ment field required to give results which are typical of the material being studied and the filtering characteristics of the air space separating the spectrograph and reflectance surface.

REFERENCES CITED

(1) Evans, Ralph M. *An Introduction to Color.* New York, 1948.
(2) Olson, Charles E. and Good, Ralph E. "Seasonal Changes in Light Reflectance from Forest Vegetation." PHOTOGRAMMETRIC ENGINEERING, vol. xxviii No. 1, March 1962.
(3) Steen, W. W. and Little, J. C. "A New Portable Reflectance Spectrophotometer for the Selection of Film and Filters for Aerial Photography." PHOTOGRAMMETRIC ENGINEERING. vol. xxv. No. 4, September 1959, pp. 615–618.

Acknowledgements: The author wishes to express his sincere gratitude to Prof. Donald J. Belcher, Prof. Taylor D. Lewis and Dr. Floyd O. Slate for serving as his special committee and for their assistance and criticism during the research program. The advice given by Prof. Carl W. Gartlein and Dr. Gale C. Sprague of the I.G.Y. Aurora Data Center is deeply appreciated.

Biography of a C-4 *

C. M. COTTRELL and MILTON GLICKEN,
Fairchild Aerial Surveys,†

ABSTRACT: *In 1934 a C-4 Stereoplanigraph was imported into the United States by Fairchild Aerial Surveys. Until 1945 it was the only Universal Plotter in the country and is still the only C-4. Despite rapid technological advances in mapping, the instrument is still earning money for its original owners. The history of this unique instrument is the subject of this paper.*

THIS is not a very technical paper. Rather, it is the history of a particular stereo plotting instrument—how it was developed, how it performed some assignments that could not otherwise be performed, and what its recent history has been. Nor is this an obituary, for the instrument is still going strongly.

The beginnings go back to the late 1920's, when the C-3 was the current model of the Carl Zeiss Company, in Jena, Germany. Improvements and changes in the C-3 became obviously necessary as the technology advanced. A Mr. Gulbranson was the chief designer, when the C-4 stereoplanigraph was finally announced by Zeiss in July of 1930. It was a fine instrument, not only by 1930 standards, but even by 1960 standards, as we shall presently see.

In the years 1931 to 1937 a total of 20 C-4 stereoplanigraphs had been constructed but only one came to the United States during that period. That one is the subject of this paper. The others went to places like Mukden, Nanking, Berlin, Delft, Moscow, Madrid and Oslo—all in countries which suffered considerable destruction in wars between then and now. Whether any of these C-4's survived is not known, but it is interesting to contemplate that the one which came to the United States also played an important part in some of that warfare.

But that is getting ahead of the story. In 1931, when Fairchild Aerial Surveys placed its order for the C-4 the instrument wasn't considered a weapon of war. In fact previously the U. S. Army wouldn't consider it at all for any purpose; topographic mapping by aerial methods was not accepted technique by any U. S. Government agency. But Leon T. Eliel of Fairchild had made a trip to Europe in 1930 and was convinced not only that mapping by aerial means was going to be the only technique of the future but that the recently announced C-4 was the instrument to use. The problem, however, was to convince the mapping agencies of the U. S. that topographic work could be done by stereoplotting equipment in general and by the C-4 in particular, faster and cheaper than by methods currently in use.

At the same time, Fairchild had purchased a four-couple camera from Zeiss with the ob-

* Presented at March 24–30, 1963 ASP-ACSM Convention, Hotel Shoreham, Washington. D. C.
† 224 East 11th St., Los Angeles 15, Calif.

ject of using its pictures in the C-4 which was designed for it. Eliel then proposed that, if the Air Corps took the pictures of a suitable test area with the four-couple camera and if the U.S.G.S. provided the control, the maps would be drawn at Jena by the Zeiss experts and the Government could compare it with existing unpublished information. The area selected was the Bushkill Quadrangle in eastern Pennsylvania.

But big projects like this never work out as planned. The Air Corps took the pictures, but there weren't many Government dollars available for ground control in the long, hard winter of 1932–33. When the control was finally obtained in the late summer of '33, it was shipped to Jena, But there was another last-minute change. It was decided to ship the instrument and the data to the United States and do the work in this country instead of Jena. The plotter arrived in Washington in May of 1934 and was assembled in space donated by the Interior Department.

Dr. Heinz Gruner, well known in the Society, was given a leave of absence from his civilian job at Wright Field, and came to Washington to help draw the Bushkill Quadrangle (he had, in fact, taken the photography also). He was assisted by Russell K. Bean and Leon T. Eliel, and later by C. M. Cottrell, the senior author of this paper.

One evening during that summer, Bean, Cottrell and Eliel quit work early and visited at the home of Captain Scott Reading. It was there and then that the American Society of Photogrammetry was born.

The Air Corps report on the Bushkill Quadrangle appeared in 1935, four lesiurely years after the conception of the project. But it was to be many years more before the Federal Government acquired a stereoplanigraph despite the favorable tone of the report. This was not due to resistance to progress, however. There were other factors involved but the fact remains that it was ten years before a stereoplanigraph was used by the Government.

The C-4 did another small topo job at Mexican Springs, New Mexico, that summer of 1934 before it was dismantled and shipped from Washington to Los Angeles.

