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# CALIFORNIA SPACE SHUTTLE TASK FORCE

**Space Shuttle...**
**returnable, reusable.**
**Benefitting life on earth**
**while reducing space costs.**

CALIFORNIA
SPACE
SHUTTLE
TASK
FORCE

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Unionamerica

ROBERT H. VOLK, *President*

The Space Shuttle represents more than an extension of America's program for the exploration of outer space and the environment of Earth. It is, in fact, a basic transportation system for men and materials from Earth to outer space and back, and thus will serve as the foundation for future programs of space research and interplanetary exploration.

California's industries, manpower and technological resources, as well as our space flight facilities, have played a major role in engine, booster vehicle and space capsule design and manufacture from the first orbiting shot of Explorer I through Apollo. These capabilities stand ready to play a major role in the Space Shuttle program.

Those of us on the California Space Shuttle Task Force, created by U.S. Senator Alan Cranston and Lt. Governor Ed Reinecke, heartily endorse the program as essential to the furtherance of our national goals. The development of knowledge and the utilization of space will lead to a better understanding of our earth environment for the benefit of all mankind.

Robert H. Volk

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CALIFORNIA SPACE SHUTTLE TASK FORCE

*"Creativity is as unconfinable as ideas. Space Shuttle is one of those conceptions; a resourceful means for man to make use of space in a less expensive manner. But creations of this scope require cooperation, teamwork and a concerted effort. Individual effort only really becomes meaningful when it is joined with others in a similar goal. Space Shuttle is the kind of goal that can encompass a broad range of American talents to achieve a solution in which America has a demonstrated capability."*

Ronald Reagan
Governor, State of California

*"We are on the verge of a practical possibility. Inventive talents and technical capabilities are not necessarily confined to one nation. Among observant men there comes a time when there appears to be sufficient knowledge at hand to resolve a need. At this point in history, America has the vision and the talents to create a Space Shuttle. We would not want to willingly abdicate this opportunity and its follow-on benefits. It is an acceptable challenge and opportunity for America."*

Ed Reinecke
Lt. Governor, State of California

*"Problem-solving of large and complex challenges that channel technology into the service of mankind is a particularly American skill of recent decades. The Space Shuttle is our challenge of the Seventies and the Eighties. Herein lies our opportunity for a highly-flexible, yet less-costly, means of utilizing a capability in space to benefit man on earth."*

William Mailliard
Member, United States House of Representatives, California

*"By destiny or design each nation fulfills its role in a family of nations. One of our roles has been creator and supplier of technological advancements that can be useful to mankind. Respect for the living standard of our labor force compels us to search for opportunities other than matching foreign competition. Instead, we sense that our destiny and our well-being exists in serving the world as purveyor of advanced technological capabilities. During the 1970's, Space Shuttle will come into being. The Shuttle, its applications, and the technological spinoffs constitute our opportunity to serve men, here and abroad, without oppressive exploitation."*

Alan Cranston
United States Senator, California

*"America is confronted with an array of worthy programs, each with its own priority on funds and time. Space Shuttle is one of these. The Space Shuttle will be a substantial investment in the future. It will be a bridge to our hopes for manned space flight in coming years. It promises the development of new technologies. It is a priority for the Seventies. We must begin now to move in an economical and orderly manner toward this goal."*

John Tunney
United States Senator, California

*"Our nation is in the process of converting space capabilities from scientific exploration to practical application. Exploration will continue and application has been well under way for several years. Yet, the trend toward application will accelerate, particularly now that we have successfully passed through the era of forced development with its penalties of higher costs to overtake time delays. The Space Shuttle is conceived as the means of furthering this era of practical application while reducing the costs of our initial space era."*

Chet Holifield
Member, United States House of Representatives, California

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CALIFORNIA SPACE SHUTTLE TASK FORCE

## CHALLENGE OF THE 1970's

# Improve our living on earth through expansion of practical applications in space technology.

During the past decade and a half we have established our place in space. We developed the thrust. We achieved orbit. We began scientific exploration. We realized practical applications.

Meanwhile, we are also rightfully interested in improving our existence on earth. Conveniently, however, several techniques for guiding the improvement of life on earth are inherent in our new-found capabilities in space and the applications that a space-ability makes possible.

Yet, we want to pursue this capability with a greater flexibility, and at the same time, reduce the cost substantially. Therein lies the promise of: Space Shuttle.

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## Achieving Objectives

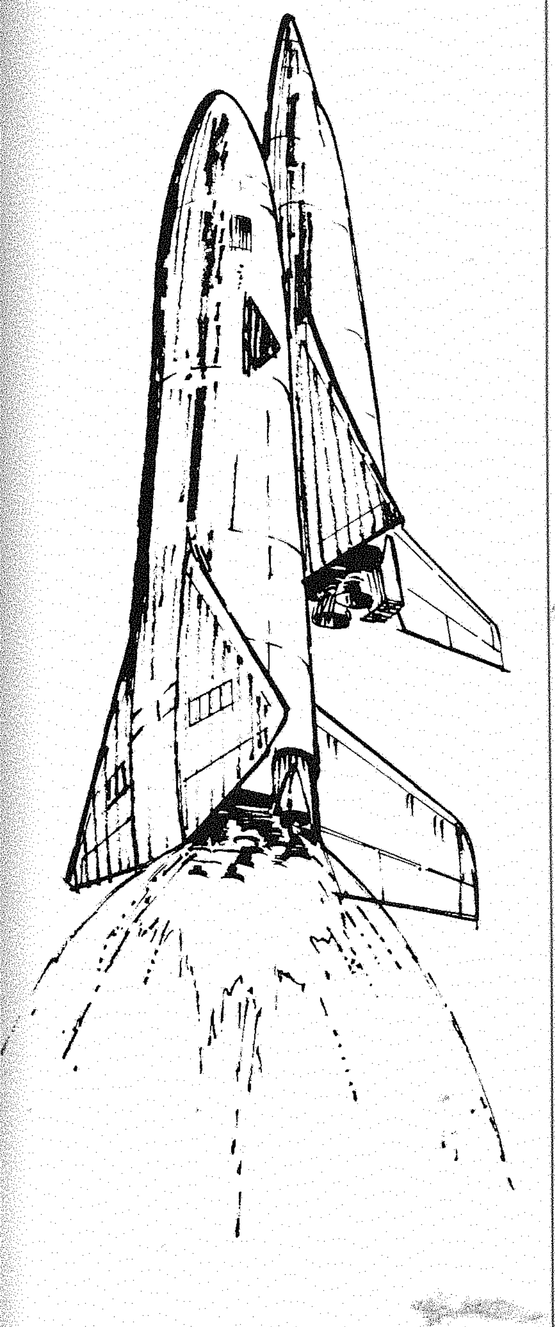
President Richard M. Nixon
March 7, 1970

"...we must devise less costly and less complicated ways of transporting payloads into space...We are currently examining in greater detail the feasibility of reusable space shuttles as one way of achieving this objective."

## Pursued With Vigor

Charles H. Townes
Chairman, National Academy of Science, Space Science Board;
Professor of Physics, University of California
October 21, 1970

"A successful space shuttle, including further lowering of costs and the possibility of assembly and adjustment of equipment in space, should produce a marked change in the style with which science and space applications are carried out...I believe its study and development should be pursued with vigor."



## WHAT IS THE SHUTTLE?

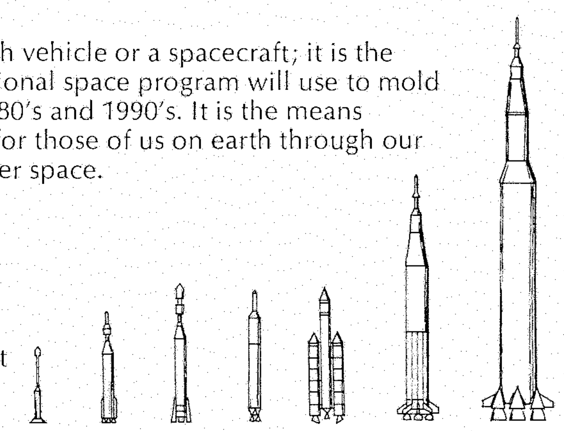
It is a launch vehicle, a spacecraft, an airplane. It is a multi-purpose tool for replacing all but the smallest and the largest of today's launch vehicles. But, unlike them, it returns intact and is completely reusable. It combines low-cost operations with great versatility. It merges the manned and unmanned programs to gain the most from each and the maximum return for the nation.

### Basic Transporter

The shuttle is not just a launch vehicle or a spacecraft; it is the basic implement that our national space program will use to mold the space programs of the 1980's and 1990's. It is the means toward deriving a better life for those of us on earth through our knowledge of the uses of outer space.

### One Replaces Many

Space Shuttle will replace all of today's launch vehicles except the small Scout rocket and Saturn V, which may be used for a few specialized missions.




### Resembling Aircraft in Space

Although the shuttle is a manned space vehicle, it resembles two airplanes rather than one spacecraft. Its two crews, one in each stage, serve primarily to pilot the stages in aircraft-like maneuvers.

### Reusable

The value of space to residents on earth has been demonstrated. Yet, the economics of that value now dictate that a less costly way be found to move to and from orbit. The shuttle is that way. Its basic economic attraction is multiple use. Each can be used for 100 or more launches instead of just one, as are today's launch vehicles.

### Reducing Costs

The cost of continuing with today's expendable, one-shot launch vehicles has been compared with the projected use of the shuttle. Comparisons were based on the current rate of 30 launches a year, which is considerably fewer than during the peak years of the 1960's. Looking ahead, even when an estimated shuttle development cost of $8.3 billion is added to estimated operational costs, the Space Shuttle method would equal, within just six years, the cost of continuing with today's expendable vehicles. Thereafter, savings through use of the shuttle would amount to $2 billion a year, and savings would proceed to increase as the shuttle system is continually reused.

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## WHERE DO WE STAND IN SPACE?

We have launched our aspirations toward space since 1958. We have developed an admirable range of capabilities. But, beginning in 1967, the frequency of American space launches declined and has continued to do so ever since.

By comparison, the Soviet Union has accelerated the number and frequency of launches. During the past 13 years, the Soviet Union has launched 20 percent to 30 percent more missions of rocket missile modules roughly comparable in scale to American launches. Furthermore, Russian space missions are increasing in size-capacity and technical sophistication.

Competition is neither the sole reason nor the guiding factor in directing our space program, however.

Space represents an unknown realm of thought and action. The challenge is inviting. We detect, from a faith born of achievements in the past, that our advancement continues to depend on exploration of the unknown.

"Doing it because it is there" is not our sole purpose either.

We do it to attack problems and challenges posed by existence on this planet.

And in so doing for over a decade, we have developed an array of practical applications; we foresee an increasingly impressive pantheon of useful possibilities; we recognize the space program's importance to our economic well-being—both as individuals and as a nation, and we know instinctively that international pre-eminence demands that we demonstrate continually improving capabilities in space.

