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A Camera Mount and Intervalometer for Small Format Aerial Photography

A versatile mount for two small-format aerial cameras and an electronic intervalometer suitable to trigger such cameras are described in detail.

Introduction

Managers of renewable resources have long recognised the value of aerial photography and photo-interpretation in the assessment and management of those resources. In particular, large-scale aerial photographs are now an accepted medium for vegetation analysis. Much use has been made of black-and-white photography exposed in large-format cameras (230 by 230 mm), although in recent years there has been a marked swing towards the use of color films and small-format aerial cameras (70- and 35-mm focal length).

Color films are used because of their value in recording additional information which can be related to botanical or ecological factors or to variation in tree or stand condition caused by damaging agents. Small-format cameras are used to provide vertical aerial photography to supplement conventional photography and have the advantages of versatility and low cost coupled with increased control by the user over the photographic specification.

Abstract: *Scarcity of commercially available ancilliary equipment for small-format and large-scale aerial photography has encouraged the development of specialized devices by users. Approaches to the design and use of two items of equipment useful in the acquisition of small-format aerial photographs are described—a dual camera mount for 70-mm aerial photography and a camera intervalometer for small-format aerial photography.*

These developments have, however, posed problems for the user because there is a scarcity of commercially available ancilliary equipment for small-format photography, e.g., camera mounts and intervalometers. To meet these challenges, resource managers have developed a number of devices such as camera mounts to meet their own requirements. There have been many different approaches and thus many different solutions. Some of these developments have been reported formally, but many are recorded only in internal reports, if at all.

This report describes two devices developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, Division of Forest Research in the course of a program of research on the application of large-scale aerial photography to forest management problems. The equipment will assist in mounting small-format cameras internally in light aircraft for vertical photography and controlling the intervals between exposures for a number of cameras (*inter alia* providing a facility for sampling).

An Adaptable Dual Camera Mount for 70-mm Aerial Photography

The use of supplementary aerial photography taken with small-format cameras to provide the forest manager with up-to-date information for planning and recording purposes is well established (Aldrich *et al.*, 1959; Zsilinszky, 1969; Spencer, 1974). The camera mount is a critical part of the

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aerial photographic apparatus which can make the difference between sharp, drift-free photographs and blurred, 'crabbed' exposures.

Many small-format camera mounts have been described in the literature. The diversity of the designs reflects the variety of mounting situations encountered by the aerial operator, the camera equipment available, the type of photography required, and the nature of its application. The particular design chosen will be influenced by the following considerations:

- camera format—35 mm or 70 mm or other;
- camera make, shape, and attachment points;
- number of cameras required;
- camera accessibility during flight;
- camera vibration damping mechanism;
- drift sight and setting requirements;
- make and size of aircraft;
- availability of suitably modified aircraft and mapping camera mounts; and
- budget.

In order to put the mount which is described here into perspective, the main approaches and design features of some other small-format mounts which have been described in the literature will first be summarized. A simplified classification of small-format camera mounting systems, as they have been described, is shown in Figure 1.

One of the most specialized types of small-format mounting system is the external mounting of two cameras at a known distance apart to obtain fixed-base stereo photography. These cameras are usually mounted at the ends of a steel boom attached beneath a helicopter (Lyons, 1961; Spencer, 1979) or through a helicopter (Rhody, 1977). They have also been mounted at the ends of a metal frame which was hand held in a helicopter (Avery, 1958) and at the wing tips or on the wing struts of a fixed-wing aircraft (Williams, 1978; Benson et al., 1984). Cameras of 70-mm format have generally been used, including Hulcher (Lyons, 1964), Hasselblad (Rhody, 1977; Benson et al., 1984), and Vinten (Spencer, 1979), but the use of an F24 camera with 127-mm format has been reported (Lyons, 1961).

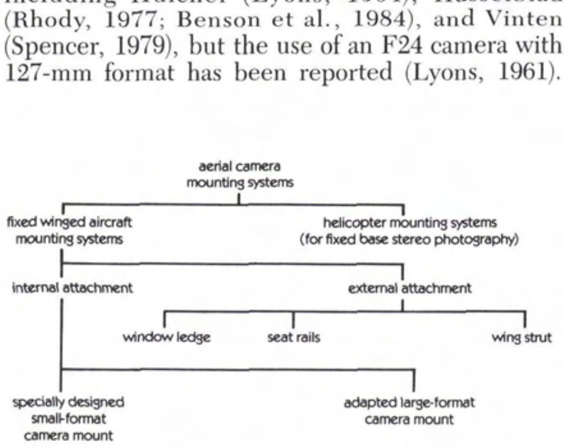


FIG. 1. Classification of small-format aerial camera mounting systems.

