Payload Construction Considerations & Techniques

Flight Vehicle Constraints

- Federal Aviation Authority (FAA) places constraints on what can be flown on a balloon without a flight waiver
  - Maximum weight of ~5.4 kg (~12 lbs.)
  - Density less than 13.2 g / cm^2 (~3 oz / in^2)
- Weight of balloon vehicle is ~2.5 kg
  - Leaves about 2.5 kg for student payloads
  - We will fly about 5 payloads, so each payload will be constrained to ~500 grams

LaACES Student Ballooning Course

LaACES Vehicle Interface

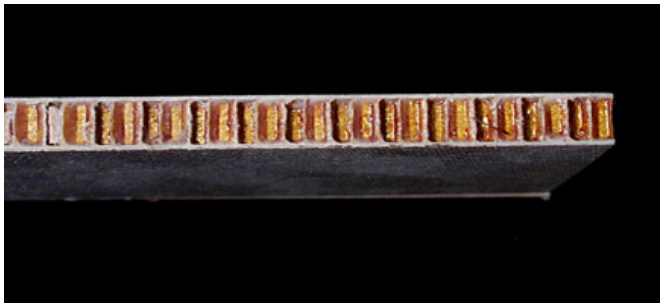
- Only a mechanical interface between payload & flight vehicle
- Two flight string cords are separated by ~17 cm
- Both strings must pass through payload with a break
- Use a thin walled tube (straw) secured to payload structure
- Payload secured vertically on flight string with spring clips

Construction Materials - Metal

- Advantages of using metal like Aluminium
  - Strong and relatively light weight
  - Comes in many different forms & sizes
  - Easily machined and bolted together
  - Relatively inexpensive
- Disadvantages of using metal
  - Heavy (15 cm cube with 1 mm sheet Al would weigh ~360 grams)
  - Excellent thermal conductor

Construction Materials - Composites

- Composites include materials such as G-10, Fiberglass, Carbon fiber extrusions, NOMEX honeycomb sandwich
- Advantages of using composites
  - Extremely strong and light weight
  - Comes in sheets and extruded shapes
  - Relatively easy to cut
  - Excellent thermal insulator
- Disadvantages of using composites
  - Can be very expensive
  - Can be difficult to form and glue



Polystyrene Foam

- Extruded Polystyrene (XPS) is a composite material
  - Polystyrene resin mixed with critical additives in extruder
  - Continuous smooth skin formed during extrusion process gives cladding
- Advantages of XPS foam
  - Inexpensive and readily available
  - Strong and rigid
  - Lightweight
  - Thermal insulator (R value of 3 with ½" thickness)
  - Easy to cut and glue
- Disadvantages of XPS foam
  - Available as sheet stock only
  - Not as strong as other composite materials or metals

XPS Properties

- Trade name is Foamular® and Duramate®
  - Foamular website site http://www.foamular.com/
  - Foamular thickness from ½" to 4" and sheet size from 2' x 8' to 4' x 8'
  - Duramate thickness from ½" to 4" and sheet size of 2' x 8' or 4' x 8'
  - Can be bought at Home Depot and Lowes as well
  - https://www.lowes.com/pd/Dow-Common-0-55-in-x-4-ft-x-8-ft-Actual-0-55-in-x-4-ft-x-8-ft-Residential-Sheathing-R3-Faced-Polystyrene-Foam-Board-Insulation-with-Sound-Barrier/1000168167

