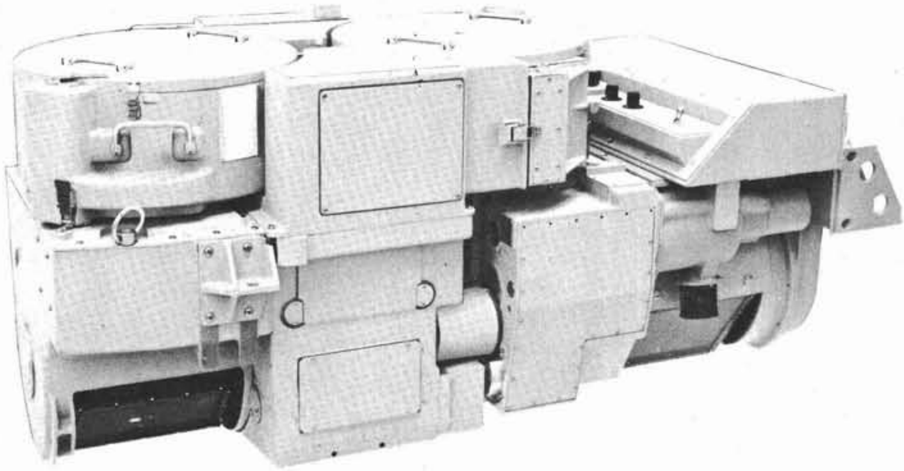

FIG. 1. KA-92 panorama camera.

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The KA-92 Camera System*

A new approach to photographic reconnaissance.

(Abstract on page 1226)

INTRODUCTION

IN 1969, the U. S. Navy issued a requirement for a panoramic photographic system which would fulfill its reconnaissance needs for present and future carrier-based tactical reconnaissance jet aircraft. The main design objectives for the system were specified as:

- Single sensor for operation throughout the complete flight envelope of the aircraft.
- Highest practical uniform ground resolution performance over the entire flight envelope.
- No thermal conditioning of the camera system to meet the performance other than that normally provided by the aircraft's environmental system.
- Full 180° horizon-to-horizon field of view, perpendicular to direction of flight, and long-distance linear coverage along the line of flight.

The KA-92 Camera System, shown in Figure 1, has been designed to fulfill these objectives. Full panoramic coverage (180° scan angle) is provided over the entire range of operation encompassing the low-, the medium-, and the high-altitude missions. The capability to provide this wide coverage has been incorporated within a single operating camera utilizing two photographic channels. Several additional subsystems within the camera provide the necessary controls and adjustments to insure high performance throughout the wide operating range. Provision is made for obtaining the imagery on many film types including black-and-white emulsions of different sensitivities and resolving powers, infrared color film, and Ektachrome type color films. Five-inch wide, thin base, perforated film is used. Two inter-

*Presented at the Annual Convention of the American Society of Photogrammetry in March 1974 in St. Louis, Mo.

changeable film cassettes are provided for film storage.

A low-profile camera configuration has been designed, installed and flight tested in a high performance Navy aircraft. With this form factor the camera will readily fit in other existing and future Navy aircraft.

System Concept

The panoramic camera system approach implemented consists of a single camera system into which have been incorporated two photographic channels to provide selectable channel imaging on a single image plane. (See Figure 2, Camera Configuration). These photographic channels provide for panoramic performance at the two selected focal lengths of 9 inches and 24 inches with channel upon the single imaging plane. An image is formed, by the selected photographic channel, in the rotary image plane. The image velocity is proportional to that of the scanning rate and the optical barrel radius. The film located in the rotary image plane, is moved in contrarotation to that of the image at a rate such that the required relative velocity for image-to-film synchronization (proportional to the selected focal length and to the scanning rate) is attained. A single film transport mechanism provides the proper contrarotational film velocity at the rotary imaging plane.

One film supply and takeup assembly provides the necessary film transport functions to and from the rotary image plane. A variable-width slit mechanism is utilized for

Abstract: *The KA-92 Camera is the latest panoramic camera development of the U. S. Navy, designed and manufactured by Fairchild Space and Defense Systems. The system is designed to provide high-resolution horizon-to-horizon panoramic photography over the present and future range of military aircraft flight envelopes. This is accomplished by providing a unique system with two selectable lens focal lengths within the single sensor. The desired lens channel can be selected remotely by the operator providing maximum flexibility for altering mission plans in flight. The design, which includes a novel automatic focusing feature, permits immediate use of the equipment with no preconditioning required to attain optimum performance. A built-in stabilization system has been incorporated to obviate the necessity for a stabilized mount to compensate for aircraft motion during the photographic run. A high-speed, solid-state data-annotation system, meeting the requirements of MIL-STD-782, is provided to record aircraft data on moving film.*

minimum duplication of major and minor subsystem functions. (Selection of these two particular focal lengths has been made in consideration of the maintenance of high performance throughout the requisite altitude and *V/H* ranges and within prudent limits of the mechanism and film dynamics for long life and high reliability). The resultant maximum commonality and minimal duplication of functions provides the user with maximum reliability and minimum overall complexity for the high performance and wide-range coverage required of the overall system.

