as photographs of some of man's accomplishments in communications. The story told is essentially that all creatures communicate. Some have more highly developed senses than man, but man because he can think and reason has developed his ability to communicate to a far greater degree than any other form of life.

Senses Area. Here speech, vision, and hearing are examined. There are two major exhibits—a demonstration of Visible Speech and Voice Prints, and one of the Artificial Larynx and the Vocoder.

Because the voice is transmitted on the telephone, Bell has devised ways of studying it. The Visible Speech Translator shows us the sounds of the voice on a television screen.

The Visible Speech exhibit features an isolation booth in which a volunteer from the audience reads a sentence. His speech patterns appear to the audience on a television screen.

The Artificial Larynx is demonstrated as the Bell Telephone Laboratories invention which restores the gift of speech to those who have lost their vocal chords.

In the Vocoder exhibit it is shown how this experimental machine samples the voice, selecting only parts for transmission and reconstructing them into a complete conversation at the receiving end. It will actually be demonstrated how your voice can be taken apart and put back together again.

One wall includes an animated display of the ear, eye and throat, explaining how they function. The visitor is also able to test his skill at pitch matching, and to participate in an optical illusion game.

Telephone of Today and Vision. Two displays make up this area. They demonstrate some of the products of over 80 years of Bell System research. The first exhibit explains the development of telephone instruments and services from our earliest offerings to the modern instruments and services. The second exhibit demonstrates how research in the area of vision has enabled us to gain knowledge in areas where we were once unable to see. It ranges in scope from the electronic microscope to the radio telescope.

Basic Science Exhibit. The major display in this area demonstrates crystal growth. It is supported with displays of the dramatic developments that have been made possible by knowledge acquired through research on the structure of crystals—the transistor, solar battery, Maser and Laser. One wall is devoted to a display of the dramatic impact on our lives that has resulted from these inventions, namely, miniaturization of electronic equipment, use in satellites, computers, transmission, radio and television equipment, etc.

Waves Exhibit. The waves exhibit features a Torsional Wave Machine that demonstrates the behavior of waves. It is demonstrated that waves carry information and that this fact makes it possible to transmit voice, music and television over great distances.

Supporting displays show the various transmission media—cable, coaxial cable, wave guide, microwave, Maser and Laser.

Tasi Complexity Exhibit. This exhibit shows the underseas cable routes and how they operate. The Tasi demonstration explains how utilization of these routes is almost doubled by using the silent times occurring in a conversation (e.g., time spent listening, thinking or pauses) to transmit parts of another conversation. In the foreseeable future, the Vocoder, demonstrated in the Senses Area, will be used in conjunction with Tasi to more than quadruple the information-carrying capacity of the underseas cable.

In support of these exhibits, there are logic and memory games in which the audience may participate. There is an age-guessing game, a Roman numeral translator and a Tic-Tac-Toe game.

Picturephone (Television Telephone). Here the audience participates in an actual research project conducted by the Bell Telephone Laboratories on TV telephones. There are six picture telephones in this area which are interconnected so that a participant may use any one to see and speak with any one of the others. Bell Laboratories staff members interview participants to determine such things as what kind of picture phone instruments they would desire, what kinds of services they would like it to perform, how they would use it, what the value of a service of this kind would be to them, etc.

Data Exhibit. This exhibit demonstrates the services offered by the Bell System that makes it possible for machines to talk to machines. It emphasizes many of the ways that information may be passed between machines and the tremendous speeds of transmission made possible through the use of this medium.

Network. In a pyrotechnic-like display of moving multi-colored light on a treated plexi-glass wall that wraps almost halfway around a circular theater, the Network Story is told. In forty steps the story builds from a single call into the nationwide network. Data, the Defense Lines, the Cable and Microwave Systems all combine into one vast network which then expands into its world-wide capability, and, with the effect of a shrinking world, will ultimately evolve the extension of the network into space through satellites and the Maser or Laser.

THE TRANSISTOR

The transistor performs in a solid what the electron tube does in a vacuum: it conducts, modulates, and amplifies electrical signals. By virtue of its unique way of doing it, the transistor has revolutionized the electronics and communications industries.

In the summer of 1948 Bell Laboratories announced the invention of the transistor, a new semiconductor device. Since then the transistor has stimulated the growth of dozens of other semiconductor devices, it has made possible the design of electronic circuits previously not feasible, and it has helped foster solid-state physics as a major area of research and development.

In order to understand better how the transistor accomplished all this, let's examine briefly how this tiny device, made out of a solid material, came to be and what its main advantages are.

The transistor is an outgrowth of an attempt to understand fundamental physical phenomena. The work that eventually resulted in the transistor was begun in the late 1930's when Bell Laboratories decided to explore the behavior of electrons in solids. The work was deferred for a while during World War II and then resumed in 1946 by a group of scientists who focused their attention on two semiconductors, silicon and germanium. (These materials are called semiconductors because they conduct electricity better than insulators, but not as well as metals or conductors.)

The original transistor was called a point-contact transistor because it was essentially a wafer of germanium with two pointed wire contacts made close together on one side. On the other side of the wafer a third contact was made using a flat metal electrode.

The resistance of one point contact was found to depend on the current flowing through the other point contact. In other words, the resistance effect was transferable from one point to the other; hence the name *transistor*.

Soon afterwards a different structure for the transistor was found which showed that the transistor effect took place through the body of the semiconductor rather than merely along the surface as some had thought. This provided the basis for a proposal that another type of transistor—not dependent on point contacts—was possible. Called a junction transistor, it too was invented at Bell Laboratories.

Today the transistor is no longer one device: it is a family of devices made in dozens of different ways.

