The Examination of Occupant and Vehicle Responses to Low Speed Rear-End Crashes

Team 2

Presenters: Jacob Dunne,

William Smith, and Caroline Walker

Caroline Walker

Team Introductions

Caroline Walker
Team Leader

Dylan Tinsley
Financial Advisor

Jacob Dunne
Instrumentation Engineer

Orion Yeung
Modeling Engineer

William Smith
Design Engineer

Caroline Walker

Introduction to the Sponsor

- **Cummings Scientific, LLC.**
  - Forensic engineering consulting firm
    - Accident reconstruction, biomechanics, human factors, simulation (Cummings Scientific, LLC, 2017)
  - Expert witnesses for litigation purposes
  - Located in Tallahassee, FL and Atlanta, GA

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PROJECT BACKGROUND

Motivation

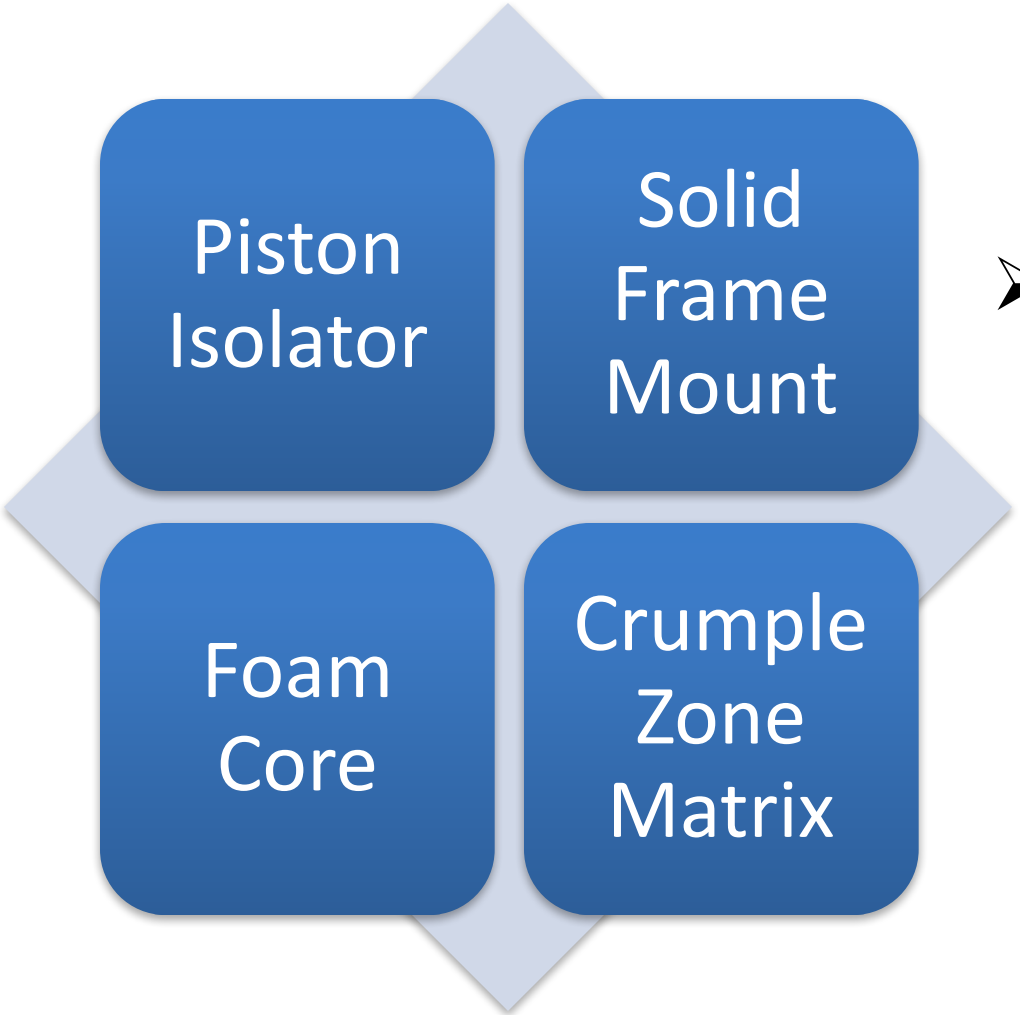
- **Currently:**
  - Cummings Scientific takes 100 cases each year where claims of catastrophic injury come from low speed collisions.
  - Low speed collision models are extrapolated from high speed data (20-40 mph).
  - Vehicles are not reused for live crash testing purposes.
    - High speed crash tests result in significant structural damage.

