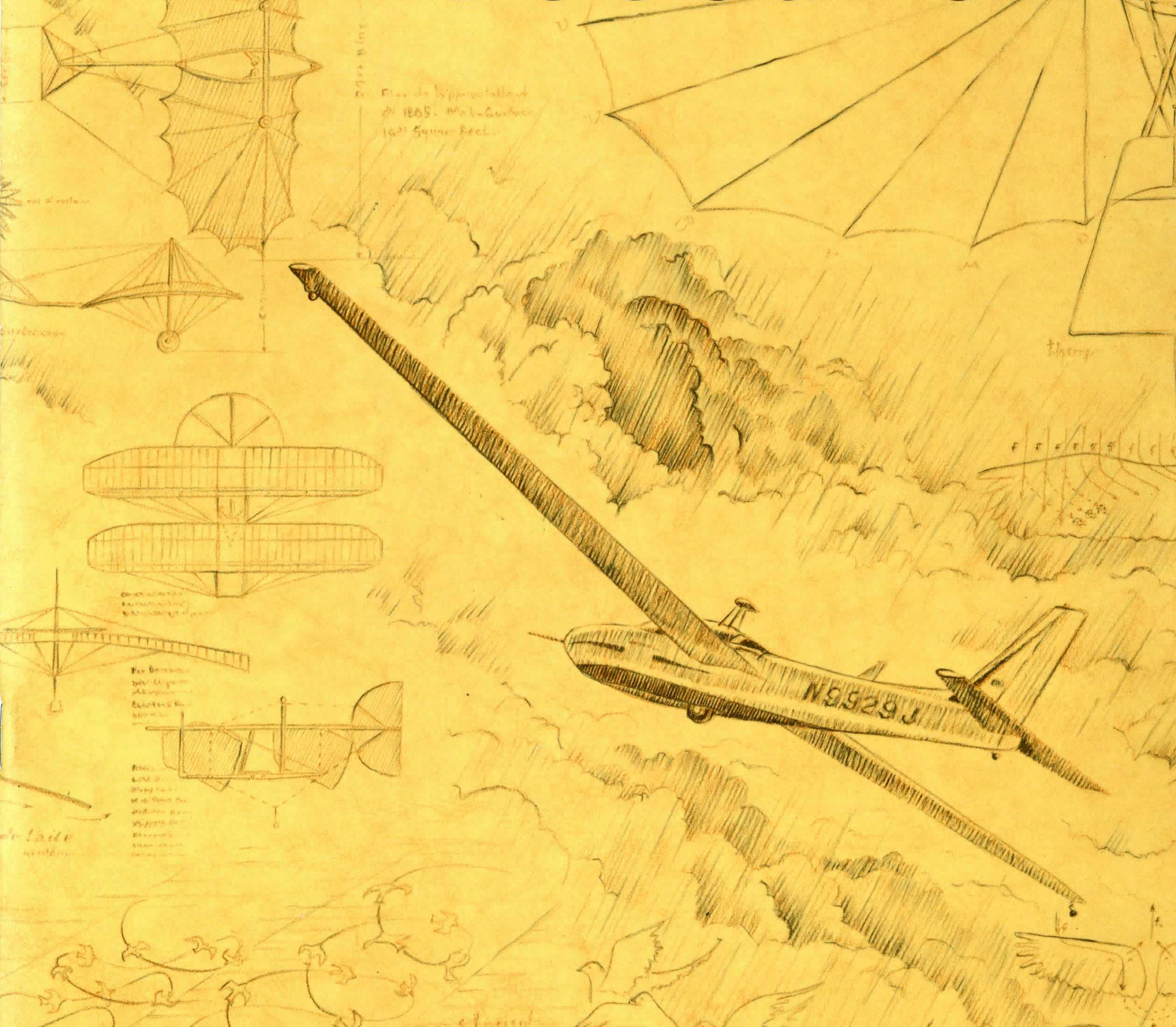
FACILITIES FOR

NO. 15 DECEMBER 1970

atmospheric research



NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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NCAR

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Aviation

Ballooning

Field Observing

Research Systems

Notes

Cover: Modern sailplanes are the descendants of an aeronautical tradition that dates as far back as the Middle Ages. Renaissance thinkers contributed great insights to the principle of flight, but apart from a few, poorly documented episodes, glider flight was not successfully achieved until the late 19th Century. Until the invention of powered aircraft, flight by any means was sought, and bird anatomy was imitated in most aircraft designs. When the traditions of powered and glider flight diverged, true sailplanes came into being. Great advances in aeronautical design and in soaring techniques during the 1920s and 1930s made the sailplane a useful atmospheric research tool. Modern sailplanes can sensitively probe air motions and provide a passive, nondisturbing platform for research instruments. An article beginning on page 2 describes the use of a sailplane at NCAR.

The Explorer at NCAR

Scientific instruments have been installed by NCAR on a Schweizer 2-32 sailplane and research missions have been flown to collect cloud physics data.

During the past 18 months scientists from NCAR, in cooperation with the National Oceanic and Atmospheric Administration (NOAA), have made 34 research and testing flights using a Schweizer 2-32 sailplane, the *Explorer*, to study steady-state wave clouds, small cumulus clouds, and clear air turbulence (CAT). The sailplane was given to NOAA by the Explorers Research Corp. in July 1969 and has since been instrumented for cloud physics and atmospheric motion studies by members of the NCAR Cloud Physics Program in consultation with personnel from Advanced Research Projects (ARP), Environmental Research Laboratories of NOAA.

Joachim Kuettner is director of ARP, and Doyne Sartor is director of the NCAR Atmospheric Physics Department of which the Cloud Physics Program is a part. ARP research includes studies of the horizontal and vertical structure of mountain lee waves and CAT; NCAR's cloud physics research focuses on cloud droplet growth and distribution correlated with measurements of temperature, pressure, humidity, atmospheric motions, and electric fields.

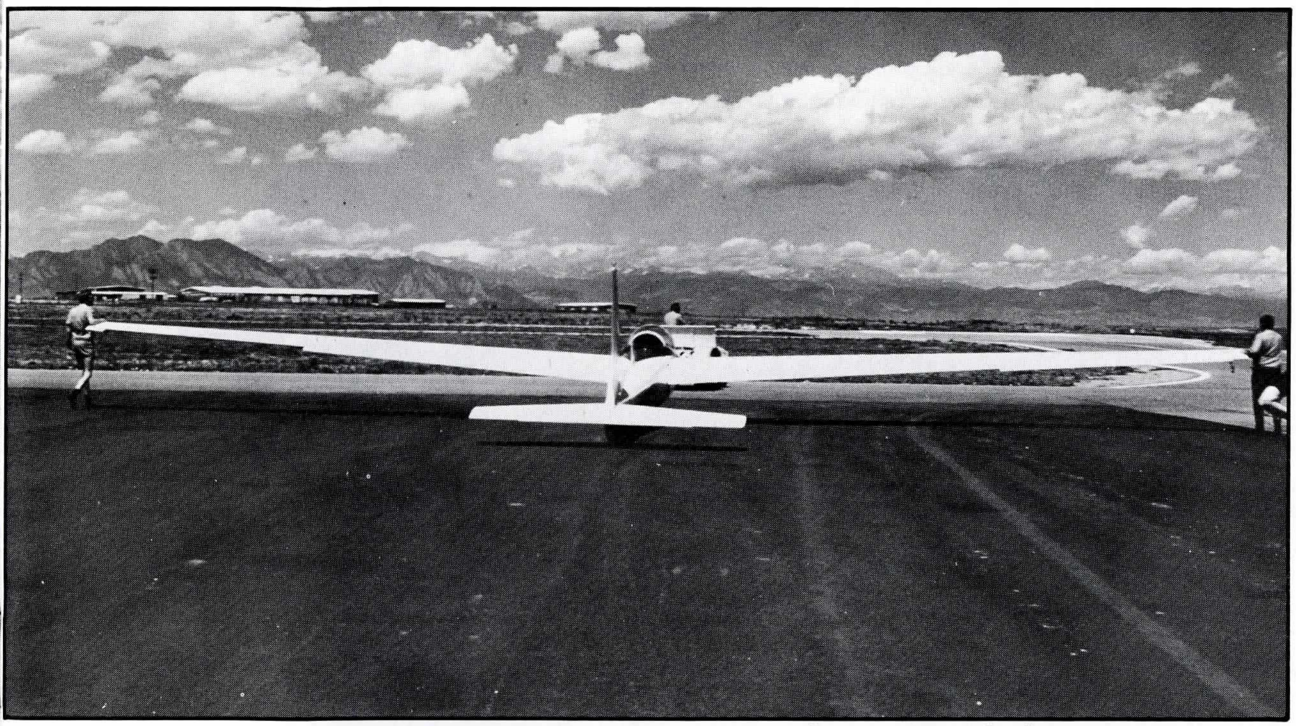


Photo courtesy of Jon Saunders, Boulder, Colorado

The Explorer *is moved to a position at the head of the runway by the ground crew and is towed by powered aircraft to an altitude where steady lift is found. The sailplane pilot can release or retain the tow according to his judgment of available lift. The highest altitude reached in a research flight is 9.9 km (above sea level). Flights generally last from 2 to 5 hr.*

Wim Toutenhoofd of the Cloud Physics Program is the supervising scientist-pilot for research undertaken with the *Explorer*. He is assisted by pilot-observer Daniel Marshall of the NCAR Research Aviation Facility which assumed operational responsibility for the *Explorer* on 1 July 1970. Marshall supervises flight planning, maintenance, instrument development and installation, and certain other engineering and scientific support activities.

Data from six cloud-study flights are now being analyzed by the cloud physics group. Studies conducted during the fall and winter are outdoor laboratory experiments to investigate the growth of cloud droplets and ice crystals in wave clouds which frequently provide steady-state conditions for airborne observations. In the summer months similar investigations are made in cumulus clouds. The results of these studies and of work planned for the future will contribute to an understanding of the microphysics of clouds. The data will also provide useful information for numerical cloud models being devised by other NCAR scientists. During early spring 1970 the sailplane, along with five powered aircraft, collected data in the 1970 Colorado lee wave study (see *Facilities for Atmospheric Research* No. 12, March 1970).

Research Instrumentation and Flight Equipment

The *Explorer* carries sensors for measuring static pressure (altitude), rate of change of static pressure (rate of climb), pitot pressure (indicated airspeed), and outside air temperature. An air-to-ground telemetry system enables voice transmission and continuous collection of scientific and standard sensor data on magnetic tape and chart recorders. Other instruments aboard are an in situ cloud particle camera (see page 7), a 35 - mm reflex camera, a vertical axis accelerometer, a cloud droplet impactor slide gun, and an electrostatic disdrometer that provides cloud droplet distribution measurements. The pilot-observer uses the slide impactor to gather samples against which cloud liquid water content and droplet distribution data from other sampling instruments can be compared.