Surface Treatments

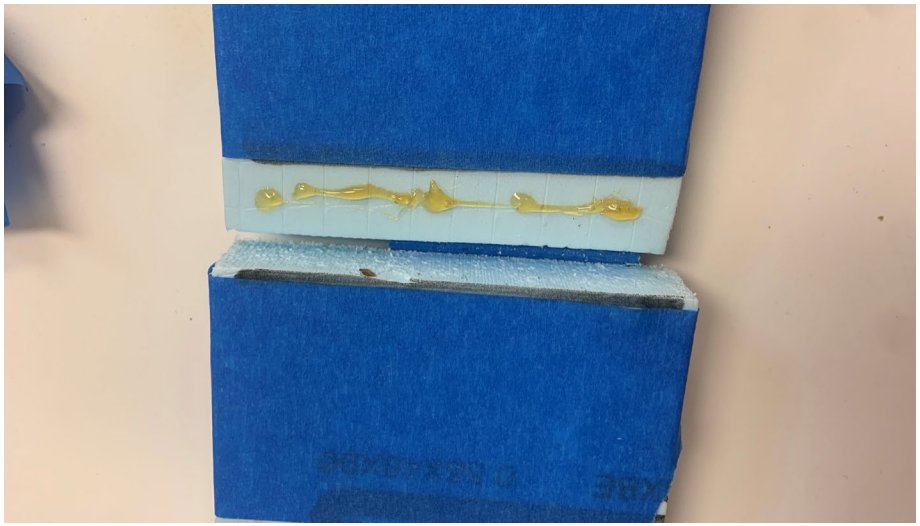
- Can apply lightweight plastic shrink wrap (Econokote) to XPS foam to improve resistance to moisture
  - Also reduces foam degradation from UV exposure and cold
  - Bright orange/yellow/white color for visibility
- Can use desiccant packs to reduce condensation
- EMI shielding by securing Al foil to outside surface
  - White (Elmer's) glue or tape appears to work fine
  - Electrical contact with taped down, roughened copper foil strips
- Al foil surface also good for thermal properties

Adhesives

- Polyurethane (Gorilla) glue is adhesive of choice for critical joints
  - High adhesion and resilience even at low temperatures (-40° F)
  - Moisture activated, expands while curing (~3x), moderate curing time
- Epoxy is very strong but can become brittle in extreme cold
- Cyanoacrylate (super glue) for quick bonding of non-porous surfaces which mate closely
- 3M Kapton tape ("space tape") is strong, bonds to nearly everything but is very expensive
- Low-temperature, hot-melt glue for joints
  - More rigid but no cold embrittlement
  - Glue cools slowly, so have a moment for alignment
  - Reaches full strength in about a minute
  - High-temp, hot-melt tends to melt the foam

Tips for Polyurethane Glue

- Best to wear gloves when working with Gorilla Glue
- Lightly moisten the surface before applying the glue
- As the polyurethane glue cures it will expand outside the newly created joint.
- Two ways to deal with issue
  - Place masking tape on both edges of the joint before mating, remove tape after glue is finished curing
  - Wipe glue away as it cures with tongue depressor



Apply tape to both sides of the joint before gluing

Cutting XPS

- Materials needed for construction
  - Modeling knife and a good supply of new, sharp blades
  - Machinist's square, metal straightedge (12", 36"), spring clamps
  - Cutting surface (large cardboard or hardboard) and flat work table
- Keep knife blade sharp
  - Replace blade after 3 – 5 feet of cutting
- Clearly mark where to cut using square and straightedge
  - Measure twice, cut once!
- Cut in three passes
  - Hold knife blade against straightedge and cut upper surface on 1st pass
  - Don't move straightedge and on 2nd pass cut through foam
  - On 3rd pass cut through bottom surface of the XPS foam

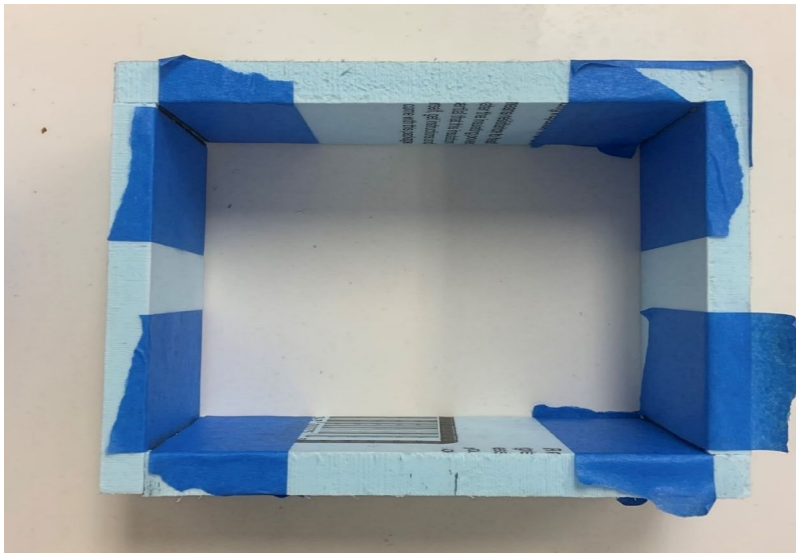
Cutting XPS (optional)

