INTERIM DESIGN REVIEW
AIR BEARING UPGRADE FOR SHPB EXPERIMENT

Group 1

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Sponsored by Eglin Air Force Research Laboratory

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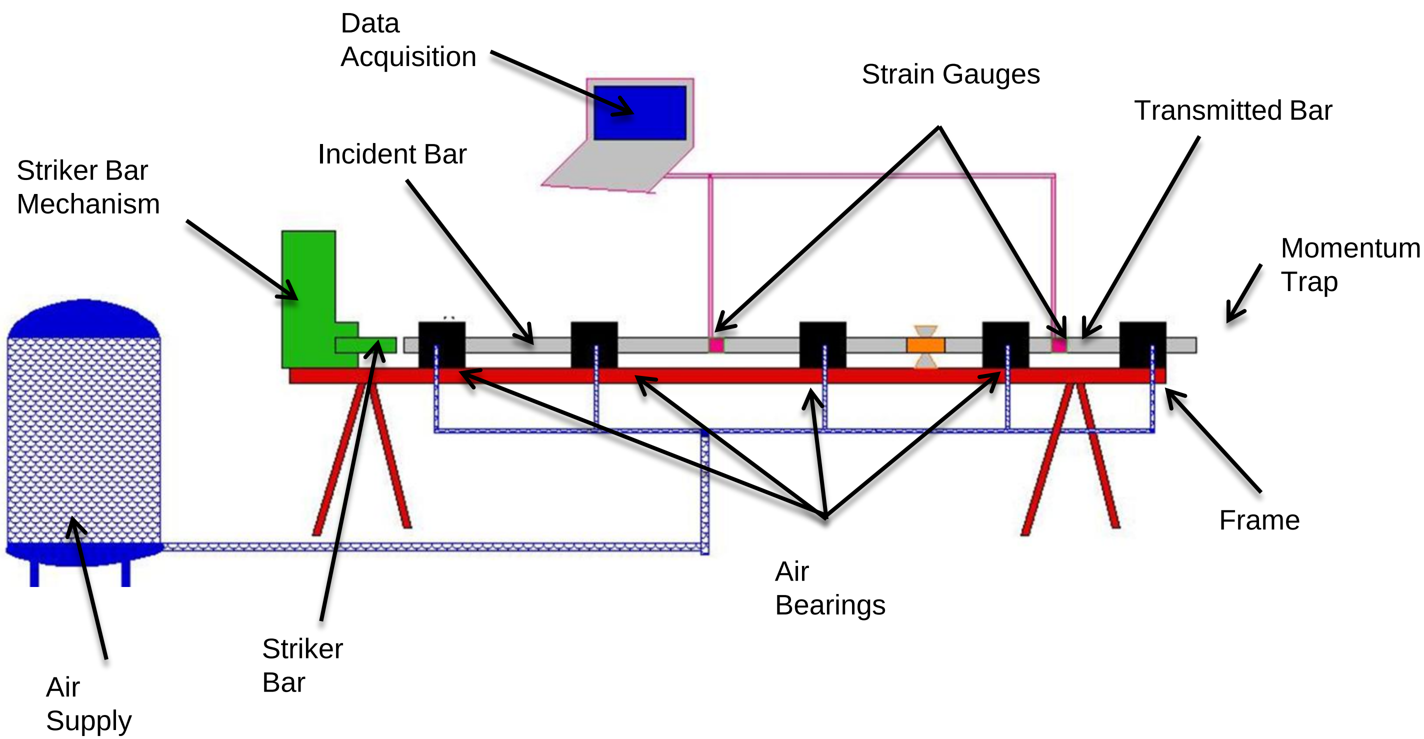
Overview

- Introduction
- Requirements
- Chosen Concepts
- Decision Matrix
- Cost Analysis
- Remaining Schedule
- Summary
- Questions
- Calculations