Most of the reported systems are rigidly mounted to the boom with some adjustment for camera levelling on the ground. One allowed for lateral or longitudinal tilt of both cameras simultaneously in the air to counteract aircraft tilt or to allow oblique photography (Rhody, 1977). Anti-vibration damping was included in one mount (Lyons, 1964). Drift-setting ability is not necessary because the two cameras are exposed simultaneously to obtain a stereo pair. Cameras are inaccessible during flight.

Most supplementary aerial photographs are exposed sequentially in a flight line to obtain stereoscopic coverage rather than from a fixed base. Mounts for obtaining sequential photographs may be either external or internal. External mounts have the advantage of not requiring modifications to the aircraft and are, thus, more versatile because they can usually be mounted on more than one aircraft. Three methods of attachment which have been used are to the window ledge, the seat rails, or the wing struts. Fisher and Steever (1973) described a simple metal frame mount which was hand-held out of a Cessna window. It contained four 35-mm Robot cameras for multispectral photography. The most commonly-reported method of external attachment is to the window ledge. Willingham (1979) used a wooden mount for a 35-mm Canon camera. Klein (1970) included vibration damping to his window mount for a 35-mm Miranda camera. Parker and Johnson (1970) mounted a large-format camera on a door-clamping frame, the K-20 with a 102-by 127-mm format. The mount could be levelled in flight. Meyer and Grumstrup (1978) described a sophisticated window-ledge mount for a variety of 35-mm cameras. This mount, which is now commercially produced, featured a wind deflector to protect the camera, levelling control, an aiming sight, and a hinged runner to permit retraction of the camera. None of these externally-mounted cameras allowed compensation for drift. Mason and Matthews (1979) devised a versatile mount which would accommodate either one or two 35- or 70-mm cameras and allow camera retrieval in flight as well as levelling and attitude adjustment. Attachment of the large mount is effected by two clamps on the window ledge and by four 127-mm heavy duty suction cups bearing against the aircraft exterior. Quite a different approach was described by CSIRO (1981) in which a Hasselblad 70-mm camera was mounted horizontally on the window ledge and aimed at an external mirror to achieve the vertical view. The advantages are that the camera is not exposed to the slip-stream and it is very accessible for lens or magazine changes.

Another approach to external mounting which has been used for 35-mm cameras is to clamp a retractable rod to the seat rails internally and project the camera through the open doorway (Spencer, 1974; Mennis, 1978). These mounts allow in-flight levelling but no drift adjustment and the cameras are exposed in the slip-stream. Cameras have also been clamped to the wing struts of Cessna aircraft. Strut mounts for 35-mm cameras have been described by Neustein and Waddell (1973) and Willett and Ward (1978), and for a 70-mm Hasselblad camera by Benson *et al.* (1984). These systems could not be levelled in flight nor adjusted for drift. The Hasselblad mount includes a wind deflector to shield the camera from the slip-stream.

All of the reported external mounting systems for small-format cameras except the strut mounts have the disadvantage of requiring an open window or door during flight, which can increase crew discomfort, impair aircraft performance and handling characteristics, and increase the risk to camera and personnel. Internal mounting systems suffer none of these limitations, they lend themselves to levelling and drift adjustment during flight, and the cameras are not buffeted by the slip-stream. However, they do require a modified aircraft.

Perhaps the simplest method of incorporating levelling and drift setting adjustment into internal, small-format mounting systems is to modify an existing mount designed for a large-format camera. These mounts usually have some vibration isolators in their construction. The modification usually necessitates fabrication of an adapter plate to hold the number and type of cameras desired, and which can be supported on the mounting rings of the large camera mount. A number of workers have described such modifications for single and multiple camera installations (Heller *et al.*, 1959; Aldrich, *et al.*, 1959; Marlar and Rinker, 1967; Ulliman *et al.*, 1970; Black, 1980; Kirby, 1980). An aircraft with a large camera port (400 mm or more) is required for the multiple camera installations described by Marlar and Rinker (1967), Ulliman *et al.* (1970), and Kirby (1980). A port of this size is usually only possible in a twin-engine aircraft or in large single-engine aircraft. With slight modification, Kirby's mount can be adapted for external mounting beneath a helicopter.

