Occupant and Vehicular Responses to Low Speed Collisions

Team 2

Presenters: William Smith, Dylan Tinsley, and Caroline Walker

Caroline Walker

Team Introductions

Caroline Walker
Team Leader

Jacob Dunne
Instrumentation Engineer

William Smith
Design Engineer

Dylan Tinsley
Financial Advisor

Orion Yeung
Modeling 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

Caroline Walker

Dylan Tinsley

PROJECT BACKGROUND

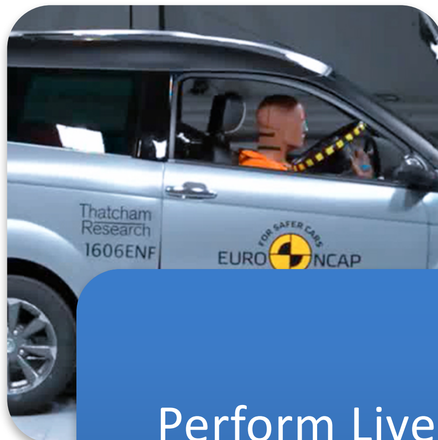
Motivation

- **Currently:**
  - Cummings Scientific takes hundreds of 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.

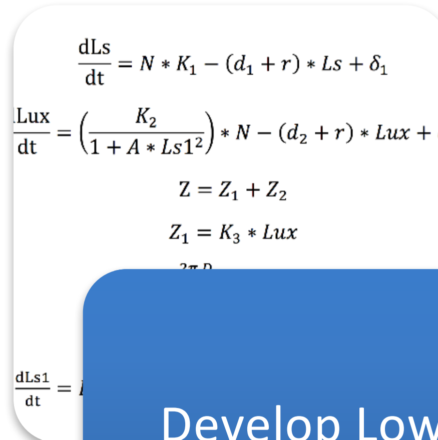
Dylan Tinsley

Project Scope

Design Interchangeable Bumper Mount (IBM)



Perform Live Crash Testing and Simulation



Develop Low Speed Collision Model

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

Dylan Tinsley

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)

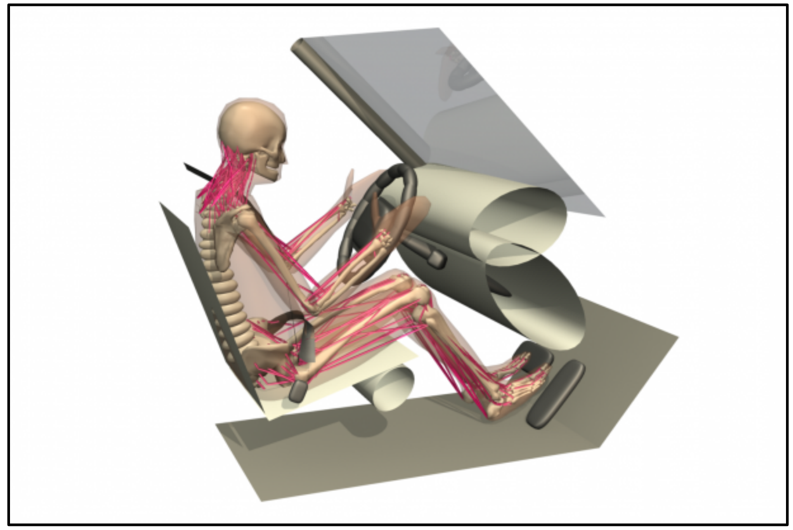


Figure 1. An example model in the MADYMO software suite (TASS International, 2017)

Overview of Project Status

Tasks Completed in the Fall:

- Defined project scope
- Created functions and targets for IBM and models
- Generated design concepts for the IBM
- Selected initial design concept for the IBM

Figure 2. An acquired test bumper

Spring Tasks:

- Finalized detailed design through impact calculations ✓
- Ordered parts for IBM ✓
- Order sensors and instrumentation for live crash testing
- Fabrication of IBM
- Perform live crash testing
- Data processing
- Generate occupant and vehicle models

(Clker.com, 2018)

Dylan Tinsley

William Smith

DETAILED DESIGN

Design Review

- Targets
  - 15 Crash Tests
  - 3 Bumper Styles
    - Foam core
    - Piston isolator
    - Steel
  - Test Vehicle: 1999 Mazda B3000
    - Frame yield strength of 36ksi
  - 4 mph ΔV of crash vehicle

Figure 3. Mazda B3000 test vehicle

William Smith

Design Review

- Concept Generation
  - Initial Phase
    - System and sub system concepts
    - Group and individual ideation
  - Evaluation Phase
    - Analyzed against targets/functions
  - Final Phase
    - Created new, more detailed versions of high scoring concepts
    - Reevaluated new designs

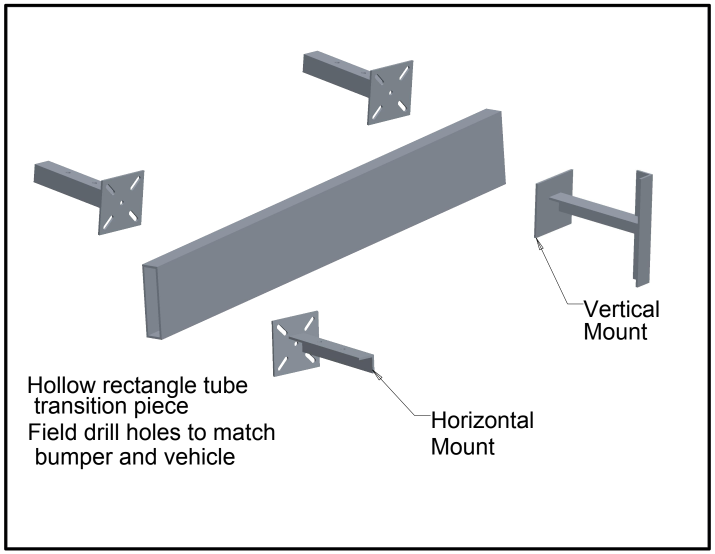


Figure 4. Conceptual Design

William Smith

Design Overview

- Modular design for adapting to different bumpers and test vehicles
  - No field modification apart from bolting together
  - Calculations were performed using impact factor of 2

