SURVEYS FROM ABOVE

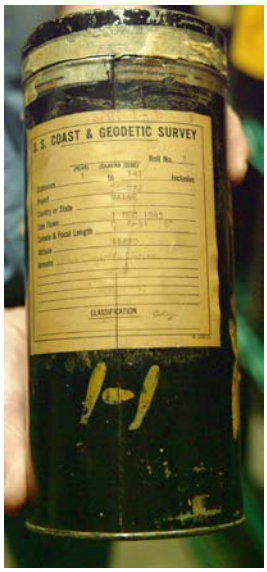
A BRIEF HISTORY OF AERIAL SURVEY PHOTOGRAPHY IN THE C&GS

1919-2006

In 1919 the Superintendent of the Coast and Geodetic Survey (C&GS), Earnest Lester Jones, wrote "There has been much talk in recent months, in regard to surveying the country from airplanes. This is a subject in which the C&GS is much interested, because *it seems probable that the airplane can be used to a great extent in revising the topography along the shore of the country, and in some parts of the interior, and also in making original surveys."*

Mr. Jones would certainly be pleased to discover that C&GS has, in its archives, an un-broken collection, from 1943 to the present, of aerial images of our coastlines and airports. The half-million plus aerial photographs come from an assortment of C&GS owned or enlisted aircraft and a variety of aerial cameras. Our film collection represents an amalgam of ongoing technical achievements in the areas of aviation, surveying, camera making, film structure, electronics, and recently, satellite navigation. These advances have contributed to refinement in the art and science of charting our coastlines and airports.

Part of the C & GS roll-film archive.



The 1st C & GS film roll dated 1943

If Superintendent Jones had been able to visit during the 200th anniversary of the C&GS in 2007 he would find that nautical charts, aeronautical charts, and airport obstruction charts are indeed revised from photography taken from aircraft; that original surveys are routinely done of shoreline and airports; and that the Survey is experimenting with other methods of what are now called "remote sensing". Hyper-spectral scanners, radar, lidar, both large and small format digital cameras, and satellite imagery are

available technologies being tested for use in data capture. As of this writing the Survey is using two 35mm digital cameras converted to expose simultaneously; one devoted to the color spectrum, and the other to black & white Infrared.

Mr. Jones would also find a variety of improvements to the cameras themselves: a Venturi vacuum funnel no longer needs to be attached outside of the aircraft. Modern aerial film cameras have internal electric motor vacuum pumps whose purpose is the same as it was in 1919, to flatten the film to a micro-flat plate, reducing distortion across the film frame. He will find, as it was then, that too much vacuum will dimple the film by pulling it into the vacuum holes, and too little vacuum will introduce distortion by not keeping the film flat. He will recognize that a valve was introduced to control the vacuum in the K-1 camera which is controlled today by electronics.

He would see that flight crews no longer use a stopwatch to time the release of the next exposure in order to produce the overlapping stereo vision-effect used in modern mapping. Aerial film cameras from the late 1930s to the present use a "moving" grid in a view finder to establish "end laps" (overlaps, usually 60%, used to produce stereo-vision). Since the mid 1990's C&GS modern aerial cameras, he would find, incorporate GPS satellite positioning to accurately determine the camera position in 3 dimensions at the moment of exposure. These positions along a flight line are now pre-determined by a computerized "flight management system". Flight lines may be planned in an office or on the aircraft. In 1919 the flight lines were also planned in an office, but flight-line navigation was done "by eye".

