A Microcomputer-Based Camera Control System

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ABSTRACT: It is economical and preferable to use helicopters for the acquisition of small format, large-scale aerial photographs in northern Canada due to the large land area and small number of airports. To facilitate air photo procurement, a computer-based control system was designed and packaged for rapid installation into unmodified helicopters, to operate from its own source of battery power, and to work in conjunction with an external, removable camera pod. This paper describes the requirements, design, and performance characteristics of the camera control system that was developed.

INTRODUCTION

THE USE OF HELICOPTERS IN PHOTO ACQUISITION

There are few airports and runways in northern Canada. As a result, long ferry flights are required to move conventional fixed-wing aircraft to the site of an air photo mission. Helicopters, however, are often located and available in small communities. Though their rental cost is higher than fixed wing aircraft, this is justified by shorter ferry distances and their capability to land in small clearings. The slower forward flying speed and lower flying height capabilities of helicopters are also preferable when photo scales of 1:200 to 1:2000 are required. For example, a typical photo scale for sampling regeneration stocking is 1:500 (Hall, 1984); and a typical scale for sampling timber volumes is 1:1000 (Aldred and Lowe, 1978).

HISTORY OF THE PROJECT

The Northern Forestry Centre (NoFC) in Edmonton, Alberta, has previously been involved in research to develop and refine methods of obtaining and applying small format, large-scale aerial photographs for forest inventory surveys (Kirby and van Eck, 1974; Kirby, 1980; Hall, 1984, Spencer and Hall, 1988).

In 1974, a mechanical camera control system (van Eck and Bihuniak, 1978) was developed for aerial photo operations. In 1981, the requirement arose for a more functional system that would be simpler to use, and yet provide for more rigorous control of photogrammetric parameters such as overlap and image motion.

An advanced control system for 70- and 35-mm cameras at that time was in operation at the Ontario Centre for Remote Sensing (Roberts and Hiscocks, 1981). This system included a Commodore PET computer * and is capable of controlling up to four cameras of three different types (Vinten, Hasselblad, Nikon). A joint redesign effort was undertaken to adapt that system for helicopter use, reduce the size and weight of the system by using newer electronic technology, convert the system to battery power, and interface and connect the system to the cameras and radar or laser altimeter that were in a self-contained helicopter camera pod. The system software was completely rewritten to improve the operator interface, and the control system was redesigned to mount into an aeronautically approved instrument rack, which attaches to the seat rails of the Bell 206B Jet Ranger helicopter.

Since then, operational use has resulted in a number of technical refinements, the building of a second system for the Yukon Northern Affairs Program, and the manufacture of an additional system for private industry. The purpose of this paper is to describe the components, funtionality, and performance characteristics of the camera control system.

THE CAMERA CONTROL SYSTEM

THE CAMERA MOUNT

In the past, both internal and external camera mounts have been used on helicopters. Internal camera mounts allow access to the cameras for film changes, leveling, and drift adjustment, but they require modified aircraft (Benson *et al.*, 1984). External camera mounts have the advantage of not requiring modifications to the aircraft, but they require preflight leveling and the aircraft must land to change film magazines. The NoFC system uses an external camera pod (Figure 1). A photograph and brief description of its features in relation to other systems is given in Spencer and Hall (1988).

The camera pod mounts to the underside of the helicopter and contains two 70-mm Vinten aerial cameras, a radar or laser altimeter and annotation display unit, and a monochrome video camera. Cables link the electronics in the pod to the camera control system rack inside the helicopter.

CONTROL SYSTEM HARDWARE

The camera control system instrument rack inside the helicopter contains a Commodore 64 computer, a Commodore 1541 disk

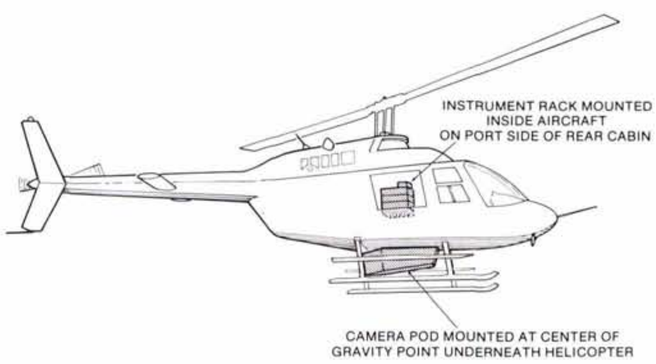

FIG. 1. Illustration of camera pod and instrument rack installed on helicopter.

*The mention of trade names does not imply endorsement by the authors.

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drive, an electronics subrack, the power management unit, 117-volt alternating current (AC) inverter, the control unit for the laser altimeter (or altitude indicator for the radar altimeter), and a consolidated battery power pack (Figure 2).