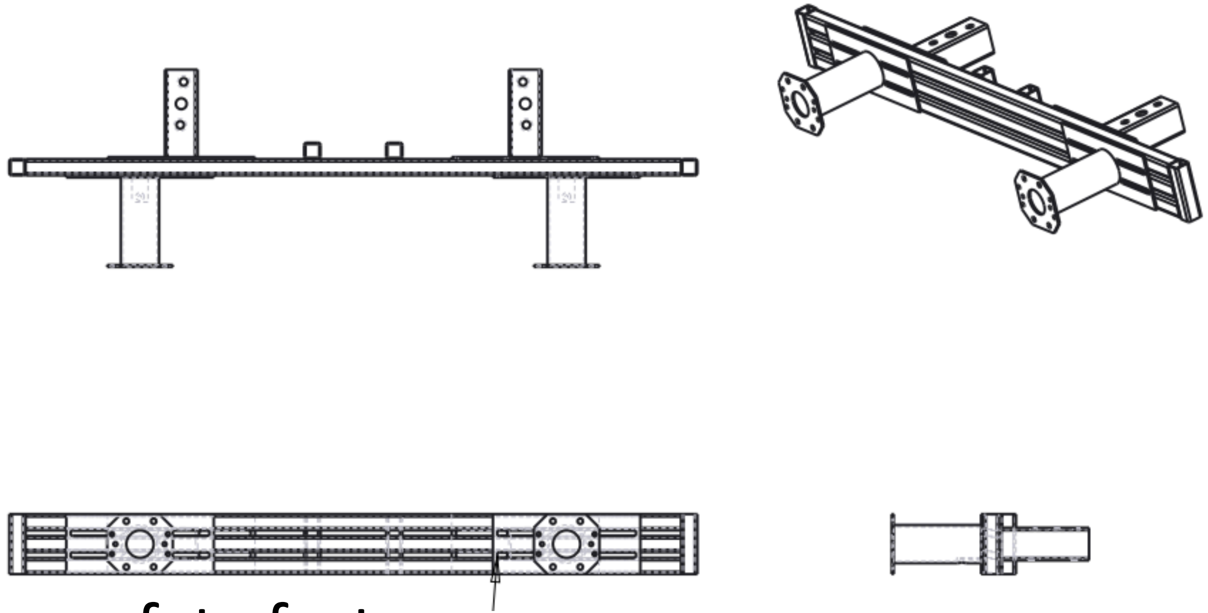


Figure 5. Detailed Design

Overall design safety factor:

2.218

William Smith

Horizontal Connection

- Allows mounting to test truck and steel bumper
  - Enlarged bottom holes to allow access to bolt with socket

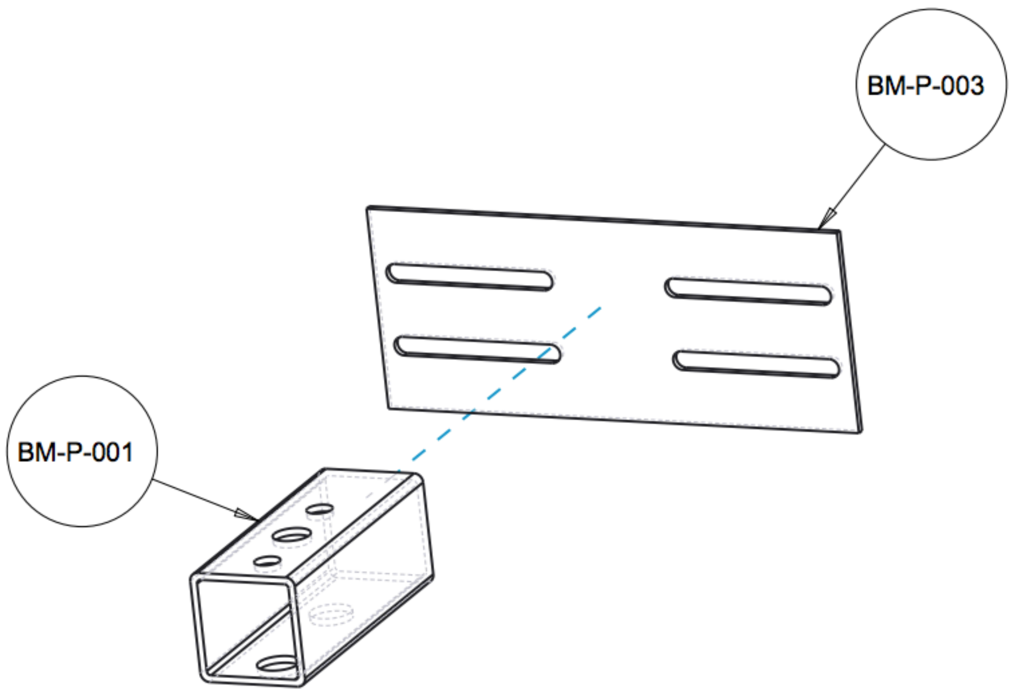


Figure 6. Steel bumper mount

Safety factor:
3.757

William Smith

Vertical and Insert Connection

- Allows mounting to foam core and piston isolator
  - Symmetrical plate to for both sides of bumper
  - Hollow tube for piston isolator insertion

