Foamcore Payload Construction

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Note to 2nd Ed: The 1st Ed of this paper was published in Proceedings of the First National Small Balloon Symposium, EOSS, 06/1993. This 2nd Edition has been converted to a Word97 file, Fig. 1 has been embedded, sketches illustrating miter joints added, and some material has been updated.

ABSTRACT: Foamcore sheet is a versatile and inexpensive material for use in fabricating custom balloon payload enclosures. Salient properties, design and construction techniques and flight experience are described.

Life for a high-altitude balloon electronics package can be rough. At birth, it's crammed full of radios, electronic goodies and batteries, and its skin is perforated with connectors and antenna feedlines and emblazoned with ham graffiti. Unnecessary appendages are chopped away to save weight. It flops around a workbench for weeks while its guts are tweaked and twisted with accelerating fervor as launch day approaches.

At the crack of dawn on the appointed day, it's rustled up and jostled out to some desolate spot, where it gets a few more pokes and jabs for good measure before being bound and strung up like a horse thief.

With a sudden jerk and a sigh of relief, it's hoisted up and away from its earthly turmoil. But soon it faces even more grueling insults. As it ascends at over 10 mph, rushing air tugs at its supports, and wind shear tosses and twists it like a small boat on high seas. Its internal gasses belch forth as it rises through ever thinning air. Passing through the depths of the tropopause makes New Year's Eve at the North Pole seem like a tropical beach party. Rising into the stratosphere provides a welcome respite, as the nearly non-existent air becomes calm, and everything warms up in the intense, unfiltered sunlight blazing forth from the black sky.

Just as life seems to getting a bit cozy, the support lines suddenly go limp, and our package finds itself plummeting helter-skelter down into the sky below. Whatever vestige of warmth may have penetrated its skin is ripped away by 200 mph winds, and the frigid tropopausic air forces its way into every crack, chilling its viscera to the core. After surviving another roller-coaster ride through the jet stream, the infiltrating air begins to warm, allowing it to carry quite a bit of water. In fact, the welcome shade of a cloud can fill our package with fog which readily condenses all over its frigid guts.

The ever-calming ride back to the planet ends with perhaps the most severe assault of all: a collision with the earth which would total a modern car. If the surface wind has picked up since the launch, the parachute will keep on plugging, bouncing its dazed passenger across whatever the surface may be until something strong and stationary snatches the package and wins the tug of war.

After what seems like an eternity in an even more desolate site, a swarm of fiercely-armed T-hunters converge on our voyager, attracted by plaintive cries for help driven by dying batteries though an antenna which may be buried up to its feedpoint. After a primitive ritual, the victorious captors load their quarry once again into a vehicle, this time with much less ceremony, for a considerably longer jostle back to its spawning grounds.

The next day, its creators commence their poking and jabbing again, scratching their heads in search of an explanation of how such a hastily crafted package could have survived its ordeal without dumping its contents all over the recovery site or even showing even moderate signs of wear.

“Foamcore”, they finally proclaim, “It might have been the foamcore!”

PACKAGE REQUIREMENTS:

The foregoing story is fiction, of course, but it attempts to give the reader a feel for the environmental rigors which a high-altitude balloon payload should be prepared to endure. A well-designed and built payload package will reliably protect its contents from the environment without adding excessive weight.

If the package fails, then so will its contents in which you and your balloon group have invested so much time and money. Mechanical package failure can leave priceless goodies strewn along the flight path, or more likely, electrical connections may be damaged during landing shock thus shutting down the tracking beacon so important to the recovery task. Thermal failure can cause onboard electronics to malfunction from a combination of low temperatures and condensed moisture.

Design of a strong, well-insulated package becomes non-trivial when the burden of minimized weight is tacked on. Helium and balloon costs rise exponentially with payload weight, and once the several FAA weight limits are passed, flight clearances and logistics are complicated.

