Building a Hot Air Balloon

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Why Build a Balloon Rather than an Airplane?

- Cheaper and less labor - $10,000 + 200 hours
- Flight testing is much less “interesting”
- Can be built in a 10’ by 10’ workspace
- Simpler inspection and maintenance
- Something different
- Room for experimentation -- mix and match

The Very Basics of Ballooning

- Internal air temp controls buoyancy
- Heat added with propane-fueled burner
- Heat lost through radiation/conduction or (for rapid descent or deflation) opening a vent

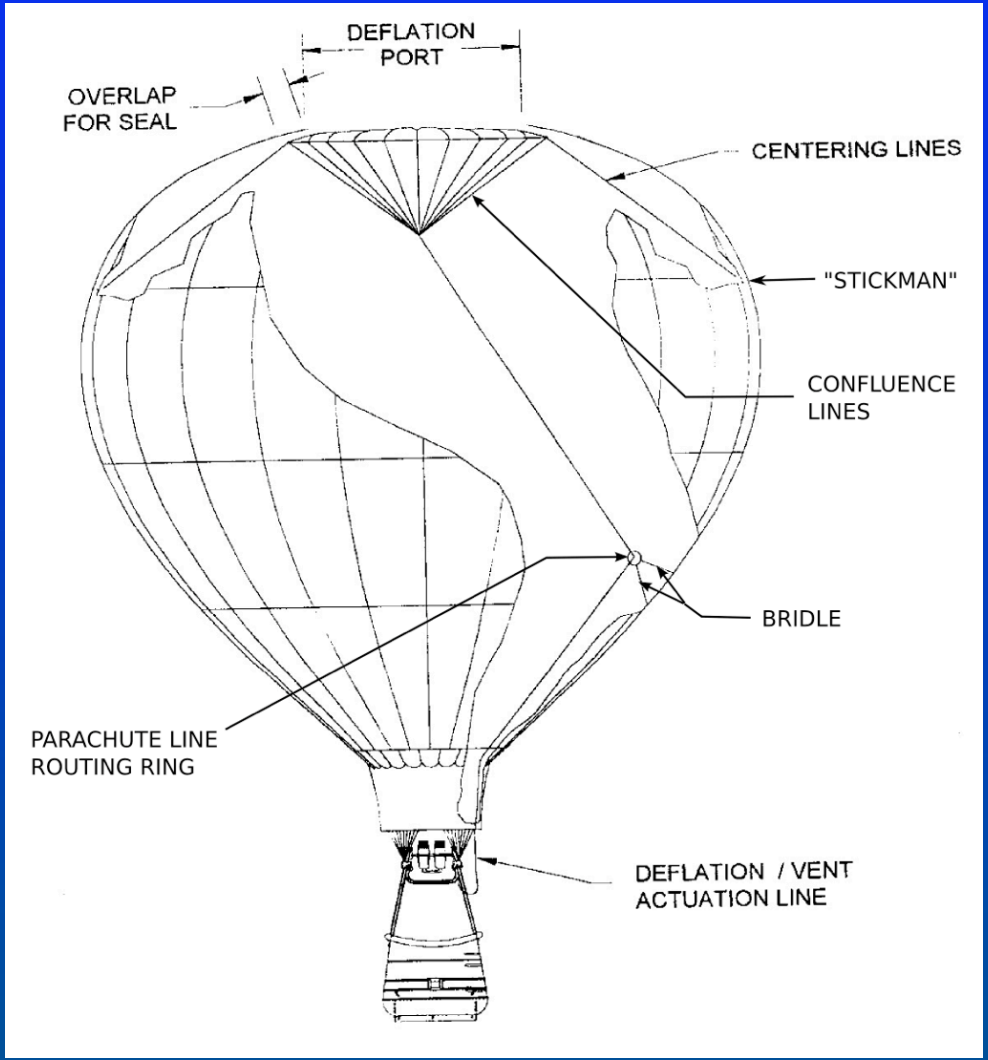
Two Major Components

Envelope -
A Big Bag-o-Hot-Air

Suspension lines

Bottom-End -
Everything Else

Parachute-style Vent



Two Regulatory Options

- Ultralight - a.k.a "a hopper"
  - Under 155 lbs empty weight
- Experimental/Amateur-built
  - Envelope usually treated as the "major portion" (a.k.a. 51%) of the aircraft

Forum Tomorrow

Getting Your
Balloon Rating
Bill Hughes
10:00 AM
002 GAMA Forum

A Typical First Project

- Build an envelope
- Buy a bottom-end
  - Lots of used bottom-ends are available because they last much longer than envelopes
- Almost nobody builds their own burners or tanks

Envelope Basics

- Envelope material is nylon
  - Nylon melts at 400+ F
  - Operated below 250 F
  - Few minutes at 275 F

Envelope Fabric

- Rip-stop weave of nylon material
- Sometimes coated with either Silicone and/or Urethane
- Different weights
  - Stated in ounces per sq yard
- Be careful, almost nothing is standardized when it comes to fabric!