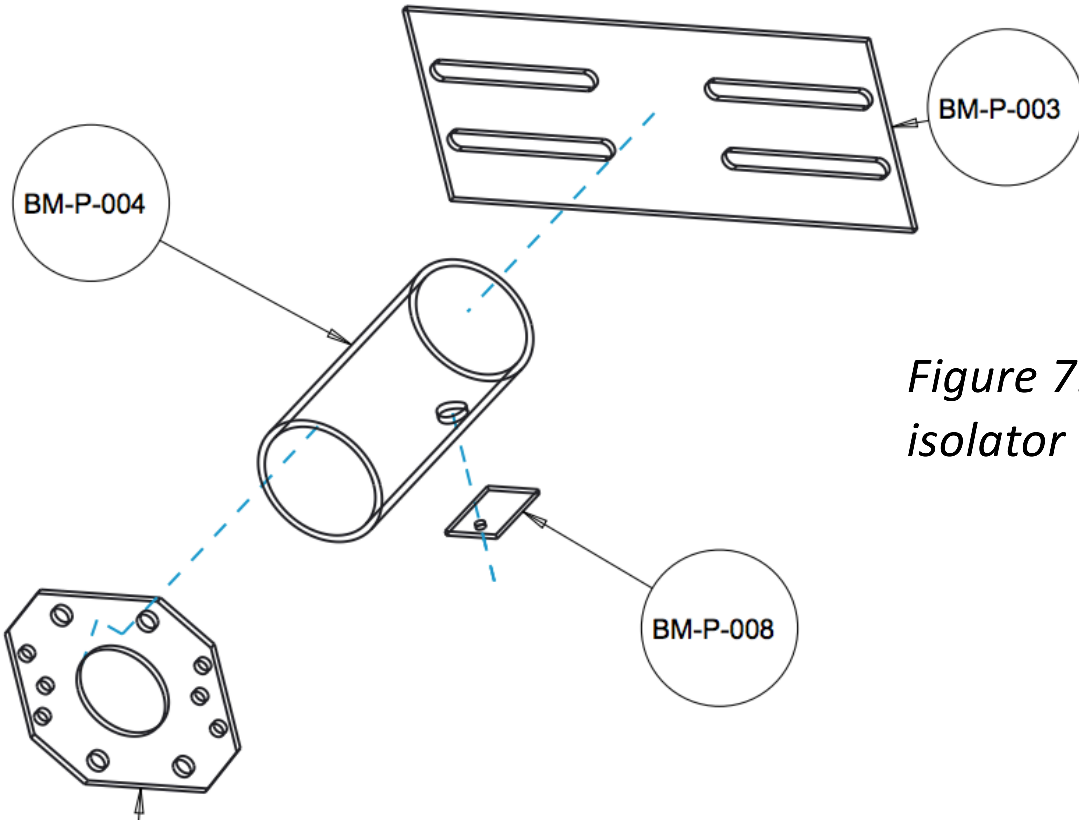


Figure 7. Foam core and piston isolator connector

Safety factor:
2.218

William Smith

Middle Connecting Piece

- Slotted to allow width adjustment
  - Wide enough for full size truck

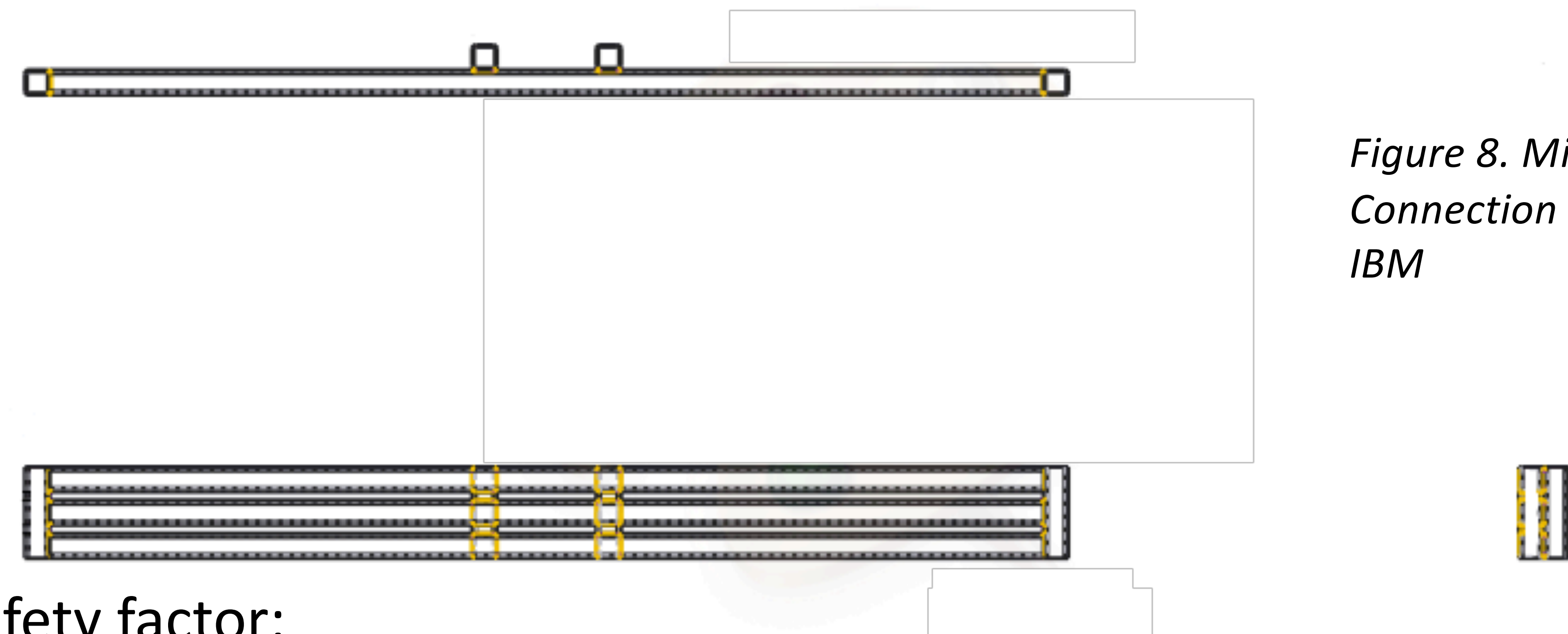


Figure 8. Middle Connection of IBM

Safety factor:

