# Lighter than Air (LTA) Envelope Manufacturing and Further Considerations for Fabrication of Large Softgoods Structures

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ILC Dover

Airships to the Arctic VI
December 6, 2011
Seattle, Washington

# Topics

- Introduction to ILC Dover
- Manufacturing Airship Envelopes
- Further considerations for Large Lighter Than Air Softgoods Structures

# ILC Dover



**Photo courtesy of Airship Ventures**

**LZN07 "Eureka"**

**Frederica, Delaware Facility**

**Dover, Delaware Facility**


**Dover AFB**

# Company Overview

Recipient of NASA's George M. Low Award for Quality and Excellence


Privately held (Behrman Capital)

## 420 Skilled Employees

- Engineering 25%
- Manufacturing 44%
- Quality 10%

(40 on site at NASA - Houston)
(40 on site at NASA - Houston)

## Quality Oriented Systems

- Registered to ISO 9001:2008
- NHB-5300.4 (1D-2), MIL-Q-9858A, and MIL-I-45208A quality and inspection systems
- AS 9100 Compliant
- Lockheed Martin Star Supplier

## Extensive Facilities

- 280,000 sq ft total (163,000 sq ft High Bay Production)
  - ⇨another 60,000 sq ft entered production in May 2010
- Development, Test Lab, Fabrication, and Production Areas

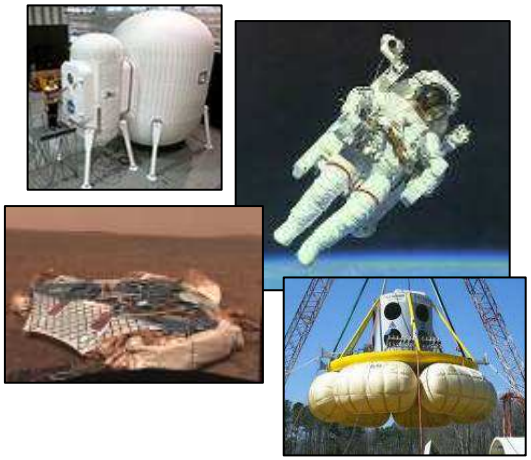
**Established in 1947**

**Origins from International Latex Corporation (ILC, Playtex & Reichold Chemical Corporation)**

# Product Overview

**Design & Manufacturing Experience since 1947**

**Space**

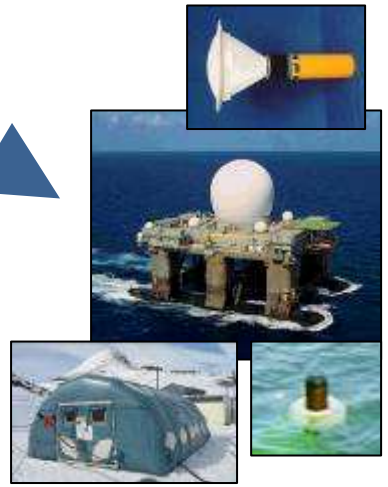


**Lighter-Than-Air**


**Protective Equipment**

**Industrial**

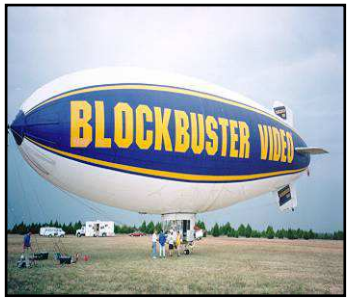
**Engineered Inflatables**



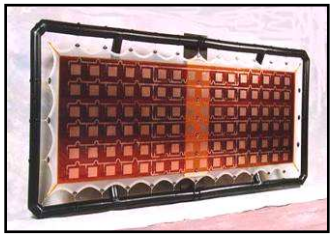
**We leverage our competencies in materials, softgoods design and manufacturing to create highly safe & reliable products that protect people & equipment in hostile environments**

# Core Competencies

**Engineering / Design**
- Using softgoods to solve life critical problems
- Designing softgoods to replace traditional hard elements
- Designing articulated soft pressure vessels

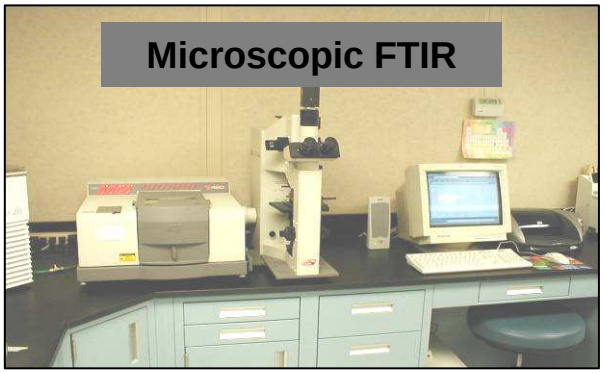



**Materials Development**
- Structural containment for use in extreme environments
- Barrier films
- Structural /Laminated materials

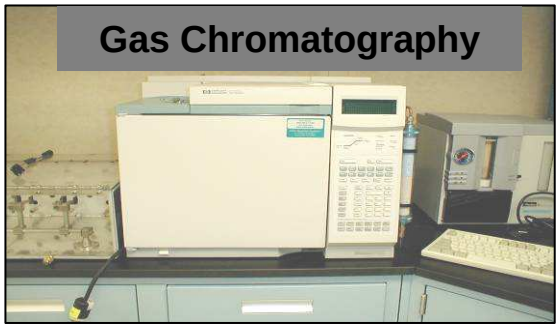


**Manufacturing**
- Production, inspection and testing of large inflated structures
- Precise, reliable sealing for critical applications

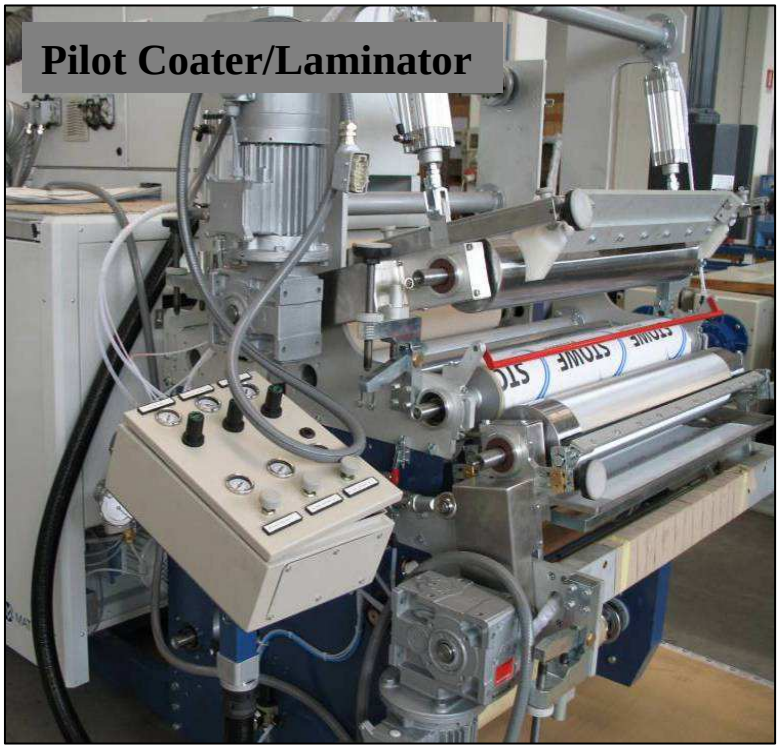
# Key Capabilities: Materials Development and Analysis