Both photographic channels operate on the same basic principle—that of obtaining panoramic imagery by rotation of the optical barrel assembly which includes the frontal scanning mirror, lens, and rear image-directing mirror about a common axis. This rear mirror provides for channel selection by direction of the light rays of only the desired imaging. Range focusing is accomplished by displacement of the center-of-rotation of the optical scanning barrel with respect to that of the contrarotating film transport wheels and represents a single function that is common to both photographic channels. Only the separate iris assemblies necessary for individual control of the lens apertures, and the forward motion compensation (FMC) mechanisms, deliberately designed as separate and independent functions because of practical mass and momentum considerations, represent duplicated functions in this dual channel camera. Additionally, a single temperature/pressure correction focus adjustment is applied to the 24-inch focal-length channel to provide optimum performance of this channel without thermal preconditioning.

Each photographic channel operates in the autocycle mode only to provide the total

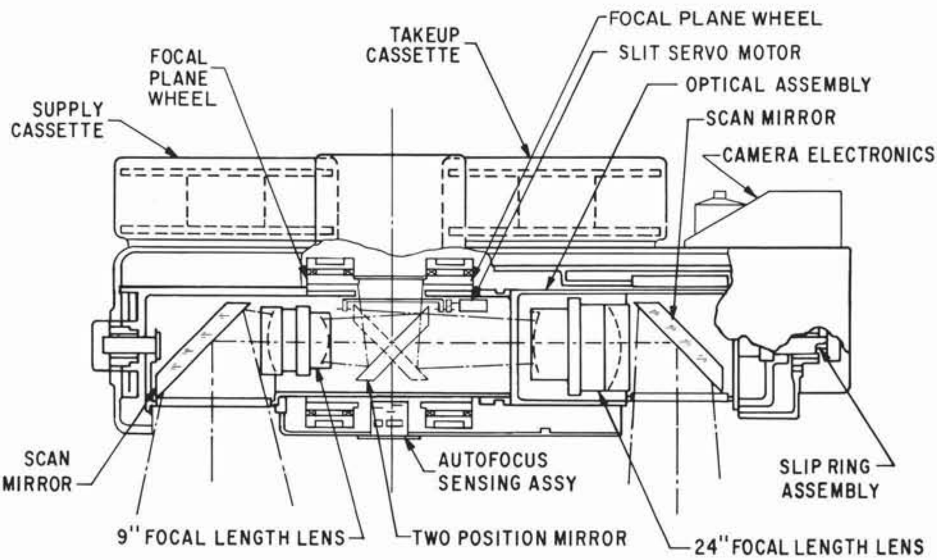

FIG. 2. KA-92 ( ) camera configuration.

necessary coverage of the complete altitude and velocity range. Most of the control problems, introduced by the two-channel design, are offset by the omission of the usual pulse mode operational controls and the complexities attendant thereto. Compensation for aircraft motions, often attained by expensive gyro-stabilized multi-gimbal platforms (in and of themselves complex electromechanical systems), is accomplished simply and reliably by corrections applied to the camera scanning/film synchronization and FMC mechanisms already provided within the camera system. Roll and pitch rate gyros mounted within the camera provide the signals determine the aircraft motion.

The camera system incorporates an Instantaneous Data Annotation System meeting the MIL-STD-782 data block. The recording system utilizes an array of gallium light-emitting diodes and represents a major advance in data annotation systems providing recording on moving film at speeds up to 250 inches per second.

The single KA-92 camera sensor replaces two or three complete camera systems in combination with one or more accompanying stabilized platforms. Accordingly, cost effectivity and higher reliability has been achieved because of this reduction in complexity.

A summary of the camera parameters is given in Table 1.

Scan Drive System

Panoramic scanning is accomplished by rotation of the optical barrel barrel about its longitudinal axis. The frontal mirrors scan the ground. The mirrors bend the rays 90 degrees, directing them into the lens, which in turn images the photography, by means of the focal-plane mirror, through the exposure slit, and onto the cylindrical focal plane. (See Figure 3, Optical Barrel Configuration). As the focal plane radius is less than the focal length of either lens, the relative image linear velocity must be larger than that provided by the scanning rate. The film, therefore, must move in the opposite direction to that of the slit.