8.517

William Smith

Fabrication

- Going through FSU machine shop
  - All components are carbon steel
  - All connections are filet welded

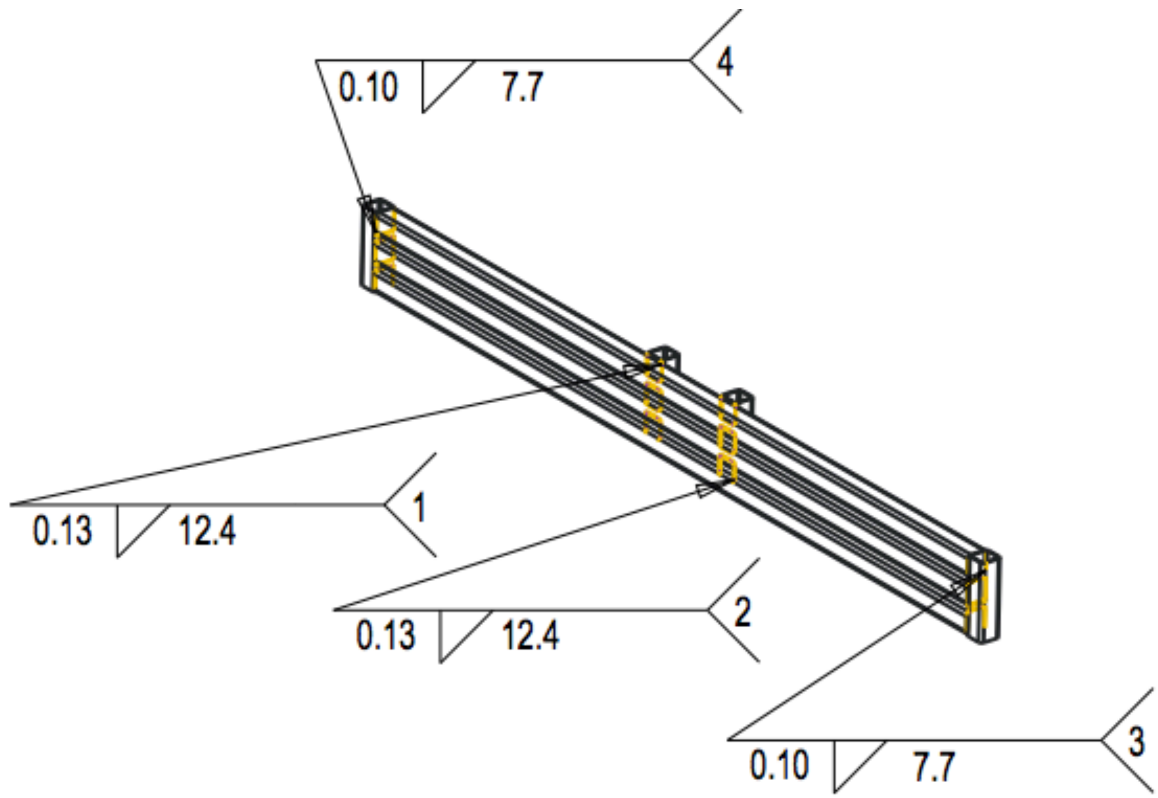


Figure 9. Example of weld call-outs

William Smith

Dylan Tinsley

BUDGET UPDATE

Budget Update

Current expenditures:

- IBM raw materials
- Sensor testing

Future expenditures:

- IBM fabrication (potentially)
- Sensors and instrumentation
    - Tri-axial accelerometers
    - High-speed cameras

