Join the SkyShield
Saturn V & SkyShield Beta Team

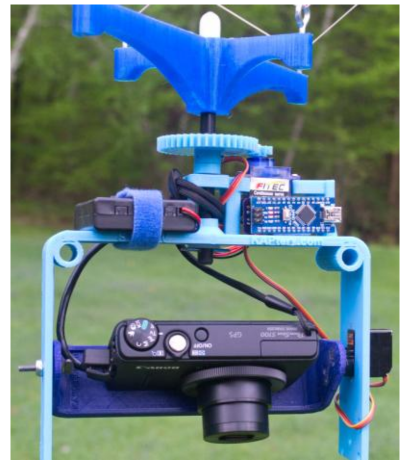
Assembly and use instructions for the

Saturn V Rig and SkyShield

Beta version

Assembly

Mounting the camera



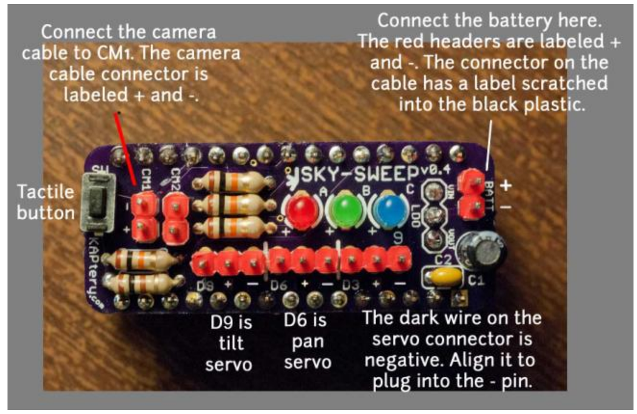
The camera tray may already have a hole for a tripod screw. If this will fit your camera it might be sufficient. Instructions for placing and drilling a new tripod hole are in Step 2 of the document about the Redstone Rig: http://kaptery.com/files/documents/redstone-kit-guide.pdf. However, balancing the camera's mass is different for the Saturn V Rig for two reasons: 1) the camera tray is not centered under the Picavet suspension (it is offset by the tilt servo connection), and 2) the Saturn V Rig has batteries and servos which influence the balance of the rig. So balancing the camera properly requires having the entire rig in flying condition and finding a position on the tray where the camera allows the rig to hang level. To test for balance, hold the rig with one finger under the bottom end of the Picavet shaft. Level cameras take photos that are much tidier to stitch together into panoramas, but then again, few aerial photos are ever perfectly level.

If drilling a new tripod hole is required, removing the camera tray from the rig might be easiest. This can be done easily by removing the screw into the center of the tilt servo spline (the "gear" at the end of the servo drive shaft), and the bolt and nut at the other end of the tray. However, if the tray is reattached haphazardly onto the servo spline, the tilting angles will be incorrect. So the position of the camera tray relative to the servo spline will have to be precisely marked as you remove it (very hard), or carefully adjusted later by running the SkyShield to observe where the upper and lower tilt positions are. This is easy and just requires playing with the SkyShield to see how it operates the tilt servo. The goal is to have the lowermost tilt position point straight down. The best program mode to use to adjust the spline connection is Mode 4 (see below).