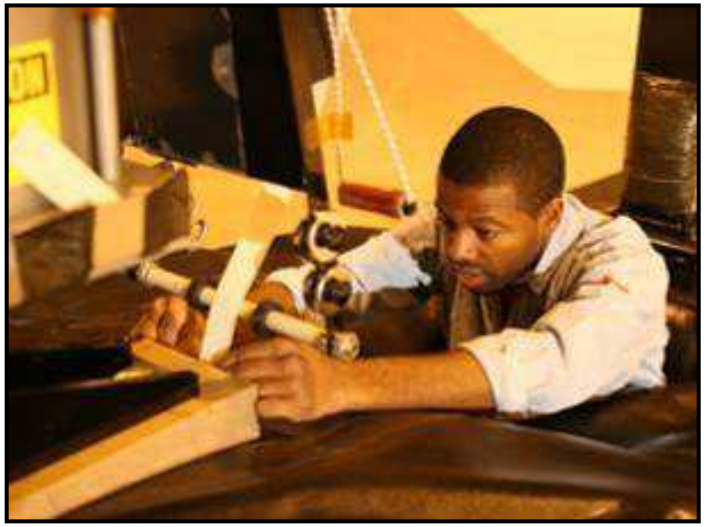



# Key Capabilities: Test Resources

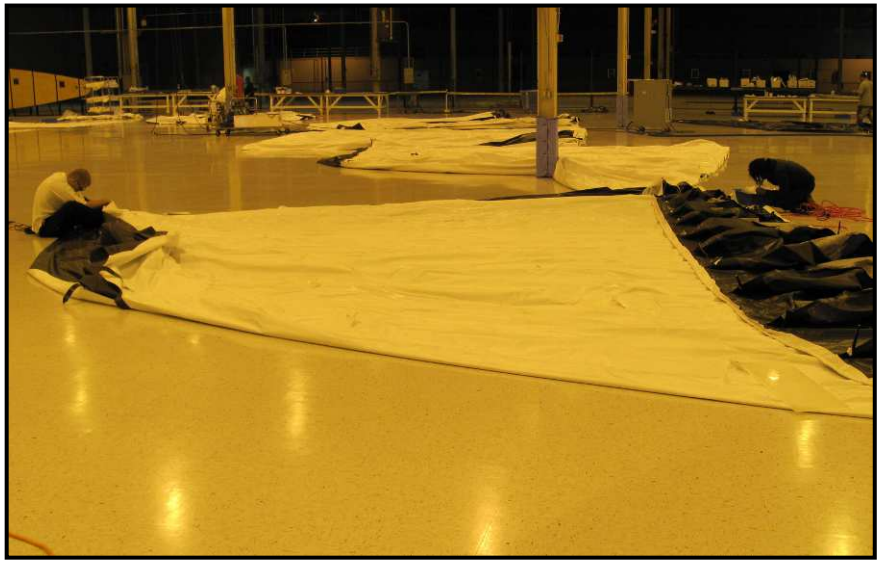
## Capable of Performing a Wide Range of Testing in the Rubber, Plastic, Composite and Textile Fields

- Instron Tensile/Compression Testing at
  - Ambient or Service Temperature
  - Extremes (cryo to 600F)
  - Bi-Axial loading
- Accelerated Aging
  - QUV
  - Chamber Ovens
  - Environmental Chamber, Selected Temperature and Humidity
- Gas Permeability Testers
- Abrasion Testers
- Flex Fatigue (several)
- Electrical Properties - Surface and Volume Conductivity
- Specialty test fixtures
- Protection Factor Test machines & chambers
- Manned test area and environmental chamber

# Key Capabilities: Manufacturing



- **190 Trained Manufacturing Personnel**
- **30 Trained Softgoods Inspectors**
- **125+ Heat Sealers**
- **In house heat sealer design and fabrication**
- **More than 220,000 ft$^2$ of High Bay production**




# ILC Dover LTA Experience

# Aerostat/Airship Experience 1982-2011

| Description | Envelope Size ($ft^3$) | Quantity Built | Customer | Deployment Location |
|---|---|---|---|---|
| StarTower | 20-40,000 | 2 | Global Near Space | US |
| 56K/56KXL Aerostat | 56-64,000 | 27 | GE/Lockheed Martin | Caribbean, UK, Iraq |
| A-60+ | 68,000 | 27 | American Blimp | Worldwide |
| 74K Aerostat | 74,000 | 94 | Lockheed Martin | Iraq, Afghanistan |
| A-150 | 150,000 | 10 | American Blimp | Worldwide |
| A-170 | 170,000 | 4 | American Blimp | Worldwide |
| A-170G | 170,000 | 1 | American Blimp | Worldwide |
| 275K Aerostat | 275,000 | 16 | GE/USAF | Florida |
| LZN07 | 300,000 | 5 | Zeppelin | Germany, Africa, Japan, US |
| CycloCrane | 330,000 | 1 | AeroLift | Oregon |
| 365K Aerostat | 365,000 | 5 | TCOM/Westinghouse | Israel |
| 420K Aerostat | 420,000 | 25 | Lockheed Martin/TCOM/ITT | Caribbean, Southern US |
| HALE-D | 500,000+ | 1 | Lockheed Martin | US |
| 595K Aerostat | 595,000 | 5 | GE | Caribbean, Southern US |
| Logging Balloon | 620,000 | 2 | Skyhook | British Columbia |
| LEMV | 1,400,000 | 1 | Northrop Grumman | US |
| AirCrane | 4,000,000 | 1 | TCOM/Cargolifter | US |

