CHAPTER SEVEN

Remote Imaging from Near Space

"I've seen things you people wouldn't believe."
- Roy Batty (Blade Runner)

Chapter Objectives

1.0 Types of Imaging Available

I find the range of imaging technology available for near space exploration to be absolutely amazing. This range is divided into two broad types, still images and video. Each type is divided into two more categories, those that are transmitted (live images to ground stations) and those that are recorded for later retrieval. This matrix illustrates the range of options available.

	Still Images	**Video**
Recorded	Camera	Camcorder
Transmitted	Slow Scan (SSTV)	Fast Scan/Amateur Television (ATV)

In general, images recorded for later viewing have better quality than transmitted images. The quality of recorded images is seen in both their color quality and image resolution. While of lower quality, transmitted images still have a great interest with Ground Crews because of their live nature. There is a way to combine the two categories of recorded and transmitted images that gives you the best of all worlds: couple the A/V output of a camcorder or digital camera to an ATV or SSTV system. This combination gives a taste of what is to be expected after the near spacecraft is recovered. Of course, this does add weight to the near spacecraft. Now let's discuss these different imaging devices in more depth.

1.1 Still Cameras

Types and examples of imaging available with cameras include the following
Panchromatic: Basic Black & White, or Infrared
Multispectral: Color Film and Digital

1.1.1 The Good and the Bad

Systems to record still images on film or in memory have several benefits:

1. They're usually a lightweight and self-contained system.
2. They have excellent image resolution.
3. They have good color resolution.

Infrared image of the ground - *The foliage appears red because the chlorophyll in plants reflects infrared along with green. Between the near spacecraft and the ground are clouds in a row formation.*

On the negative side we have some limitations:

1. Some camera systems contain moving parts that may jam during a flight.
2. You can't always operate them electronically out of the box; some kind of modification or mechanical system must be devised.
3. The number of photographs that can be recorded on a single flight is limited to the film or memory in the camera.

1.1.2 Details

One way to reduce the limitations of number of frames and possibility of mechanical failure is to use digital cameras. More “film” can be added to the camera with a larger memory that doesn’t take up more space. With few moving parts, a digital camera is less likely to suffer from a mechanical failure. But with digital cameras you run into the problem of lower resolution than film, unless a relatively expensive camera is used.

The best film images are recorded using cameras with large film formats, like 120 film. The less an image is compressed to fit on film stock, the finer the details that are recorded on the film. Unfortunately these same cameras also tend to be the most expensive to purchase. I have yet to find an affordable 120 camera with motorized controls that I can modify for computer control.

A good compromise film camera is either an APS or 35 mm camera. There are several requirements for a film camera to operate in near space. First, it must have auto film advancing. This lets you concentrate on taking pictures rather than with building complex mechanical devices for advancing the film. Second, the camera must be capable of properly focusing at infinity. Once the near spacecraft is launched, everything visible is at infinity (i.e. more than 30 to 50 feet away). This issue is a big gotcha. Some $20 cameras claim they are focus-free, giving the impression that they are properly focused for distant subjects. Actually, many inexpensive focus-free cameras are focused for subjects twenty feet away from the camera, or the typical distance for which you photograph friends.

Other cameras are made focus free by stopping down their lens. Stopping down a lens means the diameter of the lens of the camera is reduced with a mask (iris), which reduces the light entering the camera. A camera for near space must be either manually set to infinity or capable of setting its focus to infinity by adjusting the lens' focus. If possible, set the camera's focus in advance, as this will not require the camera to move the lens. Some mechanical movements may freeze up in cold of near space. If the mission is flying a camera with a moving lens, get a camera with a lens movement that is internal to the camera body. Just to give an example, I used one camera with a lens that physically moved outside the camera body. After its second flight it quickly discharged any batteries loaded into the camera. I believe the focusing motor shorted out when the camera lens froze into a fixed position, thereby destroying any further use of the camera.

One of my early successful cameras is the Vivitar AF400. It is a veteran of over 20 flights. A servo operated the camera’s shutter button before I learned how to modify the camera to be operated directly by a computer. One early failure was the Big View 35. That camera froze up early one flight. Its last photograph is an interesting image of sunrise at 66,000 feet. The sun became a wide streak on the horizon, as the shutter began to fail and operated very slowly while the near spacecraft rotated. In the next section are directions for modifying cameras, or how to get them modified.

Sunrise at 66,00 Feet – *The sun became a wide streak on the horizon as the camera froze up and the shutter began to fail.*

1.2 <u>Camcorders</u>

1.2.1 The Good and the Bad

Recording video has several benefits:

1. Their images are video and not stills that may be aimed in the wrong direction when recorded.
2. Their moving images have reasonably good resolution in pixels.
3. Video images have good color resolution.

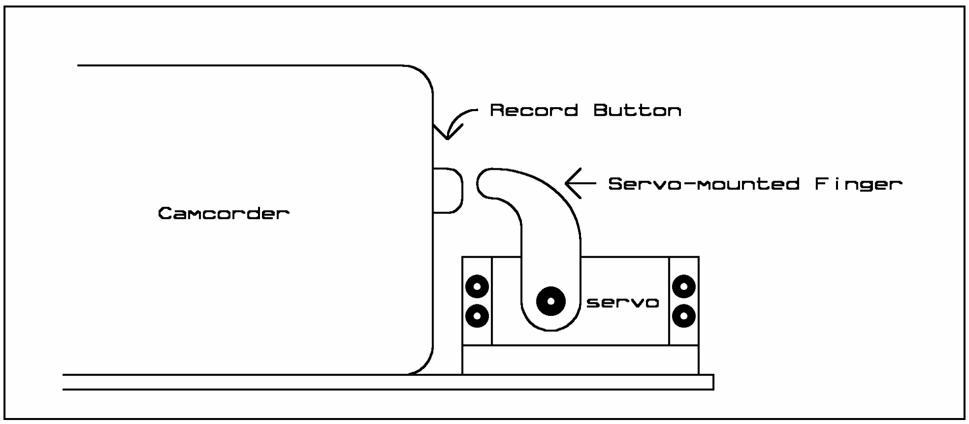
On the negative side, limitations to consider:

1. Camcorders are heavy, about 2.5 pounds for the lightest.
2. I know of no way to operate them electronically; a mechanical system must be devised.
3. Camcorders shut themselves off if when they do not record for five minutes, so they must run continuously from launch.

Perhaps the digital camcorders that are now available will change this. However, cost has prevented me from experimenting with them yet.

1.2.2 Details

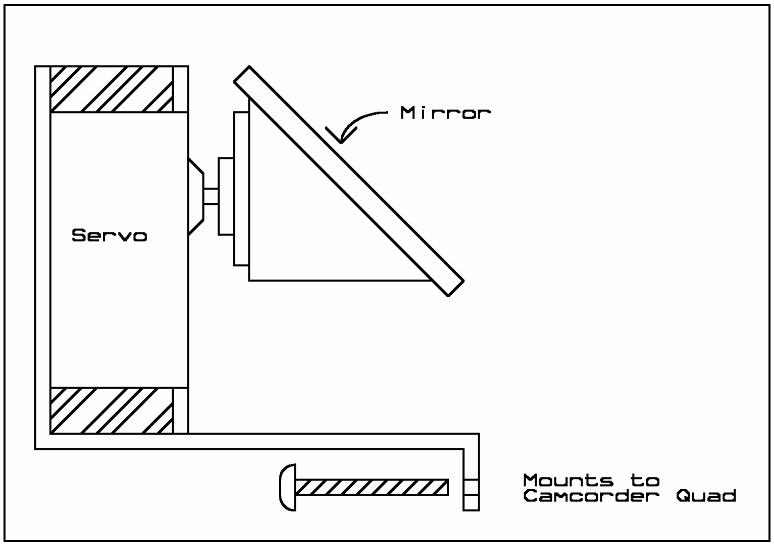
I've had a lot of success with sending camcorders into near space. Quasar is the camcorder I use in near space. The Quasar camcorder is basically a Panasonic, compact VHS camcorder. With a 60-minute videocassette and slow record setting, the compact VHS records two hours of video, enough to record the ascent and balloon burst, but not the landing. Both Jeff Melanson (KD7INN) and Mark Conner (N9XTN) have experience with camcorders that can record longer than two hours. To record the descent of a near space flight with a two-hour tape in the camcorder, the camcorder must be shut off for portions of the mission. A flight computer controlled servo positioned to press the record button turns the recording function on and off. Since the camcorder shuts itself off after five minutes of idling, a flight computer must continually press the record button in cycles of less than five minutes.



Servo-activated camcorder *– When the servo rotates, the finger pushes the record button.*

The camcorder ends up recording snippets of the flight until the camcorder is left recording. Be aware that once a camcorder shuts itself off, you must physically reset the ON/OFF button, a difficult proposition with a servo. It would of course be best if you can lay your hands on a service manual for the camcorder and discover how to "computerize" the camcorder. You'd think with all the moving parts in a camcorder, they'd be a nightmare in the cold of near space. Fortunately camcorders generate lots of heat, so they keep themselves warm in near space.

Unfortunately camcorders are large and heavy enough to make it difficult to rotate them with a servo. The way to get around this is to mount a mirror in front of the camcorder lens at a 45-degree angle. As the mirror rotates, the camcorder’s view changes, giving the camcorder a 180-degree view of the world.



Rotating Mirror – *Mounts to camcorder quad.*

On the negative side, the image is reversed. This may be fine for general viewing, but it makes if difficult to interpret images of the ground below. You may be thinking, "Ah, I'll just add a second mirror!" True, this reverses the reversed image, but it also requires the second mirror be larger than the first mirror to avoid cutting off the image. With the wide angle of view in a camcorder, this gets too unwieldy. Of course you could set the camcorder lens to zoom and reduce the angle of view. But then the image moves too rapidly though the field of view as the near spacecraft rotates. It's best to correct the reversed images through video capture software. There is one more method to avoid rotating large camcorders. Recording VCRs are getting smaller and more affordable. Before long I expect amateurs to send small CCD (charged coupled device) cameras into near space in place of a camcorder. A small CCD camera is easy to servo mount and its video images can be recorded with the VCR onboard the near spacecraft. By using a splitter, it may be possible to record high quality images onboard the near spacecraft while transmitting poorer quality ATV to Chase Crews.

Later in this chapter are directions how to make a camcorder cradle and a servo controlled mirror for rotating the direction of view of a camcorder.

1.3 <u>Slow Scan Television</u>

1.3.1 The Good and the Bad

Slow Scan has several benefits:

1. The images are transmitted slowly as audio tones over the radio (slow transmission decreases the bandwidth required for the signal and improves its quality over long distances).
2. The images are live images.
3. The imaging method is very similar to how NASA does their imaging.

Limitations to consider:

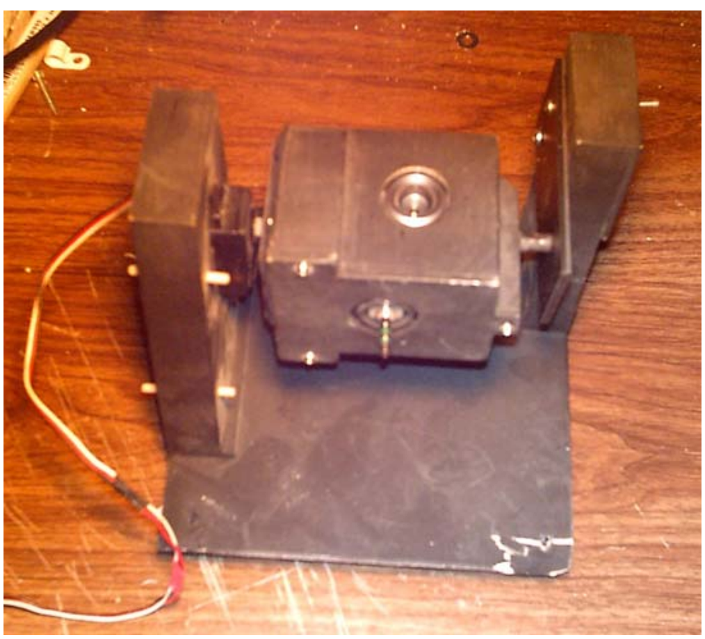
1. They may not have the best image resolution.
2. They may not have the best color.
3. The images take time to transmit.

1.3.2 Details

The easiest SSTV unit to adapt for near space is the Kenwood VC-H1. This compact unit requires a HT to send images, so there are two HT sized devices onboard the near spacecraft. The aspect I like best about the VC-H1 is that its imaging head can be removed from the main body, where the imaging processing occurs. The VC-H1 camera head sends images to the VC-H1's main body for capture and processing for transmission over the attached HT. The captured image is converted to audio tones, which indicate the color and intensity of each pixel. It takes the VC-H1 32 seconds to transmit images in Robot format. Since the transmission rate of a SSTV image is slow, the image quality received doesn't degrade as much with transmission distance as ATV images do. Images recorded at 120 miles way are as good as those recorded 20 miles away from the near spacecraft.

To prepare the VC-H1 for near space work, remove the imaging head and connect it to the VC-H1 body with an audio cable from Radio Shack. The processing unit is kept inside the capsule, while the imaging head is mounted to a scan platform. Building a scan platform is covered in Chapter Five, Section 3.4, and building a camera box for the VC-H1 is covered in this chapter, Section 3.1.

***Kenwood VC-H1 Slow Scan Television –** The camera head can be removed from main body.*



VC-H1 Scan Platform

The VC-H1 can be set to transmit images every three minutes. This simplifies the process of acquiring images. Alternately, a communications cable for operating the SSTV from a PC is available. Once you know the communications protocol, a flight computer should be able operate the unit.

