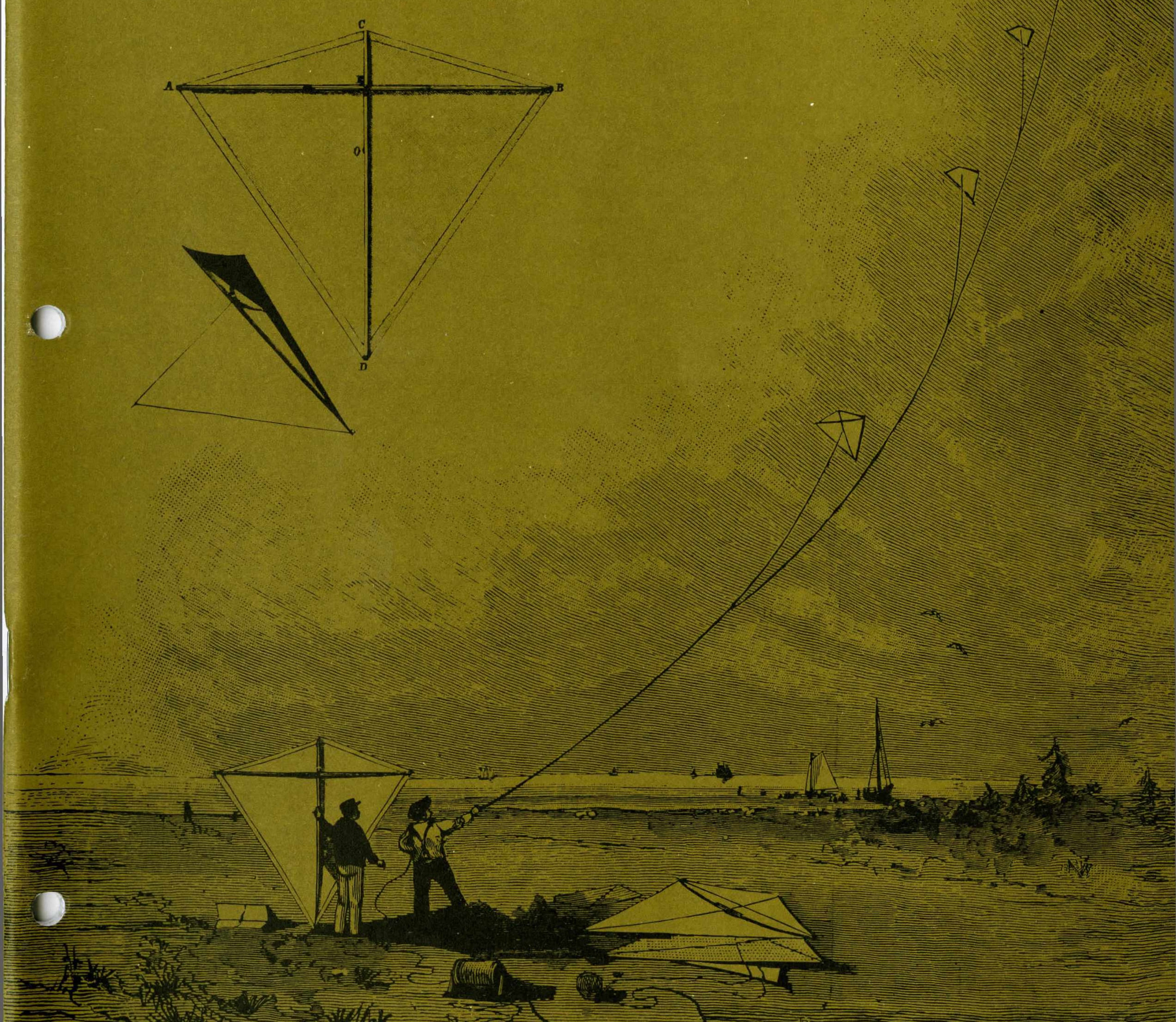
FACILITIES FOR

NO. 3 SPRING 1967

atmospheric research



NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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atmospheric research

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NCAR

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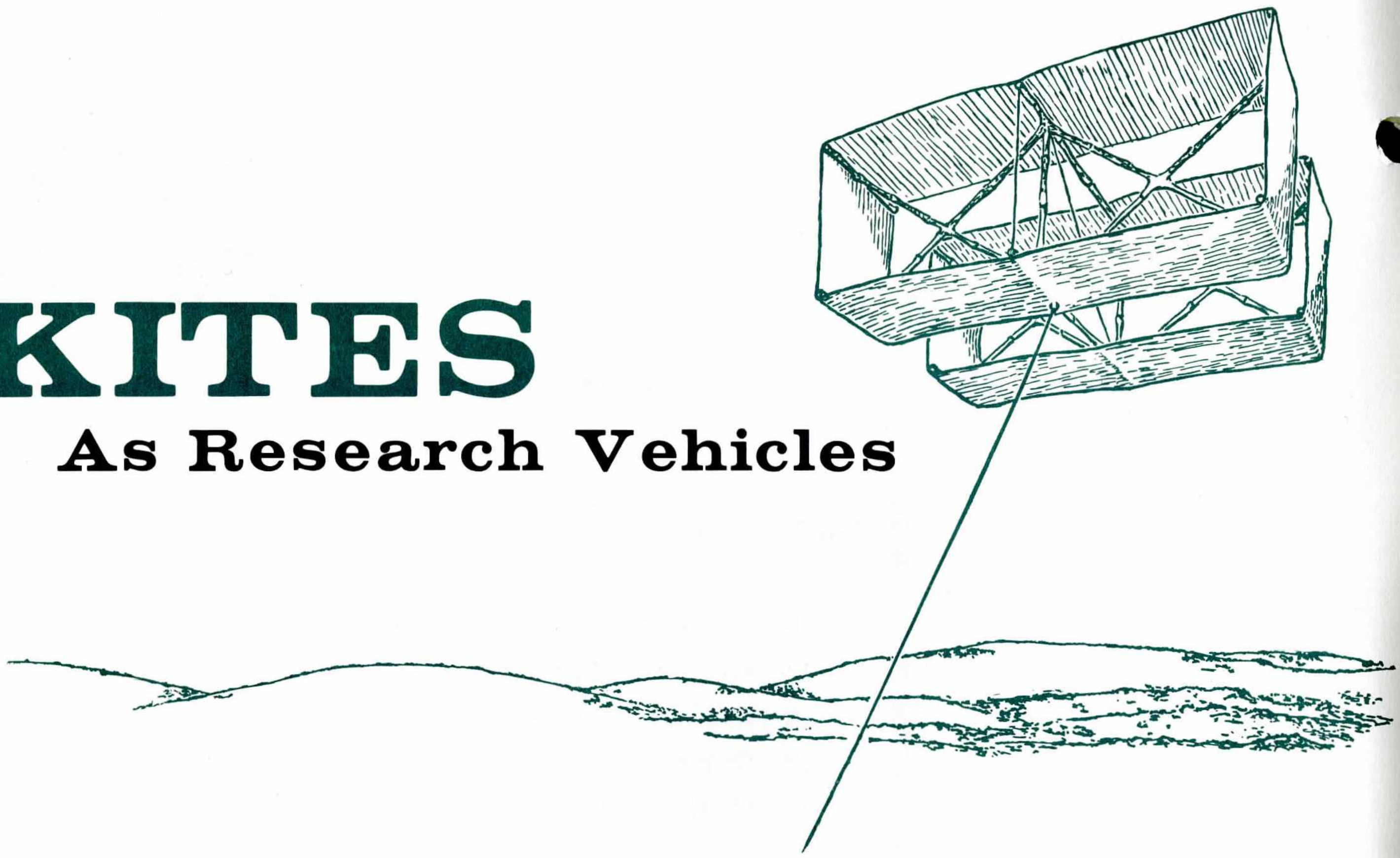
Cover. Raising aerial thermographs by means of kites at Blue Hill Observatory (Scientific American, September 15, 1894.)

KITES

As Research Vehicles



Cal Queal, Empire Magazine, The Denver Post

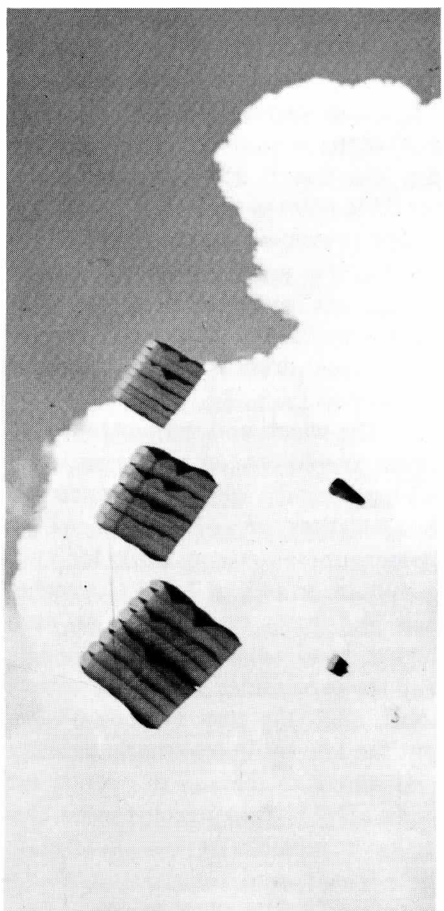
The box kite, one of the earliest bits of technological fallout from aerospace research, was invented about 1892 by the Australian engineer Lawrence Hargrave, as part of his long-continued effort to design a flyable airplane. The Hargrave kite was more stable and had considerably more lift than any kite previously known, and these excellent flying qualities quickly attracted the attention of meteorologists in Europe and the United States who saw it as a possible vehicle for sounding the atmosphere up to several thousand feet above the ground, and for recovering data promptly and surely.

Starting about 1895, box kites were flown in various research and operational meteorological programs. The best known of these was the U.S. Weather Bureau program, in which profiles were flown from kite stations every day that winds permitted, for many years. When the last station closed in 1933, it seemed that kites had finally been made obsolete by improved capabilities of airplanes for carrying meteorographs, and by possible flight hazards of kites to aircraft.

CSU's Kite Program

In recent years, however, new research uses for kites have developed, aided by some substantial improvements in kite design. A significant part of this renaissance of the kite has been carried out since 1964 at Colorado State University, in a program directed by Professor Lewis Grant and supported by the Atmospheric Sciences Section of the National Science Foundation. Grant wanted to put recording and collecting instruments into the orographic or cap clouds that develop over mountains, particularly in winter. He considered airplanes, and free and tethered balloons, before he decided that kites might be quite a bit better for his purposes. Grant views his program as one of meteorological research, in which kite development has been purely supportive. Nevertheless, the capabilities that have now been developed for kites, in large part as a result of Grant's program, offer a new dimension of measurements for a variety of possible research interests.

Kite flying from large CSU kite control trailer near Climax, Colorado.



Grant first considered possible improvements to the conventional Hargrave box kite that might be achieved by using new materials available only in the last few years. However, when it appeared that box kites were inherently limited by difficulties of assembly and storage, he turned to kite-balloons, and enlisted Domina Jalbert, of the Jalbert Aerology Laboratory, Boca Raton, Florida, to consult on new designs.

The Jalbert Airfoil

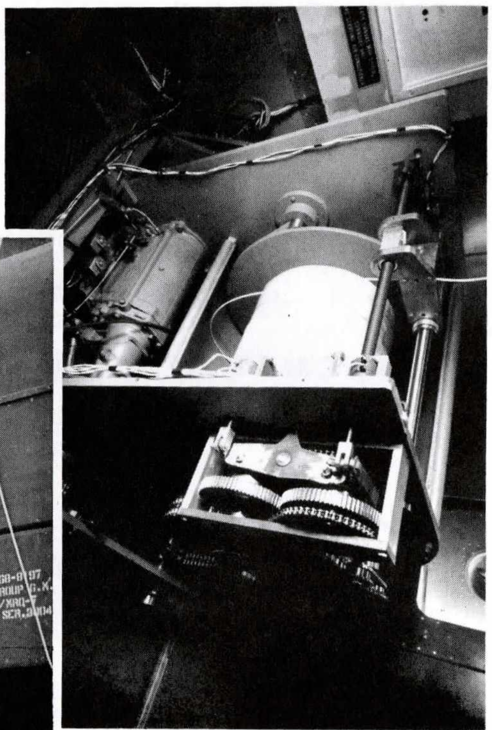
Jalbert had been producing the Kytoon, a tethered blimp-like balloon which secures some lift from its shape and from fins, and is effective for lifting instruments in winds below about 20 mph. The winds related to orographic clouds are consistently stronger than that, and Grant decided his project couldn't use systems incorporating gas cells. He urged Jalbert to experiment with tethered fabric airfoils which, he felt, might perform well in high winds.

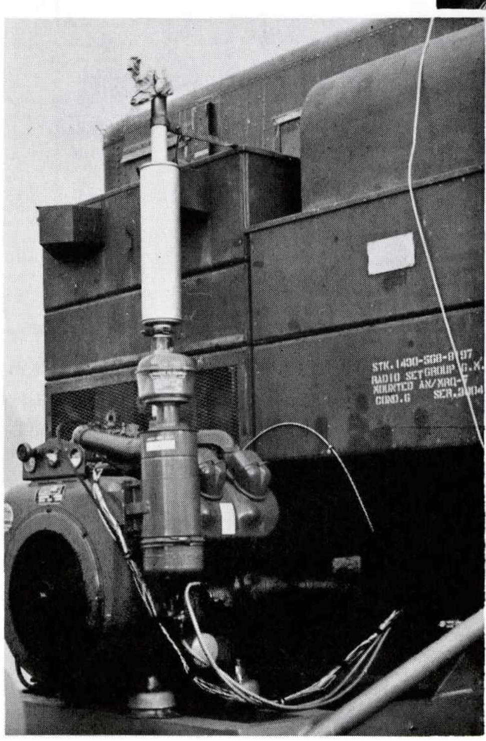
Jalbert came up with a cellular fabric wing, whose main design feature is reminiscent of the wind sock: the cells have large openings at their leading edges and smaller exits at their trailing edges, creating a positive air pressure in each cell which keeps the wing inflated and maintains its airfoil shape. Jalbert's first design flew, but proved to have a very low lift-to-drag ratio. It carried its tether out to a great distance horizontally in relation to the vertical height achieved, and in a high wind it put a tremendous drag on the line.

From this first model Jalbert has worked out improvements which, along with developments in tethering lines and winches, give his present kites unprecedented performance characteristics. They can lift weights adequate for any of Grant's current or foreseeable instrumentation needs, to 18,000 to 20,000 ft — an elevation in the upper portion of most of the orographic clouds in the central Rockies. In tandem or series. they should go much higher. In strong winds, the kites fly only about 10° off vertical and provide a highly stable anchorage for instruments. Waterproof fabric makes them indifferent to rain and to the moisture content of clouds, and in flight the constant flutter of the fabric sheds ice as fast as it forms. Thus they are excellent foul-weather vehicles for wintertime experiments, the conditions and season most useful to Grant's research interests. Flights of 12 to 15 hr have been achieved in field experiments.

