B-7

RESEARCH AND TECHNOLOGY FOR THE FUTURE

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My predecessors have given you a good view of the space program - accomplishments and what the future may bring. Klein has discussed the role of nuclear energy in space propulsion and electric power generation. Von Braun has discussed large launch vehicles and missions. Naugle has shown the exciting things coming or possible in space sciences, lunar exploration, and space applications.

The difference between success and failure of these missions, between reaching and falling short of our objectives, between winning and losing a race with others, lies in our knowledge of the flight sciences and our skill for applying this knowledge to the development and operation of space vehicles. We acquire this knowledge and technology through research where new ideas and processes are conceived, are nurtured by theory and experiment, and are brought to maturity in the form of new equipment or operations. A natural characteristic of technology is its multiapplicability; an improvement in guidance or communication equipment, for example, may find many uses in space missions as well as non-aerospace applications. A key to making this process productive, as measured by the creation of new knowledge and techniques, is a continuing research program, well planned and well supported, that has a good balance between the effort in the scientific and engineering disciplines and in the technologies needed to explore the unknown.

The part of the NASA program that I will discuss is concerned with acquiring new space flight capability through research and technology. The primary goal is to provide a sound technology base for performing new and more useful space missions not possible with today's state-of-the-art. This gives the Nation flexibility in choosing the space systems that are the most suitable and economical for accomplishing these missions. A secondary goal is to assist others in solving development and operating problems of existing systems. In striving for these goals, we are advancing national engineering capability and promoting the wide-spread use of new technology.

In FY 69, the R&D program for research and technology in aeronautics and space is 285 million dollars. Of this, about one third is aeronautics and two thirds space technology. About a third of the research is done in-house, a tenth by universities, and the balance by industry.

Our effort ranges from fundamental to applied research and on to building and testing of prototype equipment for proof of new concepts or the study of complex systems. It is organized into disciplines and subsystems that are used across the board in all space vehicles - structures, propulsion, space power, electronics, for example. However, in describing this work, I will relate it to equipment for accomplishing some of the missions you have heard described.

I will start first with launch vehicles. At present, we have a stable of seven reliable launch vehicles ranging from the all-solid propellant Scout which carries 300 pounds into orbit for a little over a million dollars to the mighty Saturn V which will carry roughly a thousand times more payload than the Scout at a cost that can approach about 200 million dollars. These vehicles drew on the fifty billion dollar missile R&D of the 1950's plus other technology, notably the hydrogen-oxygen rocket technology of the Lewis Research Center, developed during the same period. The launch vehicles, backed by competent teams from government and industry laboratories, have reached or are nearing a stage of perfection and high reliability; they are examples of a national capability of which we can all be very proud. But we who are engaged in research and technology are never satisfied with what is within our grasp - we constantly strive to go beyond this, to improve existing equipment, or to seek entirely new concepts. In the launch vehicle area we are pushed by an urgent problem of another nature - the mounting cost of boosters. The great need for the next generation of boosters is not only to retain the best of the present qualities, such as high reliability, but also to find the means for making booster less expensive to build and operate. This means, for example, simpler launching methods, more economical propulsive energy, recovery and reuse of the more expensive vehicle subsystems, and simpler ground control, tracking and communication. Most importantly, it means that the present costly test and qualification methods must be made significantly more economical. While we can identify these problems, we need to do a good deal more work before we can come up with solutions. One point that comes up almost immediately in speaking of costly boosters is that they are single-use equipment and this leads naturally to the question: why not develop reusable boosters? Unfortunately, the answer is not as simple as the question. We and others have studied expendable versus reusable boosters and find that the technology for reusable boosters is not at hand and that our best estimates of their development and manufacturing costs are very high. This means that their use must be frequent enough to amortize the huge investment required. But this large amount of traffic is not in the forecasts for the next decade and so we are turning to intermediate steps such as a low-cost booster and boosters where the more costly equipment can be placed in the upper stages and recovered.

We are, therefore, focusing a good deal of attention on the concept low-cost single-use boosters and the prime candidate for achieving low cost is the large solid motor. We and the Air Force have made considerable progress in the technology of large solid motors. Figure 1 shows the Large Solid Motor test record through last year. You can see that there is a considerable amount of experience with large motors - nine tests of 156 inch diameter motors and three tests of the 260 inch diameter motors. Figure 2 shows the static test of the 260 inch SL3 solid motor in June 1967. Peak thrust was 5.9 million pounds, a world record of high thrust for a single motor, we believe. Near the end of the firing, however, there was a spectacular display resulting from ejection of burning fragments. This was caused by the improper bonding of batches of propellants during loading and is one of the problems that must be cleared up.

Another problem is lower cost nozzles, insulation, and cases through the use of different materials and techniques. Another problem requiring more attention for achieving lower cost is thrust vector control. We feel that these problems can be solved with one or two more years of technology effort and the firing of another 260 inch solid. Concurrent with this, we are making vehicle design studies and possible missions and these indicate that a vehicle with a earth-orbit payload of about 100,000 pounds is an optimum size for a new booster. This size could be met by using a first stage consisting of either a cluster of 156 inch solids motors or a single 260 inch motor and a modified SIVB as the initial upper stage. We are examining ways that the SIVB could be simplified for this mission as, for example, removal of restart capability. Another way to achieve low booster cost is to have a simpler liquid stage, the so-called "big dumb booster." Comparison of cost estimates for the large solid and liquid booster do not show significant differences and indicate that more research is needed. At the moment, however, the large solid has the edge in terms of technology readiness.

In addition to pushing the technology of chemical boosters to reduce cost, we are also pushing forward to develop the NERVA 75,000 pound thrust engine to increase our booster capability. Klein has amply covered this important aspect of our work, which is carried out jointly with the Atomic Energy Commission, but let me add this observation. A great amount of study, debate and soul searching, both within and outside the agency, has emanated over the issue of development of the NERVA engine. The technology program has been an outstanding success with reactor and breadboard engine systems operating smoothly over a wide range of conditions. Figure 3 is a view of an operation typical of the 509 minutes of accumulated reactor and engine system test time from 1964 to now. The technology is at hand - hard won technology that assures us the opportunity for continued leadership in this field. We believe the Nation should take full advantage of this technology by proceeding with the development of a flight engine. The first logical use of the engine would be for a stage to replace the SIVB of Saturn V.

We are recommending that the NERVA engine and stage be ready as early as 1977 for a possible mission. We are working with other NASA offices in studying planetary and other types of missions that can best take advantage of the unique capability of the NERVA engine.

The two obvious manned flight activities beyond Apollo are earth orbiting laboratories and lunar exploration. I have spoken about the booster for lifting payloads to orbit and beyond; now I want to talk about man's return from earth orbit or lunar exploration. All of us have witnessed the successful parachute sea landings of Mercury, Gemini, and the first Apollo landing October 22. You must be impressed also with the extensive use of recovery forces that these landings involve.

Clearly a simpler recovery method than parachute landing in the sea is necessary for reduced cost of round trips to earth orbit or to the moon. Research has been under way for some time on the concept of steerable parachutes for land landings. Figure 4 shows one type of steerable parachute called the parawing. Over a thousand manned landing tests have been made with a parawing having a keel or centerline length of about 20 feet. The next objective is to investigate materials, fabrication techniques, packaging, deployment, aerodynamics, and structural characteristics of a parawing with a keel of about 100 feet and capable of landing a 15,000 pound spacecraft.

The second recovery method for manned return is the lifting entry concept. Lifting entry vehicles have sufficient lift so that they can glide and maneuver in the atmosphere and land horizontally in the same manner as aircraft. Such vehicles may carry a small propulsion unit for maneuvering for landing. The concept also offers a possible way of recovering the expensive subsystems of a booster such as guidance, controls, power, and rendezvous propulsion. While conceptual configurations have been developed for a range of hypersonic L/D's, one class - the lifting body - is further advanced and is presently undergoing investigation to determine the handling characteristics from supersonic speeds down to landing. Three configurations are in the test program. These are the HL-10, M-2, and X-24A. The M-2 is inactive following an accident on landing. Flight tests are under way on the HL-10, shown by Figure 5, and are highly successful. The X-24A shown by Figure 6 is being readied for tests. Heat shield technology, including research on ablative materials and the effect of ablative gases on heat transfer, constitute ancillary investigations.

Sometime in the future, a lifting body equipped with ablative surfaces may be tested for the entire flight regime from orbit to landing. Even further in the future are completely recoverable vehicles, possible using an air breathing propulsion system for the initial stage. This would be the merging of space transportation needs with hypersonic aircraft. We submit that research towards lower cost space transportation systems is one of the greatest research incentives in the space program.

Let us now turn to spacecraft and their trends, starting with orbital types.

Radio astronomers see, as an ultimate need, an antenna of 20 kilometers diameter for observations between a few hundred MHz and a few hundred KHz. This obviously will require major advances in structures technology. We are working on one concept for a 1.5 Km diameter structure. It uses thin aluminized ribbons arranged in a large open grid with spacing between ribbons of about two feet. The ribbons appear preferable to fine wires to minimize degradation from meteoroid impacts over a long time. The parabolic form is provided by the design of the grid and the supporting structure of wires from the central mast. The shape is maintained by a slow rotation of the antenna about its axis of one revolution ever 16 minutes. Figure 7 illustrates a deployment technique for such an antenna. Initially, as packaged for launching, the entire system would be in a cylinder 18 feet in diameter and 20 feet long. The five sketches on the left of the figure illustrate sequences in the deployment. It begins at the extreme left with an extension of two auxiliary masts from the initial package on which are mounted small jets. These jets impart an initial spin. As spinning begins, the antenna grid and its restraining lines are unreeled from storage rollers and bobbins by centrifugal force. The initially flat mesh disk becomes gradually larger in diameter as indicated in the next two sketches, and as it does so the rate of rotation decreases. As the antenna net achieves full diameter, as indicated in the fourth sketch, the central mast starts to extend. The fully deployed system with the antenna net achieving its design parabolic form is shown in the fifth sketch at the extreme right. We have conducted preliminary deployment experiments on two and five meter models in a vacuum chamber. This type of experiment is limited by gravitation and eventually we will have to go to a zero gravity environment.

Another important aspect is that relating to pointing the antenna. It will be necessary both to sweep the antenna through all directions for scanning and to point its axis precisely toward a signal source.

A promising control technique would utilize the interaction of electrical currents in the rim of the antenna with the Earth's magnetic field. Consequently, we are concerned with the effects of the Earth's magnetic field on the antenna in order to determine if the magnetic field forces can provide the required pointing torques without excessive distortion of the antenna surface. Some preliminary tests with a small model have been conducted to study the effects of a magnetic field on this type of flimsy network structure. A picture of this dynamic model under magnetic field test is shown at the right of the figure.

I have given only the highlights of this work but it illustrates some of the painstaking research and technology that must precede the development of equipment for the astronomer to use in probing beyond our solar system.

We are also working on the technology of optical observatories where there are many problems, such as maintaining the accuracy of the mirror, [illegible] pointing control, and structural stability from thermal gradients and elasticity, but I want to move on to other types of spacecraft.

Large manned orbiting laboratories will need advances in many technologies - control and stabilization, shielding and meteoroid protection, thermal balance, electric power, life support, communications and data handling, automatic rendezvous and docking, and others. I want to touch briefly on only two types of activities - human performance and life support.

To many people, the limiting variable, the greatest unknown is the development of long-duration space flight capability, in man himself. As a former submariner, I am well aware of many of these problems - confinement, stress, etc. - and the amazing adaptability of man but I can also appreciate how these are accentuated in space along with other factors not present in our experiences on earth. We need to know more about normal man and his limitations so that we can be assured we have the best combination of man and machine to carry out space missions. Key to research on man are innovations for measuring his functions and his responses to physiological and psychological stimuli characteristics of long-duration flight.

One innovation is a device developed to measure the physiological effects of flight stress in aviators but is equally applicable to experiments on space flight stresses. It is an elastic vestlike garment (Figure 8) which contains large, segmented, dry silver-coated electrodes. It does not require any skin preparation or paste. The vest holds the dry electrodes against the skin to pick up the electrocardiogram signals. Using several electrodes properly placed, a vectorcardiogram can be obtained which permits the physician to visualize the heart's electrical activity in three dimensions. The vest is easily donned and may be worn for long periods without discomfort.

Another new instrument measures the velocity of blood flow by the use of a noninvasive ultrasonic technique. When placed on the skin directly over a blood vessel it propagates ultrasonic energy, measures the return signal, and uses the doppler principle to determine velocity.

A third bioinstrument innovation determines blood pressure within the veins and arteries of animals. It is an intra-arterial catheter with a capacitance type transducer small enough to be threaded through a hypodermic needle. Experiments have shown that signals are recorded more faithfully with this transducer than with other available devices. On the left of Figure 9 the device is shown held by a person threading it into a small cannulae in preparation for injection. On the upper right is a magnified view of the device showing internal construction. The recorded pattern on the lower right shows a comparison with results from a commercial transducer. High frequency components of the pressure wave are better recorded with this capacitance transducer.

Two sensors spaced a known distance apart can determine the pulse wave propagation velocity which gives a measure of the elasticity or hardening of the arteries. Additional research is planned toward assembly of two transducers arranged in a single cathether, as in a pitot probe, to determine the blood velocity by measuring the total head pressure and the static pressure. Due to their small size, high sensitivity and high frequency response these transducers should find many uses in research and clinical applications. It is interesting to note that the transducers used were a type originally designed to measure pressures of aircraft flight models in wind tunnel tests and illustrates the important cross-feed between different disciplines operating in a common environment.

With improved measurement techniques and an orbiting laboratory, we will be equipped to study man's performance in space and determine his capability for more difficult missions in the future.

Life support is a key technology for extending man's capacility in space. Air for breathing, water, food, heat, and moisture must be supplied; carbon dioxide, body waste, heat, odors, gases from equipment, and other harmful substances must be removed. In Mercury, Gemini and Apollo, life support waste is discarded after use. For long duration trips, however, the stores needed become great so a major consideration is resupply and its frequency. Obviously a manned orbiting laboratory and lunar bases can be resupplied without great difficulty so the question of on-board regenerative systems that treat and reuse certain ingredients versus discard of all waste becomes a consideration of safety and economics. For long-duration, self-supporting missions, such as to the planets, regenerative systems become essential. In all cases repair and replacement techniques are necessary for sustained operations. Both regenerative systems and repair-replace techniques are in the early stages of technology and the manned orbiting laboratory is ideal for proof of new concepts in life support equipment.

We are working on water and oxygen recovery, solid waste management, sensors for oxygen, carbon dioxide, water vapor, and inert gas, trace contaminants, and food management. Water recovery represents a major weight saving potential and I will discuss it as a typical example of life support research.

One group of studies investigate methods to recycle waste water for drinking and washing purposes. The basis of one such system is the evaporation of clean water from urine-saturated wicks. Hot air evaporates clean water from the wick leaving a residue behind. Approximately 4% of the urine processed was retained in the wicks in the form of solids; the rest evaporated and was reclaimed as clean water. However, this method has several major problems particularly short wick life. Improved wicks have been made by they remain the limiting factor of the method.

We have found it desirable to chlorinate stored water but the use of chlorine presents special problems in a closed environment because of its toxicity. This has been overcome by generation of chlorine only as needed by a technique using the electrolysis of a chloride solution. Electric current controls the rate of chlorine generation and makes automation of the system an easy step.

A promising method of water reclamation is a vapor diffusion technique which appears simple, compact and highly efficient. A laboratory model has been built that uses a semipermeable membrane in an evaporator and a porous plate sublimator to condense the water vapor and separate condensate from diffusion gas. Tests with this laboratory model look very promising. For example, it is estimated that only 15 pounds of water at launch will be required for each man for 100 days using such a system as contrasted to 600 pounds of water per man needed on the same period without reclamation.

A reverse osmosis technique appears to be a promising method for wash water reclamation. The technique, however, requires a special membrane which NASA has not yet developed. Last year, the Office of Saline Water, which was conducting related work, did some test for NASA on the use of tiny hollow glass tubes for membranes and this joint effort is continuing.

Similarly, representatives of the Federal Water Pollution Control Administration have met with NASA scientists to exchange research information on the handling of wastes to prevent water pollution. As a result of meetings last year, NASA and FWPCA undertook a joint program on a new process which removes dissolved organic compounds from water by oxidation. A specially prepared catalyst is required. It is expected that the process can be used by NASA to reclaim water from urine or by the FWPCA to remove stubborn, dissolved organic compounds from municipal sewage and industrial wastes.

Lunar exploration is a logical follow-on to the first Apollo landing. Nuclear electric power systems, based on SNAP 8 technology, are particularly applicable here. Smaller and mobile power equipment will also be needed. In speaking of space power in general, the multiplicity of power ranges and combination of energy sources and conversion methods, coupled with the universal need for electric power in space and on earth, indicates that the potential pay-off from research in space power systems is high. Greater emphasis on a few highly promising systems is indicated for reasonable progress. Klein has described a major portion of this program, the part involving nuclear energy. Non-nuclear research includes batteries, fuel cells, and solar cells.

Research on a new rechargeable battery with one or two auxiliary electrodes has progressed to the point that it has been selected for use on the Orbiting Astronomical Observatory (OAO) spacecraft and on the Apollo Telescope Mount.

These are two important uses of battery technology developed under this program. Heating during recharge and effective battery weight are reduced with a significant increase in cycle life (number of reliable recharges).

We are now trying to extend the cycle life of these batteries to five years. As a result of improvements in the manufacture of zinc electrodes, incorporation of the new separator and better packaging of components, five amp-hour, silver-zinc batteries have recently been cycled for well over 2, 500 cycles at 20% depth of discharge, and over 2, 000 cycles at 30% depth, both at room temperature and for simulated 90-minute orbits. Even at 212°F, more than 500 cycles were run. We thus have, for the first time, a truly rechargeable silver-zinc cell. This is now being scaled up to larger size and modified to permit sterilization in sealed condition.

In solar cell technology, we are striving towards the goal of 20 watts per pound and power levels up to 50 kilowatts. This requires very light structures to hold the cells and one approach to this is bonded beryllium as illustrated by Figure 10. The 13 ft. 8 inch spar which weighs about two pounds is the longest continuous beryllium structure ever assembled. As a result of this work, it is now possible to roll sheets of beryllium longer

13 feet and to fabricate complex adhesively bonded structural joints such as illustrated in the figure. The assembly on the left of Figure 10 would require 40 spars and eight joints of the type illustrated.

Another approach to large solar power is a retractable solar array such as illustrated by Figure 11. This shows the potential of the "rollup" or window shade concept to achieve moderate weights (for example, 12 watts per pound), the most compact stowage for launch, and the capability to be automatically deployed and rolled up again many times. We are trying to increase the power level from 500 watts to 2,500 watts, requiring 250 ft^2, and to increase performance from 12 to 30 watts per pound. The higher power level and reduced weight are needed for potential future missions using solar electric propulsion, for broadcast satellites, and manned space flight.

Let us now move on to planetary spacecraft. Planetary missions involve a wide variety of spacecraft including interplanetary probes, solar probes, planetary orbiters, planetary and planet satellite landers, and, eventually, manned planetary landers. These have in common the need for efficient propulsion systems, attitude control, accurate guidance and navigation, ample electric power, versatile sensors, high data storage capacity, and high communication rates over long distances, all of which must be designed to withstand the hostile elements of the space environment. Additional requirements are high temperature systems for solar probes and Venus landers, atmospheric entry vehicles, decelerators, and landers. I will touch on two of these subjects, atmospheric entry and landing and electronics.

The atmospheric entry successes of Mercury and Gemini, based on earlier technology, tend to lessen awareness of the much larger problems of entry that must be solved for successful entry of probes into planetary atmospheres and, eventually, earth atmosphere entry from planetary missions at higher speeds. These problems stem from lack of knowledge of fluid flow processes at very high velocities and unknown composition of planetary atmospheres. Present effort, focused on obtaining a better understanding of turbulent heating and on ablation in the presence of a turbulent boundary layer, at very high velocities, is limited by our ability to simulate flow conditions and heating rates. For example, our estimates show that the Russian Venus probe experienced radiative heating rates of about 6 kilowatts per square centimeter. These levels considerably exceed, our present test capabilities to study the heating environment or the response of an ablation material to that environment. If a probe of the Jovian atmosphere should be desired, technology permitting entry into hydrogen-helium atmospheres at speeds of about 50 kilometers per second would be required. Again, these conditions exceed our current experience and our ability to conduct ground-based experiments and clearly calls for innovations both in the research technique and in gaining the needed technology.

Present research indicates, however, that blunt conical shaped entry vehicle would be suitable for Mars entry. Once decelerated we encounter the problem of deceleration from supersonic speeds to landing.

Last year we successfully completed the first phase of high-altitude flight tests of large parachutes for this purpose. These tests provided us with data on opening shock loads and deployment at supersonic speeds (M 1.6), and low atmospheric densities in the large wake of the bluff entry vehicle. We also obtained data on the deceleration and orientation characteristics of the parachute. The extent of the technology acquired is indicated in Figure 12. The artist's sketch on the right of the figure illustrates the nature of the problem. Here we show the initial stages of deployment of a large parachute extracting the payload from a Mars entry aeroshell. One of the problems investigated was that of opening and deployment of the parachute at supersonic Mach numbers and low atmospheric densities in the wake of the large bluff entry vehicle. We also needed to know what the opening shock loads were during this period. Following deployment, the fully opened canopy then decelerates the payload to the desired terminal velocity and provides aerodynamic orientation to allow on-board instrumentation to control the precise firing of retrorockets for the final soft landing. This requires parachutes which are very stable during descent; therefore, these characteristics were also investigated in our flight research program.

