The Nine-Lens Camera of the Coast & Geodetic Survey

In 1934 multiple lenses were needed to cover the field of view afforded today by the superwide-angle aerial cameras

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When that memorable group of photogrammetrists gathered in 1934 at the home of Lt. Oliver Scott Reading (Figure 1) to consider the formation of the American Society of Photogrammetry, Reading had also an important technical matter on his mind: he was heavily absorbed in the completion of the design of an innovative nine-lens aerial camera. Later that year Fairchild Camera Corp. was awarded a contract for $24,350 to construct that camera. Among those who assisted Reading were Thomas W. McKinley, mechanical engineer, and Reynold E. Ask, optical engineer.

At that time a wide-angle aerial camera lens had an angular field of view of only about 63 degrees. A much wider coverage was needed for mapping in order to minimize the number of photographs required and also the density of ground control points. To meet this requirement multiple-lens cameras were produced by the Fairchild company for the U.S. Army Air Services: three-lens, four-lens, five-lens, and two five-lenses cameras in tandem (one turned 45°) (Bagley, 1941).

The following is a chronology of the development of the Coast & Geodetic Survey (C&GS) nine-lens system including the camera, a transforming printer for producing a 34-inch square composite photograph from the nine sections imaged on the 23-inch wide aerial film, a rectifying camera for removing the effect of accidental aerial tilt, and two stereoscopic plotters for compiling topographic maps (Smith, 1981):

1919—The Coast & Geodetic Survey began using aerial photographs (mainly multi-lens) for mapping ocean shorelines and for aeronautical charting.
1927—The three-lens camera was deemed not sufficiently applicable for the C&GS.
1928—Lt. Reading was listed as an aerial photographer using a Fairchild T-2A four-lens camera.
1933—Design of the nine-lens camera began under the direction of Lt. Reading.
1934—Designs were submitted for bidding and a contract was concluded.
1935/36—The camera was received.
1936—Field tests were completed and the camera was placed in operation.
1943—An aircraft crash badly damaged the camera.
1945—Fairchild rebuilt the camera and it was put back into service.
1949—Two stereoscopic (Reading) plotters were put into service (made by a different firm).
1963—The nine-lens camera system was retired from service and presented to the Smithsonian Institution.

The C&GS nine-lens camera was of unusual design and was large and heavy (Figure 2). Camera data were as follows (Swanson, 1949):

Focal length—8.24 inches; field of view—130° by 130° square.
Net weight—306 pounds; gross weight 750 pounds.
Size of camera—29 inches wide, 27 inches fore and aft, and 31 inches high.
Size of film—23 inches wide by 200 feet long (plus leader) for 100 exposures.
Size of composite photograph—35.4 inches square,
Coverage at 1:10,000 scale—5.6 miles square when taken from an altitude of 6,875 feet. (Ordinarily, the camera was operated at either this scale or 1:20,000.)
Tilt of oblique views—38°.

The nine-lens camera embodied several desirable features which distinguish it from other multi-lens cameras of that time. One was that all of the multiple views were imaged on a single piece of film instead of having a separate roll of film for each view. The separate printed views of contemporary cameras were rectified, and fastened with tape or paste to a single cardboard templet for viewing and compiling. For the nine-lens camera, however, the transformed print was essentially a single vertical photograph 34 inches square with relatively unnoticeable butt junctions between the separate views.

To achieve this single composite view, all the lenses were mounted in the same plane, and the oblique views were reflected into their respective lenses with mirrors attached on the outside of the lens plane (Figure 3). The lens plane (camera body), the mirror supporting cone, the mirrors, stud bolts, nuts, and screws were all forged from the same ingot of stainless steel whose composition assured a favorable coefficient of thermal deformation—the entire assembly expanded and contracted as a single unit. This scheme proved to be completely successful: as indicated by repeated camera calibrations, the flatness of the mirrors remained essentially unchanged for six or more months of photography within one or two fringes of light as compared with an optical flat glass.

Each mirror was about $^{5}/_{16}$-inch thick, about 10-inches long, $4^{1}/_{2}$-inches wide at one end, and $5^{1}/_{2}$- at the other. Although the camera was carried in a

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FIG. 1. O. S. Reading

hoisted position at the ceiling of the aircraft cabin, it was lowered during photography so that the mirror cone extended into the slipstream. This had the effect of eroding the mirror surfaces, especially on the leading edge. Consequently, from one to three mirrors were exchanged at the end of each season's operation. The mirrors were machined as flat as possible, polished, an evaporated reflective metallic coating was applied, and finally a protective transparent quartz coating was added. As a mirror was seldom sufficiently flat, its mounting provided a means for further flattening. Each mirror was fastened to the cone with nine stud bolts having 80 threads per inch, enabling one to push or pull on the mirror very slightly while observing the pattern of interference fringes. Thus, the mirrors were flattened to ten fringes or less over the entire working area.

