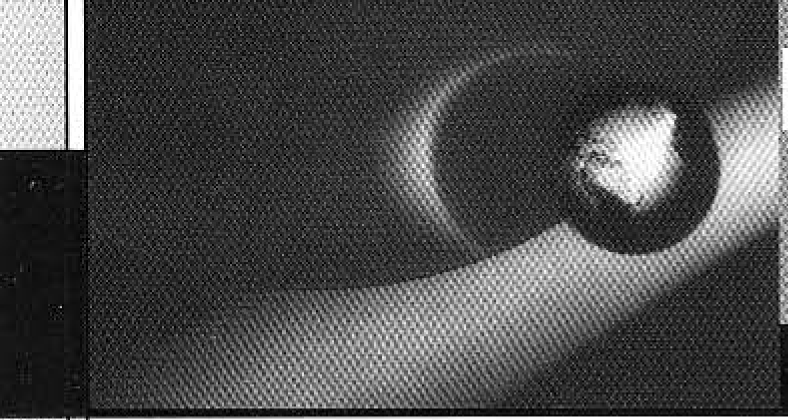


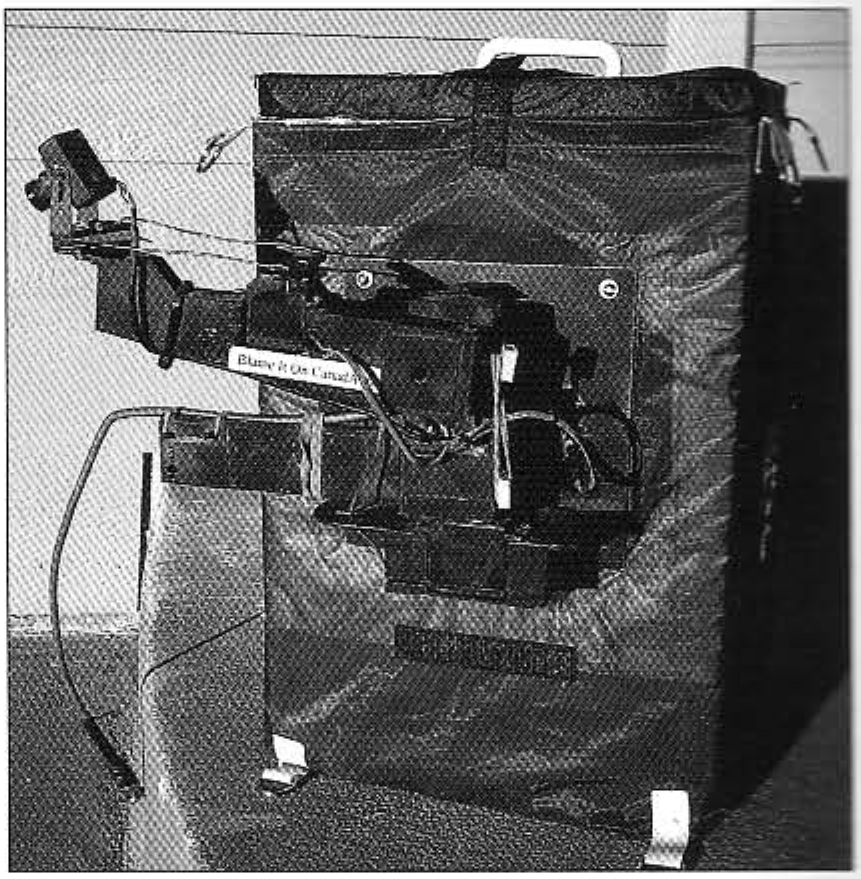
# NEAR SPACE

APPROACHING THE FINAL FRONTIER

■ BY L. PAUL VERHAGE

# THE BLAME IT ON CanadArm*

**AS YOU KNOW, THE SPACE SHUTTLE often carries an extraordinary robotic arm in its payload bay. The arm, called the CanadArm in recognition of its origin, is Canada's contribution to the Space Shuttle program. In my near space program, I often attempt to design near space versions of real space items. So, in recognition of the CanadArm, I have developed my version, the "Blame it on CanadArm." In this article, I'll describe how I constructed this arm.**



The near space arm mounts to the exterior of the near spacecraft. Since it was design for amateur television use, the Blame it on CanadArm (BioCA) carries a small CCD imager at its tip rather than an end effector like the Space Shuttle's CanadArm. The BioCA is designed to point its CCD camera in any direction in front of the near spacecraft (the near spacecraft blocks the view behind it). The arm can point its camera to the ground, horizon, or the balloon itself. It can even monitor experiments during a near space mission.

It takes a flight computer onboard the near spacecraft to operate an arm like this. In my book (*Near Space Exploration With the BASIC Stamp*), if you'll read Chapter 3, you'll learn about the flight computer I'm currently using to control an arm like this. The first few chapters of my book are available as a free download from Parallax (**www.parallax.com**). Click on the Resources tab, then Customer Applications, then the Near Space link in the list of customer applications. While you're there, check out the other near space applications Parallax has put online. Before constructing the BioCA, I want to give you a little information on amateur television.

## A BRIEF BACKGROUND TO AMATEUR TELEVISION (ATV)

There are two kinds of amateur television in use today: fast scan and slow scan. Fast scan sends 24 frames per second and slow scan requires — depending on the transmission type — a few seconds to over 30 seconds to send a single frame. Fast and slow scan require a camera, radio transmitter, and antenna. However, slow scan also requires a microcontroller to capture a CCD image. The BioCA can be used for either type of television transmission.

