Dr. Homer E. Newell

PAYLOAD IMPACT OF SPACE SHUTTLE AND TUG*

SLIDE 380 (LEFT)

So far today Mr. Myers has given us an overview of the Space Transportation System program, and two contractors have discussed their plans for the Space Shuttle Phase B studies. We will now discuss the payload impact of the space shuttle and tug. The payloads, of course, are the cargo, hence the reason for the existence, of space transportation systems. Man has many things to accomplish in space. He wants to investigate, experiment, expand his knowledge and utilize space in many practical ways for the benefit of all. These motivations generate the payloads that the space shuttle and tug are to transport.

EXCHANGE FOX

SLIDE 378 (LEFT) SLIDE 379 (RIGHT)

Over the years the many and varied space objectives have required spacecraft of a large variety of sizes and shapes. Some of these are shown in this montage. On the left, displayed chronologically from left to right, are representative spacecraft of the late 50's and the decade of the 60's. The ECHO

*Presented by Dr. Homer E. Newell, Associate Administrator, NASA, at the ELDO/Space Shuttle Briefing in Bonn, Germany, 7-8 July 1970.

balloon toward the left was an early elementary experiment in space communications. Radio signals were reflected from it and thereby relayed from one point on Earth to another. Today, the INTELSAT satellites are operational in synchronous equatorial orbits, linking many countries of the globe. Toward the right we have the ORBITING ASTRONOMICAL OBSERVATORY which astronomers use to study the heavens free of the filter of our atmosphere. In the picture on the right, again displayed in chronological order from left to right, are spacecraft of the 70's. Many of these are still in the conceptual stage, and it is appropriate, indeed, important to ask: What are the effects of the space shuttle and space tug on these spacecraft? In developing an answer, let us first consider how spacecraft have been launched in the past, then examine a few spacecraft in more detail, and finally explore the new approaches that are opening up to us.

<u>SLIDE 390 (LEFT) (RIGHT OFF)</u>

This is a picture of the ORBITING ASTRONOMICAL OBSERVATORY being launched by the two-stage ATLAS CENTAUR launch vehicle.

ATLAS CENTAUR is an expendable launch vehicle, which costs on the order of 15 million dollars. Each ATLAS CENTAUR can be used only once.

SLIDE 70-390 (LEFT) SLIDE 502 (RIGHT)

Here we have a sketch showing an INTELSAT III spacecraft attached to the top of a Delta launch vehicle and encapsulated in a nose fairing that protects it during the ascent through the atmosphere. The nose fairing is discarded at an altitude of about 100 kilometers. INTELSAT III is an example of a spacecraft with no parts that are extended in space. Other spacecraft have appendages that are extended or unfolded after they are in orbit. At launch all such extensions must be constrained within the nose fairing both because of space limitations and also to withstand the launch accelerations of about 6g. This type of launch vehicle now costs around 5 million dollars.

SLIDE 381 (LEFT) (RIGHT OFF)

Now let us look at some examples of current spacecraft in greater detail. The first three examples have been under study at the Goddard Space Flight Center to determine how they might best operate with the shuttle and tug. They are the ORBITING

ASTRONOMICAL OBSERVATORY, the APPLICATIONS TECHNOLOGY SATELLITE, and the TIROS OPERATIONAL SATELLITE. These were chosen for study because they represent three markedly different types of spacecraft: a scientific observatory in relatively low earth orbit, a technology satellite in synchronous equatorial orbit, and an operational applications satellite in nearly polar orbit. A last example, the RADIO ASTRONOMY EXPLORER, has some features of particular interest in considering operation with the space shuttle.

SLIDE 381 (LEFT) SLIDE 307 (RIGHT)

This is the ORBITING ASTRONOMICAL OBSERVATORY which has been operational for about 18 months in a 720 kilometer circular orbit. Its design life was one year. Its principal experiments are those of the Smithsonian Astronomical Observatory to make an ultraviolet survey of the sky, and the University of Wisconsin to make special ultraviolet observations of selected celestial objects. Features of particular interest to us today are the large solar paddles that were folded against the sides of the spacecraft during launch and deployed in orbit, and also the two other extensions shown in this picture which are balance booms with weights on the ends. At launch, these extensions were confined to a 3 meter diameter.

SLIDE 381 (LEFT) SLIDE 478 (RIGHT)

This is a concept of satellites F and G of the APPLICATIONS TECHNOLOGY SATELLITE series which is designed to investigate and flight test technology common to a number of satellite applications. F is scheduled to be launched in 1973 and G in 1975. They will operate in synchronous equatorial orbit. The parabolic reflector is 9 meters in diameter and the extended solar panels are 15 meters from tip to tip. At launch the spacecraft fits within a 3 meter diameter. The parabolic reflector is composed of individual petals. For launching these petals rotate and curl around the truss structure. At deployment a hoop cable is separated by a cable cutter and the petals are unfurled by spring action. These satellites will have a 3-axis stabilization system. The parabolic antenna points at Earth and the cylinder at the end of the truss structure contains experiments in addition to feeds for C, S, and L-Bands.

SLIDE 381 (LEFT) SLIDE 69-390 (RIGHT)

TIROS M is a NASA meteorological satellite launched in January 1969. When its experiments were completed it was turned over to the Environmental Science Services Administration as an operational satellite. When it became part of the National

Operational Meteorological Satellite System it was renamed IMPROVED TIROS OPERATIONAL SATELLITE 1. It was launched by a Delta vehicle within a 1.5 meter diameter nose fairing. The three solar panels were unfolded in orbit. The satellite is operating in a 1500 kilometer circular polar orbit.

SLIDE 381 (LEFT) SLIDE 500 (RIGHT)

The RADIO ASTRONOMY EXPLORER has some very interesting features. It was launched by a Delta launch vehicle and was constrained to a diameter of less than 1.5 meters. However, when in orbit it extended antenna arms that are about 225 meters in length. The overall extent of this satellite in orbit is about 450 meters. The antennas form a giant orbiting "X" that intercepts radio signals from the galaxy that would be attenuated or completely absorbed by the Earth's atmosphere. Measurements of these signals are then relayed on a different frequency to receiving stations on Earth. The antenna arms are tubes of beryllium that are stored flat in a coil until deployed in orbit. As the ribbon of metal is fed out it curls itself into a fairly rigid tube about 60 millimeters in diameter. It operates very much like flexible steel rules familiar to most everyone. This satellite is of particular interest in regard to shuttle operations because the shuttle permits one to recover satellites and use them again. But how does one get a 450 meter long satellite back in the shuttle? In this case it's easy. Putting the motors in reverse, the beryllium ribbons are wound back into the satellite for the trip back to Earth. This feature was designed into the satellite because it was not certain that the array would remain rigid and stable in orbit. The antennas were fed out in small increments and the effect on the stability of the satellite was noted. If it had been found that the satellite was becoming unstable, the reversing feature on the motors would have permitted pulling the ribbons back in again. For shuttle operations, such features would be included to facilitate recovery of the satellite into the shuttle for return to Earth.

An important point to emphasize from these examples is that spacecraft must have certain characteristics in order to do their jobs. In the future such characteristics would be designed into the spacecraft in such a way as to permit taking advantage of the shuttle's ability not only to launch, but also to revisit and recover orbiting spacecraft.

The cost of these spacecraft programs is always a matter of management concern. Using the expendable vehicles for launching, the costs are quite sizeable. The ORBITING ASTRONOMICAL OBSERVATORY program including a total of four spacecraft costs about 360 million dollars. The first five APPLICATIONS TECHNOLOGY SATELLITES cost a little under 150 million dollars. One IMPROVED TIROS OPERATIONAL SATELLITE (TIROS M) costs about 20 million dollars. The RADIO ASTRONOMY EXPLORER program, including two spacecraft, will cost a little over 20 million dollars, about 5 million dollars of which will cover extra costs involved in placing the second satellite in a lunar orbit. It is expected that use of the shuttle for launching will permit substantial reductions in payload costs for reasons we will now explore.

