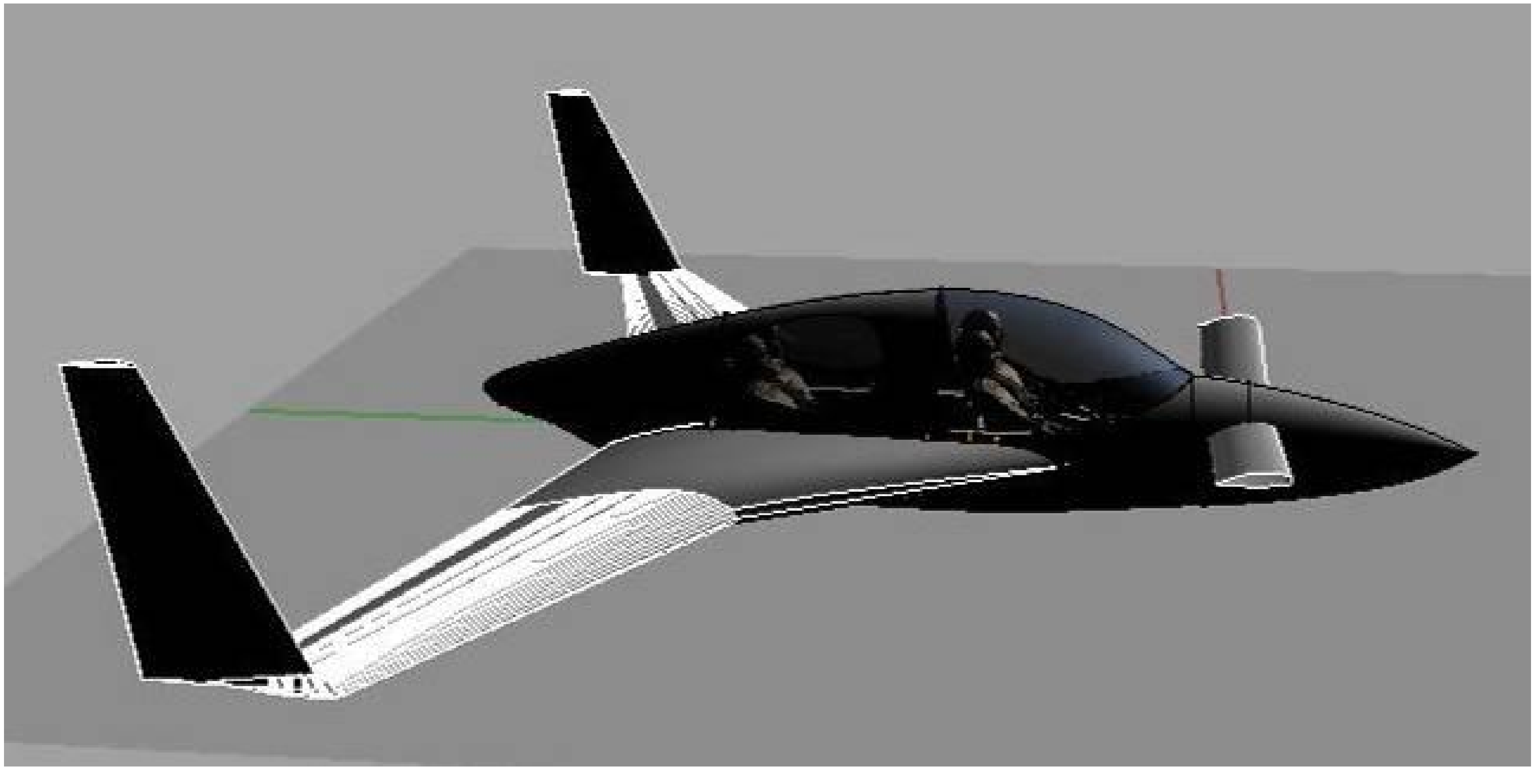
Design and Destructive Testing of Seats in a Canard-type Aircraft