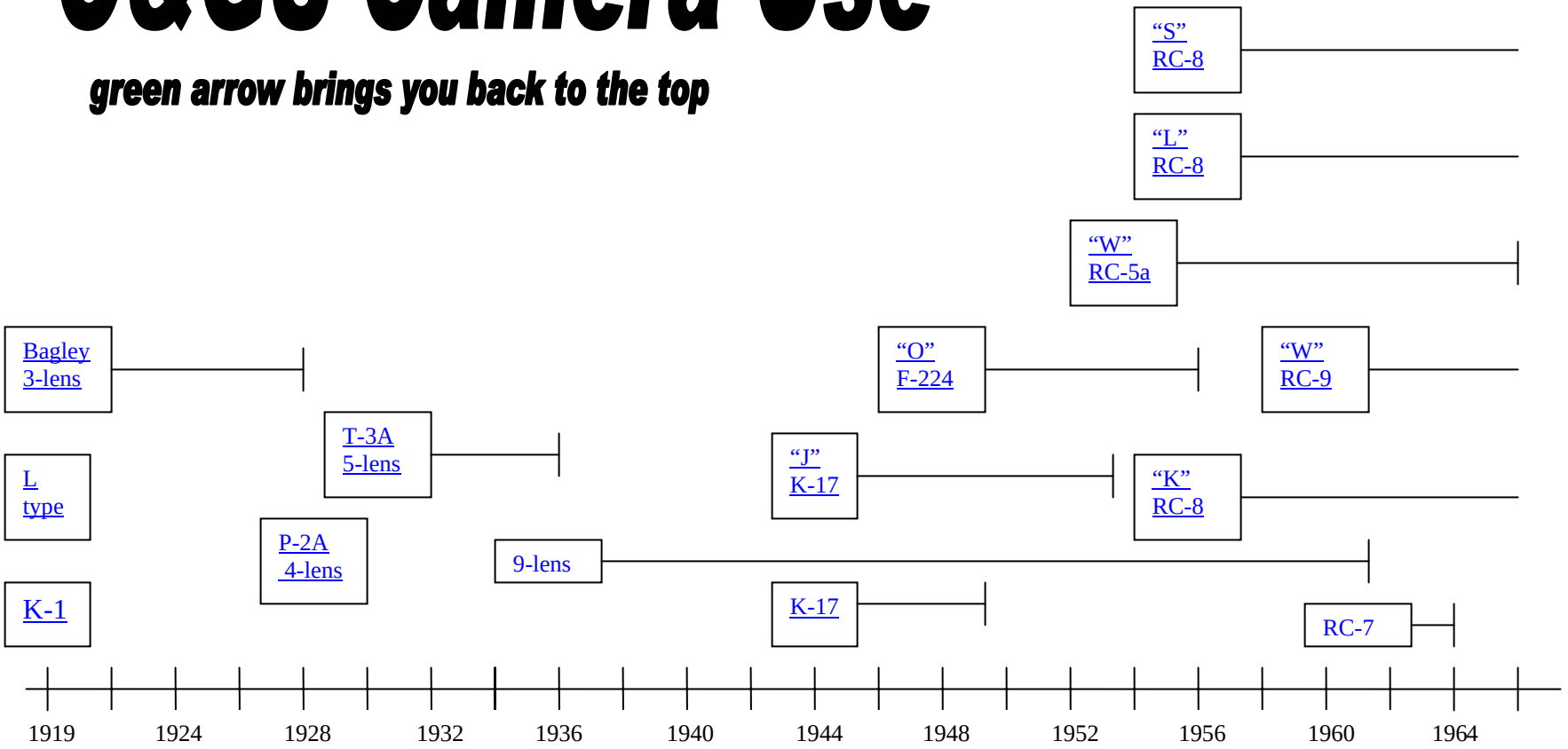
Modern advances in lens-making have given the C&GS aerial survey cameras wider-angle lenses with flatter-field images. Coatings on the lenses re-direct different wavelengths of light to a tighter focus and better color balance. Advances in optical quality glass making have given better clarity and resolution. A flat-field lens, color-corrected, of optimum optical quality gives an almost distortion-free image