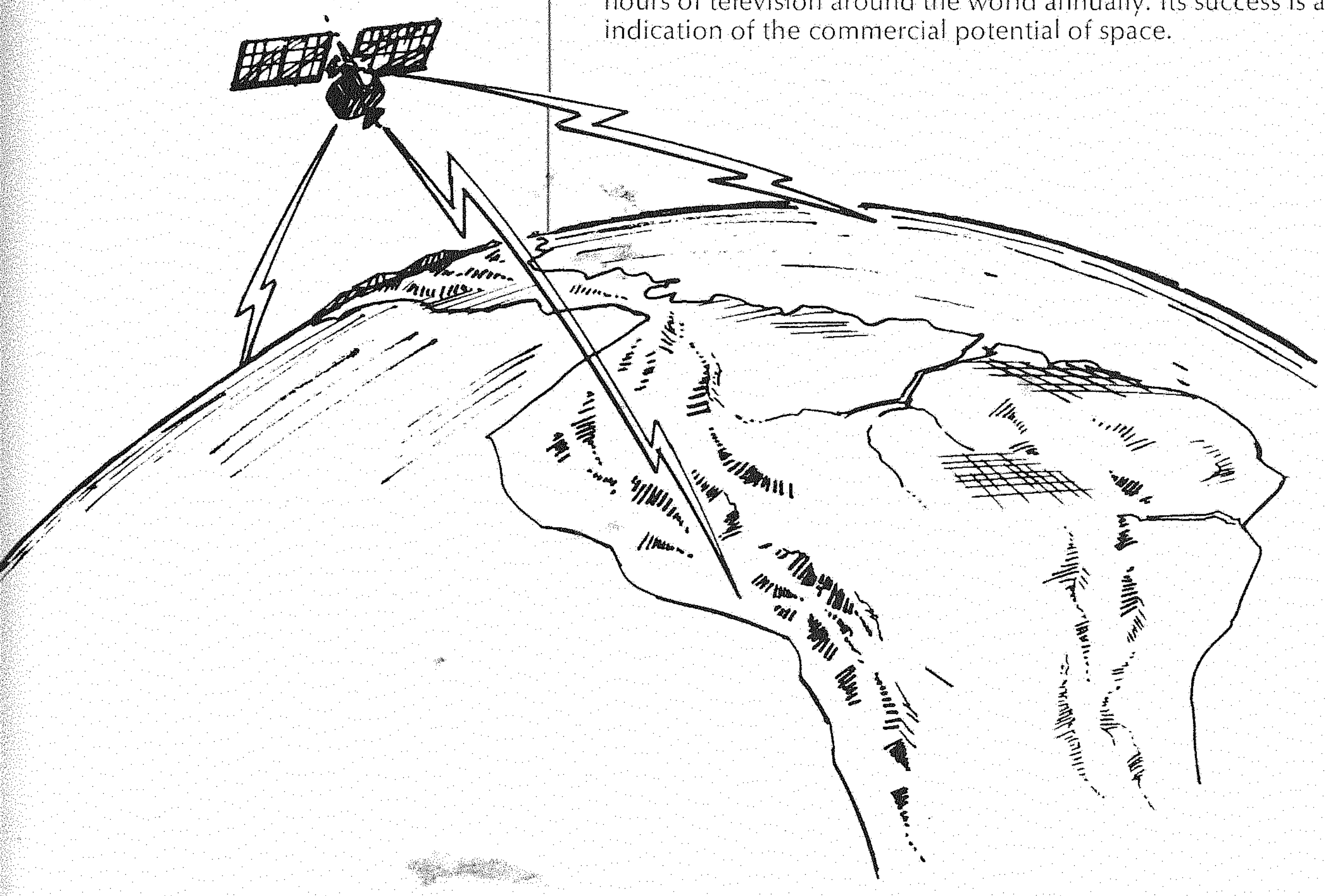
Thus, the ensuing pages scan briefly some of our direct accomplishments in space, beneficial spinoffs, our future possibilities, and the economic advantages of the space program.

## Communications

Satellite communication has, within a decade, moved from novelty to accepted convenience. Communications satellites have become an important adjunct to other communications carriers.

Television via satellite relay is widely familiar to the viewing public, and international communications are routine. The Intelsat IV satellite conveys 9,000 phone calls, 12 color television channels, or any combination, between North and South America, Europe and Africa. The dependability of these satellites is so high that they were utilized as a replacement for transatlantic cable transmissions during repair of the international cable. Such satellites also represent a substantial communications cost reduction: relay costs approximate $4,000 per channel per year via satellites, as compared with $25,000 per channel per year when using the recently laid submarine cable.

In communications, 76 nations are joined in space's first commercial venture, the Intelsat network. The network is now orbiting fourth-generation spacecraft. It has 42 ground stations in 29 countries, it leases 2,000 circuits full-time, and it relays 1,000 hours of television around the world annually. Its success is an indication of the commercial potential of space.



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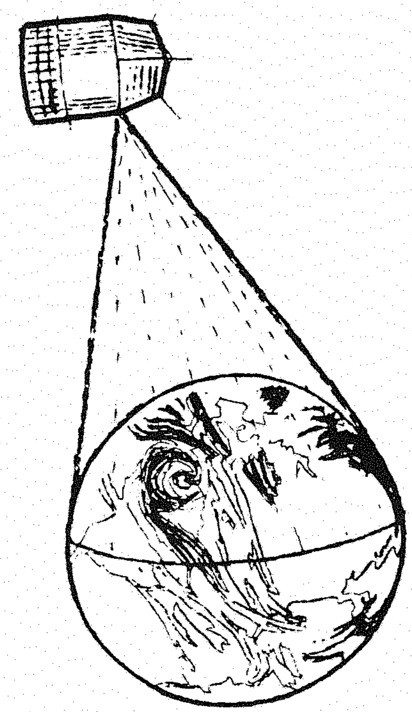


## Weather

Meteorological observation via satellite has provided one of the most significant advances in weather reporting of this century. Global weather reporting, through international cooperation, has been expanding for more than 75 years. Yet until the advent of weather satellites, this weather data came from less than 20 percent of the Earth. The other 80 percent, primarily the oceans, was subject to only scattered observations.

Early in the 1960's, however, the weather satellite made possible the observation of the Earth's surface, on an all-encompassing basis, with information transmitted immediately, and the ability to undertake analysis within a useful time frame.

Since 1966, orbiting spacecraft equipped with cloud cover cameras have provided man on earth with the opportunity to observe the atmosphere on a continuous basis, a convenience that gave us the ability to study the formation, path, and dissipation of severe storms. At an altitude of 22,300 miles above the equator, the ATS-3 spacecraft can scan the earth from west to east, while the scene below passes by, requiring precisely 24 hours to complete one revolution. Four synchronous meteorological satellites, properly spaced around the earth, could monitor nearly all of the earth's cloud cover all of the time. In so doing, they would give meteorologists the capability of watching and following hurricanes and severe storms.

Weather forecasting is one of the most obvious beneficiaries of space to date. Some 50 nations use the information provided by our network of orbiting satellites. Advanced Tiros and Nimbus spacecraft, planned during the 1970's, are steps toward developing a comprehensive worldwide weather model.

During the 1970's, advanced operational satellite-computer technology should make routine the performance of reliable long-range weather predictions of two weeks or longer.

Eventually, the weather satellite could be one of several devices making possible weather control and modification through such techniques as clearance of supercooled stratus and fog, the increase or decrease of precipitation, the suppression of lightning, dissipation of pending hail storms, the moderation of severe storms, and varying the activity of large-scale circulations.

Air pollution will be observed by satellites and they will become an invaluable tool in charting corrective action as they report the transport and diffusion of pollutants and the effects of weather and climate in the creation and dissipation of pollution.

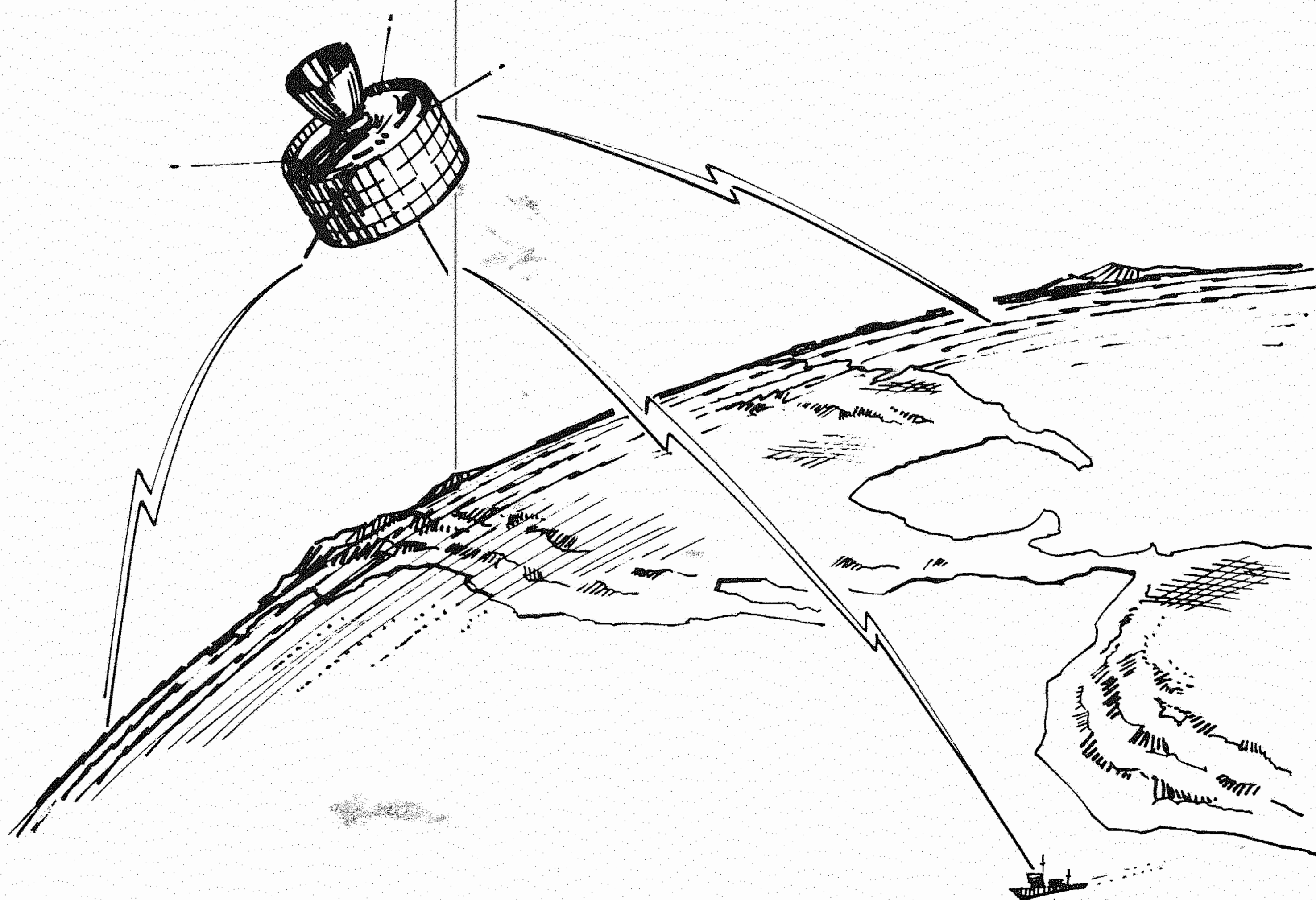
Eventually, atmospheric structure will be understood through satellite observations that will aid us in establishing a set of standards for describing the atmosphere. This knowledge will be invaluable in guiding aircraft operations, understanding the performance characteristics of space vehicles, the planning of space operations, and resolving the problems of reentry into the earth's atmosphere.