Grant has tested kites ranging from 27 to 300 sq ft. The capabilities of this family of designs are shown by the fact that one of the intermediate sizes, a 108-sq-ft model, can lift a man in a 30-mph wind. Yet these all-fabric kites are extremely light in weight: the 160-sq-ft model weighs only 11 lb.

Large kite control winch





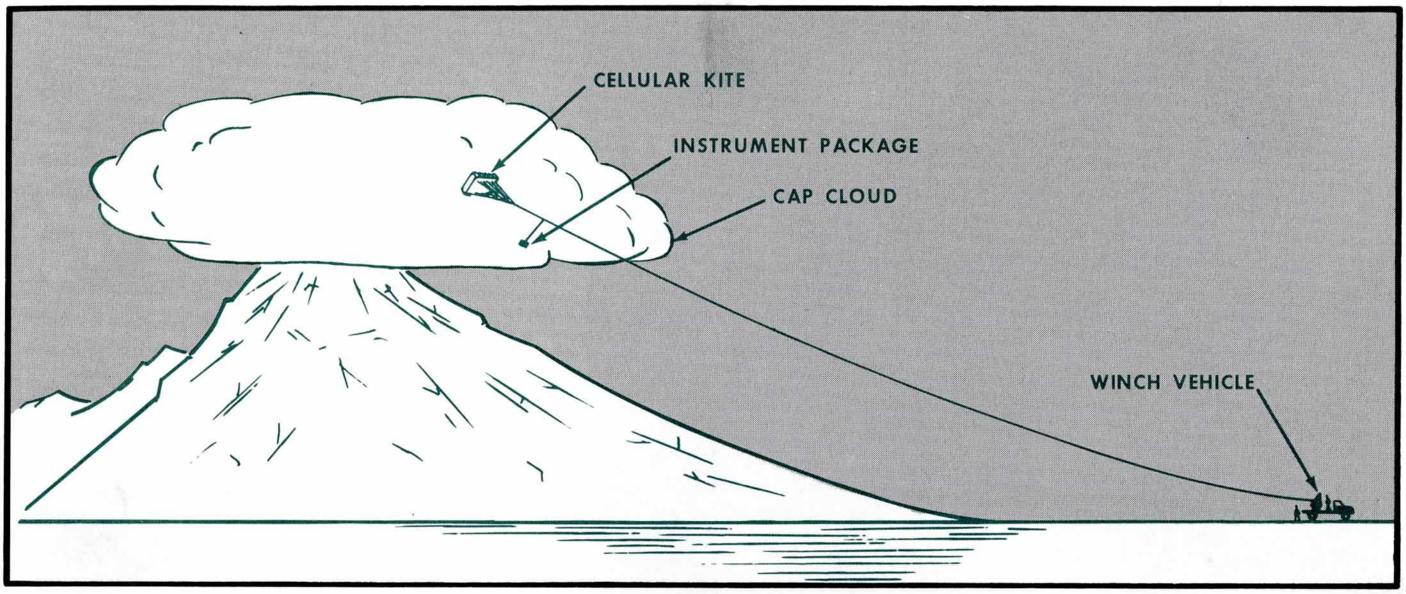
60-hp motor drive for large kite control winch.

Winch Capabilities

Light winds require the larger kites, but if the wind picks up after launching or at altitude, the pull on line and winch can become very great. Much effort at CSU has gone into designing winches capable of handling these loads.

The CSU project staff estimated that multiple kite trains reaching into the jet stream — a possible research objective — would produce drag forces from 2200 to 2500 lb, and so they designed a winch to take 3000-lb loads. The heart of this winch is a 60-hp gasoline motor which works a steel-drum system mounted on the floor of an old M-33 radar van. Two Dodge automobile transmissions, mounted in tandem and built into the side of the van, control reel-in speeds, which can vary from ½ to 30 mph. A tension meter reading directly from the kite line is red-lined below the breaking point of the line. The wound-in compressional forces on the drum can become greater than the tension on the line, and require special consideration in the reel-drum design. The present drum is made of ½- and ¾-in. steel.

The winch unit permits launches under conditions as severe as, say, 40-mph winds with an outside air temperature of −20°F, in which human operators can work for only a minute or two at best. (Launches can and have been made at even higher wind velocities.) The winch, and the capabilities of the kite vehicle itself, allow the crew to hook-on and put the kite up in less than a minute, and retreat to the van to operate the flight. The highest winch speeds also make it possible to launch kites in light winds, and to make quick recoveries if a kite starts to fall.



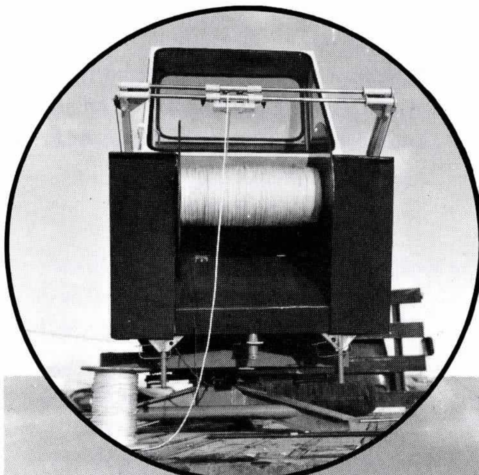
Scheme for placing kite in cap cloud, where close approach to the peak is impossible.

After the studies had provided adequate information for the preparation of design specifications for a winch system, it was put out for bid. The only contractor who responded bid $120,000, a figure far beyond what the CSU group felt they could afford or the job should cost. They turned to the Mechanical Engineering Department in their own university, where one undergraduate student, under faculty supervision, designed and built the system for less than one-tenth the bid price.

The drawback of this heavy winch is inherent in the nature of the research project: Grant is studying cap clouds which form primarily in winter, and he needs to get the kite as close under the cloud as possible, before launching. He has been working at Chalk Mountain at 12,000 ft on the Continental Divide, just east of Climax, Colorado, and when the winch van is taken to the top of the mountain in the fall it is soon snowed in and cannot be brought out until spring.

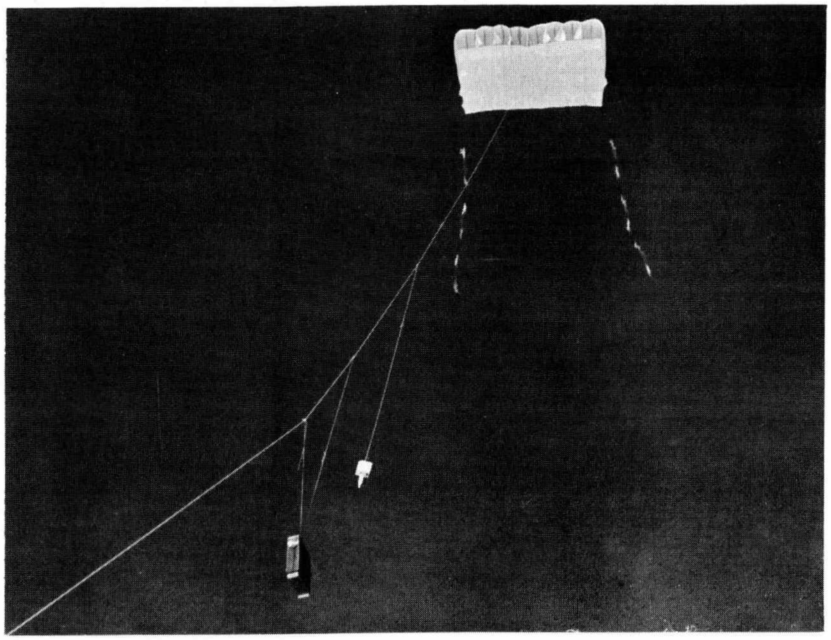
A Portable Winch

To gain scope for additional research flights, CSU has recently built a portable winch system, which takes tensions up to about 2000 lb. In this



Line-feed mechanism on portable kite control winch.

Portable kite control winch on flatbed truck.



system the winch cab is mounted on a flatbed truck, and rotates 360° excepting for the sector of the truck cab, so that it can readily follow wind shifts. The cab can also tilt to follow the angle of the kite line, and has a windshield to protect the operator.

The portable winch, which is commercially available from Western Scientific Associates in Ft. Collins, uses a 15-hp motor and gears from a Farmall Cub tractor.

Grant expects to use this mobile unit in cooperative experiments with a research group from the University of Wyoming, at Elk Mountain, Wyoming, where a beautiful cap cloud often forms. As at Chalk Mountain, they are interested both in securing standard meteorological measurements (which are telemetered to the ground), and in using the kites to put seeding packages into the clouds and to trace the effects of seeding. Grant also recovers air samples, ice nuclei, and ice crystal replications from the clouds. The nearest ground approach to Elk Mountain leaves them a long way out from the mountaintop, and Grant expects that Jalbert's early, heavy-drag airfoil may prove to be useful here, where the customary 80° or nearly overhead angle flown by current Jalbert models would miss the cloud unless the kite were heavily weighted.

Rigging

With a well-built kite, probably the most critical factor for successful flights is careful rigging. Jalbert applied experience with barrage-balloons and parachutes to distribute the load from the tether along the lower edges of the kite ribs by tying shroud lines to triangular flaps. Grant has flown the Jalbert kites with both nylon and piano wire lines, and is interested in experiments elsewhere with Fiberglas and titanium wire, since thinner lines will reduce the drag of the line itself, a serious limiting factor in higher-altitude flights. (The effective area of 10,000 ft of 3/16-in. nylon rope can amount to about 150 sq ft — a non-lifting sail which drags against the kite.)

Using multiple kite trains to increase performance so that instruments can routinely be placed in the jet stream, for example, will require a more efficient line material than the nylon primarily used at present, and probably will require improved rigging techniques as well. Grant at first estimated that a string of six kites would be needed to reach jet-stream levels, but he now believes it can be done with three.

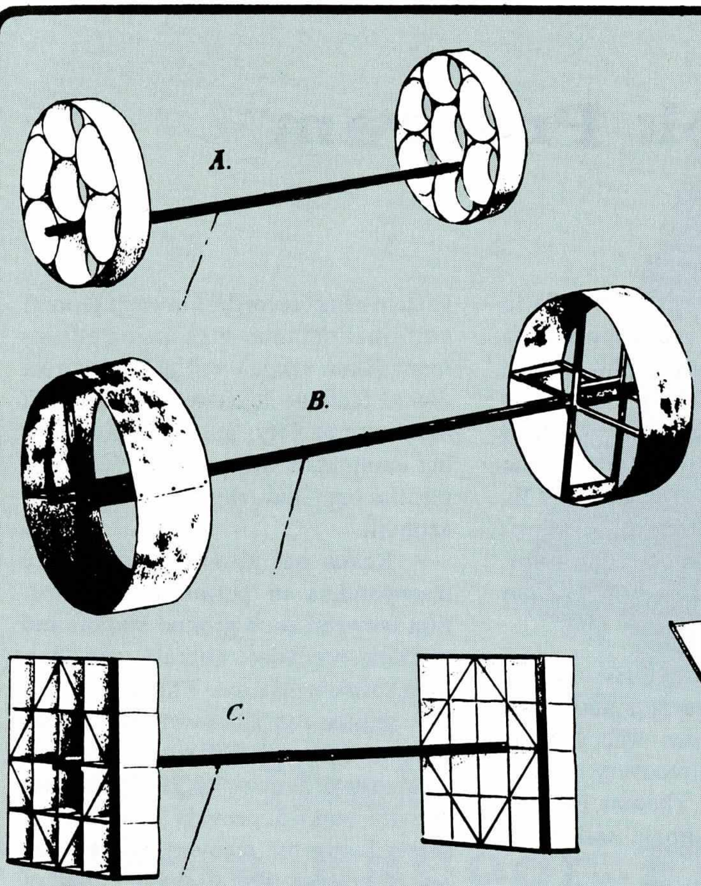
He does not suspend his instruments directly on the kites, but attaches them to the line, a hundred feet or so below the kite. Under the tension of flight conditions the line is remarkably rigid, and instruments attached to it and held with braces are as stable as though fixed to structural members.

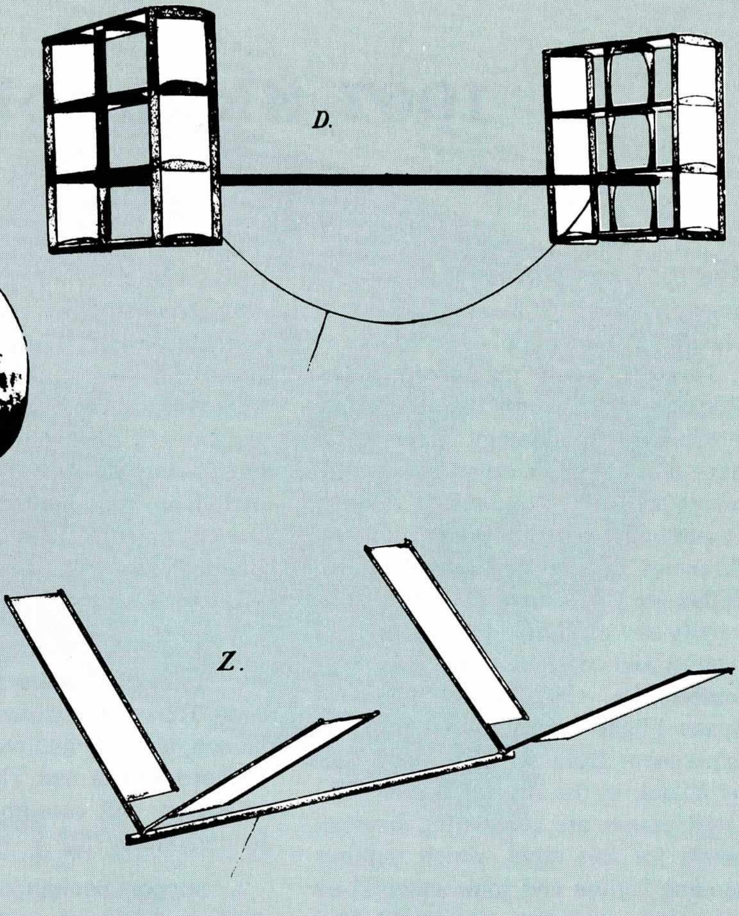
Where to Fly?

The greatest problems in these kite experiments are no longer costs or design, but administrative and jurisdictional problems of keeping kites safely separated from aircraft. Grant hopes, with the cooperation of other interested research institutions, to secure reserved air space in mountain areas for kite experiments. For programs where kites will be flown on wire he will need not merely a reserved area, but one with no power lines downwind that could possibly be interfered with by a broken wire trailing cross-country. Such areas still exist, even though the rural and mountain landscape becomes more built up each year.