Oshkosh Canard Forum, 30 July 2010

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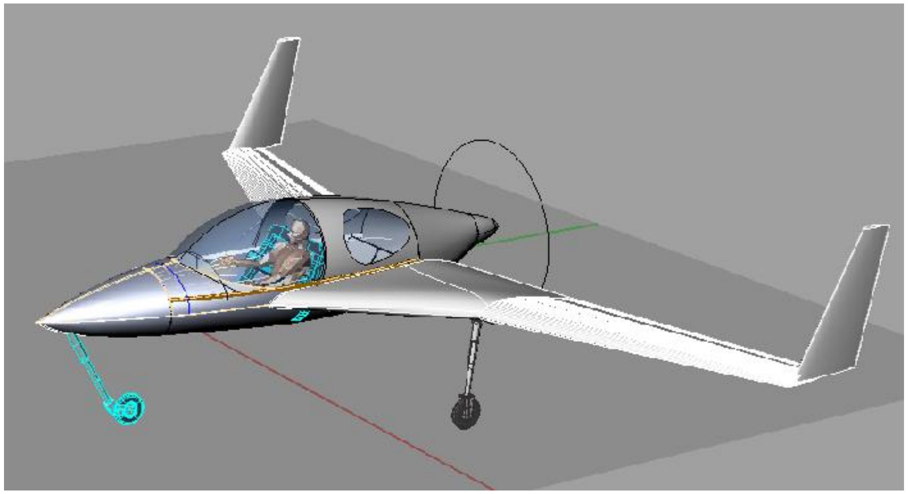
Introduction

- New design canard pusher – highly modified from the Cozy MkIV
  - Inspired by Steve Wright's Stagger-EZ and the SQ-2000
  - 4 seats, same wing, canard and major dimensions as the MkIV

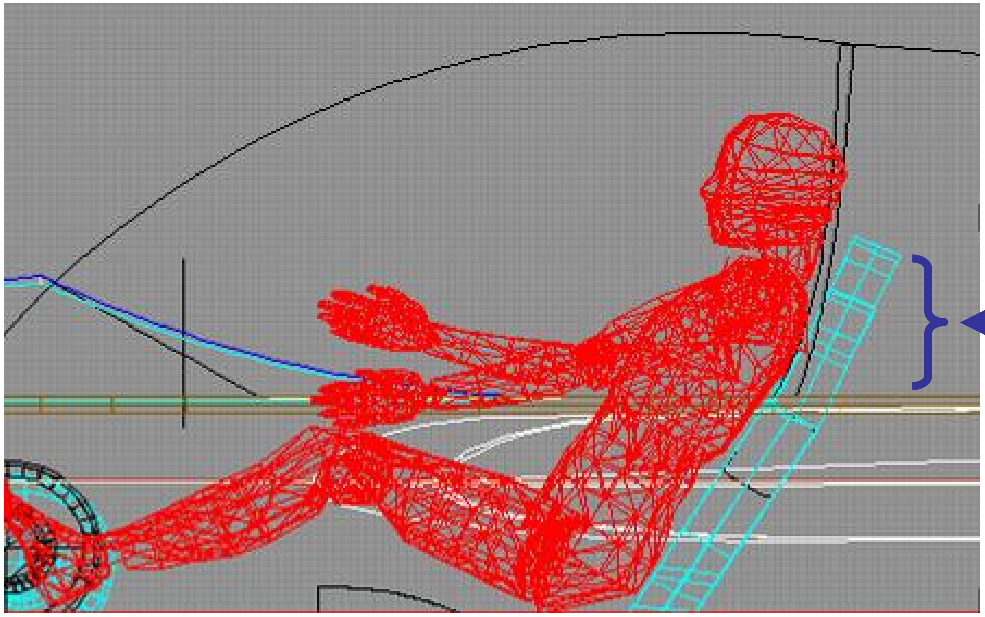


- Key Modifications:
  - Rounded fuselage w/larger canopy
  - Integrated roll-bar
  - Rear Gull-wing door
  - Retractable landing gear

- Borrowed the "bead-and-cove" technique from boat-building to form complex curves in foam

Design Problem: Anchoring the Safety Harness

- Anchor points for shoulder harness must be no less than 5 degrees below shoulder height, or risk compressing spine in a crash
- Modified fuselage is shallower than the Cozy MkIV, with more upright seating for visibility -- traded fuselage depth for a bigger canopy
- Unable to use a Cozy-type seatback brace as the shoulder-harness anchor point
  - Occupant shoulder is 9” above the longerons
  - Raising the seatback brace to shoulder-level would obstruct view from rear cabin and require rebuilding the fuselage



Shoulder is 9” above longeron

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How Do Other Aircraft Solve This?

