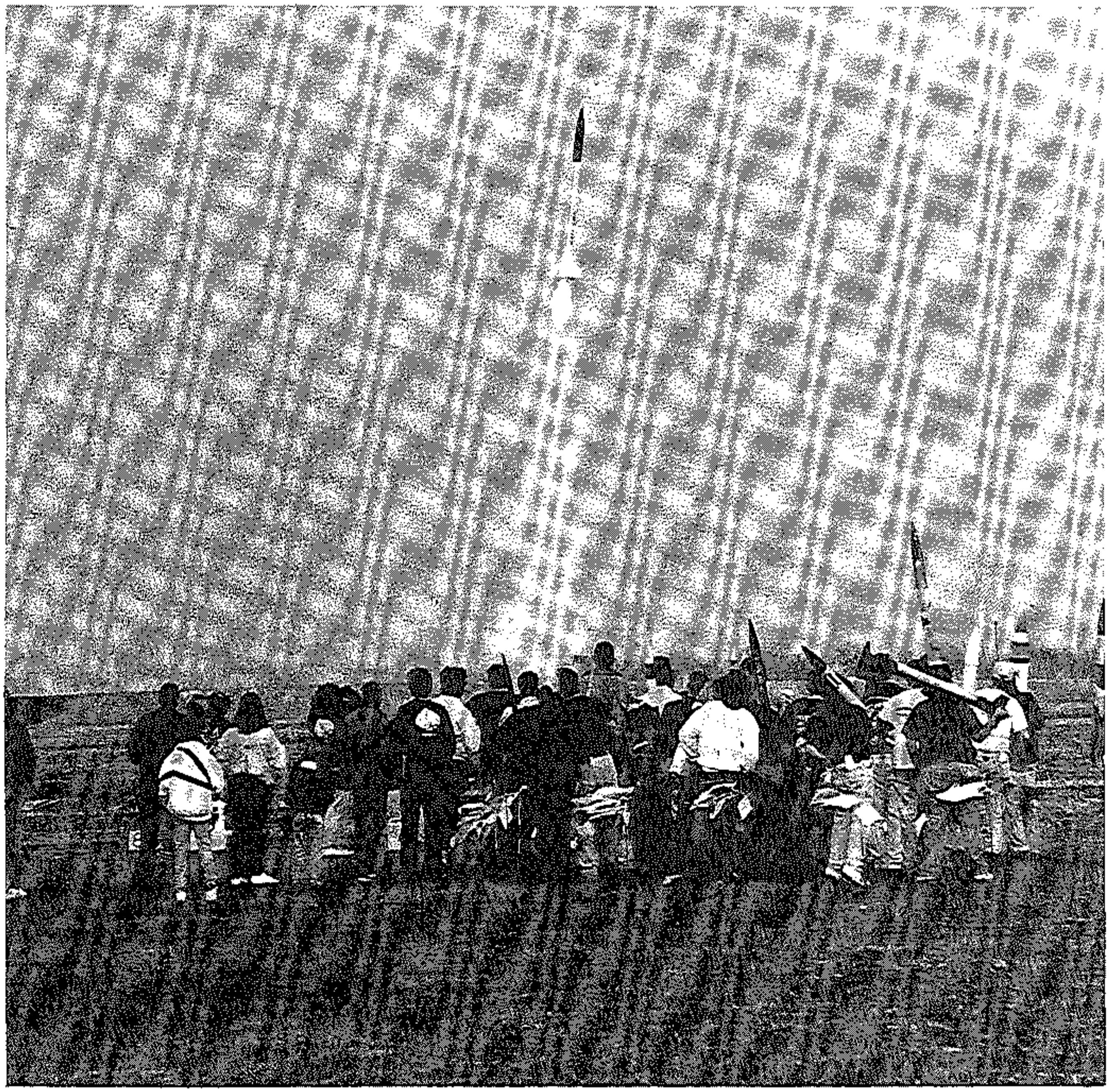
SNOAR NEWS

Srping/Summer 1991 THE LEADER IN SPACEMODELING $2.50

HEADING FOR THE SUN!



Model Rocketry's Longest Publishing, Most Controversial Newsletter!

Spring/Summer 1991 Volume 16, Number 3 & 4

"The Future's So Bright, I Need to Wear Sun Glasses"

With the recent resolution of hostilities between the NAR and Tripoli, the future for rocketry looks very bright. What had been a fractionalized, divided hobby for many years now looks to be converging on a common purpose with a common Safety Code. The introduction of reloadable high power rocket motors has added to the excitement, as now it is possible to fly high power rockets with ther expense and hassle that Class B motors used to bring.

As we wind down *SNOAR NEWS*, it is very gratifying to see rocketry go down this path. Ten years ago this summer, SNOAR hosted the first LDRS because we wanted to fly high power rockets. Now, it is easier and safer than ever. We'd like to think we helped bring some of that about. *JD McNeil*

JD's Garage and Speakeasy...

QUOTABLE

"About five years ago, Dane Boles presented us with a list of things he wanted to see in the Safety Code, including the infamous Dane Boles Memorial One-Minute Moratorium. One of the things he pressed for was a change from "I will launch my model rockets in a cleared area..." to "I will launch my model rocket OUTDOORS in a cleared area..." When we told him this was ridiculous, he replied, "Our marketing data shows that the most popular room is the kitchen."

C. D. Tavares, discussing recent Safety Code revisions.

COVER STORY:

A huge ARCON rocket takes to the air over the crowd at Danville Dare V. *(Matt Steele photo.)*

CREDITS:

Front Ends: JD McNeil; **Tune Ups:** Matt Steele; **Spark Plugs:** Robyn Steele; **Brakes** Chris Pearson and George Gassaway; **Rear Ends:** Tony "Maddog" Williams; **Lube Jobs:** Chas Russell, Dan Kafun, Mary Roberts; **Mufflers:** J. Pat Miller, Chuck Rogers; **Interiors:** CCA, NCR, ISP, MRC, and the NRA.

IMPORTANT STUFF

SNOAR NEWS is published in a random manner by SNOAR, NAR Section #337.

Subscriptions are no longer available. Be thankful you got this issue. This is a DOUBLE issue (count the pages) and constitutes TWO issues towards completing your subscription. This saves us money at the Rip Off, er, Post Office.

Any resemblance to any real persons in this publication is a damn shame. Some people don't get our point, and like to bitch about it, but we don't really care. The opinions and viewpoints expressed within do not represent SNOAR, the NAR, or anyone else.

Publishing Funds: Courtesy North Coast Rocketry

Published with a Mac SE and a Laserwriter IINX.

Development of a Sun Based, On Board Guidance System

by the Zunofark Team,

Geroge Gassaway, Matt Steele, and Chas Russell

Editor's Note: This report won first place in Research and Development at NARAM-30.

Summary

It seems that very little work has been done in past years for active onboard guidance for model rockets. Of course, very few models rockets need any guidance as most fly on a fairly predictable ballistic flight path, guided only by fixed fins. Some models, however, may have special needs. In particular, asymmetrical vehicles such as the space shuttle, Navajo, and Titan IIIC may have need for active guidance. Radio-control rocket boosted gliders has been nearly perfected, but this has been difficult to adapt to normal model rockets. It, also, is not as desirable as an automatic onboard system which can respond much faster than a pilot watching for minor flight path deviations of a rapidly moving model.

Using the sun as a reference point, we realized that sensors and associated electronics could command a model airplane type servo (or servos) guide a model skyward. The servo would position control surfaces to orient the model as desired about the intended axis (or axes). Two different forms of sensors and guidance electronics were developed and tested: the "Infrared Comparator" method and the "Differential Photocell" method.

The IR/comparator looked at which half of the model was receiving the most light, and signalled the servo control unit to move the flight control surfaces to even out the light source. Once the model moved enough for the opposite side to be brighter, the opposite control signal was given to the servo. In effect a two-position "either/or" form of guidance.

The differential photocell sensors used a pair of cadmium sulfide photocells closely matched in resistance response to different light levels. They were mounted facing outward and slightly upward, at identically opposed angles (two legs of a triangle). Connected in series, they acted as a voltage divider. When pointed at an angle not straight ahead, one side received more light and the other side less, with corresponding decreases and increases in resistance. The resulting change in voltage was directly applied to the servo control circuit, providing a sensitive and proportional response to sun angle errors. Unlike the IR/Comparator method, this required little additional electronics other than adjustment potentiometers. This differential photocell method was adopted for all remaining flights after proving itself.

Flight testing proved that pitch/yaw guidance would make the model fly straight towards the sun. This was useful since most rocket flying is possible during mid-day when the sun is not too low in elevation.

Fortunately it was found that the guidance system would work under overcast or cloudy skies, guiding the model for vertical or near-vertical flights. Sensitivity had to be increased for flying under such conditions. As such, this could be considered as sun-sky sensing as opposed to true sun sensing only.

Roll only control was also proven to be possible, using the sun as a reference. By its nature, it would not work as well under overcast conditions, unless launched at less than vertical to force one side to have more illumination from the clouds than the other side.

As a result of our tests, we have concluded that it is possible and practical to use sun-sky referencing guidance in model rockets. The weight and size of the system is reasonable for a number of projects. This method has a great amount of potential for space shuttle and other unusual scale or sport/research models. It can also be used to stabilize the roll axis for models flying movie cameras. Unlike gyros and reaction control jet systems, this method is a low cost, pretty much "off the shelf" system that can be assembled for less than $100. The method does not require any advanced electronics to assemble and troubleshoot. We feel that this method of guidance has significantly increased the state of the art of model rocketry.

Theory:

Could a form of model rocket guidance be developed which used the sunlight as a reference? The concept seemed practical, if a suitable sensor or sensing method could be developed to drive a servo to move the control surfaces. Used in both pitch and yaw control, such a model rocket should fly an approximate straight line path towards the sun. This would be an acceptable form of flight path guidance control as long as the sun was high enough in elevation not to cause risky or dangerous shallow flight paths.

The sensors used for the project would not be too demanding in their light sensing requirements. It would not be necessary to be concerned with specific portions of the light spectrum other than the range of visible light. In the case of "infrared" phototransistors, their response would be in the in the near-infrared range, close enough to the rest of the visible light spectrum so as not to encounter any difficulties such as confusion caused by heat sources.

What was unknown was whether such a form of guidance would require direct sunlight to work. If it would not work on an overcast day, it's usefulness would be limited.

Evolution of The Project:

This project began as an offshoot of the development of a homemade chart recorder to be used to plot out temperature and wind changes for thermal prediction/detection. The recorder used regular model airplane servos to move the recording pens. A columnist for Model Aviation, Ron Van Putte, offered to send copies of a servo testing circuit to persons sending a SASE request. This circuit was obtained and built in late December 1987. The servo motion was determined by positioning a potentiometer which varied the current flow to control the servo pulse width.

Art Rose was very interested in the thermal chart recorder, and in early January 1988 he sent a servo tester circuit which was smaller and simpler than the first one. There remained difficulties in developing a temperature sensing amplifier to vary the current, however, as the servo control circuit still required. It would be much easier if varying voltage could be used instead of varying current to control the servo pulse width. One of Forrest Mims' experimenter's notebooks, on 555 timer circuits, included a voltage controlled oscillator which was similar to the servo control circuit except that it made use of the 555 timer's control voltage pin. It was found that all that was necessary to control the servo pulse width was to apply varying voltage to the voltage control pin of the timer which created the pulse width. One potentiometer adjusting the current was still of use, in the form of a small trimpot to make centering adjustments.

In anticipation of and actual experimenting with such a servo control circuit, other possible applications were considered. Previous experimentation with infrared (IR) phototransistors and Op-Amp comparators had indicated how such circuits could be made sensitive to sunlight, particularly in detecting direction. It seemed possible that IR phototransistors and op-amp comparators could be combined with a servo control circuit to provide active onboard guidance of a model rocket, using the sun as an aiming point or a reference point. It might not work on overcast or cloudy days, but with direct sunlight it seemed feasible.

In late January 1988 a very crude 2-position sensing and servo control unit was developed. Far too crude and large to fly in a model, it did indicate in ground tests that it would sense the sun and drive a servo to alter the flight path. This led to a decision to proceed with development and flight testing. By the end of February the work on the chart recorder was completed, so full attention could be paid to developing the flight guidance unit and model.

Guidance Testing Goals and Criteria:

1) Investigate the possibilities of using the sun for active guidance.

2) Experiment with sensors and associated electronics to determine which is best; using reliability, accuracy, simplicity, and ease of use as primary evaluation criteria.

3) Investigate pitch and yaw control to provide a sun-homing flight path.

4) Investigate potential use of sensing method to provide roll control.

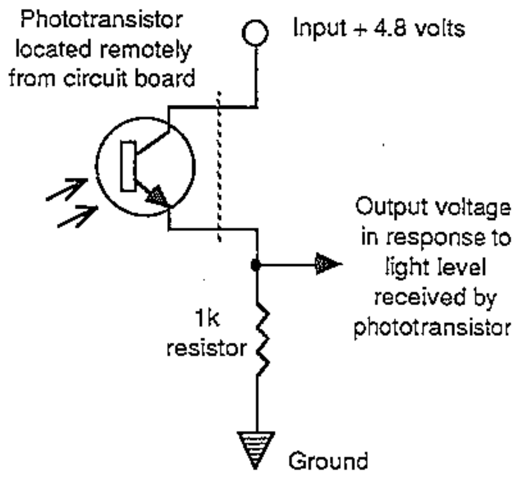
5) Evaluate how well the guidance methods work, especially under less than ideal conditions such as cloudy or overcast skies (will it work at all without direct sunlight?).

6) Evaluate system characteristics such as: control capability, minimal mass, minimal size, simplicity, ease of use, and cost. The test models were targeted to be under 16 ounces for all test modes. If the electronics and techniques are not too complex, more people will be capable of building and flying this guidance system.

Guidance Sensing and Electronics

The phototransistors used for the comparator guidance were "infrared" type, which were actually sensitive to the near-infrared light spectrum. The IR phototransistors used were type TIL-414, in a T-1 3/4 case similar to an LED (The IR phototransistors available from Radio Shack). Non-infrared phototransistors would work as well, but they were not as easily available as the infrared type.

With the IR Phototransistor (or detector) connected in series to a resistor of 1000 ohms, a tap between them would produce changes in voltage. The voltage tap output was in response to the light received. With two

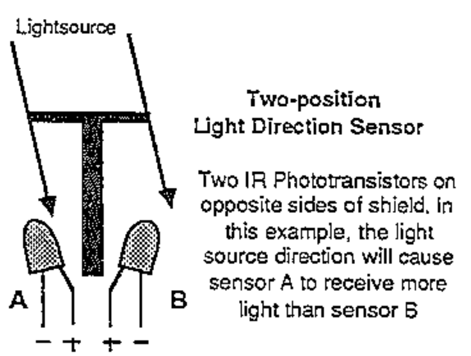


Phototransistor voltage output circuit

such IR detectors on opposite sides of a model (or opposite sides of a light shield), one would produce a higher voltage than the other or vice-versa, depending on which was receiving more light. This was the basis for a crude form of guidance which would steer the model towards the light source in an attempt to provide equal light levels on each side of the model.

The first flight test sensing unit (as well as the crude prototype ground tested before) made use of two IR phototransistor detectors set equally apart (split by a shield) to compare light levels between one side of the model and the other. Operational Amplifiers (Op-Amps) were used in comparative mode to compare the voltage levels between the two IR detectors (for more information about op-amp comparators, see Appendix-A). If the IR detector in position A had a higher voltage than the IR detector in position B, then op-amp 1 would go high and op-amp 2 would go low. If the IR detector in position A had a lower voltage than the IR detector in position B, then op-amp 1 would go low and op-amp 2 would go high. Outputs from those two op-amps were connected to separate adjustable

IR / Comparator Guidance (2 position)



potentiometers to set the appropriate servo control surface deflection position to move the model towards the brightest source (the sun).

In this form, there would be no proportional control, and no neutral position, just either/or control response (up correction/down correction, or left/right). It was expected to produce a crude form of flight path control in pitch and/or yaw which would oscillate, or "porpoise" back and forth along the general flight path. There were concerns about whether this would be effective, or prove to be too sensitive.

The output from each comparator was connected to an adjustable potentiometer to act as a dropping resistor to drop the voltage to the desired level to move the servo (and control surfaces) to the desired correction position. The voltage output from the comparator circuit was connected directly to the control voltage pin of the servo control circuit.

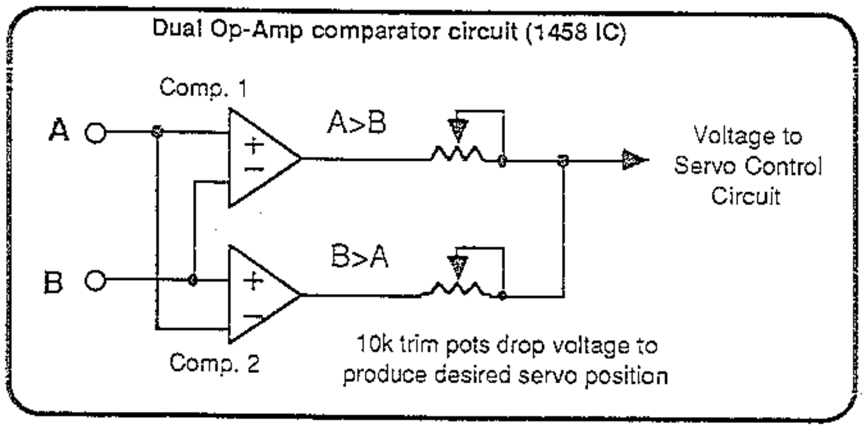
Multiple IR detectors

More advanced versions of the 2-position IR control were planned. These would use from three to five IR detectors, one pointed straight ahead and the other pair (or pairs) set at different sensing angles. They would detect flight path errors within a given range of angles, tied into groups of Op-Amp comparators to perform logic. There would be from 3 to 5 outputs to produce 3 to 5 different control surface deflection positions. For the 5 position method the corrections would be full up, partial up, neutral, partial down, and down for pitch, and similar for yaw or roll. Such a three detector circuit would require 6 comparators (12 for pitch and yaw). This would require at least two integrated circuit (IC) chips, as op-amp or comparator chips have a maximum of four available per chip. A five detector circuit would require at least 13 comparators, possibly more, which would require more than three IC's per control axis, a minimum of 7 IC's for two-axis pitch/yaw guidance.

The complexity of using the multiple sensors and comparator logic was not desirable, but a possible necessity if the simple 2-position method was too crude and other sensing methods were not developed. This led to consideration of photocells (photoresistors) for possible use in guidance sensing

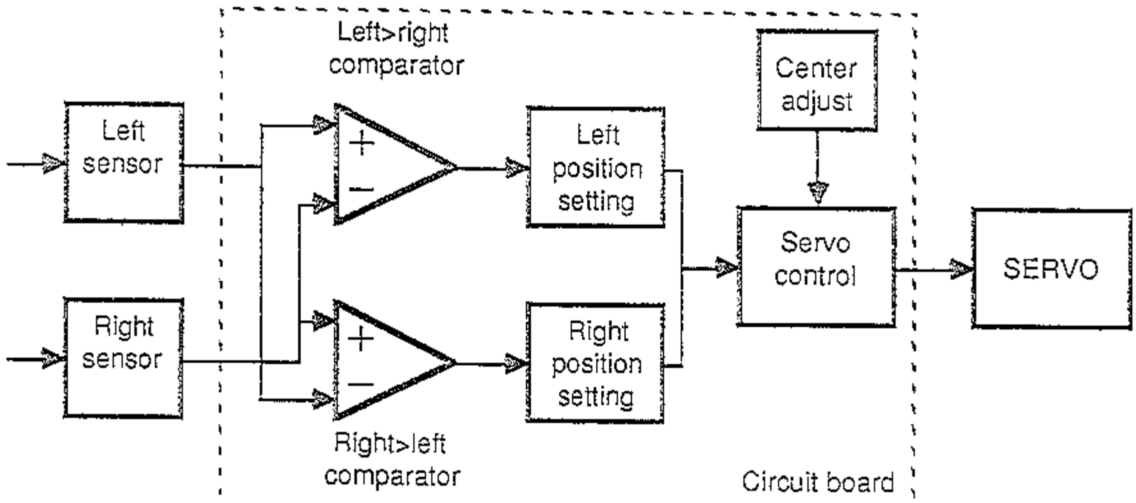
Differential Photocells

The photocells used for guidance were 3/8" diameter Cadmium Sulfide (Cd S) photoresistors. These photocells vary their resistance values in response to light levels, higher resistance in darkness and lower resistance in brighter light. Although particularly sensitive to green light, the response to the rest of the visible light spectrum was sufficient to act as a reliable

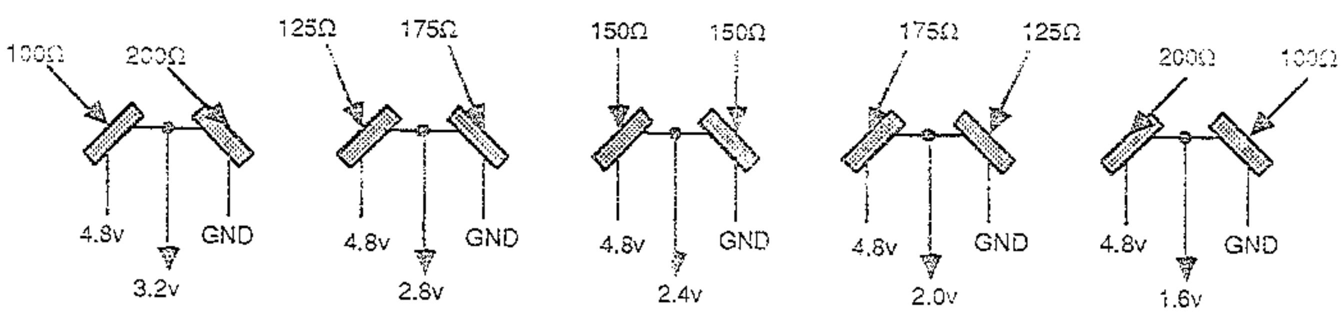


IR/Comparator guidance using two IR detector voltage inputs for 2-position guidance detection and control

Block diagram of IR/Comparator 2-position guidance



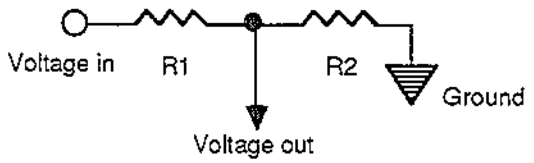
Differential photocell resistance response to light angles, with resulting output voltages
(Resistance values for explanatory purposes only)



sensor. Indeed, the response to the visible spectrum is similar to that of the human eye, over a slightly wider range. Once reason that photocells had not been tried earlier was their relatively slow response in comparison to sensors such as phototransistors. However, response time for guidance purposes once tested was found to be quite good. Indeed the servo would prove to be the slowest portion of the guidance system, not the sensors.