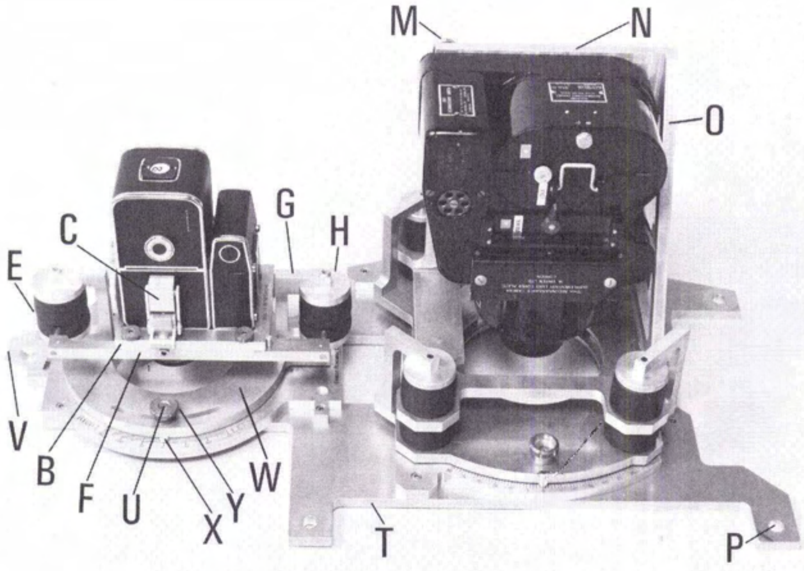
Other workers have preferred to fabricate special internal mounts for small-format cameras. Only small camera ports need to be cut in the aircraft. These are substantially cheaper than large ports and permit the use of smaller, less expensive aircraft. Zsilinszky (1972) described several mounts which carried from one to four 35-mm cameras and used three screw-legs for levelling in flight. Spencer (1974) used a similar levelling technique for a mount designed for one 70-mm Vinten camera and Sabins (1973) used a four leg support for a 70-mm Hasselblad mount. These mounts all had drift compensation and shock absorbers to isolate vibration. Totterdell *et al.* (1971) clamped a robust mount for two 70-mm Vinten cameras directly to the seat rails. Woodcock (1976) described an elaborate mount for a 70-mm Hasselblad and a 35-mm Leica camera which incorporated gimbal rings for correcting tip and tilt, a prism viewfinder, a drift indicator, a light meter, and a stop watch for timing intervals between exposures.

The dual camera mount which was developed by the CSIRO Division of Forest Research falls into the last category. It is an internal mount designed to suit the camera equipment to be used and the available modified aircraft. It is a robust and versatile mount which suports two 70-mm Hasselblad model 500 EL/M cameras or one 70-mm Vinten model 492 camera and one Hasselblad over two separate 150-mm holes in the floor of a Piper Cherokee Six aircraft (see Frontispiece and Figure 2). The mount allows drift correction and limited flight attitude compensation and has efficient vibration damping.

The main components of the mount are the base plate, which enables attachment to the aircraft floor, and interchangeable camera cradles, two for Hasselblads and one for a Vinten. All flat components are made of aluminum plate 12-mm thick. The base plate is designed to clamp into the seat retainers on the floor of the aircraft when one of the rear seats is removed. The forward camera hole in the base plate is 130 mm in diameter, which restricts its use to the Hasselblad cameras only. The rear hole is 210 mm in diameter to accommodate either the Hasselblad or the Vinten lenses. The latter are larger in diameter due to their aperture-setting motor drive mechanism.

Quite different designs are used for the Hasselblad and Vinten camera cradles due to the difference in size, weight, and shape of the two cameras. The basic Hasselblad cradle consists of a drift ring, a suspension frame, and a camera platform. The drift ring has a drift setting scale engraved on its perimeter to allow accurate setting of up to 30° of left-hand or right-hand drift. It is firmly attached to the base plate by four recessed cap screws, and it supports a teflon ring bearing on which the suspension frame turns.

