NEW DEVELOPMENTS FOR AERIAL RECONNAISSANCE*

Colonel George W. Goddard, USAF Chief, Photographic Laboratory, Engineering Division Hq., Air Matériel Command, Wright-Patterson Air Force Base, Dayton, Ohio

THE importance and scope of photography in military operations have been undergoing many rapid and radical changes for the past few years. *Complete* reconnaissance, including weather and radar as well as photographic coverage, is required. The requirements, of course, call for round-the-clock coverage at all latitudes, for altitudes up to many miles; in short for all conditions under which it is planned to operate aerial platforms of one sort or another.

Although 80 to 85 per cent of all allied military intelligence was secured by aerial photography, twice within our lives a lack of aerial photographic lenses has resulted in a mad scramble. We recall at the start of World War I the hue and cry that went out to photo shops, studios, and private citizens, begging for long focal length lenses. We recall the response—hodgepodge of soft focus, special effect, and straight objective lenses, the larger part of which were of German manufacture. We recall that there were only two major companies and two smaller operators in the entire country qualified to produce the large aerial lenses. Acutely conscious of these facts and the World War I shortage, the Photographic Laboratory at Wright Field planned a long-range program of lens research.

This program ran afoul of the natural American aversion to military might. Not only did the lens program suffer, but few new cameras were designed due to the shortage of funds. Available money was used to improve the reliability of existing equipment. A contract for 100 cameras often took more than a year to complete, and much of our optical glass for aerial lenses and filters was being imported.

German photographic and optical research were two of Germany's important industries. Our photographic industry was smaller, newer and forced into competition with foreign firms of world renown. Zeiss' profits were turned back into research and development. Children, carefully trained in the grinding and polishing of glass, and top research scientists were called into service whenever the need arose. Our scientists were busy in colleges or in industry working in competition.

The Photographic Laboratory, in 1940, was in no position for a world war. Consequently, with war, came a cloud-burst of confusion. The Ground Forces and the Navy, as well as the Air Force, had urgent needs for cameras, films, prisms, lenses, periscopes, and other photographic and optical devices. Everyone found new uses for photographic equipment. Agencies competed in frantic haste to place orders. Thus World War II caught us looking through rose-colored glasses instead of precision lenses.

To the credit of American industry, two years after war was declared, in addition to the Army Air Forces supply, thousands of aerial cameras went to the Navy and our allies. Every fighter plane was equipped with gun cameras; bombers carried cameras to record bomb strikes and damage. Reconnaissance aircraft carried at least three cameras.

* While not identical, this paper is essentially the same as that given at the 1949 Annual Meeting of the Society, as a description of the subject matter and as an explanation and description of a large number of most interesting and instructive illustrations. A large reduction in the number of illustrations was necessary—*Editor*.

There is never enough time for research; peacetime facilities are always needed for maintenance. The research performed by colleges helped tip the scales in our favor. It is imperative that military research be continued, thinking in terms of the distant future. Present long-range research programs were established at Boston University and Wesleyan University, and investigations pertaining to adapting radar to aerial photographic mapping, at Ohio State University.

Although 19,000,000 square miles, one-fifth the earth's surface, were covered with black-and-white photography during the war, future progress is indicated in a 51-minute flight with a P-80, which photographed 16,000 square miles.

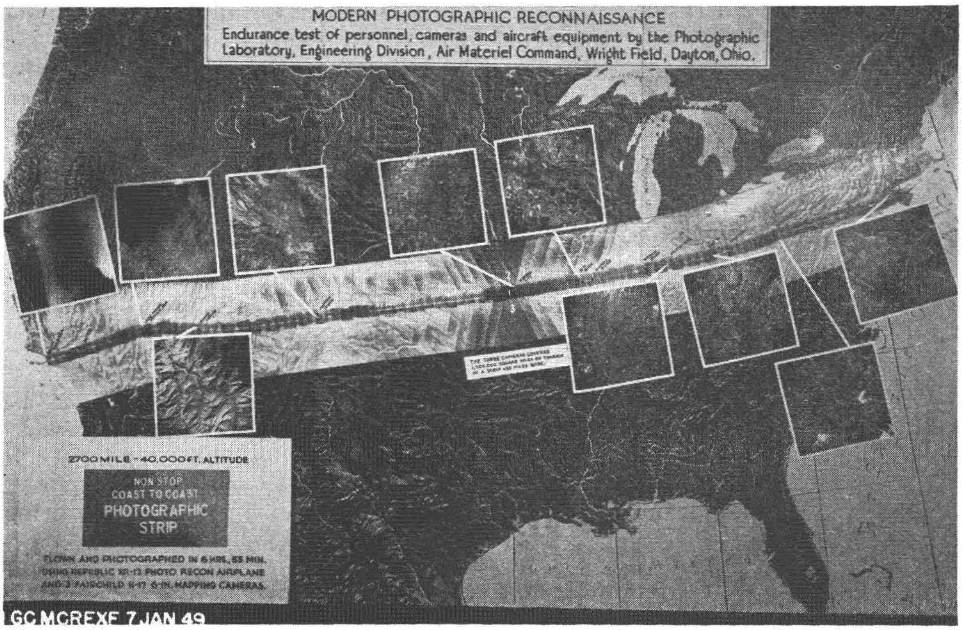

FIG. 1. Non-Stop Coast-to-Coast Photographic Strip.

Supersonic speeds and tremendous altitudes will bring new problems to the operation of the camera. Can images be transmitted from the plane in flight to the bases? Will photography aid in steering guided missiles to their objectives? Today's equipment is only the crude model of that needed for the future. Continued research will be required to face any new international emergencies.

In this paper, it is intended to review a few of the current developments underway in the Engineering Division Photographic Laboratory at Wright Field. I shall not attempt to cover the work completely, because of space limitations and security regulations, but intend to cover those items of greatest probable interest to Photogrammetric Engineers.

To give you some idea of the speed in which a large area can be covered, I am including a strip across the United States (Figure 1). It was made during the month of September 1948 when our reconnaissance airplane climbed to an altitude of 40,000 feet over Los Angeles and flew to New York City in six hours and fifty-five minutes. The total flight was made at 40,000 feet, using the trimetrogon camera arrangement, with supplementary photography of larger scale. Pinpoint pictures are shown—from left to right: Santa Barbara, Hoover

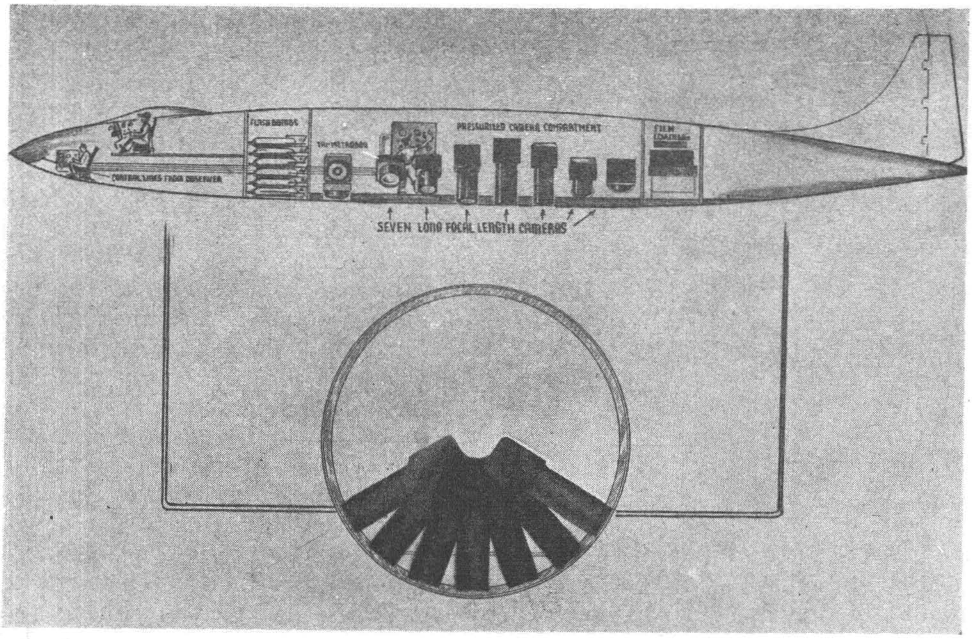

FIG. 2. Typical Reconnaissance Airplane Installation.

Dam, Grand Canyon, Alamosa, Colorado, Kansas City, Mississippi River, Indianapolis, Dayton, Pittsburgh, and New York.

Figure 2 is included to present the general idea of equipment and arrangement of a reconnaissance airplane. It will be noted that the navigator and photographer are located in the noise of the airplane, then the photoflash bombs, then the tri-metrogon installation of 6-inch 9×9-inch cameras. These are followed by the seven large cameras arranged to cover an angle of view of about 140 degrees at large scale. These are the K-40 Cameras using the 48-inch $f/6.3$ lens with 1,000 feet of film. These are needed to meet the minimum intelligence requirements.

Figure 3 shows a mock-up of the K-40 Camera now being developed by the Fairchild Camera & Instrument Corporation. This camera has the moving film feature so that the movement of the film can be synchronized with the image movement, and has a focal plane shutter with speeds up to 1/800th of a second. This camera, fully loaded with 1,000 feet of film, may weight as much as 600 pounds.

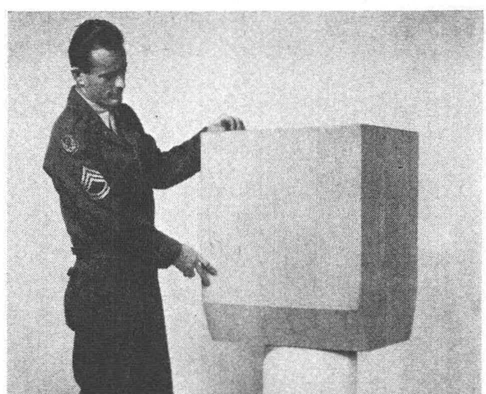

FIG. 3. Mock-Up of 48-Inch 9×18-Inch K-40 Camera.