1.4 Fast Scan/Amateur Television (ATV)

1.4.1 The Good and the Bad

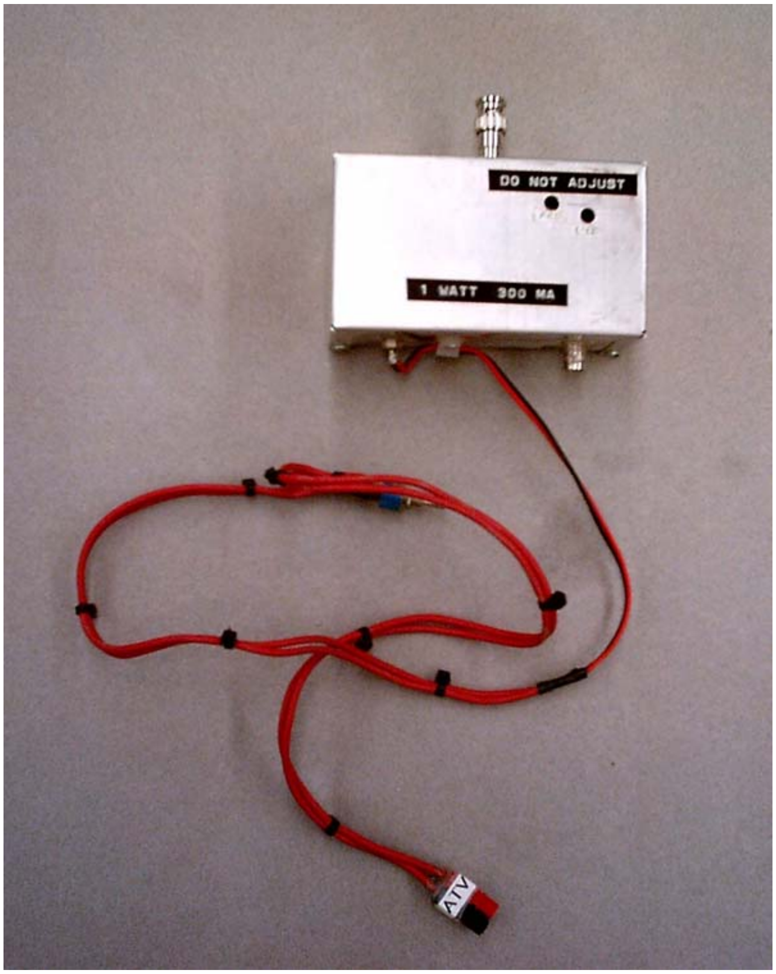
Transmitting video has several benefits:
1. The images are video, not just snapshots that may be aimed in the wrong direction.
2. The images are live from near space.

On the negative side we have limitations:
1. ATV transmitters can be power hogs.
2. Signal quality drops off rapidly with distance or altitude. Good images require beam antennas, a difficult antenna to use from a moving chase vehicle.

1.4.2 Details

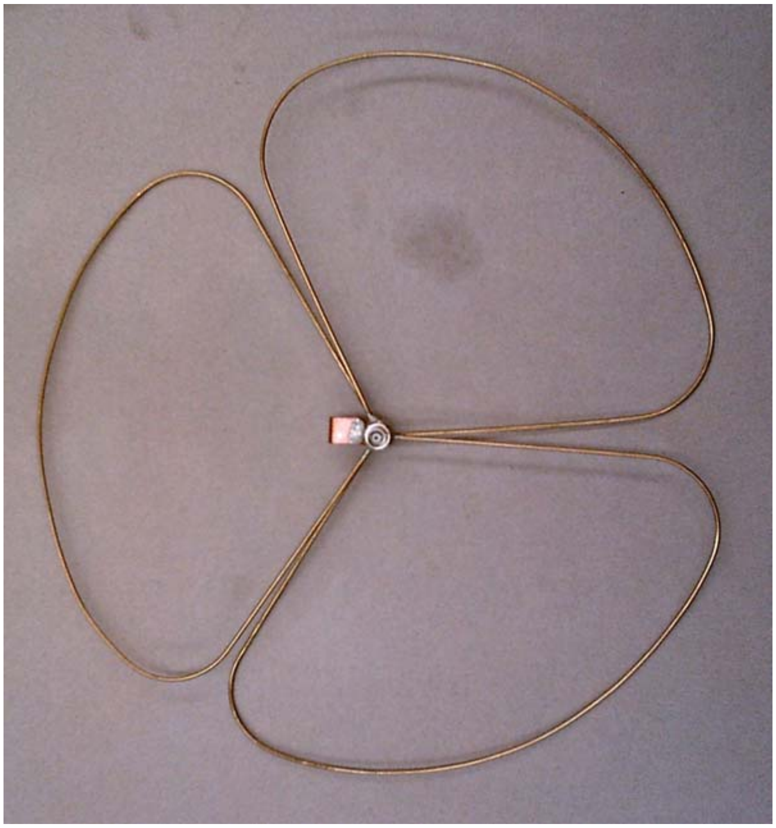
A CCD camera and 1 watt transmitter makes an excellent, lightweight ATV set up. However, a one-watt ATV signal drops off rapidly with distance. You get wonderful video at launch and great video from the landing, if you're lucky enough to be close. I've looked into sending up an amplifier. As I recall, a ten-watt amp requires about 3 amps of current at 12 volts (about 25% efficient). A good battery is needed to power the amp. A good set of NiCds or lithiums are probably the best battery to use. Three amps of current for a three-hour flight require a battery pack of 9000 mAh. This much capacity is available in some “D” cell form-factors. Operating at 12 volts for three hours, the battery produces 36 watts of total power. The surplus lithium “D” cells available from S&G Photographic can produce this level of power, but the batteries are getting older and more expensive.

Pretty much the only place to get ATV equipment is through PC Electronics. The transmitter best for near space is the TX5A. It is a bare board that you mount inside a metal enclosure. Use bypass capacitors to bring power into the enclosure, as this filters out any AC ripple in the power supply.



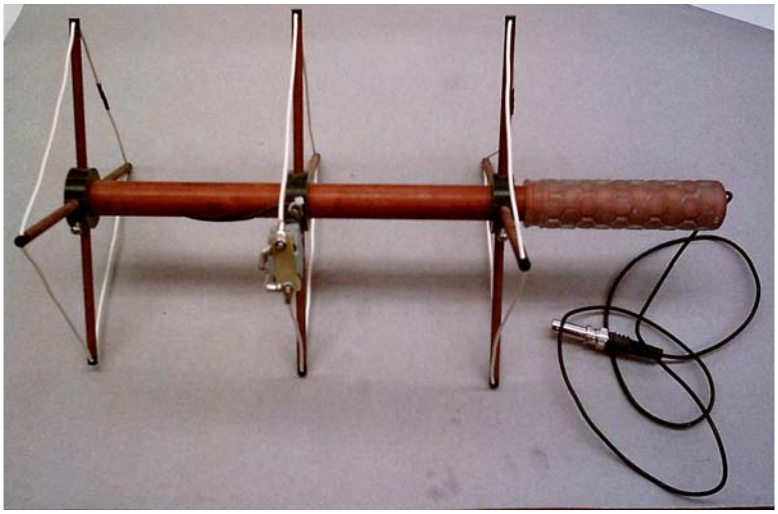
Fast Scan/Amateur Television (ATV) Transmitter

Dave Clingerman of Olde Antenna Labs has done a wonderful job for me building the bare board into an enclosure; I'd recommend his work to you also. Images from ATV are best sent over a mini-wheel antenna. This antenna is circular in design, giving it a very uniform radiating pattern. The polarization of this antenna is horizontal. The construction of the mini-wheel antenna has been described in past issues of ATV Quarterly. You can also purchase them directly from Olde Antenna Labs.



Mini-Wheel Antenna

Mount the ATV antenna beneath the airframe as rotation of the stack leads to spin modulation of any antenna mounted off one side of the near spacecraft.



ATV Quad Antenna

Input to the ATV transmitter is from a CCD camera. Small, lightweight CCD cameras with color output are now available for less than $50. Lightweight CCD cameras like this are mounted to scan platforms. Suitable CCD cameras are available from Super Circuits.

2.0 Modifying Cameras for Flight Computer Control

2.1 Cameras to Use and Cameras to Avoid

Older cameras and some inexpensive cameras use a mechanical shutter system. When the shutter button is depressed, mechanical linkages open and close switches and relays, triggering the camera to operate. A computer can only control this style of camera if the shutter button is depressed by a servo or solenoid. The mechanical alignment needed for this type of camera is not impossible, but it is not reliable, either. Oregon Scientific makes an inexpensive digital camera that the author has experimented with. From our experiments, we learned that the camera shuts downs too quickly when not in continuous use. As a result, photographs must be taken in rapid succession. This requires a large memory card, and it is best if it is a 64 Mb card. Read the directions that come with the camera, and look for battery saving features that shut down the camera.

Most currently available 35mm cameras include four important features: electronic shutter, auto-focus, electronic exposure control, and auto film advance. When the shutter button is depressed, an electric connection is made inside the camera, triggering a sequence of events. First, when the first contact is made in the shutter switch, the auto-focus of the camera determines the distance to objects in the camera's field of view and focuses accordingly. At the second contact, the camera shutter opens, exposing the frame for the proper length of time. After the exposure is made the film advances to the next frame. Three of these four features are required to easily modify the camera for computer control.

There are some focus-free cameras with a fixed focus lens. These cameras don't require focusing because the lens is permanently set for a fixed distance of some few tens of feet. These kinds of cameras are suitable for photographing friends but not landscapes. In near space, everything is infinitely far away. A focus-free camera of this type will only return blurry pictures.

Automatic exposure control is useful, but not essential. If the exposure and f-stop can be set in advance, then automatic exposure control is not needed.

Auto-film advance is required to make modifying a commercial camera to computer control practical. Without this feature, a servo is required to advance the film after an exposure. Just like mechanical shutter controls, the alignment issues make cameras without auto-film advance impractical to convert to computer control.

So, the features needed for a near space camera are as follows:

A. The shutter button must be a simple switch closure. The shutter button cannot be connected to a mechanical release. The electrical switch is replaced with a transistor and resistor. Once the switch is replaced the flight computer is capable of operating the camera.

B. The auto-focus must really focus during the exposure. Do not use a camera with a fixed focus unless the focus can be manually set to infinity.

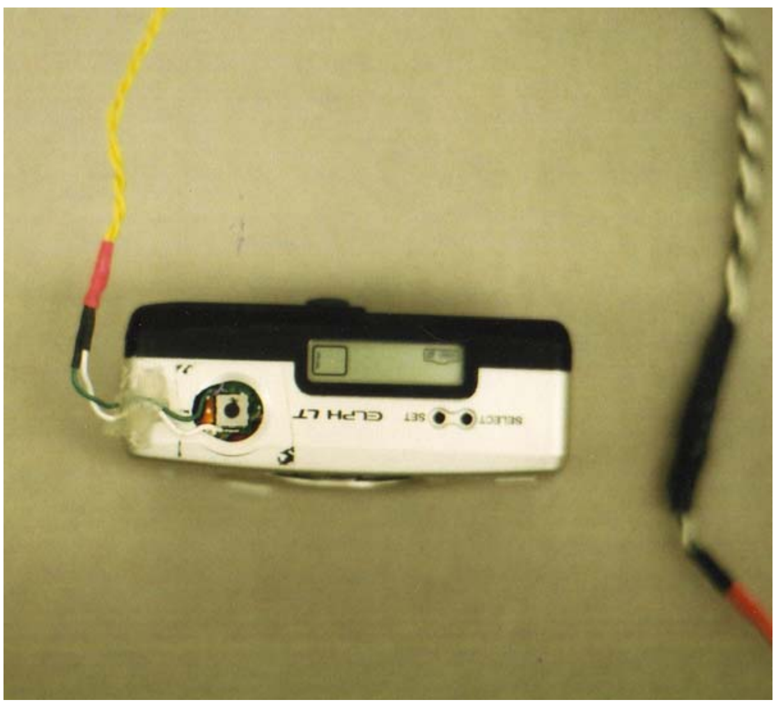
C. The camera must be capable of determining the proper exposure on its own, or the exposure time for each frame must be set before launch.

D. The camera must have auto film advance. Once a picture is exposed, the motor inside the camera must automatically advance to the next frame.

2.2 Getting the Camera Modified

If you're worried about ruining a new camera, then have a camera shop modify a 35mm camera for you. Two cameras that can be modified are the Canon Sure Shot Owl and the Canon Elph APS. Most other modern cameras can be modified, but talk to the camera shop first. It should only cost $45 to modify a camera. Here are the instructions you want to give to the camera repair shop modifying your camera. You want the camera opened up and two wires soldered to the button pads. If there is a switch closure position for the auto-focus, then you want that shorted to the shutter switch position. When the modification is completed, the camera will focus its lens and take a photograph when the bare ends of the wires are touched together. When the two wires are separated, the film will advance to the next frame. If the camera doesn't automatically advance, don't panic right away. Some cameras need to be loaded with film to take a picture and advance. So I'd recommend you get some exposed film (or waste a roll) and mount it inside a reusable film cartridge. Have a camera store show you how to do this. With this test roll, you can check out cameras at will. If you have trouble finding a camera store to modify your cameras, try Mr. Ken Tromburg at Photek, in Boise, Idaho[A]. He has modified several cameras for me over the years and I have been very happy with his work.

2.3 Modifying the Shutter of the Canon Elph At Home



Canon Elph Camera *– With shutter modifications*

Bill All (N3KKM) of NSBG told me how to modify the Canon Elph. He originally found these instructions on an amateur rocketry site on the web. Unfortunately, when Bill told me how to make this modification, he couldn't find the site. So whoever you are, thanks! The Canon Elph is an inexpensive and easy camera to modify. The following steps explain how to modify the shutter switch of the Elph.

Section 2.4 of this chapter, Adding a Transistor Switch, explains how to complete the process for the Elph and any other camera with wires soldered to its shutter switch. The procedure works for other cameras if you can safely close them after the modification.