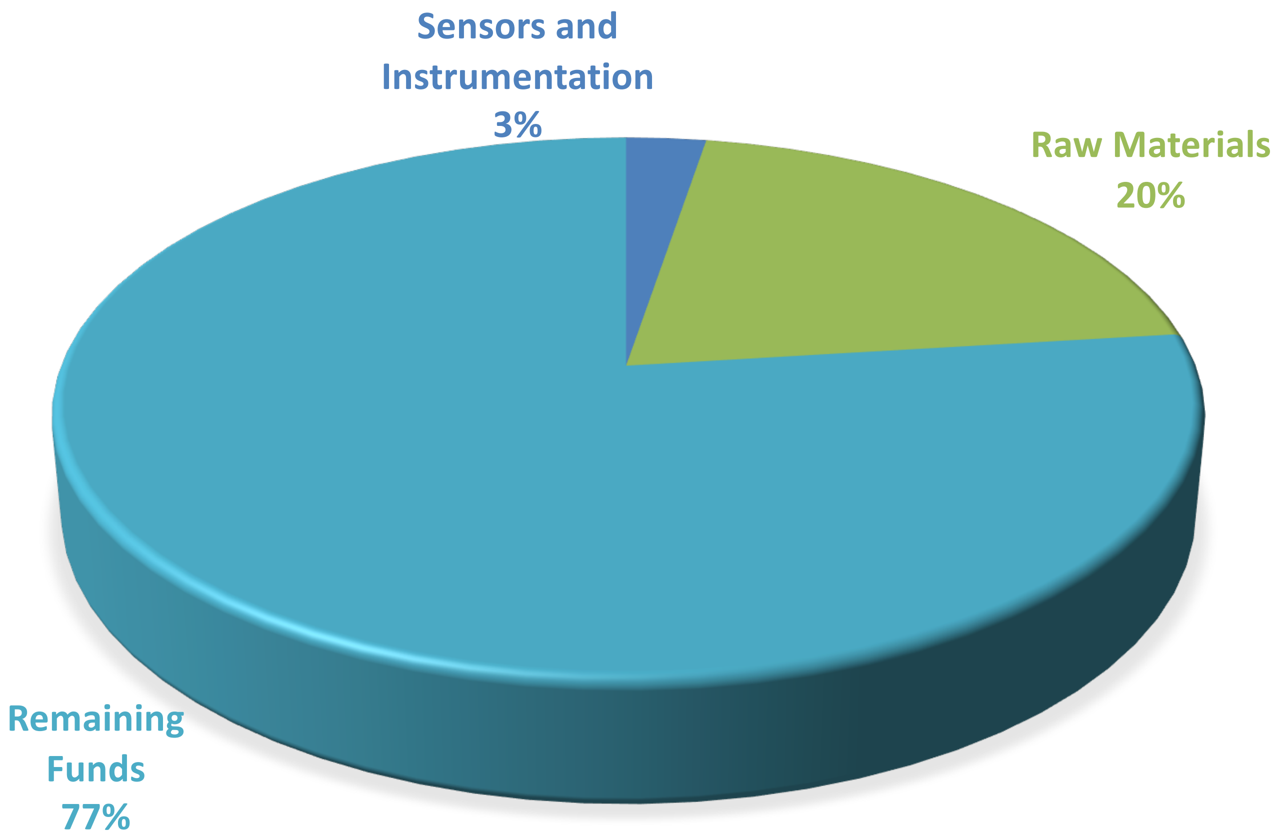


Figure 10. Representation of Team 2 budget

Dylan Tinsley

Budget Update

Table 1: Team 2 Purchases

	Part Name	Qty.	Unit Amount	Total Amount	Vendor	Purchase Date
IBM Materials	Bolts	2	$7.70	$15.40	Grainger	2/5/18
	Nut	1	$8.05	$8.05	Grainger	2/5/18
	Nut	1	$5.85	$5.85	Grainger	2/5/18
	Square Tube	1	$100.18	$100.18	Grainger	2/5/18
	Square Tube	3	$30.60	$91.80	Grainger	2/5/18
	Steel Plate	2	$63.59	$127.18	Grainger	2/5/18
	Circular Tube	1	$60.06	$60.06	Disc. Steel	2/5/18
Sensors	Acceleromter	1	$15.00	$15.00	Digi-Key	2/12/18
	Teensy 3.2	1	$24.94	$24.94	Digi-Key	2/12/18
	LGA Breakout Board	2	$6.29	$12.58	Digi-Key	2/12/18

Total spent: $461.04

Remaining Total: $1,538.96

Dylan Tinsley

Caroline Walker

FUTURE WORK

Project Schedule

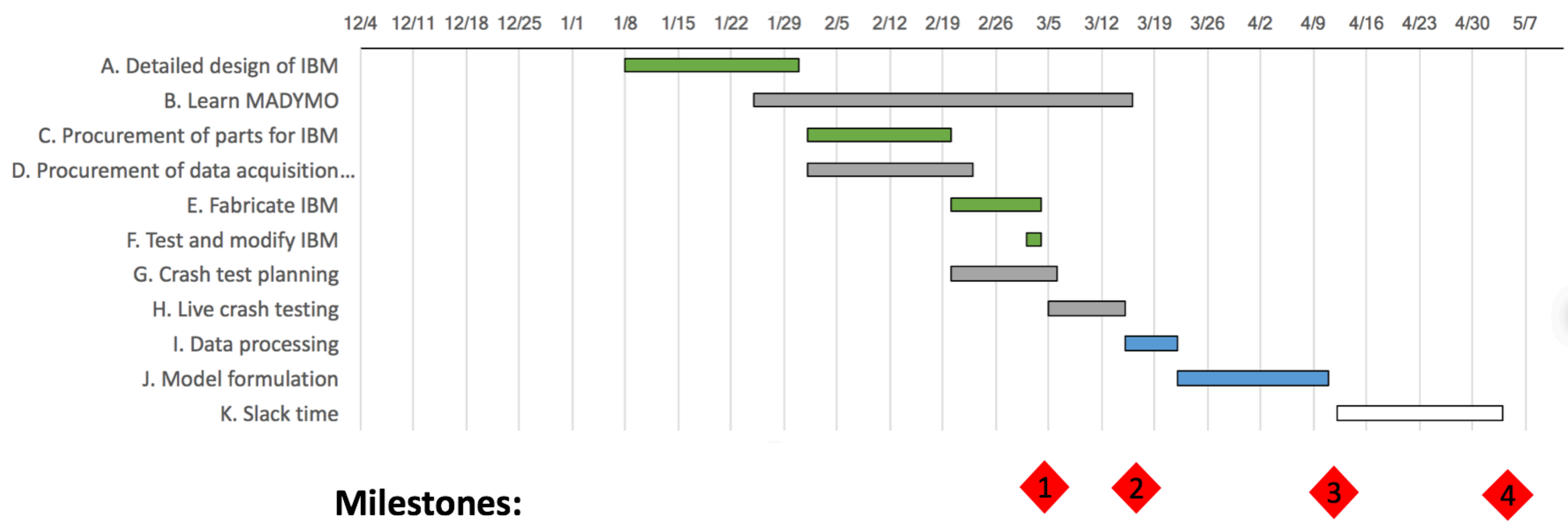
Key:

Tasks relating to Interchangeable Bumper Mount (IBM)

Tasks relating to model formulation

Tasks relating to live crash testing

Slack time



Milestones:

1 - Fully working IBM (3/4)

2 -Completion of live crash testing (3/15)

3 -Engineering Design Day and completion of empirical model (4/12)

4 -Graduation and completion of project (5/4)

