U.S. Peacetime Strategic Reconnaissance Cameras, 1954–1974: Legacy of James G. Baker and the U-2

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James G. Baker contributed to optics, optical design, and, as this chapter describes, was a pivotal player during the development and deployment of the U-2, and the optics of the U-2. To briefly mention some of his contributions outside of the U-2 is itself a challenge. He graduated from Harvard in 1942 with a Ph.D. in Astronomy and Astrophysics, advised by leading astronomer Harold Shapely, and went on to make innovative contributions for nearly 70 years including developing ray tracing and optical design code using the second largest computer ever built (the first one was delivered to Richard Feynman for the Manhattan Project). He not only designed large format cameras for reconnaissance but also fabricated and tested the large aspheric components personally. He is perhaps best known in the public for his design of the Baker–Nunn tracking cameras and for designing and supporting the fabrication of the first freeform surface in mass production as part of the Polaroid SX70 camera, to name a few examples.

This chapter features his work not only as the optical designer for the optics for the U-2, but also his lesser known contributions as a leading member of the group that convinced then President Eisenhower to authorize the U-2 program. The sources for this chapter were selected to be as original as possible, and are dominantly CIA reports that were developed by the CIA History Staff in the 1980s and released as classified reports within the CIA. These were later declassified with redactions when the existence of the National Reconnaissance Office (NRO) became known to the public in the late 1990s. All of the material in this chapter comes from Baker's personal files that were made available to the author by the Baker family.

Baker's involvement in reconnaissance cameras began in 1941, when he was invited by Major George Goddard to spend two months at the Wright Field in Dayton, Ohio [1]. Perhaps the most succinct introduction to Baker's role in the U-2 and related programs is from an NRO press release that announced the first "Pioneers of National Reconnaissance" on 18 August 2000. The release states: "James G. Baker, Ph.D.—A Harvard astronomer, Dr. James Baker designed most of the lenses and many of the cameras used in aerial over-flights of 'denied territory,' enabling the success of the U.S. peacetime strategic reconnaissance policy" [2].

To write only on his technical accomplishments for reconnaissance cameras would overlook a key role Baker played in bringing President Eisenhower to authorize the U-2 to carry the camera. The first section of the chapter will highlight Baker's roles in that area—roles that often consisted of leading key technology committees, which led to the authorization of the U-2 program specifically as described in [3]. In the context of the U-2 program, these roles began in 1951 with the establishment of what came to be called the BEACON HILL Study Group, named for the location of the study group headquarters on Beacon Hill, in Boston. The group was made up of chairman Carl Overage, a physicist at Kodak, Baker, Edward Purcell from Harvard, and a total of 12 others that included Edwin Land of Polaroid, Richard Perkin of Perkin-Elmer, and

significantly, Lt. Richard Leghorn from the Wright Air Development Command, who later became the founder of ITEK where the CORONA program was developed in later years. This group toured airbases, laboratories, and companies every weekend for two months in January and February of 1952. From there the members invested three months preparing a classified document they presented on 15 June 1952—the BEACON HILL Report. The report, with 14 chapters, discussed various technologies from radio to photography including infrared and microwave reconnaissance systems. One of the key recommendations from the report was the need to develop high-altitude reconnaissance.

Reaction to the BEACON HILL Report came a year later, in the summer of 1953, after Dwight D. Eisenhower became president. The specific timing of the president's interest was driven by an early report of a new Soviet intercontinental bomber, designated "Bison" by NATO. This was a B-52 class bomber (the B-52 was just entering production in the U.S.). This report was validated at the Moscow May Day air show. In July of 1953, the Intelligence Systems Panel (ISP) was established, chaired by Baker, to advise both the Air Force and the CIA on ways to implement the construction of high-flying aircraft and high-acuity cameras. In parallel, during World War II (WWII), Baker had established a full-scale optical laboratory, the Harvard University Optical Research Laboratory. After the war, Harvard asked that the laboratory end its relationship with the university and it was moved to Boston University to become the Boston University Optical Research Laboratory (BUORL), with the move funded by the Air Force. Baker, however, elected to stay at Harvard where he continued to design lenses for use in photoreconnaissance. BUORL was destined to become ITEK in 1957 under the leadership of Richard Leghorn.

At the first meeting of the ISP on 3 August 1953 the discussion centered on the fact that the best intelligence on the interior of the Soviet Union was based on German aerial photos taken near the end of WWII. Discussions continued to review incremental modifications that either were being attempted or planned to create a high-altitude airframe from existing production aircraft. At the third ISP meeting on 24–25 May 1954, a critical outcome was to establish that to be successful, a high-altitude aircraft would need to fly above 70,000 feet, something that could not be achieved with modifications to existing airframes. The other pivotal event at this meeting was that the panel learned of a lightweight, high-flying aircraft that was being developed at Lockheed Aircraft Corporation. Baker dispatched a member of the panel to learn more about the project. The plane was conceived by the now legendary Kelly Johnson, leader of the Skunk Works, who had designed essentially a single engine jet powered glider, which was called at the time the Lockheed CL-282. On 24 September 1954 Baker convened the ISP panel to discuss the new airplane. The panel moved to support the CL-282, but the Air Force, which had been aware of the CL-282, had already made a decision not to fund the development of the aircraft.