Photocells could be used as light angle sensors in the following manner. If two relatively closely matched photocells were mounted at identically opposed angles, they should be directionally sensitive to a light source (It is very likely this opposed angle principle has been developed for other uses, but we did not come across it in our search of resource materials).

After developing this concept we did locate in a NASA tech brief a sun sensor using two photocells for each axis, but they were mounted flat inside of a hollow shade shield, an approach which would not work over as wide of a range of sun angles or provide the desirable proportional control surface motion as our method.



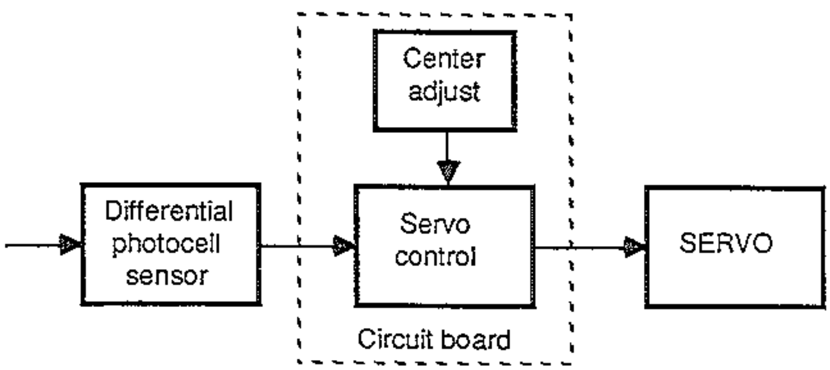
$$\text{Voltage out} = \text{Voltage in} \left(\frac{R2}{R1+R2} \right)$$

Connected in series, the center tap between two differentially mounted photocells would produce a changing voltage (acting as a voltage divider). Initial testing with two photocells both angled 45° in opposing directions did show wide changes in voltage when pointed in different directions toward and away from a strong light source. When pointed straight at the light source, the voltage would be approximately half of the input voltage (ideally it should be exactly half, if the photocells were perfectly matched). This was considered to be the centering voltage. For example, when the light source was left of the sensor the voltage would increase in proportion, and conversely decrease if the light source were to the right of the sensor (depending on polarity, the voltage swing could be in reverse). The swing in voltage was in proportion to the light angle, which would be capable of controlling a servo to respond in proportion to the pointing error.

Maximum swing in voltage would occur when the photocell sensor pair had reached their maximum difference in resistance ratio. This could occur when one photocell had light reach it at a perpendicular angle, when the other photocell was shaded from direct light, or at some point in between (also dependent on photocell resistance change characteristics). Beyond the maximum voltage swing point, further aiming of the sensor away from the light source would cause the voltage to return towards the center voltage level. The return to center voltage was gradual, so much so that a model would be likely not to have a problem with the sensor "losing sight" of the sun unless the model were pointed almost directly away from the sun. Before that would ever happen, the guidance system should have had ample opportunity to control the model so that it would not point too far from the sun (too far would be considered to be significantly more than 90 degrees, perhaps150 degrees depending on possible sensor configurations).

With this sensor producing its own voltage changes in response to pointing errors, it seemed much better suited for guidance than the IR/Comparator guidance. It had the major advantages of proportional sensing to move the servos, thus control surface deflection, and much simpler electronics (the tap voltage from the

Block diagram of differential photocell guidance



sensor connected directly to the servo control circuit).

The three-wire cables to the sensors had previously been hard-wired, soldered together without any capability for disconnection without desoldering. In the new board, each three-wire cable to the sensors had a 3-pin socket to accept a 3-pin plug attached to another 3-wire cable from the sensor. These 3-pin connectors were not polarized, and wired such that the outer pins were positive and negative while the center wire was the voltage tap from the sensor. This would allow easy reversal of the control surface response should it turn out to be opposite of what it should be.

The total weight of the new circuit board was .76 ounce with connectors. With a sensor weight of no more than .25 oz. each, servo mass of .47 ounce each, and switch/battery mass as low as .7 ounce, the total mass for 2-axis pitch/yaw guidance system could be as low as 2.9 ounces, a roll only system as low as 2.2 ounces. Those weights do not include linkages, flight control surfaces, or mounts to hold the components of the guidance system. Those weights would be dependent on the model design, size, and strength required. For example, the pitch/yaw nose control unit weighed 5 ounces, about 2 ounces of which included the mounting structure, linkages, control surfaces, and nose cone.

Sensor Configuration

It was found that sensors would work well when mounted inside of an opaque plastic nose cone. Rather than glue the sensors to the inner nose cone wall, they were attached to a holder anchored inside the end of the body tube (it could have easily been a removable base of a nose cone). It was found that the photocells could sense the region of the nose cone that they faced, there could be an air gap between the photocell and the inner nose cone wall. The photocvells were mounted to sense horizontally, which should provide the maximum amount of angle sensing.

Some or a large part of angle sensing sensitivity would then be dependent on the region of a nose cone were the sensors were located. If located in an area where the sides of the nose cone were parallel (at the base), there would be a great amount of voltage change in response to light angles. If located closer to the tip of the nose where the side walls were angled less (more blunt), the voltage swing in response to light angles would be less. Stray light from the front of the nose cone would reduce sensitivity, to cure that an opaque disk was mounted just above the photocells.

It was also found that by sensing the sides of the nose cone, the sun could be very much to the rear of the model yet still provide a significant sensing by the photocells. Particularly if the photocells were sensing near the base of the nose cone where the sides were nearly parallel to each other. This would provide more control response should a model suffer very late or no ejection, it would transition into a steep glide more rapidly.

It was found that the translucent plastic nose cone could be painted yet still allow good operation of the sensor, which would allow most scale models to use guidance sensors underneath painted nose cones. The test nose cone was painted red, the color not chosen for any particular light spectrum reason. It was not intended to get into deep testing of which colors would or would not allow proper operation of the sensor. The exact color probably would not matter as much as how translucent or opaque the layer or layers of paint were, combined with the translucent nature of the nose cone plastic. Out of curiosity the worst case color, black, was tested. Black paint blocked the light too much to allow proper light sensing.

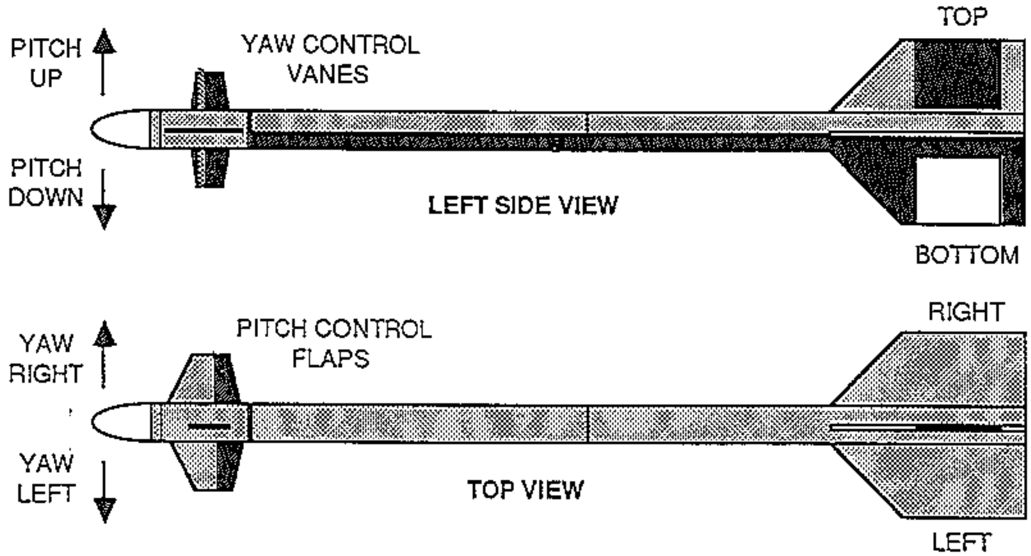
The conclusion drawn from this was that a scale model would need to have the sensors mounted inside or glued underneath a nose section area which did not have a heavy coating of white primer or the final color paint, and the color could not be too dark or opaque. If this were a problem, it might be sidestepped by mounting the photocells in a different area which was painted in a manner that better met the sensing requirements, or finding a remote area of the model which would allow sensing through the paint. Very small photocells might be used in particularly small tight areas (BCD Electro offers 1/8" diameter photocells, which were tested and foun_ to operate well as guidance sensors when properly matched).

Test Model Design

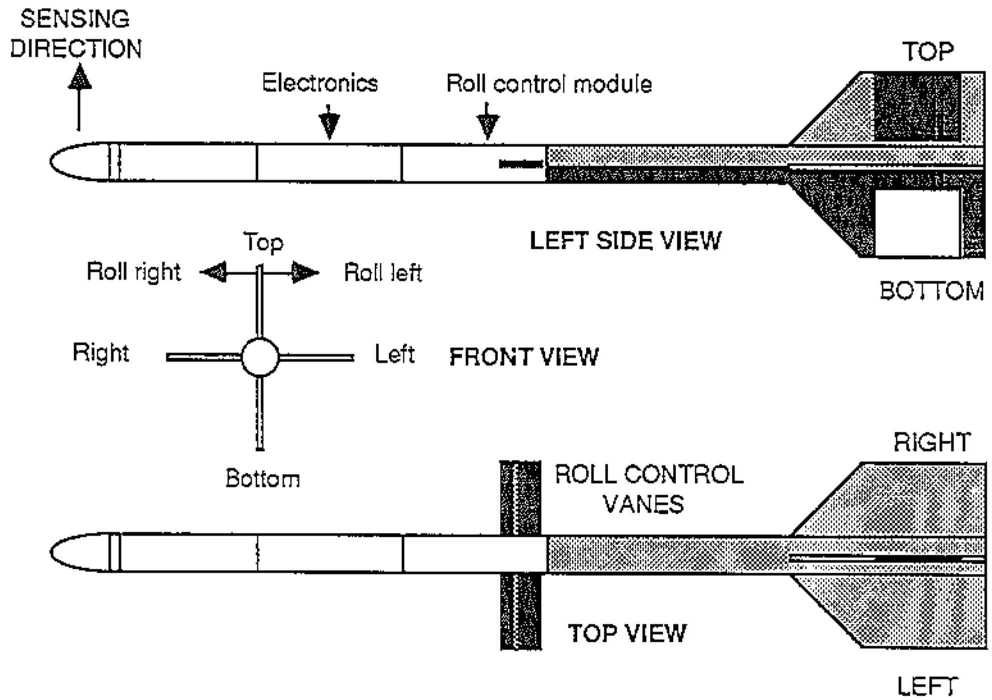
For practical considerations of construction, controllability, ongoing modification, and simplicity, the basic flight test model design chosen was based on the Chaparral/Sidewinder missile. This provided a fairly proven configuration, with nose control fins which could be modified easily. As the guidance electronics, servos, and batteries might take up significant space and mass, they could easily fit within the upper half of the model and more mass would help, not hurt, the stability of the model. A model configuration using rear fins for control was considered too complex for a basic test vehicle, due to the necessity of mounting the servos on or in the rear portion of the model. Two models were built, one to test pitch/yaw and one to test roll. After a crash (not due to the guidance), a third model airframe would be built to carry the pitch/yaw nose guidance unit.

Nominal mass for the pitch/yaw model without the motor was 10 ounces. The pitch/yaw control unit itself had a mass of 5 ounces. The roll only model had a mass

Model 1 with pitch and yaw control unit



Model 2 with roll control module



Note that model should roll to present this top view to the bright light source (i.e., SUN) of 8 ounces. Neither model nor control units would represent an absolute minimum weight configuration, due to the need to allow flexibility for potential modification during flight testing.

Propulsion

Estes D12 power would be used for nearly all flights. This choice was made due to the acceptable power D12's could provide as well as relatively low cost. Depending on the test configuration and desired flight altitude/velocity, D12 powered flights were either single stage or multistaged (using unibody staging). Multistage flights were thought provide a better demonstration of guidance control due to the longer flight time. Two pitch and yaw flights carrying a Cineroc would be made using an Aerotech E10-2.

Servos

The servos used for the flight models were Cannon CE-9 Super-Micro servos. These were used for the project due to their very light weight and size, as well as the fact that they we had several on hand from flying radio-controlled rocket gliders. The servo mass was .47 ounce, with a size of .46" wide, .97" long, and 1.25" tall. These servos could be arranged to fit and operate easily inside of an Estes BT-60 body tube.

Batteries

Battery power was supplied by 4.8 volt Nickel-Cadmium (Nicad) rechargeable battery packs as used for radio-control. Some flights used 70 Milli-Amp Hour (mAh) 4.8v packs weighing .77 ounce, other flights used 50 mAh 4.8v packs weighing .57 ounce (particularly the roll only flights).

Test Model Guidance Sensing and Electronics

The first test model incorporated 2-position IR/Comparator guidance about the pitch axis only, aimed to home the model in pitch towards the sun. It was intended for the model to roll slowly which would allow the single-axis pitch corrections to correct the model towards the sun about both pitch and yaw directions of flight. This concept is used for such missiles as the Redeye.

The first flight worked well, as the model pitched from vertical towards the sun, then on overshooting slightly in pitch beyond the sun the model corrected itself back in the opposite direction, and continued correcting back and forth while flying a path towards the sun. This "porpoising" type of flight path oscillation was expected, due to the 2-position form of guidance response.

The second flight did not go as well as the model roll attitude at launch was different than from the first flight such that the pitch corrections were about the wrong flight axis, yaw rather than pitch. Fortunately the model eventually rolled enough for the pitch corrections to finally be about the proper flight axis to pull the model away from the ground and upwards for a safe ejection and recovery.

A third flight of pitch only was made, this time with roll tabs added to increase the roll rate. The roll tabs caused too much roll for the pitch control to respond properly, the model flew an essentially unguided ballistic path.

Apparently, to emulate the same type of guidance as the Redeye missile, the servo speed would have to be much faster as well as provide more control surface force, combined with a roll rate which is neither too fast nor too slow. Due to the risky nature of this flight mode, no more pitch only flights were made. As the guidance concept did seem proven, the next phase of flight testing would include yaw control as well as pitch. The only future single axis control flights would be to test roll correction only which would have no effect on flight path, just roll position.

For the next series of test flights, yaw control was added to the test model. The yaw control made use of the newly developed differential photocell type sensor. The 2-position IR/Comparator guidance was retained for pitch control. The model made three flights in this configuration, using one method for pitch sensing and another for yaw sensing. The model homed in on the sun, proven quite well by the fact that the flights were made with the sun at angles between 45 and 60 degrees of elevation, and held course rather than going ballistic on such climb angles. It was noted that the model had a rapid oscillation at higher airspeeds when locked onto the sun, attributed to the 2-position IR/Comparator guidance. Such oscillations would cause higher dynamic flight loads during flight than normal, the test model was strong but other models might not be. Considering the simplicity and more desirable proportional control characteristics of the differential photocell type sensor, all future flights made use of that form of sensing exclusively. The 2-position IR/Comparator guidance was not tested further, as it was felt the concept had proven itself but had been surpassed by the differential photocell sensing guidance method.

Multiple IR detectors

Only the 2-position IR detector/Comparator guidance was tested. No multiple (three or five) position detector/comparator guidance was built or tested. It was felt that the differential photocell type sensors which had just been developed rendered multiple detectors/comparators unnecessary.

Differential Photocells

This type sensor was adopted for flight use exclusively after proving itself during the short series of mixed sensing pitch/yaw flights where a differential sensor sensed Yaw while IR/Comparator guidance was used for pitch.

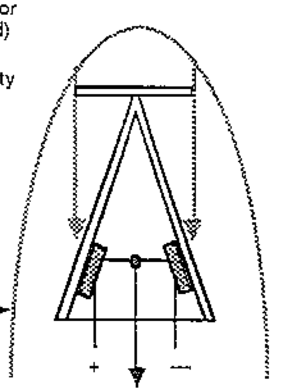
Direct sunlight on the photocells oversaturated them. This degraded the sensitivity resolution and brought about such low resistance values as to draw too much current. They had to be masked to reduce the amount of light they received. The solution was to glue them to white styrene plastic of .04"-.06" thickness. The plastic was translucent enough to pass on adequate light to provide good sensing of light angles. To prevent sunlight reaching the photocells from the rear, they were enclosed in triangular housings. The top of the triangle had a flat plate added to cast a shadow onto each half of the photocell area (this to magnify the pointing error, putting all of one photocell area in direct sunlight and shading the other). A clear plastic nose cone provided an aerodynamic shroud for the triangular housings of the sensors.

A side benefit if masking/reducing the light received was that the photocells could be glued to the inside walls of hollow plastic nose cones, eliminating the need for clear nose cones or "windows". After further testing, it was found that the photocells could be mounted to a holder inside the nose cone, with an air gap between the photocells and nose cone wall, direct gluing was not necessary.

One drawback apparent early on was the difficulty in matching up pairs of photocells which would have similar resistance values under different lighting conditions. There would always be some slight difference, pairing two photocells that were within at least 10% of each other under two very different lighting conditions were found to work well. Photocells which did not have similar resistance values when exposed to the same light levels would not work acceptably for guidance sensing. The straight ahead aiming, which ideally should be half of the sensor input voltage, would be abnormally high or low depending on which photocell had a lower resistance than the other when exposed to equal lighting. Even though it could be corrected partially by the servo adjustment potentiometer, the resulting servo response would be very uneven. For example, a 30° left sensor error could result in 20° of control surface movement while a 30° right sensor error could result in only 10° of control surface movement. Such uneven response would be unacceptable for proper guidance control. On top of these problems, the sensor would vary voltage widely depending on the overall light level (direct sunlight, obscured sun, overcast).

Part of the early trouble in matching up photocells was due to having to obtain the photocells in an assortment from Radio Shack. Later on a better source for photocells was located, BCD Electro (mail order), who offered three different values and sizes of photocells. The guidance project adopted use of a 3/8" photocell listed by BCD as 20k dark and 25Ω light. These photocells proved to be much more consistent, but did still require testing to match up similar pairs (a

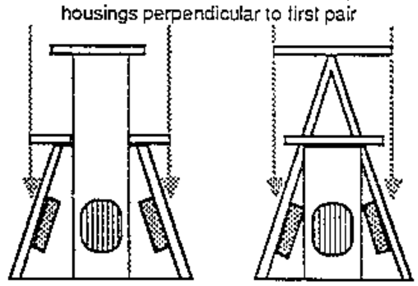
First Differential Photocell Sensor (note sunshield) Near panel omitted for clarity



Clear plastic nose cone housing

Center tap voltage to servo control circuit

Pitch/Yaw Differential Photocell sensor (near side panels and wiring omitted for clarity). Original sensor modified with the addition of new photocell housings perpendicular to first pair



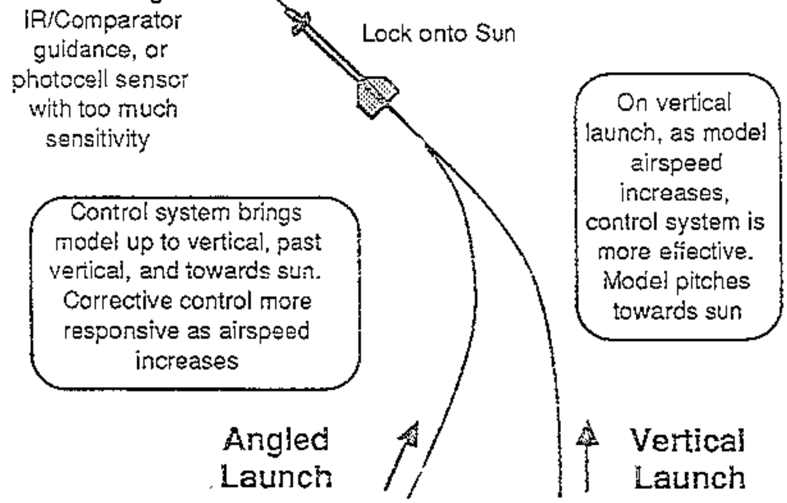
Second pair of sensors have same wiring arrangement as first pair.
Positive & negative wire pairs from each sensor must go to their respective sensitivity selection resistors on circuit board.

sun for calibration, as the differential photocell sensors would often not be exactly centered under different lighting conditions. The model's roll position would be such that the axis being adjusted would sense to the left and right as the person holding the model faced the sun (It assured the guidance section was perpendicular to the ground about the axis being adjusted, as opposed to holding the model such that the elevation angle of the sun would affect the centering process)

The appropriate servo centering potentiometer for either pitch or yaw was adjusted to provide a straight ahead control surface position when aimed at the sun. Due to possible variations in ambient lighting, especially when the sun was obscured, after making the centering adjustment the guidance section was rotated 180° to check that the control surface was still properly centered. If not, adjustments were made for an average between the two. This type of adjustment was of primary need to provide a smooth flight path towards the sun, without it the model could wobble or barrel roll generally towards the sun as the model rolled of its own accord. It was unlikely that a centering error would cause a dangerous flight or crash unless it was an extreme error which should have been obvious before flight.