Introduction

- Design small scale SHPB system

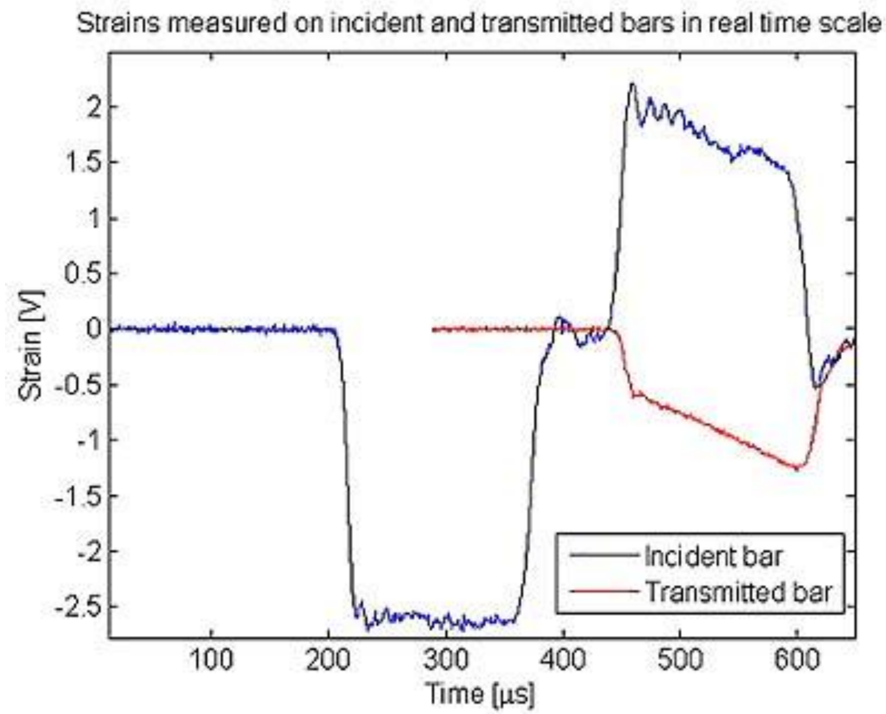


Requirements

- Analyze SHPB design based on use of air bearings
- Provide analysis of:
  - Hardware cost
  - Interface requirements
  - Installation procedures
  - Impact on bar geometry
- Provide assessment of strain gauge technology
- Develop procedure to align bars
- Design a working prototype to show knowledge of system

Striker Bar Mechanism

- Sets the whole system in motion.
- Generates square pulse

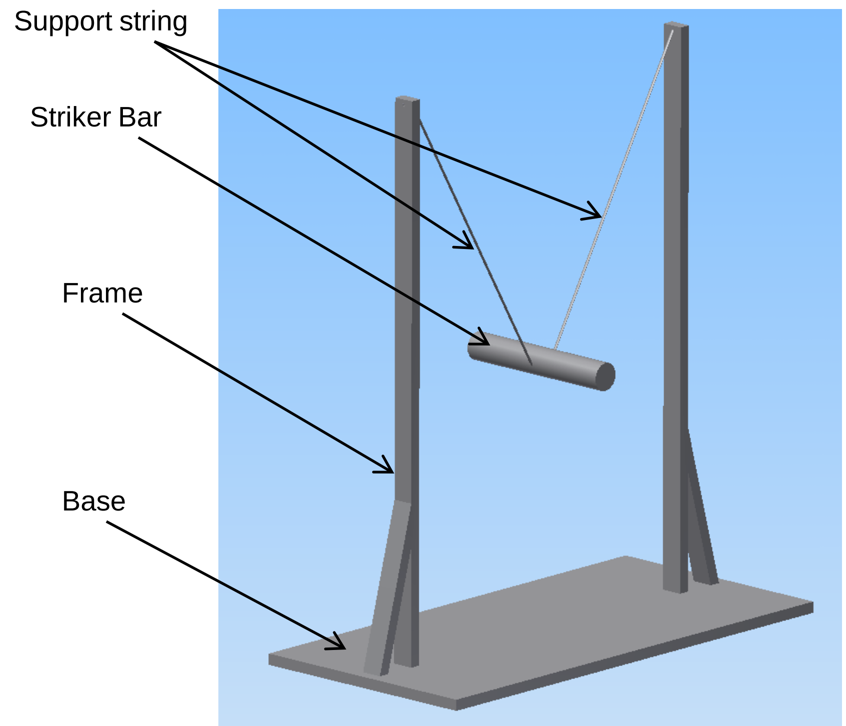


- Constant velocity
- For this project – simple.

