KH-9 Hexagon Spy in the Sky Reconnaissance Satellite

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In 1965, Central Intelligence Agency Director John McCone laid down a challenge to a selected few companies with experience in designing cameras for the intelligence community. He wanted a new generation of surveillance satellites that combined the broad area coverage of CORONA with the high resolution of the KH-7 GAMBIT.

Thus was born what would eventually become the KH-9 Hexagon spy satellite. It was the last film-based orbiting reconnaissance camera for the United States government. It was a marvel of engineering achievements that resulted in a fine optical instrument that was capable of taking stereo photographs of the entire earth as well as concentrating on small areas of interest and able to distinguish objects two to three feet in size from an altitude of 90 miles above the earth. The system would become an invaluable asset and provided intelligence information credited with persuading President Nixon to sign the SALT-1 treaty in 1972. It was also acknowledged at the time to have been "the most complicated system ever put into orbit." The first launch was on 15 June 1971 and the last of 19 successful missions sadly exploded 800 feet above the pad on 18 April 1986 just a few months after the tragic *Challenger* explosion.

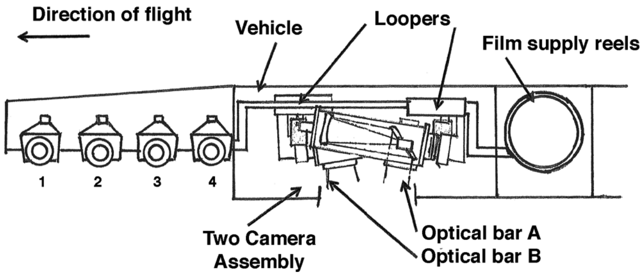
The vehicle weighed 30,000 pounds, was 60 feet long and 10 feet in diameter, and each of the two cameras carried 30 miles of film. The film traveled at speeds up to 204 in./s at the focal plane and was perfectly synchronized to the optical image captured by a constantly rotating scanning camera. The exposed film was periodically returned to Earth in four re-entry vehicles caught by an Air Force C-130 over the Pacific. A photograph of the entire vehicle and a schematic diagram of the vehicle are shown in Figs. 1 and 2, respectively.

The story started out as the author was working for the Perkin-Elmer Corporation, and with a small group who studied the concept for over a year. The results were presented to the CIA at night in an innocuous-looking safe house in Washington, DC. Albert "Bud" Wheelon, the first CIA Deputy Director of Science and Technology (from 1963 to 1966) said that the agency thought highly of the group's concept.

The group then spent an extremely intense six weeks writing a proposal. It culminated in May 1966 when Perkin-Elmer CEO Chester Nimitz, Jr., the son of the famous World War II admiral, stood up at the end of the final proposal presentation to the CIA, put his foot up on a table and said, "We want this f———g job and we're gonna get every f———g agency and every f———g engineer from here to Florida. We recognize the importance to national security and we're capable of doing the job." It was a memorable event.

A second memorable event came five months later on 10 October 1966, when the group was told to gather at 10 a.m. in the large engineering room, in an isolated and secure area across the street from one of Perkin-Elmer's two main plants. Group vice president Dick Werner, the group's program manager Mike Maguire, and contract specialist Charley Hall walked in shortly after 10. They were all dressed in stylish suits. In those days everyone wore ties and jackets, although the latter were soon discarded as each day progressed. As they reached the front of the room Dick reached into his right inside jacket pocket and took out one of the longest cigars imaginable. The first words out of his mouth were "We won." A great cheer went up from the

▲ **Fig. 1.** Photo of the Hexagon vehicle (minus 2 re-entry film capsules).



▲ **Fig. 2.** Schematic of the entire Hexagon vehicle.

group. Dick and Mike then each spoke a few words of praise for the great team effort along with wishes for success in this new adventure.

As soon as the meeting broke up, group members immediately made phone calls. Many called their wives to say that the group had won a big program that would keep them employed for a long time.

Some employees called their stockbrokers to buy as much Perkin-Elmer stock as they could afford. Of course, this was illegal as it was trading using insider information. The next day a secretary went around asking everyone if they had purchased shares and if so, how many. This list was eventually given to the Perkin-Elmer legal department, and all who had bought stock expected to be reprimanded and possibly made to sell the shares or void the purchases. But nothing further was heard, and it turned out to be a lucrative investment, especially for those who had the courage to invest "serious" funds. The company stock split seven times in the next dozen years.

Hiring a skilled technical staff was difficult because the program was top secret, so potential candidates could not be told the nature of the program or the specific tasks to which they would be assigned. In addition, completing the required background and security checks took from four months to a year, and permanent employment depended on clearing security screening.

New hires were told not to discuss or even speculate with others what the program was about. While awaiting their clearances, most of them worked on unclassified projects in a non-secure part of the building called "the tank." It also was called "the mushroom patch," because the people working there were kept in the dark and fed a lot of crap.

