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THE SPACE TRANSPORTATION SYSTEM AND ITS IMPACT ON LATIN AMERICAN DEVELOPMENT

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16. Abstract

The article describes the three components of the Space Transportation System: the space shuttle, the permanent orbital space station and the transorbital vehicle. The stages of completion of the various plans are described and the impact of the project's implementation is discussed with particular reference to Latin America and with special emphasis on the telecommunications sector.

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THE SPACE TRANSPORTATION SYSTEM AND ITS IMPACT ON LATIN AMERICAN DEVELOPMENT

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The preparation of a detailed article on modern space exploration raises various problems in the use of suitable Spanish terms. For example, many of the new instruments which we use in space have names which are new even in English. Thus, in some cases I have had to derive equivalent names in Spanish. I attempted to do this carefully by using compound constructions and taking as a base, more than anything, the knowledge of the functions of the instruments to which I refer.

Perhaps, therefore, this exercise has served the double purpose, not only of informing the Hispano-American public about these topics, but also of stimulating a little the technological development of our language. In any case, I would like to express my most sincere gratitude to several people without whom this article would not have been possible: Ivelisse Rodriguez, NASA Radio and Television, Washington, D.C.; Orlando Gutierrez, NASA Director of Hispanic Employment, Washington, D.C.; Jose Perez, NASA Customer Relations, Houston, Texas; Raul Mejia, NASA Flight Operations Training Branch, Houston, Texas; Jaime Forero, NASA Vehicle Integration Test Team, Houston, Texas; Patricia Forero, Houston, Texas; Sergio Simunovic and Andres Palma, ASTEK Engineering, Watertown, Massachusetts; Maria Eugenia Chang, Manager of the Bilingual Secretarial Services Co., San Jose, Costa Rica; Roberto Scioville-Samper, OEA Department of Cultural Affairs, Washington, D.C., and all those who contributed in some form or another to the production of this manuscript. To all... many thanks!

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PART ONE
(Figures 1-14)

INTRODUCTION

/1

Starting in 1970 the U.S. space program turned to the practical use of the advantages inherent in the Earth orbit. These advantages are manifested most clearly in the area of local telecommunications via satellite, as well as in the area of remote sensing of sources and natural resources of the planet. But other areas such as the production of drugs, alloys, superconductors and semiconductors and other exotic materials, whose manufacture requires considerable homogeneity and purity, are very promising and are now the object of intense research.

Thus the routine operation of the Space Shuttle provides from day to day a means of safe and relatively economical transport, capable of maintaining a rather high traffic of payloads and satellites into Earth orbit. The fleet of shuttles (Columbia, Challenger, Discovery and Atlantis) will be the first component of a triad which is called generically the Space Transport System (STS). The other two components of this triad are: a permanent space station in low Earth orbit (300-500 km) and a transorbital vehicle (TV), which will be used as a link between the station and the high geostationary orbits (35,800 km) where most of the telecommunications satellites operate.

The plans and projections indicate that this triad may be operating around the middle of the 1990s, and it will not only provide the usual launch means for domestic and international use, but it will also include complete and continuous service for repair and maintenance in orbit for the global satellite network. These services will be accomplished by astronauts, either on board the space station or conducting repairs "in situ" on board the TV.

This panorama will have a very profound positive impact with regard to the cost of the equipment and systems which will be used in space as well as with regard to the architecture of the satellites themselves. Certainly the possibility of repair and maintenance will open new avenues in the design and construction of satellites and payloads. For example, the satellites which are being built today with multiple redundancy (that is, two or three identical systems in the same satellite, in case one fails) will not be so necessary, since they can be recovered and repaired in orbit. This implies a reduction in cost of equipment and construction. On the other hand, reduction of redundant systems will contribute to the reduction of the weight of the support equipment needed, and will thus increase the payload capability.

Another important aspect will be the modality of the communication systems, which, combined with easy access to them, will allow us to modify them in orbit in accordance with the capabilities of the supplier and the needs and requirements of the user. These modifications will certainly keep pace with the technological development of both.

All these changes in the methods of operating in space will have a profound effect on all developing countries. On the one hand, the cost of these systems will decrease perceptibly; on the other, rapid technology transfer will impose accelerated development on the Third World countries, inducing in them a technological leap and consequently a greater demand for sophisticated equipment. Indeed, countries like India, Saudi Arabia, Indonesia, Mexico and Brazil already use (or will do so /2
in the next two years) their own geostationary satellites which will be used to link closely the most remote and inaccessible regions of their territories. These satellites will transmit by microwave educational television programs, instant medical information and very important weather information for agricultural and fishing communities.

The above uses give some examples; the various applications of these means of communication and observation are so numerous that it would be a difficult task to list them all here. But the most important ones will be discussed further below.

THE SPACE SHUTTLE

At present the only operating element of the STS triad is the Space Shuttle. This vehicle has achieved total success in many manned missions into space. This year alone, seven more are planned, with an increase of the annual number of missions until the desired level of one or two per month is reached.

The Space Shuttle (Fig. 1) is a very different vehicle from its predecessors: the Mercury, Gemini and Apollo spacecraft, and it differs from them in two or three important aspects. First, it is an almost totally reusable system. Secondly, it is designed as a cargo vehicle operating only in low Earth orbit (300-500 km). Finally, it is capable of maneuvering autonomously in space, reentering the atmosphere, gliding in it and landing at a certain place using a runway similar to those used by commercial aircraft.

In space the orbital vehicle offers maximum support to the payloads it carries, whether they are experimental payloads (such as the space laboratory Spacelab) or commercial payloads such as communications satellites, meteorological satellites, or other types for remote sensing.

The shuttle is also flexible enough to carry a Remote Manipulator System (RMS) or mechanical arm (Fig. 2), which facilitates many of the missions with ejectable payloads within a radius of approximately 15 meters above the cargo compartment. The RMS is extremely useful in operations of maintenance and repair of satellites. This use was demonstrated widely in April 1984 in mission 41C of the Space Shuttle Challenger [1].

Another important element of the auxiliary equipment of the Space Shuttle is the Autonomos Maneuvering Unit (AMU; Figs. 3 and 4) which was tested for the first time in mission 41B on February 7, 1984. The AMU is a self-contained propulsion system which is attached to the astronaut's back. By this means a person can carry out excursions within a radius of approximately 100 meters from the orbital vehicle with no cable, mooring or umbilical cord connecting him to the vehicle. The unit is controlled by the astronaut through the computer and uses small jets of gaseous nitrogen as propulsion means. This system will increase the human flexibility in repair and maintenance missions. /3
For example, some satellites rotate in such a way that it is impossible or dangerous to capture them with the mechanical arm, unless the rotary movement can be restrained. This stabilization mission may be accomplished by an astronaut using the controllable thrust of his AMU.

MAIN USES

Satellite Launches

One of the main uses of the Space Shuttle is as a launch platform for communications and data transfer satellites, both foreign and domestic. Up to now with the Space Shuttles Challenger and Columbia, eight communications satellites have been launched, mainly of the type HS376 (Fig. 5) buit by the Hughes Aircraft Company. Canada and Indonesia were the first foreign governments to use this service, but India, Mexico, Saudi Arabia and Australia will launch theirs within the next two years.

The satellites of the type HS376 are architectonically similar and belong to the basic class of communications satellites [2]. They are very compact and efficient units operating by means of transponders with frequencies in the microwave bands S, C and Ku at 3, 5 and 16 GHz, respectively.

They generally use small hydrazine propulsion units to carry out small orbital corrections and they use photovoltaic cells to provide electricity to their systems at power levels 0.5 to 1 kW on a continuous basis [2].

This type of satellite is carried from the low orbit where it is launched by the Space Shuttle to its final orbit by means of an auxiliary module called PAM (Payload Assist Module). The main component of PAM is a solid fuel motor, termed the PKM (Perigee Kick Motor), which converts the low circular orbit into an elliptical orbit of approximately 36,000 km apogee and 300 km perigee. Another solid fuel motor in the satellite body, termed the AKM (Apogee Kick Motor), will later cause the orbit to become circular at 36,000 km altitude above the equator.

Whereas almost the entire body of the satellite rotates on its longitudinal axis (to remain gyroscopically stable), the main antenna remains aligned with a point on the Earth by means of a system of electrical motors and special bearings. At the same time the system of antennas and waveguides is designed to project a beam of radiation which conforms to the geography of the territory which it has to cover; the small amount of electrical energy is used as efficiently as possible.

At the Latin American level, one of the first geostationary /4
communications satellite systems will be established by Mexico by the middle of 1985. This system, called Morelos*, will include two hybrid geostationary satellites which will operate by microwave in the C and Ku bands. The two satellites are of the abovementioned HS376 type, and they will be controlled locally from the Iztapalapa station in the vicinity of Mexico City [3].

The Morelos system is one of the most ambitious telecommuni-

*Named in honor of Father Jose Maria Morelos y Pavon, hero of the Mexican Revolution.

cations projects to be implemented by a Latin American country. The satellites will provide the basic tool for establishing a massive program for rural education. At the same time, they will provide the establishment with a network of communications and data transfer which will make it possible to link, and thus to optimize, production centers with consumption centers, both at the national and at the international level. Similar systems are being contemplated for other Latin American countries such as Brazil, and for groups of countries such as those of the Subregional Andean Pact (Venezuela, Colombia, Ecuador, Peru and Bolivia), and possibly for the Central American and Caribbean nations.

It is important to note that the useful life of these satellites is nine or ten years, determined not by the average life of the electronic components, but by the amount of fuel which can be stored onboard. Therefore it is obvious that the ability to refuel these satellites in orbit will have a very positive economic impact, especially for poor nations whose satellites can not, for economic reasons, and will not have to be replaced every ten years.

Within a few years' time, when the geostationary satellite network is within the reach of the STS, refueling of these units will be carried out on a routine basis. At the same time, it is hoped that the satellites' architecture will be of the modular type, so that the same basic structure may evolve as the technology progresses and as the user's needs change. As was mentioned before, access to satellites also allows their repair, which reduces the need for redundant systems and very possibly reduces their cost per unit of information transmitted.

The TDRSS System

Another type of satellite (Fig. 6) which should be mentioned was launched on mission No. 6 on board the Space Shuttle Challenger.

It is a tracking and data relay satellite with high capability and power. This vehicle was specially designed to increase the communication capabilities between the Space Shuttle and its ground control center. Called the TDRSS (Tracking and Data Relay Satellite System), this system will ultimately include three identical units in geostationary orbit (two active and one spare). The complete system will include a separate control and command station located in the desert at White Sands, New Mexico, operated by the Satcom company.

The unit of the TDRSS system called TDRS(E) is now in opera- /5 ation. This satellite is located above the equator about 850 km east of the Brazilian coast. The White Sands control and command station is also operating in the state of New Mexico. Thanks to the use of the TDRSS system, it is possible to maintain day-to-day contact between the Earth and the Space Shuttle over 70% of the trajectory of the spacecraft. There is a great difference between this figure and the 17% which had been obtained earlier with the worldwide network of tracking stations.

Remote Sensing Satellites

Besides communications satellites, the Space Shuttle will be used to launch, refuel and repair another type of satellite which we term remote sensing satellites. Typical examples of this category are the Landsat satellites in polar orbits, which photograph the Earth's surface in various bands of the electromagnetic spectrum. These satellites are used to determine the abundance or scarcity of natural resources, as well as their relative geographic distribution. Other satellites of the same type are the already common meteorological satellites, generally in geostationary orbits. In mission 41G this year, the ERBS satellite (Earth Radiation Budget Satellite) will be launched, which will measure the amount of solar radiation received by the Earth.

These systems have an immense impact on the mining industry, on agriculture and on the fisheries industries of a region. For example, by means of infrared photography (Fig. 7), it is possible to look at critical aspects of a crop, such as the amount of water needed to obtain maximum yield, the time and optimum amount of the yield. In certain cases it will be possible to detect diseases and pests (Fig. 8) affecting a crop before the massive use of pesticides is needed. These pesticides, moreover, are expensive and contaminate the environment.

Pilot and Applied Science Missions

Another type of payload which will be noted with greater frequency in Earth orbit is experimental systems. These will be pilot systems, which will investigate the possible economic advantages of certain processes being carried out in the natural environment of space. The most promising areas are those connected with the pharmaceutical industries and the processing of ultrapure materials with applications in microelectronics.

One process which has given interesting results is the separation of living cells by continuous flow electrophoresis [4]. This process uses the characteristic net electrical charge of a group of cells in a liquid compound. The separation is accomplished by means of applying electrical fields in the appropriate direction. Electrophoresis may be obtained on the Earth, but the yield is very low, so that it becomes an expensive process. The main obstacles are sedimentation and convection currents generated by changes in temperature and in the Earth's gravitational field.

In orbit, however, gravitational acceleration is cancelled by centrifugal acceleration, which causes weightlessness. This orbital phenomenon, lack of gravity, eliminates sedimentation and convection totally. That is why it is estimated that it will be possible to carry out electrophoresis in orbit with a ten times greater yield than that achieved on Earth. /6

To this end, the North American companies McDonnel Douglas and Johnson and Johnson have launched a joint project, termed CFES (Continuous Flow Electrophoresis System; Fig. 9). This consists of a small plant whose operation will be studied in space and perfected after several missions. It is hoped to fly this experiment several times until an optimum system is obtained which can be left in orbit to operate automatically.

The elimination of convection currents will also be beneficial for the production of alloys and semiconductor materials, which are very important for microelectronics. In certain cases it is possible to produce these materials in space (Fig. 10), with a degree of perfection which is practically impossible to achieve on Earth. In other cases the level and homogeneity of necessary impurities in the production of semiconductors (Fig. 11) can also be obtained more easily and with greater control in space.

It is important to repeat that many of the orbital processes which will be beneficial are as yet unknown. Thus, research and exploration go hand in hand with development.

Long-Term Experiments

It was noted that many experiments must be exposed to orbital conditions for a period of more than the seven or eight days for which the Space Shuttle remains in orbit. Moreover, many of them are easily affected by slight vibrations and disturbances occurring in the vehicle when a maneuver begins, or due to crew movements.

To eliminate these problems the Long Duration Exposure Facility (LDEF) was built. This an unmanned system capable of housing nearly 90 different experiments. The structure is carried into space by the Space Shuttle (Fig. 12) and is left in space in exact alignment with the Earth's gravitational gradient. This orientation is stable and avoids the characteristic wobble of a vehicle lacking an active stabilization system. In spite of being basically passive, the LDEF is equipped with a magnetic shock absorber which counteracts second order vibrations caused by extremely small variations in the Earth's gravitational field. The LDEF was placed in orbit in April 1984 on mission 41C of the Space Shuttle Challenger. The complete module will be recovered and returned to Earth at the beginning of 1985.

Purely Scientific Missions

Probably the most ambitious scientific mission accomplished up to now was that called 41A, better known as Spacelab-1 (Fig. 13). Spacelab flew for the first time on board the Columbia Space Shuttle in November 1983. It was a ten-day mission, with a crew of six, operating continuously 24 hours a day. Two groups of three astronauts relieved each other every 12 hours. It would be difficult to describe in a few paragraphs the scientific achievements of this mission, and I will restrict myself to mentioning that the massive amount of data collected is still the object of intense study [5, 6, 7].