http://www.tut.fi/files/Pictures/mkar_hop21.jpg

Concept 1

- Pendulum
- Simple
- Cost efficient
  - ~$30
- Easy to operate

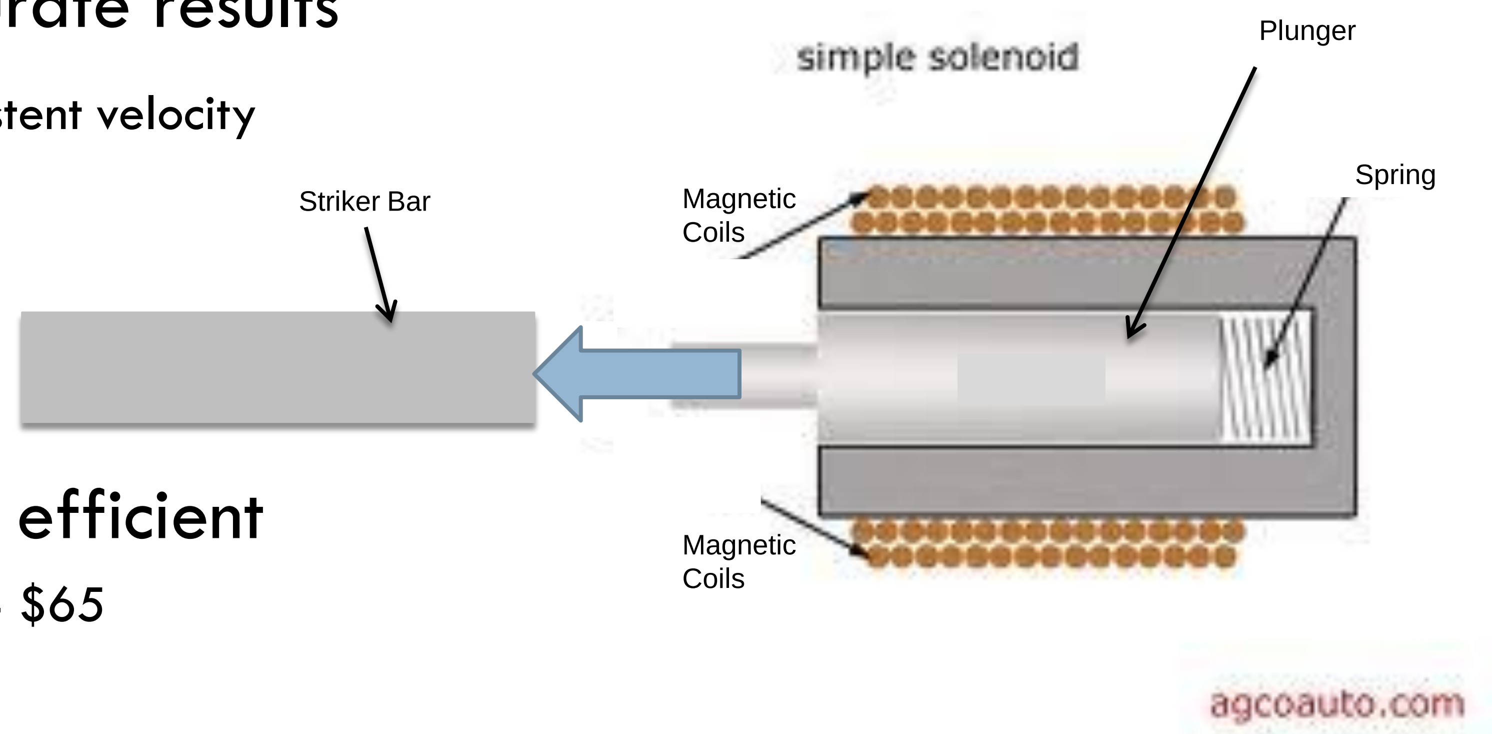


Concept 2

- Push solenoid

- Accurate results

  Consistent velocity



- Cost efficient

  $20 - $65

Striker Bar Mechanism Decision Matrix

Design Factor	Weighing Factor	Pendulum	Solenoid
Cost	0.2	4	3
Simplicity	0.2	5	3
Accuracy	0.3	3	5
Durability	0.2	4	5
Weight	0.1	4	4
Total	1	3.9	4.1

Scale: 1 = worst
5 = best

Bar & Air Bushing Sizes

- Bushing Specifics
  - Companies: New Way , Nelson Air
    - 0.5” diameter
      - $210.00 each (New Way)
      - $262.00 each (Nelson)
    - 0.75” diameter
      - $265.00 each (New Way)
      - $331.00 each (Nelson)

- Bar Specifics
  - Company: McMaster-Carr
    - (2) 36” length
    - 0.5”diameter
      - $20.00 - $55.00 each
    - 0.75” diameter
      - $30.00 - $80.00 each
    - Diameter Tolerance: -0.0005” to -0.001”
    - Straightness: 0.002” per ft.

Bar Decision Matrix

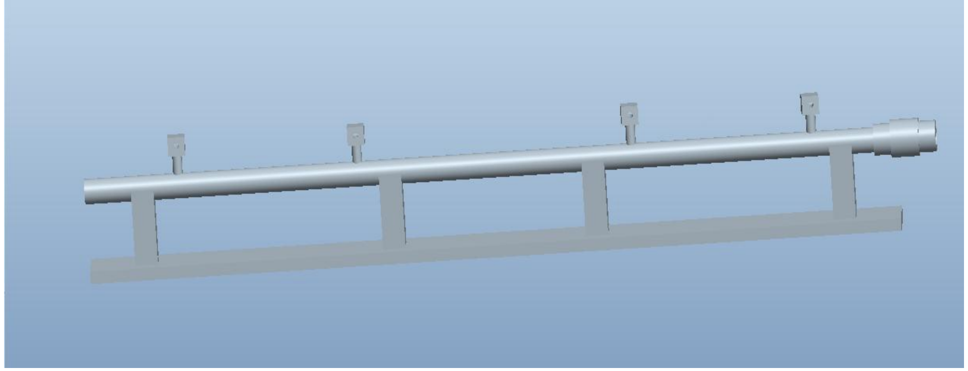
	Weight	.5"	.75"
Cost	0.1	4	3
Weight	0.2	4	4
Size	0.1	5	5
Durability	0.2	5	5
Portability	0.1	4	4
Accuracy	0.2	3	4
Data Quality	0.1	3	4
Score	--------	4.0	4.2