Attaching the Picavet shaft

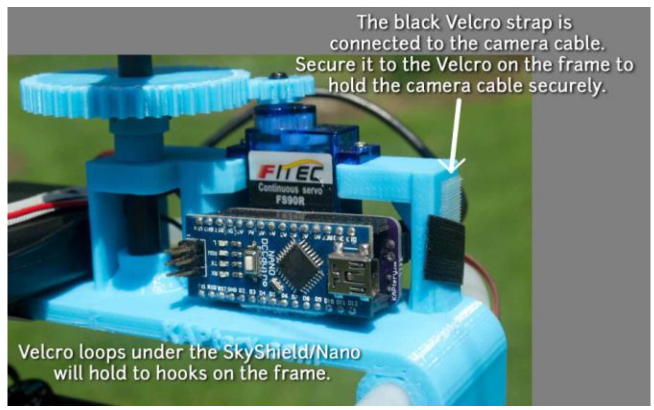
The shaft of the Picavet suspension attaches easily to the top of the rig. The photo shows the order of things. The locking cotter pin at the bottom is recommended because it is the only thing that holds the rig to the Picavet. Some practice (and a tool) is required to insert and remove this strong pin, but when it is in place it holds securely. The weight of the rig rests on (and turns on) the nylon washer above the cotter pin. The big gear must be firmly locked onto the shaft with a set screw. A small divot in the shaft allows the set screw to lock securely. A spacer under the gear keeps the shaft from sliding down. The shaft should be able to rotate freely.

Connecting the SkyShield autoKAP controller



Four cables must be plugged in to the SkyShield. (There are additional headers for connecting a second camera and third servo.)

Power: The connector on the wires from the battery case is a three-pin connector and plugs in to two pins on the SkyShield. It is hard to plug it in wrong (with polarity reversed), but pay attention to avoid that. The headers on the shield and the connector on the wires are labeled with + and -. Match + with +, and match - with -.



Camera: The USB cable to the camera should be plugged in to “CM1” (CM2 is for a second camera or other device). Pay attention to get the polarity correct (+ to +, - to -). The USB cable is stiff and is moved by the tilting camera, so to secure the cable connection to the shield a Velcro strap is connected near the connector. A small piece of Velcro on the servo support will hold the Velcro strap tightly to keep the cable in place. Secure this strap after the SkyShield has been seated on its own Velcro pad.

Servo leads: Each servo has a three-wire lead with a three-pin connector. On the shield the three-pin headers for the tilt and pan servos are labeled with yellow tape (T is for Tilt, and P is for Pan). The ground pin on each is labeled with a minus sign. That pin always connects to the dark colored wire on the servo lead.

Battery case: The battery case has Velcro loops underneath, and there are Velcro hooks on the top of the rig frame. There is also a Velcro strap to wrap around the case and the frame. Precise positioning of the heavy battery case is easy and important for final balance of the rig (both side-to-side and forward-back). Keep this in mind when positioning the camera for a new tripod hole. The battery case has an on/off switch which is the main operating switch in this system. Use four fresh alkaline AAA batteries. Rechargeables might not have sufficient voltage. Old batteries can cause erratic servo behavior.

Seating SkyShield: There is Velcro tape on the SkyShield and on the rig frame. After the cables are attached and the mode selected (see below), push the SkyShield against the pan servo and press it onto the Velcro. Then attach the Velcro strap on the camera cable to the Velcro on the servo support. If everything is fitted snugly, no other support is needed.

Legs and Bumpers

Four oak legs can be inserted into the leg brackets (don't force them too hard). Two lengths of polyethylene tubing can form two half loops behind the camera for protection. The lower loop (not shown at right) can attach to the leg brackets. The upper loop can attach to the brackets at the top of the rig frame. A loop in front of camera would show up in the photos because the camera tilts, but extensions of tubing from the upper brackets can avoid the camera if they curve outwards. So two short lengths of tubing are included. They have little pieces of acetal rod to make a better connection with the ends of the tubing inside the upper brackets.

Configuration

CHDK

At every pan/tilt position a pulse is sent to the USB port of the camera. Canon PowerShots running CHDK can be configured to trigger the shutter when this pulse is detected. In the CHDK menu, under "CHDK settings/Remote Parameters" select:

Enable Remote [0] (selected)
Switch Type [OnePush]
Control Mode [Quick]
Enable Synch [ ] (not selected)

Camera settings

Exposure: Typical settings that produce good aerial photos include fast shutter speed (1/640 or 1/800 second), low ISO (80 to 200), mid-range f-stop (f/3 to f/8, avoid maximum aperture if possible), and focus locked on infinity (or "infinity mode" if manual focus is not available). Most of these settings require that the camera be in "Program" mode, not "Auto" mode. Some cameras have a shutter priority mode (Tv) which keeps the shutter speed high while adjusting f-stop to expose each photo properly. CHDK provides this feature on any PowerShot.