- If available it is best to cut XPS with a bandsaw or table saw
- DO NOT wear any loose clothing while operating the band saw
- DO NOT put your hands in line with the blade path at any times
- DO NOT lean into the band saw while making cuts
- ALWAYS wear eye protection while operating the band saw
- Use a band saw guide to help make cuts along marks
- For angled cuts you can adjust the angle of the saw's table

A bandsaw with table angled down

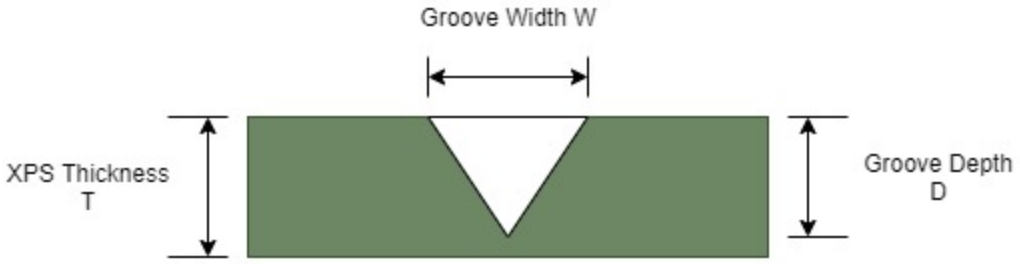
Gluing XPS foam

- When gluing edges or walls together it is necessary to apply pressure as the glue cures
- This pressure can be applied with weights, clamps, or tape.
- Do not clamp directly on to the foam



Making Bends

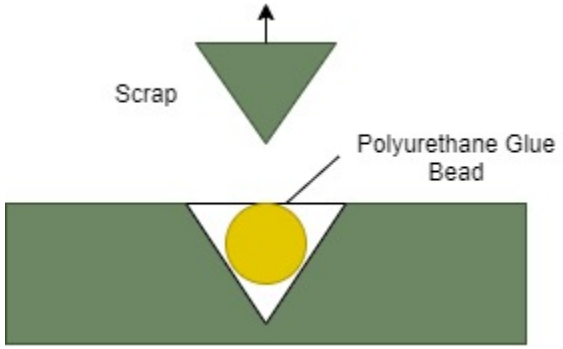
- Mark center and diameter of hole on both sides of XPS foam
  - Use a straight pin pushed perpendicular to the foam to transfer the hole center
- Use knife to cut groove into foam
- For a mitered bend cut a groove of width W through the top clad and the foam to depth D
  - Put polyurethane glue in groove and bend
  - For a bend of angle Θ the groove width is $W = 2(D)\tan(\Theta/2)$
  - EX: 90° angle & D = 0.5” ➔ $W = 2(0.5)\tan(90/2) = 1$”