Although vacuum tubes continue to play an important role in electronics, transistors have several inherent advantages:

1. *The transistor does not need a warmup period because it usually operates cold.*
2. *The transistor has low power requirements. It requires merely a fraction of the power that a vacuum tube needs.*
3. *The transistor is resistant to shock and vibration.*
4. *The transistor is tiny. It can be made as small as a pinhead, allowing extreme miniaturization.*
5. *The transistor is extremely reliable. It can be trouble-free for decades when properly manufactured and operated within its design limits.*
6. *The transistor, for many applications, is simpler and lower in cost than an equivalent vacuum tube.*

In the Bell Telephone System the transistor is being used more and more to help achieve an even better telephone system. It has made practical an all-electronic telephone switching system that performs interconnection functions with speed and ease, it permits automatic dialing from a "memory" system, and has made possible telephone headsets for the hard-of-hearing, to name a few applications.

The transistor has lived up to all its expectations. It is revolutionizing the world around us; it is creating new industries and giving us new understanding of the technology by which men communicate with each other.

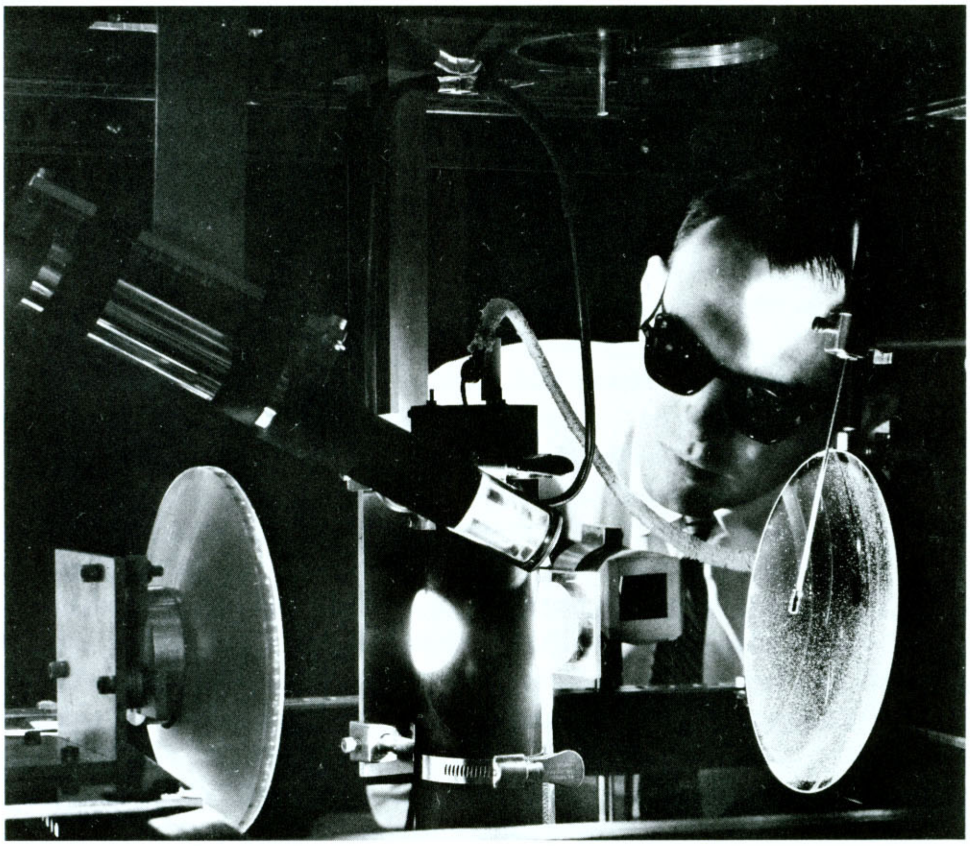
MASER

(Microwave Amplification by Stimulated Emission of Radiation)

Radio signals that travel a long path to the receiver arrive very weak and barely distinguishable from noise from the sky. The signal and the noise pass through the receiver together and are amplified together. During this process, conventional amplifiers may generate even more noise and this is added to the input signal. The cumulative effect is that the signal may be drowned out by the noise. That is why for many years engineers have been concerned with the development of "quiet" (low-noise) amplifiers.

In 1954, Columbia University Professor C. H. Townes, J. P. Gordon (now at Bell Laboratories) and H. J. Zeiger built the first maser amplifier and oscillator. Their new device was based on the principle that excited atoms or molecules can be stimulated by the presence of radiation to emit their excess energy as additional radiation. If this energy is imparted to an electromagnetic field, the energy of the field will be increased or amplified.

In the first maser a beam of ammonia molecules was passed through an electric field. The ammonia molecule emitted or absorbed energy at about 24 thousand million cycles per second (24-kmc). Low-energy-absorbing ammonia molecules were pulled from the gas flow by the electric field. The high-energy excited molecules passed through a chamber with highly reflecting walls which stored their 24-kmc energy. As these molecules were stimulated by electromagnetic radiation in the chamber, they emitted their energy. As new molecules



passing through the chamber provided a continuous supply of 24-kmc energy, a steady-state release of energy was created which could be used either as an oscillator or an amplifier.

The first *solid-state* maser was built at Bell Telephone Laboratories by H. E. D. Scovil, G. Feher and H. Seidel. Its design was based on the theoretical work of Professor N. Bloembergen at Harvard University.

At the heart of the solid-state maser is a crystal which is mounted in a resonant cavity and cooled by liquid helium to a temperature approaching absolute zero. The cavity containing the ruby and its coolant is surrounded by a magnet.

When the atoms of the crystal are subjected to a magnetic field, they become excited and rise to a higher energy level. A signal from a "pump" (such as a klystron oscillator) maintains the atoms in an excited state. As these atoms drop from a higher to a lower energy state, they give off radiation. This is the energy used to amplify signals.

In 1956, scientists at Bell Laboratories developed a highly sophisticated amplifier known as the traveling-wave maser. This was the prototype maser used in receiving signals from the Echo and Telstar satellites. Here is an amplifier that makes almost no internal noise. When used with the horn antenna at the Bell System earth station in Andover, Maine, it forms a receiver so sensitive that it can detect clearly a signal with the power of only one billionth of a millionth of a watt.