Air Bushing Supplier Decision Matrix

	Weight	New Way	Nelson
Cost	0.2	3	2
Weight	0.2	5	5
Size	0.1	5	5
Durability	0.2	5	4
Portability	0.1	5	5
Accuracy	0.2	5	4
Score	--------	4.6	4

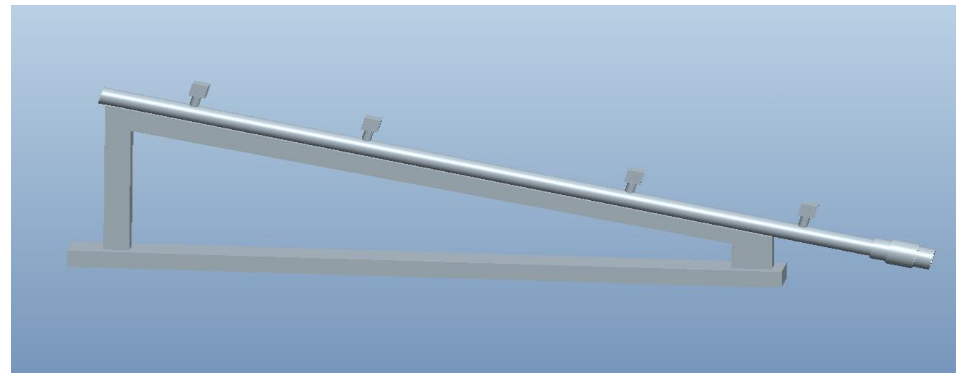
Air Supply Manifold

- Design 1: Horizontal Manifold
  - Steel Pipe
    - < $20.00
  - (4) Air supply valves
  - End valve release
    - Purging valve



Air Supply Manifold

- Design 2: Declined Manifold
  - Steel Pipe
    - < $20.00
  - (4) Air supply valves
  - End valve release
    - Purging valve



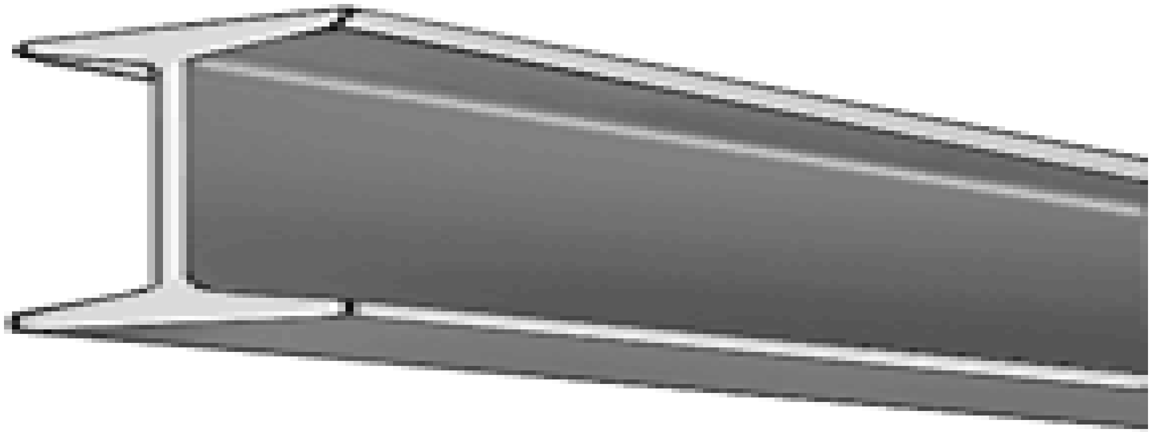
Air Manifold Decision Matrix

	Weight	Horizontal	Declined
Cost	0.2	3	3
Weight	0.1	3	3
Size	0.2	3	3
Simplicity	0.1	5	3
Durability	0.2	4	4
Portability	0.2	3	3
Score	--------	3.4	3.2