A great source of ATV transmitters can be found at PC Electronics. They're online at **www.hamtv.com**

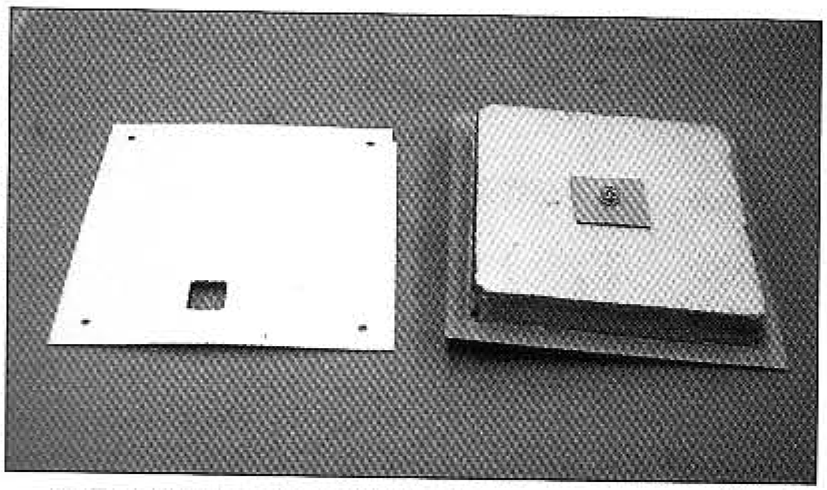
The antenna I recommend for ATV is the mini-wheel. The antenna is made by Dave Clinger of Olde Antenna Labs and you can order it from PC Electronics.

Your best source for up-to-date information on ATV is Gene Harlan's magazine, *ATV Quarterly*. You can find information for this magazine at **www.hampubs.com**

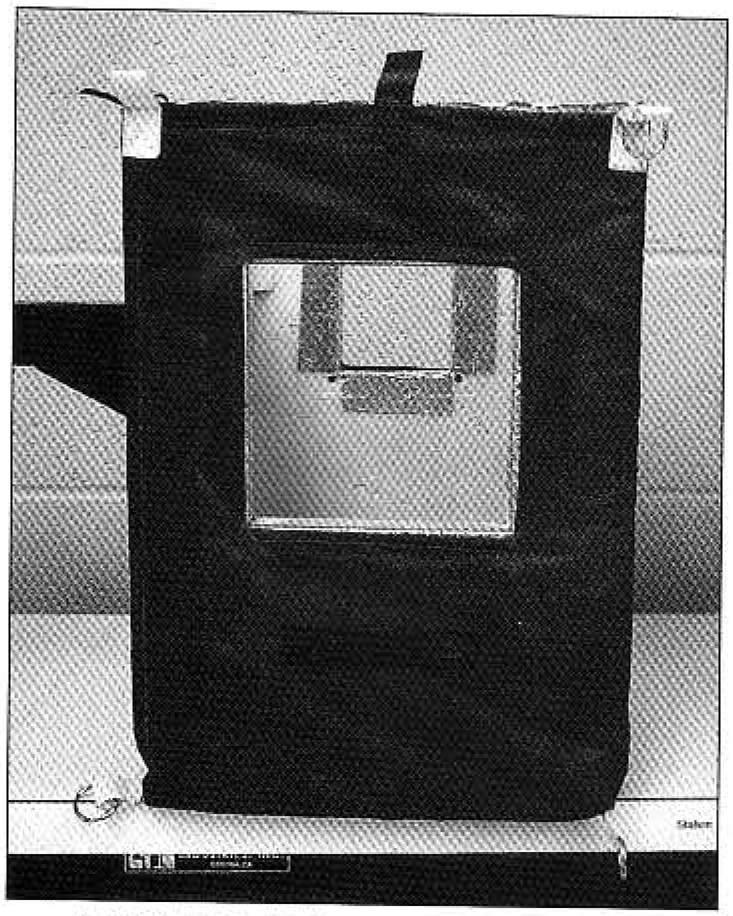
If you live near south central Idaho, you have a great source of ATV information in Lee Kelly (K6ZVA) in Twin Falls.

## BACKGROUND ON MY AIRFRAMES AND QUAD PANELS

The BioCA is designed for my near space fleet. So let me briefly describe how I build an airframe. I build it out of 3/4 inch thick Styrofoam, the kind used for house insulation. I cut Styrofoam panels with an Exacto knife and hot-glue them into a box. The box becomes an airframe after it's covered in multi-layer insulation and a fabric jacket. Three sides of the airframe have square openings where experiments are mounted. The openings are all the same size (a standard for my near space program) and are called access ports.



■ FIGURE 2. The Styrofoam measures 5-1/4 inches across and the plywood six inches across.



■ FIGURE 1. The access ports on this airframe measure 5-1/4 inches SQUARE.

An experiment is bolted to an access port with a quad panel. A quad panel is a 3/4 inch thick Styrofoam square epoxied to a 1/8 inch thick plywood square plate. The Styrofoam square measures 5-1/4 inch on a side and fits snuggly into a access port. The plywood square measures six inches across. While an experiment is permanently attached to a quad panel, the quad panels can be moved to any of the access ports in the airframe. In addition, since every one of my airframes has same size access ports cut into it, I can also move experiments between airframes.

A quad panel bolts to an access port with four bolts. The bolts pass through the inside corners of the Styrofoam square and to a thin plastic plate interior to the airframe. The quad panel remains on the airframe because the sides of the airframe are sandwiched between the quad panel and the interior plastic plate.

Using quad panels makes reconfiguring a near spacecraft a breeze. This brief description should be enough for you to construct a quad panel.

## MAKING THE BIOCA

The BioCA is mounted to a quad panel just like any other experiment. The BioCA uses two standard 42 inch-ounce servos and one micro-servo to move its CCD camera around. The first servo is the yaw servo and it rotates the arm's base to the left and right. The second servo is the pitch servo and it raises and lowers the arm. The final servo is a micro-servo and it's the CCD camera's pitch servo. It rotates the CCD imager left and right so it can view objects just beyond the BioCA's range.

To reduce the workload on the flight computer, a Scott Edwards SSC II controls the three servos in the arm. With the SSC-II, the flight computer can control the BioCA through a single I/O connection.