Fabric Strength

- Two measures of strength
  - Pull (a.k.a. tensile) strength
    - 50 to 100 lbs per linear inch
  - Tear strength
    - Slit test - 5 to 15 lbs
- Pull strength used as a proxy for tear strength after construction

Envelope Webbing

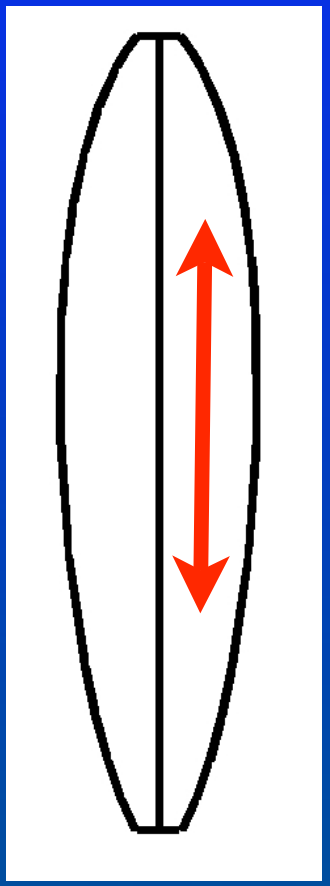
- Also made of nylon
- Often called “tapes”
- Typically only 3/4” to 1” wide
- Amazingly strong -- e.g. 1,000 lb test
- Carry entire weight of bottom end
- MIL-SPEC available !!!

Envelope Shape

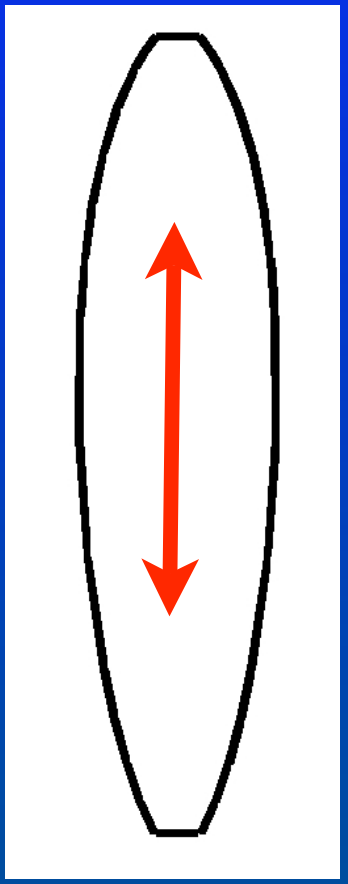
- Barrel-shaped tube
- Opening at the top -- “top port”
  - Covered with a “parachute” vent
  - Used to deflate at end of flight
- Opening at the bottom -- “mouth”
- “Staves” of the “barrel” called “gores”
- Gores made up of “panels”