PACKAGING MATERIALS:

Edge of Space Sciences (EOSS) has flown packages made from molded styrofoam packaging material, built-up insulation-grade styrofoam sheet, bulk closed-cell polyethylene foam and foamcore sheet.

Although low density styrofoam exhibits excellent thermal insulation properties, it is difficult to cut cleanly and is easily damaged by landing shock. It’s also difficult to find molded styrofoam packaging even close to the right size and shape to fit the intended contents.

Bulk polyethylene foam is even rarer, being used primarily as packaging buffers for heavy, high-cost products. Being more rigid, it can be formed somewhat more easily than styrofoam and exhibits excellent shock resistance. Airtight seams and fine details are impractical to form, however, and common adhesives won’t stick well to it.

Foamcore is readily available in large sheets. It cuts and forms easily with sheet-metal precision, bonds with practically all adhesives, is exceptionally strong in shear stress, resists puncture, is very lightweight and offers moderate thermal insulation. Precision details, such as pc board mounting slots, are easily fabricated. Using foamcore, one can design an near-optimal payload package for the contents rather than trying to work around other materials’ limitations.

FLIGHT EXPERIENCE:

The EOSS ATV module, Fig. 1, was built entirely from 0.21” foamcore in one weekend. The U-shaped package form was designed to protect the mirror from landing impact while housing the camera, servo, title board and ATV transmitter with minimal wasted space. The mirror, its drive and servo are integrated into a single module which slides into a mating slot in the package wall. Extra space was designed in to accommodate a filter wheel and servo for future video experiments.

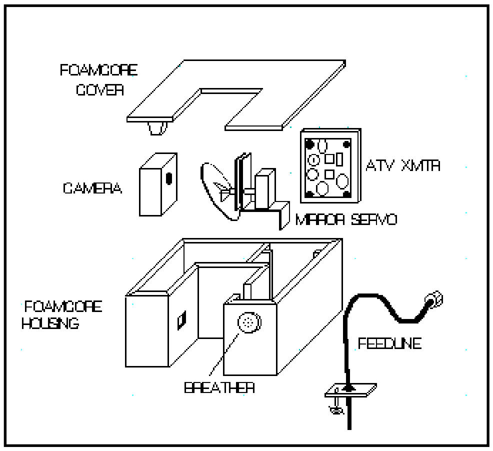


Figure 1: EOSS ATV Module

This 5-oz. housing has survived the rigors of six launches and recoveries. The only repair required was strengthening the camera holdown strut after its first flight. Since then, preflight preparation consists of no more than cleaning the mirror and fitting dry desiccant.

The loran-C receiver preamp is supported 8 feet below the main payload package to reduce QRN from the payload computer. It’s packaged in a 2” diameter heptagonal approximation to a cylinder with conical ends to minimize drag. It’s survived five trips and a number of field disassemblies to troubleshoot loran reception problems.

FOAMCORE PROPERTIES:

Foamcore, also known as mattboard, is a composite sheet material comprising a core of closed-cell, high-density styrofoam sandwiched between two sheets of thin posterboard. It’s sold in hobby and art supply stores in thicknesses ranging from 0.2 to 0.4 inches. Although used primarily for matting pictures for framing, it is occasionally used in architectural models and packaging mockups of proposed electronic products. A 2 x 4 ft sheet of white ¼” foamcore, enough for several large payload packages, retails for about $5.00.

The 0.21” thick material used for the ATV package weighs 2.12 oz. per square foot. Despite its light weight, foamcore is surprisingly strong and rigid. The optical alignment between the camera and mirror has remained unchanged through six landings.

The styrofoam core material provides an moderate thermal R-value. The 175 cubic inch interior of the ATV module held above -30 F during a 2.5-hour flight to 93,000 feet and back with less than 5 watts interior heat dissipation. Thicker foamcore provides more insulation, but an ordinary low-density insulation grade sheet foam liner inside thinner a thinner foamcore shell is more weight-effective.