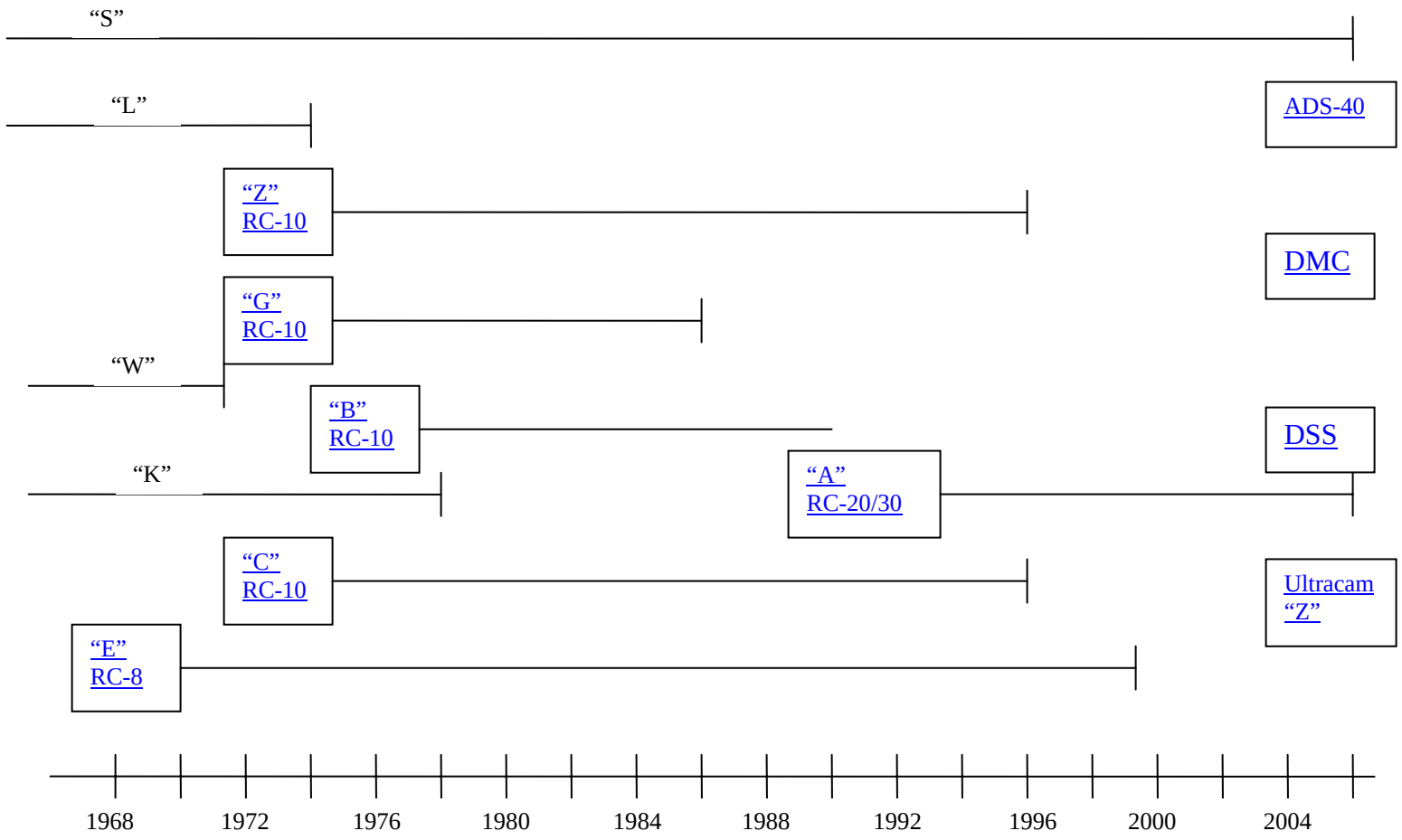
Advances in aerial film manufacturing would captivate Mr. Jones. He would see that the Survey has used four different films (emulsions) in its history: black and white, color, false color (color infrared), and black and white infrared. Films have become faster, finer-grained, and more stable over the decades. C&GS began using black and white infrared film in 1955 to map the MHW (Mean High Water) and MLLW (Mean Lower Low Water) lines for nautical charts. Color films have been used by C&GS since the late 1940s for shoreline mapping projects. Finer-grained films allow a photogrammetrist to look deeply into an image and measure features in micrometers (.001mm).

Finally, Mr. Jones would be fascinated to learn that modern aerial cameras employ an "active" vacuum plate, one that holds the film flat to the focal plane and can be computer-coordinated with the aircraft ground speed to actually move the plate and film frame against the direction of flight during exposure. This feature, called Forward Motion Compensation "freezes" the frame by eliminating the smearing of the image due to the aircraft foreword movement in the split-second when the shutter is open.