The first Spacelab mission was so successful that it is /7
planned to devote another flight at the end of 1985 to continue several of the experiments which could not be accomplished due to delays in the first launch.* This mission, termed EOM (Earth Observation Mission), will concentrate on studies of the planet's surface as well as on plasma physics studies, studies of the ionosphere and of the Earth's magnetic field.

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*Many experiments require special orbital conditions related to the time of the year, the angle of the Sun, and the absence of the Moon at night.

Besides this additional flight, several missions have been planned for the period 1984-1986, each focusing on a specific discipline. The first Spacelab flight at the end of 1984 will be devoted mainly to biological sciences, whereas the next one at the beginning of 1985 will be devoted more to astronomical and astrophysics studies.

Other purely scientific missions include the launching of a space telescope (Fig. 14). This giant instrument, operated by remote control from Earth, will be capable of reaching optical resolutions ten times greater than the most powerful telescopes on Earth. This system will be free of the distorting effect of the atmosphere, and it will make it possible for the first time to search optically for planets which may exist around the closer stars.

Advantages

Despite the apparent similar cost, the main advantage of the Space Shuttle as compared with conventional (discardable) launch vehicles continues to be its inherent ability not only for testing and repairing possible defects occurring in satellites after liftoff from the Earth, but also for returning them in case the repair can not be completed. Actually, certain orbital vehicles such as the astronomical satellite Solar Max can be repaired and reconditioned by the Space Shuttle crew. They become permanent instruments whose useful life extends indefinitely and whose capacities will increase gradually as technology improves. Later, with the expansion of the capabilities of the STS, it will be possible to repair or to return to the Earth even geostationary satellites which today are beyond our reach.

Thus it is important to note that one of the main factors allowing flexibility of operation is the human presence. Up to now, no automatic or remote control system of reasonable cost has been able to surpass human adaptability and creativity as regards operations in space.

PART TWO
(Figures 15-23)

THE PERMANENT SPACE STATION /9

Basic Concept

The second member of the STS triad, and probably the next large-scale North American space project, is building a permanent space station. Assembling this system in orbit will proceed gradually, possibly starting at the end of this decade. It is hoped that the complete installation will be operating by the mid 1990s.

The space station will considerably expand the capabilities of the Space Shuttle. It is important to note that the initial design of the shuttle will incorporate the future existence of this station in orbit. This means that the Space Shuttle was not designed for long stays in space, but as a refueling vehicle and, as its name implies, as a shuttle.

Once it has been built the space station will be used as a link or starting point for more ambitious operations, including manned interplanetary missions. Modules of all types of satellites will be assembled and repaired in the station. It will also be used as a platform for experimentation and observation both of the Earth and of space. Many tests and experiments related to advanced propulsion systems will be possible in the natural vacuum where they would operate once they are built. At present such experiments are being carried out in a very limited way in large vacuum tanks which, as well as being extremely costly, are not capable of simulating all the conditions of space flight.

Design Philosophy

The basic design philosophy to be followed is based on simplicity and autonomy. The problem is to establish a place where it is possible to implement innumerable simultaneous and interdisciplinary operations. It is hoped to make maximum use of the human presence, and at the same time to reduce the need for constant support from the ground control center, which will be better used to control the high traffic of space shuttles and transorbital vehicles which, it is hoped, will exist by then.

Typically the architecture of the station will follow the concept of the "distributed system," that is, no critical operation will be located totally in one place. The primary systems such as power generation and distribution, environment control and stabilization, navigation and control systems will be better distributed in such a way that each one will be capable of withstanding at least three consecutive failures before presenting a serious danger to the crew. With these design rules, the first failure affects only the redundancy of a system but does not incapacitate it in the accomplishment of its operation; it is said, therefore, that the system is "fail operational." The second failure of the same system incapacitates it in terms of its operation, but in such a way that the safety of the crew and payloads is ensured; therefore this system is termed "fail safe." This design concept is characteristic of North American spacecraft and is called FOFS (Fail Operational Fail Safe). The importance of this type of design was demonstrated extensively in the Space Shuttle missions.

Construction /10

The station will be built in modules which will be carried into low Earth orbit and assembled there. The assembly will be accomplished in a series of missions, probably four or five. It is hoped that a partial platform can be manned for the first time by the end of the second flight in this series. In broad outline the plan is as follows.

The first module in orbit (Fig. 15) will be the power generation and distribution module. In this system electrical power will be generated by photovoltaic cells in two folding solar panels. The total generating capacity will be about 200 kW continuously, using rechargable lithium or nickel-cadmium batteries for the night periods (approximately 45 minutes in each orbit). It was also proposed to use electrochemical plants on the basis of hydrogen and oxygen similar to those used today in the Space Shuttle. The disadvantage of this alternative is that the power source is not yet regenerative. All the possibilities are being evaluated, and probably the final result will be a hybrid system which will contain elements of each.

The second module (Fig. 16) will be a pressurized cylinder which can be manned. In it a reduced crew (three or four astronauts) will check the initial operation of the systems. At the same time, simple control and command operations will be executed which will allow the linkup of the Space Shuttle during later phases.

It is important to note that the control and command system must be capable of adapting automatically to the development of the geometry of the station as well as to its changes in mass, inertial moment and oscillation characteristics. The dynamic stabilization of light and flexible space structures is one of the most interesting problems in automatic control engineering. To study dynamic behavior a solar panel more than 30 meters long will be deployed in the inaugural mission of the Space Shuttle Discovery in August of this year.

It is very possible that initially in the station simple experiments and repair and maintenance missions can be carried out.

However, it will be possible to accomplish these activities fully when the third module is added (Fig. 17). This will be a small, multipurpose workshop where it will also be possible to refine industrial processes which will later be carried out automatically by larger plants in orbit.

It is also possible and, according to the initial emphasis which will be put on the station (for example, operations vs. research), that the third module will be similar to the second (Fig. 18). In this case an interchangeable storage module and a folding hangar which will house the first prototype of a transorbital vehicle will also be installed. The control and command capabilities necessary to support high traffic of satellites of all types from the station will thus be increased.

The final configuration (Fig. 19) will be obtained in two or three additional missions. More pressurized modules will be added which will have specialized functions and increase the number of crew members on board. A special structure, also of the folding type, will be used to fix various experiments requiring exposure to the environment. Later, to avoid vibrations, contamination or other disturbances to sensitive experiments, they /11
will be fixed on platforms flying freely near the station.

Finally it is important to add that all these systems are developing rapidly. The variety of architectonic concepts can be estimated in Figs. 20 and 21. In the latter, spacious hangars may be noted which contain transorbital vehicles. Up to now, the final decision on building the station has not been taken by the U.S. Congress; however various fairly extensive exploratory programs have been started, which have defined very completely the basic requirements and functions of the station.

THE TRANSORBITAL VEHICLE

Concept

The third and final component of the STS triad is a transorbital vehicle, TV, termed in English the OTV (Orbit Transfer Vehicle). Basically the philosophy behind this vehicle is based on the power economy resulting when payloads are sent into space in stages. The OTV itself is the higher stage of the satellite, but with the advantage that the complete system may be recovered.

Because it does not have to operate in the Earth's atmosphere, the OTV does not need to be aerodynamic. This clearly facilitates the design enormously. The structural requirements are also much less difficult to satisfy, since there is no need to deal with the forces of dynamic pressure or friction which exist during the reentry of the Space Shuttle into the atmosphere. The basic system consists of four essential elements: a propulsion system, a fuel system, a control module (pressurized if manned), and a harness or device in which the satellites and experiments which must be carried are fixed. The four components, connected with each other by a fairly light structure (Fig. 22), constitute the typical transorbital vehicle of the future.

Up to now designs of transorbital vehicles have been rather preliminary. But the technology is sufficiently developed to allow the construction of an OTV any day. The main aspect which must be defined more clearly is that of the exact requirements this vehicle must have. For example, it has not been decided yet whether it is worth the trouble to design a totally automatic OTV instead of designing one taking into consideration the well-being and safety of a human contingent. On the other hand, the human flexibility and adaptability demonstrated up to now are difficult to surpass with automatic systems. Very possibly, as happens in these cases of parallel technologies, a symbiosis will be possible; that is, the human presence will be used to implement and supplement the capabilities of the automatic system. This synergism is vividly illustrated by the Space Shuttle itself.

Function /12

The main function of the OTV is to be used as a cargo and supply vehicle. Thus it will carry loads from the station into geostationary orbit and other high orbits. The OTV will also carry fuel to refuel satellites as required and will be used as a mobile workshop to carry out "in situ" repairs to damaged satellites.

Following the general philosophy of space vehicles, the OTV will necessarily be a modular system. It can rapidly be configured to satisfy the requirements of a given mission. In certain cases the OTV will also be used as an observatory and laboratory for scientific purposes.

Design

The main interesting aspect of the OTV from the point of view of space engineering is that it will be the direct predecessor of future manned interplanetary vehicles. Thus its design will evolve according to new, developing technologies. This development will be accomplished mainly in three important fields: regenerative or closed-circuit environmental control, advanced propulsion systems, and light electrical plants with high specific power. Of these three topics, the first refers to advanced systems being studied for use in the space station. In this article I limit myself to listing some references [8, 9]. The other two topics relate to the design of the OTV and they will be discussed briefly below.

Advanced Propulsion Systems

The efficiency of a rocket propellant is measured by its specific momentum, termed I_{sp}. This variable is directly proportional to the square root of the exhaust temperature, or more directly, to the velocity of the gases in the nozzle. In effect, the hotter the exhaust, the more efficient the engine, and the less fuel needed to move from one point to another. In a conventional rocket engine, the maximum temperatures are limited by the materials of which the nozzle is made. At present the most efficient chemical engines manage to reach temperatures of several thousand degrees Centigrade, and these are the ones supplied by the hydrogen-oxygen reaction.

Other less efficient but relatively simple chemical engines are those using hypergolic fuels such as hydrazine and nitrogen tetroxide. These are the preferred fuels for present satellites, since they do not require special refrigeration, as is needed by hydrogen and oxygen. The simplest engines but at the same time the least efficient are those using solid fuels. They have the additional drawback that they are not of the multiple ignition type.

Very probably the first prototype of a transorbital vehicle will use hypergolic fuels, since these same liquids will have to be carried to refuel satellites. However other much more efficient engines are contemplated in the near future.

Plasma Engines /13

At very high temperatures the exhaust is ionized and is converted into an electrically conductive plasma. This condition is very fortunate, since it can be contained and controlled in this state by means of electromagnetic fields. These fields are also used as insulators, reducing the heat exchange to the walls of the nozzle, thus allowing very high temperatures. Plasma based systems are the subject of intensive research [10, 11, 12] and some small prototypes have already been used in space.

Although plasma engines have high temperatures, they require considerable electrical power to generate power. Nowadays, however, the photovoltaic electrical and electrochemical sources are inadequate. For propulsion purposes these sources are extremely weak when they are compared with chemical engines. In other words, the present plasma engines have high efficiency but low thrust. The development of electrical sources of greater power and duration is a very important factor in space transport of the future. This brings us to the second topic.

Advanced Electrical Plants

Modern communications satellites operate at power levels of hundreds of watts. These vehicles generate electricity by means of solar panels. On the other hand, the Space Shuttle operates at levels of 15-25 kW by means of electrochemical reactors using hydrogen and oxygen as fuel. This level is comparable with the electrical consumption of a furnace in an industrialized country. The space station, perhaps using a hybrid system with very extensive solar panels, will not achieve levels much higher than 200-300 kW. But more important, in missions beyond the solar system, the radiation density decreases rapidly (inversely to the square of the distance to the Sun). In this type of flight, solar panels would not be effective.

The electrical plants of the future will be of the thermoelectric type, using nuclear sources based on fissionable isotopes such as uranium-235 and plutonium-239. These plants will operate continuously without refueling for periods of over six years and at levels of 1-5 MW. The predecessors of these electrical plants, operating at low power, have provided power to the group of experiments called the ALSEP (Apollo Lunar Surface Experiments Package) left on the Moon by the Apollo missions. Also the unmanned interplanetary probes such as Viking and Voyager used this energy source. A project called SP100 (Fig. 23) is attempting to develop a thermoelectric nuclear plant capable of generating continuous power of 100 kW for several years [13]. Further in the future, perhaps at the beginning of the 21st century, plasma engines will generate their own energy internally by means of controlled thermonuclear fusion. When this is achieved, the thermoelectric plants based on uranium and plutonium will be discarded.

The development of new capabilities in space will be intimately connected with the available levels of electrical power. Consequently, this is an area of intense research. At the same time, it is totally feasible that the development of these systems will not only change the panorama of space operations, but will also contribute directly to the development of poor nations here on Earth. This subject will be discussed below.

PART THREE
(Figures 24a, b, and c)

IMPACT OF STS ON LATIN AMERICAN DEVELOPMENT /15

Geostationary Orbit

Geostationary orbit is that in which the translation speed of the satellite is equal to the speed of rotation of the Earth. In this orbit the satellite stays for 24 hours with the total revolution of the Earth.* Obviously, the satellite seen from a point on the Earth's surface seems to be motionless or stationary, which gives it its name. This is the ideal orbit for telecommunications satellites, since these, besides the fact that they are not hidden, do not require mobile or automatic tracking antennas.

Geostationary orbit requres two basic ingredients imposed by the laws of physics. First a translation period of 24 hours requires an approximate altitude of 36,000 km above the Earth's

*The exact figure is 23 h 56 min 04.091 s.

surface. Secondly, the plane of the orbit should coincide with the plane of the Equator. These two elements imply simply that the geostationary orbit is unique and corresponds to a circle of approximately 44,000 km radius above the equator.

Acknowledging that there is only one orbital circle (360 degrees) available, it should be determined how close one satellite may be to another without resulting in interference. In this connection it should be noted that for operating on the same frequency band, the minimum separation is two degrees of arc. With this reasoning it is easy to determine that there are about 180 spaces available. The immediate conclusion is that the number of available spaces for communications satellites is limited. This number can increase or decrease according to the optimism of those who calculate it; but basically this gives us an idea of the geometrical nature of the problem which restricts us.

Fortunately this geometric law may be avoided partially if the satellites operate on different frequency bands. Nowadays, three different bands are used: S, C and Ku at frequencies of 3, 5 and 16 MHz, respectively. This new or variable dimension allows us effectively to triple the number of available spaces. Figure 24 estimates the total population, present and future, of geostationary satellites in the three frequency bands.

In spite of this increase it is important to note that the lack of space in the geostationary orbit will be obvious within a few years. Basically the geostationary orbit can be considered a natural resource. To regulate it, it will be necessary to establish space treaties among the equatorial nations and international agreements. These agreements will make it possible to ensure equitable use of this resource among the developed and developing nations.