SLIDE 382 (LEFT) (RIGHT OFF)

Now that we have reviewed some current spacecraft and present launch practices, let us consider the impact of the space shuttle and tug on payload design, use, and cost. In the past we have had essentially one basic mode of placing payloads in space: expendable spacecraft flown on expendable launch vehicles. The introduction of the space shuttle will open three new mission modes to the experimenter. First, the shuttle will provide economical transportation of experiments to a space station. ELDO was given a briefing on the space station program last month, so we will not dwell on this. Secondly, the shuttle operating in the sortie mode will provide an opportunity for short duration experiments requiring up to two weeks in orbit. The advantages of the sortie mode include short lead times and manned operation. Thirdly, the shuttle can serve as a launch vehicle to place various spacecraft in orbit, some of which will contain additional stages for propulsion into special orbits or deep space trajectories.

This is probably a good place to explain the function of the space tug. The shuttle will be designed to fly to a space station in a 500 kilometer circular orbit inclined at an angle of 55 degrees, and also to fly to other altitudes and inclinations. Experimenters, however, want to place spacecraft in a wide variety of orbits, some of which will be beyond the capability of the shuttle and some spacecraft will be designed to escape the Earth entirely. The space tug is conceived as a reusable stage operating from low Earth orbit. Some spacecraft will be carried to low Earth orbit by the shuttle and then carried on to their desired orbit or trajectory by the tug. The space tug will be discussed in more detail by Mr. Culbertson tomorrow afternoon.

SLIDE 1112 (LEFT) (RIGHT OFF)

Returning for a moment to the space shuttle operating in the sortie mode, we think of this as being much like our operations in the Convair 990 aircraft. It takes off about once a month with a load of experiments that can be conducted during a flight, and when it returns the data are immediately available and either the same experiments are replenished with film or tape, or new experiments are introduced.

SLIDE 1112 (LEFT) SLIDE 505 (RIGHT)

Here we see men operating the experiments in the aircraft during a 1968 expedition investigating the Aurora Borealis. The presence of men can significantly reduce the complexity, cost, and lead times associated with short duration experiments. The 990 aircraft has also been used to chase eclipses of the sun in order to extend experiment time over what would be available at one point on Earth. It has been used for photographic missions in support of the Earth Resources Survey Program.

SLIDE 383 (LEFT) SLIDE 505 (RIGHT)

Operating in the sortie mode the space shuttle is expected to provide one to two weeks on orbit, a shirtsleeve environment, short lead times and quick reaction to special opportunities. Manned operation should permit simplicity, economy, and on-orbit repair; and the ability to take advantage of unexpected opportunities. We will be able to return photographic and other data to Earth at the end of the flight.

SLIDE 383 (LEFT) SLIDE 506 (RIGHT)

Finally, in the sortie mode the space shuttle will permit extended environmental tests in zero g. Here we see an artist's conception of a zero-g test of a mirror for an ORBITING ASTRONOMICAL OBSERVATORY or LARGE SPACE TELESCOPE type spacecraft while attached to the shuttle. In the one-g environment on Earth it is not possible to align space optical systems in the environment in which they are to operate. We have conducted zero-g experiments in drop towers for periods of about six seconds and in aircraft for a substantial part of a minute. Zero-g tests played an important part in the investigation of the Apollo 13 failure. Experiments in a drop tower gave us the burning rate of Teflon in an oxygen atmosphere under zero g. Other short duration zero-g experiments have investigated propellant behavior in tanks and the operation of electronic devices such as semi-conductors that are subject to failure in space due to particles of contamination floating up against active elements.

SLIDE 384 (LEFT) (RIGHT OFF)

The third new mission mode that we mentioned earlier is the launch of fairly conventional spacecraft by the space shuttle and tug. The main features of this mode are economical transportation, a low-g launch environment of about 3g rather than on the order of 6g with unmanned vehicles, or considerably higher if solid rockets are used, and an opportunity to recover spacecraft and use them again. This will be most important for the more expensive spacecraft. With the shuttle we will be able to return photographic and other data, repair, refurbish and resupply experiments, and either update or replace experiments.

It has been our experience that launch vehicles sometimes fail and when they do the spacecraft is lost. The space shuttle will be designed for intact abort. If the shuttle must abort its mission it will return to Earth with its cargo intact; it will not be required to jettison its cargo. Finally, the shuttle will have a large payload capability, both in terms of more weight (11,000 kilograms), and volume (a cargo bay 4.5 meters in diameter and more than 18 meters long).

SLIDE 384 (LEFT) SLIDE 385 (RIGHT)

We will look in more detail at a few of these shuttle features and discuss some of the design considerations involved in realizing the potential advantages. You should regard these thoughts as a check list of items we are considering in our studies; we do not have at this time preferred design approaches for spacecraft which will be flown on the shuttle.

If spacecraft are to be recovered and reused we will, of course, require a reusable style of construction. The extensions from the spacecraft such as paddles, booms and antennas must be retractable or, if possible, it would be better to avoid such design features. If they are necessary, you will recall that the RADIO ASTRONOMY EXPLORER shows how even very large structures can be both extended and retracted. Spacecraft that are 3-axis stabilized would be easiest to recover. Spin stabilized spacecraft will probably have to be despun by some means. Several methods of changing spin rates are currently in use. An unstable spacecraft that is perhaps tumbling will also require special consideration for capture and recovering.

SLIDE 384 (LEFT) SLIDE 386 (RIGHT)

To benefit from the repair and refurbishment possibilities offered by the space shuttle we may want to design spacecraft inside out, or by some other means make its components accessible. A modularized type of construction would facilitate replacement of faulty units by an astronaut. Diagnostic routines can be operated either in orbit or from Earth, as is the current practice. Depending upon the complexity and cost of the failed components, we may use a one trip mode of repair in which a replacement unit is flown up, or a two trip mode in which a module is returned to Earth for repair.

SLIDE 384 (LEFT) SLIDE 387 (RIGHT)

A most attractive feature of the space shuttle is the opportunity it affords to design spacecraft for minimum cost. Very large amounts of money have been spent on microminaturization, weight reduction, and highly sophisticated automation techniques. Considerable savings should be made by expanding spacecraft into the generous space and weight capability of the shuttle, and by utilizing the crew to reduce spacecraft complexity. To realize these benefits, discipline will be required. Experimenters will want to utilize the added capability for additional experiments and designers will still want to produce the finest possible design. To save money on spacecraft flown on the shuttle, the spacecraft must be kept simple and possibly even crude. We must keep our sights on the experimental results desired and not an advanced sophisticated design for its own sake if we are to actually realize the possible savings. Alternatively, the additional weight and volume capability of the shuttle could be used to greatly increase the amount of experimentation and data return from a spacecraft by continuing to use the more costly micro-miniaturization techniques. The important point is that we will have the choice of either reducing cost or increasing data return, a most valuable flexibility.

<u>SLIDE 384 (LEFT) SLIDE 388 (RIGHT)</u>

A few additional benefits of the space shuttle and tug are worth noting. Recovery of hard data including photographs can be a very significant improvement over limitations of electronic data transmission. We will be able to resupply spacecraft as required with propellants, batteries, control gases, photographic film, and recording tapes. We will be able to update or recalibrate experiments or install new ones.

<u>SLIDE 501 (LEFT) SLIDE 1087 (RIGHT)</u>

With all of the foregoing in mind, we can picture for ourselves a variety of future spacecraft operations using the shuttle. Here, for example, are artists' conceptions of two spacecraft designed for operation with the space shuttle. On the left is pictured a shuttle-launched ORBITING ASTRONOMICAL

OBSERVATORY or LARGE SPACE TELESCOPE. On the right is a concept of a HIGH ENERGY ASTRONOMICAL OBSERVATORY shown operating in conjunction with the space station. These approaches are in early stages of investigation, detailed designs have not been completed, but the advantages of using the shuttle to launch, service, or recover such spacecraft will be those we have discussed.

<u>SLIDE 389 (LEFT) (RIGHT OFF)</u>

In summary, the space shuttle and tug offer many advantages for space operations:

- economical transportation to a space station and operations in orbit.
- frequent sorties, with flexible scheduling, for experiment missions.
- an economical and flexible replacement for conventional launchers.