On the left of the figure, parachute size (diameter in feet) is plotted against Mach number. Prior experience with parachutes and other decelerators is indicated by the shaded region along the vertical and horizontal axes. At that time we had experience only at very low speeds with large parachutes on the order of 180 feet in diameter. At the other end of the Mach number scale, experience at higher Mach numbers up to about four was with small parachutes and other drag devices of the order of a few feet in diameter. The region of interest for a Mars probe is indicated in the center of the graph. The cross-hatched areas shown within this region represents those covered by current research program. Parachutes up to 85 feet in diameter were tested at Mach numbers up to 1.6, and smaller parachutes up to 40 feet in diameter were tested at Mach numbers near 2.6.

Two parachute configurations in the program were identified as having satisfactory characteristics for use in the Mars probe application. Detailed design data were obtained which have shown that such parachutes can be made to operate properly at considerably higher speeds than was previously believed possible. We plan to continue the investigation of parachutes and other decelerators using the rocket-launch system to obtain additional data.

Planetary spacecraft will stretch almost every aspect of electronics technology - guidance, control, tracking, data acquistion, storage and handling, and communications. The need for increased reliability and life, important for all missions, is accentuated for missions to the planets and beyond because some might call for useful lives up to ten years.

The packaging of 39,220 individual electronic parts into a 575 pound spacecraft (Mariner IV) mentioned by Naugle underscores this need for high reliability as well as the rising complexity of space vehicles. This rising complexity is illustrated by Figure 13.

Explorer I had about 500 discrete parts. Mariner-Venus 67 had almost two orders of magnitude increase in parts - about 41,000 parts. However, some were incorporated into integrated circuits so the number of devices wired was about 25,000 as shown by the bottom curve. The trend shown by the upper curve of discrete parts count is a rapid rise and underlines the need for integrated circuits or multifunction devices to reduce the electronic complexity. We are quite excited about a revolutionary new trend in electronics with the somewhat confusing misnomer of large-scale integration or LSI. Life and reliability of electronic parts increased by orders of magnitude as technology progressed from vacuum tubes to transistors to integrated circuits. The latter have a number of parts, such as transistors, resistors, etc., formed and connected on a single chip of silicon to perform a complete function. The success of single-function integrated circuits has pointed out the feasibility and promise of circuit integration on a larger scale. The new field-effect transistors, have enabled us to make larger circuit arrays, more simply and economically, while performing many electronic functions. Figure 14 compares the single circuit device that performs one function with a large scale integration (LSI) array that performs 100 functions. The LSI device has one-third the number of process steps, 1/100 the hand connections, and at least one-tenth the weight and volume. Already a few LSI devices have been flown on IMP satellites by the Goddard Space Flight Center and have performed well. It is this type of emerging new technology that underscores both the need and the potential of increased research in electronics. We are increasing our efforts in electronics research through the Electronics Research Center in Cambridge, Massachusetts.

Before closing I want to mention the possibilities of nuclear aircraft. You recall the abortive effort some years ago for this application. Since that time, aircraft have grown considerably larger. The jumbo jet, for example, will weigh about 700,000 pounds and a million pound aircraft may not be far away. These trends to very large sizes have led us to take a fresh look at the use of nuclear propulsion for aircraft. Our work thus far consists of design analyses and a study of the safety problems involved.

In closing, I have described some research trends and problems in space technology. We believe this program, along with the other programs described here, provide a unique and peaceful means for this Nation to develop new capability in science and technology that will benefit us all.

LIST OF FIGURES

LARGE SOLID MOTOR TEST RECORD

MOTOR DESIGNATION	TEST DATE	PROP WGT (10^6 LB)	MAX THRUST (10^6 LB)	BURN TIME (SEC)	TVC TEST	COMPANY
156–1	5–64	0.42	0.9	108	JET TABS	LOCKHEED
156–2	9–64	0.63	1.1	143	JET TABS	LOCKHEED
156–3	12–64	0.69	1.4	126	GIMBAL	THIOKOL
156–4	2–65	0.80	3.3	59	NONE	THIOKOL
156–5	12–65	0.69	3.1	55	LIQUID INJ	LOCKHEED
156–6	1–66	0.27	1.0	65	LIQUID INJ	LOCKHEED
156–HG	4–66	0.16	0.3	122	HOT GAS INJ	LOCKHEED
156–7	5–66	0.13	0.4	110	LIQUID INJ	THIOKOL
156–9	5–67	.27	1.0	77	FLEX BEARING	THIOKOL
260, SL–1	9–65	1.7	3.6	114	NONE	AEROJET
260, SL–2	2–66	1.7	3.6	114	NONE	AEROJET
260, SL–3	6–67	1.7	5.9	70	NOZZLE STRUCTURE ONLY	AEROJET

DAC DATA

NASA HQ RP67-17073
Rev. 1-25-68

Figure 1

STATIC TEST OF SL-3 SOLID MOTOR

JUNE 17, 1967

PEAK THRUST — 5.9M POUNDS

THROAT DIAMETER—89 INCHES

WEIGHT ——— 1.7M POUNDS

NASA HQ RP67-17040
Rev. 1-25-68

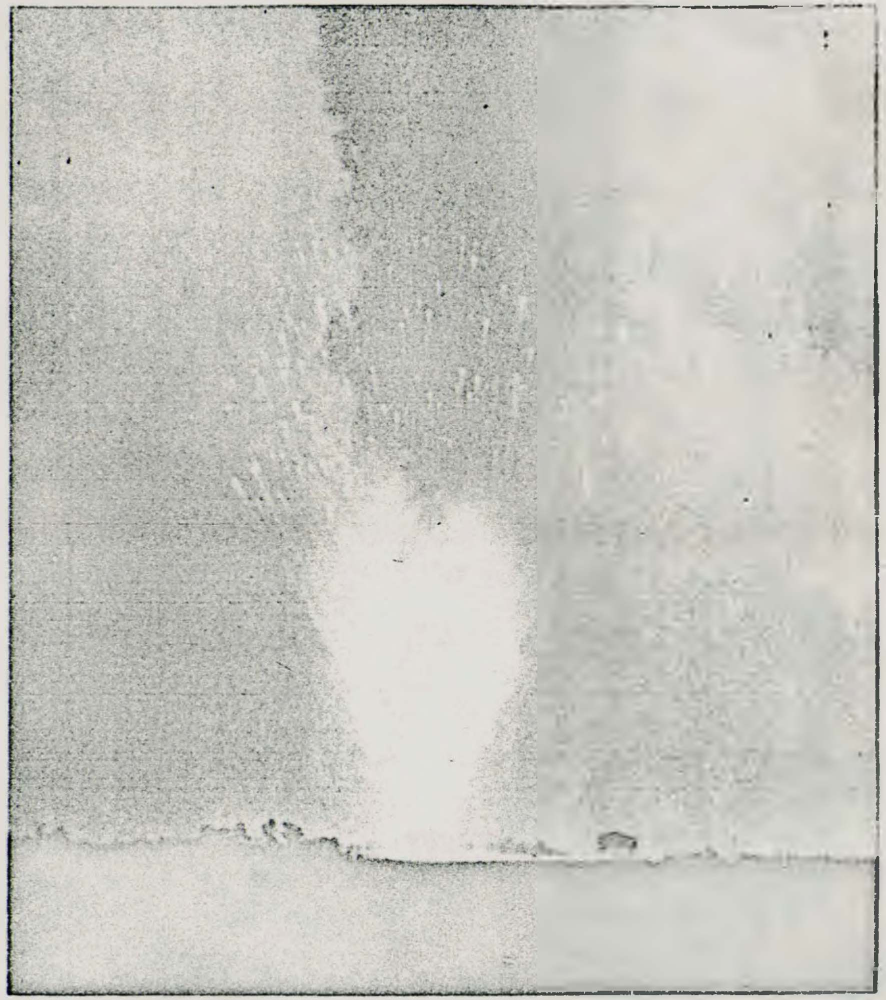
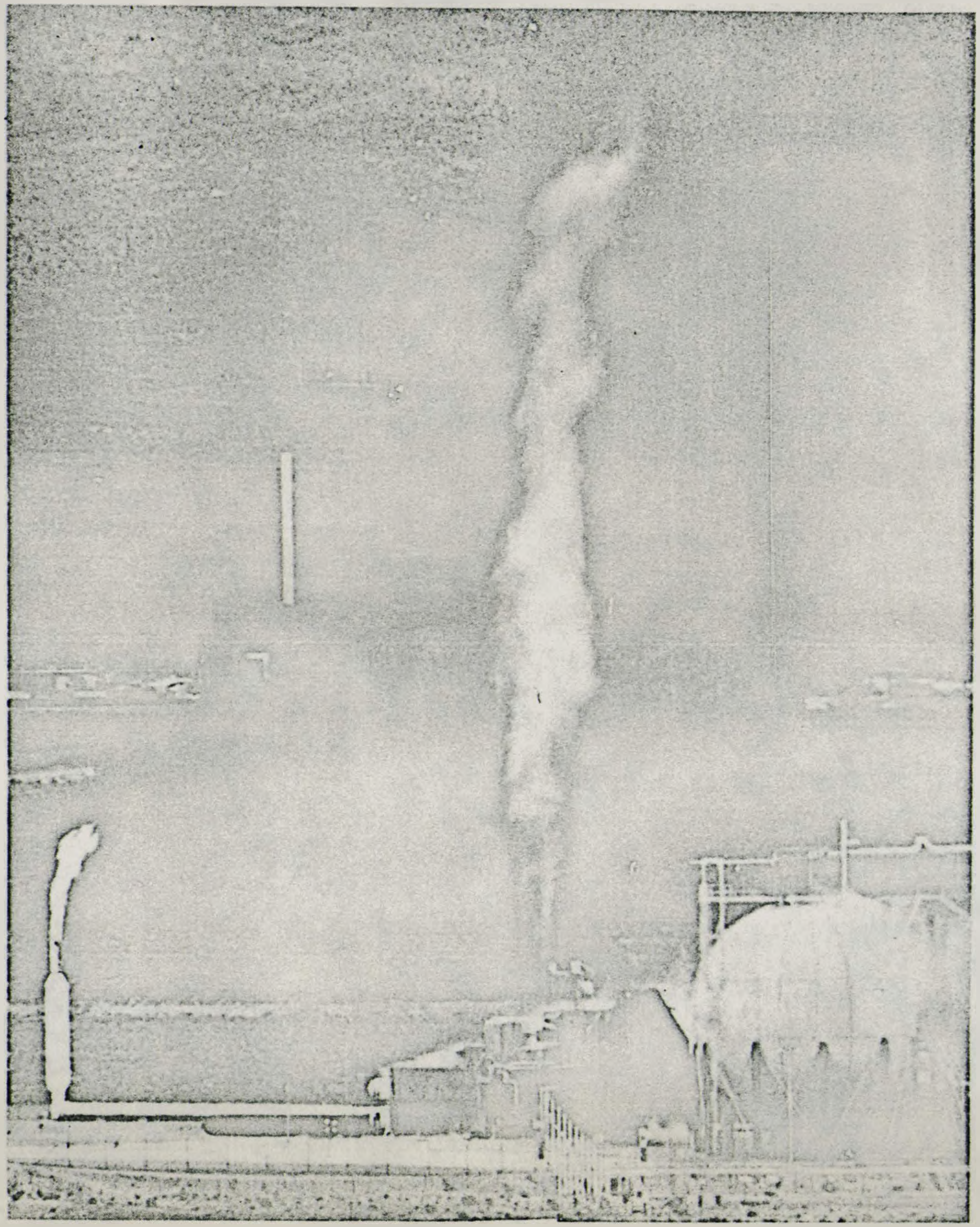
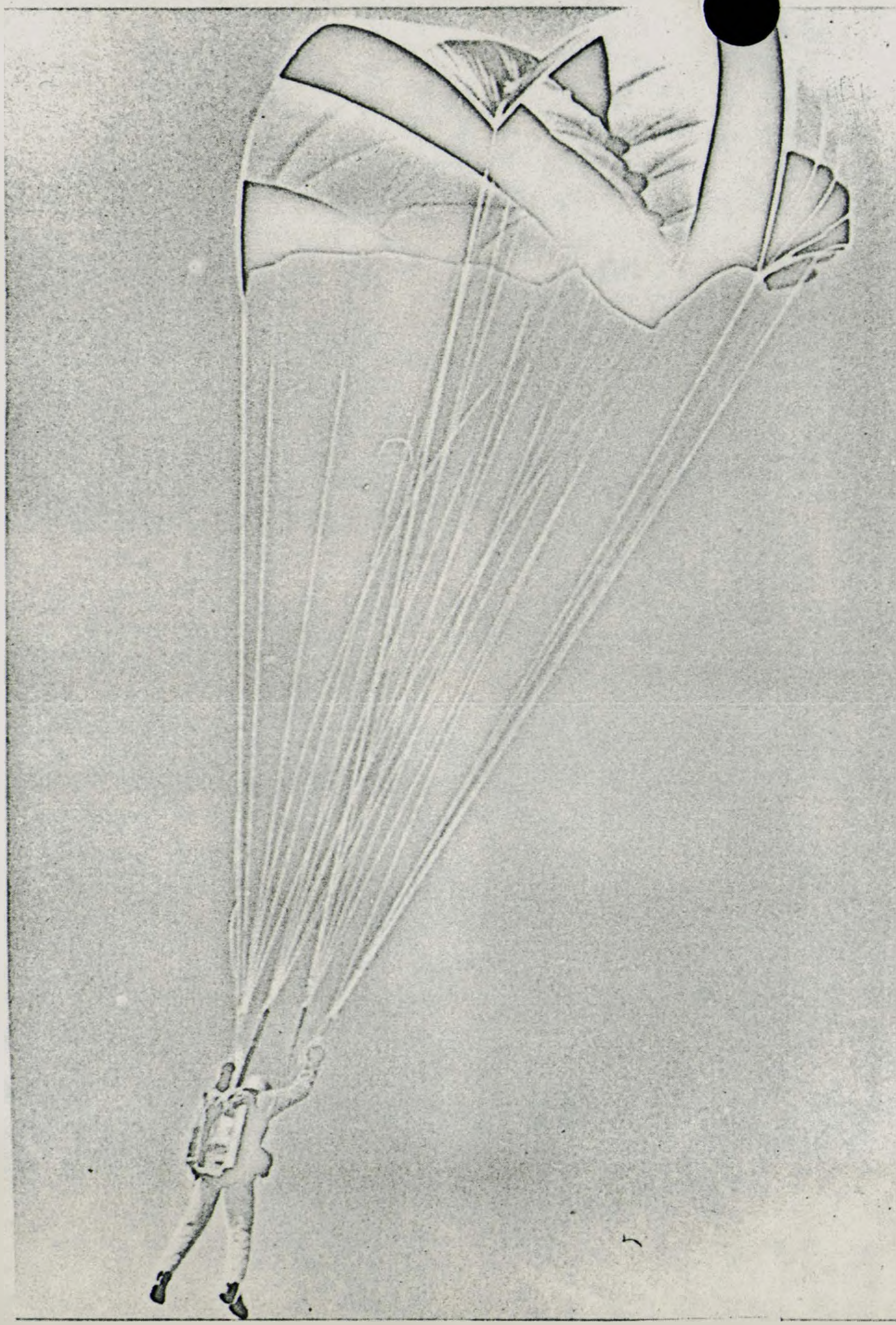