SURFACE AND MOISTURE TREATMENTS:

The posterboard surface tolerates moderate amounts of water without damage. Moisture resistance can be improved with a light coat of acrylic spray paint, however. Loud orange provides a highly visible target for the recovery team. Clear Scotch brand packaging tape is nice for attaching “Return to Sender” labels and has served well for package closures in lieu of Kapton tape.

Interior condensation during descent through a cloud may be averted by including a desiccant-filled breather. We used a plastic pill bottle with each end perforated by about ten 1/16” holes. The bottle cap is glued with RTV into a matching hole in the package wall, and the bottle is filled with 1 oz of dry silica gel desiccant before the flight. This 2 oz of prevention may be dispensed with if your weather forecast is clear. Desiccant packs found in the packaging for consumer products may provide some lighter-weight protection.

A brightly-colored plastic newspaper sack can provide both moisture and abrasion protection for packages shaped like rolled-up newspapers.

EMI shielding is easily applied by gluing ordinary aluminum foil to the foamcore surface using Elmer’s glue. Good electrical contact to the foil is achieved by taping down ½” wide strips of copper foil. The copper is roughened to form gastight contact into the aluminum foil with sharp dimples made with a center punch. Similar strips with points on both sides of the foil are used to bond cover seams. Conductive adhesive metal EMI tape is ideal, but rather expensive.

ADHESIVES:

Ordinary silicone sealant (RTV) has proven to be an excellent adhesive for balloon payload packages. Its adhesion and resilience appears to be unaffected by the extremely low temperatures encountered in flight. Its only disadvantages are long curing time and outgassing of acetic acid vapor. Where an ultra-reliable joint is a must, RTV is the adhesive of choice.

Epoxy is very strong and can set up fairly fast, but it’s picky about the surfaces which it will bond to and embrittles in extreme cold.

Cyanoacrylate (super-glue) is great for quick bonding non-porous surfaces which mate closely. We use it to bond critical knots in the payload string jus prior to launch. But it’s expensive, bonds poorly to rough or porous surfaces and probably embrittles when chilled.

Another excellent joining material is 3M Kapton tape, also known as “space tape.” It’s very strong, and the acrylic adhesive bonds very well to nearly anything. It’s also outrageously expensive; we have found industrial sources of recently outdated tape which is still quite sticky. Watch out for bargain basement deals; the adhesive on long-outdated tape may not stick as well as needed. Test a piece before you buy; you should need a knife to remove it from your fingernail! We use a few patches of space tape to hold the covers closed on the package just prior to launch.

We have had excellent results using low-temperature hot-melt glue on foamcore joints. Hot-melt is resilient at room temperature, but more rigid than the same width bead of RTV. So far, it has shown no signs of cold embrittlement. Hot-glued joints are stronger than the foamcore. The only joint failure we have encountered to date was attributable to delamination of the foamcore paper; this was corrected by enlarging the joint area.

A freshly glued joint cools slowly on this material, providing a few seconds of free time for alignment. An about a minute, the joint reaches full strength, so you needn't plan your project around a series of overnight adhesive cures. The high-temperature variety of hot-melt is usable with foamcore, but it tends to melt away the foam before it cools. A high-temperature glue gun operated at about 50% line voltage from a variac or light dimmer works fine with low-temperature glue; if the gun is too hot, the glue discolors.

FOAMCORE JOINERY:

Foamcore is a stiff, planar material which crimps when overstressed, so curved shapes can't be formed. But it can be cut by hand with near-machine precision, and strong, straight bends of practically any angle can be formed quite easily. With a few simple tools, some patience and a fertile imagination, one can quickly fabricate some pretty elaborate shapes.