These advantages include many potential benefits for payload design, construction, and use. To secure and maximize these benefits, we must define mission requirements carefully and exercise discipline in designing payloads. This can be done, and we are vigorously studying how best to use the new opportunities afforded by the shuttle. We invite you to do the same.

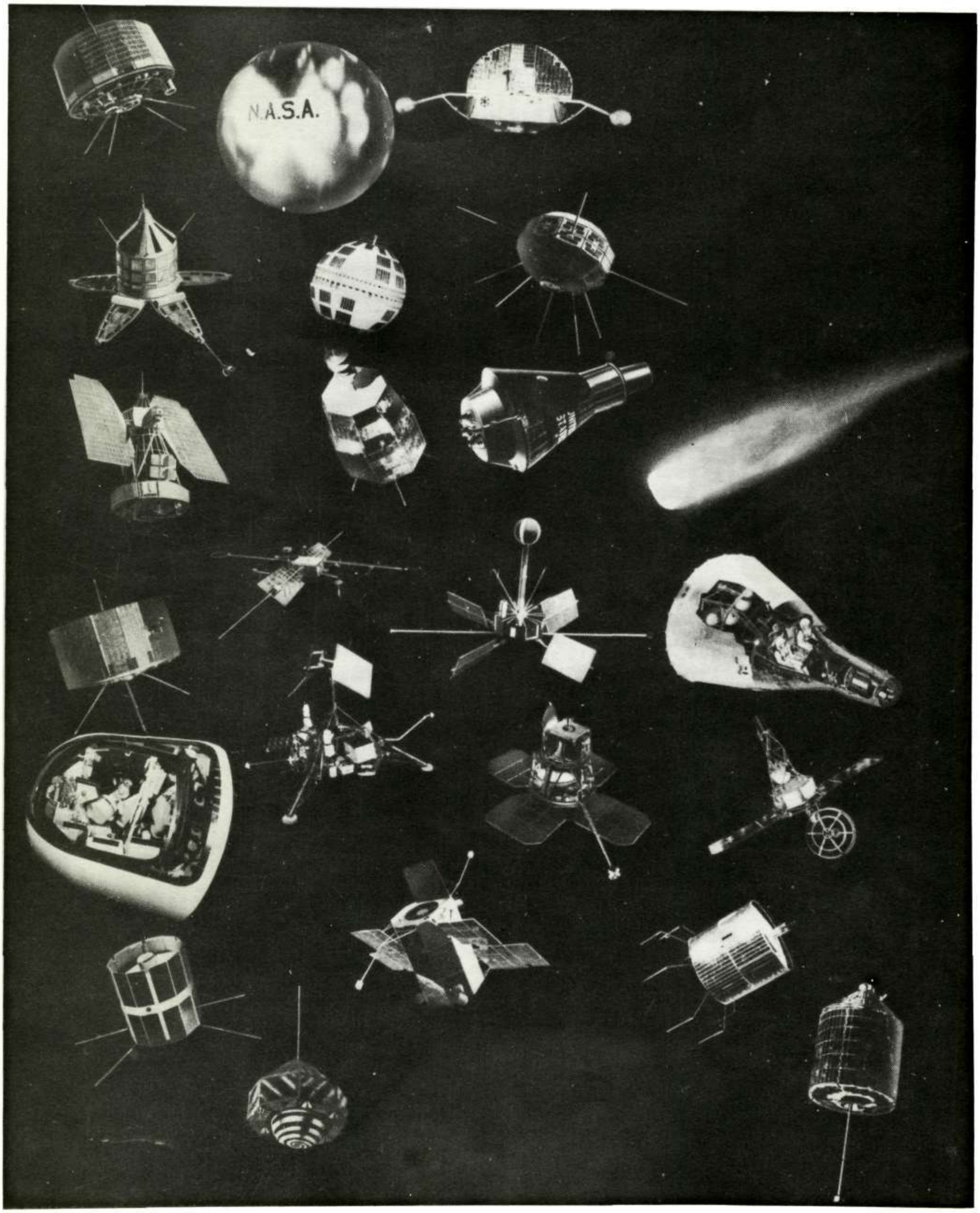
ORDER OF GRAPHICS

NUMBER	TITLE
380	PAYLOAD IMPACT OF SPACE SHUTTLE AND TUG
378	MONTAGE OF SPACECRAFT
379	MONTAGE OF SPACECRAFT
70-390	CONVENTIONAL LAUNCH VEHICLE
502	PAYLOAD ON LAUNCH VEHICLE
381	EXAMPLES OF CURRENT SPACECRAFT
307	ORBITING ASTRONOMICAL OBSERVATORY
478	APPLICATIONS TECHNOLOGY SATELLITES
69-390	TIROS M
500	RADIO ASTRONOMY EXPLORER
382	SPACE SHUTTLE PROVIDES THREE NEW MISSION MODES
1112	NASA CONVAIR 990
505	EXPERIMENTS IN CONVAIR 990
383	SPACE SHUTTLE IN SORTIE MODE
506	ZERO-G MIRROR TEST
384	SPACECRAFT LAUNCHED BY SHUTTLE/TUG
385	RECOVERY OF SPACECRAFT
386	REPAIR/REFURBISHMENT OF SPACECRAFT
387	DESIGN FOR MINIMUM COST
388	ADDITIONAL SHUTTLE/TUG ADVANTAGES
501	OAO/LST TYPE SPACECRAFT
1087	POSSIBLE HEAD USE OF SPACE STATION AND SHUTTLE
389	SUMMARY