Vertical Panel Envelope

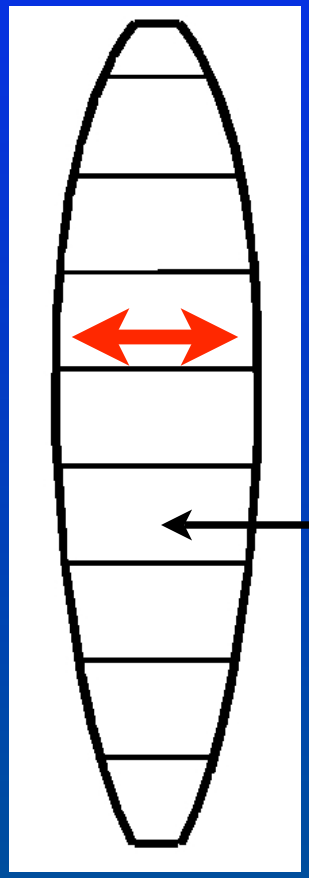
2-Panel

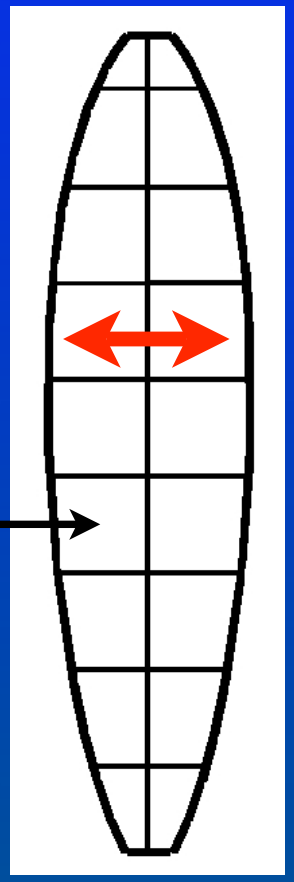


1-Panel



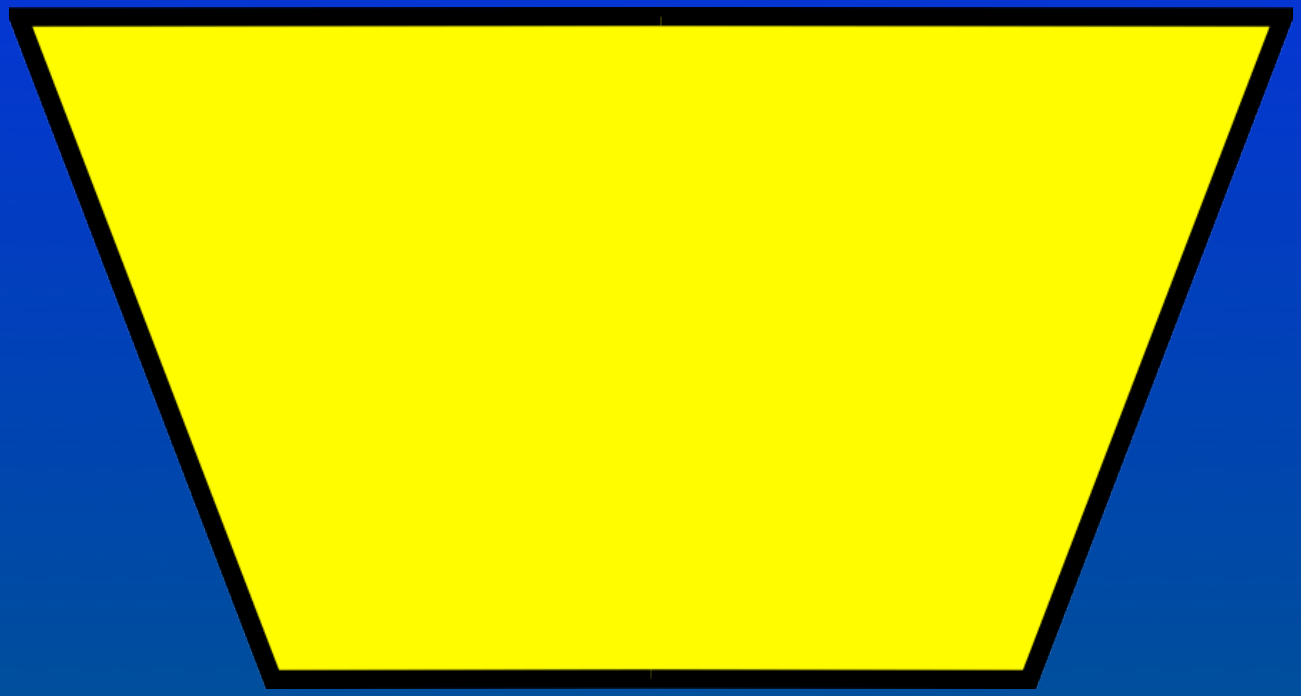