Informatics

The main use of geostationary satellites is as relay stations for voice, pictures or data. This amalgam of information transmitted is called informatics. Nowadays, informatics is a very interesting topic in the development of nations. For example, apart from telephone links, it is possible to send television pictures with educational programs to villages and towns of a country. This means long-distance mass popular education. The programs are received by portable, relatively economical receiving antennas. This eliminates the need for costly ground relay networks, which require continuous maintenance and which are exposed to the inclemency of the weather.

It is possible to link up also through satellites commercial centers of a country with each other or with the rest of the world. Any kind of required information can be transmitted almost instantaneously from one place to another. The system is used in the area of public health, allowing transmission of medical information from urban to rural centers. Agriculture and fisheries are also affected positively, since meteorological information acquired by the remote-sensing orbital units can be transmitted directly to the areas most needing this information.

Because of the altitude, the satellite has access to large areas of terrain. Actually one satellite can cover territory corresponding to that of several countries, and three satellites separated by 120 degrees of arc will provide global communications. Thus the satellite is converted into a reference point through which it is possible to have access to any other point on the Earth's surface.

Implications for Latin America

The basic problem of the agrarian nations of Central and South America has two aspects. First, agricultural production is carried out by means of intensive human labor, and secondly, the cost of its products on the world market is relatively low. These two elements result in: low income, low lifestyle and continued scarcity of foreign exchange for modernization. It is a vicious circle. While the industrialized countries become richer, the poor ones become poorer.

The flow of knowledge through the development of informatics will rapidly change the educational level of the Latin American populations. This will be the starting point for a drastic change in socio-economic structures. New knowledge will make the people capable of exchanging agrarian labor for specialized technical work. The great worldwide demand for cheap labor in fields such as microelectronics, the production of computer components and high technology systems will be supplied by the young nations of Latin America. In return, the beneficial inflow of foreign exchange will allow the mechanization of agriculture, which will be accomplished more efficiently on a large scale. In this connection, agrarian reform will be converted rapidly into an obsolete topic. Simple access to instantaneous information and education over an entire country will cause another important effect: many socio-economic changes will be implemented without the need of migration from rural regions to urban regions. In this way it will be possible to prevent many problems of provisioning, health, transport and environmental /17
contamination which have been caused by these migrations.

Nowadays Latin America represents a very dynamic region on the planet. The nations are generally young and thus have a great capability for training in new technologies. As is apparent in Fig. 24, the Latin American nations plan to establish their own geostationary satellites within a few years. The main impact of this will be manifested more clearly in two important areas: telecommunications and remote sensing. In the first, the use of a single satellite will make it possible to have a much closer link, not only among the nations of one region, but between them and the rest of the world. The satellite will allow the technology transfer so necessary to Latin America in these times. The use of satellite technology will be very important for the technological development of the South and Central American nations, as well as the islands of the Antilles. In reality, a geostationary satellite will provide Latin America with the basic tool needed to achieve a great technological leap. This leap will allow the accelerated and efficient development of natural wealth and will doubtless raise the standard of living of the common ordinary citizen. Perhaps this is the road to peace.

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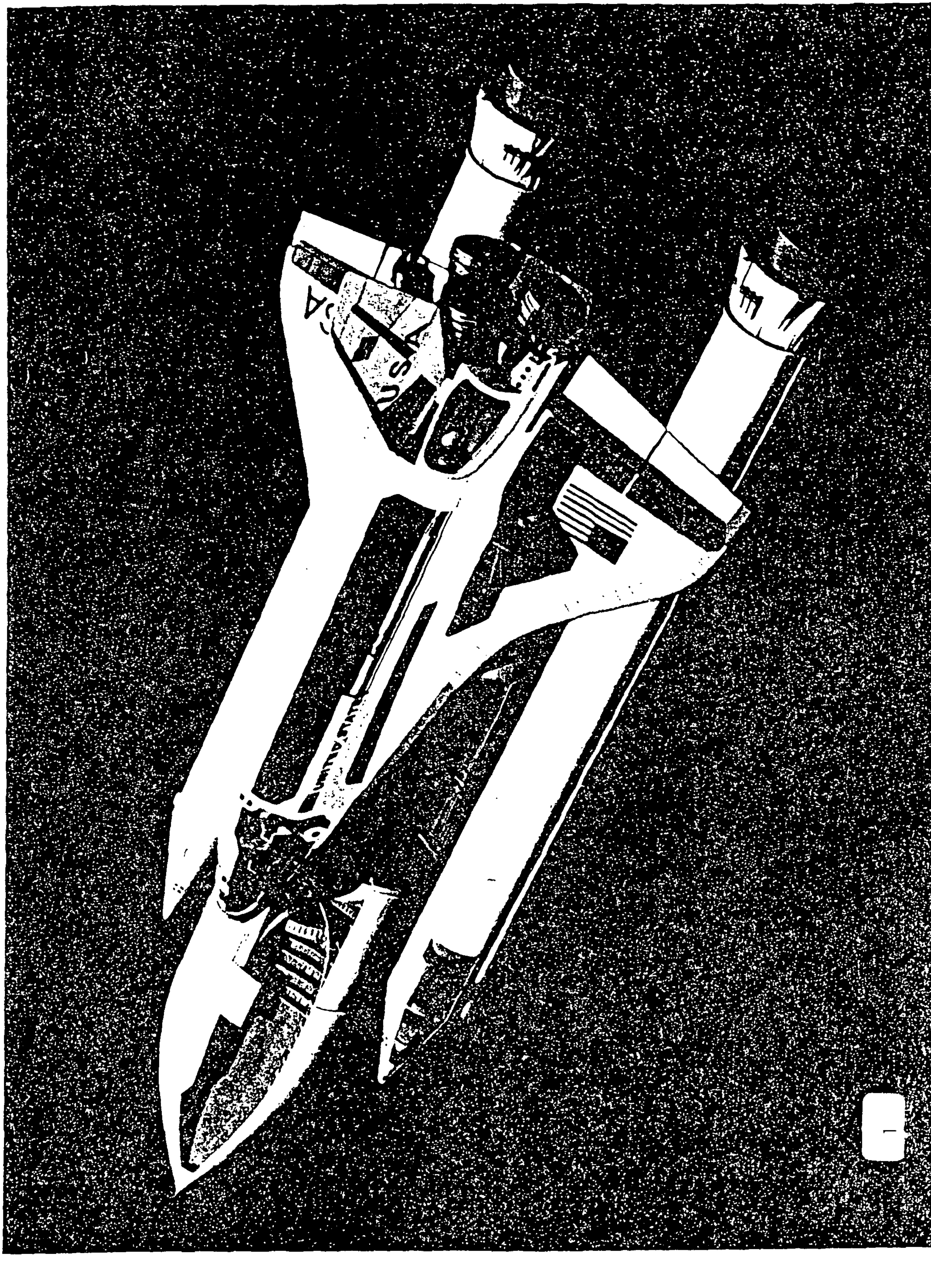

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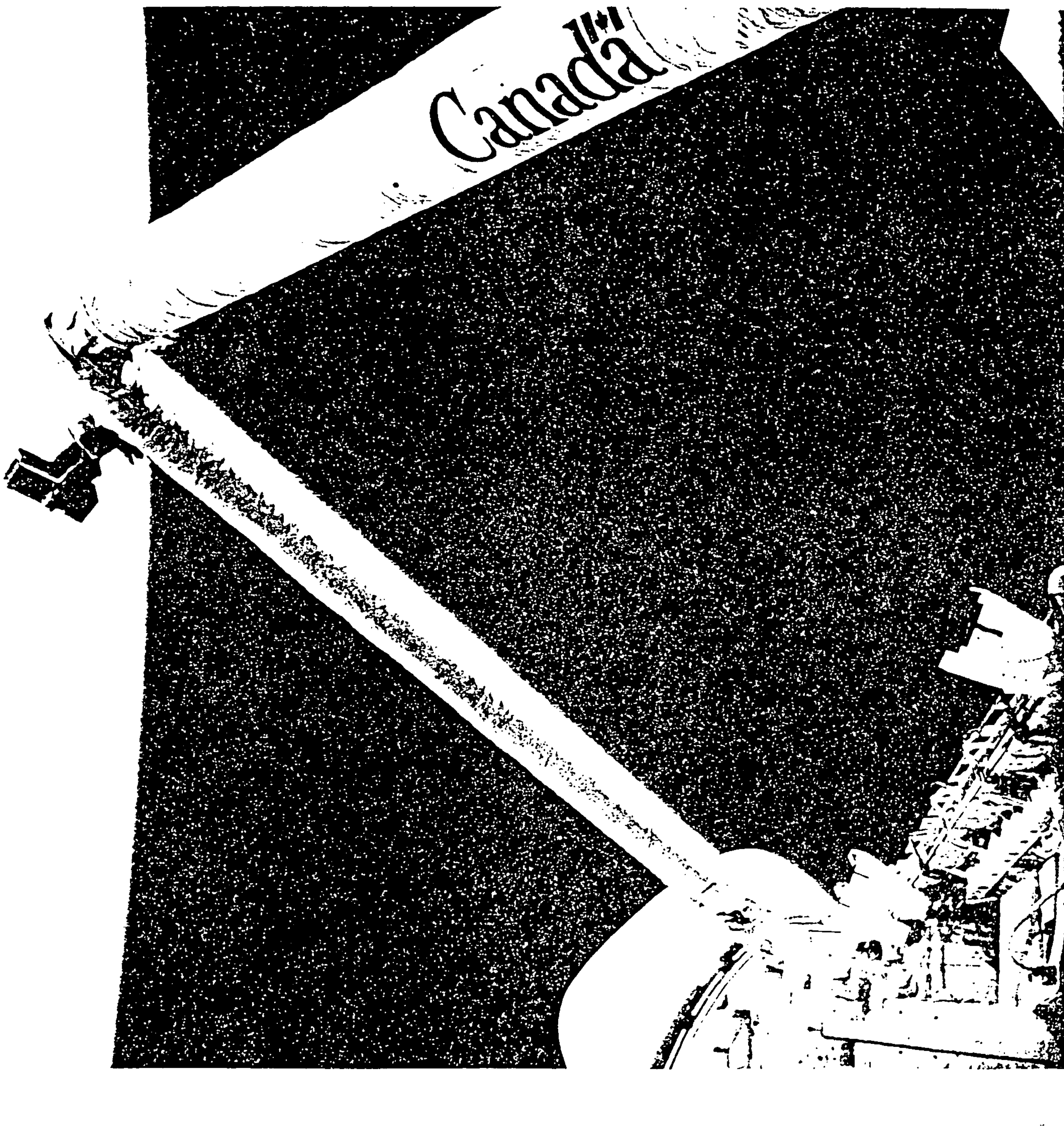

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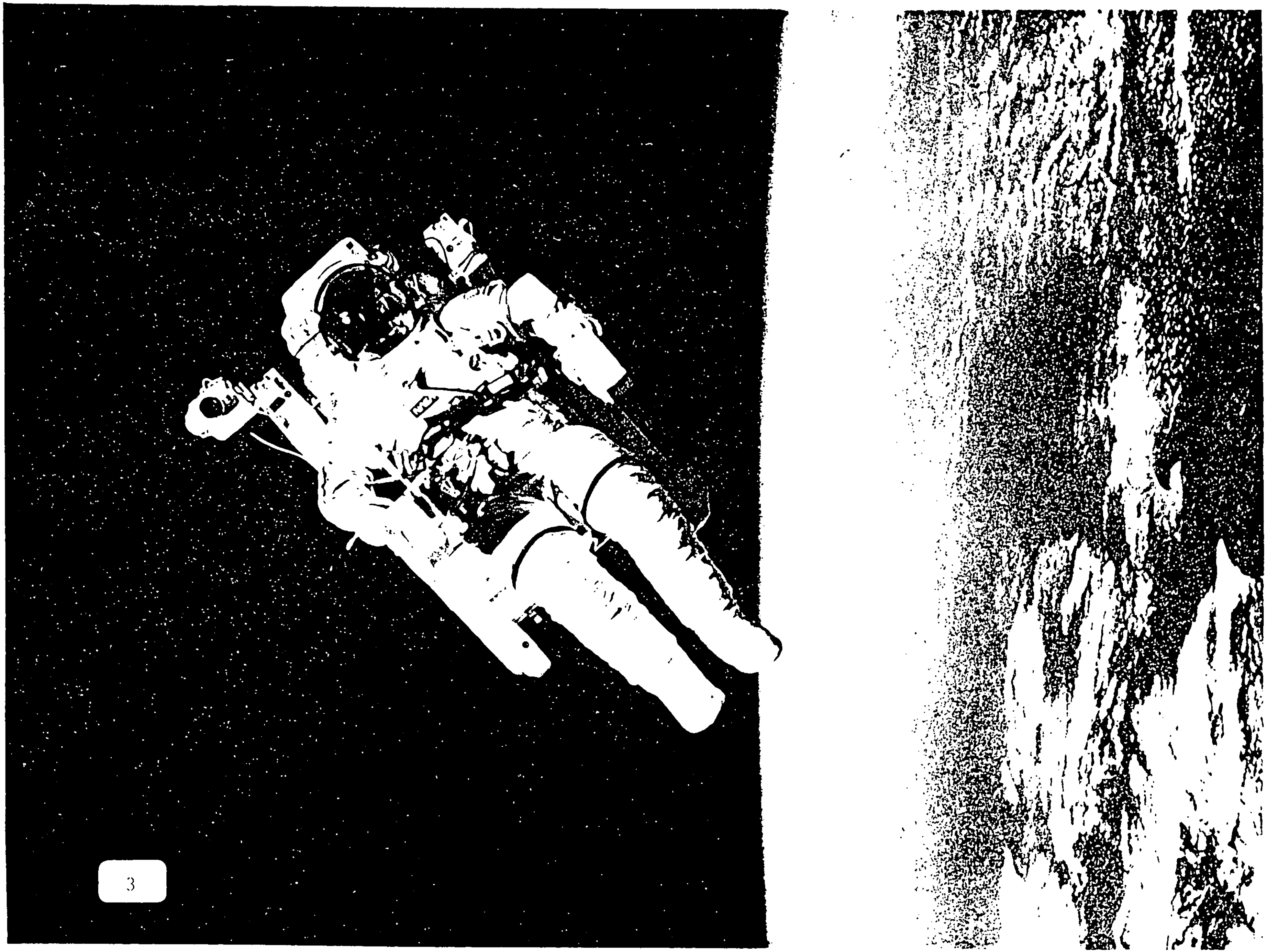