Before long it had another assignment—Boulder Dam in Black Canyon (now called Hoover Dam) had been completed and water was beginning to back up into the newly created Lake Mead. Someone suddenly realized that maps were immediately needed of the bottom of the new lake for use in subsequent studies of silting and reservoir capacity. Fairchild flew the area with the four-couple camera and immediately began establishing control starting at the upstream face of the dam. Luckily, Black Canyon was deep and narrow at that point, so the water hadn't covered too much area as yet; by hard and fast work the control crews managed to keep ahead of the rising water; and they obtained the necessary control. Any means of mapping other than the C-4 and four-couple camera would have created a requirement for more control than could possibly have been obtained in time.

The map was checked by low-altitude single-lens photos of the shore line at 20 foot elevations of the reservoir. A special plane and crew were held in Las Vegas for this purpose and they took off whenever the gaging station recorded an additional 19.95 feet of water, to take new photos which were compared with the contour map. This was perhaps the most rigorous and the most graphic check of contouring ever devised. It could also be called the most uncontestable and final check, for there could be no rebuttal to it.

In spite of this project and similar triumphs, aerial mapping caught on slowly in those years. Though the C-4 was kept moderately busy in the years 1935–1939 doing mapping for the TVA and the Army Corps of Engineers, there was no move by anybody to import a similar unit into the United States. Thus it happened that when the increasing pressure of the defense program began to be felt, the C-4 began to receive a good deal of that pressure.

In the spring of 1940, an order was received for a cantonment area near San Luis Obispo, California. Specifications and instructions were received by Fairchild in Denver one day; the next day the photography was taken and on the following day the control party left for the site. An assistant went along to do the computing on the spot and as soon as enough control has been assembled it was rushed back to Los Angeles for starting the drawing. And that's pretty much typical of what happened in the next five years. Everything in a hurry, and understandably so, for this was the only means in the U. S. of turning out topo work with a combination of *speed*, efficiency and economy of scarce manpower.

The conversion to single-lens photography took place in 1942. Two aircraft were to fly some quadrangles in eastern Pennsylvania. They picked up three K-17 cameras at the Long Island plant of Fairchild Camera, flew to Pennsylvania to take the photography and then took the cameras to Rochester. There

the lenses were taken from two of the cameras, placed by Bausch & Lomb in special lens barrels and shipped to Los Angeles. They were installed in the C-4 along with a special projection lens that had been designed there, and in a week's time the instrument had been converted for use with 6-inch 9×9 metrogon photography.

In a certain sense, the C-4 was thus converted to the American type of mapping photography which with some refinements but no major change of focal-length or format, is still in use. This change stood the instrument in good stead, as the ubiquitous K-17 camera was distributed through all the Army Air Force mapping and reconnaissance aircraft, and even through the R.A.F.

As the war progressed and the C-4 in Los Angeles was the sole source of quick maps from tri-metrogon photography, assignments came to it from everywhere. First cantonment areas, then training camps, then Southern France, then Central France, then the South Pacific, then Japan. In all, 244 quadrangles were drawn, mostly at 1:37,500 with 10 meter contours, and much of it from tri-metrogon photography. Though a number of other agencies were turning out quadrangles too, the C-4 was the tool chosen when time was tight. A set of photographs of Borneo, for example, was rushed to Los Angeles and in three weeks eighteen quadrangles were delivered to the lithographers for reproduction; a week later a special Navy transport plane was standing by to fly the maps to the South Pacific. Therein lay one of the real advantages of the C-4 for it was the only drawing instrument that could use tri-metrogon photography without prior rectification; when time was of the essence, this was of crucial importance.

At this point it would be romantic to say that the C-4, sitting impressively in its darkened room, took on an awesome personality of its own, as it quietly but efficiently consumed operators as well as diapositives, working around the clock for years at a time to win singlehandedly a war against its own creators. Its operators gave it some nicknames in keeping with their half-serious awe of this center of their lives. But, although it may some day appear that way in a popular magazine article, the truth is merely that the instrument, with routine maintenance, continued to operate well and that the operators thought no more of it than a stenographer does of her typewriter.

After World War II, Government orders fell off, but the dammed-up commercial demand took up the slack and the instrument was kept busy continuously for a number of years. There was no longer the monopoly that had previously existed, of course. Wild instruments and other stereoplanigraphs had been imported into the United States, and the Kelsh Plotter,—capable of doing many of the things previously reserved for universal instruments—appeared on the market. But the C-4 was still irreplaceable for bridging and other chores and remained in very active service until 1953.

In that year Fairchild bought the first of its two C-8's to supplement the A-5 it already had. The C-4 then became obsolescent. It was limited to metrogon lenses, whose use was becoming less and less frequent in mapping photography, and setting up a model took much longer than on the new C-8's. So the C-4 became something of a museum piece whose cover was lifted only to show it to a visitor. But the Fairchild management was reluctant to sell or scrap the instrument. After all, its optics were still sharp and the mechanical parts in excellent working condition—it was simply that there were more efficient ways of doing the same thing.

Then, in 1962, the picture changed again. With a new lens system to handle planigon photography, the C-4 could draw contours on models with too much relief for a Kelsh. Also in certain economically marginal conditions, considering that it is completely amortized, the C-4 might do some bridging. So the new lenses were ordered and the instrument was brought out of retirement.

Today the C-4, designed in 1927–1929 and manufactured in 1931–33, is still efficient and accurate enough to be making money for a commercial firm in a highly competitive industry. The first and still the only one of its kind in the U. S., its very existence as a productive instrument in 1963 is a tribute to the ingenuity of its designer, the skill of its fabricators, the foresight of its importers and the business abilities of its owners. It appears to have many constructive years ahead of it, as any 30-year old should, and another chapter may some day have to be written to this biography before the instrument's life span is completed.