Horizontal Panel Envelope



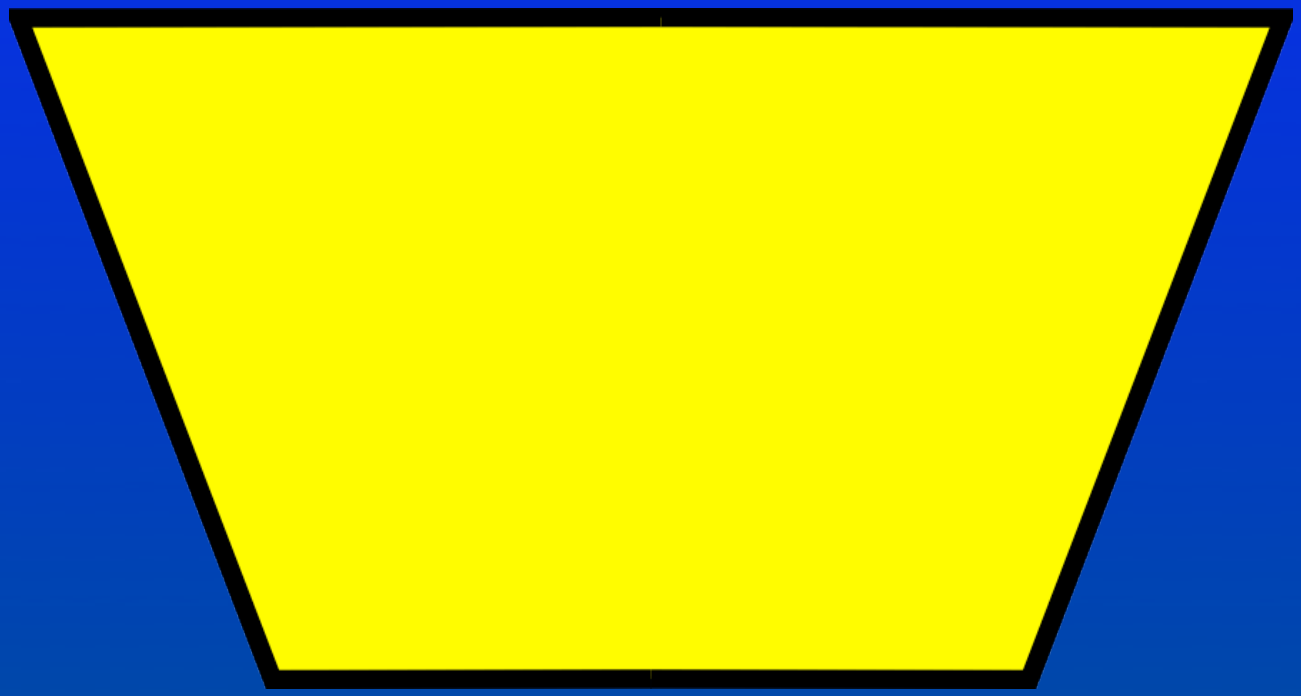


Panel

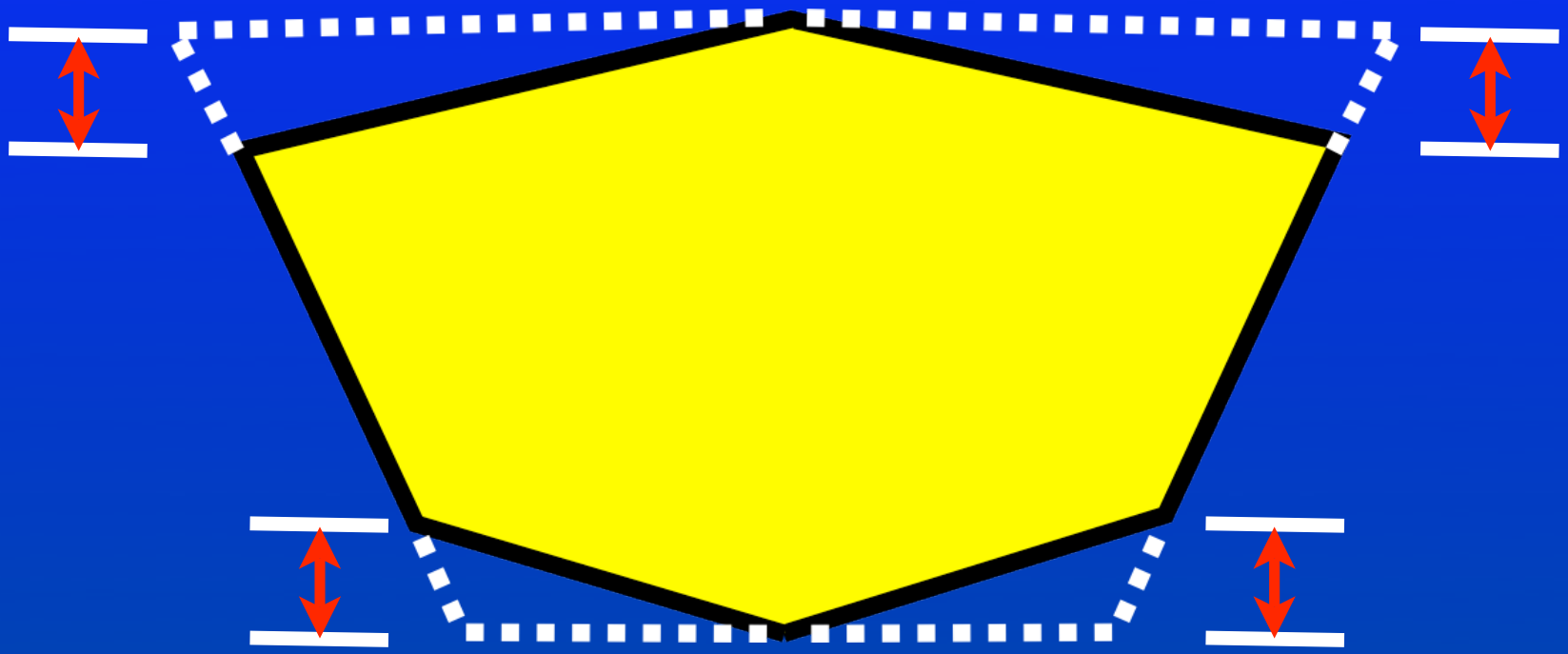
Horizontal Full Panel
Trapazoid Shape
No Curves Necessary!