## Navigation

Navigation requires the determination of position, the discerning of the direction of movement from one point to another, and the ability to communicate that information. Navigation via satellite affords that ability. Additionally, it offers the possibility of doing so safely, of preplanning routes at minimum cost, and of transmitting position information to others in cases of search and rescue.

Satellite navigation systems can provide global coverage. They are practically invulnerable to weather, available day or night, and are capable of responding instantaneously.

Earth-orbiting navigation satellites discern ship and aircraft positions much more accurately than previous systems. In the fast-moving environment of air traffic, such a capability is essential for traffic control and collision avoidance. With satellite-assist, controllers can pinpoint an aircraft's position within approximately one mile.



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## Agriculture and Forestry

Observation via satellite offers a substantial improvement in the kind of crop and forest observation that was initially made possible through aerial photography. The satellite method makes possible regular, periodic observation, on a routine basis, from distant, all-encompassing views that can incorporate multi-spectral scanners, infrared sensitive film, television and conventional photographic techniques.

By aid of satellites and their remote sensors, man is assisted in his management of food crop and timber resources. He can monitor the health of the earth's timber resources, aid in determining the best time to plant and to harvest for maximum yields, detect potential damage to crops, help improve land use, conduct periodic crop inventories, spot plant blights before they spread, and be forewarned of impending droughts, erosion and floods.

Enlightened forestry is made more likely with satellite observations that detect the rate and direction of spreading diseases, than can aid in estimating timber yields, that scan remote areas in a survey of timber, and that offer an early-warning technique for spotting floods and forest fires.

Among the possibilities for agriculture and forestry:

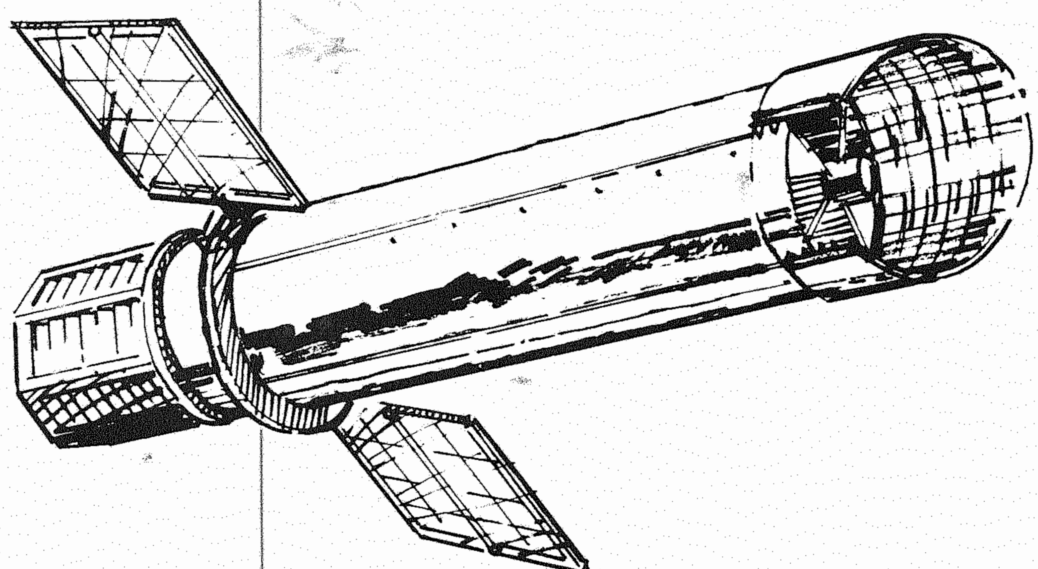
| | |
|---|---|
| Range surveys | Crop disease and insect invasion detection |
| Forest fire detection | Agricultural development projects |
| Land use changes | Watershed and hydrologic studies |
| Crop identification | Forest disease and insect invasion detection |
| Soil classification | Crop acreage control programs |
| Natural vegetation | Forest species identification |
| Flood control survey | Recreation site evaluation |
| Wildlife habitat | Irrigation development |

## Astronomy

Earth-bound astronomers have heretofore been limited in their observations of space by the earth's obscuring atmosphere. Observing equipment placed outside earth's envelope aid substantially in understanding celestial mechanisms. By study across the entire spectrum in wave length regions, astronomers have discovered additional x-ray emissions from various regions of the sky, detected ultraviolet and soft x-ray energies coming from the sun, and discerned radio signals emanating from the earth that are similar to radio waves that appear to be coming from the planet Jupiter.

Astronomy pursued via space shuttle and sortie missions will be substantially improved. Instruments of larger size and greater capability than used thus far by missile-borne satellite could be transported by shuttle. Ordinarily, such instruments increase greatly in cost when unmanned capabilities are added to their size and complexity. But manned attendance of such instruments within the Shuttle orbiter will allow for modification adjustment, maintenance, repair, and film recovery and replenishment.

Advancement such as this will assist in transforming astronomy from mere data gathering to achieving a better understanding of the universe.



CALIFORNIA SPACE SHUTTLE TASK FORCE

## Earth Resources

From space, a new and comprehensive view of earth's resources is offered to man. It is a view that can contribute to conservation as well as utilization, to planning and to development.

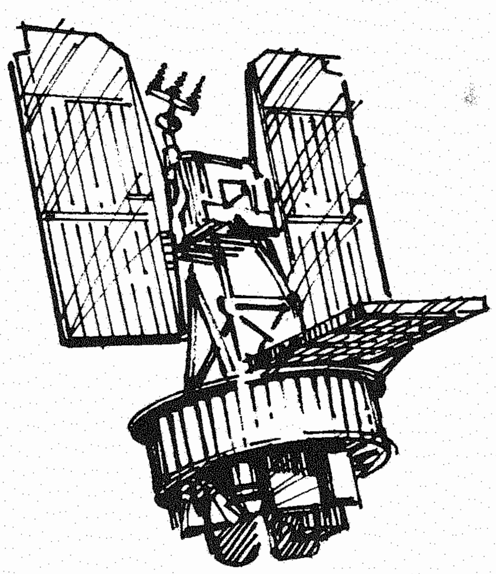
Every chemical element reflects or radiates a distinctive signature across a spectrum of wave lengths such as ultraviolet, visible, infrared, microwave, radio, etc. Photography by film sensitive to these radiations provides information about earth resources that heretofore was unavailable. With the proper use of this information, a pattern of our resource supply can be matched with that of our resource demands. Surveying of the earth's resources from outer space is a significant extension of man's file of knowledge.

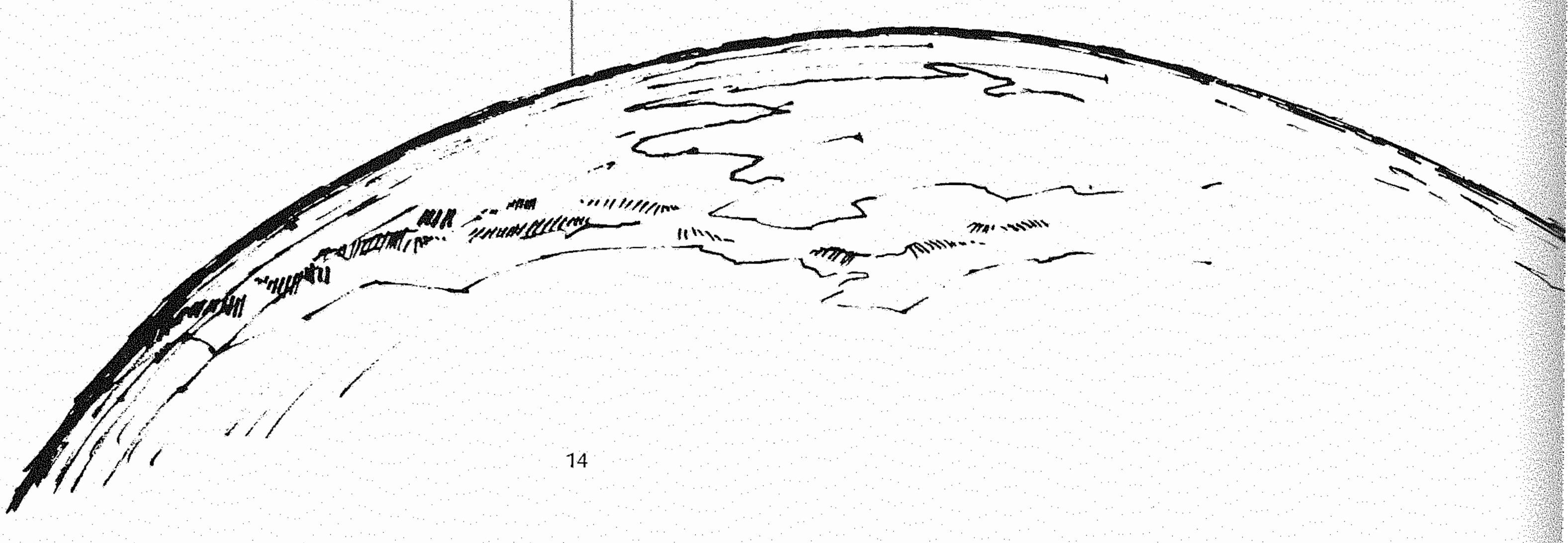
Our geologic knowledge, via space observation, investigates the earth's composition, structure, stratigraphy and history. The technique gives us the capability to map geology and geophysics on a regional basis. Eventually we will be able to develop methods for monitoring natural disturbances.

Mineral resource observation encompasses the ores, such as iron, copper, and gold; the non-metallic deposits, such as sand, gravel and limestone; and oil and gas.

Electromagnetic energy and the electrical properties of rocks and terrains are even more satisfactorily observed from space than from the limited height of aircraft observation. Observation from a limited height, while revealing, has to contend with the variables of sun angles and temperature and moisture changes. Optical observations from space, providing a chance to "see" large structural situations, improves upon this technique.

Gemini and Apollo series photographic observations gave us the first all-encompassing views of the Himalayas and the Andes, the practical applications of locating new oil deposits in Australia, and a photo mosaic of Peru more accurate than any map.





## Oceanography

Two-thirds of the earth's surface is covered by the oceans. They can be viewed in their vast scope only from a distant point in space. It is this distant point of view that can be utilized to increase our understanding of the oceans, to utilize them as a medium of transport, to detect their influence on weather and climate, and to evaluate them as fishing grounds.

Current means of investigating and reporting on the oceans are scattered, sporadic, and economically inefficient if a saturation of coverage is desired. The present methods include shipboard observation, reporting buoys, aircraft survey and coastline observation. The vastness of the oceans limits our ability to extend these methods in volume.