C&GS Camera Use

green arrow brings you back to the top




"S"
"L"
ADS-40
"Z"
RC-10
DMC
"G"
RC-10
"W"
"B"
RC-10
DSS
"K"
"A"
RC-20/30
"C"
RC-10
Ultracam
"Z"
"E"
RC-8
1968
1972
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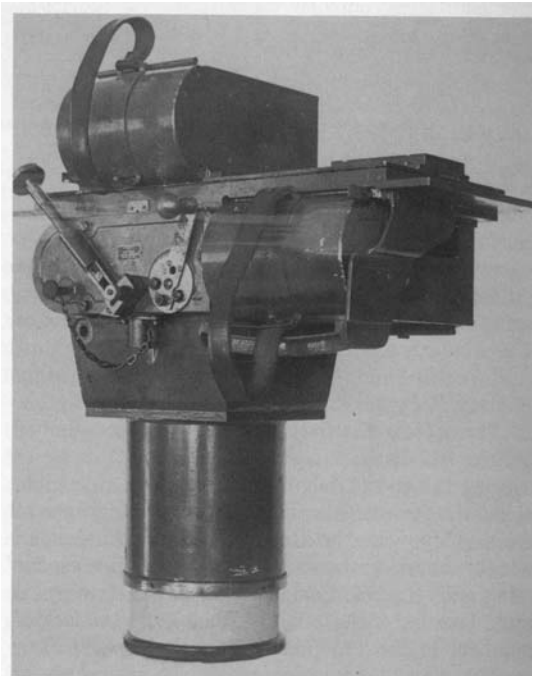
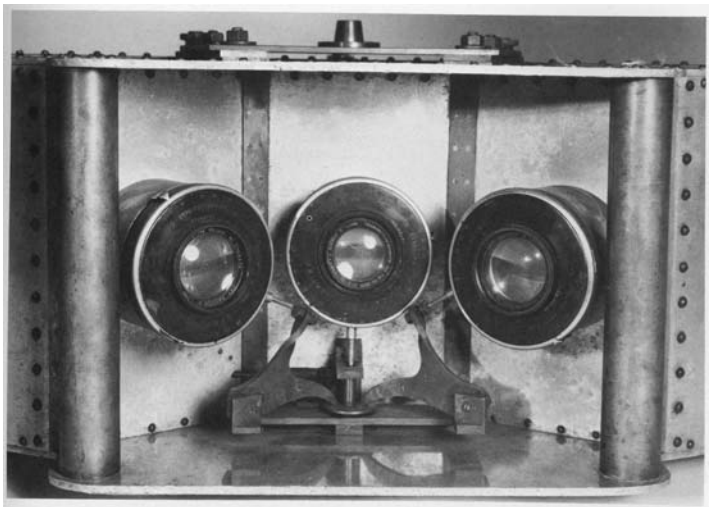


L-Type Aerial Camera
US Army Air Service
1919-1920

Lens Configuration: Single Lens
Focal Length: 10.125”
Emulsion: glass plates (25)
Negative Size: 4” x 5”
Mount: fixed
Vacuum: none
Viewfinder: none



Bagley
US Army Air Service
1919-1928

Lens Configuration: multi (3-lens)
Focal Length: 5”(127 mm) center lens, 7” (178 mm) outer window
Emulsion: roll film

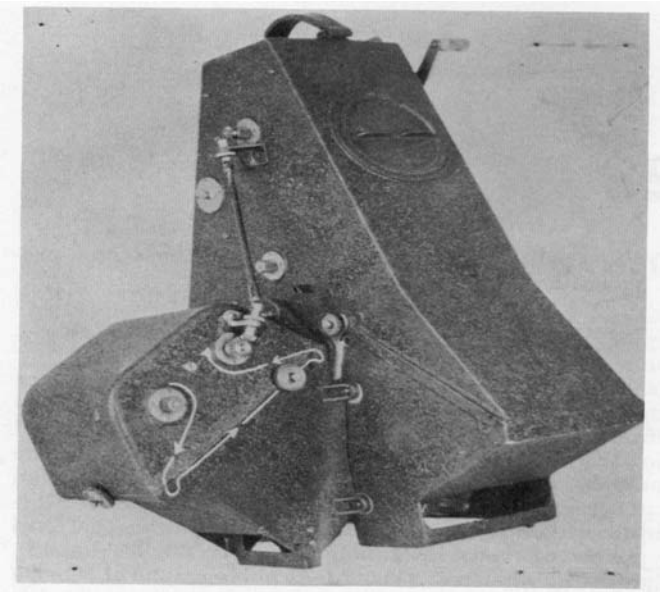
Bagley 3-lens photograph.

Multi- Lens cameras were developed for C&GS aerial surveys becassue of early aircraft ceiling limitations. The multi-lens configuration covered a larger area, and required less ground control points.

K-1
1919

Manufacturer: Folmer & Schwing Deptartment of Eastman Kodak and Fairchild Camera Co.
Lens Configuration: Single
Focal Length: 12”
Emulsion: Film 75’ roll
Negative Size: 7” x 9.5”
Mount: Gimbal
Vacuum: Venturi-outboard mounted

Note: raised vacuum plate with vacuum holes visible.