Sidewall / roll-bar anchor (e.g. Diamond)

- PROS: Simple, great access / visibility for rear cabin
- CONS: Limited to 3-point harness, side can be a weak anchor point

Roof anchor (e.g. Stagger-EZ)

- PROS: Simple; allows use of 4-point harness
- CONS: Blocks access/visibility to rear cabin; requires structural reinforcements to roof.

Integrated Seat-Safety Harness (e.g. Cirrus)

- PROS: Great access/visibility to rear cabin; allows use of 4-point harness
- CONS: Seatback carries the forces – complex and heavy

Conclusion: Most 4-seat aircraft shoulder-harness systems compromise either ergonomics, weight, or safety.

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Design Goals: Seat / Safety Harness Anchor

1. Meet FAA FAR 23 standards *(not required but a good idea!)*
2. Use a 4 or 5-point safety harness
3. Minimal weight and complexity
4. Aesthetically pleasing
5. Good visibility from rear cabin

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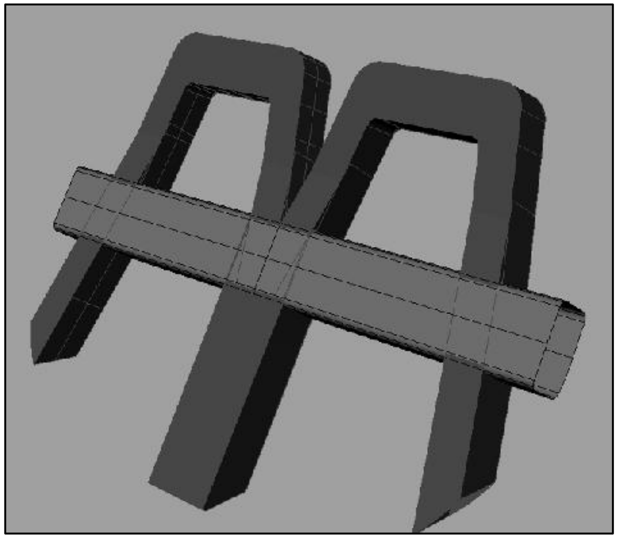
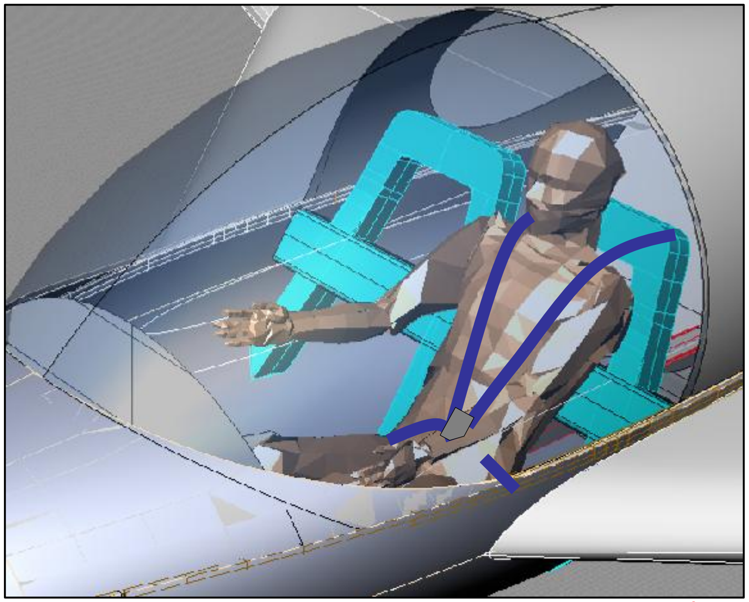
Design Concept: Integrated- Seat/Harness System with Cross-beam

- A-Frame structure, with 4-point harness attached around top and base

- Cross-beam to carry bending loads
  - Reduces moment-arm of shoulder-harness load by 63%, permitting lighter structure
  - Spreads loads across longerons
  - Maintains Cozy MkIV fuselage characteristics