The suspension frame is a ring which supports two vibration isolators from which the camera is suspended, and it also has a pointer positioned over the drift scale. Two captive clamping nuts attached to bolts protruding through curved slots in the ring allow the suspension frame to be positively clamped to the drift ring once the drift has been set on the scale. The two vibration isolators isolate the camera from aircraft vibrations. Each consists of two pads of high-density foam rubber compressed between two aluminum caps which are held by a vertical 'C' shaped support. The camera platform support is suspended by two brass bars which pass between the compressed rubber pads and which are held in place by an aluminum retaining lug inserted vertically into the center of the pads. The advantage of these isolators is that there is no metal-to-metal contact between the drift ring and base plate and most of the aircraft vibrations are absrobed by the rubber



FRONTISPIECE. Dual camera mount with Hasselblad and Vinten cameras in position (for explanation of symbols, see Figure 2).

pads. The weight of the camera and platform gradually deforms the rubber pads with time so they need annual replacement. This is a very simple procedure.

The platform on which the camera rests in the mount is attached to the suspension frame by four captive clamping bolts. The camera rests on the platform on a thin rubber sheet in a recess which helps to accurately position it. It is held firmly to the platform by two spring-loaded over-center clamps which hook onto the shoulder-strap lugs on the side of the camera. This separate camera platform is necessary to enable a riser to be inserted between the suspension frame and the camera platform when lenses of focal length >150 mm are being used, so that the lenses will not protrude through the floor into the slip-stream.

Camera attitude in the longitudinal plane cannot be adjusted during flight but is fixed prior to takeoff so that the cameras are level when the aircraft is in its normal photographic cruise configuration. This is achieved for each different aircraft by varying the length of the legs which fit into the seat retainers and the position of the support prop at the front of the base plate. Compensation for ±5° of aircraft rotation in the rolling plane is achieved in the Hasselblad mount by the rotation allowed by the design of the rubber vibration isolators. The longitudinal axis of the suspension frame passes through the center of gravity of the loaded camera so that the camera's weight causes the camera to maintain verticality.

The camera cradle for the Vinten camera incorporates most of the principles of the Hasselblad cradle but is in a different configuration due to the greater weight and larger size of the Vinten. The drift ring differs only in shape and size, as does the lower portion of the suspension frame. The major differences are in the suspension mechanism. Four vibration isolators are required to support the greater weight of the Vinten which removes the lateral-tilt compensation feature. The camera platform is suspended directly from the isolators by extensions in the four corners of its horizontal component. A vertical brace gives strength to the vertical backing plate to which the camera is bolted at its mounting points. No riser is required because retraction of the longer lenses from the slip-stream is achieved by mounting the camera higher on the backing plate.

This camera mount for small-format aerial photography is a versatile robust design. The vibration isolators are very effective in eliminating camera vibration as evidenced by the very high resolution of photographs exposed when using the mount. The method of suspension of the Hasselblad reduces the effect of aircraft tilt on the photographs. The mount is very useful for film and filter comparisons and 'piggy back' or sampling photography as well as single-camera operations for supplementary map-