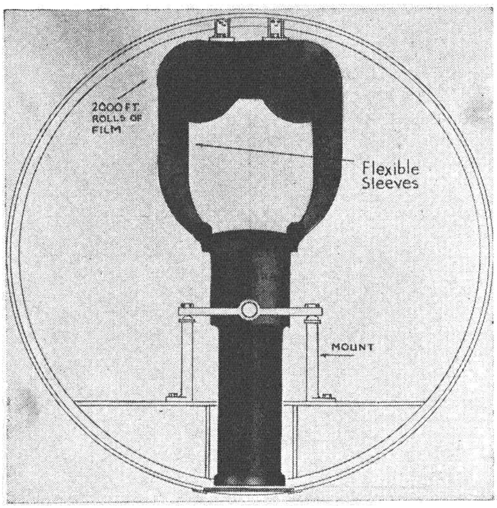

FIG. 4. Schematic Diagram of Transverse Panoramic Camera.

The multiple camera method of covering a wide angle of view at large scale is unsatisfactory from the standpoint of bulk and weight and also from the standpoint of added maintenance problems, and, therefore, another idea is being exploited which is partly illustrated in Figure 4. In this new camera, which is now under development for us at the Perkin-Elmer Corporation, the film is located in the roof of the airplane and is fed down through a sleeve into the focal plane, in which manner we can make use of large film capacities without being required to stabilize the heavy rolls of film. It also makes possible film capacities great enough to equal the capacity of the seven cameras mentioned previously. The optical system of this cameras was designed by Dr. James G. Baker and includes a rotating prism system directly below the 48-inch lens. This rotating optical

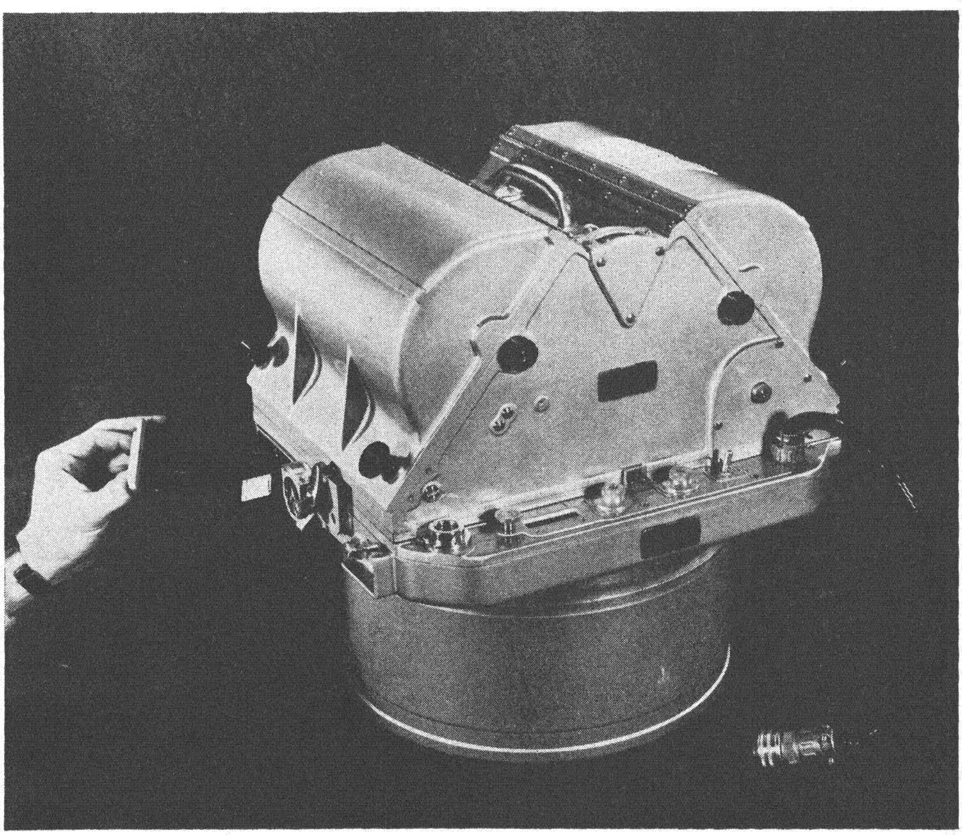

FIG. 5. T-9 Mapping Camera.

system, combined with film transport scheme, provides a sweeping camera which will make a horizon-to-horizon sweep in a direction perpendicular to the line of flight. The resultant photograph will be 18 inches wide by several feet long. This camera, together with similar cameras of even longer focal length, may be the final answer to meeting fully the intelligence requirements for large scale horizon-to-horizon photographic coverage. For the present, we are calling it the Transverse Panoramic Camera.

Figure 5 shows the T-9 Camera recently delivered to Wright Field for tests. This camera, developed by the Fairchild Camera & Instrument Corporation, has a single-bladed shutter which is easily removable for maintenance and inspection. It also has along the edge the arrangements for recording of instruments and Shoran counters. This camera has the 6-inch metrogon lens, carries

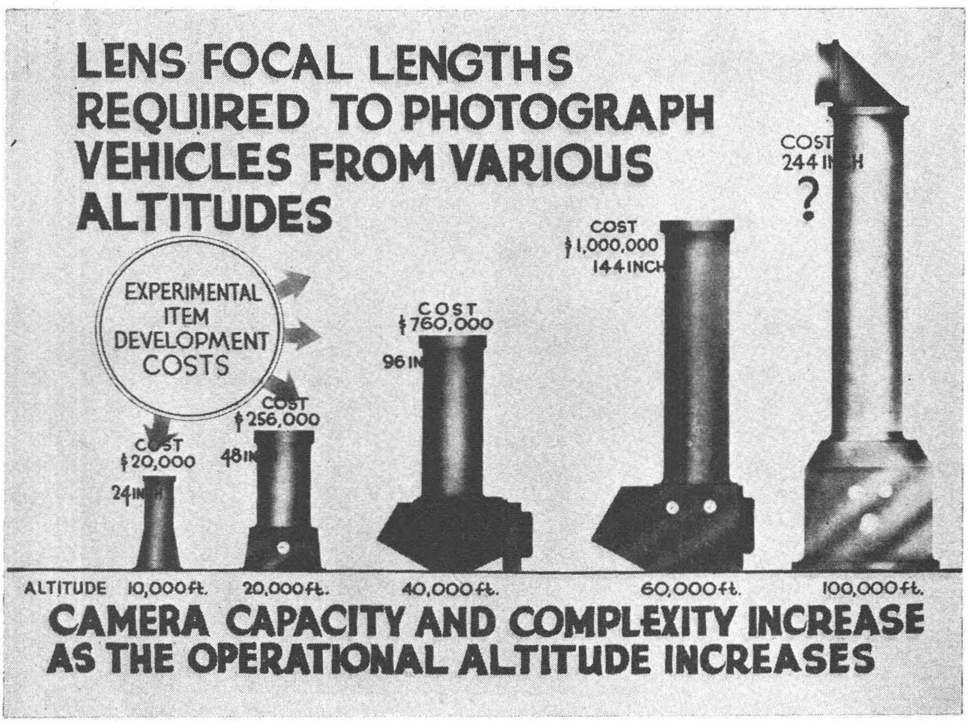

FIG. 6. Comparative Developmental Costs of Cameras.

400 feet of film, and embodies the moving film feature. Photogrammetric Engineers will, no doubt, question the need for moving film in a mapping camera of small scale which is ordinarily used at high altitudes; however, we feel that the moving film feature is desirable and will be necessary for use in high speed aerial platforms, especially at the high latitudes where long exposures will be required. Only extensive tests will show the importance of the moving film feature in a mapping camera of this type, and these tests are just now beginning. The movement of the film is accomplished by moving the vacuum back plate, and the fiducial marks are exposed with flash lamps. The shutter has a range of 1/100th to 1/350th of a second.

To give you an idea of the cost of developing cameras, I include Figure 6. The sharply increasing costs indicated are the result of several things: first, is the rapidly increasing demands on photography for larger scale photographs at

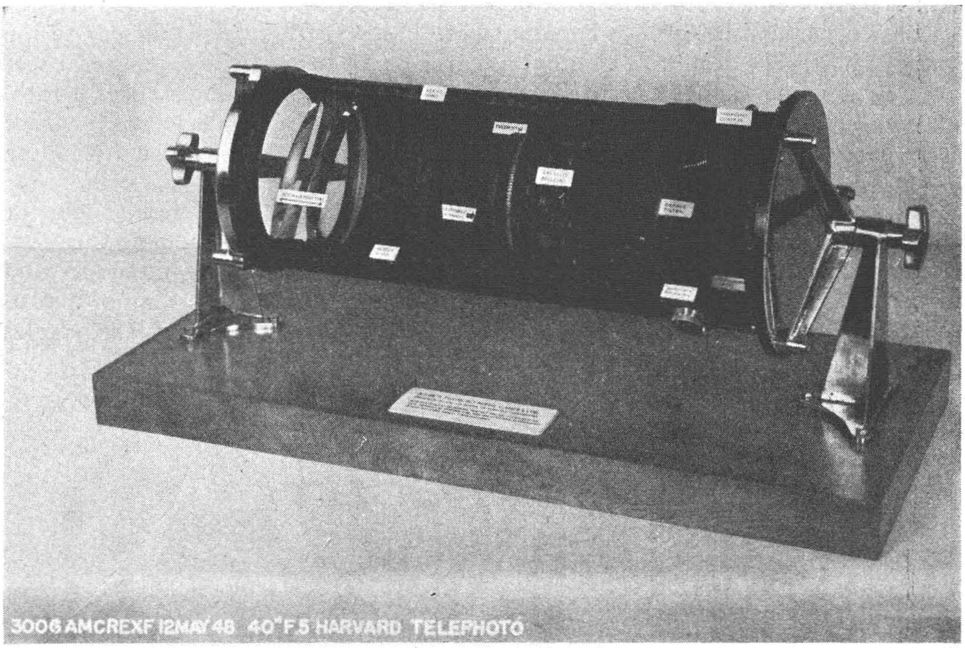

FIG. 7. Cutaway View of 40-Inch F/5.0 Telephoto Lens.

higher and higher altitudes and of wide angles; second, is the fact that we have gotten completely away from any similarity to commercial products; and, third, of course, is the increasing cost of development work generally. The cost of developing a 24-inch camera several years ago was, perhaps, $12,000 to $14,000; whereas, in the last war, it was about $20,000. Then, when we went into the development of the 48-inch camera, we found that an outlay of $256,000 was required to cover the cost of the camera and lens. Then, as new requirements were stated for reconnaissance at altitudes of 40,000 feet, we entered into the development of a 96-inch camera. We estimate the cost of such a development, when completed, will have been $760,000. Now when altitudes of 80,000 feet are being talked of, we are finding it necessary to start the development of still longer focal length cameras and have under development one of 144-inch focal length, costing $1,000,000, and one of 240-inch focal length, the cost of which will not even venture to estimate.