Somewhat independently, on 26 July 1954, President Eisenhower commissioned another panel of experts, led this time by James Killian, then the president of MIT. This panel had 42 of the nation's leading scientists, including Baker, segmented into three project groups. This group met 307 times over nine months and included field trips and conferences. Baker was a member of the Project 3 committee, which was led by Edwin (Din) Land of Polaroid. Land believed the optimal committee size was one that could fit into a taxi and, as a result, this was a small group consisting of Baker and only a few others, including notably mathematician John W. Tukey. In mid-August 1954, Land and Baker went to Washington where Land was shown the details of the CL-282, after which he is quoted as having phoned Baker to say, "Jim, I think we have the plane you are after." Following a somewhat convoluted path that was dominantly political and too lengthy to describe here, Land and Killian met directly with President Eisenhower in November 1954 and the president directed that CL-282 be developed by the CIA. Even with the president's support, the competitive situation was complicated, but a key deciding factor in the end was that Kelly Johnson promised to deliver the plane in eight months for $22 million, which he did, under budget. A final contract was signed on 2 March 1955 with Lockheed to deliver 20 planes between July 1955 and November 1956. To give some perspective on the priority of the project, Richard Bissell of the CIA wrote a check to prestart the work and mailed it to Kelly Johnson.

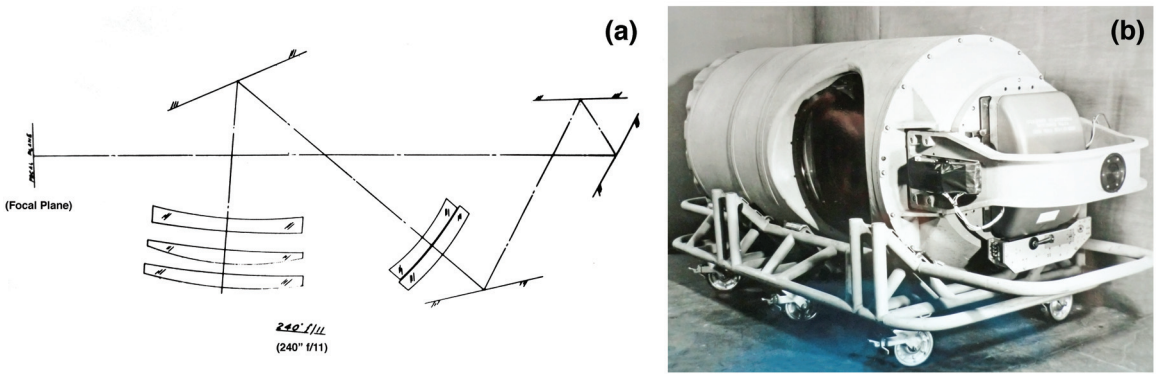
With this background on how the U-2 airframe, a version of which is shown in Fig. 1 [3], came to be authorized, this section will present Baker's work on some of the lenses that were considered or used on cameras that flew on the U-2. This material is based on [4] and from the article written by Baker [5].

◀ **Fig. 1.** U-2R (World Air Power Journal, Vol. **28**, Spring 1997 published by AIRtime Publishing, 10 Bay Street, Westport, Conn. 06880).

To frame the challenge, the dominant aerial cameras that were used in WWII were the Fairchild K-19 and K-21 framing cameras with focal lengths from 24 to 40 inches. In the period that the U-2 was authorized, a typical ground resolution was 7–8 meters when flying at 10,000 meters. For the U-2, due to the new objects of interest, there was a need for 3-meter ground resolution from >20,000 meters, or a 4× improvement. In the mid-1940s, Baker, working with Richard Perkin of Perkin-Elmer, had developed a 48-inch focal length scanning camera that was installed in a B-36 that resolved two white softballs on a green from 10,000 meters. However, this camera weighed more than a ton and the weight budget for the U-2 was near half of this.

Baker began work on a "radical new camera" in October 1954, but quickly realized that it would take more than a year to design, even with his computer access, whereas the plane needed a camera well before this. Consulting with Richard Perkin, the decision was made to base the improved camera on the Hycon K-38. This camera, with weight reduction implemented by Perkin-Elmer and improved optical design developed by Baker in a few weeks, became the A-1 camera working at f/8 that was used in the first flights in mid-1955. A high-impact innovation at this stage was that instead of flying three cameras, one down-looking and two oblique, Rod Scott of Perkin-Elmer developed a rocking mount to gather the oblique and down-looking images with one camera.

As soon as there was a plan set for a camera to support the early U-2s, Baker began work on a totally new concept, the B-camera. This was a 36-inch focal length f/10 lens with aspheric surfaces, personally polished and tested by Baker. The use of aspheric lenses was essentially unheard of in this era and is one of the reasons Baker's lenses set a new standard for high-acuity cameras. Developed in



▲ **Fig. 2.** (a) Layout of a proposed Camera-C (this version at f/11), (b) an assembled Camera-C, 240" EFL, with a final configuration at f/12.

collaboration with Rod Scott of Perkin-Elmer, the B-camera used only one panoramic imaging lens with 18 × 18 inch format frames. This lens, and variations on it, became a key component of all cameras throughout the U-2 program.

Independently, Baker's concept for the ultimate U-2 camera, called the C-camera (see Fig. 2 [6]), was a 240-inch focal length lens to be operated at f/20. However, in conversation with Kelly Johnson he realized this format would never be small enough or light enough for the U-2. Eventually he developed a 180-inch focal length lens operating at f/13.85. While this design would typically have taken years to complete in that era, his state-of-the-art computer allowed it to be completed in 16 days. However, in a test flight of the Hycon manufactured lens, the conclusion was that the 5× longer focal length made the lenses too sensitive to vibration. Apparently this result was never relayed to Baker, who learned of it years later. When he learned of the source of the decision to not use the C-camera, he wrote a terse letter stating he had solved that, should they have bothered to ask.

References

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