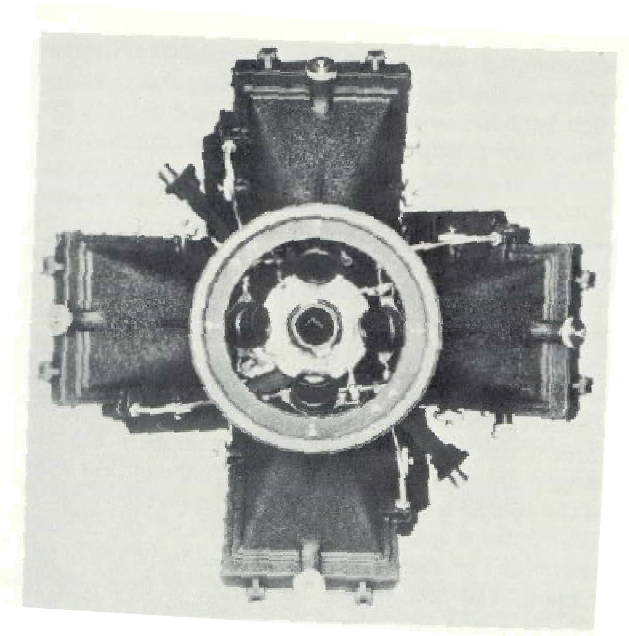


P-2A
1928-1930

Manufacturer: Fairchild
Lens Configuration: multi-lens (4-lens)
Emulsion: roll film
Vacuum: venturi- outboard mounted

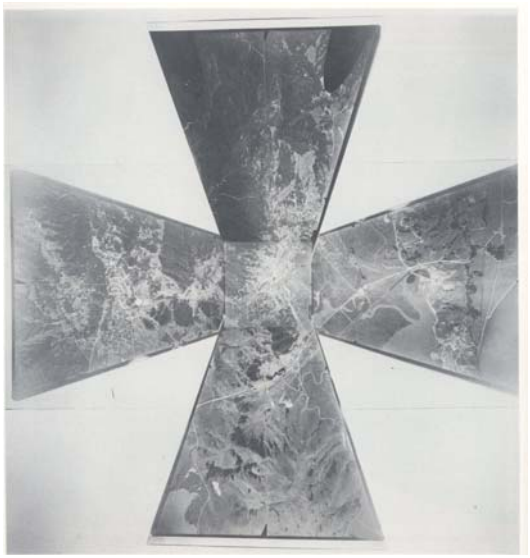
US Army Air Corps camera, crew, and aircraft in 1928

4-lens photograph

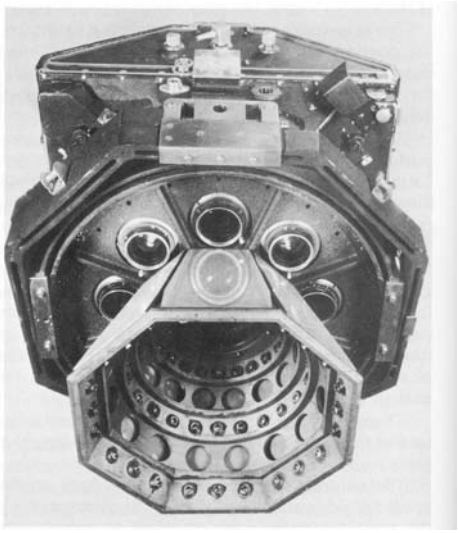


T-3A
1930-1936

Manufacturer: Fairchild Co.
Lens Configuration: multi-lens (5-lens)
Focal Length: 6”
Emulsion: film, 200’ roll
Negative Size: 5.5” x 6”
Vacuum: venturi – outboard mounted



5-lens negative



9-lens
1936-1961

Manufacturer: Fairchild Camera Co.
Lens Configuration: Multi-lens (9-lens)
Focal Length: 8.25” (210 mm)
Emulsion: film, 200’ roll
Negative Size: 23” x 23”
Mount: gimbal
Viewfinder: Traveling grid

9 lens negative.

9 lens film and roll.