Furthermore, the continually changing state of the sea requires that information, in order to be useful, must be gathered quickly. Several techniques via satellites are in various states of use or development. They include:

State of the sea, insofar as the relationship between wave height and wind force is discernible by remote wave-height sensors.

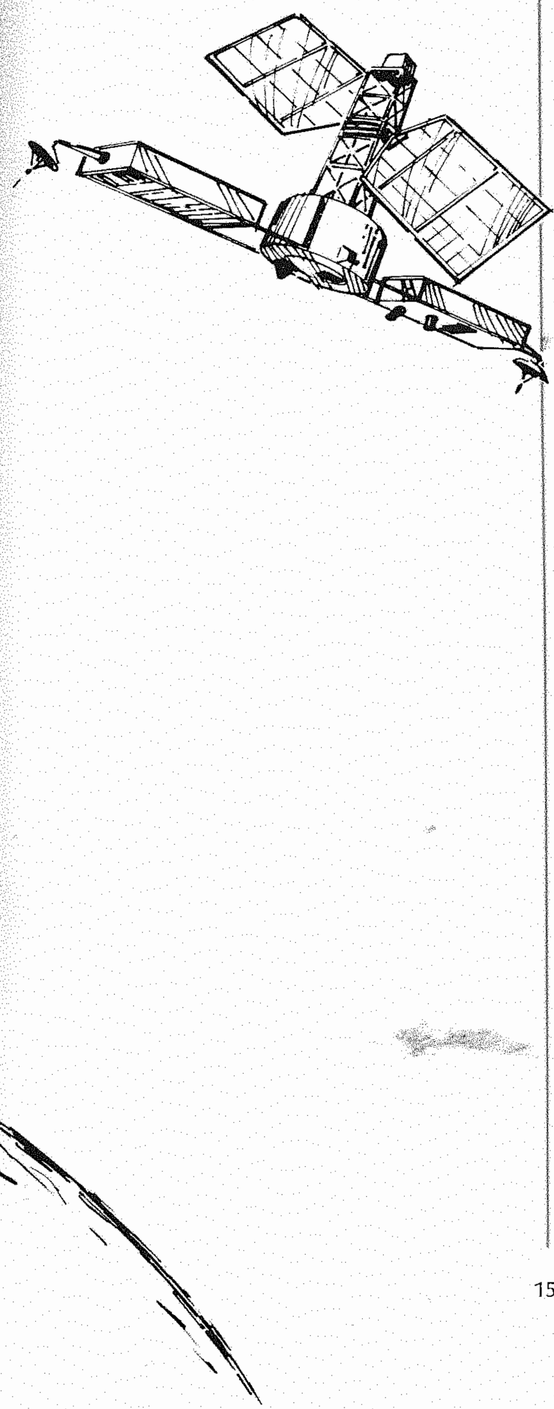
Thermal conditions and the temperature of the sea surface are among the variables that can also be discerned by remote sensing.

Sea ice was among the first oceanographic features transmitted by the original meteorological satellite, TIROS 1, launched in the Spring of 1960.

Location of currents and water masses by thermal characteristics, as well as by water coloration, have been reported from space observations.

Mapping of coastal areas, regardless of weather conditions, is possible from satellites and aids in rapid detection of shifts in shoreline as a result of storms and floods.

Movement of biological phenomena in the oceans, discernible either by heat or color, can imply a possible relationship between concentrations of fish and marine organisms. The capability to make these observations may assist in understanding the significance to man of commercial fishing policies and the wise use of our fishing resources.



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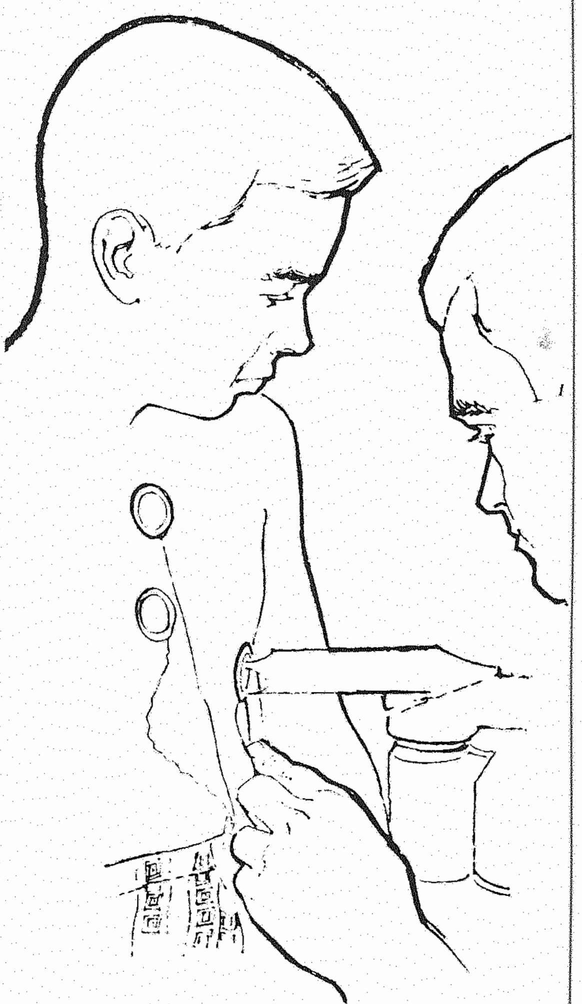


## Spinoffs, the Extra Bonus

Some of the returns from the space program are not easy to price-tag. These are discoveries made during development of space hardware, discoveries that have been transferred into everyday life. The magnitude and challenge of the space program have led to revelations in almost every conceivable science, technology and craft. The revelations have been converted to practical applications. No American is unaffected by them.

The spinoffs from space are more than products and techniques; in some cases they are new industries, or new directions for established industries. Systems-engineering and the science of reliability are examples of the former; the advances in computer technology and microminiaturization illustrate the latter.

One of the biggest beneficiaries of space research has been medicine. The merging of bioscience and engineering, forced by the demands of adapting man and space, has resulted in numerous medical devices and techniques.

Dry, spray-on electrode techniques enable an electrocardiogram to be taken, for instance, in an ambulance on the way to a hospital. Sensors smaller than the head of a pin can be inserted into a vein for measuring blood pressure without interfering with circulation. An automatic living-cell analyzer can produce almost instantaneous blood counts .A switch is now in existence which can be operated by eye movements of a paralyzed patient. A telemetry unit monitors cardiac patients in intensive care units.

New materials have been developed in response to the quest for lightweight, strong, heat-resistant components used in space. A new type of pipe, built of plastic mortar and reinforced with fiber-glass, is light, thin-walled, noncorrosive, and practically unbreakable, making it perfect for water, sewage, and irrigation systems. A polyurethane spray foam is now used to insulate the hold of a tuna boat. Another space insulation—an aluminized plastic only half a thousandth of an inch thick—is being sold commercially as an emergency blanket; it has unique heat-reflecting properties and surprising strength.

Sampling other spinoffs: an electromagnetic hammer, originally devised for space use, now used in building ships and autos; a plastic material for packaging meat; foamed resins employed to refloat sunken ships; adhesives for bonding auto trim; a fire-resistant material which can be made into soft, resilient garments; semi-conductors 3/16th of an inch in diameter which contain more than 1,000 circuits; an anti-skidding technique for freeway-driving trucks; and computer programming which has been adapted to such diverse uses as an instant flight and reservations system for airlines and swift handling of stock market transactions.

There are other, less tangible payoffs. Our basic knowledge has been enriched enormously in many fields: the biosciences, physics, astronomy, geology, engineering. Space research has resulted in technological advances ranking with mankind's most significant discoveries. Space has been among our best salesmen abroad. Few of our accomplishments are so influential in demonstrating our capabilities, demonstrating our goodwill through the services of space satellites, and in enhancing U.S. prestige around the world.

The transfer of knowledge both by intent and coincidence continues. The possibilities for transfer stimulate new economic enterprises.

## FUTURE

### Pollution Control

The interrelationship of all the factors that contribute toward pollution requires the distant, all-encompassing view from outer space. This use of outer space will aid us in locating and minimizing pollution of the oceans and major lakes. It will detect the heat and content changes that typify pollution growth, and it will continue to detect disease and insect growth patterns.

### Space Manufacturing

The Shuttle's cargo bay, and ability to service stations in space, make it an ideal mechanism for aiding in the development of products that are more easily created in the weightlessness and hard vacuum of space. These possibilities include foam-type steel that has the strength of solid steels yet the lightness of balsa wood; the growth of crystals for industrial uses; and the production by filtration of medical vaccines and drug cultures that can be made better and less expensively in space.

Vacuum of a greater volume than practical in laboratory operations is one of the prime advantages of operations in space. Manufacturing and assembly techniques that utilize vacuum will receive a significant boost once the shuttle makes space more easily accessible.

In addition to the prime advantage of vacuum, operations in space could also make use of:

Radiation, or the absence of radiation
Weightlessness, and near-zero gravitational forces
Various temperature extremes
Clean environments free of gaseous contamination
Quiet, and absence of sound

### Returning Weights to Earth

Heretofore, we have envisioned as our immediate goal the task of delivering weights, or payloads to space and to orbit. Ultimately, we will find it feasible, and to our advantage on earth, to return weights from space.

Those materials and resources which are increasingly short of supply on earth, or more expensive to provide on earth, may become available to us from space. Our task will be to bring them to earth. Among the possibilities is the retrieval of methane, gradually diminishing in earth-bound availability but potentially harvestable in space. Metals and ores, of which we may yet be unaware, may become evident in space and aid us in replenishing a depleting earth.

Thus, for the first time, the Space Shuttle system will provide a mechanism for harvesting space, for bringing back more than we deliver, and for selecting for return to earth those items needed by man.

## NATIONAL SECURITY

### The Influence of Capability

Ideals and goals, no matter how worthy, must be matched by a recognized talent and strength to support those goals. Intentions can be good. But for intentions to be believed or endorsed, a capability for follow-through has to be evident.

The evidence of producing and operating a Space Shuttle system gives believable "tooth" to our capabilities, and makes it feasible to endorse our intentions. Those intentions can be protection of our integrity, or the extension of that protection to weaker members of the international community.

The technical challenges of creating the Space Shuttle will advance our knowledge and ability.

The existence of a Space Shuttle will help to secure our international position.

From a national security standpoint, the Space Shuttle affords a wise balance encompassing prudent defense as well as an active, maneuverable position apart from an earth-bound existence, and includes:

- Photographic reconnaissance
- Electronic reconnaissance
- Radar mapping
- Infrared mapping
- Communications
- Ballistic missile early warning
- Nuclear detection
- Satellite retrieval
- Satellite interception

A capability for advanced systems requiring the flexible, returnable, maneuverable, man-sustaining features of the Shuttle.