The Commodore 64 computer is responsible for executing the control functions, timing the cameras, and acquiring data from a radar or laser altimeter. The disk drive stores the operational programs for the system and the height data from the flight mission.

The center of the electronics subrack contains the video display screen, which shows computer data readouts and status indicators, menus for software operation, the video camera ground image, the moving grid that is synchronized to the speed of the ground image for determining cycling intervals, drift lines, and displays of the field of view of the two photo cameras. The left side of the electronics subrack contains power supply and plug-in cards for the camera relay interface and radar or laser interface. Empty card slots are available for future expansion of the system.

The power management unit serves a number of miscellaneous functions. Its principal purpose is to act as a connection point for the 17 cables to the pod electronics and to organize and distribute the system electrical power. It also contains a digital voltmeter to monitor system voltages, power on and off switches, 117-volt AC outlets, and control functions for the Vinten cameras. The camera control functions consist of two single-shot relay interfaces, electromechanical frame counters, camera heater switches, 8 picture per second (PPS) and 4 PPS selector switches, film wind indicators to confirm that film is moving through the camera, switches for selection of continuous or single-shot camera operation, and selector switches for the motor-driven lens apertures. Noise filters in the power management unit isolate

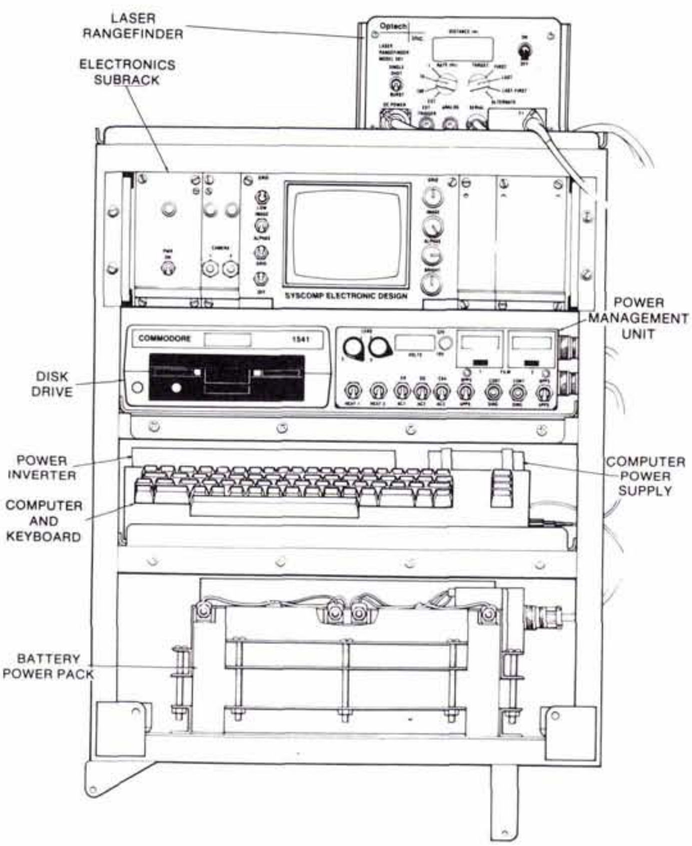

FIG. 2. Camera control system components mounted on the instrument rack.

the 40-millisecond, 20-amp noise pulses generated by the Vinten camera from the rest of the electronic circuitry.

The inverter (Flite-tronics PC -16) converts the direct current of the battery to 117-volt, 60-Hertz alternating current (sine wave) for operation of the disk drive, the computer, the electronics subrack, and any ancillary test equipment. The provision of AC line voltage simplifies maintenance, allows any unmodified disk drive or computer to be used in the system, and makes it possible to operate the system from AC line power when located in a hangar.

The system was designed to operate from a battery pack because some helicopters are not equipped with an auxiliary power connector. The battery pack supplies 12-, 24-, and 30-volts direct current (DC) from a series and parallel arrangement of 6- and 12- volt gel cells. Each output has a capacity of approximately 40 amp-hours, and the battery will operate the system for about 3.5 hours. The battery pack weighs 39 kg and has circuit breakers and Mil connectors for the system and battery charger. During flight operation, two identical battery packs are alternated. While one is in use a second identical battery unit is charged on the ground. Although ni-cad and lead-acid cells are physically smaller and weigh less than gel cells, gel cells were used because they are completely sealed, they do not vent hydrogen or spill electrolyte, and they could be certified for aircraft use. To take advantage of helicopters situated at various locations, heavy duty shipping cases were built for the pod, the rack, and each of the two battery units.