2.3.1 Materials

- A small jeweler's Phillips screwdriver
- Two colors of very thin stranded, insulated wire, try #30 AWG
- Black electricians tape
- Hot glue

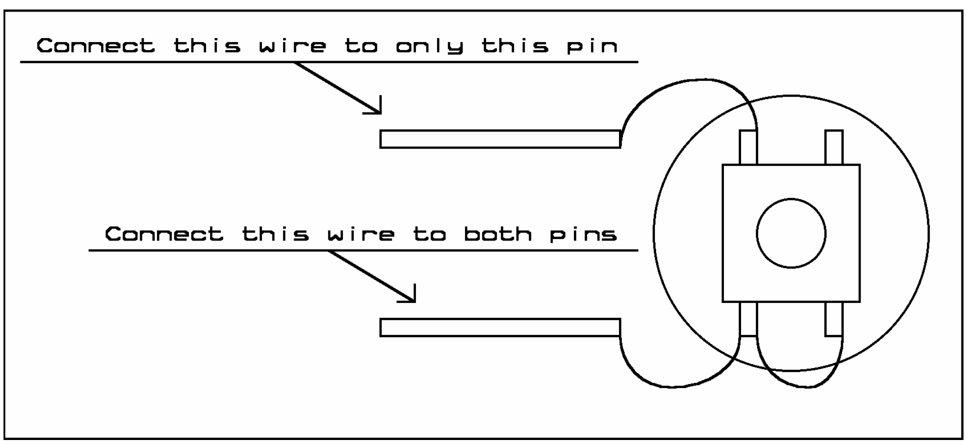
2.3.2 Procedure

- √ Remove the screws holding the camera case together (the screws are tiny Phillips).
- √ Turn the front of the camera to face you.
- √ The flash capacitor is located on the right side of the camera – **DO NOT** fool with this end of the camera.
- √ Open the case, at least enough of the silver front of the camera to access the shutter button.
- √ Remove the plastic button.
- √ Identify the micro-switch underneath the plastic shutter button.
  - o There are four soldered pads on the switch:
  - o The front two focus the camera and trigger the exposure.
  - o The back left pad is the ground.

    Note: The front refers to the side of the camera with the lens.

Perform the following test on the switch:

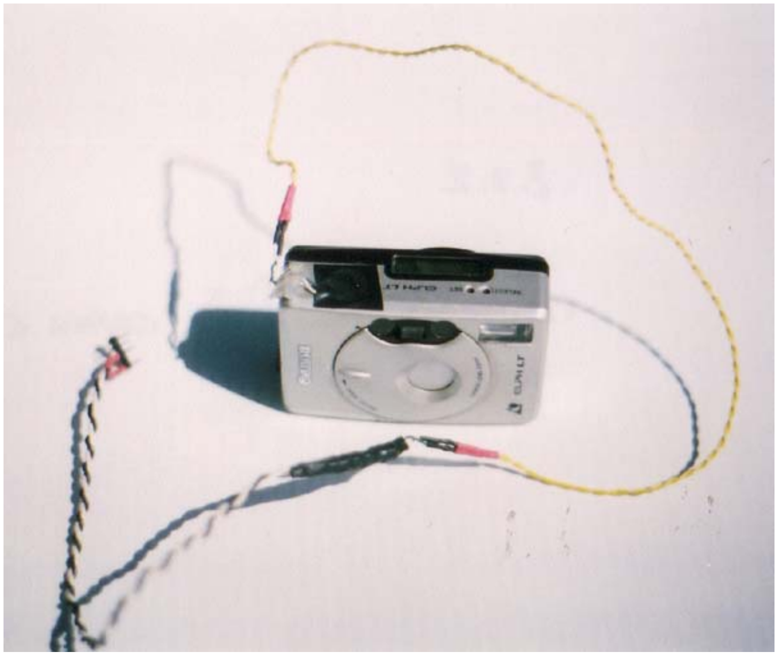
- √ Cover the flash with electricians tape so you are not blinded.
- √ Cut a short length of wire and strip insulation from both ends.
- √ Short the front left pad and back left pad together.
- √ Short the front right pad and back left pad together.
- √ You'll notice one combination focuses the lens and the second exposes a frame.
- √ Cut two pieces of thin wire to a length of one foot (make one wire a dark color).
- √ Strip the insulation from both ends of each wire.
- √ Solder the dark wire to the back left pad.
- √ Solder the other wire to both pads on the front of the shutter switch.



Shutter Switch Wiring Diagram

- √ Pass the two wires through the open hole of the plastic case where the shutter button used to be.
- √ Test the electrical connection by shorting the two free ends of the wires together (the camera should operate).
- √ Close the camera case and replace the screws.
- √ Cover the open hole with a piece of black tape.

- √ Use a little hot glue to "tie" the wires to the camera case (as a strain relief).
- √ Twist the wires together to keep them under control.
- √ Go to the next section to complete the modification.



Modified Camera – *With wires twisted*

2.4 Adding a Transistor Switch to a Modified Camera

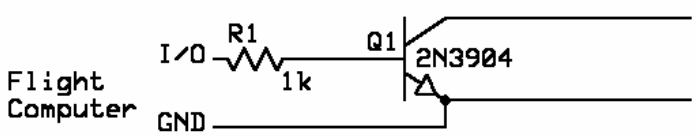
Once you have a camera with two wires soldered to its shutter switch, you'll need to solder a transistor and resistor to the wires.

2.4.1 Materials

- 1k Ohm resistor
- 2N3904 transistor
- Two colors of #24 AWG stranded wire
- Connectors for the wires to the flight computer
- Perf board
- Hot glue
- Heat shrink tubing large enough to cover the transistor switch perf board
  (I can get by with a ¾" diameter heat shrink, but your mileage will vary)

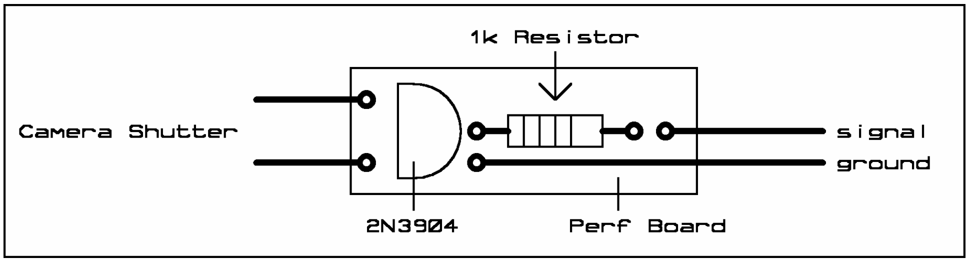
2.4.2 Procedure

The schematic of the transistor switch is shown below.



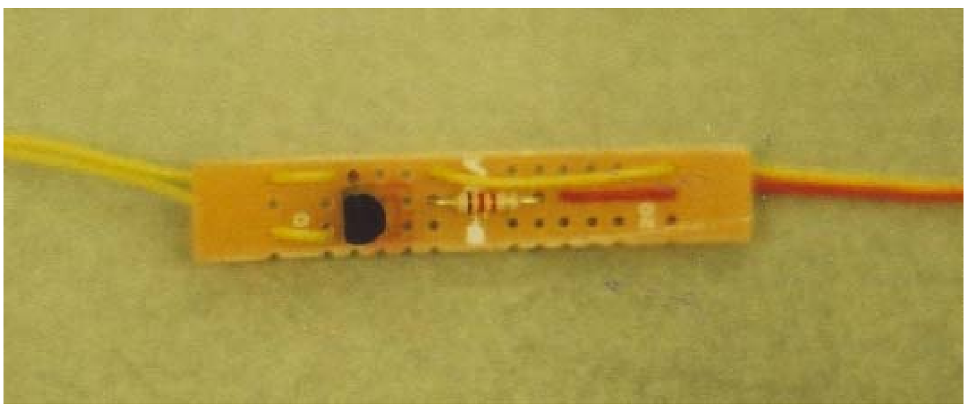
Camera Transistor Switch Schematic

Placement of components on the perf board is not critical, but try laying them out before soldering.



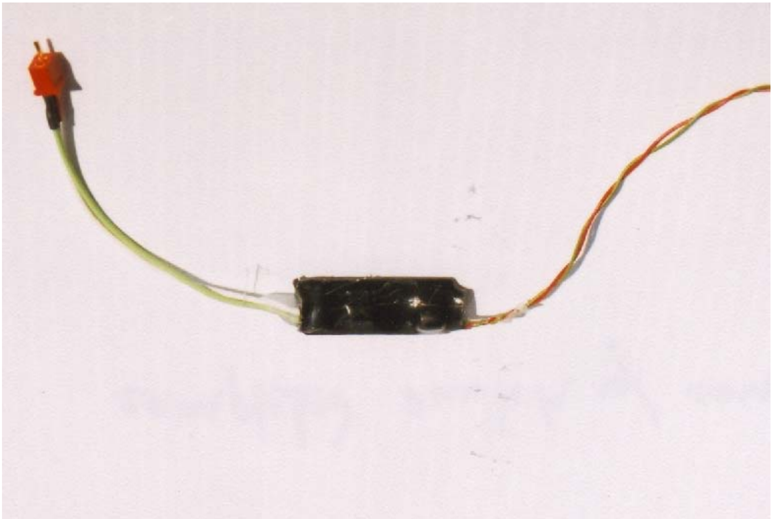
Parts Placement – *For the camera transistor switch*

- √ Connect the ground wire of the shutter switch to the emitter of the 2N3904.
- √ Connect the focus and exposure wire to the collector of a 2N3904. Note: which wire connections are made to the emitter and collector does not matter in the author's experience, but I still want to play it safe.
- √ Connect one end of a 1k resistor to the base of the transistor.
- √ Outline the size of perf board needed to fit all the components currently on the board.
- √ Cut a small piece out of the board first and sand its edges smooth.
- √ Replace the components and solder them.
- √ Cut two lengths of #24 AWG stranded wire, about 18 inches long.
- √ Solder the ground (black or green) wire to the emitter of the transistor.
- √ Solder the signal wire to the open end of the resistor.
- √ Attach connections to the open ends of the wires to interface them to your flight computer: the wire soldered to the emitter is connected to ground and the wire connected to the resistor is connected to the I/O pin.
- √ Test the transistor switch as explained in section 2.4.3.



Camera Transistor Switch – *Built on perf board*

- √ Apply a thin layer of hot glue to the perf board.
- √ Cover the perf board and its components with heat shrink tubing and shrink.



Camera Transistor Switch – *After perf board is covered with heat shrink.*

In place of a transistor, Zack Clobes (W0ZC) uses an opto-isolator to make the connection. The CC/PS controls an LED to operate the opto-isolator.

2.4.3 Operating the Modified Camera

To operate the camera, use the following code.

```
camera con 10

debug “click”, cr
high camera
pause 2000
low camera
debug “finished”, cr
end
```

The program’s constant, “camera”, is the I/O pin connected to the base resistor (which in this example is I/O pin 10). If constructed properly, the camera will take a photograph just after the Debug Terminal displays the word “click”. Experiment with the PAUSE statement to determine the minimum time the camera requires taking a photograph.

2.4.4 How it Works

When the camera I/O pin is set high, it energizes the base of the NPN transistor, saturating the transistor. A saturated transistor creates a low resistance path from the collector to the emitter where the two contacts of the switch are wired. This path acts as a closed switch when the transistor saturates allowing the two contacts of the shutter to now see each other. It’s as if you shorted the shutter’s two contacts and the camera responds as if the shutter button has been pushed (in essence, it has). See Appendix A, Lesson Nine for a lab with the transistor switch.

3.0 Camera Boxes and Camcorder Cradles

3.1 Camera Boxes

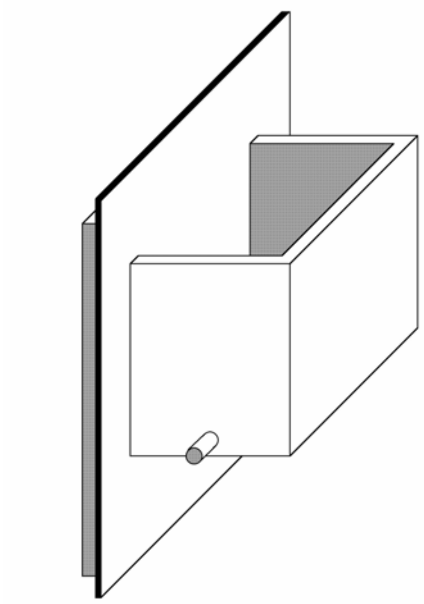
The camera boxes described here can mount a camera to the outside face of an E-Quad. Camera boxes are mounted either fixed to the E-Quad, or as a part of a scan platform. Stationary camera boxes are mounted to orient the camera either up towards the balloon and parachute, sideways to the horizon, or down towards the ground. By mounting the camera box to a scan platform, photographs of the balloon, horizon, and ground can be returned with a single camera. Whether the camera box is mounted fixed to an E-Quad or as part of a scan platform, its construction is the same. The scan platform is made to fit the camera box, ensuring that the camera box can rotate properly in the scan platform.