The disdrometer, one of the most sophisticated instruments aboard the *Explorer*, was designed by scientists at the Massachusetts Institute of Technology for the Air Force Cambridge Research Laboratories, but has been considerably modified at NCAR by Charles Abbott. The instrument samples at 1.5 cm^3/sec and gives continuous, direct readout of droplet spectra into nine channels in the range 4 to 31 μm radius, with ± 1.5 μm resolution; a tenth

The Schweizer 2-32 is a high-performance, all-metal sailplane with a soaring altitude capability of 15 km. Empty weight is 377 kg, and maximum certified gross weight is 649.2 kg. Length is 8.16 m, and wing span is 17.4 m. Minimum sink (the rate of descent in level flight through still air) is about 1 m/sec and the maximum glide ratio is 30:1 at about 95 km/hr indicated airspeed (at a height of 1 km in still air, it can glide to a landing 30 km away). A two place carrier, it can accommodate an observer, elaborate navigation equipment, and scientific instrumentation.

channel counts all droplets over 31 μm. The data are read out each 0.5 sec, thus giving an average size distribution over distances as small as 15 m for usual sailplane flight speeds.

The *Explorer's* scientific package and flight instrumentation, and the 9-channel VHF telemetry system are powered by a 1,200 W-hr battery. The basic avionics and flight safety equipment are owned by NOAA and include radio for navigation and communications, a radar transponder, gyroscopic instruments for cloud flying, and a built-in high altitude automatic pressure-demand oxygen system. A rear instrument panel has recently been installed to provide real-time display of output from the onboard sensors. Planned additions to the *Explorer's* instrumentation include a humidiometer, electric-field probes, and a commutated channel for slow recording of secondary information (e.g., battery voltage and temperature, cabin temperature, and switch positions).

Pilot Qualifications and Flight Restrictions

Research flights are frequently nonvisual, and the pilot must have both a sailplane and an instrument rating. The instrument rating must be earned on a powered aircraft because FAA standards have not been established for an instrumented sailplane. Experienced pilots usually develop an instinctive ability to sense the locations of updrafts and thus, in most cases, to guide their flight to the regions of greatest scientific interest.

Whenever the *Explorer* is navigated by instruments, it is under the direction of the Denver Air Traffic Control Center which has authority over all aircraft flying on instruments or flying at altitudes above 7.3 km (24,000 ft). When the sailplane is flying neither on instruments nor above 7.3 km it is subject to Visual Flight Rules. Most of the sailplane studies have been in clouds at 4.5 and 7.0 km (above sea level) and one flight reached 9.9 km (above sea level).

Flight Techniques

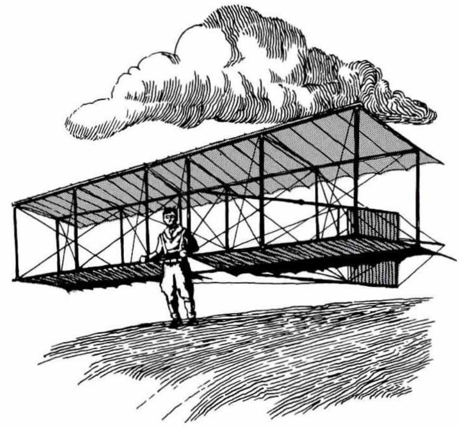
The sailplane is towed aloft by a powered aircraft but then stays airborne by "soaring." In effect, soaring represents a conversion of kinetic energy from an air mass to potential energy of the ascending sailplane. "Gliding" refers only to descent.

Thermals and certain types of clouds are the principal sources of lift. A thermal is an updraft rising above terrain that is warmer than adjacent areas. Dry land and well exposed hills are excellent thermal-producing terrains; woods, irrigated land, and plains with vegetation are not. Generally there is a high correlation between rising air and cloud development; dry thermals which do not produce a cloud are currently a secondary concern in the use of the sailplane.

Both cumulus and wave clouds indicate to the sailplane pilot where lift can be found. Altitude is gained by spiraling inside cumulus clouds and by traversing horizontally (crabbing) along the upwind side of wave clouds.

Advantages of the Sailplane for Airborne Research

In addition to carrying meteorological instruments, the sailplane itself serves as an atmospheric probe to determine the vertical and horizontal components of the wind flow. Because it can hover over one location while gaining altitude, the sailplane has a unique vertical sounding capability. It can sustain stable flight at low vertical speeds so that its own motion can be used as a measure of vertical air motion.



It can remain for several hours within a wave flow to make quantitative measurements.

The sailplane provides an effective platform for cloud microphysics measurements because it does not pollute the air being sampled, and its low airspeed causes negligible disturbances to the atmosphere.

Projected Plans for Sailplane Research

Scientific flights are scheduled to begin in midwinter after further test flights have been completed. Research missions for wave cloud studies will be flown in conjunction with the NCAR Queen Air and Sabreliner aircraft. The sailplane will enter wave clouds to measure drop size distribution and vertical wind components, to photograph cloud particles, and to obtain certain standard meteorological information. The Queen Air will collect aerosol samples in the cloud environment, and the Sabreliner will collect data on air motions in the vicinity of the cloud.

Other plans for the *Explorer* include studies of radar-detectable thermals at Wallops Station, Virginia; these studies will be made in conjunction with measurements by the Wallops radar facilities. In late summer the *Explorer* is tentatively scheduled to participate in the National Hail Research Experiment in northeastern Colorado. It will be flown in missions to investigate cumulus clouds before their development into thunderstorms. ●

NCAR GARP Task Group Formed

In November 1970 a new organization within NCAR––the GARP Task Group––was established to promote participation by the university scientific community in the planning and execution of GARP field experiments and to provide a focus for the GARP-related activities, both scientific and engineering, already in progress at NCAR. These activities include research on global atmospheric circulation, convection, and turbulence; the development of mathematical models, data handling techniques, sensing methods, and complex observing systems; participation in large field projects; and involvement in national and international planning for GARP.

The Task Group was established in response to a recommendation made by the National Academy of Sciences GARP Committee that UCAR and NCAR should set up a mechanism for promoting university participation in GARP and for providing scientific advice and planning support to the Project Office (to be established within NOAA) for the next major GARP field project––the Atlantic Tropical Experiment––to be carried out in 1974.

The Task Group is made up of seven NCAR staff members who have been assigned full time to the group, and four more who will participate regularly on a part-time basis. This staff will be augmented by two university scientists to be appointed to the group as long-term visitors and by two postdoctoral appointees to be added to the Advanced Study Program in support of GARP-related work. In addition, the group will call upon other NCAR scientists for advice and assistance.

Daniel Rex heads the Task Group, Edward Zipser is in charge of scientific activities, and William Lanterman has primary responsibility in the areas of engineering, logistics, and operations.

The Task Group will communicate with the university atmospheric science communities, mainly through the newly formed UCAR GARP Council, consisting of UCAR-university scientists interested in GARP programs. A primary function of the group will be to determine the needs and wishes of university scientists with respect to the scientific objectives of the Atlantic Experiment (and other GARP projects) and to marshal the scientific resources of the universities in support of GARP projects. Members of the group will also examine the various experiments proposed for the Atlantic Experiment to ascertain their technical and economic feasibility within the framework of the overall experimental program and the resources available.

Another major Task Group activity will be to identify key scientific and developmental problems that must be solved to keep the GARP effort moving forward. The group will take the initiative in forming ad hoc UCAR working groups, based at NCAR or elsewhere, to solve these problems or to call them to the attention of existing planning groups. In addition, the group will participate in the studies conducted by these ad hoc working groups and provide most of their staff support. The first such group has already been formed to study data from the Line Islands Experiment and BOMEX. The results of these studies are needed to optimize the experimental design of the Atlantic Experiment.

Other functions of the Task Group include setting up an information center on tropical meteorology and maintaining a computerized compilation of GARP schedules and plans to aid in the identification of critical decision points and potential problem areas.

The success of the Task Group will depend very much upon cooperation with other organizations involved in planning and conducting GARP projects, and appropriate channels of communication with these organizations are being established. Thomas O'Neill, NCAR representative in Washington, has been assigned to the group and will provide direct liaison with NAS, NSF, NOAA, NASA, and other U.S. agencies; similarly, Stanley Ruttenberg, who is in Geneva on loan from NCAR to the WMO-ICSU Joint Organizing Committee for GARP, has been assigned to the group. In addition, the other members of the group will visit and consult frequently with the other U.S. GARP planners to insure a maximum exchange of information. •

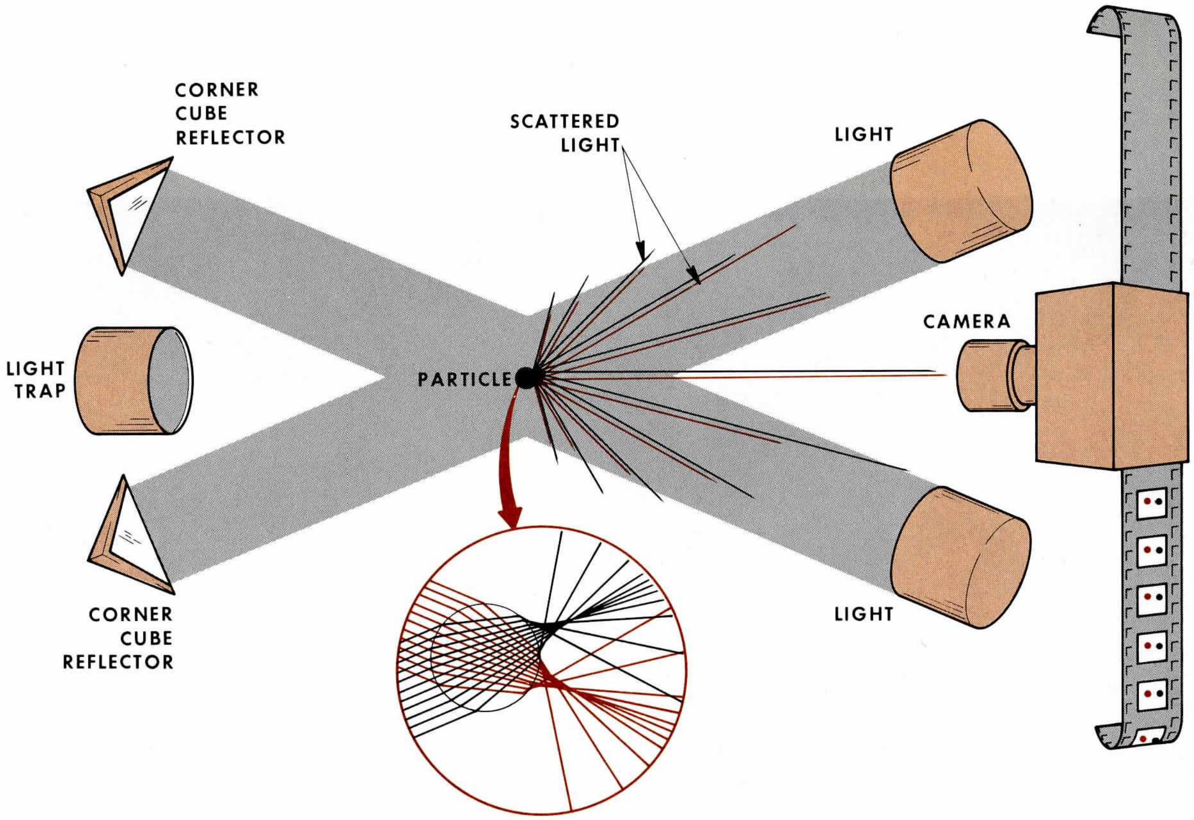
Cloud Sampling by Photography

A new method for in-cloud photography is based on the use of high resolution film and a source of microsecond-duration light pulses.

