



**LaACES
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Ballooning
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Mechanical Design Guidelines



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Mechanical Design Topics

- How to produce mechanical drawings
- What mechanical interfaces do you need to specify
- How do material choices affect your payload
- What are the steps for producing a sound mechanical design
- What should your testing procedure be
- Handy, pocket size reference book is “Pocket Ref” by Thomas J. Glover available at ACE Hardware stores.



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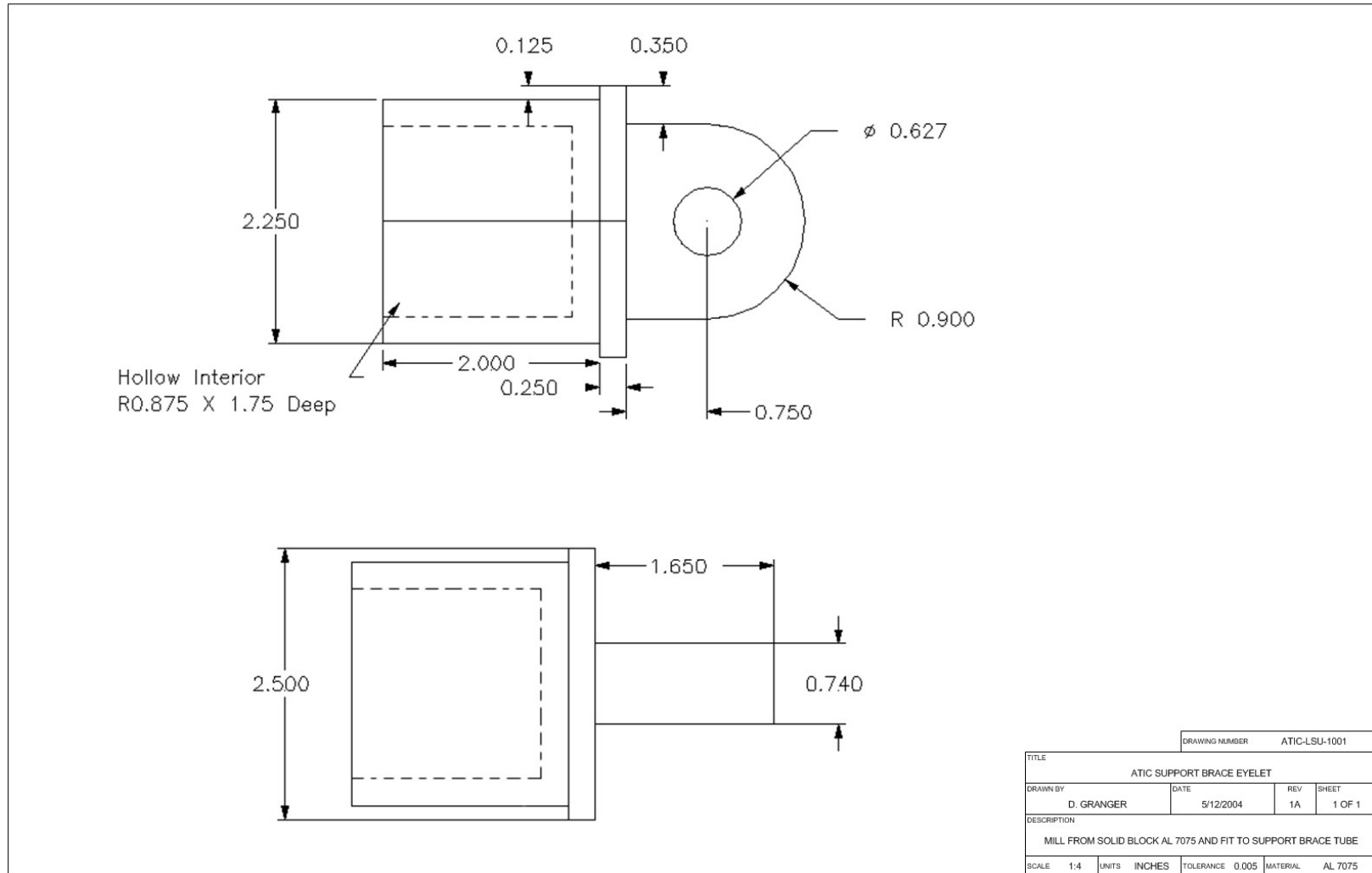
Reasons for Producing Drawings

- Aide to configuration planning
 - Help determine what components are needed
 - Determine how components will go together
 - Check that dimensions & locations are consistent
- Specify what is to be built
 - Proper drawings are needed by shop personnel
 - Communicate with management & reviewers
- Document what has been built
 - Track changes in the configuration
 - Provide record of experiment configuration