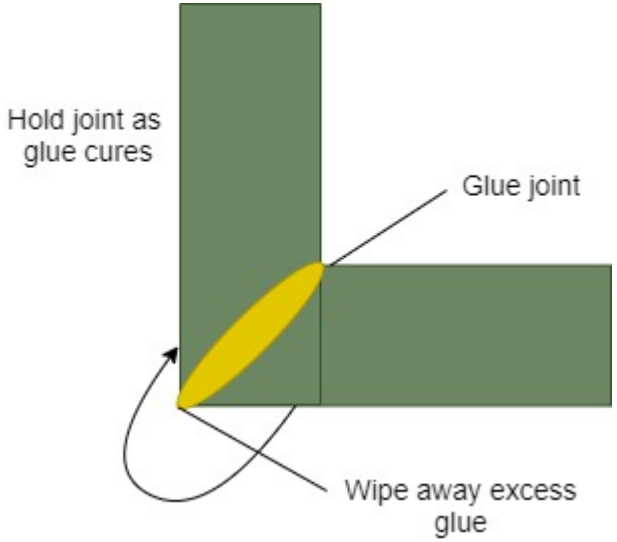
Steps for Mitered Corner

Step 1

Step 2



Step 3

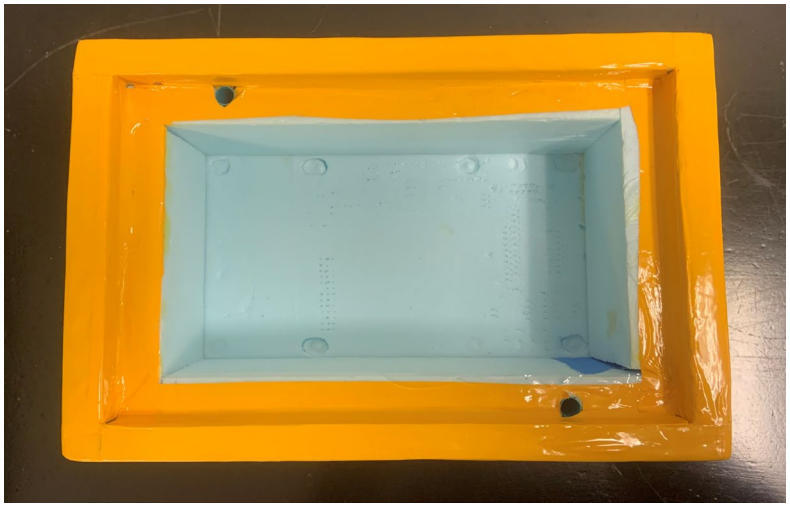


Other Construction Tips

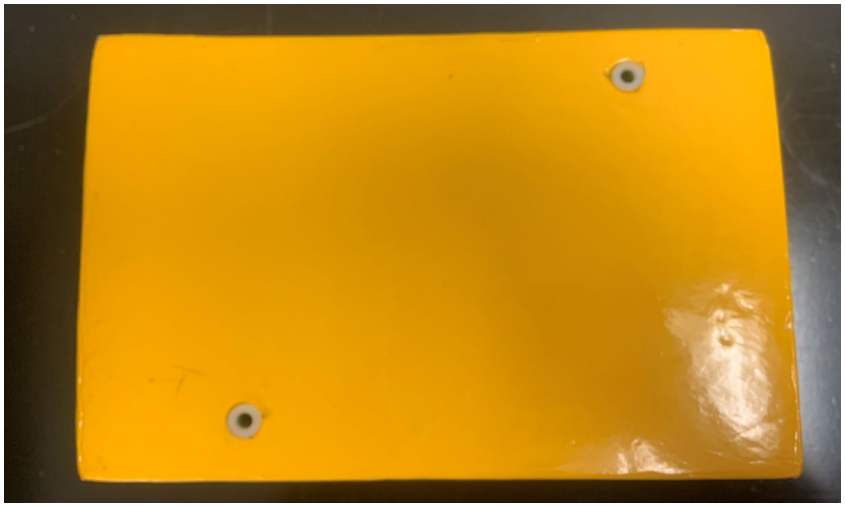
- Can also make curved shapes using same groove and folding technique
  - For an N-sided polygon to fit over a circle of radius R the width of each side is $W = 2(R)\tan(\pi/N)$ computed in radians
  - Ex: for a hexagon to snugly fit over a circle of radius 5”
  - $W = 2(5)\tan(\pi/6) = 5.773$” (~ 5” 25/32”)
- Minimize number of glue joints and reinforce when needed
- Heavy components (e.g. batteries) should be distributed near floor of box and supports reinforced
- Might use a double walled box to further protect components from temperature/moisture
- Access to interior is usually best through top where stress is less

Adding Flight String Holes

- To interface with the flight string you will need to make two holes 17 cm. apart that extend vertically through the payload.
- This is best done with a drill or drill press and a 0.25” bit
- Glue straws in holes for reinforcement
- Glue plastic grommets into the holes to further secure the flight strings and keep the strings from wearing away at the foam.