A promising method for obtaining in situ data on the types, sizes, and distribution of cloud particles has been recently announced by Theodore W. Cannon of the NCAR Laboratory of Atmospheric Science. Combining the capabilities of high resolution film and microsecond-duration light sources, Cannon has developed a particle camera that is capable of photographing ice and water droplets as small as 15 μm in diameter.

The camera has undergone successful testing both in a laboratory cloud chamber and in natural clouds at ground level; airborne evaluation is planned in the near future. The photographs depict the size and spatial distributions of particles, and allow relatively accurate distinction between the ice and water phases. It may be possible to speed the compilation of results by using microdensitometer readings of the film negatives as input for computer analysis.

The camera should overcome some of the disadvantages of other devices now in use, such as replicators and electrostatic probes. These devices tend to disturb the samples they measure and when mounted aboard aircraft require careful calibration as a function of airspeed. Particles are apt to shatter against the apparatus, causing erroneous or indeterminate results. None of the



Schematic arrangement of the particle camera.

presently used instruments are able to record the spatial distribution of particles.

Since the photographic method does not require capture of or close contact with particles, it causes no disturbance of the sampling volume. Moreover, a "pictorial" sample clearly shows both the size and spatial distributions of particles.

The primary components of Cannon's apparatus are an electric 35 - mm camera, and twin, short-duration light sources with associated power and control units. The 13.5 - cm focal length camera lens is protected by a heated anti-fogging window. The camera focuses images about 36 cm in front of the lens, with a magnification of 1:1. A battery power pack provides 2 hr of operation at 3 frames/sec with each charging; the camera can take 250 exposures before reloading. The entire apparatus weighs only 61 lb.

Particle Photography

The application of photographic methods to record cloud particle data has been largely bypassed because of gaps in the necessary technology. The inherent difficulties in photographing small particles can be reduced but never quite eliminated. Even with a perfectly corrected lens and with film of infinite resolution, light diffraction will impair the quality of the image. Diffraction by the lens limits resolution to particle diameters of about 10 - 15 μm; below this size a particle's own diffraction pattern increasingly masks its structural features. If strong magnification is used to aid the resolution of small particles, the depth of field and in-focus volume become intolerably small. Even at 1:1 magnification the narrow depth of field limits the number of particles in focus per film frame. This can be an advantage for studying spatial distribution since particles in focus are contained in an extremely thin slice of air; however, it inconveniences the determination of size distribution since only a few particles are in focus in a given film frame.

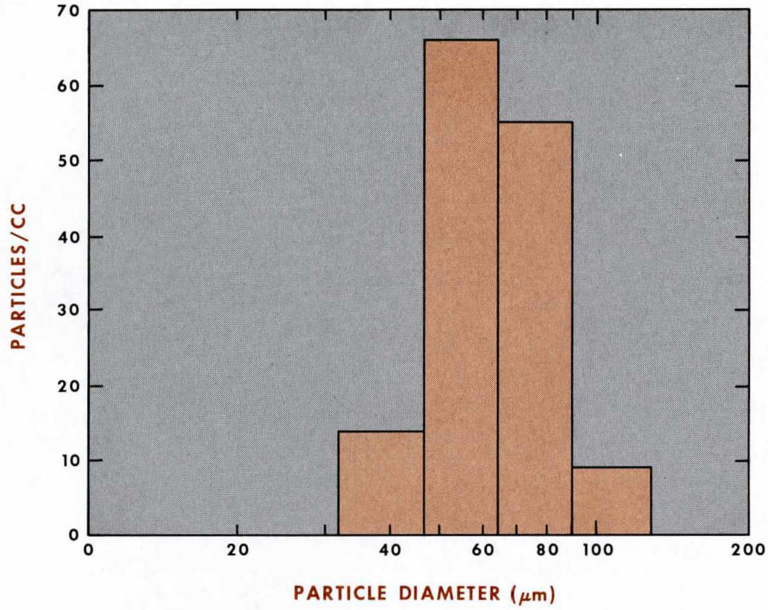
Film and Illumination

High quality optical components are a necessity for particle photography. The use of 1:1 magnification requires film with sufficiently high resolution to resolve particles at their actual sizes. Cannon has experimented with films that have recently become available; among these are Recordak types 5456 and 5459, with respective speeds of 250 and 64, and resolutions of 350 and 530 lines/mm at 1,000:1 test object contrast. Clean-room conditions and pure solutions are needed for film processing to avoid scratching and contamination which would impair particle size and concentration determinations.

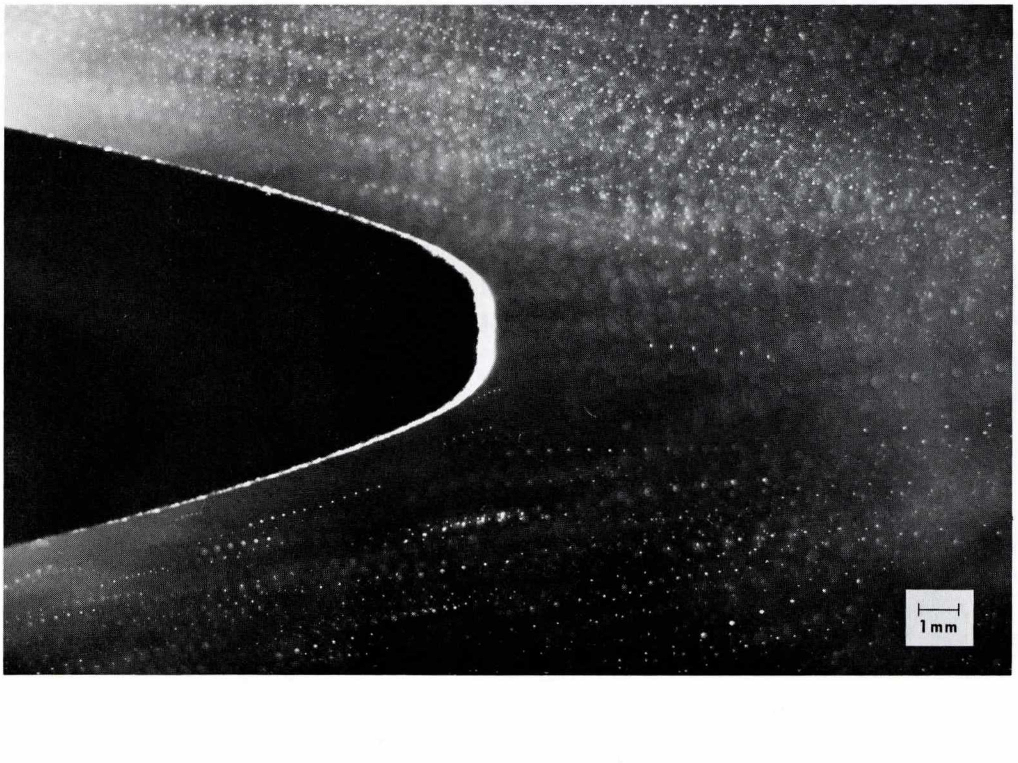
A second necessary element for successful particle photography is a source of very short duration lighting. Pulses lasting only a few microseconds provide sharper exposures than the mechanical action of even the most rapid shutter. Cannon has used light pulses of 1.25 to 7 μsec. The lights are mounted at 25° to the camera's optical axis, and are directed toward corner reflecting mirrors at opposite sides of a light-absorbing dark-field area. The reflected light fills the in-focus volume but does not shine into the camera lens. The camera thus views the in-focus volume as a dark field. With each flash of the lights, cloud drops in this volume refract and scatter light toward the lens and are recorded on film as bright dots against the dark field. Dark-field illumination has the advantage of minimizing halation as well as the adverse effects caused by particle motion during the exposure.

Multiple exposures can be made on any one frame of film. This application is useful in the laboratory for measuring the collection efficiencies of other particle sampling devices, and for studying particle interactions under varying conditions of humidity, temperature, electric field, and potential gradient. These

PARTICLE SIZE DISTRIBUTION ATOMIZER SPRAY



The particle size distribution in an atomizer spray was determined from five film negatives. The number of particles per unit volume is based on a curve of the depth of field vs sphere diameter.



Droplet trajectories are obtained by using a burst generator to produce as many as ten short-duration high-repetition light pulses, and hence ten sequential exposures per film frame. Here, the trajectories of particles moving past the nosepiece of an electric particle-sizing probe are analyzed to determine the probe's collection efficiency.

Photograph of ground level cloud particles at the edge of Crested Pool, Yellowstone National Park, shows large inhomogeneities in droplet distribution. Airborne use of the camera may reveal similar conditions in atmospheric clouds, though probably on a larger scale. Photographic evidence would be of basic importance for understanding precipitation growth. Use of the lights in a repetitive mode allows visual inspection of cloud inhomogeneities from aircraft.

topics have been among the research interests of the NCAR cloud physics group for several years.

Ice vs Water

Photographs are also useful in making apparent the distinction between ice particles and water droplets. A translucent or opaque ice particle reflects light from the illuminated sampling volume and its true image appears on the film. The size of the image is equal to the actual particle size. A transparent water droplet, on the other hand, acts as a small lens, focusing light from each of the two light sources, and appears as a pair of dots on the film. In the smaller size ranges the viewer must take care not to mistake the single-dot image of a small ice particle for an out-of-focus droplet whose usual double image has merged to a single image near the limit of focus.

To establish standards of recognition

Cannon photographed solid and liquid particles at various distances from the camera and compared the films with exposures taken through a microscope. He also compared camera and microscope photographs of targets of synthetic polymer spheres to measure the exact effect of loss of focus on dot pair separation. Tabulated to show depth of field vs particle size, these data indicate that dot pairs can be accurately discerned throughout a depth of field which is 20 times the diameter of a particle. The actual size of a droplet is 1.8 times the measured distance between dot centers on the film.