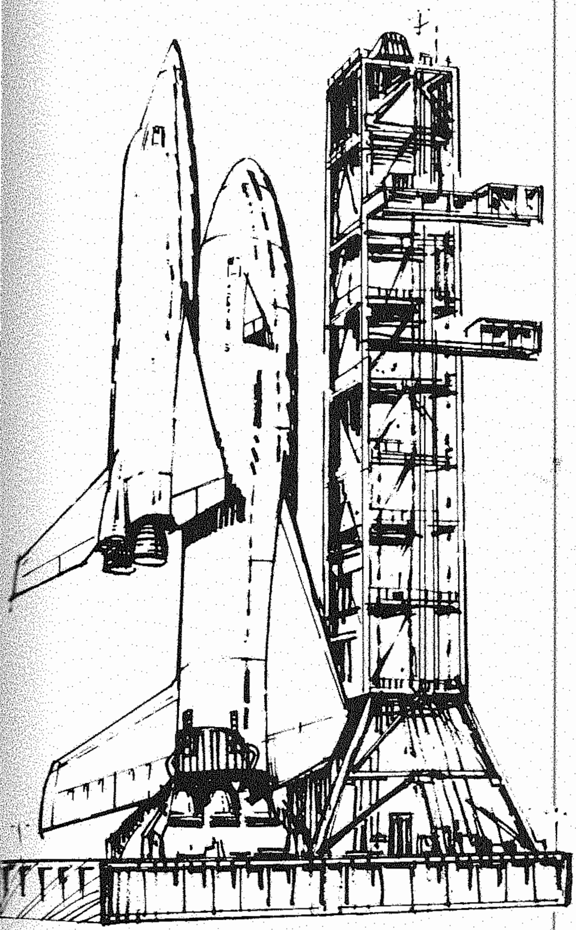
## SPACE SHUTTLE IN OPERATION

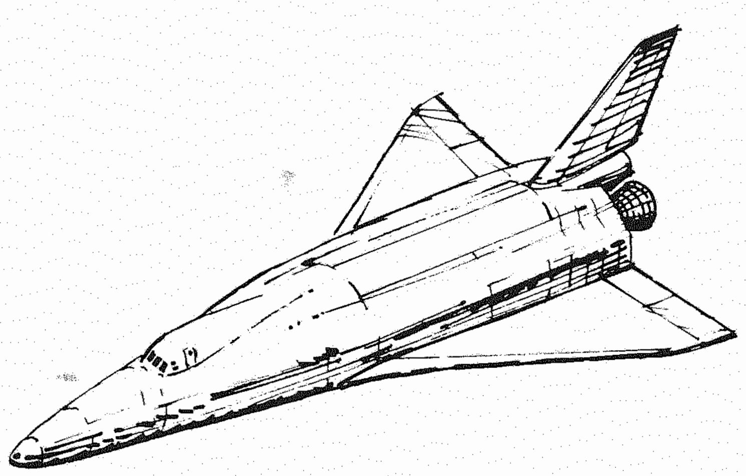
### A Mighty Duo

Standing at the pad the booster will measure 270 feet in length with a wingspan of about 150 feet, roughly comparable to a 747 or C5A aircraft. Affixed to the booster, either on the back or belly-to-belly, is the orbiter. The orbiter will measure 190 feet in length with a wingspan of 107 feet. Thus, the orbiter approximates a 707 airplane. Mated for launch, and depending on the configuration, they will stand between 270 and 290 feet high.

### Delta-Wing Maneuverability

The orbiter's configuration will be delta-winged, permitting a cross-range capability of 1,100 nautical miles, the equivalent of Earth's eastward movement during the time span of a single polar orbit. This delta wing cross-range capability allows the craft to maneuver laterally during reentry, making fewer landing sites necessary, as well as providing the capability for an immediate, one-loop, return to the original base. The delta wing configuration will reenter the atmosphere at lower angles of attack and achieve a higher hypersonic lift-to-drag ratio. A severe thermal environment is encountered during this reentry at a lower angle and thereby requires intensive work in the development of thermal protection systems.



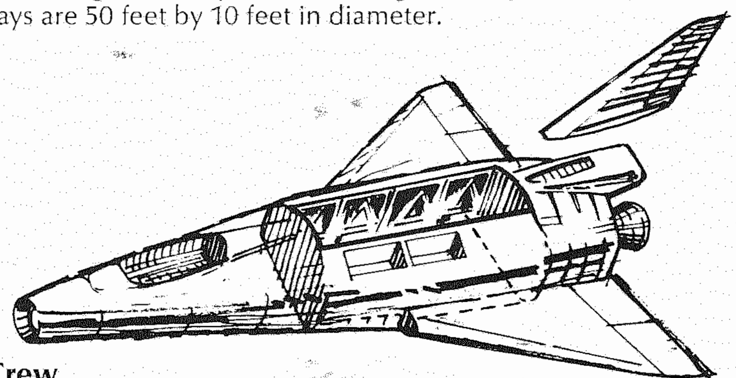


## Hefting Into Space

Fully loaded, the two will have a liftoff weight of approximately 4.6 to 5 million pounds. Of that weight, 40,000 pounds can be payload going into a polar orbit. Or, if an eastward equatorial launch is planned, the payload could be as heavy as 65,000 pounds by taking advantage of the eastward thrust of the rotating earth. Differences in payload weight vary according to direction of launch and altitude of orbit.

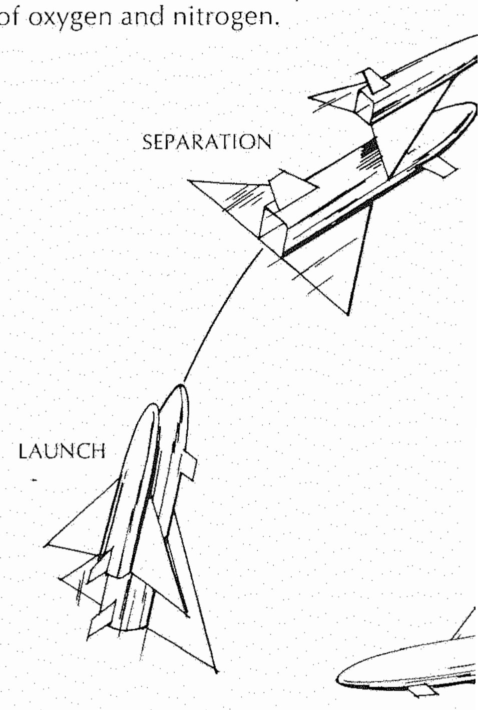
## Cargo Compartment

The payload will be housed in the orbiter's cylindrical cargo bay measuring 15 feet by 60 feet in length. Today's launch vehicle cargo bays are 50 feet by 10 feet in diameter.



## Crew

Both booster and orbiter have crew compartments. The booster's accommodates two pilots who will return the craft for landing. The orbiter also has a crew of two to navigate returns, but it will also be able to carry up to 12 passengers. The cabins in both will have a shirtsleeve environment, wherein spacesuits will not be necessary, which will be served by an atmosphere of oxygen and nitrogen.



## Thrusting Into Space

Upon liftoff, the mated Shuttle rises vertically. By the time it has achieved 40 miles in height, the Shuttle will be traveling at almost 7,000 miles per hour. Yet, the rate of boost will have been throttled to within a 3g limit of acceleration that is tolerable for non-astronaut passengers, as compared with the 10g boost acceleration of current space rocketry, which requires training and a high degree of physical fitness for astronaut passengers.

## Separation, Return

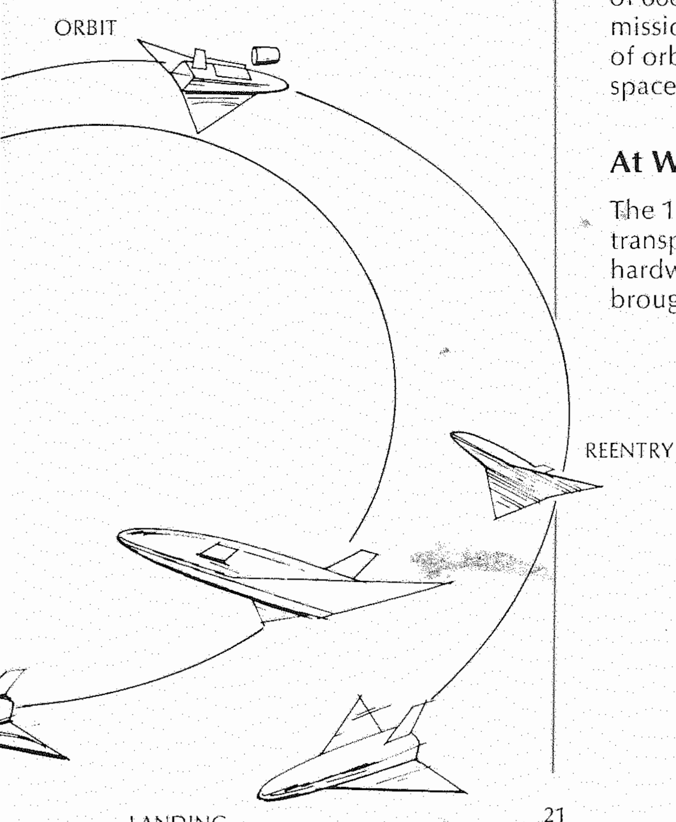
At about a 40-nautical-mile height, three and a half minutes after liftoff, the orbiter will separate from the booster. The two units will be about 115 nautical miles down-range at that time. The booster then descends at a high angle of attack to minimize heat pulse, reenters the earth's atmosphere and decelerates or slows down through friction with the atmosphere for the two-hour return cruise to the landing field. When the booster reaches subsonic speed, jet engines are started for an approximate 400-nautical-mile cruise back at about a 13,500-foot elevation to the launch or nearby retrieval base.

## Orbiting

The orbiter, meanwhile, has continued, under power of its two main rocket engines, to proceed to an orbital speed of approximately 18,000 miles per hour. The orbiter is injected into an elliptical parking orbit and then to a circular rendezvous orbit. The orbiter will be designed to operate in low-earth orbits up to an altitude of 600 nautical miles. There, the craft has a nominal seven-day mission capability, but will also be qualified for as much as 30 days of orbital operation, the weight of expendables for survival in space beyond the seven days being charged against the payload.

## At Work in Space

The 10,000-cubic-foot internal cargo bay may house passengers, transport satellites to orbit, provide repair facilities for servicing hardware in orbit, or serve as a retrieval carrier for items being brought back from space.

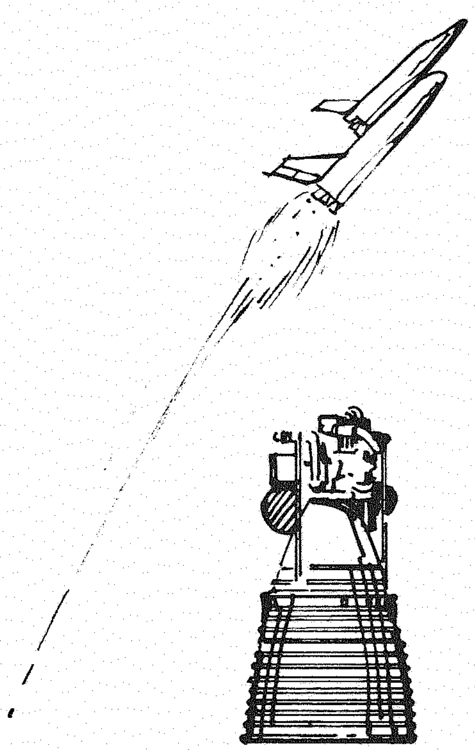


## Clean, Forceful Power

Propulsion for both booster and orbiter will be by means of liquid oxygen/liquid hydrogen engines utilizing the same basic engine design for both vehicles. One of the truly great developments of the 20th Century, the liquid oxygen/liquid hydrogen engine burns "clean," leaving behind a trace of harmless water vapor. It has been developed to deliver an enormous thrust energy; it is of a non-toxic, non-corrosive nature, and it is powered by relatively inexpensive and readily available oxygen and hydrogen reduced to liquid form.