**200+ Lighter than Air Envelopes Delivered Worldwide**

# 56K/74K Aerostats

## Purpose: Surveillance, Airspace Control, Drug Interdiction


**Volume: 74,000 $ft^3$ (2,095 $m^3$)**

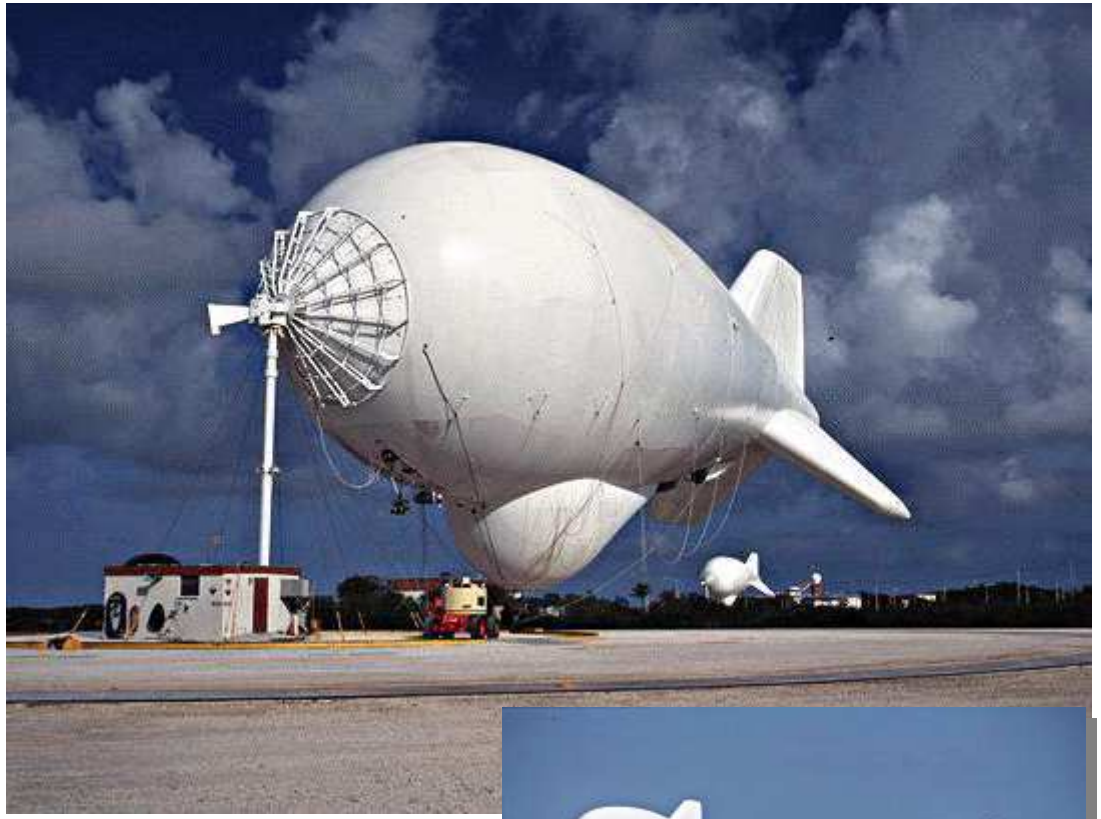
**Major Diameter: 39.0 ft (11.9 m)**

**Length: 119.0 ft (36.3 m)**

**Payload/Altitude: 1,100 lb to 4,900 ft (500 kg to 1,500 m)**

# 275K Aerostat

## Purpose: Surveillance, Airspace Control, Drug Interdiction



**Volume: 275,000 $ft^3$ (7,788 $m^3$)**

**Major Diameter: 62.5 ft (19.1 m)**

**Length: 187.0 ft (57 m)**

**Payload/Altitude: 1000 lb to 12,000 ft (454 kg to 3,658 m)**

# 420K Aerostat

## Purpose: Surveillance, Airspace Control, Drug Interdiction

**Volume: 420,000 $ft^3$ (11,895 $m^3$)**

**Major Diameter: 69.5 ft (21.2m)**

**Length: 208.5 ft (63.6 m)**

**Payload/Altitude: 2000 lb to 15,000 ft (908 kg to 4572 m)**

# ABC Lightships

## Purpose: Advertising


**Volume: 68,000 to 170,000 ft$^3$**

**Major Diameter: up to 43 ft**

**Length: up to 125 ft (38.1m)**

**Capacity: up to 10 People**

# Zeppelin Airship

## Purpose: Passenger Flights, Advertising, Environmental Survey,


**Volume: 300,000 ft (8,496 m$^3$)**

**Major Diameter: 46.5 ft (14.2 m)**

**Length: 234 ft (71.3 m)**

**Capacity: 14 people**

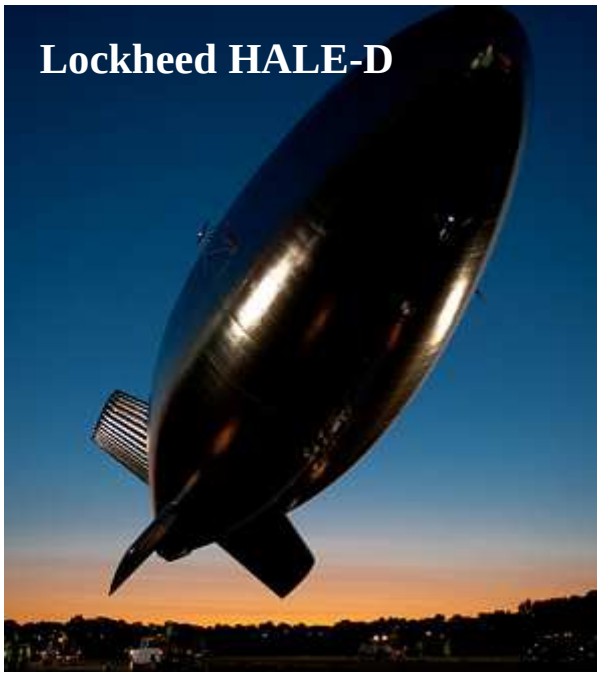
**Foreground: Internal Frame**



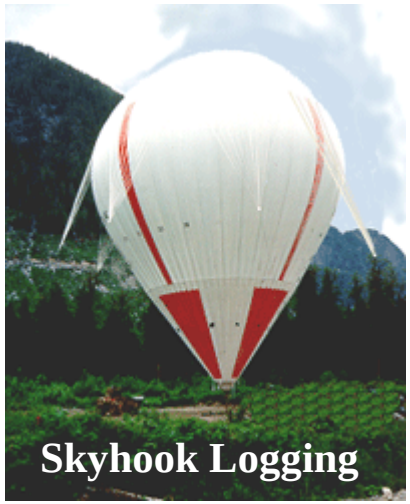
**Background: Envelope during proof testing**