PAYLOAD IMPACT

OF

SPACE SHUTTLE AND TUG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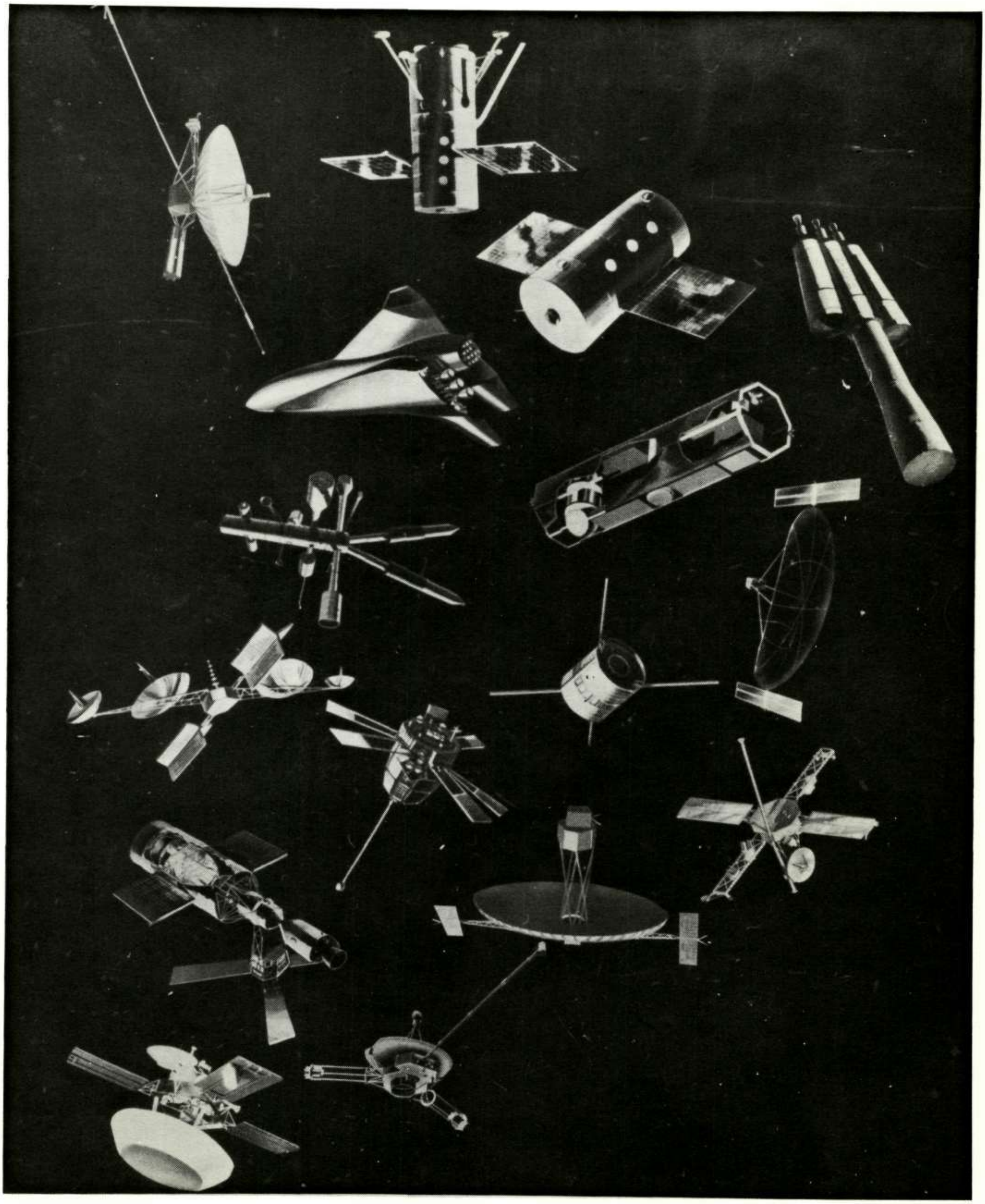
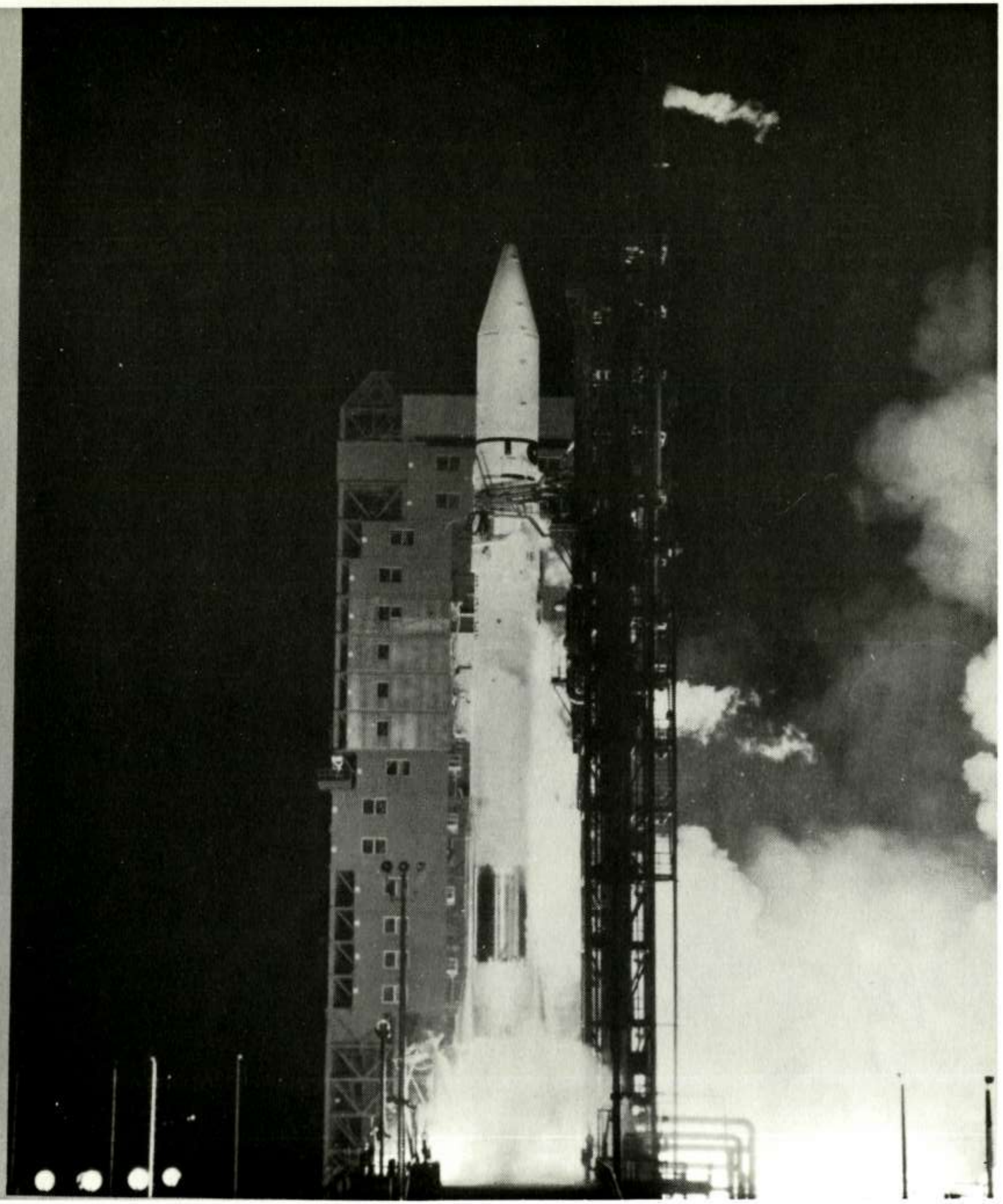
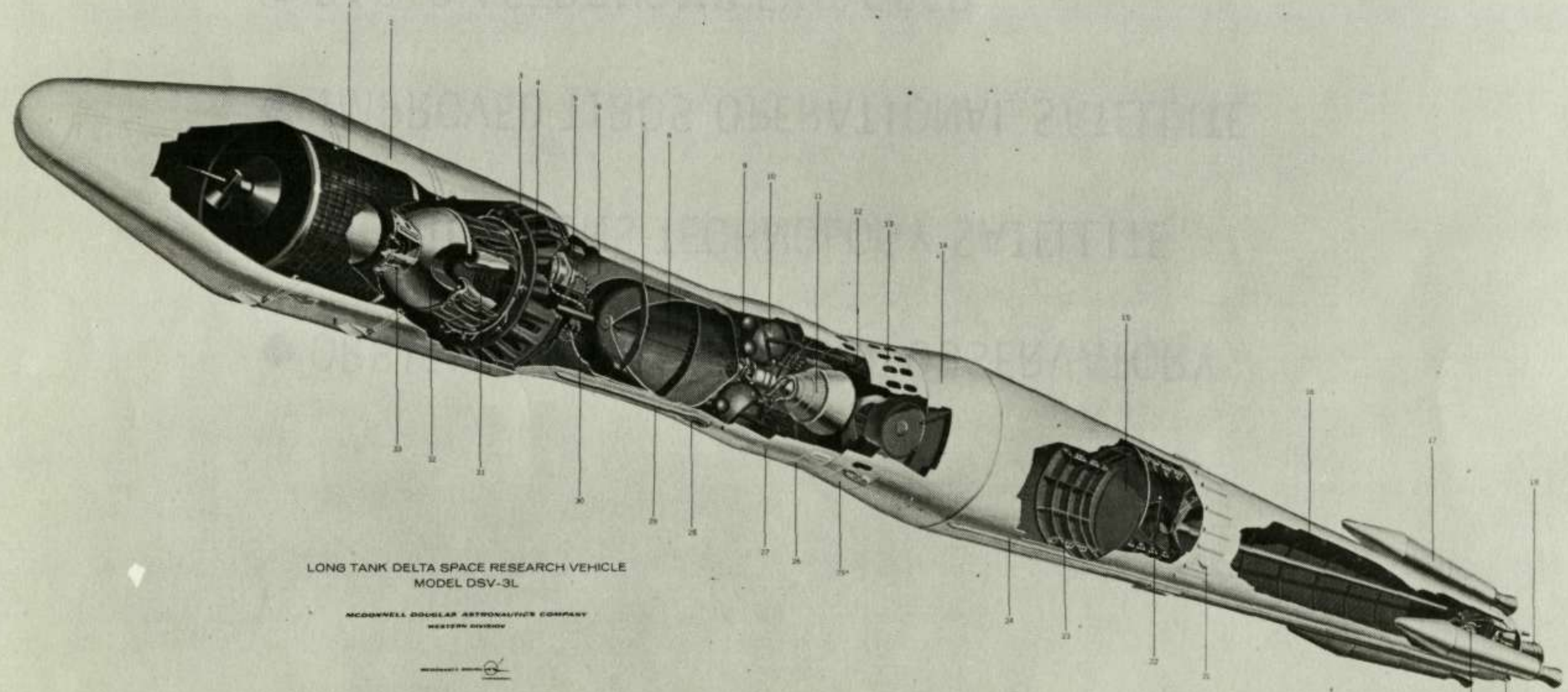