CAMERA TIMING

A major portion of the system software is a Commodore BASIC program that operates the computer displays and accepts operator data. It uses two small machine code programs: a screen editor and a camera timing routine. The screen editor simplifies the operator data entry process, provides rudimentary editing facilities, and locks out some errors that would otherwise abort a BASIC program. Using this routine, the operator enters the values for the camera film size, focal length, and desired overlap. The focal length of the video camera is usually fixed and is therefore given a variable name in the BASIC program. This variable is simply changed with the screen editor, however, if a video camera lens of a different focal length is employed.

Camera timing begins with a measurement of grid speed. Using a front panel control, the camera operator adjusts the rate of the moving grid (or grid speed) to the speed of the moving video image. Using the previously entered camera parameters, grid speed, and the intervalometer formula (Roberts and Hiscocks, 1981), the required firing intervals for the two cameras are calculated to obtain the desired forward overlap between photographs. The firing interval information is then passed to the machine-code timing-routine for the actual triggering of the cameras.

Grid speed may vary over a wide range and so the computer uses an adaptive measurement scheme that maximizes accuracy and minimizes the time between speed updates. At low grid speeds, a small movement of the grid across the screen is sufficient to obtain an accurate measurement. At high grid speeds, movement across the entire screen is used. In either case, the computer establishes a suitable distance for the grid to move and then measures the time (to a resolution of 1/60 second) for the grid to move that distance.

Sixty times per second, the Commodore 64 is interrupted from its operation of the main BASIC program to scan the keyboard, check the position of the grid, and check the camera trigger routine to determine if a camera should be fired. If a camera is to be fired, the electronic rack relay interface is actuated, which then triggers the Vinten Controller circuit.

The Vinten camera is a simple mechanism, consisting essentially of a motor-driven belt (shutter blind) with a slit shutter.

A cam switch closes at the beginning of a shutter cycle and opens at the end of a cycle. The Vinten controller circuit is required to apply full voltage to the camera motor at the beginning of a camera cycle and to short circuit the motor to dynamically brake it when the cam switch opens. In this system, the application and removal of voltages is accomplished by a combination of electronics and relays.

The speed of the shutter blind is controlled by a centrifugal switch inside the Vinten camera, which can be set to 4 or 8 PPS. In the 4 PPS position, the width of the slit gives an exposure of 1/1000 second: in the 8 PPS position, the belt speed is doubled and the exposure is halved. The shutter blind can be changed to obtain different slit widths.

Camera Timing Modes

The hardware controls and the software timing routines can be combined to operate the cameras in a number of different modes (Figures 3).

Continuous Framing. Under continuous framing, a steady DC voltage is applied to the camera belt motor and the camera will frame continuously at either 4 or 8 PPS. Continuous framing is intended for rare instances when photography from a high-speed, low-altitude aircraft is necessary. In this system, continuous framing is primarily used to check that a camera is working properly.

Single-Shot Framing. Most aerial photography is acquired in this mode. In single-shot mode, the cameras can be triggered manually by push-buttons or automatically by the computer. The computer can automatically calculate the timing interval between frames from the grid speed and the camera parameters (grid mode), or it can cycle the cameras on the basis of a manually entered timing interval between frames (manual mode). Manual-mode is useful when flying conditions are too unstable to use the video grid mode. The operator calculates the timing intervals between frames using a separate NoFC flight planning computer program, based on aircraft altitude and speed, camera focal length, film size and overlap, and cycling rate and shutter speed. The operator then manually enters the calculated interval.

Burst Mode. A camera in burst mode fires a burst of frames and waits for a specified interval before firing another burst. Burst mode is often used for sampling when 100 percent coverage of a flight line is not required. The operator specifies which camera is to be in burst mode, the number of frames per burst, and the waiting time, in seconds, between bursts. The timing interval between frames during the burst may be automatically calculated by the computer from the speed of the video grid to give the desired overlap, or it may be entered manually.

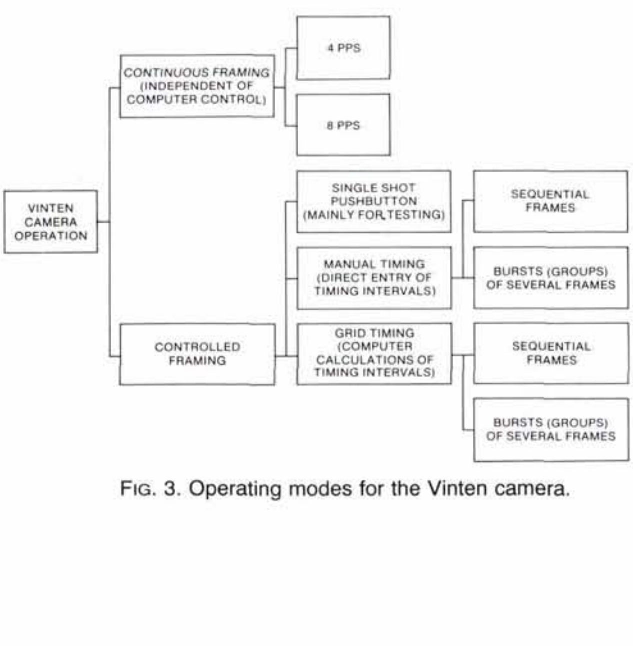

FIG. 3. Operating modes for the Vinten camera.