Figure 2



NASA HQ RC68-15828 1-6-66

Figure 3



NASA HQ RC68-15883
1-18-68

Figure 4

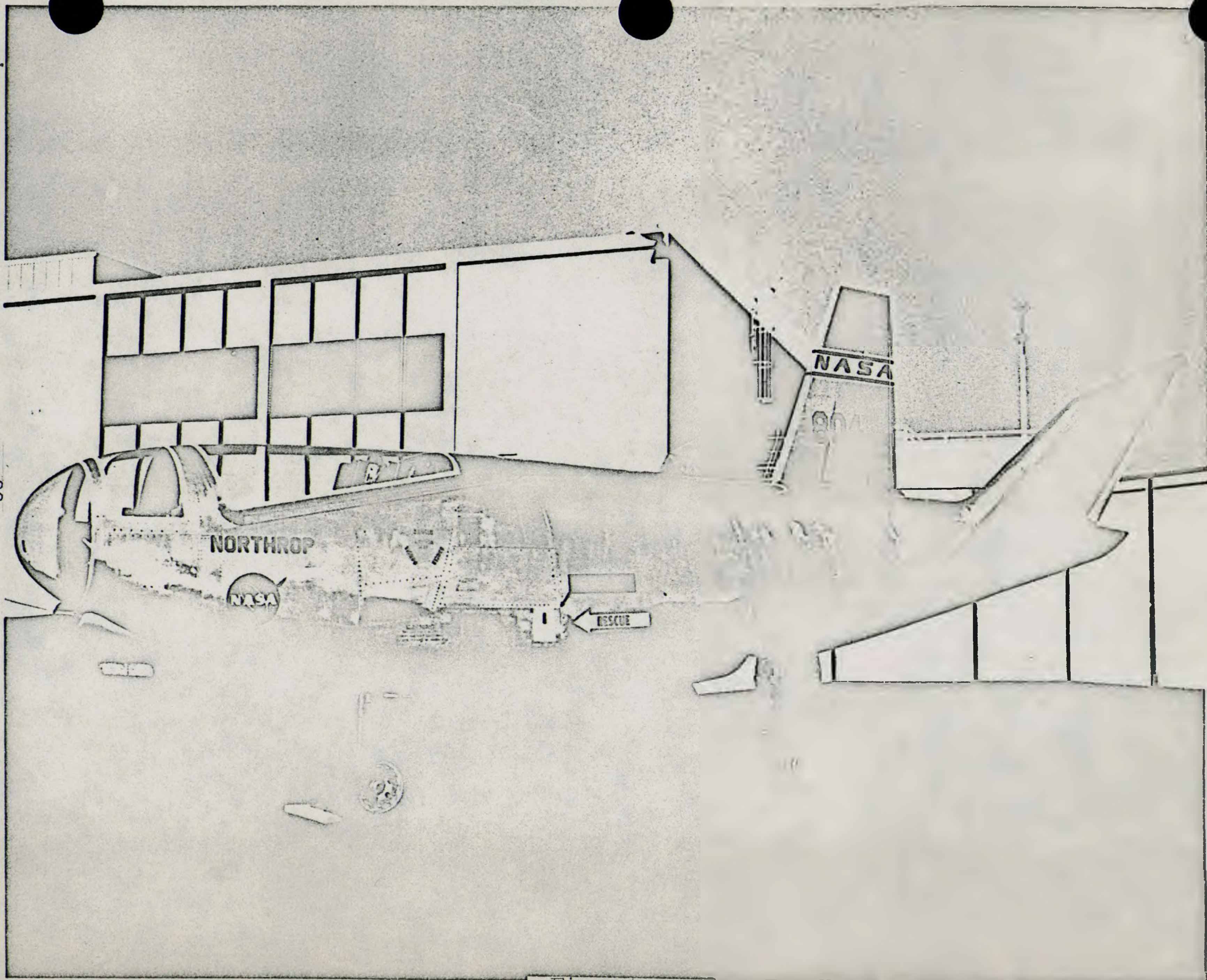


Figure 5

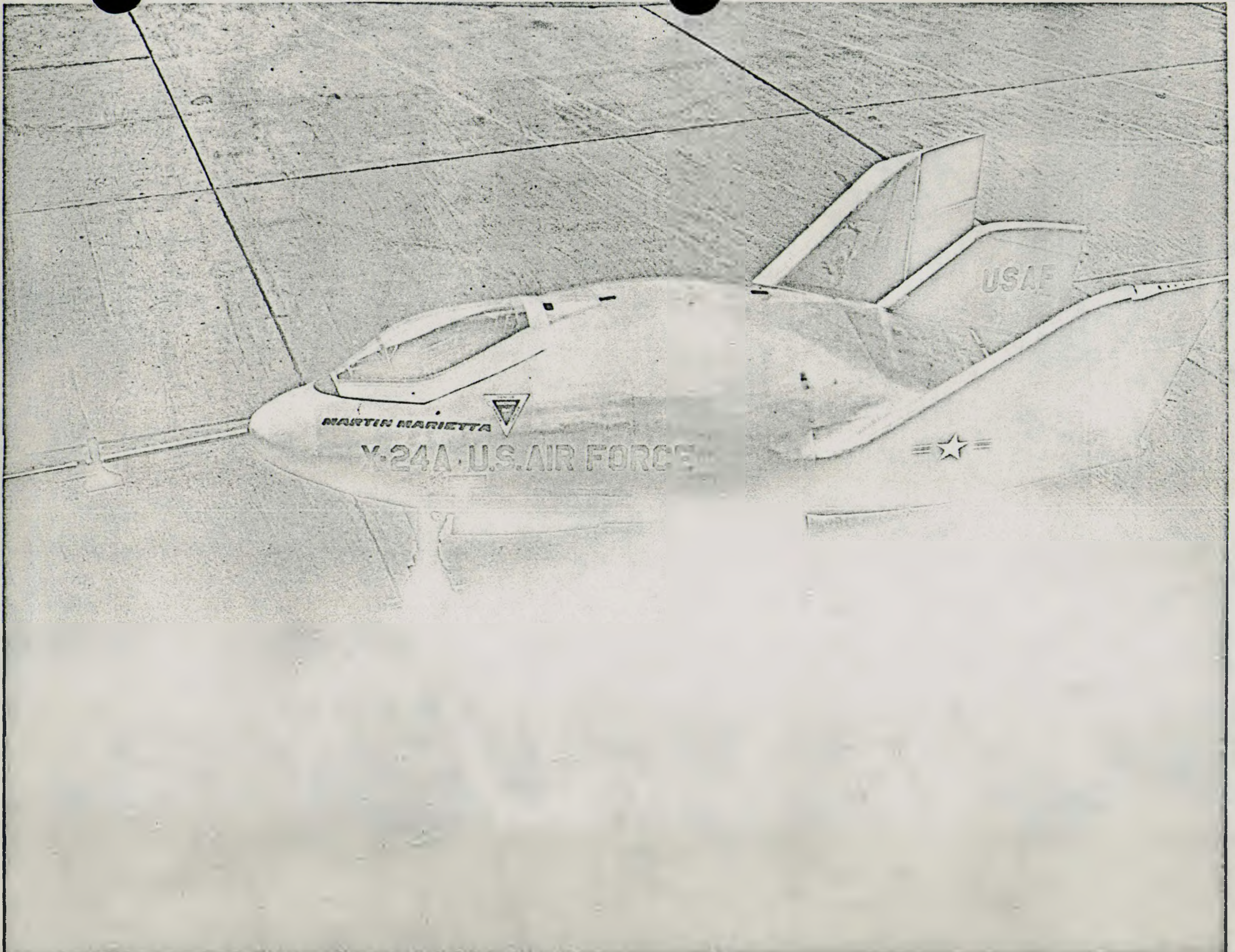
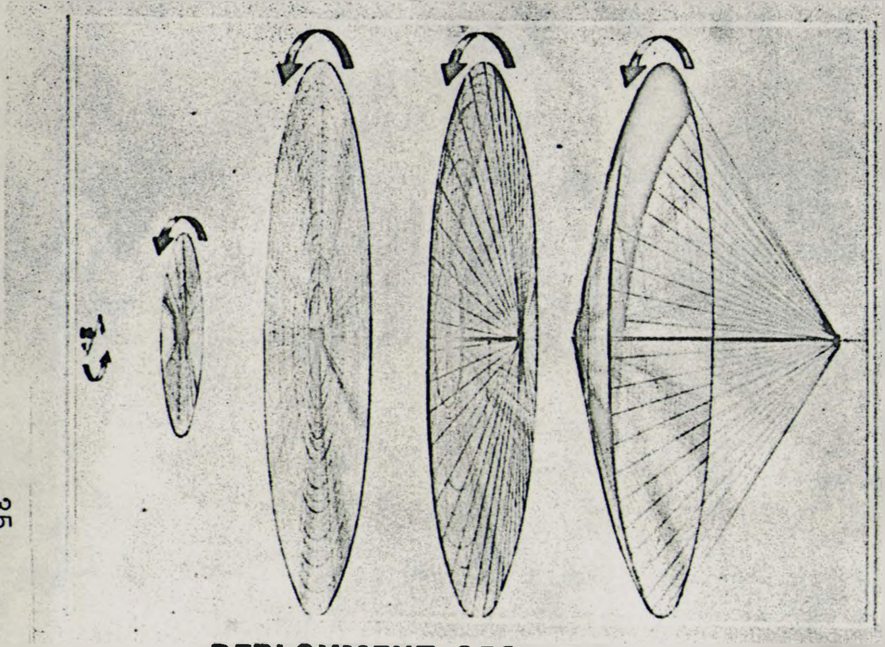
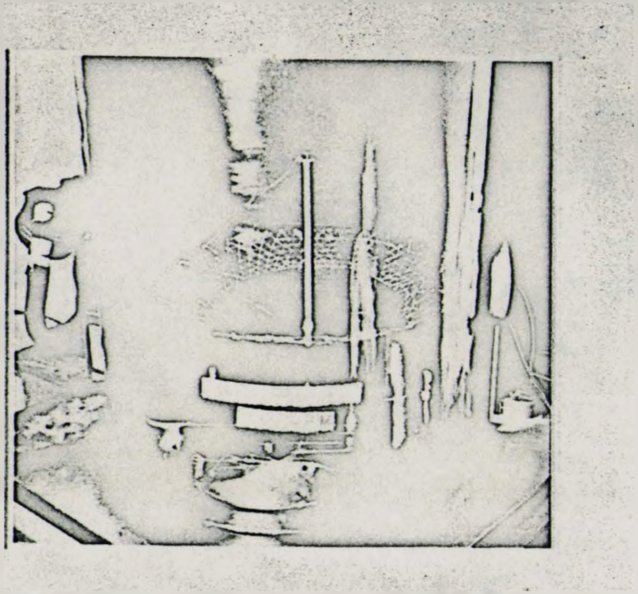


Figure 6

STRUCTURES TECHNOLOGY - ORBITING RADIO TELESCOPE



DEPLOYMENT SEQUENCE



MAGNETIC FIELD TESTS WITH DYNAMIC MODEL

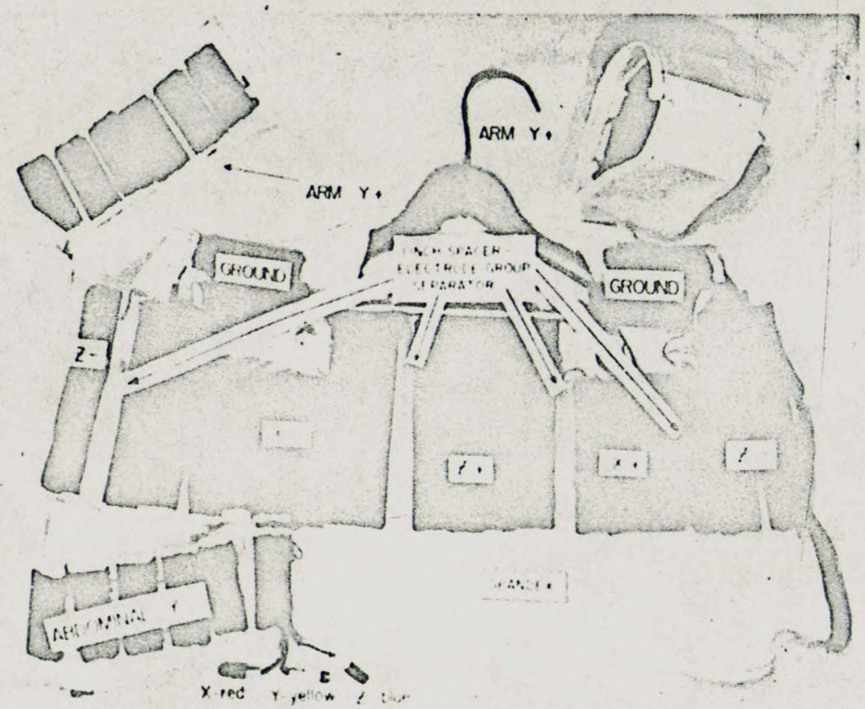
EFFECTS OF EARTH MAGNETIC FIELD

- PROVIDE REQUIRED POINTING TORQUES
- DISTORT ANTENNA SURFACES

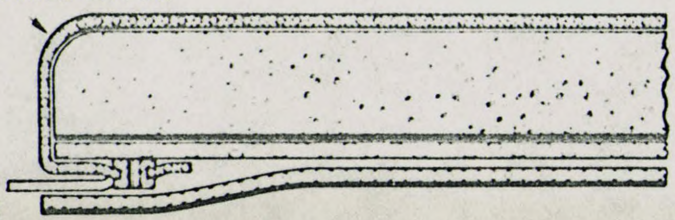
NASA RV68-1126
1-12-68

Figure 7

BIOINSTRUMENTATION
STRESS EFFECTS IN AVIATORS



DRY ELECTRODE PADS IN VEST



CROSS SECTION

FLIGHT RESEARCH CENTER

Figure 8

INTRA-ARTERIAL PRESSURE MEASURING SYSTEM

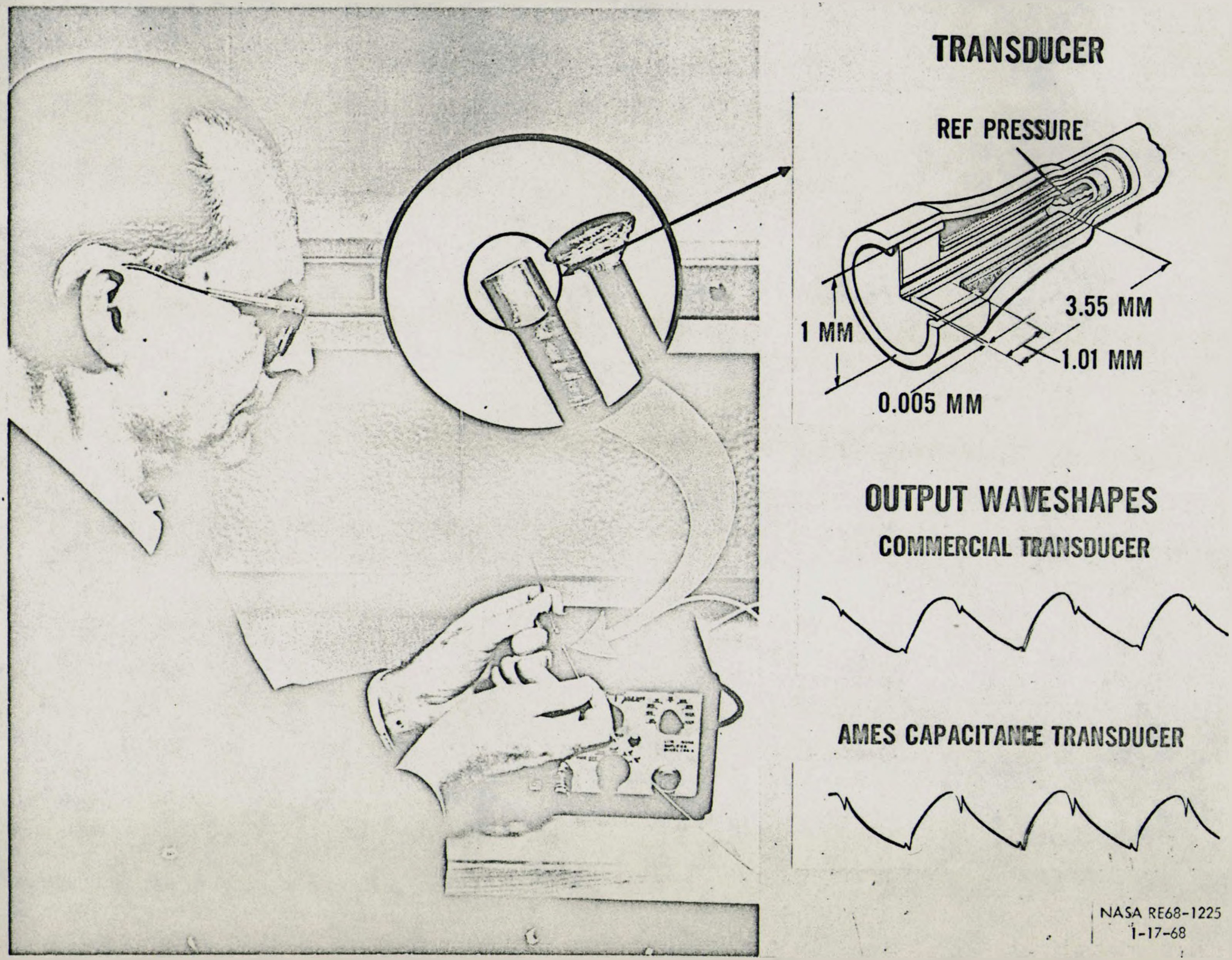
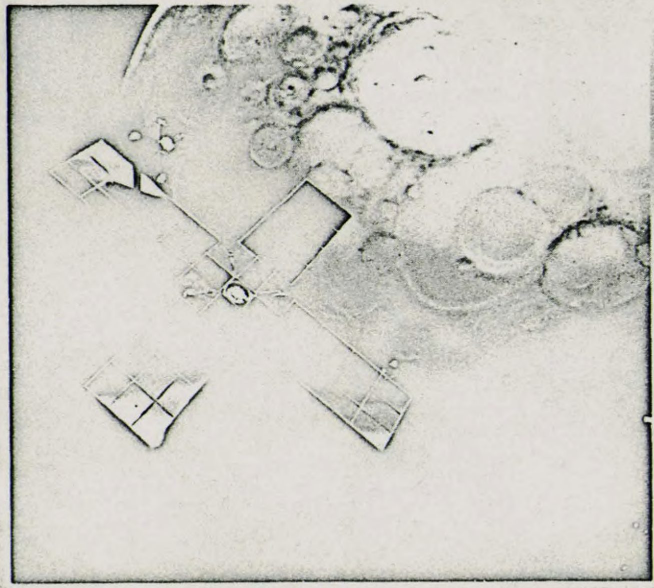
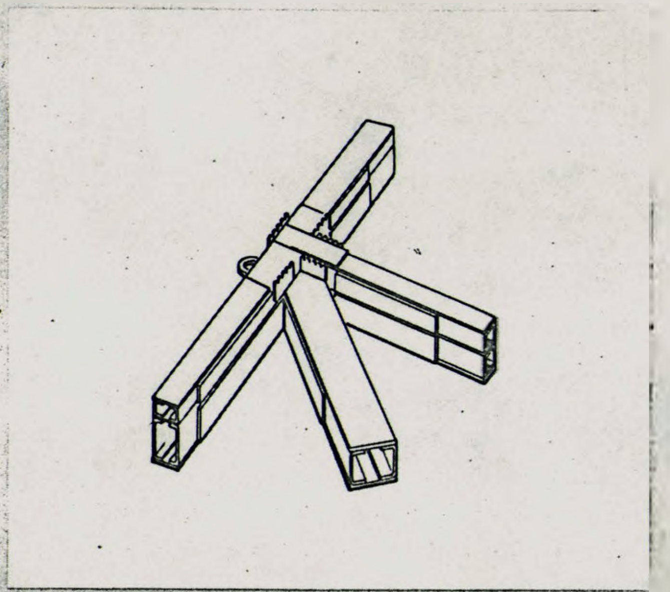


Figure 9

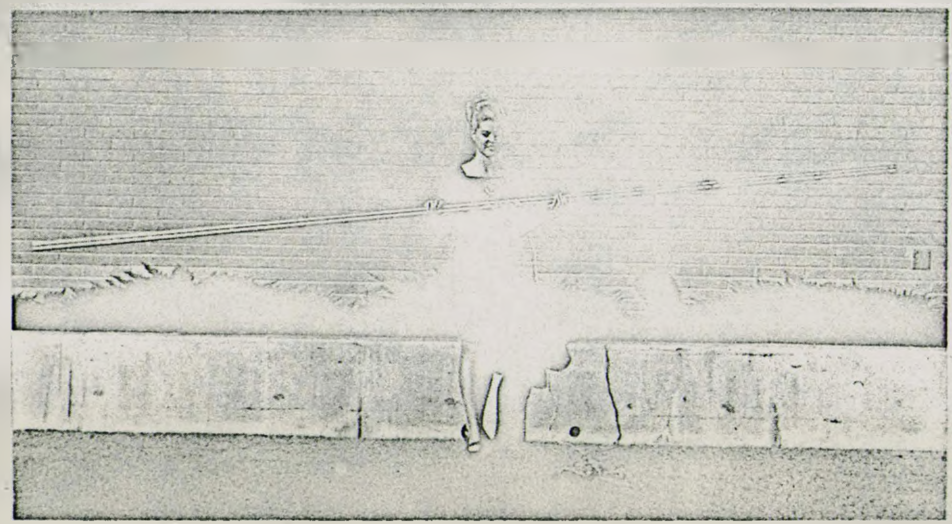
HIGH POWER SOLAR CELL ARRAY
PROGRESS IN LIGHTWEIGHT BONDED BERYLLIUM



GOALS: 5000 FT^2, 50KW, 2500 LBS



COMPLEX JOINT; ARRAY SUPPORT STRUCTURE



NASA RN 68-1231
1-17-68

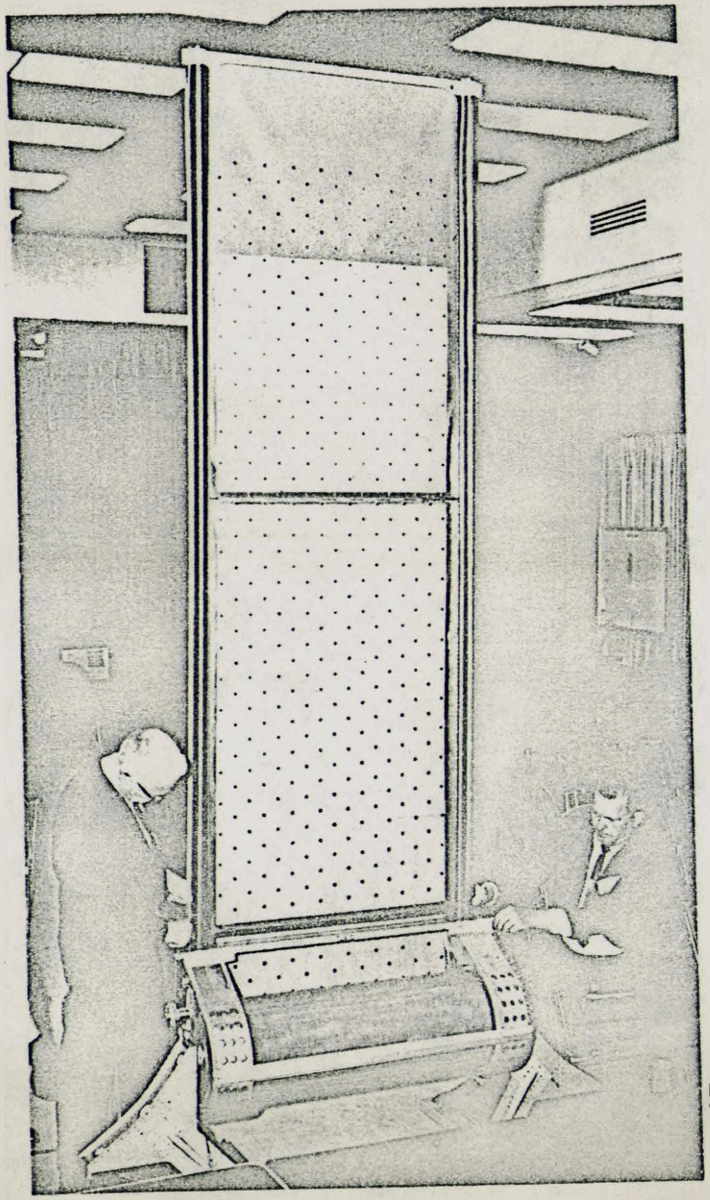
13 FT-8 IN, 2 LB, SUBPANEL SPAR

Figure 10

RETRACTABLE SOLAR ARRAY

1967 RESULTS

- DEMONSTRATION OF 50 FT^2 MODEL
- ACHIEVED 12 WATTS PER LB. IN 500 WATT SIZE
- INITIATED WORK TOWARD ADVANCED DESIGN



FY68-FY69 GOALS

- FABRICATE 250 FT^2 MODEL
- 2500 W OUTPUT
- 30 W/LB.