The scan angle for both channels is 180 degrees. If the radius of the focal-plane wheels is half of the 9-inch lens focal length, and if the optical barrel and the film move continuously, the exposed film will just clear the 180-degree focal plane while the scanning mirror is masked by the camera. Thus, the end of the exposed film and the exposure slit will meet at the beginning of the 180-degree photographic scan. This mode of operation has been chosen for the 9-inch channel, permitting the practical use of high cycling rates due to the absence of intermittent film motion. (Actually, the focal plane radius is 4.25 inches to provide for data space between frames). The 24-inch lens channel must operate with intermittent film motion, however, because the above consideration cannot be satisfied by a single focal plane. The maximum cycling rate of the 9-inch channel is 8 cycles/second to obtain a 55-percent overlap. The maximum cycling rate of the 24-inch channel is 1.5 cycles/second. The details of the film han-

TABLE 1. KA.-92 CAMERA SYSTEM PARAMETERS

Camera Type:	Reconnaissance, Panoramic, Dual Photographic Channel, Moving Film, Low-High Altitude	
Channel Designation:	Low Altitude Channel	High Altitude Channel
Lens:	9-inch, *f*/4.0	24-inch, *f*/4.0
Nominal Format:	Fixed Format: 4.5 × 28.3 Inches	Selectable Formats: (A) 4.5 × 75.4 Inches (B) 4.5 × 37.7 Inches
Film Capacity:	5-Inch by 4,800 feet, Thin Base	
Mode of Operation:	Autocycle with Manual Selection of the Two Channels	
Forward Overlap:	55 Percent	
Exposure Control:	Relative Shutter Speed and Lens Aperture Automatic. Manual Selection of AEI and Filter Factor.	
Data Recording:	Coded Solid State Data Matrix Recording per MIL-STD-782 and Fixed Data	
V/H Range:	0.119 to 1.79 Radians/Second (0.070 to 1.06 Knots/Ft.)	0.015 to 0.126 Radians/Second (0.009 to 0.075 Knots/Ft.)
Cycling Rate (Autocycle):	0.53 to 8.0 CPS (55% Overlap)	0.167 to 1.5 CPS (55% Overlap)
Shutter Speeds:	1/60 to 1/1,500 Sec. at 0.53 CPS 1/900 to 1/22,000 Sec. at 8 CPS	1/450 to 1/11,000 Sec. at 1.5 CPS 1/48 to 1/1,200 Sec. at 0.167 CPS
Dynamic Bench Test Resolution (EK 3400 Film) High Contrast):	95 Lines/MM at 3 CPS	90 Lines/MM at 0.5 CPS
Range-Focus	Built-In Automatic Correction	
Lens Focus:	Built-In Automatic Focusing System in 24" Channel (Temperature & Pressure)—No Camera Preconditioning Required	
IMC Range:	1.10 to 16.1 Inches/Second	0.36 to 3.03 Inches/Second
Electrical:	AC, Three Phase, 115/200 Volts, 400 Hz, 1200 Watts Max. DC, 24 to 28.5 VDC 170 Watts Max. (No Roll Correction) 310 Watts Max (Max. Roll Correction)	
Vehicle Motion Compensation:	Built-In Roll and Pitch Correction (Rate Gyros Internal to Camera)	

dling system and the other camera components are described below.

The scan-drive servo provides the driving torque for the optical barrel assembly and focal-plane film wheels, and controls the rate of film exposure across the scanning slit. Control of the scan rate is proportional to the *V/H* input modified by the pitch rate, and the mode of operation (9-inch or 24-inch channel) signal inputs. (Pitch rate is included inasmuch as its effect on cycling rate is essentially the same as that of V/H).

To provide the camera resolution levels, the required extreme accuracy in synchronization between the scanning motion of the optical barrel and the film velocity must be maintained. This is provided by a *jitter*-free friction drive system to the barrel and wheels. A motor driven mechanical speed-changer changes the speed ratio between the barrel and focal-plane wheels to accommodate the two respective channels.