Flights were made using single D12-3 or 2-staged D12-0/D12-5 power, the exceptions being two E10-2 powered Cineroc flights. Single D12-3 flights were often used to check the general flight responses. The 2-staged D12 flights provided a better evaluation of the flight path and guidance corrections. The model would start correcting the flight path shortly after leaving the launcher, as the airspeed increased the control surfaces were more effective. Once the model aligned itself towards the sun (or "locked on"), it would hold that path until the airspeed was too low to keep the nose aimed at the sun. The model would pitch over and usually eject shortly thereafter. On staged D12 flights, the lock onto the sun was more noticeable as often the model would aim at the sun early into the second stage burn if not before. Some staged flights were more rigorous, with the model aimed 10-20 degrees away from vertical, along an azimuth opposite of the sun (in other words, a north azimuth when the sun was to the south). On these flights the model would climb at close to its initial launch angle until reaching enough velocity for the control surfaces to be effective, climb up to vertical, go past vertical, and lock onto the sun.

During the course of test flying, there was one crash. It was not due to the guidance system, but to a prepping error. A 2-staged flight failed to stage, as the upper stage motor was installed backwards. The model corrected its flight path as expected towards the sun during the first stage burn. At burnout there was no



staging, although the upper stage motor did ignite backwards at the ejection end. The model coasted to apogee, then nose down and picked up airspeed. After falling about halfway down the model began to deviate from a ballistic flight path. Despite the sun being located behind the model (approximately 150 degrees) the control surfaces were deflected. Part of this deflection was due to partial sun sensing/light sensing and part was likely due to uneven photocell resistances with both shaded from the sun. With the model falling nose-first, it would not take much control force to deflect the nose towards the side. With the airspeed high enough for the control surfaces to become effective, the model began a small transition from vertical. As the model pulled more horizontally, the light differential on the sensors became greater, especially when one photocell became exposed to sunlight again. The model performed a steep glide type of pullout, transitioning from a vertical fall to close to horizontal flight. The model hit the ground at about a 20-30 degree angle just as the glide pullout had nearly peaked. The model bounced and slid along the ground for about 30 feet. As it hit the ground the upper staged motor's propellant ignited backwards, producing a flare of flame and smoke as the model came to a rest (the delay had been burning since the ejection charge was ignited).

On picking up the crashed model, the guidance system was still working. The near-horizontal crash, while causing major damage to the model airframe and flight surfaces, was gentle enough not to damage to the internal portion of the guidance system itself (electronics, servos, mechanical linkages). Even the nose cone and sensor were spared as the nose control surfaces bore the brunt of the initial contact with the ground. Had this model not pulled out into a near glide to soften the crash, it would have impacted ballistically onto an asphalt runway. Such a crash would likely have wiped out the entire guidance system, including major damage or destruction of the servos.

It had been theorized that should a model with pitch/yaw guidance have a late ejection or no ejection it might go into a glide, albeit a steep and fast glide. However, it was not planned to make any such tests intentionally. The mistake in prepping did allow such a flight to occur. Later, a Cineroc pitch/yaw flight had such a late ejection that the model went into a steep glide before ejecting at about 30 feet of altitude. Had that flight fallen ballistically it would have crashed before ejection. This indicates that at the very least models with pitch/yaw sun-homing guidance can either give the ejection charge extra time to go off, or reduce the severity of a crash (perhaps saving a payload from destruction).

Roll Tests

Although the pitch and yaw control was the primary goal of this project, the possibility of roll control was also investigated. Flight tests were of a more limited nature, as the roll model used proven techniques adapted from the same differential sensor and servo control as developed for pitch/yaw. Roll control was intended to affect only the roll orientation of the model. It would not affect the flight path, so roll flights would be ballistic the same as regular model rockets.

The test model utilized two roll control vanes mounted 180° apart. They were set up to rotate in opposing directions to provide roll control, in the same manner as ailerons on a conventional airplane. The servo, linkages, and vanes were mounted in a short length of tubing to act as a roll module. This would allow the sensor and electronics to be located in another area of the model, electronically linked to the roll module by a 3-wire cable. The roll module was located near the middle of the flight test model so that the roll control vanes would be closer to the center of gravity, a more forward location would introduce the possibility of the vanes providing some small canard effect.

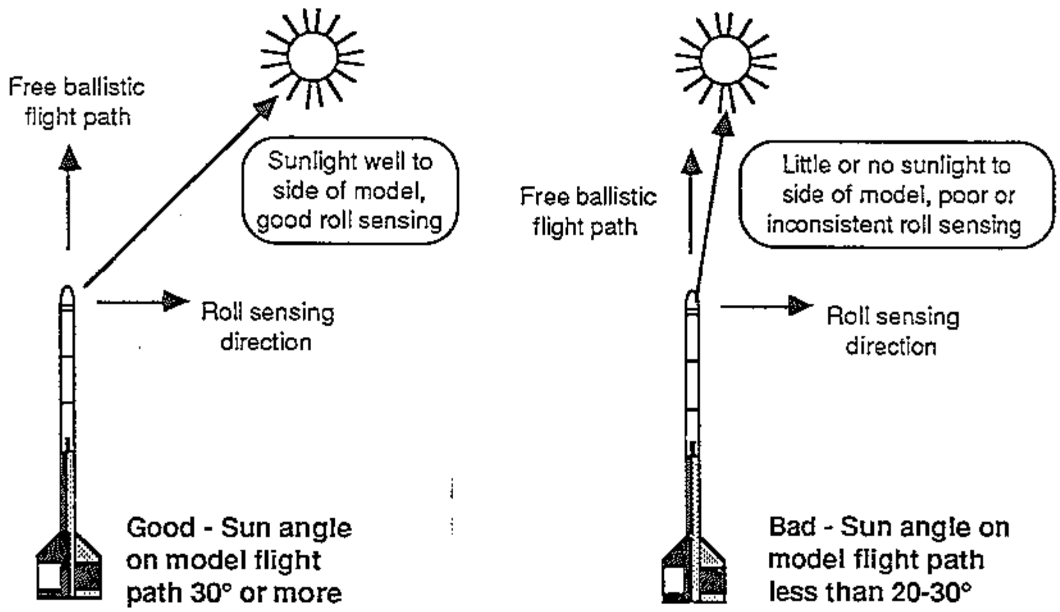
The sensor for roll was a differential photocell sensor mounted horizontally (perpendicular to the airframe), inside of a clear plastic nose cone. The servo control circuit was a single unit as used earlier with the pitch testing.

By rotating the position of the roll sensor (or the whole nose section) befor flight, the model could be made to rotate and hold position in flight relative to the sun position. One side of the model would thus be facing the sun throughout the rest of the upward flight until apogee or until weathercocking towards the sun.

It would be important to prevent the model from pointing towards the sun or within 20-30 degrees. To properly sense roll there needed to be at least some amount of sunlight coming towards the side of the model. With a steep angle the amount of light sensed would be reduced, and a large roll error of the model would produce less corrective deflection of the control vanes. The control response then be reduced, and as the model faced closer to the sun the response would be erratic. Should the model be aimed towards the sun it would also be likely to weathercock past the sun, where the roll control would then begin to stabilize the model 180° opposite of the intended azimuth direction.

Flight testing showed the above theories and ground testing indications to be correct. It is desirable to fly when the sun elevation is not too high, and/or launch the model so that its flight path will be certain of providing adequate angular difference between the sun and the model.

The first two flights were single-staged. The first flight was oriented 90° roll left of the sun. The model



In-flight roll sensing criteria

rolled slowly right about 90° before burnout, an seemed to hold that position. In case the model naturally rolled left, the next flight was oriented 90° roll right of the sun. That flight rolled slowly left about 90° before burnout, then seemed to hold that position. Those two flights together indicated the roll control worked, as the model rolled each time toward the sun even though the flights were oriented in opposite directions.

As the roll corrections were so slow, the roll control vane size and span was increased. This was expected to produce more rapid corrections which would be more apparent in flight. The first flight with the larger vanes flight suffered an engine catastrophic failure on launch, providing no information.

The last two roll control flights were made with a Cineroc movie camera onboard, using 2-staged D12 power. The first flight was obviously too sensitive as the model rolled back and forth in severe roll oscillations. The control vanes were cut down for the next flight to reduce the oversensitive control force response. That flight worked out much better, though still sensitive. More observations from the Cineroc flights will be discussed later in the report.

Flight tests with Cineroc

Five flights were made which carried a Cineroc movie camera onboard to record the control surface and model response during flight.

Pitch/Yaw Cineroc

Three pitch/Yaw flight were made:

Flight 1 (single stage E10-2) OK, good control response

Flight 2 (single stage E10-2) Good response, late ejection pullout

Flight 3 (3-stage D12) Homed and held course well, was launched at 15° from vertical opposite of sun

Roll Cineroc

Two roll flights were made:

Flight 1 too sensitive

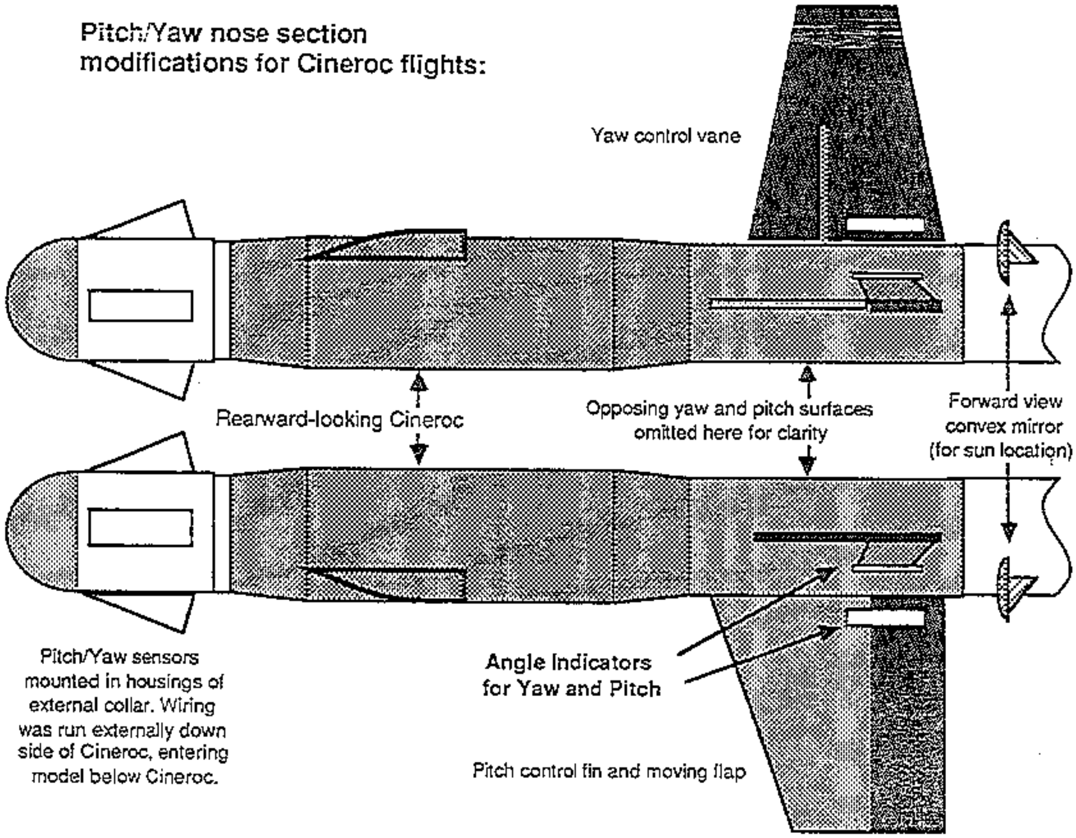
Flight 2 - better, held general direction but rolled back and forth, still too sensitive.

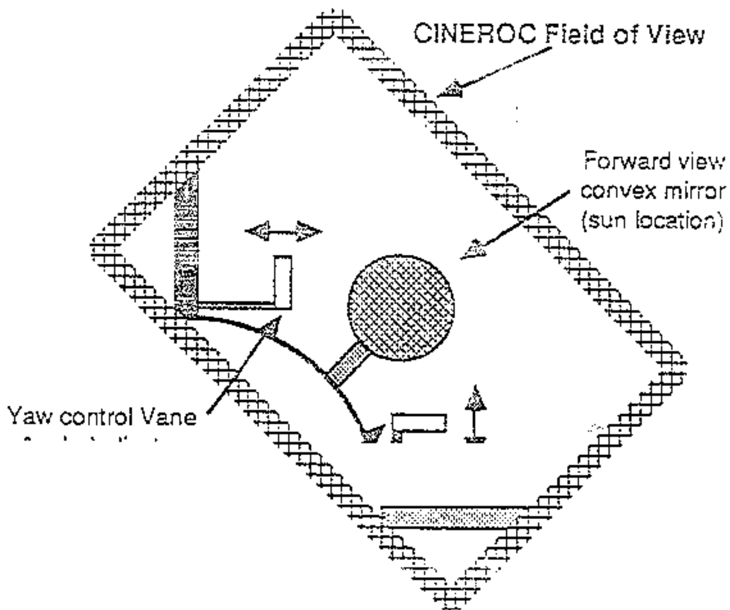
The Cineroc flights showed the importance of matching the roll control response and sensitivity to the model. The roll control surfaces from the first two flights were apparently close to optimum for the model to begin with. The conclusions on the pitch/yaw flights were that the control responses were smooth, as shown by the angle indicators. Servo speed was not too slow such as to hunt or be behind the model, at least given the flight control force set-up, sensitivity, and maneuverability of the model as flown. There was no noticeable control surface flutter. The mirror showed the sun position as it homed in.

Flight Test Summary

*References to opposite angle in flight results means that model was launched at an angle that was away from vertical and opposite of the sun location.

Pitch/Yaw nose section modifications for Cineroc flights:





Model configuration Engines Sky
Results

Tests of Mar19,1988

1) Single-Axis Pitch D12 Sun,w/clouds
Good-pitched from vertical towards sun & held path

2) with 2-pos. IR/Comp.D12/D12 Sun,w/clouds
Bad-near crash due to slow roll orientation

3) with 2-pos. IR/Comp. D12 Sun,w/clouds
Bad-ballistic, no correction due to fast roll

Tests of April 9,1988

1) Pitch/Yaw w/2-pos. D12 Sun,clear sky
Good-pitched from vertical towards sun

2) IR & Diff. Photocell D12/D12 Sun,clear sky
Good-pitched from opposite angle towards sun*

3) IR & Diff. Photocells D12/D12 Sun,clear sky
Good-pitched from opposite angle towards sun

4) Roll only mode D12 Sun,clear sky
Good-seemed to correct roll towards sun

5 Using Diff. Photocell D12 Sun,clear sky
Good-seemed to correct roll towards sun

Tests of April 23, 1988

(From this point, all guidance sensing used Differential Photocells)

1) Pitch/Yaw D12 Thin overcast
Good-pitched slowly towards bright sky area of sun

2) Pitch/Yaw D12 Obscured sun
Good-corrected towards area of sun

3) Pitch/Yaw D12/D12
Hazy sun
Good- pitched from vertical towards sun

4) Pitch/Yaw D12/D12
Hazy sun
Good-pitched from opposite angle towards sun

5) Roll only mode D12 Hazy sun
No result due to engine malfunction

Tests of May 21, 1988

1) Pitch/Yaw D12/D12 Sun,w/clouds
Good-some homing oscillations due to sensitivity

2) Pitch/Yaw D12/D12 Sun beh.cloud
Good guidance operation despite crash due to installing upper stage engine backwards

Tests of June 5, 1988 - all tests with Cineroc

1) Roll-Cineroc D12/D12 Sun,clear sky
Mixed-too sensitive, extreme rapid roll corrections

2) Roll-Cineroc D12/D12 Sun,clear cky
Fair-sensitive, but better than first flight

3) Pitch/Yaw-Cineroc E10 Sun,clear sky
Good-pitched from vertical towards sun

4) Pitch/Yaw-Cineroc E10 Sun,clear sky
Good-pulled into glide before late ejection

5) Pitch/Yaw-Cineroc D12/D12/D12 Sun,clear sky

Good-held course well on final stage burn

Tests of July 16, 1988

1) Pitch/Yaw D12/D12 Sun,w/clouds
Good-pitched from opposite angle towards sun

2) Pitch/Yaw D12/D12 Bright Overcast
Good-pitched from launch angle up to vertical

3) Pitch/Yaw D12/D12 Hazy sun
Good-pitched from opposite angle towards sun

Flight Totals To Date:

Pitch only test flights:
3 flights made, 1 successful and 2 not successful

Pitch/Yaw test flights:
15 flights made, all successfully guided towards sun or towards overcast sky. One crash due to engine prepping error causing staging failure (backwards upper stage motor), which guidance pulled into a steep glide to prevent major damage as opposed to a vertical ballistic crash.

Roll only test flights:
5 flights attempted, 3 successful with one mixed result (1 flight provided no results due to engine malfunction). Two flights smoothly corrected roll. Two Cineroc flights were too sensitive in corrective response, one flight overcorrecting too much to be considered acceptable.

Results:

Infra-red phototransistors with comparators

(IR/Comparator guidance)

A series of test flights showed that this method would indeed provide adequate sun direction sensing and flight path correction to aim the model at the sun. The manner of flight path correction was not smooth but was effective - as the model would pitch towards the sun, then on overshooting slightly in pitch beyond the sun the model corrected itself back in the opposite direction, and continued correcting back and forth while flying a path towards the sun. This "porpoising" type of flight path oscillation was expected, due to the 2-position form of guidance response. The oscillations were no more than ±10° from the general flight path towards the sun.

The 2-position IR/Comparator guidance indicated in ground testing it might be capable of working under overcast conditions, but this was not test flown. On the day of the first test flights the sky was partly cloudy. Ground testing of the model guidance before a planned flight indicated that with a cloud in front of the sun the model aim path would be in some cases as much as 60° from vertical. Exactly what the model was sensing was not known, but it was suspected to be sunlight reflected off of clouds at low elevation angles. For this reason it was determined that flying with the sun blocked behind a cloud would be far too risky. The flights were made when the clouds obscuring the sun drifted past to allow direct sunlight. This false sensing problem may not have been a problem on a completely overcast day, but no flight testing of the IR/Comparator guidance was made during overcast conditions.

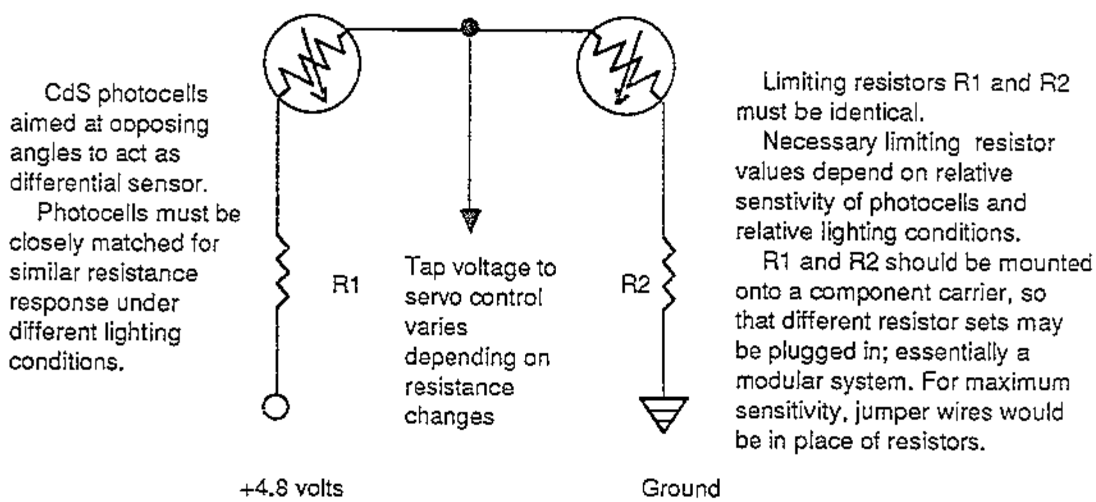
Differential Photocells

Under bright sunlight the differential photocell sensor voltage change even with minor pointing errors could be significant, too sensitive. Sensitivity could be so much that for the first 30° of aim away from the sun the control surface angular movement would actually be greater than the aiming error. For most flight models this would be too sensitive, and did run the risk of over-rotating the servo in a manner which could cause damage to the servo or control linkages.

The solution was to add a limiting resistor in series with each photocell, both resistors of the same value. The inclusion of these limiting resistors caused the overall shift in voltage to be lower. The greater the value of the fixed resistors, the lower the voltage swing caused by photocell sensing. The equation for a two-resistor voltage divider was explained earlier in the report. In the case of adding limiting resistors, the equation for the photocells and limiting resistors would be:

For example, without limiting resistors if photocell 2 had a value of 200Ω and photocell 1 had a value of 100Ω, with an input of 4.8 volts, the output voltage of the center tap would be 3.2 volts (an input of 4.8volts * (200/300)). If limiting resistors of 270Ω were added to each photocell, the center tap would be 2.69 volts (an input of 4.8volts *(470/840)). Note that the centering voltage for a 4.8volt input would be 2.4 volts if the photocells were well matched and installed properly for equal sensing.

The limiting resistors worked fine for days of direct sunlight, but on cloudy or overcast days it was not sensitive enough. After the April 23 tests, changes were made to allow easy change of the sensitivity and balance by use of a plug-in module with fixed resistors soldered to it (The module consisting of a DIP component carrier, to plug into a conventional DIP IC socket). Several different limiting resistor modules were made up, so that the one best suiting the light



Differential Photocell sensor schematic.
Includes sensitivity limiting resistors

conditions in the field could be selected for flight. The resulting guidance response could be lowered by using higher value resistor modules, or sensitivity increased by using lower value resistor modules (including a module with jumper wires in place of resistors, for maximum sensitivity).

The original differential sensor guidance block diagram would now look like the schematic shown below.

About halfway through the pitch/yaw flight testing the ongoing modifications to the original circuit board had reached a point where an optimized circuit board could and should be built. All circuit components would be included on the one board to control two servos. The board used was a Radio Shack Experimenter's IC Board (#276-150) which included 2 bus strips. One bus strip was used to distribute the +4.8v battery power and the other as ground. The board width was trimmed to fit inside of a BT-60, the length was 2.83".