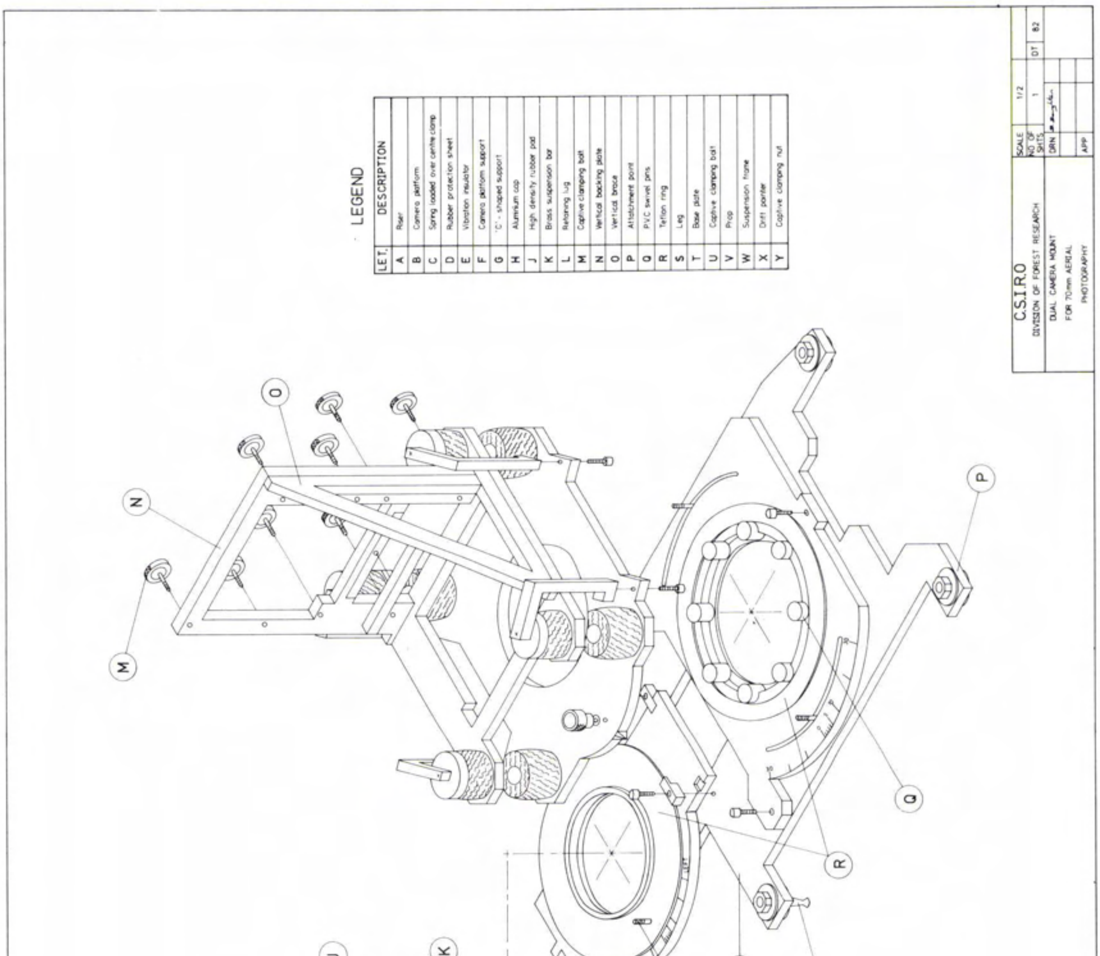


FIG. 2. Exploded isometric drawing of dual camera mount.

ping photography. It is readily adaptable to any other aircraft configuration by simply transferring the camera cradles to another base plate with appropriate holes for camera ports and anchoring points.

Camera Intervalometer for Small-Format Aerial Photography

Aerial photographs are generally produced by the sequential triggering of a camera such that some specified overlap of frames within the flight line is obtained. Systems to achieve this control vary from stop-watch regulated manual operation of the shutter release to the sophisticated intervalometers, supplied by manufacturers of survey-format cameras, which allow constant monitoring and adjustment of overlap along a flight line.

With the increased use of small-format (70- and 35-mm) cameras for aerial photography, often in the hands of the non-specialist, there has been an increasing demand for simple control systems appropriate to the cameras and to the varied applications for which they are used. The extensive literature indicates that workers in forestry and other natural resources use small-format camera systems for a wide range of tasks, including research into techniques (Heller *et al.*, 1959), routine map revision (Spencer, 1974), and inventory (Sayn-Wittgenstein and Aldred, 1967). These tasks require different approaches because some depend on multiple cameras, some consistently use small-scale photography with long intervals between frames, and others involve very large-scale photographs with their attendant short intervals. The requirements for fixed-base photography are different again and are not dealt with here.

Intervalometers specific to particular brands of camera are available. Sometimes they have been used for aerial work without alteration (Marlar and Rinker, 1967) but more often modifications have been made to their power supply (Sabins, 1973) or relay switches provided for the cameras (Ulliman *et al.*, 1970). Some of this developmental work was followed by the commercial introduction of control equipment more appropriate to the triggering of multiple cameras in an aerial configuration, e.g., the Hasselblad Command Unit and Intervalometer III.