Airborne Use

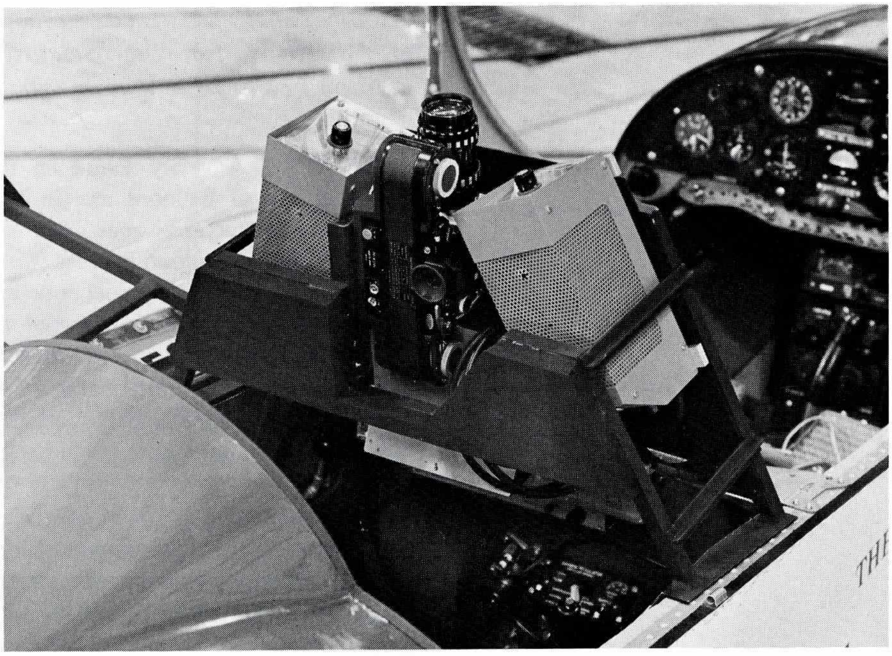
The droplet camera is being prepared under the direction of Daniel Marshall (Research Aviation Facility) for use aboard the *Explorer* sailplane. The relatively slow speed of the sailplane (30 m/sec vs 75 m/sec for the slowest NCAR powered aircraft at a pressure altitude of about 500 mb), as well as its nonturbulent wake and lack of contaminating exhaust, make it an ideal platform for many airborne studies. To insure clear film exposures at flight speeds, Cannon and Marshall have supplemented the short-duration light source with a rotating mirror. The mirror is electronically adjusted to the speed of the sailplane and compensates for the motion of particles in the airstream.

Among the promising uses of the camera in airborne research will be the study of inhomogeneities in clouds over small spatial intervals. Ground level clouds, photographed with the camera and observed visually with illumination by high speed lights, have been found to contain voids, swirls, and other spatial inhomogeneities. If similar conditions exist in clouds aloft—as they are thought to on the basis of recent drop size determinations with electrostatic probes—they may have an important link with processes of precipitation particle growth. ●

For further reading:

Cannon, T. W. 1970: High-speed photography of airborne atmospheric particles. *J. Appl. Meteorol. 9(1),* 104 - 108.

——, 1970: A camera for photographing airborne atmospheric particles. *Image Technol. 12(3),* 37 - 42.



Installation of the camera aboard the Explorer.

Scientific Ballooning Requirements for 1970-1980

James M. Shoemaker, NCAR

Based on needs expressed by scientists, NCAR's ballooning Advisory Panel has made recommendations for the Scientific Balloon Facility's long range goals.

The NCAR Advisory Panel on the Scientific Use of Balloons met in May 1970 to recommend goals for the NCAR Scientific Balloon Facility (SBF) in the next decade. The panel reviewed the results of a survey conducted by SBF to determine anticipated needs of the scientific community, and based most of its recommendations on that survey. Three actions were taken by the panel.

Panel Action No. 1: "That first priority be given to the development of long duration balloon systems with initial emphasis on the development of zero pressure balloon flights up to 72 hours duration, and continuing and long term emphasis on the development of superpressure balloons capable of flights of several weeks duration; that second priority be given to the procurement and launching of balloons of volume as large as 100×10^6 ft^3 [$3{,}000 \times 10^3$ m^3] with special emphasis on the use of in-flight deployment techniques."

Panel Action No. 2: "The Balloon Panel, having reviewed the responses of the Questionnaire related to long range goals of ballooning, feels that the development of improved telecommand, telemetry and data handling systems for use by the scientific community continues to be of high priority and should be implemented and made operational with even greater emphasis than at present. A second priority is all-weather operational systems, which include wind screens and in-flight deployment. Balloon pointing systems continue to hold a low priority in terms of a concentrated development effort, however, NCAR should develop a capability for providing advice, collecting information on present systems, developing requirements, etc. NCAR will then eventually be able to provide pointing capabilities for a range of scientific experiments."

Panel Action No. 3: "The Balloon Panel recommends that NCAR actively pursue the development of a high quality balloon facility in the Southern Hemisphere augmented with field expeditions to meet specific scientific requirements."

In a separate action, the Advisory Panel unanimously endorsed the proposal for a new launch pad and staging building at the Scientific Balloon Flight Station, Palestine, Texas.

Ballooning Services Summary

Probably the most significant trend revealed by the responses to the SBF's survey is the need for flights of longer duration. Sixty percent of the respondees consider flights of longer duration more important than flights at higher altitudes or with increased payload weight. To gain increases in all three categories, scientists will accept some sacrifice of reliability. The minimum reliability figure of 0.5 includes both the operational reliability of the balloon system, flying in a manner which will fulfill the scientists' needs, and the reliability of the scientific equipment during flight. The current levels of reliability for NCAR flights and for most scientific equipment are both about 0.85. These levels were generally acceptable to respondees, but NCAR will continue to improve its standard for flight reliability. One of the necessary aspects of increasing the reliability of large, complex payloads will be to implement better methods of thermal control at high altitudes.

More efficient ways will be required for launching and recovering heavy and complex payloads. Mobile-base, all-weather, and low-acceleration heavy-load launch methods need to be developed. Ship-based launch systems are not feasible because of the high cost and complex logistics. Payload recovery could be greatly improved by the use of helicopters and cargo aircraft in addition to ground transportation.

For scientists making solar observations or requiring flights during turnaround wind periods, balloon launching at a precise time is critical. This problem can be solved if SBF can provide all-weather launching and tracking facilities. There is also a need to increase the present 320-km tracking range to greater distances beyond the launch site.

A few respondees suggested manned scientific balloons as a means of insuring in-flight repair and adjustment of equipment. Though manned flight is feasible, it would be advantageous only in very special circumstances. •

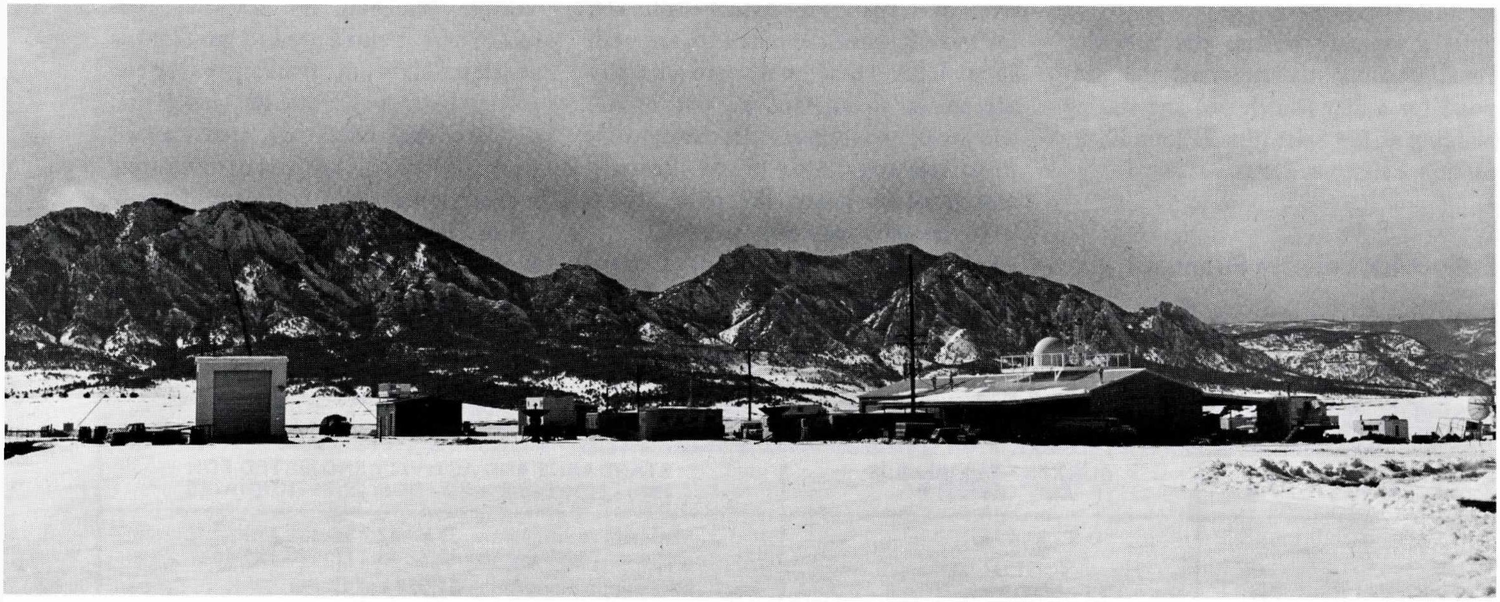
SCIENTIFIC BALLOONING REQUIREMENTS

SUBJECT	CURRENT STANDARDS AND ACTIVITY	STANDARDS AND ACTIVITY PROJECTED FOR 1970 - 1980 COMPILED FROM QUESTIONNAIRE
Altitude	33.5 - 36.6 km	Minimum requirements: 39.6 - 42.7 km (36.4%)[1] Optimum requirements: 42.7 - 45.7 km (28.1%)
Payload	22 - 4,000 kg	Minimum requirements: 0 - 227 kg (42.4%) Optimum requirements: 907 - 1,361 kg (25.8%)
Flight duration	Mean: 8 hr	Minimum requirements: 6 - 12 hr (33%) Over 12 hr (42.3%) Optimum requirements: 12 - 18 hr (25%)
Balloon size	300×10^3 m^3	Balloons larger than 600×10^3 m^3 required by 35% of respondees
Flights per year	~ 100	~ 100
Operational reliability	0.85	Minimum operational reliability acceptable to achieve a rigorous scientific requirement: 0.5
Geographical launch locations	Palestine, Texas; Argentina (1 in 1970); Northern hemisphere other than Palestine (3 in 1970)	Palestine, Texas: 29.4%[2] Southern hemisphere (Argentina, Australia, India): 23.5% Equatorial: 13.7% Northern Canada: 13.7% Other: 19.7%
Distribution of scientific experiments	Astronomy: 63% Physics: 16% Atmospheric science: 10% Other: 11%	Astronomy: 45% Physics: 30% Atmospheric science: 18% Other: 7%

[1] The percentages given in parentheses are taken from a frequency distribution of the various requirements; shown are the class intervals in which the greatest number of requirements fall, and the percentage frequency of requirements within each interval.