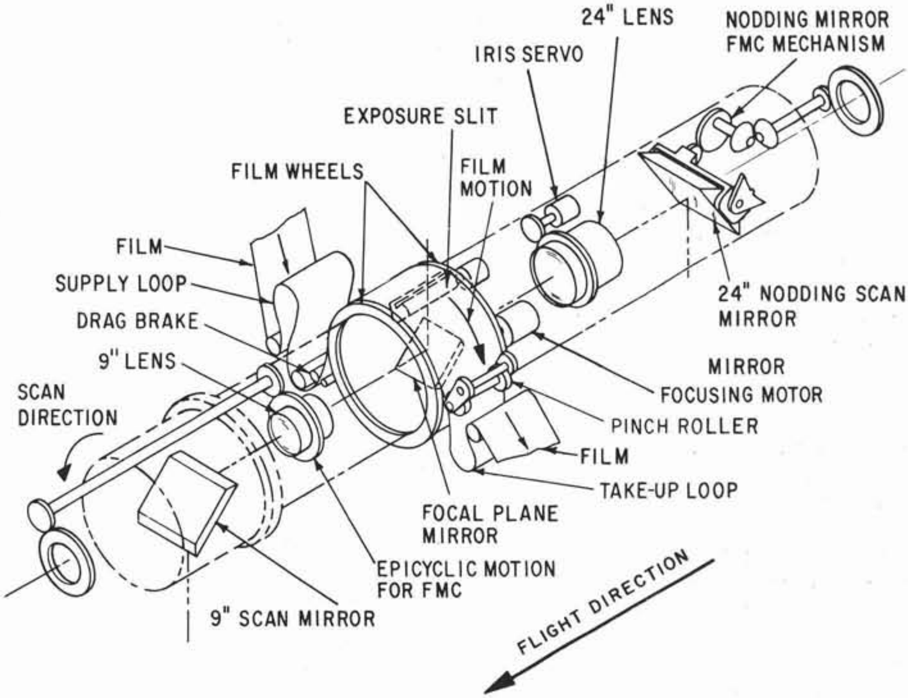

FIG. 3. Optical configuration.

FILM TRANSPORT SYSTEM

The Film Transport System controls the flow of the film throughout the camera from supply spool to take-up spool. It automatically satisfies the film-motion requirements for both channels of camera operation. It consists of three film-handling subsystems, the upper film drive, the lower film drive, and the focal-plane transport. The film transport through the camera system is powered by two separate and distinct sources. The film-drive servo powers the upper and lower film-drive subsystems and the scan-drive servo powers the focal-plane transport subsystem and the optical scanning.

The upper film drive controls the unspooling of fresh film from the supply spool, the feeding of film into and out of the shuttle storage region, and the winding of exposed film on the take-up spool. The film-drive servo motor drives the film continuously during camera operation in either channel through a three-speed transmission. Suitable clutches are used in the film-drive assembly to provide nominal film speeds proportional to cycle rate for the different camera modes of operation. Two film-tension arms control supply spool braking torque and take-up spool drive torque as a function of film tension. The supply arm acts as a variable-drag torque coupling to ground and the latter as a variable-torque clutch between take-up spool and drive.

The lower film drive controls film motion between the upper film drive and the focal-plane transport. It makes fresh film available on demand at the input to the focal plane transport subsystem and accepts exposed film at the output. The lower film drive meters film continuously during camera operation in the 9-inch channel and intermittently in the 24-inch channel.

The focal-plane transport subsystem controls film motion through the focal plane region, i.e., over the film wheels. The subsystem contains the necessary mechanisms to provide proper film tension and braking at the focal-plane wheels, and the pinch-roller mechanism necessary to provide film transport at the film wheel speed. Film is metered continuously during camera operation in the 9-inch channel and intermittently during the 24-inch channel operation. The film wheels are driven by the scan-drive motor servo in proper speed relationship with the camera cycle rate, as previously described.

FILM LOOP CONTROL

Film velocity, through the focal-plane area during photography, must be precisely controlled in synchronism with scan velocity, whereas throughout the rest of the camera there is less need for such accuracy, so long as average long-term film velocities are alike.

In order to prevent interactionwith the upper and lower film drives as a result of instantaneous velocity differences, provision is made for isolation by maintaining slack film loops on the supply and take-up sides of the focal-plane transport subsystem. The limited storage capabilities of these loops coupled with other transport system constraints mandate close control of loop size at all times.

The supply loop size is controlled by utilizing three light-emitting diodes (LED) and photodetectors (operating in the red portion of the spectrum) to monitor supply loop size. Film drive speed correctons are made in accordance with the size of loop monitored.

Two loop sensors, each consisting of an LED and a photodiode, are located in the lower film loop guide assembly. These sensors signal short and long loop limits, and will interrupt camera power if the film loop travels beyond the proper limits.

Film-Drive Servo Electrical System

The film-drive servo tracks the film velocity across the focal-plane wheels as determined by the scan-drive velocity with roll correction. An optical incremental tachometer is geared to the scan-drive shaft by a ratio which provides pulse at proper intervals for triggering the data annotation head. The frequency generated by the rotation of this tacometer is proportional to the velocity of the focal-plane wheels, and hence the film velocity.