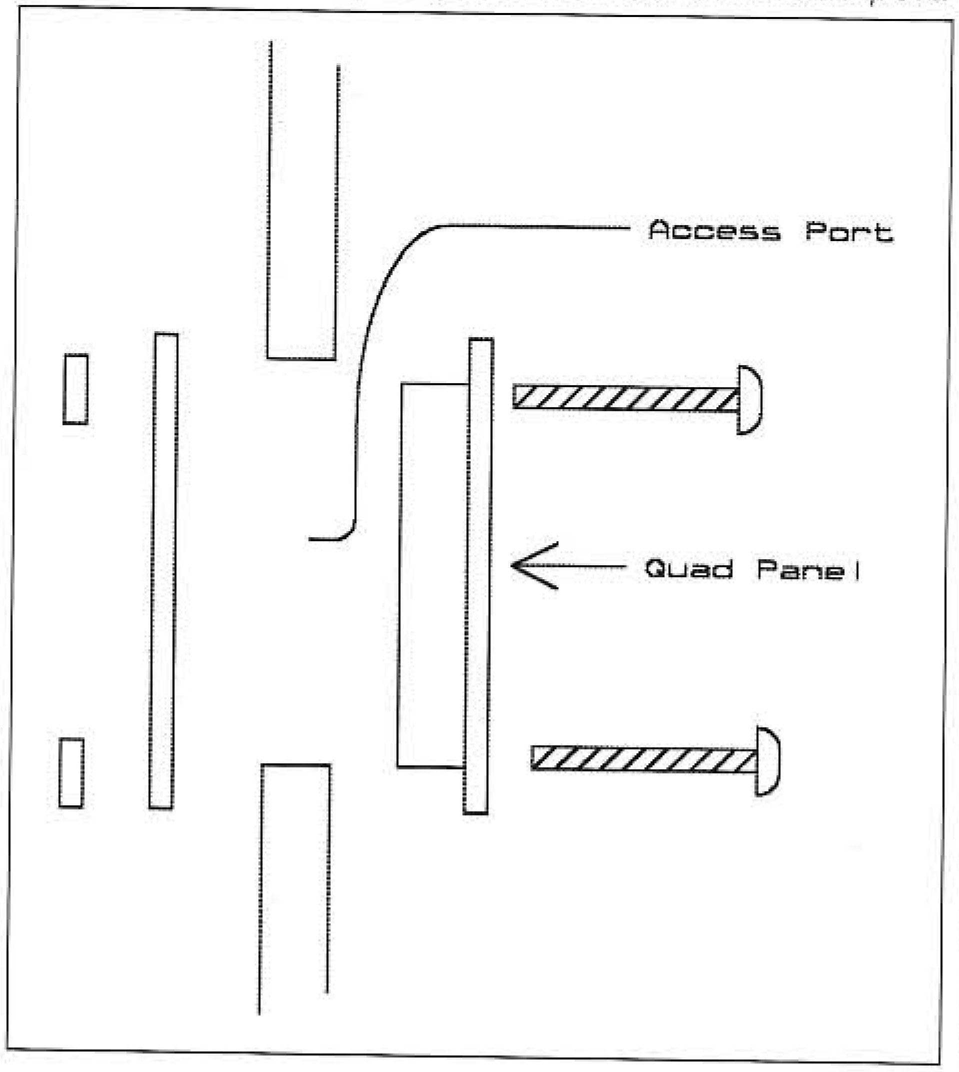
The weight of the camera combined with its distance from the servos places some torque on the servos. To keep the torque at a minimum and to reduce the drain on the battery, the rest of the arm is built to be lightweight. A large portion of the torque is counteracted with a rubber band. As you will see, the arm is constructed from Styrofoam for lightness and thin plywood for strength.

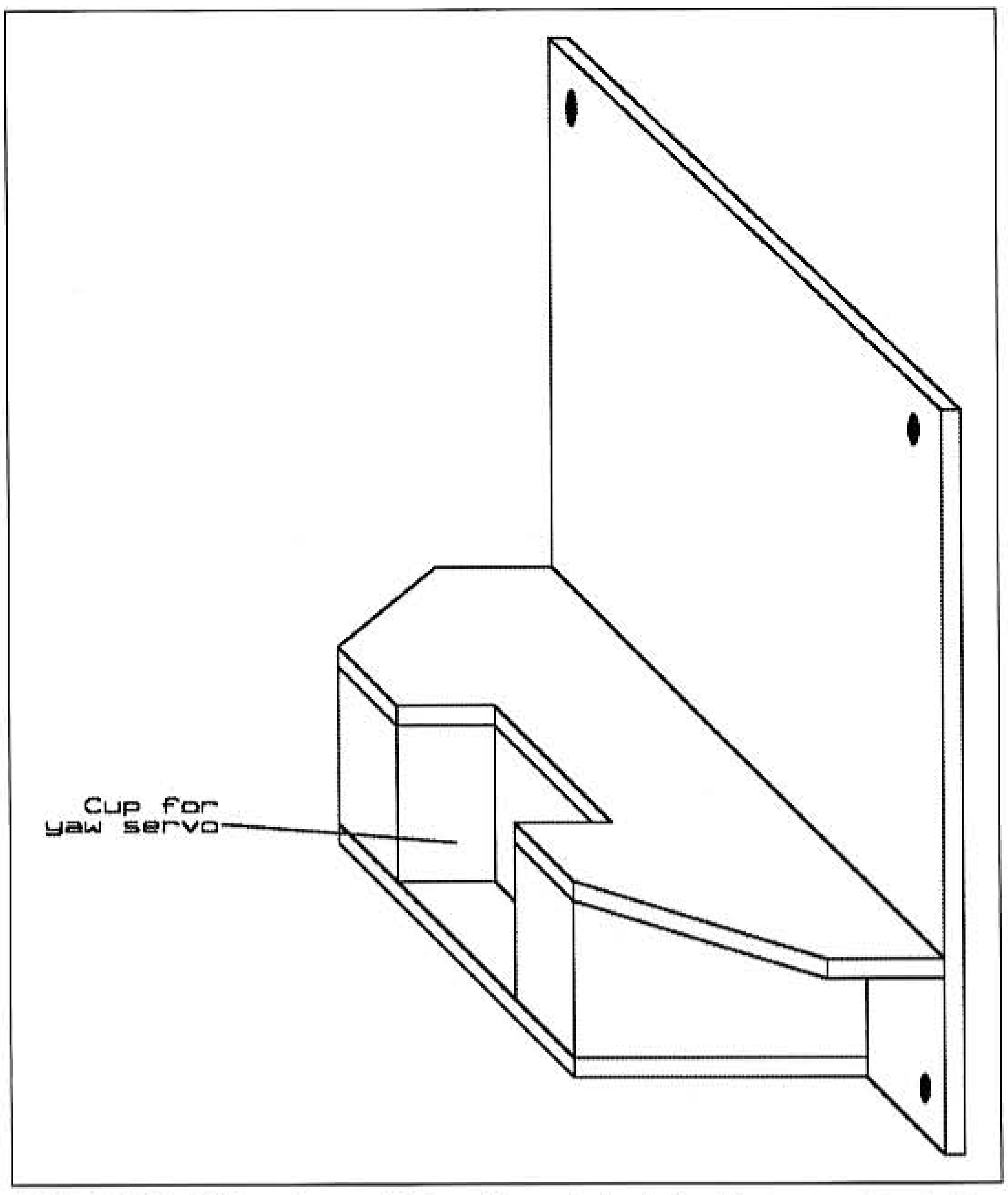
The quad panel is the first item to build. Cut a 5-1/4 inch by 5-1/4 inch square of 3/4 inch thick Styrofoam and a 6 x 6 inch square of 1/8 inch thick model plywood. Center and epoxy the Styrofoam to the plywood. Drill four 1/8 inch holes through the plywood at the corners of the Styrofoam. The Styrofoam side of the quad panel is the interior face and the plywood side is the side with the arm.