The maser has greatly increased the range of radio astronomy—weak signals once obscured by noise in the receiving circuits are now detected at good signal-to-noise ratios. Perhaps most significant is the fact that the first demonstration that stimulated emission of radiation can be controlled and applied. It has opened the door to new research and has already had a decisive impact on the technology of science.

LASER

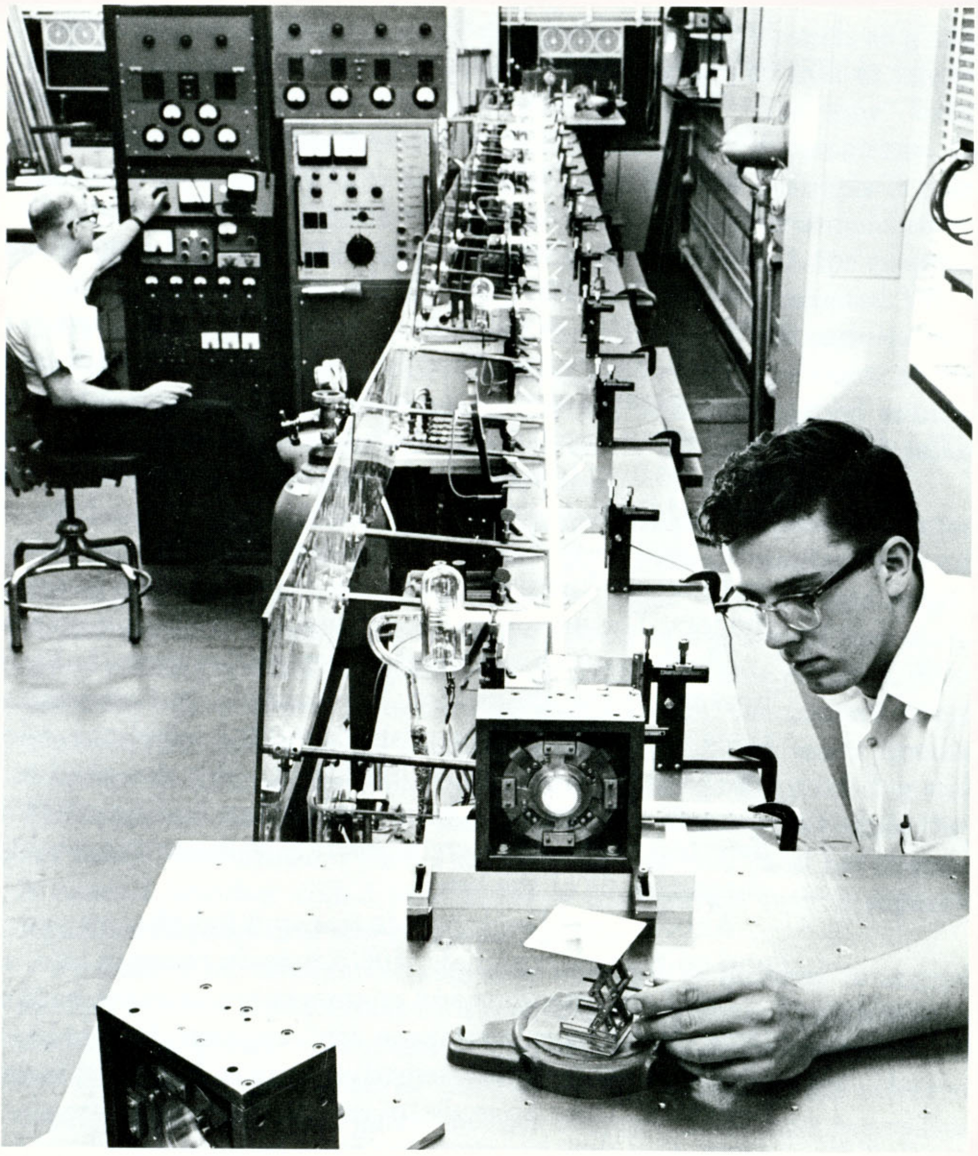
A New Light for Technology

A little over six years ago two scientists came up with some ideas on how to harness light waves. These ideas have since grown into the "optical maser," or "laser," a device which has opened new directions to the sciences of optics and electronics.

The laser was conceived by Arthur Schawlow, a physicist at Bell Laboratories and Charles Townes, maser pioneer. These men saw the device as an extension of the principle of the maser—the microwave amplifier used in space-communications experiments, which utilizes radiation of atoms for transmission.

That atoms emit radiation is well known. The "excited" neon atoms in the neon signs we see every day do just that. But normally they radiate their characteristic red light in random directions and at random times and the resulting light is incoherent. Incoherent is a technical term meaning just what you might expect—a jumble.

The trick is to find the right atoms, with the right internal storage mechanisms and arrange an environment in which they can all cooperate—to give up their light at the right time and all in the same direction. A laser is a device to make light waves *coherent*.



Basically, a laser consists of cylindrically shaped active material—solid, liquid, or gas—excited by some external source of energy. Reflective surfaces at both ends of the rod permit energy to reflect back and forth, building up on each passage.

Such a device can generate a powerful and highly directional beam of light which is coherent (well organized) and of nearly a single frequency. This beam may someday provide a carrier signal with a very large capacity for telephone, television, and data transmission.

Many other applications have been suggested and tried. They include such things as micro-welding and drilling, optical radars, use in special types of tumor surgery, and as a tool in physical and chemical research. Over 500 industrial and academic research organizations are now reported to be conducting research on the laser.

In early 1960 Schawlow and Townes received a patent, assigned to Bell Laboratories, for the laser. That summer Theodore Maiman at

Hughes Aircraft Co. built the first working laser—a pulsed device using a ruby rod with silvered ends and a powerful flash lamp.

In February 1961 Bell Labs scientists Ali Javan, William Bennett Jr., and Donald Herriott announced they had constructed a gaseous laser—a continuously operating device using a mixture of helium and neon gases and a radio frequency generator as the source of external energy.