After conversion to a proportional DC voltage this information is used as the input command to the film-drive servo. The tracking accuracy of the film-drive servo is determined by the accuracies of the frequency to DC conversions and by the servo gains. However, even with the best possible accuracies in these elements, a small error in velocity will be present which would accumulate to deplete the free loops at the film wheels. To avoid this, speed correction information obtained by loop-length sensors is used to trim the scaling of the film drive to maintain proper loop lengths.

Vehicle Motion Compensation

Compensation for image motions due to camera attitude perturbations, as a result of aircraft pitch and roll, is achieved by utilizing two rate gyros to generate pitch and roll velocity information to which the camera can respond. The gyros are located in the forward end of the camera above the optical barrel.

Roll rate information is fed into a servo which drives the planet carrier of a mechanical traction-drive differential mechanism, in the film-wheel drive train, to modulate the velocity of the film wheels.

Pitch rate information is combined with the *V/H* signal input to the scan servo which drives the optical barrel.

Proper synchronization between the velocity of the optical barrel (scan rate) and the velocity of the film wheels is maintained because these elements are driven by the same motor.

Camera Optical System

As shown in Figure 3, two mirrors (scanning mirrors) in object space, one in front of each lens, bend the optical path 90 degrees. Rotation of the optical barrel along the longitudinal axis causes the scanning mirrors to scan out a linear raster in object space whereas the focal-plane mirror located in image space bends the optical path approximately 90 degrees and directs the imagery onto the curved focal plane. The rear elements of the two photographic objectives face each other enabling focal-length selection by appropriate orientation of the focal plane mirror in the image space shared by each objective. The focal-plane mirror is pivoted inside the optical barrel and rotates around an axis located at the mirror surface. The angle of rotation is such as to focus the selected lens into the focal plane. The rotation is performed by an actuator motor and is controlled remotely by the operator from the aircraft control panel.

Both lenses are designed and manufactured by Fairchild. The short focal-length lens is a low-distortion, 9-inch focal length, *f*/4.0 objective of a reverse-telephoto form to afford sufficient back focal length for folding the optical axis in the image space through an angle of 90 degrees. In addition, the vertex-to-vertex dimension of the design is constrained to a minimal value. The design is an eight-element asymmetric double Gauss construction.

The long focal-length lens is a low-distortion, 24 inch focal length, *f*/4.0 objective with a vertex-to-vertex distance of only one-half the focal length. This compact form allows sufficient back focal distance for folding the optical axis, in the image space, through an angle of 90 degrees. The design is a compact nine-element form with all elements having spherical surfaces.

The designs of both lenses have been optimized for low-contrast resolution by reducing the image errors that depend on aperture (spherical aberration, oblique spherical aberration, and coma). Special attention has been given to color correction in the designs. Through particular glass selection and optical power distribution, the residual chromatic aberration (secondary color) has been reduced to afford greater versatility in the choice of aerial films, particularly the new color films.

Special attention was given to the thermal and mechanical stability of the folding optics and their mounting configurations. This is particularly critical in the present application where the mission configuration is such as to provide an extremely short time from start of mission until operational status must be reached. This short period will not provide adequate soaking time at operational temperatures for the mirror/mount assembly to reach thermal equilibrium thus subjecting the mirror/mount to a high degree of thermal and mechanical distortion. The tendency is to warp the flat mirror surface adding uncontrolled power to the optical system effecting focus and thereby degrading imagery. In addition, for the 9-inch focal-length channel mirror, the deflections caused by the forces on the mirrors due to the high-speed optical barrel rotation was also considered to assure satisfactory optical performance.

By the proper selection of materials and the incorporation of a new mirror mount design, these problems have been eliminated. *Cer-Vit* is used as the mirror substrate for its desirable thermal and stiffness characteristics. A unique mounting arrangement has been provided for the three mirrors offering a minimum strain caused by mechanical and thermal forces. The mirrors are mated to the barrel support with mirror rods in holes passing through the mirror neutral plane. Sylastic pads separating the rods and the mirror provide the necessary stiffness to maintain pointing of the mirrors and yet sufficient compliance to allow for thermal changes.