Project Scope

- **Goal:** Develop an empirical model of low speed* rear-end collisions
  - Occupant and vehicle responses
  - Effect of different bumper structures
  - Based on live crash testing and dynamic modeling

*Low speed crash: delta-v less than 7.5 mph (Wang & Gabler, 2007)

Bumper Structures



- Effect of each type to be tested with interchangeable bumper mounting device

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Foam Core and Piston Isolator

Figure 2a. Combination foam core and piston isolator bumper from bumper inspections

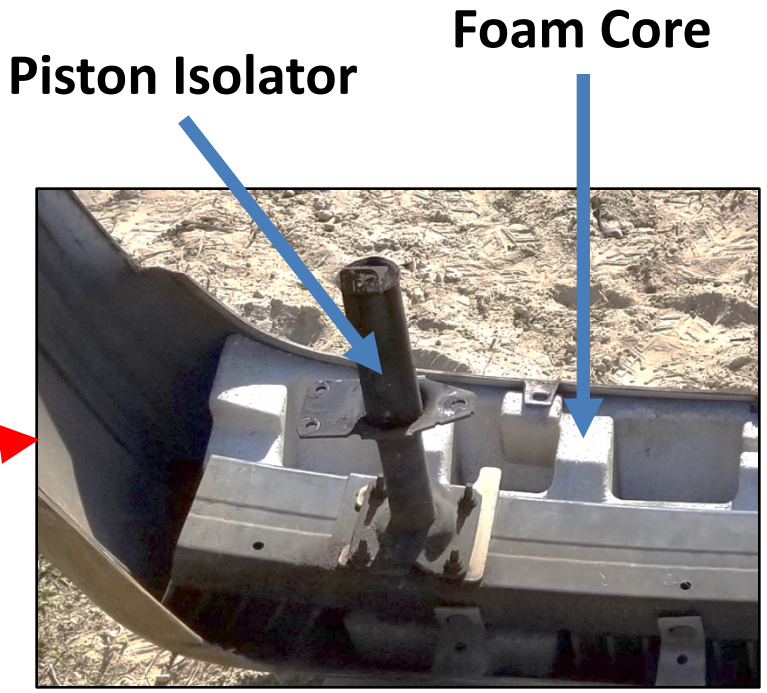

Figure 2b. Detailed view

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Solid Frame Mount

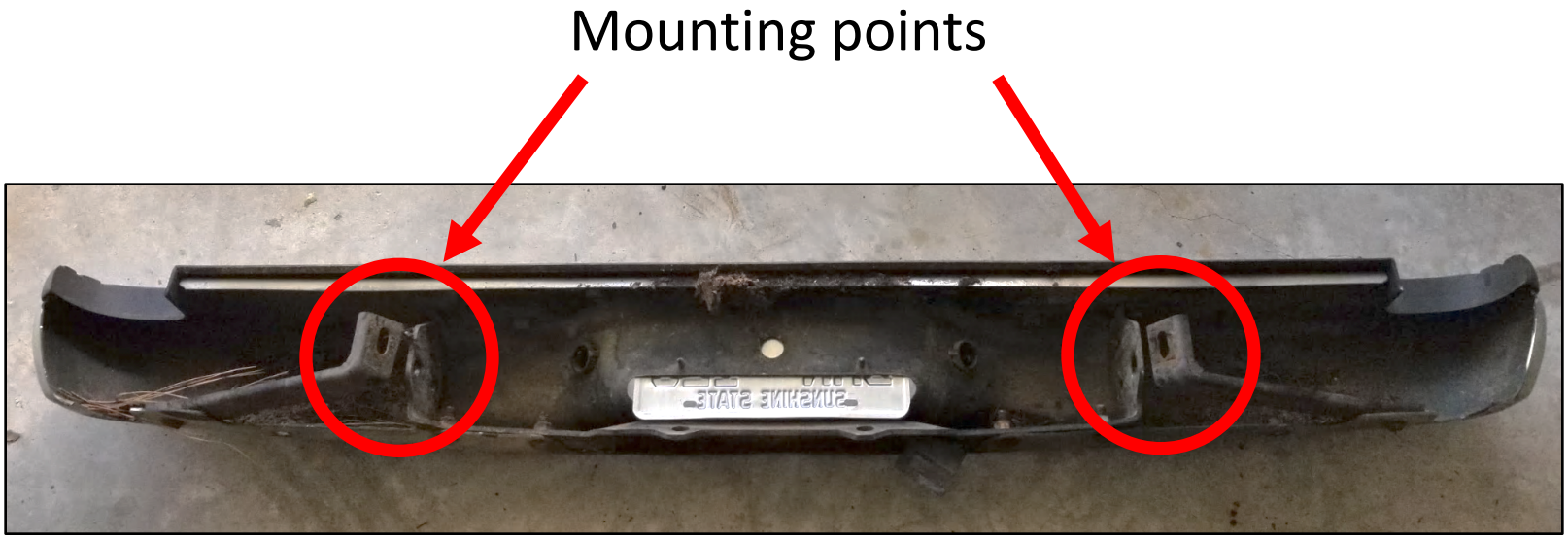

Figure 3. Solid frame mount bumper pulled from test pickup truck

MAthematical DYnamic MOdels (MADYMO)

- MADYMO is a tool for analyzing dynamic systems
  - Multi-body, Computational Fluid Dynamics, Finite Element Analysis (Tass International, 2017)
- Occupant response analysis
  - Dummy and human models
- Structural deformation analysis
  - (Tass International, 2017)