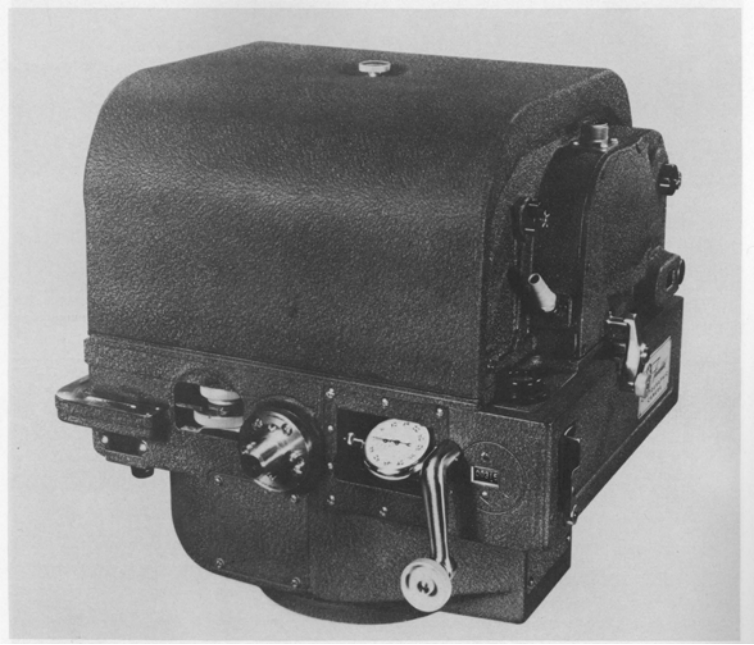
CAPT O.S. Reading (C&GS Ret’d) developed and in conjunction with the Fairchild Camera Co., constructed the C&GS 9lens camera in 1935. All 9 lenses were exposed on the same 35”x35” film frame.

K-17
1944-1949

Manufacturer: Fairchild Camera Co.
Lens Configuration: single lens
Emulsion: roll film
Negative size: 9” x 9”
Mount: gimbal

K-17
1944-1953

C&GS (NOS) Designator: “J” cam
Manufacturer: Fairchild Camera Co.
Lens Configuration: single lens
Focal length: 6”
Emulsion: roll film
Negative Size: 9” x 9”



F-224
1948-1956

C&GS (NOS) Designator: “O” cam
Manufacturer: Fairchild Camera Co.
Lens Configuration: single lens
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal

RC-5a
1954-1966

C&GS (NOS) Designator: “W” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: film
Negative Size: 9” x 9”
Mount: Gimbal
Vacuum: venturi through hull
Viewfinder: fixed field

A Wild Co. RC-5a camera with filter cowl removed

RC-8
1956-1978

C&GS (NOS) Designator: “K” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: venturi through hull
Viewfinder: traveling grid

The “K” camera focal plane was modified to focus infrared light at specific wavelengths above 740 nanometers. It was subsequently used with black & white infrared film only. It is presently on display at the National Air-Space Museum near Dulles Airport.

RC-8
1956-1974

C&GS (NOS) Designator: “L” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: venturi through hull
Viewfinder: traveling grid

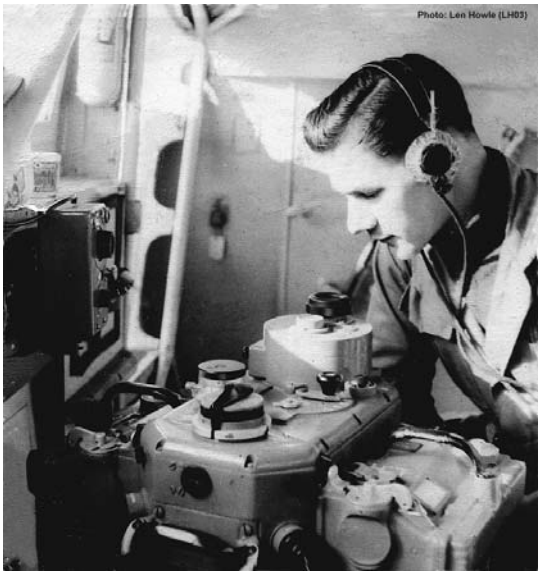
RC-8
1957-present

C&GS (NOS) Designator: “S” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: venturi through hull
Viewfinder: traveling grid

The “S” camera was tested and purchased from the Wild Company; the first RC-8 sold in the USA. It is still used for training and for site verification functions.