Figure 7 is a photograph of a cutaway model of a very fine lens, which will give you an idea of what goes into a modern lens cone. This lens was developed by Dr. James G. Baker while at Harvard University during the early part of the war. We made room for Dr. Baker and his staff by throwing the books out of one of the libraries at Harvard and set up an optical research center. This small group later became a part of the effort under the National Defense Research Committee, and then after the war, it was taken over by our Boston University Optical Research Laboratory which I will describe further on in this paper.

This lens cone was designed and built to automatically compensate for the effects on focus caused by the rare atmosphere at high altitudes and was provided with thermostatically controlled electric heat to keep the camera at a predetermined temperature. The automatic focussing compensation for pressure changes is quite unique in lens construction in that several small bellows act to move the rear element of the lens to compensate exactly for the effects of the low atmospheric pressure. It is not the pressure, of course, but the lower index of refraction of thin air which causes the focus changes which are compensated by this means. This was a seven-element telephoto lens, 40-inch f/5.0, covering a 9×9-inch picture.

Another lens cone is illustrated in Figure 8, which is a photograph showing all of the parts which go into the Eastman 48-inch f/6.3 telephoto lens. This lens cone is provided with manual adjustment for focus, and some models in-

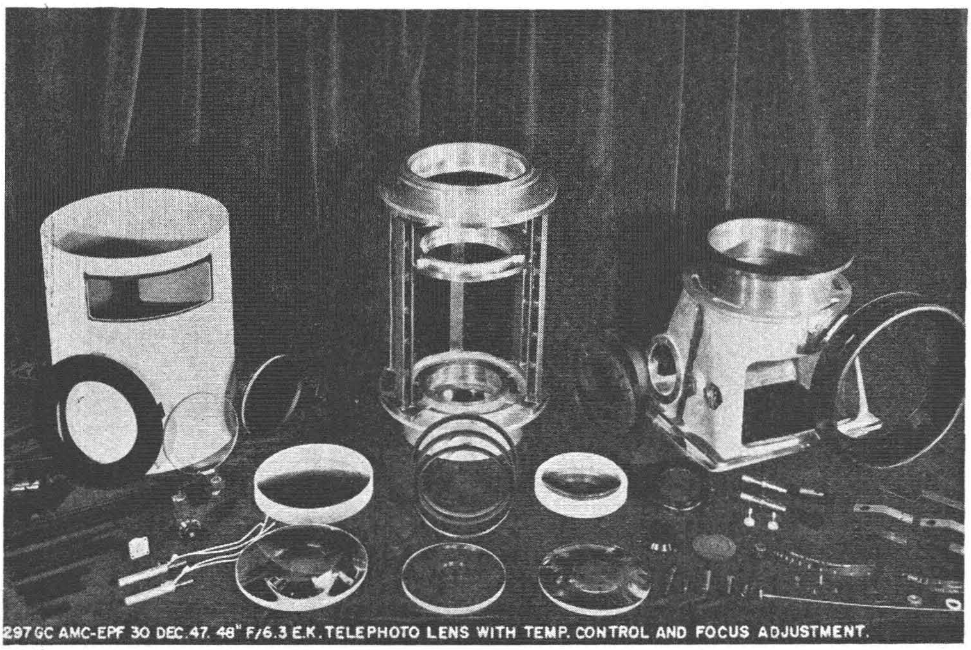

FIG. 8. Parts for 48-Inch F/6.3×18-Inch Telephoto Lens.

clude thermostatically-controlled temperature. This is a five-element lens which will probably cost about $5,000 each in production quantities.

Figure 9 shows the 100-inch camera with the "figure-four" optical system. The lens for this camera is 100-inch f/10, designed and built at Harvard College Observatory during the war, the camera proper being built by the Mount Wilson Observatory. The electric blanket shown was made by the General Electric Company. This camera has performed extremely well, and the efficiency of the heating blanket is indicated by the fact that it has been operated in an ambient temperature of 87 degrees below zero, while the camera was maintained at a temperature of 40 degrees above zero Fahrenheit. The large scale produced by this camera, together with its excellent lens and good mechanical performance, means that here we have a camera which satisfies most of the existing requirements of intelligence. Such a camera would have been extremely valuable for pinpoint photography during the last war. I think particularly of a case where the British were attempting to interpret photographs of the V-2 activity at Peenemunde. Their 36-inch lens simply would not produce the definition and scale required at the 32,000-foot altitude at which they found it necessary to fly. We have very good photographic evidence to indicate that the 100-inch camera would have done the job.

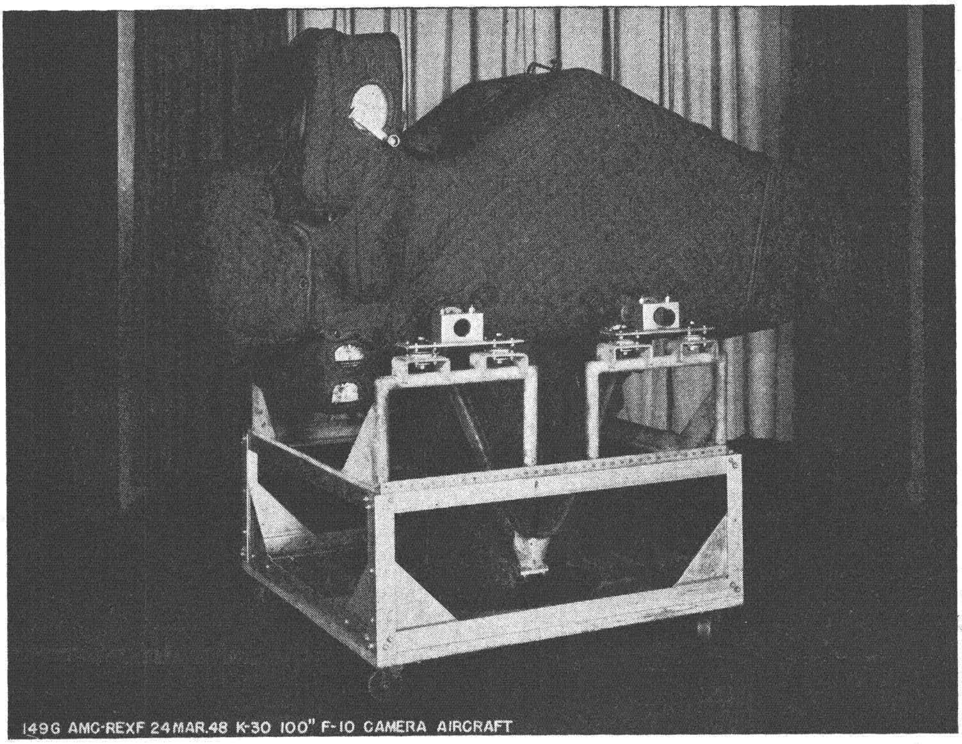

FIG. 9. Type K-30, 100-Inch F/10, Aerial Camera.

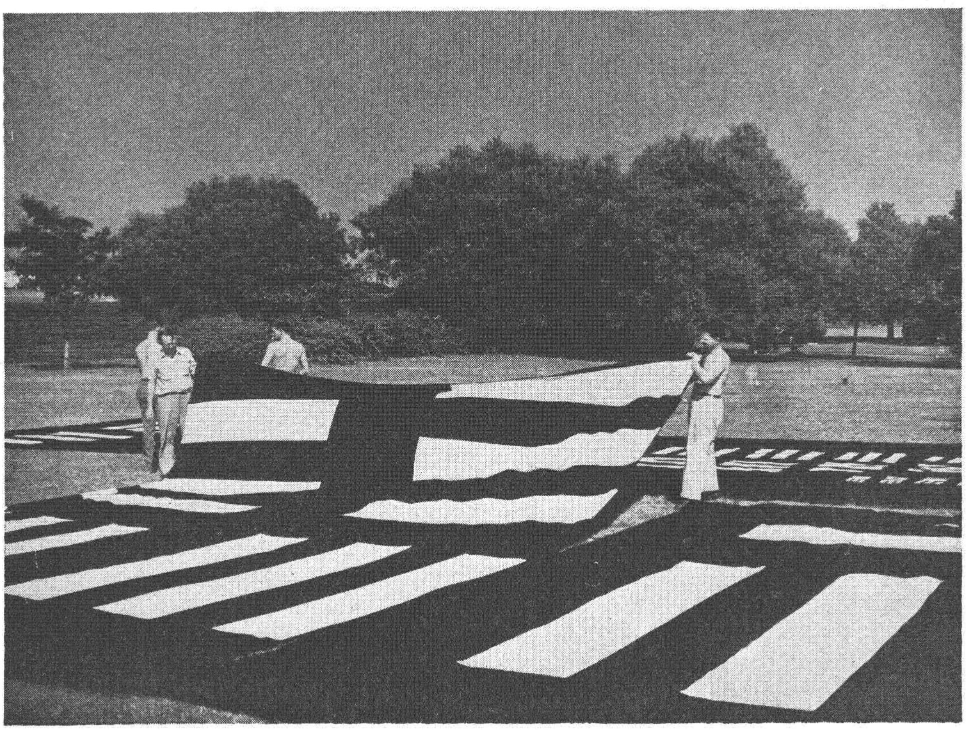

FIG. 10. Resolving Power Targets.

Figure 10 is included to show some resolving power targets used in our aerial testing. We have adopted the three-line pattern as our standard and give our results in terms of lines per millimeter resolved. Other targets, which have been constructed and are now being constructed, are made of concrete. We are now constructing a target strip which is 20 miles long, with the large center target which is 180 feet in diameter. This center target will be in the form of an annulus, of concrete, with all the various types of resolution targets and color panels. This is being constructed at Muroc Air Force Base, California, where we have still another installation of white metal strips about the size of railroad ties, spaced at 20-foot intervals and extending for approximately three miles. These strips will be used in testing strip cameras to check synchronization, roll, etc. Supplementing the formal targets will be an array of salvaged tanks, guns, and airplanes for more nearly simulating the type of targets photographed during war.