Conclusion

A number of other research organizations have used Jalbert kites, or have thought about using them, for such diverse purposes as lifting targets to calibrate radars, dispensing seeding agents to disperse runway fog, photographing wave patterns and collecting samples of ocean water, raising antennas, and recovering cameras from rocket flights. The lifting capacity, stability and flight duration, and low cost of these kites seem likely to stimulate their use in still other ways in the future.

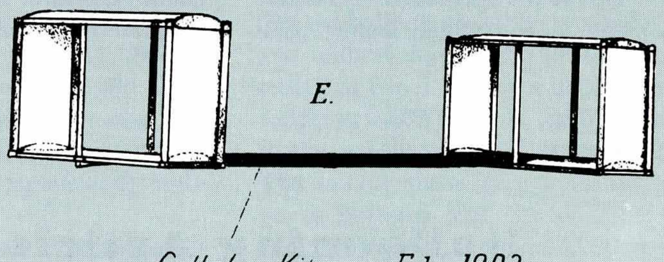




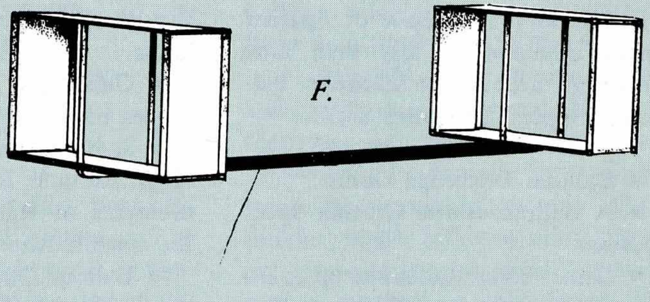
First Box Kites

Hargrave's "cellular" kite combined two discoveries of earlier 19th century aeronautical inventors. It had been proposed in the 1860s that airfoils to support the heavy weights involved in mechanical flight might be arrayed vertically, with parallel separation between the planes. A decade later, it was found that a design consisting of two planes separated by an interval in the direction of forward motion was more stable in flight than the same area in a single airfoil. Hargrave added one other essential: vertical planes for stability. Once he arrived at the principle of this composite kite, he experimented exuberantly with design forms, as shown in these drawings, before settling on the now classical box kite as the most efficient for his purposes. (Following the lead of other inventors, he also found that kite E, with convex horizontal surfaces, pulled about twice as hard on the string as kite F, with plane surfaces.)

Hargrave concluded, perhaps a bit wishfully, "Theoretically, if the kite is perfect in construction and the wind steady, the string could be attached infinitely near the centre of the stick, and the kite would fly very near the zenith. It is obvious that any number of kites may be strung together on the same line, and that there is no limit to the weight that may be buoyed up in a breeze by means of light and hand tackle."



Cellular Kites. Feb. 1893



1967 Skyhook Program

The 1967 Ft. Churchill Skyhook program, conducted by the Office of Naval Research, will get underway 1 June 1967 with the arrival of Dr. Rockus Vogt from the California Institute of Technology. Representatives of eight other organizations will arrive between 1 June and 18 August, to participate in this year's program. A series of twelve "throw-away" flights for Dr. Kinsey Anderson, University of California, will begin on 15 August and continue through 15 September. Dr. Carl Fichtel, Goddard Space Flight Center, will launch an experiment from Resolute, Cornwallis Island, in the Barrow Straits. The ONR people are completing arrangements for this flight, which requires sending helium and some materiel by sea. The remaining equipment and personnel will travel from Ft. Churchill in the ONR C-47 aircraft.

This year's operation may include as many as forty-three flights, compared with thirty-three in 1966. As in 1966, balloons will be supplied by Winzen Research, Inc., and Raven Industries' Flight Service Division will furnish field services. Payload weights will range from 20 lb for the throw-away packages to over 550 lb, excluding command/control instrumentation and auxiliary equipment. Balloon sizes will range from 0.25 to 10.6 million cu ft.

A total of twenty-three balloon and electronics technicians and pilots from Raven Industries will provide launch, tracking and recovery service. Richard Keuser and Thomas Pappas, of Raven, will coordinate and direct field services.

Support equipment has been improved in several respects. Aneroid altitude devices and barocoders have been replaced by highly accurate electronic pressure sensors designed to continuously telemeter pressure data to strip-chart recorders at each ground station. Distance-measuring equipment (slant range) will provide direct digital readout at either Ft. Churchill or Uranium City, and direction-finding equipment will provide electronic positioning and digital readout of azimuth.

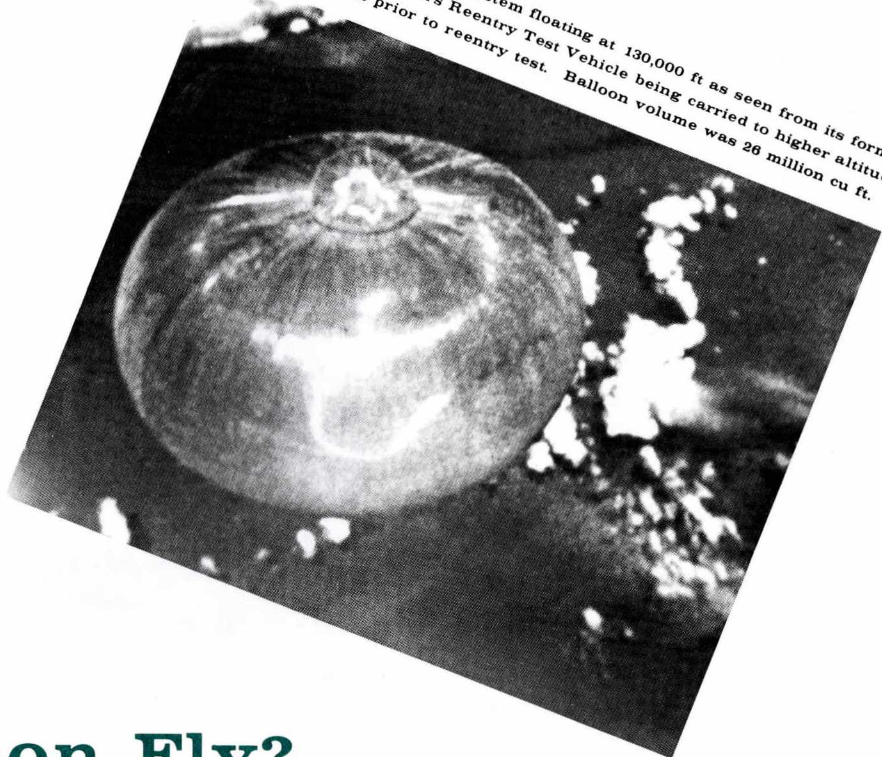
Raven has also developed voice transponders to permit communication between each ground station and tracking/recovery aircraft, via balloon instrumentation. This equipment will reduce the increasing difficulties encountered with HF single sideband communication due to rising sunspot activity, and will provide an additional safety factor for recovery pilots when out of normal aircraft VHF range of Uranium City. In tests of this equipment during the 1966 program, a ¾-watt walkie-talkie at Ft. Churchill easily carried on two-way conversation with Uranium City, over 500 miles away.

Ballooning Articles in "Applied Optics"

The February 1967 issue of *Applied Optics* contains no less than nine full-length articles on scientific ballooning topics. The titles are:

- Balloon Telescope Optics
- A Balloon-Borne Grating Spectrometer
- Direct Solar Radiation up to 30 km and Stratification of Attenuation Components in the Stratosphere
- Fourier Spectrometry from Balloons
- Guiding of Balloon-Borne Telescopes by Off-Set Sun-Tracking
- A Research Program Aimed at High Altitude Balloon-Borne Measurements of Radiation Energy from the Earth's Atmosphere
- Balloon Observations of the Radiance of the Earth Between 2100 cm^{-1} and 2700 cm^{-1}
- Ultraviolet Polarimetry Using High Altitude Balloons
- Improvements to a Balloon-Borne Sun-Seeker

This issue of *Applied Optics* also contains a letter entitled "Frictionless Bearing for Balloon," and a description of the Spectro-Stratoscope program which is being carried out by the Fraunhöfer Institute of Freiburg, West Germany.



Voyager Tandem Balloon System floating at 130,000 ft as seen from its former payload, a Voyager Mars Reentry Test Vehicle being carried to higher altitude by rocket motors prior to reentry test. Balloon volume was 26 million cu ft.

How High Can a Balloon Fly?

Justin Smalley, NCAR

For many balloon-borne experiments an additional few thousand feet of altitude can make a significant difference in the quality of the data secured. In attempting to meet the needs of research scientists for the highest possible altitudes, balloon ceilings (and payloads, too) have gradually increased over the years. These gains have been reflected in higher costs for both balloons and launch operations. For some types of experiments, present-day capabilities are adequate and the additional costs are not justifiable. But when altitude is all-important and cost is not a deterrent, balloon designers are often asked, "Can we go higher?" and even, "How high can a balloon possibly go?"

We can, indeed, expect to go higher than our present operational ceilings, but our ability to do so will require better materials, new manufacturing techniques, new launching procedures, design improvements, and a better understanding of the balloon environment. With so many contributing factors, the gains will come slowly, and an advance in one area will not necessarily result immediately in reliable flights to significantly higher levels.

The ultimate practical ceiling for scientific flights can be predicted within limits, and has been the subject of a brief study at NCAR. Some aspects of that study, related only to the balloon vehicle, are presented in the accompanying figures.

Bigger Balloons

Figures 1 and 2 show float altitude as a function of volume at float altitude, for specified fixed parameters. In Fig. 1 we assume that 12 per cent of the balloon weight consists of load-bearing meridional tapes, and that the balloon design is fully tailored and natural-shape. The lower set of curves in Fig. 1 are for a balloon film weighing 0.005 lb/sq ft, approximately the weight of 1-mil polyethylene. The curves show that a 10 million cu ft balloon will lift a 2000 lb load and float at about 119,000 ft, or a load of 100 lb and float at about 139,000 ft. With the same material and the same percentage of balloon weight in tapes, a 100 million cu ft balloon would carry a load of 2000 lb to an altitude of 154,000 ft.

Thus, Fig. 1 shows that as balloon volume is increased, the same load can be carried to higher and higher altitudes. It might be concluded from these curves that by simply building bigger balloons, ever-increasing altitudes can be achieved. However, as we shall see, the effective load that can be lifted will eventually set ceilings for balloon operations. For example, the figure shows that a 100 million cu ft balloon can lift 100 lb to about 161,000 ft. But it is difficult to imagine that the end fittings, excess material, ducts, controls and scientific payload of such a huge balloon would weigh only 100 lb. More likely, under the best circumstances and even neglecting scientific payload, this load must be nearer 500 lb. (The weight of components alone, for a present-day 10.6 million cu ft balloon, made of 0.7-mil polyethylene, amounts to 950 lb.) Thus it appears that the minimum possible practical load is one limit on balloon altitude.

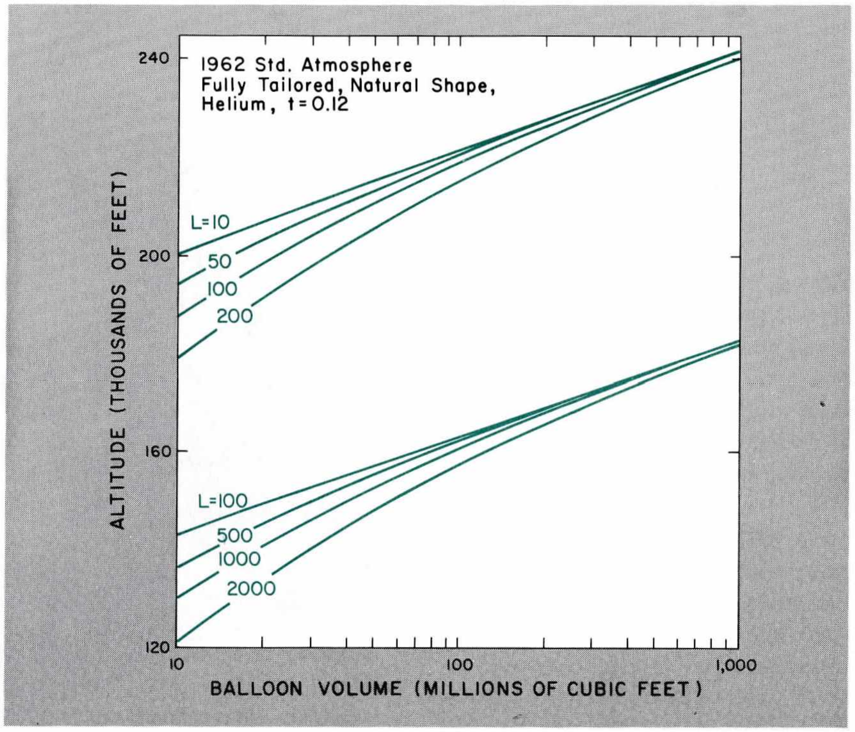


Fig. 1.

Thinner Films

The thinnest balloon films used today weigh less than 0.005 lb/sq ft, while the thinnest polyethylenes now available (but not yet used in balloons) approach a weight of 0.0005 lb/sq ft. If such extremely light materials prove to be adequate gas barriers for a reliable balloon, they will also help to provide higher altitudes. The upper set of curves in Fig. 1 suggests the possible gains, but it should be noted that these lighter-weight balloons are limited to much lighter loads because the supporting tapes are also lighter and proportionately weaker.

Another approach to low film weights is in materials such as polyurethane, which retains its strength under very large elongations. A balloon of such material could be designed to stretch and become thinner, and acquire less weight per unit area as it rises.

Effect of Tape Weight

Figure 2 shows the effect of varying the ratio of tape weight to balloon weight, and gives the altitude vs volume relationship for a 100-lb load, with a constant gas barrier (film) weight. As the percentage of tape weight increases, float altitude decreases, of course. If the ratio of

SYMBOLS

L = load on balloon (lb)
F = weight of balloon film (lb)
T = weight of load-bearing tapes (lb)
W = weight of balloon (lb) = F + T
G = gross load (lb) = W + L
V = design volume of balloon (cu ft)
Z = float altitude (ft)
t = T/W
W = unit weight of gas barrier material (lb/sq ft)

We assume that only two items contribute to the balloon weight — the tapes and the gas barrier. The weight of the gas barrier, F, consists *only* of w times the theoretical surface area of the balloon. Thus the load, L, comprises all other parts of the balloon system such as ducts, valves, end fittings, excess balloon film material, parachutes, flight controls *and* the scientific payload. This distinction between balloon load and balloon weight is important. Many items normally considered part of the balloon are here considered part of the load.

If we omit considerations of free lift and ascent ballast, the mass of the balloon system is fixed. At float altitude, the weight of air displaced is exactly equal to the weight of the system. This weight, called the gross weight, consists of two parts, the weight of the balloon, W (tapes plus gas barrier), and the load, L, lifted by the balloon.