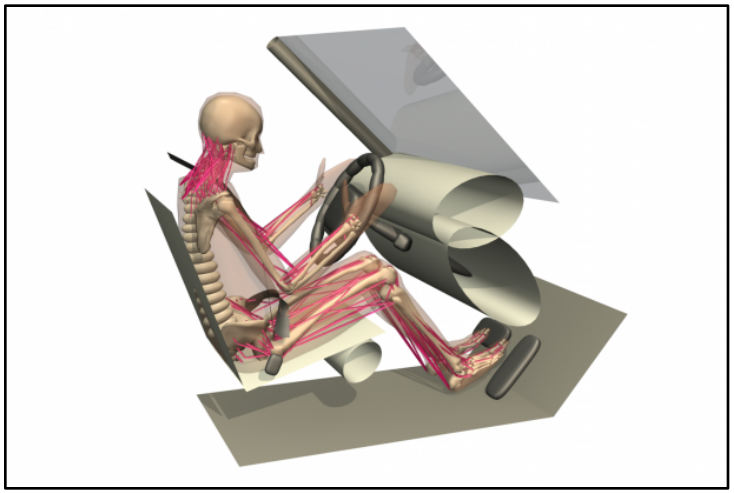

Figure 1. An example model in the MADYMO software suite (Tass International, 2017)

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Project Overview

Design Interchangeable Bumper Mount

Perform Live Crash Testing and Simulation

$$\frac{dLs}{dt} = N * K_1 - (d_1 + r) * Ls + \delta_1$$

$$\frac{dLux}{dt} = \left(\frac{K_2}{1 + A * Ls1^2}\right) * N - (d_2 + r) * Lux + \delta$$

$$Z = Z_1 + Z_2$$

$$Z_1 = K_3 * Lux$$

$$\frac{dLs1}{dt} = L$$

Develop Low Speed Collision Model

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FUNCTIONAL DECOMPOSITION

Interchangeable Bumper Mount

- Attach multiple bumper types to test vehicle for rear-end impact testing
- Withstand multiple crash tests
- Allow sensor integration for measurement of crash parameters
- Transfer dynamic response of impact to vehicle and passenger

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Crash Model

- Characterize vehicle response to low-speed impulse
- Transfer the input signal to a passenger response
- Output measures (i.e. force, acceleration, etc.) that are contained in the MADYMO output