The servo control circuits were essentially the same as before, but changed in layout. Rather than use two 14 pin 556 dual timer IC's, one for each control circuit, the 2-servo control board was designed to use one 8 pin 555 single timer IC and one 14 pin 556 dual timer IC. The 555 timer would generate the clock pulses which were fanned out to each of the timers in the 556 IC to develop the pulse width for servo 1 and the pulse width for servo 2 (for an explanation of how the timers develop the servo pulses, see appendix-B). This change which reduced the number of IC pins from a total of 28 to a total of 22 allowed some extra space on the board to make construction easier, as crowded boards are more difficult to work on.

The board would include an IC socket to accept a DIP component carrier with the limiting resistors soldered to it. The DIP carrier with limiting resistors would act as a plug-in sensitivity module. By having several modules on hand, each with a different set of resistor values, the proper sensitivity could be selected for the lighting conditions or model control response needs.

The three-wire cables to the sensors had previously been hard-wired, soldered together without any capability for disconnection without desoldering. In the new board, each three-wire cable to the sensors had a 3-pin socket to accept a 3-pin plug attached to another 3-wire cable from the sensor. These 3-pin connectors were not polarized, and wired such that the outer pins were positive and negative while the center wire was the voltage tap from the sensor. This would allow easy reversal of the control surface response should it turn out to be opposite of what it should be.

The total weight of the new circuit board was .76 ounce with connectors. With a sensor weight of no more than .25 oz. each, servo mass of .47 ounce each, and switch/battery mass as low as .7 ounce, the total mass for 2-axis pitch/yaw guidance system could be as low as 2.9 ounces, a roll only system as low as 2.2 ounces. Those weights do not include linkages, flight control surfaces, or mounts to hold the components of the guidance system. Those weights would be dependent on the model design, size, and strength required. For example, the pitch/yaw nose control unit weighed 5 ounces, about 2 ounces of which included the mounting structure, linkages, control surfaces, and nose cone.

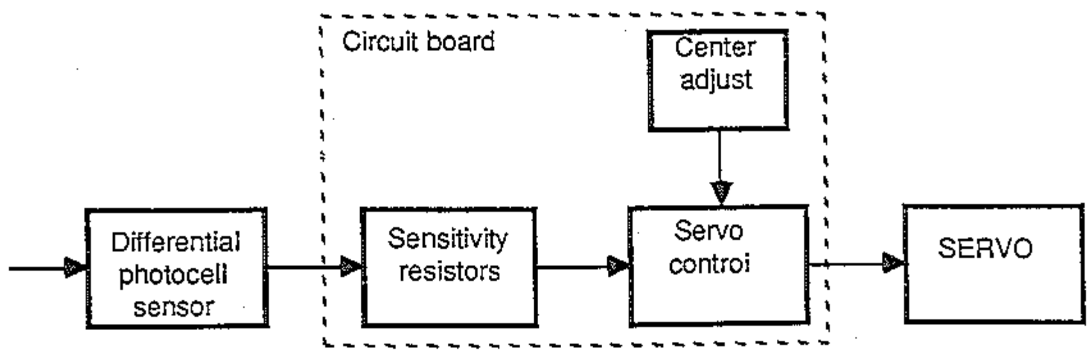
The final version of the 2-servo circuit board is shown in the image below.

A wiring diagram and components list is presented in the following pages.

Sensor Configuration

It was found that sensors would work well when mounted inside of an opaque plastic nose cone. Rather than glue the sensors to the inner nose cone wall, they were attached to a holder anchored inside the end of the body tube (it could have easily been a removable base of a nose cone). It was found that the photocells could

Block diagram of differential photocell guidance with sensitivity resistors



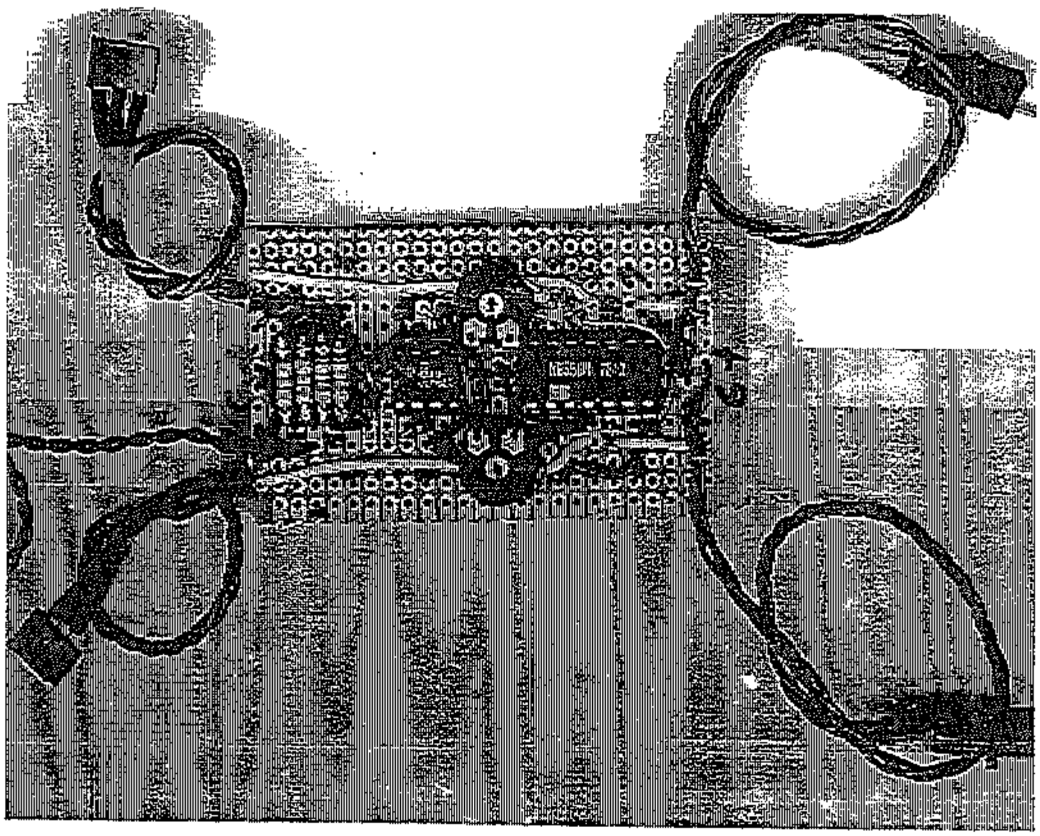
sense the region of the nose cone that they faced, there could be an air gap between the photocell and the inner nose cone wall. The photocvells were mounted to sense horizontally, which should provide the maximum amount of angle sensing.

Some or a large part of angle sensing sensitivity would then be dependent on the region of a nose cone were the sensors were located. If located in an area where the sides of the nose cone were parallel (at the base), there would be a great amount of voltage change in response to light angles. If located closer to the tip of the nose where the side walls were angled less (more blunt), the voltage swing in response to light angles would be less. Stray light from the front of the nose cone would reduce sensitivity, to cure that an opaque disk was mounted just above the photocells.

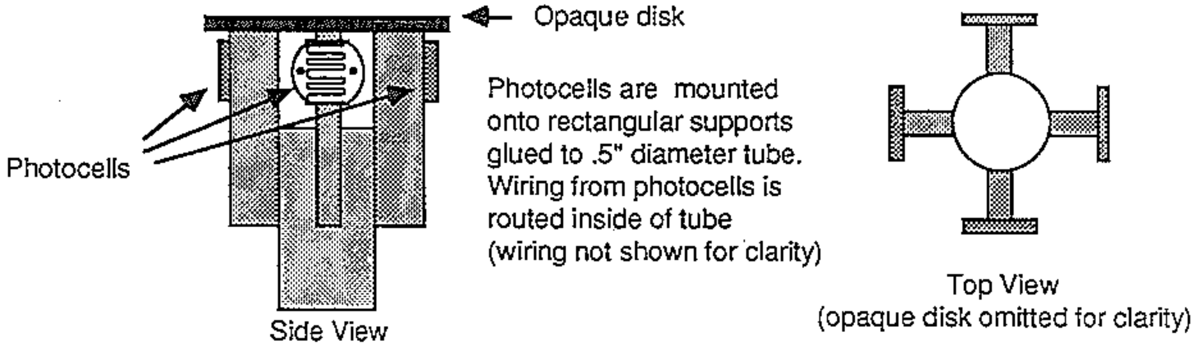
It was also found that by sensing the sides of the nose cone, the sun could be very much to the rear of the model yet still provide a significant sensing by the photocells. Particularly if the photocells were sensing near the base of the nose cone where the sides were nearly parallel to each other. This would provide more control response should a model suffer very late or no ejection, it would transition into a steep glide more rapidly.

It was found that the translucent plastic nose cone could be painted yet still allow good operation of the sensor, which would allow most scale models to use guidance sensors underneath painted nose cones. The test nose cone was painted red, the color not chosen for any particular light spectrum reason. It was not intended to get into deep testing of which colors would or would not allow proper operation of the sensor. The exact color probably would not matter as much as how translucent or opaque the layer or layers of paint were, combined with the translucent nature of the nose cone plastic. Out of curiosity the worst case color, black, was tested. Black paint blocked the light too much to allow proper light sensing.

The conclusion drawn from this was that a scale model would need to have the sensors mounted inside or glued underneath a nose section area which did not have a heavy coating of white primer or the final color paint, and the color could not be too dark or opaque. If this were a problem, it might be sidestepped by mounting the photocells in a different area which was painted in a manner that better met the sensing requirements, or finding a remote area of the model which would allow sensing through the paint. Very small photocells might be used in particularly small tight areas (BCD Electro offers 1/8" diameter photocells, which were tested and found to operate well as



Horizontal sensing photocells (pitch and yaw)

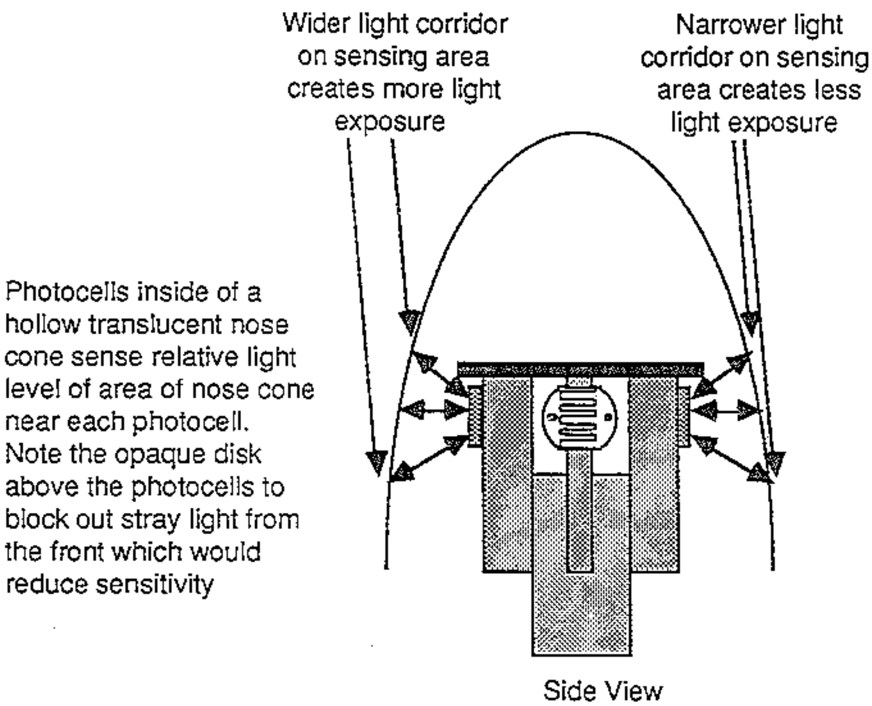


guidance sensors when properly matched).

Pitch/Yaw Guidance

Flight tests proved the concept of sun-homing to work well. The model would fly on a path towards the sun. The path would be slightly less than the elevation angle of the sun, as there would need to be a few degrees of pointing error to deflect the control surfaces to keep the nose of the model from dropping down as it normally would in a ballistic flight. The difference in sun elevation and flight path angle would depend on several factors, one being sensitivity. Other factors would be the sun angle (the higher the angle the less the nose would tend to drop due to gravity, thus less corrective force would be required), and the model velocity (as velocity increased, so would the force of the control surfaces for the same given deflection angle).

A few flights were made under overcast or near-overcast sky conditions such that there was no direct sunlight. It was found that the guidance system would work under such conditions. The overcast sky would act as a general light source from above. The differential photocell sensors could detect this quite well, particularly when set for high sensitivity (sensitivity module with low value resistors or jumper wires in place of resistors). In this case the model would not fly along an exact path, but along a vertical or near-vertical path. The flight path could be biased somewhat towards an area of the sky which was brighter than the rest of the sky (the area blocking the



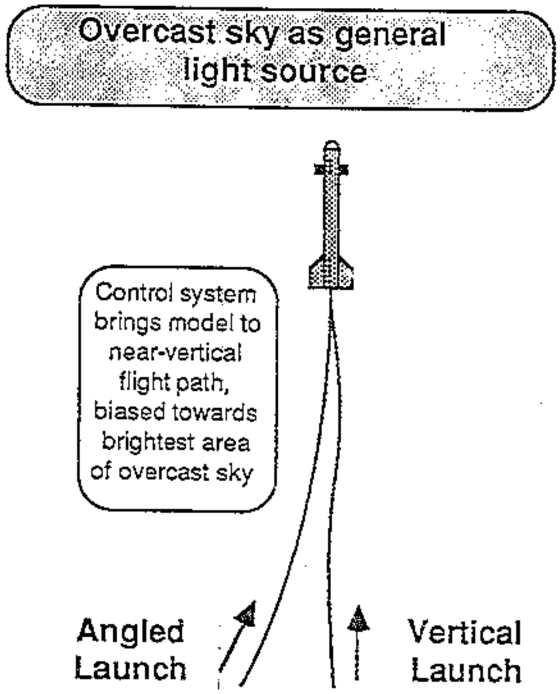
sun, or an area of thinner cloud than the rest). Some test flights were aimed away from vertical, the model corrected to fly vertically or corrected the flight path towards a brighter area of the sky. The success of the system under overcast conditions meant that the guidance system would not be limited to days when there was direct sunlight. The guidance system was not just sun-sensing, but sky sensing.

Several control surfaces were flown during testing, both in type and size. One type made use of a flap attached to a fixed surface (the canard equivalent of a conventional tail surface with a moving elevator attached to a fixed stabilizer). The other type was a vane which rotated about the shaft it was mounted to (the canard equivalent to an all-moving type stabilator as used by 727 and DC-9 airliners). Both types worked well. The flap type had an advantage in being less prone to landing damage due to the fixed portion, and a lower loading of the movable flap control surface. The vane type had the advantage of being easy to change to a different size or replace a damaged vane in the field. There was little to indicate that a model should use one type over the other for control force reasons. Different sizes were used to produce more or less control force for the same given sensitivity or sensor arrangement. In particular, the Cineroc flights required much larger control surfaces to counteract the more forward center of gravity caused by the Cineroc mass.

A concern during the early testing was whether the control forces generated would be too little or too much. This was found not to be much of a problem, keeping in mind the type of model being flown. Due to the relatively forward center of gravity, near the middle of the model, it would take more control force to cause the model to respond. The very large fixed fins at the back also provided a high stability margin which would require more control force to counteract than if the fins were significantly smaller. A model with a more rearward center of gravity with small fins would require very little control force to maneuver the same as the model we tested. Another factor in this is the model velocity, as the control force generated by the control surface deflection is in proportion to the velocity. Much smaller surfaces or surface deflections would be required to control a model flying at 200 ft/sec than one flying at 100 ft/sec.

Anyone building and flying models using guidance must take into account such factors as above so that the model will not be under controlled or too overcontrolled. It is highly suggested that a boilerplate test model be made first to test out and determine the proper sensitivity and control surface movement for each individual design. It should also be noted that models should have an adequate stability margin, as the control system may cause the model to reach angles of attack not normally reached by ballistic models (in the

Typical Pitch/Yaw Control flight path profile under overcast sky



case of canard configurations, the deflection of the surfaces themselves will cause higher lift values up front than indicated in normal center of pressure calculations).

It was found that if a model was somewhat overcontrolled or sensitive, it would not seriously hurt the overall flight. The overcontrol would produce some oscillations once the model locked onto the sun, as the servo motion could not keep up with the rapidly changing pitch or yaw motion towards the sun, past the sun, and back. This was exhibited in the form of relatively minor pitch/yaw changes of from 5 to 10 degrees (approximate) in very rapid fashion (on the order of 2-3 cycles per second)while the model flew along a generally straight path towards the sun. This was acceptable for general flying purposes. However, it would be desirable not to have so much sensitivity (or overcontrol) for many types of models as it could put high stress loads on the model. In the case of a scale model, a smoother flight control response would be desired.

No flights were attempted using control force arrangements which would cause extreme overcontrol. Such flights might overstress the vehicle, if not lead to a crash due to the servo being unable to keep up with extremely rapidly changing flight path errors.

A few flights were made with sun elevation angles of between 45 and 50 degrees. These flights homed in on the sun properly to hold a straight flight path. It was noted that those flights reach significantly higher velocities than normal, most especially the 2-staged flights which locked onto the sun before or shortly into the second stage burn. While gravity and drag constrains upward velocity, only drag constrains horizontal velocity, so the models could reach high overall velocities when flying lower angle paths. The test model was designed to handle higher velocities so this did not cause any problems in testing. However, any models which are flown with the sun elevation at 45 degrees or slightly above should keep this in mind. For safety reasons no pitch/yaw flights below 45 degrees sun elevation were made, and are not recommended.

Roll Control

Roll control was proven to be possible, although with more flight constraints and tighter set-up tolerances than for pitch/yaw flights.

It is desirable to have the model aimed so that it does not fly towards the sun. As the model points near the sun, there is less light differential for the sensor to detect. This is not too difficult as long as the model is not allowed to be launched such that it naturally weathercocks towards the sun or is flown close to midday (midday flying could be done by aiming the model a bit away from vertical opposite of the sun azimuth). Should the model weathercock towards the sun the roll sensor would lose accuracy and become erratic, then upon the model weathercocking past the sun the model would stabilize roll about 180° from the intended azimuth.

As found on the Cineroc flights, it is important to set up the sensitivity and/or control surfaces for the proper amount of roll correction. Too much will cause the roll system to overshoot, possibly with severe oscillations. Too little and the roll control may be unable to prevent the rolling action (there must be adequate control authority to override any roll disturbances or inherent roll of the model). This would require some flight testing to determine the proper sensitivity and control arrangement.

Unfortunately roll control did require sunlight to operate properly. Under the light sensing theory, the only way that roll control could work under an overcast sky would be to launch the model at an angle away from vertical so that one side of the model would have more light from the overcast sky than the other. Such would require a flight path of perhaps 20-30° from vertical, if not more, which would lead to problems with weathercocking and gravity turn. If the model using roll control was for purposes of steadying roll for movie camera of photo camera operation, the flier may not wish to make such flights in overcast conditions anyway.

Other Observations

As was briefly noted previously, the control force generated by the flight control surfaces is proportional to model velocity. This was well illustrated during some of the 2-stage pitch/yaw flights. When launched 10-20° away from vertical and opposite of the sun azimuth, the model would climb slowly at about the initial launch angle, slowly climb near vertical, and shortly before or after staging the model would pitch over to lock onto the sun. The model responded little during the early climb, and increased response as the velocity increased. This indicated one significant problem with using aerodynamic flight control surfaces, if a model truly needing guidance were to go off course due to a thrust imbalance or thrustline/center of gravity imbalance, it might crash before flight control surfaces could respond (similar effect to some boost gliders which pitch nose-down at launch due to the thrustline/CG imbalance, then as they pick up speed often pull nose-up).

Should a model be likely to go off course rapidly after launch due to thrust rather than aerodynamic reasons, aerodynamic control surfaces may be useless. Such a model would instead need direct-acting control forces. There seem to be two possibilities; thrusters or engine gimballing. It is possible to create small cold propellant thrusters fed by a central tank of freon (the safety code legality of such a cold propellant system is not clear). Engine gimbaling could be accomplished by the same servo system as used for aerodynamic surfaces.

Direct thrust type correction would seem to have the opposite problem of aerodynamic surfaces, as the model reached higher velocities the thrusters or gimbal thrust would be less effective. If the model had aerodynamic imbalance trying to pull it off course, those imbalances would gain more force as velocity increased, possibly beyond the point of the thruster or gimbal thrust to counteract.

Safety Recommendations

Flying sun-homing models can be most interesting and enjoyable. However, it brings about special responsibilities. Models should never be flown when the sun elevation angle is low. That would be extremely dangerous. We recommend the following to anyone who flies sun-homing models:

• Models using pitch/yaw control for sun-homing should not be flown with a sun elevation angle of less than 60 degrees unless the model has been previously flown successfully and the control surfaces have been adjusted to track the sun without error.

• Models using pitch/yaw control for sun-homing should not be flown with a sun elevation angle of less than 45 degrees under any situation whatsoever.

The above applies to sunny conditions only. It may be possible for overcast conditions to allow near-vertical flights even when the sun itself is low on the horizon (but hidden by the overcast).

If in doubt, never fly in overcast or cloudy conditions when the sensing unit does not center when pointed vertically or within 30° of vertical.

Potential Applications:

Pitch/Yaw

Flight path control towards sun when sun visible, generally vertically under overcast conditions. Wide variety of models can use this method. Unusual scale or unique configuration sport/research models with likely problems flying a straight path are most likely to benefit. Possible use for any special project requiring a rocket to fly along a generally straight path at a specific climb angle or azimuth (climb angle or azimuth determined by sun position for a limited time each day)

Roll

Maintain one side of the model facing towards sun. If overcast, roll control might be forced to work if model launched away from vertical. Possible uses - radio-controlled models where pilot would prefer automatic roll correction in order to concentrate on controlling pitch and/or yaw axis (This would allow radio-control of non-winged rockets which are difficult to impossible to see well enough to control roll). For models carrying movie or video cameras, can stabilize the roll axis so that the ground seen below does not spin around (because the rocket will not spin around).