# Other Lighter Than Air Programs





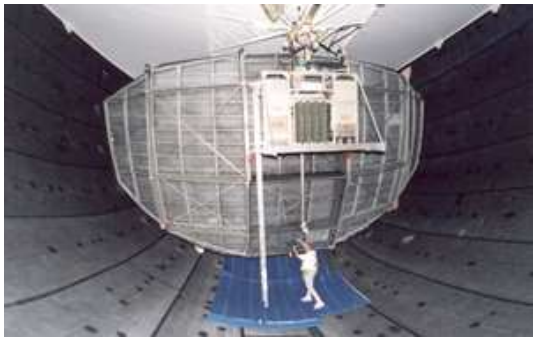


# Manufacturing of an LTA Envelope

- Define Requirements
- Design
- Fabrication
- Checkout

# Requirements Definition

- General
  - Purpose
  - Geometry
  - Configuration
  - Volume
  - Mass
  - Pressurization Gas
  - Service Life
  - Manned/Unmanned



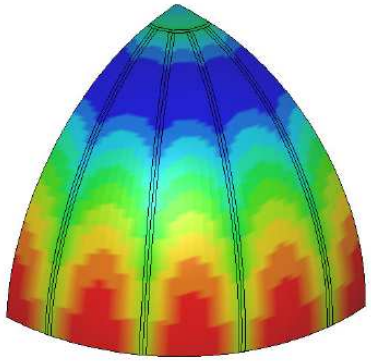
- Operational Environments
  - Temperature Min/Max
  - UV exposure
  - Humidity
  - Ozone
  - Dust
  - Mold/Mildew
  - Packing/Unpacking Cycles
  - Field Repairability

- Structural Load Requirements
  - Static Pressurization Loads
  - Aerodynamic Loads
  - Thermal Loads
  - Payload Locations/Size/Weight
  - External Attachment Locations and Loads

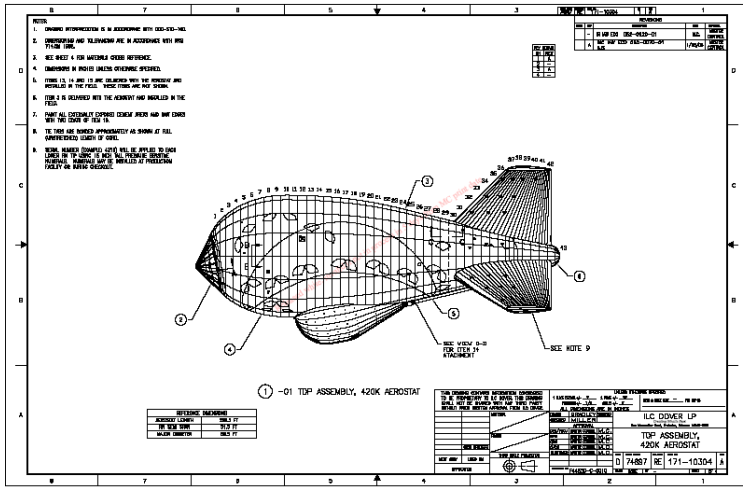


- Other Design Considerations
  - FAA Certification Requirements
  - Color/Reflectance/Transmittance/Absorbtivity
  - Radar Transmittance

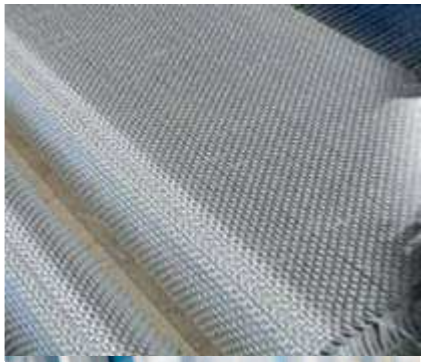
# Design Effort



- Analysis
- Materials and Seam Development and Testing
- Subassembly Design and Testing
- Develop Production Documentation



# Materials and Seam Development and Testing



Pilot Coater/Laminator

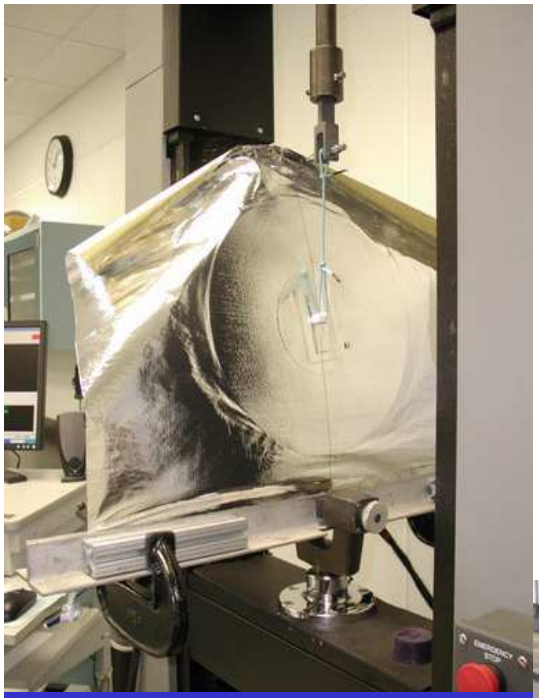
- Material Selection
  - Fabric
    - Fiber
    - Denier
    - Count
    - Twist
    - Weave
  - Films
    - Type
    - Thickness
  - Adhesives
    - Chemistry
    - Adhesion
    - Thickness
    - Color
- Material Testing
  - Weight
  - Tensile
  - Modulus
  - Tear
  - Width
  - Adhesion
  - Seam Strength
  - Seam Durability
  - Permeation
  - Resistance to Pinholing
  - Environmental

Adhesion Testing

High Temp/High Humidity Seam Test

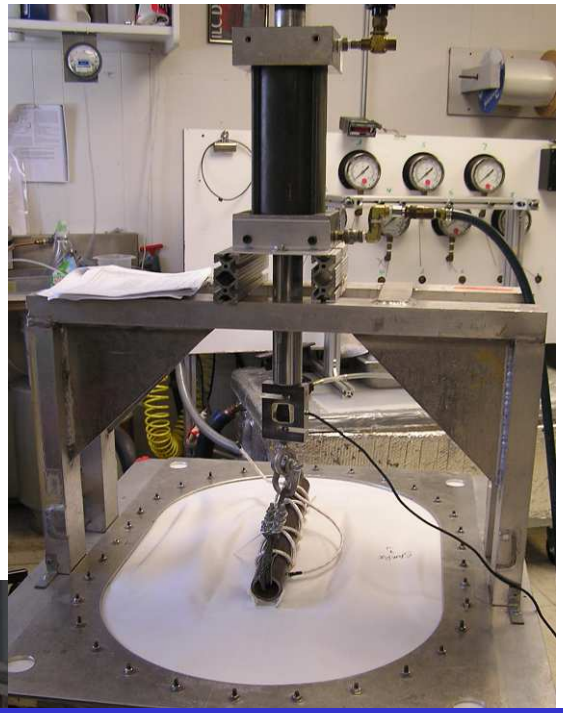
Design

# Subassembly Design and Testing



Tie Tab Testing

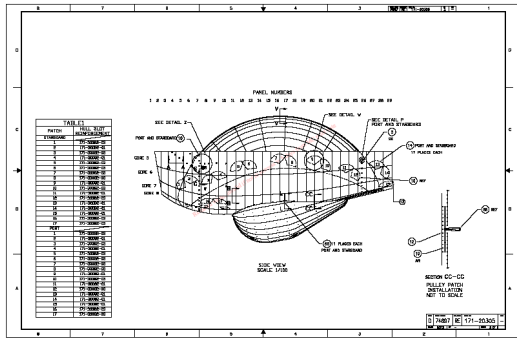
- Iterative Process
  - Analyze
  - Design
  - Fabricate Samples
  - Test