Figure 11. Spring Semester Schedule

Caroline Walker

Sensors and Instrumentation

- **Current status:** Components ordered for initial testing
  - Teensy 3.2 Microcontroller
  - Tri-axial accelerometer (max acceleration 32g)
- **Future work:**
  - Establish communication with accelerometer
  - Purchase remaining accelerometers and mount to IBM

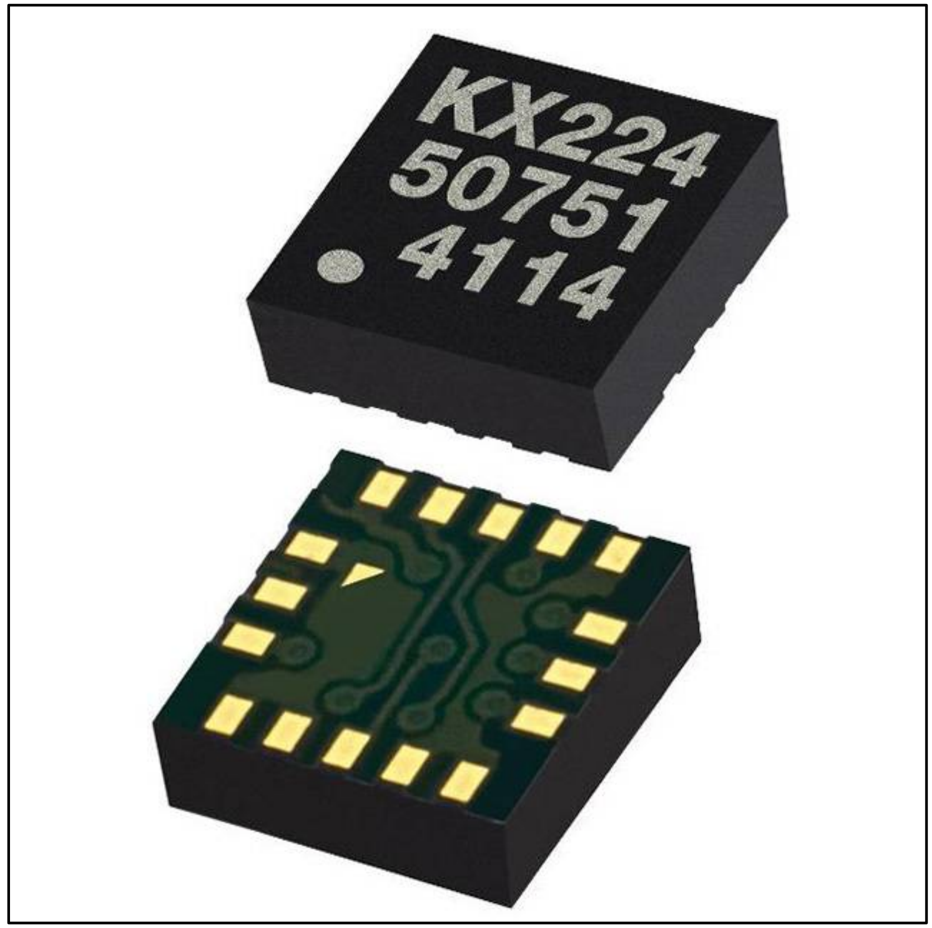


Figure 12. KX224-1053-SR tri-axial, surface mount accelerometer

Caroline Walker

Live Crash Testing

- **Current status:**
  - Will occur after fabrication of IBM
  - Planning for tests has begun