HEIGHT MEASUREMENT SYSTEM

Both a radar altimeter (Honeywell APN194-V) and a laser altimeter (Optech 501) have been interfaced to the camera control system. The radar altimeter outputs height data in binary format, 12 bits of information, corresponding to a resolution of one foot in a maximum range of 4095 feet. This information is delivered from the radar in a serial stream, which is then formatted and displayed on the video screen (as either feet or metres). The laser outputs metric data in four parallel, binary-coded decimal digits, corresponding to a resolution of 1/10 metre over a maximum range of 500 metres. This information is converted to a serial stream, input to the computer, and again displayed in feet or metres. Either altimeter is read at a 60-Hz rate as part of the interrupt routine of the Commodore 64 computer.

FLIGHT REPORTING

When *flight reporting* is toggled on, a flight record entry is made every time either of the two cameras is fired. Each data entry consists of the film frame counts for the two cameras and a height reading from the radar or laser altimeter. The flight record is stored in the shadow Random Access Memory (RAM) underneath the BASIC Read Only Memory (ROM) in the Commodore 64, where there is sufficient room for 1000 entries, corresponding to two rolls of camera film. The flight records contained in shadow RAM are then written out to a file on floppy disk when flight reporting is toggled off. A separate BASIC program is used at the conclusion of the flight to print out the flight record disk file.

The laser altimeter has an RS-232 serial output that is connected to a height display film annotation unit on Vinten camera #1. The annotation unit is synchronized to the Vinten relay controller so that the height reading is frozen when the camera shutter is in motion to allow the height reading to be recorded on the film frame.

THE VIDEO SYSTEM

There are three video sources in this system: the video camera display of the ground image, the computer alphanumeric video, and the moving grid signal. The ground image signal (from a 12-volt DC monochrome television camera, RCA type TC2055) and the moving grid signal (generatd by a special purpose digital circuit) are synchronized to the Commodore 64 alphanumeric video and then added together to generate the combined video screen image. Any combination of these sources can be displayed, and two rear panel connectors supply the camera image signal and the display screen image signal. Either can be recorded by a videotape recorder to obtain a video record of the mission.

A rectangle can be drawn on the video display to represent the field of view of the photo cameras because the aerial camera and video camera focal length information are employed in computer calculations. This is particularly useful when a ground feature must be centered in the photo camera frame. (The field of view of the video camera must be greater than that of the photo cameras.)

SUMMARY OPERATIONAL EXPERIENCE

Many features of the system have worked particularly well:

- There is independent overlap control for cycling both cameras using either aircraft ground speed from video tracking, or direct entry of previously calculated camera timing intervals.
- Flight recording information, which includes the camera frames fired and their associated flying heights above ground, has been employed in post flight film annotation and documentation.
- Operation from AC line power as well as battery power has been valuable in system training, testing, and software development.

- System monitors such as the film advance indicators and digital voltmeter have provided warning of potential faults as they have occurred.
- The system endurance on battery operation (3.5 hours with cameras firing) is satisfactory.

On the other hand, there are some limitations, which will be addressed through future development:

- The battery packs are heavy, and recharging in remote areas requires carrying a portable AC generator and fuel. Some helicopters are equipped with a connector to the 28-volt aircraft power bus and, where this is available, it should be used.
- The system currently uses 17 military connectors to connect to the pod electronics, all of which have to be connected with each system installation. This setup is time-consuming, and some form of quick disconnection would be preferable.
- Film exposure is currently set using a sun angle computer program, film step wedges, average gradients, and a Kodak aerial exposure computer. A light metering system and an aircraft attitude indicator, integrated into the camera control system, would provide optimal results. The differential light metering system by Fent and Polzin (1986) has been adapted for low altitude applications, but has not been integrated into the overall LSP camera system.
- The flight planning program is invaluable for preflight planning and calculations of camera timing, image motion, film consumption, and other parameters. The current NoFC program runs on a Hewlett Packard 9816 or 9825 computer and will be rewritten for the Commodore 64 and IBM PC. The latter is because of its more common platform and the program will be made available for public use.

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