19. Video Surveillance of Active Volcanoes Using Slow-Scan Television

By Bruce T. Furukawa, Thomas L. Murray, *and* Kenneth A. McGee

ABSTRACT

Video monitoring using slow-scan television has proved to be a valuable monitoring tool at Mount St. Helens. The system provides a permanent video record of events at the volcano and is also an important aid in planning field logistics and operations. Such a system is particularly valuable at remote volcanoes, where continuous observations are otherwise not feasible.

INTRODUCTION

Video monitoring of Mount St. Helens volcano using slow-scan television (SSTV) began on September 4, 1987. The system consisted of a video camera, a scan converter, a radio transmitter, and a power system, all located on a ridge 8.5 km north of Mount St. Helens; a radio repeater on a high point west of the volcano; and a scan converter, video monitor, and recording equipment at the Cascades Volcano Observatory (CVO) in Vancouver, Washington (fig. 19.1). After several months of operation, the system was modified to turn off at night and back on again in the morning in order to conserve power. A later enhancement included the capability to remotely control various other functions, such as zoom and pan.

Video monitoring of active volcanoes has several attractive benefits. First, there is the potential to significantly reduce the cost of monitoring a volcano. Adverse weather conditions as well as steam and dust conditions can be observed and considered before planning daily field activities. Second, the need for aircraft observation flights is reduced. Third, a reliable video system can significantly reduce hazards to field personnel during periods prior to and during eruptive activity, by supplementing on-site observations of field personnel. Remote variable-power zoom can allow observers to remain a safe distance from the activity. Fourth, video information available during daylight hours is easily correlated with other telemetered monitoring data to assess current conditions. At night, an SSTV monitoring system could utilize an infrared camera for monitoring hot spots. Or a video cassette recorder (VCR) could be connected at the output of the video camera in parallel with the output of the scan converter and triggered to turn on in response to either a control signal from a base station or a signal from a monitoring device in the field such as a seismometer or a trip wire, in order to continuously record events such as eruption plumes, debris avalanches, or lahars for subsequent detailed analysis. It is even possible to design a transportable SSTV system that could be rapidly deployed at volcanoes threatening to erupt. Finally, video information can be stored on magnetic tape for future analysis.

The earliest video system at Mount St. Helens was a closed-circuit television system installed in July 1980 in response to the onset of eruptive activity earlier that year (Miller and Hoblitt, 1981). This system was extremely valuable to scientists monitoring the ongoing eruptive activity at the time, but was hastily assembled under emergency conditions and operated for less than one year before succumbing to problems related to its complex microwave technology and large power consumption. In January 1984, an idea to use a microprocessor-controlled digital video camera with radio modem to obtain images from Mount St. Helens was proposed, but not acted upon. In the winter of 1985–86, CVO seriously considered a proposal to establish a permanent microwave link to Mount St. Helens that would carry telemetry and video signals from field monitoring stations. The idea was later abandoned because of the high equipment cost and system maintenance. Finally, in 1986, the idea of employing slow-scan television for video monitoring of Mount St. Helens was adopted as a goal for CVO. The system described in this paper is the result.

Slow-scan television, first developed by amateur radio experimenters in the 1950's, is a system whereby video images are converted line by line to a varying tone for transmission through a narrow-band radio system. Conventional television requires a bandwidth of 6 MHz for transmission of video signals, whereas SSTV requires only a standard 3 kHz voice channel. This critical difference in RF spectrum requirements results in many significant advantages for SSTV over conventional television systems (lower cost and power requirements, less complex radio-telemetry systems, and ease of servicing). Furthermore, because of the narrow bandwidth, SSTV images can be stored on standard audio magnetic tape rather than video tape. A disadvantage of SSTV is that the video information is discontinuous, because it is displayed as a time series of video snapshots. However, for volcano observatories which must monitor one volcano or several volcanoes over periods of years, slow-scan television may be the method of choice.

DESCRIPTION OF SYSTEM

The current slow-scan television system at Mount St. Helens consists of a camera, scan converter, and controller at the field site; a scan converter, remote controller, TV monitor, and recorder at the Cascades Volcano Observatory; and a radio system, including a repeater, for transmitting video and control signals (fig. 19.1). Appendix 1 lists the equipment used by CVO.

