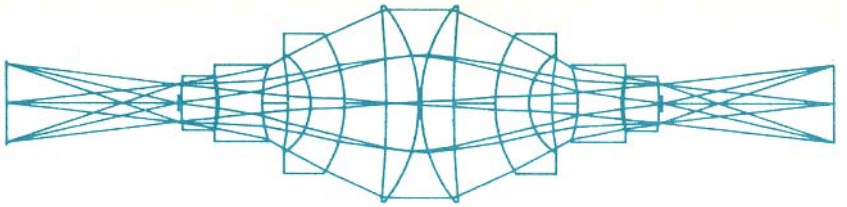

Optics in the early forties at the Harvard College Observatory

By James G. Baker

The author appreciates the opportunity to recall a few of the development efforts having to do with optical instrumentation during World War II at the Harvard College Observatory nearly 47 years ago. Except for the National Defense Research Committee (NDRC) Section 16.1 Summary Technical Volume (Columbia University Press, 1946), nothing has been published formally concerning quite substantial efforts at the Cambridge, Mass., observatory. Presentations, accompanied by slides and minor exhibits, have been made in recent years at local meetings, including the New England Local Section of OSA, the Amateur Telescope Makers of Boston, and the American Astronomical Society, Division on History.

The project in the period from 1941 through 1945, known as the Observatory Optical Project (OOP), grew to a peak and then faded from sight owing to its orientation in optical development as part of a wartime NDRC effort. Some of the concepts arising from these intensive efforts on the part of many individuals, some closely associated with the observatory, carried over to join the expansion of post-war research in a variety of ways.

The first official day of work on the embryonic project was Aug. 4, 1941. However, there had been preceding stages of planning derived from similar interests in optical astronomy. The author, as a graduate student, had been engaged earlier in work with telescopes, some of which was published in later years. The author was also privileged in 1940 to teach a summer school course in optics and then again in the spring of 1941 to teach the theory of optical design to senior and graduate students in mathematics. Finally, the author visited a number of observatories in Germany in 1938 and also visited the Zeiss and Schott Companies in Jena.

Space prohibits any attempt here to sort out the instrumental projects found to be worthwhile in the period from 1941–45. In comparison to the intense R&D efforts in today's world, the extent of R&D in industry in the United States and within colleges and a few institutions such as the National Bureau of Standards was feeble indeed. While much can be written on the situation at large in 1941, it suffices here to review briefly the instrumental setup at Harvard Observatory at the time.

Early telescopes

The largest telescope in the east was the 61-inch Wyeth Reflector at the Oak Ridge Station of Harvard Observatory, located in the town of Harvard, Mass. This telescope was in use for photoelectric photometry, for direct photography at the Newtonian focus, and to a limited extent for spectra. In addition, the 16-inch Metcalf photographic doublet had been in operation at the new site for five years or so. Several smaller instruments that had been mounted

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on Observatory Hill in Cambridge already by 1941 had been transferred to the Oak Ridge Station. These included the 12-inch Metcalf photographic telescope, the Roe small refractor, and also from earlier years the 24-inch Common reflector.

In the years 1938–1941, a principal activity had been the initiation and completion in observatory shops of a 24–31 inch Schmidt telescope known as the Jewett, which began to produce good results early in the forties. However, the decrease in staff caused by the onset of the war and the redirection of effort of those remaining prevented the full ripening of instrumentation activities begun in the late 1930s.

One realizes now—in the proliferation of computing technologies and of supporting equipment of every description, not to mention large-scale government support—how very handicapped the research staffs of those days really were. Calculations that took many months on the desk-type machines of the 1940s—Marchants, Monroes, and Friedéns—can now be repeated in seconds to greatly improved standards of automatic procedures and precision. In the shops at Harvard, the various metalworking machines were those of even pre-World War I design, in all ways controlled by operators. Elsewhere, turret lathes were widely in use, but in the Observatory shop there were no modern machines even of that time.

The warclouds that were gathering for the United States in 1940 from the mighty European conflict became truly threatening in early 1941, many months before Pearl Harbor. Already in January 1941, as a result of discussions between Director H. Shapley of the Observatory and C.E.K. Mees of Eastman Kodak, the author spent a few weeks at the Wright Field Photographic Laboratory in Dayton, Ohio, and became familiar with some of the problems in aerial photography. On return to Harvard, the author set about preparations for optical laboratory facilities to be financed by the Army prior to the carefully planned organization of American science and technology under the NDRC. Shapley was fully supportive of this rather novel undertaking in optics at the observatory, even though no immediate astronomical purpose seemed to be served.