Tools required:

- Modeling knife with a good supply of sharp blades. Single-edged razor blades will also work in a pinch.
- Machinist's square.
- Metal straightedge. The scale on the machinist's square works fine for most work. Longer cuts and bends may need a metal yardstick clamped in place at one end.
- Hot-melt glue gun and glue. The low temperature variety is preferred.
- A large piece of cardboard for a cutting surface.
- A flat work table.

Other common hand tools, such as needle-nose pliers, may be helpful for handling smaller pieces. A sewing needle pressed into the end of dowel is handy for holding small pieces and for marking the centers of holes on both sides of a sheet. Straight pins serve well to help align less manageable joints prior to gluing.

SIMPLE CUTS:

The keys to making clean, precise cuts are a sharp blade and metal straightedge. Mark the cut line with a pencil or pen directly on the paper surface. Then place your workpiece on a cutting surface which extends past both ends of the cut. Align the straightedge directly over the cut line and plan on holding it steadily in place until the cut is complete. A C-clamp is handy for long cuts, but in most cases, the edge can be held in place fine with one hand while you cut with the other. Be careful not to crush the foam; it's especially susceptible to crushing at cut edges.

The cut should be made in at least three end-to-end passes. The first pass should just penetrate through the upper paper surface and only slightly into the core. For accuracy, the blade should be aimed slightly into the straightedge so that it won't drift away; this will also minimize the gap between the cutting edge and the straightedge.

Start the cut by poking the blade point squarely into the surface through the top paper layer. Then reduce the angle between the material surface and the blade edge to no more than about 30 degrees to avoid tearing the surface. Using a steady motion, pull the blade through to the end of the cut.

Remember, the first pass should only cut the upper layer. A dead end cut may be terminated precisely with a near-vertical poke of the blade.

Keeping the straightedge in place, make the second pass like the first, except this time, cut through the foam and slightly into the surface of the bottom paper layer. This pass establishes the angle of the cut edge. If you want a simple square cut, then be careful to hold the blade perpendicular to the foamcore surface through this pass. Square up any dead ends with vertical pokes completely through the lower paper.

The third pass should cut completely through the lower paper. You may dispense with the straightedge this time, but it's still possible to let the blade drift off at this phase if you're not careful. Keep the blade angle steady from end to end, and use enough force to cut completely through the lower paper. If the lower paper is not cut through end to end, turn the workpiece over. Incomplete parts of the cut line should at least be visible as a distinct ridge; if so, insert the tip of the blade into a cut portion and carefully pull it through the ridge, allowing the blade to self-align on the opposite side. If a ridge isn't visible, then get a new blade and repeat the third pass from the first side.

A sure sign that your blade is getting dull is ragged cut edges in the foam or tearing of the paper. A fresh blade is good for about 3 - 5 lineal feet of cutting. Blade life is definitely extended by use of a clean cardboard cutting surface. I've had a little luck resharpening Exacto blades with a fine oilstone, but I've never gotten them any better than "half-dull". A brand-new blade is a pleasure to use; make sure you have enough on hand before you start your project.

MAKING HOLES:

Rectangular and polygonal holes can be made simply by a series of straight deadend cuts. This method is simple and well-advised even for screw holes as small as #6 UNF.

Round holes require a blade with an acutely pointed tip used like a saw on both sides of the workpiece. Even the smallest holes, as for a #4 screw, are best made using this technique. A twist drill will pull the paper away from the foam, and forcing a punch through will crush the surrounding foam.

Start a round hole by marking its center, then draw the cut line on one side of the workpiece with a drawing compass or circle template. Extend the center mark through to the opposite side using a straight pin or the needle tool. Be careful to align the pin perpendicular to the surface before pushing it through. Turn the workpiece over and repeat the cut line with the compass.

Using a sharp pointed model knife aimed nearly perpendicular to the surface, cut just through the paper surface along the compass line using short, sawlike strokes. Do this on both sides of the workpiece, then carefully complete the cut through the foam, halfway from each side. The plug should push right out. This process is also handy for making disc-shaped pieces.