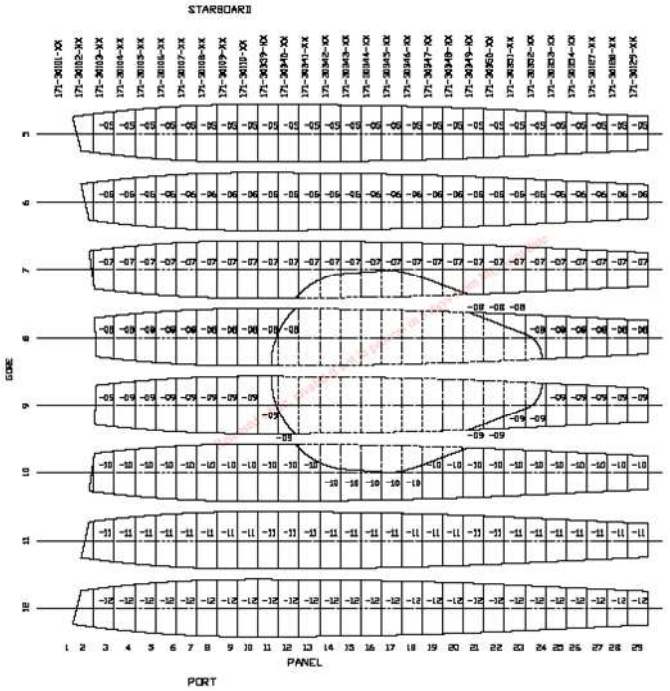
Lacing Strip Testing

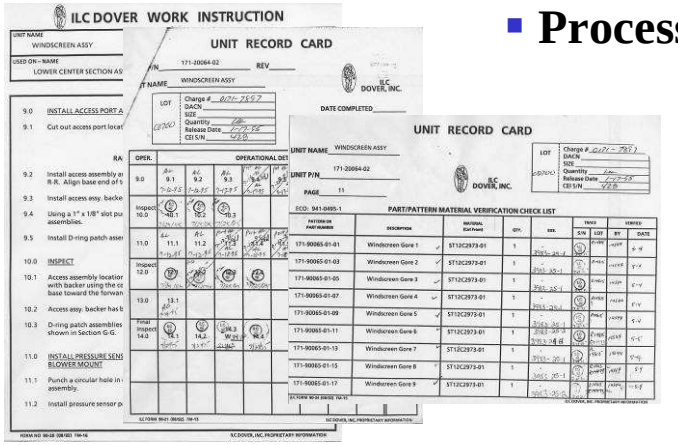
Load Patch Testing

# Documentation



- Specifications
- Drawings
- Work Instructions
- Cut Files
- Manufacturing Specification
- Standard Repair Procedure
- Process Control Cards




LTA
Process Control Card

Date Issued: 11/30/2011
Last Revised: 11/30/2011
Machine No.: 05 8" HEAD

| Materials: | | Machine Set-Up Info: | |
|---|---|---|---|
| Base Material: | ST12C2995-XX | Controller Setpoint: | NA |
| Structural Tape: | ST12C2977-XX | Pyrometer Temp (F): | 250 F, +/- 5 |
| Cover Tape: | ST12T2988-XX | Dwell Time (sec): | 20 +/- 5 |

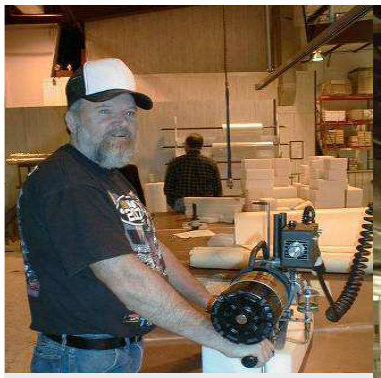
Fabrication

# Receiving Inspection

- Trained inspectors inspect all incoming material to specifications
- Certified mechanical inspectors who dimensionally check hardware including tooling to customer/drawing specifications
- Responsibilities:
  - Verify product meets or exceeds specifications through, visual/dimensional inspection
  - Prepare and process any test requirements Review test data results for compliance
  - Review supplier certifications
  - Light box material for defects when specified
- Acceptance Testing performed by Test Lab
  - Complete Standard Fabric Test Capabilities

Fabrication

# Precision Cutting



STACK CUT

DIE PRESS

LASER CUTTER

100' WHEEL CUTTER

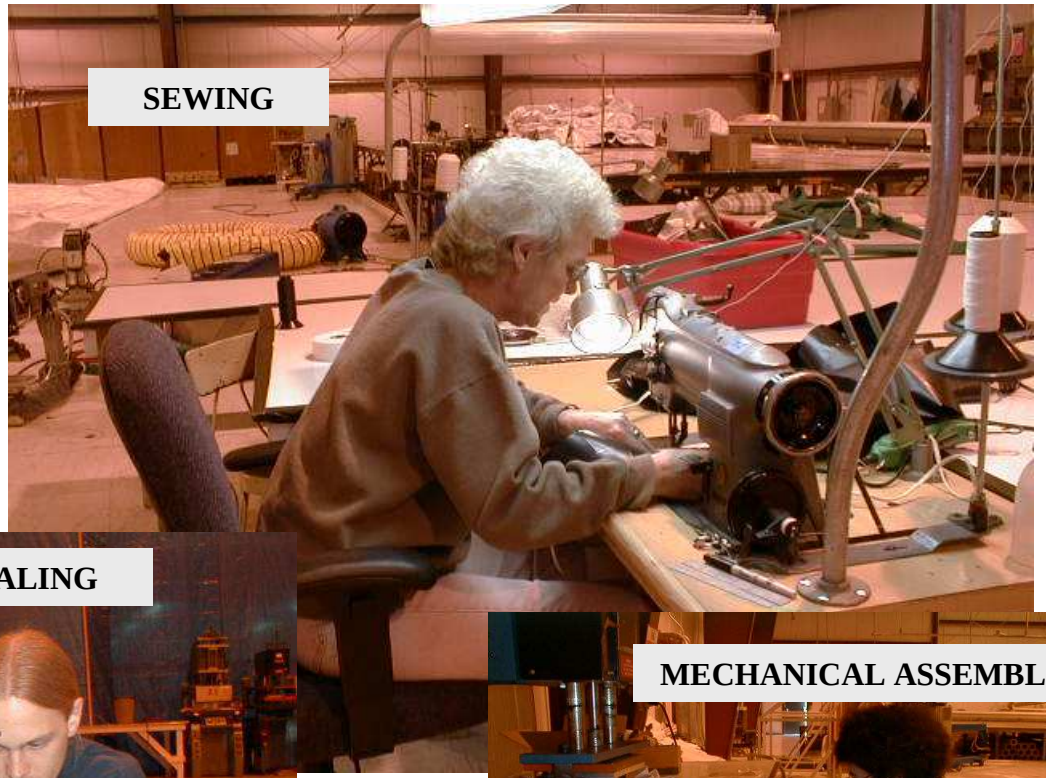
- Cut Files Developed using Computer Aided Design
- Files reviewed, approved and released in ILC Configuration Management System
- Three CNC Wheel Cutters
- Other methods
  - Laser cutting
  - Reciprocating knife
  - Die Press