Since then, dozens of improvements and innovations on the laser have poured from research laboratories. There are now several crystalline materials, in addition to ruby, which will work—at least five of them in continuous operation. The original helium-neon mixture has been operated at several additional frequencies, and it has been joined by nearly a dozen other gases and mixtures of gases. The entire group provides over two hundred potential frequencies for communications.

In addition to crystals and gases, lasers have been made from liquids, plastics, and glass. A little over a year ago scientists at G.E., IBM, and Lincoln Laboratories succeeded in making lasers from semiconductors. The most popular of these has been gallium arsenide.

Much research and development still remains to be done, primarily how to control the device. For example, in communications applications we need adequate means of putting telephone, television, or data signals on the carrier, or light beam. We also need to find a way to amplify the signals. These needs mean finding efficient modulators, detectors, and amplifiers to operate at the extremely high frequencies characteristic of the laser.

Another problem is how to transmit light beams over long distances and still get clear signals, difficult to do through rain, snow, and fog.

Bell Labs scientists and engineers are working hard on these problems. There have been some achievements. People have found materials that are properly sensitive so as to be useful in modulators and detectors. They have discovered ways to increase the power of the laser. And they are studying ways to transmit a laser beam, so that it will not be seriously affected by the earth's atmosphere, by putting it inside a shielding tube.

These are preliminary steps. And even if the technical problems are solved, use of the laser for communications will depend on whether it can compete with other systems already in existence or under development. As Schawlow pointed out in a *Scientific American* article, the laser's vast communications potential "is still far in the future."

TASI

(Time Assignment Speech Interpolation)

TASI is a recent development, now being used on undersea cable, that increases the conversation capacities of the cables. The equipment takes advantage of the times when people are listening or pausing. The voice channels they leave temporarily unused are automatically assigned to other talkers; and when a listener starts to talk, he instantly has the use of a channel which another person has left idle.

In practice, the system does not work with only two talkers on one line since they would frequently be speaking at the same time. However, where a larger number of channels is available, such as a submarine telephone cable, an averaging effect occurs so that at any instant there is a greater probability of sufficient "free time" being available to accommodate the larger number of conversations. Increasing the capacity of a 36-channel system to 72 channels is more feasible with TASI than doubling the capacity of a 5-channel system.

TASI is essentially a group of high-speed switches. If, for example, 36 cable channels were available, 72 talkers could be connected. When there are more talkers than channels, the equipment will connect talkers who become active by disconnecting talkers who are silent at that moment. In turn, this disconnected talker will be assigned another momentarily inactive channel when he starts to speak again. A talker will be disconnected only when he is silent.

When a talker starts talking, his voice actuates a speech detector. The speech detectors are scanned by a control circuit similar to a modern digital computer. When a talker becomes "active" this control circuit initiates a coded tone burst consisting of a group of four audio tones which precedes the voice over an available cable channel. After the tone burst, which lasts only 10 milliseconds, the control circuit connects the talker to the same channel. The coded tones operate switches to connect the talker to the proper line at the receiving end. The tones are not heard since the listener is not connected while they are being transmitted. When a talker is not "active" and his channel is needed, another coded tone burst is transmitted over a separate signaling channel and severs the connection.

Switching of talkspurts from one channel to another is accomplished in a few milliseconds by a time-division switch. Speech is sampled for about two microseconds and the resulting pulses steered to the appropriate idle channel during the sampling by the selective operation of transistor "gates" in each channel. This short interval of sampling makes it possible to sample all active talkers 8000 times a second and then reconstruct the speech from the samples before it is transmitted over the undersea cable.

The signaling system in TASI keeps the receiving end informed of the connections that the transmitting end has established. Four groups of audio tones are employed for signaling purposes—four tones in each of three groups and three in the fourth group. Each signal comprises one and only one tone from each group—if more or less are present, an error is indicated and appropriate steps are taken to correct it. "Connect" signals which precede the voice signal at the beginning of the speaker's talkspurt are sent over the same channel as the speech. Disconnect and connection checking signals are sent over a separate channel used only for this purpose.

All of the circuits for TASI are completely transistorized. Terminals for doubling the capacity of the transatlantic cable require several thousand transistors of four different types, and tens of thousands of semiconductor diodes and passive components.

UNDERSEA TELEPHONE CABLES

The Bell System's international telephone service reaches more than 170 overseas countries and territories. Circuits are provided via high frequency radio, over-the-horizon or tropospheric scatter radio systems and on a network of undersea cables.

Because these cables are reliable, and carry many conversations simultaneously and clearly, they are being used increasingly for telephone circuits between the United States and foreign countries.

The first undersea telephone cable was laid in 1921 between Florida and Cuba. Radio telephone service—between New York and London—was established six years later. But it was not until 1956 that the first transatlantic telephone cable was laid.

This was placed between Oban, Scotland, and Sydney Mines, Nova Scotia, via Clarenville, Newfoundland. It was made possible by the development of undersea repeaters for amplifying telephone signals.

An undersea cable between Seattle and Ketchikan, Alaska, was laid that same year and a California-Hawaii cable followed in 1957.

The second transatlantic cable was put into service in 1959 between Sydney Mines, Nova Scotia, and Penmarch, France. Other cables link Florida and Puerto Rico and the U.S. mainland and Bermuda.

Each of these cables carries 48 one-way channels. Two cables are required for each link.

To meet the increase in the volume of overseas telephone service, Bell Laboratories developed a new cable capable of carrying 128 two-way conversations, more than any other ocean cable in use today. The cable gets its strength from a core of 41 steel wires and does not require the outer armoring used in previous deep sea cables.

The armorless cable has a new type of repeater, stationed every 20 miles along its length, which amplifies telephone signals 100,000 times. These repeaters have new high-vacuum electron tubes that will not change significantly over a 20-year life span.

