SMITHSONIAN

MEMO FOR THE RECORD

27 Sept. 1967

Called James Cornell Jr. the public information officer at the Smithsonian Institute. I asked him if the Baker Nunn Camera could practically used for detecting UFOs. He replied that the camera was designed for satalite tracking and was used for looking at objects from 100 to 600 mi high. The track speed etc. is based on the predicted trajectory of the satalite. He said that they often get "unidentified tracks on these films" but they are assumed to be tracks of space junk or other satalites. He also mentioned that this camera can only go down to about 15 degrees above the horizon.

I asked him if he knew of any wide angle cameras that could photograph most of the sky. He mentioned:
DC-4 used by the Coast Geodetic Survey
Super Smitt
and the Prarie Network which is used by the Smithsonian in tracking mereorites. This network covers all quadrents of the sky. He said he would send me some more info. on the Prarie Network and the Baker Nunn but he further added that he didn't think that the Smithsonian would take on any additional tasks.

SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY
60 GARDEN STREET CAMBRIDGE MASSACHUSETTS 02138
TELEPHONE 617 864-7910

July 31, 1967

#7

Mr. James C. Manatt, Colonel, USAF
Dept. of the Air Force
Headquarters Foreign Technology Div. (AFSC)
Wright-Patterson Air Force Base, Ohio 45433

Dear Col. Manatt:

In answer to your request for information concerning the Smithsonian Astrophysical Observatory's field stations, I have enclosed two maps showing the locations of our installations in the United States and abroad. I have also enclosed some general descriptive material that you may find useful.

Neither the general material nor the maps includes detailed information concerning our network of visual observers called "Moonwatch." The Observatory coordinates the activities of approximately 100 teams of semi-professional, volunteer, satellite observers. The Moonwatch organization is perhaps best known for its work in tracking decaying, or reentering, objects.

Because of the limited time available to its volunteer members, the Moonwatch network gives top priority to "decays." Unfortunately, this means that the organization is unable to participate in any additional or long term programs such as UFO investigations. (Incidentally, during our 10 years of operation, no Moonwatch team has ever reported a single UFO.)

Should you need special assistance on individual cases, however, the Observatory would be happy to help in every way possible. All inquiries regarding Moonwatch teams should be forwarded directly to: Mr. William Hirst, Moonwatch Director, Smithsonian Observatory, Cambridge, Mass. 02138.

Requests for information concerning other Smithsonian observing networks, including the Baker-Nunn cameras, can be directed to my office.

I hope that we may be of some assistance in the future.

Sincerely,

James Cornell

James C. Cornell Jr.
Public Information Officer

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SPACE SCIENCES AND SATELLITE TRACKING
AT THE SMITHSONIAN

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
60 Garden Street
Cambridge, Massachusetts 02138

- A Bureau of the Smithsonian Institution -

For Further Information
call or write:

The Information Office
Smithsonian Observatory
Cambridge, Mass. 02138
(617) 864-7910 ext. 463

THE HISTORY AND ORGANIZATION OF SAO

The Smithsonian Astrophysical Observatory (SAO) is a bureau of the Smithsonian Institution with research facilities and administrative headquarters on the grounds of the Harvard College Observatory in Cambridge, Massachusetts.

The Smithsonian Observatory was established in 1890 by Dr. Samuel Pierpont Langley, third secretary of the Smithsonian Institution. Langley intended the Observatory to be a center for what he called the "new astronomy," and its first research pioneered in studies of the relationship between solar and geophysical phenomena.

In 1955, the Observatory moved its scientific headquarters to Cambridge, where its work, although fully independent, became closely associated with that of the Harvard College Observatory. Dr. Fred L. Whipple of Harvard was named Director at this time.

Today, the Smithsonian Observatory employs over 500 men and women, both in Cambridge and at far-flung field stations around the world. Observatory scientists are engaged in research activities supported by private funds from the Smithsonian Institution, by Federal appropriations, and by grants from private foundations. Major grants are received from the National Aeronautics and Space Administration for the Observatory's space programs, including the optical tracking of satellites. In a very real sense, SAO can be considered "the national astrophysical observatory."