Fabrication

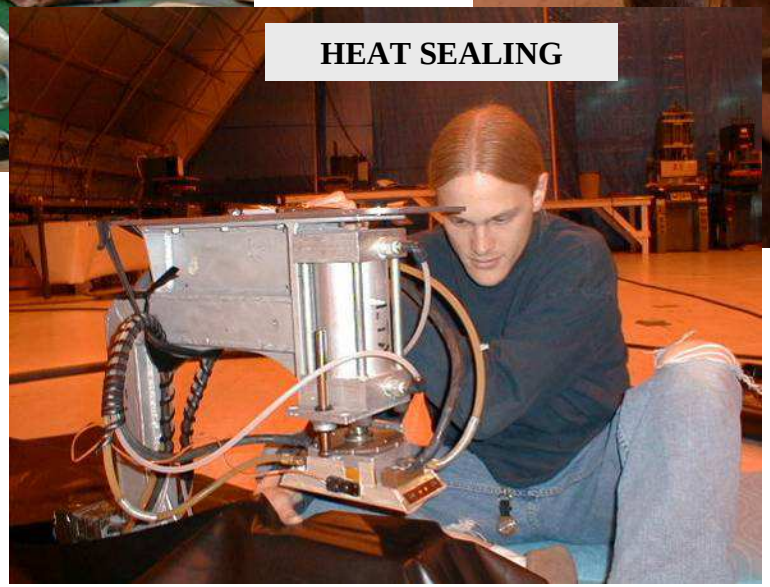
# Subassembly Fabrication

**ADHESIVE BONDING**

**SEWING**



**HEAT SEALING**



**MECHANICAL ASSEMBLY**

Fabrication

# Subassembly Installation

HEAT SEALING

PAINT/SEALANT

ADHESIVE BONDING

Fabrication

# Panel Sealing


8' SEALER

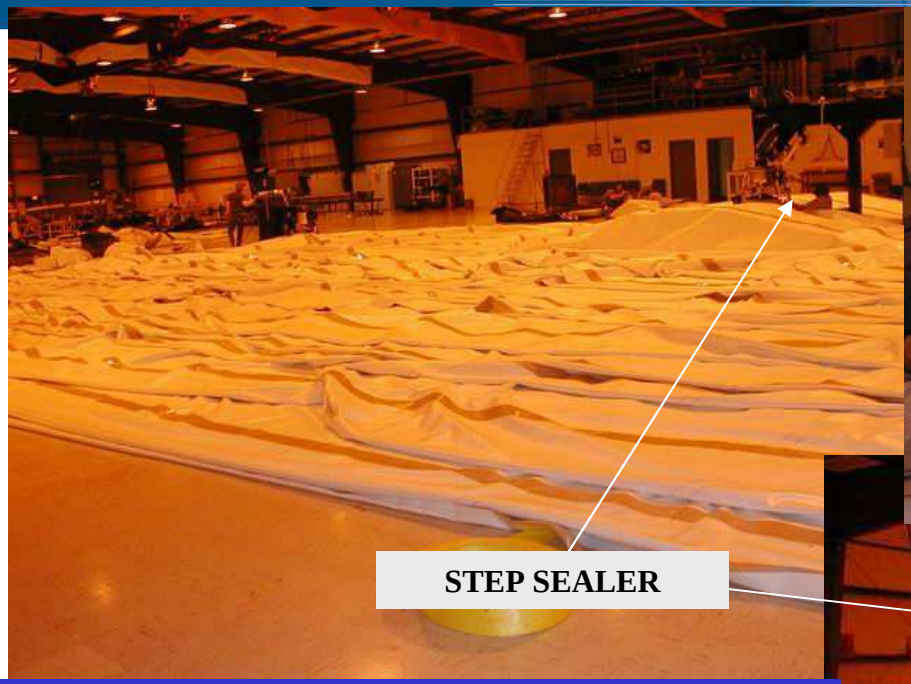
- Panel Seams are all straight seams
- Sealer: 8' Sealer or Step Sealer
- Gore is still flat following panel seaming and can be rolled up for storage and handling.