CONVENTIONAL LAUNCH VEHICLE



NASA SV70-390
6-24-70

PAYLOAD ON LAUNCH VEHICLE



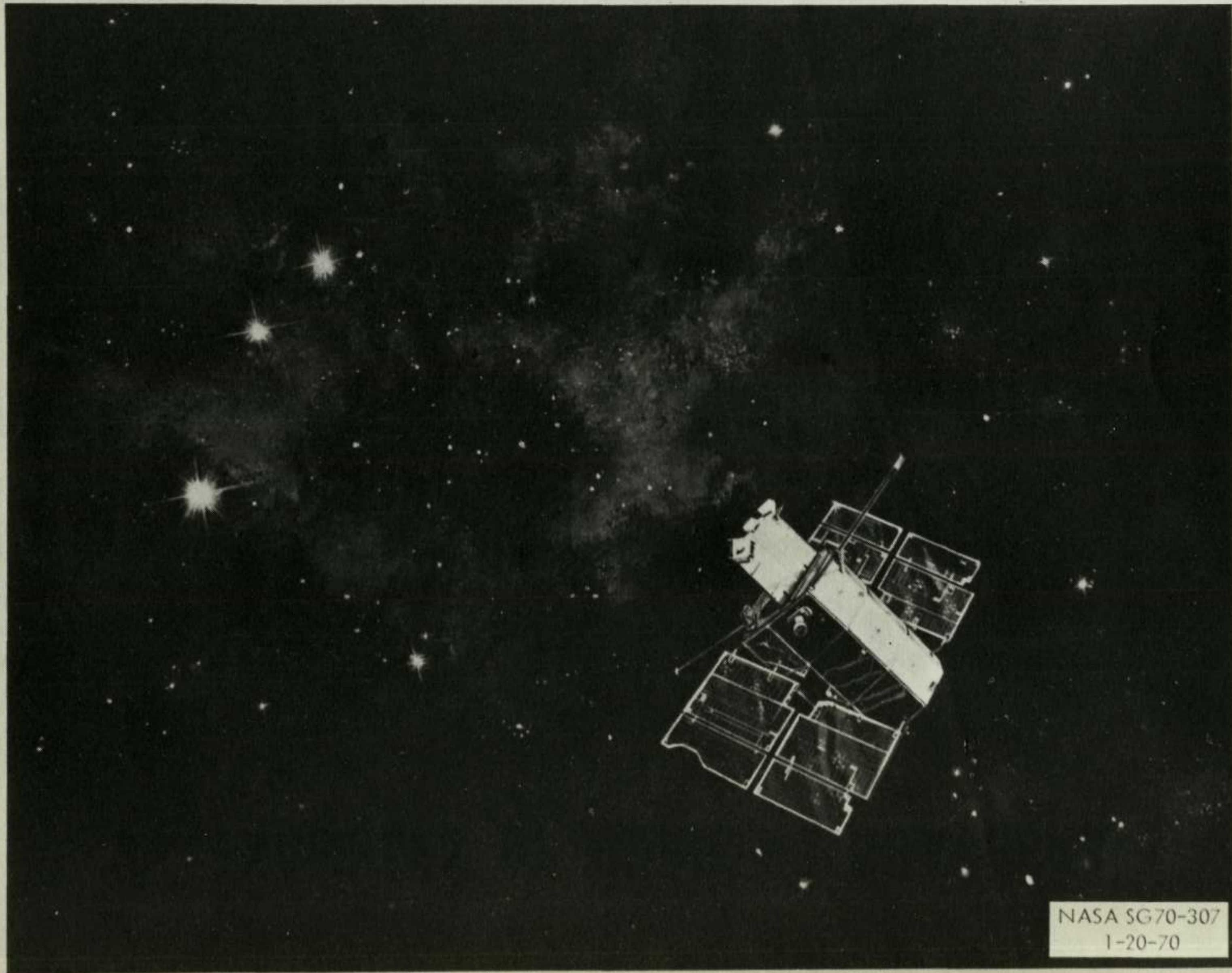
NASA SV70-502 (3)
6-30-70

EXAMPLES OF CURRENT SPACECRAFT

- ORBITING ASTRONOMICAL OBSERVATORY
- APPLICATIONS TECHNOLOGY SATELLITE
- IMPROVED TIROS OPERATIONAL SATELLITE
- RADIO ASTRONOMY EXPLORER