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Jacob Dunne

TARGETS

Overview

- **Targets:**
  - Generated for two main components of the project
    - Interchangeable bumper mount
    - Live crash testing
  - Formed from functional decomposition
  - Drives concept selection
  - Continue to append to target list as project progresses

Interchangeable Bumper Mount

Target	Value
Number of different bumper styles tested	4
Minimum yield strength of mount	36 ksi*
Delta-v of crashes	Less than 4 mph
Number of tests	Minimum of 15

*(Cars.com, 2017)

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Live Crash Testing

Target	Value
Range of accelerometers	$\pm 10g$
Minimum sampling frequency of accelerometers	100 Hz
Minimum number of accelerometers	3
Delta-v of crashes	Less than 4 mph
Number of tests	Minimum of 15

Jacob Dunne

William Smith

CONCEPT GENERATION

Background

- Ideas generated on the system and sub-system level
  - Overall mount design
  - Component design
- Individual and group ideation sessions
  - Multiple sessions
  - No evaluation of idea quality or feasibility initially

William Smith

Vehicle Inspection

- Concepts generated after inspecting provided test vehicle (1999 Mazda B3000 V6 pickup truck)

Figure 4a. Looking forward at the pickup truck after bumper removal (Frame boxed in yellow)

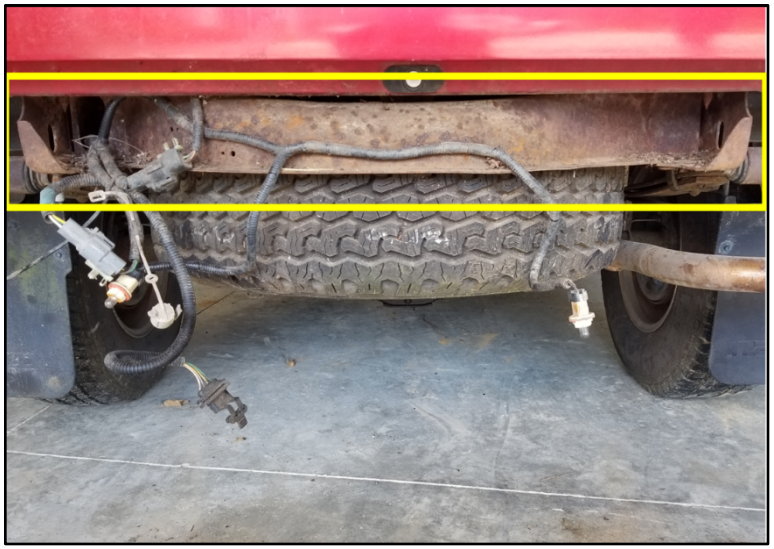

Figure 4b. Detailed view

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Vehicle Inspection

- Concepts generated after inspecting provided test vehicle (1999 Mazda B3000 V6)

Figure 5a. Isometric view of vehicle frame and mounting points (boxed in yellow)