THE SCIENTIFIC OBJECTIVES OF SAO

More than 55 Observatory scientists are engaged in a broad, dynamic program of astrophysical research. Their investigations range from cosmology and stellar structure to celestial mechanics and the history of the solar system.

Observational data are provided by a world-wide network of Baker-Nunn cameras, by meteor radars and cameras, by instruments in orbiting satellites, and by conventional telescopes.

The scientific objectives of the Observatory are intentionally flexible so that response to new research opportunities can be prompt. The research program also reflects the interests of the individual scientists so it can be easily adjusted to recognize the interests of new staff members. In addition, the Observatory has always specialized in those fields of research which were often ignored by other scientists, such as meteoritics.

Research results are disseminated rapidly and without cost to scientific and educational institutions, governmental agencies, libraries, and to any individuals interested in the space sciences. SAO publications include the Contributions to Astrophysics, the Special Reports: Research in Space Science, other technical and non-technical reports, information releases, and educational materials.

The Smithsonian Observatory also serves as headquarters for two international science information bureaus. The Central Bureau for Astronomical Telegrams of the International Astronomical Union receives, confirms, and distributes information concerning astronomical discoveries. The Central Bureau for Satellite Geodesy, established under the auspices of the International Union of Geodesy and Geophysics, serves as the clearing house for data concerning the use of artificial satellites for determining the Earth's shape and other characteristics.

THE RESEARCH PROGRAMS OF SAO

1. *Planetary Studies* includes research in celestial mechanics, planetary environments, and exobiology. SAO's research also includes the study of Earth as a planet through geodesy and geophysics. The Observatory's Baker-Nunn camera network provides data for measuring the earth's shape, size, gravitational potential, and atmosphere.

2. *Comets and Meteors*. The Baker-Nunn network also provides data for the photometric study of comet head structure, for the establishment of cometary orbits, and for the photographic study of comet tail motion and development.

   SAO also maintains a camera network in the Midwestern United States for the photography of bright meteors, the determination of their orbits, and the possible recovery of any resultant meteorites. A radar network, also in the Midwest, measures the distribution of micrometeoroids in our atmosphere to determine their possible danger to space craft.

3. *Meteorites and Cosmic Dust*. SAO is one of the world's largest centers for the recovery and analysis of meteoritical material. Several research groups are studying the composition, distribution and history of meteoritical material in space, in orbit around the earth, and in the earth's atmosphere. SAO also maintains laboratories for the radio-isotopic analysis of meteorites, cosmic dust, and recovered satellite material, plus facilities for the study of the metallurgy, mineralogy, and petrology of meteorites.

4. *Gamma-Ray Astronomy* includes studies in high-energy physics and the development of X-ray and gamma-ray detection and measurement instruments for balloon and satellite flights. SAO will expand its ground-based gamma-ray research with the construction of a 35-foot light collector designed to observe the Cherenkov radiation generated when primary gamma-rays strike the upper atmosphere.

5. *Flight Experiments* include the development of satellite instrumentation to observe ultraviolet radiation from the heavens. This satellite package, called Project Celescope, is part of NASA's Orbiting Astronomical Observatory program and should yield new information unattainable from ground observatories. SAO has also assisted in the analysis of data from NASA's Orbiting Solar Observatory program and has prepared its own balloon-flight packages for gamma-ray experiments in the upper atmosphere.

6. Theoretical Astronomy includes investigations of the history and evolution of the solar system, stellar atmsopheres, atmospheric physics, and the development of computer programs for defining planetary orbits. SAO scientists pioneered in the application of high-speed digital computers to the analysis of the physical processes that create the spectra of stars. By comparing predicted stellar spectra with actual observations, they have already acquired important new information about the physical structure, composition, and evolution of stars.

   SAO scientists have also used computers to check astronomical theories of the past and to develop new theories about the possible astronomical uses of prehistoric structures and monuments. For example, one SAO scientist has found that the alignment of stones and stone holes at Stonehenge with important positions of the Sun and Moon indicates that the mysterious monument might have been used as a calendar and a computer for predicting celestial events such as eclipses.