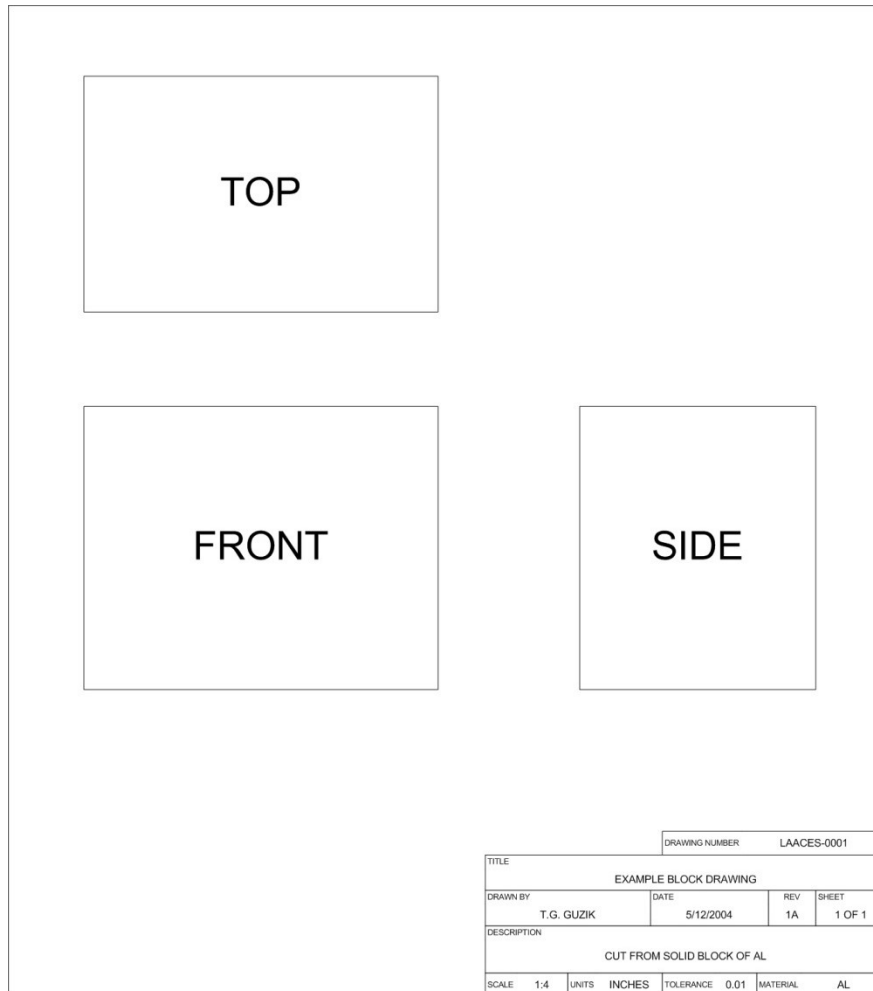
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Sample Drawing





Basic Views in a Drawing



- Most drawings provide Top, Front and Side views
- What the component would look like if viewed from that direction
- Views arranged usually as if object were unfolded
- Sometimes an isometric (3D) view is provided