NASA SV70-381
6-25-70

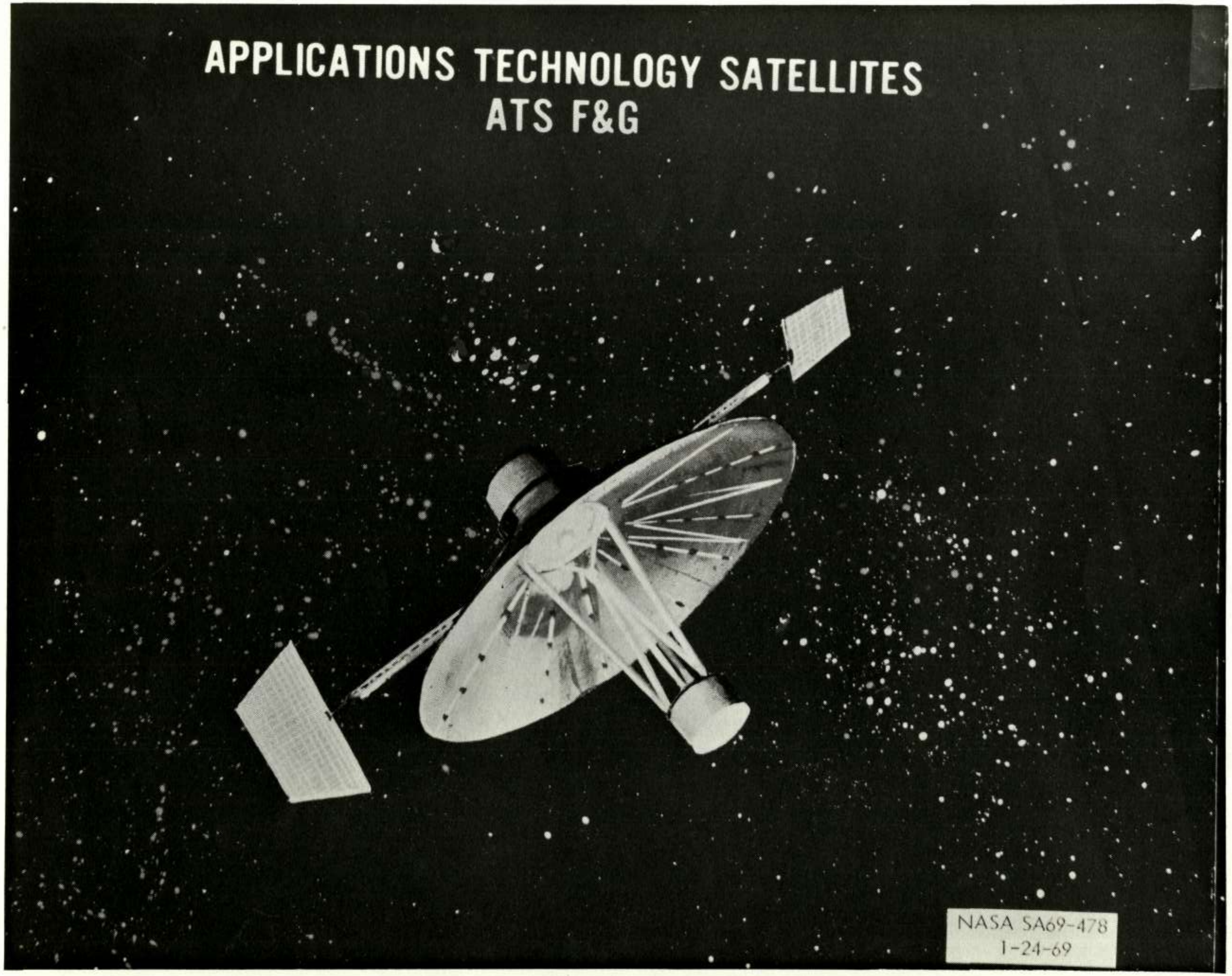
ORBITING ASTRONOMICAL OBSERVATORY

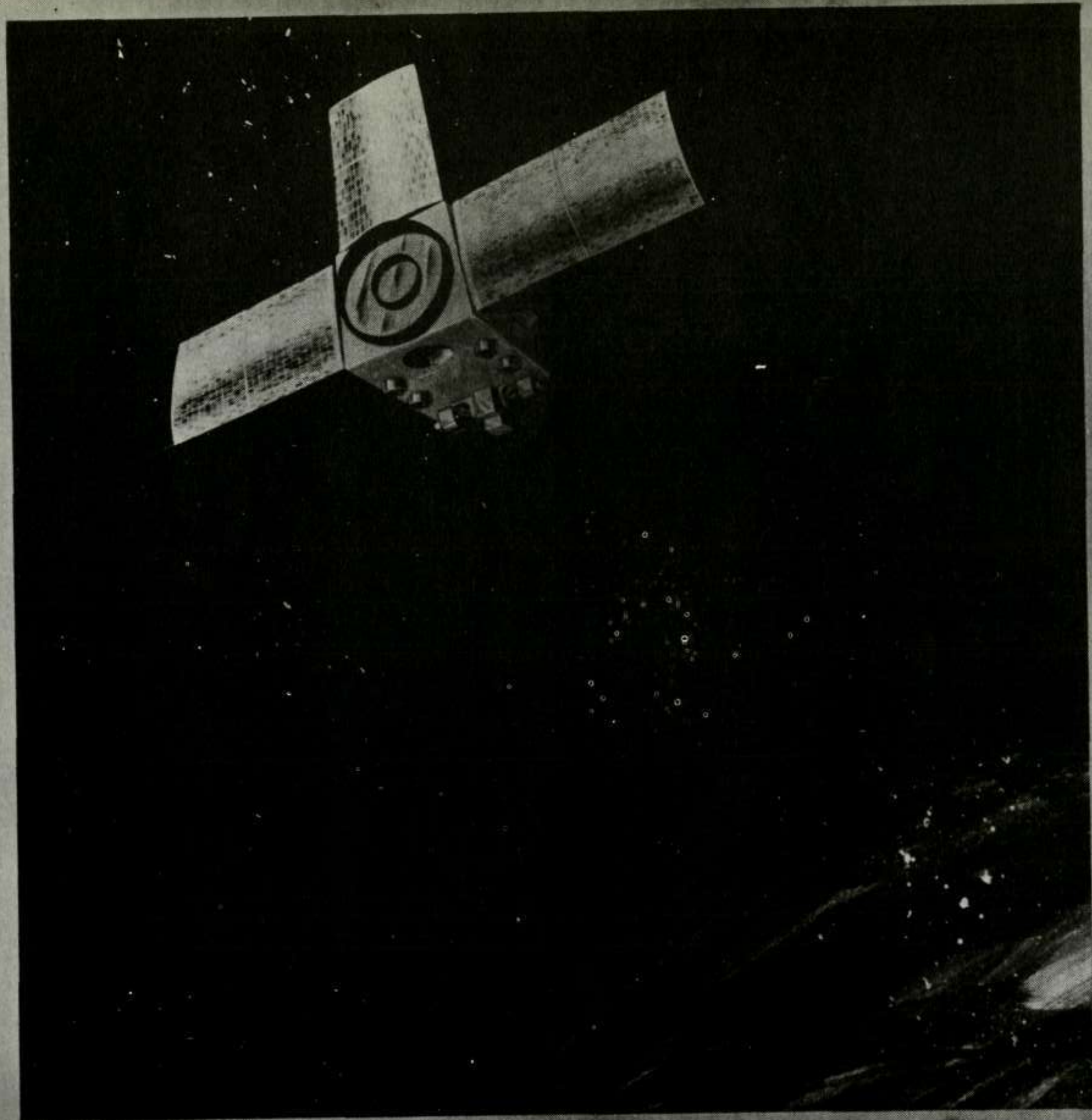


EXAMPLES OF CURRENT SPACECRAFT

- ORBITING ASTRONOMICAL OBSERVATORY
- APPLICATIONS TECHNOLOGY SATELLITE
- IMPROVED TIROS OPERATIONAL SATELLITE
- RADIO ASTRONOMY EXPLORER