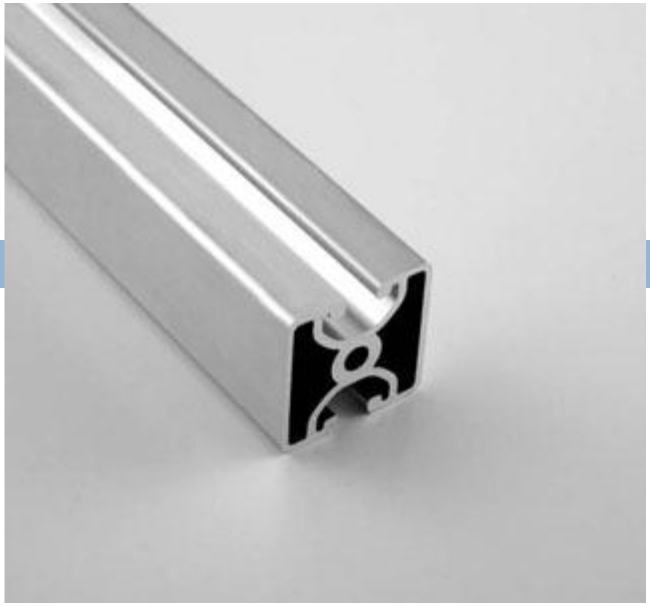
Base

Concept 1 I beam

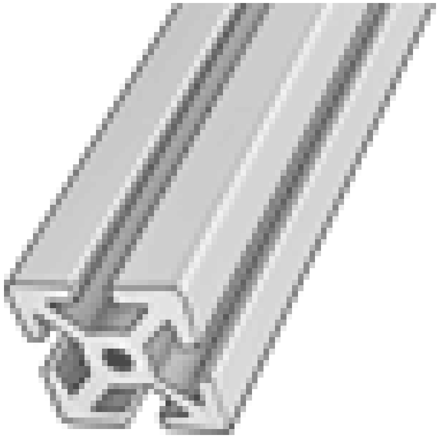
- Cost ~ $96 6 foot section
- Steel
  - High strength
  - Heavy
- Simple alignment
- Scalable



Base Concept 2 T-Slotted Framing



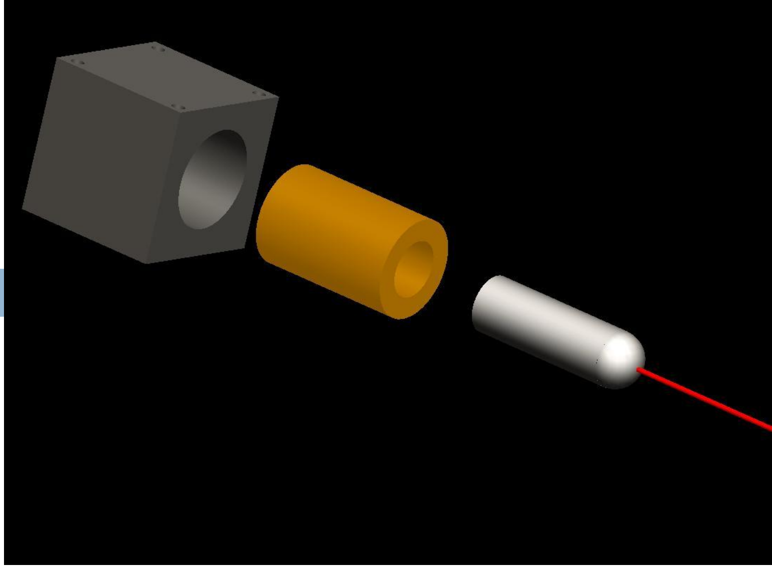
- Cost ~ $45 8 foot section
- Aluminum
  - Lightweight
  - Rigid geometry
- Automatic alignment
- Scalable



Base Decision Matrix

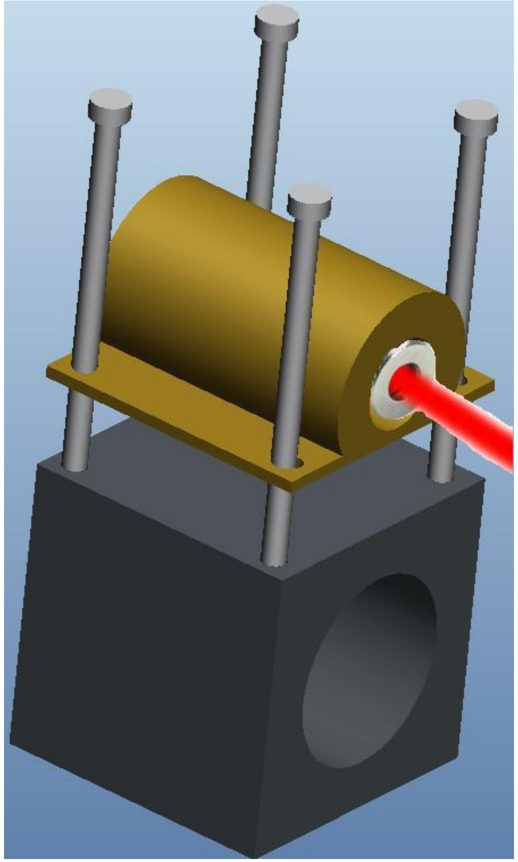
	Weight	I – Beam	T-Slot
Cost	.3	3	5
Simplicity	.2	4	4
Weight	.2	2	4
Portability	.3	4	5
Score	--------	3.3	4.6

Bearing Alignment Concept 1 Center Bore Alignment



- Maintains axial alignment
- Simple insert and check
- Can be scaled to any size radius
- Accurate