- Retains rear-cabin visibility and access, but is complex and might be heavy





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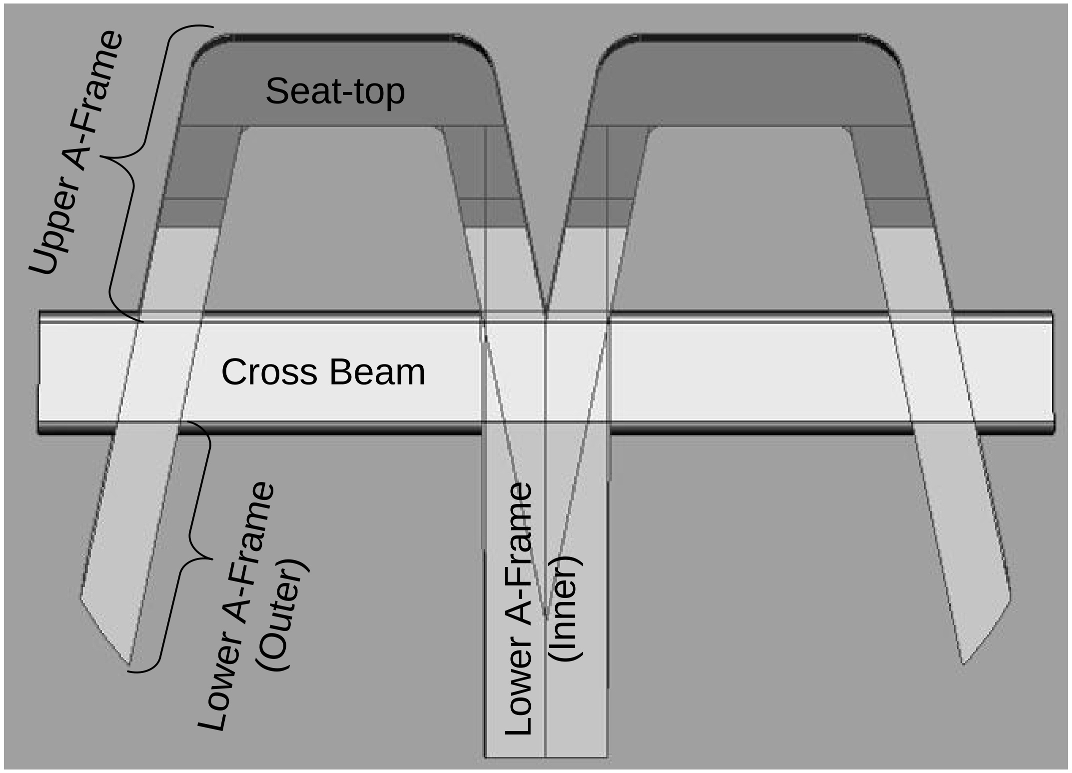
Engineering Problem – Where are the loads?

- Design load based on FAR 23 = **5,031 lbs / seat**
  - 215 lb occupant * 9Gs * 1.3 (safety factor) * 2.0 (hand-layup factor) = 5,031 lb
  - 40% load on shoulder straps, 60% on waist belt

- Box-beam structure – minimizes engineering complexity
  - Structure divided into simple beam elements for load analysis

Load Analysis

- **A-Frame Top:** Simple supported beam (15x3x3.5") @ 2,012 lbs
- **Upper A-Frame:** Cantilever beam (12x3x2.75") @ 1,006 lbs (x2)
- **Crossbeam:** Distributed force, supported beam (46x5.5x3.5") @ 6,300 lbs
- **Lower A-Frame (Inner):** Simple supported beam (14x3.5x2.75") @ 1,509 lbs
- **Lower A-Frame (Outer):** Simple supported beam (11x3.5x2.75") @ 1,509 lbs