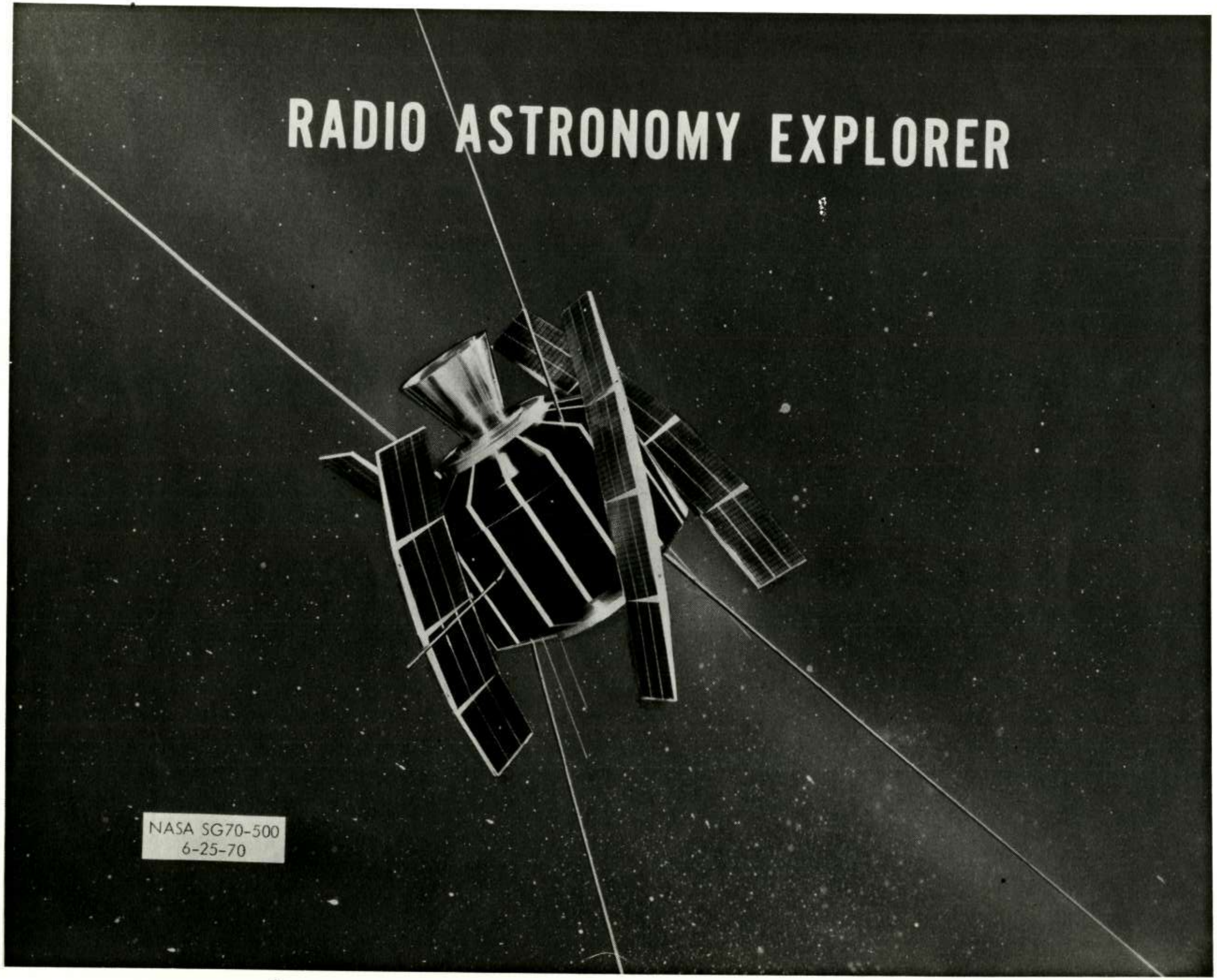
NASA SV70-381
6-25-70


APPLICATIONS TECHNOLOGY SATELLITES
ATS F&G
NASA SA69-478
1-24-69



TIROS M

NASA SA69-390
1-10-69


RADIO ASTRONOMY EXPLORER
NASA SG70-500
6-25-70

SPACE SHUTTLE PROVIDES THREE NEW MISSION MODES

- TRANSPORTATION OF EXPERIMENTS TO SPACE STATION
- EXPERIMENTATION IN SHUTTLE OPERATING IN SORTIE MODE
- LAUNCH AND PLACEMENT OF SPACECRAFT BY SHUTTLE/TUG

NASA SV70-382
6-25-70

NASA CONVAIR 990

NASA SL69-1112
6-30-69

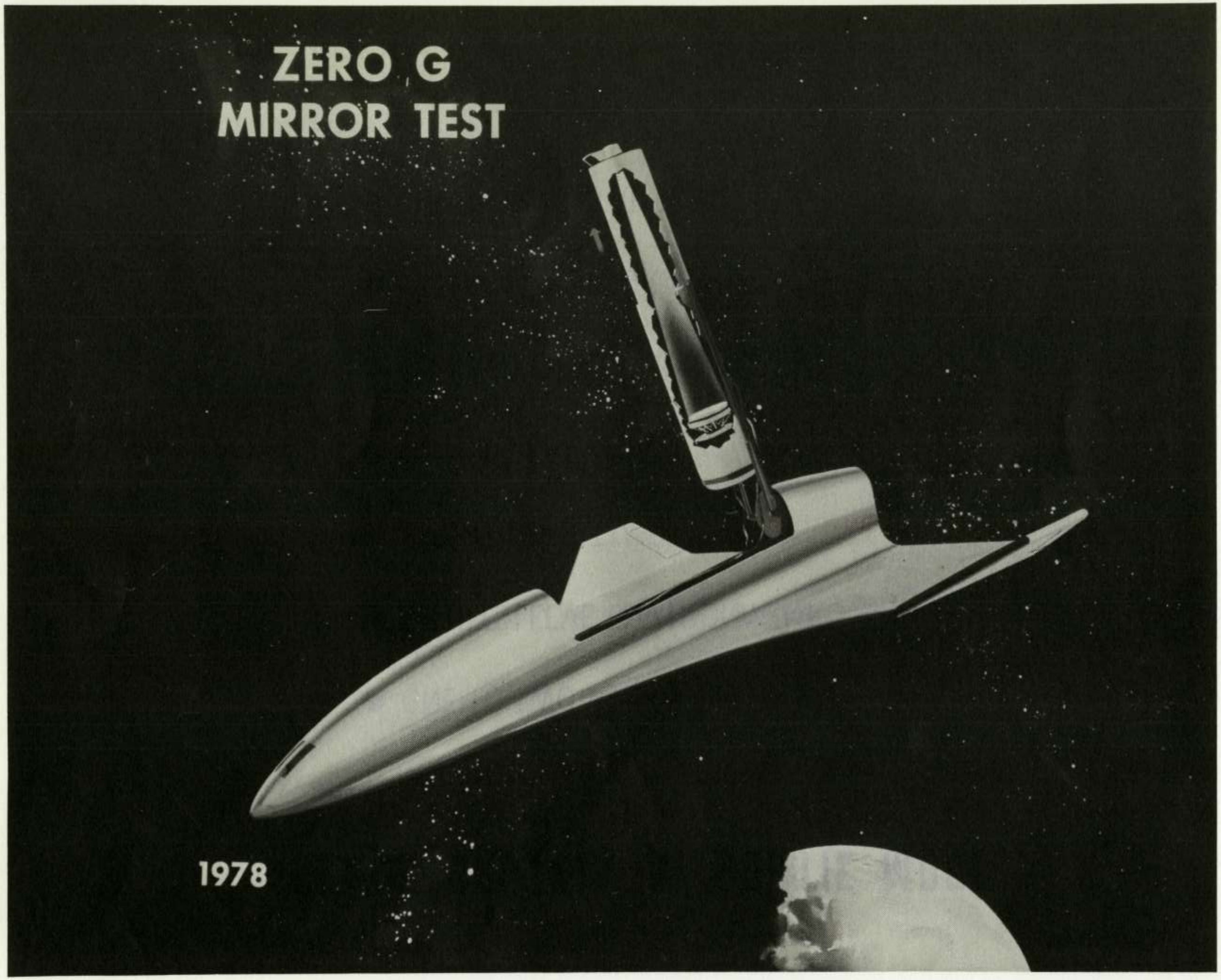
EXPERIMENTS IN 990 AIRCRAFT

NASA SV70-505 (2)
6-30-70

SPACE SHUTTLE IN SORTIE MODE

- ONE TO TWO WEEKS ON ORBIT
- SHIRTSLEEVE ENVIRONMENT
- SHORT LEAD TIMES
- QUICK REACTION
- MANNED OPERATION/REPAIR
- RETURN PHOTOGRAPHIC AND OTHER DATA
- ENVIRONMENTAL TESTS

NASA SV70-383
6-25-70


ZERO G
MIRROR TEST
1978

SPACECRAFT LAUNCHED BY SHUTTLE/TUG

- ECONOMICAL TRANSPORTATION
- LOW G LAUNCH ENVIRONMENT
- SPACECRAFT RECOVERY AND REUSE
- PHOTOGRAPHIC AND OTHER DATA RECOVERY
- REPAIR, REFURBISHMENT, AND RESUPPLY
- UPDATE OR REPLACE EXPERIMENTS
- INTACT ABORT
- LARGE PAYLOAD WEIGHT CAPABILITY
- LARGE PAYLOAD SPACE AVAILABLE