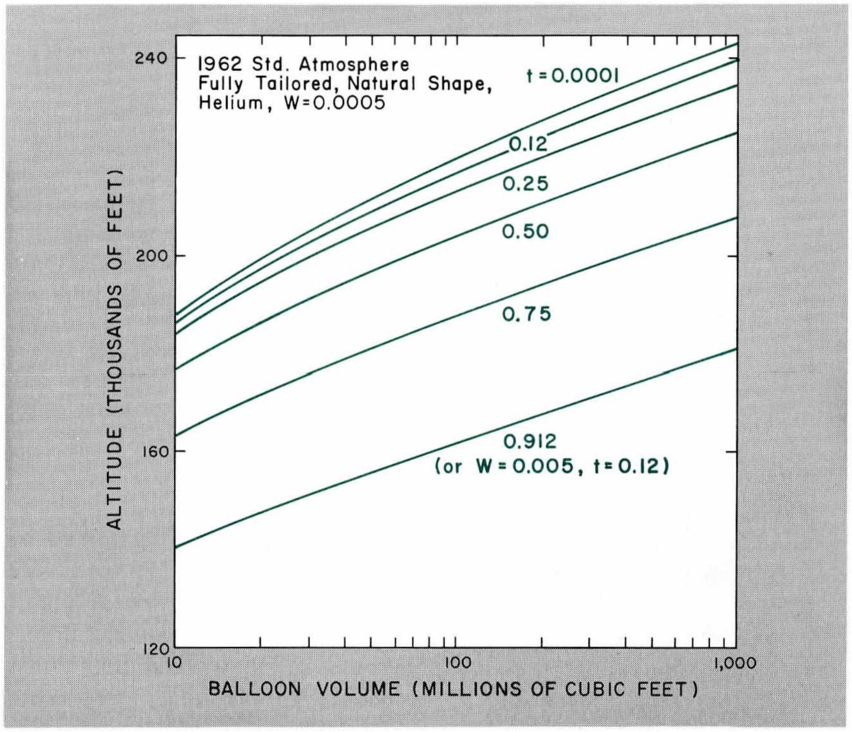


Fig. 2.

tape weight to total weight is increased to 91.2 per cent while using film weighing 0.0005 lb/sq ft, all the advantage of light film is lost. The altitude to which 100 lb can be carried will then be the same as if the material weight were 0.005 lb/sq ft and the tape weight percentage were back to 12 per cent. The latter ratio, while arbitrary, is typical of balloons today. The development of improved tapes with higher strength-to-weight ratios could reduce the required percentage, and thus allow higher altitudes to be achieved.

Other Weight Reductions

Since we gain altitude as load is decreased, any means of reducing load may be important. For example, present-day balloons have relatively large and heavy ducts on their sides, which exhaust gas as float altitude is approached. A lighter-weight device to replace the ducts would be desirable. It would also be advantageous to micro-miniaturize the balloon controls to reduce their weight and power requirements. (These changes would also have the effect of reducing the weight of necessary batteries.) In addition, present-day balloons require considerable ballast to maintain altitude when passing through a sunset or flying over cold cloud layers. A design which would eliminate the need for ballast without adding equivalent weight would be a useful step toward achieving higher altitude.

More Efficient Shapes

Balloon shape can also affect altitude because, if other factors are equal, the shape with the most efficient volume-to-weight ratio will reach the highest altitude. In this respect it might be possible to improve on the fully tailored natural-shape balloon postulated in the present study. For example, if we could use a balloon film with enough strength to support circumferential stress, the inflated balloon could be more nearly spherical and thus achieve higher altitude.

Manufacturing and Launching Techniques

The analysis represented in Figs. 1 and 2 considers only the equilibrium conditions for the balloon at float altitude. The problems of building and launching such balloons must also be considered. The largest balloons built thus far have had volumes of 26 million cu ft. Significant changes in manufacturing practice may be necessary if we are to build considerably larger balloons, or balloons of materials weighing 0.0005 lb/sq ft or less.

New operational techniques may also be required to handle such large balloons. For example, vertical launches have been used for the largest balloons built so far. Such launches are more susceptible to surface winds, and it may be necessary to launch the larger and more delicate balloons of the future from sites offering particularly gentle environmental conditions. But these sites may not be the most suitable ones from the standpoint of the scientific experiments to be flown.

During ascent, balloons are sometimes subject to violent atmospheric disturbances. New techniques may be needed to carry the future balloons through the strong wind shears and cold temperatures associated with the tropopause. One possible technique is the tow balloon, used in some launches today. In the future we may lift the entire flight train with a tow balloon, and deploy the main balloon from a container after reaching the stratosphere.

Conclusion

We have suggested some practical limitations to the ultimate ceilings that can be achieved with scientific balloon flights. It should be evident that most of the steps that can be taken to increase altitude will be in the direction of increasing costs. The interplay of economic and technical factors will determine the new, higher ceilings that will actually be reached in the next few years.

More Speed for NCAR Computer

Installation of six Control Data model 861 drums has sped up the processing of certain types of data on NCAR's Control Data Corporation 6600 computer, making it one of the world's fastest general-purpose computers. These drums supplement the disk through which input data may enter the central processor, and in which the central processor may store data temporarily. Although the drums hold less material than the disk (4 million characters of six bits each, on each of six drums, vs 70 million characters for the disk), the information is more rapidly available, since the time spent transferring material in and out is substantially reduced.

There are now four ways of storing material to be remembered by the computer and of introducing this material into the computer — cards, magnetic tapes, disk, and drums. Comparative sizes of memory and speeds of input using these different methods are shown in a generalized way on the accompanying table.

Cards, with their small memory capacity and slow input, are used primarily in programming but are not efficient for input of large amounts of data. Tapes, disk, and drums, which have much greater memory capacities and input speeds, are all used for data input, according to the size and nature of the computing job at hand. Actual computing time is the same for all — the potential of the 6600 is greater than any available input rate. But the initial delay as the input device seeks the proper position varies, as does the speed of input.

On short jobs, using small amounts of data, it is probably advantageous to use tapes, since the access time per record is so short (5-10 msec), even though the input rate (120,000 characters per second) is relatively slow. Tapes are used also for all material to be permanently stored.

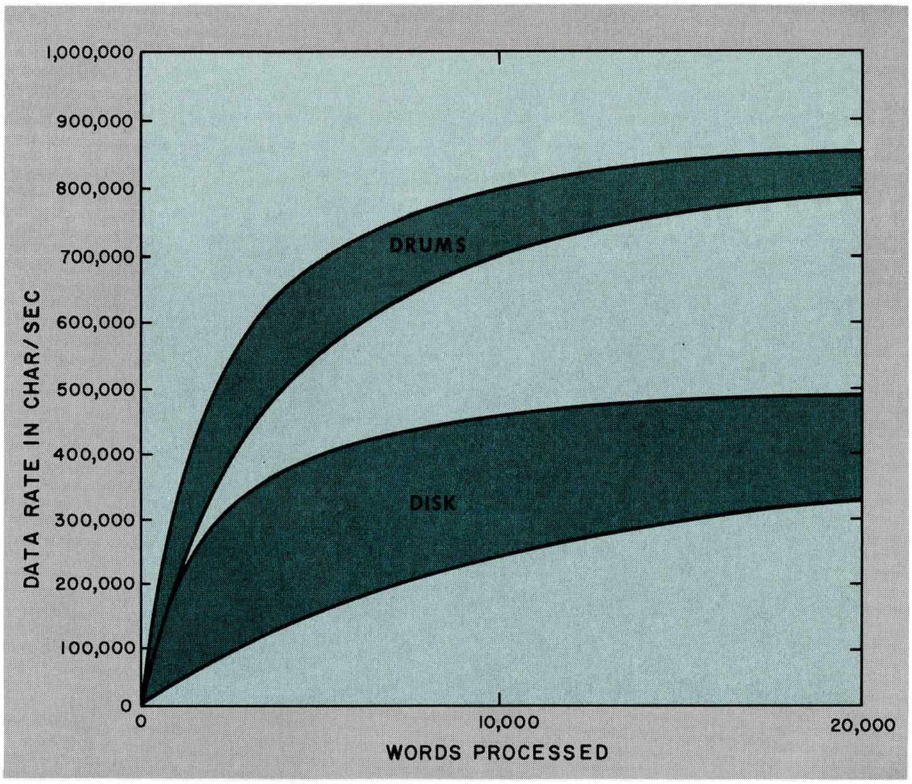
When larger blocks of data are involved, the disk or the drums are far speedier, and when there are frequent changes to different sections of material the drums offer a distinct speed advantage. Positional delay on the disk, as the head searches for the proper "address" as programmed by the computer, is about 225 msec — a span of time equal to 6 million multiplications. Fixed heads on the drums identify material without this delay. Rotational delay occurs with both disk and drums, averaging 33 msec for the disk, 17 msec for drums. In addition, input time is about twice as rapid for the drums.

Large projects, such as the general circulation and atmospheric simulation studies being carried out at NCAR by Akira Kasahara and Warren Washington, in which input-output times are major constituents of the total computer time, have been sped up greatly by the use of the new drums. Since automatic clocking of

MEMORY CAPACITIES AND INPUT SPEEDS

Storage method	Memory (number of characters)	Initial delay (msec)	Information input (char/sec)
Cards	80 per card	--	1,600
Tapes	17,000,000 (x 3,000 tapes)	5 - 10	120,000
Disk	70,000,000	225 + 33 = 258	500,000
Drums	4,000,000 (x 6 drums)	17	1,000,000

Data-handling rates of disk and drums. Depending on the initial position of the head relative to the "address" sought, the data rate varies within the bands shown. For units above 5000 words, the drums are about twice as fast as the disk. For units of 1000 to 2000 words, drum speed far surpasses disk speed.



computer use includes only actual computing time, it is difficult to say exactly how much time is saved. Provided the drums are correctly used, they may do certain jobs in as little as one-fifth to one-tenth the time that would be required using the disk.

The Control Data 6600 computer and other equipment of the NCAR Computing Facility are available to qualified outside users as well as NCAR scientists for work in atmospheric research.

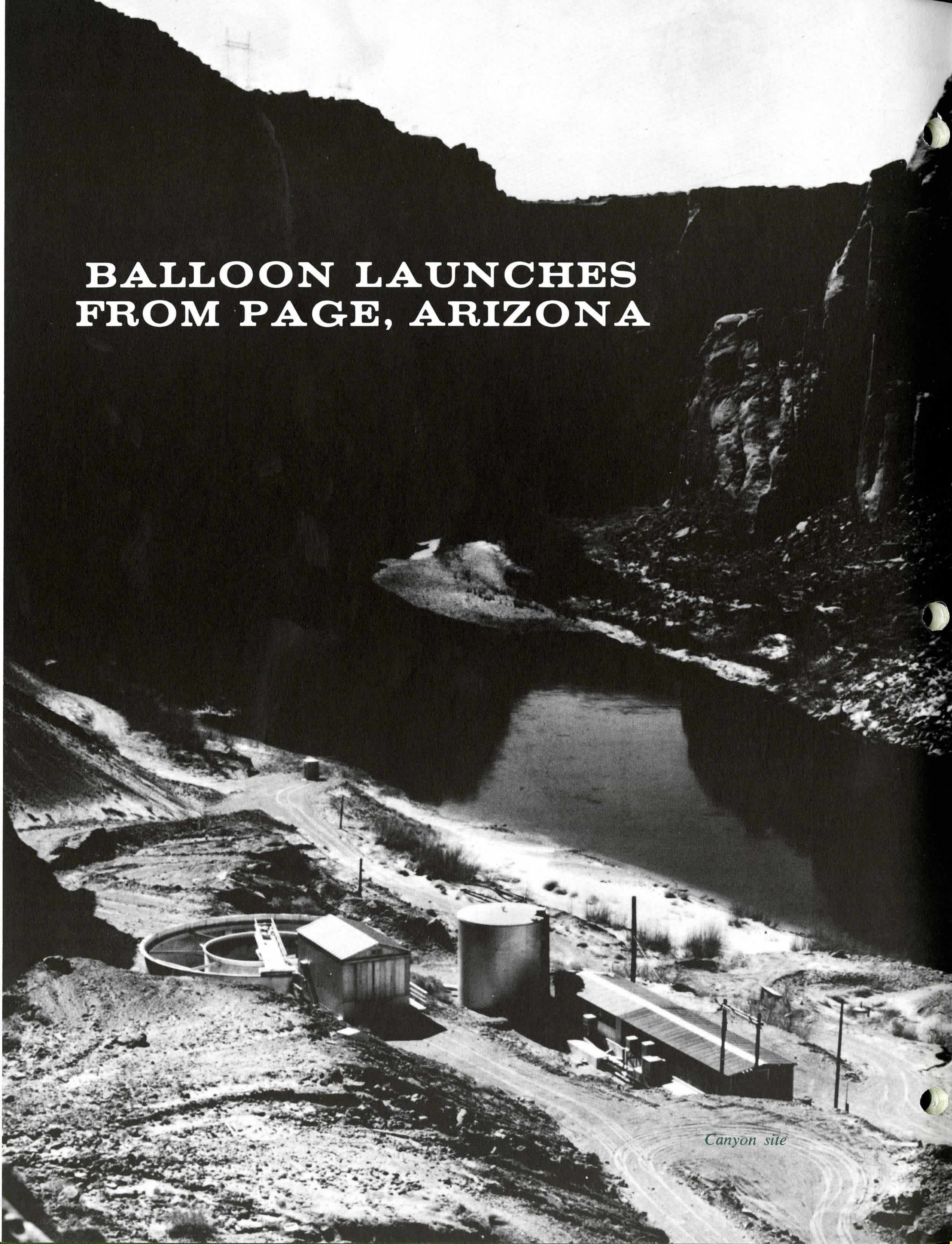
Balloon Astronomy -- The Solar Atmosphere

The first flight in the Spectro-Stratoscope program series, conducted for the Fraunhöfer Institute, Freiburg, West Germany, was flown 20 November 1966 from the NCAR Scientific Balloon Flight Station at Palestine, Texas. Dr. K. O. Kiepenheuer, director of the Fraunhöfer Institute, is principal scientist of the program. The telescope on this flight was a prototype, built by the Carl Zeiss Company, to obtain engineering data for design of the instrument to be used on later flights, which will seek time sequences of simultaneous photographs and spectra of the fine structure of the solar atmosphere.