7. Radio Astronomy at SAO includes the joint use, with Harvard College Observatory, of an 84-foot radio telescope for the investigation of atomic and molecular constitutents in the interstellar medium. In addition, the Radio Meteor Project uses radio astronomy techniques to study both the distribution of meteoritical material in space and the direction and intensity of winds in the upper atmosphere.

8. Optical Astronomy at SAO includes such diverse activities as the tracking of artificial satellites, the study of comets, the observation of flare stars, and the investigation of massive and high-density stars. The primary observing instrument is the Baker-Nunn camera which provides satellite, comet, and flare star data. SAO's construction of a multi-purpose observatory in the Southwestern United States will add several conventional telescopes, including a large 60-inch telescope, to SAO's program of stellar observations.

OPTICAL SATELLITE TRACKING PROGRAM OF SAO

The Beginnings: As part of the International Geophysical Year (1957-58), both the United States and Russia announced plans to launch artificial earth satellites. The Smithsonian Astrophysical Observatory agreed to establish and operate a world-wide network for the optical tracking of any satellites launched during this period. The Observatory received a grant from the National Science Foundation to carry out this program.

The original goal of the optical tracking program was to obtain photographs of satellites in sufficient number and accuracy to allow the determination of highly precise orbits. It was hoped that data derived from the orbits could provide information concerning variations in the density and temperature of the upper atmosphere, and to help construct new representations of the earth's gravitational potential and geometrical figure.

Twelve sites were selected around the world in a wide belt between 36 degrees North and 36 degrees South of the Equator, with locations in Florida, New Mexico, and Hawaii, plus Australia, Asia, South America, Europe, and Africa.

While plans for the photographic network were being completed, Dr. Fred Whipple, the Observatory Director, organized a global network of visual observers. This organization, called Moonwatch, was made up of amateur astronomers who volunteered their time to aid in the tracking experiment. (This network is still in operation, and plays an important role in manning the "death watch" for reentering or decaying satellites.)

The Camera: A special satellite tracking camera, the Baker-Nunn camera, was designed and built to the specifications of Smithsonian scientists. The camera is named for Dr. James G. Baker, who designed the optical system, and for Joseph Nunn, who designed the mounting and mechanical systems. The first of the camera units was completed in time to photograph the first man-made satellite, Sputnik I, less than two weeks after launch.

The camera is approximately 8-feet high and 10-feet wide, and weighs about 3 tons. It combines an extremely fast Schmidt optical system with a film transport using 55-mm Royal-X film. (Each frame is approximately 12 inches long, covering a photographic field of 5 by 30 degrees.) Although it operates as a large, movable telescope, the Baker-Nunn is better known for its light-gathering capacity than its magnifying power. Thus, star images 3000 to 30,000 times fainter than those visible to the naked-eye can be recorded by a 1.6-second exposure of the Baker-Nunn.

Although other tracking systems, such as radar and radio, have been developed to near-perfection since the beginning of the space age, the Smithsonian's Baker-Nunn camera still provides one of the most accurate means of tracking satellites. For example, the first Vanguard satellite--a 6-inch sphere--was photographed at a range of some 3500 miles; and more recently, the apogee motor firing on the Syncom satellite was photographed at a distance of 24,000 miles from earth. The cameras could photograph a 20-foot balloon at the distance of the Moon.

Optical tracking has its drawbacks, of course. Obviously you cannot photograph when it is cloudy, foggy, or daylight. In fact, because most satellites are not illuminated and merely reflect sunlight, the camera has to be in darkness and the satellite in sunlight for photographs to be made. Under most conditions, this means that satellite photography is best done in the hours immediately following sunset or preceding dawn.

Without precise timing, even the best photographs of satellites would be useless. The Baker-Nunn camera is supported by an electronic timing system accurate to 1/10,000 of a second. The time on these electronic clocks is compared periodically with radio time signals such as those broadcast by the U.S. Bureau of Standards. A slave clock inside the camera duplicates the time presentation of the electronic clock and records it on each film so the satellite is pinpointed in both time and space.