The yaw servo attaches to the quad panel with a shaped Styrofoam block. The top and bottom face of the block is covered in thin plywood for strength. The reinforced block is epoxied to the plywood face of the quad port. The servo slides into its pocket in the block and is held in place with two bolts. Figure 4 shows a diagram of the block I designed.

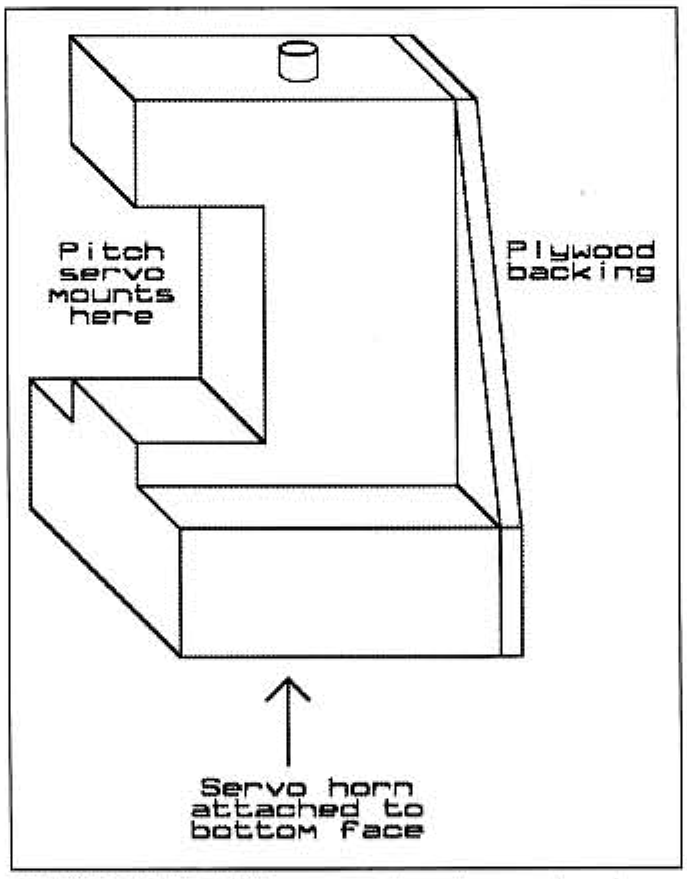
Now that the yaw servo is attached to the quad panel, we can attach the rest of the arm mechanism. The next piece is the rotation base. The rotation base holds the pitch servo, which raises and lowers (pitches) the arm. The rotation base is

■ FIGURE 3. An x-ray view of how a quad panel bolts to an access port.





■ FIGURE 4. The shaped Styrofoam block for the yaw servo. In this diagram, it's already epoxied to the face of the quad panel.



■ FIGURE 5. The rotation base looks like a horseshoe on its side and IS mounted to the wide base.

pressed on to the rotation servo. When the rotation servo yaws left and right, it turns the rotation base and the arm attached to it.

The rotation base is made from a shaped block of Styrofoam and covered in thin plywood for strength. The pitch servo is bolted into an opening that's cut into the rotation base. Cutting a block out of the rotation base will weaken it structurally, so the opening is reinforced with 1/16 inch thick plywood. Not only does the reinforcement keep the rotation block from breaking where it was cut for the servo, but it's also a place to bolt the pitch servo.

A servo horn is bolted to the center of the bottom face of the rotation block. This is the servo horn that snaps into the rotation servo in the quad panel. A vertical axis runs through the rotation base. At its bottom is the center of the servo horn. The axis extends above the top of the rotation base where it creates an axle at the top of the rotation base. The rotation block is kept from falling over by the rotation servo at the bottom and a bracket at the top.