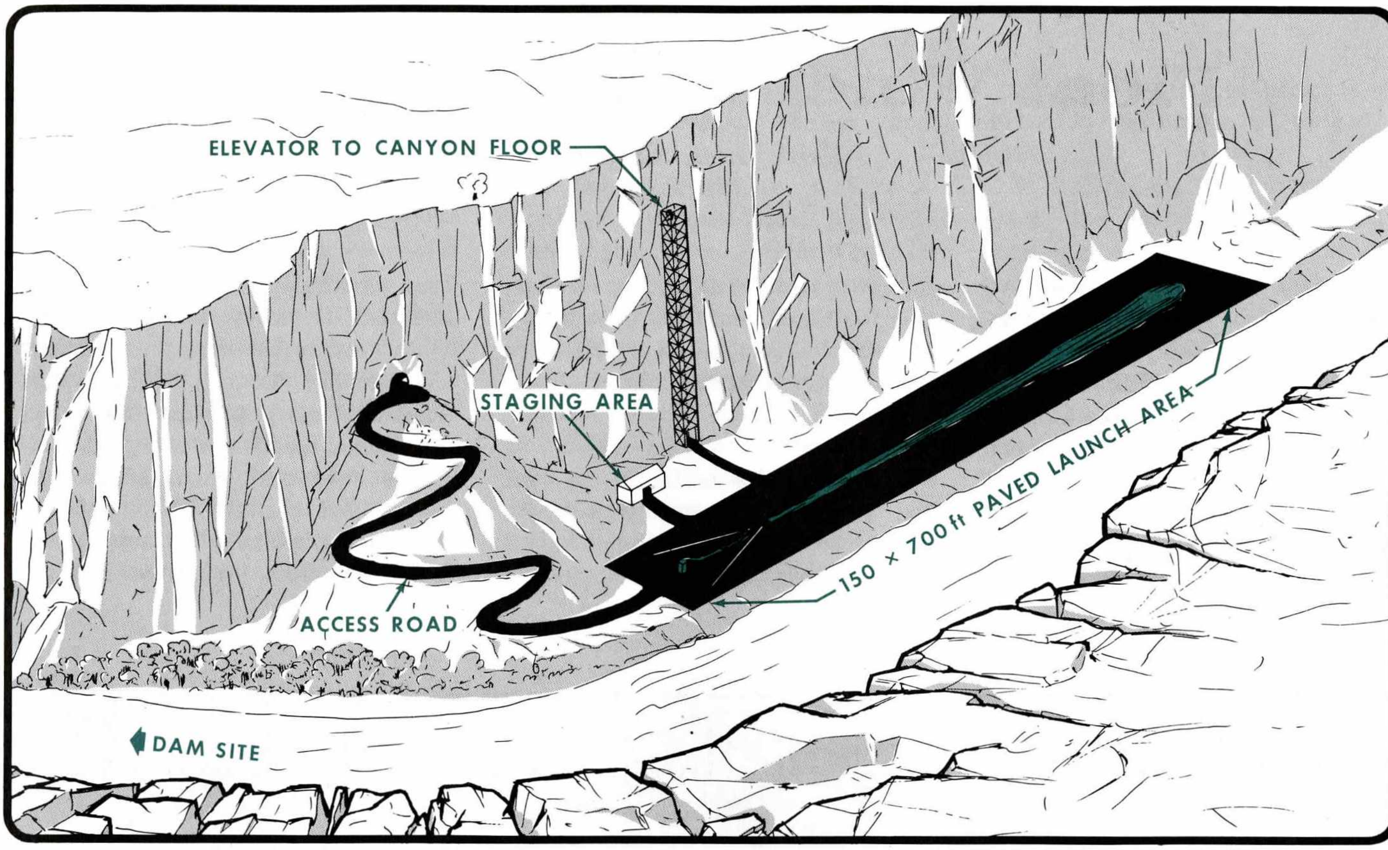
The 4378-lb payload was lifted with a Mylar scrim 3.2 million cu ft balloon. The delicate nature of the instrument required that payload accelerations be kept below 1 g at launch. Three-axis accelerometers mounted on the payload indicated that maximum acceleration for the entire flight was 0.5 g, at launch. The balloon system floated for 5.5 hr at 85,000 ft, during which data were obtained on scope rotation, sun acquisition, and tracking accuracy. Temperatures were recorded from 84 different locations on the telescope.

The payload was recovered near Alexandria, Louisiana, with only superficial damage. It was shipped to the Carl Zeiss Company, Oberkochen, West Germany, for modification to the scientific version. The second flight (the first scientific flight) is now planned for spring 1968.

BALLOON LAUNCHES FROM PAGE, ARIZONA



Canyon site



Plan of projected canyon launch site

During winter the NCAR balloon launch site at Palestine, Texas, is not a suitable starting point for long-duration flights, due to the prevailing eastward direction of the upper atmosphere winds. Instead of drifting westward overland, as they do in summer, balloons on long flights would be carried out over the Atlantic where recovery of the payload would be extremely difficult. To meet an increasing number of requests for long-duration winter flights, NCAR operates an alternate seasonal launch facility at Page in northern Arizona, the construction townsite for Glen Canyon Dam.

The idea of using Page regularly during the winter arose after NCAR made a number of successful balloon launches from Glen Canyon below the dam in late 1962 and early 1963. The first of these, in December 1962, was a test flight for the University of Arizona Project Polariscope which involved vertical inflation and static launch methods. Other possible sites in the southwestern U.S. also have light surface winds during winter, but Page has two great advantages: (1) the natural, 700-ft deep shelter provided by the canyon below the Glen Canyon Dam is eminently suitable for static launch of very large balloons and delicate payloads which cannot tolerate the accelerations of a dynamic launch, and (2) the location is well away from established airlanes.

NCAR experience at Page supports the conclusion drawn from meteorological studies — that both Page Airport (above the canyon) and the tail-water area are good winter launch sites. Since 1962, NCAR has launched a total of 29 flights from Page. In 1967, between mid-January and mid-March, 9 flights were made — of which 8 were operationally successful. Experiments on these flights were carried out by the University of Arizona, the University of California at San Diego, NASA's Institute for Space Studies, Ohio State University, Louisiana State University, and Massachusetts Institute of Technology. The usual launch crews this year consisted of 10 contract crewmen, 2 NCAR staff members, and a meteorologist from ESSA.

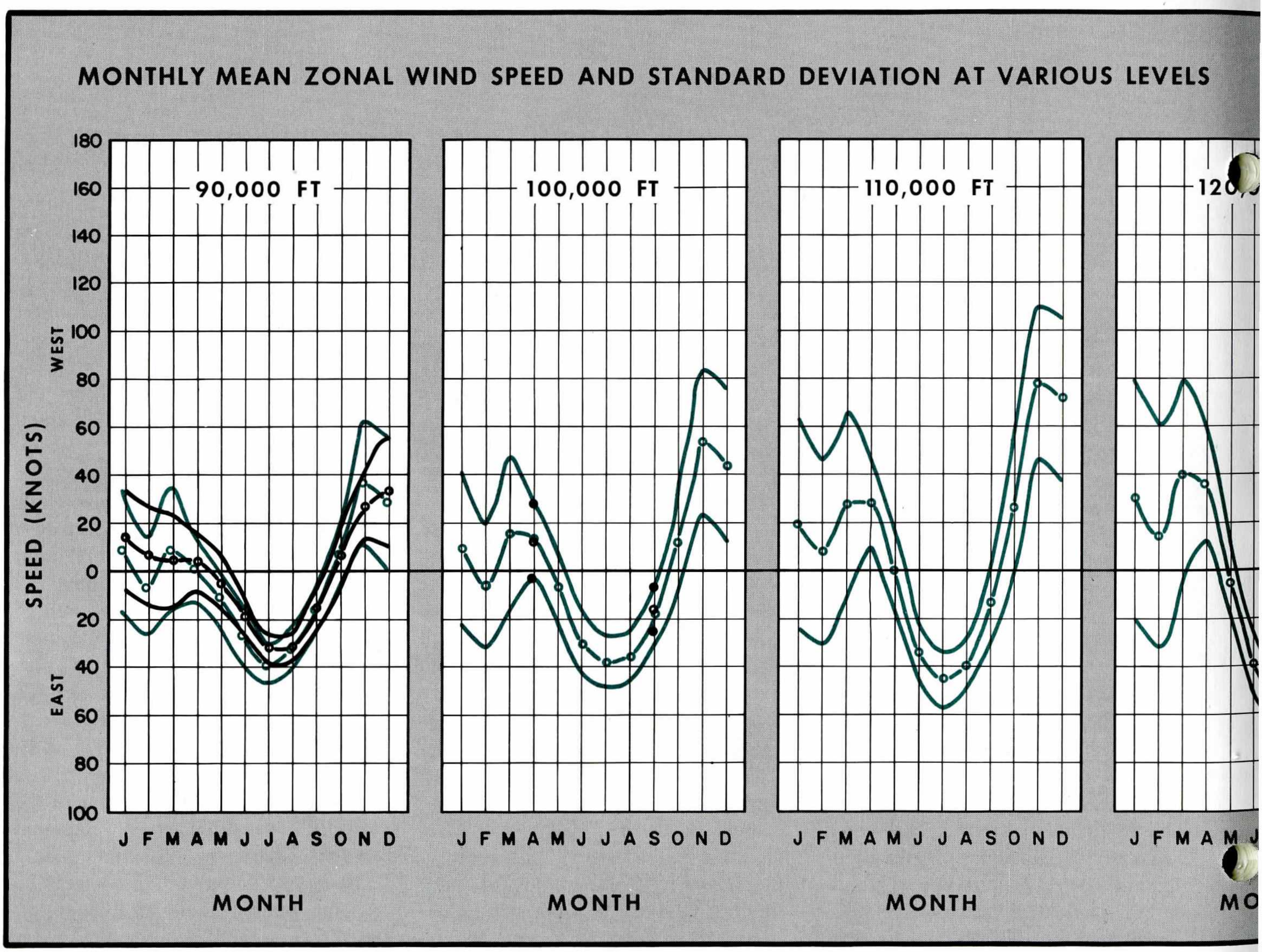
Up to now, NCAR has rented a hangar each year at Page Airport and the launches have generally been made from the end of the runway. However, in the near future it is hoped to activate two long-term agreements between the Bureau of Reclamation and the National Science Foundation, for the use of land at the airport and at the canyon site. The permanent winter launch facilities at the airport would consist of an 80 x 40 ft prefabricated metal building to contain offices, workshop and staging areas, and a graded and stabilized launching area measuring 750 ft square and located at the northeast corner of the airport. The projected development of the canyon site would comprise a 150 x 700 ft paved launch area, a staging building, and an elevator — as shown in the diagram.

Float Winds For Palestine

Keith Giles, ESSA

To aid potential users of the NCAR scientific ballooning facilities at Palestine, Texas, a series of graphs has been prepared by the ESSA Air Resources Field Support Office attached to the Palestine station. These graphs, based on rocket wind data obtained from the White Sands Missile Range, New Mexico, can be used to estimate how far and in what direction a balloon may drift — depending on date, design altitude, and flight duration — and thus to help assess problems of recovery for a planned launch from Palestine.

Rockets are presently the best source of data on winds at altitudes above 100,000 ft, and White Sands is the nearest range to Palestine that fires meteorological rockets with any degree of regularity. From these data (published by the Secretariat, Range Commanders Council, White Sands Missile Range) the monthly mean zonal wind speeds and standard deviations have been extracted for the years 1961 through 1965 and are presented graphically for each 10,000-ft interval from 90,000 to 150,000

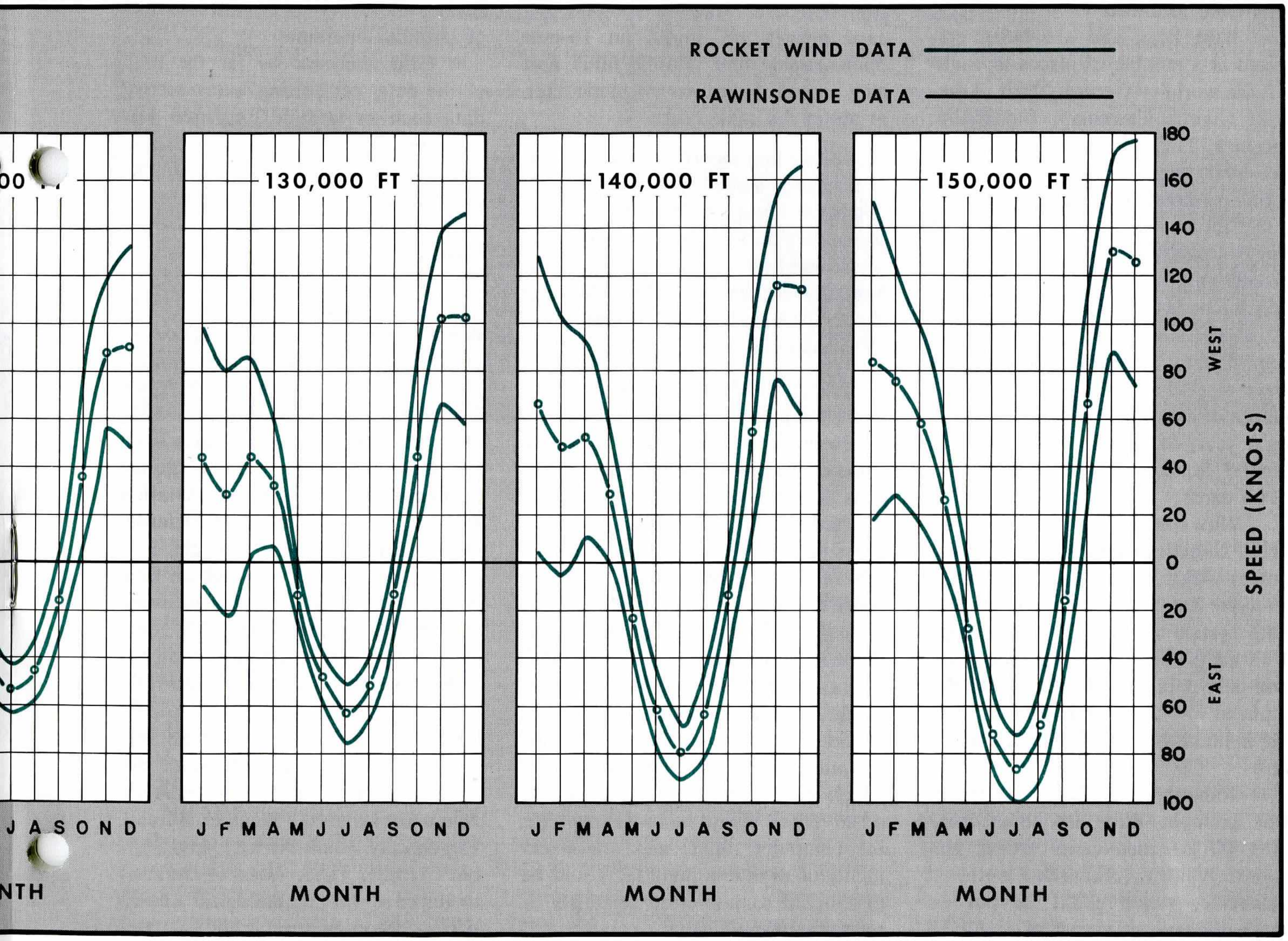


ft. West winds (i.e., winds *from* the west) are shown as positive, and east winds as negative.

For comparison, rawinsonde data from Fort Worth, Texas — the closest source of such data — are also shown on the graphs wherever the number of observations exceeds 100. These data cover the years 1960 through 1964, but the only level for which there is a complete set of monthly values is 90,000 ft. As can be seen, at 90,000 ft and for the two values at 100,000 ft, there is reasonable agreement between the rocket wind data and the rawinsonde data.