Bearing Alignment
Concept 2 Exterior Mount Alignment



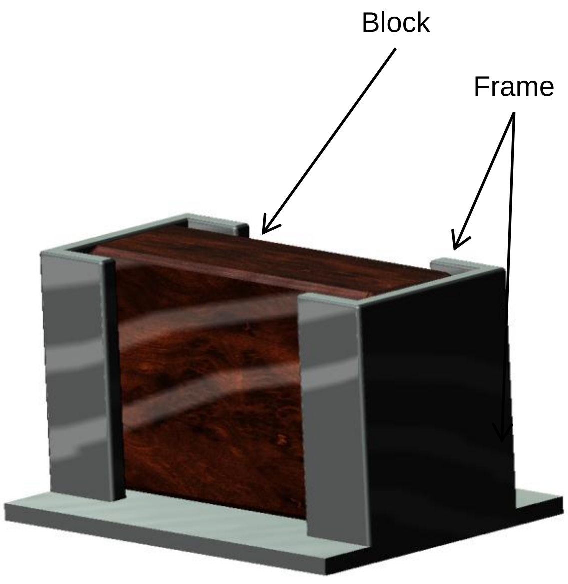
- Uses secondary axis for alignment
- Must be remounted for each bearing
- Can be easily scaled
- Accurate

Bearing Alignment Decision Matrix

	Weight	Inserted	Mounted
Cost	0.2	3	3
Simplicity	0.1	2	4
Scalability	0.2	4	3
Accuracy	0.4	5	4
Ease of Use	0.1	5	3
Score	--------	4.1	3.5

Momentum Trap

- Absorbs transmitted wave to reduce system shock.
- Requirements: low cost, high impact absorption
- Concept 1: Custom Impact Bumper
  - Simple, Durable, Low Cost
    - Replaceable, cheap absorber
    - $30 range
  - Shock absorbing material
    - Soft Wood
    - High Density Rubber



Custom Impact Bumper

Momentum Trap

- Concept 2: Manufactured Bumper
  - Readily available
  - Various styles
  - $30 range
  - Less easily replaced

Manufactured Bumpers

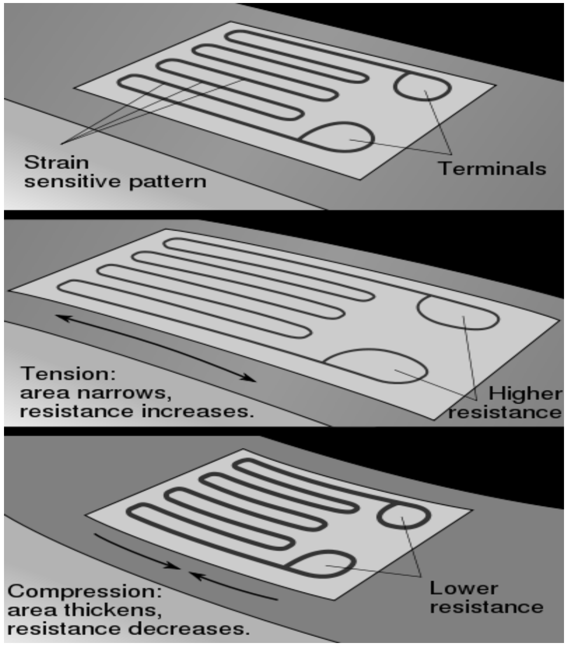
Momentum Trap

Design Factor	Weighing Factor	Custom	Prefabricated
Cost	0.2	4	4
Weight	0.1	4	3
Size	0.1	3	3
Simplicity	0.1	4	4
Durability	0.25	4	3
Scalability	0.15	4	3
Ease of Use	0.1	4	4
Totals	**1**	**27**	**24**
Weighted Averages		**3.9**	**3.4**

Scale: 1 to 5
Best = 5

Strain Gauges

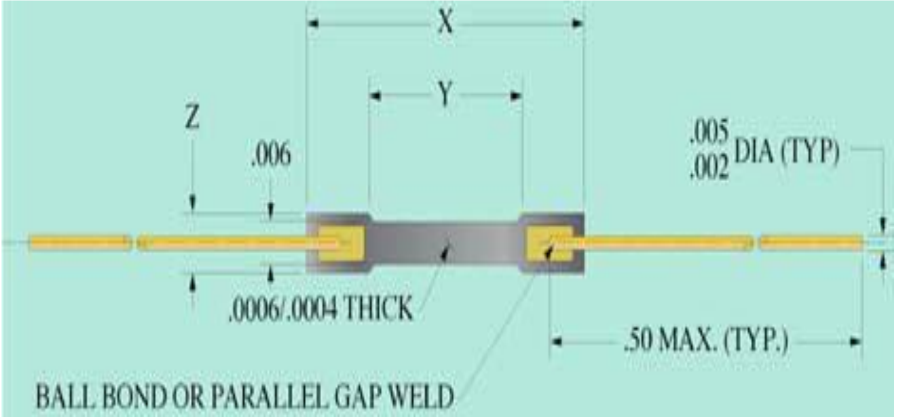
- SHPB experiment
  - < 1% Strain on Bars
- Foil Strain Gauges
  - Durable
  - Utilized on AFRL SHPB
  - Cost
    - $10 to $20 each (x8)
    - $80 to $160 total cost