Design work begins

In the spring of 1941, the author began designing several of the optical systems already proposed to the Army Air Corps. These included two versions of a spherically symmetrical camera lens of 4-inches focal length and f/2.8 speed. One of these was mounted in an encompassing spherical ball or metal shell on polar pivots, such that a rotational sweep covered an angle of 120° diameter on a concave spherical image field, curved accurately about the axis of rotation. Figure 1 shows a view of the camera after completion of the first aerial testing.

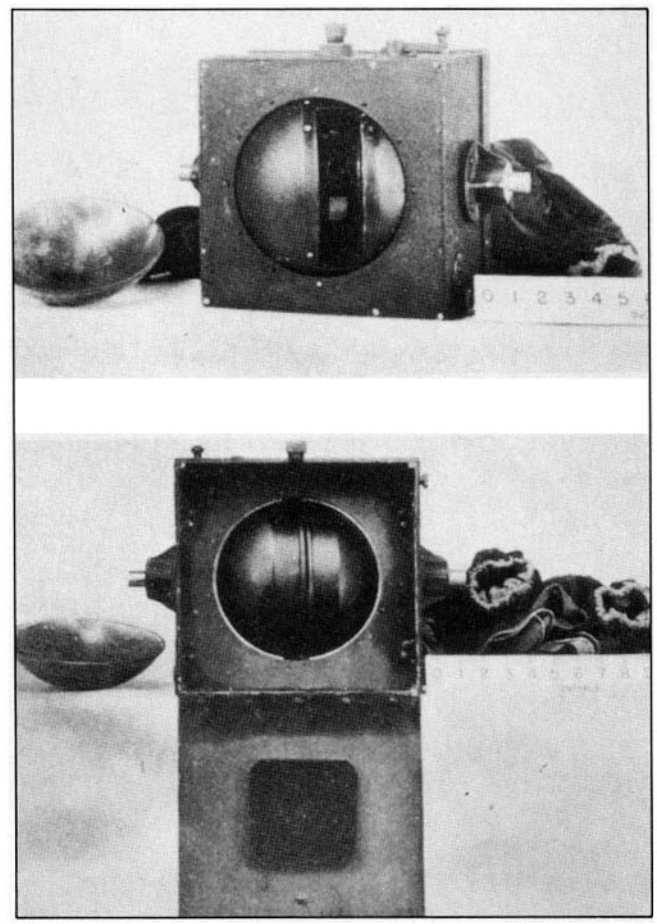

FIGURE 1. Front and rear views of wide-angle camera with f/2.8 spherical lens.

Each of the two prototype objectives consisted of four elements, all curved surfaces concentric, with the several elements made of readily available Bausch & Lomb optical glasses of light crown and heavy flint. The lenses yielded essentially diffraction quality images within the assigned spectral band-width. Designers and students of optical history will recognize that the forerunner of this kind of spherical lens system appeared nearly a century earlier in the form of a water-filled thick glass spherical shell by Sutton in 1859. For the Harvard lenses in 1942, thin glass shells were made up in the optical shop to an inside concave radius equal to the focal length. These shells were coated by Eastman Kodak with an aerial high-speed emulsion for flight-testing, also shown in Fig. 1.

Included in the initial proposal were the design and con-

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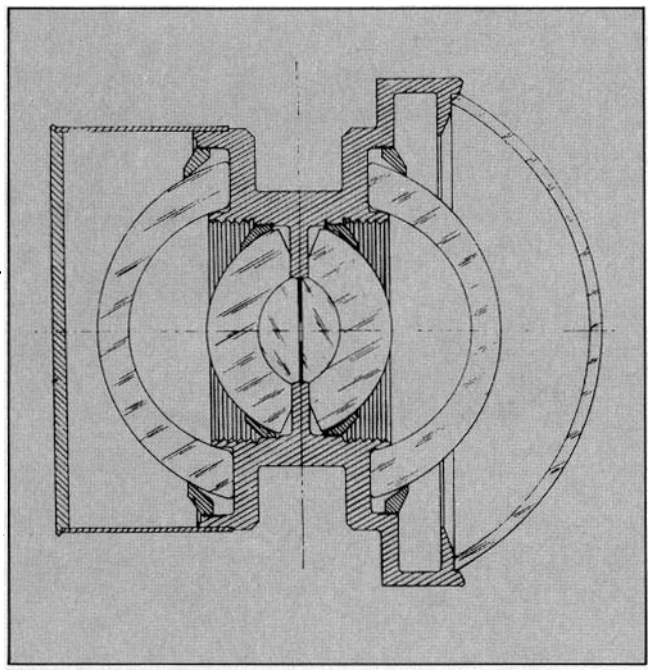

FIGURE 2. Projection lens for spherically curved negatives.