The graphs reveal several interesting characteristics of the zonal wind:

- The amplitude (i.e., total variation) of the wind speed increases with height, as both winter westerlies and summer easterlies are stronger at higher altitudes.
- The standard deviations are small during summer months and increase during winter. The larger deviations in winter are partially due to directional fluctuations, which are quite small during the summer.
- Summer easterly wind speeds peak in July at all levels.
- Winter westerlies peak, in the mean, in November at almost all levels.
- During late winter and early spring the "westerlies" can become easterlies. The February means show a relative minimum in westerly speeds at all levels except 150,000 ft. At 90,000 and 100,000 ft the means even become easterly.
- The mean spring reversal occurs from late April to early May. The mean fall reversal occurs from late September to early October. However, standard deviations indicate appreciable fluctuations in actual winds.



Computer-Ready Meteorological Data

Immense amounts of atmospheric data have been and are being collected at a number of places throughout the world — Geneva, Paris, Asheville (North Carolina), Stockholm, Moscow, Tokyo, to name only a few. However, most of the data are not in forms completely suitable for computer input, and must be reworked for computer use, a process which usually involves transferring them to punch cards and magnetic tape. If all of the world's incoming conventional meteorological observations were punched on cards, there would be about 50,000,000 cards to punch each year, at a cost (if done in the United States) of $45 to $50 per 1000 cards.

With some weather data, this expense is now avoided by using computers which read data directly from teletype lines. However, the world's data system is not yet able to cope with the problem of making incoming and past data available for computer input at low cost; often there is trouble in making even printed data available.

Some data are already on cards. For example, there are about 300,000,000 punched cards at the National Weather Records Center at Asheville, which could be put on magnetic tape at a cost of about $5 per 1000 cards. Another 200,000,000 card images are stored on 16-mm photographic film (Fosdic film) and can be transferred to magnetic tape at about the same cost.

Once the records are on tape, it is normally desirable to identify and correct major errors which may have originated during observation, transmission, key punching, or other handling of the data. The checking process is time-consuming and therefore also expensive.

At NCAR, Roy Jenne of the Computing Facility, assisted by Dennis Joseph, has been active in easing some of the meteorological data problems of research workers by preparing selected data for computer input. As a result, NCAR now has numerous sets of data on magnetic tape. They consist largely of grid analyses, but include also some sets of actual observations. Rather than allow these tapes to become "dead" storage, Jenne can supply copies of them to outside users. In addition, he is attempting to foster programs under which most common types of world observations would be made available for computer input, and announcements of available material would be distributed to interested scientists or scientific organizations.

Data at NCAR for Computer Input

Data available at NCAR fall into three groups:

- Geographic data: world land-surface elevations at 1° intersections of latitude/longitude.
- Grid analyses: by far the bulk of the data, comprising many sets of data such as latitude/longitude grid analyses of southern hemisphere surface pressure and 500-mb heights during the IGY, and National Meteorological Center (NMC) and Air Weather Service (AWS) analyses on the 1977-point octagonal grid of the northern hemisphere. The NMC and AWS grid analyses made prior to 1962 include only a few levels; after 1962 they cover ten to twelve levels from the surface to 10 mb. For 1955-1960, one million punched cards from the 433L Project — a joint project conducted by the Federal Aviation Agency, the Department of Defense, and the Department of Commerce — have been corrected and put on tape in octagonal grid format. Also available in computer form are U.S. Navy grid analyses for selected periods.
- Observational data material: obtained in connection with specialized research at NCAR. These files now include whaling ship data obtained for Harry Van Loon (NCAR), Johannes Taljaard (Weather Bureau, Republic of South Africa), and Harold Crutcher (U.S. Weather Bureau) to improve the climatological knowledge of the circulation in the southern

Discipline	WDC-A (USA)	WDC-B (USSR)	WDC-C
Meteorology	Asheville, N.C.	Moscow	Geneva, Switzerland
Geomagnetism	Washington, D.C.	Moscow	Charlottenlund, Denmark; Kyoto
Aurora	College, Alaska; Ithaca, N.Y.	Moscow	Stockholm; Edinburgh
Airglow	Boulder, Colo.	Moscow	Paris; Tokyo
Ionosphere	Boulder, Colo.	Moscow	Slough, England; Tokyo
Solar activity	Boulder, Colo. Boulder, Colo.	Moscow Simeis, Crimea	Zurich, Switzerland Arcetri-Firenze, Italy; Meudon, Pic-du-Midi, France; Freiburg, Germany; Sydney, Australia
Cosmic rays	Minneapolis, Minn.	Moscow	Stockholm; Tokyo
Longitude and latitude	Washington, D.C.	Moscow	--
Glaciology	New York, N.Y.	Moscow	Cambridge, England
Oceanography	Washington, D.C.	Moscow	--
Rockets and satellites	Washington, D.C.	Moscow	Slough, England
Seismology	Washington, D.C.	Moscow	Strasbourg, France
Gravimetry	Washington, D.C.	Moscow	Uccle, Belgium
Nuclear radiation	Asheville, N.C.	Moscow	Stockholm; Tokyo

Institutions which collect atmospheric data were organized into three World Data Centers in 1955 during the planning for IGY, and now serve as collection centers and as channels for the international exchange of information.

The United States and the USSR each operate a World Data Center (WDC-A and WDC-B) including all IGY disciplines. A third World Data Center (WDC-C) consists of archive subcenters located in 21 institutions in Western Europe, Australia, and Japan.

To guard against accidental loss of irreplaceable data, and to make access as convenient as is practical, the information archived in each of three World Data Centers is to a large extent duplicated at the other two.

hemisphere; selected precipitation and stream runoff data (annual and monthly), collected by Vujica Yevdjevitch in connection with his hydrological studies at the Colorado State University Department of Civil Engineering; and data showing the energy in the solar spectrum from 2080 to 2600A assembled by Jitendra Dave and Paul Furukawa (NCAR).

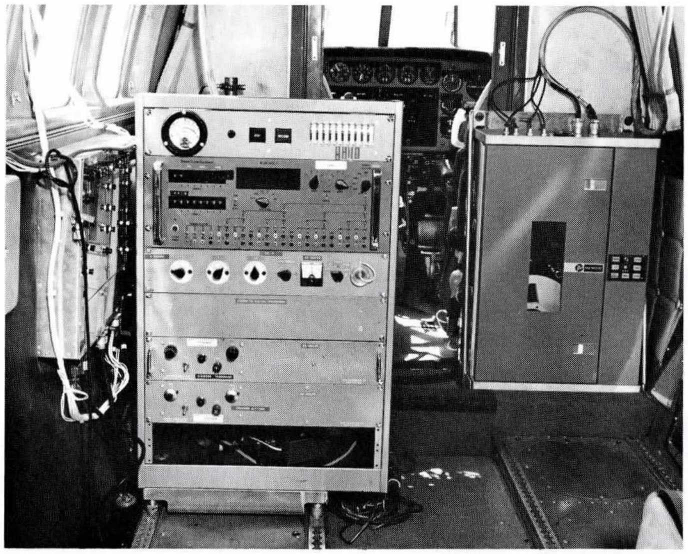
NCAR's computer-ready data can be copied onto magnetic tape, at no more than cost, to fulfill requests. Jenne and his staff invite requests from interested scientists, and hope to trade data with various organizations. They hope that such cooperation will help to reduce costly duplication of effort in acquiring and organizing data that are already available in computer form.

Material To Be Available

The NCAR Computing Facility will continue to acquire sets of northern hemisphere grid analyses from the National Meteorological Center and from the Air Weather Service, and also plans to obtain continuing series of atmospheric, sea/air heat exchange, water temperature, and water current grid analyses from the Navy. Pacific Ocean monthly surface temperatures compiled by the Bureau of Commercial Fisheries are nearly ready for general use. Southern hemisphere surface grid analyses for January 1951 - May 1957 have been ordered. Rocket network data, southern hemisphere whaling ship data, and selected recent upper air observational data from New Zealand and Australia are being received.

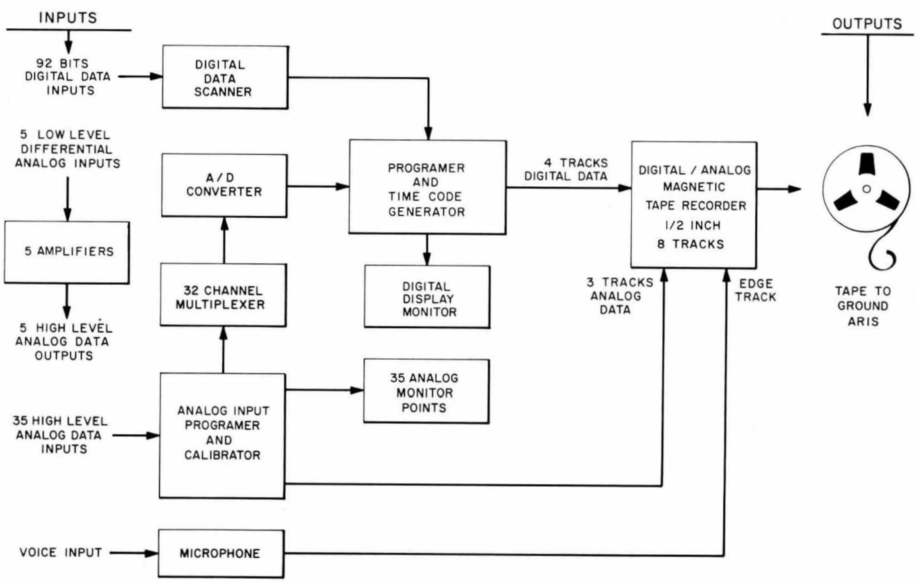
ARIS

Aircraft Research Instrumentation System



Airborne ARIS. The tape recorder is on the right.

AIRBORNE ARIS



ARIS, a general-purpose data acquisition system developed by NCAR, has now been in operational use for more than a year on aircraft of the NCAR Research Aviation Facility. This highly flexible system combines the advantages of both analog and digital recording techniques, to meet a wide range of different data acquisition requirements. ARIS consists of airborne equipment for monitoring and recording scientific data, and ground-based equipment for transferring the data onto various types of permanent records.

The airborne equipment, which will accept signals from any compatible sensor, can record simultaneously up to 35 analog data channels, 23 decades of binary coded decimal (BCD) digital data, 8 decades of internally generated time data, and a voice channel for comments by flight observers. Generally speaking, analog recording techniques are employed for high-frequency data and digital techniques for low-frequency data. All data are recorded on standard ½-in., 8-track magnetic tape. Six recording speeds are available, from 1⅞ to 60 in./sec.

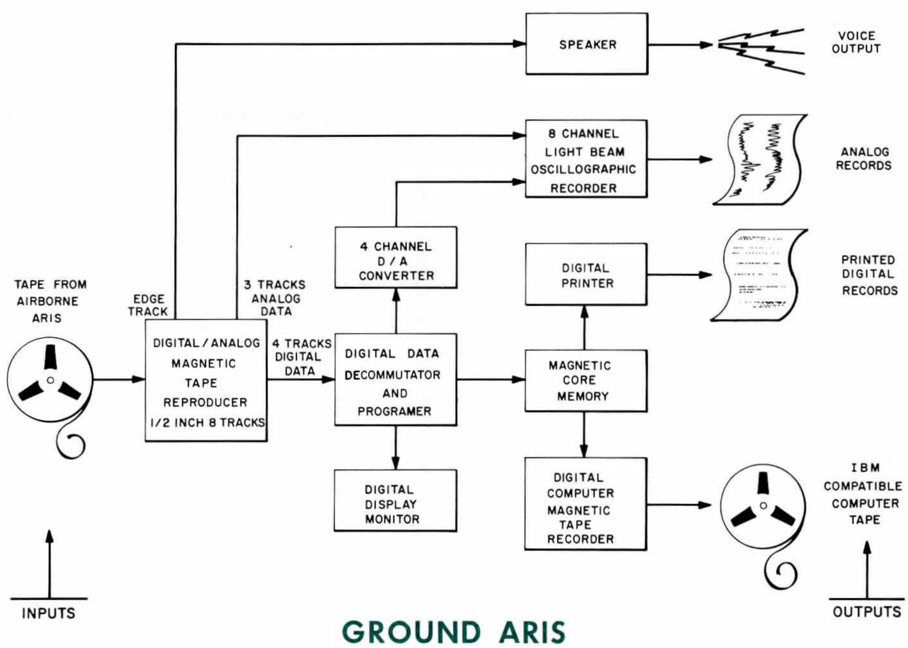
Three of the 35 analog data inputs are recorded in analog form and the remaining 32 are converted and recorded digitally. The former can be recorded either directly or by an FM technique, as desired, by means of interchangeable plug-in modules. (The direct recording method offers better bandwidth capability, while the FM technique allows greater accuracy.) The other 32 analog channels are sampled sequentially by a solid-state multiplexer and passed through an analog-to-digital converter. If fewer than 32 channels are sufficient for a particular requirement, the inputs can be cross-strapped to increase the sampling frequency and hence the bandwidth capability.

Both analog and digital data can be monitored during flight. Any digital channel can be displayed via a 5-decade readout on the front of the control panel, and all 35 analog inputs are available at jacks for monitoring

Air tape recording speed (in./sec)	Recording time per reel (hr)	Data Recorded in Digital Form			Data Recorded in Analog Form	
		Sampling rate at all inputs (samples/sec)	Data bandwidth at each of 32 analog inputs (Hz)	Total analog data bandwidth (Hz)	Data bandwidth on each FM channel (kHz)	Data bandwidth on each direct channel (kHz)
1-7/8	8	8	0 - 2	0 - 64	0 - 0.625	0.3 - 6
3-3/4	4	16	0 - 4	0 - 128	0 - 1.25	0.3 - 12
7-1/2	2	32	0 - 8	0 - 256	0 - 2.5	0.3 - 25
15	1	64	0 - 16	0 - 512	0 - 5	0.3 - 50
30	1/2	128	0 - 32	0 - 1000	0 - 10	0.3 - 100
60	1/4	256	0 - 64	0 - 2000	0 - 20	0.3 - 200

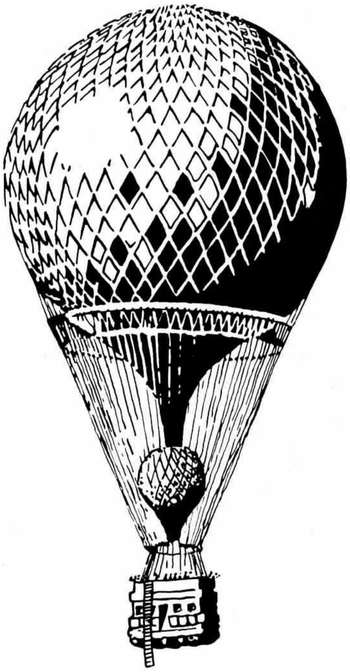
ARIS performance chart

The ARIS ground station.



with an oscilloscope or other display device.