A carefully controlled program of testing various methods of printing aerial photographs is underway in the Laboratory, and some very interesting results have been obtained. These indicate that the usual method of contact printing causes a limit of approximately 40 lines per millimeter to be set as far as the print is concerned. This means that no matter how perfect the negative may be, 40 lines per millimeter is the limit that can be obtained by contact printing where the light source is close to the negative. These tests indicate that printing by a distant light source or by projection is much to be preferred.

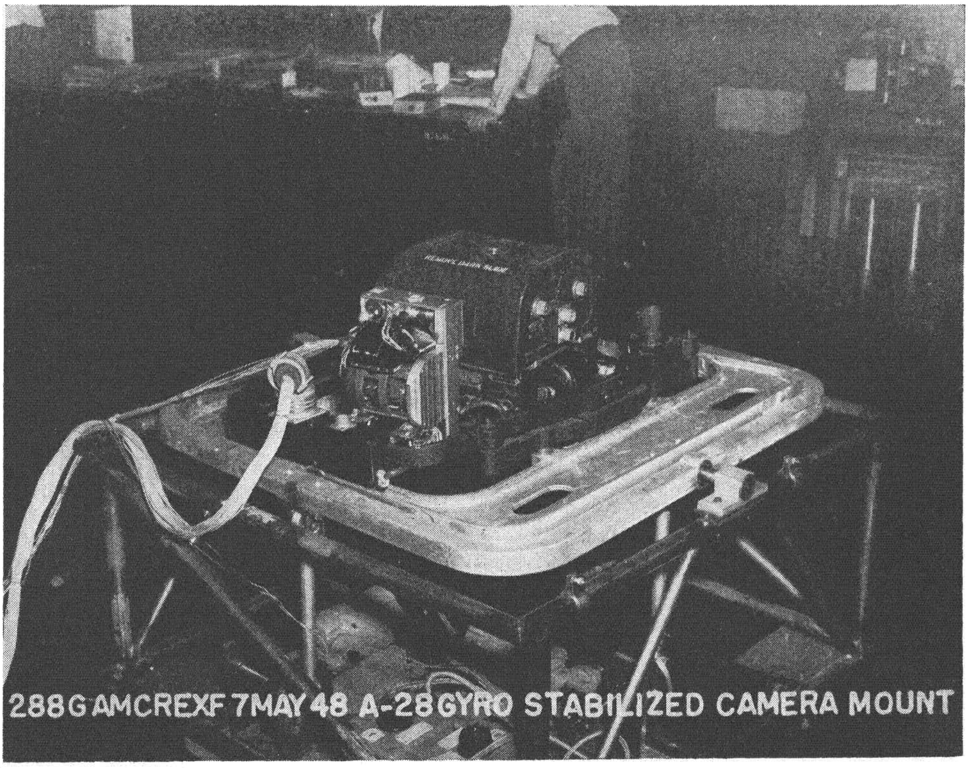

FIG. 11. Type A-28 Gyro-Stabilized Vertical Camera Mount.

Figure 11 shows the vertical stabilized camera mount with a 6-inch K-17 (9×9-inch) Camera. This camera mount utilizes two gyroscopes with small mirrors onto which a light beam is projected and reflected to two photoelectric cells. Stabilization is then accomplished by servomechanisms which restore the camera to level. This project was originally started in Germany, where I found two German scientists working on it near Hanover. They are now finishing it, and one production prototype is already on contract. I realize that this is probably the project of greatest interest to Photogrammetric Engineers, since a mount such as this, which will maintain a camera level to within 10 minutes of arc, will save many hours of labor on the part of those who reduce the mapping photographs to the finished maps. This mount has been under thorough tests at Wright Field for some time, and several different test methods have been developed for evaluating its performance. We believe that it will soon be ready for commercial applications.

Another development of considerable interest to Photogrammetric Engineers is the extension of Shoran. Tests are being run in which a relay airplane relays the shortwave energy to the advance photographic airplanes in our attempt to increase the range of this method from 250 miles to 500 miles.

Figure 12 is a schematic drawing of another development of considerable interest to Photogrammetric Engineers. By perfection of this scheme, we hope to be able to extend aerial triangulation over enemy territory for, perhaps, 1,000 miles. It is not possible to give the details of this scheme at the present time.

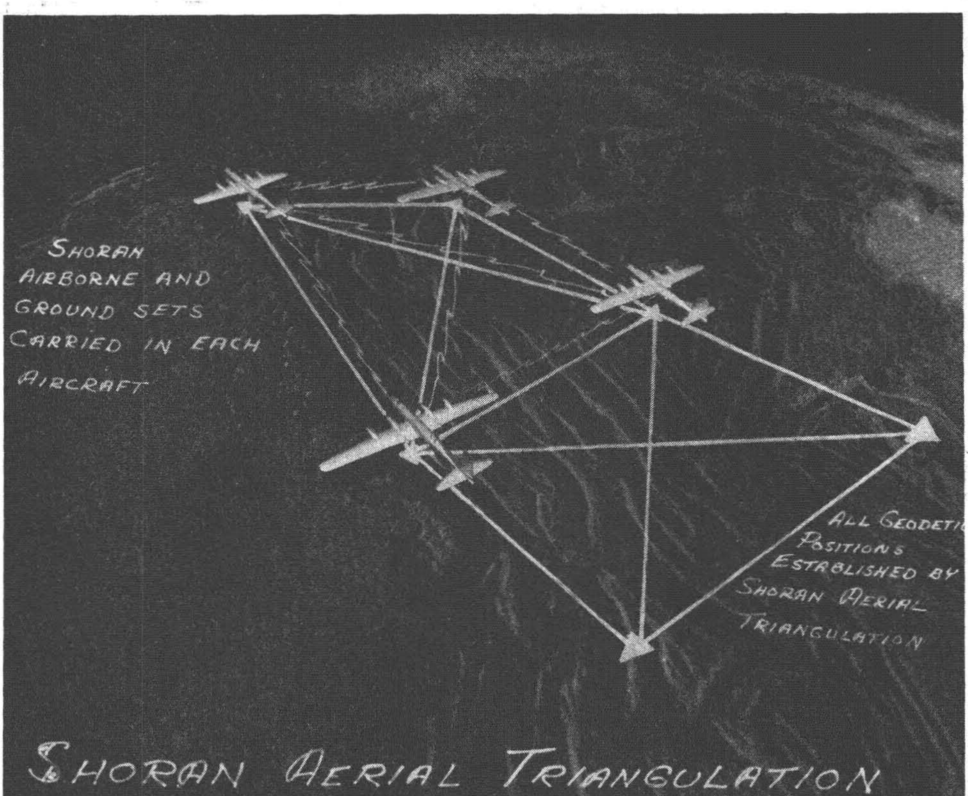

FIG. 12. Shoran Aerial Triangulation.

Another important forward step in the improvement of reconnaissance cameras is the principle of moving the film in synchronism with the movement of the image. Perfect synchronization is not required to obtain important improvements in the definition of photographs. This statement is particularly true of cameras in high-speed airplanes at low altitudes. Figure 13 shows two photographs made with two cameras at the same time and at the same shutter speed, and they clearly show the increased definition obtained in the camera with the moving film magazine.

Other methods for compensating for the forward movement of the airplane over the ground were tried out during the war. One, for example, was the experimental work on the swinging mount. Another was the use of rotating prisms below the lens to impart a motion to the image which would compensate for the forward motion caused by ground speed. All this experience indicated that the most desirable solution to the problem was that of moving the film in synchronism with the image during the time of the exposure.

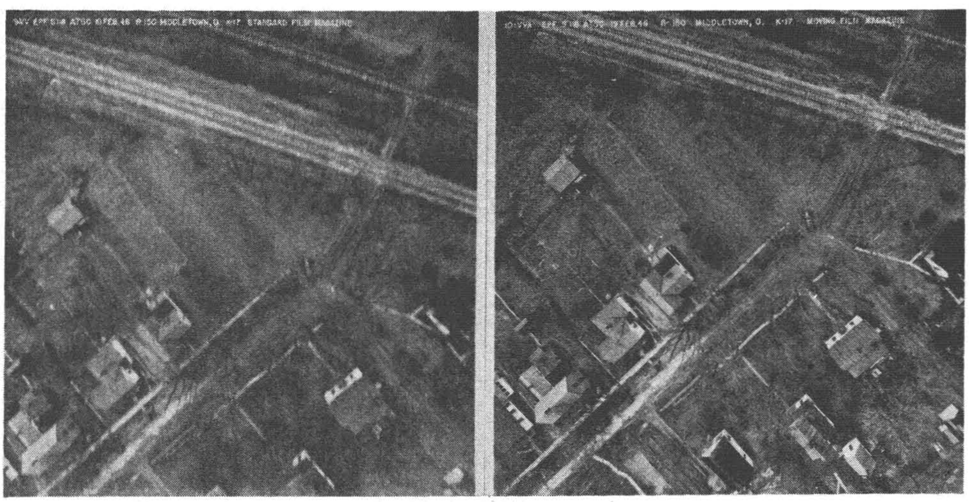

FIG. 13. Comparison of Results Obtained with Conventional and Moving Film Magazines.

This plan of moving film and image together is now being adapted to Shoran recording. Figure 14 shows a recording camera which produces a strip photograph of a radar scope image. This camera works with the "A" type radar scope presentation.

Figure 15 shows the photographic hours per day throughout the year for 70 degrees North latitude. This chart is included to illustrate the importance of night photography in our over-all development program. It represents the photographic hours suitable for use with an f/6.3 lens to an f/2.9 lens, assuming a film of the speed of the standard Air Force Class "L" aerial roll film.

Two types of night photography were used during the war to a limited extent. Useful pictures were made with the Type M-46 Flash Bomb, at 9,000 feet and under. This is a 25-pound bomb producing an illumination of 500,000,000 candlepower. The Type T-9 Bomb carries 70 pounds of powder and produces 1,000,000,000 candlepower. The latter bomb, however, was not available during the war. The other method of obtaining night aerial photographs was by the use of the flash lamp, a high-voltage xenon-filled lamp of high intensity and short duration.