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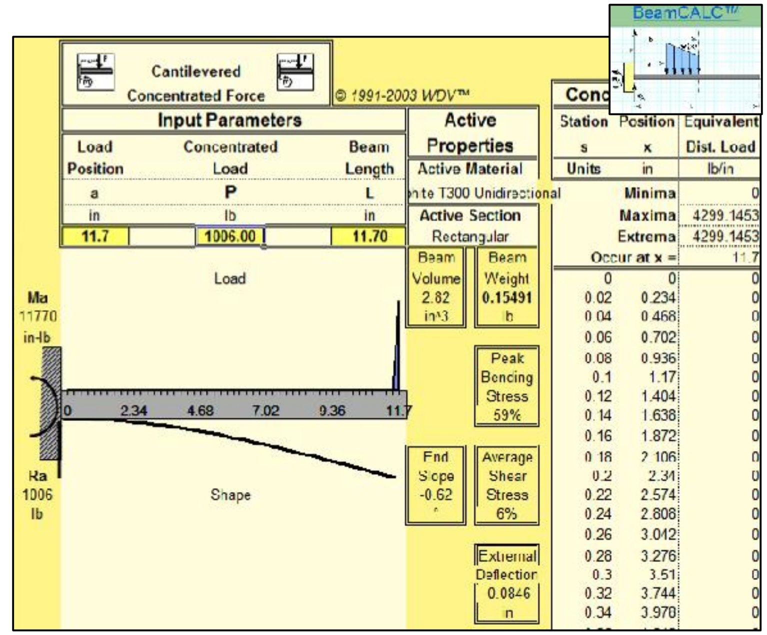
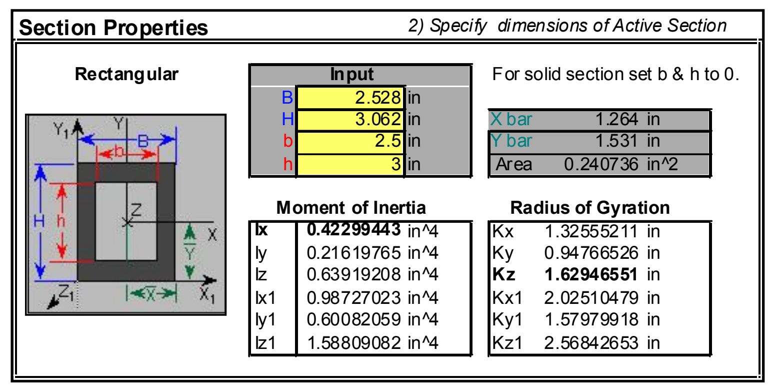
More Math: Optimizing with Composites

- BeamCALC: MS Excel tool based on linear beam theory
  - Models cantilever, simple supported beams, distributed forces, + others
  - Customizable material properties library, including carbon and fiberglass hand-layups
- Explored trade-offs between cross-section and layup thickness/materials
- Small-scale destructive tests to validate calcs.
  - Destroyed 4 1x2x8" and 2x2x8" test coupons
  - Failures at +/- 30% of predicted strength
- Good starting point, but too many unknowns:
  - Structure of the fuselage at attach points?
  - Difficulties modeling properties of varied layups (CRP UNI, BID, and fiberglass)
  - Impact of bends in the seat geometry





Conclusion: Full-scale destructive testing will be necessary to resolve engineering limitations and uncertainties

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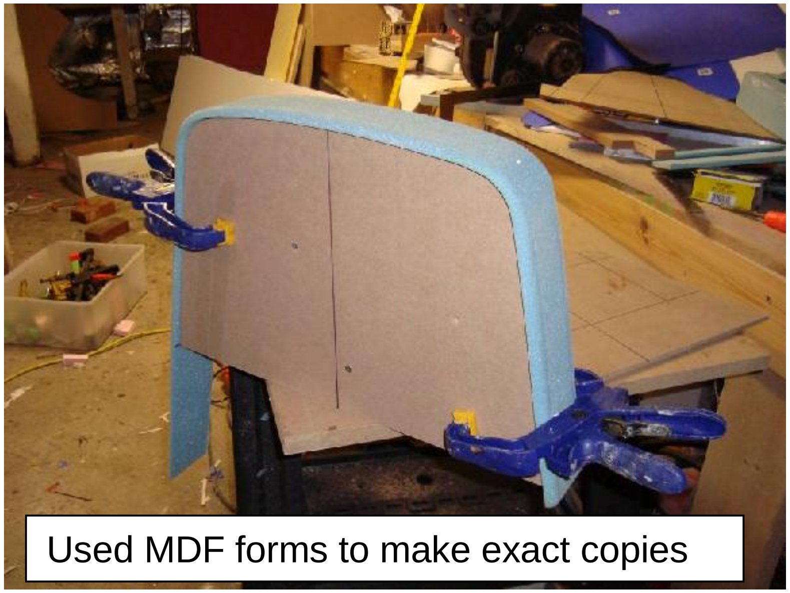
Building the full-Scale Prototype (1)


Used MDF forms to make exact copies


Complex Geometry – Not worth the trouble!