The ground-based equipment is used to transfer the tape-recorded data from the airborne equipment, onto any of three different types of permanent records — strip charts, printed-page digital records, or computer-compatible magnetic tapes for subsequent reduction and analysis of the data on a general purpose digital computer. The ground equipment also provides a speaker for monitoring voice information, a 5-decade readout to show the time as recorded on the air-tape, and a 3-decade readout for displaying any one of the digital data channels.



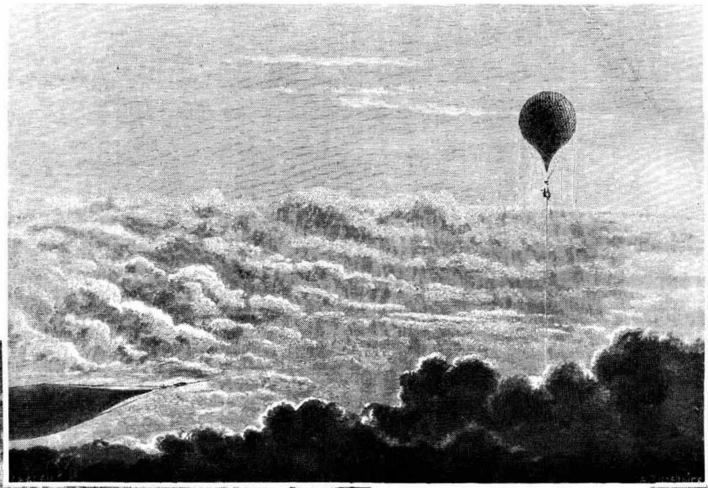
Scheduled Balloon Flights

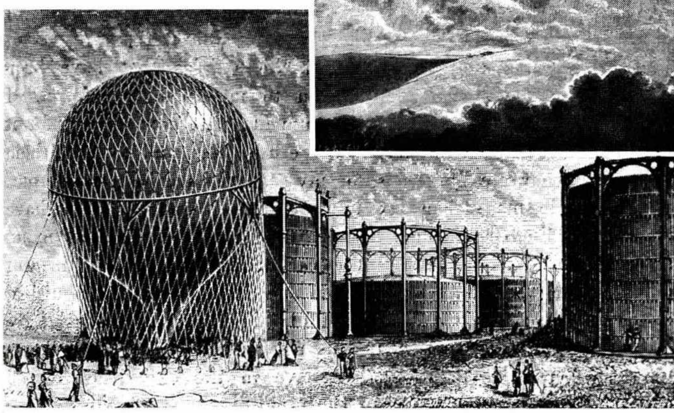
States or Provinces for *Scheduled Flights* and *Flight Record* locations:

Albrook Air Force Base, Canal Zone, Panama
Alegrete, Brazil
Bemidji, Minnesota
Canal Zone, Panama
Chico, California
Ft. Churchill, Manitoba
Goodfellow Air Force Base, Texas
Holloman Air Force Base, New Mexico
Natal, Brazil
Page, Arizona
Palestine, Texas
Sioux Falls, South Dakota
St. Paul, Minnesota
Uruguaiana, Brazil
White Sands Missile Range, New Mexico

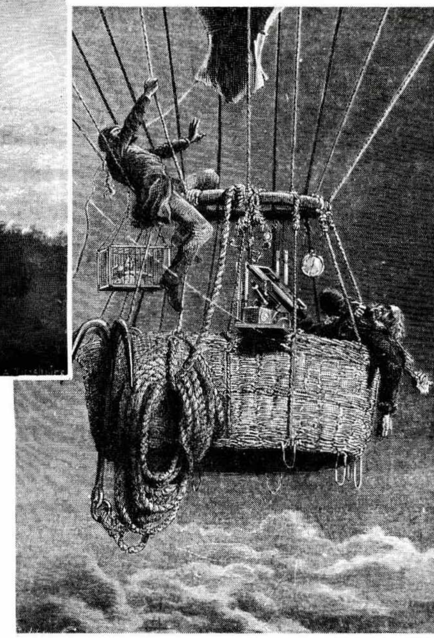
Date (1967)	Location	Sponsor	Investigator	Flight operation conducted by
April	Palestine	NASA	R. Vogt (Cal Tech)	NCAR
"	"	ONR, NASA	W. Webber (U. Minn.)	"
"	"	NASA	G. Chapman (ORNL)	"
May	"	"	J. Klarman, (Wash. Univ.)	"
"	"	"	J. Overbeck (MIT)	"
May	Palestine	NSF	R. Huggett (LSU)	NCAR
"	"	NCAR	D. Ehhalt (NCAR)	"
"	"	NASA	G. Hogan (GSFC)	"
"	"	Bristol	P. Fowler (U. Bristol)	"
"	"	NASA	R. Novick (Columbia U.)	"
May	Palestine	AFOSR	R. Haymes (Rice U.)	NCAR
"	"	NASA	K. Frost (GSFC)	"
"	"	"	G. Clark (MIT)	"
"	"	"	E. Chupp (UNH)	"
"	"	"	L. Peterson (UCSD)	"
"	"	"	Metzker (JPL)	"
June	Chico	"	L. Alvarez (U. Calif.)	GTS

Balloon shadow on cloud





Launch from gasworks



Glaisher insensible at 7 miles altitude

Some episodes from 19th century ballooning

Balloon specs (volume in cu ft; polyethylene unless specified)	Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
10.6 million; 0.5 mil capped	144,000	12	120	Primary cosmic rays	6 flights
2.94 million; 0.7 mil	125,000	10	400	Gamma ray astronomy	2 flights
5 million; 0.75 mil	128,000	6	500	Solid-state gamma ray detector	– –
10.6 million; 0.5 mil capped	140,000	10	350	Gamma ray detector	– –
10.6 million; 0.5 mil capped	135,000	10	450	"	– –
10.6 million; 0.9 mil capped	130,000	12	1,200	Ultra-high energy particles	– –
1.6 million; 1.0 mil valve descent	100,000	7	800	Air sampling	– –
80,000; 0.75 mil	70,000	96	150	Tracking test	– –
10.6 million; 0.5 mil capped	140,000	15	400	Nuclear emulsions	2 flights
450,000; 0.5 mil	100,000	8	250	Gamma ray background study	2 flights
10.6 million; 0.7 mil capped	136,000	10	600	Gamma ray astronomy	– –
10.6 million; 0.7 mil capped	136,000	12	550	"	2 flights
10.6 million; 0.5 mil capped	140,000	10	400	Proportional counter	– –
3 million; 0.5 mil	130,000	12	50	Gamma ray detector	4 flights
10.6 million; 0.5 mil capped	140,000	12	400	Gamma ray astronomy	4 flights
5 million; 0.75 mil	133,000	12	250	Gamma ray detector	– –
crim	90,000	– –	10,000	High altitude particle physics	Tandem balloon system

Balloon Flight Record

Date (1966)	Location	Sponsor	Investigator	Flight operation conducted by	Balloon specs (volume in cu ft; polyethylene unless specified)
(1966) Jun 10	Ft. Churchill	ONR	P. Meyer (U. Chicago)	Raven	10.6 million; 0.7 mil capped
" 10	"	"	"	"	6 million; 0.5 mil
" 15	"	"	"	"	10.6 million; 0.7 mil
" 15	"	"	P. Meyer, J. L'Heueux (U. Chicago)	"	6 million; 0.5 mil
" 15	"	"	R. Vogt (Cal Tech)	"	10.6 million; 0.6 mil
Jun 20	Ft. Churchill	ONR	P. Meyer (U. Chicago)	Raven	6 million; 0.5 mil
" 27	"	"	P. Meyer, J. Fanselow (U. Chicago)	"	10.6 million; 0.7 mil
" 27	"	"	R. Vogt (Cal Tech)	"	10.6 million; 0.6 mil
" 27	"	"	E. Ney, Rosen (U. Minn.)	"	250,000; 0.5 mil
" 30	"	"	"	"	250,000; 0.5 mil
Jul 3	Ft. Churchill	ONR	R. Vogt (Cal Tech)	Raven	10.6 million; 0.6 mil
" 7	"	"	V. Balasubrahmanyan (GSFC)	"	10.6 million; 0.5 mil
" 11	"	"	R. Vogt (Cal Tech)	"	10.6 million; 0.6 mil
" 13	"	"	V. Balasubrahmanyan (GSFC)	"	10.6 million; 0.5 mil
" 13	"	"	W. Webber (U. Minn.)	"	10.6 million; 0.5 mil
Jul 14	Ft. Churchill	ONR	C. Deney (U. Rochester)	Raven	10.6 million; 0.5 mil
" 15	"	"	R. Vogt (Cal Tech)	"	10.6 million; 0.5 mil
" 16	"	"	V. Balasubrahmanyan (GSFC)	"	10.6 million; 0.5 mil
" 16	"	"	T. Foelsche (LRC), R. Mendell (NYU)	"	2.94 million; 0.7 mil
" 16	"	"	W. Webber (U. Minn.)	"	4 million; 0.7 mil
Jul 24	Ft. Churchill	ONR	T. Foelsche (LRC), R. Mendell (NYU)	Raven	325,000; 1.5 mil
" 25	"	"	W. Webber (U. Minn.)	"	10.6 million; 0.5 mil
" 26	"	"	R. Vogt (Cal Tech)	"	10.6 million; 0.5 mil
" 26	"	"	U. Earl (U. Md.)	"	1 million; 0.5 mil
" 30	"	"	C. Deney (U. Rochester)	"	10.6 million; 0.5 mil

Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
133,200	19	962	Electron-positron ratio	Successful flight
135,000	17	491.5	Primary cosmic radiation spectra and flux	"
132,600	17.5	1960	Electron-positron ratio	"
135,000	10.4	488	Primary cosmic radiation spectra and flux	Successful flight; telemetry lost due to faulty RF converter
148,000	17.4	369	Measurement of flux and spectrum of heavy nuclear particles	Successful flight
136,500	20.8	499	Primary cosmic radiation spectra and flux	Successful flight
136,000	16.4	960	Electron-positron ratio	"
144,800	14.9	374	Measurement of flux and spectrum of heavy nuclear particles	"
107,100	3.8	130	Vertical distribution of dust and ozone	"
107,700	3.9	126.5	"	"
143,800	10.4	380	Meaurement of flux and spectrum of heavy nuclear particles	Successful flight
145,100	16.4	370	Galactic cosmic rays	"
144,600	15.5	371	Measurement of flux and spectrum of heavy nuclear particles	"
142,500	19.9	450	Galactic cosmic rays	"
151,200	12.7	368	"	"
139,200	18.8	548	Flux and spectrum of charged particles	Successful flight
147,200	21.4	385	Measurement of flux and spectrum of heavy nuclear particles	"
143,400	21.1	447	Galactic cosmic rays	"
125,000	17.9	537	Measurement of flux and spectrum of fast neutrons	"
133,200	11.4	352	Galactic cosmic rays	Successful flight; cutdown 3.5 hr early
74,000	20.9	751	Galactic cosmic rays	Successful flight; duct shortened 35 ft before launch
145,000	18.4	648	Electron showers	Successful flight
142,600	15.5	379	Measurement of flux and spectrum of heavy nuclear particles	"
118,200	17.9	312	Measurement of flux and direction of cosmic ray electrons, protons, alpha particles	"
143,000	19.3	543	Flux and spectrum of charged particles	"

Balloon Flight Record

	Date (1966)	Location	Sponsor	Investigator	Flight operation conducted by	Balloon specs (volume in cu ft; polyethylene unless specified)
(1966)	Jul 30	Ft. Churchill	ONR	U. Earl (U. Md.)	Raven	1 million; 0.5 mil
	" 31	"	"	T. Foelsche (LRC), R. Mendell (NYU)	"	325,000; 1.5 mil
	Aug 2	"	"	"	"	10.6 million; 0.5 mil
	" 6	"	"	"	"	325,000; 1.5 mil
	" 6	"	"	U. Earl (U. Md.)	"	5.25 million; 0.8 mil
	Aug 7	Ft. Churchill	ONR	C. Deney (U. Rochester)	Raven	10.6 million; 0.5 mil
	" 7	"	"	F. McDonald (JPL)	"	5.25 million; 0.7 mil
	" 27	St. Paul	"	J. Earl (U. Md.)	Winzen	749,000; 0.5 mil
	" 30	"	"	"	"	749,000; 0.5 mil
	Sept 7	"	"	"	"	749,000; 0.5 mil
	Sept 14	Bemidji	ONR	D. Hagge (GSFC)	Winzen	10.6 million; 0.6 mil
	" 14	"	"	"	"	10.6 million; 0.6 mil
	" 16	Canal Zone	AEC	G. Frye (Case Inst.)	Raven	10.5 million; 0.5 mil
	" 18	Albrook AFB	"	AEC	USAF*	1.6 million; 1.5 mil
	" 19	Goodfellow AFB	"	"	"	3.5 million; 0.8 mil
	Sept 19	Bemidji	ONR	D. Hagge (GSFC)	Winzen	10.6 million; 0.6 mil
	" 21	Albrook AFB	AEC	AEC	USAF*	5.25 million; 1.5 mil
	" 21	Goodfellow AFB	"	"	"	1.6 million; 1.5 mil
	" 22	Albrook AFB	"	"	"	45,000; 1.5 mil
	" 22	Canal Zone	"	G. Frye (Case Inst.)	Raven	9 million; 0.75 mil
	Sept 22	Goodfellow AFB	AEC	AEC	USAF*	45,000; 1.5 mil
	" 23	Bemidji	ONR	D. Hagge (GSFC)	Winzen	2.94 million; 0.7 mil
	" 23	Albrook AFB	AEC	AEC	USAF*	242,000; 1.5 mil
	" 23	Goodfellow AFB	"	"	"	242,000; 1.5 mil
	" 24	Albrook AFB	"	"	"	1.6 million; 1.5 mil
	Sept 25	Canal Zone	AEC	G. Frye (Case Inst.)	Raven	10.5 million; 0.5 mil
	" 26	Goodfellow AFB	"	AEC	USAF*	10.6 million; 0.7 mil capped
	Oct 13	"	"	"	"	1.6 million; 1.5 mil
	" 16	"	"	"	"	45,000; 1.5 mil
	" 20	Natal	"	"	"	242,000; 1.5 mil
	Oct 20	Goodfellow AFB	AEC	AEC	USAF*	242,000; 1.5 mil
	" 21	Natal	"	"	"	10.6 million; 0.7 mil capped
	" 22	"	"	"	"	1.6 million; 1.5 mil
	" 23	"	"	"	"	3.5 million; 0.8 mil
	" 24	"	"	"	"	45,000; 1.5 mil