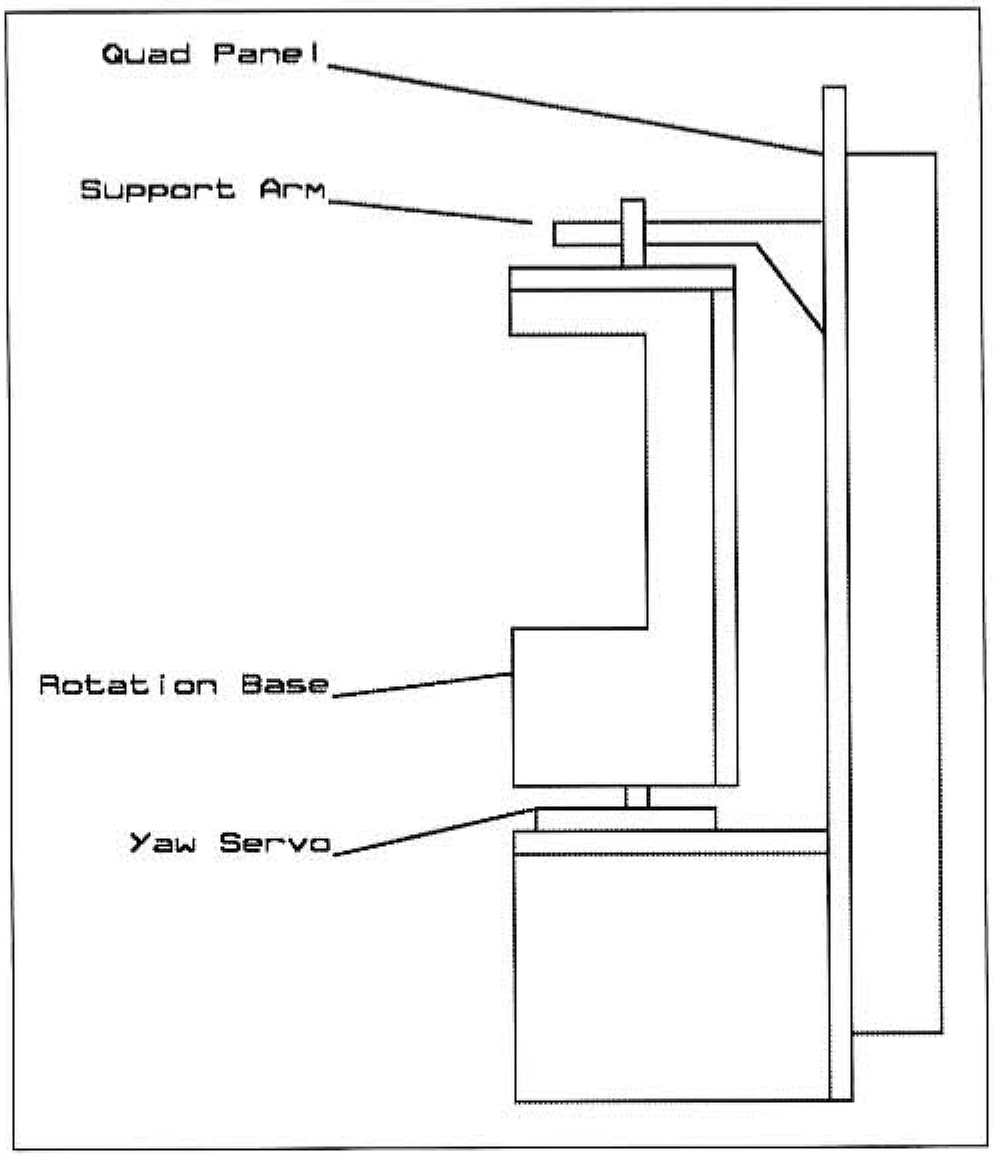
The axle is a 1/8 inch diameter wooden dowel. Drill a 1/8 inch diameter hole through the top of the rotation base. Drill this carefully, as you want the dowel to be as centered and vertical as possible with respect to the servo horn on the bottom of the rotation block. Drill the hole about one inch deep. Cut a piece of dowel 1-1/2 inches long. Epoxy the dowel into the hole and let it set. You'll trim and round the top of the dowel after making its support bracket.

The support bracket bolts to the quad panel and holds the top axle of the rotation base.

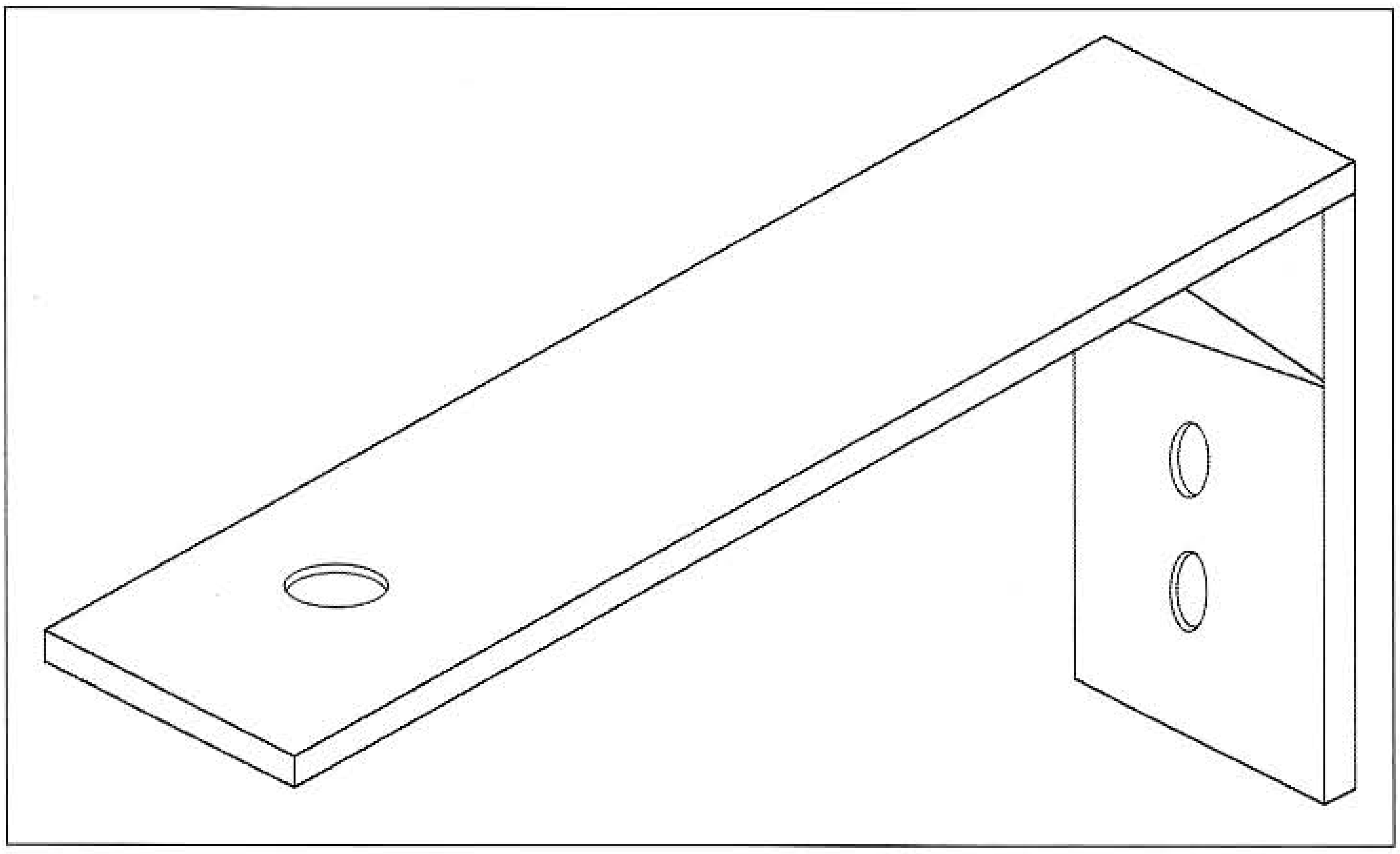
The support bracket is made from 1/8 thick plywood and is basically a right angle bracket reinforced with more plywood. There are three holes in the support bracket: two to bolt the bracket to the quad panel and the other for the axle at the top of the rotation base. I drilled two 1/8 inch diameter holes for the #6-32 bolts that attach the support arm to the quad panel. The diameter of the hole for the axle is slightly larger than 1/8 inch so the axle in the top of the rotation base can spin inside of it without binding.