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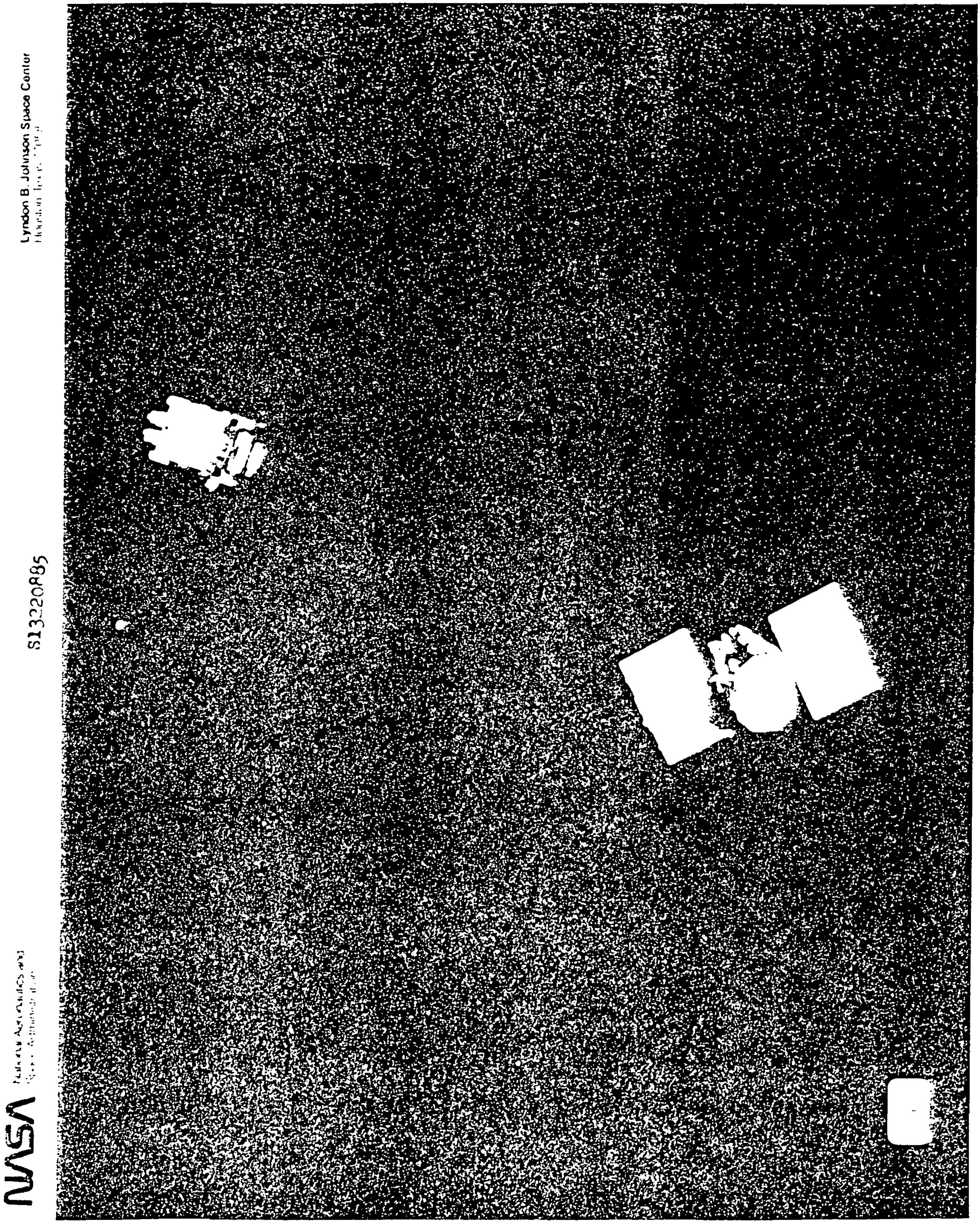

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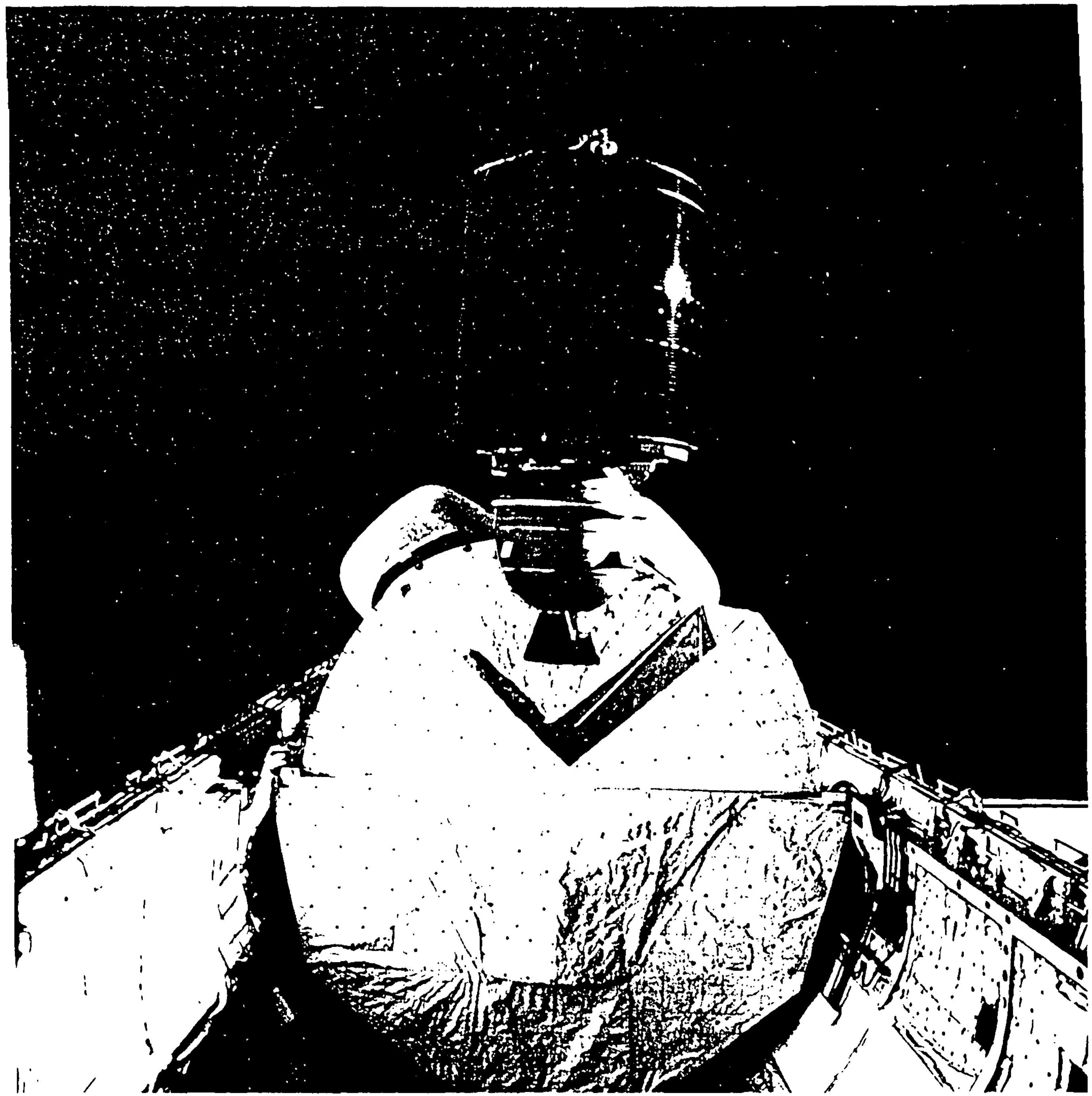

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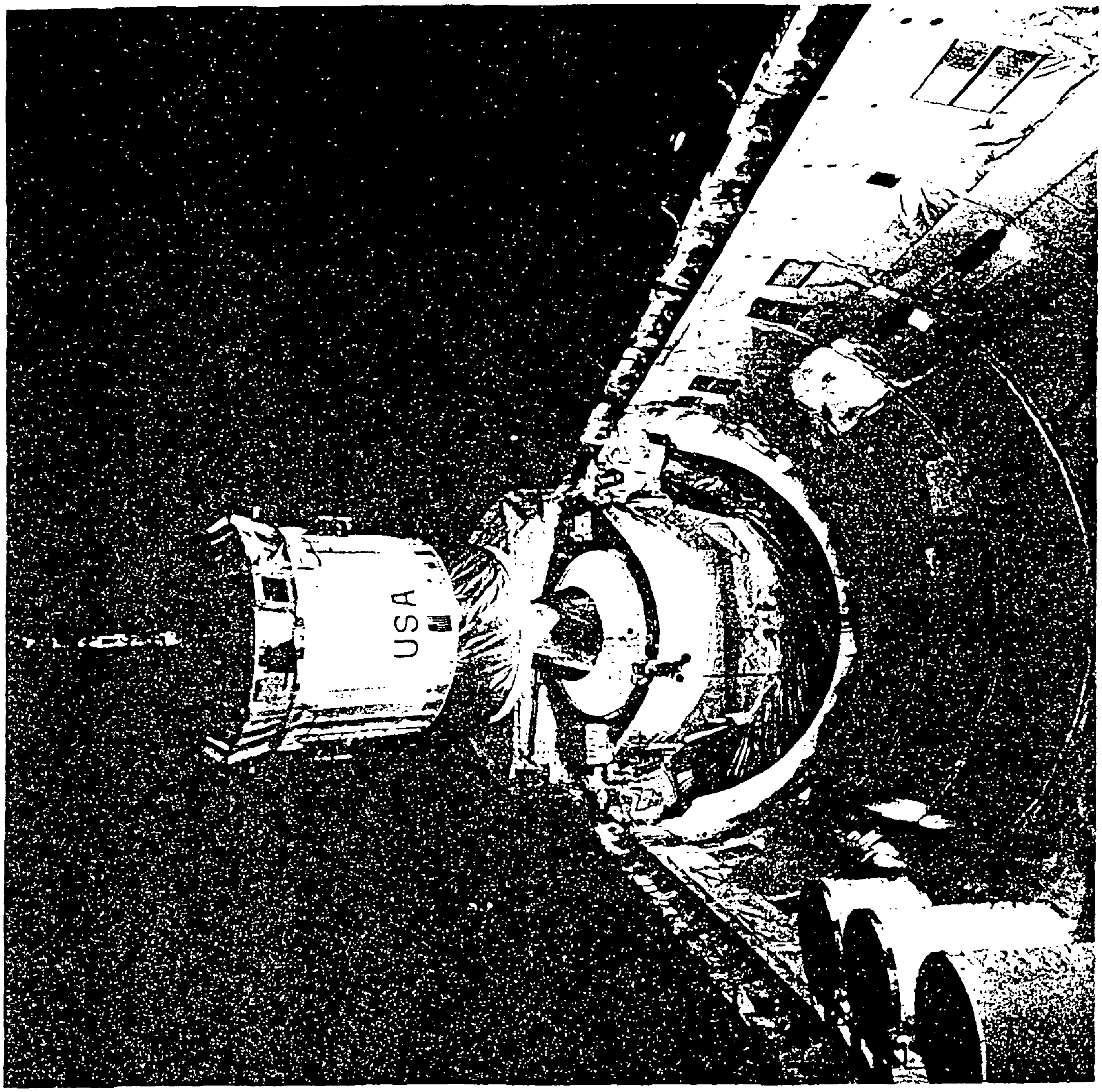

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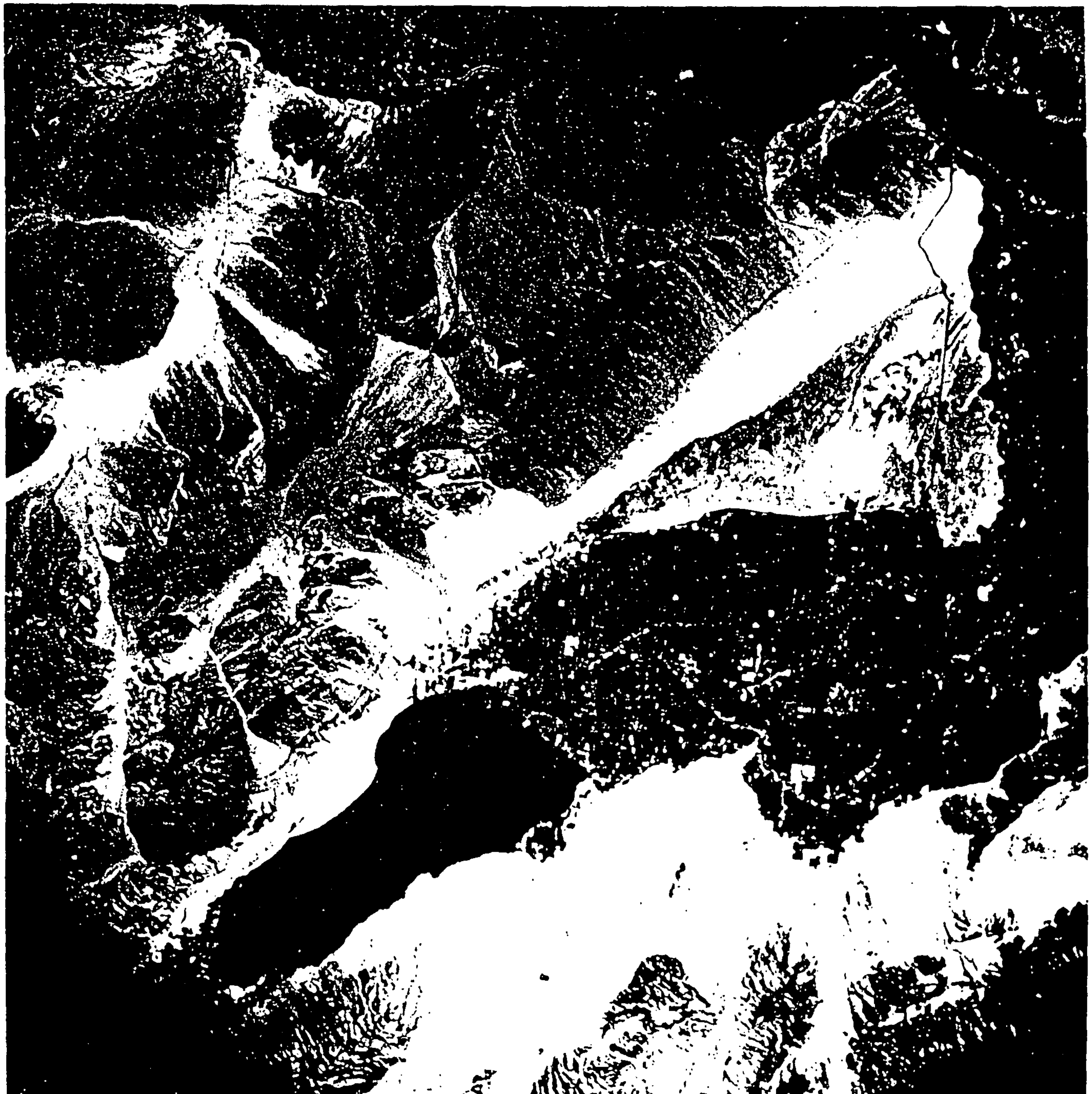