The peculiar path of satellites across the sky creates special tracking problems. Like a star, a satellite rises into the sky from the horizon, reaches a high point, and then sets. The similarity between the satellite and star paths ends here, however. Satellite culmination, or high point, is not limited to the observer's meridian, nor is the path necessarily semi-circular or symmetrical. The angular velocity (apparent speed) of a satellite may change greatly between the horizon and its culmination. For these reasons, the traditional telescopic mount (sideral mount) designed to track the stars is inadequate for satellite tracking.

Instead, the Baker-Nunn camera is set in a gimbal ring that allows it to turn on a triaxial mounting at predetermined speeds that match the predicted motion of the satellite. At full speed, the camera can sweep from horizon to horizon in 93 seconds.

When tracking a satellite the operator sets the camera for the proper azimuth, altitude, and tracking angle so that the camera and the satellite both pass through the same point in the sky at the same time and direction.

Tracking Procedure: The satellite tracking operation naturally begins with the launching of an artificial earth satellite.

In the early days of the Space Age, the first visual observations were often made by volunteer teams of SAO "Moonwatchers." From these observations, the Computations section in Cambridge calculated an approximate orbit for the satellite, and predictions were computed for the various SAO tracking stations around the world. These predictions (which give a satellite's azimuth, altitude, angular velocity, and time of closest approach in respect to each of the stations) were then teletyped to the stations.

Today, however, the National Aeronautics and Space Administration--or any other launching agency--can easily predict the approximate orbits of satellites before launch. Predictions derived from the nominal orbital elements are teletyped to the stations several days before the launch date.

At lift-off, the stations are simply notified to begin tracking on schedule. The observers at a station set the camera at the proper tracking angle and speed to photograph the satellite at the predicted time.

There are two methods of photographing satellites: first, the camera remains stationary and the satellite image trails across the film; and second, the camera tracks the satellite so that the satellite image is stationary on the film (and should appear as a pin-point image) while the stars in the field appear as trails on the film.

The exposed film is developed in the station's darkroom. The developed film is then placed on a light table and a transparent star chart (drawn to the same scale as the film image) is placed over the exposure and lined up to match the background of stars in the photo. The satellite image is located on the film and its position is read from the "X-Y coordinates" (celestial longitude and latitude) on the star chart. The time of the exposure is read off the photograph of the clock face shown on the film. This type of "field reduction" is accurate enough to determine the satellite's position to within 2 minutes of arc on the celestial sphere.

The field-reduced time and position of the satellite are teletyped to Cambridge and fed into a computer, which calculates a refinement of the orbit for use in making future passage predictions for the tracking stations.

The actual films will later be shipped to Cambridge and final measurements of the satellite will be made by the Observatory's Photoreduction Division. Photoreduction technicians can usually obtain an accuracy of better than 10 seconds of arc and 2/1000 of a second of time. In other words, they can locate an object 1000 miles away with a possible error of less than 10 to 15 yards--or better.

Satellite Data Utilization: Today, ten years after the beginning of the Space Age, the Observatory is still providing optical tracking support for the National Aeronautics and Space Administration. Recently, the Observatory has undertaken a growing number of operational requirements, including increased participation in both the manned-space flight and international geodetic programs. In addition, SAO provides an optical back-up for almost every NASA launch and contributes data to the U.S. Air Force's continuing survey of all man-made objects in space.

More important, perhaps, is the use of optical tracking data by Smithsonian scientists engaged in various basic research programs, such as satellite geodesy. For example, more than 10 years and 40,000 satellite observations went into the recent publication of the "Smithsonian Standard Earth," a new representation of distances between land masses on the earth accurate within tens of feet (compared to previous measurements accurate only in hundreds of feet.) The "Standard Earth" is perhaps the most precise representation of the earth's shape and size ever devised.

The Smithsonian Star Catalog, based on thousands of Baker-Nunn observations of the sky, gives the photo and visual magnitudes, proper motion, spectral type, and other data for approximately 250,000 stars. This single, uniform catalog of the heavens contains most of the data previously found in more than 40 separate catalogs and atlases.