Fast or slow: More recent and higher end PowerShots can process each shot quickly and shoot faster than older or cheaper PowerShots. It is important to experiment with your camera to determine if the fast or slow SkyShield modes are more appropriate for your camera. With slower cameras, and with fast cameras in some conditions (dark days, or homogenous scenes when no manual focus is available) the camera will not be able to take the photo before the next pan or tilt motion and that photo will be missed. Experimenting inside a room may not replicate the results outside on a sunny day (when it is easier to focus, etc). Failure to focus quickly is a common cause of missed photos, so use manual focus if it is available.

Field of view: The widest focal length of a typical PowerShot lens is 28 mm (eq.). Some higher-end PowerShots have a slightly wider 24 mm (eq.) lens. A wider lens requires fewer photos to allow a complete 360° panorama to be stitched together. The SkyShield modes allow about 40% overlap between adjacent photos if the designated focal length is used, so it takes about eight or nine photos to cover 360°.

The autoKAP modes

An Arduino microcontroller does not have an operating system. A single program (sketch) can be loaded into its memory and it will run every time the Arduino is turned on or reset. The sketch is retained in memory until another sketch overwrites it. The sketch on the SkyShield includes eight different routines ("modes") that operate the pan and tilt servos and send a pulse to the camera. Any mode can be selected by pressing a button when the SkyShield is powered on or when it is reset. Each routine will continue to run as long as power is supplied.

Six of the eight modes are designed to take photos which cover 360° horizontally and all angles of tilt from the nadir to about 45° from the zenith. One photo is taken at every position, and there are 32 (4 rows and 8 columns) or 45 (5 rows and 9 columns) positions occupied before the routine repeats. Some modes move the camera less between shots to allow more overlap between adjacent photos and to accommodate longer focal length (less wide angle) lenses. Some modes wait longer between moves to accommodate cameras which process slower and cannot shoot as quickly. Two of the eight modes cover only about 180° horizontally in order to focus on a particular part of the scene. These two modes currently don't really work as intended.

Repeatability

Standard servos can return to a particular position (e.g., tilt angle) with some precision. The tilt servo is a standard (micro) servo. The pan servo on the Saturn V Rig is a continuous rotation servo which works differently. This servo does not know what position it is in. To move to a new pan position, the servo moves with a designated speed, duration, and direction. The exact angle of rotation cannot be predicted because the speed varies somewhat with battery charge and acceleration. So the panning precision is somewhat variable. This is a minor problem with 360° rotation because as long as the camera pans close to 360°, the entire circle will be captured in photos. Testing is recommended with fresh alkaline batteries in the battery pack. If the rig does not pan the full 360° in the designated number of steps, stronger batteries might be needed. If the rig pans more than 360° in the designated number of steps, make sure there will be sufficient overlap between photos for good stitching. To reduce the angle of each pan move, the sketch will have to be edited, or try another mode.

For modes which are designed to cover less than 360°, the covered scene may drift with each row (each tilt position). Panning 180° in four steps and then returning to the starting point in one large move is often inaccurate. So all the photos may not be pointed over there toward that Superfund site of interest. More experimentation is needed to get predictable results with non-360° coverage (Maybe returning to the start point in the same number of small steps?). Mode 6 and Mode 7 are 180° modes.