Basic Trapazoid Shape

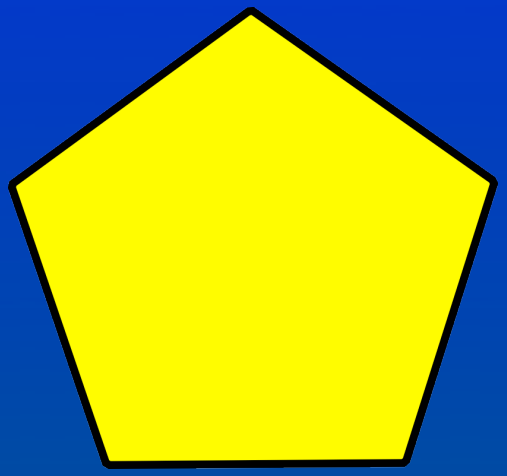
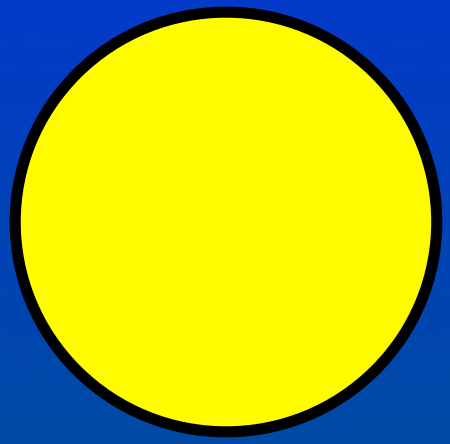


Trapazoid Trimming



Red arrows show amount "trimmed"
Not to Scale - Trim greatly exaggerated.
Actual amount about 2% of panel height.

Effect of Trimming on a 5 Gore Balloon

Amount of Trim	None	Some	Lots
Top View			

No Trimming of Horizontal Panels

Some Trimming of Horizontal Panels

“Pumpkin” Balloon

Extensive Trimming of Horizontal Panels

Panels Orientation Pros and Cons

- Horizontal
  - No curved edges - trapazoidal
  - Less fabric waste - e.g. 5% vs 25%
  - Shorter cutting table
- Vertical
  - Slightly less sewing - e.g. 10%