Potential Future Uses For Sun-Sensing Control
Glide Direction Control

Possible to use sun-sensing along yaw axis during glide, with sensor pre-aimed to make model glide in a specific direction (not necessarily towards the sun, but throughout 360°). On a windy day, model could be adjusted to fly into the wind, so it would not land far downwind (if glide velocity exceeds wind velocity, model would land upwind). This is similar in principle to magnetically steered slope gliders flown by European model airplane enthusiasts, the model adjusted to glide in a particular direction into the wind (hoping there will be no shift in wind direction). It may be possible to do this without a servo, using a very small pulse type magnetic actuator or nitinol wire for a lightweight system. Even so this would have very limited use, as the weight would not be practical for many gliders gliders (possibly C powered gliders, above that radio control becomes a viable option). For someone not into radio-control, this would be more attractive.

Sun-reference combined with more advanced guidance

The sensing methods used in our project may find applications in more advanced forms of guidance projects. It may be possible to replace one or two gyro control axes with sun-reference control. An ideal combination may to be use gyro roll control with sun-referencing pitch and yaw, for flight paths which may be in any desired direction regardless of sun position. It could be possible to make pre-programmed flight course changes.

Notes on Two-servo Circuit Board with sensitivity module

This circuit board configuration was designed for Radio Shack Experimenter's IC Perfboard #276-150, which includes 2 bus strips. Board is 2.83" long, width was trimmed and component layout designed to fit inside a BT-60.

Power- 4.8V Nicad battery pack with switch is connected to the bus strips of the circuit board. This provides power for the sensors, servo circuit, and servos themselves.

Sensor connection - Uses 3-wire cable and a 3-conductor connector for each sensor

Sensitivity module - Consists of a DIP component carrier, which plugs into an IC socket. The module has four sensitivity limiting resistors soldered to it, resistors R1 through R4. The value range will depend on photocell response and desired sensitivity for given lighting conditions (such as bright sun, hazy sun, obscured sun, near-overcast, and deep overcast). Several modules should be made up, each with a different resistor value set (more resistance for less sensitivity, less resistance for increased sensitivity). For the test flights resistor modules using 1k, 470Ω, 220Ω, and 100Ω were made up. For maximum sensitivity, another module was made up with jumper wires soldered in place, so the photocell voltage would not be limited at all.

555 Timer IC - This timer produces the clock pulse which is fanned out to both of the timers in the 556 IC. Output from pin 3 of this timer triggers pins 6 and 8 of the 556 timer.

556 Dual Timer IC - One timer develops the servo pulse width for servo 1, the other timer the pulse width for timer 2. The voltage output from the sensor 1 voltage tap goes to pin 3, the voltage output from sensor 2 goes to pin 11 (these are the voltage control pins for each timer in the 556). The servo pulse width may be adjusted by using trimpots R9 or R10 for their respective servos, to make centering adjustments (to center the control surfaces when the sensor is pointed towards the sun). The pulse signal output from each timer is connected to the signal wire of each servo. The positive and negative servo wires are connected to the respective bus strips.

Circuit board parts list (nearly all available from Radio Shack)

Resistors (1/4-1/8 watt preferred)

R1, R2,R3,R4 - Values as required for sensitivity (see circuit notes above).

Exact values not important, close matching is important

R5 - 270,000 Ω

R6, R9, R10 - 10,000 Ω

R7, R8 - 10,000 Ω horizontal mount trim potentiometers (1/8W)

Capacitors (Avoid ceramic capacitors, they may break)

C1, C2, C3, C4 - 0.1μF (0.1 micro Farads)

Semiconductors

555 Timer IC

556 Dual Timer IC

Other components

Circuit board - Radio Shack #276-150 Experimenter's IC Perfboard

Switch - SPST for battery power

Battery - 4.8V nicad (four cells from a "9-volt" nicad battery to make a 4.8v, 70 mAh pack)

DIP Component Carrier- quantity as needed (8-pin, from 16-pin carrier cut in half)

IC Sockets- for DIP component carrier and timer IC's (two 8-pin, one 14-pin)

Connectors for sensors (optional)- two pair (non-polarized preferred)

Connectors for servo - two pair (type depends on servo brand)

Miscellaneous

3-wire cable to sensors and to servos, other hook-up wire, solder, etc.

Matching Photocells

Matching photocells for sensor pairs:

Below are the resistance values of 14 assorted photocells from Radio Shack. Each was placed behind .04" white styrene plastic, held 1" from a 60 watt light bulb, then 4 feet from dual 100 watt ceiling light bulb assembly. Of these, 8 were selected for 4 sensor pairs.

(All values in ohms).

Bright	Dim	Pair set
90	1850	B-1
73	1150	C-1
112	2250	A-1
90	1560	B-2
94	2500	
113	2200	A-2
112	2400	D-1
160	7850	
275	9100	
65	1000	C-2
70	1260	
82	2360	
86	2700	
132	2490	D-2

The chart on page 29 response to two different levels of light by 8 different photocells which were matched together into 4 pairs. Pair sets were A-1 and A-2, B-1 and B-2, and so on.

Note that the line chart is for comparison of the end values only (low resistance representing brighter light, higher resistance for dimmer light). Actual values at intermediate light levels might not be linear, but would likely be similarly close. Photocells which matched each other well in dim and bright light seemed to be similarly well matched at intermediate light values.

Photocell pairs B and C were used for the external collar type sensors as used on the Cineroc pitch/yaw guidance flights. Photocell pairs A and D were used for another pitch/yaw sensor set.

Resistance values of three photocells from BCD Electro, rated 20k dark, 25Ω light were plotted. Testing was done in a darkened room, with a 60 watt lamp as the only light source. Resistance readings were taken at 4" intervals for a distance of 36". Photocells were not masked off, as the masked photocells in sunlight had similar values as unmasked photocells exposed to a 60 watt lamp (resistance in the 75-300Ω range typically for masked photocells sensing in sunlight).

Of the above three photocells, only photocell 1 and 2 were suitably matched to act as a differential sensor pair. Photocell 3 could not be used with either photocell 1 or 2. Photocell 3 could only be used with another photocell with light response values similar to its own.

Unless noted otherwise, voltage tests were made in direct sunlight. Sensors were mounted to a Centuri Sky Trak for accurate angle readings. Input voltage was 5.04 volts, from a regulated source.

The graph shows the absolute change in voltage as a typical sensor was turned from left to right of the sun throughout a wide angle range. With an input voltage of 5.04 volts, the center voltage was 2.52 volts

The graphs below showing voltage changes to left or right light angles are made to show voltage change either above or below the centering voltage. Rather than produce a sine-wave type graph as above, the right side values have been made positive so that near-symmetrical response may be better evaluated. Because voltage controls the servo, this graph configuration also best shows the control surface deflection left or right (or up/down) in response to light angle. The graph above and graph below reflect the same set of data.

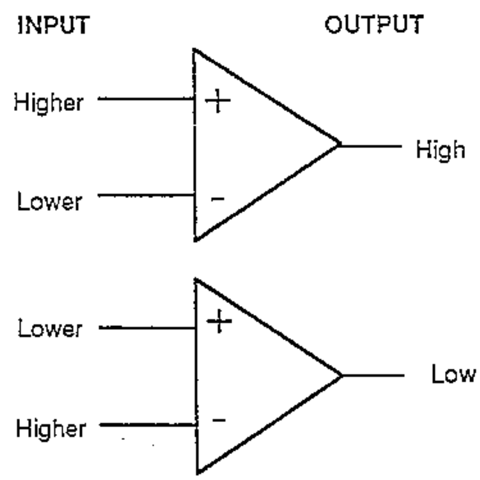
The graph indicates the voltage changes peak as light is more perpendicular to the model, then begins to drop with increased rearward angles. The voltage response beyond 165 degrees became quite erratic, as resistance with both photocells so relatively darkened would become uneven. The uneven response was partly due to uneven distribution of ambient light, and partly due to uneven resistance values of the two photocells with both relatively darkened. Any model using the sensor for guidance purposes would never get to such extreme angles during powered flight. Such angles would most likely not be reached until after apogee as the model pitched towards the ground. It is likely that the uneven voltage responses at rear angles of 165° or more would produce enough control surface deflection to cause the model to deviate from a vertical downward path, and eventually generate enough of non-vertical descent for the sun or sky light to cause further voltage changes. Thus the model would pull itself into a fast steep glide descent as seen on the staging failure crash and the very late ejection Cineroc flight.

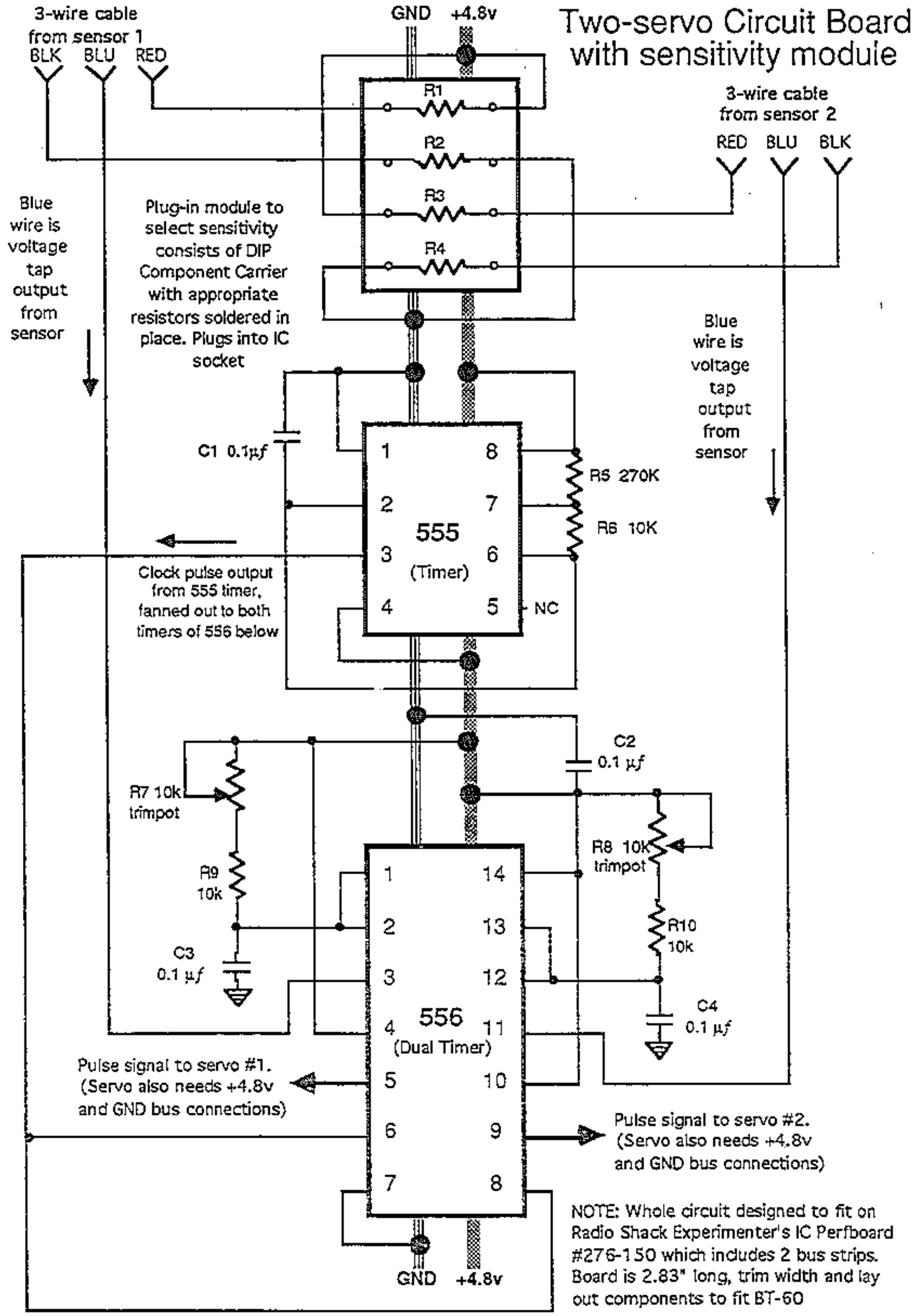
On the next page, typical sensor voltage response to light angles of ±45° is shown. Voltage changes rapidly at low light angles, then levels off as the photocells begin to reach their maximum differential in resistance. This is a desirable control voltage characteristic for flight control, the large changes in voltage near center

Short description of Op-Amps in comparator mode

Op-Amps without feedback resistors act as comparators, going high or low depending on the voltages applied to the two inputs. Comparators are sensitive to very small voltage differances.

Op-Amps have inverting (-) and non-inverting (+) inputs. If the voltage into the (+) input of a comparator op-amp has a higher voltage than the (-) input, the output is high. If the voltage into the (-) input is higher than the (+) input, the output is low.

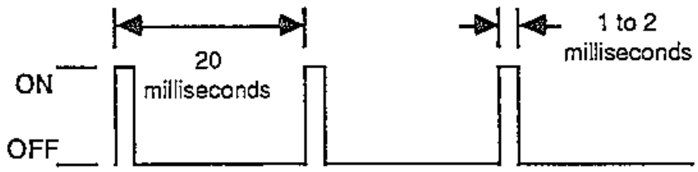



Two-servo Circuit Board
with sensitivity module
3-wire cable
from sensor 1
BLK BLU RED
GND +4.8v
3-wire cable
from sensor 2
RED BLU BLK
R1
R2
R3
R4
Blue
wire is
voltage
tap
output
from
sensor
Plug-in module to
select sensitivity
consists of DIP
Component Carrier
with appropriate
resistors soldered in
place. Plugs into IC
socket
C1 0.1µf
555
(Timer)
R5 270K
R6 10K
NC
Clock pulse output
from 555 timer,
fanned out to both
timers of 556 below
C2
0.1 µf
R7 10k
trimpot
R8 10K
trimpot
R9
10k
R10
10k
C3
0.1 µf
C4
0.1 µf
556
(Dual Timer)
Pulse signal to servo #1.
(Servo also needs +4.8v
and GND bus connections)
Pulse signal to servo #2.
(Servo also needs +4.8v
and GND bus connections)
GND +4.8v
NOTE: Whole circuit designed to fit on
Radio Shack Experimenter's IC Perfboard
#276-150 which includes 2 bus strips.
Board is 2.83" long, trim width and lay
out components to fit BT-60

Servo signal pulses (for positive pulse servos)

First timer develops clock pulse, which is constant. Output of timer can be fanned out to trigger other pulse width timers

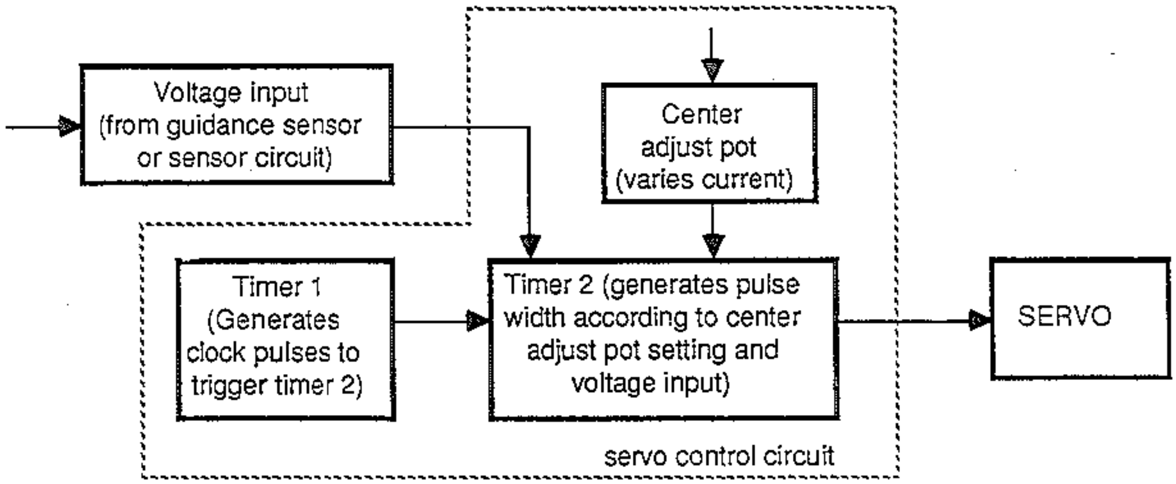
Second timer develops pulse width. The pulse width will vary depending on centering trimpot setting and voltage input from sensor.

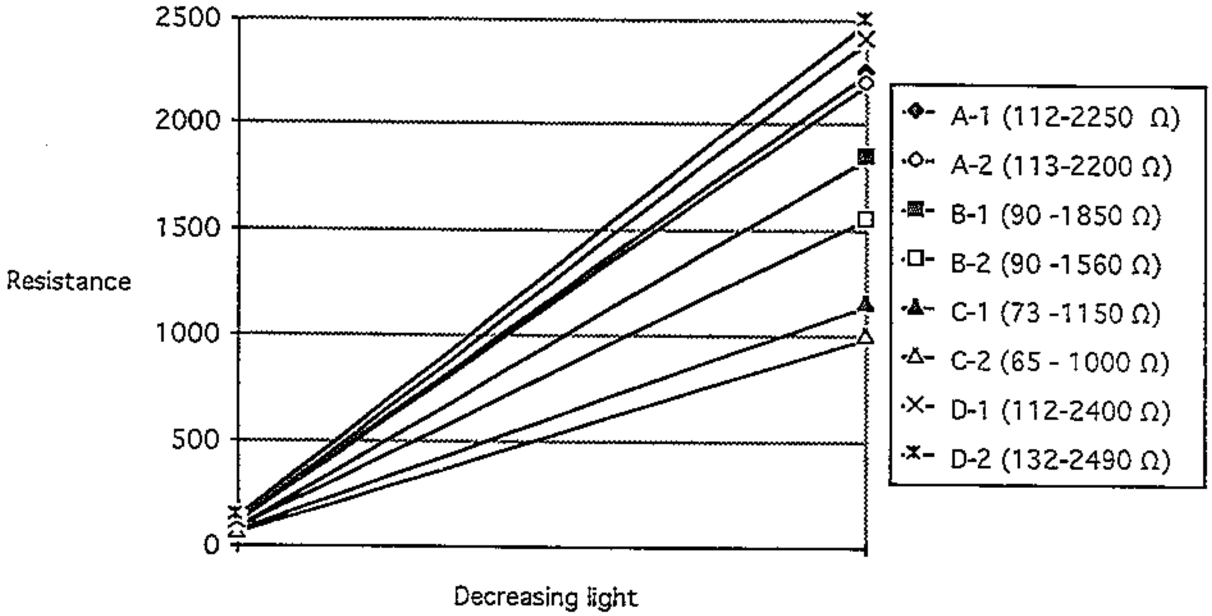


The width of the pulse determines the proportional response of the servo. A wider pulse makes the servo respond towards one direction, a shorter pulse makes the servo respond towards the other direction.

For most servos1.5 or 1.4 milliseconds centers a servo, with a ±.5 millisecond range for control

Basic servo control circuit block diagram



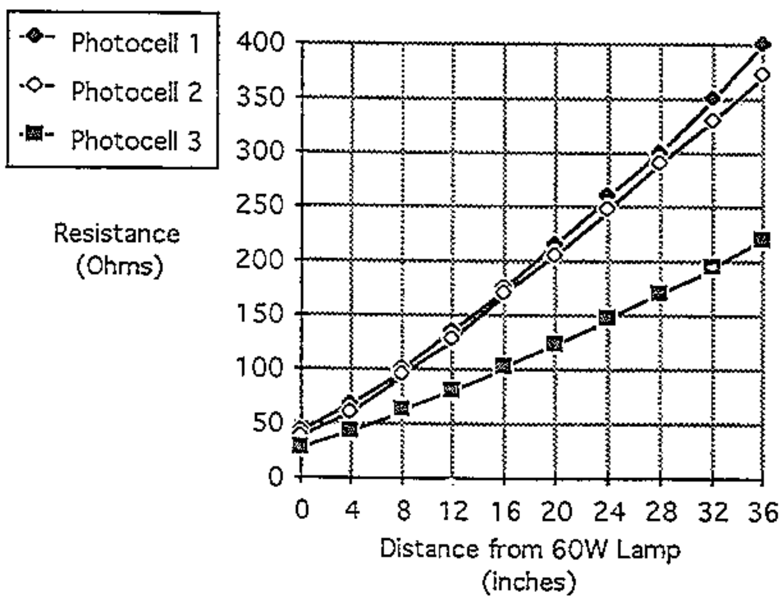


allow for the control surfaces to correct the model with a high degree of resolution. Depending on sensor configuration and sensitivity, the control surfaces could be deflected as much or more than the light angle itself at low angles near center.

The near-center voltage response characteristics may be varied for the same light angles, by changing the differential angle of the photocell sensor pair.

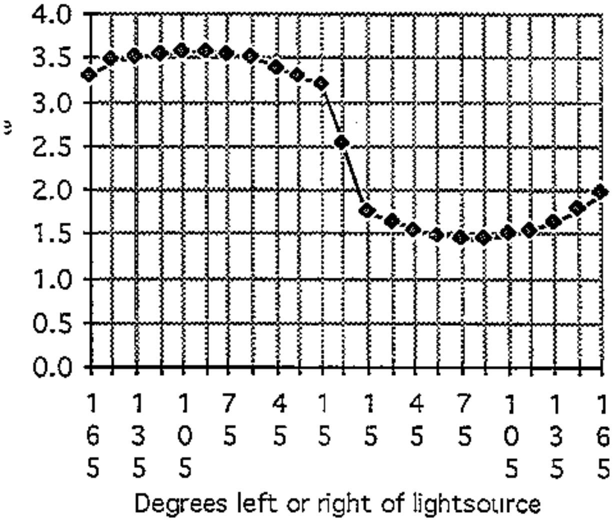
In the above test, the same photocell pair was mounted to triangular housings of 30, 60, and 90 degree nose angles. As expected, the sharper the nose angle, the higher the voltage response at low light angles. The sensor differential angle may be chosen to produce the desired level of control response for the model, and/or angle resolution accuracy. For sun-homing flight a steeper angle may be desirable for most models. A higher angle may not b : able to produce enough sensitivity for good pitch/yaw control on an overcast day.