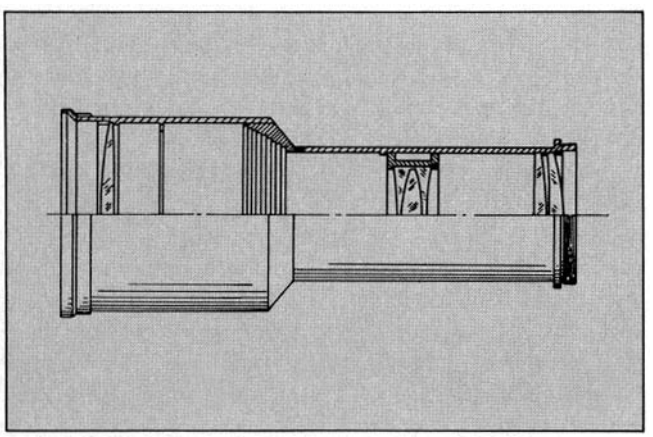

FIGURE 3. The 36-inch f/8 fluorite apochromatic aerial lens for 9 × 9-inch format.

struction of two rectifying lens systems for projecting the 120° spherically curved negatives onto 40 × 40-inch distortion-free flat photographic positives. D. Grey, a 1941 Harvard graduate, joined the project in the early summer of 1941 and worked into the fall and winter on the design of the various lens systems. Indeed, Grey invented and carried out the design for the 120° rectifying wide-angle projection lenses, two of which were made. Figure 2 shows the lens construction and glass shell negative.

The proposal to the Army Air Corps in the spring of 1941 covered not only these two spherically symmetrical wide-angle systems (the second for the near ir), but also two forms of large telephoto lenses that in aerial photography were referred to as 40-inch f/5s. These telephoto lenses were appreciably shorter than the 40-inch EFL and, in fact, were approximately 32 inches long to the image plane. As a further part of the same proposal, there was also a still larger telephoto lens, a 60-inch f/6.0 U-shape camera, suitable for use with a Fairchild K-22 camera body, focal plane shutter, and standard 9 × 9-inch magazines.

WWII means longer hours

America's participation in the war served mainly to intensify our resolve and to lengthen our hours. The first prototype of the wide angle camera shown in Fig. 1 was delivered to Wright Field in June 1942. The first 40-inch f/5.0 telephoto lens ready for use with the K-22 body was delivered that October. The author went along as photographer on the experimental flights on both occasions. On the first, the wide-angle camera was used to photograph most of Dayton, Ohio, from low and medium altitudes through an open port in the floor of the fuselage of a B-24 bomber. For the second mission, focusing runs were made from altitudes of 10,000 and 20,000 feet from a B-17 over Cincinnati.

Based on encouraging results, the observatory project was expanded and aided with additional funding, and by 1943 was incorporated into the activities of the NDRC. After that, professional administrative help from above did much to facilitate further efforts. Among these, we were privileged to be the first to use the fluorite crystals developed for NDRC by D. Stockbarger of M.I.T. Our first test objective, necessarily only 2 inches in diameter, was made in the form of a cemented triplet refractor with the fluorite element in the middle. The quality of the performance over the visual spectrum was a treat to our astronomical eyes.

In the later period of the project, we designed and constructed two forms of fully apochromatic flat-field photographic cameras, which in later years were effectively used

for solar eclipse observations. Basically, the optical designs were closely related to Cooke triplets but actually employed six elements, only one of which was fluorite. Figure 3 shows a cut-away of this f/8 objective.

Improving the telephoto lens

The greatest single effort of the Observatory Optical Project was centered around the 40-inch f/5 telephoto lens. The early prototypes have been mentioned above, but in the time period 1943–44, considerable work was devoted to optical and mechanical improvements of this compact system. Among these were modular design and assembly, a remote-controlled iris diaphragm, a change-over from aluminum to steel for the barrel, and a temperature-controlled environment for the elements. Above all, the later systems were equipped with automatic focusing in compensation for changes in ground distance and air density. Automatic focusing at this early time was accomplished by concepts and designs contributed by C. Avila, now retired president and chairman of the board of the Boston Edison Co. Figure 4 shows a cut-away view of the internal construction of this lens.

The final prototype, ready for aerial use, according to collimator and test chamber results produced adequate focus compensation from 3000–40,000 feet. Figure 5 shows the laboratory testing results achieved in 1944.

In 1944 we designed and constructed prototypes for a 36-inch f/8 telephoto objective, covering a 9 × 18-inch format on roll film. This design was constrained by a requirement that the objective be interchangeable with the standard 24-inch f/6.0 objective manufactured both by Eastman Kodak and Bausch & Lomb, in the same mount and between-the-lens shutter. Figure 6 shows a cross-section of the optical design.