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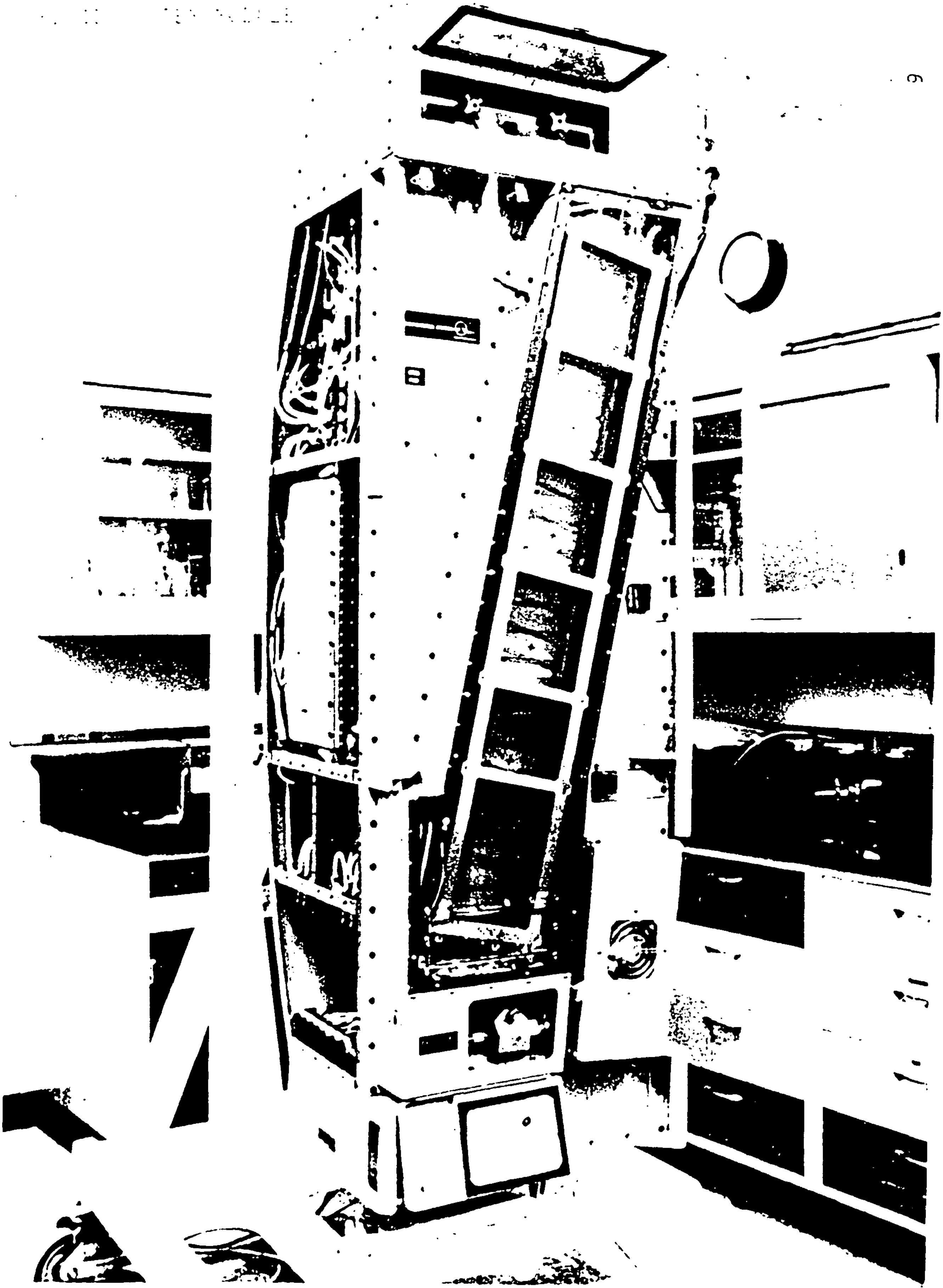

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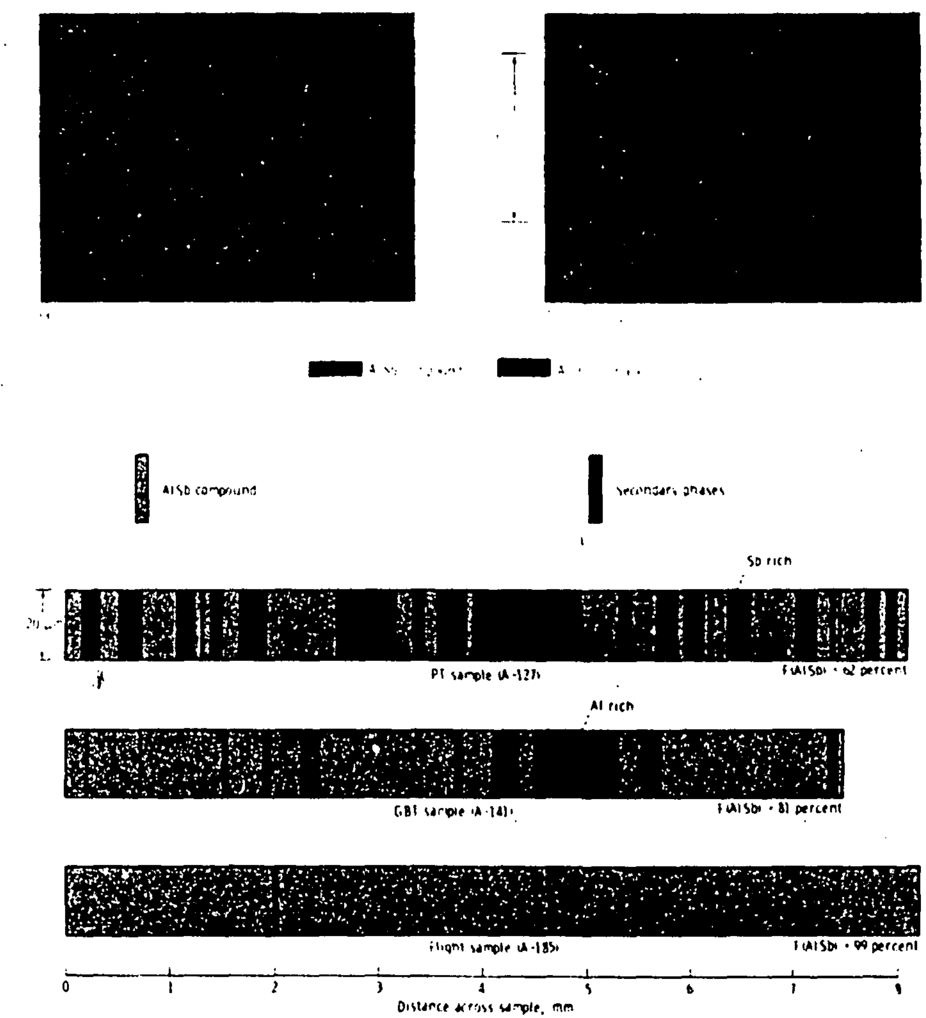

Figure 7–7. Distribution of AlSb compound throughout the samples. Top shows typical cross section of flight sample (a) compared with ground control sample (b) processed under identical condition except for gravity. The bottom shows comparisons between 20 micron scans taken across a prototype sample (top) which represents commercially available AlSb the ground based test sample (middle), and the flight sample (bottom). It is apparent that low-g processing resulted in the formation of considerably more of the desired AlSb compound and much less of the secondary phases than either the ground control sample on the prototype sample.

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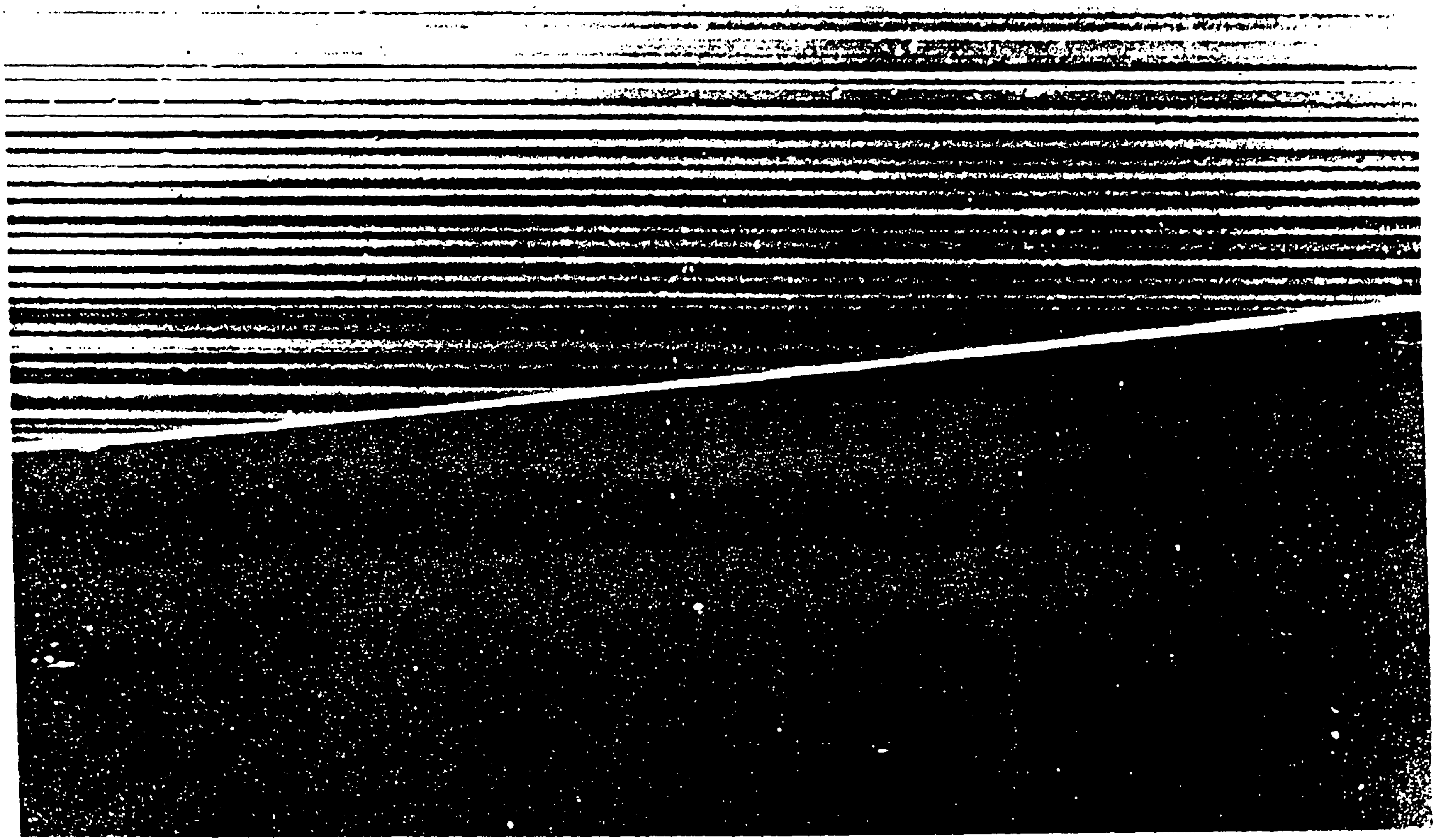

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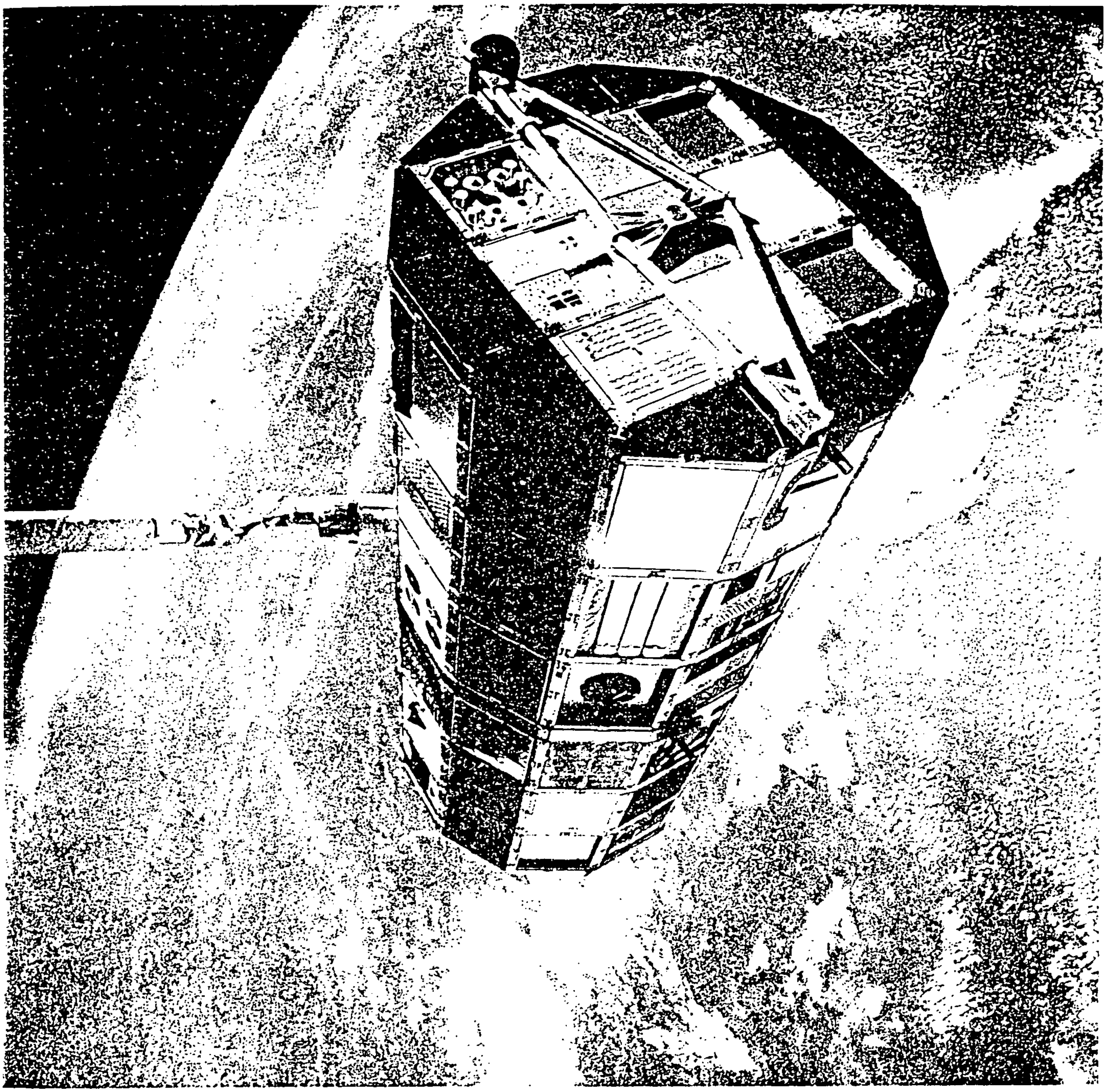