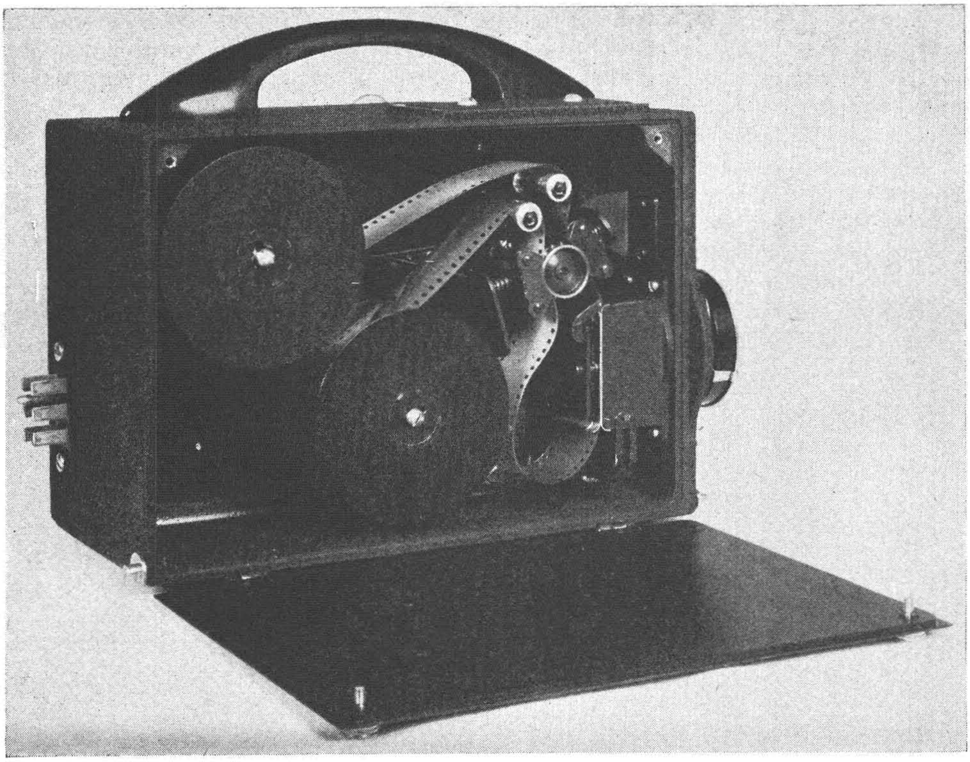

FIG. 14. Oscillo-Record Camera.

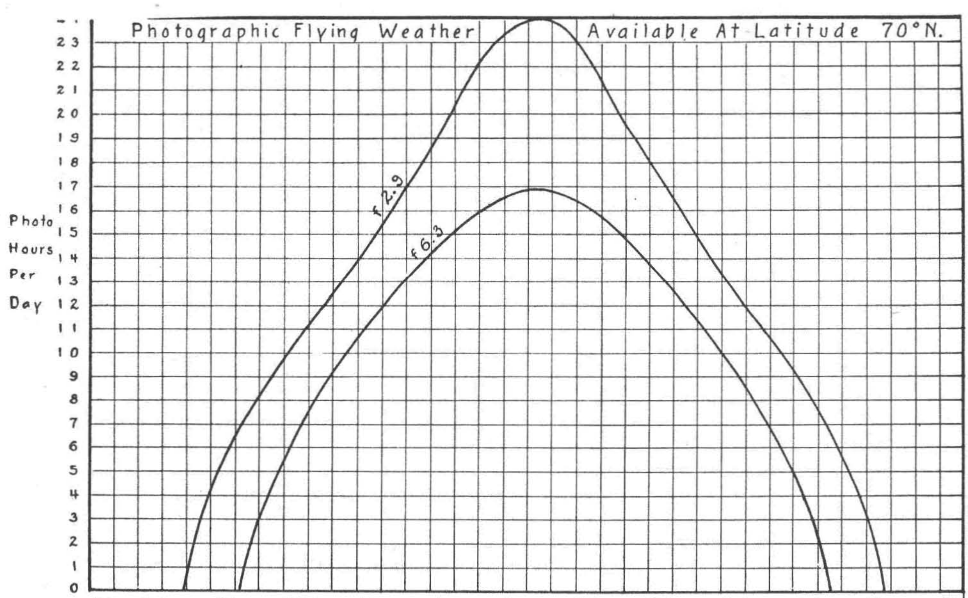

FIG. 15. Photographic Hours Per Day versus Time of Year at 70° North Latitude.

Figure 16 illustrates the method of using the flash bomb. The technique is to release the bomb which is set to explode at approximately two-thirds of the distance to the ground. A photoelectric cell trips the shutter, and the camera automatically rewinds and is ready for the next picture. It is obvious, of course, that the trail angle of the bomb must be such that it is not in the angle of view of the camera at the time it explodes. Such bombs give a total exposure of approximately 1/6th of a second, and the shutter is usually set to pick out peak light for about 1/100th of a second. This system, of course, wastes much of the light, and one of our current developments calls for opening the shutter at the beginning of the explosion and closing it after the explosion is completed. The

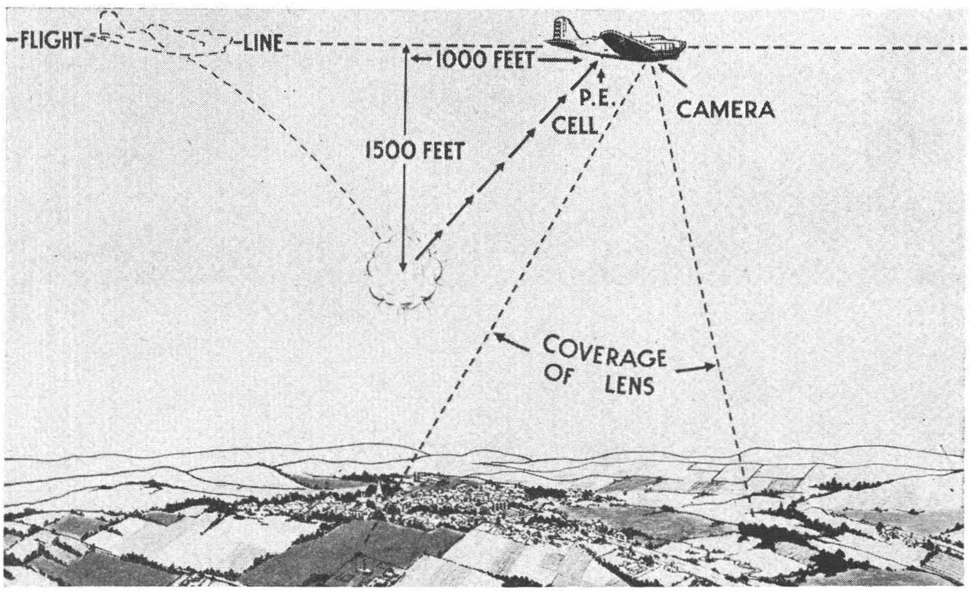

FIG. 16. Schematic Diagram at Night Photographic Systems Using Photoflash Bombs.

moving film principle is used in that case in order to permit the longer exposure required.

Development is now progressing on what we popularly call a dust bomb. In this type of bomb, the explosion scatters the powder into a cloud where it is ignited to give a tremendous illumination. This should make it possible to take night photographs at high altitudes. Figure 17 is an illustration of the use and effectiveness of this bomb as opposed to a bomb of the conventional type.

The problem of releasing photoflash bombs at high speeds presents considerable difficulty. Tests at 40,000 feet and 500 miles an hour indicate that bombs of the old type of construction tumble considerably and fail to hold to the required accuracy of trail angle. A development is currently underway to solve this problem.

One development directed toward the ejection of bombs at high speeds is illustrated by the rocket discharger shown in Figure 18. This ejects the bombs from a series of barrels, in the case illustrated, at the rate of one per second. These bombs are in the form of small cartridges for use at relatively low altitudes and weigh from one-half pound up to three pounds. The light from the

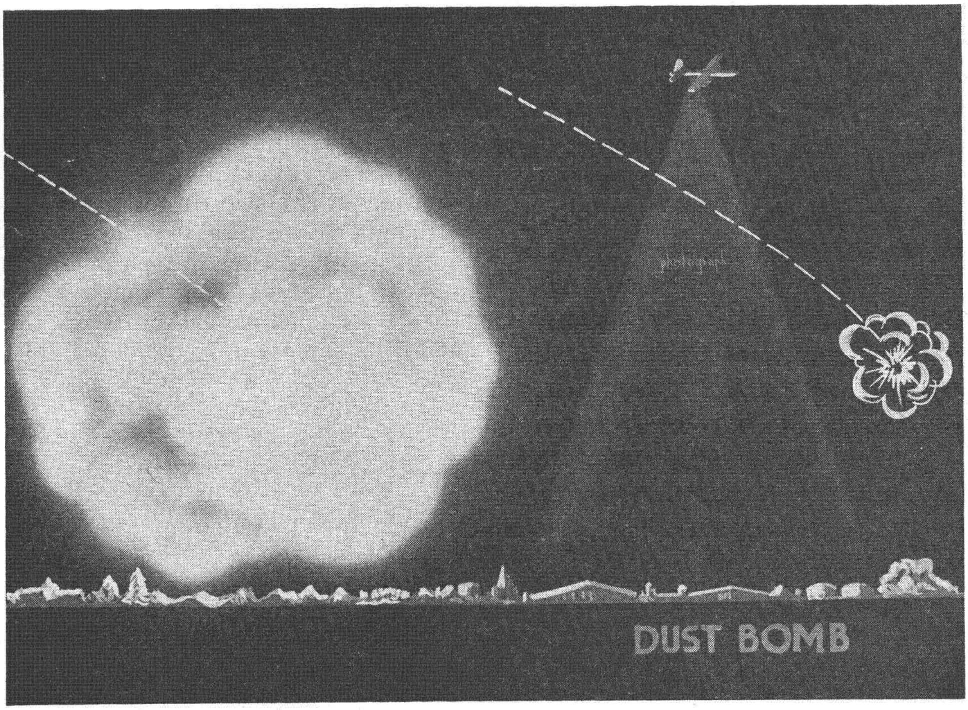

FIG. 17. "Dust" Bomb.