Everyone in the tank eagerly awaited their security clearance. Dick Carritol, a systems and servomechanism engineer, recalls being called to the security office. "I was given a bunch of documents to read and sign. I remember being awed by the words I was reading. It seemed like I was being told more than I needed to know. After 40 years the memory is a little hazy, but I do remember something like this: '... *a study program leading to the design and development of a photo reconnaissance satellite, to conduct covert operations for the CIA, under cover as the Discoverer Program. This high resolution system is to carry out search and surveillance missions over the Sino-Soviet Bloc... the program name is FULCRUM.*'" (It later was changed to Hexagon.)

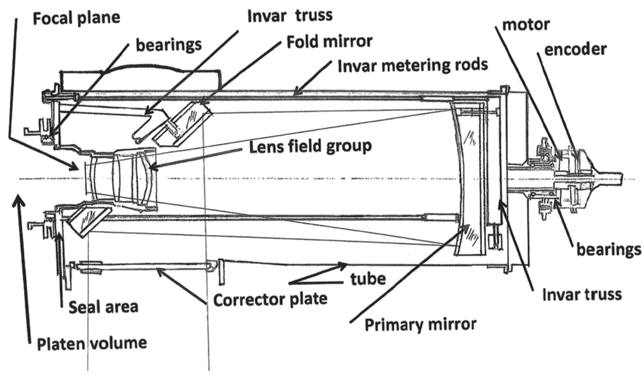
Carritol continues: "The documents droned on about not revealing, acknowledging, or commenting on the existence of the program, the program name, the customer's name, or any of the participants in the program. This ban on discussion included everyone from one's family and friends all the way to others on the program with the proper security clearance but without an explicit need to know."

"When I had finished all the reading and signing, the security officer asked if I was surprised. I didn't have a feeling of surprise. I felt numb. I had just read a lot of words and concepts that I had never considered before. Covert Operations, Under Cover, Search and Surveillance of the Sino-Soviet Bloc, and compartmentalized security clearances were all new and quite foreign to me. I had a lot to learn! No, I didn't feel surprise, I felt like I had just joined the 'Big Leagues.'"

The design environment in the late 1960s was very different from that of today. Computers were large general-purpose mainframes which received input on punched cards and produced output on magnetic tape or an impact printer. Analysis programs were limited to early versions of NASTRAN (for mechanical structural analysis) and SINDA (for thermal analysis).

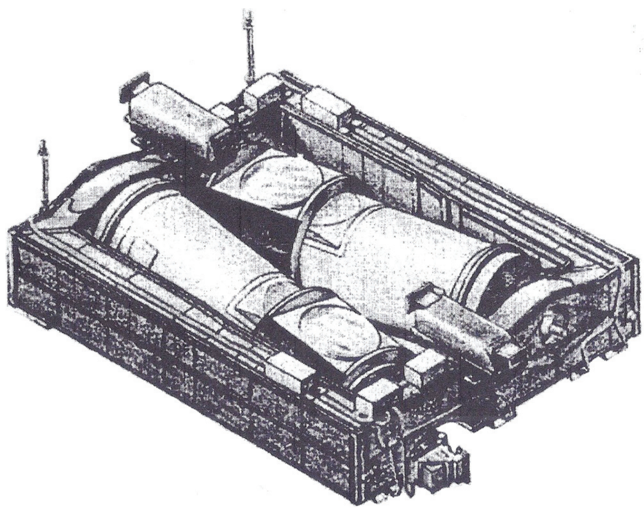
There were no CAD (computer aided design) systems. Designs were drawn on drafting boards using pencils, and major changes required much erasing or starting a new drawing from scratch. Large machines that used ammonia and other chemicals copied the drawings to make real "blueprints." The smell of ammonia permeated the blueprinting department, and copies retained the odor for quite a while. There were no graphic printers or displays, and drawings could not be rotated on a screen and nor parts observed in three dimensions. Most engineers did math on slide rules or desktop calculators; pocket electronic calculators did not arrive until the early 1970s. By modern standards, the tools used for testing, visualizing, and analyzing, and in some cases for fabrication, were antiques.

Each camera, called the optical bar, was an f/3 folded Wright optical system with a focal length of 60 in (152.4 cm). Its configuration is shown in Fig. 3.



▲ **Fig. 3.** The optical bar.

Each of the two identical optical bars contained an entrance window, a fold-flat mirror, a 26-in. primary mirror, and a field group of lenses. The mirrors were 4 in. thick and made of two faceplates fused to a hollowed-out core and made by the Heraeus Corporation. Perkin-Elmer polished them to an rms wavefront quality of 1/50th of a wave. The image was imposed on the focal plane located 1 in. behind the last lens. One optical bar was tilted 10 deg to look forward, and the other 10 deg to look back, creating a 20-degree stereo angle. A two-camera-assembly isometric is shown in Fig. 4.