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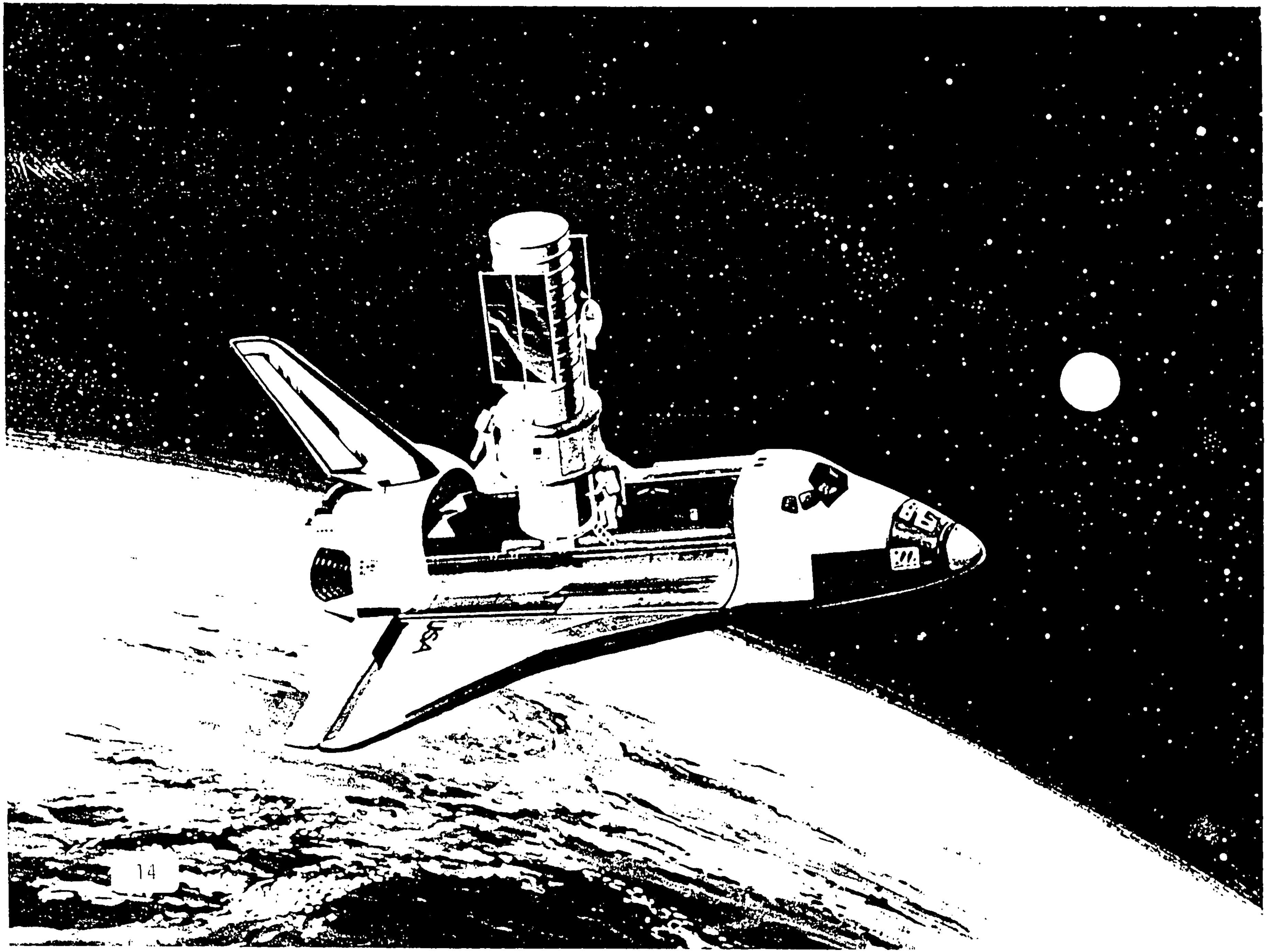

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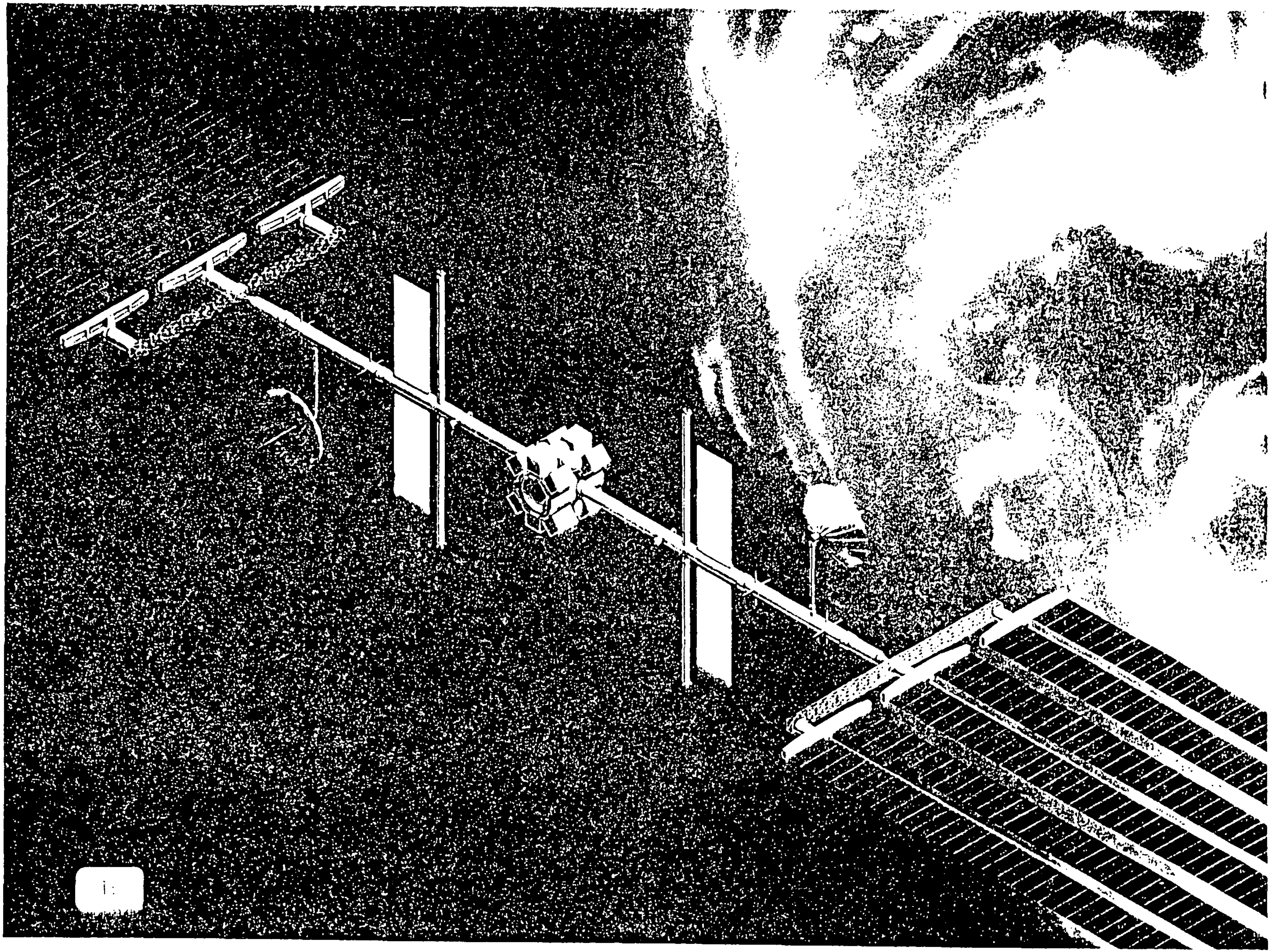

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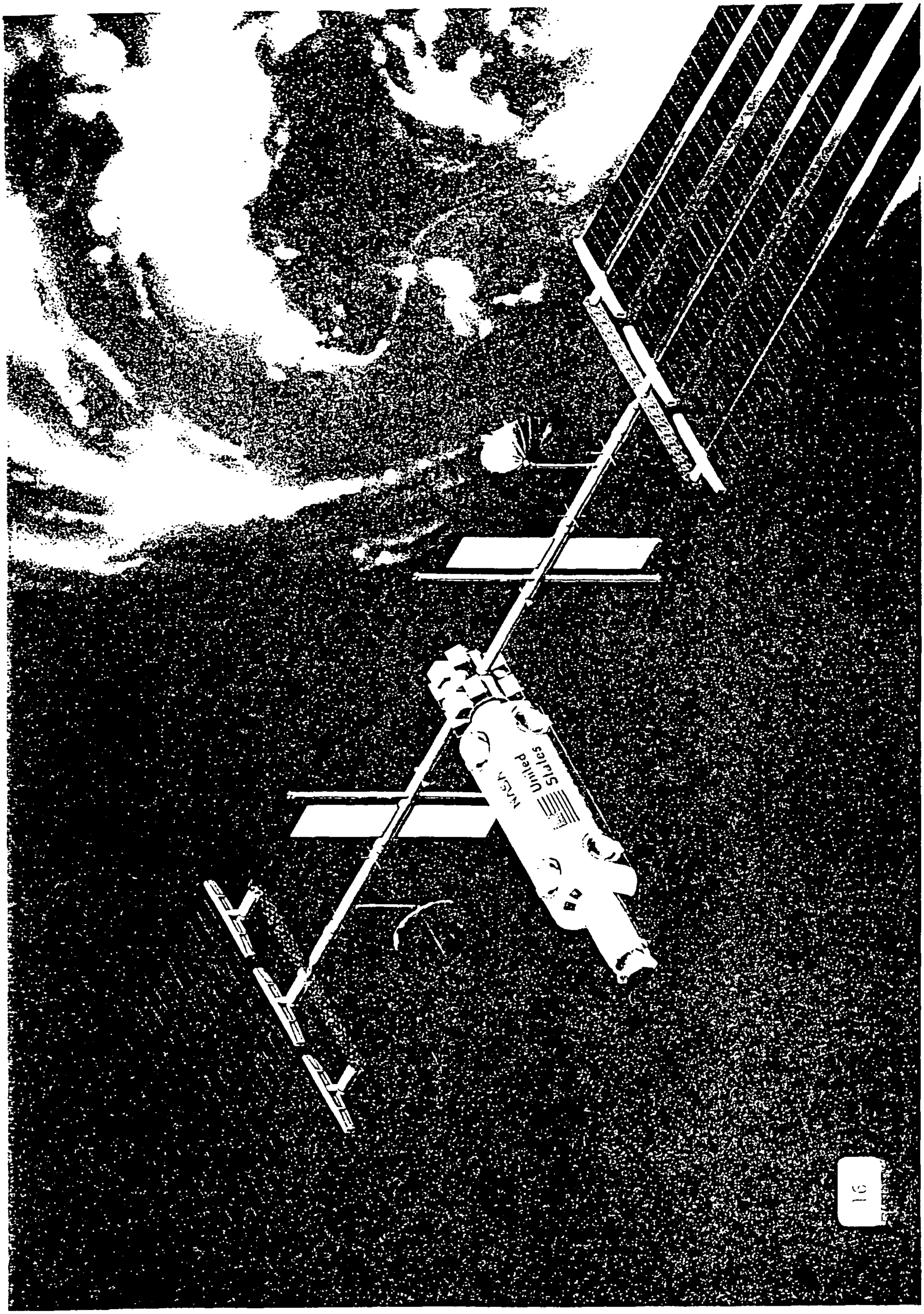

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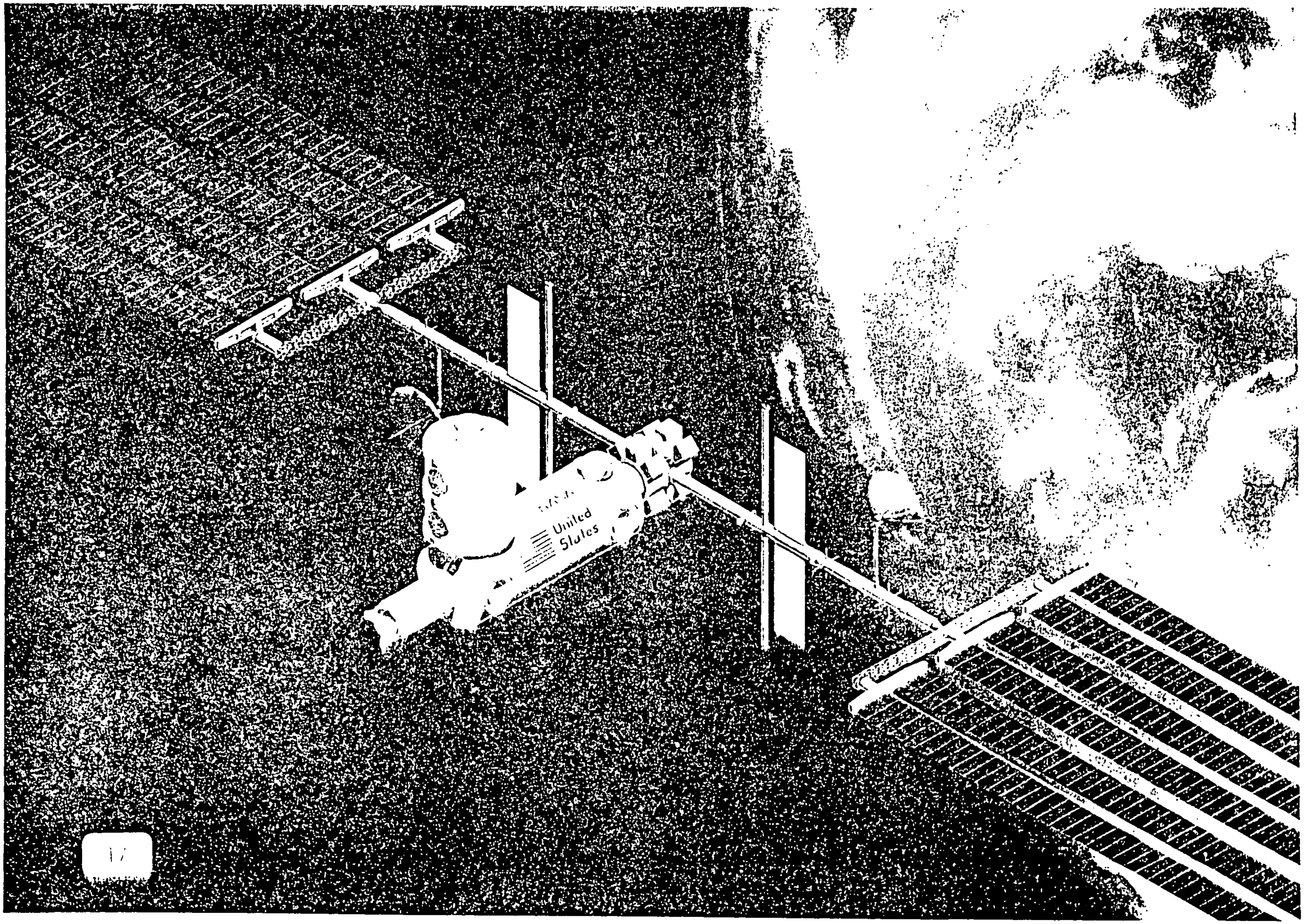

