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 / cm² (~3 oz / in²)
- 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 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 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
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 $\Theta$ the groove width is $W = 2(D)\tan(\Theta/2)$
  – EX: $90^\circ$ angle & $D = 0.5"$ $\Rightarrow W = 2(0.5)\tan(90/2) = 1"$
Steps for Mitered Corner

Step 1
Make knife cuts

Step 2
Scrap
Polyurethane Glue Bead

Hold joint as glue cures

Glue joint
Wipe away excess glue

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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.
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