## Engine Commonality

Twelve identical engines on the booster will each deliver 550,000 pounds of thrust at sea level. Two additional engines of similar design will be mounted on the orbiter where their performance in vacuum will deliver 632,000 pounds of thrust. Each engine consists of the common powerhead joined to a fixed nozzle of different contour than that of the booster engine, plus a unique extendible skirt. After separation from the booster, the orbiter's engine skirt will be extended before the engine is started to achieve a higher expansion ratio and higher specific impulse.



## Reusable Engines

The engines are similar to those used recently in Saturn's second and third stages. Yet, the goal now is not merely a single use. The shuttle engines will be capable of 7½ hours of burn time achieved during 100 different flights over several years of operation.

## Power Within Earth's Atmosphere

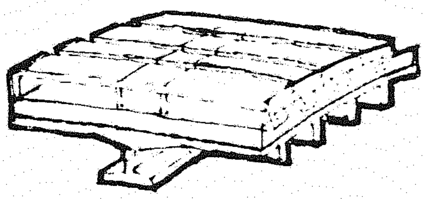
Air-breathing, auxiliary propulsion engines will be required for return of the booster to the launch base, and possibly by the orbiter for a similar reason. Consideration is given to elimination of auxiliary engines on the orbiter, thereby maximizing the payload while minimizing the fuel and equipment that would be required to orbit, and return, solely for powered flight purposes prior to landing.

## Advancing Engine Technology

The auxiliary engines will also use oxygen and hydrogen as propellants, thereby maintaining a commonality with the main propulsion systems. The ability to light-up for a powered return is requiring an intensive investigation of new technology in ignition devices, large diameter propellant valves, gas generators, turbo-pumps and heat exchangers. The aim is to provide instant reliability in starting a system that converts liquid to gaseous propellant efficiently and avoiding waste.

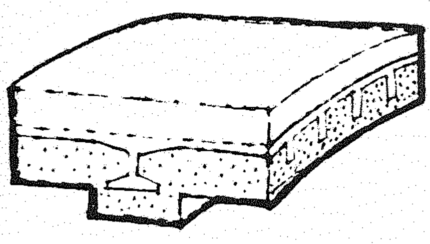
## Heat-Resisting Skin

During reentry of the Space Shuttle, temperatures will reach 2,000°F or higher on such areas as the nose and leading edges. This suggests the desirability of a reliable, light-weight, reusable thermal protection system which is now undergoing intensive investigation. The thermal protection system, or TPS, could be re-radiative metallic or non-metallic systems.



## Metallic Protection

The metallic protection skins being studied include the super-alloys such as Rene 41, TD-NiCr (Thoria dispersed nickel chrome), and coated refractory metals such as Columbium. Columbium has high-temperature strength and low weight, providing an excellent strength-to-weight ratio for hypersonic space vehicles. Tantalum is also considered, particularly because its corrosion-resistant properties are similar to glass, yet it has the strength of steel in addition to superior heat transfer capabilities.

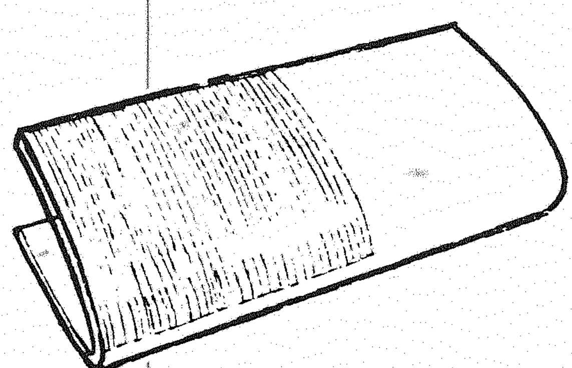


## Fibre Insulation

Various types of mullite hardened-compacted-fibres, backed up by insulation and applied to the exterior of the vehicles, are also being examined.

## Reusable Replaceable Panels

Panels will be reused as often as possible to adhere to a manageable rate of replacement and quantity. For instance, on the booster, one study foresees over 3,900 panels of 475 different types being useful for about a dozen missions with careful service prior to replacement.



## Return to Earth

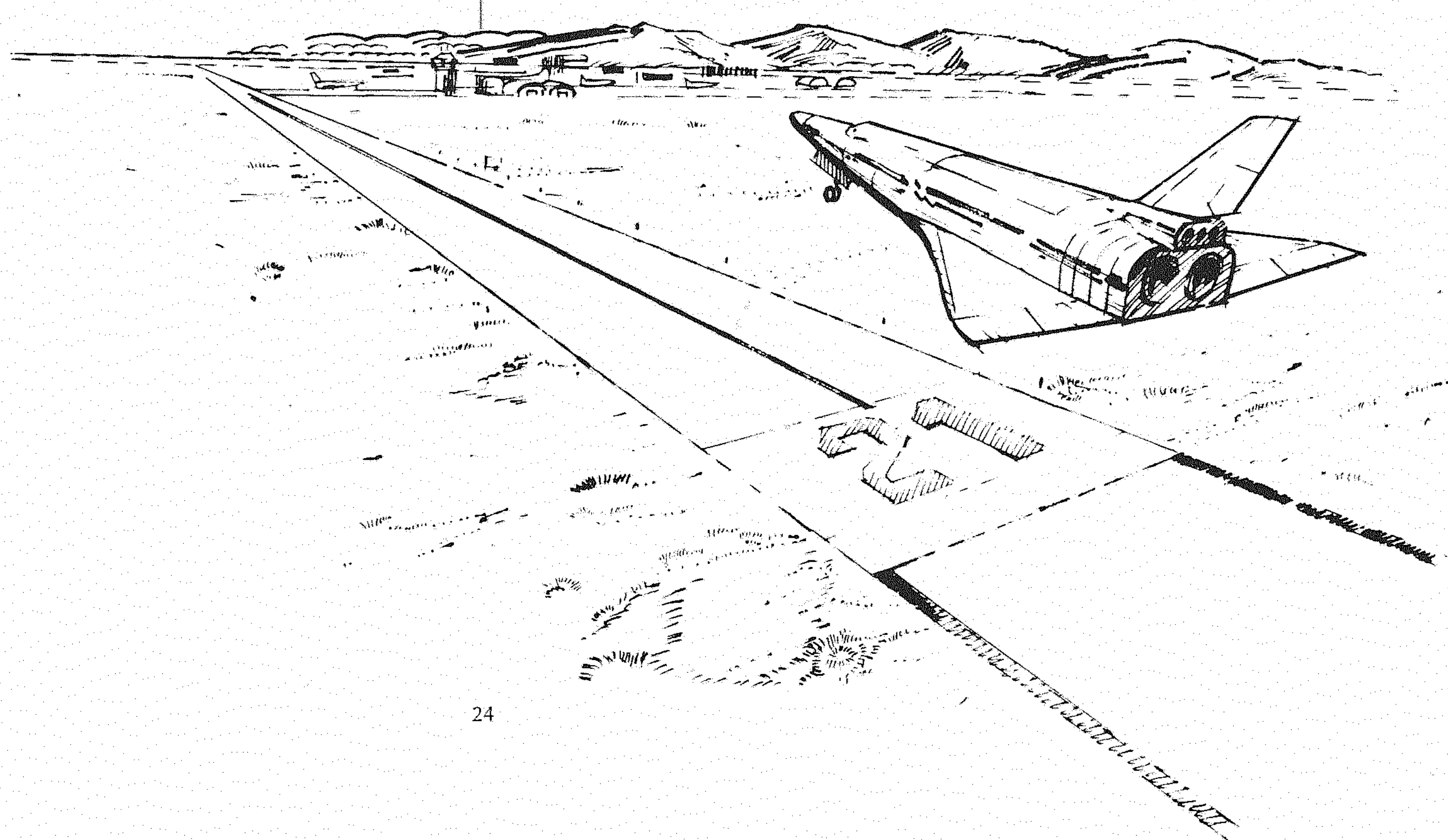
Both vehicles will return to earth through initial and modest rocket deceleration. They reenter the earth's atmosphere, crossing through the supersonic high-temperature region, slowing to subsonic speed, and cruise or descend to land like a jet aircraft. In some recent experiments at the Edwards, California, base "lifting bodies" resembling scaled-down orbiters have been landed through a sharp dive and a last moment aerodynamic lift to cushion the horizontal landing.

## Landing Speeds

Landing speeds for the booster may be slightly greater than that of the 747 aircraft, or about 155 knots. The orbiter will land relatively faster, somewhat like the Concorde or a supersonic transport, at about 170 knots.

## Airfield Runway

Ten-thousand-foot runways, with additional 2,000 feet overruns at each end, are anticipated as a requirement for Shuttle landing facilities. Once down, the booster will be towed to a "safing" area for cooling and for purging of liquid hydrogen/liquid oxygen propellants from the tanks. A similar maintenance procedure is used on the orbiter. Then, both vehicles will be towed to maintenance shops for refurbishment, thermal protection system checkout, payload removal, analysis of maintenance recorder tapes and logs, and readiness for the next launch.



## Two-Week Turnaround

Ideally, the Shuttle vehicles are planned to be ready for flight again within about a two-week interval. Ground turnaround operations may resemble the next generation of conventional airline procedures rather than the more laborious, one-at-a-time preparation that has characterized missile launches of the past decade.

## Prelaunch

Prelaunch preparations will include placing the payload aboard the orbiter and mating the orbiter to the booster. Whether the mating of the two should be done horizontally or vertically has not been ascertained, as yet.