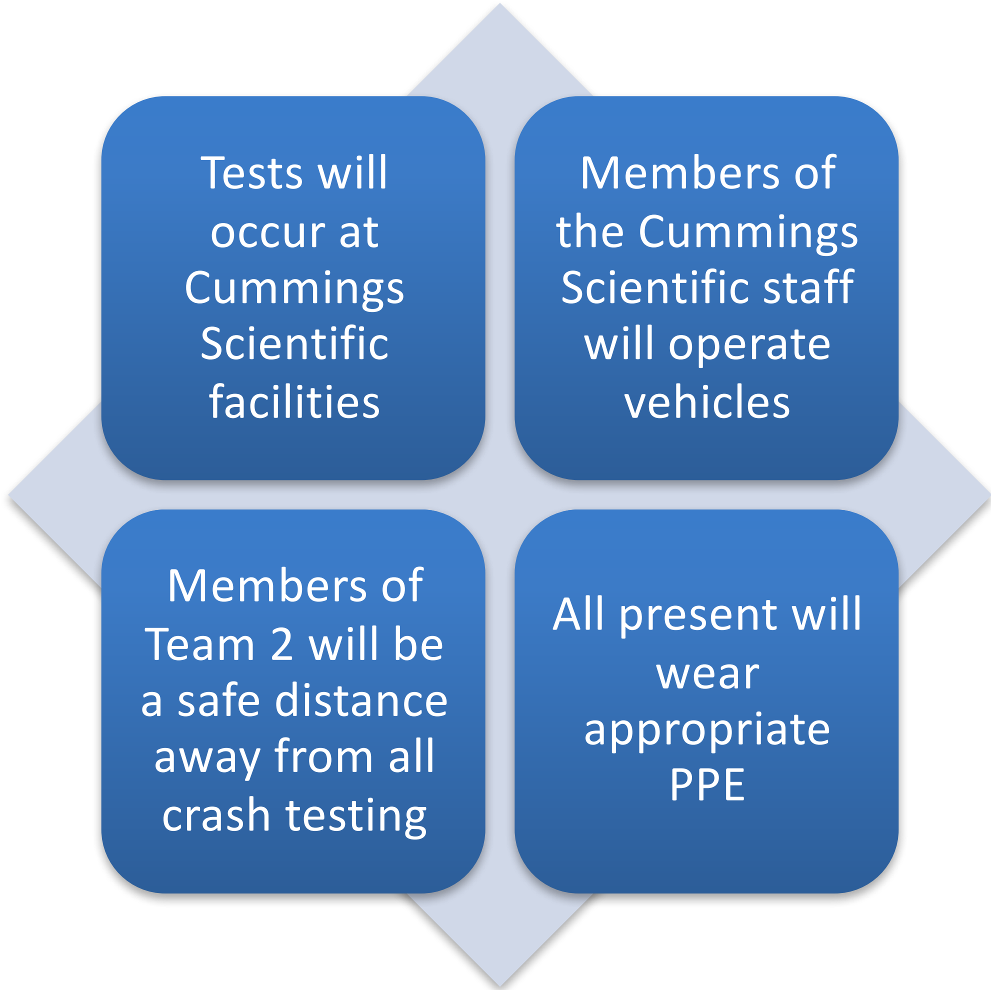


Figure 13. Important Test Information

Caroline Walker

Model Generation

- **Current Status:**
  - Background research on current models
  - Initial session to get acquainted with MADYMO
- **Future work:**
  - Test data will be processed in MADYMO
    - Built-in filters
  - Finished product will be a MADYMO model

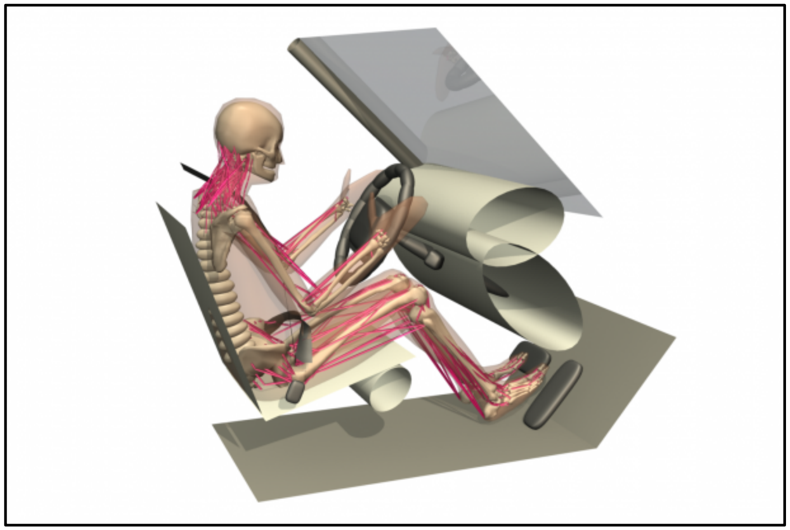


Figure 14. An example model in the MADYMO software suite (Tass International, 2017)