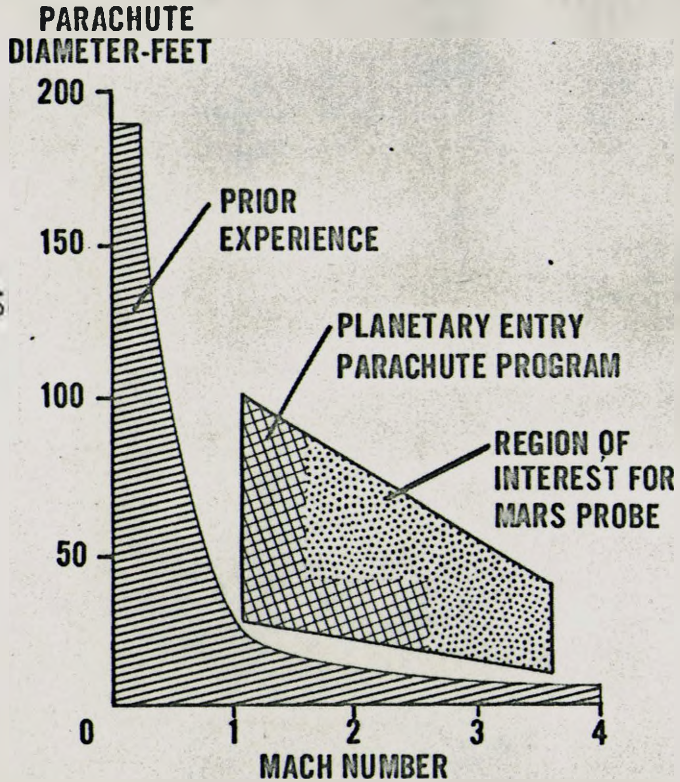
50 FT^2 MODEL

NASA RN68-1137
1-12-68

Figure 11

PLANETARY ENTRY PARACHUTE PROGRAM

SIMULATED MARS PARACHUTE DEPLOYMENT



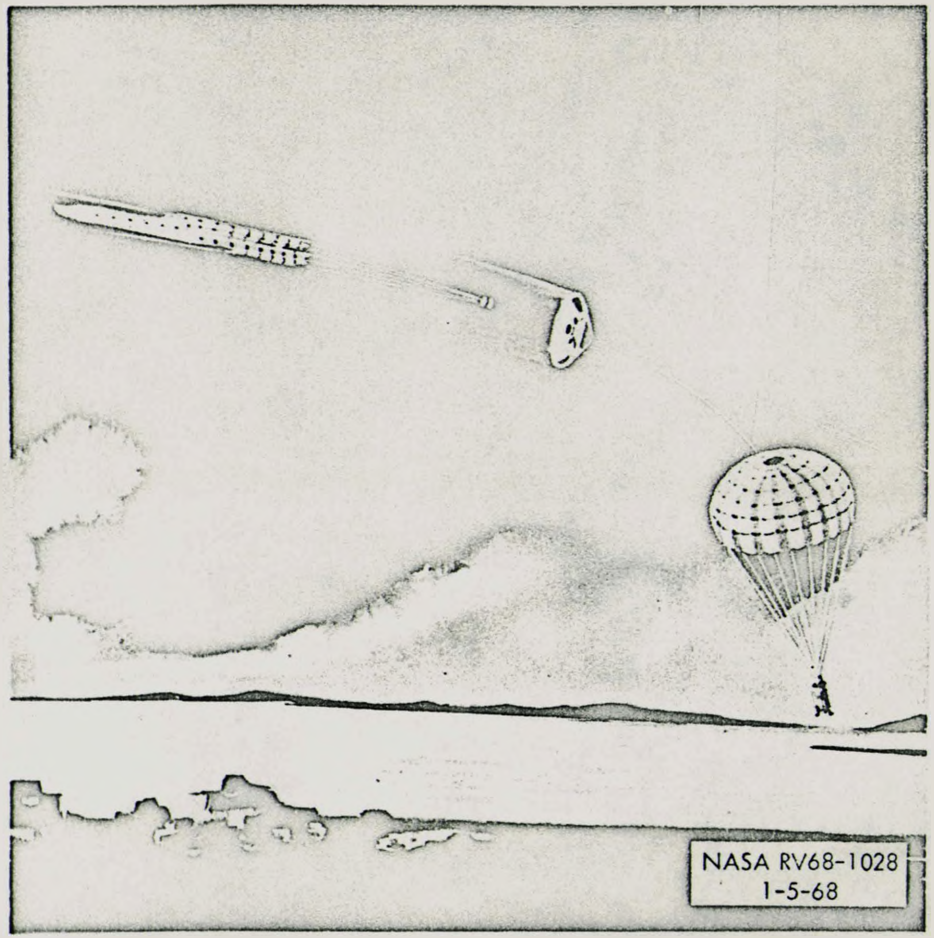


Figure 12

PARTS/DEVICES TREND

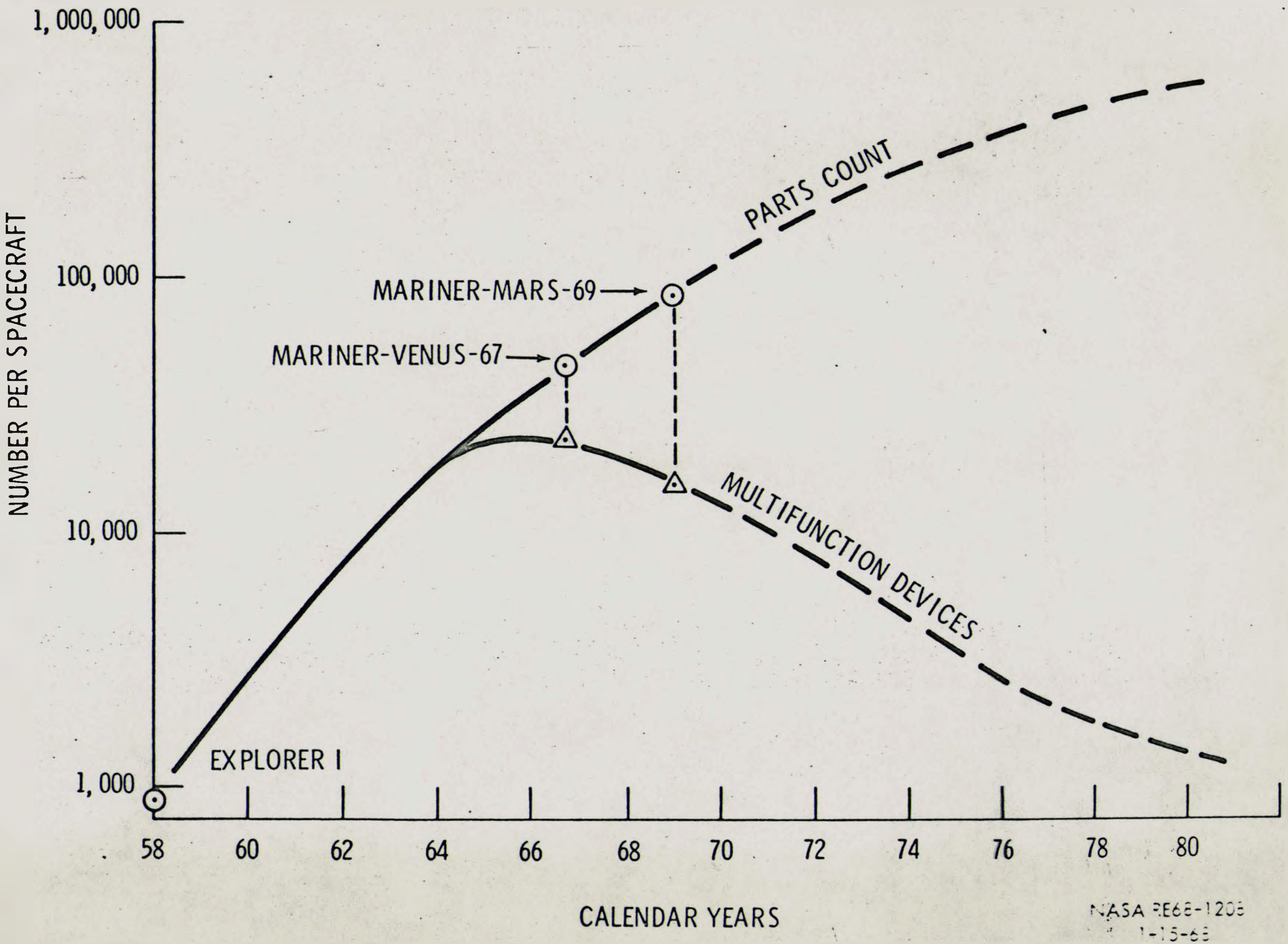


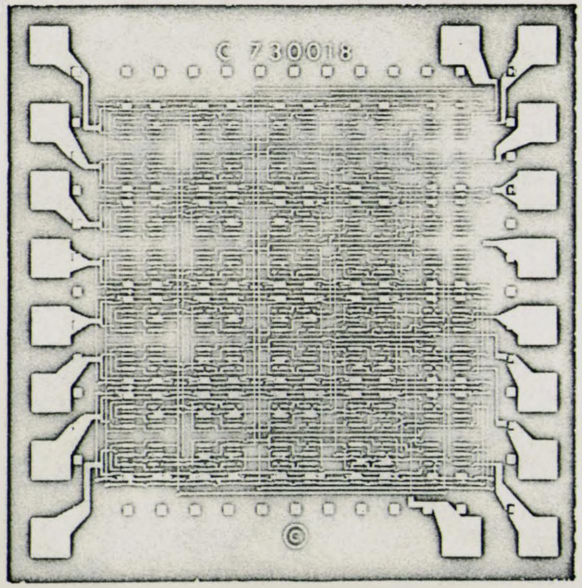
Figure 13

MULTICIRCUIT ARRAYS

40 x MAGNIFICATION

SINGLE-CIRCUIT SILICON DEVICE

PERFORMS 1 FUNCTION



40 x MAGNIFICATION

MULTI-CIRCUIT (LSI) DEVICE

PERFORMS 100 FUNCTIONS

- WITH 1/3 THE NUMBER OF PROCESS STEPS
- WITH 1/100 THE NUMBER OF HAND CONNECTIONS
- IN 1/10 THE WEIGHT AND VOLUME

NASA RE 67-1302
REV. 12-15-67

NASA-HQ

Figure 14

B-8

ADVANCED RESEARCH AND TECHNOLOGY

James M. Beggs

Associate Administrator for Advanced Research and Technology

National Aeronautics and Space Administration

AIA Fall Conference
Phoenix, Arizona

November 20, 1968

The primary role of the Office of Advanced Research and Technology in NASA is to provide the technology needed for future aeronautical and space systems. This gives the Nation maximum flexibility not only in choosing specific national objectives in air transportation or space exploration but also in choosing the best and most economical systems for meeting these objectives.

A secondary but vital role is to assist others on problems where we have competence. By "we" I mean the government - university - industry teams that work together on the research tasks that make up our program. By "others" I mean 1) other NASA offices with responsibility to develop and operate space flight equipment, 2) other government agencies such as the Departments of Defense, Transportation, Commerce, and Health, Education and Welfare, and 3) industry such as those who wish to make use of our unique facilities or our technology to solve a problem or to develop new capability.

A third role of OART, which follows from the activities of the first two, is the advancement of knowledge in physical and life sciences that is useful in many fields beyond aeronautics and space.

Figure 1 shows the elements of the program grouped as aircraft and space technology and technology basic to both. In aircraft technology, we conduct research on the various engineering disciplines and on problems related to classes of aircraft. I will return to these in a few minutes. In a similar manner, space technology covers pertinent engineering disciplines and systems applicable to launch vehicles and spacecraft for classes of missions. The technology basic to both aeronautics and space involves human factors, electronics, materials, and physics.

In FY 69, the R&D program for research and technology is 285 million dollars. Of this, about one third is aircraft technology and related research and two thirds space technology. About sixty percent of the program is carried out by industry, ten percent by universities and non-profit institutions and the remainder in-house.

I want to discuss three major needs, which can have important implications in future aerospace trends, and what we are doing about them.

The first of these is the need for increased aeronautical research. The aircraft technology portion of our program goes back 53 years when the National Advisory Committee for Aeronautics was formed to conduct research on the problems of flight with a view towards their practical solution. When NASA inherited the 300 million dollar NACA research plant and staff of some 8,000 people in 1958, it also inherited an international reputation for excellence in aeronautical research. During the early years of the space program, much of this NACA talent was diverted from aeronautics to the rapidly developing space program and as a result the amount of aeronautical research went down sharply. The problem was recognized several years ago and since then we have been slowly but steadily building up the aeronautical portion of the NASA program with excellent support from Congress and others.

In FY 1961, for example, most of the aeronautical research was done in-house with less than a million dollars in R&D funds. By FY 1967 this had risen to 35 million dollars and this year it is 95 million dollars with industry carrying out the major part of the program. We are doing all we can to keep the aeronautics program growing in a sound and orderly fashion because there is much more that needs to be done. We also see an even higher share of the funding going to industry for reasons I will bring out later.

A large portion of the aeronautics program continues the NACA role of research and support to the aircraft industry and to the military but with emphasis on civil transportation.

In research, we are applying modern analytic and experimental techniques to obtain new information in the older aeronautical sciences.

Take aerodynamics research for example. The simpler, first order aerodynamic characteristics of this oldest of aeronautical disciplines are well understood and amply documented.

As aircraft become more complex and their performance and range increases, however, second and third order aerodynamic effects, which are not well understood, become critical to the success or failure of the design. This need, coupled with the modern computer, has stimulated research on complex problems such as boundary layer growth, transition, and separation and the determination of drag, lift, and moment values over a range of speeds.

This type of work is just beginning as we seek to bridge the gap between it and the older, empirical techniques. An illustration of recent aerodynamic research, where we are attempting to combine the old and new approach, is shown by Figure 2. We have been working of airfoils for subsonic transports for several years to find ways of preventing a sharp increase in drag as high subsonic speeds are approached. The increase in drag is caused by a shock-induced air separation on the upper surface of the airfoil normally occurring at the point labeled "shock position 1."

Judicious shaping of the airfoil and using a slot at the rear of the airfoil proved effective in moving the shock back to the position labeled "shock position 2" and this resulted in an 18 percent increase in speed before encountering high drag. While this improvement was worthwhile, we were not satisfied because the slot adds weight, structural complexity, and fabrication costs. We continued the research to better understand the aerodynamics involved and found that we could eliminate the slot and its complexity. An unslotted airfoil is also shown schematically and it is almost as effective as the slotted airfoil in allowable speed increase before high drag occurs. The new supercritical wing permits thicker wing sections without increasing cruise drag over that of former designs. This means a higher lift-drag ratio and increases in payload and range and hence earning power of the aircraft. We plan to apply these results to military aircraft also and believe that through analytic techniques still more gains in aerodynamic design are possible.

Another venerable aeronautical discipline is loads and structures. We are developing methods of predicting loads induced by unsteady flight resulting from rough air and pilot input and means for alleviating these through automatic flight controls. We are also developing design procedures for use of new materials including composite materials and metal-composite combinations.

An interesting new result in loads and structures research is the use of a tape impregnated with boron fibers as a structural strengthening technique. Considerable work is being performed by industry and by other Government agencies, particularly the Department of Defense, on boron fibers and structures containing boron. Boron tape is a new development with some exciting new possibilities. Figure 3 compares relative weight ratios between aluminum with and without the boron tape for the same loading, 4700 pounds. Dimensions and weights of the two samples shown. The aluminum tube with boron tape weighs less than half the all-aluminum tube for the same strength. On the left of the figure is a comparison of the relative weight to strength ratios for the two samples. The boron tape, which resembles ordinary recording tape in appearance, uses epoxy to embed the boron fibers. It is applied to the metal surface with epoxy cement.

Figure 4 illustrates the calculated potential weight savings in a typical aircraft structure. Shown on the left is a panel reinforced with Z-section stiffeners made of aluminum, typical of today's aircraft construction practice. The panel would weigh 5.69 pounds and would sustain 46,000-pounds compressive load applied at the edges in the lengthwise direction. The sketch on the right shows a panel of the same length and width as the panel of the left designed to sustain the same compressive load - 46,000 pounds. The panel on the right, however, would have boron tape applied to one surface of the Z-section stiffeners which would allow considerable reduction in the size of the stiffeners. The thickness of the plate was kept the same in both cases. The reduction in the size of the stiffeners resulted in a calculated weight reduction of 24% for the structure on the right.

The design principle being pursued in this work is the application of the high-strength boron fibers at the location of maximum stress in the structure, thus using the material in the most efficient manner and reducing costs. We are presently evaluating replies from industry in response to our request for proposals for ways of best utilizing this structural concept.

In addition to applying new techniques in older disciplines, we are expanding our program in the newer sciences of importance to the advancement of aeronautics such as avionics, human factors, flight dynamics and operational environment. Let me illustrate these with one example: aircrew performance.

We know, of course, that aircrew performance deteriorates with fatigue. There are many stress factors that reduce man's physiological and psychological fitness for sustained flying. We are studying what stresses contribute to the total effect of fatigue and developing methods for measuring fatigue. It is obvious that such research can have widespread implications in civilian life, industry, the military, and space flight for situations where man must perform under high stress.

One new instrument for monitoring the heart has been developed by the Flight Research Center and is illustrated by Figure 5. It is an elastic, vest like garment which contains dry silver-coated electrodes. The vest simply holds the dry electrodes against the skin to pick up the electrocardiogram which allows the heart's electrical output to be studied in three dimensions. The vest is easily donned and is comfortable for wearing for long periods.

In other research, aircrew performance is studied to reduce the workload - particularly during landing such as a Category II condition or a minimum ceiling of 100 feet and a runway visual slant range of about 1,250 feet. At normal approach speeds and glide angles the crew has about 10 seconds after visual contact to judge whether or not it is safe to land. The Ames Research Center has adapted a flight simulator to study this workload problem illustrated by Figure 6. The degrees of physiological stress experienced by pilots in such situations is being determined by measuring the amount of stress hormones in their blood and urine. There are other related studies under way but these are illustrative of the group.

The second major part of aircraft technology deals with the problems of aircraft classes, as illustrated by Figure 7. We see an increasing potential of all these classes. We are giving more attention to general aviation and the problems of the private pilot, particularly in the areas of safety and ease of operation. As you well know, there are over a 100 thousand of these aircraft today and this number is expected to double in ten years.

For example, in cooperation with the FAA, we are working on warning indicators as a means for avoiding air collisions. One possible method for clear weather condition is the use of xenon flashing lights and electronic detectors. The lights not only give a brillian visual flash but also emit a large amount of infrared energy. The latter can be picked up by an infrared detector and used to alert the pilot who can then visually sight the other aircraft and avoid a collision. Figure 8 shows an experiment of this concept conducted by the Electronics Research Center. The Xenon light is shown mounted on the aircraft in the lower left. The detector in the bottom center was on the ground. The results, shown on the bottom right, indicate that the technique is feasible.

Perhaps the greatest future potential in aviation, however, is the short-haul market using VTOL or STOL aircraft. We are stepping up our pace of work on these type aircraft with the emphasis on making them more economically feasible and capable of all-weather operation. As you are aware, the rate of development of operational V/STOL aircraft, with the exception of helicopters, has been disappointing.

Some years ago we thought the gas turbine would provide the answer and many different types of V/STOL aircraft were build to prove it. The reasons for the failure of the development of V/STOL aircraft, despite the obvious civil and military needs, are becoming increasingly evident. One problem is illustrated by Figure 9, which shows the trade off between hover time, needed for maneuvering around crowded airports, and cruise speed, needed for good economy. No single VTOL type meets both of these performance requirements for economical operation. Another problem is the ability to take off quickly, quietly, and precisely with great regularity from small airports in all types of weather. This involves problems of flight dynamics, navigation, and terminal guidance. Here is where avionics will play an increasingly important role. Another problem is the transition between forward motion and lift which must be done efficiently and smoothly under well-controlled conditions.

We are working on these problems and virtually all the VTOL aircraft shown. Typical tasks include the jet flap rotor to increase helicopter speed and reduce vibration, the dynamics of stowed rotor helicopters, wind tunnel tests of the tilt rotor type, flight standards using the XC-142 tilt wing, and lift-fan technology using the XV-5 in cooperation with the Army.

Our work in supersonic transports is directed primarily at propulsion and flight dynamics of second-generation transports and to give technical support to the FAA in the development of the SST when needed. We are continuing, but at a reduced level, our research on hypersonic type aircraft for the distant future. The work is directed towards the practicality of cruise speeds of Mach

6 to 12 with emphasis on propulsion, structures, and aerodynamics.

One significant trend in our aircraft technology program, one that carries us beyond the role of the old NACA, is into proof-of-concept activities. Civil aviation has historically received the fruits of military aviation R&D but in recent years these benefits have been decreasing. This comes from an increasing divergence between military and civil aircraft requirements. This divergence is opening a gap between research and prototype flight equipment or aircraft and we are moving to fill this gap. Noise is a typical example of this military-civil divergence. The military places little or no emphasis on noise reduction if there is any potential performance penalty involved. As a result, most engines today, which are descendents of military developments, are quite noisy. The public outcry over aircraft noise has resulted in a step into the realm of proof-of-concept in noise research.

We are working on three approaches to alleviating or reducing noise from aircraft. The first and short range solution is to suppress the noise generated by current engines by use of acoustic absorption methods. Our first objective is to achieve a 6 to 10 PNdb reduction in fan-compressor noise during the landing approach by the modification of the nacelles of existing jet transports. The work is being performed under contract to both McDonnell-Douglas and Boeing. In the McDonnell-Douglas program, we have completed the evaluation of acoustical materials, fan exhaust and inlet design studies and duct model tests and full-scale boilerplate ground tests. The next stage will be a flight demonstration of a DC-8 equipped with modified noise suppressing nacelle to be completed by March of next year. The Boeing program, in addition to acoustic treatment of the nacelle, is also investigating the use of inlet choking by modification of the inlet geometry in flight to prevent the noise generated by the fan-compressor from propagating forward. Here we have also completed material evaluations, conducted full-scale duct tests and inlet design studies choked inlet tests and boilerplate inlet and duct tests with prototype nacelle. The next stage will be the fabrication of modified nacelles and flight tests with four modified nacelles on a Boeing 707-320C airplane to be completed by July 1969. The results of both programs will be completely documented by next fall. While these programs are not scheduled for completion for over a year the results have been disseminated throughout the industry as rapidly as they become available.

Some very encouraging results have been obtained in the program, as illustrated by Figure 10. Shown, is sound pressure level in decibels versus frequency in cycles per second for a JT3D engine currently in use on 707 aircraft. The solid curve is for the 707 production nacelle with a short fan-discharge duct. When an acoustically treated duct discharge 3/4th length of the nacelle is used, significant reduction in sound pressure level is obtained in the frequency bands in which the ear is particularly sensitive.

A second way to reduce noise is to use a steeper glide slope for landing and take-off. In tests we obtained reductions in peak ground noise of 8 PNdb by increasing the landing glide slope from 3 to 6 degrees with the decrease coming both from distance and power reduction effects. Our flight tests have been directed toward the additional guidance and control aids needed to fly the steep path. As part of this program a new flap system was installed on a Boeing 707 prototype by the Ames Research Center. Figure 11 illustrates the direct lift control devices. We are also studying pilot workload and the information he will need for utilizing steep approach paths.