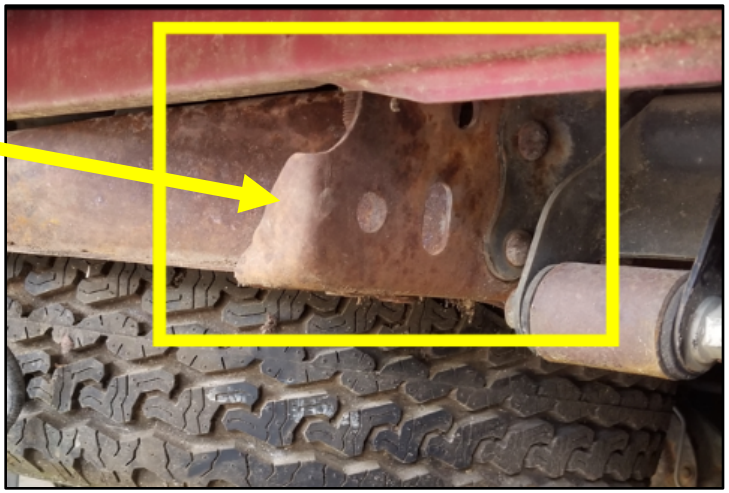

Figure 5b. Detailed view

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System Level Concepts

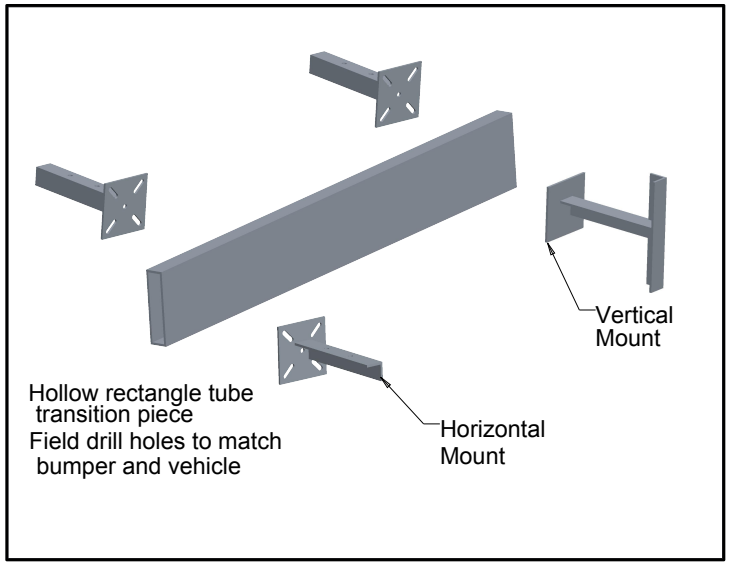

Figure 6. Rectangular tube system. Adapted by drilling as needed.

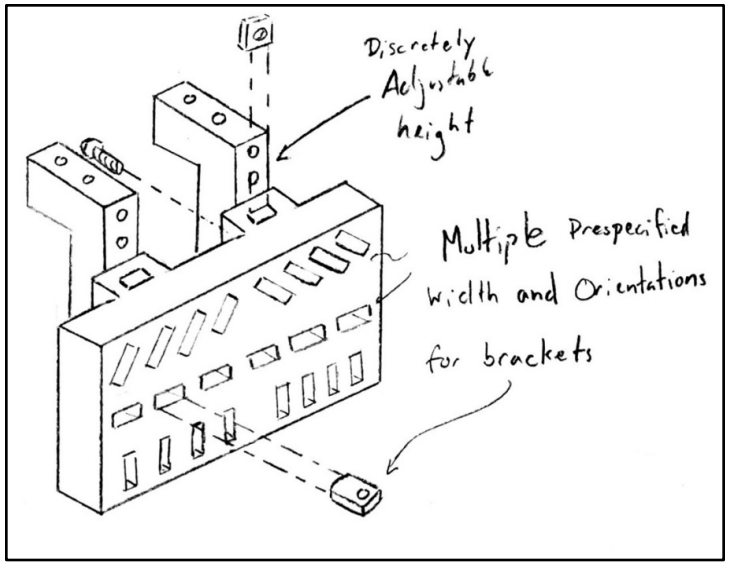

Figure 7. A plate and bracket system with pre-specified slots.

Figure 6	Function	Figure 7
✓	Multiple Bumper Types	✓
	Multiple Tests	
✓	Sensor Integration	✓
✓	Dynamic Response	