Any good video camera with a 12-volt DC operating voltage, or specifications similar to those listed in appendix 1, can be used in this application. CVO's camera, located 8.5 km north of Mount St. Helens, can be zoomed in to view only the interior of the crater or zoomed out to view the entire volcanic edifice and nearby terrain through the use of the remote control system described below. The camera is mounted on a pan and tilt servo-controller unit. When fully implemented, this pan-tilt unit will allow the camera to pan 150 degrees to the left or right from center and to tilt 30 degrees up or down from horizontal.

Video output from the camera is fed directly into a slow-scan video color converter that has been modified to operate from a 12-V DC power source. The

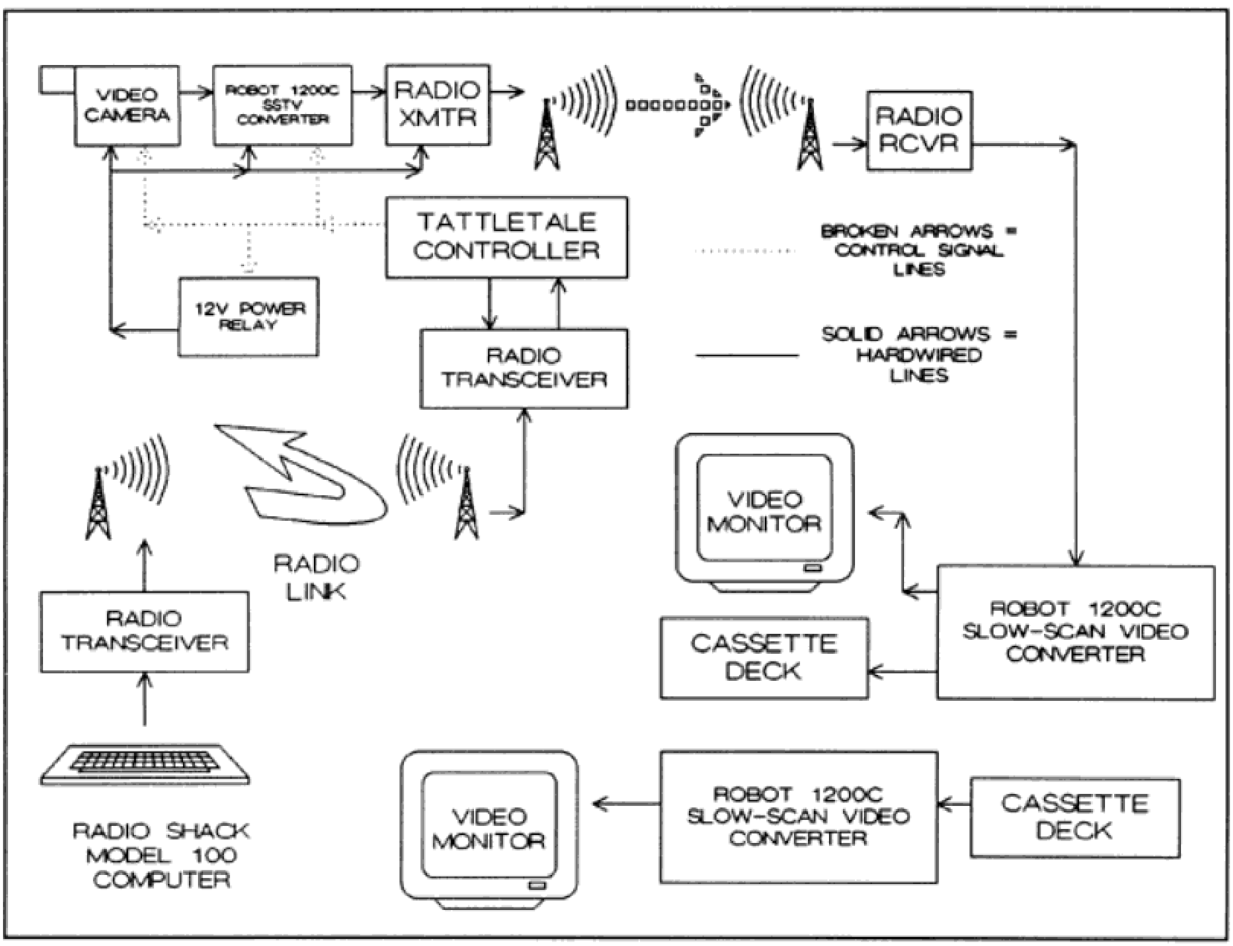

Figure 19.1. Flowchart illustrating components of CVO SSTV system.