The third approach to reducing noise is to design an engine from the start that will be quieter than current engines. It is this approach that leads to proof-of-concept later. The first step, nearing completion, includes engine-cycle analysis and preliminary design analyses to arrive at designs that minimize noise and retain reasonable efficiency.

The engine will have a high by-pass ratio to reduce exhaust noise. Reduction in fan tip speed appears to offer the greatest potential for reducing fan noise. The attainment of efficient fan performance at reduced speeds, however, is a problem receiving considerable attention. A requests for proposals has been issued to industry for detailed design, fabrication, and tests of a research engine. The ultimate goal is a demonstrator engine that will incorporate the best noise reduction techniques and be 20 db quieter than comparable engines in the 20,000 pound thrust class.

I mentioned earlier that in the past most new aircraft technology evolved from military requirements which bore most of the costs between technology and application. Commercial aviation could adopt the new technology at small risk and cost. But as I also mentioned previously, the noise problem is of small concern to the military so the cost of solving it will have to be shared by the industry. The cost will be very high as thousands of engines are involved. Moreover, if a proposed solution proved to be unacceptable, the costs could be disastrous to the industry. The problem also involves land use, aircraft operational control, and regulations, which are all beyond industry responsibility. In view of the national importance of this problem it seems reasonable that the government take the initiative, which it has, and that NASA should be responsible for providing the needed technology and proving its validity. It is this type of activity, proof-of-concept, that I had in mind earlier in pointing out a trend towards industry carrying an increased portion of our program.

Summing up for aircraft technology, we are increasing our effort by increases in old and new aeronautical disciplines, in V/STOL technology, and in noise reduction. The last is carrying us into proof-of-concept activities to fill a need formerly fulfilled by military R&D and this will lead to increased participation by industry in our program.

The second major need that will influence future aerospace activities is low-cost space boosters. We have seven reliable launch vehicles for space ranging from the all-solid propellant Scout, which carries about 300 pounds into orbit for a little over a million dollars, to the mighty Saturn V which will carry almost a thousand times more payload at a cost that can approach 200 times as much. These vehicles drew on the great military missile R&D of the 1950's plus other technology, such as the hydrogen-oxygen technology of the NASA Lewis Research Center developed during the same period. These launch vehicles, backed by competent teams from government and industry, have reached or are nearing a state of high reliability; they are examples of a national capability of which we can all be very proud. However, we are faced with an urgent problem - the mounting cost of these boosters. The pressing need is for boosters as reliable as those we now have but which can carry their payloads at a fraction of present costs. This means a fresh approach to the entire concept of boosters and a critical examination of each step in the complex process from the drawing board to the end of the boost operation. It would be ideal, of course, to have reusable boosters that could make multiple flights like aircraft. We and others have studies reusable boosters and find 1) the technology is not on hand and 2) the R&D costs will be very high so there must be enough traffic to amortize the huge investment. Since this amount of traffic is not in the forecast for the next decade, we have turned to an intermediate solution, a low-cost single use booster, a later refinement of which could be recoverable upper stages carrying the more costly electronic equipment and flight subsystems.

There are two candidates for a low-cost first booster stage, the large solid propellant motor and the large simplified liquid engine, the so called "big dumb booster." Cost analyses, which are not too reliable at this state of the technology, indicate no significant cost difference. The technology for large solid motors, however, is probably farther along than for the simple liquid booster. Figure 12 shows the test record of large solid motors through last year. The Air Force program on 156 inch diameter solid motor has had nine tests and there have been three 260 inch diameter solid motor firings in the NASA program. Figure 13 shows the static test of the 260 inch SL3 solid motor in June 1967. Peak thrust was 5.9 million pounds, a world record of high thrust for a single motor, we believe. Near the end of the firing, however, there was a spectacular display resulting from ejection of burning fragments. This was caused by the improper bonding of batches of propellants during loading and is one of the problems that must be cleared up.

Another problem is lower cost nozzles, insulation, and cases through the use of different materials and techniques. Another problem requiring more attention for achieving lower cost is thrust vector control. We feel that these problems can be solved with one or two more years of technology effort and the firing of another 260 inch solid as a proof-of-concept. Concurrent with this, we are making vehicle design studies and possible missions and these indicate that a vehicle with a earth-orbit payload of about 100,000 pounds is an optimum size for a new booster. This size could be met by using a first stage consisting of either a cluster of 156 inch solid motors or a single 260 inch motor or a simple liquid propellant stage and a modified SIVB as the initial upper stage. We are examining ways that the SIVB could be simplified for this mission as, for example, removal of restart capability.

The third major need with a large impact on future aerospace activities is the use of nuclear energy for propulsion and electric power generation in space.

The phenomenal success of the nuclear rocket program, jointly conducted by the AEC and NASA, is a record of which we are very proud. Figure 14 shows the accumulated reactor and engine test time which totals 509 minutes. Last year a reactor was operated an hour at full power and numerous tests show the versatility of the system for start, restart, and variable power operation. Figure 15 is a photograph of a typical test. The time has come to make full use of this storehouse of technology by developing a flight engine. The engine, illustrated by Figure 16, would develop 75,000 pounds thrust and have a specific impulse almost double the best chemical system in use. The first logical use of the NERVA engine would be for a stage to replace the SIVB of Saturn V. It about doubles the payload and is most effective for high velocity missions such as to the planets. We are already in the design stage and we are recommending that the NERVA engine development be continued with engine and stage ready for a mission as early as 1977. We are working with other NASA offices in studying planetary and other types of missions that can use the high performance capability of a nuclear engine.

We are also working jointly with the AEC on nuclear electric power generation. Radio isotope electric power systems for low power ranges, 25 to 65 watts are already being used or planned for flight missions. The largest reactor electric generator is SNAP 8 which will generate 35 to 50 kilowatts. It is a turbomachine operating on the Rankine thermodynamic cycle, Figure 17, with three liquid metal flow loops. A sodium-potassium loop conveys heat from the reactor to a boiler where it heats mercury which drives the turboalternator.

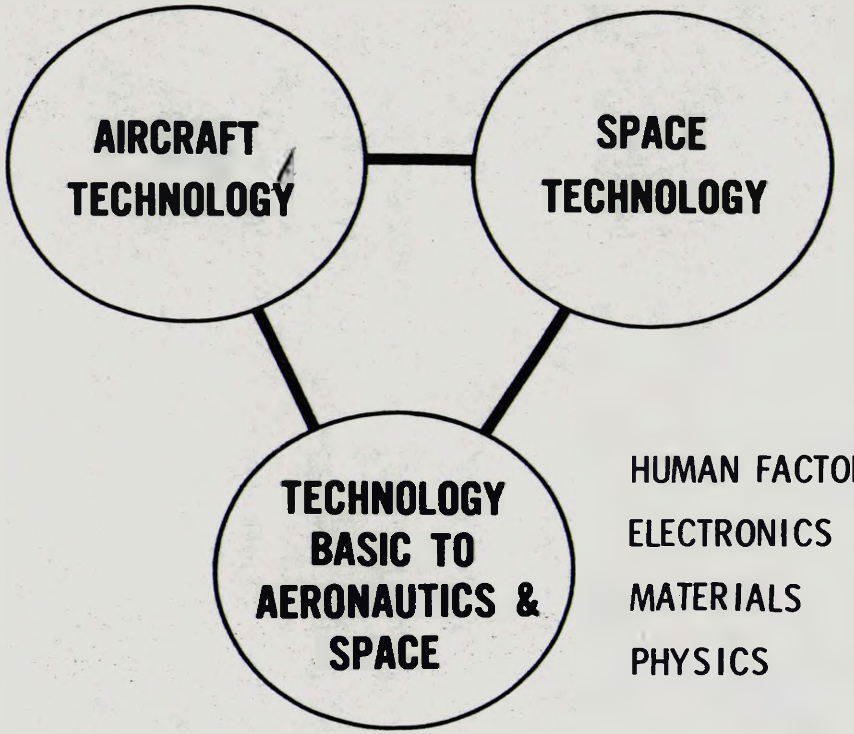
A second sodium-potassium loop removes waste heat. A fourth loop lubricates the turboalternator and pumps. The problems encountered have been formidable but we are now operating the major components in endurance tests with accumulated time of several thousand hours with a goal of 10,000 hours or better. A possible early application for such a power system would be on the lunar surface.

In summary, I have covered the role of OART in providing the enabling technology for future missions and assisting in solving current problems I have discussed three major needs-increased aircraft technology, low-cost boosters, and utilization of nuclear energy in space. I have indicated that as we move towards proof-of-concept work, industry, which already carries out the major part of our program, will become more deeply involved.

LIST OF FIGURES

ADVANCED RESEARCH & TECHNOLOGY

- SYSTEM STUDIES
- AERODYNAMICS
- STRUCTURES
- PROPULSION
- FLIGHT DYNAMICS
- OPERATING PROBLEMS



- SYSTEM STUDIES
- AEROTHERMODYNAMICS
- STRUCTURES
- PROPULSION
- SPACE POWER

HUMAN FACTORS

ELECTRONICS

MATERIALS

PHYSICS

NASA HQ RC68-15710
12-6-67

Figure 1

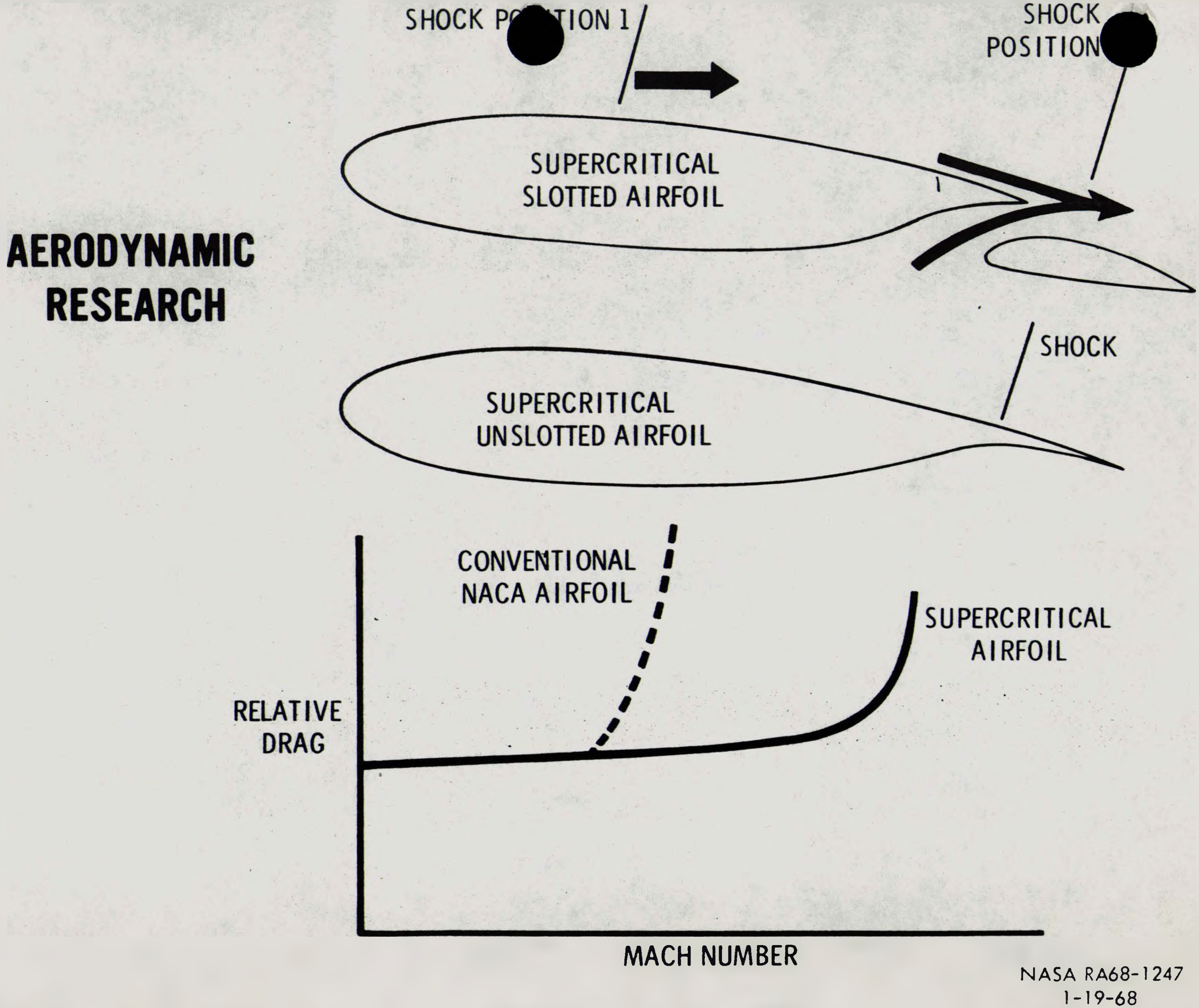
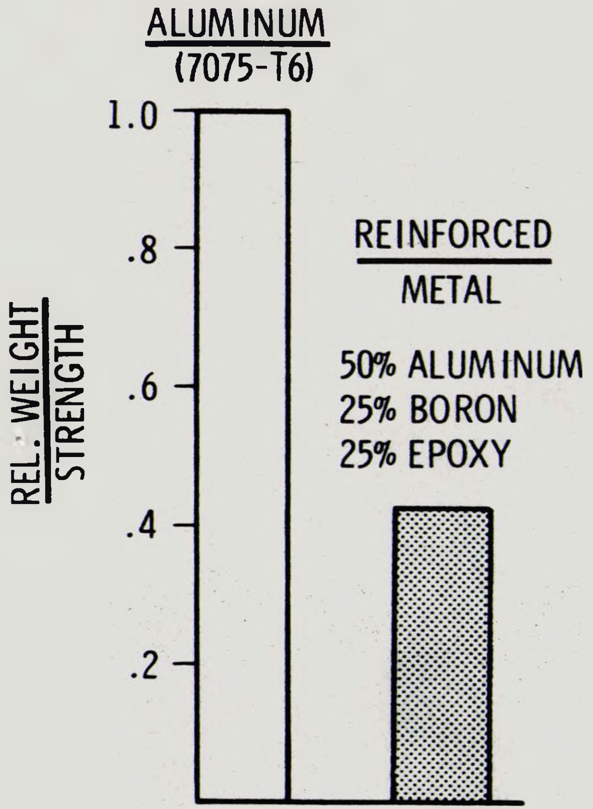
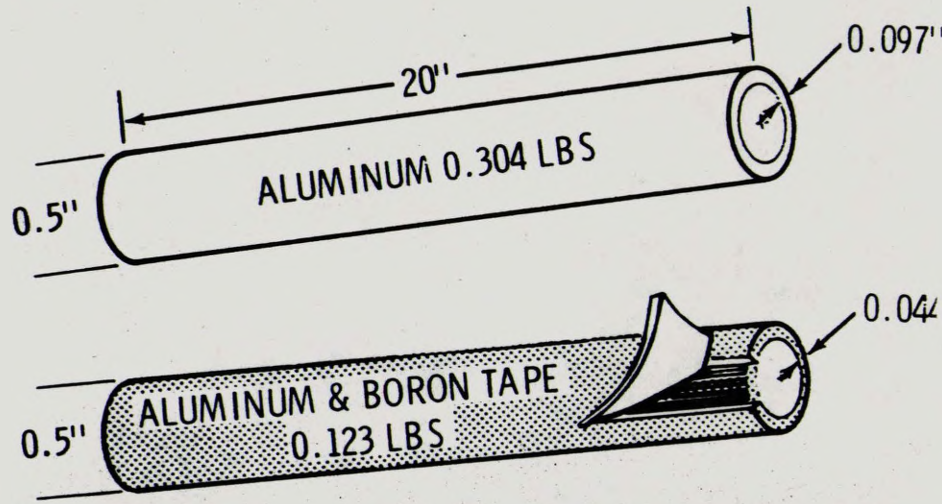

AERODYNAMIC RESEARCH
SHOCK PO TION 1
SHOCK POSITION
SUPERCRITICAL SLOTTED AIRFOIL
SHOCK
SUPERCRITICAL UNSLOTTED AIRFOIL
CONVENTIONAL NACA AIRFOIL
SUPERCRITICAL AIRFOIL
RELATIVE DRAG
MACH NUMBER
NASA RA68-1247
1-19-68

Figure 2

RELATIVE WEIGHT RATIOS

COMPRESSIVE LOAD 4700lbs



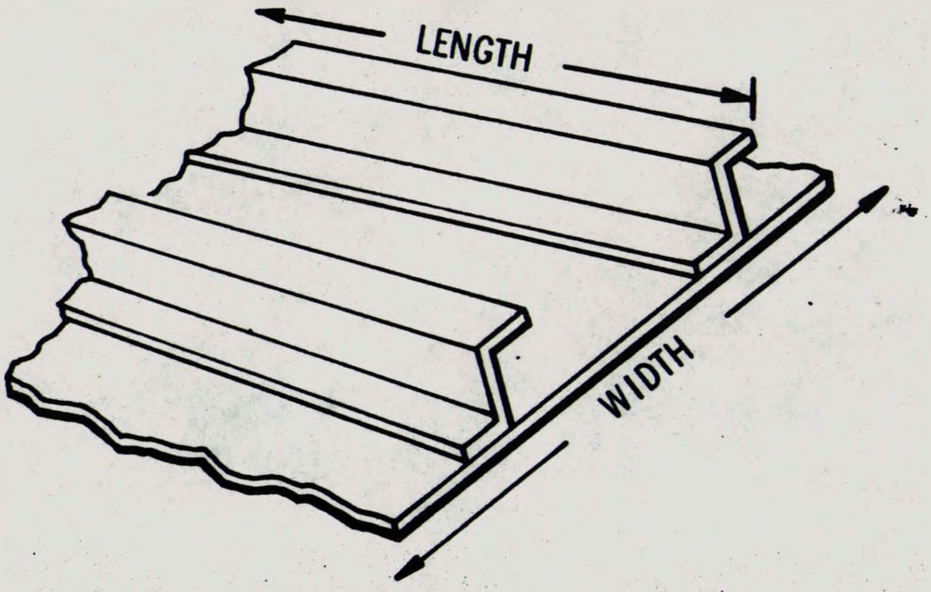


NASA RA68-1183
1-15-68

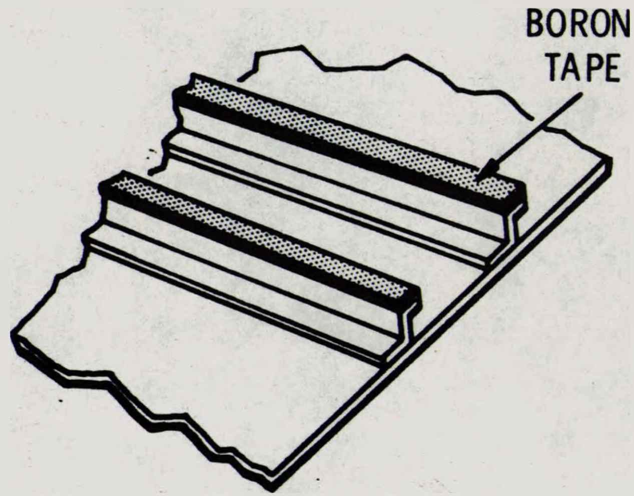
Figure 3

WEIGHT REDUCTION FOR
TYPICAL AIRCRAFT STRUCTURE

COMPRESSIVE LOAD 46000 LBS FOR 10-INCH WIDE PANEL



ALUMINUM (7075-T6)
WEIGHT – 5.69 LBS.