## Horizontal Mating

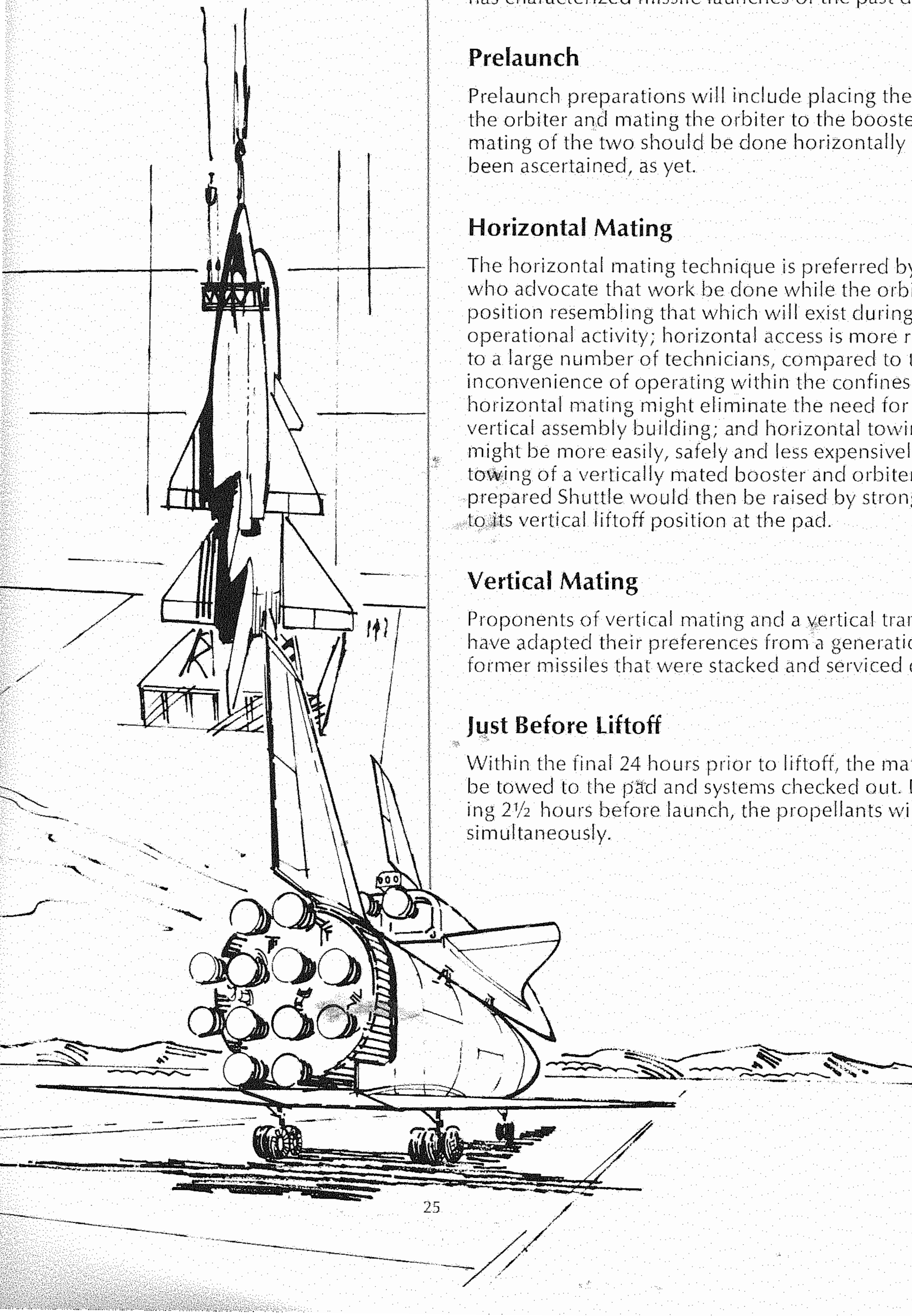
The horizontal mating technique is preferred by those professionals who advocate that work be done while the orbiter is in a horizontal position resembling that which will exist during most of its operational activity; horizontal access is more readily available to a large number of technicians, compared to the delays and inconvenience of operating within the confines of a vertical elevator; horizontal mating might eliminate the need for an unduly high vertical assembly building; and horizontal towing to the launch sight might be more easily, safely and less expensively achieved than towing of a vertically mated booster and orbiter. The horizontally prepared Shuttle would then be raised by strong-back or strong-arm to its vertical liftoff position at the pad.

## Vertical Mating

Proponents of vertical mating and a vertical transport to the pad have adapted their preferences from a generation's experience with former missiles that were stacked and serviced during readiness.

## Just Before Liftoff

Within the final 24 hours prior to liftoff, the mated vehicles will be towed to the pad and systems checked out. During the concluding 2½ hours before launch, the propellants will be loaded simultaneously.



## Scheduling a Decade

This, then, is the pattern that may be followed for launches and flight regime which may proceed at the rate, initially, of about 25 a year, reach a schedule of 50 annually, and by the close of the 1980's exceed 75 a year.

## Space Rescue

At last, the Space Shuttle will bring within our capability a quick reaction for space rescue. The intent is to create a system which could be available within two hours notice and possess the maneu-verability to go where help is needed and the capability for a safe and guided return to earth.

## Intact Abort

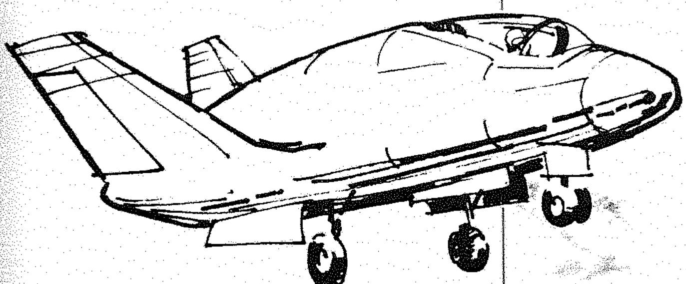
Intentionally, the Shuttle will be designed to survive the malfunction of many of its systems and provide a crew with the opportunity to employ piloting techniques for a safe return to earth of crew, vehicle and payload. This aim of an "intact abort" strives for a goal of launching into orbit with a minimum necessity for avoiding trajectories that pass over populated areas and to minimize the necessity of ascending flight over broad expanses of water solely for emergency landing purposes.

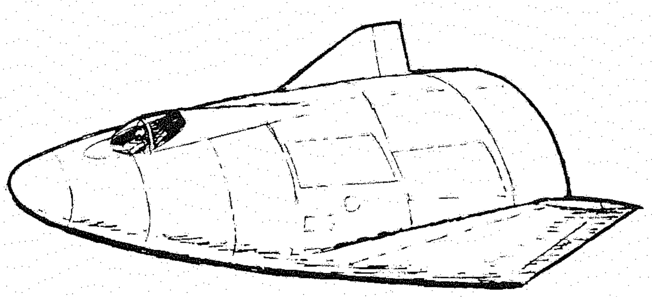
## Testing

The initial number of Shuttle vehicles to be produced will be small, perhaps not more than five or six, and testing will take place with vehicles intended for a long-term operational use.

## Background of Experience

At the Edwards, California, base, a series of tests on so-called "lifting bodies" have been conducted from 1966 to the present. This test experience with unique forms and shapes that have earned descriptive phrases such as "Flying Bathtub" (M2-43), "Flying Flatiron" (HL-10), and "Flying Football" (X-24) provides some basis for our understanding of orbiter possibilities. Nearly 200 X-15 flights provided useful data about such flights to an altitude of 67 miles with speeds in excess of Mach 6. The X-24 has explored the flight regime from Mach 2 to horizontal landing.





## Wind Tunnel

Looking ahead to the Shuttle area, 2,000 to 3,000 hours of wind tunnel time may be required for each configuration selected for the Shuttle.

## Horizontal Flight Test

Initially, horizontal flight testing will probe handling qualities, the operation of basic systems, trajectories and approaches to landing from high altitudes to ground level. Both orbiter and booster may each undergo as many as 400 hours of horizontal flight testing, both suborbital and orbital.

## Vertical Flight Test

Ultimately, vertical launch will cap the testing program. Some specialists prophesy that this ground and flight vertification program will be as extensive as eight years of operation.

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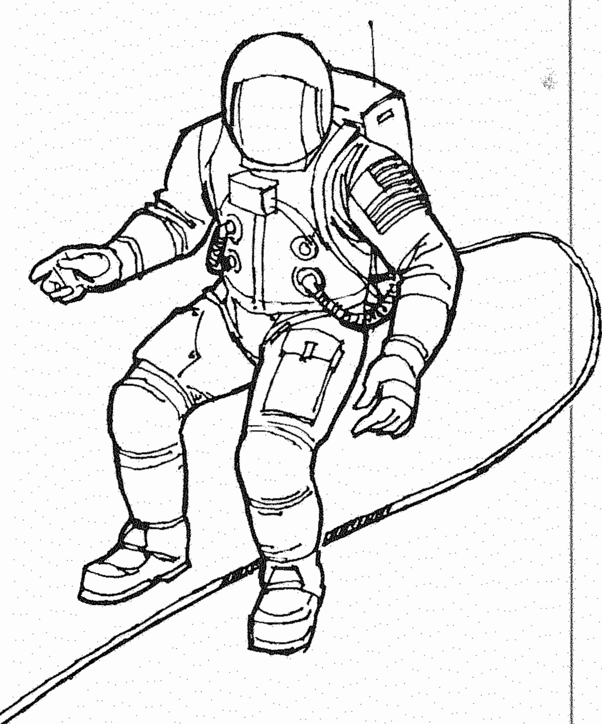


## COST ADVANTAGES

By reducing the cost per pound of payload and eliminating the duplication in launch vehicle costs, the Shuttle contributes greatly to economy in these immediate and vital areas of vehicle operation.

But, the Shuttle also contributes to another, not so readily apparent, economy: it increases significantly the capabilities of automatic spacecraft; or, conversely, it decreases the cost for the level of capability the Shuttle makes possible.

Design of today's automated satellites is restrained by such limitations as the amount of propellants or gases that can be carried for extended operation. Opportunities are constrained by the relatively short lifetime of certain components such as batteries. Costlier operations are inherent in today's need for alternate substitute systems so the entire mission—spacecraft and launch vehicle—are not wasted because of the failure of a key element. Today's orbiting spacecraft also have to be confined in size and shape to fit within current shrouds and nosecones. They are exposed to the stresses and severe variations of pressure, heating, vibration and noise that accompany present-day launches. They frequently require explosive separation systems to be separated safely from shrouds, elaborate deployment systems for antennas and sensors, and additional propulsion systems to adjust orbits and maintain proper attitude.

Doing it automatically is frequently complex. Complexity breeds expense.

The presence of man with all his intuitive capabilities, his talent of making decisions and guiding actions, will reduce the cost of automation.

Automated and unmanned systems are unnecessary with Shuttle. The payloads will be stored aboard the Shuttle's large cargo bay, sheltered further from the mild environment of the Shuttle launch. The bay will accommodate odd sizes and shapes. Once in orbit, Shuttle crewmen can position satellites precisely and deploy antennas and sensors. Crewmen can repair malfunctions and replace old equipment with new. If necessary, the Shuttle will bring the entire satellite back to earth for refurbishment and repair. It is anticipated that such retrieval and relaunching will result in savings of 55 percent to 60 percent in payload development costs as compared with today's expenditures.

### Pushing the Technological Frontier

Advancements in technology lead to abilities . . . abilities of men and of manufacturers. When America has the talent and the capabilities, particularly those skills and products not readily available elsewhere, we become the purveyor to the world. We have evidently elected not to compete by lowering our wage scale. Instead, we have demonstrated an ability to compete through superior production. Space Shuttle requires our furthering this process by pushing the technological frontier in several categories. Resolution of those technical problem categories should enhance our capabilities for competition, and to do so through benefit and appeal rather than through coercion or exploitation of human working potential.