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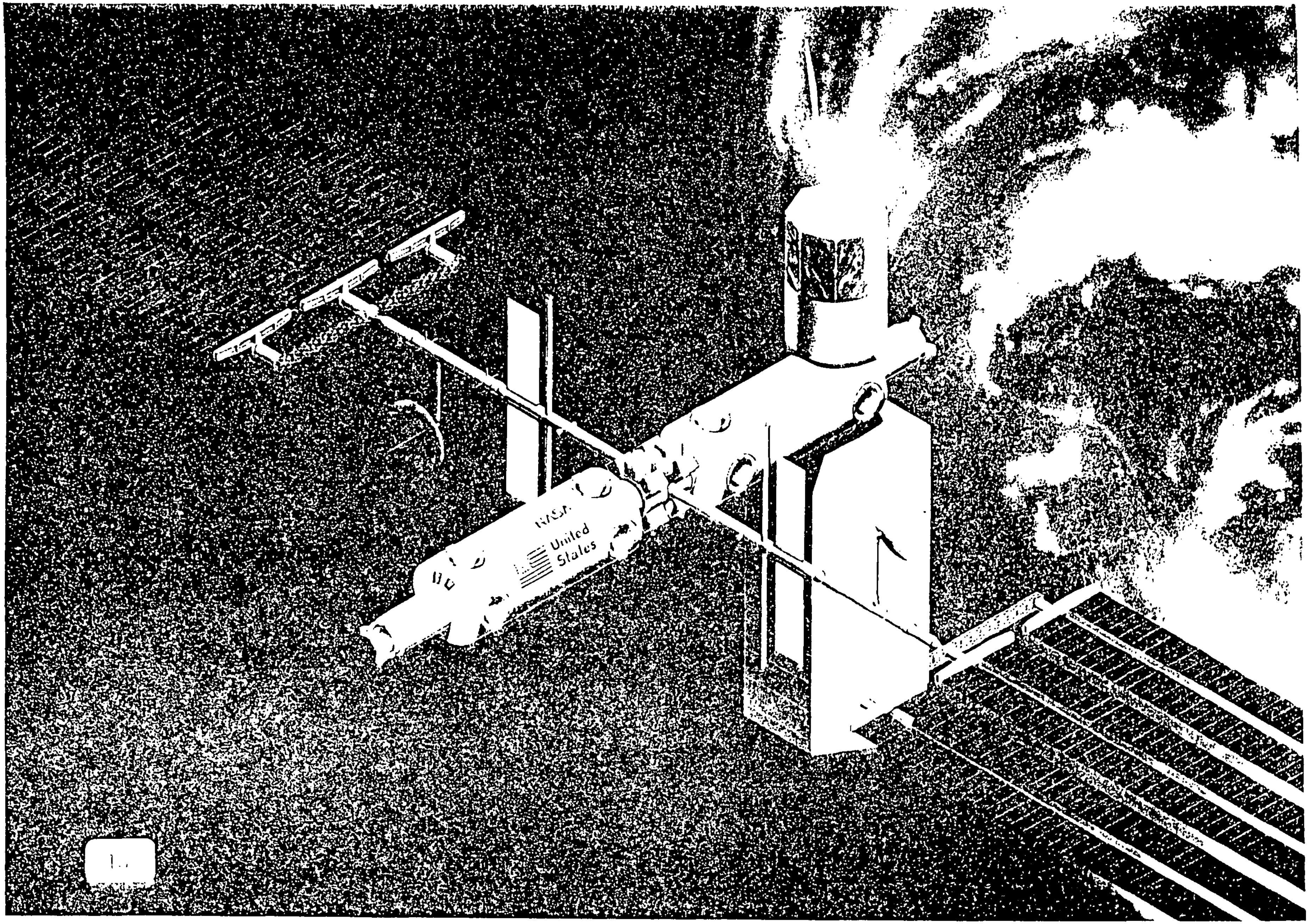

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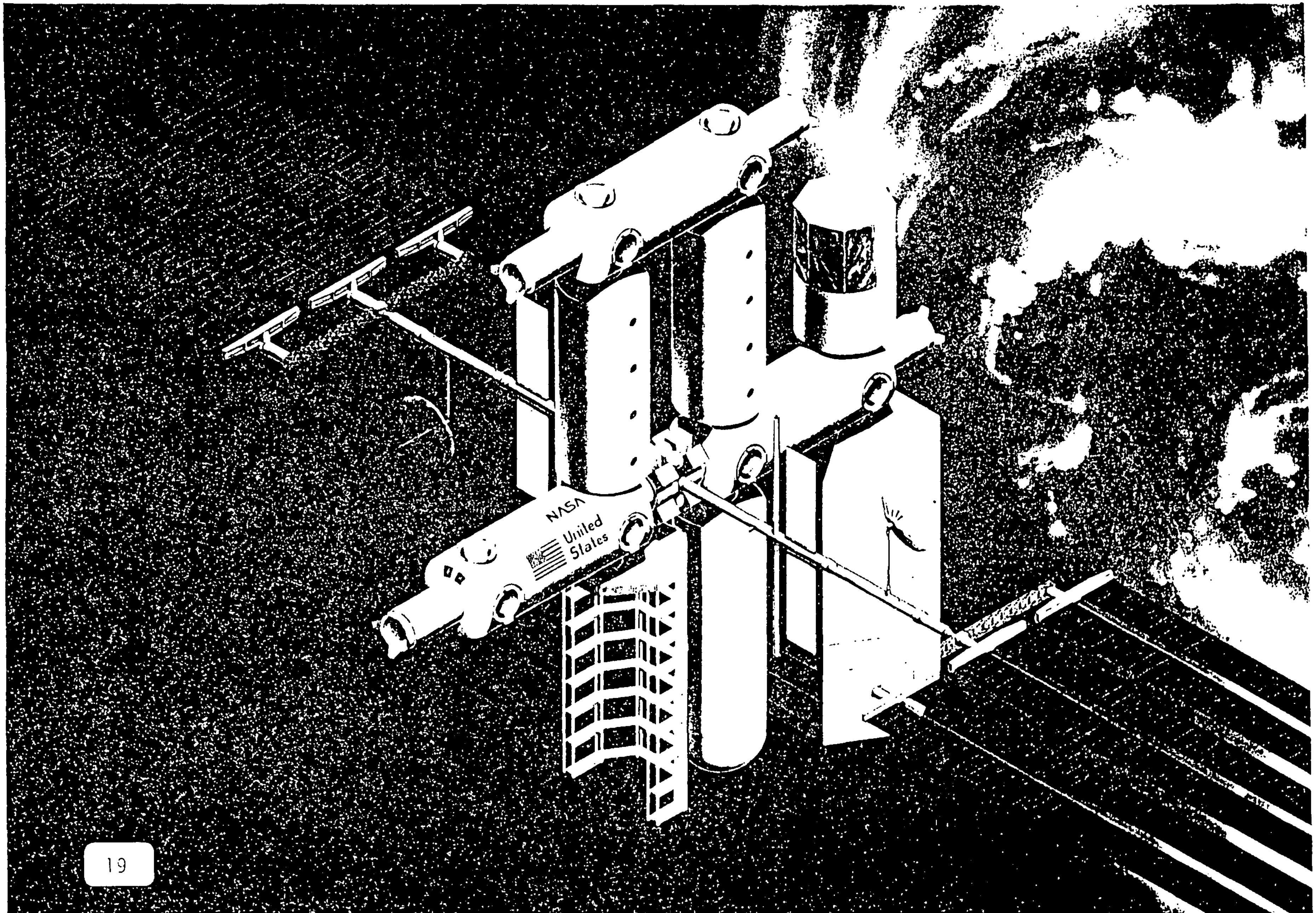
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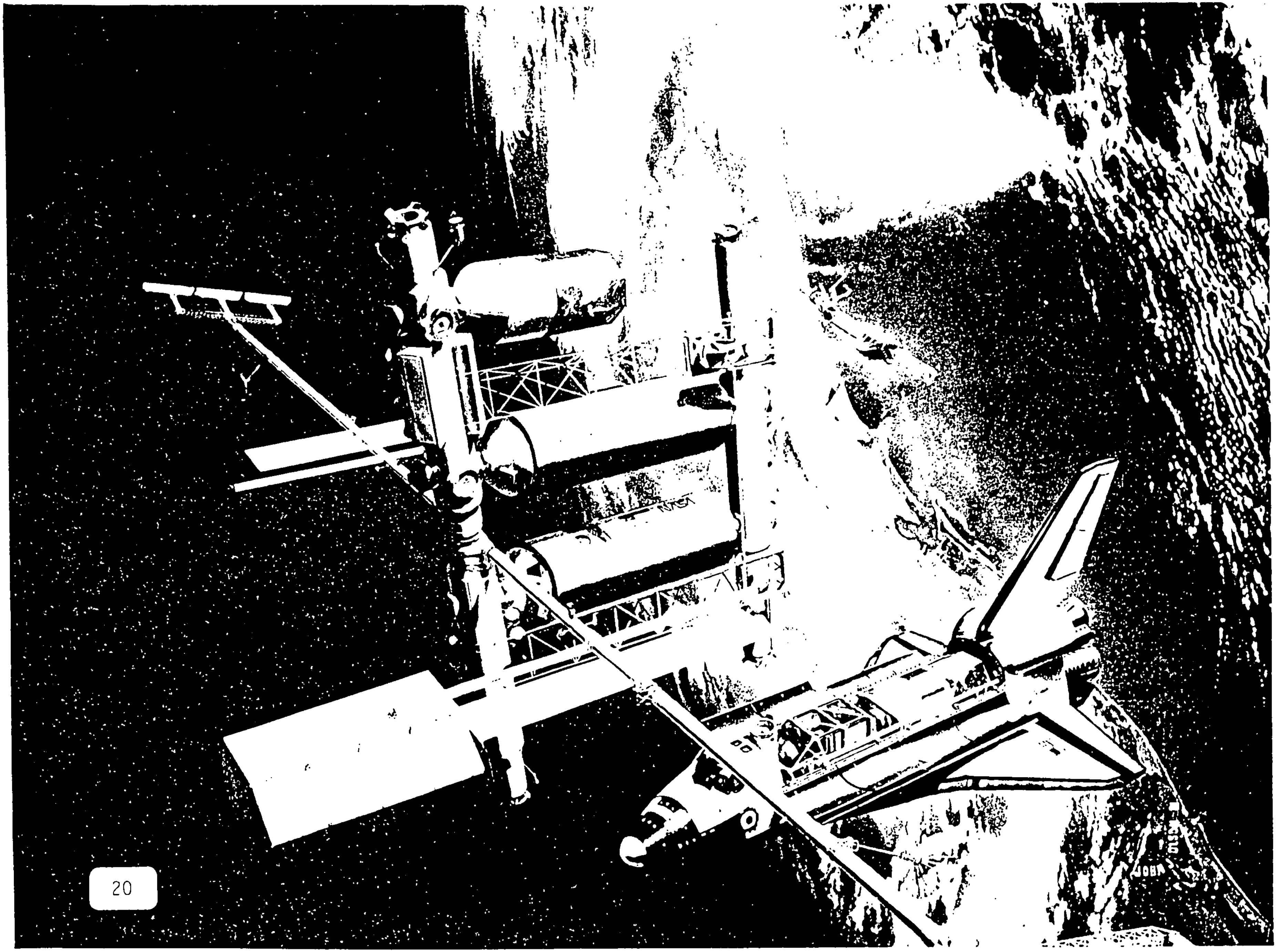

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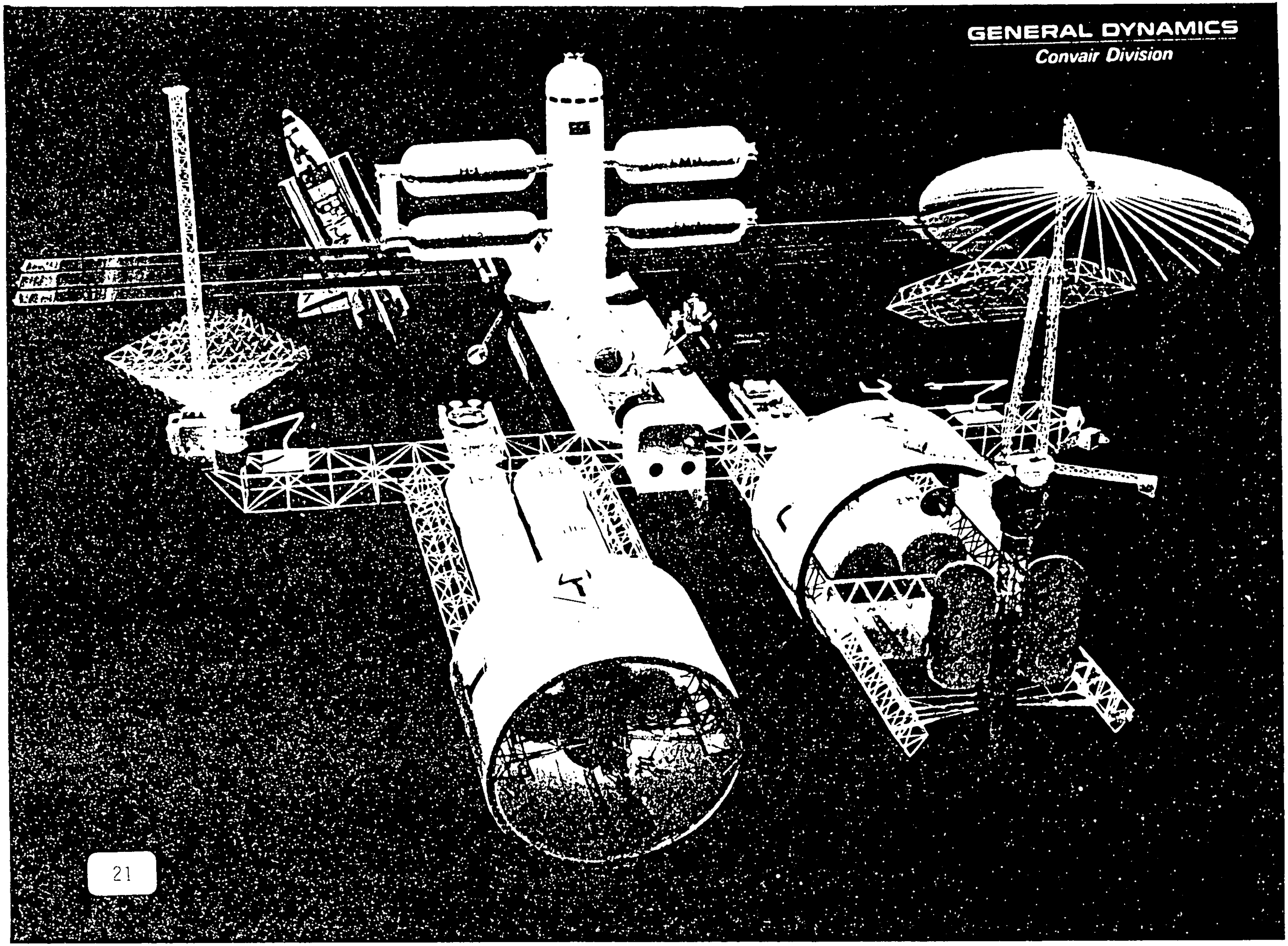