Elliptical holes, as used on the ATV mirror backing plate joint to the servo shaft, are a bit more tedious. First, mark the center of the hole with a pencil on the foamcore and draw in the major and minor axes; extend the ends of the major axis so it's visible on the opposite side. Then cut a cylindrical object of the proper diameter to the desired angle; for the ATV servo, this was the actual mirror drive dowel. Hold the cut surface down on the foamcore, aligned properly per the axis marks, and trace around it with a sharp pencil. Then use the needle tool centered on the ellipse center and tilted to the same angle and along the axis to transfer the ellipse center to the opposite side. Turn the workpiece over and mark the major axis; this line should fall through the pinhole and both major axis end marks made from the other side. Draw in the minor axis, and trace the ellipse as before.

The elliptical hole may now be cut using the same technique as for round holes. When cutting through the foam, bear in mind that the blade angle relative to the surface will vary from perpendicular when crossing the minor axis to the full angle crossing the major axis; allow the blade to self-align by passing it through both sides while cutting the foam.

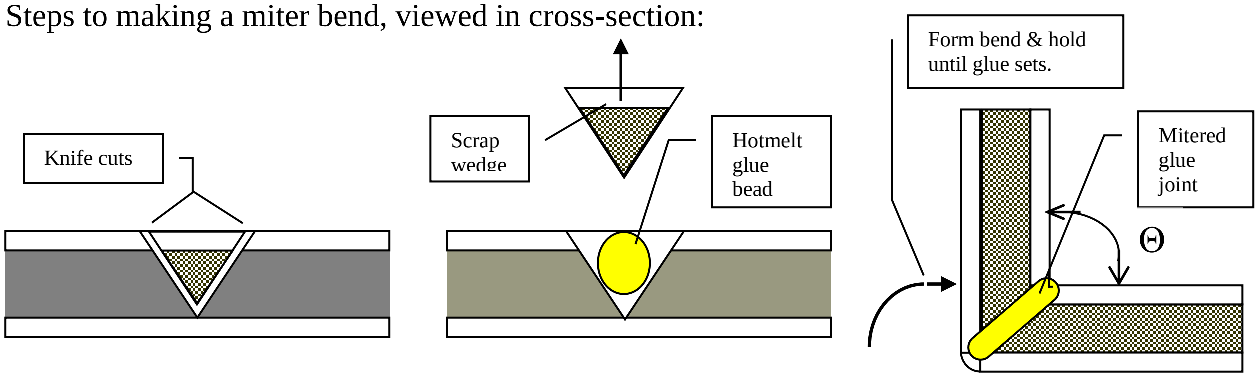
MAKING BENDS:

The simplest "bend" is just an end-to-side butt joint between two separate pieces of foamcore. This method leaves an ugly raw end showing, which can also allow moisture penetration. Its strength depends solely upon the paper peel strength.

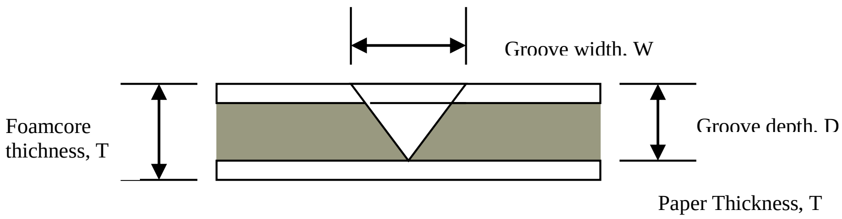
Strong, accurate and stable linear bends can be made by first cutting a V-groove on the inside of the bend with a depth just down to the inside surface of the outer paper. After the V-shaped strip is removed, apply a bead of hot-melt glue to half-fill the slot and form the final bend.

After the glue sets, the bend is permanent and in most cases doesn't need reinforcement. The outside corner is neat in appearance since the paper runs continuously around it; this also contributes to strength and moisture-resistance.