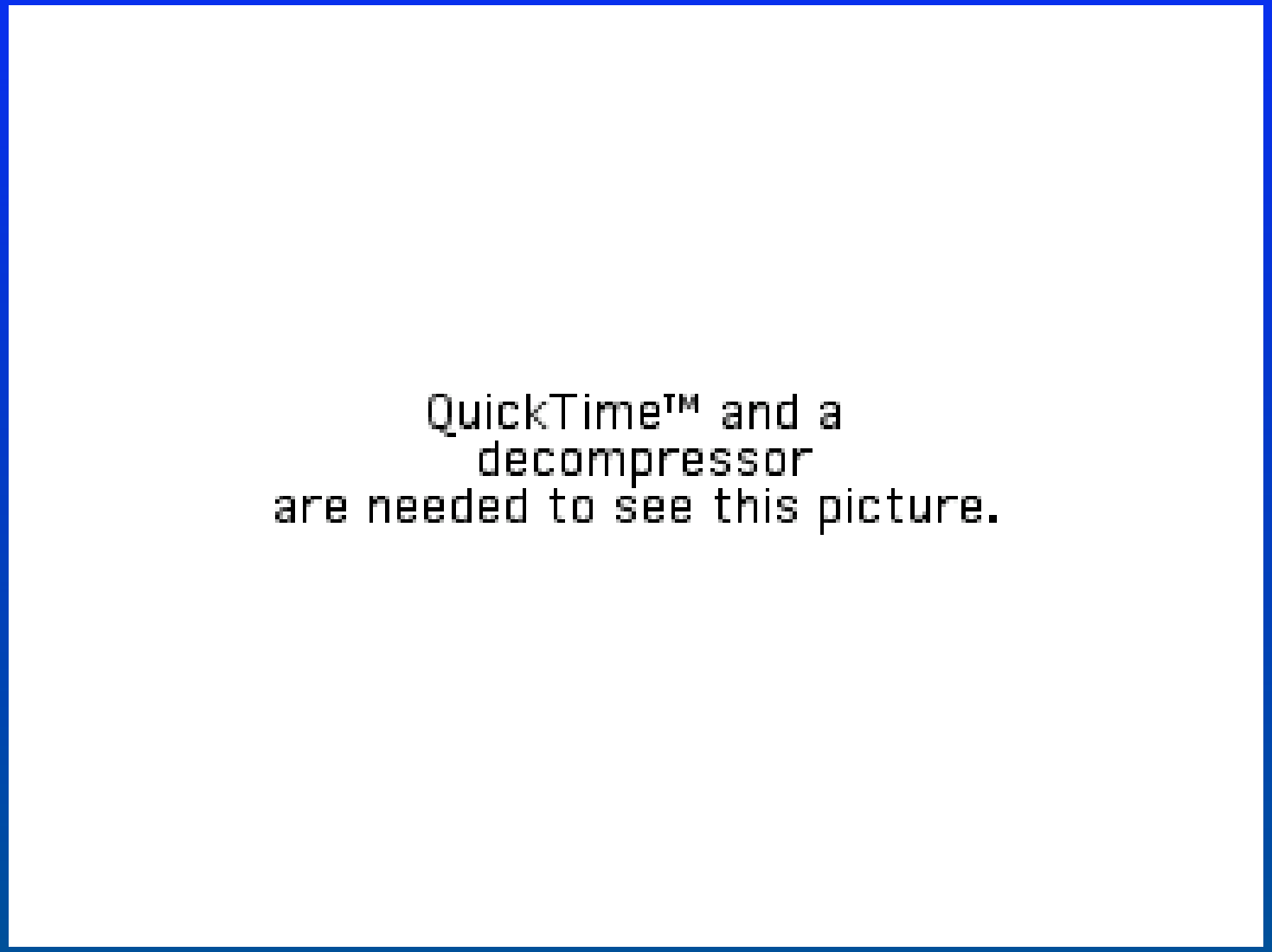
Classic Rattan Baskets

Cloth-Sided Basket

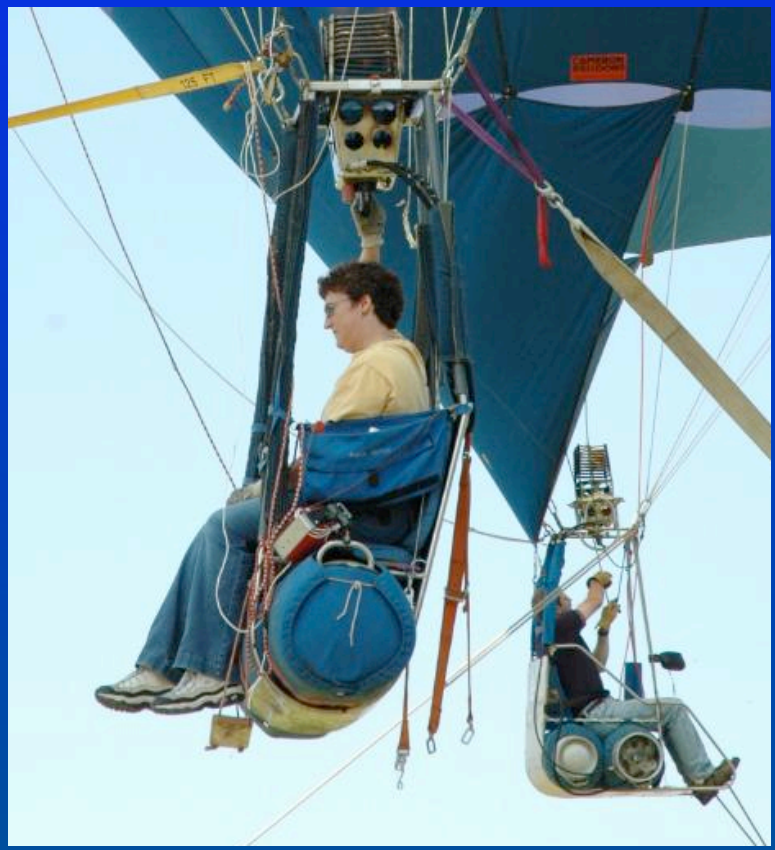
“Trash Can” Basket

Non-basket Designs Hopper-style

A “Sporting” Landing



Non-basket Designs "Chariot"-style



Non-basket Designs
Forden Sled

Basic Design Issues

- Decide on a bottom-end style
  - Aesthetics/Taste
  - Availability
  - Cost
- Selection of heating components
  - Burner
  - Tanks - steel vs aluminum vs composite
- Type and weight of envelope fabric

Basic Envelope Sizing

- A bit less than 20 lbs of lift per 1,000 cubic feet