All the optical elements are mounted in a tubular aluminum structure. The structure consists of three sections, piloted and bolted together. The center section is split longitudinally into two pieces for ease in assembly and adjustment of the focal-plane mirror. Figure 4 illustrates the optical barrel construction. The entire optical barrel assembly is dynamically balanced to minimize self-induced vibration. The barrel is supported at both ends in precision ball bearings, a preloaded duplex pair at the aft end and a single one at the forward end. The duplex pair provides preloaded axial constraint and the single forward bearing allows for free axial movement in both fore and aft directions. The axial freedom provided at one end is necessary to allow for expansion or contraction of the barrel due to temperature changes. The barrel is driven in a rotational mode by the Scan/Film Drive Servo via a precise friction-drive system of hardened pucks.

At the end of the barrel, a rotary slip ring assembly is used to feed electrical signals into the drum while it is rotating. In addition, a one-revolution-per-cycle timing disc is keyed directly to, and driven by, the barrel. The timing disc is a code wheel which is part

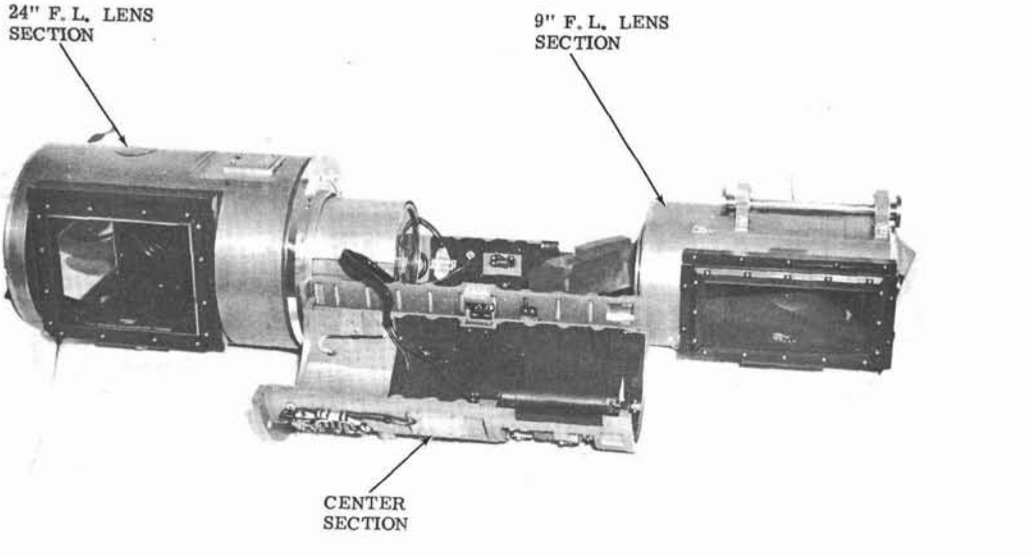

FIG. 4. Optical Barrel (shown with center section open).

of the sequence timer system, which controls camera cyclic functions such as intermittent film transport, fiducial firing and data print.

Forward Motion Compensation

Forward Motion Compensation (FMC) in the 9-inch F. L. channel is obtained by translating the camera lens along an axis normal to the principal axis of the optical barrel. The motion of the lens is sinusoidal with a fixed peak amplitude of displacement about the center of barrel rotation and in proper phase with the scan angle. The phase relationship is such that peak linear velocity (zero displacement off barrel center) of the lens is achieved at the center of scan (nadir). Translation of the lens is accomplished in an epicycloidic mechanism which causes the lens pivot member to rotate in the same direction and at twice the rate of the optical barrel. The net result of the configuration and relative motion of the mechanism is a rectilinear sinusoidal motion of the center of the lens relative to a coordinate system rotating with the barrel.

Forward Image Motion Compensation in the 24-inch F. L. channel is obtained by nodding the scan mirror sinusodially through a fixed angle of displacement about the nominal 45° tilt and in phase with the scan angle. The angular displacement of the scan mirror is determined by a rotating eccentric cam and follower arrangement built into the mirror support assembly. The cam is driven by rotation of the optical barrier at an exact rate of one revolution per camera cycle. Mechanical power is transmitted via a system of gearing from a planetary gear on the mirror support assembly to an orbiting *stationary* sun gear on the barrel shaft. The sun gear is held stationary by an integral pawl on the camera body.

Focus Compensation

Compensation for focus shift due to changes in range, temperature, and pressure are built in the KA-92 Camera System. Both channels have provisions for range focus correction. The 24-inch channel has additional provisions for temperature and pressure focus compensation. The small focal length shift in the 9-inch channel, due to temperature and pressure variations, does not require this correction.

Range focal shift occurs if the object distance is shorter than the hyperfocal distance of the lens. Fairchild has developed a compensation technique applicable to cameras with a cylindrical focal plane that does not require dynamic tracking of the scan angle as a function of altitude, and is consequently more reliable at high cycling rates.