The first two-way armorless cable was laid in 1963 between Florida and Jamaica and recently was extended to the Panama Canal Zone.

Another armorless system—the third transatlantic cable—was completed that same year. It extends 3,500 nautical miles from Tuckerton, N.J., to Widemouth, England. The system includes 182 repeaters. It went into service October 14, 1963.

An undersea cable of this kind from Hawaii to Japan, via Midway, Wake, and Guam, is expected to be ready by the fall of 1964; and before the end of this year an armorless cable system between Hawaii and the continental United States is scheduled for completion.

To lay the armorless cable and its two-way repeaters, a new type of cable ship was designed and built. This ship, the CS Long Lines, holds 2,000 miles of undersea cable in its tanks. It includes a new type of cable engine that has tractor-like grips to handle both small-diameter cable and large-diameter repeaters. The engine lays out cable smoothly at a constant rate.

Bell Laboratories is also developing an armorless cable system that uses transistor amplifiers. This system will be able to carry 720 two-way telephone conversations simultaneously.

VOICEPRINTS

Voiceprints, sometimes called "visible speech", are pictures of a person's speech. They resemble contour maps; but instead of indicating various elevations, the lines of a voiceprint indicate the intensity of the voice in various levels of pitch. A voiceprint is, in a sense, a "print" of a person's vocal tract. It is as distinctive as a fingerprint. It can reveal basic similarities and differences among voices of speakers saying the same words. This type of fundamental knowledge is essential to the development of means for transmitting speech over channels of reduced bandwidth while retaining the naturalness of the voice.

The technique of making visible-speech representations of the human voice began about 20 years ago at Bell Telephone Laboratories under a group headed by Ralph K. Potter. This work resulted in the bar-diagram sound spectrogram. Then, in 1960, A. J. Prestigiacomo and B. F. Logan developed a contour sound spectrogram. It presents a continuous picture in which the relative sound amplitudes, or intensities, are displayed in terms of contour lines.

Prints are obtained in this way: The voice sample, which cannot exceed 2.8 seconds, is recorded on magnetic tape, and is played back repeatedly for analysis. A piece of facsimile paper is placed on a drum which rotates in synchronism with the play back. An electric stylus in contact with the facsimile paper records the result of the analysis.

You can think of the voiceprint as being a drawing of a spoken word showing frequency, amplitude, and time. Each voiceprint shows seven "contour" levels which represent the amplitudes of the frequencies in your voice. Each level is six decibels apart; this means that the spectrogram measures a total voice range of 42 decibels.

Recently, in an acoustics research program conducted by Lawrence G. Kersta, voiceprints were made of the same word spoken by different persons. Each utterance of the word was voiceprinted on a separate card. Then the cards were shuffled, people without previous training were asked to identify each voice. Out of about 25,000 decisions, the right identification was made more than 99 per cent of the time.

These findings from basic research in communication may lead to valuable aids for personal identification. Law enforcement agencies, given enough different word samples from an unidentified speaker, may be able to identify the speaker's voice from millions of others—despite any attempt by the speaker to disguise his voice.

Since voiceprints can be analyzed and coded by computer, the code of an unidentified voice could be matched against those on file. Final identification, as in the case of fingerprints, would be made visually by an expert from a number of prints that are similar.

TIC-TAC-TOE MACHINE

You can play a game of tic-tac-toe with a machine developed by William Keister of Bell Telephone Laboratories, but don't expect to win. The machine can be tied but cannot be beaten. The machine represents the kinds of processes that can be built into telephone systems. It illustrates how relay-type equipment (like that used in telephone systems) makes logical decisions in connecting one caller with another.

The face of the cabinet is divided into nine squares. When you press a button near one of the squares to light it with a figure, such as "x", the machine automatically places the other symbol, in this case an "o", in another square and waits its turn for another play. The electro-mechanical brain can make three decisions. If you succeed in marking two symbols in a row, the machine makes a defensive play by filling in the third space in the row. If the machine itself has two in a row, it will fill in the third and win. If there is no immediate chance to win and no need to block you from winning, the machine marks the most advantageous square.

No matter how good you are, the best you can hope for is a draw.

THE DUPONT SHOW

Wonderful World of Chemistry

Synopsis of Chemistry Demonstrations for the Du Pont Pavilion:

1. Freezing a Flower in Freon. In this demonstration a flower such as a carnation or a rose is dipped for a few moments in Freon. Since the Freon is at about 50° below zero, the flower freezes instantly. The flower is removed from the Freon and when struck on the table top, it shatters like glass.

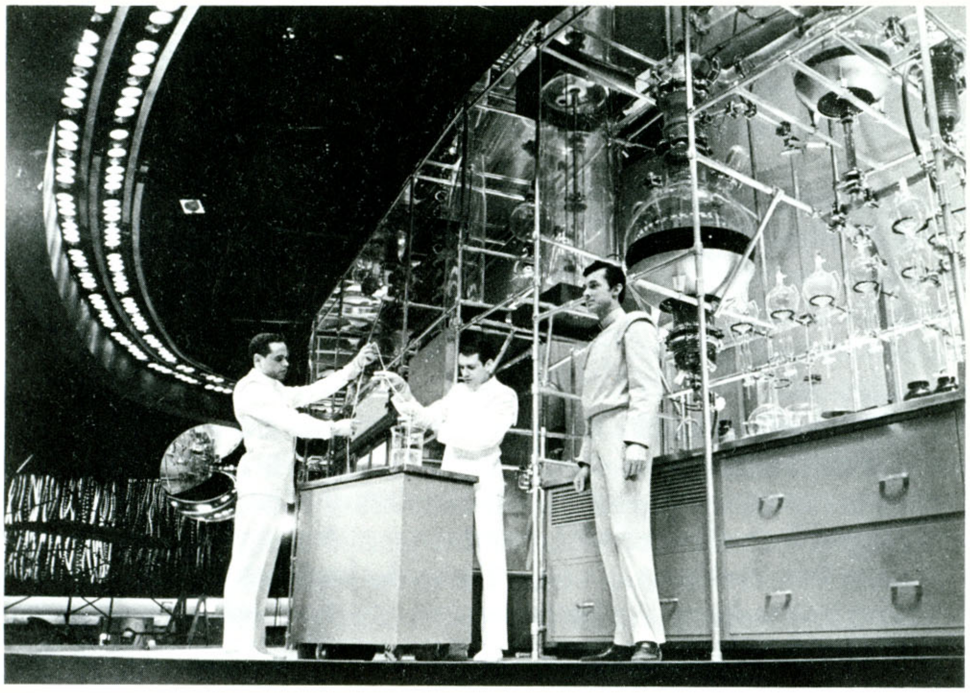
2. Rubber vs. Adiprene Balls in Freon. A rubber ball frozen in Freon will shatter like glass when dropped on the floor. A ball made of Du Pont Adiprene, on the other hand, retains its elasticity and bounces after its immersion in Freon.