  - In other words, a bit more than 50 (55 to 60) cubic feet needed for each lb
- Lift determined by max operating temperature
  - Higher temps reduce fabric longevity
  - 250 F typical max
  - Some pilots prefer to keep temps below 200 F to extend fabric life

Sample Weight Budget

Item	Lbs Each	Qty	Subtotal
Envelope	100	1	100
Basket	100	1	100
Burners	2	25	50
Tanks	25	2	50
Hoses	2	5	10
Fuel	4.2	40	84
Misc	50	1	50
Subtotal			444

Gross Lift of a 54K envelope = 54,000/55 = 982 lbs

982 - 444 = 538 lbs available for humans

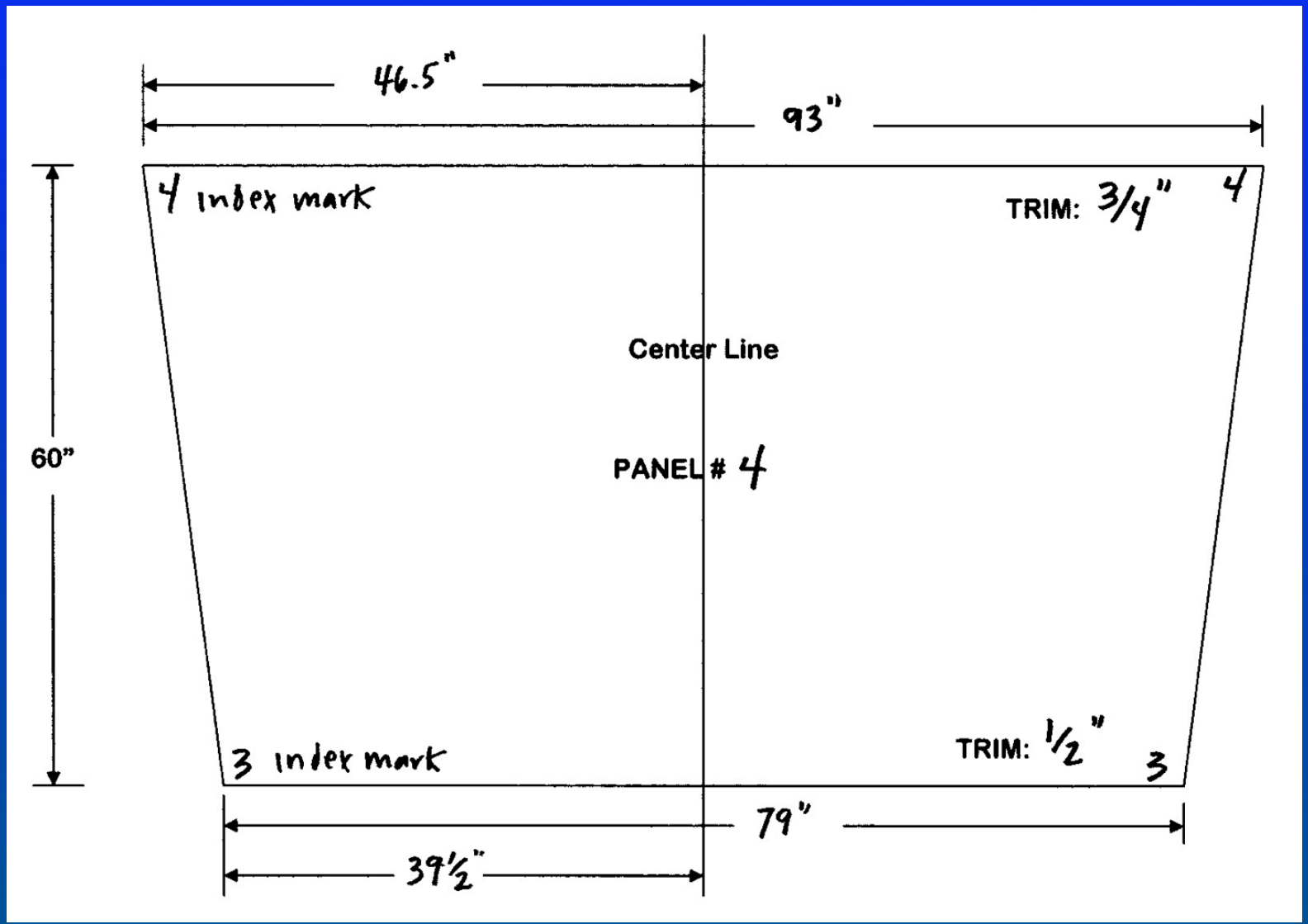
Going from an Envelope Size to an Envelope Pattern