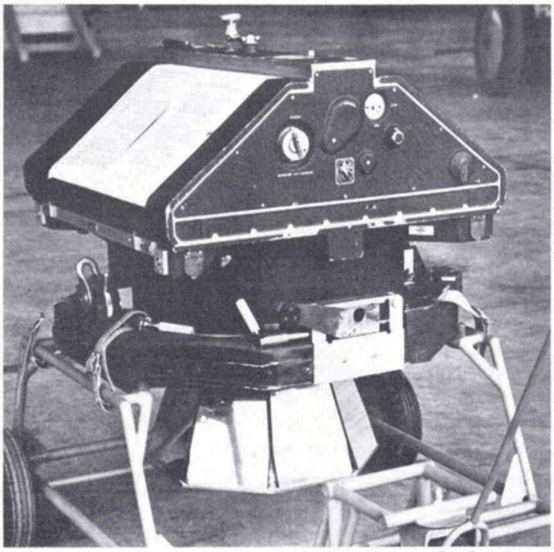

FIG. 2. The nine-lens aerial camera ready for being hoisted into the aircraft for a season of mapping photography.

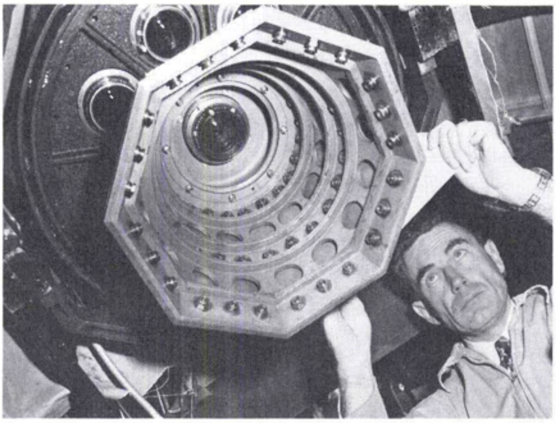

FIG. 3. The mirror cone and lenses of the nine-lens aerial camera suspended from the ceiling of the aircraft cabin. Photographer Byron W. Hale is shown washing the mirrors in preparation for the next day's operation.

Another feature was that the nine lenses comprised a matched set (as to focal length and distortion) of Ross Xpres F-4 objectives produced for aerial photography. As Flight altitudes were chosen so that the scale of the center section of the photograph had a scale equal to the map to be compiled, the image resolution was remarkably sharp.

A transforming printer was also built by Fairchild under the initial camera contract. The printer had adjustments convenient to the photographer for minimizing the junction discrepancies and for applying camera adjustment parameters. Each view was printed, one at a time, onto the same sheet of photographic paper, and at the same scale as the center section. If the photographs were to be compiled with a plotter, the photographic paper was first cemented to an aluminum sheet (about 0.025 inch thick) to prevent differential paper distortion.

A special field calibration site for the nine-lens camera was established in 1947 near McClure, Ohio. The area was photographed at the beginning and end of each season for determining constant corrections to the several parameters of the transforming printer as a consequence of the annual change of mirrors. The 5-mile square area, nearly flat, showed 80 permanent targets whose positions and elevations had been determined using precise geodetic techniques. The area constituted one complete photograph at 1:10,000 scale.

Shoreline surveys were usually compiled by graphic transfer, using stereoscopes, and with radial-line plotting. The stereoscopic plotters were used for compiling topographic maps based on radial-line plotting as an aerotriangulation technique.

A source of annoyance of the nine-lens camera system for topographic mapping was the small image mismatches along the junctions of the nine views, attributed to uneven film deformation. Aerial film was not as stable in the 1930s as today, and the deformation was noticeably different in the longitudinal and lateral directions of the film. The difficulty was exacerbated by the geometric fact that the two common edges of each oblique junction were imaged 90° apart on the film before being inverted and transposed to the opposite side of the center section during transformation printing, thus always maximizing the magnitude of the mismatch.

The nine-lens camera system served its intended purpose admirably with regard to accuracy, economics, and map production. As an example, 1,200 square miles in the northern part of Chesapeake Bay were photographed in 1937 for 1:10,000 scale planimetric coastal mapping using 380 photographs, with considerably improved speed and economy over previous methods. Also, 323 $7^1/_2$-minute topographic quadrangles were compiled at 1:20,000 scale with a 10-foot contour interval as a part of the war mapping program in the mid 1940s. In more recent years the camera was used principally for coastal mapping in Alaska. Nine-lens photographs were applied successfully for airport mapping inasmuch as a single photograph often covered a complete area, and, where the ground was relatively flat, a simple rectification produced essentially an orthophoto.

After 27 years of valuable service, the nine-lens camera system was retired from operation in 1963, a victim of the development by private manufacturers of super wide-angle cameras and appropriate stereoscopic plotting instruments. The four elements of the system are now the property of the Smithsonian Institution in Washington, D.C.

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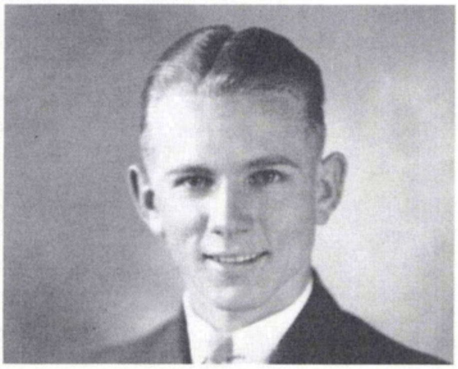

Eldon D. Sewell as a college student in 1934.

Vance A. Rogers in 1934.

Harold A. Shaber testing oblique functions of the first operational K-3B S/N 003 from the Fairchild Plant in Jamaica, NY.

John Sharp was a swimming counselor at Bantom Lake, CT on July 29, 1934.