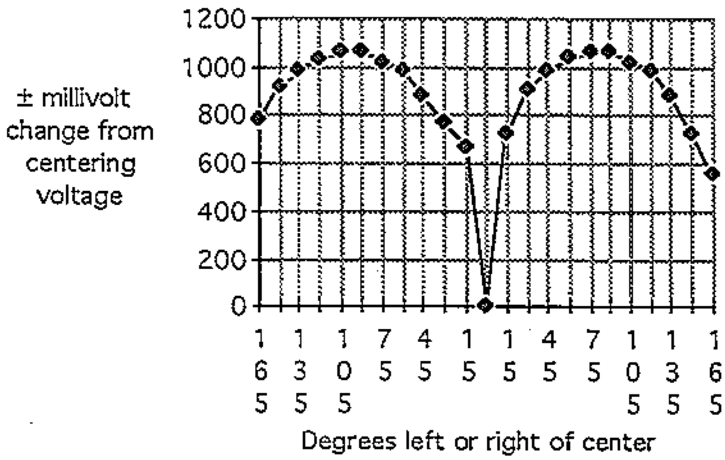
A sensor with a wider differential angle such as 90 degrees may be more suitable for roll control. A roll



control flight could be much more forgiving of a small angular resolution error.

(The tests of the 30, 60, and 90° differential angles required identical lighting over a relatively long period of time, so that outdoor testing in sunlight was not practical. The above graph was produced with data collected while testing indoors with a 60 watt lamp as the only light source. It is expected that sunlight testing would produce different graphs, but the comparison between the three should be similar. Observations of test model control surface movement when controlled by different angled sensors in sunlight showed similar motion response as indicated in the graph.).





Conclusions:

Sensing methods were developed which would work reliably to aim a model axis towards the sun or a bright light source. The Differential Photocell type sensor proved to be reliable, simple, and produce a proportional voltage to drive the servo.

Pitch only control combined with a constant roll was shown to be risky and in need of further development.

The model flight path was controlled by the guidance system when flown in a pitch and yaw configuration. The model was capable of correcting onto a straight path towards the sun, then hold that path until the model slowed too much for the control surfaces to be effective.

Roll control was shown to be possible. It does require particular flight constraints and proper control force set-up

The sensing method proved workable under overcast conditions for pitch and yaw guidance. However, roll control requires direct sunlight to work well.

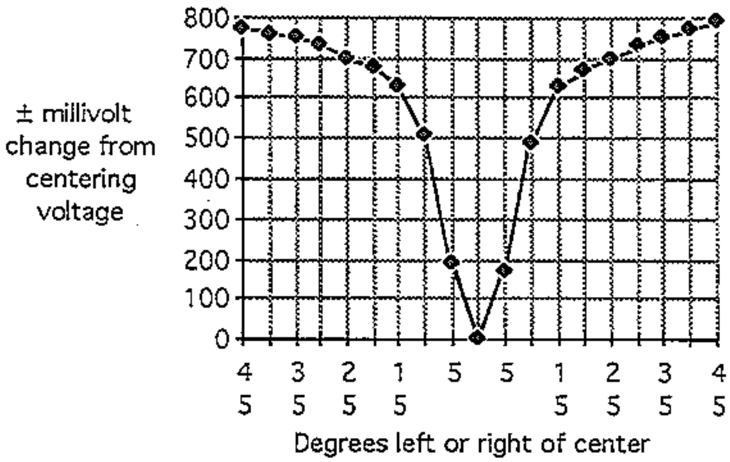
Model size could be quite reasonable, the pitch/yaw test unit could be shortened to fly in a Big Bertha sized model.

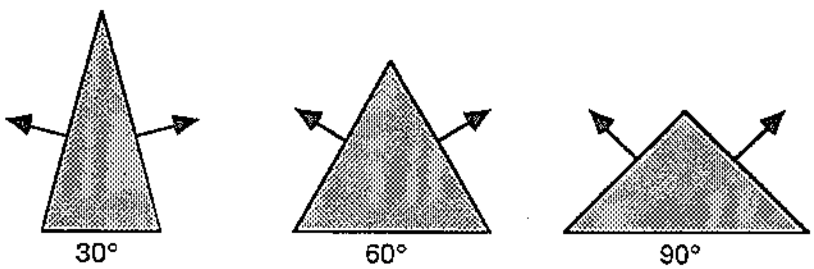
Mass was reasonable, 5 ounces for the pitch/yaw control unit could perhaps be reduced to 4 ounces. For roll only, the control unit mass could be cut to about 3.5 ounces. This is low enough to easily allow flights in model rockets weighing less than 16 ounces.

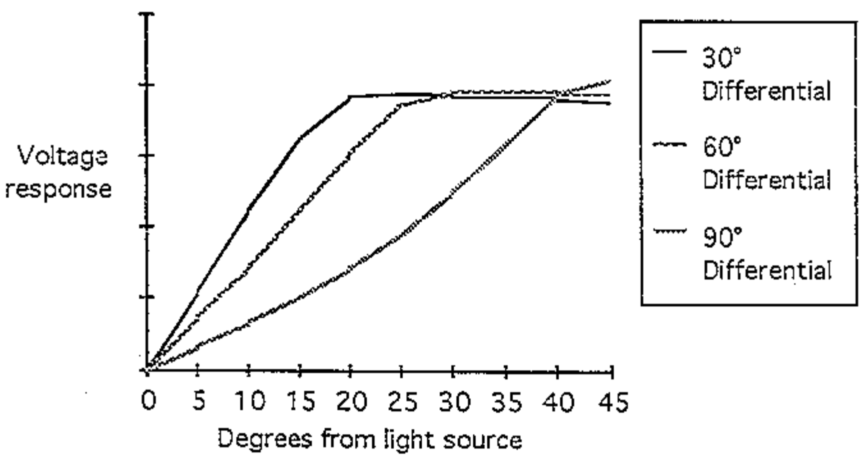
Pre-flight requirements are reasonable. The adjustment procedure takes 1-2 minutes.

Cost for a 2-axis control circuit board and sensors is approximately $12-25, depending on sources. A small 4.8v nicad battery pack about $7. Servos are the most expensive part of the system, Canon super micro servos cost $40 each. Some micro servos from other sources may cost as low as $15 each, at somewhat larger size and higher weight than Cannon super micro servos.

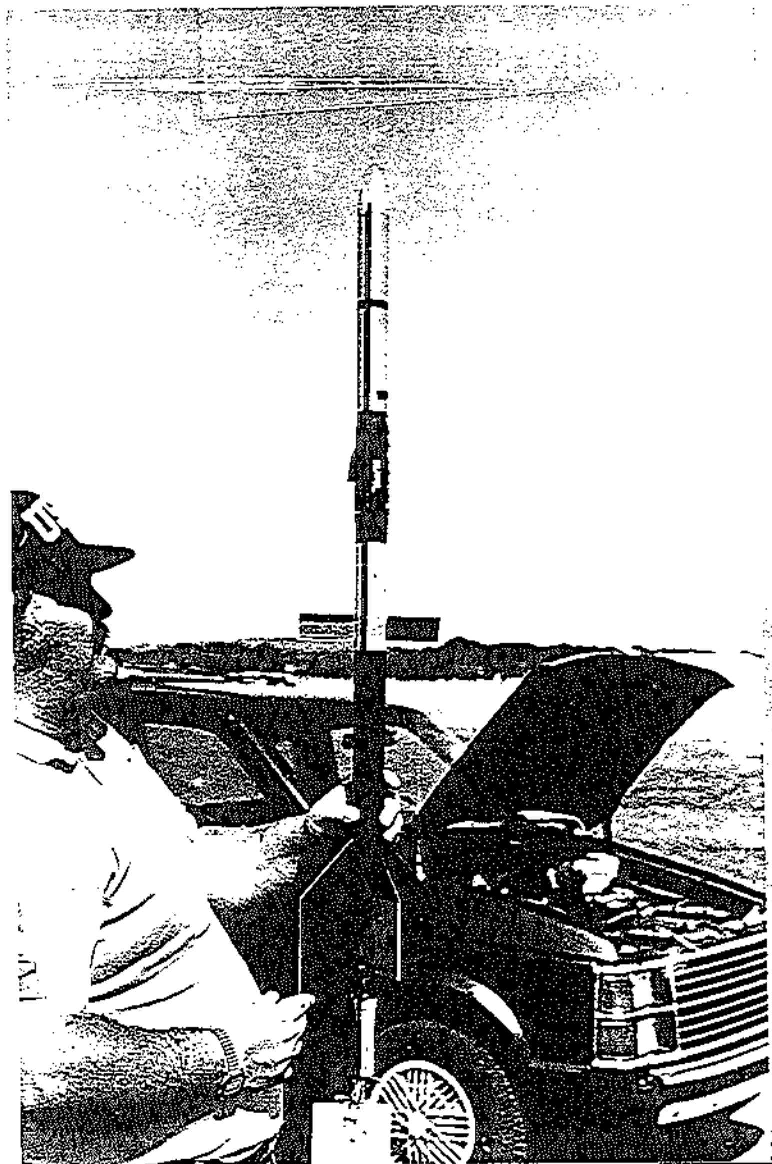
The overall system, for pitch/yaw or for roll, is reliable and simple enough for a wide range of people to build and fly. Some electronics experience is required, anyone who can build a simple electronics kit could build this.

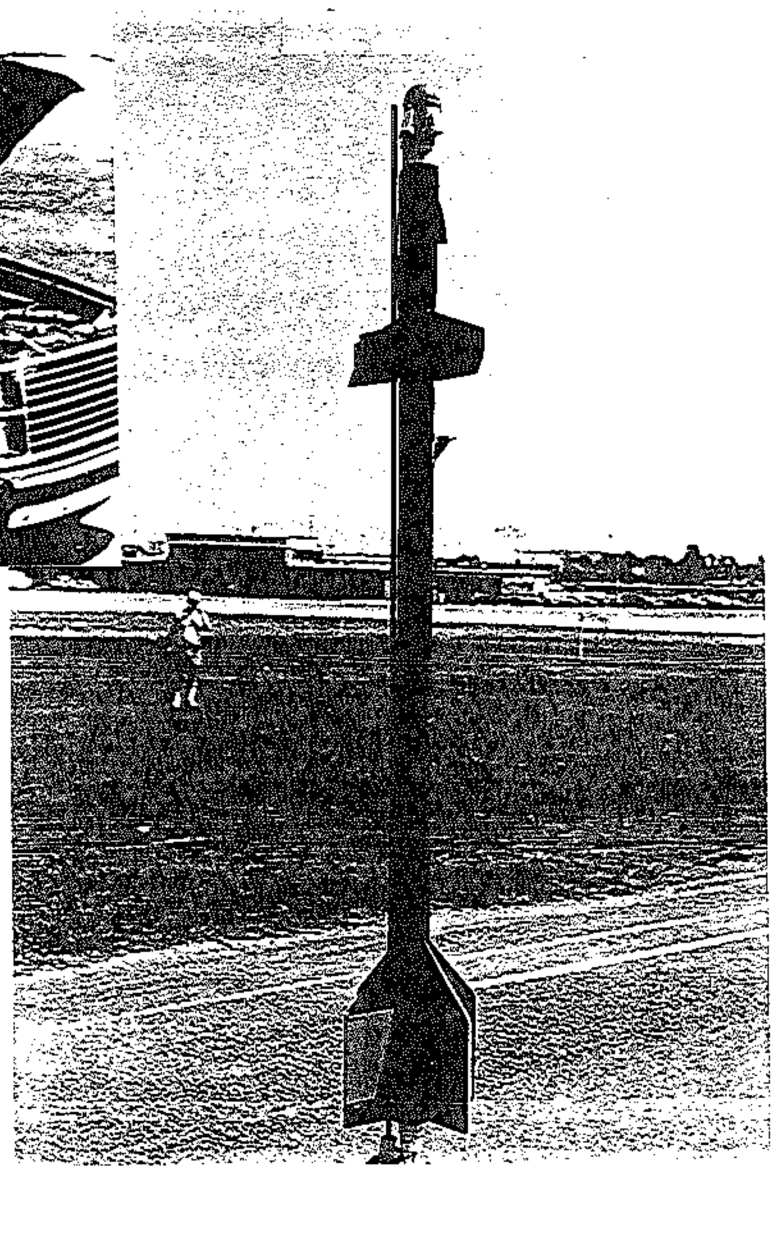

± millivolt change from centering voltage
800
700
600
500
400
300
200
100
0
45 35 25 15 5 5 15 25 35 45
Degrees left or right of center


30°
60°
90°


Voltage response
0 5 10 15 20 25 30 35 40 45
Degrees from light source
30° Differential
60° Differential
90° Differential

Left and Below:
Two different versions of the Sun Seeker test vehicle, complete with Cineroc for on board data acquisition. Note the forward fins on both models. The version at left is the "roll control" version; below is the full up "pitch-yaw" version.



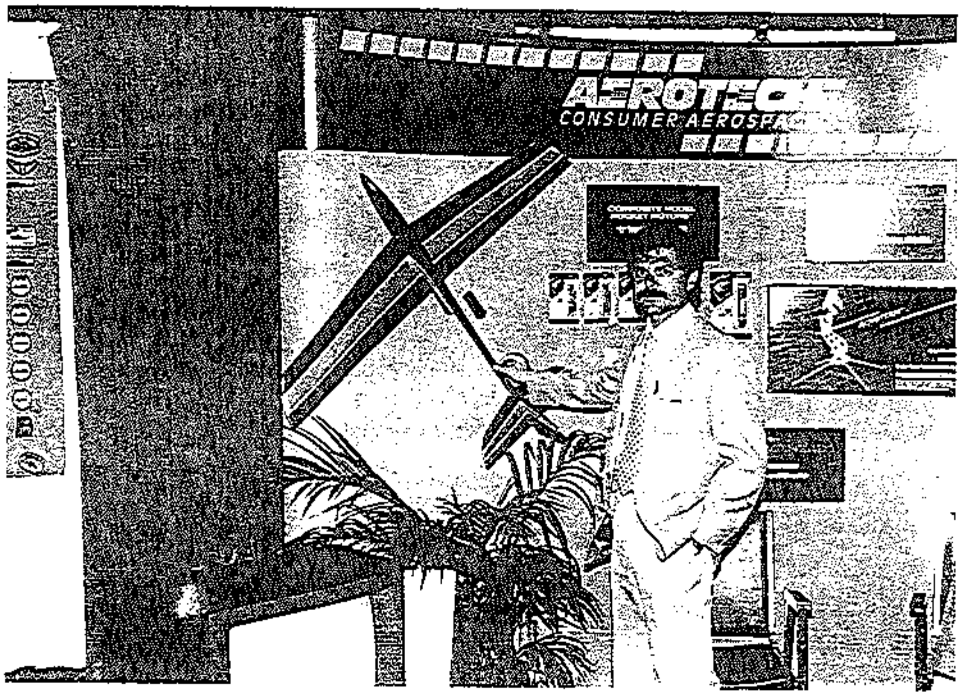


Missing in Action?

These items were shown at the Chicago Model Show (RCHTA) in November of 1990, but have yet to appear on store shelves.

Top: Gary Rosenfield poses with the Phoenix RC rocket glider. This bird uses two channel radio control to allow the pilot to fly both boost and glide. The design is by Bob Parks.

Bottom: Matt Steele and Chris Pearson pose with Mary Roberts and a 1/45th scale Saturn 1B. The model was built around the old Centuri Little Joe II kit, and had a motor mount for 24mm motors. It was very light...probably less than 2 pounds!



TRUE FACTS ABOUT NARAM-32

by Chris Pearson

• Number of items on the menu of "Le Mesquite" Mexican Restaurant at the Days Inn where NARAM-32 participants stayed: 79

• Minimum number of items that they were out of at any one time: 32

• Average time it took to get an order: 47 minutes

• Average number of times that NARAM 32 Contest Director Scott Hunsicker lost his temper in one day on the range: 7.2

• Number of NARAM 32 participants that could have done a better job than Scott: any of them

• Definition of "SNAP": Scott Needs A Personality

• Number of "fire ant" bites taken on the flying field: billions and billions

• Number of people who want Scott to host another NARAM: 0

• Average outdoor temperature: 92 degrees F.

• Average indoor temperature: 85°F (except in Chas Russell's room, when his girlfriend Mary was visiting, where it was 105°F!)

• Number of cowboy hats in the hotel bar during any one night: 27

• Number of rock songs on the bars jukebox: 0

• Cost of a can of beer at the bar: $2.00

• Closing time of all the beverage stores in Dallas on Friday night: 9:00PM

• Number of beers the average NAR Trustee consumes at NARAM: 23 (five day week)

• Time in hours it took to have your room cleaned: 3.5

• Average number of stains on the rug and furniture in each motel room: 29

• Maximum number of English words that any one member of the motel staff spoke: 12

• Area in square meters that a particular NAR member's head would cover after having two pounds of TNT shoved down his throat and detonated while forcing the NAR Board of Trustees to sing: 5.9

• Average rainfall in Dallas in August in inches: 7

• Rainfall during the first three days of NARAM in inches: 8

• Average NARAM 32 bedtime: 3:15AM

• Number of people who made it to the flying field for range opening each day: 2

• Time the manufacturer's party ended on Friday night: 5:00AM

• Actual sign seen on NARAM 32 Range Store and Office: "Please go away!"

• Number of good looking babes at "Wet and Wild": too many to count!

• Skin temperature (in degrees Kelvin) reached by former NAR Trustee turned astronaut, Jay Apt, during reentry into Earths atmosphere after forcible ejection from the Space Shuttle Atlantis: 1200

• Skin temperature (in degrees Kelvin) of any NARAM participant with severe sunburn: 1300

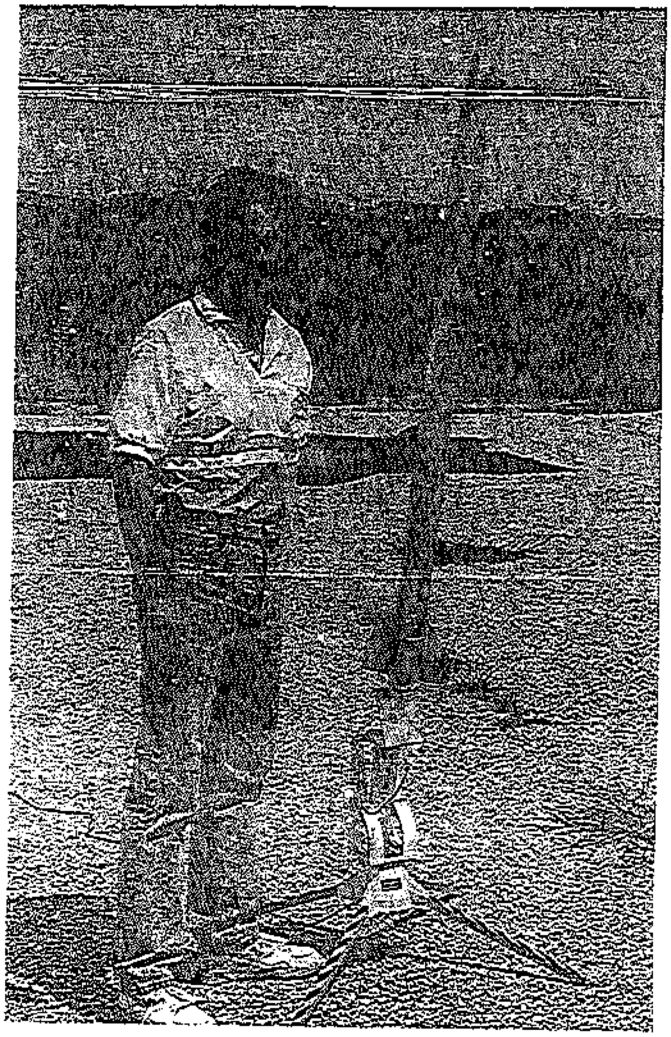
• Number of topless bars within a five minute drive from the Days Inn: 5

• Number of memberships were required to purchase drinks: 1 per location! What a concept!