Other users have independently developed control systems to meet specialized requirements. Heller and Claypool (1957) described a high-speed electronic intervalometer which was subsequently used extensively in research on small-format color aerial photography in forest pest and disease surveys in the United States. Totterdell *et al.* (1971) sought to overcome limitations in the then-available intervalometer for Vinten cameras and developed a system capable of powering two Vinten cameras, either separately or together, which incorporated circuitry to conserve battery power and would take a frame as soon as it was switched on for a particular run. Incoll (1973) described a device to trigger a single motorized Nikon 35-mm camera mounted on the strut of a high-winged aircraft, and fitted with a frame counter and indicator to monitor the operation of the camera.

A control system, which would expose groups of overlapping photographs with predetermined intervals both within and between groups, was reported by van Eck and Bihuniak (1978). In this case two Vinten cameras were involved, one continuously taking overlapping small-scale photography and the other periodically taking groups of several photographs at large scale to provide more detailed samples.

The most advanced control system for 70- and 35-mm cameras yet reported was described by Roberts and Hiscocks (1981). This is based on a microcomputer which, combined with a video camera and monitors, provides a drift sight and intervalometer system capable of controlling four cameras of three types (Vinten, Hasselblad, and Nikon). It also provides a sampling option and, because of the power of the computer, it can also be used to control certain other functions associated with the aerial missions and to maintain records. No information on costs was provided, but the complexity and bulk of the installation will limit its potential application to relatively few users. Many users of small-format cameras have been encouraged to do so by low costs and are thus likely to be interested in relatively low-cost if somewhat rather limited control systems.

A comprehensive yet inexpensive camera control system has been developed at the CSIRO Division of Forest Research. As well as satisfying an immediate research need, features were incorporated in the specification which were of general value in order that management-oriented users might be encouraged to use the design.

The specification called for a device capable of providing triggering pulses for up to four cameras of the Vinten, Hasselblad, or Nikon types. Only triggering pulses were to be generated because the power requirements and methods of applying it were so different for the three types of camera. Power to all cameras thus was to remain conventional, i.e., external 24 volt DC gel cell batteries for the Vinten, in-built 6.25 volt DC dry cell batteries for the Hasselblad, and in-built 7.5 volt DC dry cell batteries for the Nikon.

The intervalometer which resulted has the following characteristics:

- it can generate triggering pulses for up to four cameras for simultaneous or independent operation;
- a pulse is generated as soon as the device is switched on, with subsequent pulses being timed according to preset intervals;
- pulses are timed within the range of 0.5 to 99.9 seconds in increments of 0.1 second;
- a sampling option is provided which can generate groups of pulses of predetermined number and interval between 'group starting' pulses;

- group start pulses are timed within the range of 1 to 99 seconds in 1 second increments;
- the number of exposures in a run and the number of groups within the run are displayed when the run is completed;
- part of the liquid crystal display flashes at intervals of 1 second to indicate that particular cameras are operating; and
- there is a built-in power supply for the intervalometer with an integral battery-level test circuit.

The concept of providing only triggering pulses allowed the use of printed circuitry (PC) with complementary metal oxide semi-conductor (CMOS) components which have extremely low power requirements, a high degree of reliability, and no appreciable heat output. Printed circuits as such offer reliability, reproduceability, compactness, and serviceability.

Each camera is controlled by a set of three PC boards—a crystal board, a timer control board, and a display board. The crystal board can serve as a master (with crystal oscillator attached) or as a slave (without crystal). Only one crystal master board is required for a complete unit, slave boards being used for each camera apart from the first.

Central to the whole system is the 1 MHz crystal oscillator which generates highly accurate timing pulses. These pulses are successively divided and used to drive various components at 10 and 1 Hz. The 10 Hz signal is fed to the timer control board which contains two timers—a frame interval timer and a group interval timer. The frame interval timer is incremented by the pulse from the crystal until the value set on the digiswitch is reached. At this time, pulses are sent to the camera, which is fired, and to the group size counter on the display board, which is incremented. The 1 Hz pulse from the crystal board to the group interval timer increments a counter which, when it reaches the preset digiswitch value for the interval between group starts, sends a pulse to the controlling integrated circuit and the sequence starts over again.

Information on the number of pulses generated by the frame interval timer is fed to the display board and displayed on the liquid crystal display along with the number of frames in each group. Once the group size counter reaches the preset digiswitch value, it sends a signal to the controlling integrated circuit, which stops the camera firing until a new group start instruction is received. The controlling integrated circuit is also independently controlled by a manual stop/start switch. Figure 3 illustrates the system flow outlined below.