This technique has been incorporated on this camera system. The center rotational axis of the film wheels (focal plane) is displaced upwards in relation to the principal axis of the optical barrel as a function of the vehicle altitude for the proper focal shift compensation at nadir. Focus shift at the horizon is essentially zero and increases as a function of scan angle to the proper position at nadir. Computations show that the residual geometric errors in the proposed compensation system are smaller than 0.0002 inch for all camera scan angles. It should be noted that changes in range focus automatically cause compensating changes in the image velocity and no film velocity adjustment is required.

The implementation of this mechanism is accomplished by mounting the film wheels in a carriage assembly which, in turn, is supported in the camera body on a single pivot shaft and a cam/follower mechanism. The pivot axis is parallel to and displaced from the optical-barrel axis, and hence the film-wheel axis, by approximately 9 inches. Rotation of the two cams drives the carriage up or down thereby displacing the wheel axis from the barrel axis. A servo system responding to altitude signal information from the vehicle drives the cams and hence the carriage to the proper position.

The 24-inch lens focus shift occurs due to temperature and pressure changes causing a focal-length change and the thermal elongation or contraction of the camera structure. Long periods of camera soak in a controlled thermal environment would be required to permit peak photographic performance in this channel without the autofocus system provided. This unique feature automatically compensates for small deviations in camera optical characteristics providing for *best-focus* photography under a broad range of temperature and pressure conditions. The autofocus sytem functions by directly sensing deviations in the back-focal distance of the 24-inch F. L. lens, as a result of temperature and/or pressure changes, and automatically restores the camera to a *best-focus* condition. The autofocusing procedure takes place each time the 24-inch channel is switched into Ready mode.

The diagram of the autofocus system, Figure 5, depicts the only two additional optical elements necessary to provide the autofocus feature. They consist of an optical transmitter/receiver unit which is rigidly fixed to the camera body directly underneath the motor driven focusing mirror, and a flat

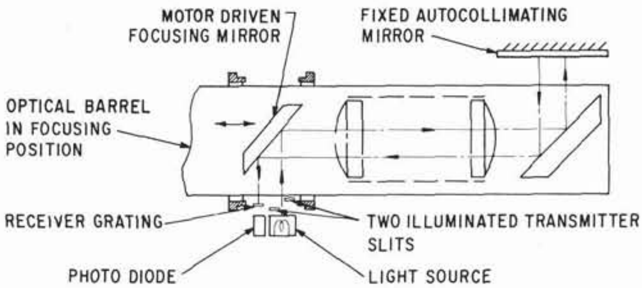

FIG. 5. Autofocus system.

mirror also fixed to the camera body and located directly above the 24-inch F. L. lens-scan mirror. A light source in the optical transmitter/receiver unit illuminates two transmitter slits which are longitudinally staggered along the optical axis and laterally offset slightly from one another. Light energy passing through these two slits is collected by the 24-inch F. L. lens, transmitted through the lens, reflected back by the autocollimating mirror, transmitted back through the lens and returned to the receiver portion of the transmitter/receiver unit. The receiver consists of two gratings in the same plane (i.e., no separation along the principal optical axis), and a photodiode detector behind them.

The 24-inch F. L. lens forms an image of each transmitter slit in the receiver, one in front and one beyond the receiving gratings, respectively. Rotation of the optical barrel causes the images of the transmitter gratings to be swept across the receiving gratings resulting in two bursts of light energy, getting through the receiver grating for each transmitted slit. The light energy passed through the receiving grating falls on a fast-response photo-diode converting the light energy to electrical pulses proportional to the total amount of light falling on the detector in a given time.

The transmitter/receiver unit is positioned along the principal optical axis and relative to the 24-inch F. L. lens back-focal distance so that at *best focus*, for a given position of the focal-plane mirror, the images of the transmitter slits are formed equidistantly in front of and beyond the receiving grating. This situation results in equal light-energy bursts falling on the detector and like pulses emitted therefrom. Any change thereafter in the camera which would cause the images of the transmitter gratings to be disposed unequally about the receiver grating would result in unbalanced energy bursts. Comparison of the two pulse shapes, after suitable amplification and conditioning, results in an error signal which is applied to a step motor which drives the focal plane mirror incrementally, to change the back-focal distance until balance is achieved.

This optical transmitter/receiver unit consists of a light source, condenser optics, a prism, a field lens, and the photodiode detector. The transmitter optical path is folded for packaging convenience, and both transmitter slits and receiver gratings are deposited on the prism faces for permanent control of spacing and registration. The entire assembly is doweled to the camera body and may be removed for routine cleaning of the grating surfaces or lamp replacement without loss of adjustment or optical settings.