• Number of minutes waited in an Olive Garden for seating before walking out: 75

• Number of contestants who want to return to Dallas within the next century: 0

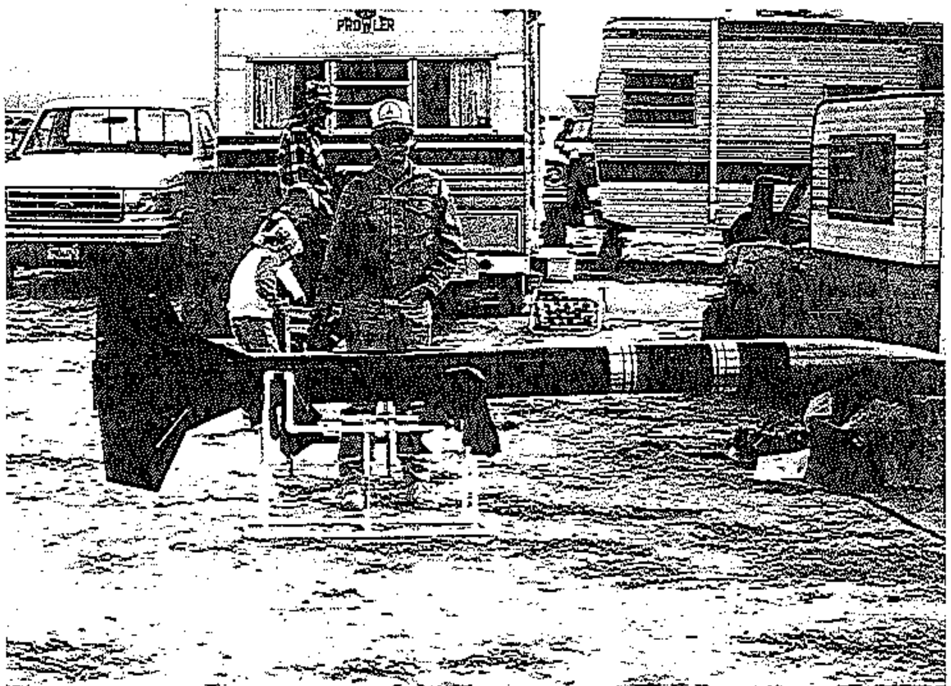
• Number of JR Ewing sightings: 6

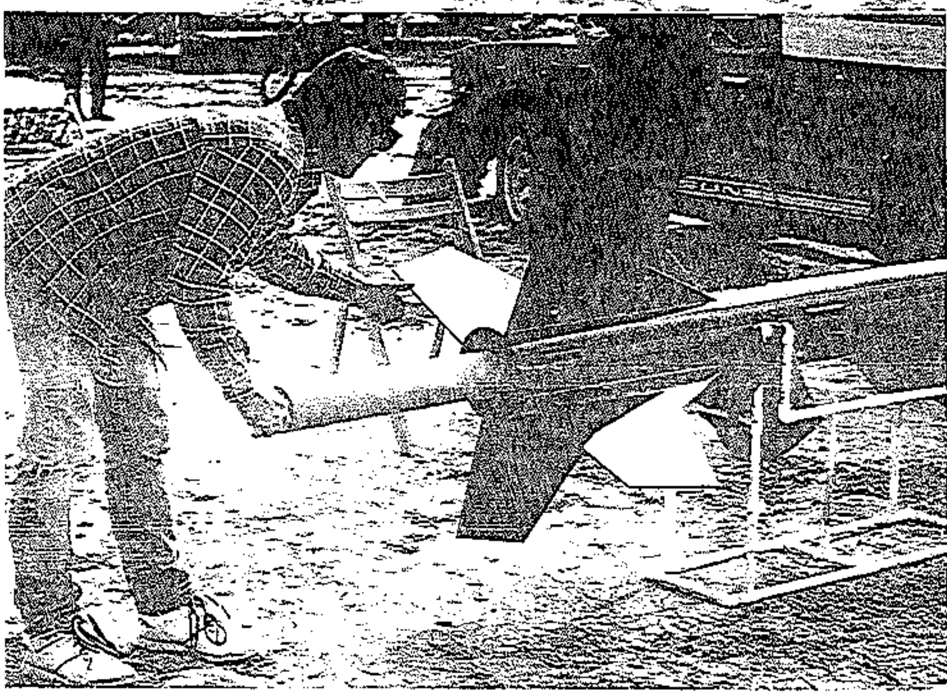


Above Left: Gary Rosenfield demonstrated the new reloadable technology at NARAM-32.
Above right: Chris Johnston was actually sighted at NARAM-32! He is shown here being accosted by Dan Kafun.
Below: The Rocket City Aces were national champions, incldung Matt, and George. and Chas

Winterfest '91

Lucernce, CA February, 1991

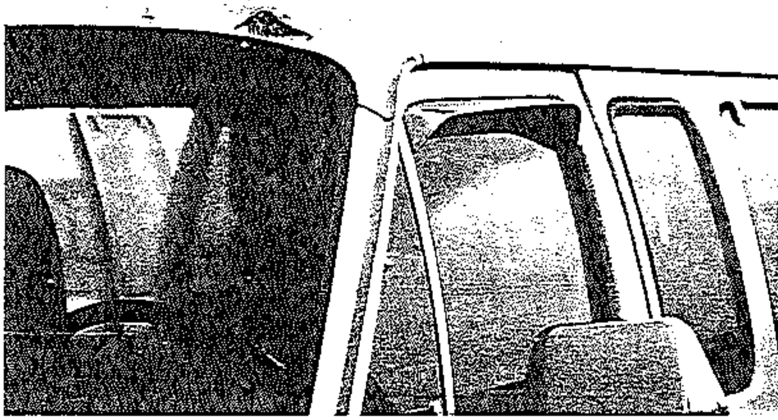


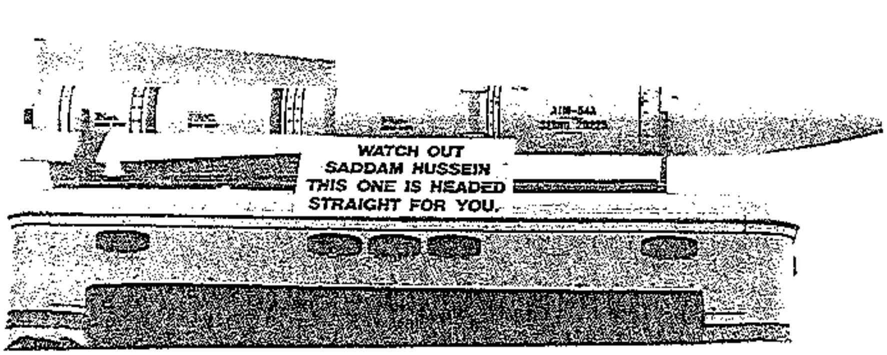


Top: One of the best birds at the event was California Consumer Aeronautics' EXCALIBUR. Constructed from 8" tubing, it was immaculately finished. Mark Atkinson looks on.

Center: The L size motor is installed.

Bottom: The parachutes failed to eject, making the model much shorter.





Top Left: A large two stage model failed to deploy a parachute on the first stage, hitting this van. It caused a sizeable dent, mostly from the batteries in the electronic staging unit. Tumble recovery on a big rockets is a no-no!

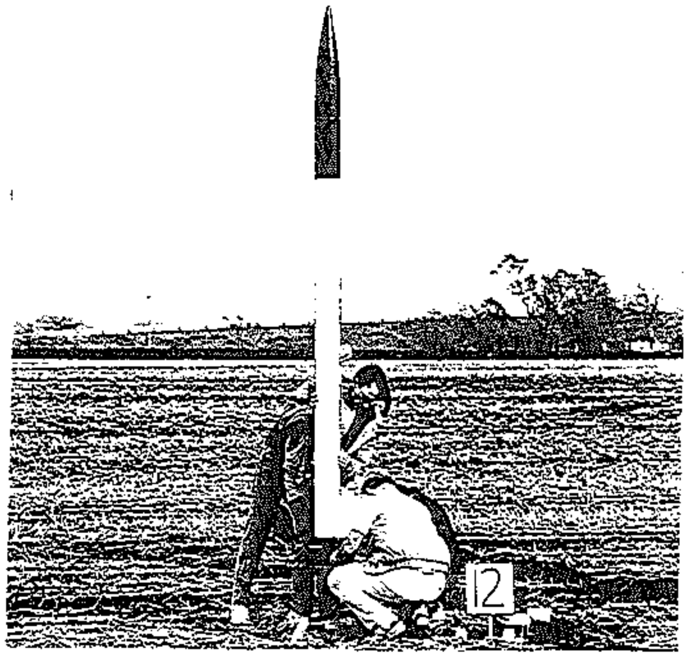
Top Right: Everyone's favorite rocketeer was busy selling motors. Reliability of the motorshe sold left much to be desired. But, there's one born every day!

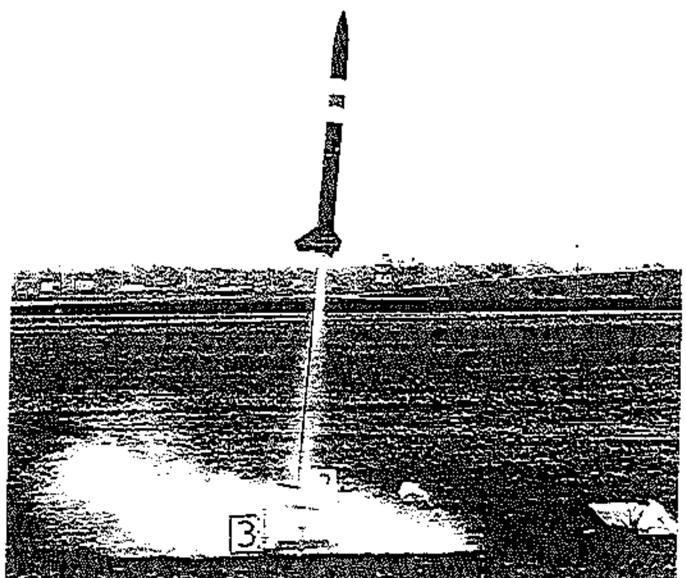
Center: The principals in the accident discuss the situation with Chuck Rogers.

Bottom: CCA also had a message for Saddam. This was also 8" in diameter!

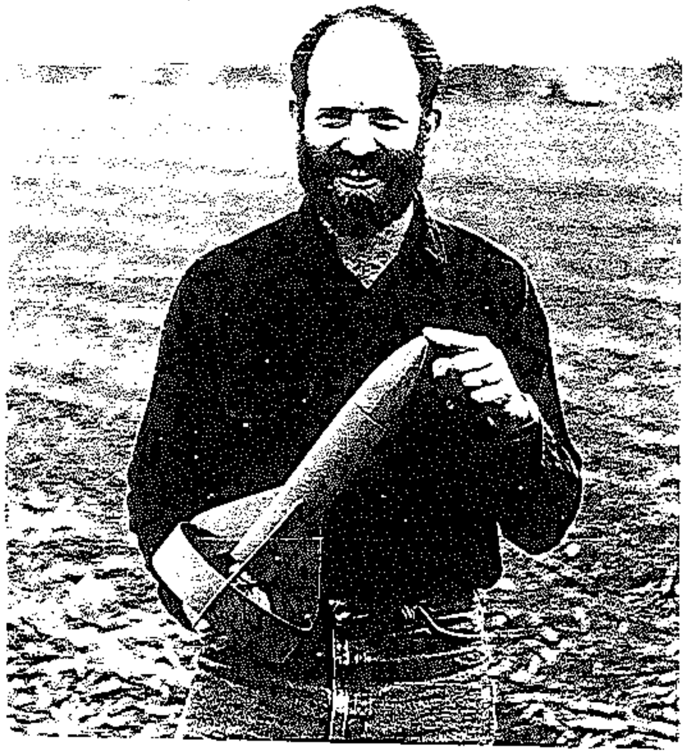
DANVILLE DARE V

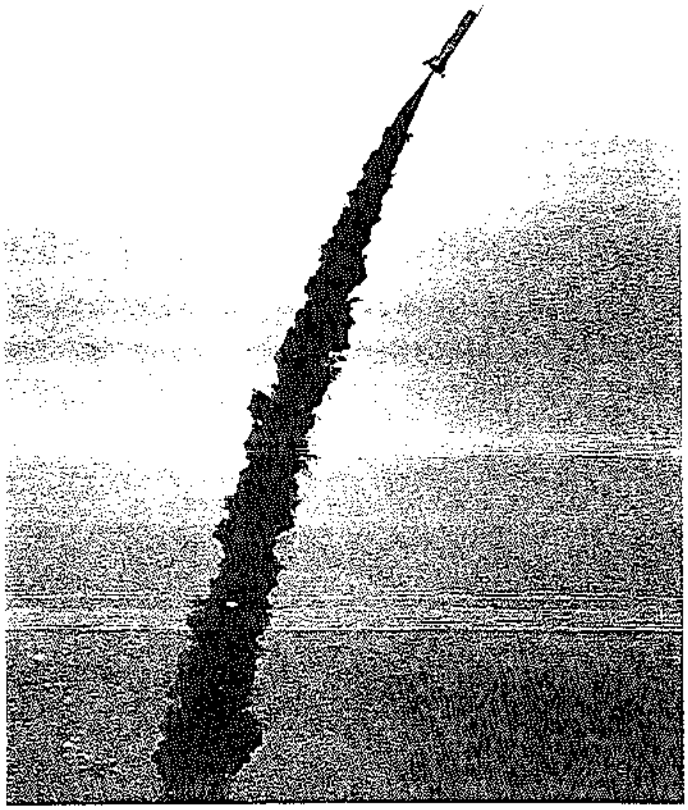
Danville, IL April 1991

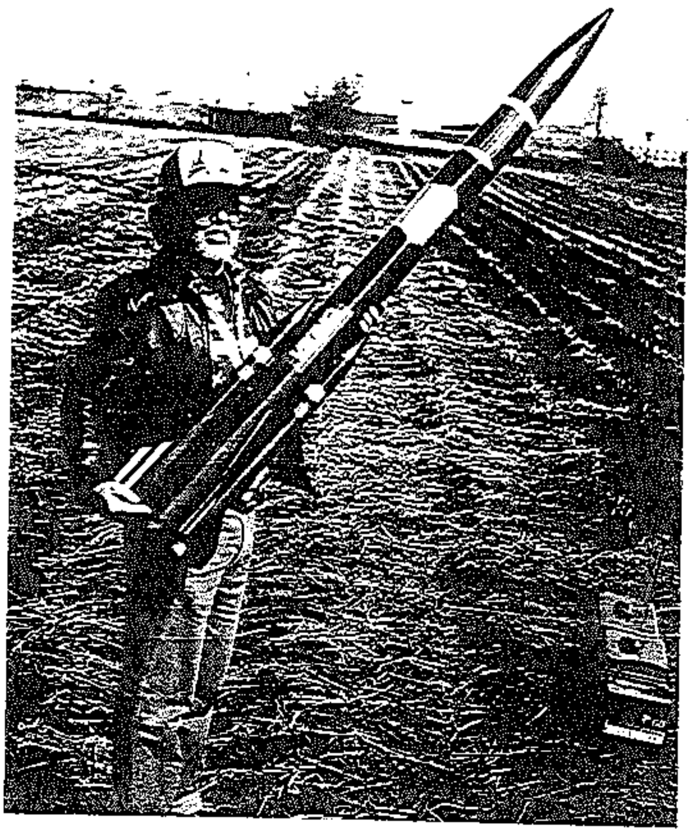




Top Left: Matt and Chris show off the NCR ASAT-21X.
Top Right: The Arcon (featured on the cover) is prepped for launch.
Bottom Left: Liftoff of a Magnum with a Hellfire K500 motor.
Bottom Right: Paul Ste. Marie had a beautiful paint job on this custom design.

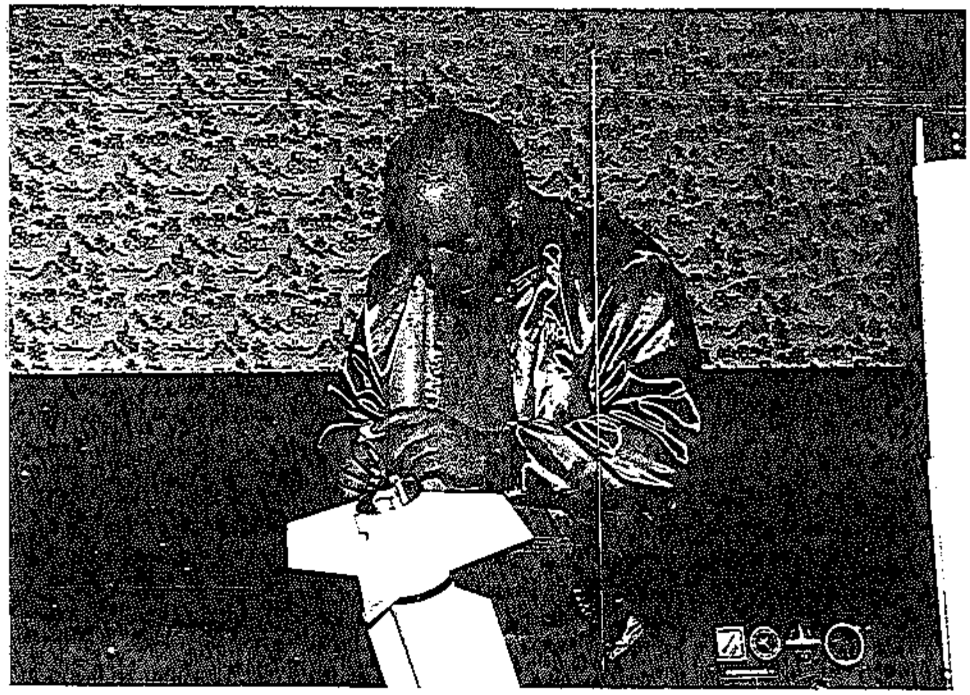


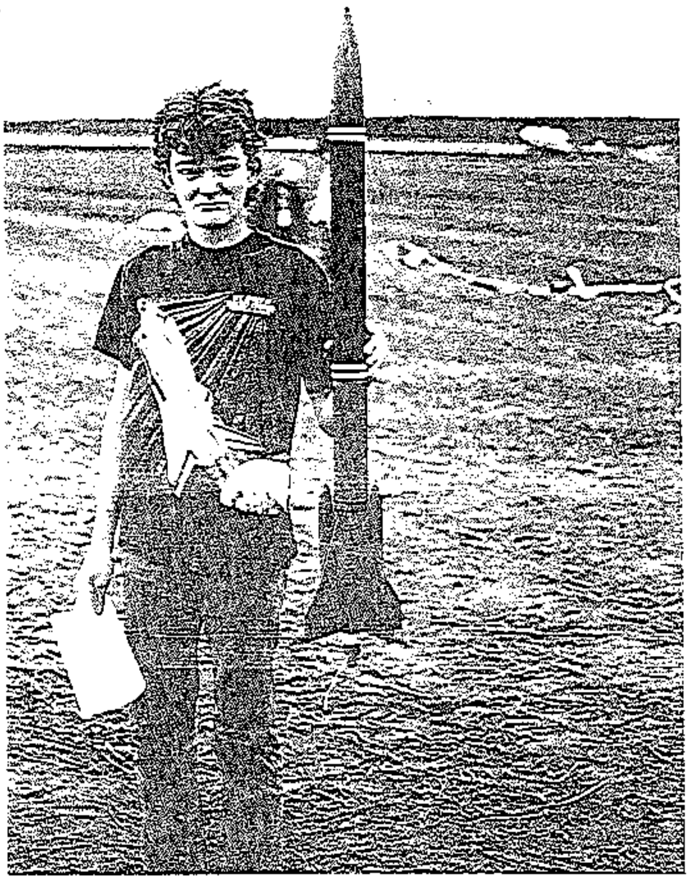


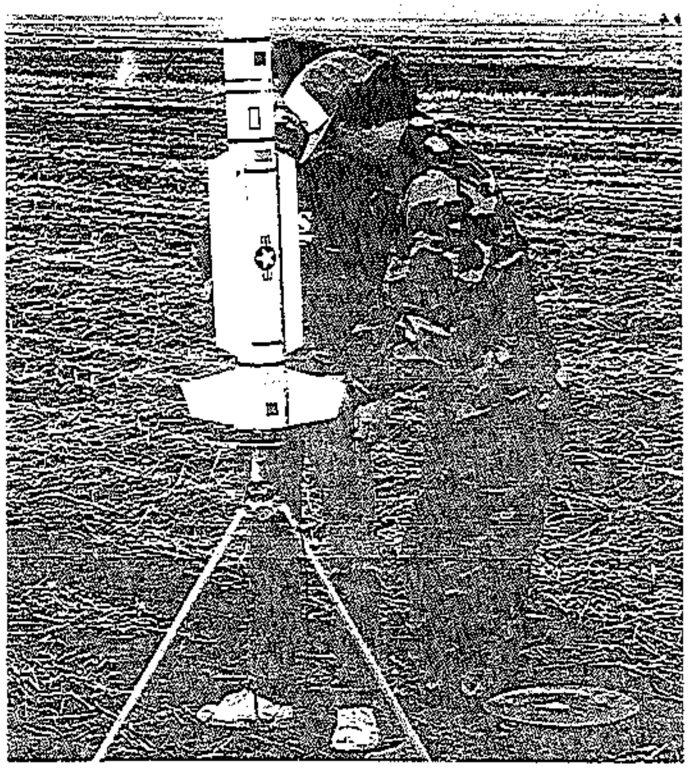


Top Left: Matt with the new NCR Patriot.
Top Right: Bob Kaplow showed up with a Sprite on steriods!
Bottom Left: Liftoff of a Smoky Sam.
Bottom Right: Jack Long with an NCR Viking. Power was by an H reloadable and two F7-4s.

Top : Chris shows the damage on the Viking when one F7 exploded!
Center: Randy Gilbert sold quite a few Blue Maxes. This is a well engineered kit that's worth a second look.
Bottom: Chris takes time to help a younger modeler.







Top: Matt preps an Archer with a G40 and two D12's.
Bottom Left: Joe Randolph had an H powered Viking II. It screamed!
Bottom Right: Gary Rosenfield assists Chris in prepping the Archer.

The LAC Newsletter Award

by Matt Steele

Every year, the Leader Administrative Council (LAC) awards the Rockwell Trophy at NARAM to the best NAR section newletter. The winning editor gets to keep the trophy for a year before turning it over to the next winner. This is also the NAR's oldest trophy, having been first awarded in 1969. With such a long lifespan, the trophy has enjoyed a rich legacy.

Competition for the trophy is intense every year and some rivalries have evolved over the past years. One of the greatest was between the *Spotter* (published by Doug Kushneric and Thor) and *Zog 43* (published by NARAMS). During the 1974-1977 time frame, these two sections battled it.

Another battle was between the *NOVAAR Free Press* and *SNOAR News* during the 1979-1982 time frame.

The winners of the award have had vastly different styles. *View from Zenith* combined a mix of cartoons, plans and basic articles with a ditto format to come up a winner. Multiple award winner, *NOVAAR Free Press* featured up-to-the-minute news, expansive contest coverage and numerous photos to take home the award. The *Spotter* and *SNOAR News* often took a humorous look at the hobby; the *Leading Edge*, the *Cosmic Stepping Stone* and *NFP* were quite serious in tone. The *WARP Launch Window* was oriented toward the WARP club; *SNOAR News* often dealt with subjects on the national level. No one formula or blue print dictates who will win the N/L award. The only sure way of winning is to have a good newsletter.

There is also the supposed "Curse of the LAC Trophy". For some strange reason, after winning the award, newsletters either drop in quality or fold altogether. For example, *View From Zenith, Cosmic Stepping Stone,*and *WARP Launch Window* all quit publishing shortly after winning the award. The *Spotter, WVP* and *Zog 43* all left the scene after winning their last trophy. Only the *Leading Edge*, and *SNOAR News* have beaten the "Rockwell Jinx". Popular theory has it that clubs and editors put considerable time and effort into winning the newsletter award, then burnout after taking the trophy. Others insist that the contents of the trophy are cursed in such a way that anyone who views them loses all interest in publishing a newsletter. Whatever the cause, it is one of the unfortunate myths surrounding the Rockwell Trophy.