These telephoto lenses were designed for yellow and red filtered aerial photography for a 20-inch diagonal to the picture area specifically for a 9 × 18-inch format. The

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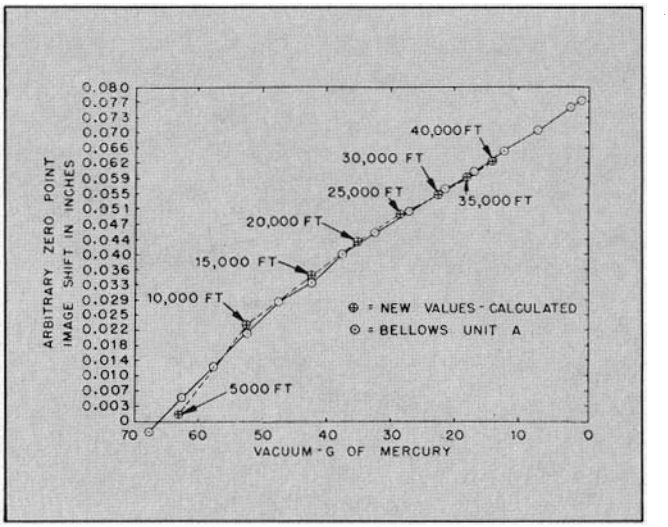

FIGURE 4. Cut-away view of the 40-inch f/5.0 telephoto.

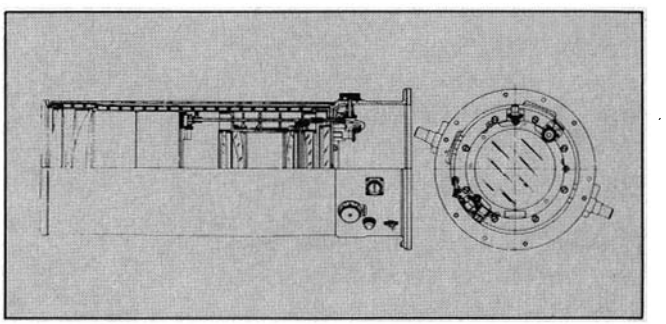

FIGURE 5. Observed and calculated bellows movement.

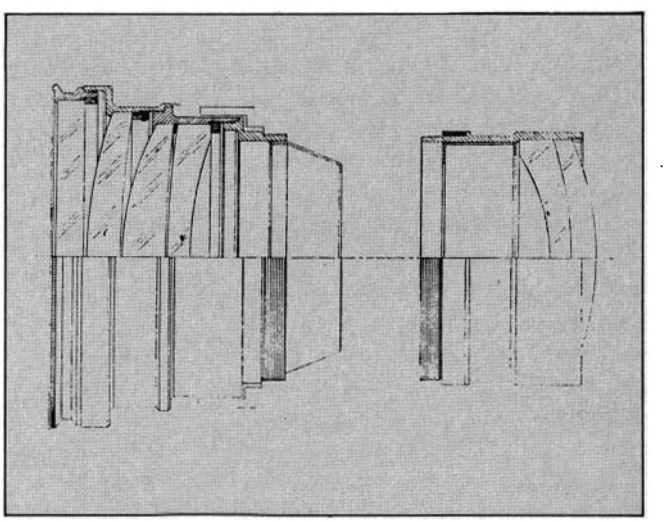

FIGURE 6. The 36-inch f/8.0 telephoto for 9 × 18-inch format.

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But toward the fall of 1945, as in many other laboratories set up purely for wartime R&D, rearrangements were quickly made, staff dismissed, and equipment sent to specified storage places.

production lenses were required to meet an AWAR (area weighted averaged resolution) of about 50 line-pairs per millimeter over the full field on a Super-XX fast aerial emulsion of that day.

In 1943 our expanded project had moved away from the Observatory to far larger quarters on the first floor of the Harvard Deposit Library Building on Western Avenue, Brighton. In 1945 a new brick building of two stories was erected for the project, contiguous to the library building. By this time, our staff had grown to perhaps 30 individuals. Upon the rapid completion of the new building, further staff and equipment were added, whereby the optical program became broadened into other types of instrumental applications.

But toward the fall of 1945, as in many other laboratories set up purely for wartime R&D, rearrangements were quickly made, staff dismissed, and equipment sent to specified storage places. Even the new brick building was razed. Some of the technical staff and much of the equipment went to nearby Boston University to become, in time, a new and enlarged laboratory for the Air Force.

Acknowledgments

The author would like to express his continued appreciation for the dedicated efforts of so many friends and associates of the wartime project. In particular, the author would like to thank again the Amateur Telescope Makers of Boston for their substantial contributions to the entire list of projects in the wartime laboratory. The author would also like to acknowledge with much appreciation the support given by the Harvard professional staff and by the many members of the Wright Field Photographic Laboratory, including especially Amrom Katz, who maintained close interest and support for our efforts. Only a very few of the participants are left now, but those of us who are still around can reflect with satisfaction on the intensive optical enterprises and group activities of the optical laboratory at Harvard College Observatory from 1941 through 1945.

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