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Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
116,200	14.3	349	Measurement of flux and direction of cosmic ray electrons, protons, alpha particles	Successful flight
69,000	5.1	936	Galactic cosmic rays	Flight terminated early due to unfavorable trajectory
137,500	19.4	587	"	Successful flight
76,600	19.4	816.5	"	"
130,600	15.8	371	Measurement of flux and direction of cosmic ray electrons, protons, alpha particles	"
141,400	18.8	554	Flux and spectrum of charged particles	Successful flight
132,000	15.2	675	Cosmic ray measurements	"
113,000	10.5	215	"	"
105,000	24	235	"	"
107,000	23.5	250	"	"
141,000	13.5	321	Cosmic ray measurements	Successful flight
143,000	10	286	"	"
140,200	6.3	616	Cosmic ray spark chamber	"
105,000	6.8	488	Particulate debris collection	"
120,000	7.5	656	"	"
– –	4	337	Cosmic ray measurements	Flight terminated at 128,000 ft
120,000	8.1	555	Particulate debris collection	Successful flight
105,000	5.2	513	"	"
90,000	4.9	352	"	"
137,500	3	623	Cosmic ray spark chamber	– –
90,000	5.2	356	Particulate debris collection	Successful flight
124,000	6.2	341	Cosmic ray measurements	"
80,000	3.7	285	Particulate debris collection	"
80,000	4.1	363	"	"
105,000	6.2	485	"	"
– –	– –	620	Cosmic ray spark chamber	Balloon burst at 54,300 ft
135,000	6.2	543	Particulate debris collection	Successful flight
105,000	5.1	519	"	"
90,000	3.8	344	"	"
80,000	4.2	360	"	"
80,000	3.8	366	Particulate debris collection	Successful flight
135,000	7.02	545	"	Collection system malfunction
105,000	2.1	459	"	Successful flight
120,000	7.6	637	"	"
90,000	4.5	350	"	"

Balloon Flight Record

Date (1966-67)		Location	Sponsor	Investigator	Flight operation conducted by	Balloon specs (volume in cu ft; polyethylene unless specified)
(1966)	Oct 25	Natal	AEC	AEC	USAF*	242,000; 1.5 mil
	" 27	"	"	"	"	3.5 million; 0.8 mil
	" 28	"	"	"	"	1.6 million; 1.5 mil
	" 29	"	"	"	"	45,000; 1.5 mil
	" 30	"	"	"	"	10.6 million; 0.7 mil capped
	Nov 3	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
	" 4	Holloman AFB	AFCRL	J. Payne (AFCRL)	AFCRL	78,000; GT-12 scrim
	" 11	Alegrete	NCAR	P. Furukawa (NCAR), A. Krueger (NOTS)	NCAR	180,000; 0.55 mil
	" 12	Uruguaiana	"	"	"	180,000; 0.55 mil
	" 14	GoodfellowAFB	AEC	AEC	USAF*	45,000; 1.5 mil
	Nov 14	Alegrete	NCAR	P. Furukawa (NCAR), A. Krueger (NOTS)	NCAR	180,000; 0.55 mil
	" 14	"	"	"	"	180,000; 0.55 mil
	" 15	Goodfellow AFB	AEC	AEC	USAF*	242,000; 1.5 mil
	" 28	Palestine	AFOSR	R. Haymes (Rice U.)	NCAR	10.6 million; 0.7 mil capped
	" 29	"	NASA	J. Strong (Johns Hopkins)	"	2.94 million; 1.5 mil
	Nov 30	Palestine	NSF	J. Lord (U. Wash.)	NCAR	1.5 million; 1.0 mil
	" 30	"	"	"	"	1.5 million; 0.75 mil
	Dec 7	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
	" 9	Holloman AFB	AFCRL	J. Crummie (AFCRL)	AFCRL	2.01 million; 1.5 mil
	" 9	Goodfellow AFB	AEC	AEC	USAF*	242,000; 1.5 mil
	Dec 9	Palestine	NASA	J. Strong (Johns Hopkins)	NCAR	2.94 million; 1.5 mil
	" 11	"	"	E. Chupp (UNH)	"	2.94 million; 0.6 mil
	" 12	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
	" 13	Holloman AFB	AFCRL	A. Giannetti (AFCRL)	AFCRL	125,426; 2 mil
	" 13	Palestine	ONR	J. Waddington (U. Minn.)	NCAR	10.6 million; 0.5 mil capped
	Dec 14	Chico	AFCRL	A. Korn (AFCRL)	AFCRL	804,000; 2 mil
	" 14	Goodfellow AFB	AEC	AEC	USAF*	5.25 million; 1.5 mil
	" 29	Palestine	NSF	R. Huggett (LSU)	NCAR	3 million; 0.75 mil
(1967)	Jan 3	Goodfellow AFB	AEC	AEC	USAF*	153,000; 1.5 mil
	" 5	Holloman AFB	AFCRL	S. Steinke (AFCRL)	AFCRL	804,000; 2 mil

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Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
80,000	4.3	258	Particulate debris collection	Successful flight
120,000	7.2	652	"	"
105,000	6.7	442	"	"
90,000	4.6	355	"	"
135,000	7.7	552	"	"
105,000	5.3	541	Particulate debris collection	Successful flight
38,000	2.0	3000	Evaluation of 3 launch methods	– –
34,500	N/A	22	Measurement of ozone variations during eclipse	Telemetry signal lost
53,000	N/A	38	"	Strong surface winds; clouds 10 min after launch
90,000	4.9	352	Particulate debris collection	Successful flight
45,500	N/A	22	Measurement of ozone variations during eclipse	Balloon burst at 45,500 ft
45,500	N/A	22	"	"
80,000	3.9	362	Particulate debris collection	Successful flight
131,500	6.0	1103	Radioactive debris in Crab Nebula	"
– –	– –	2715	Dummy load flight test	Ground abort; safety timer box jarred at launch
111,600	0.0	405	Exposure of nuclear emulsion package	Balloon reached ceiling and began descending; flight terminated
111,500	2.6	405	"	Balloon performance good; early termination to avoid Gulf of Mexico
– –	1.6	487	Particulate debris collection	Premature termination
95,800	7.6	1027	Test and evaluation of VOR balloon locating system	Successful flight
79,600	4.8	359	Particulate debris collection	"
95,000	0.2	2715	Dummy load flight test	Successful flight
132,500	3.5	250	Solar gamma rays	"
– –	3.3	489	New command control system	Incomplete
56,000	4	712	Balloon-borne radio-relay system	Successful flight
130,000	2.0	1060	High energy gamma rays	"
72,000	5.7	2000	Balloon test; operational checkout of Tufts launch platform	Successful flight
118,600	5.6	534	Particulate debris collection	"
– –	0.0	1245	Measurement of interaction of ultra-high energy particles	Balloon burst at 50,000 ft
– –	2.03	346	New command control system	Experiment complete; balloon ascended beyond 65,000 ft before failure
– –	1.7	834	Photographs of parachute reaction during valve-down operation and of balloon burst	Defective balloon selected for test-burst at 44,000 ft

Balloon Flight Record

Date (1967)	Location	Sponsor	Investigator	Flight operation conducted by	Balloon specs (volume in cu ft; polyethylene unless specified)
(1967) Jan 5	Goodfellow AFB	AEC	AEC	USAF*	450,000; 1.5 mil
" 5	Palestine	NSF	R. Huggett (LSU)	NCAR	3 million; 0.75 mil
" 9	"	NASA	J. Strong (Johns Hopkins)	"	2.94 million; 1.5 mil
" 10	Holloman AFB	AFCRL	S. Steinke (AFCRL)	AFCRL	125,426; 2 mil
" 10	Chico	"	A. Korn (AFCRL)	"	804,000; 2 mil
Jan 11	Goodfellow AFB	AEC	AEC	USAF*	242,000; 1.5 mil
" 13-27	Holloman AFB	ASD	Sanders Associates	AFCRL	26,000; dacron
" 19	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
" 20	"	"	"	"	10.6 million; 0.7 mil
" 20	Albrook AFB	"	"	"	450,000; 1.5 mil
Jan 21	Albrook AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
" 23	"	"	"	"	242,000; 1.5 mil
" 30	Goodfellow AFB	"	"	"	3.5 million; 0.75 mil
Feb 2	White Sands Missile Range	AFCRL	E. Young (AFCRL)	AFCRL	26,000; dacron
" 2	Goodfellow AFB	AEC	AEC	USAF*	450,000; 1.5 mil
Feb 3	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
" 4	Page	NSF	R. Huggett (LSU)	NCAR	2.94 million; 1.5 mil
" 7	Goodfellow AFB	AEC	AEC	USAF*	242,000; 1.5 mil
" 8	Holloman AFB	AFCRL	L. Grass (AFCRL)	AFCRL	14,080
" 8	"	"	"	"	26,000; dacron
Feb 9	Goodfellow AFB	AEC	AEC	USAF*	3.5 million; 0.75 mil
" 10	Albrook AFB	"	"	"	450,000; 1.5 mil
" 11	"	"	"	"	1.6 million; 1.5 mil
" 12	Chico	AFCRL	U. Calif.	AFCRL	3.03 million; 1 mil
" 12	Goodfellow AFB	AEC	AEC	USAF*	1.6 million; 1.5 mil
Feb 12	Albrook AFB	AEC	AEC	USAF*	242,000; 1.5 mil
" 12	Page	NASA	G. Clark (MIT)	NCAR	10.6 million; 0.5 mil
" 14	Holloman AFB	AFCRL	B. Cildenberg (AFCRL)	AFCRL	800,000; 2 mil
" 17	"	"	"	"	800,000; 2 mil
" 17	Page	NSF	R. Huggett (LSU)	NCAR	2.94 million; 1 mil

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Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
89,300	5.4	349	Particulate debris collection	Successful flight
– –	0.0	1284	Measurement of intraction of ultra-high energy particles	Balloon failed immediately after leaving spool
92,000	6.3	2613	Dust, gaseous materials in corona	Successful flight
47,000	2.4	848	Calibration of burst switch	– –
71,760	3.15	1995	Balloon test; operational test of Tufts launch platform	Successful flight
80,300	4.1	365	Particulate debris collection	Successful flight
300-1100	1-5	731.5	Airborne electronic equipment test	9 tethered flights
103,000	4.7	678	Particulate debris collection; normal and high volume sampling systems compared	Successful flight
139,000	6.7	453	Particulate debris collection	"
90,300	4.5	387	"	Successful flight; aerial recovery
104,100	4.7	472	Particulate debris collection	Successful flight
80,100	4.3	390	"	"
– –	2	678	– –	Balloon failed near 75,000 ft
2,000	3.4	237	38-ft spherical balloon and data reduction program evaluation	Tethered system
88,900	6.1	325	Particulate debris collection	Successful flight
102,700	5.3	671	Normal and high volume sampling systems compared	Successful flight
101,000	8.5	1272	Measurement of interaction of ultra-high energy particles	"
78,300	3.9	362	Particulate debris collection	"
N/A	N/A	N/A	Viron blimp checkout	Hangar test
600	1.05	68.5	38-ft spherical balloon and data reduction program evaluation	Tethered system
– –	1.1	684	– –	Balloon failed at 4,000 ft
89,900	5.5	397	Particulate debris collection	Successful flight; aerial recovery
105,600	5.7	459	"	"
93,000	5.5	2617	Lawrence Radiation Lab HAPPE ½ gondola test	Successful flight
100,900	5.4	672	Particulate debris collection; normal and high volume sampling systems compared	"
81,000	3.3	393	Particulate debris collection	Successful flight; aerial recovery
132,400	12.2	865	Gamma ray telescope	Successful flight
65,000	1.7	673	Balloon dynamics test	– –
40,000	0.9	673	Balloon failure data using FPS-16 digital track, cameras, accelerometers	High jet turbulence; failure at 40,000 ft
102,000	8.1	1306	Measurement of interaction of ultra-high energy particles	Successful flight

Balloon Flight Record

Date (1967)	Location	Sponsor	Investigator	Flight operation conducted by	Balloon specs (volume in cu ft; polyethylene unless specified)
(1967) Feb 19	Page	NASA	J. Shaw (JPL)	NCAR	2.94 million; 1 mil
'' 21	''	''	W. Hoffmann (NASA)	''	360,000; 0.75 mil
'' 27	''	''	L. Peterson (UCSD)	''	6 million; 0.5 mil
'' 28	Goodfellow AFB	AEC	AEC	USAF*	5.25 million; 1.5 mil
Mar 1	Page	NASA	L. Peterson (UCSD)	NCAR	360,000
Mar 7	Page	NASA	L. Peterson (UCSD)	NCAR	3 million; 0.55 mil
'' 8	Goodfellow AFB	AEC	AEC	USAF*	450,000; 1.5 mil
'' 8	Page	NSF, NASA	T. Gehrels (U. Ariz.)	NCAR	10.6 million; 0.9 mil
'' 17	Palestine	NCAR	R. Keuser (Raven)	''	2.94 million; 0.7 mil
'' 17	''	NASA	R. Vogt (Cal Tech)	''	10.6 million; 0.6 mil
Apr 3	Palestine	NASA	R. Vogt (Cal Tech)	NCAR	10.6 million; 0.5 mil
'' 7	''	''	''	''	10.6 million; 0.5 mil
'' 8	''	''	W. Webber (U. Minn.)	''	5 million; 0.75 mil
'' 8	''	''	R. Vogt (Cal Tech)	''	2.94 million; 0.7 mil
'' 10	Sioux Falls	Raven	Raven	Raven	92,000; 1.5 mil
'' 15	Palestine	NASA	R. Vogt (Cal Tech)	NCAR	2.94 million; 0.7 mil
'' 19	''	''	''	''	10.6 million; 0.5 mil

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Float altitude (ft)	Flight duration (hr)	Payload (lb)	Experiment	Remarks
104,000	6.8	1032	Measurement of temperature variations with height	Successful flight
92,700	12.3	220	Infrared sky survey	,,
128,700	6.4	622	Lunar X-rays	Successful flight; early cutdown due to gondola malfunction
118,400	7.9	666	Particulate debris collection; normal and high volume sampling systems compared	Successful flight
81,500	5.2	509	Background radiation with shielded detector	,,
– –	– –	362.5	Background radiation with shielded detector	Balloon started descent at 55,700 ft
87,700	5.4	346	Particulate debris collection	Successful flight
120,700	15.7	1805	Ultraviolet photopolarimetry of stars and planets	,,
119,000	3.5	504	Flight electronics and experimental parachute evaluation	,,
144,000	2.1	372	Primary cosmic radiation spectra	Flight terminated early
139,900	7.4	392	Primary cosmic radiation spectra	Successful flight
16,500	5	555	,,	Balloon failed to reach altitude
– –	– –	657	Cygnus X-ray source observation	Flight aborted due to low-level winds
121,800	2.9	403	Primary cosmic radiation spectra	Early termination to avoid Gulf of Mexico
70,000	3	334	Instrumentation and balloon test	Successful flight
122,100	9.6	379	Primary cosmic radiation spectra	,,
89,000	– –	555	,,	Balloon failed to reach altitude