Why is there such an intense interest in winning the trophy? Well, for one, to win the trophy is to become part of the legacy. The Rockwell trophy is huge with plenty of storage space. As a result, there is plenty of room to hide items inside of it. Over time, tradition has developed that the winning editorial staff gets to contribute memorabilia to the trophy.

Of course, it is also traditional that no one reveals the contents of the trophy to anyone who is not involved. As a result, a sort of mystique surrounds the winning of the trophy. Half the fun of winning is seeing what is inside and the other half is to decide what to place inside. And what is inside? Well, tradition states that the contents cannot be revealed, but it is possible to confirm the rumor that there is indeed an MMI Rock-a-chute motor as part of the trophy's prize collection. The only way to win the LAC newsletter trophy to see all of what is inside is to win it!

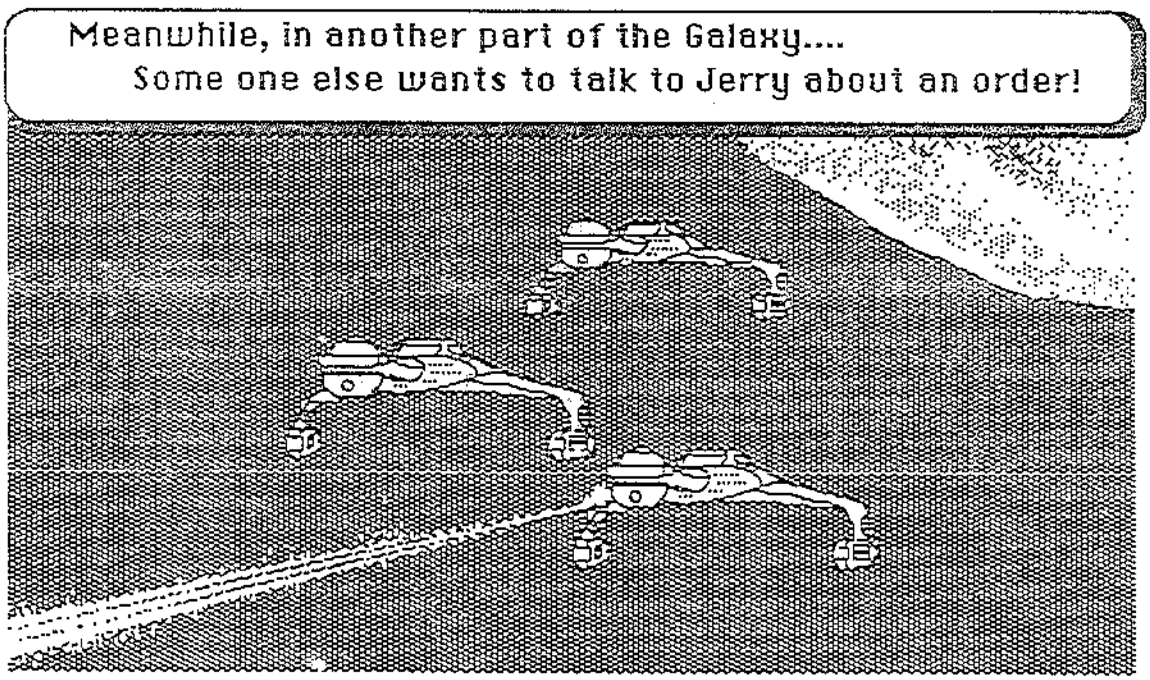
LAC Newsletter Award Winners

1969	ZOG 43	NARHAMS
1970	CON-TRAILS	Three Rivers
1971	The MODROC Flyer	South Seattle Rocket Society
1972	NOVAAR Free Press	NOVAAR
1973	ZOG 43	NARHAMS
1974	The Spotter	THOR
1975	ZOG 43	NARHAMS
1876	The Spotter	THOR
1977	NOVAAR Free Press	NOVAAR
1978	NOVAAR Free Press	NOVAAR
1979	View from Zenith	Zenith
1980	SNOAR News	SNOAR
1981	Tarheel Rocketeer	Carolina Rocket Society
1982	Leading Edge	NIRA
1983	WARP Launch Window	WARP
1984	Leading Edge	NIRA
1985	SNOAR News	SNOAR

1986	The Launch Rack	GSSS
1987	T-5	HUVARS
1988	Ascent From Midgard	Vikings
1989	Star Date	ASTRE
1990	ZOG 43	NARHAMS

Multiple Winners

ZOG 43	4
NOVAAR Free Press:	3
Spotter	2
Leading Edge	2
SNOAR News	2



Do you like all your fingers and thumbs?

Making Your Own Rocket Motors

Provided by C. D. Tavares
By Jim Flis

This question was recently asked on Compuserve's Model Net:

"I once heard of a corporation in Sunnymead Ca that was publishing a book called "Building Your own Rocket Motors" that was a comprehesive real book (none of this MATCH HEAD mumbo jumbo) that claimed that with chemicals from a fertilizer store and a rock tumbler you could make G-100 motors. I would very much like to know if anyone here had/has one of these books, and what the quality is?"

This book last came up here a month ago. I guess it will be a regular question. I can't think of a better response than what Jim Flis posted back then.
Here it is:

Lord, I don't flame often, but this can't wait. I don't know what others experiences are, but I know my own. I used to do this. I don't anymore.

Let me bend your ear for a moment with a story...

Many years ago I loaded my own motors. I used a black powder mixture and I packed it into a cardboard casing, not unlike those used by model rocket motor manufacturers. I had clay nozzles and all. I packed the powder with a metallic rod and a mallet. I had made hundreds of these things, with no problem. Then one blew up...

It blasted a 6" deep by 24" wide hole in a solid concrete floor and threw me part way through a sheet rock wall. The mallet was shattered and the rod went God only knows where. I had mutiple facial burns and lacerations, a long scratch along my temple and I was blind in my left eye. It was determined that I had burned the lens of my left eye and the impact of the blast deformed that eye. It was not known (at that time) how I got the deep scratch by my temple. After cleaning up the basement we found the rod behind a book case, covered with hair, blood and skin...

My reminder of this incident is my vision. I *was* nearsighted. I am now nearsighted in one eye and farsighted in the other. The injury has resulted in a steady deterioration of my vision. I am currently leagaly blind and require a new eyeglass prescription every 24 months or so.

I don't know if you would do it any differently than I. I don't care. I do know that if you are acting as an individual, at home, then you are NOT equiped to even ATTEMPT this. If you get a chance, check out how Estes does it and you will see the type of precautions the folks who know what they are doing take. It is impressive and yet even they have had accidents (they also have safety measures to reduce the impact of these potential accidents).

I don't know how else to say it. Don't do it. Stop anyone you see doing it. You CANNOT do it as cheaply, efficiantly or safely as a professional. You will not win the admiration of your peers and, needless to say, you would not be able to launch them publicly. Such motors constitute fireworks, they are NOT model rocket motors and they are against the law.

Add to that this tid-bit: Given enough time, you will either kill or maim yourself or a loved one.

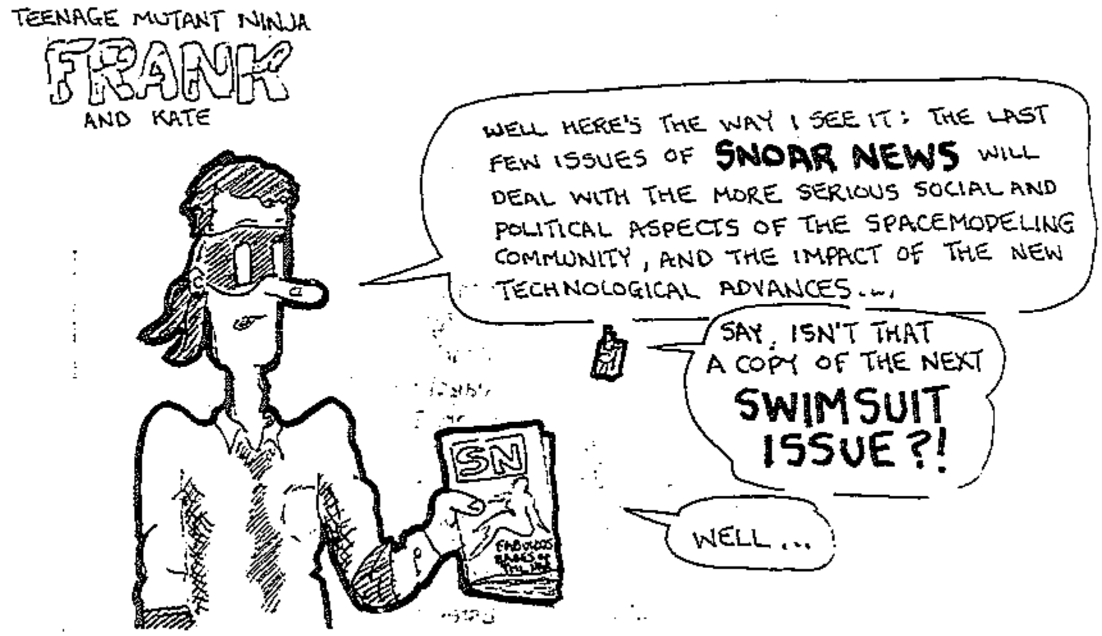
ok, ok, I'll get off my soap box...
Sorry for the down note,

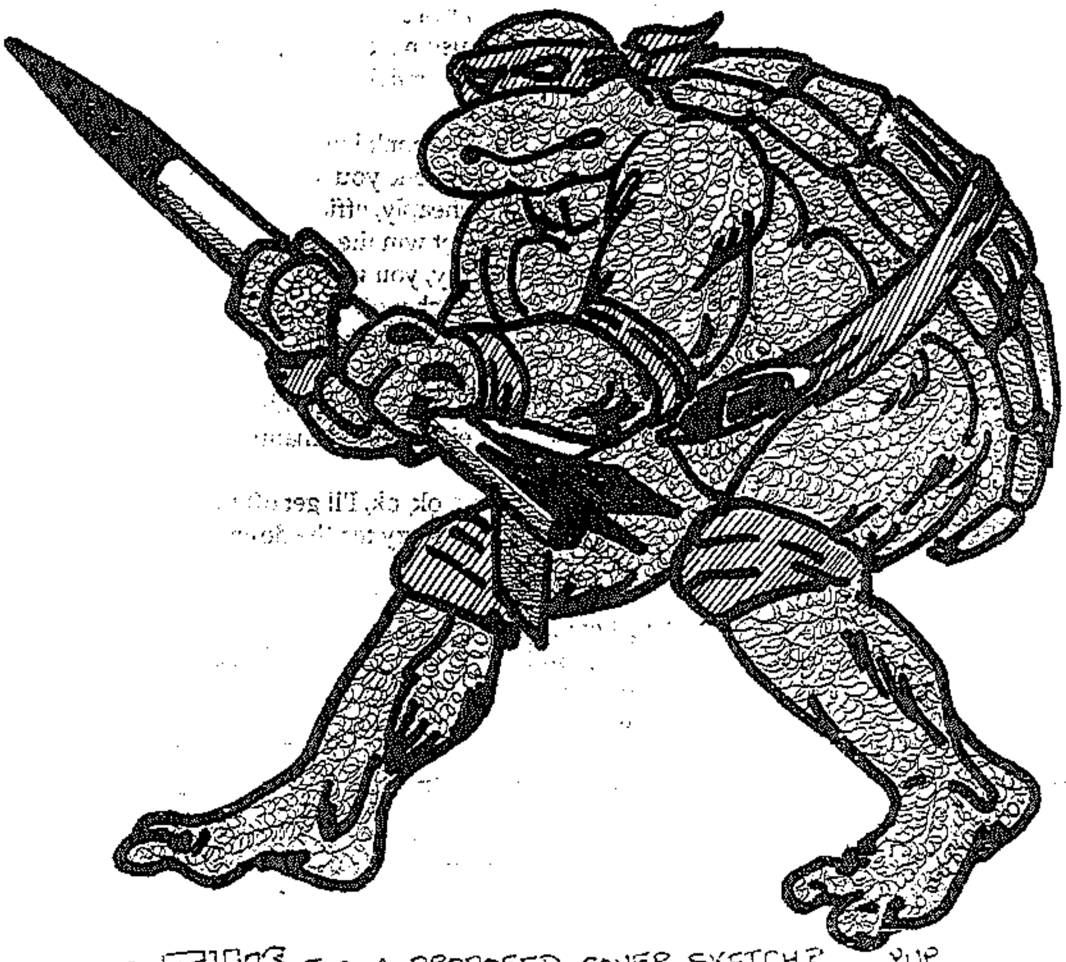
Jim

Editor's Note:
With the advent of reloadable motors, the temptation to make your own grains will loom large for some people. Don't do it. Propellants are by nature dangerous. If you do not have the proper equipment, you, too, might end up like Jim.

Humor

by Mr. Maddog





HOWZ 'BOUT THIS FOR A PROPOSED COVER SKETCH? YUP, TEENAGE MUTANT NINJA TURTLES INVADE THE WORLD OF SPACE MODELING ROCKETS ON A HALF SHELL ... WHAT A CONCEPT!

BULL SHEET

We have been able to confirm that Estes is seriously developing composite motor manufacturing capability. According to our sources, the time frame for introduction is not clear, but considerable effort has been devoted to date.

In other Estes news, there has been a management shakeup, with a new General Manager now in place. Supposedly an executive with Hasbro, he took the job in Penrose sight unseen (did he know what he was getting into?). The shakeup seems to be oriented towards keeping Estes in a financially healthy position.

The Aerotech Astrobee D introduction has been pushed back until late this year. Aerotech has been concentrating their efforts on the new reloadable motors and the Phoenix rocket glider instead.

Initial assessment of the Space Model International (SMI) motors seems to be very good. They look like standard B-C motors, but have a different propellant than the standard black powder motors. The smoke trail is very good and the liftoff is slow; it's very impressive. No word yet on when they'll be available in hobby shops.

In order to consolidate operations, North Coast Rocketry is moving its headquarters to Alabama. With business increasing, the move was made to concentrate customer service in one location, and manufacturing operations in another. All correspondence should be sent to: 13011 Branscomb Rd., Huntsville, AL 35803. Shipment and product returns should still be sent to: 5500 Kenbridge Dr., Highland Hts, OH 44143.

Apogee is moving, too! Due too Honeywell's generosity, Ed Lacroix's wife received a promotion earlier this summer. The catch was that they had have to move to Phoenix, Arizona. Apogee will remain in Minneapolis at its current address and phone number until about mid-August. As of September 1st, send your orders to:

Apogee Components
19828 N. 43rd Dr.
Glendale, AZ 85308

All customers will receive a formal mailing including phone number.

Wondering what went on with ARIS, the on-line rocketry service? Well, in owner Bill Maness's words, here's what happened: "*The initial ARIS offering *was* a bust. We had a few customers send us checks, which we refunded when we realized how far in over our heads we were (converting from a beta to a production system). We're still not yet on-line, and we won't be accepting orders until LDRS X. We'll be down there with a computer so people can try the service out first hand, and then we'll be selling starter kits and accounts from that point on. Basically, we had a great beta test version of the service which proved totally inadequate for production use. We screwed up. However, we *didn't* screw anyone out of their money, and there are some compuservies that can attest to the refunds. ARIS and Impulse Aerospace are still going concerns, just going slower than we had initially planned, and are running quite a bit more realistically now.*"

MRC and Bill Stine have parted ways, according to sources....likewise for Dane Boles and Aerotech.

New rocketry books are on the way! Harry Stine is shopping for a publisher for his sixth edition of the *Handbook of Model Rocketry*. Doug Pratt is also finishing up a revised version of his book as well.

On Saturday June 15 and Sunday June 16, further Tripoli Motor Certification testing took place at the AeroTech/ISP facility in Las Vegas, Nevada. Present for the testing were: Chuck Rogers and Bill Wood (Tripoli Representatives), Frank Kosdon, Chuck Corway, Gary Rosenfield (AeroTech/ISP). Jerry Irvine (US Rockets) showed up but did not stay long. Over the two day period 231 motors were tested in various thrust-stands. The maximum motor size tested was low 'J' motors. Motors were tested from many manufacturers among them: AeroTech/ISP, Kosdon Reloadables, Propulsion Industries, PlasmaJet, Rocketflite, SynerJet, US Rockets, Vulcan and Bill Wood motors. The overall reliability rate for all the motors fired was 98-99%. Motors fired ranged from the AeroTech 18mm RMS reloadable to the ISP J180 RMS motor (Moonburner). Most of the motors tested were either 29mm or 38mm diameter.

PHOTO FUN!

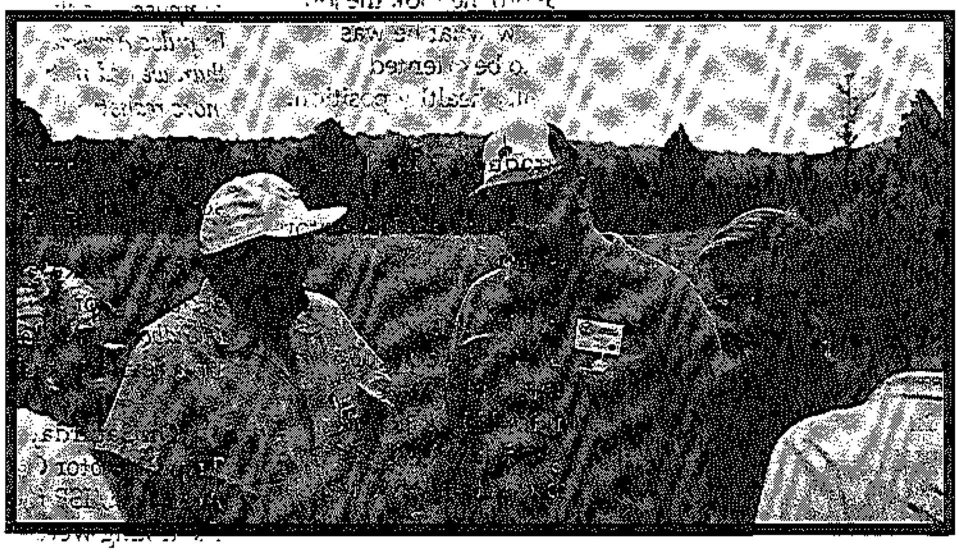
Left:

Hey Doug!

How big is yours?

Right:

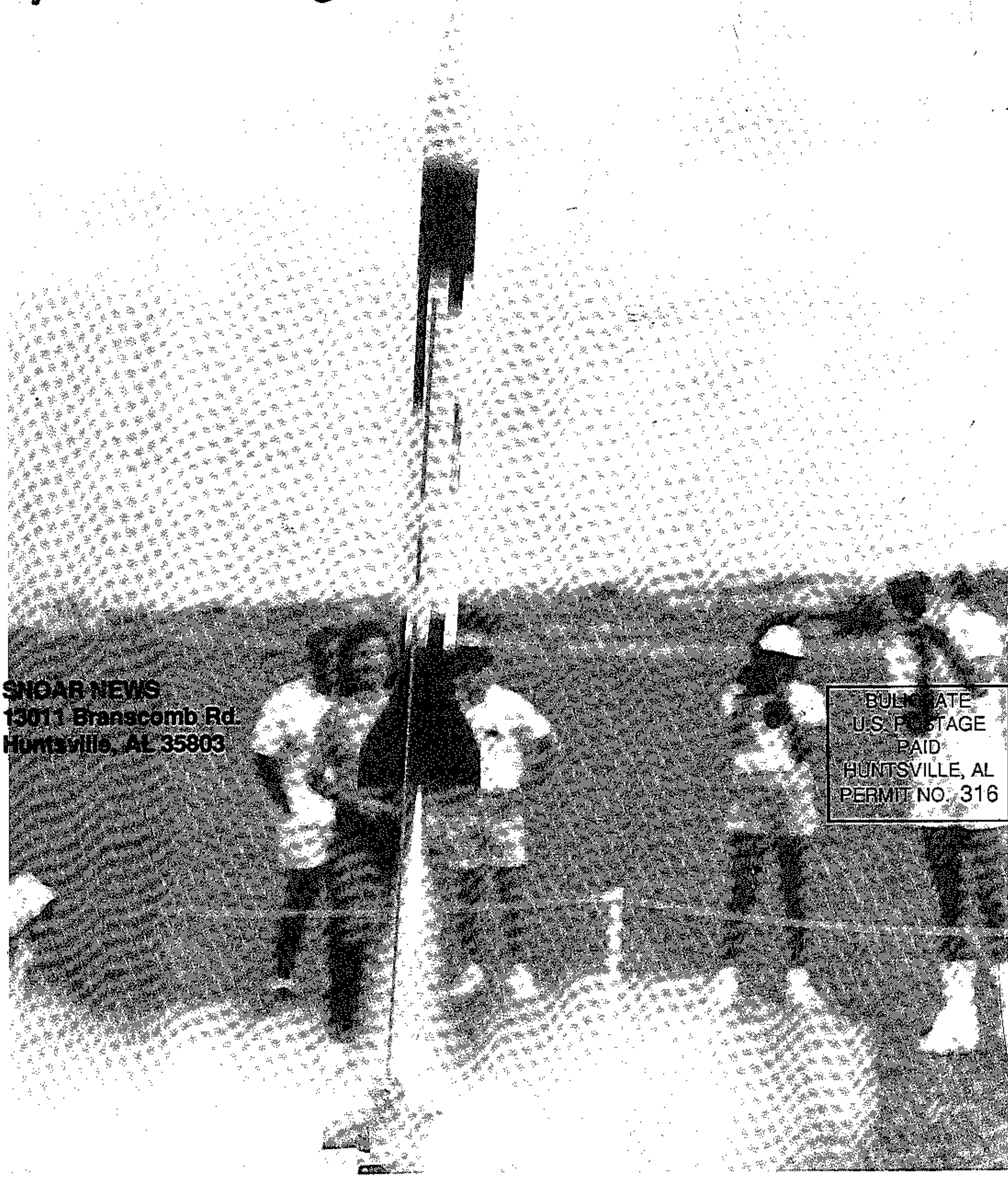
So then I says to Harry, "Har, Har, You know, I manged to buy one of those chocoalte MMI nose cones you used to joke about."



Left:

Do you think anyone will notice that I slipped an F45 into this B Eggloft Altitude model?

The Leader in Spacemodeling!



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