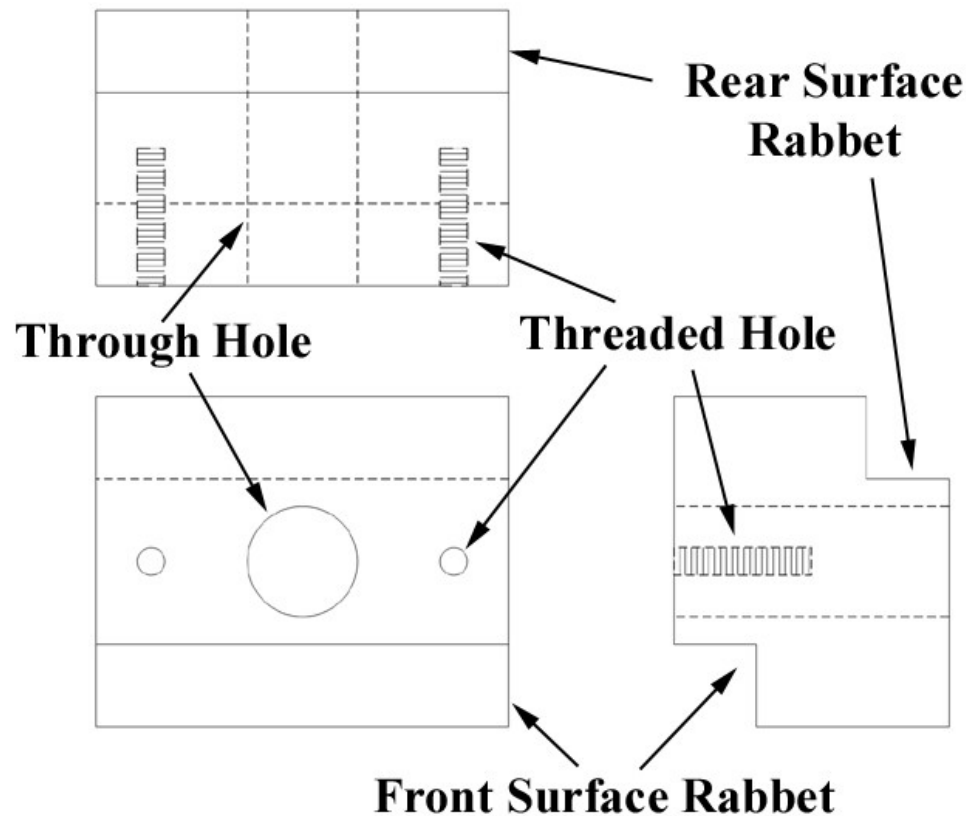
Drawing Label

- The label provides all of the information necessary to interpret the drawing and track revisions
- Included in the label should be a drawing number, title, author, date, revision number, sheet number, scale, units, tolerance, material and a description of any other relevant information

		DRAWING NUMBER		LAACES-0001	
TITLE					
EXAMPLE BLOCK DRAWING					
DRAWN BY		DATE		REV	SHEET
T.G. GUZIK		5/12/2004		1A	1 OF 1
DESCRIPTION					
CUT FROM SOLID BLOCK OF AL					
SCALE	1:4	UNITS	INCHES	TOLERANCE	0.01
				MATERIAL	AL



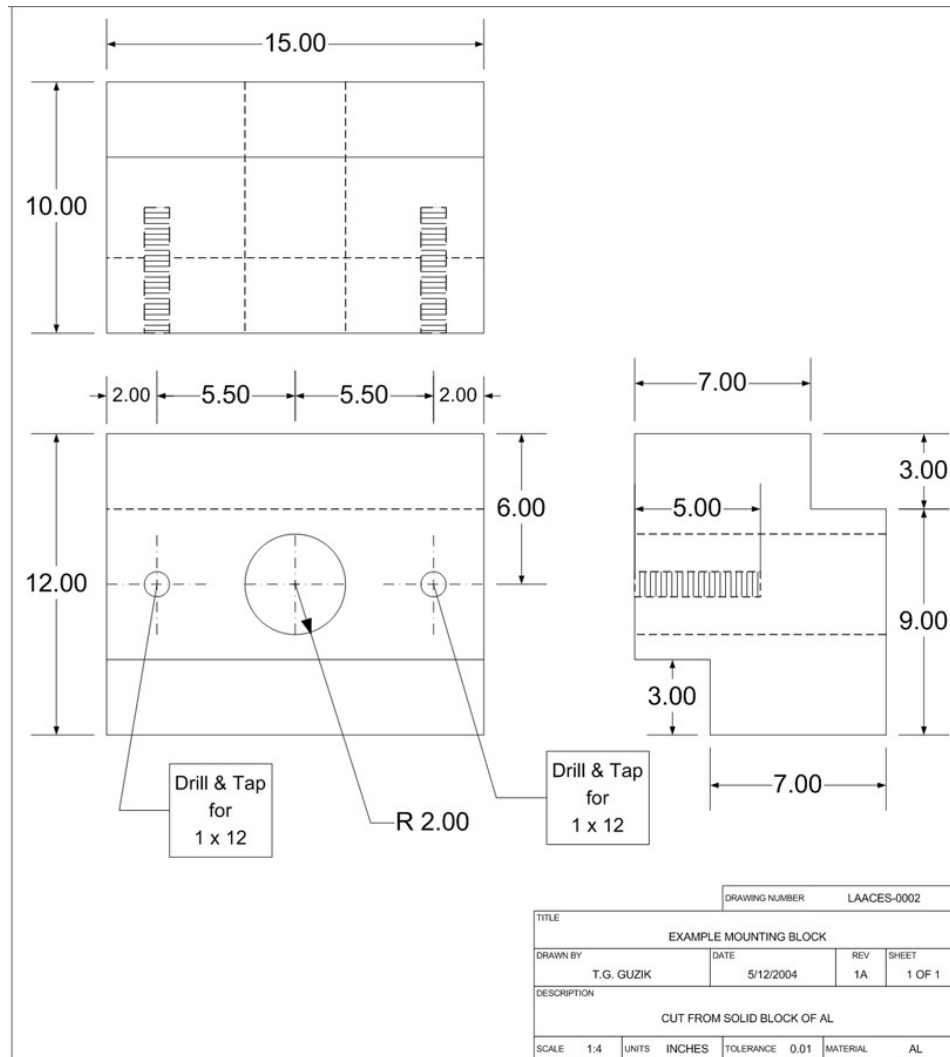
Representing Hidden Surfaces



- Surfaces that can be seen in a particular view are indicated by a solid line
- Surfaces that are “hidden” are indicated by a dashed line
- Through holes are solid circles face on and dashed for side view
- Threaded holes have perpendicular or diagonal dashing to indicate screw threads