System Level Concepts

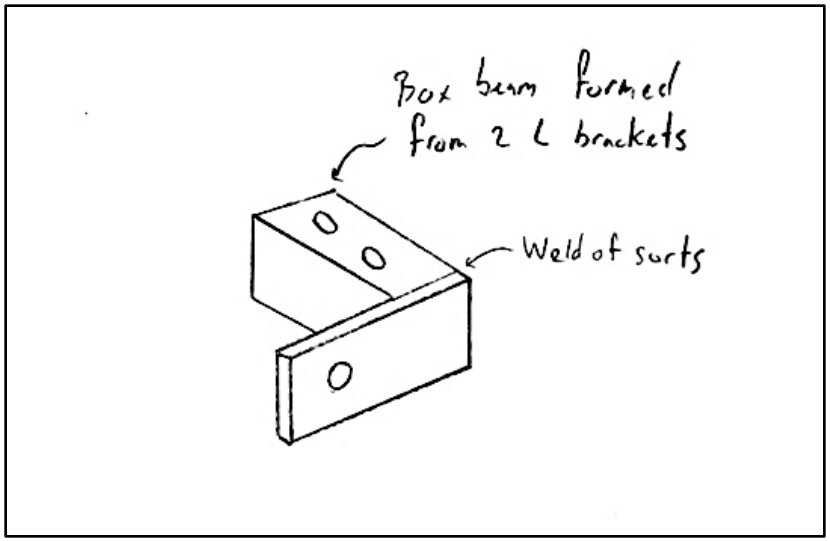

Figure 8. Simple box beam and plate. Made to fit to a specific bumper

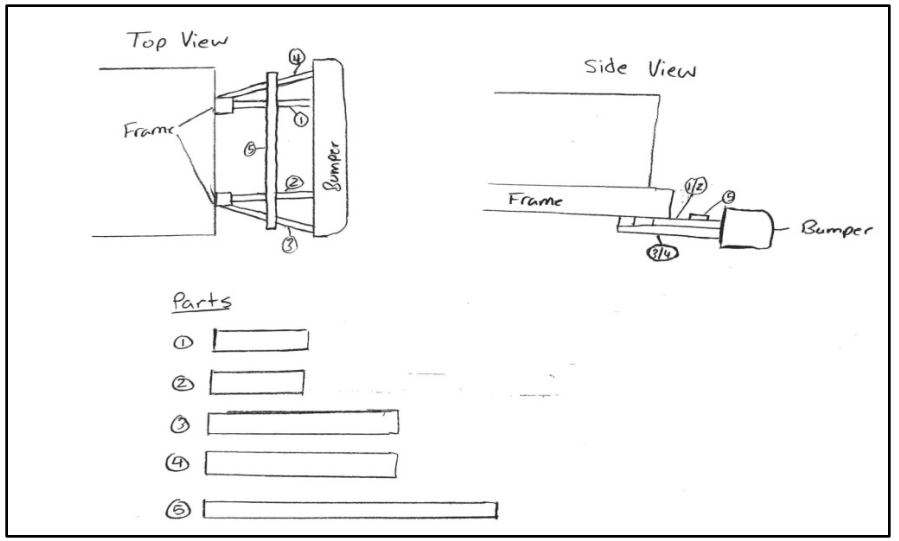

Figure 9. A design consisting of flat bars and spacers.

Figure 8	Function	Figure 9
	Multiple Bumper Types	✓
✓	Multiple Tests	
✓	Sensor Integration	
✓	Dynamic Response	

Sub-System Level Concepts

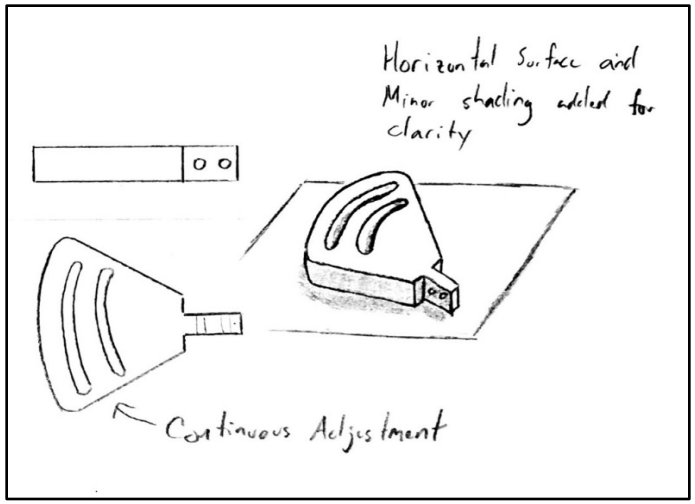

Figure 10. A slot joint designed for high resolution in specifying position. Can be extended to linear sliding.