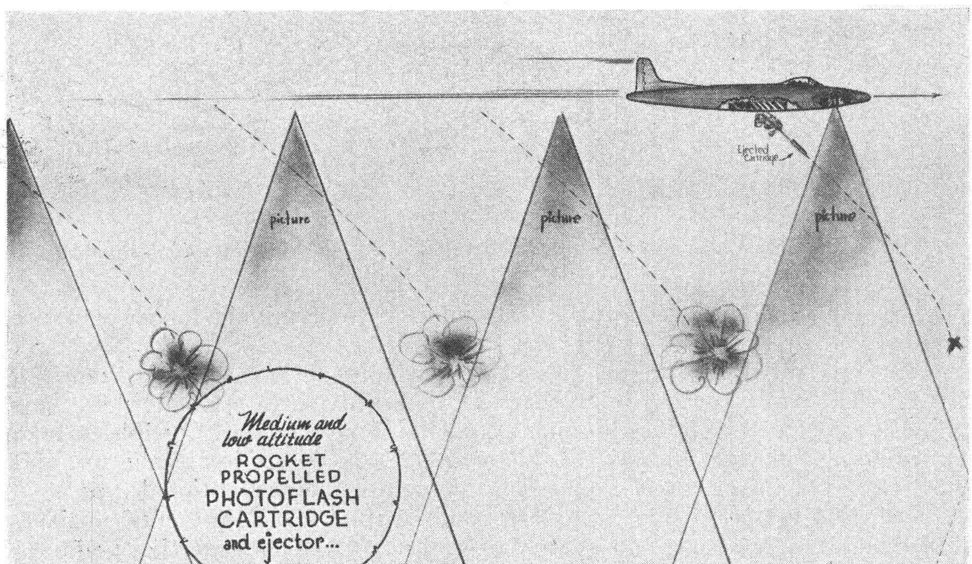

FIG. 18. Rocket-Propelled Photoflash Cartridges and Ejector.

explosion falls on a photocell which acts to start the motor, which pulls the film through for the next exposure. The film in such a system is always in motion, at high speed between exposures and at synchronized speed during the exposure. Satisfactory photographs have been taken with such small cartridges with as little as six ounces of flash powder at 2,000 feet.

Still another system of night photography involves a system of projecting an invisible infra-red strip of light on the ground and photographing this strip with the continuous strip camera. This projected beam is one-half degree wide and forty-five degrees long and is projected to form a strip at right angles to the line of flight. Promising photographs have been made with this equipment up to

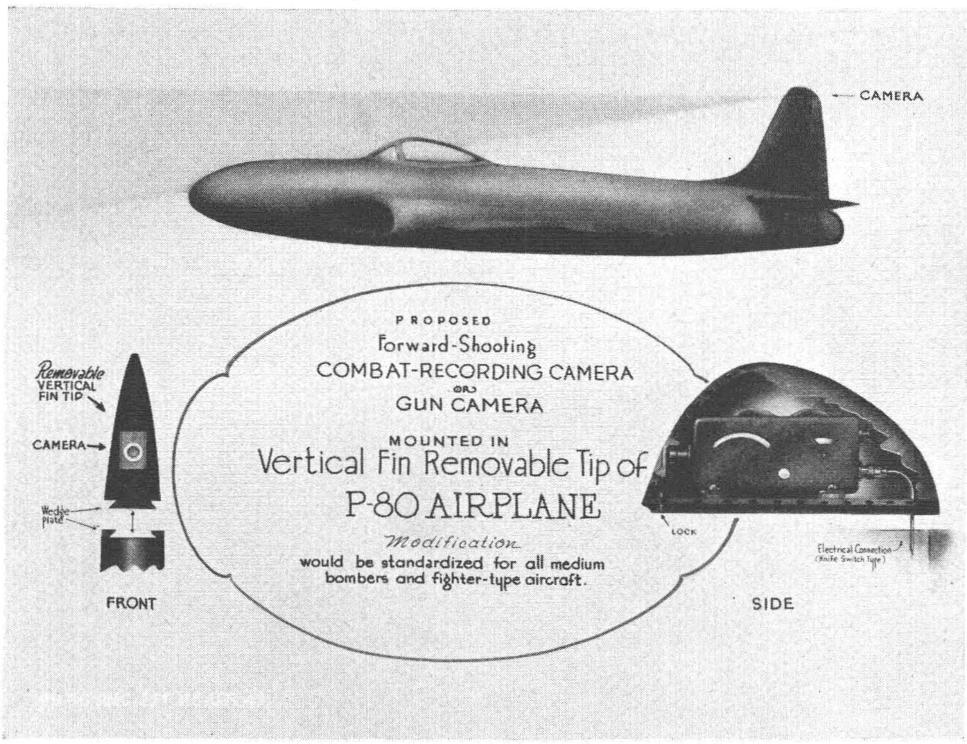

FIG. 19. Combat Recording Camera Installation in P-80 Airplane.

1,500 feet. This equipment was the result of a development during the war and shortly thereafter at Rochester University under the National Defense Research Committee.

Those of you who have seen gun camera photographs made during the last war realize the desirability of improving this type of photography. We are now developing a small combat recording camera designed for installation in a removable tip of the vertical fin of the P-80 airplane and other airplanes of this type. Figure 19 illustrates the installation of this camera, which we have named the "Skinny-Cine."

Figure 20 is included to illustrate one type of photography for which smaller cameras are being developed. This shows one of the reasons why German trains

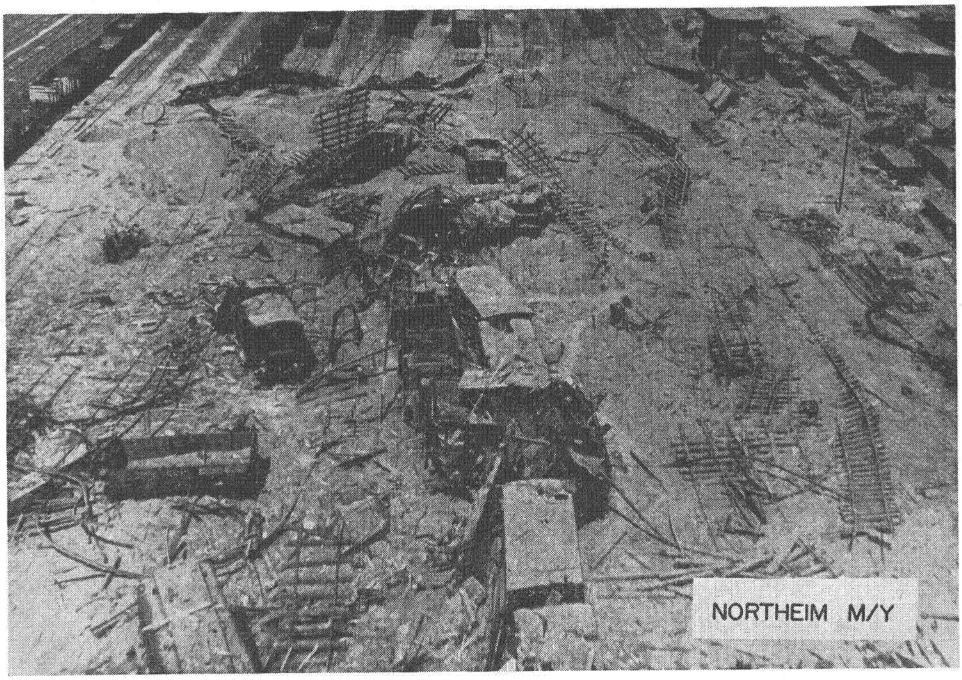

FIG. 20. Bomb-Damage Record.

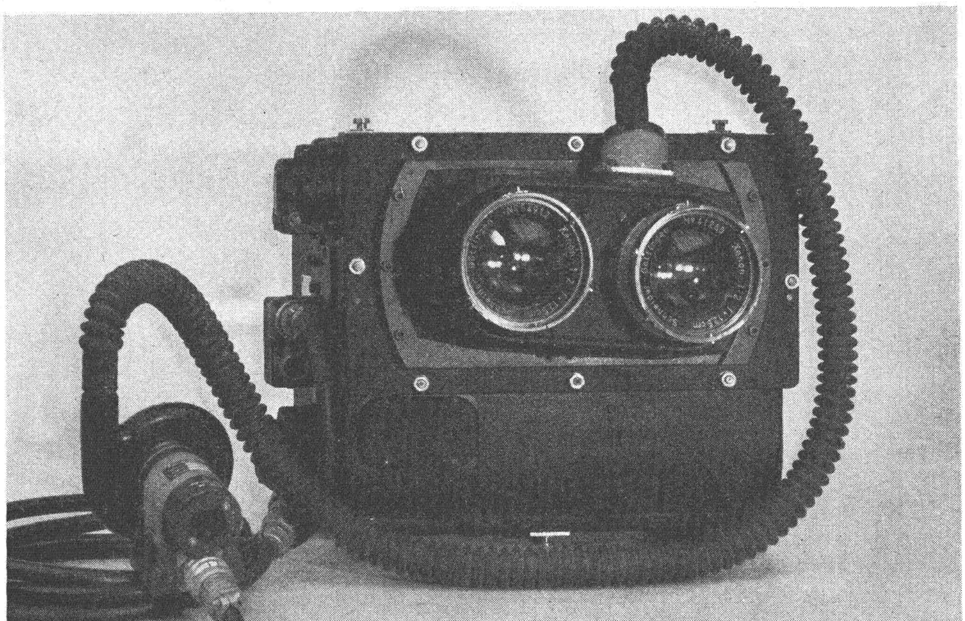

FIG. 21. Type S-7 Camera with Stereo Lens Cone.

were slightly behind schedule during the latter part of World War II. A new camera which is being developed for such photography as strike-attack is the Type P-1 70 mm. camera. This is a small camera making a maximum of five pictures per second using a focal plane shutter. An attempt has been made to incorporate component parts which are readily removed for maintenance.

An important development being emphasized at this time is in the field of strip cameras. The S-7A, the latest type of strip camera, has been declared standard equipment for tactical reconnaissance missions. The development of this equipment was started at Wright Field in 1939 as a result of a study made of the camera in general use for recording the results of horse racing. It was ready for use in the last war during the winter of 1943, but, unfortunately, its value was not fully appreciated in its early stages of development. Figure 21 shows the S-7 Camera with 5-inch f/2.0 stereo lens cone and a blower to insure a clear exposing slit; a product of the Chicago Aerial Survey Corp.