Now it's time to build the arm itself. The arm is made from 3/4 inch thick Styrofoam and laminated with thin plywood on its top and bottom surfaces. There's a servo horn attached to the base of the arm, a micro-servo to its mid-section, and the camera platform to its end.

The first step to making the arm is to cut the Styrofoam to shape. Notice in Figure 8, that there's a cutout in the arm large enough to



■ FIGURE 6. A side view of the quad panel and rotation base.



■ FIGURE 7. Your dimensions will vary, since your BioCA will probably not BE exactly the same size as mine.

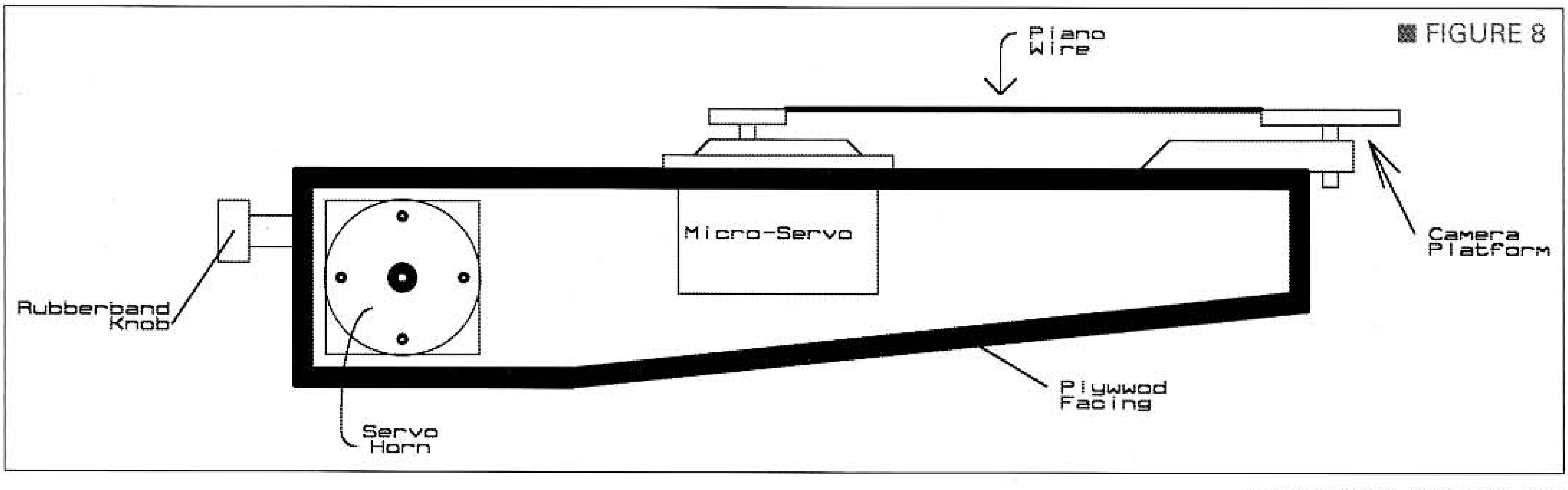
hold a micro-servo. After cutting out the arm, laminate the 3/4 inch thick sides in thin plywood (use epoxy as the adhesive). For increased strength, use 1/16 inch thick plywood for this lamination. Next, epoxy 1/8 inch thick plywood panels to the sides of the arm that will cover the micro-servo cutout (there's no need to cover the entire sides of the arm in plywood since there's very little sideways force acting on it). The 1/8 inch thick plywood forms the sides of a pocket for the micro-servo. The plywood also strengthens the arm where the micro-servo cutout has weakened it.

Now mount a servo horn at the bottom of the arm for the pitch servo. Before the horn can be mounted to the arm, the end of the arm must be reinforced. Cover both sides of the arm where the servo horn will be attached with thin plywood. Use epoxy and 1/8 inch thick plywood. After the epoxy sets, hold the servo horn up against the plywood side and mark the location of the servo horn's center and the four outer holes in the horn's arms. Drill holes through the plywood reinforced arm at these locations. The center hole needs to be 1/4 inch in diameter, because the servo mounting screw goes through this hole. The holes in the ends of the servo horn arms are drilled for the mounting hardware you'll use to bolt the servo horn to the arm. I used small screws, but I recommend using something like #1 bolts and nuts.