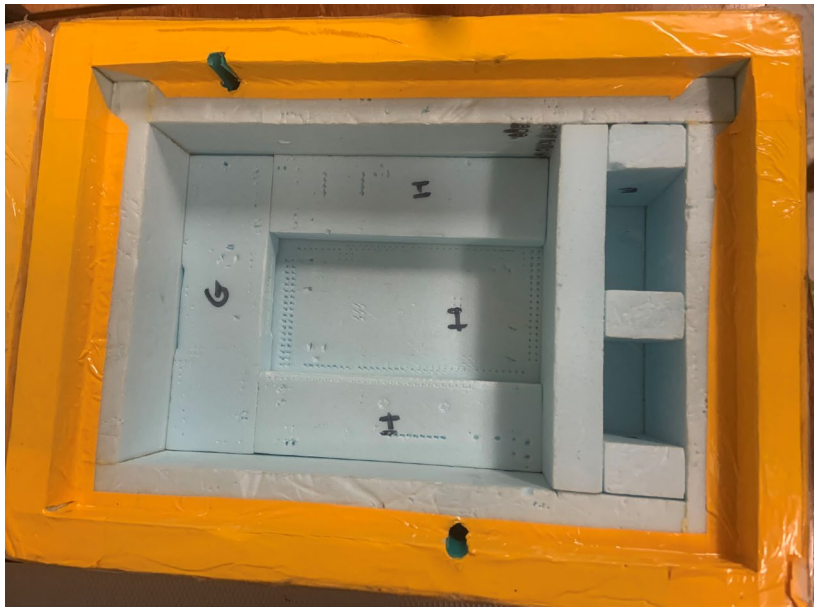
Holes with straws added for reinforcement



Grommets added to the outside of holes

Interior Attachments

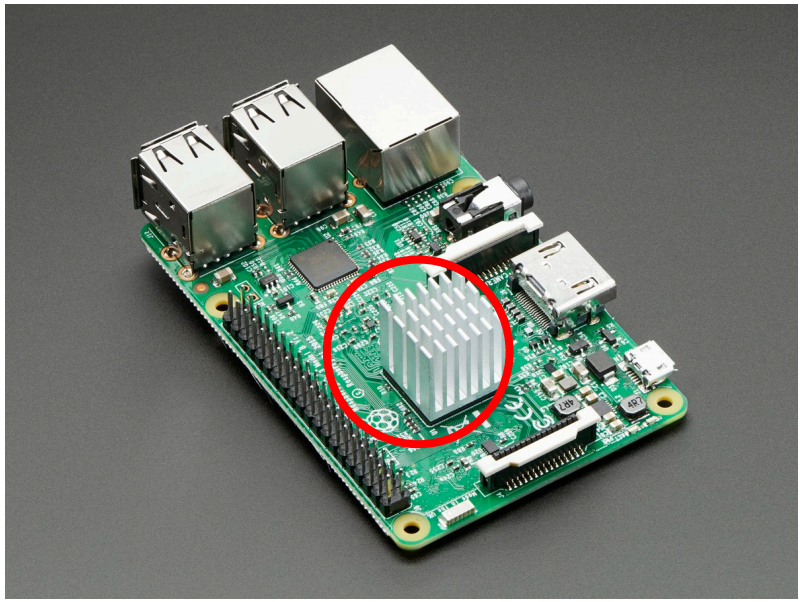
- T-nuts or ordinary nuts taped or glued to the foamboard can be used for machine screw mounting
- Extra foam inserts inside the payload can help secure components
- Connectors / electrical feedthroughs / switches need to be hot-glued to snug-fitting holes in the wall
- Flight vehicle string interface tubes should penetrate box top and bottom and be securely glued to joint corners



A standard MegaSat box with foam inserts

Payload Best Practices

- Some sensors will need to be placed outside the payload
  - Make sure holes for cabling are made and are of proper size before applying Econokote
  - It is usually good to tape external sensors down to prevent interference with the flight string
- Make incisions into foam inserts/walls to prevent stress on internal cables
- Consider the thermal properties of your box and electronics
  - Heaters or heat sinks may be required
- Hot glue potentiometers, SD cards, etc. to prevent movement during flight



Heat sink on Raspberry Pi microcontroller

References

- http://www.foamular.com/ - Website of XPS products board products