NASA SV70-384
6-24-70

RECOVERY OF SPACECRAFT

- REUSABLE CONSTRUCTION
- RETRACTABLE EXTENSIONS OR NO EXTENSIONS
- 3-AXIS STABILIZATION OR DESPIN
- CAPTURE TECHNIQUE

NASA SV70-385
6-25-70

REPAIR/REFURBISHMENT OF SPACECRAFT

- INSIDE OUT FOR ACCESSIBILITY

- MODULARIZED

- DIAGNOSTIC ROUTINES
  - IN ORBIT
  - FROM EARTH

- ONE TRIP MODE - REPLACE IN ORBIT, OR
- TWO TRIP MODE - REPAIR ON EARTH

NASA SV70-386
6-25-70

DESIGN FOR MINIMUM COST

- EXPAND SPACECRAFT INTO LARGE PAYLOAD BAY
- RELAX WEIGHT CONSTRAINTS
- REDUCE SPACECRAFT COMPLEXITY BY UTILIZING CREW

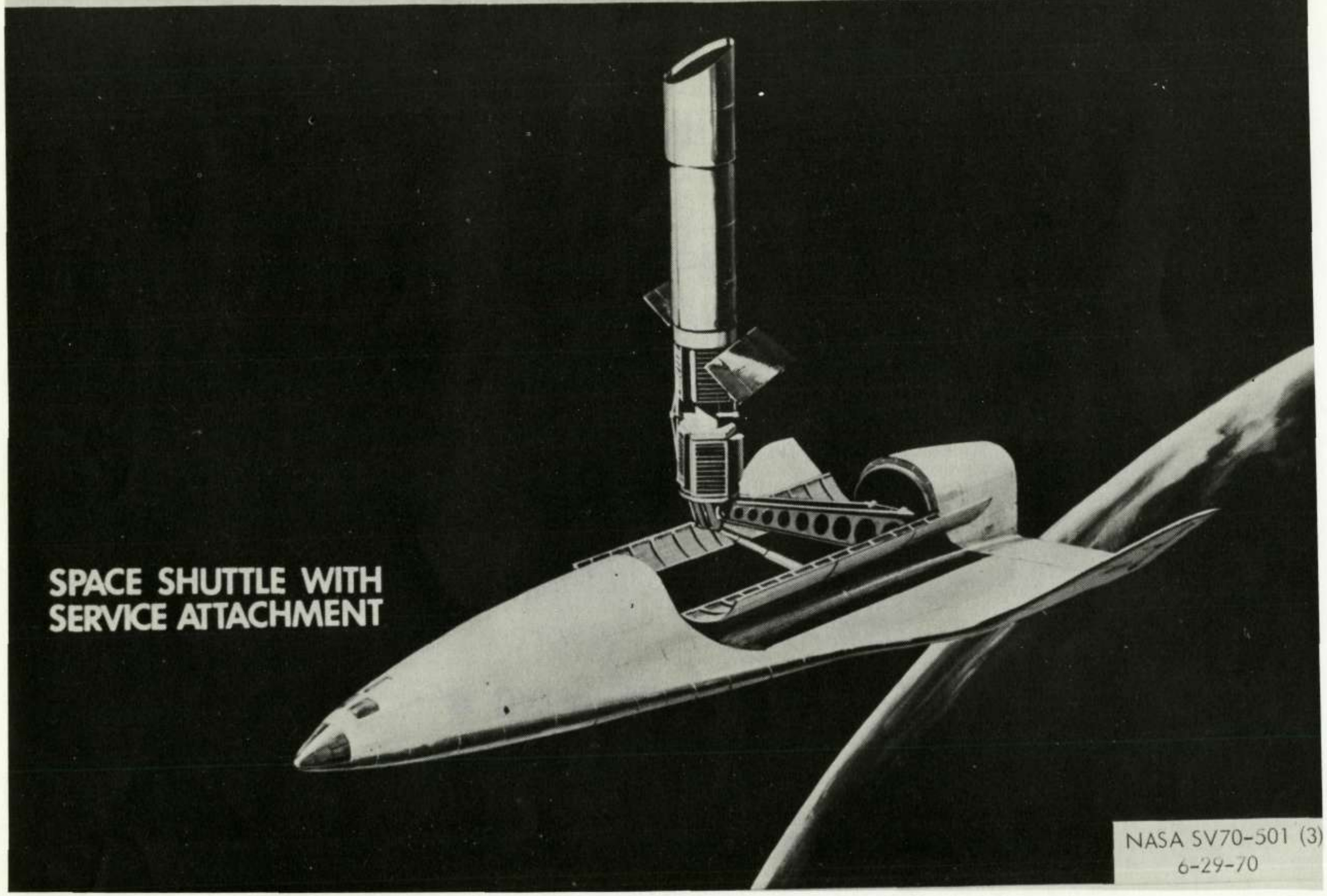
NASA SV70-387
6-25-70

ADDITIONAL SHUTTLE/TUG ADVANTAGES

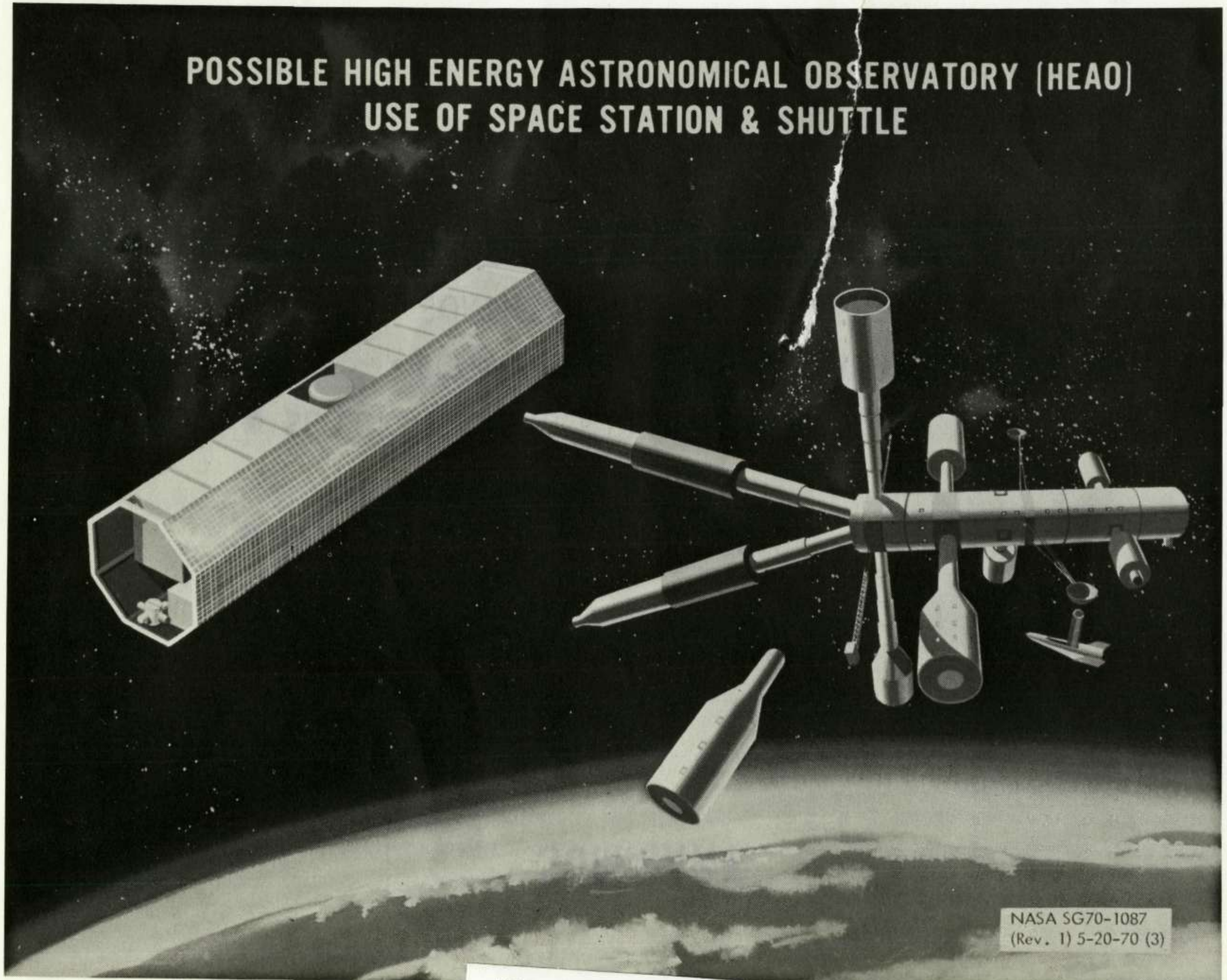
- DATA RECOVERY
- RESUPPLY
  - PROPELLANTS
  - BATTERIES
  - CONTROL GASES
  - FILM
  - TAPE
- EXPERIMENT UPDATE OR RECALIBRATION
- INSTALLATION OF NEW EXPERIMENTS

NASA SV70-388
6-25-70

SHUTTLE LAUNCHED ORBITING ASTRONOMICAL OBSERVATORY/LARGE SPACE TELESCOPE



NASA SV70-501 (3)
6-29-70


POSSIBLE HIGH ENERGY ASTRONOMICAL OBSERVATORY (HEAO)
USE OF SPACE STATION & SHUTTLE
NASA SG70-1087
(Rev. 1) 5-20-70 (3)

SUMMARY

- SHUTTLE/TUG OFFER MANY ADVANTAGES
- DEFINE MISSION REQUIREMENTS
- SELECT APPLICABLE SHUTTLE MODE
  - ECONOMICAL TRANSPORTATION TO SPACE STATION
  - SORTIES FOR SHORT DURATION MISSION
  - SPACECRAFT DESIGNED TO MAXIMIZE BENEFITS