Selecting a mode: Less than a second after powering on or resetting the SkyShield, press and hold the tactile button on the SkyShield. The three LEDs will cycle through all eight possible combinations of being lit or not. If a lit LED represents 1, and an off LED represents 0, the three LEDS display the numbers 0 through 7 in binary. This is the sequence in which the LEDs are illuminated:

LED C	LED B	LED A	Mode
0	0	0	Mode 0
0	0	1	Mode 1
0	1	0	Mode 2
0	1	1	Mode 3
1	0	0	Mode 4
1	0	1	Mode 5
1	1	0	Mode 6
1	1	1	Mode 7

When the LEDs signal the desired mode, release the button. That mode will begin and the camera will point and shoot in the designated pattern. At any time the white reset button on the Nano can be pressed and another mode selected. The default mode is Mode 0.

Arduino sketch

To alter the parameters of the eight modes, the Arduino sketch can be edited. Install the Arduino IDE from here: http://www.arduino.cc/en/Main/Software. This is a friendly integrated development environment and easy to install and use. The sketch which is loaded on the Nano will be available at the Sky-Sweep GitHub repository (https://github.com/p-v-o-s/sky-sweep) any day now. Your edited sketch can be loaded onto the Nano via USB cable.

Description of modes

All six of the 360° modes below include tilt positions which cover everything from above the horizon to the nadir (straight down). These six modes vary in number of steps to pan 360° (8 or 9) number of tilt positions (4 or 5), delay between moves (fast or slow), and nesting of pans in tilts versus tilts in pans. A goal of these modes is to take all 32 or 45 photos as quickly as possible so they are taken before the rig has a chance to move very far. This is the only way the photos will stitch together into a complete panorama.

Mode 0: 360 8x4 (slow version)

8 pan positions nested within 4 tilt positions. Pans cover 360° and happen together, and then the camera tray tilts to the next position for 8 more pan positions (360°). Requires a wider lens, of approximately 24 mm (eq.), to capture enough overlap between adjacent photos. Completes one cycle (32 photos) in about 100 seconds.

Mode 1: 360 8x4 (fast version)

Same as Mode 0 but faster. Completes one cycle cycle (32 photos) in about 80 seconds.

Mode 2: 360 9x5 (slow version)

9 pan positions nested within 5 tilt positions. Pans cover 360° and happen together, and then the camera tray tilts to the next position for 9 more pan positions (360°). Requires a focal length of approximately 28 mm (eq.), to capture enough overlap between adjacent photos. Completes one cycle (45 photos) in about 150 seconds.

Mode 3: 360 9x5 (fast version)

Same as Mode 2 but faster. Completes one cycle (45 photos) in about 110 seconds.

Mode 4: 360° 5x9 (fast version)

5 tilt pan positions nested within 9 pan positions. Tilts happen together, and then the rig pans to the next position for 5 more tilt positions. Pans cover 360°. Requires a focal length of approximately 28 mm (eq.), to capture enough overlap between adjacent photos. Completes one cycle (45 photos) in about 144 seconds.

Mode 5: 360° 5x9 (slow version)

Same as Mode 4 but slower. Completes one cycle (45 photos) in about 173 seconds.

Mode 6: 180° 4x3 (experimental)

4 pan positions nested within 3 tilt positions. Pans cover about 180° and happen together, and then the rig pans back to the starting pan position and tilts to the next position to start 4 more pan positions (180°). Requires a focal length of approximately 28 mm (eq.), to capture enough overlap between adjacent photos. Variation in battery strength may cause the pan return move to start the next row while not aligned perfectly with the start of the previous row (requires testing). Tilt angles do not include the nadir. Completes one cycle (12 photos) in about 30 seconds.

Mode 7: 180° 4x4 (experimental)

4 pan positions nested within 4 tilt positions. Pans cover about 180° and happen together, and then it pans back to the starting pan position and tilts to the next position to start 4 more pan positions (180°). Requires a focal length of approximately 24 mm (eq.), to capture enough overlap between adjacent photos. The tilt positions cover above the horizon and the nadir (straight down). Variation in battery strength may cause the pan return move to start the next row while not aligned perfectly with the start of the previous row (requires testing). Completes one cycle (16 photos) in about 45 seconds.