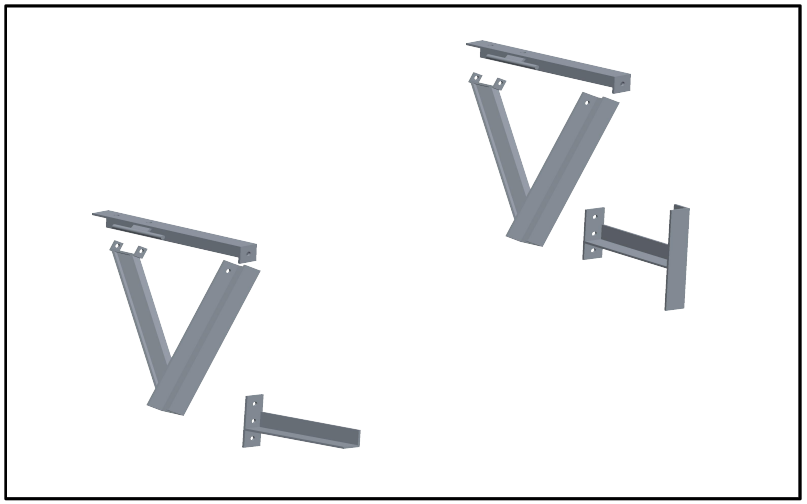

Figure 11. Strong swivels to allow for motion resolution without relying on friction of connectors.

Figure 10	Function	Figure 11
✓	Multiple Bumper Types	✓
	Multiple Tests	
	Sensor Integration	✓
	Dynamic Response	

Sub-System Level Concepts

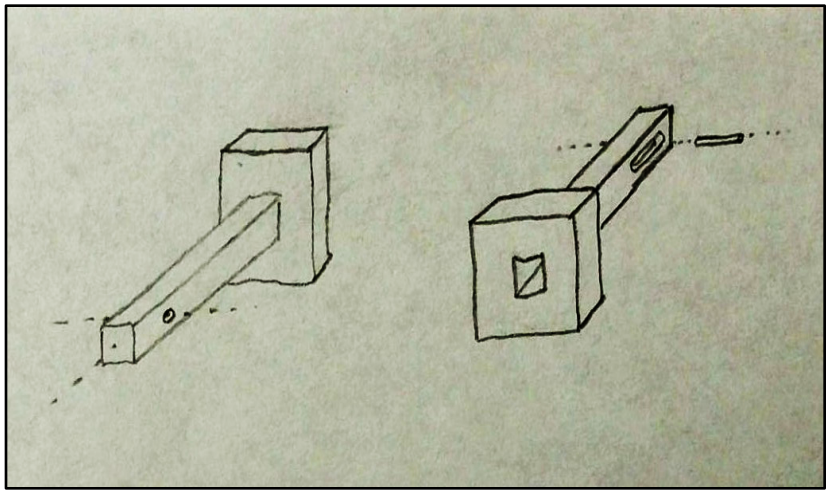

Figure 12. Connection method similar to a trailer hitch. Uses a pin to lock positions.

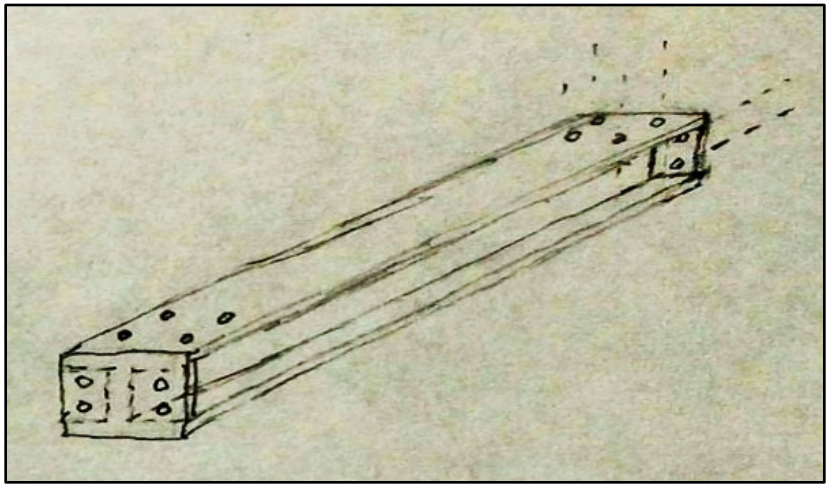

Figure 13. A spacer for connecting the bumper to the vehicle frame in the form of an I-beam.