Figure 22 is a photograph of the strip camera complete with the scanning unit. The scanning unit is an optical device for synchronizing the film automatically with the movement of the image, across the focal plane. A grid arrangement with photoelectric cells in the focal plane of the device sets up beat frequencies which are fed through the amplifying unit to control the film winding system. A detailed explanation of this device is not considered to be within the scope of this paper.

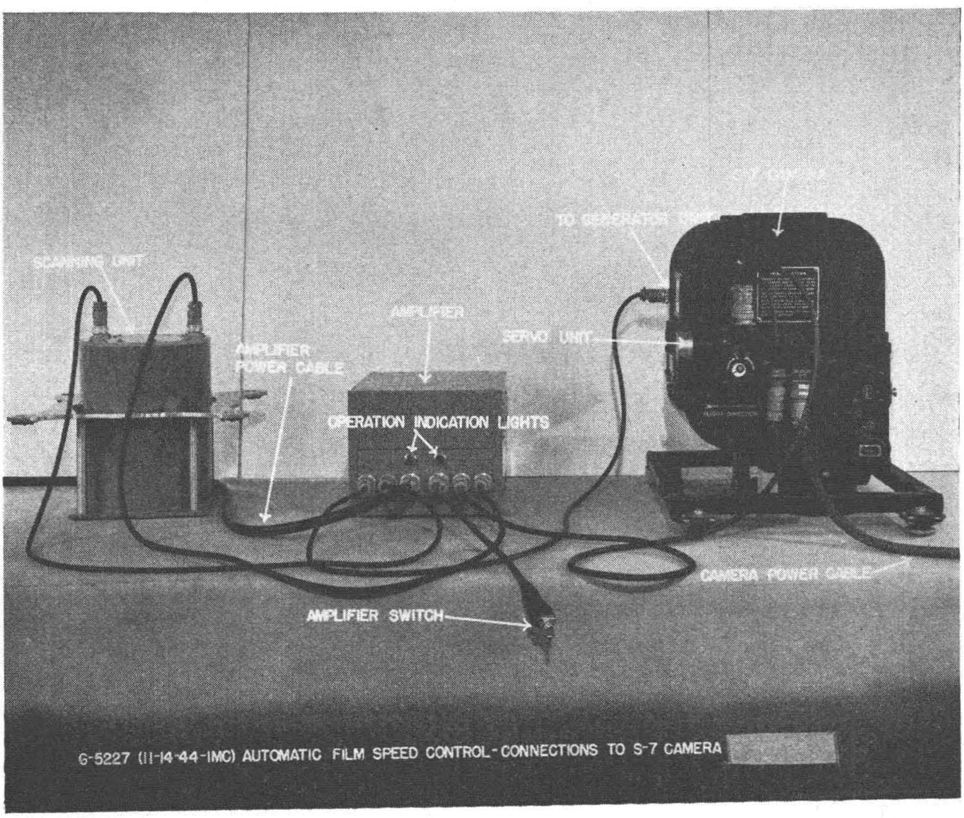

FIG. 22. Type S-7 Camera with Automatic Film Speed Control.

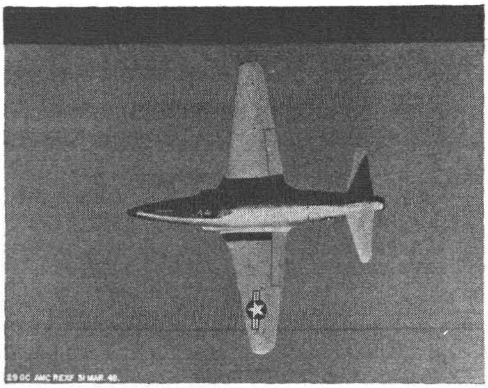

FIG. 23. Photograph Made at Speed of 1,000 Miles Per Hour.

The strip camera lends itself extremely well to photography from high speed airplanes and this is illustrated in Figure 23. This photograph was made of a P-80 airplane going south at 500 miles an hour at 1,000 feet altitude, from another P-80 airplane carrying the strip camera and going north at 500 miles an hour at 1,500 feet altitude, to give an effective speed of 1,000 miles an hour. The half-tone reproduction, of course, will not do justice to the definition contained in the original negative, but it is considered to be an extremely sharp photograph. A simple modification in the presently standard camera will make it possible to operate it at 3,000 miles-per-hour at 1,000 feet altitude

Figure 24 is included to illustrate the value of low-altitude strip photography to an interpreter. In this case, a factory near Columbus, Ohio, was photographed which shows diesel engine parts laid out along the railroad. A good interpreter can tell from such a photograph many things, including the type of engine being produced in the factory. This picture was taken from a P-38 airplane at 1,000 feet and 360 miles-per-hour.

FIG. 24. Outdoor Storage of Manufactured Machine Parts.

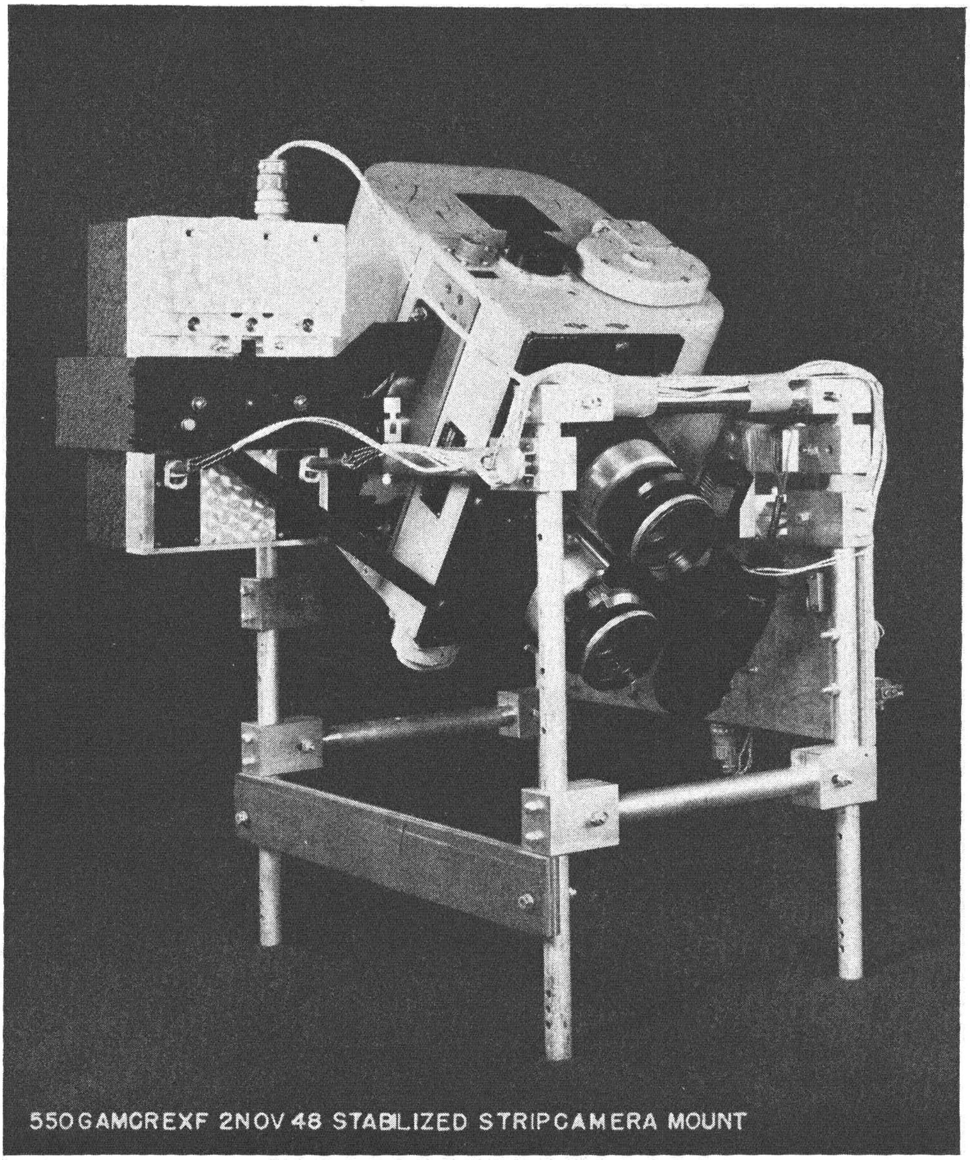

FIG. 25. Stabilized Strip Camera Mount.

Flight tests have indicated that strip photography will also be extremely useful in northern latitudes where light is very poor most of the year. Such photography shows the interpreter the types of airplanes and ground installations, in detail.

One of the serious problems which faced the engineers on strip cameras in the early stages of strip camera development was that of stabilization. It is obvious what effect roll and vibration have on the strip photograph. This problem is currently being solved by the development of stabilized mounts, and Figure 25 is included to show a strip camera, with 20-inch lenses stabilized, as it is installed in the P-80 airplane. In this case, the camera is held at an angle of 40 degrees from the horizon and is maintained in this attitude by the stabilizing mount.

There are many variations to the strip camera idea, one of which is that of a stereoscopic camera using two slits instead of a single slit. In this case, only one lens is used, which makes such a design suitable for use with extremely large lenses.

The increasing size of aerial cameras and the greatly increasing rate at which film will be used makes the problem of processing equipment more acutely important. Figure 26 shows a continuous processing machine recently delivered to Wright Field from the manufacturer. This is the Type A-7 Film Developer and D-1 Printer Unit developed to meet anticipated needs for quantity production printing and development at base or advance base photographic laboratories. The two units form a train which will turn out 9×18-inch or 9×9-inch prints at the rate of 30 feet per minute or develop film at speeds up to 20 feet per minute. This machine was made by Technical Service, Inc.