Special computer programs developed by the Observatory's Data Department has enabled Smithsonian scientists to use Baker-Nunn data for analyses of the earth's upper atmosphere, including studies of the relation between variations in temperature and density and solar activity. In fact, much of what modern man knows about the earth's atmosphere above 200 kilometers have been revealed by Baker-Nunn data. Other programs have allowed irregularities in the earth's gravitational field to be determined from their effects on the motion of satellites.

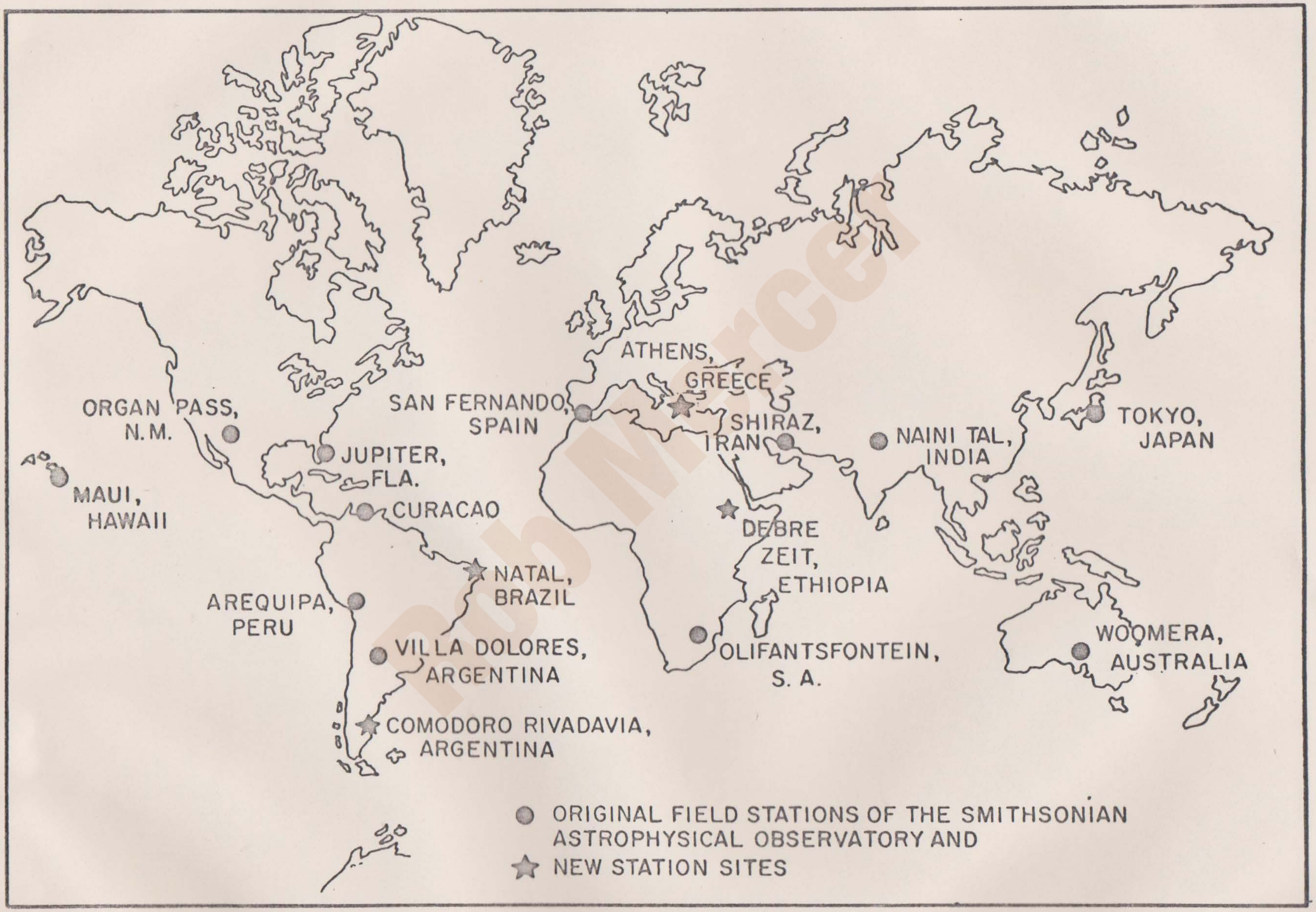
Other Uses: The Baker-Nunn cameras are used for more than merely observing satellites, however. The Smithsonian network provides astronomers with an around-the-world "comet patrol" for the constant surveillance of newly discovered comets and this surveillance is often expanded to include other objects such as asteroids and super novae.