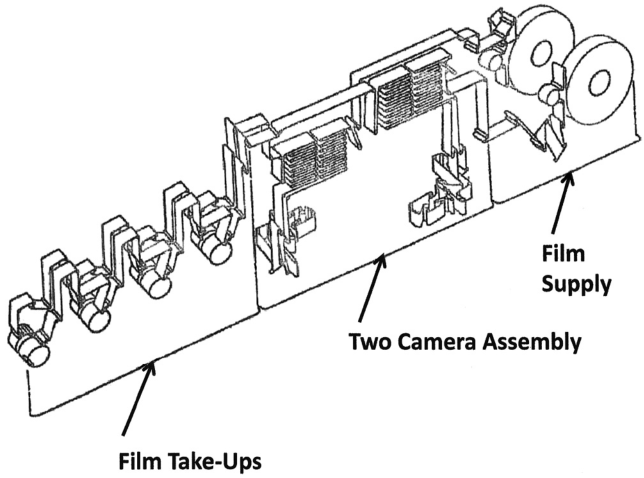


▲ **Fig. 4.** Two-camera-assembly isometric.

The optical bars rotated continuously in opposite directions during photography, as did the other major rotating components of the vehicle, for momentum compensation. They rotated at a constant speed depending on V/h (the orbital velocity divided by the altitude above the earth). Photographic imaging occurred only during scans of ±60 degrees or less on either side of nadir (looking straight down). During photographic scans the film's linear velocity and rotational speed (that was also a function of V/h) in the platen had to be synchronized exactly with the moving image.

The film exited the supply reels at a constant velocity of 70 in./s. After the film left the supply, it had to be moved in accordance with a prescribed film velocity profile to enable photography to occur at the proper time and to utilize as much of the film as possible. The film path, shown in Fig. 5, was approximately 100 feet long and contained many rollers over which the film traveled. The film was accelerated to photographic speed in the platen.

The platen was the assembly that controlled film speed and synchronization with the image at the focal plane. At perigee, the lowest point in the satellite's orbit, the film speed was 204 in./s. After the exposure occurred, the film was decelerated and driven backward so that the next exposure was made with only 2 in. of film between exposures. The film was then stopped so that an electronic data block could be inscribed on the film in this narrow space. At altitudes higher than perigee, all of the film and camera rotational speeds slowed down proportionately.



▲ **Fig. 5.** Overall system film path schematic (cameras not shown).

The oscillating portion of the platen was synchronized to the rotating portion of the optical bar. The real key to the success of the Hexagon camera system was the invention of the twister. This relatively simple device consisted of a few rollers and two pivoted air bars (D-shaped cylinders through which dry nitrogen passed, enabling the film to ride linearly and up and down on a thin air gap without incurring damage). The twister was a self-aligning, passive device that allowed the film to be rotated in synchronization with the optical bar during photography.

The job of accommodating the film velocity profile from constant low velocity at the supply to variable high speed at the focal plane in the platen and storing the film during the non-photographic cycle (240 deg or more) of the optical bar was accomplished by means of a film storage device called the looper. It contained a carriage and many rollers. The carriage traveled linearly back and forth. During motion in one direction it drew the proper quantity of film from the supply reels into the entrance side of the looper while simultaneously feeding film into the platen for exposure.

After exposure the film during the reverse motion was stored in the exit side of the looper. It was then wound up at constant velocity again at 70 in./s onto the take-up assembly in the forward section of the vehicle. After the first of four take-up reels (each in its own re-entry vehicle) was filled, the film was wound and cinched onto the core of the next take-up reel then cut. At the appropriate time during one of the next orbits the filled re-entry vehicle was jettisoned and returned to earth.

It took almost five years of development and testing to reach the next big date, which was 15 June 1971. The author sat next to Mike Maguire, the group's director and general manager, and several others in the "war room" listening to the Vandenberg launch controller countdown to ignition and liftoff of a Titan 3D rocket with about 3 million pounds of thrust. Silence followed, then periodic updates on altitude and speed. Eventually the controller confirmed that the payload had reached orbit. It would be the first of 19 successful launches.

Known to the public as "Big Bird," Hexagon succeeded beyond anyone's dreams. The program helped ease Cold War tensions and became the most successful film-based spy satellite the United States ever orbited. It was eventually succeeded by electronic digital imaging systems that could deliver images to the ground much faster than possible with film.

The last date etched in the author's memory was 18 April 1986. For the twentieth time, the countdown was heard: "Ten, nine, eight, seven, six, five, four, three, two, one, launch, we have liftoff." A noisy and powerful exhaust came from the rocket as it rose off the pad at Vandenberg Air Force Base in California. Then disaster happened. The rocket exploded in a fiery blast before it reached 1,000 feet, destroying the last Hexagon. Those who worked on the program could not share their stories for another quarter century, until the National Reconnaissance Office finally declassified the program in a 17 September 2011 ceremony attended by the author along with many colleagues who had worked on the Hexagon project.

This chapter was based on [1].

Reference

1. P. Pressel, "Spy in the sky: the KH-9 Hexagon," Opt. Photon. News **24**(10), 28–35 (2013).