Circuit diagrams for the three boards are reproduced in Figure 4. A parts list and information on connecting wiring and photographs illustrating the layout of components on the boards, together with the negatives necessary for their manufacture, are available from the authors.

The cost of the materials required to make a four-camera intervalometer similar to the one described

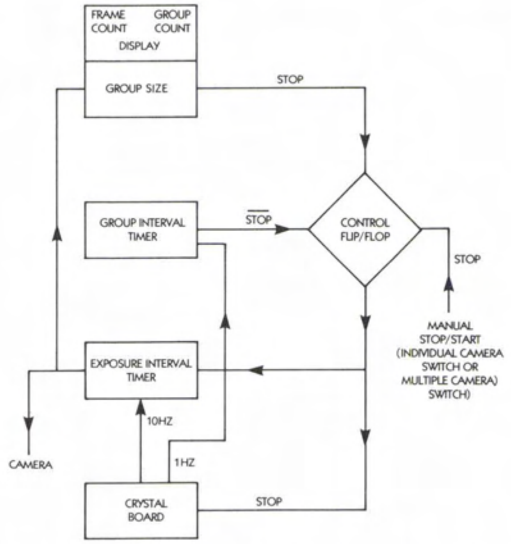


FIG. 3. Camera intervalometer system flow diagram.

would be approximately $A850 (including $A300 for the PC boards, $A240 for digiswitches, and $A120 for liquid crystal displays). The cost of labor to assemble and test the system is additional. As the circuitry will control up to ten cameras, it is not difficult to built a system to suit specific requirements. The cost for a particular unit will finally depend on the number of PC boards produced at the same time because there are significant economies in multiple manufacture.

Figure 5 shows the operator's panel of the intervalometer. The camera selector switch is used to connect the camera plugged into the corresponding camera socket. The individual camera switch is used to activate a particular camera while the multiple camera switch is a gang switch wired to activate all cameras which have been connected by their selector switches.

The time interval required between frames, the interval between group starts, and the group size are set on the three separated areas of the digiswitch. The total number of frames taken and the number of groups are displayed on separate areas of the liquid crystal display. Zero reset buttons for these displays are located below.

A master switch to control the power within the intervalometer is situated at the lower edge of the unit, and a fuse is provided to protect the electronic components from incorrect battery polarity.

In the portion of the liquid crystal display separating the frame and group counter displays there is a colon which flashes at one second intervals to indicate that the particular camera is operating. The same space shows an L when the intervalometer battery voltage drops below 11.5 volts.