3. Disappearing Blue. In this demonstration a large flask containing a clear liquid changes to a deep blue color when the flask is shaken. This blue color slowly changes back into a clear solution again. This can be done repeatedly by simply shaking the flask.

This demonstration is based on the fact that a certain indicating dye will turn deep blue when combined with air which is accomplished by the shaking. Another chemical in the flask reverses this situation and the liquid becomes colorless.

4. Hindu Rope Trick. This demonstration features Du Pont Stren which is a Nylon fishing line. It is so fine and transparent that we can reconstruct the well known Hindu rope trick by attaching the Stren to a piece of manila rope and using it to lift the rope, which then hovers in mid-air as though unsupported.

5. Conductive Paint. A tape recorder is separated from its loud-speaker by a panel of transparent plastic sheet so that although the tape recorder is mechanically operating, no sound comes out of the loud-



speaker since it is not electrically connected. An aerosol dispenser containing a paint which conducts electricity is used to "spray" 2 "wires" leading from the tape recorder to the speaker. Completion of the second "wire" electrically connects the speaker and it begins to play.

6. Instant Nylon. A large container contains 2 liquids, one of them floating on the other. Where the two liquids meet, polymerization occurs and pure nylon is produced. This film of nylon can be lifted out of the liquids by wearing rubber gloves and reaching through the top liquid. This process is continuous and a cord of nylon can be drawn continuously from this container until one of the liquids is depleted.

7. Dacron 88. A strand of unstretched Dacron 88 is held and stretched to over twice its length. When the strand is released, the stretched fiber bunches up or fluffs since each individual filament has now become crimped by the stretching process.

8. Baymal. A tube about 3′ long and 4″ in diameter is partly filled with a thick white liquid, Baymal. This substance is thixotropic; i.e., the liquid gels or becomes firm in about 10 seconds so that if the cylinder is held vertically with the liquid Baymal at the bottom, in 10 seconds it can be turned over so that the Baymal stays at the top. The Baymal can be liquefied by simply shaking the tube after which it will gel again. This can be done endlessly.

9. Lucite Paint. Lucite Paint is also thixotropic, which is the reason for its "no-drip" qualities. To prove this, we drape an expensive fur or orlon coat over a table using it as a drop cloth. The open can of paint is placed on the coat and a panel held above the coat is painted.

10. Tipersul. A performer lays a piece of 1/8" Tipersul on his open palm and an assistant places a red hot bolt on the Tipersul. This thin sheet protects his hand and the performer shows the high temperature of the bolt by dropping it on a piece of wood which catches fire.

11. Mylar and Butacite Drum. Two drums about 3′ in diameter have their ends covered with Mylar and Butacite respectively. A heavy solid Lucite bowling ball is dropped on to the plastic sheets from a height of about 3′. Upon striking the Mylar, the ball rebounds sharply. The Butacite drum, however, cushions the blow and the rebound of the ball is substantially less.

12. Jacob's Ladder. A 50,000-volt arc up to a foot long is generated between two vertical rods in the form of a "V". A piece of wood placed in the gap catches fire immediately because of the intensity of the arc. A sheet of Mylar is then placed in the gap, power turned on, but the arc does not strike due to the high insulating ability of the Mylar. As soon as the Mylar sheet is removed, the arc is immediately generated.

13. Zepel. A piece of cloth is prepared with the letters Z-E-P-E-L printed on it with Zepel which cannot be seen. Stains of various sorts such as ink, tomato juice, salad oil, etc., are poured on the cloth and stain it completely except where the material has been treated with Zepel. The letters Z-E-P-E-L then stand out since they are unstained.

14. Iodine Clock. In this demonstration a small quantity of clear liquid is added to a large flask containing another clear liquid. In the order of 10 seconds the solution turns *instantly* black.

15. Color Sequence. The black solution from the previous demonstration is then poured into 4 beakers. The black solution becomes colorless, then red, then wine colored and finally blue as it is transferred from one beaker to another.

16. Parabolic Mirrors. Two highly polished parabolic mirrors 5′ in diameter are mounted to face each other. A light source at the focal point of one mirror is used to reflect light from that mirror through a distance of about 50′ to the other mirror. The second mirror refocuses the light at its focal point at which a match can be ignited.

17. Vortex Gun. A Vortex Gun 4′ in diameter generates a vortex (concentrated jet of air) which is used to blow out a flame, rattle a sheet of paper, etc. (at a distance of 40′ to 60′).

18. Chemiluminescence. A small amount of liquid is added to about a quart of liquid in a 6-qt. spherical flask. When the mixture is shaken, intense blue or yellow is produced. This light is generated completely by the chemicals in the flask.

THE IBM EXHIBIT

The main attraction of the IBM Pavilion is an "Information Machine". It shows how the methods used by computers are similar to those used in solving problems in everyday life. This is one of a number of new approaches in architecture and visual arts used by IBM to tell the story of modern information-handling techniques.