3.1.1 Materials

Camera Box on Quad Panel

Basic Camera Box

- Camera
- ½” thick Styrofoam[B] sheet (use the same kind of foam the airframe is constructed of)
- Hot glue
- Epoxy
- Metal straight edge
- Exacto knife
- 1/32” thick plywood
- 1/8” diameter wooden dowel (if building the basic camera box)



Camera Box on Quad Panel

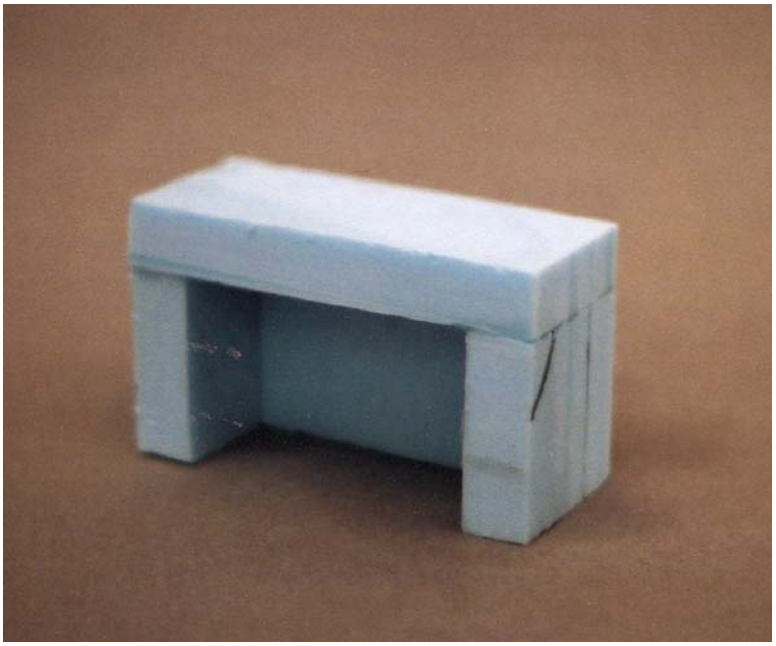
Additional Materials for Scan Platform

- 1/8” thick plywood
- ¼” diameter dowel
- Circular servo horn
- #20 solid wire, stripped
- Two Popsicle sticks

3.1.2 Procedure

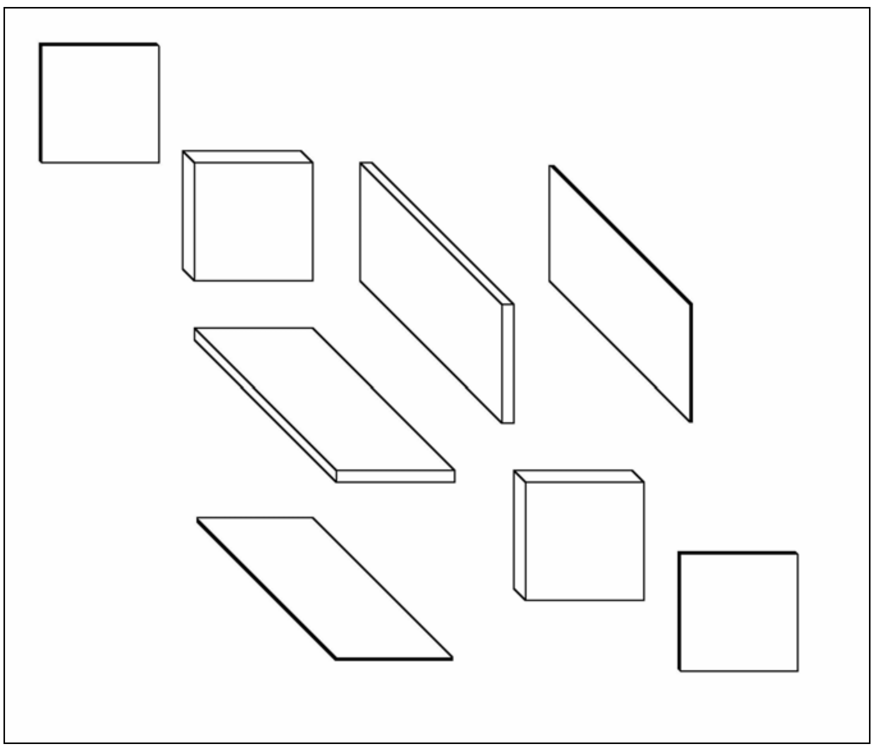
Make the Styrofoam Box

√ Measure the dimensions of the camera sides and cut two rectangles of 1/8” plywood the same size. At this time, the size of the 1/8” plywood doesn’t need to be accurate.
√ Tape the 1/8” plywood to the sides of the camera.
√ Measure the bottom footprint of the camera. Note that the camera’s footprint is now ¼” wider due to the plywood, if you are constructing a scan platform.
√ Cut a rectangle of foam just one inch larger than the camera footprint with Exacto knife and straight edge. The Styrofoam will be trimmed after construction.
√ Place the camera on the foam and determine dimensions of the box’s sides.
√ Cut out the sides of the box larger than the measured dimensions.
√ Use hot glue to glue the sides to the bottom, leaving the camera in place, but don’t glue the camera into the box.
√ Trim the box after the glue cools.



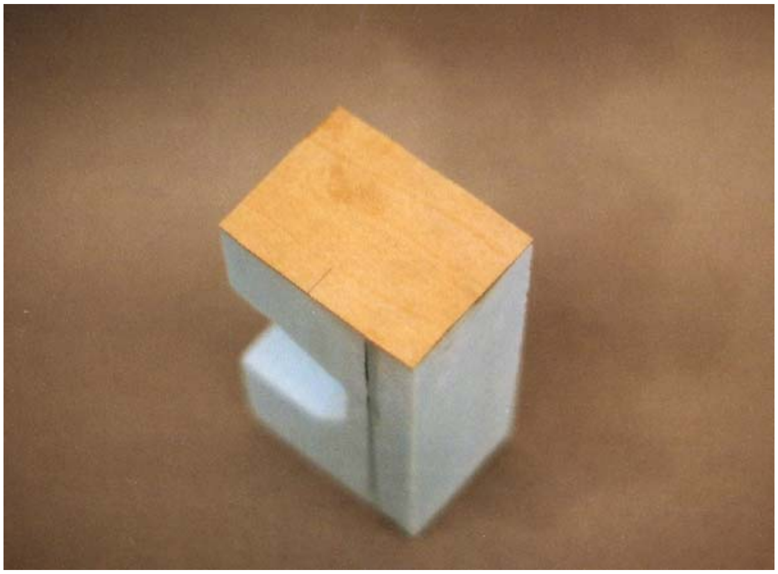
Beginnings of Camera Box –
Styrofoam Structure

Laminating the Box with Plywood



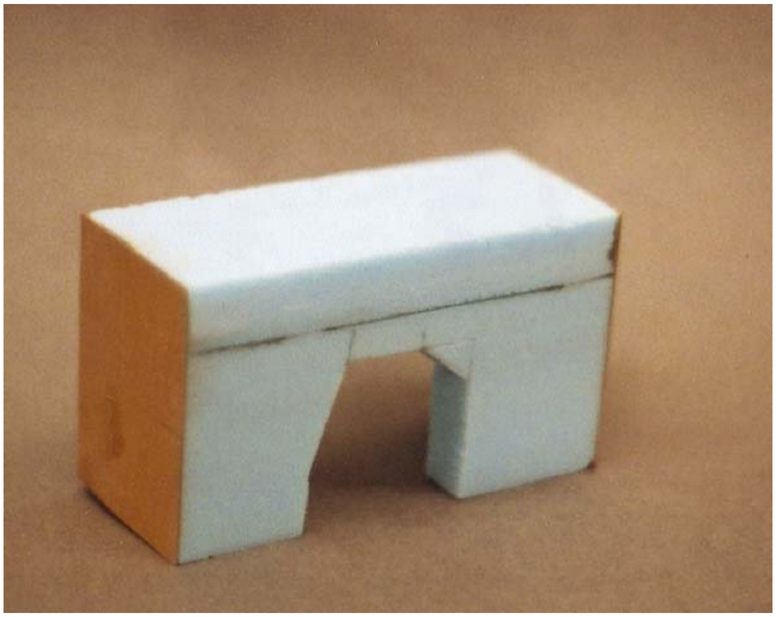
Plywood Over Box –
Exploded Diagram

- √ Laminate all sides of the box except for the surface to be mounted to the face of the E-Quad.
- √ Cut a piece of 1/32" ply slightly larger than the bottom surface of the box.
- √ Epoxy the plywood to the box.



The First Piece Epoxied in Place

- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight, such as a cast-iron muffin pan, until after the epoxy sets.
- √ Cut two rectangles of 1/32” plywood just larger than two side faces of the camera box.
- √ Epoxy the plywood on to the side faces.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.



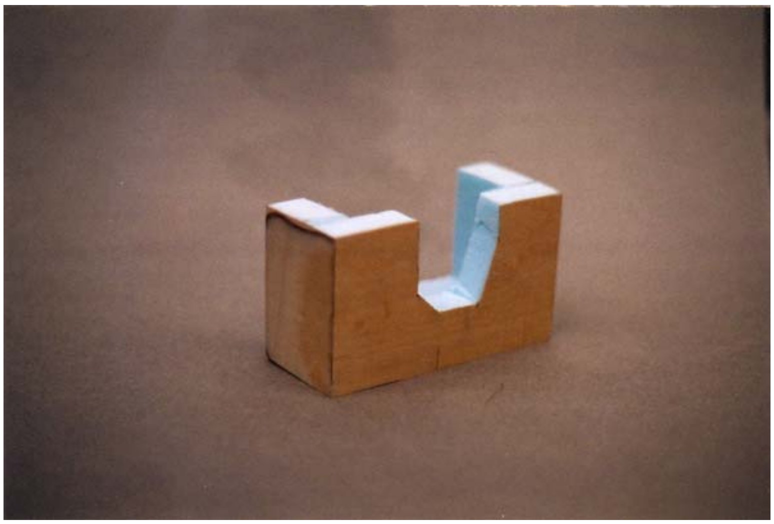
Side Faces Complete

- √ Trim the edges of the plywood to fit the Styrofoam box with a stationary sander.
- √ Cut two rectangles of 1/32” plywood just larger than the remaining two faces of the camera box.
- √ Epoxy the plywood on to the remaining faces.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.
- √ Trim the edges of the plywood to fit the Styrofoam box with a stationary sander.

- √ Fill any open gaps in the joints with epoxy and sand the joints smooth after the epoxy sets.
- √ Epoxy the 1/8" thick plywood inside the box on the side faces.
- √ Insert the camera after the sides are epoxied inside to apply force to the 1/8" ply while the epoxy sets.

Cut Lens Openings in the Camera Box

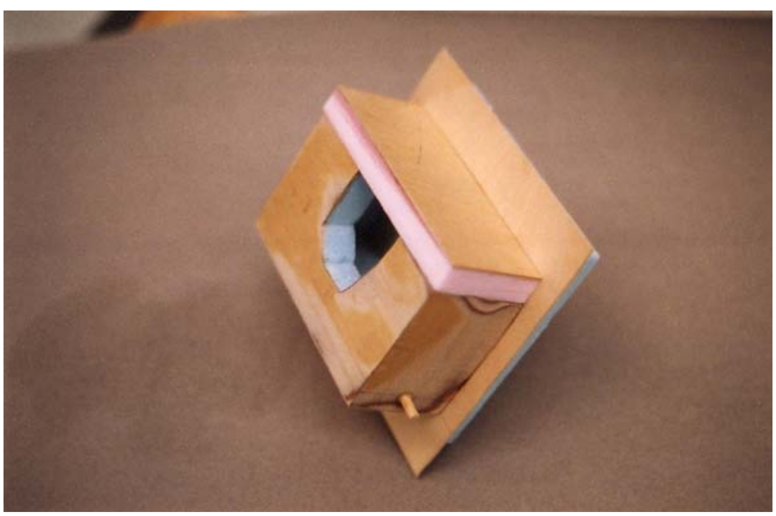
- √ Measure the dimensions and positions of the lens, light sensor, and focuser of the camera using a T-square to keep the measurements perpendicular.
- √ Transfer the measurements to the camera box, again using the T-square.
- √ Reduce the number of sharp corners by marking diagonals.
- √ Carefully cut out the openings in the camera box, as outlined by the pencil marks, with an Exacto knife.



Plywood Lamination Complete

Make the Camera Box Lid

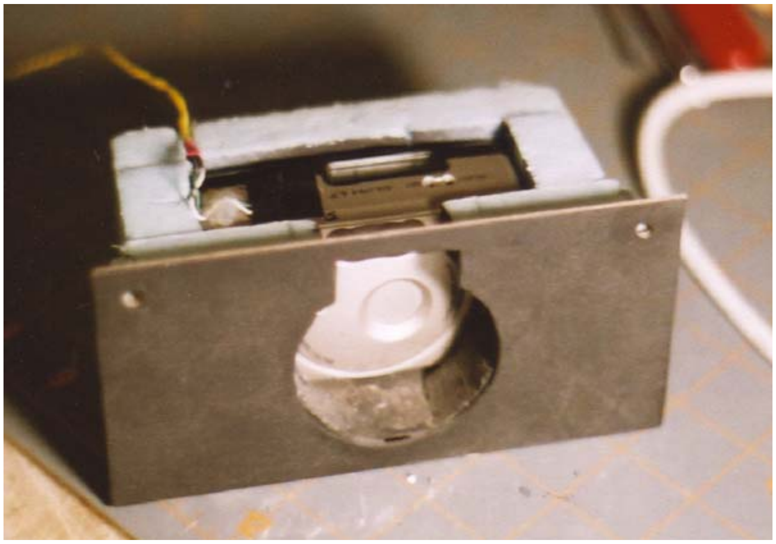
- √ Cut a rectangle of Styrofoam to cover the opened top of the camera box.
- √ Cut a sheet of 1/32" plywood to fit the cover.
- √ Epoxy the plywood to the Styrofoam lid.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.



Adding the Lid

Complete the Basic Camera Box

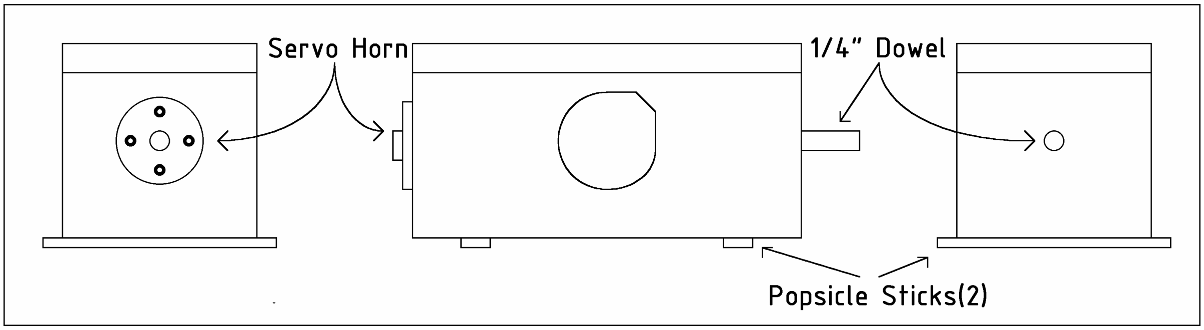
- √ Mark the center of the sides of the camera box.
- √ Drill 1/8" diameter holes in the sides.
- √ Cut two 1/8" diameters dowels to a length of one inch.
- √ Epoxy the dowels into the sides, with the dowels flush to the inside face of the camera box.
- √ After the epoxy sets, bevel the end of the dowels. The dowels are where rubber bands wrap around the camera box to hold the camera box lid in place.
- √ Epoxy the camera box to an E-Quad panel.
- √ Cut an opening in the E-Quad panel where the camera's transistor switch enters the capsule.
- √ Paint the E-Quad panel and camera box.