Steps to making a miter bend, viewed in cross-section:



The width W of the V-groove at the inner surface is determined by the depth of the groove, D, and the inside bend angle Θ. For this purpose, D should be the foamcore thickness T minus the thickness of the outer sheet of paper P.



For a right-angle bend, W = 2D = 2 (T-P). Smaller bend angles require smaller groove widths, and vice-versa. For you precision freaks, the groove width W may be calculated for any material:

$$W = 2(T-P)\tan(\Theta/2)$$

To cut the groove, mark the two edges of the groove equidistant on either side of the center. Plan to cut each side of the groove in two passes. The first pass may be done with the blade perpendicular to the surface, just to cut the paper. The second cut should be done with the blade angled so the tip just contacts the inside of the bottom paper at the midpoint of the groove; the blade angle from vertical ideally is one-half the desired bend angle. The care with which this pass is made on both sides will determine the straightness of the outside joint and the precision of the inside seam.

After the cuts are made on both sides of the groove, the V-shaped scrap should pull out cleanly. If not, don't fret; any gaps in the foam will fill with glue. At this point, it may be a good idea to form the bend and check it for accuracy before committing it to glue. If the outside bend is a bit uneven, place the inside of the bend over a square corner of the bench and lightly burnish both sides of the outside corner with a ½" diameter dowel or some such tool.

With the groove lying open, apply a bead of hot-melt glue with a diameter about ½ the groove width. Then form the bend and hold it at the proper angle until the glue sets. A couple of square-cornered blocks of wood or metal also serve nicely in this role if you are compelled to a higher calling. If a clean inside corner is required, excess glue expelled from the joint can be removed while it's hot using a scrap piece of foamcore.

Key points regarding bends:

- Make sure the groove is cut on the INSIDE of the bend; I blew about an hour's work on the ATV module walls with this stupid trick.
- Dimension the location of the bend on the INSIDE surface to the EDGE of the V-groove, not its center. When the bend is made, the two edges will come together to form a sharp inside corner.
- Cut the grooves for all of the bends in one piece before you glue the first one. A flat workpiece is easier to manipulate.

UNFOLDED JOINTS:

All balloon payload packages eventually must completely enclose a volume. It's not possible to form such a structure from a single sheet with all joints folded and no exposed seams; at least I haven't figured out how to do it. Even if it were possible, it would still be very desirable to be able to open the structure in order to put something useful inside. The bottom line is that unfolded joints, such as butts, laps and miters are unavoidable. They can be made quite serviceable, however.

If you're making a closed form where two cut ends must come together, make the final joint as a miter at one corner. Rough out your workpiece to allow at least ½" extra at both ends; its very hard to cut a clean miter right at the end of a square cut, since the foam tends to crush easily there. Glue the mitered ends together and add a ¼" square stringer inside for strength. A piece of space tape over the outside corner will finish the joint.

If a butt joint is unavoidable, reinforce it with a ½" or wider strip glued to lap the joint. Glue the reinforcement strip to one side first, then apply a bead to the exposed foam edge and the open surface of the reinforcement before closing the joint.

The strength of any joint can be significantly improved by adding triangular reinforcement webs on the inside corner. The price is added weight and lost interior volume.

"CURVED" SHAPES:

Foamcore doesn't bend without crimping, since paper doesn't stretch. So don't plan on forming a truly curved wall. A curve can be approximated by a series of parallel, close-spaced small-angle bends to form a polygonal cylinder. It should be possible even to form a near-spherical polyhedron, such as a dodecahedron (geodesic dome), from a single sheet.

The width W of each side of an N-sided polygon circumscribed around a circle with radius R is:

$W = 2R \tan(\Pi/N)$ computed in radians

Example: an octagon which will fit snugly over a 5" radius (10" diameter) cylinder has INSIDE panel widths of:

2 * 8 * 5 * tan (3.1416/8) = 4.142" (4 9/64")

When laying out the cuts on your workpiece, remember to add one groove width to the inside width of each panel.