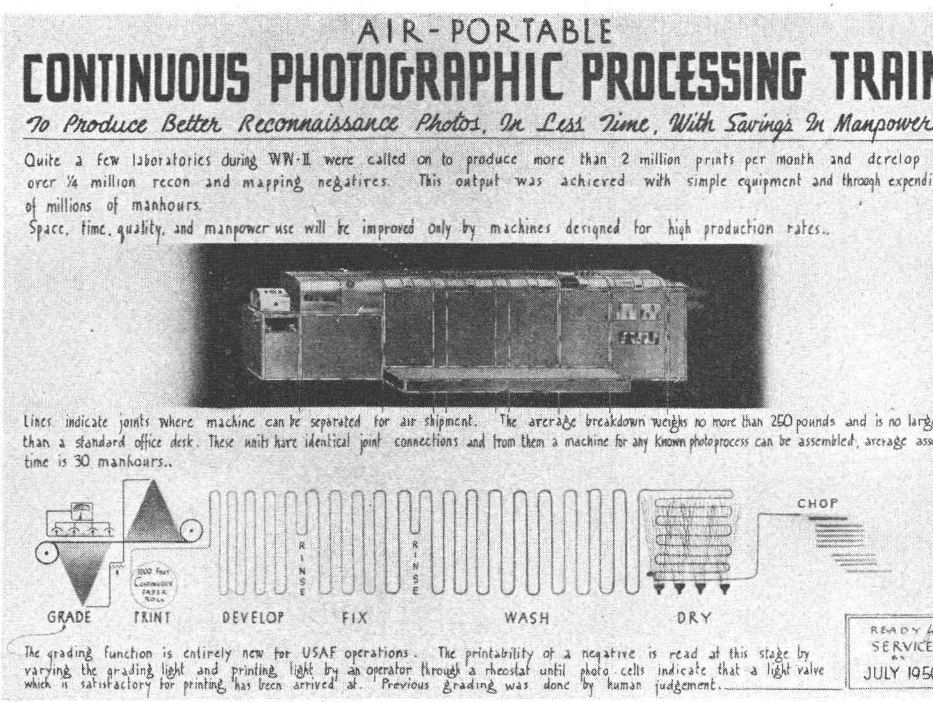

FIG. 26. Continuous Photographic Processing Train.

This rate is three times as great as achieved by any previous machine. Furthermore, print resolution will be higher, due to better contact and better lighting. For the first time in a semi-automatic printer, negative dodging by individual light control and photocell exposure control have been provided. Processing has been made more uniform by the use of temperature control units adequate to maintain a temperature to within 1 degree at any desired level between 65 degrees and 80 degrees Fahrenheit.

The developing machine will process waterproof paper, black-and-white aerial film, or duplicate film. The dryer unit of the train has infra-red strips to provide heat, and air is recirculated through the dryer cabinet by a blower. Film shrinkage in this type of dryer is sufficiently low to permit the handling of mapping negatives. An idea of its efficiency can be gained from the fact that with 8,000 watts input as compared to 5,400 watts input for the A-10A (best previous USAF film dryer) and with approximately twice the cabinet volume of the A-10A dryer, drying rates under the same over-all conditions are more than three times as great as those of the A-10A.

Behind the dryer an automatic photocell actuated print chopper is installed. It may be by-passed for film or continuous strip prints, and the material taken up on standard camera spools.

The machine has been designed for air transport and breaksdown into sections, the largest of which is 6×5×2 feet. The total weight of the machine packed for shipment is 5,100 pounds, and the machine itself weighs 3,800 pounds. Total assembled dimensions of the train are 30×2×5 feet. It may be easily transported and assembled for use. Upon its arrival at Wright Field in a

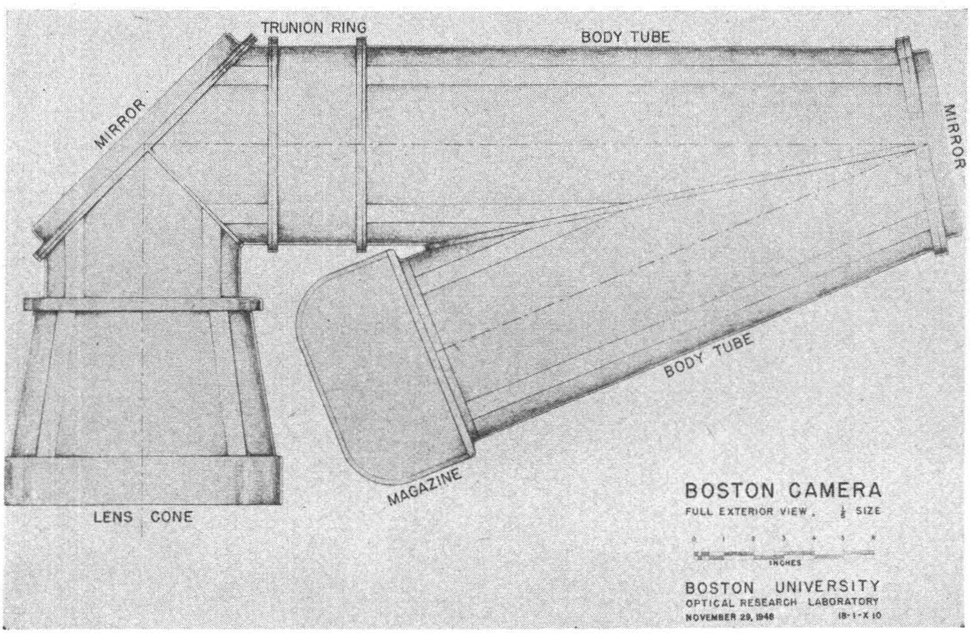

FIG. 27. Boston Camera, 240-Inch Focal Length.

Type C-82 aircraft, it was unloaded at Patterson Field, brought to Building 16 at Wright Field, and put into operation in 5½ hours by five enlisted men, the project engineer, and a representative of the manufacturer who built the machine. Only the latter two had ever seen the machine before.

As I mentioned previously, the work which originated with Dr. Baker and a small group at Harvard College Observatory, was finally turned over, after the war, to be carried on by a group headed by Dr. Duncan E. Macdonald at Boston University, called the Boston University Optical Research Laboratory. It would take a paper much longer than this for me to describe all of the many projects underway at our Boston Laboratory. One of the most important ones is the 240-inch camera.

Figure 27 is included to show a schematic diagram of this camera. The lens for this camera is 240 inches in focal length having a front element 32 inches in diameter. One of the first and most difficult problems encountered by this group was the procurement of optical glass of sufficient quality for this lens. This problem has now been solved and construction of the lens and camera are well under-

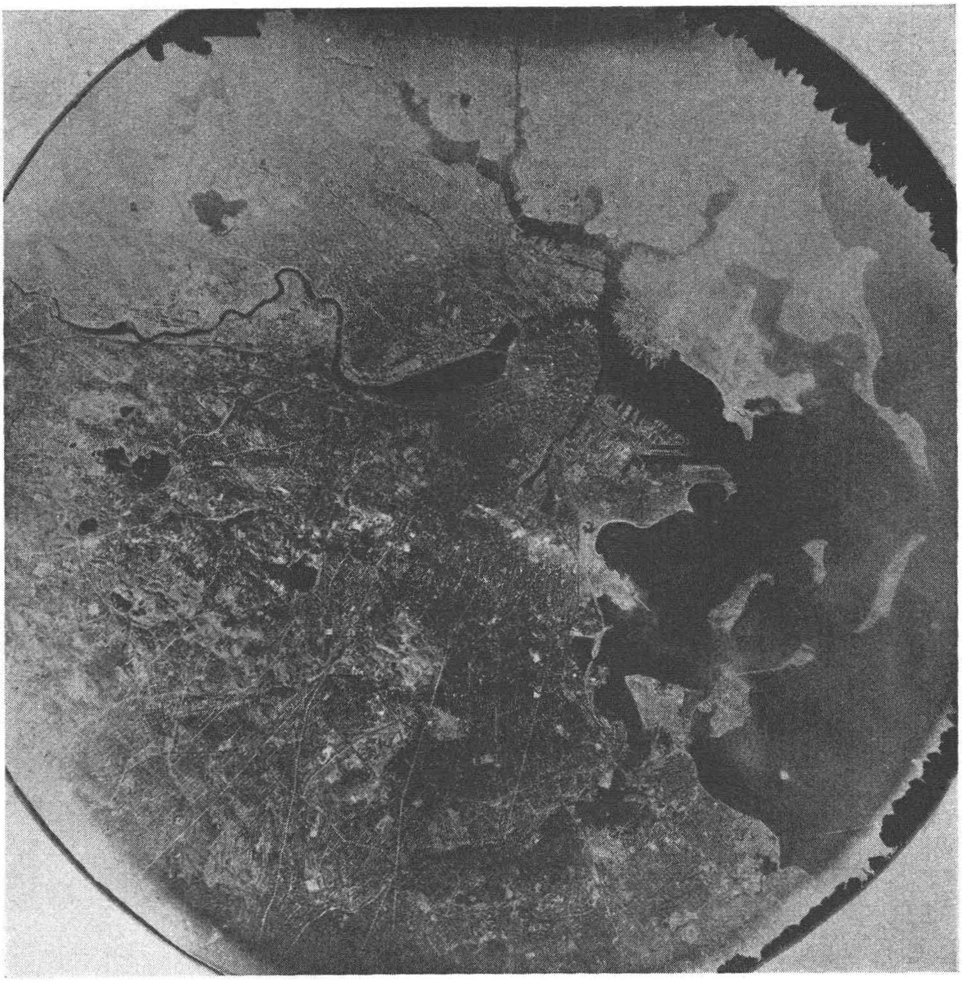

FIG. 28. Photograph Made with the 6-Inch F/2.8 Spherical Shell Camera.

way. The camera proper takes two rolls of film, each 400 feet long and 40 inches wide, to make stereoscopic photographs through the single lens. This probably sounds as fantastic to you now as did our 100-inch camera back in 1940, but we believe that eight or ten years from now such cameras as this will be in use for specialized purposes. This camera is being built purely for research purposes, and experience with it will no doubt tell us many things that we must know about high altitude aerial photography.

I will mention one other development currently in progress at the Optical Research Laboratory, which is the spherical shell camera. This camera is unique in that the negative is made on a spherical glass shell, the sensitized surface being on the inside. The lens is spherical in form and is 6-inch focal length and has a speed of f/3.5. This scheme makes possible superior photographs and results in uniform sharpness and exposure over the entire sensitized surface. Figure 28 is a print from one of the spherical shell negatives. It is highly possible that the exposure mechanism for such a camera can be made so that it will be suitable for mapping purposes, as well as for general reconnaissance.