AUTOMATIC EXPOSURE CONTROL

Exposure control is accomplished by means of a variable slit and a variable lens diaphragm. The automatic exposure control (AEC) system is designed so that the minimum possible slit width and the maximum diaphragm opening are automatically selected. This insures that all photographs are exposed at maximum shutter speed and image degradation caused by image motion is minimized. For high terrain illumination levels and low cycling rates, the slit is held to its minimum opening and the diaphragm is closed down. For decreasing terrain illumination or increased cycling rate, the diaphragm is opened to minimum *f*-number and then the slit width is increased. Both the 9-inch and 24-inch diaphragms have their own servo drive motor and feedback potentiometer. A single servo amplifier is used and is switched to the appropriate motor by a focal-length select relay.

The slit is controlled from 0.020 inches to 0.500 inches and the diaphragm from *f*/4 to *f*/16. The diaphragm control range is the same for both lenses. Therefore, the camera has the capability of controlling exposure over a range of approximately 8.65 stops. The system can also accommodate filters with the filter factor ranging from 1.0 to 4.0. There are separate controls for the 9-inch and 24-inch systems. The AEC is equipped to provide an exposure change of plus or minus one stop upon receipt of a command signal generated by the operator at the control panel.

Data Recording

The data annotation subsystem provides the capability of optically marking each frame with MIL-STD-782C data blocks. As the film is moving continuously and at extremely high velocities (as high as 250 inches per second) in the 9-inch mode of operation, a high-speed, high-intensity recording technique is required. The recording device is a gallium arsenide phosphide (*GaAsP*) light emitting diode array, which is arranged to form an image corresponding to one file of the MIL-STD-782 Block and prints simultaneously an entire file of 32 dots. The image is projected onto the film with a small recording lens. The high-intensity light output of these *GaAsP* diodes permits the recording of one file of data with an approximately exposure time of 10 microseconds. This short exposure time is sufficiently short to prevent excessive smearing of the dots even at the maximum film rate of 250 inches per second. Succeeding files of the data block are recorded by sensing film motion and repeatedly flashing the diode array at the appropriate time intervals for the proper spacing of the 18-column block.

A small interface unit is included in the system to interface circuitry between the aircraft signal converter and the solid-state recording head to permit retention of existing aircraft wiring.

Camera Test Program

Extensive laboratory testing has been conducted on the camera system. Dynamic bench resolution tests have produced resolution results of 95 lines per millimeter using the 9-inch channel and 90 lines per millimeter on the 24-inch channel using 3400 type film.

In addition, preliminary flight tests were conducted in 1973 at NAS, Albany, Georgia using a high-performance Navy aircraft as the test bed. The system was hard-mounted in the reconnaissance module. During this testing it was demonstrated that thermal preconditioning of the equipment was not required because of the built-in focusing features provided. The preliminary flight test results have shown the high performance potential of the camera system. Typical photography taken during these tests is illustrated in Figure 6.

Fig. 6. KA-92 camera photograph.

Because of the number of cycles accumulated on the camera during the laboratory and flight test program (in excess of 480,000 cycles) the camera is presently undergoing a thorough refurbishment in preparation for further flight testing early in 1974. Some additional features are also being added, such as vibration isolation, and will be evaluated during the forthcoming tests.

Conclusion

The KA-92 Camera System is one of the most advanced panoramic cameras developed in recent years. It provides a high-performance panoramic picture-taking capability for the complete range of modern reconnaissance aircraft all within a single sensor.

Its unique focusing feature keeps the film properly focused for changes in object distance, temperature and pressure/altitude variations. The special optical system thermal design, and avoidance of the use of large masses of optical glass, assures thermal stabilization of the system within the desired time. This, combined with the focusing features, eliminate the requirements for thermal conditioning to attain optimum performance, a severe limitation in all existing long focal-length camera systems. Roll and pitch motion errors are eliminated by the addition of suitable differential corrections within the scanning and forward motion compensation systems. This minimizes the degradation due to these aircraft motions without the need to resort to complex and bulky gimballed mountings.

The *state-of-the-art* high-speed data annotation system, fully meeting the stringent tolerances of MIL-STD-782, is achieved by use of a solid-state light-emitting array exposing the film *on the fly*. This is the first camera to be developed using this unique system.

Finally, a critical examination of the design indicates that the equipment is not a highly sophisticated experimental camera, but constitutes practical military hardware having a low total life cycle cost. It can be manufactured in production quantities at an acceptable delivery rate and within a reasonable cost.