RC-9
1960-1972

C&GS (NOS) Designator: “W” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 3.5” (88mm)
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: venturi through hull
Viewfinder: traveling grid

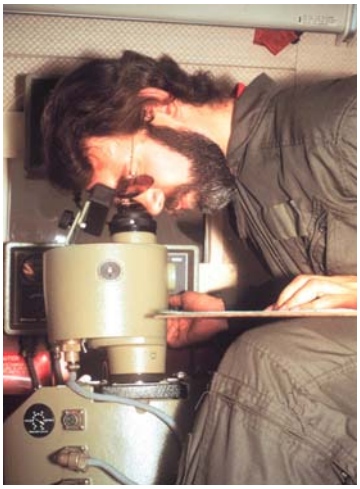


RC-7
1961-1964

Manufacturer: Wild Co.
Lens Configuration: single lens
Emulsion: glass plate

RC-8
1968-1999

C&GS (NOS) Designator: “E” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: venturi through hull
Viewfinder: traveling grid



RC-10
1973-1996

C&GS (NOS) Designator: “C”/ “Z” lens
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 3.5” C lens/ 6” ‘Z’ lens
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: internal vacuum pump
Viewfinder: traveling grid

RC-10
1973-1986

C&GS (NOS) Designator: “G” lens
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: internal vacuum pump
Viewfinder: traveling grid

This lens has been modified with a dot-matrix grid plate etched on an optical grality glass plate, fixed permanently in the focal plane. It is referred to as the geodetic lens.

RC-10
1975-1990

C&GS (NOS) Designator: “B” cam
Manufacturer: Wild Co.
Lens Configuration: single lens
Focal Length: 6”
Emulsion: roll film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: internal vacuum pump
Viewfinder: traveling grid

This camera system has been modified to record a GPS position at the moment of full shutter opening. It was used in that configuration for airport obstruction charting.

RC-20/30
1991-present

C&GS (NOS) Designator: “A” cam
Manufacturer: Wild-Heerbrugg (now Leica)
Lens Configuration: single lens
Focal Length: 6” (153 mm)
Emulsion: film
Negative Size: 9” x 9”
Mount: gimbal
Vacuum: internal vacuum pump
Viewfinder: traveling grid
GPS compatible
Titles film margins with GPS position

The RC-20/30 has forward motion compensation (FMC) and is GPS compatible. The position of the camera focal plane center is recorded on the film margin and is additionally stored on a removable hard drive, all at the precise moment of full shutter opening.

ADS-40
2005-present

Manufacturer: Leica
Lens Configuration: single lens
Emulsion: digital array (12 k pixels)
Negative Size: none
Mount: gyro-stabilized
Vacuum: none
Viewfinder: flight management system

The ADS-40 and its newest generation the ADS- 80 are large format digital cameras used experimentally by contractors for NGS. The ADS series are line scanners “push broom” using telecentric lenses. These lenses focus all light rays perpendicularly tot eh arrays, or chips, on the focal place. These arrays on the focal plane capture imagery in three positions, forward, downward, and backward.

DMC
2005-present

Manufacturer: Zeiss Imaging
Lens Configuration: single lens
Emulsion: digital arrays
Negative Size: none
Mount: gyro-stabilized
Vacuum: not needed
Viewfinder: flight management system

The DMC is used experimentally by contractors for NGS. The Zeiss DMC (Digital Mapping Camera) is a frame camera and is multi-lens. Each of the five lenses is dedicated to Red, Green, Blue, B&W, and Near- IR wavelengths.

DSS
2005-present

Manufacturer: Applanix
Lens Configuration: single lens
Emulsion: digital array
Negative Size: none
Mount: gimbal
Vacuum: none
Viewfinder: Flight Management System

The newest addition to the NGS family of mapping cameras is the Digital Sensor System (DSS) made by Applanix Corp. It is single lens and records onto a digital array. Simultaneous records of GPS position and IMU (Roll, Pitch, and Yaw of the airframe are incorporated into the DSS Hard Drive. Presently NGS uses two DSS Cameras in Tandem; one filtered and devoted to near IR.

Vexcel Ultracam-x

Manufacturer: Vexcel
Designation: “X”
Lens Configuration: large format
Emulsion: digital array
Negative Size: none
Mount: gyro-stabilized

Example of an Ultracam-x digital image.

The Vexcel Ultracam-x uses multi-lens technology, each lens projecting at a select wavelength and recorded through separate digital arrays. Used commercially NGS has accepted tests run by contractors using this Ultracam x.