Caroline Walker

Caroline Walker

CONCLUSION

Conclusion

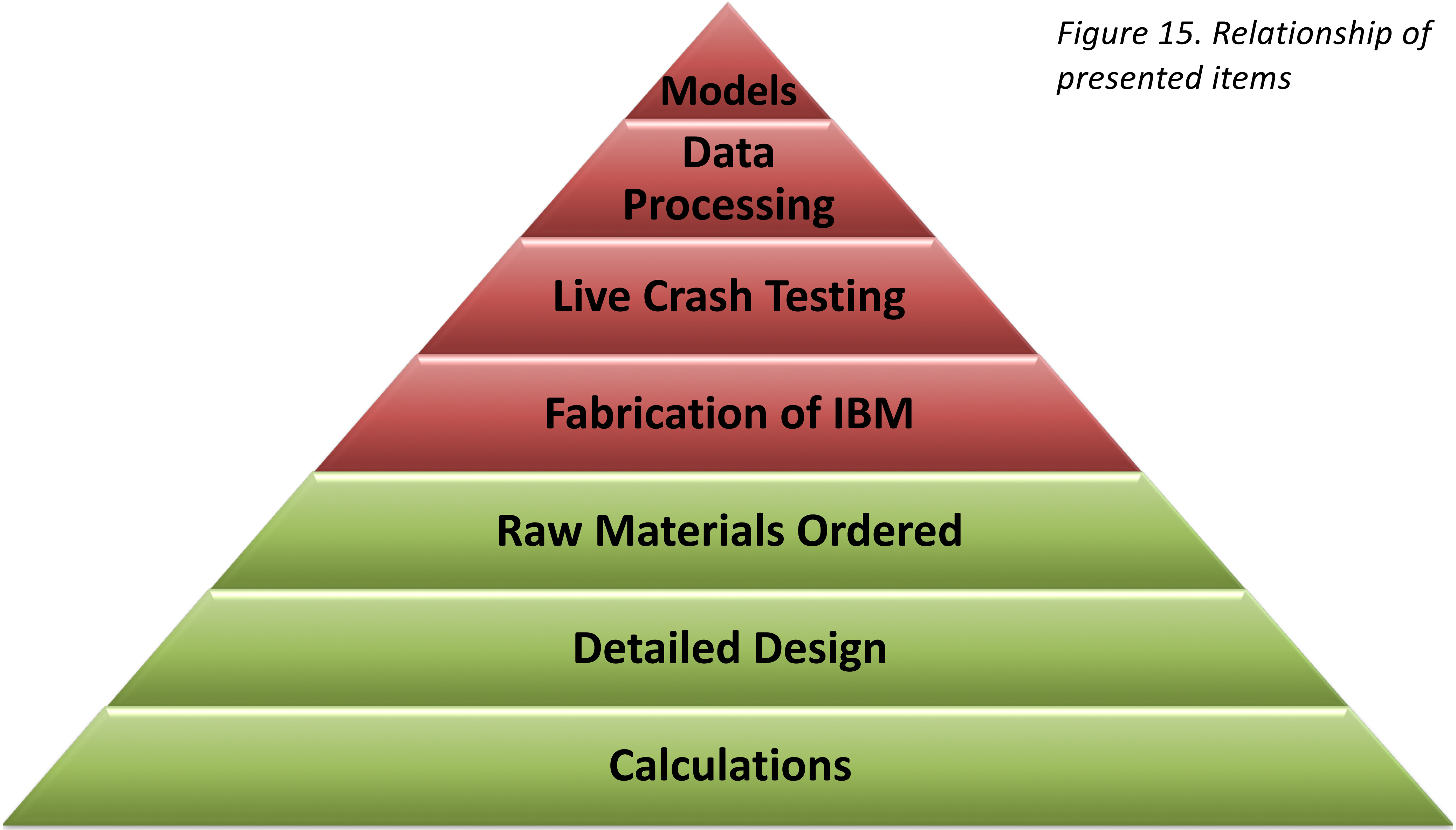


Figure 15. Relationship of presented items

References

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QUESTIONS

ADDITIONAL SLIDES

Specifications for Accelerometer

Documents & Media	
Datasheets	KX224-1053
Product Training Modules	Thin Accelerometers
Design Resources	Sensor Selector Industrial Automation Product Selector
Online Catalog	KX224

Product Attributes		Select All
Categories	Sensors, Transducers Motion Sensors - Accelerometers	
Manufacturer	Kionix Inc.	
Series	-	
Packaging	Cut Strip	
Part Status	Active	
Type	Digital	
Axis	X, Y, Z	
Acceleration Range	±8g, 16g, 32g	
Sensitivity (LSB/g)	4096 (±2g) ~ 1024 (±8g)	
Sensitivity (mV/g)	-	
Bandwidth	800Hz	
Output Type	I²C, SPI	
Voltage - Supply	1.71 V ~ 3.6 V	
Features	Selectable Scale	
Operating Temperature	-40°C ~ 85°C (TA)	
Mounting Type	Surface Mount	
Package / Case	16-LGA	
Supplier Device Package	16-LGA (3x3)	

Report an Error 1,583 Remaining Search

Retrieved from:https://www.digikey.com/product-detail/en/kionix-inc/KX224-1053-SR/1191-1048-ND/6679834

Specifications for Microcontroller

Documents & Media	
Datasheets	2756 Kinetics Peripheral Module QR K20_LH/MP5 Datasheet K20 Sub-Family Reference Manual
Design Resources	2756 Schematic
Online Catalog	Teensy 3.2 + Header Development Board

Product Attributes		Select All
Categories	Development Boards, Kits, Programmers Evaluation Boards - Embedded - MCU, DSP	
Manufacturer	Adafruit Industries LLC	
Series	Kinetis	
Part Status	Active	
Board Type	Evaluation Platform	
Type	MCU 32-Bit	
Core Processor	ARM® Cortex®-M4	
Operating System	-	
Platform	Teensy 3.2	
For Use With/Related Products	K20	
Mounting Type	Fixed	
Contents	Board(s), Accessories	

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Decision Matrix

Selection Criteria	Weights	Square Tube	Round Tube	Round Tube with Fins
Impact Strength	3	Datum	1	1
Fatigue Strength	3		0	0
Mounting accelerometers	3		-1	-1
Ease of manufacture	2		0	-1
Weight	2		1	-1
Ability to accommodate multiple types	3		0	0
Field modification	1		0	0
Buckling strength	3		1	1
Aesthetic Value	1		0	1
Score	-	0	5	0

Decision Matrix for Piston Isolator/Foam Core Connector

Decision Matrix

Selection Criteria	Weights	Angle Bracket	Square Tube
Impact Strength	3	Datum	1
Fatigue Strength	3		1
Mounting accelerometers	3		-1
Ease of manufacture	2		-1
Weight	2		-1
Ability to accommodate multiple types	3		0
Field modification	1		0
Buckling strength	3		1
Aesthetic Value	1		1
Score	-	0	3

Decision Matrix for Solid Frame Mount

Decision Matrix

Selection Criteria	Weights	Rectangular Tube	Honeycomb	Plate		Sheet	Square Tubes
Impact Strength	3	Datum	1	1		1	1
Fatigue Strength	3		1	1		-1	1
Mounting Accelerometers	3		-1	-1		0	-1
Ease of Manufacture	2		-1	0		0	-1
Weight	2		-1	-1		1	-1
Ability to Accommodate Multiple Types	3		0	0		0	0
Field Modification	1		0	-1		0	1
Buckling Strength	3		1	1		-1	1
Aesthetic Value	1		1	0		0	1
Score	-	0	3	3		-1	4

Initial Decision Matrix for Center Connection

Decision Matrix

Selection Criteria	Weights	Plate	Honeycomb	Square Tube
Impact Strength	3	Datum	-1	-1
Fatigue Strength	3		-1	-1
Mounting Accelerometers	3		1	2
Ease of Manufacture	2		-3	-1
Weight	2		1	2
Ability to Accommodate Multiple Types	3		0	0
Field Modification	1		1	3
Buckling Strength	3		-1	0
Aesthetic Value	1		3	1
Score	-	0	-6	6

Final Decision Matrix for Center Connection

Safety Factor Table

Table 1-3 Factors Used to Determine a Safety Factor for Ductile Materials

Information	Quality of Information	Factor
		F1
Material-property data available from tests	The actual material used was tested	1.3
	Representative material test data are available	2
	Fairly representative material test data are available	3
	Poorly representative material test data are available	5+
		F2
Environmental conditions in which it will be used	Are identical to material test conditions	1.3
	Essentially room-ambient environment	2
	Moderately challenging environment	3
	Extremely challenging environment	5+
		F3
Analytical models for loading and stress	Models have been tested against experiments	1.3
	Models accurately represent system	2
	Models approximately represent system	3
	Models are crude approximations	5+

$$N_{brittle} \cong 2 * MAX\left(F1, F2, F3\right) \qquad (1.1b)$$

This method of determining a safety factor is only a guideline to obtain a start-

Safety Factor Table from *Design of Machinery* (R.L Norton)