The intervalometer built by the Division of Forest

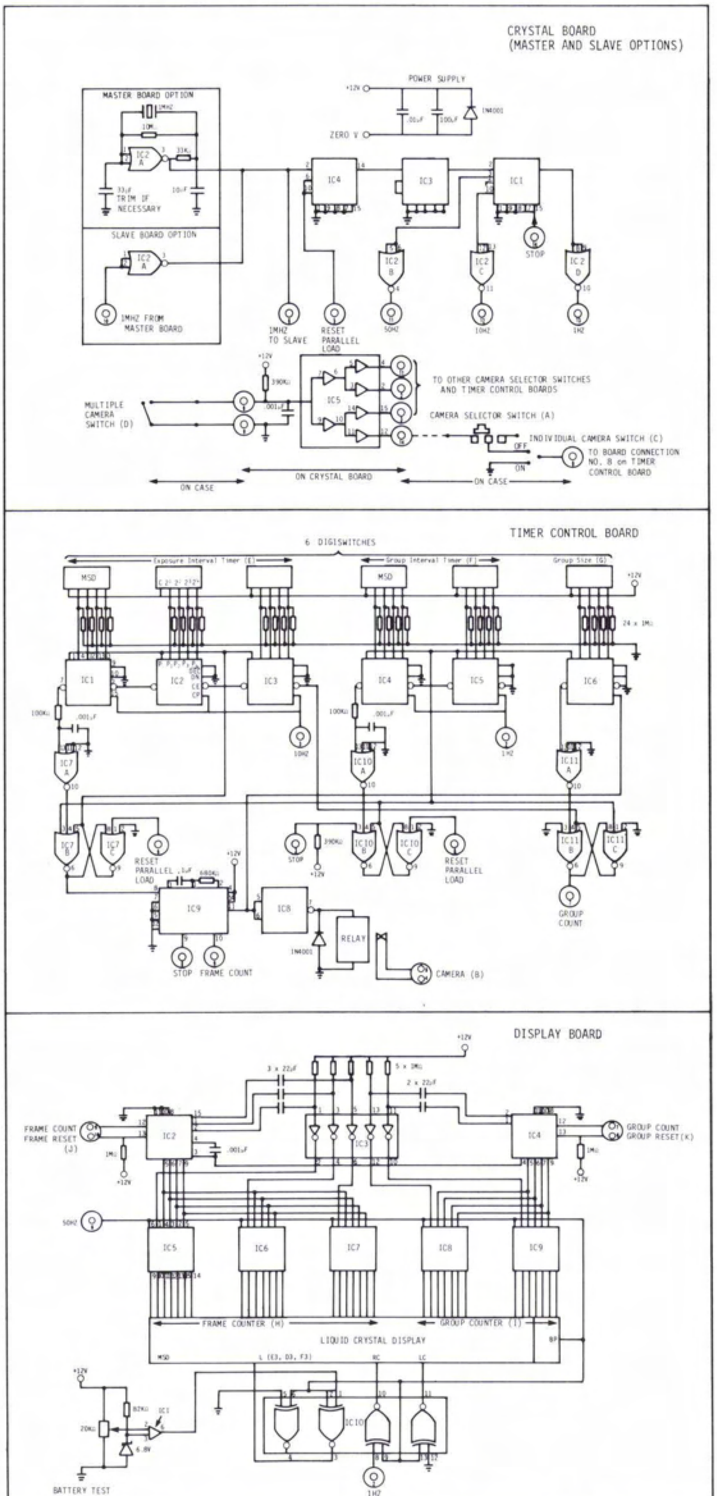


Fig. 4. Circuit diagrams for crystal, timer control, and display boards for camera intervalometer.

A — Camera selector switch
B — Camera socket
C — Individual camera switch
D — Multiple camera switch
E — Exposure interval selector
F — Group interval selector
G — Group size selector
H — Frame counter
I — Group counter
J — Frame zero reset button
K — Group zero reset button
L — Master switch
M — Fuse

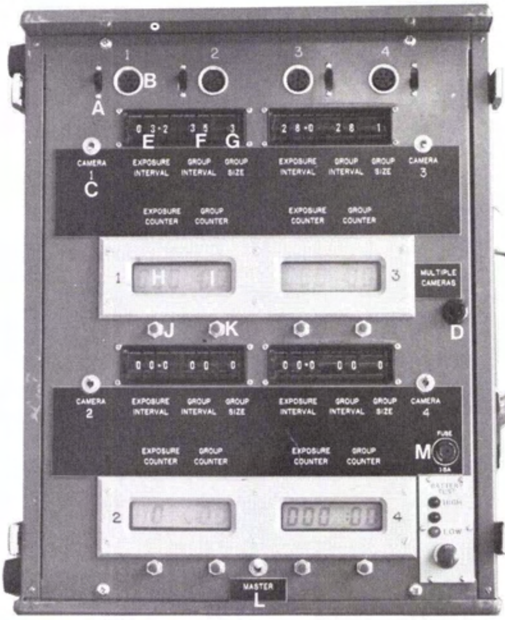


FIG. 5. Camera intervalometer showing details of control panel.

Research has been in service for about three years and has proved to be very reliable and well suited to controlling all three camera types used (Vinten, Hasselblad, and Nikon). In the case of the Vinten, it has been necessary to retain the relay switching device supplied with the camera. The intervalometer power consumption is very low (8 milliamps), and the system is not sensitive to temperature variations. It is easy to operate (set intervals, monitor operation, and read displays), being normally held on the operator's knees.

The device is extremely flexible and is, thus, an ideal system for research programs which involve multi-band or multi-scale photography. It is also robust and suited to production-oriented tasks.

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The course content will include an introduction to remote sensing; historical development; basic matter and energy relationships; data acquisition—photographic and non-photographic sensors; the Canadian satellite and airborne remote sensing programs; techniques of manual and instrument aided image interpretation; use of digital satellite data; land-use studies and classification; agriculture and forestry applications; geosciences; and many more subjects.

For further information please contact

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