GORE ROLLED AFTER PANEL SEALING

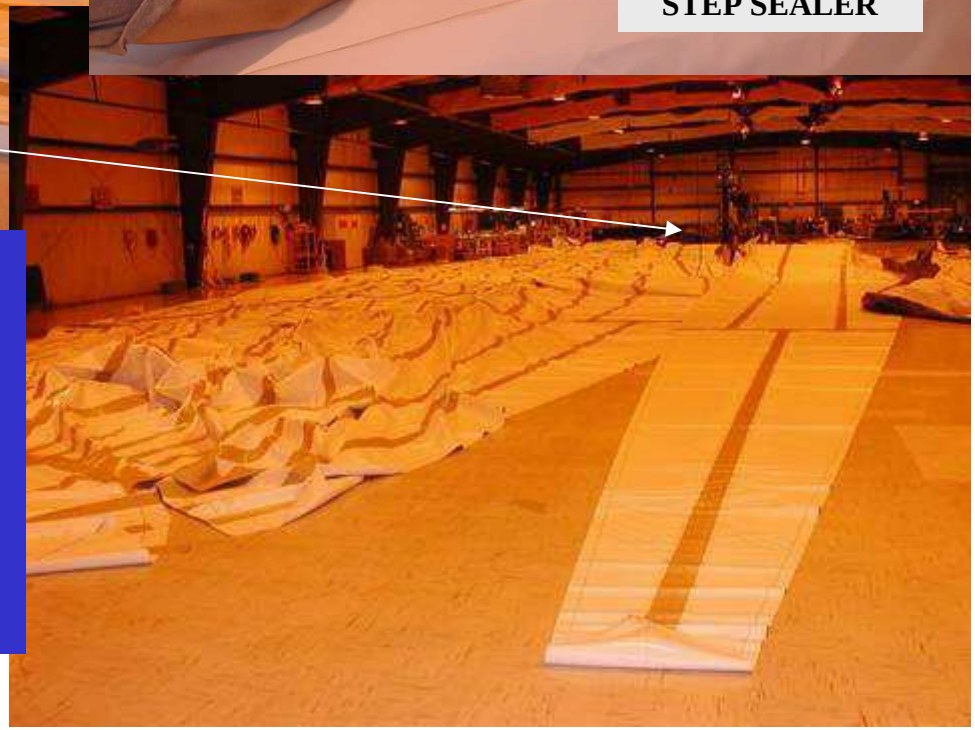
STEP SEALER

Fabrication

# Gore Sealing




STEP SEALER



- Gore Seams are curved
- Sealer: Step Sealer or small portable sealer
- Assembly will no longer lay flat after joining two gores.

Fabrication

# Join Major Sections

INSTALL ENDCAP

- More complex seams due to geometry (endcap) and materials handling
- Sealer: Step Sealer or small portable sealer

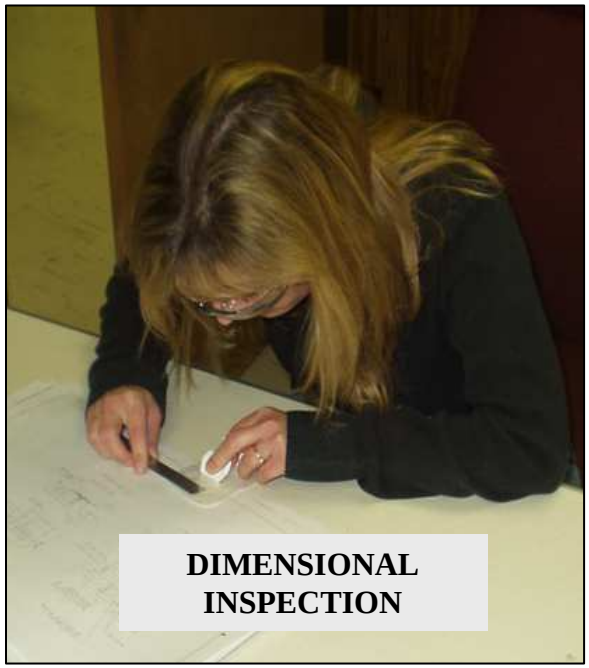
SMALL SEALER

Fabrication

# In Process Inspection and Test

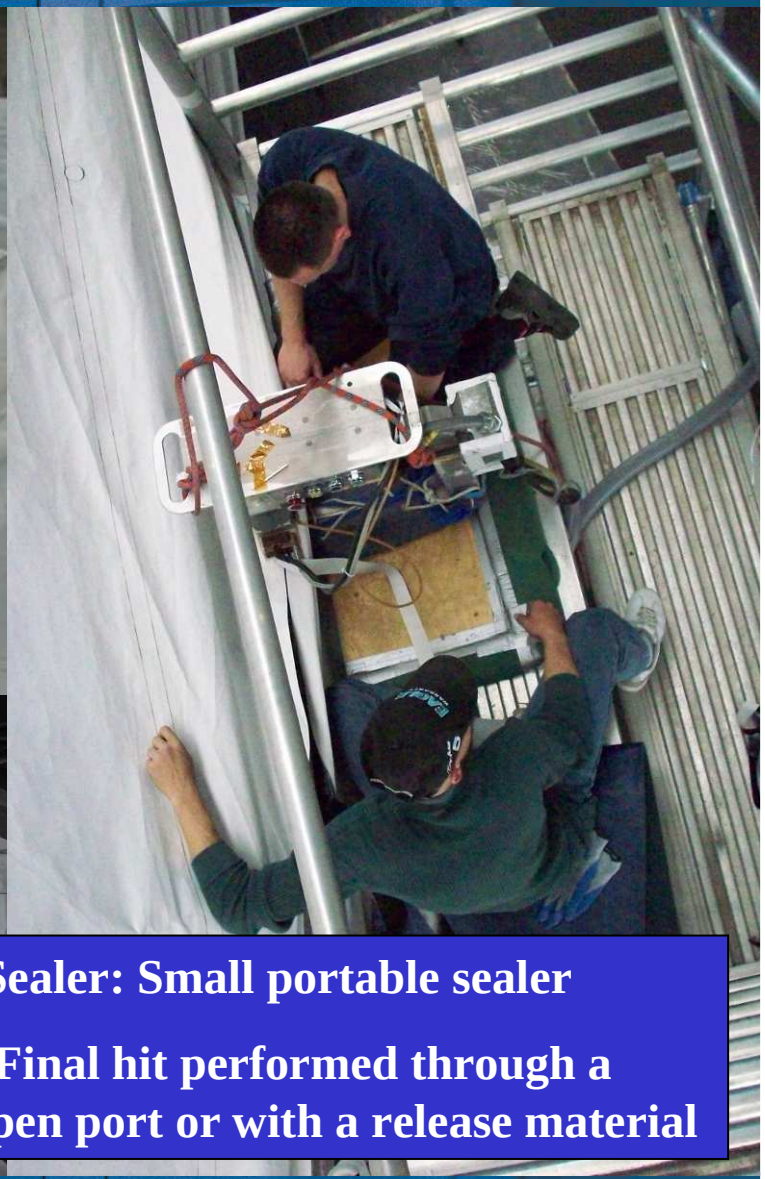
- Daily Sample for Heat Seal and Adhesive Bonding
- 100% Visual inspection of all seams and installations
- Critical Subassemblies tested prior to integration





Fabrication

# Final Closing Seam



- **Sealer: Small portable sealer**
- **Final hit performed through a open port or with a release material**

Fabrication

# Packaging for Shipment




- **Envelope packed manually for shipment to checkout location.**
- **Envelope is packaged in protective film and transported in shipping container (ISO or export quality crate)**