[2] Percentages indicate distribution of respondees preferring each location.

Questionnaire results received from 42 of the 166 scientists polled show that in the next decade an increasing number of scientists will require flights over 12 hr duration at optimum altitudes of about 50 km and with balloons larger than 600×10^3 m^3. Both physicists and atmospheric scientists anticipate growing demands for ballooning experiments and physicists in particular anticipate a need for more flights in the southern hemisphere.



The Marshall Site, with the Front Range of the Rocky Mountains to the west, is well situated for studies of mountain lee waves and mountain-influenced weather. The mesa-top area affords unobstructed visibility to the north, east, and south. The NCAR Mesa Laboratory is located at the foot of the mountains but is blocked from view by the radar dome on the main service building.

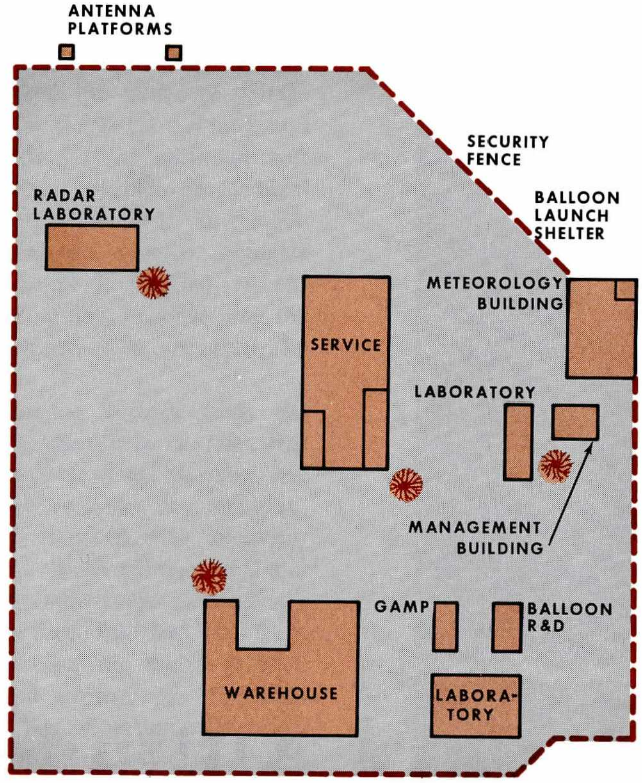
Marshall Field Site Purchased

The National Science Foundation recently purchased the Marshall Field Site, a 32-hectare mesa-top area 6 km southeast of the NCAR Laboratory. The land has been leased since 1964 and managed by the NCAR Field Observing Facility for use as a maintenance, testing, and research site.

The Marshall Site is used for fabrication, modification, and testing of radar systems, calibration of antennas, testing of laser equipment and various scientific instruments, and development and testing of balloon launch techniques. It also serves as a storage area for large field equipment and a logistics center for field experiments.

Until now development of the site has been limited to removable structures such as steel buildings and modified trailer vans; this limitation has restricted the site's usefulness and has occasionally caused inconvenience to research programs. Two steel Butler buildings acquired from the Air Force in 1965 form the nucleus of the present complex. They provide space for an environmental test chamber, radar and meteorological laboratories, vehicle shops, and storage. The Scientific Balloon Facility's operations building, a balloon inflation shelter, and a temperature-controlled building for testing and evaluating GHOST balloons are also part of the complex. Total covered space at present is 837 m^2.

Now that continued occupancy of the site is assured, NCAR is planning a systematic program of improvements to meet the future needs of major groups within NCAR. Initial improvements will include grading, security fencing, and improvement of outdoor storage areas; utility, power, and communications systems are already being expanded and improved. A proposal for a new building for maintenance and calibration of radar and meteorological equipment is being prepared for submission to the National Science Foundation. This building will also include a wind tunnel that is now located in a University of Colorado building leased by NCAR. Shop, storage, and office space will ultimately be expanded. All new buildings will be confined to the northwest corner of the site, leaving the remainder of the area open for balloon launch tests, radar and laser system tests, and radar antenna calibration, all of which require a large, unobstructed area. •



Plans for development of the Marshall Field Site include several new laboratories and workshops surrounding and incorporating present semi-permanent structures.

Workshop on BOMEX Measurements

A workshop was held at the NCAR Mesa Laboratory on 21 - 23 October 1970 to review and evaluate measurements of radiation and particulate matter made during the 1968 Barbados Oceanographic and Meteorological Experiment (BOMEX), and to make recommendations for future research. John Gille (ASP) was chairman of the workshop; participants included about 50 scientists from 17 research institutes involved in BOMEX measurements.

Three main topics were discussed: review of meteorological and cloud measurements, measurement of atmospheric particulates, and radiation measurements. The third topic included three detailed discussions of radiation measurements made during cloudless periods on relatively haze-free days, during cloudless periods on relatively hazy days, and during cloudy periods.

Session chairmen compiled a list of BOMEX results considered the most significant to date. Proposals were drafted for radiation measurements that should be repeated, and for new measurements to be made in a future tropical experiment (TROPEX).

The radiation data collected during BOMEX are more comprehensive than any obtained before, and will be useful to GARP scientists in planning for future radiation measurements. Discussants recommended that scientific groups interested in atmospheric radiation should design specific experiments to fulfill the general aims for a complete radiation experiment described in the planning document, *Problems of Atmospheric Radiation in GARP* (GARP Publications Series No. 5).

A workshop committee has assembled a catalog of available data from all experiments pertinent to the BOMEX radiation and particulate investigations; the compilation includes locations, dates, and times for which good data were obtained. The catalog and a workshop summary can be obtained after 1 February 1971 as a technical note from the Barbados Oceanographic and Meteorological Analysis Project (BOMAP), Rockville, Maryland 20852. •

Pressure-Altitude Assembly for High-Altitude Balloons

Oscar L. Cooper, NCAR

A full-range pressure-altitude transducer assembly has been developed by NCAR's Scientific Balloon Facility for use in high-altitude balloon flights. It consists of three Rosemount Model 830A pressure transducers that measure atmospheric pressure over segments of the pressure range traversed by balloons during ascent and descent. Electronic circuits select the appropriate transducer for each pressure segment and supply calibration voltages for a telemetry system.

Rosemount Model 830A transducers were chosen for NCAR balloon operations on the basis of their performance in a series of calibration, environmental, and flight tests (see *Facilities for Atmospheric Research*, No. 7, December 1968). These units have good short-term calibration repeatability and very low calibration hysteresis. They are not seriously affected by atmospheric contamination, temperature variation, or mechanical vibration. They respond rapidly and provide a continuous data readout. With careful calibration and readout procedures the pressure accuracy should be within 0.1 mb at float altitudes of 1 - 7 mb.

The Rosemount transducer is a capacitive type, using a thin taut-diaphragm sensing element positioned between two stationary capacitor plates. The space between the diaphragm and one of the stationary plates is evacuated and sealed; the space on the other side of the diaphragm is exposed to ambient pressure. The capacitances change as the absolute ambient pressure changes. The capacitors formed by the diaphragm and the stationary plates are connected to a

Three Rosemount Model 830A pressure transducers provide pressure-altitude data over the entire flight range of a high-altitude balloon. The housing behind the transducers encloses electronic circuitry.

200 - Hz, 400 - V peak-to-peak source. A diode rectifier circuit detects the capacitor current and develops a dc voltage across a resistor. The dc voltage output is proportional to the difference between the two sensor capacitances; this voltage is linear with pressure and ranges from 0 to 5 V as the pressure ranges from zero to full scale.

The three transducers cover the full ambient pressure range expected in balloon flights; each is engaged in the pressure interval to which it is most sensitive. The transducer used for low-altitude pressure measurements (below 18 km) is a 0 - 1,100-mb unit. The intermediate range transducer has a pressure range of 0 - 70 mb and serves from 18 - 34 km. The high-altitude unit has a range of 0 - 7 mb and provides detailed resolution for flights above 34 km; it has been used successfully on many recent NCAR balloon flights.

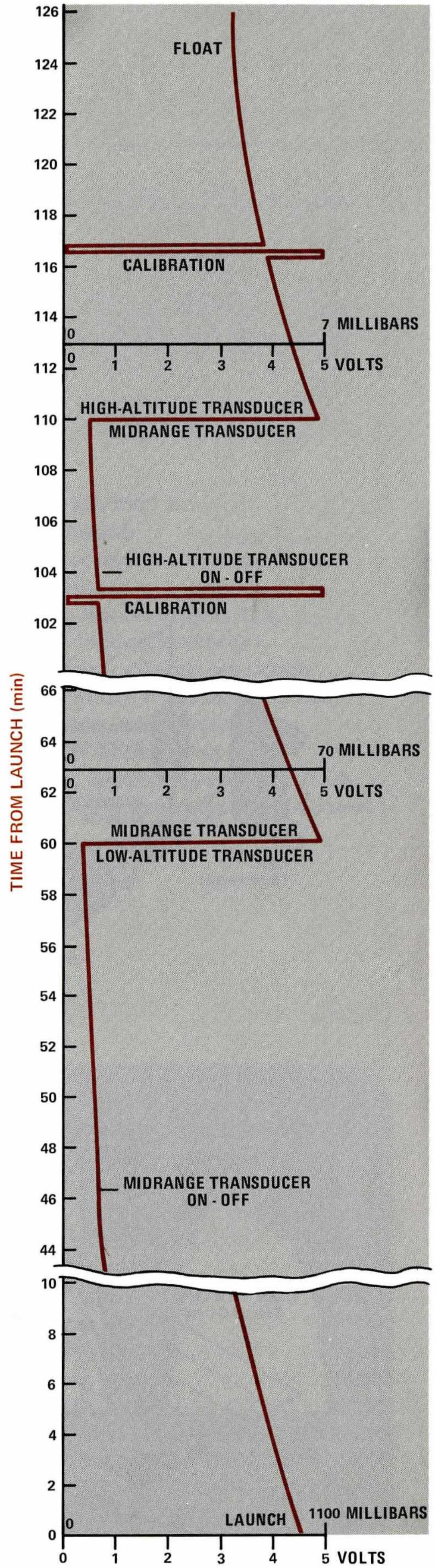
The dc analog voltage outputs of the transducers are individually applied to the input of a telemetry system. Calibration voltages for the telemetry system are also supplied with the pressure analog from the transducer interface electronics. To conserve power, an electronic sensing circuit applies power only to the transducer which is most sensitive in the pressure range in which the balloon is flying. A small power overlap will occur during ascent or descent when two transducers are operating simultaneously. In ascent, the low-altitude transducer receives power during the first portion of the balloon flight. As the balloon gains altitude, ambient pressure decreases, causing the output voltage of the transducer to decrease. When the output voltage reaches approximately 0.6 V (at 132 mb), a voltage comparator senses the voltage level and causes power to be applied to the midrange (0 - 70 mb) transducer, even though the midrange transducer cannot yet actively submit pressure data at this level.