ALUMINUM & BORON TAPE
WEIGHT – 4.30 LBS.
[WEIGHT REDUCTION – 24%]

NASA RA68-1182
1-15-68

Figure 4

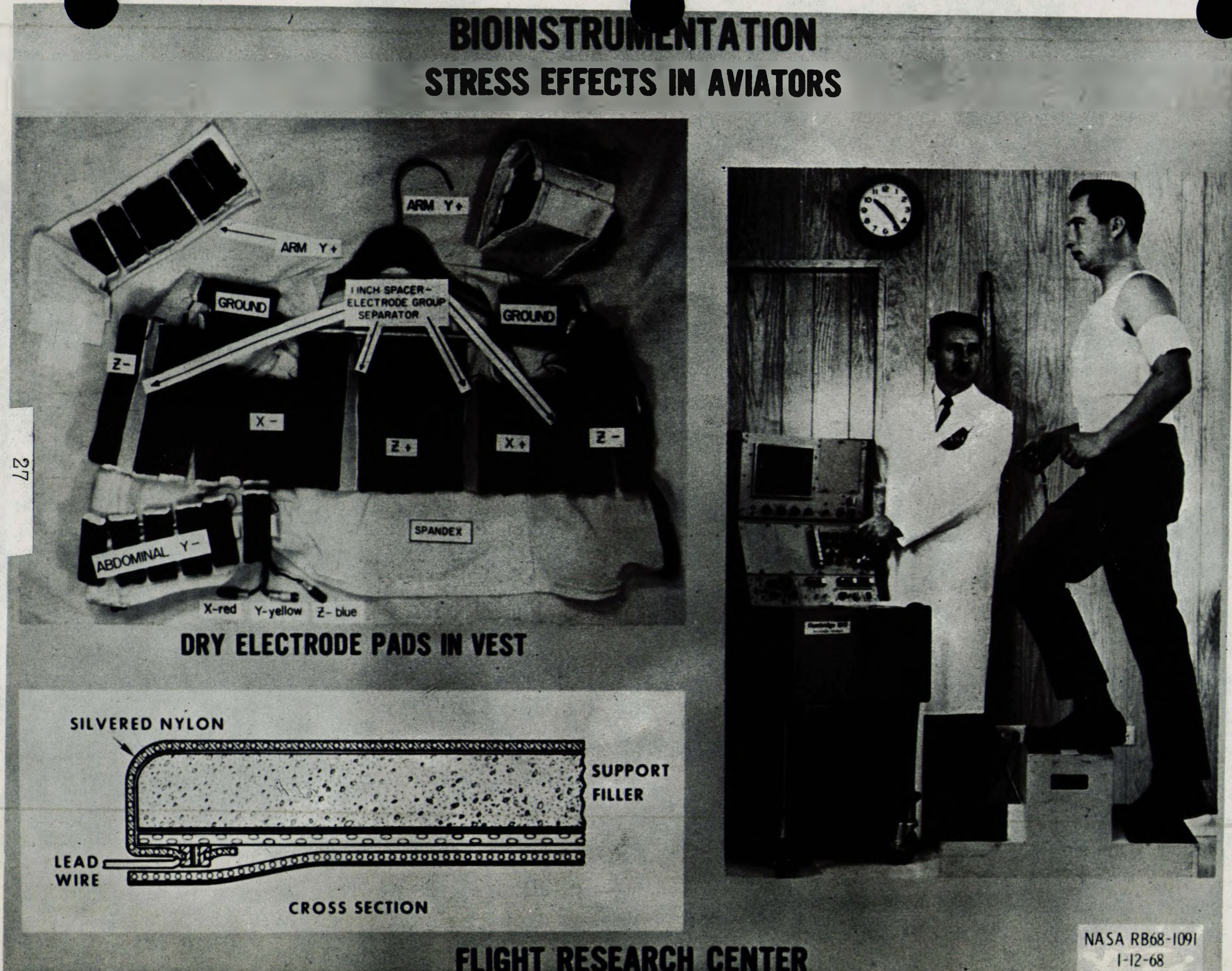

BIOINSTRUMENTATION
STRESS EFFECTS IN AVIATORS
ARM Y+
ARM Y+
1 INCH SPACER-ELECTRODE GROUP SEPARATOR
GROUND
GROUND
Z-
X-
Z+
X+
Z-
SPANDEX
ABDOMINAL Y-
X-red
Y-yellow
Z-blue
DRY ELECTRODE PADS IN VEST
SILVERED NYLON
SUPPORT FILLER
LEAD WIRE
CROSS SECTION
FLIGHT RESEARCH CENTER
NASA RB68-1091
1-12-68

Figure 5

PLANNED AIR CREW WORKLOAD RESEARCH

28

AMES RESEARCH CENTER

NASA RB68-1092
1-12-68

Figure 6


FUTURE AIRCRAFT
HYPERSONIC
ADVANCED SUPERSONIC AND SUBSONIC
ADVANCED BUSINESS AND PERSONAL
SHORT HAUL ALL-WEATHER V/STOL
NASA R 67-1343
12-28-66

Figure 7

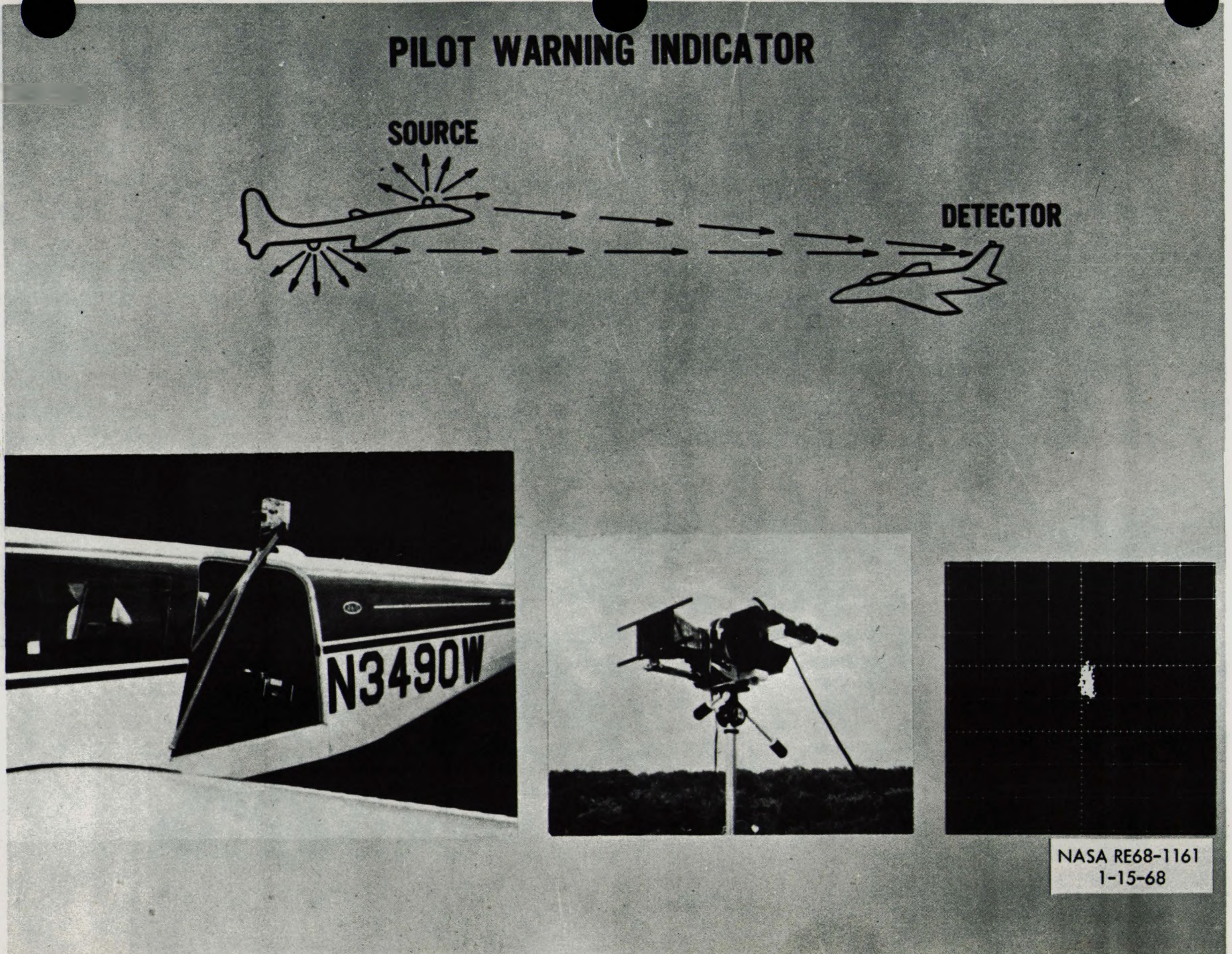

PILOT WARNING INDICATOR
SOURCE
DETECTOR
N3490W
NASA RE68-1161
1-15-68

Figure 8

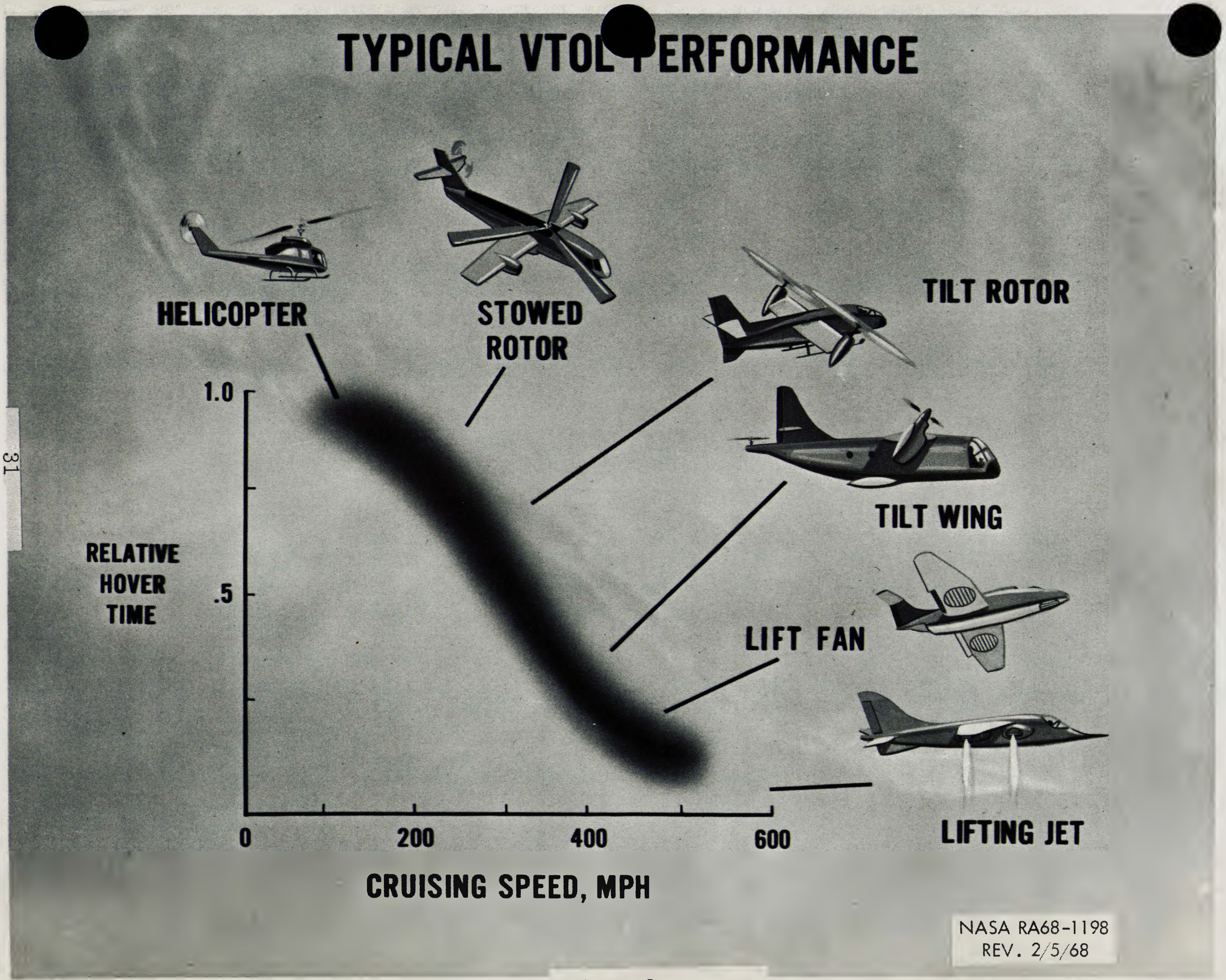
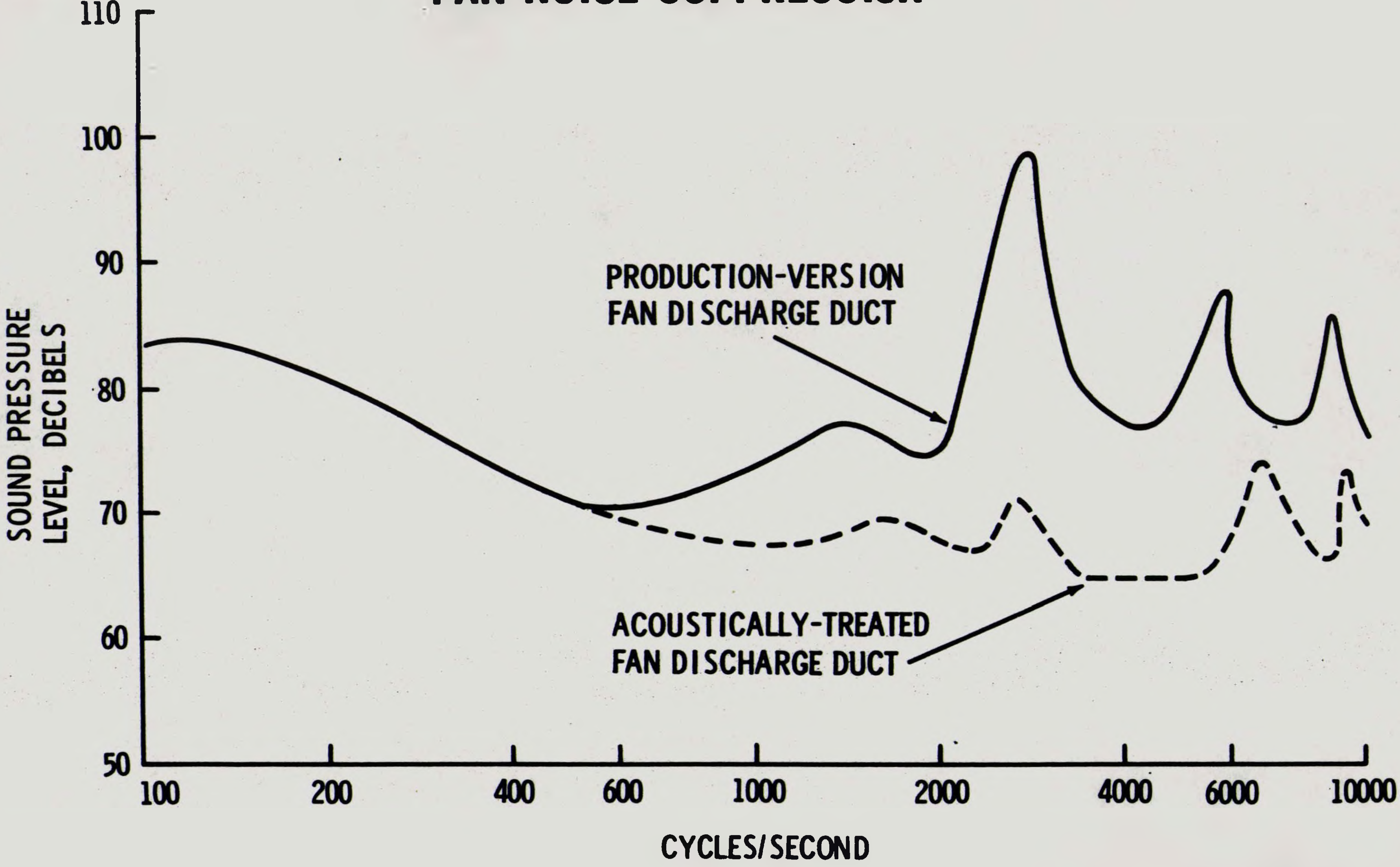

TYPICAL VTOL PERFORMANCE
HELICOPTER
STOWED
ROTOR
TILT ROTOR
TILT WING
LIFT FAN
LIFTING JET
RELATIVE
HOVER
TIME
1.0
.5
0
200
400
600
CRUISING SPEED, MPH
NASA RA68-1198
REV. 2/5/68

Figure 9

FAN-NOISE SUPPRESSION



NASA RA68-1188
1-15-68

Figure 10

DIRECT LIFT CONTROL DEVICES

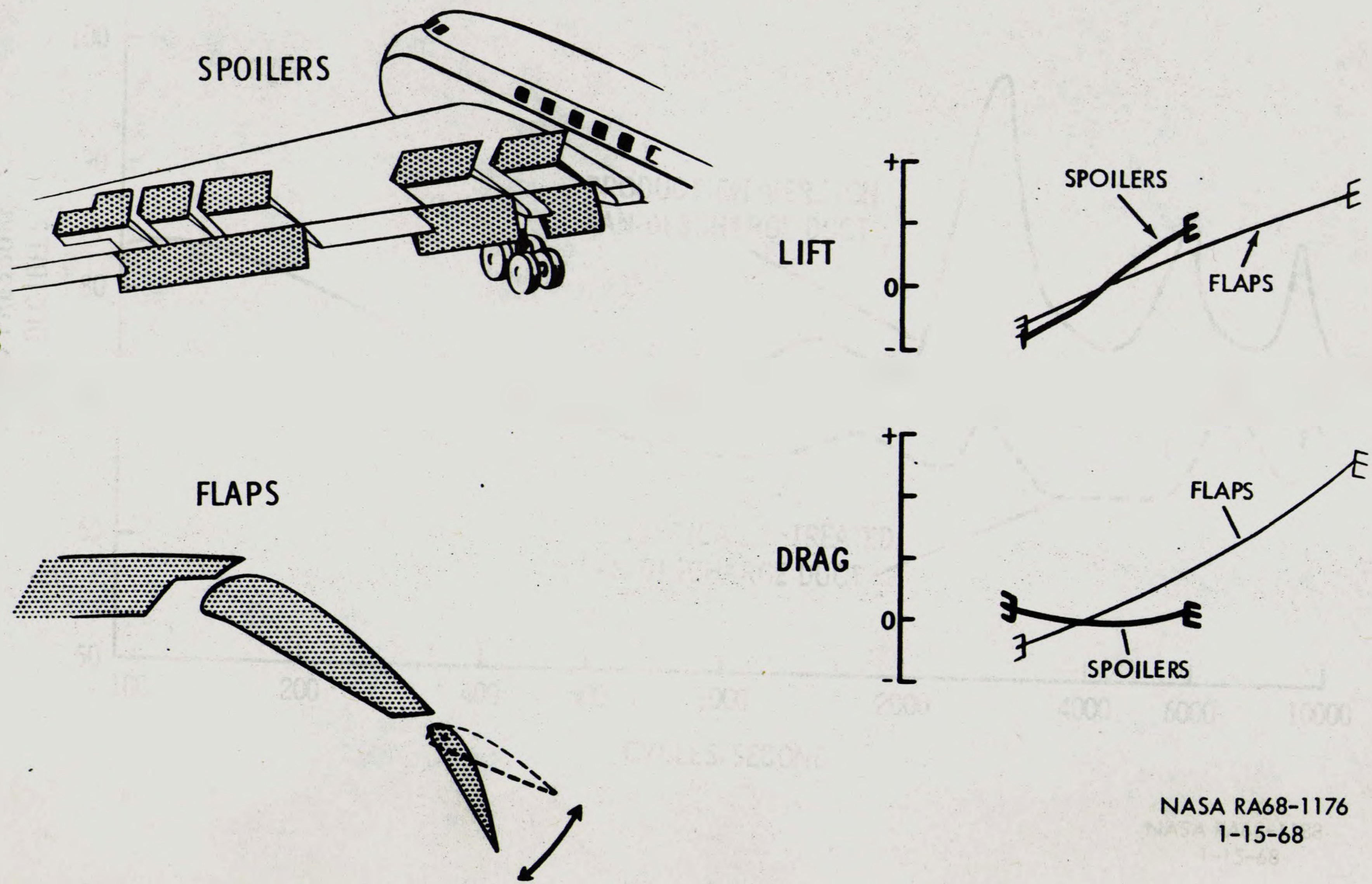


Figure 11

LARGE SOLID MOTOR TEST RECORD

MOTOR DESIGNATION	TEST DATE	PROP WGT (10^6 LB)	MAX THRUST (10^6 LB)	BURN TIME (SEC)	TVC TEST	COMPANY
156–1	5–64	0.42	0.9	108	JET TABS	LOCKHEED
156–2	9–64	0.63	1.1	143	JET TABS	LOCKHEED
156–3	12–64	0.69	1.4	126	GIMBAL	THIOKOL
156–4	2–65	0.80	3.3	59	NONE	THIOKOL
156–5	12–65	0.69	3.1	55	LIQUID INJ	LOCKHEED
156–6	1–66	0.27	1.0	65	LIQUID INJ	LOCKHEED
156–HG	4–66	0.16	0.3	122	HOT GAS INJ	LOCKHEED
156–7	5–66	0.13	0.4	110	LIQUID INJ	THIOKOL
156–9	5–67	.27	1.0	77	FLEX BEARING	THIOKOL
260, SL–1	9–65	1.7	3.6	114	NONE	AEROJET
260, SL–2	2–66	1.7	3.6	114	NONE	AEROJET
260, SL–3	6–67	1.7	5.9	70	NOZZLE STRUCTURE ONLY	AEROJET