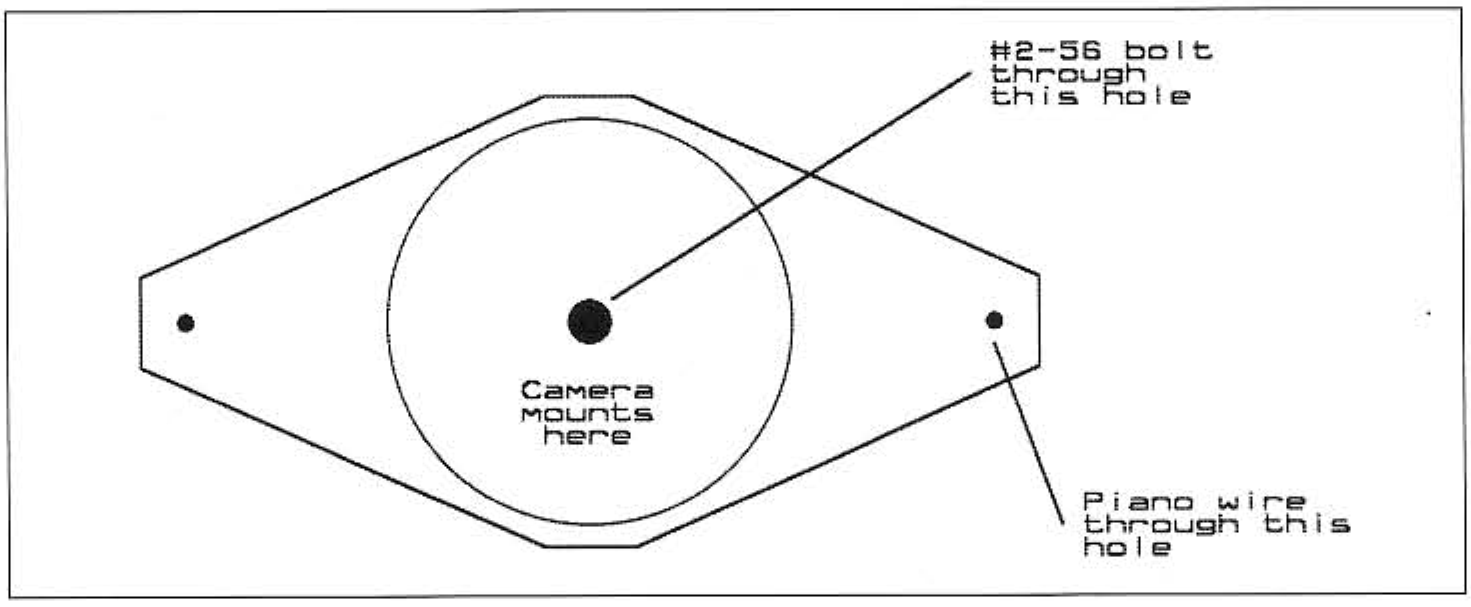
The weight of the CCD camera on the end of the arm means the pitch servo has a lot of torque to work against. This downward torque is counteracted by a rubber band pulling the arm up. The pull of the rubber band is not strong to lift the arm, it's just strong enough to counteract the arm's weight. A convenient way to attach the rubber band to the arm is with what I call the Rubber Band Knob.

Drill a 3/16 inch diameter hole in the end of the arm. Make the hole about two inches deep. Then, cut a 3/16 inch diameter wooden dowel about three inches long. Epoxy and push the dowel into the hole until only one inch of the dowel protrudes. To keep the rubber band from slipping off, you'll epoxy a stop to the end of the dowel. Make the stop from a 1/4 inch thick stick of basswood. Cut a small square shaped piece of basswood. Find the center of the square and drill a 3/16 inch diameter hole. Then, epoxy the square to the end of the dowel in the end of the arm. The rubber band that's pulling on the rubber band knob needs an anchor in the rotation base. I epoxied a short length of basswood strip to the rotation base for the anchor. With some additional plywood reinforcement on the rotation base, I believe a small eye hook could also be used as an anchor.

Next, add the camera platform and the platform shelf to the top of the arm. The platform is epoxied to the arm and the shelf is bolted to the shelf with a single bolt. The bolt is loose enough that the platform can rotate like a lazy Susan. Cut a 1-1/2 inch length of 1/4 inch by 3/4 inch basswood strip. Epoxy the shelf to the top end of the arm so that it extends about 1/2 inch beyond the end of the arm. After the epoxy sets, drill a 3/32 inch diameter hole through the shelf



■ FIGURE 8



■ FIGURE 9. A top view of my camera platform. The base of the tiny CCD imager mounts to the center of the platform.

at the center of its extension beyond the arm. A #2 bolt goes through this hole and acts as the axle for the lazy Susan platform for the camera.

The camera platform is made from a 1/16 inch thick sheet of hard modeling plywood. Do not use the light ply as it's likely to break from stress. Cut the platform large enough for your imager and two wing extensions.

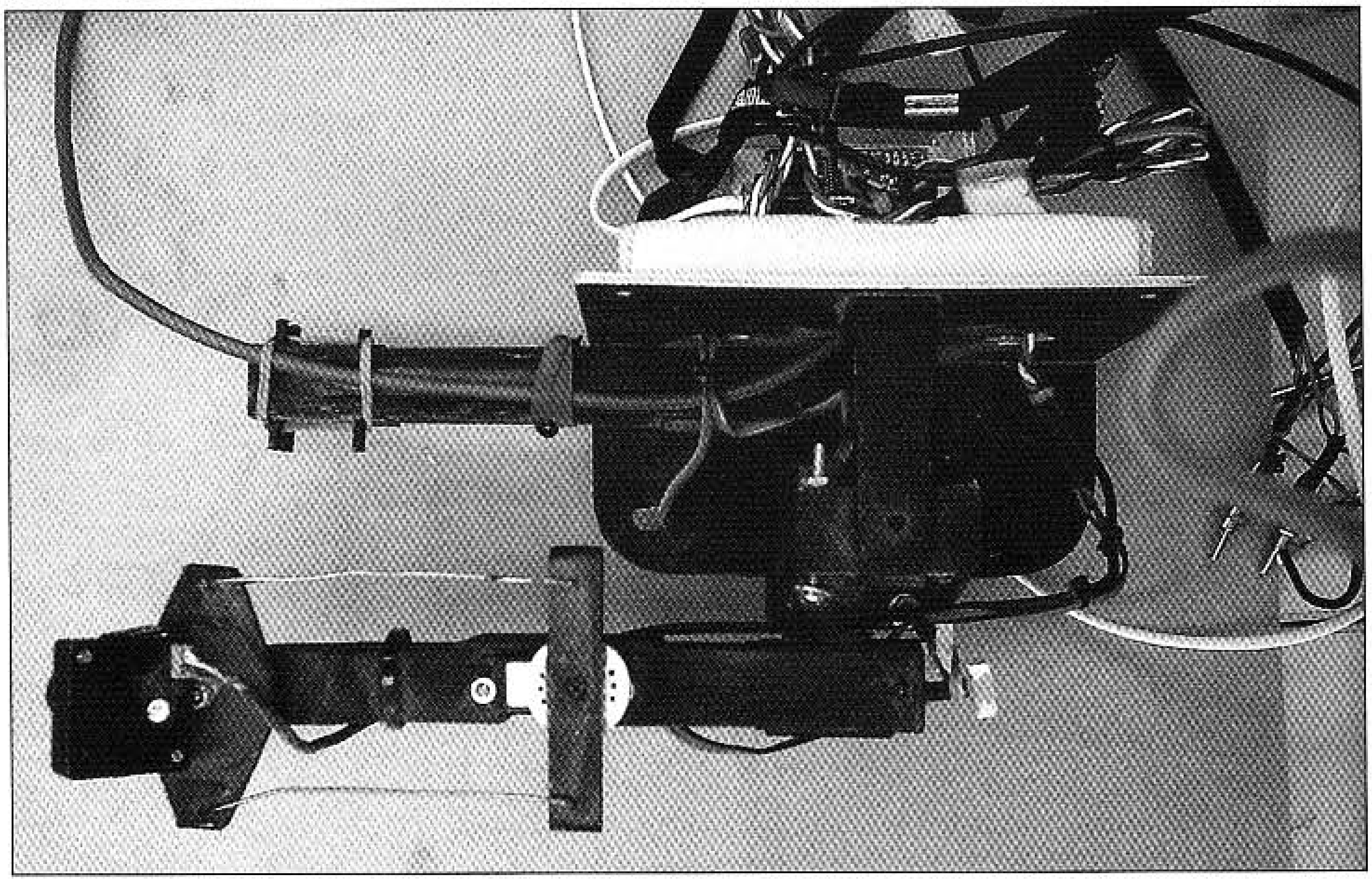
Drill a small hole in each platform wing near the ends of the shelf. Piano wires from the micro-servo connect to these holes in the wings. So when the micro-servo rotates, the camera's lazy Susan platform also rotates.