SSTV color converter is actually an integrated transceiver capable of transmitting or receiving full color images over any voice-grade communications link. The converter digitizes the video signal from the camera and, after conversion to audio tones, transmits the image line by line using a process called time-multiplexed component color in 72 seconds. At the highest resolution setting, the converter can produce a digitized image composed of 61,440 picture elements in a 256 pixel by 240 line array. When operated unattended at a field location, the functions of the SSTV converter can be controlled by a computer through an RS-232 serial port. Two different control systems have been developed at CVO and are described below.

The digitized and encoded video signal from the SSTV converter is fed into a low-powered VHF or UHF radio telemetry transmitter. The use of standard radio transmitters similar to those used for seismic or low-frequency data telemetry represents one of the biggest advantages of SSTV over other types of video transmission. The antennas used throughout the system are standard radome-protected, UHF band, five-element yagis with 10 dB gain.

All of the equipment at the field site, except for the antenna and camera, is housed in a small building. Power for the equipment is provided by combining two sets of batteries. One set consists of four Delco 2000 high-capacity deep-cycle 125 ampere-hour (Ah) lead-acid batteries designed for use in solar-charging applications. The other set is composed of six Model KCP-SA-13, 2-V 560-Ah high-capacity wet-cell batteries, manufactured by C & D Batteries, Plymouth Meeting, Pennsylvania. Both sets are simultaneously charged during daylight hours by a bank of two 30-watt solar panels.

Video information from the field-monitoring site is received at the observatory via a standard telemetry repeater west of Mount St. Helens. At CVO, the audio output from the SSTV radio receiver is fed into another SSTV converter, where the signal is decoded, converted into a standard color video signal, and fed into a standard color monitor for viewing. The converter also feeds a signal into a standard audio cassette recorder. A separate SSTV converter with cassette player and color monitor is available nearby for off-line viewing of the tapes.

As of this writing (September 1990), a slow-scan television monitoring system for Mount St. Helens has been in operation for 3 years. The earliest version of the system operated in a continuous mode. Owing to excessive power consumption, a controller was added to turn the system off at night. However, power consumption was still a serious problem, and the program was later changed to transmit a single picture every 15 minutes during daylight hours. These were marginally acceptable, temporary solutions. Finally, a remote controller was developed and installed that allows all functions to be controlled from CVO.

SSTV CONTROLLER

Two controllers have been utilized with the SSTV system. The first, an on-site battery-powered laptop computer, turned the system on and off at programmed times (fig. 19.2).

Typically, the computer activated the system every 15 minutes to transmit a single picture of 2-minute duration. Turning the system on and off in this manner decreased the average power consumption of the system dramatically and allowed solar panels to substitute for the propane-fueled, thermoelectric-generator charging system.

The second controller, developed at CVO, allows users to remotely control the system by issuing commands from CVO to the controller over a radio link (fig. 19.1). This technique allows turning the system on and off, controls the picture resolution, monitors the battery voltage, and adjusts the zoom, pan, and tilt of the camera.

Battery-Powered Computer Controller

Figure 19.2 shows how a small computer at the camera site connects to the system as a controller. Pin 4 (RTS) of the computer's serial port controls the relay that switches power on and off to the SSTV converter, camera, and radio transmitter. Commands are transmitted from the serial port of the computer to the graphics input port of the SSTV converter.

A BASIC program running on the computer controls the sequence of events and the transmit times. A typical program is listed in appendix 2. With this program, the computer powers up the system every 15 minutes between 0600 and 2000 hours, sends commands via the serial port to the controller to transmit a single picture at the highest resolution, waits 2 minutes (long enough for the picture to be transmitted), and then powers down the system. Thirteen minutes later the process repeats.

Of the two controllers, utilizing a battery-powered computer is the simpler, less expensive method. Its major drawback is that changes to the program cannot be done remotely; the site must be visited to change the program. At sites accessible by vehicle this may not be a problem, and this system may suffice.

Remote Control System

The remote control system allows users to control the SSTV system from the observatory. A menu-driven program running on a laptop computer allows users to radio messages to the controller in the field (appendix 3). The messages instruct the controller to execute any of several desired options, so site visitation is unnecessary.

Observatory staff run the menu-driven BASIC program to indicate the desired action to be performed by the controller. User input initializes the computer, which then generates the appropriate instructional command for the desired controller action. This message is sent to the radio-interface circuit via the RS-232 serial port. The interface circuit reads the command, puts the radio into transmit mode, sets the modem to originate mode, and transmits the message in standard Bell 103 format. After the command is sent, the radio returns to receive mode, and the modem to answer mode. Messages and acknowledgments sent to the base station from the field are then received by the computer.