## Reusability

The element that makes the Shuttle economical—reusability—is also the element that makes development difficult. Today's space hardware is designed for one use only; it need only last a specified minimum time to fulfill its mission.

The capability for repetitive use of the Shuttle imposes an obligation on our technical skills. It demands we overcome problems within flight structure of strain, fatigue, temperature changes and wear.

Structures require that we evolve some aircraft techniques and methods into missile and space-vehicle concepts. The shuttle will merge aircraft with space vehicle to result in structures that are lightweight yet durable.

Thermal protection systems have yet to be improved that are reusable, lend themselves to rapid changeover, and probe the frontiers of metals and fibres.

Propulsion systems will require longer life, capabilities for starts and stops, and a reusability never before demanded of missile engines.

Flightworthiness and the effects of flight over a broad regime requires that we understand the effects and challenges of this environment to a greater extent than ever before.

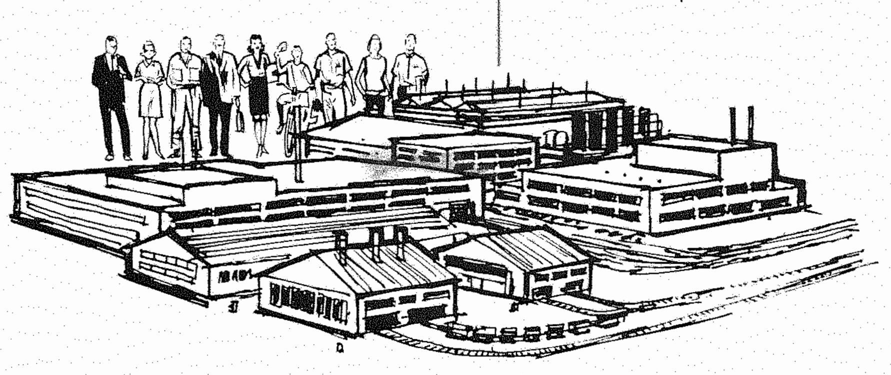
Componetry will need improvements in reliability, weight and size reduction, and adaptability to the wide variety of missions anticipated for the Shuttle.

Landing gear will need to be devised of more extensive capability than any used heretofore.

These needs impose a process of study and review, critique and test, manufacture and verification of Shuttle technology that will present us with an array of talents and products not otherwise available to man.

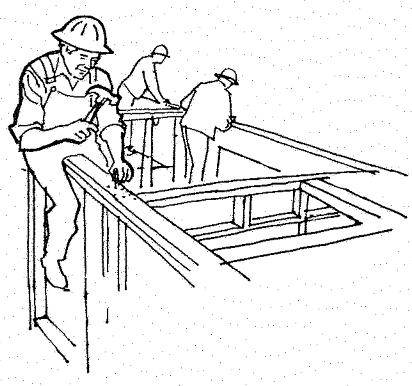
## What Shuttle Means to Industry

A government expert estimates that at the peak of its development, the shuttle will contribute 70,000 to 80,000 jobs, 90 percent of them in private industry. For decades thereafter, thousands of technicians will be employed at the launch and retrieval site base; others will work on payloads nearby. The Shuttle will help save and develop a national resource—the highly skilled, problem-solving, multi-disciplined technical force that is now being rapidly dissipated.



CALIFORNIA SPACE SHUTTLE TASK FORCE

## Shuttle's Significance to the Economy



Dollars spent on the space program go directly into the economy. They go to payrolls, public and private; they develop industry; they support construction and real estate. In short, space dollars convert to jobs.

In addition, space is a major contributor, both directly and indirectly through spinoffs, to that significant area in which we export more than we import: high-technology products.

Every dollar spent on a space program is invested on earth. This truth clarifies an incomplete assumption that we send billions into space when we might better spend the money on earth.

A recent economic study indicated that ten billion dollars invested to develop and operate the Shuttle over a period of 15 years would result in almost 27 billion dollars of additional indirect stimulation of the economy. This multiplication of impact occurs through the retail purchasing power of aerospace employees working on the Shuttle program. Thus the accumulated impact on the U.S. economy in jobs and income could be more than 37 billion dollars.

In addition to the economic advancement made possible by the Shuttle, the nation's working population will gain from a program of the Shuttle's magnitude as it did from the Apollo program. At the peak of Apollo's development, almost 400,000 workers in 48 of the 50 states were involved.

The salaries of these workers encompassed every level. But the greatest amount of money was apportioned among middle class workers having annual incomes between $6,000 and $15,000 per year. At this economic level, salaries were most often channeled directly into the economy of the nation rather than becoming idle or invested in savings and real estate.

The national economic impact of the Shuttle program was analyzed recently using an ergometric technique developed by the University of Maryland. To evaluate its impact, the Shuttle was compared with two other programs of equivalent expenditure, a residential housing program and an increased level of consumer spending (the latter could result from such programs as increased welfare or social security benefits, or a reduction in personal income taxes).

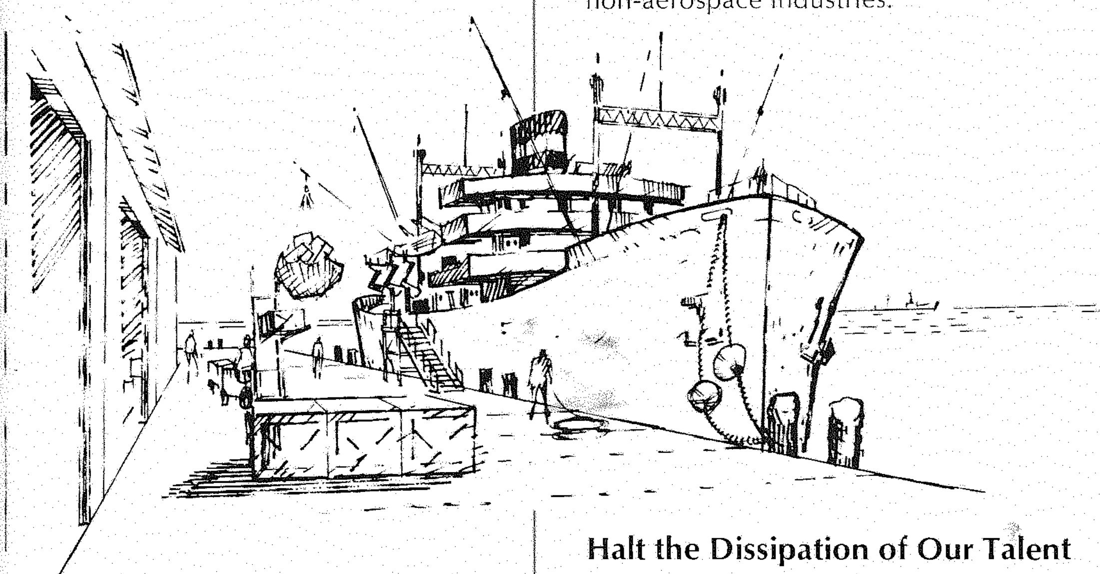
For the same dollar expenditure, total domestic production requirements would be higher for the Shuttle program than for either of the others. Based on an 8.6-billion-dollar expenditure, the Shuttle program's purchases would be $9.5 billion as compared with the smaller anticipated $8.8 billion for consumer spending and the substantially smaller $6.4 billion for the housing program.

## Favorable Balance of Trade Impact

In addition, the Shuttle would have a favorable effect on the U.S. balance of trade, by inducing high exports and considerably lower imports. The other two programs would have far less favorable effect on improving our balance of trade.

The problem of importing more than we export is a grave one and has been steadily worsening for the United States. The most significant inducement for a positive balance is through our high-technology products. Space programs stimulate this capability and therefore contribute greatly to a favorable balance; conversely, as space activity declines so does our balance of trade.

Finally, the study discerned that 407,000 man-years of employment would be created in the aerospace and allied industries, while a smaller volume of 283,000 man-years would prevail in non-aerospace industries.



## Halt the Dissipation of Our Talent

A less obvious but equally important result of Shuttle would be to stem the present trend away from engineering and scientific studies in colleges. Not only has enrollment in technical studies dropped drastically in recent years—at least in part because of an anticipated lack of employment in the aerospace, electronic, computer, and other technical industries—but many engineers and scientists have deserted their careers and professions in bitterness over layoffs and cancelled programs.

As a result, the U.S. may be inducing a "brain gap"—a shortage of qualified technical workers in the near future when they will be desperately needed. The Shuttle is one of the few national programs that can help prevent this gap.

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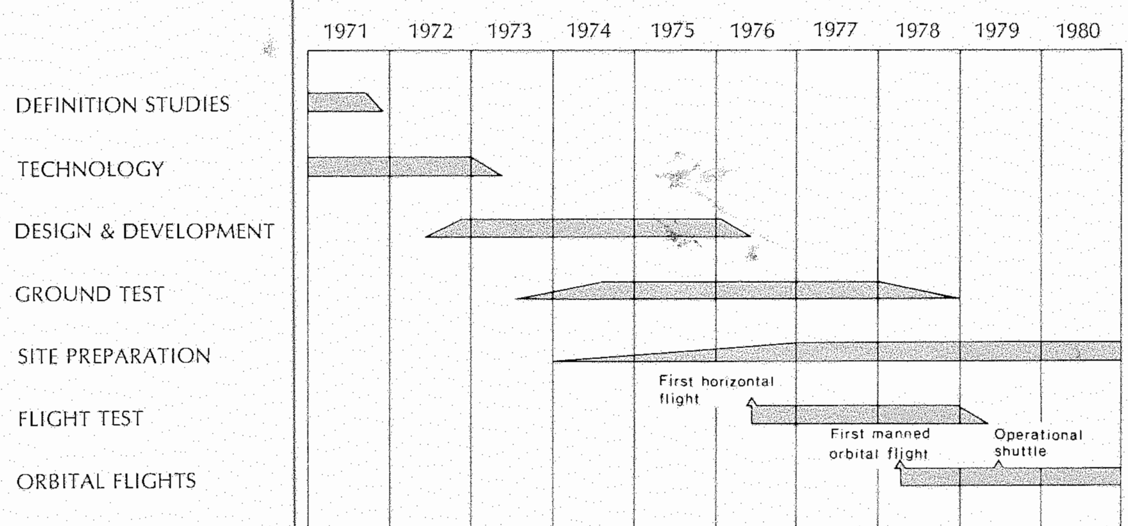
## WHY START BUILDING NOW?

Because the Shuttle is now a practical tool for changing our space effort from one of essentially scientific experimentation to one of routine operations with economic payoffs. These payoffs are two-fold: the significantly lower costs of conducting the program, and the increase in breadth and depth of direct benefits from space. Yet, creation of the Shuttle takes time. Dedication to the task is required now in order to have a useful Shuttle at the close of the 1970's.

For the short-range future, no intermediate manned launch system is undergoing development. A gap in the U.S. manned space program of at least five years is now inevitable. Consequently, Shuttle development should begin now in an orderly and balanced manner to insure the gap is as narrow as possible and to avoid a costly and risky crash program in reaction to competitive international pressures, such as the presence in space of a permanent Soviet manned space station.

By deciding now, we can fashion a future of our selection, rather than of reaction.



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