Drill a 3/32 inch diameter hole through the platform's center. Push a #2 bolt through the hole. Place washers on the bottom and push the bolt through the hole in the camera shelf. Use a locking nut (a nut with a nylon insert) to hold the lazy Susan to the shelf. Tighten the locking nut enough to take the slack out of the axle, but not so tight as to restrict its rotation. Attach the CCD imager to the lazy Susan according to the design of your imager. Be sure the lazy Susan can still rotate freely after the camera has been attached.

Now insert a micro-servo at the midpoint of the arm and screw it in place. I only used two screws (on diagonally opposite corners of the micro-servo) since there is very little force trying to lift the micro-servo out of its pocket in the arm.

Add a horn to the micro-servo and compare the width of the horn to the wings on the camera's lazy Susan. I added an extension to my servo horn to make it the same width as the camera platform. In Figure 10, you can see that I used a strip of basswood for the servo horn extension. The horn's extension is held to the servo horn with epoxy and some wire, but you should use small bolts in place of the wires. Snap the servo horn (and its extension, if it was needed), to the micro-servo and rotate the servo to its mid position. Remove the servo horn and place it back onto the micro-servo and bolt it down.

■ FIGURE 10. A top view of the arm. The rotation base is at the bottom, the micro-servo in the middle, and the camera platform at the top. Note the pair of piano wires connecting the extended arms of the micro-servo to the camera platform.



Measure the distance between the arms of the servo horn and the wings of the camera platform. Cut two pieces of stiff piano wire to the same length plus an additional inch. Insert the piano wires into the holes in the servo horn and camera platform and bend the ends over to keep them from falling out. Test the rotation of the camera platform by twisting the horn of the micro-servo. The camera platform must rotate without binding up. If all the servos rotate without binding, the exterior portion of the BioCA is complete.

Now bring the servo and camera wires inside the quad panel. I drilled two holes into the quad panel. I don't think you can get by with just one pass-through hole without the arm's rotation base binding up on wires. Since the SSC II is mounted inside the quad panel near the bottom, I drill my two holes about halfway up from the bottom of the quad panel.

After drilling the hole(s), epoxy a shelf inside of the quad panel that's large enough to hold the SSC II. I used 1/8 inch thick light ply for the shelf and used a bit of Styrofoam as a brace. After the epoxy sets, hold the SSC II in place and mark the location of its mounting hole in the shelf. Drill the holes and bolt SSC II to the shelf. I only used two of the mounting holes because there isn't much force trying to pull the SSC II off its shelf.

Pass the servo cables through the holes in the quad panel and connect them to the SSC II. You may have to extend the length of the cables to get them to reach. I extend servo cables by cutting the servo cable in half near the middle and solder extension wires between the ends of the cut cable. Be sure to slide heat shrink on each wire before soldering it to the servo cable. After the servo cables, pass the camera cable into the quad panel.

Use wire zip ties to keep the cables under control. Without them, there's a possibility of a servo cable getting pinched and stopping arm movements. I tied cables to the mid point of the arm and left some cable slack near rotation points in the BioCA. To reduce the chances of video interference from servo signals, route the video cable away from servo cables. You don't want servo commands showing up as snow on the video signal.

The last item to make is the plastic panel that helps hold the quad panel to the access port. Cut a sheet of 0.03 inch thick styrene plastic into a six inch square. Drill four holes near its corners that correspond to the holes in the BioCA's quad panel. The holes for the servo and camera cables and the shelf for the SSC II will prevent a flush fit between the plastic panel and the quad panel. So cut a hole in the styrene panel just large enough for these protrusions. Now insert the quad panel into the airframe. Add the first bolt and add the plastic panel. Use a washer and nut to hold the quad panel and plastic panel in place. Repeat this with the other three holes.

Well, that does it for the BioCA. I've only had a chance to test it on the ground and display it in my presentation at a recent hamfest. The audience loved it. From my experience, I now see that it's important that the servo movements be slow and smooth. So, move the servos slowly by sending intermediate positions to the SSC II, rather than slamming servos to their new position. Also, use a lightweight CCD imager to keep the inertia of the arm low.

Onwards and Upwards,<br>
Your new space guide **NV**

** No, I'm not a fan of the show, but I do like the title of the song.*