As the balloon continues to rise, ambient pressure falls within the range of the midrange unit; when the output of this unit reaches 4.9 V a voltage comparator shuts off power to the low-altitude unit and connects the pressure analog output voltage of the midrange unit to the telemetry system. Power is similarly supplied to the high-altitude transducer when the midrange voltage output reaches 0.6 V (at 8.4 mb), and cuts off power for the midrange unit when the output voltage from the high-altitude unit reaches 4.9 V. As the balloon descends the reverse sequence occurs. If power is applied to the assembly at a random pressure level the proper transducer will automatically function.

Pressure analog voltage from the assembly is supplied to a telemetry encoder. Shortly after the midrange and high-altitude transducers are activated, the output is replaced with telemetry band-edge calibration voltages of 0 and 5 V at predetermined time intervals—a 0 - V level for 5 sec followed by a 5 - V level for 5 sec for the midrange unit, and a reversed sequence for the high-altitude unit. No calibration voltages are required when the low-altitude transducer is activated, because accuracy at low altitudes is not as important as continuity of record. This scheme affords an almost uninterrupted record of pressure altitude during ascent, and simplifies pressure-range identification.

The calibration interval is determined by a unijunction oscillator circuit with a 40 - sec period. An integrated circuit divider makes it possible to increase this period in binary steps up to 21 min; this provides flexibility in selecting the recurrence frequency of the calibration sequence. Unijunction switching circuits select the 0- and 5 - V calibration levels in proper sequence. The 5 - V level is obtained from a built-in regulator. The pressure analog voltage is switched back to the telemetry encoder following the calibration sequence.

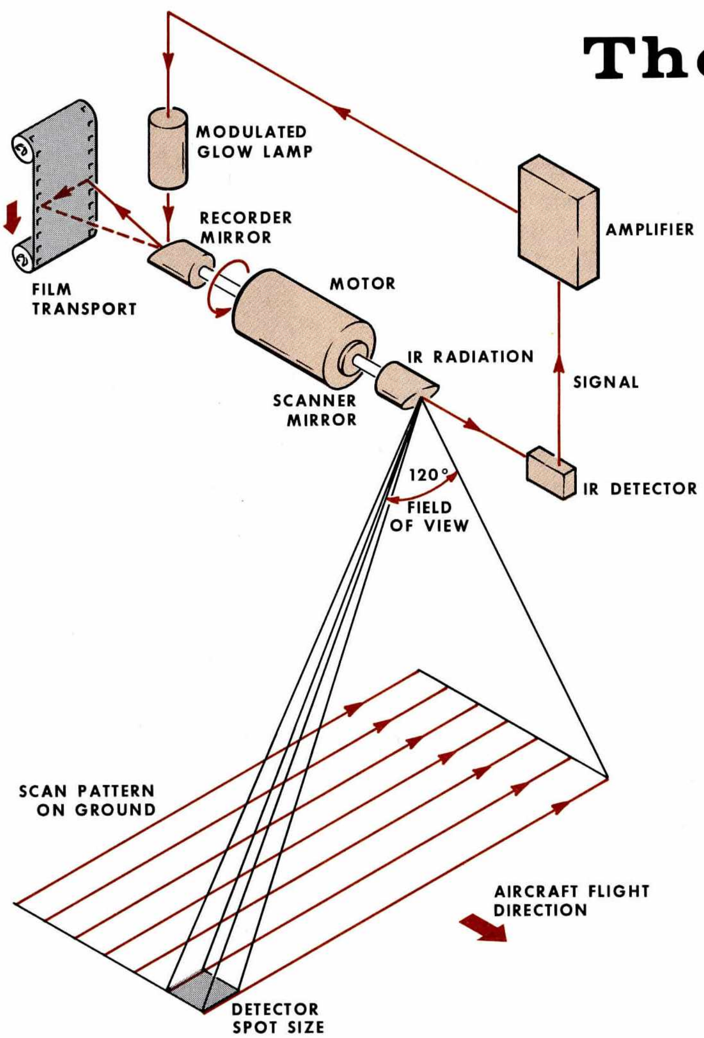
The Scientific Balloon Facility is designing a circuit which will convert pressure data to linear altitude data based on *U.S. Standard Atmosphere, 1962* tables, producing a chart recording of linear altitude deflection. A pressure-time differentiation circuit which will directly compute and display balloon ascent rates is also being considered. These circuits will bring improvements in techniques for monitoring balloon performance. ●



Pressure-time variation during a typical balloon flight, as recorded by the NCAR pressure-altitude assembly.

Thermal Mapping

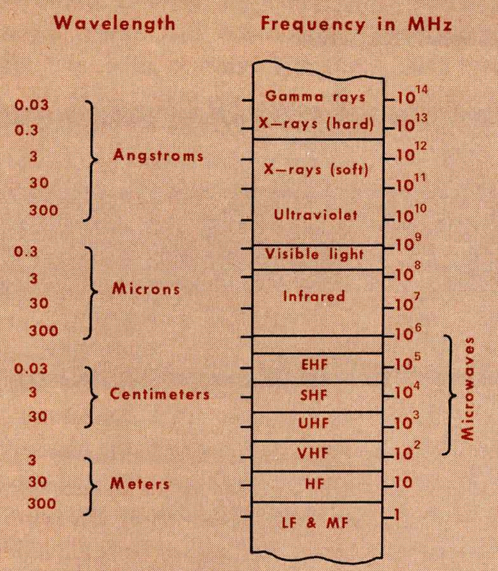
A relatively new remote sensing technique provides data in a wavelength range that is rich in information about the environment.



Thermal mapping permits imagery of phenomena that cannot be detected photographically. In a typical mapper a film strip is exposed to a light source that is modulated by the output signal from an infrared detector. The film shows variations in the scene's emissivity distribution rather than variations in reflectivity, as in photography or radar imaging.

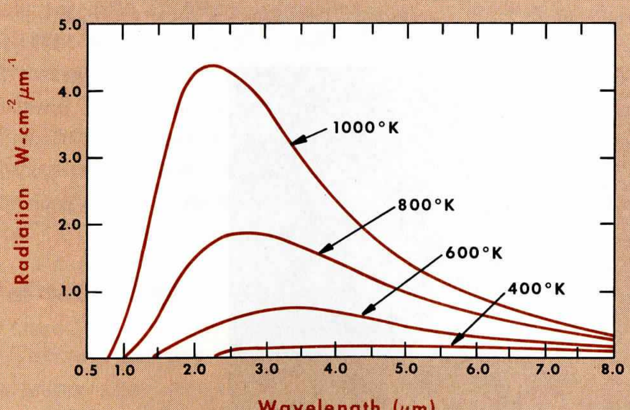
Airborne scanning with infrared detectors can provide information for the meteorologist on the thermal characteristics of many land, water, and atmospheric features, defining such details as soil moisture content, hail cover, old and new snow, ocean currents, and cloud temperature gradients. Thermal images derived from infrared detectors differ from data obtained by other remote sensing methods because they show the pattern of energy *radiated* from the scene, rather than energy *reflected* from the scene. The source of energy is thus a characteristic of the scene itself, not the illumination incident on it.

The infrared spectrum extends from 0.7 to 1,000 μm, but only in a very small portion of this spectrum, from about 0.7 to 0.9 μm, can infrared energy be recorded directly on film. The technique of infrared photography is independent of daylight conditions and is far less affected by atmospheric scattering and haze than visible-light photography. For infrared wavelengths that are too long to be registered on

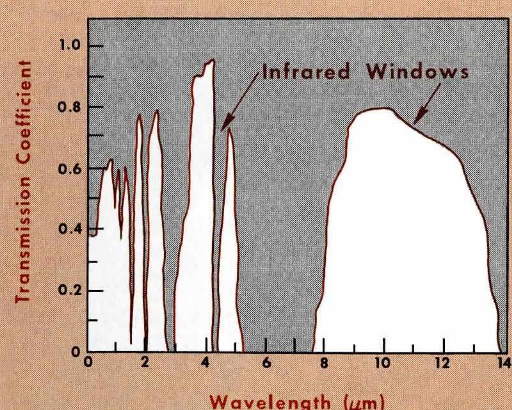


Spectrum Bands

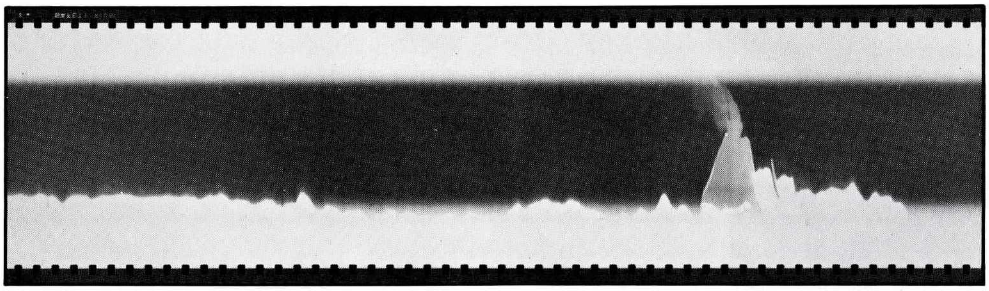
The infrared portion of the spectrum lies between the microwave and visible portions. Like visible light, infrared radiation can be focused optically, yet like microwave energy, it can penetrate some media that block light. At a given temperature a perfect emitter (blackbody) radiates a maximum of energy at a certain wavelength; the blackbody radiation curves show that the wavelength of maximum radiation shortens as the temperature increases. At certain wavelengths the atmosphere is opaque to infrared radiation, and imaging must be carried out in "transmission windows" where absorption is minimal.