Figure 12	Function	Figure 13
✓	Multiple Bumper Types	
✓	Multiple Tests	✓
	Sensor Integration	✓
✓	Dynamic Response	✓

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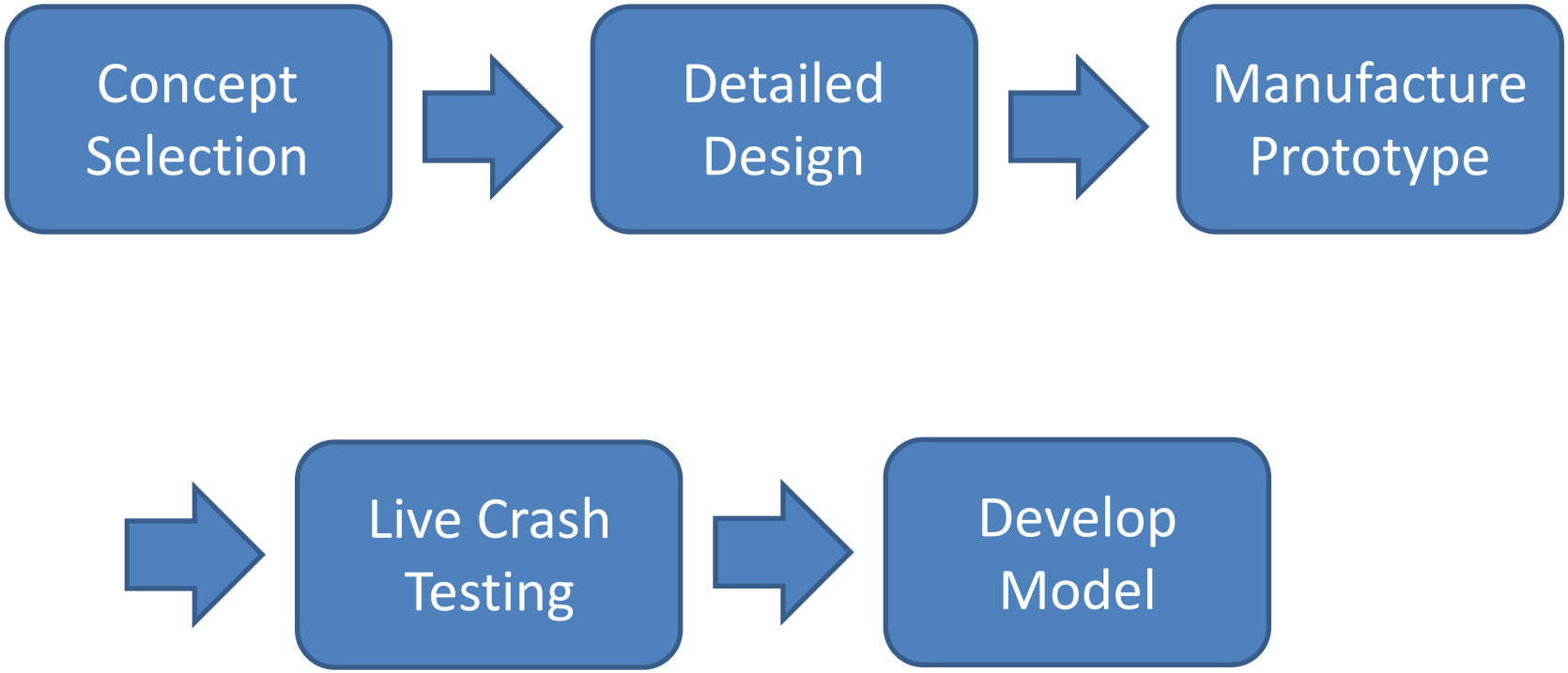
CONCLUSION

Concept Selection Overview

- Refine concepts with information from bumper inspections
- Driven by targets and functions
- Employ design selection tools
  - House of quality, selection matrix, etc.

Future Outlook



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QUESTIONS