An Onset Computer Tattletale Model III single-board controller, a radio, and a CVO-designed interface circuit (fig. 19.3) make up the controller at the camera site. Messages sent from the observatory are received by the radio, demodulated by a single chip modem in the interface circuit, and sent to a serial port on the Tattletale. A BASIC program running on the Tattletale decodes the message and performs the correct action. The SSTV controller is directed by sending commands from the Tattletale's second serial port to the graphics input of the SSTV controller. MOSFETs attached to the Tattletale's digital I/O lines provide the contact closures necessary for the zoom, pan, tilt, and system on/off controls. The entire package is housed in a watertight case.

CONCLUSIONS

The use of video systems has the potential to reduce the operational costs and risks involved in monitoring active volcanoes, particularly dangerous volcanoes in rugged or remote terrain. Slow-scan

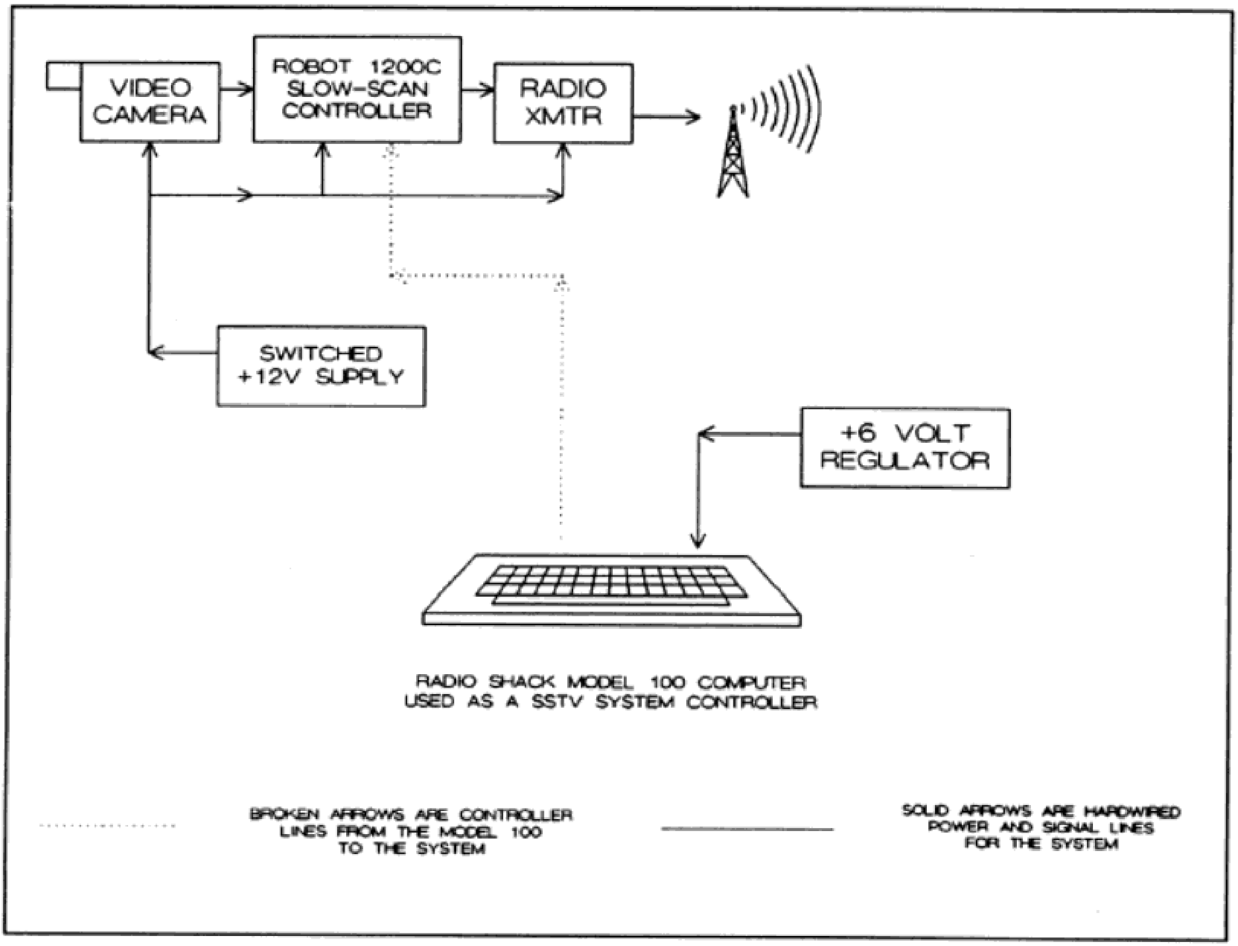

Figure 19.2. Schematic of original CVO SSTV controller.