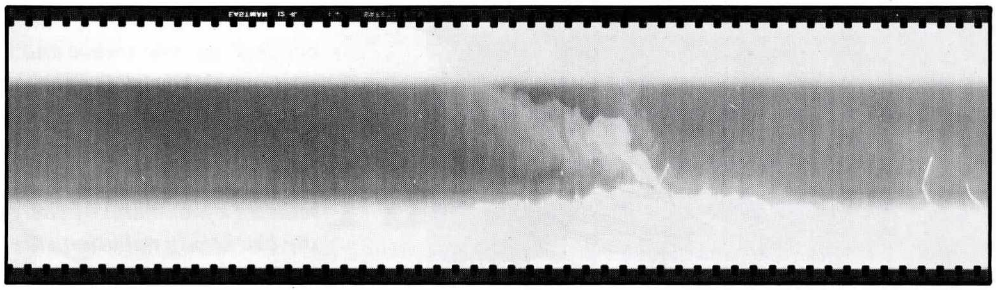


Blackbody Radiation Curves

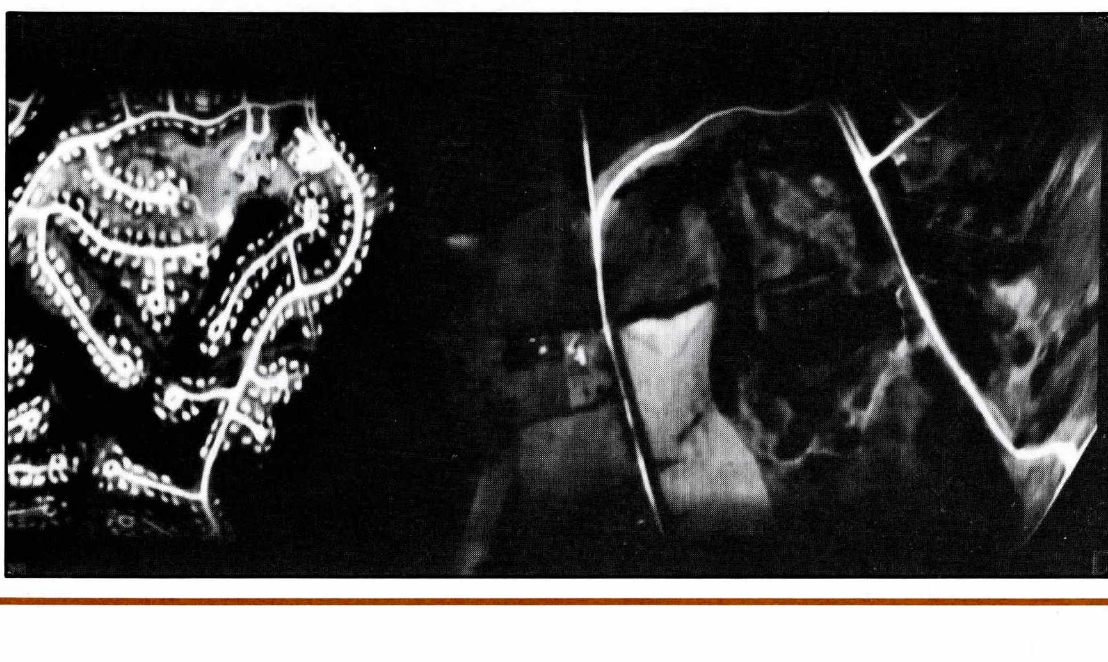


Transmission Spectra of the Atmosphere





This fall the NCAR Research Aviation Facility flew two research missions using a Bendix Thermal Mapper Model TM/CCC-1 provided by the Bendix Corp. The images at the top, taken for R. A. Ragotzkie (University of Wisconsin), show plumes of warm water extending out from the shore of Lake Michigan. Ragotzkie is directing a large interdisciplinary study of thermal pollution in the Great Lakes caused by increased electric power production. Thermal mapping will also contribute to the knowledge of near-shore circulation in the Great Lakes. The lakes are unique because they behave in some respects like an ocean but in other respects like bounded water bodies. The image at the bottom is one of a series taken for H. E. Landsberg (University of Maryland) over the Washington-Baltimore corridor where rural countryside is undergoing rapid urbanization. Landsberg is tracing the evolution and behavior of urban heat islands and their influence on micro- and mesoclimatic changes.



film, special radiation detectors are used to register the characteristics of the scene.

Infrared detectors are photovoltaic or photoconductive materials which generate an electrical signal proportional to the intensity of the infrared radiation. Workable detectors were not developed until the 1930s, although the existence of infrared energy had been known since the late 17th century. The discovery of semiconductors and subsequent advances in solid-state physics made it possible to develop highly sensitive detectors, responsive to the most useful portions of the infrared spectrum. Among the detector materials now in use are indium-antinomide, mercury-cadmium-tellurium, and mercury-doped germanium. Detectors are chosen for their sensitivity to a specific wavelength range and for their uniformity and speed of response. They require cooling to very low temperatures to provide an adequate signal-to-noise ratio.

An infrared imaging device used for thermal mapping from aircraft contains a rotating mirror or lens that views the terrain in a series of overlapping strips perpendicular to the flight direction. Infrared radiation from the terrain is filtered to remove all but the desired wavelengths, and then focused on the detector. The electrical signal from the detector modulates a glow tube which brightens or dims in proportion to the infrared energy from the terrain. The glow tube exposes a film strip which gives a photographic image of the thermal properties of the scene.

Radiant Energy

Thermal imaging is based on the principle that every object radiates energy over a broad range of wavelengths because of its own atomic and molecular vibrations. The total energy and the spectrum of this radiation depend on the object's temperature. As the temperature rises, the peak of the radiation spectrum shifts to shorter and shorter wavelengths; if the temperature doubles, the peak shifts to half the wavelength.

Most objects radiate only a portion of the maximum possible energy for a given temperature; this portion depends on an object's emissivity, which is determined by its surface characteristics. Dull black surfaces are the best emitters and shiny metallic surfaces the poorest emitters. Since individual parts of the area scanned from the air have different emissivities, they will register differently on film.

When examining thermal maps the experimenter must accustom himself to a frame of reference different from the normal visual environment. In some images contrasts are largely due to temperature gradients, as in maps of ocean currents. In others, contrasts are largely due to differences in the surface characteristics of similar materials at the same temperature, as in maps of plowed and unplowed earth. Although the contrasts in a thermal map are quite different from those in a normal photograph, the structural outlines of the terrain and of manmade objects have a similar representation.

Mapping vs Radiometry

The signal from an infrared detector is a voltage proportional to the temperature and surface characteristics of the scene and can be calibrated against a reference source to give exact quantitative data. This application, called radiometry, is probably more familiar to meteorologists than thermal mapping, although the equipment is nearly identical. Since the radiation spectra emitted at a given temperature by different materials vary considerably, radiometric measurements of temperatures are probably less accurate than measurements of variations in temperature made by thermal mapping. However, water and land surfaces are both good emitters, and sensitive radiometers can make absolute temperature measurements to an accuracy of a few tenths of a degree centigrade.

Thermal mapping instruments can be adapted for radiometric use so that the shades of gray can be correlated with specific temperatures. The advantages of a detailed image are thus combined with quantitative measurement. This can be a valuable asset in micrometeorological studies, since the particular surfaces and objects associated with temperature differences are identifiable.

Problems of Interpretation

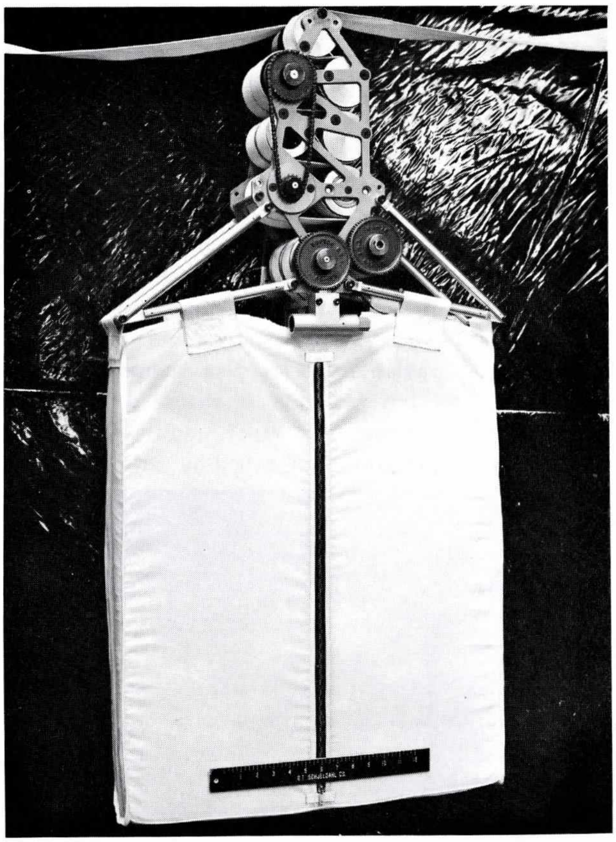
Radiometry and thermal mapping are subject to some of the same limitations, and the information from both requires careful interpretation. In addition to the infrared radiation emitted from the scene, some reflected radiation is received by the detector. At about 1 μm most of the energy received is reflected solar energy. Vegetation, for example, is strongly reflective at this wavelength. In the region from about 4 to 5.5 μm solar reflection from water is an important contaminant.

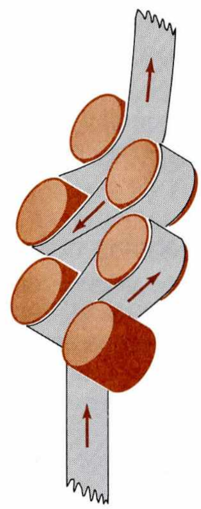
The atmosphere itself is a medium whose absorbing, emitting, reflecting, and scattering properties vary with wavelength. It can introduce error into the radiometric measurements by absorbing some energy and substituting radiation at its own temperature. At 6 μm radiation is absorbed by atmospheric water vapor, and beyond 14 μm radiation is absorbed by carbon dioxide. In the atmospheric "windows" from 3.5 to 5.5 μm and from 8 to 14 μm, absorption is minimal.