In cooperation with the Jodrell Bank Radio Observatory in England and the Parkes Telescope in Australia, the Smithsonian cameras make simultaneous radio-and-optical observations of flare activity on distant stars.

The Future: The increased role of the Smithsonian Observatory in international programs of satellite geodesy led to the development of a new camera called "the modified K-50." This camera was designed and built by Smithsonian technicians using a lens system (f/4, focal length 36 inches) originally designed by Dr. James Baker for aerial photography. The camera and its mount are 8-feet high and 3 1/2 feet wide and weigh about 2500 pounds. The K-50 camera is extremely useful for observing the bright balloon and flashing-light satellites designed for geodetic studies. (The prototype K-50 was designed by Dr. George Veis of the National Technical University of Athens; appropriately, the first fully operational K-50 station was installed at Athens, Greece in 1966.)

The Smithsonian also is experimenting with lasers coupled to the Baker-Nunn cameras. The addition of a laser system will provide highly accurate "range" measurements (ground-to-satellite distance) to complement the Baker-Nunn camera's already precise positional data. The reflected flashes from the laser beam might even allow SAO's cameras to track during daylight hours. The first such laser-camera installation is operating at the Smithsonian's New Mexico station.

The scientific results from satellite tracking have far surpassed any of the 1957 expectations for the optical system, and new discoveries and new challenges continue to make optical satellite tracking an exciting venture. In addition, the Baker-Nunn camera installations, once the fledgling pioneers of international space tracking, have developed into busy, multi-functioned, field research stations. With a vast network of communications linking all these stations with Observatory headquarters in Cambridge, the Smithsonian can virtually watch the skies around the world every minute of the day.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AREQUIPA, PERU
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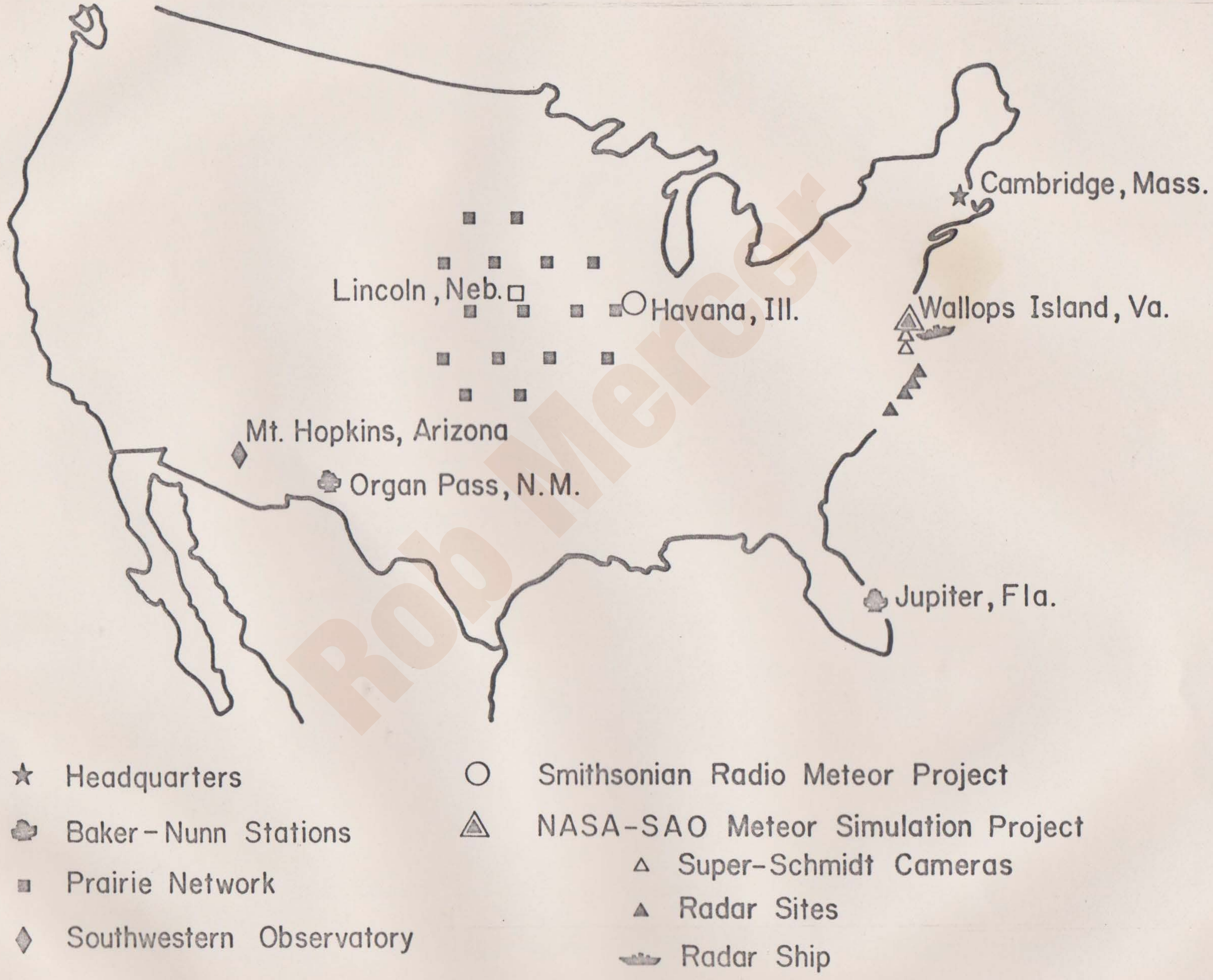
OLIFANTSFONTEIN, S. A.
WOOMERA, AUSTRALIA
COMODORO RIVADAVIA, ARGENTINA
● ORIGINAL FIELD STATIONS OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY AND
★ NEW STATION SITES