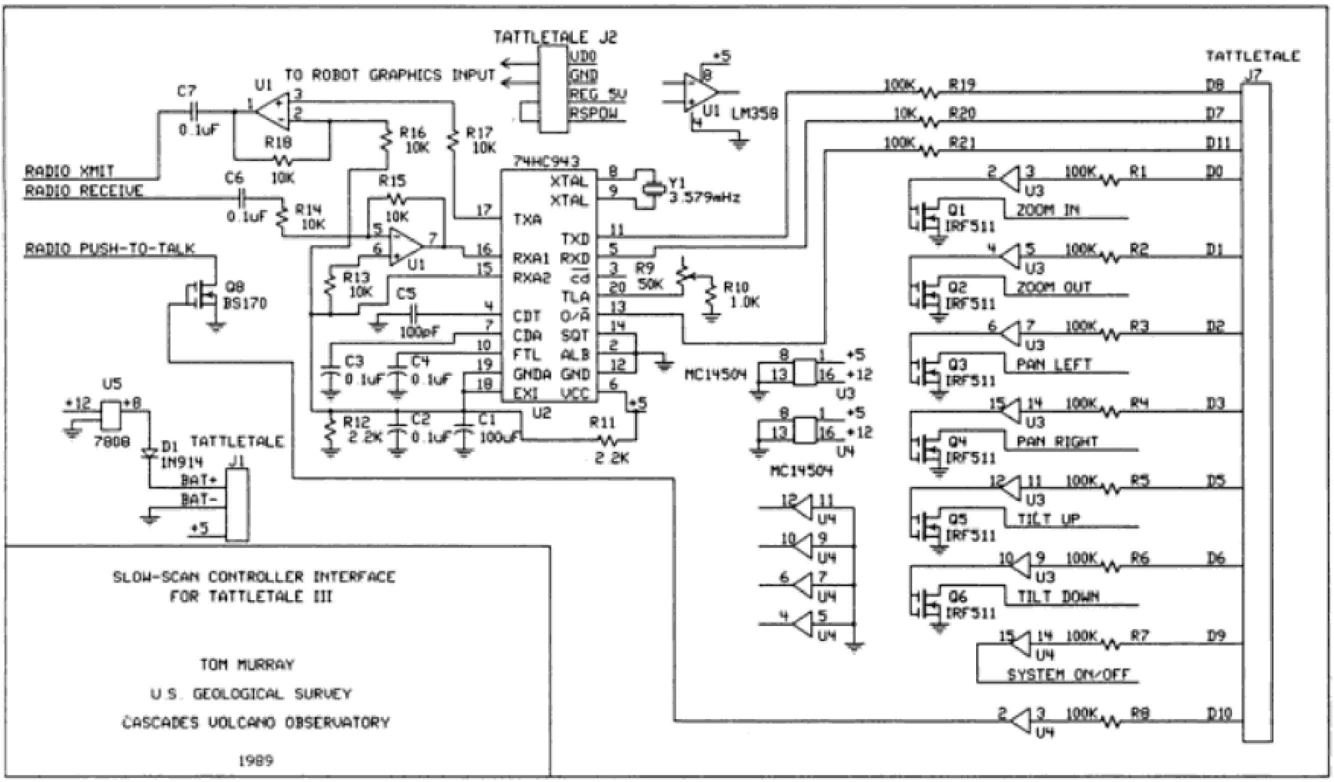

Figure 19.3. CVO-designed interface circuit.

television, with its simplicity and modest RF spectrum requirements, is an attractive low-cost alternative to conventional television systems. Although its power requirements are greater, a slow-scan television monitoring station is no more complex to install and operate than a seismic or low-frequency monitoring station, and can be optimized or enhanced for a particular application.

The slow-scan television system in operation at Mount St. Helens has evolved in design since its initial installation and has proved to be a useful and economical addition to the monitoring capability at the Cascades Volcano Observatory. Similar SSTV installations at other potentially active volcanoes should be considered.

REFERENCES CITED

Miller, C.D., and Hoblitt, R.P., 1981, Volcano monitoring by closed-circuit television, *in* Lipman, P.W., and Mullineaux, D.R., eds., The 1980 eruptions of Mount St. Helens, Washington: U.S. Geological Survey Professional Paper 1250, p. 335–341.