The Camera Box - *Painted and ready to go*

3.1.3 The Scan Platform Camera Box

The following directions convert the stationary camera box into one suitable for a scan platform.



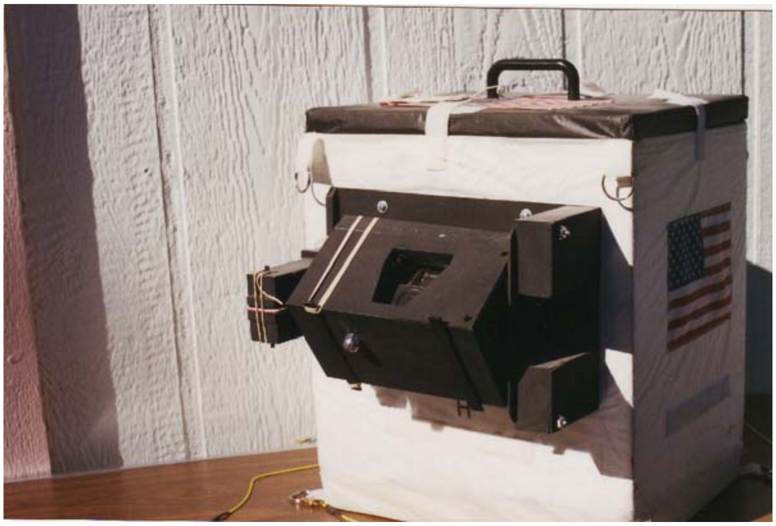
Scan Platform Camera Box

- √ Cut the Popsicle sticks to a length ½" longer than the depth of the camera box.
- √ Draw two lines parallel to the outside edges of the bottom of the camera box, one inch inside the outside edges.

- √ Epoxy and center the Popsicle sticks to the bottom of the camera box. Be sure the Popsicle sticks are positioned outside the lens openings in the camera box; the sticks protrude ¼" beyond the front and back of the box.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.
- √ The Popsicle sticks are where the rubber bands wrap around to hold the camera box lid in place. Rubber band the lid to the camera box (do not place the camera inside the box at this time).
- √ Find the center of the sides of the camera box, being sure you are including the lid when determining the center.
- √ Drill a ¼" hole in one of the centers.
- √ Cut the ¼" diameter dowel to a length of two inches.
- √ Epoxy the dowel into the side, with the dowel flush to the inside face of the camera box.
- √ Epoxy the circular servo horn to the center of the other side of the camera box.
- √ Drill at least four small holes through the servo horn and camera box with small diameter drill bits, just large enough pass the wire staples you will make from the #20 wire.
- √ Cut at least four lengths of #20 AWG wire one inch long.
- √ Coat the wires with epoxy and insert through the holes in the servo horn and camera box until the wires protrude roughly equal amounts from the inside and outside surfaces.

Servo Horn on Camera Box –
Held in place with wire "staples"

- √ Fold the wire end over to form a "staple."
- √ Coat the exposed ends of the wires with epoxy.
- √ Go to Chapter Five, Section 3.4.3 and complete the booms and servo for the scan platform.



Completed Scan Platform Camera Box

3.2 Camcorder Cradles

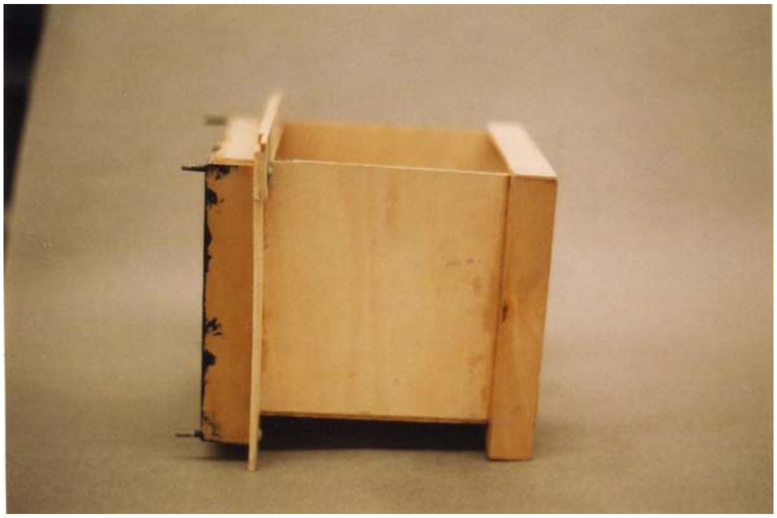
Camcorder Cradle

The camcorder cradle secures a camcorder inside an airframe. The cradle design in this chapter extends the width of the airframe and is braced on both ends by opposite E-Quad openings. One E-Quad is the opening for the camcorder lens and the opposite E-Quad is the hatch for operating the camcorder.

3.2.1 Materials

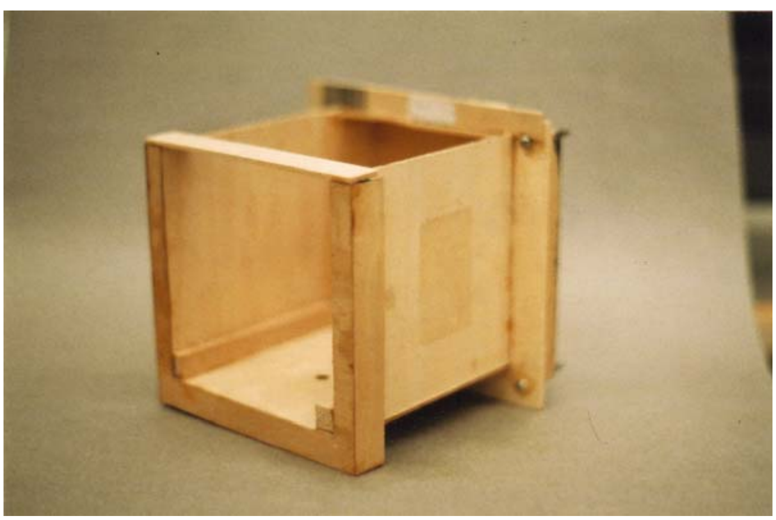
- ¾" Styrofoam sheet
- ½" Styrofoam sheet
- 1/8" thick plywood
- ¼" by ½" basswood strip
- 1/8" diameter dowel
- #6-32 threaded rod, or two inch long bolts with their heads cut off
- Epoxy
- Camcorder[C]

Procedure



Plywood Box for Camcorder Cradle

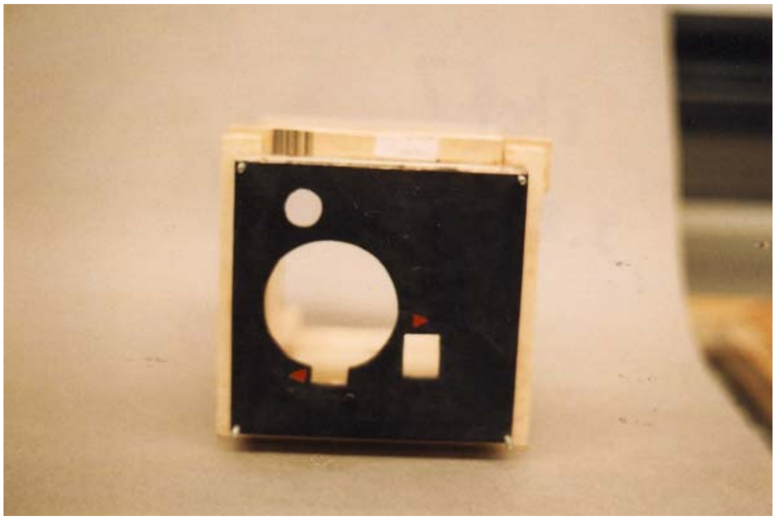
- √ Cut three pieces of 1/8” plywood to dimensions of 5.25” wide and long enough to span an airframe, usually ten or twelve inches long.
- √ Epoxy their edges together to form a “U” shaped channel capable of sliding through one E-Quad and spanning the width of the airframe. Note: This structure is fragile; treat it carefully at this point.
- √ Epoxy a 5.25” square of ¾” Styrofoam to one end of the “U” channel (this is the front panel of the camcorder cradle) and let the epoxy set.
- √ Epoxy a doubler inside the bottom of the cradle. The doubler thickens the bottom of the cradle where the ¼”-20 mounting bolt hole is drilled.
- √ Lay the camcorder inside the “U” channel and press the front of the camcorder into the Styrofoam front to form a light depression indicating where the lens is located.



Camcorder Cradle - *From another angle*

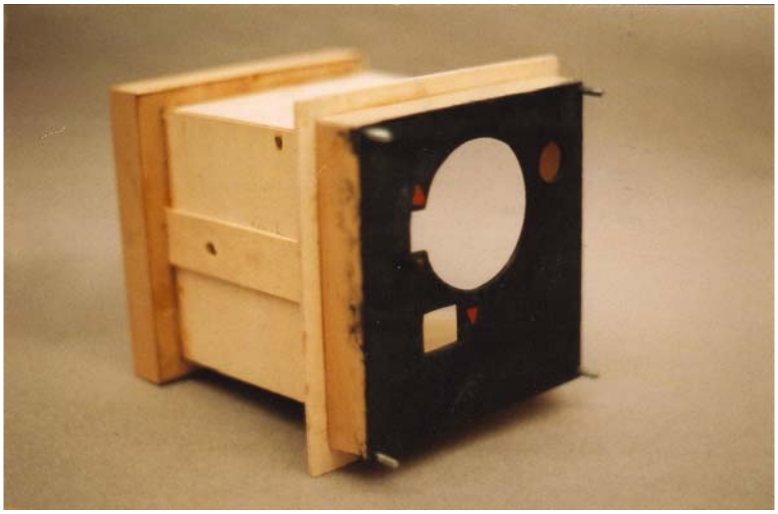
- √ Cut out an opening for the lens of the camcorder.
- √ Use the lens position to determine where to cut an opening for the camcorder’s light sensor and focuser.

- √ Note: Some camcorders have controls located on the front of the camcorder. Make all necessary holes in the front plate for these controls.
- √ Use a small probe to determine the location of the ¼”-20 mounting thread of the camcorder.
- √ Drill out the ¼”-20 hole in the cradle and bolt the camcorder inside the cradle.
- √ Cut a combination of ½” and ¾” Styrofoam to fill gaps between the camcorder and the cradle. Not all the gaps have to be filled, but use enough Styrofoam to strengthen the joints in the cradle.
- √ Cut a six-inch square of 1/8” plywood and center it over the front of the cradle. This is the front plate.
- √



***View of the Front Plate** – Here shown painted*

- √ Mark on the front plate the location of the openings in the front Styrofoam face of the cradle.
- √ Cut out the openings in the front plate.
- √ Epoxy the six-inch square front plate to the front of the cradle.



Another View of Front Plate

- √ Cut a 5.25” square of ¾” Styrofoam to fit the back end of the cradle as a rear panel.
- √ Assuming the camcorder record button is located in the back of the camcorder, cut a large enough opening in the back plate so that fingers can reach in and start the camcorder.
- √ Cut another opening to make the viewfinder visible.
- √ Epoxy the back Styrofoam plate into place.

√ Cut a 5.25” square of 1/8” thick plywood for the back plate.
√ Mark the location of the openings on the plywood back plate.
√ Cut out the openings in the back plate.

The camcorder sits next to the cradle – *next step, the test fitting.*

√ Test fit the cradle by sliding it into one open E-Quad port and making sure the back end of the cradle with the plywood back plate does not extend beyond the face of the airframe.

Cradle in the Airframe

√ Epoxy the plywood back plate in place.
√ Cut four pieces of #6-32 threaded rod to a length of two inches for the rear bolts.
√ Drill 1/8” diameter holes 1.5 inches deep into the corners of the rear panel and back plate.
√ Fill the holes with epoxy and thread the threaded rod into the epoxy-filled holes
√ Cut a six-inch square sheet of 1/8” thick plywood for the back locking plate.
√ Drill four holes in the back locking plate to match those protruding from the back plate of the cradle.
√ Cut a rectangle of ¾” thick Styrofoam for the access cover. This will cover the openings in the back locking plate of the cradle.
√ Cut a rectangle of 1/32” thick plywood to cover the face of the access cover.
√ Epoxy the 1/32” plywood onto one face (this will be the outside face) of the access cover.

- √ Lay the back cover over the opening in the back plate and mark its outline.
- √ Cut ¼” by ½” basswood strips to form a border around the back cover.
- √ Epoxy the ½” by ¼” basswood strips to the back plate, ½” face down.
- √ Test fit the back cover to be sure it fits within the boundary created by the basswood strips.

Test Fitting the Covers

- √ Find the center of the vertical sides of the basswood boundary.
- √ Cut notches through the center deep enough to lay a 1/8” diameter dowel in.
- √ Cut the 1/8” diameter dowels to a length of ¾” long and sand the cut ends smooth.
- √ Epoxy the dowels inside the cut notches.
- √ Trim the corner bolts of the cradle and the ¼”-20 camcorder mounting bolt.
  Note: Use a Dremel with a sanding disk to make the bolts just long enough to do their job.
- √ Mount the camcorder inside the cradle and test fit the cradle by sliding it into one E-Quad port and bolting the back plate to the bolts, securing the cradle inside the airframe.
- √ Note: It may be necessary to trim the top of the cradle over the ¼”-20 bolt to be able to lift the cradle high enough to clear the bolt head at the bottom of the cradle.

If your camcorder has function buttons on its top face, then follow the next steps to construct a top hatch that prevents Styrofoam peanuts inside the airframe from changing camcorder settings.

- √ Load camcorder into the cradle.
- √ Insert the cradle into an airframe.
- √ Cut a sheet of ½” thick Styrofoam large enough to cover the exposed open top of the cradle. This will be the top hatch. Note: The top hatch must be supported on its sides by the cradle, but do not create a significant overhang.
- √ Cut ¾” wide strips of 1/8” plywood to the same length as the top hatch.
- √ Epoxy the 1/8” strips to the sides of the top hatch, flush with the top edge and extending ¼” below the bottom edge.
- √ Use masking tape to hold the 1/8” plywood strips into place while the epoxy sets.
- √ Test fit the top hatch after the epoxy sets. The fit can be loose, as the top hatch just prevents Styrofoam peanuts from getting into the cradle.
- √ Paint the cradle.