Using the heat gun


Carbon fiber UNI, fore, aft, and sides, with carbon BID sheer-web on all sides

Building the full-Scale Prototype (2)

- Also built a fuselage cross-section, to test the seat attach points
  - Matches the plans layup schedule, longerons, roll-bar anchors, center-keel.
  - Concerned that the 3/8” foam + 3 ply UNI (x2) sides are the weakest link
- Total seat + crossbeam weight: 18-20 lbs
  - Built one A-Frame using fiberglass, to save $
  - Anticipate 5 lb weight savings, using all-carbon and better QC.

Vacuum bagging

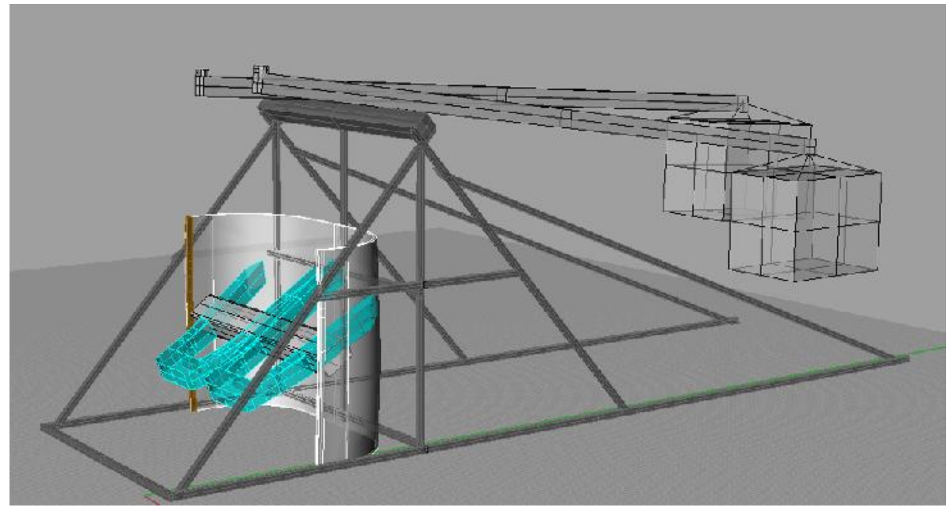
Building the Cross-beam

Fuselage cross-section

Completed Prototype Seat-back (*aka 12 months*)

Destructive Testing: Where do you get 10,000 lbs?

- Build a Giant Lever (or two)!
  - Independent 11 foot lever arms
  - 10:1 mechanical advantage
  - 500 lbs weight = 5,000 lbs / arm
  - 1” steel tubing, w/24 bolts holding the fuselage cross-section to frame



- Progressive tests on each belt
  - Tested the carbon-fiber A-Frame to 3,000 lbs w/out failure (50% above design load)

- Final test: 10,100 lbs, shoulder and lap belts concurrently…

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No Structural Failure at 10,100 lbs!

5,050 lbs / seat, held for 5 minutes without failure (~23 Gs)

Lessons Learned

- Testing is the only way to validate major design changes to safety equipment
  - But very expensive and time consuming
- Don't be intimidated by engineering
  - Most problems have been solved by others or can be reduced to one's skill level
- May have been less expensive and time consuming to purchase and learn to use FEA software at the beginning.
- Lack of failure at forces well above design loads indicates some elements are too strong = heavier + more expensive.
  - Difficult to optimize composite construction without many prototypes
  - Should have built more test coupons earlier, to calibrate the software calculations
  - Tapered beams would have saved weight
- **Next Steps:**
  - Test the Cozy MkIV seatbelt attach points *(what else do you use a 5-ton lever for?)*
  - Considering a drop-test for the seat

Questions?

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