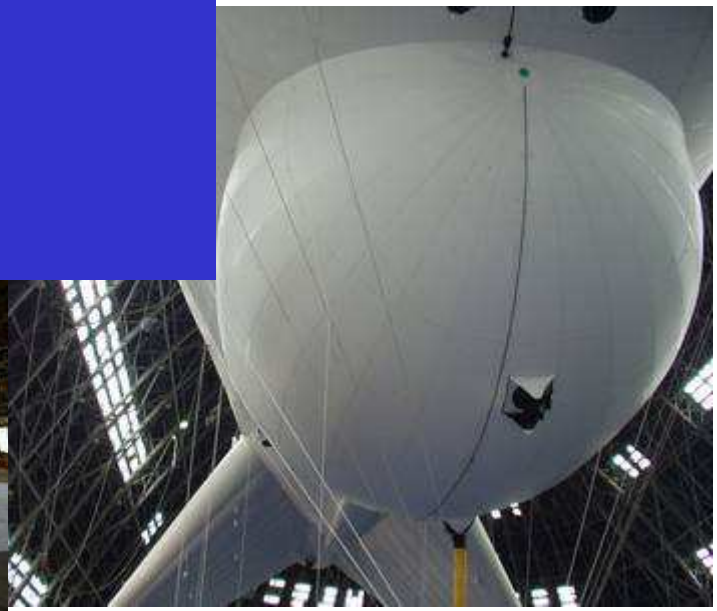




Fabrication

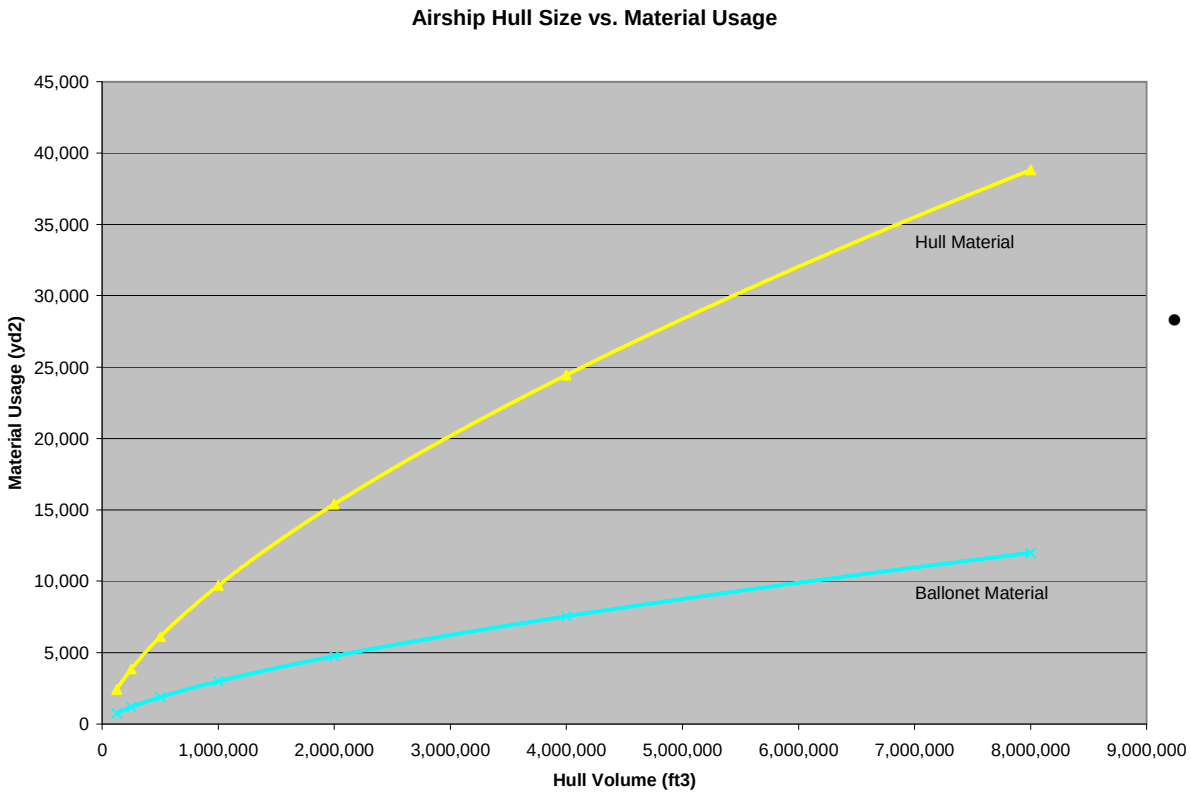
# Final Envelope Acceptance

- Final acceptance takes place offsite due to production building height limitations
- Typical acceptance testing includes:
  - Inspection
  - Proof Pressure Test
  - Leak Test



# Materials

- 420K Aerostat requires:
  - ~ 2.5 acres of custom materials
  - ~ 12 miles of custom tapes




- Current State of the Art LTA Materials are limited to ~ 60" width
- Wider Materials are highly desirable for larger envelopes
  - Reduced Material cost
  - Reduced labor cost
- Larger Envelopes will need increase tensile, tear and seam performance
  - High Tenacity Fibers
  - Increased Adhesion for high load high durability seams

Further Considerations

# Material Handling

- The key to efficient large envelope fabrication is to minimize materials handling
- Envelope sections take up significant space (600,000 $ft^3$ envelope requires > 30,000 $ft^2$ of floor space)
- Large and Typically Heavy In-Process section which require movement and folding during the production process
- Must allow for brief but significant manpower
  - Sections need to be properly staged
  - Precise scheduling to coordinate the manpower needs with the production demand

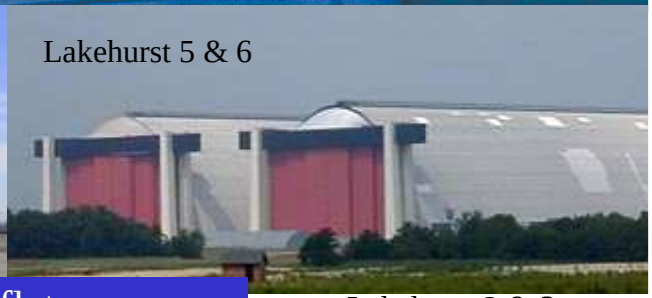
ILC DOVER
creating what's next

Further Considerations

# Final Assembly/Hangar Space


Moffet 1

Moffet 2 & 3


Lakehurst 5 & 6


Tustin 1 & 2


Lakehurst 2 & 3

- There are relatively few hangars big enough to inflate even small airships
- As ships increase in size the list drops of dramatically
- Larger Envelopes will likely be fabricated in transportable sections and final assembled at the integration and checkout site
- Assembly site can be co-located at the final assembly site
- Current airship designs are limited to the size and availability of the existing structures
- Selecting the Final Assembly/Integration site can be a Program driver and needs to be settled early in the program

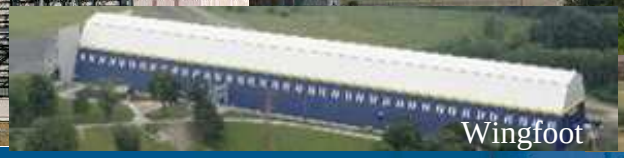

Lakehurst 4


Tillamook

Pompano


Lakehurst 1


Weeksville


Wingfoot


AirDock

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