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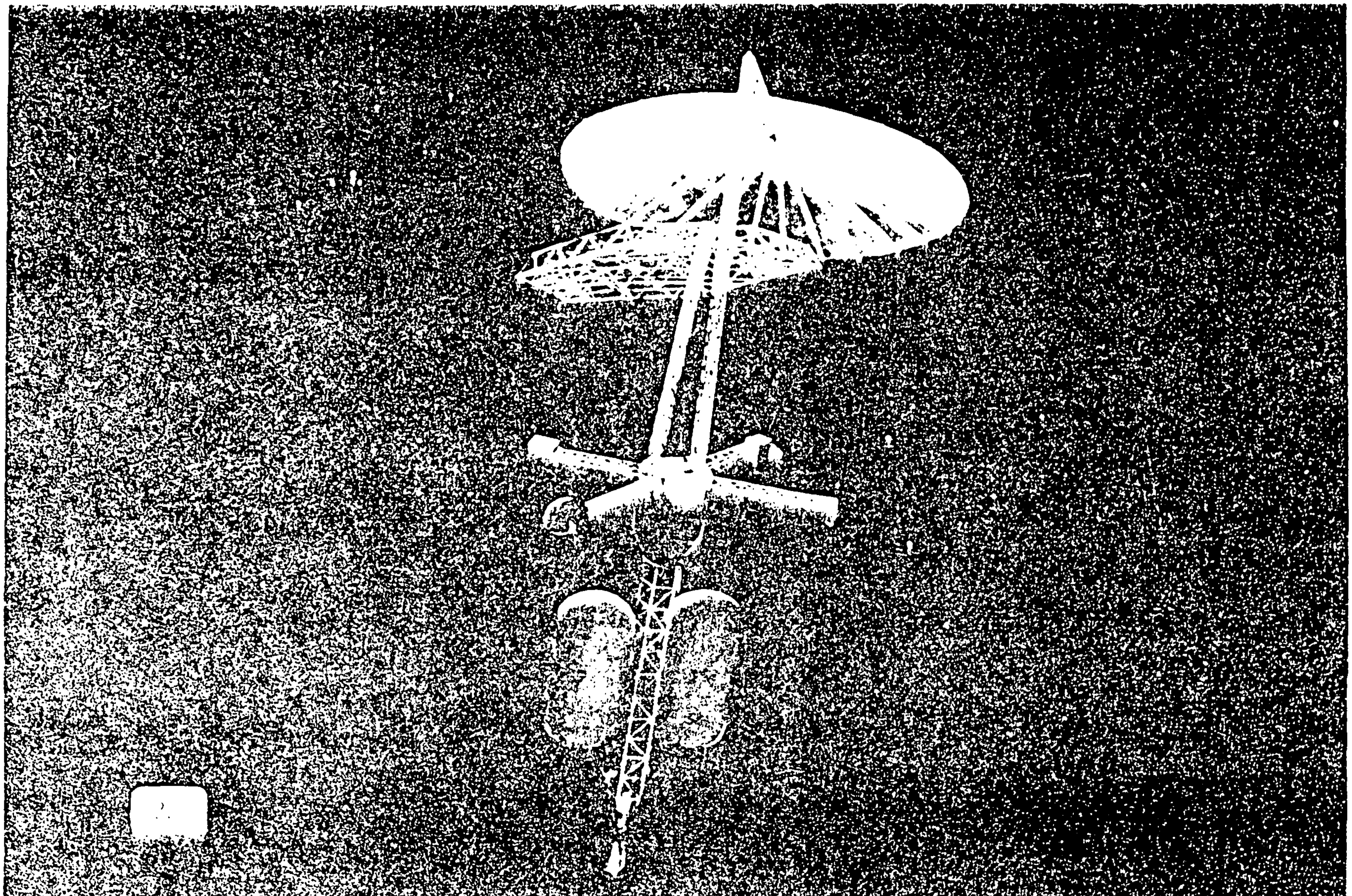

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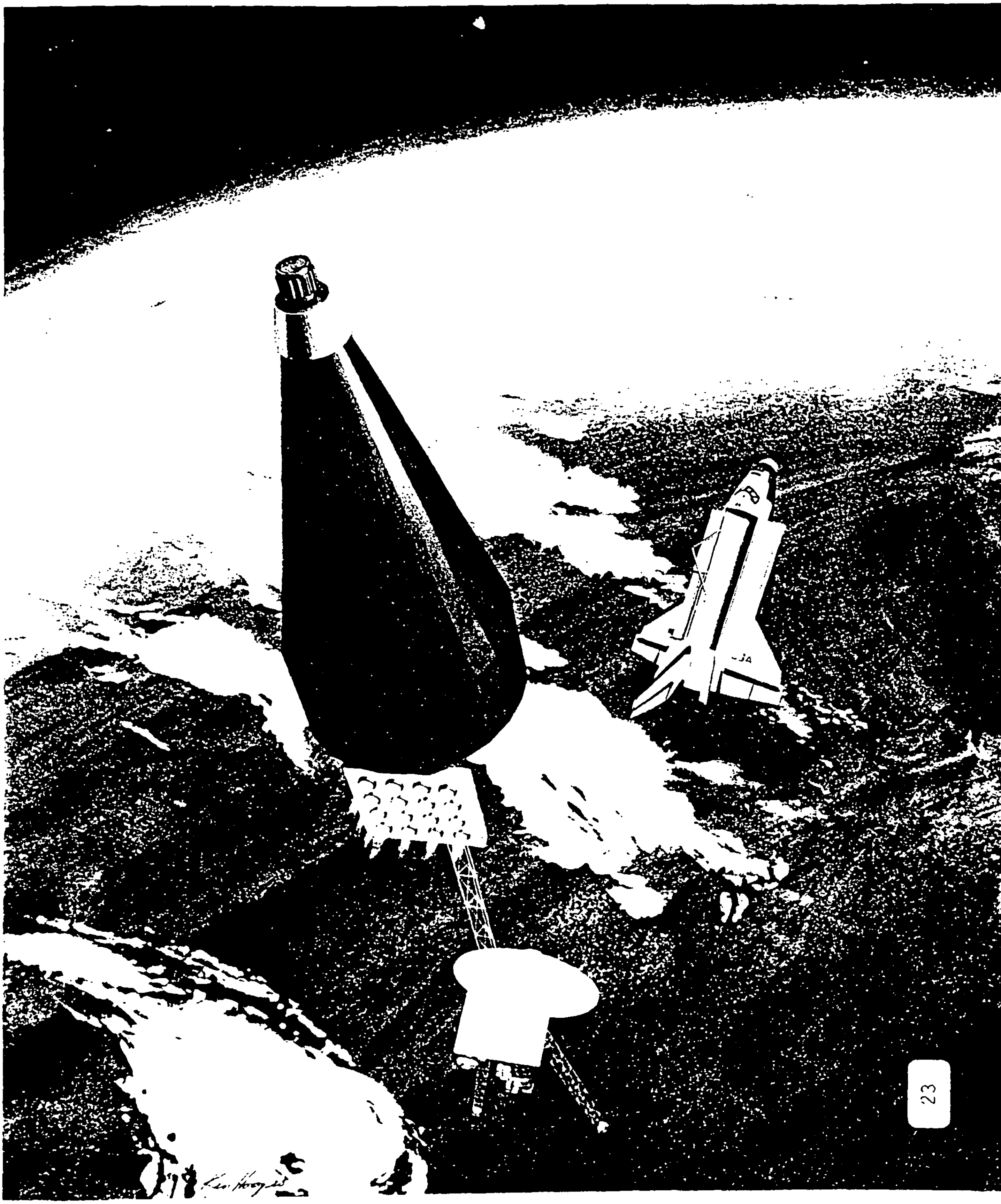

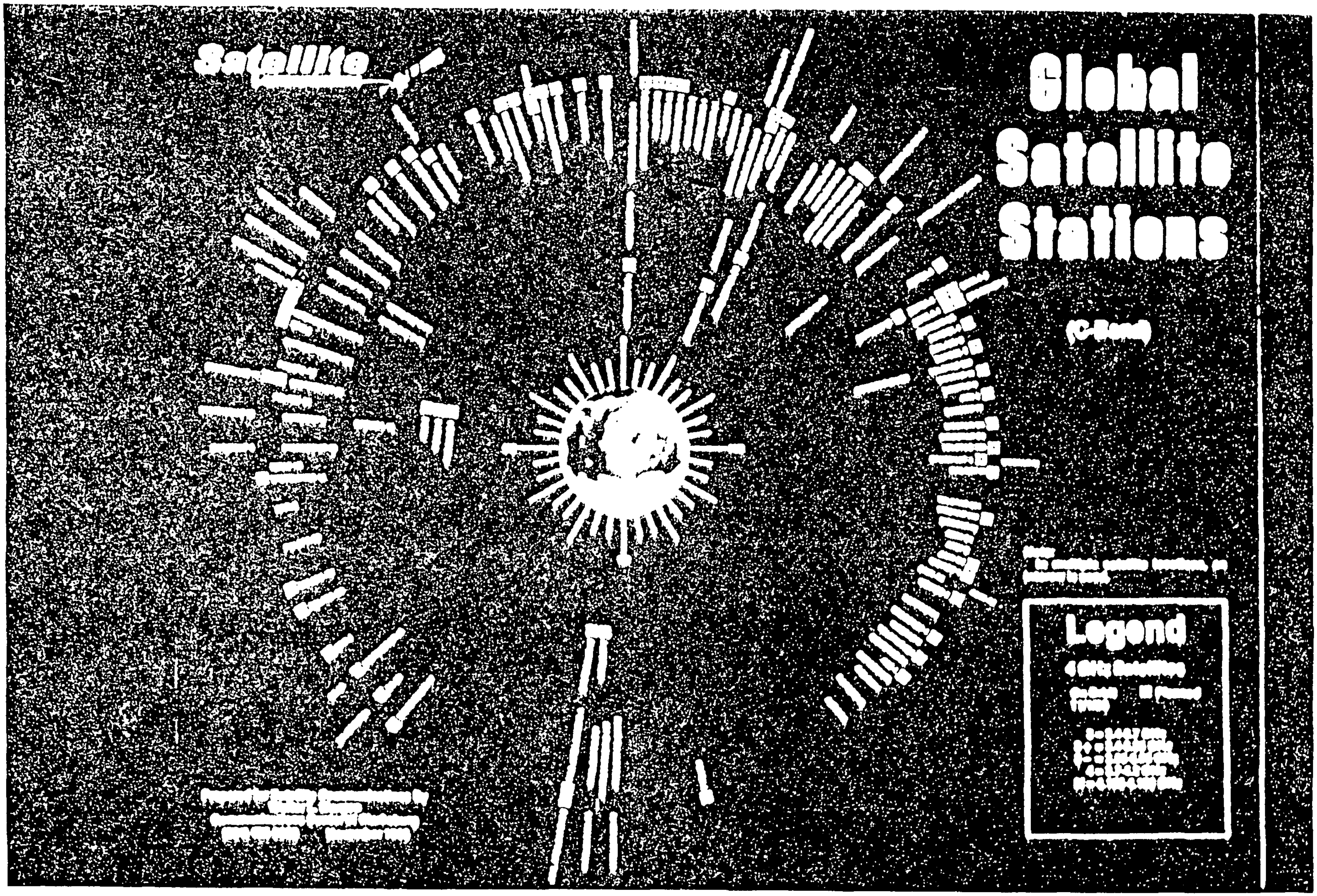
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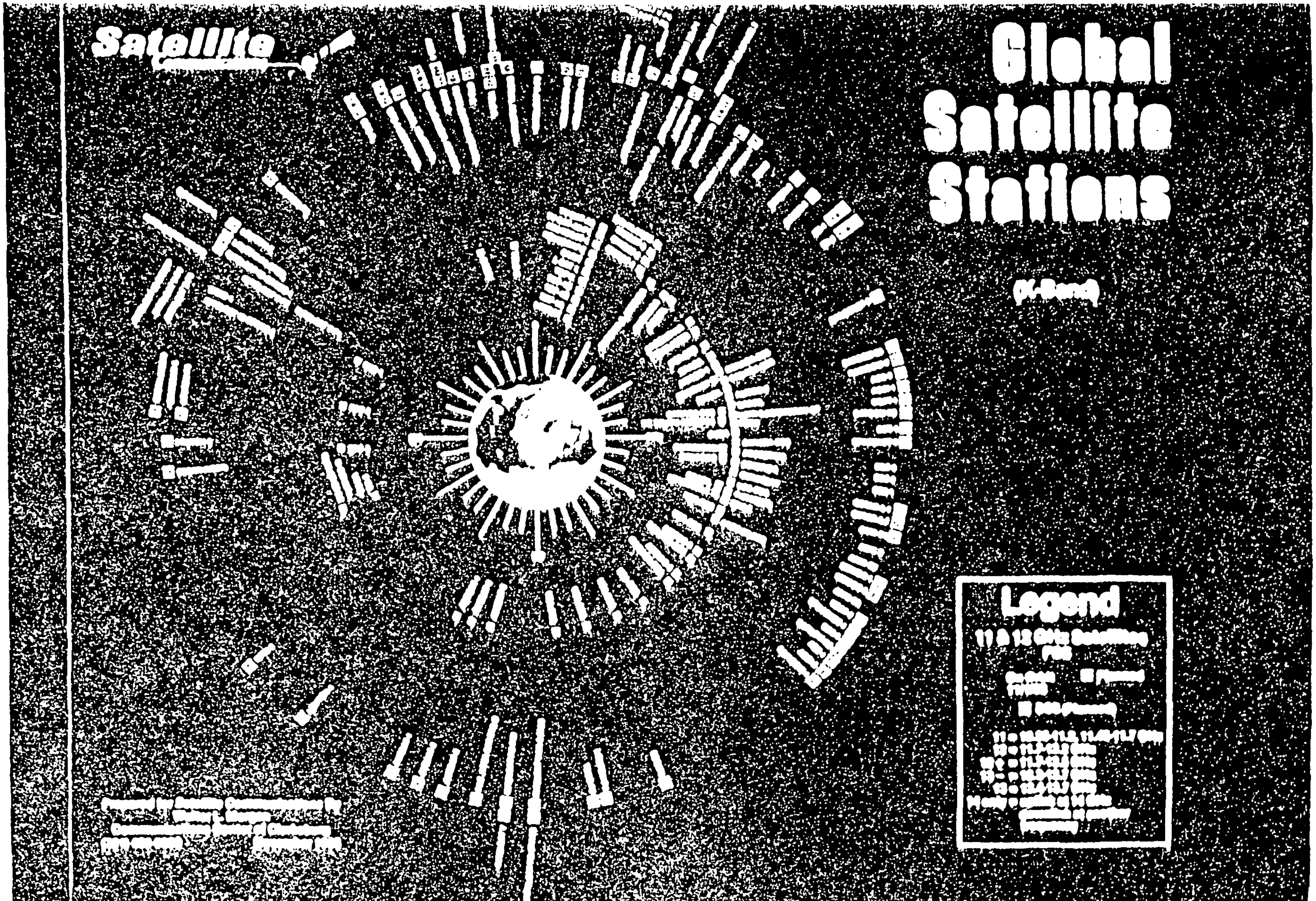

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