3.2.2 Using the Camcorder Cradle

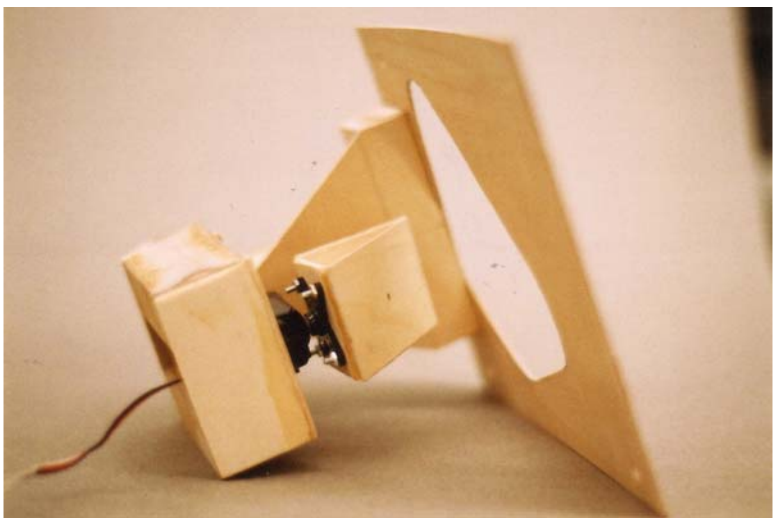
During assembly of the capsule, perform the following steps:

- √ Recharge the camcorder battery and load videotape into the camcorder.
- √ Bolt the camcorder into the cradle.
- √ Slide the back end of the cradle into one E-Quad port opening of the airframe.
- √ Push the cradle through the E-Quad until the back end is sitting on the opposite E-Quad port.
- √ Bolt the back locking plate to the back of the cradle.
- √ Attach the access cover into the opening in the back locking plate by wrapping rubber bands around the dowels and over the back cover.

Shortly before launch, perform the following steps:

- √ Remove the access cover.
- √ Start the camcorder.
- √ If the camcorder has function buttons on its top, then open the airframe hatch to operate the camcorder.
- √ Press any necessary buttons on the front of the camcorder.
- √ Ensure the camcorder is functioning properly by looking through its viewfinder.
- √ Close the access cover and rubber band into place.
- √ Close the top hatch, if needed.

4.0 Mirror Rotator



Completed Mirror Rotator

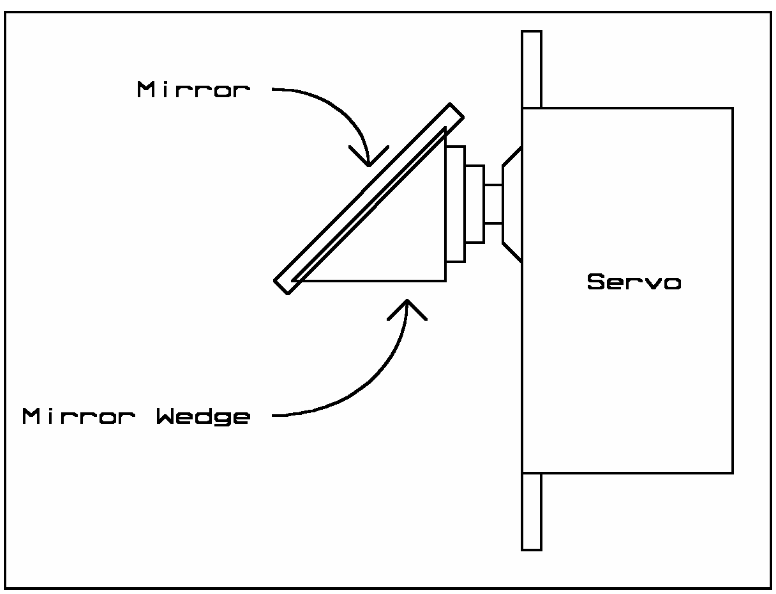
Camcorders are large enough that it's best to leave them fixed in place. This situation is fine if you are content with viewing only the horizon. For those times you are not, use a rotating mirror mounted outside the airframe to change the view of the camera. It is easier to rotate a lightweight mirror than a heavy camcorder. On the negative side, the mirror produces a reversed image. A second reflection can correct this (this is one of those few times where two wrongs make a right). However, the field of view of most camcorders is large enough that the second mirror must be at least six inches across. So, I'd recommend against using a second mirror. Instead of using a second mirror, video from the camcorder can be captured on a PC and rotated in software.

A mirror mounted at a 45-degree angle in front of the camcorder lens creates a view 90-degrees away from the original optical axis of the camcorder. When the mirror is rotated along the axis between the center of the mirror and the camcorder lens, the view from the camcorder also changes. Rotating the mirror though an arc of 180 degrees lets the camcorder see the ground, the horizon, and the balloon. This section describes the construction of a rotating mirror mount for a camcorder. A simpler version of this device was used on KNSP's 1997 ATV near space missions.

4.1 Materials

- First surface mirror (size to be determined)
- Glasscutter
- Fine tip felt tip marker
- Metal straight edge
- 2" thick Styrofoam
- ½" thick Styrofoam
- ¾" thick Styrofoam
- Epoxy
- 1/32" thick plywood
- 1/8" thick plywood
- Popsicle sticks
- Servo
- Servo horn
- #24 AWG stranded wire, preferably three different colors
- Two diameters of heat shrink tubing to cover individual servo wires and a second larger diameter to cover all three of the servo cables
- #2-56 hardware, ½" long
- Nylon cable zip tie mounting plates
- #6-32 hardware (bolts lengths to be determined later)

4.2 Procedure

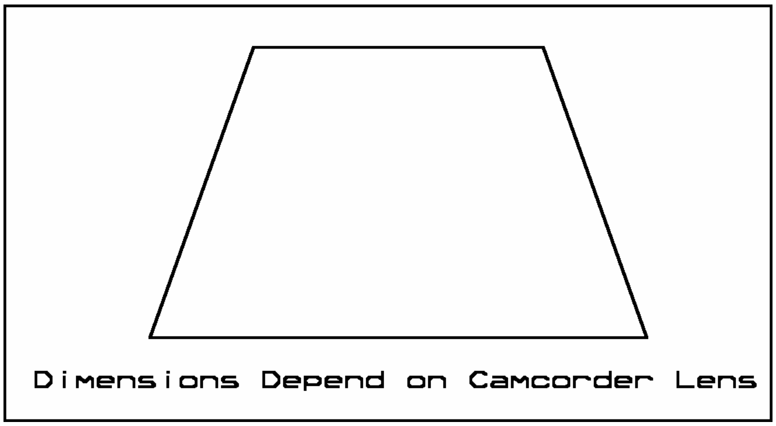


Mirror Rotator Diagram

The mirror rotator is a unit designed as an optional attachment for the camcorder cradle. Near space flights in which the camcorder only records the horizon do not carry the mirror rotator. However, those flights carrying a camcorder to record images within an arc from the ground to the balloon carry the mirror rotator mounted to the front face of the camcorder cradle. Alternatively, the mirror rotator can be permanently mounted to the face of camcorder cradle, like KNSP's first camcorder cradle.

Cut the Mirror

- √ Place the camcorder within the cradle.
- √ Hold an index card in front of the camcorder lens at a 45 degree angle.
- √ Look through the viewfinder and draw the field of view of the camcorder on the index card. The result should be an oval.
- √ Since it's difficult to cut circles in glass, draw a trapezoid (keystone-shape) around the oval field of view.
- √ Cut out the shape on the card.



***Trapezoid-shaped Mirror –** The dimensions depend on the camcorder lens.*

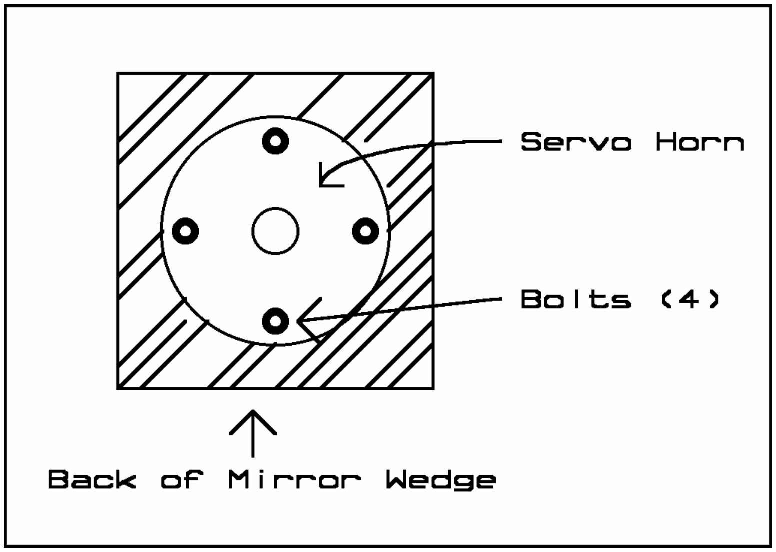
- √ Transfer the cardboard shape to the mirror with a marker.
- √ Cut out the mirror with a straight edge and glasscutter.
- √ Clean the glass of cutting oil and set the mirror aside.

Alternative Mirror Shape

An alternative to a truncated triangle shaped mirror is to cut the mirror to a rectangle shape. This shape wastes weight, but may be easier to cut.

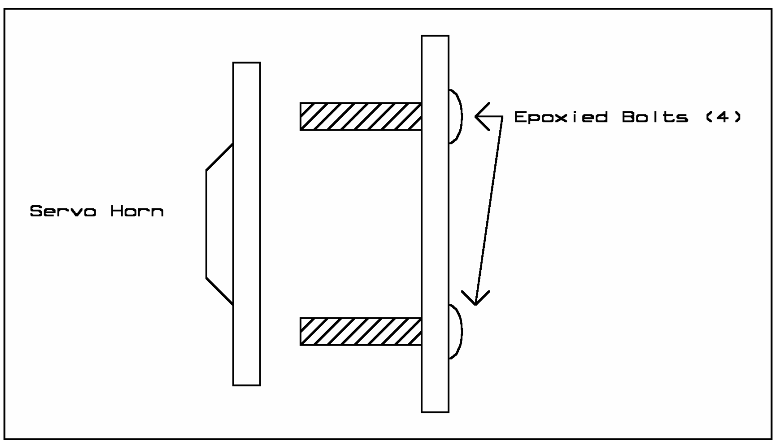
Making the Mirror Wedge

- √ Make a square in 1/8" plywood with each side equal to the smallest dimension of the mirror trapezoid. This square forms the base of the mirror wedge.
- √ Draw diagonal lines from opposite corners of the mirror wedge base.
- √ Place a servo horn on the mirror wedge base, centered on the drawn cross.



Servo Horn on Mirror Wedge Base

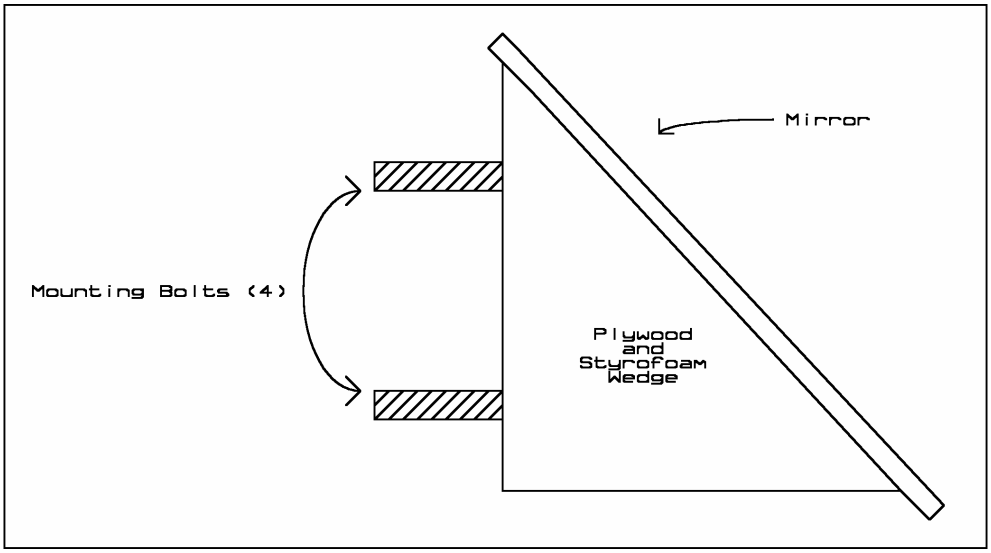
- √ Mark the location of the outer hole in each servo horn.
- √ Enlarge the outer hole in each arm of the servo horn (the hole has to be large enough for #2-56 bolts).
- √ Drill four holes in the 1/8” plywood mirror wedge base just undersized for the #2-56 bolts.
- √ Epoxy and thread the bolts into the plywood mirror wedge base and let the epoxy set.



Mirror Wedge Base

- √ Test fit the servo horn; it needs to slip on and off the bolts in the mirror base.
- √ Cut a cube out of Styrofoam with sides equal to the sides of the mirror base.
- √ Press the cube on the bolt head side of the mirror base, making impressions in the Styrofoam at the location of the bolt heads.
- √ Cut small pits into the cube at the location of the bolt heads.
- √ Test fit the cube; it should sit flush on the mirror base.
- √ Epoxy the cube to the mirror base, trapping the bolt heads between the mirror base and the cube.
- √ Measure the dimension and corners of the cube; insure the cube is as close as possible to a perfect cube.
- √ Cut 1/32” plywood to fit the sides of the cube.
- √ Epoxy the plywood to the sides of the cube. Do not epoxy plywood to the top of the cube.
- √ Mark a 45-degree diagonal line on two side of the cube.
- √ Carefully cut the cube in half along the line, creating a wedge attached to the mirror base.

√ Trim the 45-degree face of the former cube to make it flat and smooth, with a stationary belt sander if possible.