DAC DATA

NASA HQ RP67-17073
Rev. 1-25-68

Figure 12

STATIC TEST OF SL-3 SOLID MOTOR

JUNE 17, 1967

PEAK THRUST — 5.9M POUNDS

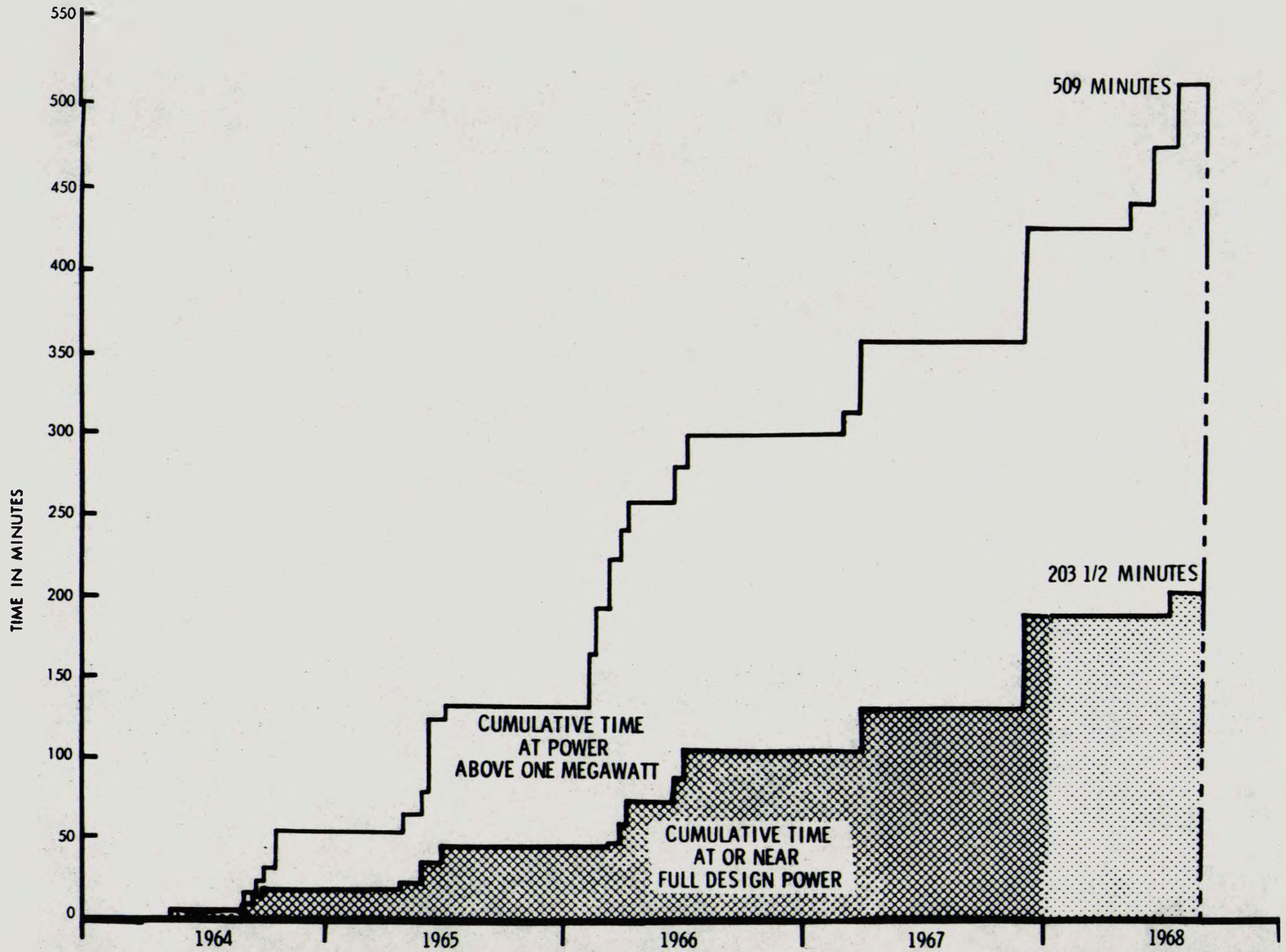
THROAT DIAMETER—89 INCHES

WEIGHT ——— 1.7M POUNDS

NASA HQ RP67-17040
Rev. 1-25-68

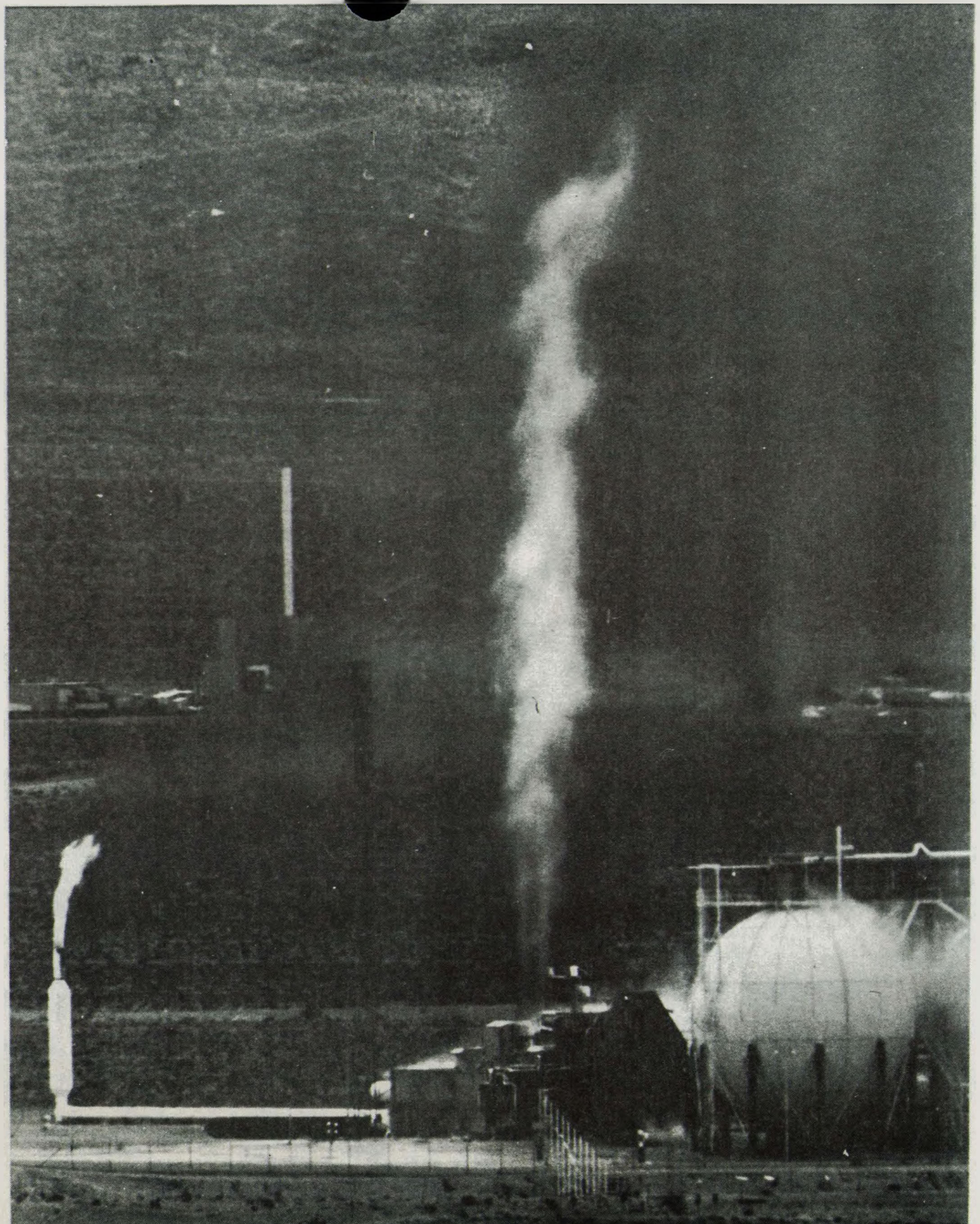
Figure 13

REACTOR AND ENGINE SYSTEM CUMULATIVE TEST TIME
1964-1968



NASA NPO67-1569
Rev. 10-30-68

Figure 14

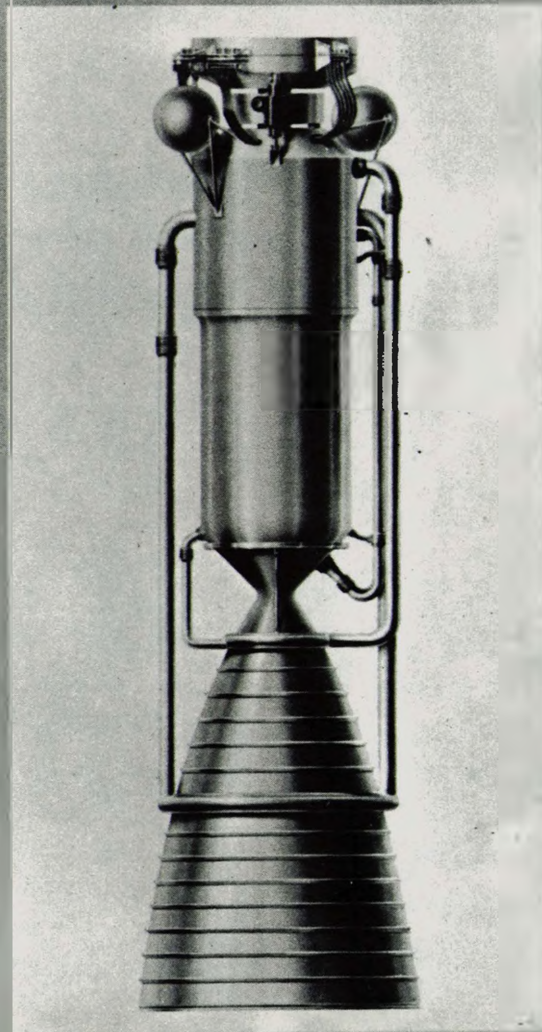


NASA HQ RC68-15828 1-8-68

Figure 15

NERVA ENGINE

- THRUST, LB.
  APPROXIMATELY 75,000
- SPECIFIC IMPULSE, SEC.
  825
- CHAMBER TEMPERATURE, °R
  4,500
- PROPELLANT FLOW RATE, LB/SEC.
  90



NASA HQ NPO 68-15840
REV. 2-5-68

Figure 16

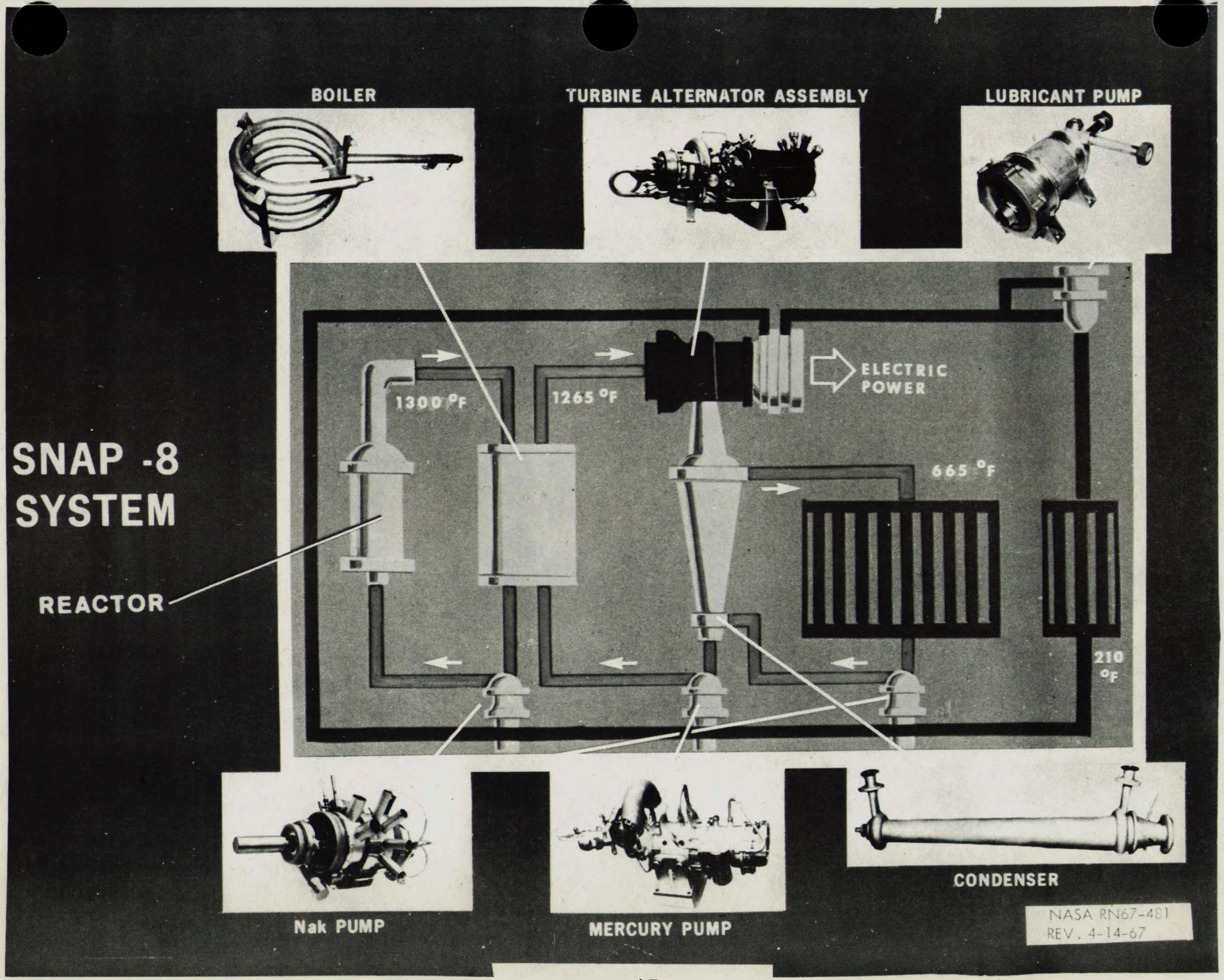

BOILER
TURBINE ALTERNATOR ASSEMBLY
LUBRICANT PUMP
SNAP -8
SYSTEM
1300 °F
1265 °F
ELECTRIC
POWER
665 °F
210
°F
REACTOR
Nak PUMP
MERCURY PUMP
CONDENSER
NASA RN67-481
REV. 4-14-67

Figure 17

B-9

THE OUTLOOK FOR THE SPACE PROGRAM

BY

JOHN E. NAUGLE
ASSOCIATE ADMINISTRATOR FOR
SPACE SCIENCE AND APPLICATIONS

PRESENTED AT
NASA PASADENA OFFICE
THIRD ANNUAL AWARDS CEREMONY

OCTOBER 4, 1968

IT IS GOOD THAT WE ANNUALLY REVIEW THE WORK OF INDIVIDUALS AND GROUPS TO SEE WHO SHOULD BE COMMENDED FOR SUPERIOR PERFORMANCES. IT IS ALL TOO EASY THESE HECTIC DAYS TO CONCERN OURSELVES ONLY WITH THOSE PARTS OF THE PROGRAM WHICH ARE IN TROUBLE WHILE ACCEPTING A SUPERIOR PERFORMANCE AS ROUTINE, SOMETIMES WITHOUT EVEN REALIZING THAT THE DEMANDS OF THE SPACE PROGRAM ARE SUCH THAT A ROUTINE SUCCESS IN OUR WORK WOULD BE REGARDED AS A PHENOMENAL ACHIEVEMENT IN MOST HUMAN ENDEAVORS.

THIS HAS BEEN A TRAUMATIC YEAR FOR NAPO AND FOR THOSE OF YOU WHO WERE WITH THE WESTERN SUPPORT OPERATION PRIOR TO ITS INCORPORATION INTO NAPO. YOU PEOPLE AND YOUR DIRECTOR, MR. SAMPLE, ARE TO BE COMMENDED FOR YOUR FORBEARANCE AND FOR THE FORTHRIGHT WAY YOU HAVE GONE ABOUT SOLVING THESE EXACERBATING REQUIREMENTS WHICH WE IN HEADQUARTERS HAVE--RELUCTANTLY--HAD TO PLACE ON YOU.

FOR ALL OF THESE REASONS, IT IS A PARTICULAR PLEASURE FOR ME TO BE ABLE TO JOIN WITH YOU TODAY TO HONOR THE ACHIEVEMENTS AND SERVICE RECORDS OF NAPO EMPLOYEES.

IT ALSO SHOULD BE NOTED THAT THIS CEREMONY IS TAKING PLACE DURING THE MONTH WE ARE CELEBRATING NASA'S TENTH ANNIVERSARY. THE SIGNIFICANCE OF THESE OCTOBER CEREMONIES LIES IN THE FACT THAT NASA IS A CREATURE COMPOSED OF MANY INDIVIDUAL ELEMENTS--LARGE AND SMALL, SCIENTIFIC AND ADMINISTRATIVE, GEOGRAPHICALLY DISPERSED FROM THE ATLANTIC TO THE PACIFIC. EACH OF THESE INDIVIDUAL ORGANIZATIONS IS INEXTRICABLY INVOLVED IN AND CRITICAL TO NASA'S MISSION--ONE WHICH I THINK WE ALL FEEL IS ONE OF MAN'S GREATEST ENTERPRISES--THE EXPLORATION OF SPACE.

IN ASSESSING THE OUTLOOK FOR THE SPACE PROGRAM, WE NEED TO LOOK BACK FOR A MOMENT AT THE ACHIEVEMENTS OF THE PAST DECADE TO SEE WHAT THEY MAY TELL US ABOUT THE FUTURE. I BELIEVE WE HAVE A RIGHT TO BE PROUD. OVER AND ABOVE THE HIGHLY SUCCESSFUL MANNED AND AUTOMATED FLIGHT RECORD, THERE IS THE INDISPUTABLE FACT THAT WE HAVE CREATED OVER THESE YEARS A GROUP OF PEOPLE WITH A BASE OF EXPERTISE TO TACKLE THE EXCITING AND PRODUCTIVE PROGRAMS WHICH WE SEE IN THE YEARS AHEAD. IF WE COMPARE THE SIZE AND CAPABILITY OF THIS INSTITUTIONAL BASE TO THE INSTITUTIONAL BASE WE HAD BACK IN 1958, AND USE WHAT WE HAVE ACCOMPLISHED WITH THAT BASE TO EXTRAPOLATE WHAT WE MIGHT DO IN THE

NEXT DECADE WITH OUR PRESENT CAPABILITY, ONE MUST BE MIGHTILY IMPRESSED. THE SPACE PROGRAM HAS ATTRACTED SOME OF THE MOST CREATIVE AND PROMISING PEOPLE IN OUR SOCIETY AND PROVIDED THEM WITH SOME OF THE MOST DIFFICULT AND CHALLENGING PROBLEMS EVER PLACED BEFORE MEN. THAT INSTITUTIONAL BASE OF WHICH NASA'S PASADENA OFFICE IS A PART--IS PERHAPS ONE OF THE MOST OVER-LOOKED AND UNDERESTIMATED FEATURES OF OUR SPACE EFFORT. IT IS SIGNIFICANT BECAUSE NO FLIGHT PROGRAM--HOWEVER IMPORTANT--CAN COME TO FRUITION EXCEPT THROUGH THE ORGANIZED EFFORTS OF TEAMS OF PEOPLE--IN NASA, IN THE UNIVERSITIES, AND IN INDUSTRY. SO WHEN I LOOK BACK AT THE ACHIEVEMENTS OF THE FIRST TEN YEARS, I SEE NOT ONLY THE DRAMATIC RESULTS OF WHAT IMAGINATIVE MEN AND WOMEN HAVE ACCOMPLISHED IN THE DESIGN AND EXECUTION OF SPACE FLIGHTS BUT, MORE IMPORTANTLY, THE ORGANIZATION WHICH HAS BEEN CREATED AND WHICH IS AVAILABLE TO MEET THE EVEN GREATER CHALLENGES OF THE FUTURE. LET'S LOOK AT THE FUTURE--NOT THE DISTANT FUTURE--BUT THE NEXT FEW YEARS AND SEE WHAT KIND OF CHALLENGES THEY MAY PRESENT.

EACH OF US KNOWS THAT THE SPACE PROGRAM HAS TAKEN SOME SUBSTANTIAL CUTBACKS IN FUNDING AND OTHER RESOURCES. IN THAT RESPECT, OUR EXPERIENCE IS NOT UNLIKE MANY OTHER GOVERNMENTAL AGENCIES. AS THE ENVIRONMENT WITHIN WHICH WE MUST OPERATE CHANGED, WE HAVE HAD TO ACCOMMODATE TO NEW NATIONAL PRIORITIES AND CHANGING REQUIREMENTS. BUT KEEP IN MIND, LADIES AND

GENTLEMEN, THAT NEITHER THE INSTITUTIONAL BASE I MENTIONED PREVIOUSLY, NOR MAN'S QUEST FOR KNOWLEDGE, NOR THE IMPORTANCE OF THIS NATION'S OPERATIONS IN SPACE ARE EPHEMERAL PHENOMENA, SUBJECT TO THE WINDS OF PERSONAL OR POLITICAL FORTUNE. TAKEN TOGETHER, THEY CONSTITUTE A FORMIDABLE COMBINATION--ROUGHLY CORRESPONDING TO THE SINEW, SPIRIT AND DRIVE WHICH HAVE BROUGHT THIS NATION TO ITS PRESENT POSITION OF POWER.

WHAT CAN WE REALISTICALLY LOOK FORWARD TO IN THE NEXT YEAR OR TWO? ONE IMPORTANT DATA POINT IS NASA'S OPERATING PLAN FOR FY 1969. IT CALLS FOR AN AMBITIOUS EFFORT IN BOTH AERONAUTICS AND SPACE. IN THE AREA OF PHYSICS AND ASTRONOMY, WE WILL CONTINUE WITH OUR SOLAR AND ASTRONOMICAL OBSERVATORIES, WITH A SUBSTANTIAL NUMBER OF EXPLORERS AND WITH A BALANCED SOUNDING ROCKET PROGRAM. IN SPACE APPLICATIONS, WE HAVE INITIATED ADDITIONAL ADVANCED TECHNOLOGY AND NIMBUS SPACECRAFT WHICH WILL CONTINUE TO PROVIDE US WITH STABILIZED EXPERIMENT PLATFORMS IN POLAR AND SYNCHRONOUS ORBIT. EVEN IN THIS YEAR OF CONSTRAINT, OUR PROGRAM FOR PLANETARY EXPLORATION HAS TAKEN HOLD WITH A PROMISE OF EVEN STRONGER SUPPORT IN THE YEARS AHEAD. OUR PROGRAM INCLUDES, IN ADDITION TO THE MARS '69 FLIGHTS, A START ON ADDITIONAL PIONEERS TO GO TO JUPITER, AND THE INITIATION OF THE MARINER MARS '71 AND TITAN MARS '73 MISSIONS. ALTHOUGH OUR PLANETARY PROGRAM, AS CURRENTLY PROJECTED, IS SCALED DOWN

FROM THE VOYAGER APPROACH, IT STILL REPRESENTS A DYNAMIC SERIES OF FLIGHT MISSIONS, WHICH WILL PROVIDE THE KNOWLEDGE AND EXPERIENCE WHICH WILL ENABLE US TO MOVE ON TO SYSTEMATIC EXAMINATION OF THE NEARBY PLANETS AND EXPLORATION OF THE PLANETS OUT TO AND BEYOND JUPITER.