To reach the 90-foot-high ovoid theatre, a series of elevated walkways lead visitors to 12 tiers of moving seats—a "People Wall"—where, after being seated, they are lifted 400 at a time by a hydraulic mechanism into the unique theatre. There, nine screens in combination, together with music and narration, are used for the presentation.

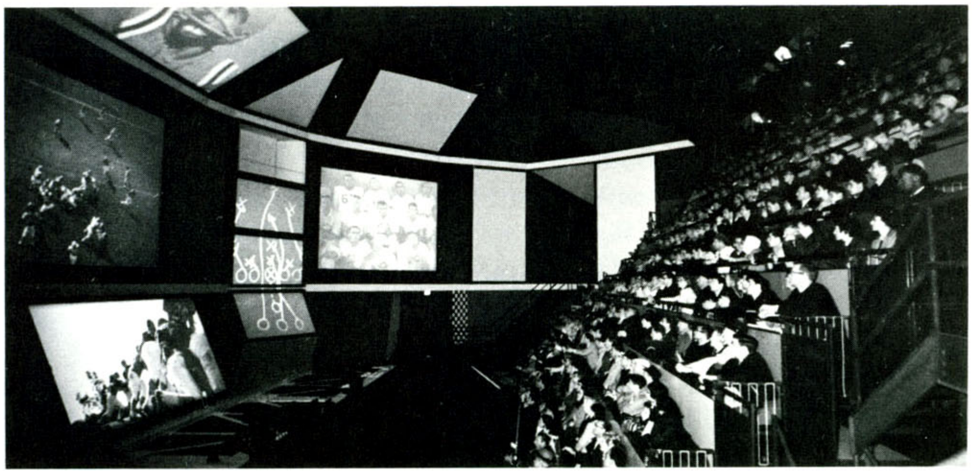
Supporting this main event is a series of exhibits. The entire pavilion has the form and atmosphere of a garden, and the exhibits are housed beneath a grove of steel trees. There is a group of little theatres that offer simple and entertaining explorations of computers and other electronic data processing equipment. Here, mechanical puppet-like devices are synchronized with lights, music, narration and sound effects to explain such subjects as computer logic, speed, miniaturization and information handling systems.

Besides the theatrical displays, the audience sees a large-scale IBM data processing system at work in the Computer Court. It is used to demonstrate the solution of such problems as traffic control, language translation, space guidance and information retrieval.

Located throughout the pavilion is a collection of devices and graphics to show the intimate connection between a computer and probability theory. One of the demonstrations is a 15-foot-high wall of glass resembling a vertical pinball machine. Inside, 40,000 plastic balls cascade down through a pin maze and come to rest forming a probability curve at the base.

In addition to these there is Scholar's Walk, a collection of graphics illustrating the lore of computer technology.

Language Translation: IBM's demonstration of automatic language translation at the New York World's Fair is designed to show the effectiveness of machine translations today—and also to show how



a computer can be used effectively by people many miles away from the machine itself.

The language translation is from Russian to English. The matter to be translated is transmitted over telephone lines to two IBM 1050 data communications systems in a company plant at Kingston, N.Y. The completed translation is sent back to the pavilion by the same method.

At the pavilion, a typist seated at a printer keyboard copies sentences from Russian technical reports. The typist does not understand Russian, but has learned to recognize letters of the Russian alphabet. As each Russian sentence is typed, it is instantly transmitted over the telephone lines via the IBM Teleprocessing equipment to the computer in Kingston, 90 miles from the World's Fair site.

The computer is linked to a "memory" disk that contains the coded meanings of 200,000 Russian words. The disk looks like a transparent phonograph record, and contains coded words and phrases in Russian, together with their English meanings. The words are photographically recorded in circular tracks on one side of the disk. The code for each word consists of a sequence of black rectangles of microscopic size.

A light beam searches the disk until it matches each word or phrase in the sentence with the coded equivalent of that word or phrase on the "dictionary" disk. When a perfect match is made for each word in the sentence, the light beam instantly relays the English translation and pertinent grammatical information back to the computer. The computer follows the rules stored in its own memory, clarifies meanings, and in some cases inserts prepositions, articles and auxiliary verbs so that the translation will conform more closely to English grammar instead of the Russian.

The final English translation is then transmitted back to the World's Fair site, where it is printed on an automatic typewriter.

All this happens at remarkable speed. When the typist feeds an average Russian sentence of about 15 words into the computer, the machine translates the entire sentence in one to two seconds. Then it takes about 6 seconds for the computer to print out the translation on an automatic typewriter.

In one minute, the computer is capable of translating 1500 words, or about five pages, of complex technical material from Russian to English. When a high-speed IBM printer is used, this 5-page translation can be printed in about 20 seconds.

Today in an age of rapid scientific discoveries, human translators cannot keep up with the flood of technical information being produced in French, German, Russian, Chinese and other languages.

There is a pressing need for scientists to keep up with the works of their colleagues and human translators cannot be trained fast enough to make more than a dent in the billions of words in many languages each year. A practical solution to this problem is the development of a system of rapid, automatic translation of languages by machine.

SINCLAIR
DINOSAUR EXHIBIT

The Dinosaur

by Bert Leston Taylor

Behold the mighty Dinosaur,
Famous in prehistoric lore,
Not only for his weight and strength,
But for his intellectual length.
You will observe by these remains
The creature had two sets of brains—
One in his head (the usual place),
The other at his spinal base.
Thus he could reason a priori
As well as a posteriori.
No problem bothered him a bit;
He made both head and tail of it.
So wise he was, so wise and solemn,
Each thought filled just a spinal column.
If one brain found the pressure strong,
It passed a few ideas along;
If something slipped his forward mind,
'Twas rescued by the one behind;
And if in error he was caught,
He had a saving afterthought.
As he thought twice before he spoke,
He had no judgments to revoke;
For he could think, without congestion,
Upon both sides of every question.

Oh, gaze upon this model beast,
Defunct ten million years at least.