Side View of Epoxied Mirror on Wedge

Center and epoxy the mirror to the diagonal face of the wedge with the aluminized face up.

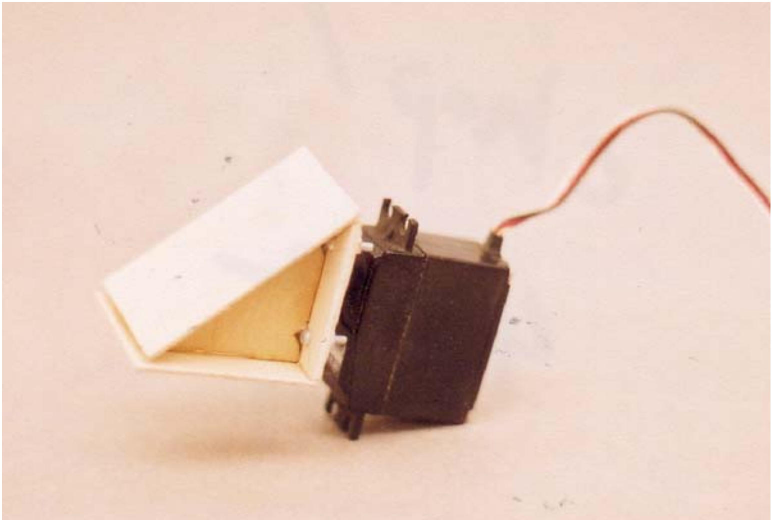
Note: When the mirror is epoxied with the aluminized side facing the wedge the mirror still reflects, but the images are slightly doubled and less crisp and bright. This is why a second surface mirror is not used.

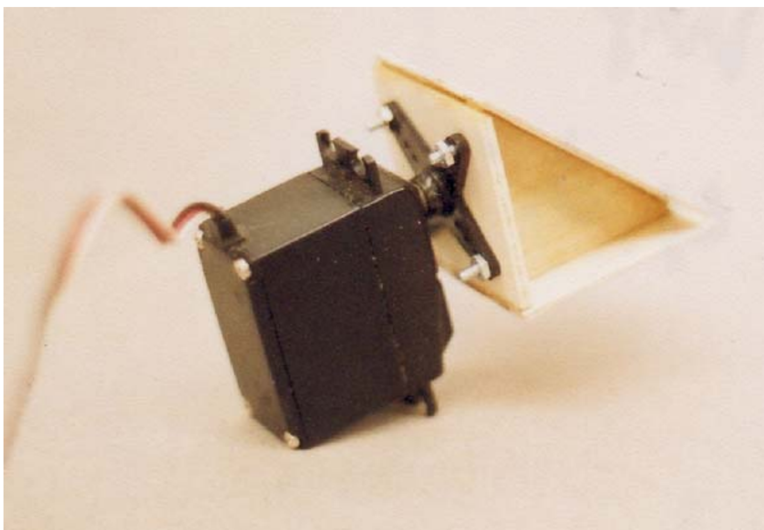
Making the Servo Holder

The servo holder positions the mirror directly in front of the camcorder lens. Since every camcorder model has different dimensions, these directions cannot give the dimensions for your particular camcorder. However, from the procedure outlined below, you can design and build a servo holder.

The servo holder is designed as an “L” shaped bracket that is bolted onto the face of the camcorder cradle. The servo holder is optional; not every flight carrying a camcorder must carry it. The servo holder positions the mirror wedge as close to the camcorder lens as possible. The servo rotates the mirror through a 180-degree arc, letting the camcorder see everything within that arc.

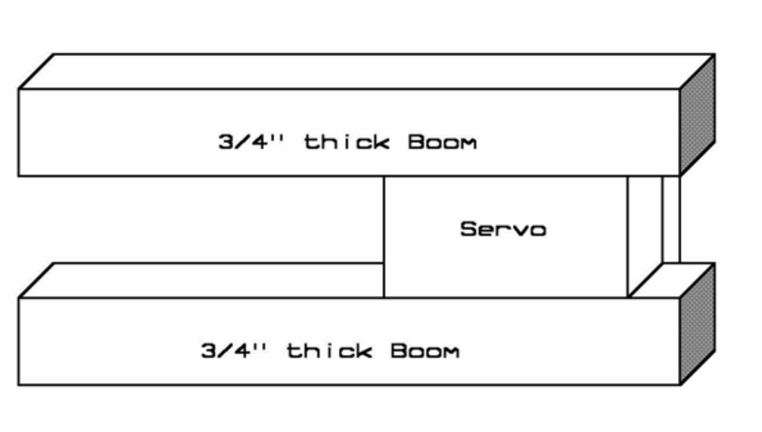
√ Place the camcorder inside the camcorder cradle.
√ Rotate the servo to its mid-position.
√ Bolt the servo horn to the servo.
√ Bolt the mirror wedge to the servo horn so that the narrow end of the mirror wedge points to the far end of the servo.





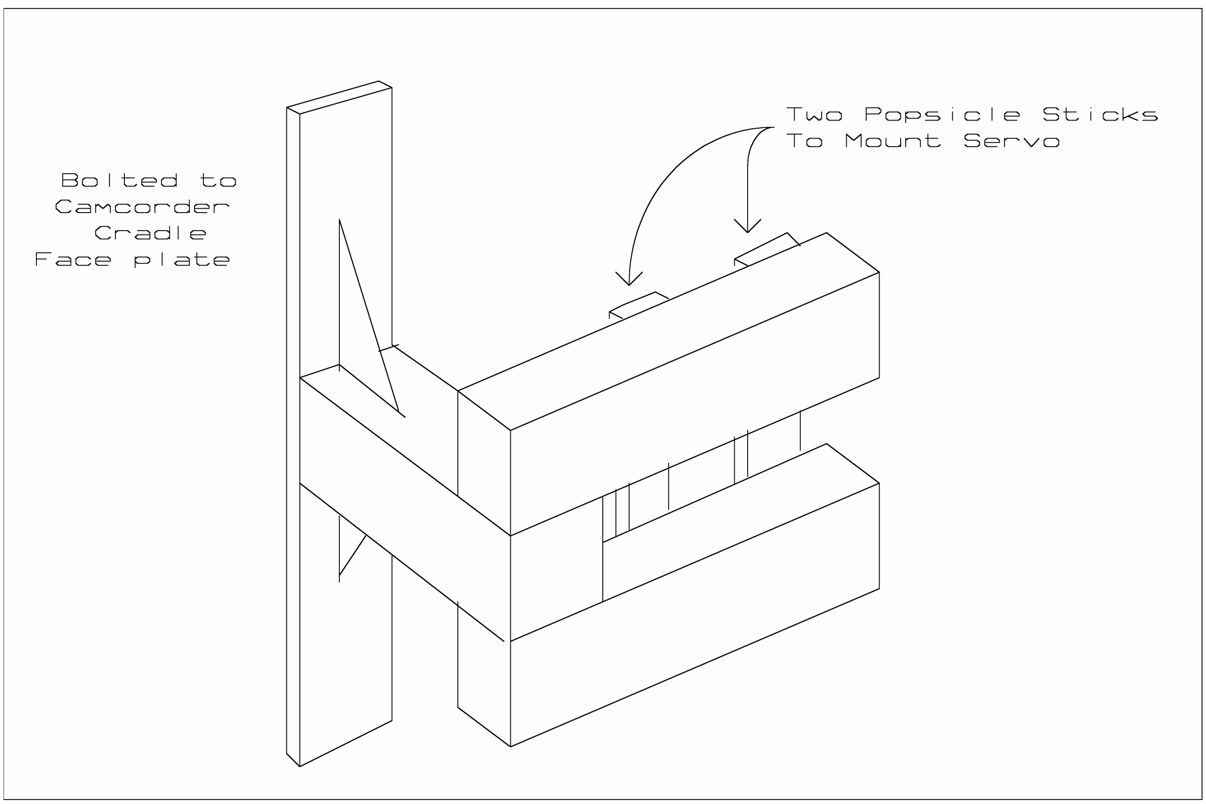
Mirror Wedge Attached to the Servo

- √ Prop the mirror wedge centered and in front of the camcorder lens.
- √ Measure the distance from the front of the servo to the far edge of the cradle; this distance is the length of the mirror rotator arm.
- √ Make two booms from ¾” thick Styrofoam and 1/32” plywood that is one inch wide and as long as the length of the mirror rotator arm. Note: Do not cover the small ends of the boom with 1/32” plywood or trim the booms at this time.



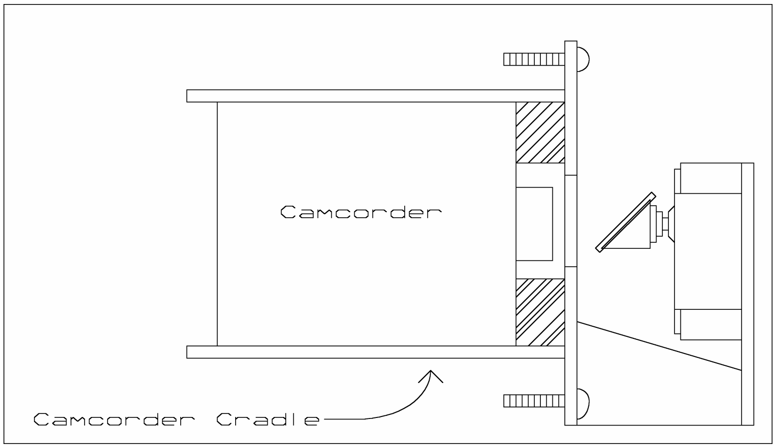
Booms Holding Servo – *Two ¾" thick Styrofoam booms support the servo.*

√ Tape or rubber band the booms to both sides of a servo.
√ Cut two Popsicle sticks to length, so they extend across the booms and servo.
√ Slide the servo away from the booms slightly, so that the Popsicle sticks slide beneath the servo-mounting tabs.
√ Epoxy the Popsicle sticks into place so that they and the booms form a box around the servo.
√ Clamp the Popsicle sticks to the booms as the epoxy sets.
√ Drill one hole in each Popsicle stick that matches a hole in the servo-mounting tab.
√ Cut and epoxy a piece of 1/8" thick plywood to cover the exposed end of the booms closest to the servo.

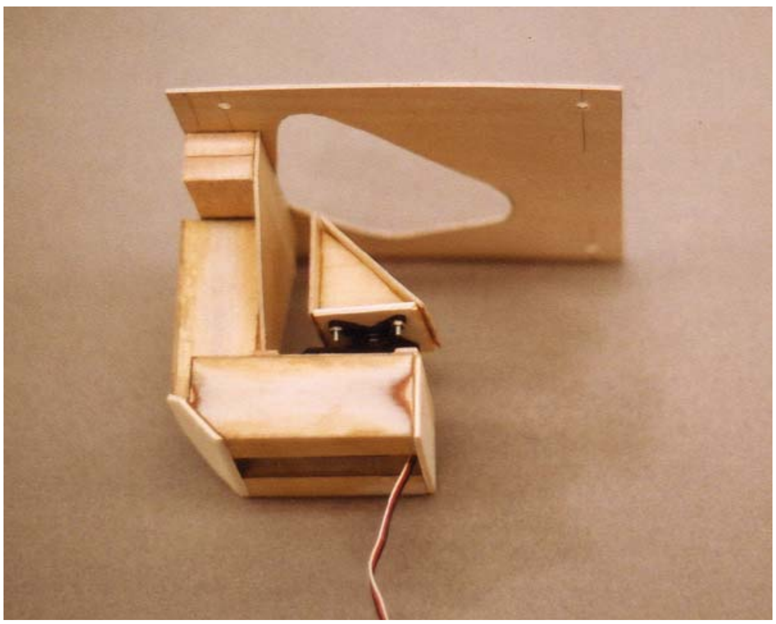


Positioning the Popsicle Sticks

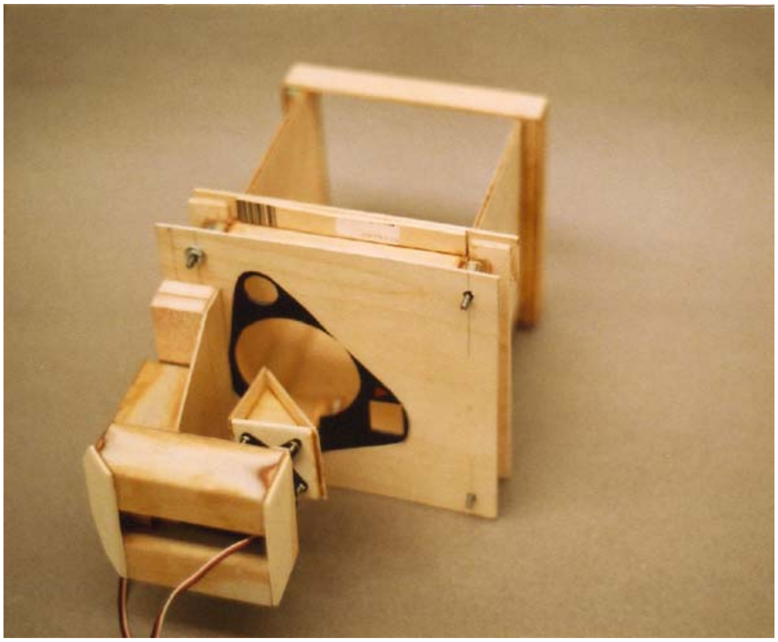
√ Bolt the servo into the end of the booms.
√ Position the booms in front of the camcorder cradle such that the mirror is centered in front of the camcorder lens (the camcorder is still inside the cradle).



Mirror and Wedge in front of Camcorder



Photograph of Mirror Assembly – *Before Mounting to Cradle*



Mirror and Wedge mounted to Cradle

- √ Measure the distance from the front of the mirror rotator arm to the front face of the camcorder cradle; this distance is the depth of the mirror rotator arm.
- √ Make one boom from ¾” thick Styrofoam and 1/32” plywood that is one inch wide and as long as the depth of the mirror rotator arm. This arm is called the mirror rotator stand-off.
- √ Check the fit of the new boom to the spacing between the servo arm; you may need to trim the foam thickness or add a doubler to the boom to make a tight fit. Note: Do not cover the small ends of the mirror rotator standoff with 1/32” plywood or trim the boom at this time.
- √ Epoxy the mirror rotator standoff between and perpendicular to the mirror rotator arm.
- √ Cut a rectangle of 1/8” plywood that is one inch wide and two inches long.
- √ Epoxy the rectangle over the end of the standoff and the rotator arm.