THE SPACE SCIENCE PROGRAM FOR FY 1969 TOTALS SLIGHTLY IN EXCESS OF 435 MILLION DOLLARS. IF WE DO NO MORE THAN CARRY OUT THE '69 PROGRAM, THE FY '70 BUDGET WILL GROW TO ABOUT $500 M. IN FY 1970 AND BEYOND, WE FULLY EXPECT TO OBTAIN INCREASES NECESSARY NOT ONLY TO CARRY OUT THIS APPROVED PROGRAM AS PROJECTED, BUT TO INTRODUCE SOME NEW AND IMPORTANT MISSIONS TO STUDY EARTH RESOURCES AND TO INTRODUCE SOME SMALL PLANETARY EXPLORERS.

IN MOVING FORWARD ON THIS TYPE OF FLIGHT PROGRAM, HOWEVER, WE MUST ALWAYS KEEP IN MIND THAT NEW PATTERNS AND CHANGING PRIORITIES IN SPACE SCIENCES ARE EMERGING WITHIN OUR OVERALL PROGRAM. DURING THE NEXT FEW YEARS, FOR EXAMPLE, IT IS CLEAR TO ME THAT OUR EFFORTS IN ASTRONOMICAL OBSERVATIONS, IN SPACE APPLICATIONS AND IN PLANETARY EXPLORATION, SHOULD RECEIVE PRIORITY AND OUR PROGRAM PLANS MUST, THEREFORE, REFLECT THESE JUDGMENTS. I BELIEVE WE HAVE REASON TO EXPECT AN INTEREST IN AND SUPPORT FOR SUCH A PROGRAM. IN ASTRONOMY, PERHAPS MORE THAN IN ANY OTHER SCIENTIFIC DISCIPLINE, MAJOR PROGRESS HAS BEEN SCHIEVED WHEN A NEW OBSERVING TECHNIQUE IS USED. IN THE

NEXT SEVERAL YEARS, WE WILL PROVIDE OUR ASTRONOMERS WITH SUCH NEW OBSERVATIONAL TOOLS--TELESCOPES AND DETECTORS IN SPACE ABOVE THE ABSORBING AND ~~OBSERVING~~ obscuring EFFECTS OF THE EARTH'S ATMOSPHERE. PERHAPS THE MOST SIGNIFICANT ASPECT OF THE ASTRONOMY PROGRAM IS THAT WE ENVISION A COMPLEMENTARY PROGRAM USING BOTH MANNED AND AUTOMATED OBSERVATIONAL PLATFORMS LEADING TO PERMANENT OBSERVATORIES IN SPACE IN THE NEXT 10 TO 15 YEARS. ON THE ONE HAND, OAO, OSO, AND THE SMALL ASTRONOMY SATELLITE WILL CARRY THE BURDEN OF AUTOMATED ~~EXPLORATION~~ observation, WHILE THE APOLLO TELESCOPE MOUNT PROVIDES US WITH EARLY EXPERIENCE IN MANNED ASTRONOMY. BEFORE VERY MANY YEARS, IT SHOULD BE POSSIBLE FOR US TO MOVE INTO ASTRA-TYPE SYSTEMS IN WHICH WE COMBINE THE BEST OF BOTH TECHNIQUES, I.E., LONG-TERM, AUTOMATED INSTRUMENTS IN ORBIT SERVICED AND MAINTAINED BY MAN, ~~AT REGULAR INTERVALS~~. SUCH A SYSTEM SHOULD PROVIDE PRECISE OBSERVATIONAL DATA ~~IN~~ for BOTH SOLAR AND STELLAR ~~REGIONS~~ astronomers BY VIRTUE OF ADVANCES IN TELESCOPE RESOLUTION, POINTING ACCURACY AND DEFRACTION-LIMITED OPTICAL SYSTEMS.

IN SPACE APPLICATIONS, OUR PROGRAM IS AIMED AT IMPROVING EXISTING OPERATIONAL SYSTEMS IN COMMUNICATIONS, METEOROLOGY, GEODESY, NAVIGATION AND IN DEVELOPING THE TECHNIQUES TO SURVEY AND EVALUATE OUR NATURAL and CULTURAL RESOURCES FROM SPACE. HERE, MO DIRECTLY THAN IN ANY OTHER AREA OF OUR SPACE EFFORT, WE ARE DRIVING AT THE CREATION OF NEW TECHNOLOGIES DIRECTLY APPLICABLE TO THE SOLUTION OR RELIEF OF MANKIND'S PROBLEMS HERE ON EARTH.

IN SPACE APPLICATIONS, OUR WORK MUST BE DESIGNED TO SUPPORT THE REQUIREMENTS OF USER OR OPERATIONAL AGENCIES, AS WELL AS TO IDENTIFY AND DEVELOP NEW USES FOR SPACE TECHNOLOGY. CONSEQUENTLY, THE NEXT FEW YEARS WILL SEE US WORKING VERY CLOSELY WITH THE ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION (ESSA), WITH INTERIOR, AGRICULTURE, AND OTHER AGENCIES HAVING STATUTORY RESPONSIBILITY IN ONE OR MORE OF THESE APPLICATION FIELDS. CLEARLY, THE SINGLE, MOST SIGNIFICANT MISSION IN THIS INTER-AGENCY ARENA WILL BE THE EARTH RESOURCES TECHNOLOGY SATELLITE UTILIZING REMOTE SENSORS. AS IN MOST CASES OF NEW DISCIPLINE FIELDS, OUR PLANS CALL FOR CONVERGENCE ON AN OPERATIONAL SYSTEM BY FIRST UNDERTAKING AND COMPLETING PRECURSOR PROGRAMS INVOLVING LABORATORY RESEARCH, SMALL SCOUT-SIZED SURVEY SATELLITES, SENSOR AIRCRAFT, TESTS IN EARLY APOLLO AND AAP TESTS, AND FLIGHT TESTS OF PROTOTYPE ERTS SPACECRAFT.

IN PLANETARY EXPLORATION, AN AREA OF OBVIOUS IMPORTANCE TO NAPO, WE HAVE INDEED COME A LONG WAY IN THE LAST FEW YEARS. THE SUCCESSFUL COMPLETION OF THE RANGER, SURVEYOR, AND LUNAR ORBITER PROGRAMS HAS LAID A FIRM FOUNDATION FOR THE FORTHCOMING MANNED APOLLO LUNAR MISSIONS. THE KNOWLEDGE AND TECHNOLOGY DEVELOPED IN THESE PROGRAMS WILL ALSO PROVIDE THE AUTOMATED SUPPORT FOR LATER EXTENDED LUNAR MISSIONS. MOST IMPORTANTLY, OUR PAST ACHIEVEMENTS IN LUNAR AND PLANETARY EXPLORATION HAVE LED TO THE GRADUAL EVOLUTION OF A BROADLY-BASED PLANETARY PROGRAM AIMED NOT AT A SINGLE GOAL OR A SINGLE PLANET, BUT AT ADVANCES IN THE

SEVERAL SCIENTIFIC DISCIPLINES INTERESTED IN THE PLANETS. TO ACHIEVE THIS GOAL, OUR PLANETARY PROGRAM HAS A CONTINUING SERIES OF FLIGHT MISSIONS OVER THE NEXT SEVERAL YEARS DESIGNED TO INVESTIGATE PLANETARY ATMOSPHERES, SURFACES, AND SUB-SURFACES. THROUGH SUCH EFFORTS, WE HOPE TO ACHIEVE BETTER UNDERSTANDINGS OF THE ORIGIN AND EVOLUTION OF LIFE IN THE SOLAR SYSTEM, AND OF THE FORCES THAT SHAPE OUR TERRESTRIAL ENVIRONMENT. IF WE ARE ABLE TO SEND PIONEERS F AND G TO JUPITER, AND IN FOLLOWING THE MARS '69 FLYBY AND MARS '71 ORBITER MISSIONS WITH A LARGER SIZE TITAN CLASS MARS '73 MISSION, AND IF WE ARE ABLE, AS WE HOPE, TO INITIATE ONE OR TWO PROJECTS IN FY '70, SUCH AS A '73 MERCURY MISSION, IT SEEMS TO ME THAT WE WILL BE WELL UNDER WAY TO MEET THE SCIENTIFIC OBJECTIVES LAID OUT FOR NASA BY THE LUNAR AND PLANETARY MISSIONS BOARD AND BY THE SPACE SCIENCE BOARD OF THE NATIONAL ACADEMY OF SCIENCES. THE MOST IMPORTANT THING WE MUST ALL REMEMBER IS TO DO EACH MISSION TO THE BEST OF OUR ABILITY, REALIZING THAT EACH SUCCESS STRENGTHENS OUR PROGRAM.

IN PROGRAM AREAS OTHER THAN SPACE SCIENCES, THE OUTLOOK IS ALSO SOMEWHAT UNSETTLED. OUR APOLLO COMMITMENT IS AS FIRM AS EVER, AND WE HAVE EVERY INTENTION AND EXPECTATION OF MEETING THE GOALS OF THAT PROGRAM. ALTHOUGH IT IS TRUE THAT OUR POST APOLLO PLANS ARE MUCH MORE MODEST THAN PREVIOUSLY ANNOUNCED, EVEN AT THESE REDUCED LEVELS, IT SHOULD BE POSSIBLE TO CARRY OUT SOME IMPORTANT NEAR-EARTH AND EXTENDED LUNAR MISSIONS

FOLLOWING THE APOLLO LANDINGS. HOWEVER, THERE REMAINS NO CLEAR PICTURE AS TO THE FUTURE OF MANNED SPACE FLIGHT BEYOND THE USE OF THE LAUNCH VEHICLES AND ROCKETS LEFT OVER FROM APOLLO. THE RESOLUTION OF THE FUTURE GOALS OF MANNED SPACE FLIGH MUST AWAIT THE ESTABLISHMENT OF THE NEXT ADMINISTRATION.

IN THE AREA OF ADVANCED RESEARCH AND TECHNOLOGY--NOW UNDER THE VERY ABLE DIRECTION OF JIM BEGGS--WE HAVE REINSTITUTED ADDITIONAL EFFORT IN AERONAUTICS WHILE STILL CARRYING ON A CONCENTRATED AND EFFECTIVE SUPPORTING RESEARCH PROGRAM DIRECTLY RELATED TO FUTURE SPACE MISSIONS. THE IMPORTANCE OF OUR ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY PROGRAMS TO THE NATION'S FUTURE CAPABILITIES IN SPACE CANNOT BE OVEREMPHASIZED. FORTUNATELY, THOSE PROGRAMS ARE KEEPING IN REASONABLE BALANCE WITH THE TOTALITY OF NASA'S EFFORT.

FINALLY, IN TRACKING AND DATA ACQUISITION, WE EXPECT TO MEET THE HEAVY OPERATIONAL REQUIREMENT OF THE NEXT FEW YEARS WHILE SIMULTANEOUSLY UNDERTAKING SEVERAL NEW STATE-OF-THE-ART ADVANCEMENT PROGRAMS BOTH IN ONBOARD AND SURFACE EQUIPMENTS AND TECHNIQUES. WE PLAN TO BUILD TWO MORE 210-FOOT ANTENNAE TO SUPPORT OUR PLANETARY PROGRAM. THIS EFFORT IS PARTICULARLY RELEVANT HERE SINCE JPL AND NAPO WILL PLAY IMPORTANT ROLES IN DEEP SPACE TRACKING OPERATIONS AND POSSIBLY IN THE DEVELOPMENT OF NEW SYSTEMS SUCH AS THE DATA RELAY SYSTEMS SATELLITE.

AS YOU CAN SEE FROM THIS BRIEF SUMMARY, MY OWN OUTLOOK FOR THE IMMEDIATE FUTURE IS NEITHER GLOOMY NOR SANGUINE. ON THE ONE HAND, WE WILL BE FLYING ADDITIONAL OBSERVATORIES AND EXPLORERS, WE WILL CONTINUE A SERIES OF APPLICATIONS SPACECRAFT, AND WE WILL INITIATE A STRONG PROGRAM OF PLANETARY EXPLORATION. WE WILL BE PROVIDING SUPPORT TO MANY GROUPS OF OUTSTANDING SCIENTISTS AT OUR UNIVERSITIES, AS WELL AS WORKING CLOSELY WITH ENGINEERING AND DEVELOPMENT TEAMS IN INDUSTRY. TO CARRY OUT SUCH A PROGRAM, ON THE OTHER HAND, WILL REQUIRE OUR MAXIMUM MANAGEMENT SKILLS BECAUSE RESOURCES CONSTRAINTS ARE LIKELY TO CONTINUE FOR SOME TIME AHEAD. IN EFFECT, THIS MEANS THAT GROUPS SUCH AS NAPO BECOME EVEN MORE IMPORTANT TO OSSA AND TO NASA. FOR EXAMPLE, WE NEED TO PLACE EVEN GREATER EMPHASIS IN THE NEXT FEW YEARS ON THE RELIABILITY OF OUR FLIGHT HARDWARE. RELIABILITY ASSESSMENT GROUPS SUCH AS THOSE HERE WHICH HAVE BEEN SO HELPFUL TO US ON PROGRAMS SUCH AS SURVEYOR, MARINER '69 AND OTHERS, WILL NEED TO MAINTAIN AND IMPROVE ON THEIR RECORDS OF ACCOMPLISHMENT. IN THE LEAN BUT ACTIVE YEARS AHEAD, EACH GROUP WITHIN NASA MUST CONCENTRATE ON QUALITY PERFORMANCE AND DEDICATED SERVICE. MORE THAN EVER BEFORE, THE PROFESSIONALISM, EXPERTISE, AND OBLIGATIONS OF NASA EMPLOYEES WILL BE TESTED IN THE FULL PUBLIC VIEW THAT HAS BECOME NASA'S TRADEMARK. EACH OF US MUST REMEMBER THAT THE PEOPLE OF THIS COUNTRY HAVE INVESTED A SUBSTANTIAL SHARE OF

THE PUBLIC WEALTH IN OUR PROGRAM. TO A CERTAIN DEGREE, THEY UNDERSTAND OUR PROGRAM CARRIES WITH IT CERTAIN RISKS COMMON TO ALL SUCH ADVANCED VENTURES. BUT THEY ALSO EXPECT--AND RIGHTLY SO--THAT NASA DEMONSTRATE FOR THEM SOME UNAMBIGUOUS RETURNS ON THAT INVESTMENT AND THAT THESE RETURNS COME EARLY, AS WELL AS LATER IN OUR PROGRAMS.

THIS IS OUR CHALLENGE FOR THE NEXT SEVERAL YEARS. IF WE DELIVER THE GOODS, THE OUTLOOK FOR THE 70'S CAN BE A MOST CHALLENGING ONE TO THOSE ASSOCIATED WITH NASA--IT CAN BE EVEN MORE CHALLENGING AND EXCITING THAN THE 60'S. EACH OF US, HOW-EVER, MUST ALSO BE MINDFUL THAT THE PACE OF OUR PROGRAM, ITS BREADTH AND DEPTH, ARE NOT ALTOGETHER DEPENDENT UPON FORCES UNDER OUR CONTROL. NASA'S TOTAL BUDGET AND ASPIRATIONS, FOR EXAMPLE, ARE HEAVILY INFLUENCED BY EXTERNAL CONDITIONS, SUCH AS THE STATE OF THE ECONOMY OR THE INTERNATIONAL COMMITMENTS. BUT IT IS STILL WITHIN OUR OWN POWER TO MAXIMIZE THE USE OF THE RESOURCES MADE AVAILABLE TO US. ONE OF THE CLEAREST FACTS OF LIFE ON CAPITOL HILL, FOR EXAMPLE, IS THAT A DIRECT RELATION-SHIP EXISTS BETWEEN THE MAGNITUDE OF RESOURCES ALLOCATED TO AN EXECUTIVE AGENCY AND THE DEGREE OF CONFIDENCE THAT CONGRESS HAS IN THE MANAGERIAL COMPETENCE OF THAT AGENCY. IN A MANNER OF SPEAKING, WE IN NASA MUST PROVE--BY RESULTS--EACH AND EVERY YEAR THAT CONTINUED INVESTMENTS IN SPACE RESEARCH AND TECHNOLOGY ARE IN THE BEST INTERESTS OF THE NATION. THE BEST WAY TO DO THIS IS BY DEMONSTRATING AN APTITUDE FOR PRODUCING PROGRAM

RESULTS WITHIN THE FUNDS WE HAVE REQUESTED AND ON THE SCHEDULE WE HAVE PUBLICLY STATED.

IT IS FOR SUCH REASONS THAT AWARD CEREMONIES HAVE A SPECIAL SIGNIFICANCE. WHAT WE ARE HONORING TODAY IS NOT SIMPLY LENGTH OF SERVICE OR A UNIQUE CASE OF ESPECIALLY COMPETENT PERFORMANCE. WE ARE REALLY HERE TO HONOR THE VERY ATTRIBUTES AND STRENGTHS WHICH ENABLE NASA TO PLAN FOR AND CARRY OUT THE PROGRAM I HAVE DISCUSSED AND TO INCREASE THE INTEREST AND CONFIDENCE OF THE CONGRESS AND THE PEOPLE.

IT IS NOT WITHOUT REASON THAT I REMIND YOU THAT NAPO HAS UNDERGONE SEVERAL RATHER UNSETTLING EXPERIENCES IN THE PAST YEAR OR TWO. I DO THIS TO MENTION THE HEARTENING ASPECT OF THESE EXPERIENCES. THE IMPORTANT THING IS THAT YOU HAVE REBOUNDED FROM THE VOYAGER PROCUREMENT TERMINATION AND THE CLOSEOUT OF WSO AND HAVE MAINTAINED A STRONG CAPABILITY HERE AT NAPO. ORAN NICKS AND DON HEARTH ASKED ME TO MENTION HOW HELPFUL NAPO HAS BEEN TO THEM IN RELATION TO BOTH PROGRAM RESPONSIBILITIES AT JPL AND IN TERMS OF OVERALL INSTITUTIONAL ADMINISTRATION. DR. CLARK OF GSFC, ASKED ME, TO COMMEND NAPO'S DELTA PROCUREMENT WORK. THE RECENT REINSTATEMENT OF OART-FUNDED CONTRACT NEGOTIATION RESPONSIBILITIES HERE INDICATES THE CONFIDENCE WHICH OART HAS IN YOUR WORK. ALL OF THESE EXAMPLES DEMONSTRATE TO ME--AND SHOULD TO YOU--THAT HEADQUARTERS

IS AWARE OF NAPO'S CONTRIBUTIONS TO THE OVERALL NASA EFFORT--IN TECHNOLOGY UTILIZATION, PATENT WORK, CONTRACT ADMINISTRATION AND OTHER AREAS AS WELL. OUR PROBLEMS IN WASHINGTON ARE SUCH THAT WE TEND TO TAKE EFFICIENT PERFORMANCE FOR GRANTED UNLESS SPECIAL OCCASIONS SUCH AS THIS ONE GIVE US THE OPPORTUNITY TO COMMEND YOU FOR THE GOOD WORK YOU HAVE DONE. I HOPE YOU WILL BEAR WITH US ON THIS POINT.

IN SUMMARY, THEREFORE, DESPITE THE UPS--AND--DOWNS OF THE PAST FEW YEARS, I BELIEVE NASA AND NAPO CAN LOOK FORWARD TO BETTER TIMES. WE HAVE A SOUND PROGRAM, EXPERIENCED AND CAPABLE PEOPLE, AND A STRONG AND CONTINUING ARGUMENT FOR SPACE EFFORTS. THERE IS A HARD CORE OF SUPPORT FOR OUR PROGRAM IN BOTH HOUSES OF CONGRESS. I BELIEVE WE CAN TAKE HEART FROM THE MEANING AND PROMISE OF THE AWARDS BEING BESTOWED TODAY, AND RENEW OUR DEDICATION TO NASA AND TO THE PROGRAM IT REPRESENTS. IN THE LONG RUN, REALLY GREAT ORGANIZATIONS HAVE THREE THINGS IN COMMON--FIRST, DEDICATION TO AN EXCITING AND SIGNIFICANT PROGRAM; TWO, THE ABILITY TO REBOUND FROM TEMPORARY SETBACKS AND, THREE, A CONTINUING PROFESSIONAL PRIDE IN THE WORK THEY TURN OUT. I BELIEVE NAPO SHOWS EVIDENCES OF BEING HIGHLY RATED IN ALL THREE AREAS. IF WE WORK TOGETHER TOWARD OUR COMMON GOALS AND ARE PATIENT WITH EACH OTHER'S SHORTCOMINGS, I BELIEVE THE FUTURE WILL BE SATISFYING TO ALL OF US.

THANK YOU.