CONICAL SHAPES:

Again, a true cone can only be approximated. But a steeple-like conical extension can easily be added to polygonal cylinder. When the workpiece is laid out flat with cylinder grooves already cut, make a cut parallel to the base of the cone at a distance equal to the side of the cone above the intended cone base. For a cone height H, and cone base B across opposite outside flats, compute the side length S as:

$$S = \sqrt{H^2 + (B/2)^2}$$

Extend the MIDPOINT of each side from the base of the cone up to the cut edge. Draw light reference lines from midpoint marks at top cut to the centers of each adjacent cylinder groove. You should end up with a sawtooth-looking pattern when you're done. Then draw two cut lines parallel to each reference line from the ends of each groove to the top. Cut V-grooves on these cut lines. Then cut through the bottom paper of each of these new grooves and pull away the triangular scrap pieces. You will end up with a crown-shaped workpiece.

Form and close the cylinder in as above, then pull the steeple pieces together and hot-melt the butt joints together. The seams may be sealed with space tape.

It is also possible to form the same structure with closed outer seams by making a series of grooves radiating outward from a common center point corresponding to the tip of the cone. In this case, the cylinder at the bottom will have butt-joined seams. This method may be preferable where the strength of the cone is deemed more critical than that of the cylinder. Details of such a layout are left as the traditional exercise for the reader.

A closing observation on cones: if the height of the cone were to approach zero, one would end up with a flat cap closing the end of the polygonal cylinder. This end might be more easily achieved with a separate piece glued in place, however.

PLANNING THE PACKAGE:

A well-designed package will minimize unfolded joints and place them where they don't carry much load, or add reinforcement if they do. The floor of the package is likely to bear the greatest load, such as batteries. The floor should be joined to the walls of the package with at least reinforced butt joints; this was the method used for the ATV package, but that floor bore only the weight of the camera.

A sturdier floor-to-wall joint will result if the walls are formed as bent-up extensions of the floor. The walls can be joined as mitered reinforced butt joints. This approach might be best for shallow packages with wall seams less than 4 or 5 inches high.

If the wall structure is complex, the bottoms of the walls can be bent inward to form ½" or so wide flanges; the ends of these flanges should be cut at the proper angle to form a tight miter when they're all folded inwards. After the floor is cut to size, it can be pushed in from the top and glued to the flanges to form lap joints. The exposed edges of the flanges can be protected by cutting a smaller second floor which just fits inside the area circumscribed by the flange edges and gluing it in place; this will add weight, but it more than doubles floor strength and R-value. It's probably an excellent approach to use if the floor is over a foot square.

Reinforcement strips should be located inside the package to present the smoothest possible surface to air and to grabby objects on the ground.

During a rough drag over the ground, battery mounts are heavily stressed. They should be designed to take it, and to prevent shorting and damage to other components if the mount fails. The EOSS Shuttle is provided with an internal foamcore battery box with a lid. The box is located near the center of the floor to control CG, and its bottom is glued to the package floor. We've encountered no structural problems so far with this method.

Distributing the cells over a wide area and supporting them near the inside corners would be structurally sounder than concentrating them all in the center of the floor. Some weight savings may be realized by eliminating reinforcement. Battery replacement would be more tedious, however.

Access to the interior of the package is best made from the top via a removable lid. The ceiling is unlikely to carry much load, and it's the least likely surface to contact the ground during landing. Thus its joints don't require much strength. The ATV module lid is a flat sheet which carries alignment strips on the inside. These strips fit snugly inside the top edges of the walls. The strips not only keep the lid aligned, but they also add to the package's torsion resistance and prevent a straight shot for water and EMI penetration. The raw edges of the lid and walls are separately sealed with space tape before aluminum foil shielding is glued on the external surface. A few space tape tags hold the lid in place during flight.