APPENDIX 1

Equipment List

Video camera	JVC Model TK-860U color video camera head, with a Sanyo TV Autofocus, f 1.2, motorized zoom lens with a focal length of 12.5 to 75 mm.
Pan/tilt controller	Daiwa Model MVH-2D pan and tilt unit, with pan of 150 degrees laft and right from center and tilt of 30 degrees up and down from horizontal.
Slow-scan video converter	Robot Model 1200C Color Scan Converter, modified to operate from a 12 VDC power source.
Telemetry radios	Monitron T40F-1 UHF radio telemetry transmitter.
	Monitron R40F UHF radio receiver.
	Synthex Model LM4400 VHF radio tranceiver.
Computers	Radio Shack Model 100 (or 102)
Field controller	Onset Computer Tattletale Model III single-board controller.
Antennas	SCALA, model RA5-450, radome-protected, five-element yagi, with 10 dB gain.

APPENDIX 2

Typical BASIC program on Radio Shack Model 100

A program for the Radio Shack Model 100 to control the slow-scan video system. The program transmits a picture every 15 minutes between 0600 hours and 2000 hours.

set the automatic running of this program on reset

```
20 IPL "SLOSCN.BA"
21 PRINT "THE SLO-SCAN WILL BE TURNED ON EVERY"
22 PRINT "15 MINUTES (XX:00, XX:15, XX:30, AND XX:45) AND "
23 PRINT "TRANSMIT ONE PICTURE. CURRENT TIME IS"
24 PRINT TIME$ : FOR I=1 TO 2000: NEXT I
26' always transmit a picture on start-up
30 GOSUB 200
```

now just loop around waiting for a 15 minute mark between 06:00 and 20:00

```
40 IF (MID$(TIME$,1,2)<"06") OR (MID$(TIME$,1,2)>"19") THEN GOTO 40
41 IF (MID$(TIME$,4,2)="00") OR (MID$(TIME$,4,2)="30") THEN GOSUB 200
42 IF (MID$(TIME$,4,2)="15") OR (MID$(TIME$,4,2)="45") THEN GOSUB 200
45 GOTO 40
50' the subroutines for delays between commands (a short and a long)
180 FOR I=1 TO 2000:NEXT I:RETURN
185 FOR I=1 TO 300:NEXT I:RETURN
190' the turn-on subroutine
191' opening the com port turns on the relay to power the system
200 BEEP : PRINT "POWER ON" : OPEN "COM:77N2D" FOR OUTPUT AS 1
205' power up delay
210 GOSUB 180 :GOSUB 180
215' issue the commands to put in the correct configuration to
216' transmit 1 (one) picture
220 PRINT "36/72" : CALL 28210,25 : GOSUB 180
230 PRINT "TRANSMIT" : CALL 28210,16 : GOSUB 180
235' do a double-push on the "camera" button
240 PRINT "CAMERA" : CALL 28210,42 :GOSUB 185 : CALL 28210,42 : GOSUB 180
245' wait until 2 minutes later and turn off.  the turn-off has the return
250 SC$=MID$(TIME$,7,2)
251 MN$=CHR$(48+((2+VAL(MID$(TIME$,5,1))) MOD 10))
252 IF (MID$(TIME$,5,1)=MN$) AND (MID$(TIME$,7,2)>=SC$) THEN GOTO 300
255' go back to the wait loop
260 GOTO 252
270' the turn-off subroutine
275' closing the port deactivates the relay that powers the system
300 BEEP :PRINT "POWER DOWN AT "+TIME$ : CLOSE
305' go back
320 RETURN
```

APPENDIX 3

Commands available in the Base Station Computer Program

Picture transmission control instructions

- Power down the system
- Transmit a single picture
- Transmit continuously
- Transmit one picture at intervals of either 5, 10, 15, 30, or 60 minutes
- Set the picture resolution

Miscellaneous instructions

- Set the Tattletale's clock
- Transmit the battery voltage

Instructions for controlling the camera

- Zoom in or out from the current position
- Zoom to an absolute position
- Pan left or right from the current position
- Pan to an absolute position
- Tilt up or down relative to the current position
- Tilt to an absolute position

Note: Zoom, pan, and tilt positioning is measured in the length of time (in hundredths of seconds) the motor drive is engaged. For example, an absolute zoom position of 125 indicates the zoom was driven completely out and then driven back in for 1.25 seconds. A relative zoom in of 25 means the zoom is driven in for 0.25 second. Pan and tilt positions are measured in the same fashion.