Foil Strain Gauge

Strain Gauges

- Semiconductor Gauge
  - Higher Sensitivity
  - Slightly Lower Durability
  - Cost
    - Micron-Instruments
    - Unmatched
      - $10 to $20 each (x8)
      - $80 to $160 Total
    - Matched Set of 4
      - $75 to $100 per set (x2)
      - $150 to $200 Total



Semiconductor Strain Gauge

Strain Gauges

Design Factor	Weighing Factor	Foil	Semiconductor
Cost	0.2	4	3
Size	0.1	4	5
Data Quality	0.3	4	5
Durability	0.2	5	4
Ease of Use	0.2	4	4
Totals	**1**	**24**	**26**
Weighted Averages		**4**	**4.4**

Scale: 1 to 5
Best = 5

Data Acquisition

- High data rates
  - 100 kS/s/channel
- Software
  - LabVIEW
    - User friendly
    - Quick setup
    - Available at COE
- Hardware
  - Expensive
    - > $500 for NI platforms
  - Solution
    - Make use of hardware available at COE.

Decision Matrix

		Cost	Weight	Size	Simplicity	Durability	Portability	Scalability	Accuracy	Data Quality	Ease of Use	Score
Base	**Weight**	**0.3**	**0.2**	**N/a**	**0.2**	**N/a**	**0.3**	**N/a**	**N/a**	**N/a**	**N/a**	
	I-beam	3	2		4		4					3.3
	T-slot	5	4		4		5					4.6
Bushing	**Weight**	**0.2**	**0.2**	**0.1**	**N/a**	**0.2**	**0.1**	**N/a**	**0.2**	**N/a**	**N/a**	
	New Way	3	5	5		5	5		5			4.6
	Nelson	2	5	5		4	5		4			4
Strain Gauges	**Weight**	**0.2**	**N/a**	**0.1**	**N/a**	**0.2**	**N/a**	**N/a**	**N/a**	**0.3**	**0.2**	
	Foil	4		4		5				3	4	3.9
	Semiconductor	3		5		4				5	4	4.2
Bar *	**Weight**	**0.1**	**0.2**	**0.1**	**N/a**	**0.2**	**0.1**	**N/a**	**0.2**	**0.1**	**N/a**	
	1/2 inch	4	4	5		5	4		3	3		4
	3/4 inch	3	4	5		5	4		4	4		4.2
Striker Bar	**Weight**	**0.2**	**0.1**	**N/a**	**0.2**	**0.2**	**N/a**	**N/a**	**0.3**	**N/a**	**N/a**	
	Solenoid	3	4		3	5			5			4.1
	Pendulum	4	4		5	4			3			3.9
Air Manifold	**Weight**	**0.2**	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**	**N/a**	**N/a**	**N/a**	**N/a**	
	Horizontal	3	3	3	5	4	3					3.4
	Declined	3	3	3	3	4	3					3.2
Bearing Alignmen	**Weight**	**0.2**	**N/a**	**N/a**	**0.1**	**N/a**	**N/a**	**0.2**	**0.4**	**N/a**	**0.1**	**1**
	Insert	3			2			4	5		5	4.1
	Mounted	3			4			3	4		3	3.5
Momentum Trap	**Weight**	**0.2**	**0.1**	**0.1**	**0.1**	**0.25**	**N/a**	**0.15**	**N/a**	**N/a**	**0.1**	
	Custom	4	4	3	4	4		4			4	3.9
	Prefabricated	4	3	3	4	3		3			4	3.4