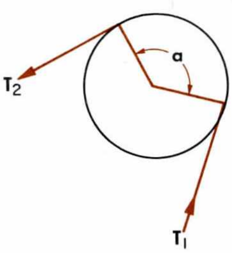
Despite some sources of reflection, the energy recorded by an airborne detector in the 4- to 5.5 - μm region is largely that emitted by the terrain itself. In this wavelength range small changes in temperature produce large changes in emission, so that thermal maps indicate relative temperature distributions with great sensitivity. The earth emits its maximum energy in the 8- to 13 - μm region where small changes in temperature produce only small changes in emission. In this wavelength range image contrasts are much lower, but can be more easily matched with reference temperatures for radiometric analysis.●

An In-flight Balloon Deployment System

John W. Sparkman, Jr., NCAR







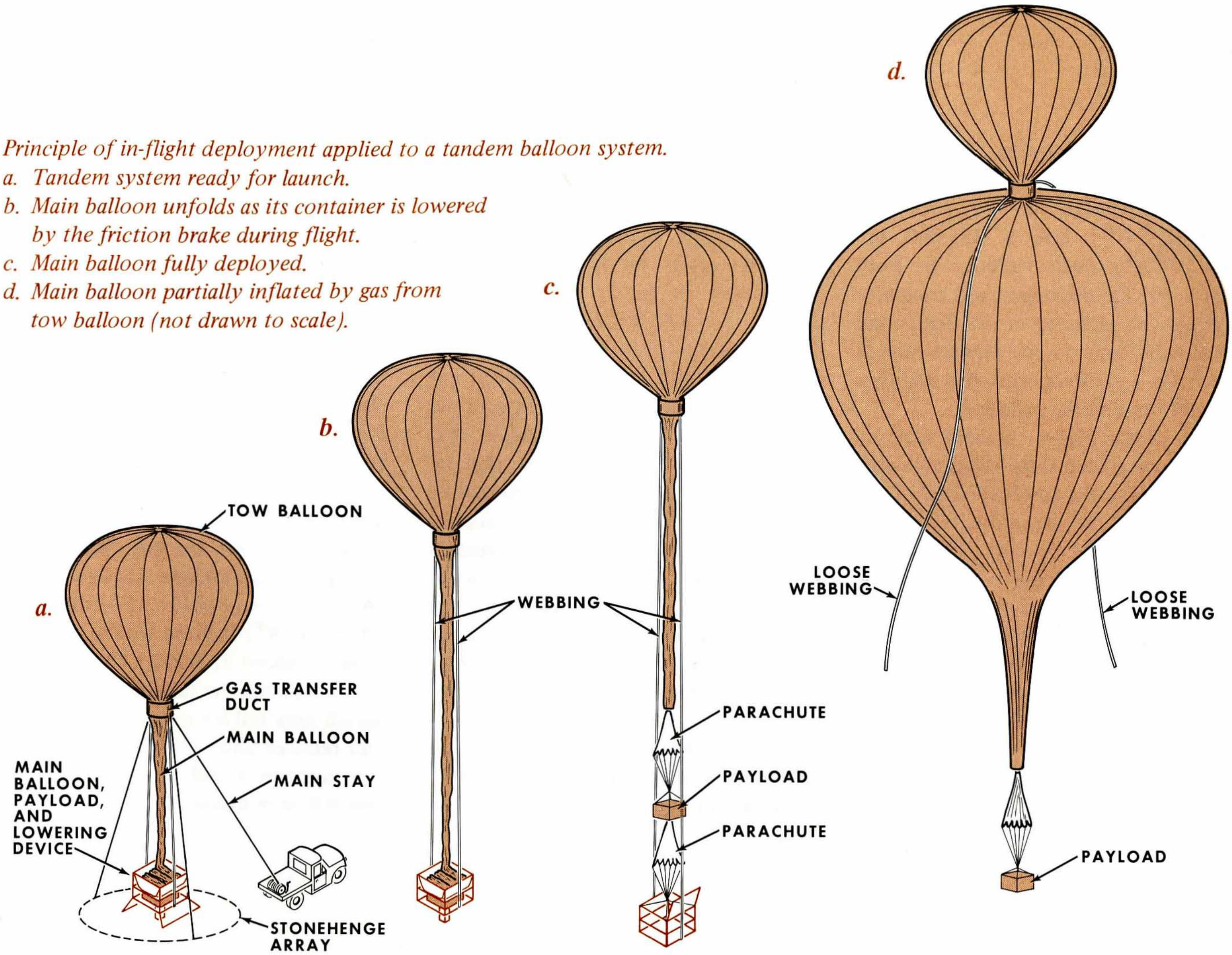
Friction brake with bag for webbing attached below. The brake measures 46 × 22 × 14 cm, and weighs 13 kg. The prototype was designed to increase the input tension of the webbing by a factor of 100. The contribution, T_2, of each of the six rigid cylinders is equal to $T_1 e^{fa}$, where T_1 is the input tension, a the angle of wrap, and f the coefficient of friction between the webbing and the cylinder surfaces; e is the natural logarithmic constant.

A balloon launching system using a load-lowering friction brake has been successfully flight tested at the Palestine Scientific Balloon Flight Station.

As the size of plastic balloons for high-altitude research has increased, so have the difficulty and cost of launching them. Conventional launch procedures expose large balloons to wind damage during launch and require large paved areas for deployment of the balloon and its flight train. A last-minute postponement of the launch may necessitate discarding a costly balloon since balloons larger than 40,000 m^3 (15×10^6 ft^3) cannot be repackaged without a high risk of damage.

More than ten years ago ballooning engineers conceived of an in-flight deployment (IFD) technique that would alleviate these difficulties by keeping the balloon partially packaged (or fully packaged if a tow balloon were used) until the system was airborne. Efforts to perfect the technique were at first frustrated by the lack of a practical mechanism for releasing the packaged balloon. Now, a device that promises to make

Principle of in-flight deployment applied to a tandem balloon system.
a. Tandem system ready for launch.
b. Main balloon unfolds as its container is lowered by the friction brake during flight.
c. Main balloon fully deployed.
d. Main balloon partially inflated by gas from tow balloon (not drawn to scale).



IFD a useful balloon launching method has been developed by the G. T. Schjeldahl Co., under contract to the NCAR Scientific Balloon Facility.

Friction Brake

The development program began in 1967 with a study of various IFD concepts. Very early it was recognized that funding would limit the study to conventional balloon systems now in use. It was also concluded that a successful IFD system would depend on the use of an energy-absorbing device to lower and unfurl the packaged balloon at a controlled rate. Among the many concepts evaluated, the most feasible was found to be a linear friction brake.

The first model to be tested consisted of a length of nylon webbing passed between two aluminum pressure plates. This brake proved to be unsuitable because the output tension of the webbing was sensitive to small variations in the webbing's thickness and to the presence of surface contaminants. Attempts to correct this problem led to another design in which the webbing was threaded through a set of fixed cylinders. After preliminary trials of various cylinder arrangements, a prototype brake was built and used in flight tests.

The brake consists of nine aluminum cylinders each about 11 cm long and 8 cm in diameter, mounted between two aluminum frames. Two 230-m lengths of nylon webbing 4.5 cm wide are threaded side-by-side through the array of cylinders. Six of the cylinders are rigidly fixed and generate enough friction to multiply the webbing's input tension by 100. The other three cylinders rotate freely: the first feeds the webbing into the brake, and the second turns a chain and sprocket assembly which drives a centrifugal clutch located inside the third. The clutch controls the rate at which the main balloon is lowered from the tow balloon. (At the time of design, little was known about the speed at which the main balloon could be withdrawn from its container without damage.) The prototype brake can lower 900 kg for 150 m at a maximum rate of 1 m/sec.

A factor limiting the brake's load-lowering capability is frictional heating of the webbing. Tests with the prototype showed that the webbing is not damaged as long as the cylinder surfaces are below 150°C. The solid aluminum cylinders draw off heat rapidly enough to remain below this temperature, but brakes for significantly larger loads will require cylinders with greater heat capacity or with supplemental cooling mechanisms.

Flight Tests

The friction-brake IFD system was flown at the NCAR Scientific Balloon

Flight Station at Palestine, Texas, in the spring and summer of 1970 and flawlessly deployed an 85,000 - m^3 (3×10^6 ft^3) and a 255,000 - m^3 (9×10^6 ft^3) main balloon. In both tests a 50 - kg instrument and telemetry package was included in the flight train to provide data on the payout rate of the brake's webbing and the temperatures of some of the cylinders.

For both flights tandem balloon systems were used since the gas transfer duct between the tow balloon and the main balloon is the most convenient attachment point for the IFD mechanism. The friction brake was attached beneath a container holding the main balloon and the instrument payload. The two webbings were passed upward along the container and were attached to the transfer duct. A modified Stonehenge launch system was used (see *Facilities for Atmospheric Research,* No. 4, Summer 1967).

Once the tandem system was airborne and drifting with the wind, the IFD system was activated by a solenoid latch release. The balloon container descended slowly on the brake, which maintained its design payout rate of 1 m/sec. The load decreased from 550 to 135 kg as the main balloon deployed. The two lengths of webbing payed out with a difference of only 3 cm over the 105 - m drop. When deployment was complete, the IFD equipment and the payload were jettisoned and lowered to the ground by parachute. In normal operational flights both would remain on the flight train and would be recovered after flight termination. The added weight of the IFD equipment (on the order of 150 kg) would reduce maximum float altitudes by less than 600 m.

The smooth deployment of the main balloon in both flights indicates that the lowering rate could probably be increased to 2 m/sec. Also, the stability of the main balloon after inflation of the tow balloon suggests that routine launches could probably be made in winds as high as 8 m/sec.

The tests demonstrated a number of benefits of the IFD technique apart from the greater protection it gives the main balloon at launch. It provides an unprecedented convenience since the flight assembly can be rigged in advance and stored in the IFD container until time for flight. If a tow balloon is damaged or if for some other reason a launch is aborted, the main balloon can be kept in the container and flown later. (An unsalvageable 850,000 - m^3 (30×10^6 ft^3) balloon would represent a loss of about $35,000.) The technical and monetary requirements for the launch area and for support facilities are also reduced since even the largest balloon systems could be launched in an area 100 m in diameter. •

Facilities R&D Reorganized

Effective 1 October 1970 the research and development activities of the Facilities Laboratory (FAL) were concentrated within a new group, the Research Systems Facility (RSF). The full staff of the Design and Prototype Development Facility and several engineers and technicians from the Field Observing, Research Aviation, and Scientific Balloon Facilities form the staff of the new facility. Stig A. Rossby, who headed the Design and Prototype Development Facility, is manager of RSF.

Consolidation of the individual FAL development functions will increase the quality and flexibility of the total FAL development effort, protect important long-range development projects from the demands of operational programs, and facilitate planning, management, and evaluation of development activities.

The basic goal of RSF is to improve the tools available for measuring the properties of the atmosphere. Specific RSF activities are:

- To conduct research and development programs aimed at providing better observational techniques and instruments
- To assist in designing and evaluating the performance of multisensor atmospheric observing systems
- To provide engineering design, test, and fabrication services
- To write and edit technical reports, to collect and catalog engineering data, and to perform searches of the technical literature
- To provide within FAL a central pool of laboratory instruments which will be serviced, calibrated, and modified as necessary
- To plan and conduct student training programs and to assist in planning and managing FAL-sponsored technical meetings and workshops

The first task of RSF is the identification of projects and studies that can make the greatest contribution to NCAR and university atmospheric research. These projects will form the core of RSF's initial R&D program. •