COURTESY OF THE CHICAGO TRIBUNE

THE STORY OF THE DINOSAURS

Sinclair's Dinosaur exhibit, called "Sinclair Dinoland", features full-scale models of nine different species of dinosaurs, ranging in size from the six-foot-long Ornithomimus to the massive 70-foot Brontosaurus, whose head towers four stories above the ground.

Three models, including the Brontosaurus, are partially animated to contribute to the realism of the scene.

Each dinosaur is shown in the terrain and flora of the geological period in which it lived. The models are spaced through an outdoor area covering approximately one acre.

Many scientists find the rise and fall of dinosaurs—their emergence some 200 millions years ago and their extinction 60 million years ago—more mysterious than the rise and fall of cultures and nations through the relatively brief period that man has ruled the earth.

Dinosaurs (from the Greek *deinos saurus* meaning "terrible lizard") lived on this planet at least 80-300 times longer than the entire existence of man. In fact, dinosaurs dominated the earth longer and more successfully than any other kind of creature of the past or present.

In the late Paleozoic (or ancient life) Era, the forerunners of dinosaurs first appeared as small, agile creatures. Through the eons of the succeeding Mesozoic (intermediate life) Era, most species of dinosaurs became massive and ponderous.

The Mesozoic Era, spanning some 160 million years, covered three distinct geologic periods: Triassic, Jurassic and Cretaceous. Dinosaurs flourished through the late Triassic, entire Jurassic and most of the Cretaceous periods. Mammals, from whom man ultimately evolved, emerged in the late Jurassic period, but lived obscurely in the shadows of dinosaurs for scores of millions of years.

Several factors are believed to have contributed to the extinction of dinosaurs in the late Cretaceous period. One theory holds that the climate changed drastically as mountains rose and seas receded. Instead of warm humid weather all the time, there began alternating seasons of heat and cold. Unable to adjust, dinosaurs perished.

Another theory points to the evolution of plant life as a key factor. During the Cretaceous period, flowering plants and hardwoods overran the land, replacing the conifers and earlier forms of flora. Plant-eating dinosaurs, according to this theory, were unable to survive on a new diet, and as they expired, so did the predatory flesh-eaters among the dinosaurs.

Still another theory lays part of the blame on the early mammals. Mammals started to multiply rapidly in the late Cretaceous period, and some of the more predatory are said to have fed on the eggs of dinosaurs, thereby contributing to their extinction.

During their heyday, however, dinosaurs were the most awesome creatures ever to inhabit the earth. One of the earliest of the truly massive dinosaurs (and one of the most widely recognized) was the Brontosaurus, a plant-eater who packed 25 or 30 tons into a frame measuring 70 feet long and four stories high. Its name originates from the

Greek *bronto saurus*, or "thunder lizard," for the earth is believed to have trembled under the step of this gigantic reptile.

Brontosaurus was one of the largest land creatures that ever lived.

Brontosaurus prowled the lowlands of North and South America, Europe and East Africa. A member of the saurischians (literally "reptile hips"), one of the two main orders of dinosaurs, Brontosaurus was a placid, plant-eating animal for all its tremendous bulk.

A life-size reproduction of Brontosaurus, partially animated for greater realism, occupies a position of prominence in the exhibit.

Another dinosaur in the collection that will be recognized by millions is Tyrannosaurus, often described as the most terrifying flesh-eater that ever lived. A latecomer in the age of reptiles (it lived in the late stages of the Cretaceous period), Tyrannosaurus carried six-inch, saber-like teeth in its massive jaws. This "tyrant lizard" spanned 50 feet from tip to tip, and its great death-dealing head rose 18 to 20 feet above the ground.

At the other end of the scale were such small and frail specimens as Struthiomimus and Ornitholestes. Struthiomimus, perched on long, thin legs, was built for speed. With its small, hard beak, it resembled an ostrich. It measured 14 feet in length, 7 or 8 feet in height.

Ornitholestes boasted little more girth than a turkey. One of the early dinosaurs, flourishing in the Jurassic period, Ornitholestes was a direct forebear of Tyrannosaurus and other carnivores to come. About six feet long, Ornitholestes had sharp claws and bird-like feet.

When the earth's climate cooled early in the Cretaceous period, docile dinosaurs of the ornithischian order (literally "bird hips"), second of two main types of dinosaurs, were forced out of the swamps into the uplands and open plains where they faced the wrath of carnivorous saurischians like Tyrannosaurus. In the interests of survival, some plant-eating dinosaurs developed defensive equipment impregnable to all but the fiercest flesh-eaters. Ankylosaurus, Triceratops and Stegosaurus stood out among these armored beasts.

Ankylosaurus, a walking fortress whose entire body was cased in thick armor plates, resembled an armadillo. For defense its body was laced with spikes and studs, while its only offensive weapon, its tail, was capped in solid bone. The squat Ankylosaurus was about 20 feet long and six feet wide, medium-sized as dinosaurs went.

Triceratops was a lavishly armored quadruped mounting three horns on a great flare of bone that sheathed its seven-foot skull. Twenty to thirty feet long and eight feet high at the hips, Triceratops resembled a rhinoceros. Despite its fearsome appearance, it was a vegetarian generally content to live and let live, though it could deal fatal retaliation if attacked.

Even in the grotesque architecture of dinosaurs, Stegosaurus was a sight apart. Packing about 4 tons in a length of 25 feet, this low-slung humpbacked creature carried a double row of triangular plates covering almost the entire length of its spine. While its bizarre appearance may have made a hungry carnivore pause before attacking, Stegosaurus was woefully ill-equipped for a battle of wits, since its brain was no larger than a small dog's.

Rounding out the collection are the duck-billed Corythorsaurus and the Trachodon. Both were plant-eaters, Trachodon attaining a length of 38 feet and a height of 16 feet and Corythorsaurus reaching some 30 feet in length. Trachodon munched weeds and roots with as many as 1,500 teeth.

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