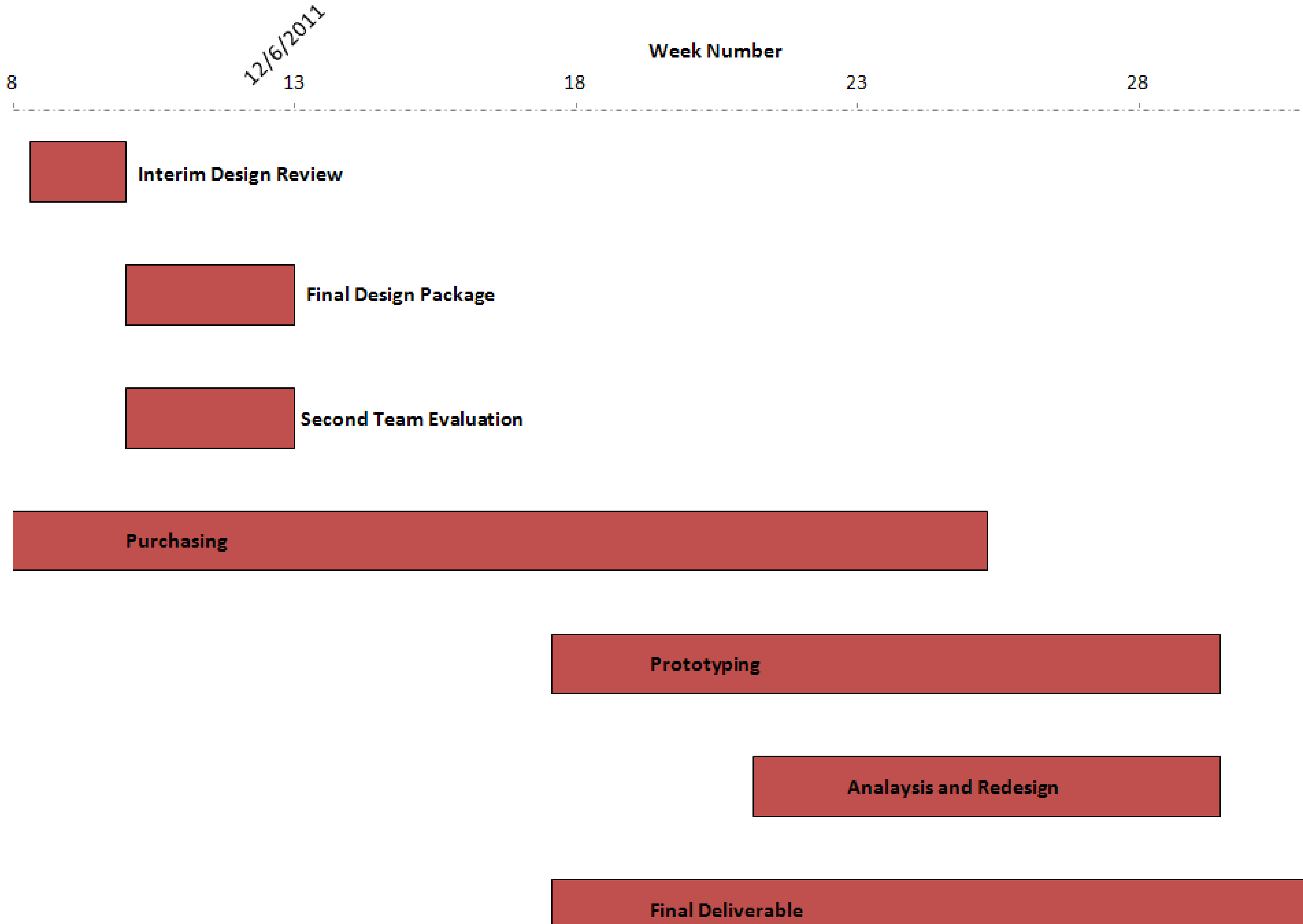
Senior Design Group #1: Preliminary Cost Analysis

*Prices do not include shipping

Budget	$2,500.00
Total Cost	$1,027.61
Remaining	$1,472.39

Item	Quantity	Unit Cost	Total Cost	Source	Part Number
Air Bushings 0.5 inch	4	210.00	$840.00	New Way	S301201
Solenoid	1	64.94	$64.94	McMaster Carr	7723K12
T-slot Framing 1 1/2 inch (96 inch length)	1	48.15	$48.15	McMaster Carr	47065T119
Incident & Transmission Bar: 1566 Steel Bar 0.5 inch (36inch length)	2	18.67	$37.34	McMaster Carr	6061K63
Air Manifold (72 inches)	1	16.34	$16.34	McMaster Carr	4457K35
T-slot Framing 1 1/2 inch (24 inch length) For stability	1	13.98	$13.98	McMaster Carr	47065T119
Striker Bar: 1566 Steel Bar 0.5 inch (12inch length)	1	6.86	$6.86	McMaster Carr	6061K33
DAQ			$0.00	COE	
Momentum Trap			$0.00	Group	
Air supply			$0.00	Group	

Senior Design Project # 1 Remaining Schedule of Responsibilities



Questions?

Comments?

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Plastic Energy Derivation

- Stress $\sigma = F/A$
- Strain $\varepsilon = (Li - Lo) / Lo$
- Gauge Factor $GF = [(Ri - Ro) / Ro] / \varepsilon$
- Data Strain $\varepsilon (Ri) = [(Ri - Ro) / Ro] / GF$

Plastic Energy Derivation

- Strain in Specimen:

$$d\varepsilon_{avg} / dt = (c_b / L_s) * (\varepsilon_{I-} - \varepsilon_R - \varepsilon_T)$$

- Integration:

$$\varepsilon_s = (C_b / L_s) * \int_0^t [(\varepsilon_{I-} - \varepsilon_R - \varepsilon_T) * dt]$$

Strain through the specimen

Plastic Energy Derivation

- Strain energy for each wave

$$\text{Kinetic energy} = 0.5 * m * v^2$$

- Initial $E_I = 0.5 * A_B * C_B * E_B * T * \varepsilon_I^2$
- Reflected $E_r = 0.5 * A_B * C_B * E_B * T * \varepsilon_R^2$
- Transmitted $E_t = 0.5 * A_B * C_B * E_B * T * \varepsilon_T^2$

Plastic Energy Derivation

- Strain energy

$$\delta S_E = E_I - E_R - E_T$$

- Plastic Energy absorbed by specimen

$$E_s = 2 * \delta S_E$$