- √ Remove the servo and mirror from the rotator arm.
- √ Sand the rotator and standoff arms with a stationary belt sander to remove any blemishes or rough edges.
- √ Replace the servo back into the end of the rotator arm.
- √ Cut a rectangle of 1/8” plywood to measure six inches long and two inches wide. This is the mounting plate of the rotator.
- √ Place the plywood on the cradle and along either the left or right edge of the cradle.
- √ Place the standoff mirror rotator arm on the rotator mounting plate.
- √ Check the fit and the gap between the mirror and cradle face, making sure the standoff is perpendicular to the mounting plate and the mirror is free to rotate.
- √ Trim the standoff arm as necessary.
- √ Double check the fit again and mark the proper location for the standoff arm.
- √ Remove the mirror wedge and set it aside.
- √ Epoxy the standoff arm to the mounting plate.

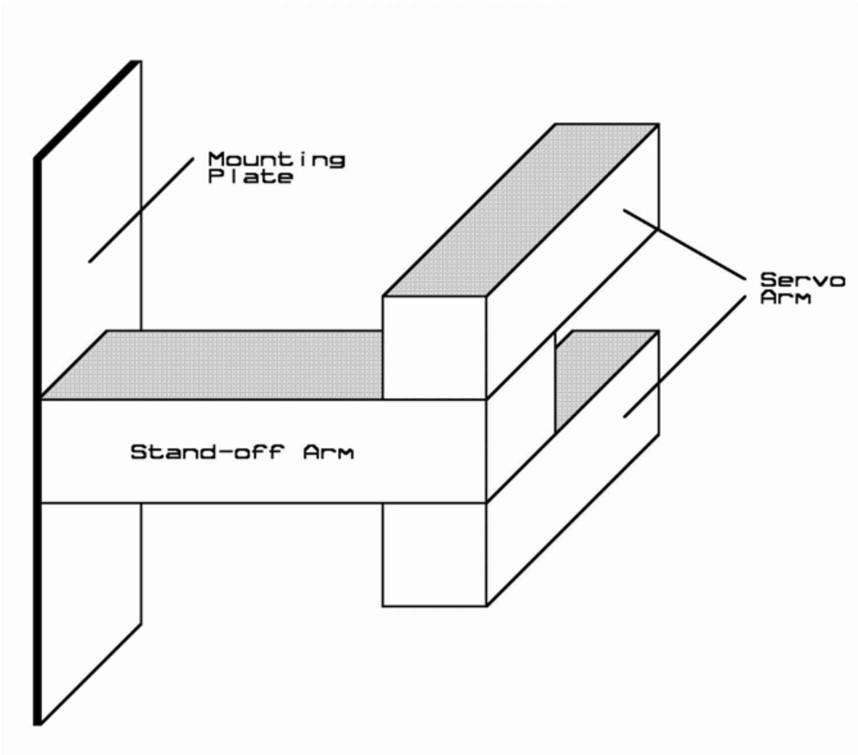


Diagram of Mounting Plate on Arm

- √ Cut two triangles of 1/8" plywood to brace the standoff arm to the mounting plate.
- √ Epoxy the plywood braces to the standoff arm and mounting plate.
- √ Remount the mirror wedge to the rotator arm.
- √ Place the rotator arm back onto the cradle and center the mirror over the camcorder lens.
- √ Determine two locations to drill two holes for 6-32 bolts. The bolts are bolted inside the cradle, with threads sticking out. The mirror rotator is attached to these bolts.

- √ Mark the location of two holes to mount the plate on the face of the cradle.
- √ Mark the location of a third hole to pass the servo cable through.
- √ Remove the mirror wedge.
- √ Align the rotator arm with the cradle face.
- √ Drill two 1/8" diameter holes through the cradle face and the mounting plate.
- √ Remove the cradle from the airframe.
- √ Insert bolts from the inside, sticking out.
- √ Determine the length of bolts needed (about ¼" beyond edge of the cradle face).
- √ Insert the proper length of bolts and epoxy inside the cradle face.
- √ Drill and cut a slot to pass the servo connector through.

Servo

- √ Cut the servo cable in half.
- √ Split the servo cables back one inch.
- √ Strip insulation from the ends of all the wires.
- √ Cut three lengths of #24 AWG wire, at least 24 inches long.
- √ Strip insulation from both ends of all three wires.
- √ Solder the wires to the ends of the wires on the servo.
- √ Slide thin heat shrink tubing onto the #24 AWG wires and cover the exposed solder joint.
- √ Slide the large diameter heat shrink tubing over the solder wires and shrink.

- √ Slide one more piece of large diameter heat shrink tubing over the #24 AWG wires.
- √ Slide three more pieces of thin heat shrink tubing over the individual #24 AWG wires.
- √ Solder the end of the servo wire to the new extension.
- √ Cover the exposed soldered wires with thin heat shrink tubing.
- √ Cover the soldered joint with the large diameter heat shrink tubing.
- √ Stick a couple of nylon zip tie mounting plates to the mirror rotator arm so that the servo cable will stay out of the way of the camcorder.
- √ Zip tie the servo cable to the arm.
- √ Paint the mirror rotator

Directions to Use the Mirror Rotator

- √ Bolt the mirror rotator to the face of the cradle.
- √ Mount the camcorder inside the cradle.
- √ Insert the cradle into the airframe.
- √ Bolt the back plate onto the cradle.

Connect the servo cable to a flight computer and write test code to determine what values command the SSC II to position the servo-controlled mirror into the desired positions.

Good to Know

The Distance To and Depression Of the Horizon From Near Space

Near Space Horizon

The higher a near space capsule ascends, the greater the distance to its horizon. A simple rule of thumb is that the distance to the horizon in miles equals the square root of one and a half times the altitude in feet. In other words:

$$D = \sqrt{1.5 \times A}$$

where D is distance in miles

A is altitude in feet

Not only does the distance to the horizon get greater as the capsule ascends, it also depresses. That is to say that the horizon gets lower as the capsule climbs higher. At the Earth's surface the horizon is 90 degrees from the zenith (the point straight overhead) in all directions. So the Earth and sky each occupy equal amounts (50% each) of your total view. As the capsule ascends, the horizon appears lower, allowing the sky to occupy more than 50% of the total viewing area of the capsule.

The angular radius occupied by the Earth is calculated by taking the arcsine of the ratio of the radius of the Earth divided by the sum of the Earth's radius and the capsule's altitude. The Earth's radius and the balloon's altitude must be in the same units so the ratio is a dimensionless number before taking the arcsine.

Angular Diameter of the Earth (at altitude H) = arcsine[Re/(Re+H)]

Where: Re is the radius of the Earth (3963 miles or 6378 km)
H is the altitude of the capsule (in same units as Re)

So while standing at the Earth's surface, with negligible altitude, we have:

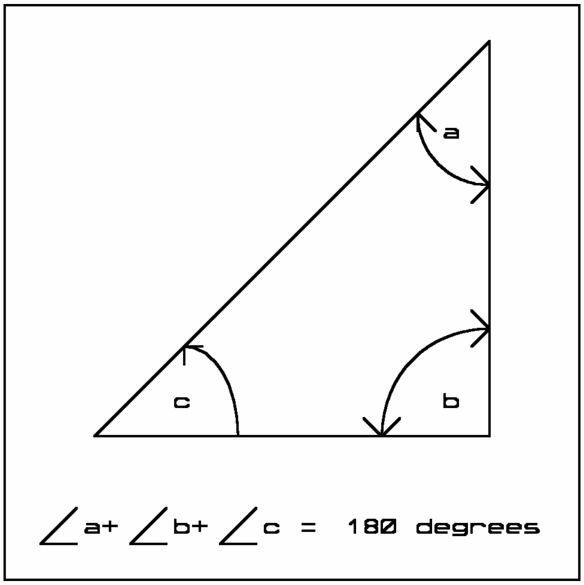
Diameter (angular)	=	arcsine [3963/(3963+0)]
	=	arcsine (3963/3963)
	=	arcsine (1)
	=	90 degrees (as expected)

At a flight reaching 100,320 feet (19 miles) though, the angular radius of the Earth changes significantly.

Diameter (angular)	=	arcsine [3963/(3963+19)]
	=	arcsine (3963/3982)
	=	arcsine (0.9952)
	=	84.4 degrees

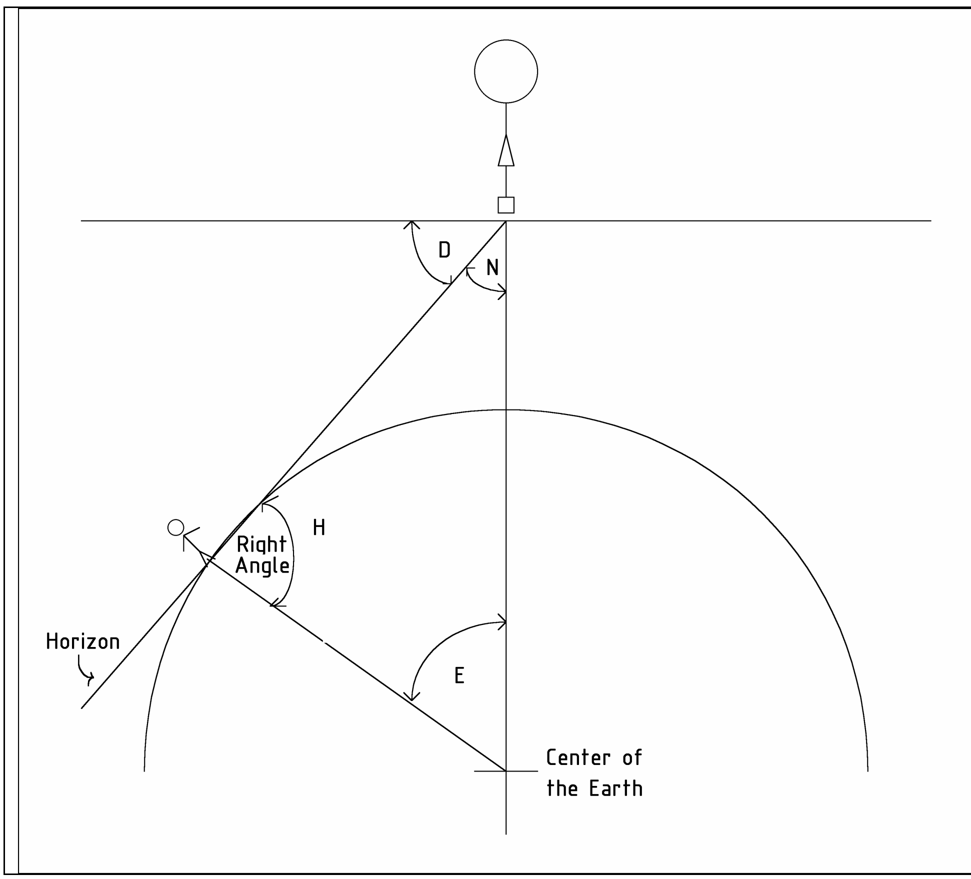
So at 100,320 feet the horizon is depressed 5.6 degrees and the sky extends 95.6 degrees from zenith to horizon in all directions.

Why is horizontal depression related to the distance to the horizon? Recall from geometry that the sum of interior angles of a triangle is equal to 180 degrees.



Triangle *- Sum of interior angles*

So, in the diagram below, the sums of the angles, E (the angular distance to the horizon), N (the angle between the capsule's nadir to horizon), and H (angle between horizon and Earth's center – always equal to 90 degrees) must equal 180 degrees. If angle H (90 degrees) is subtracted, then we find that the sum of angles N and E equal 90 degrees. At the balloon's location, the sum of angles D (horizontal depression) and N also equals 90 degrees. Setting the two sums of angles equal to each other, we have



Angle of Depression *– As seen from the balloon, depicted at top of diagram. (Not to Scale)*

N + E = N + D = 90 degrees

Subtracting N, we have E = D

The angle of horizontal depression (D) is equal to the angular radius occupied by the Earth, as seen from the balloon (N). From the earlier example, at an altitude of 100,300 feet a near space capsule views an area within a radius of 5.6 degrees of the Earth beneath it.

In the north-south direction, the distance covered by a degree doesn't change as a factor of latitude. In latitude a degree is about 69.12 miles. In the east-west direction, however, the distance covered by a degree of longitude does change as a function of latitude. The distance covered by one degree of longitude is greatest at the equator, where it is equal to the length of a degree in latitude (69.12 miles). The length of a degree in longitude approaches zero as you approach the poles. But since we're only interested in the distance to the horizon in miles, we can still use 69.12 miles per degree. At 100,300 feet then, the horizon is equal to 387.0 miles (5.6 degrees times 69.12 miles per degree). Our rule of thumb gives us 387.9 miles, or an error of less than one mile. That's not bad for a rule of thumb.

Space Mission Analysis and Design 2nd Edition, 1992 Wiley J. Larsen and James R. Wertz.

Near Space Humor - Six Things NOT to Photograph During a Near Space Mission

1. Area 51.
2. A foreign embassy building.
3. Airborne military aircraft, especially those flying higher than 100,000 feet.
   If you do photograph one, be sure Aviation Week and Space Technology pays enough for the photograph to pay your court costs.
4. Your crotch, while waiting to launch the stack (you'd be surprised how often this happens).[D]
5. A chrome-plated bulldog during landing.[E]
6. The inside of your lens cap.[F]

[A] Ken Tromburg, Photek, 3075 N. Cole, Boise, ID 83704, (208) 323-7568, photek@micron.net
[B] STYROFOAM Brand Foam is a trademark of The Dow Chemical Company.
[C] The camcorder body must be small enough to be able to enter an airframe through an E-Quad with its viewfinder folded down.
[D] Suggested by Mark Conner (N9XTN) of NSTAR.
[E] Suggested by Mike Manes (W5VSI) of EOSS.
[F] Suggested by Stephanie Lindsay of Parallax, Inc.