Putting Dimensions on the Drawing



- All surfaces, holes & cuts should be dimensioned to specify location, width, length & depth
- Consistent with units and tolerance specified in label
- Reference to common surface or point
- Holes are specified with a radius for clearance
- Threaded holes are specified with a screw size & depth
- Callout boxes provide addition information



Mechanical Interfaces

- There are multiple interfaces that you will need to identify, specify and control
- Component to component interfaces
 - Where and how does each part of your experiment contact another part?
 - Electrical connectors, motors, actuators, hinges
- Component to payload structure interfaces
 - Where and how do you secure your experiment components within the payload box?
- Payload to balloon vehicle interface
 - Interface already specified in LaACES balloon vehicle lecture
 - How will you implement this interface?
- Your documentation should list all your interfaces and specify how they will be implemented and controlled



Material Considerations

- When you choose materials for your payload you need to consider how they will affect your payload
- How will a material affect your sensors?
 - Iron / steel will distort the readings of a magnetic sensor
 - Will your observation port window transmit the desired frequencies?
 - Will the material outgas and affect the sensor readings?
- How will a material be affected by the environment?
 - The intense cold can embrittle many plastics and glues
 - Non-rigid, closed cell foam will expand dramatically in vacuum
- How much does a material weigh? Is there a lighter material that will do the same job?
- When in doubt obtain a material sample and test it.



Weight Budget

- Early on in your project establish a weight budget
- List of ALL payload parts, their weight, a weight uncertainty, the weight total and the uncertainty in this total
- Weights can be estimated, calculated or measured
 - Largest uncertainty for estimated, smallest uncertainty for measured
- Initially keep a contingency of $\sim 20\%$ to cover missing items and weight uncertainty
 - The more complete (number of items, measurements instead of estimates) your weight budget is, the lower the contingency needed
- As your design matures your weight budget should include more details, more measured components, lower uncertainty and lower contingency



Payload Design Questions 1

- **Component Layout:**
 - How many components does your experiment have?
 - Where do these components need to be located?
 - Are there issues where components need to be kept separate?
- **Component Access:**
 - What components need to be frequently accessed (e.g. on/off switch)?
 - What components need to be infrequently accessed (e.g. configuration DIP switches)?
 - If a component needs to be replaced how will this be done?
- **Component Mounting:**
 - Are there any critical alignment issues with sensors?
 - How will components be secured to not come loose during flight?



Payload Design Questions 2

- Payload Integration:
 - In what order are components assembled to produce the completed payload?
- Thermal Control:
 - What payload surface treatments are necessary to control thermal properties?
 - How much insulation of what type located where is necessary to protect critical components?
 - Do you need active thermal controls (e.g. heaters)?
- Strength:
 - How will you determine that your structure is strong enough to survive the balloon flight without falling apart?



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Develop a Testing Plan

- Many design issues can be quantified by testing under controlled conditions
- Such a Test Plan needs to address the following issues:
 - What components or systems need to be tested?
 - What test data needs to be collected?
 - What tests need to be performed?
 - What is the test procedure?
 - How will the data be recorded, analyzed and documented?
- Need to assure payload will survive the flight environment
 - Thermal testing for the extremes of hot and cold
 - Vacuum testing for the low pressure at high altitude
 - Shock testing for when balloon bursts and payload lands



Major Tests

DG1

- Develop prototypes or mock-ups
 - Test component layout and mounting
 - Develop specifications for mechanical interfaces
 - Thermal Vac chamber testing and shock testing for strength
- Thermal testing using dry ice
 - Tropopause temperature get down to $\sim -60^{\circ}\text{C}$ and dry ice surface temperature is -78.5°C
 - Test glues and other materials for embrittlement
 - Test thermal insulation properties
- A small vacuum bell jar can simulate the pressure environment
 - Material outgassing, expansion, high voltage corona / arcing, etc.
- Major shock is on landing
 - Nominal decent rate is 20 fps, so drop test article about 10 feet

Slide 15

DG1

See if you can fit a line about the Thermal Vac chamber for testing

Doug Granger, 2/3/2020



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References

- [“Pocket Ref” by Thomas J. Glover](#), 3rd Edition, 2003, Sequoia Publishing, Inc. P.O. Box 620820, Dept. 101, Littleton, CO 80162-0820, <http://www.sequoiapublishing.com/>, also available in ACE hardware stores