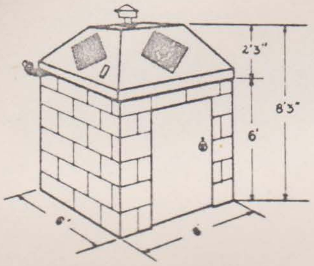
SAO FIELD STATIONS IN THE UNITED STATES

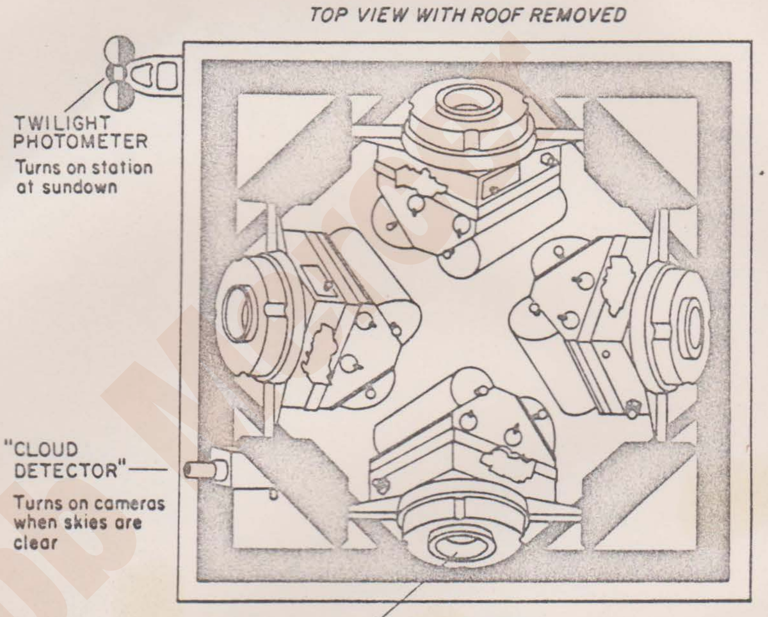


PRAIRIE BRIGHT-METEOR NETWORK

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

AUTOMATIC CAMERA STATION





T-11 CAMERA

f/6.3, 1" aperture with 85° field of view