- Use the Smalley spreadsheet
  - Calculates the curve along the edge of gore
  - Lots of secondary calculations required
- Use a pre-made set of plans
  - Purchase from a vendor
  - Convince an experienced designer to help
  - Open Content plans from XLTA.ORG

XLTA.ORG
Open Content
Balloon Plans

- Started via a grant from the Wolf Aviation Trust
- Classic 54,000 cubic foot horizontal full gore
- 16 gores with 13 panels per gore
- Parachute vent in top opening
- “Soup to nuts” -- drawings, parts lists, detailed instructions, rigging line lengths, ...

XLTA.ORG Example Panel



Industrial Fabric Bonding/Sewing

- The Good News
  - Well developed technology
  - Very forgiving of imprecision
  - Easy to inspect
- The Bad News
  - Not for the easily overwhelmed
  - Fabric changes size (temp and humidity)
  - Comedy magnet

Tools !!!

- Industrial sewing machine
  - Lockstitch, double-needle, needle-feed
  - 3/8” gauge (spacing between needles)
- Cutting table -- at least 5’ by 10’
- Hand tools
  - Specialized -- seam rippers, needle threaders
  - Standard -- Scissors, needle-nose pliers, forceps, markers, wallpaper razors, etc

Typical Envelope Build

20 hours - Cutting the fabric
60 hours - Sewing panels into gores
35 hours - Attaching gores together
(There is a trick to sewing the last vertical seam!)
15 hours - Sewing parachute
10 hours - Horizontal tapes
10 hours - Net of webbing at the top
10 hours - Finish and hem top and bottom edges
40 hours - misc

Around 200 hours total build time

Making Life Easier

- When in doubt, use lots of pins !!!
- Listen to books on tape
- Do NOT build a model first !
- To develop your technique, start by sewing the bottom panels first
- Get a friend to help with the cutting
- Cut on a table rather than the floor

Making Life Easier (continued)

- Don't reinvent the wheel
  - Use a set of plans as a guide.
  - Find someone experienced to kibitz
    - Balloon repair shop
    - Experienced builder
- Have a pro make/inspect burners, hoses, and steel suspension wires

Misc Post-Build Tasks

- Build or buy bottom end
- Instruments and gauges - Altimeter, VSI, and temp
- Inflation fan
- Trailer
  - Optional for a hopper
  - Not so optional for larger balloon
- Get airworthiness certificate
  - More or less same process as for an airplane

Safety Tips

- Hire a pro to fabricate and/or inspect
  - burners, hoses, and tanks
  - steel suspension wires
- If you design your own envelope, use a safety factor of 10 for all fabric and webbing
- Run load tapes all the way to the crown ring

What to Do for an Encore

- Build a bottom end
- Artistic envelope designs
  - Color and pattern
  - Non-standard (a.k.a. “special”) shapes

Envelopes with “Art Cuts”

Special Shapes

Special Shapes - “Tet”

Special Shapes - “Tet”

Special Shapes Continued

Current Developments at XLTA.ORG

- Plans for low-cost hopper bottom end
- Plans for envelopes of different sizes
  - Hopper envelope design
- Slides from this talk also available

Resources

- Balloon-makers email list
- Balloon Builder's Journal (BBJ)
- XLTA.ORG
  - comprehensive links page
  - online plans
  - "Building a Balloon in Under a Month" Blog
- People

The Best Resource

Dan Nachbar

XLTA.ORG