A stronger lid might be formed as a cap which fits over the tops of the walls, but one is then one is faced with a bigger snagging target.

FITTING IN THE GOODIES:

Printed circuit cards may be mounted in the conventional fashion using standoffs and threaded hardware through the package walls. It's quite easy to form card guides out strips of foamcore glued to the package walls, however. This makes access and preflight replacement a snap. If the there's not at least 1/8" free edge on the card to clear the slot, then the card can be mounted to a separate sheet of thin foamcore which slides into its own slots.

Captive machine threads may be included for ease of disassembly using T-nuts, commonly used in cabinet carpentry. Ordinary machine nuts may also be glued or space-taped in place on the foamcore surface, where screw tension pulls the nut into the surface. Large-diameter flatwashers will prevent the nut from pulling through if the screw is overtightened or subject to high stress.

Low-stress openable lap joints, such as for an enclosure lid, can be secured using sheet metal or deck screws; the threads engage OK into the paper. The needle tool makes a suitable pilot hole. A stronger joint will result if the screw passes through a double layer; this can be implemented by gluing a ½” – 1” square patch of foamcore on the inside.

External connectors for ground, power, antenna feedlines, etc. may be hot-melted into snug-fitting holes in the package wall. Connectors which are expected to be heavily stressed may be secured to patches of printed circuit board material before being glued into the package. Connectors which project out from the sides of the package are subject to drag damage. They should be avoided or shrouded; suitable shrouds may be made from foamcore. These shrouds may also be designed to mount strain reliefs for cables or their messenger lines.

Load-bearing attachment points, such as for payload support lines, are best made on vertical walls near the outer corners. It’s also possible to cradle the package in macramé fashion, but this can create a challenging tangle for the post-flight crew. Single-point attachment to the center of a flat lid is not recommended except for very small packages. A steeple-topped package will tolerate this well, but a pyramid of nylon line is much lighter. We have had some success with dowel-backed holes in the sides which accept loops at the line ends. After the loops are attached, the holes are sealed with RTV. This method avoids projecting snag targets.

If your payload comprises a number of packages strung together, design your support system to avoid transferring the weight of the lower packages through the upper package structure. It’s far better to let the support lines carry that tension past the structure than it is to burden it with heavy reinforcements. The support lines may be tied together at single points above and below the package. Compressive stress is reduced significantly by placing these points at least 3 package widths away.

Recently, we have used threaded vertical through bushings to provide both support line attachment and to secure the lid. This method keeps all of the flight line tension off the payload structure. Threaded 3/8 NPT pipe intended for lamp fixtures, along with mating nuts, washers and bushings, may be found at the hardware store. A nylon dress bushing with a hole just large enough to pass your flight line will provide a safe mating surface to a figure-8 knot in the line. Plastic tubing is lighter, but it is tedious to thread.

Package spin during flight is probably unavoidable. Its adverse effects are windup of cables running between strung-together parts of the flight system and motion sickness by those who watch the ATV image of the ground for too long. Spin has a slow, basal rate intrinsic to balloon dynamics, so I’m told, plus a faster oscillatory component. Wind shear causes suspended parts of the system to sway horizontally, creating a horizontal component of airflow around the package. Asymmetrical projections will weathervane downwind, resulting in an oscillatory yaw rates which may be much faster than the basal spin rate. Oscillatory spin might be reduced by making the package nearly cylindrical to reduce the horizontal drag coefficient, and large asymmetrical projections should be avoided.

SUMMARY:

Foamcore material has proven to be an attractive material for high altitude balloon payload package construction. The design and construction techniques described have been used successfully on over 40 EOSS flights. They were developed over just a few projects, however, and are by no means the pinnacle of the art. Others of you will develop significant improvements in materials and techniques. In the meantime, it is hoped that some of you in the high altitude balloon community will be encouraged to fly innovative new payloads using what insights might be gained from our experience.