MID-POINT REVIEW
AIR BEARING UPGRADE FOR SHPB EXPERIMENT

Group 1

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Sponsored by Eglin Air Force Research Laboratory

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Outline

- Project Scope
- Introduction
- Current Status
- Upcoming Plans
- Schedule
- Summary

Project Scope

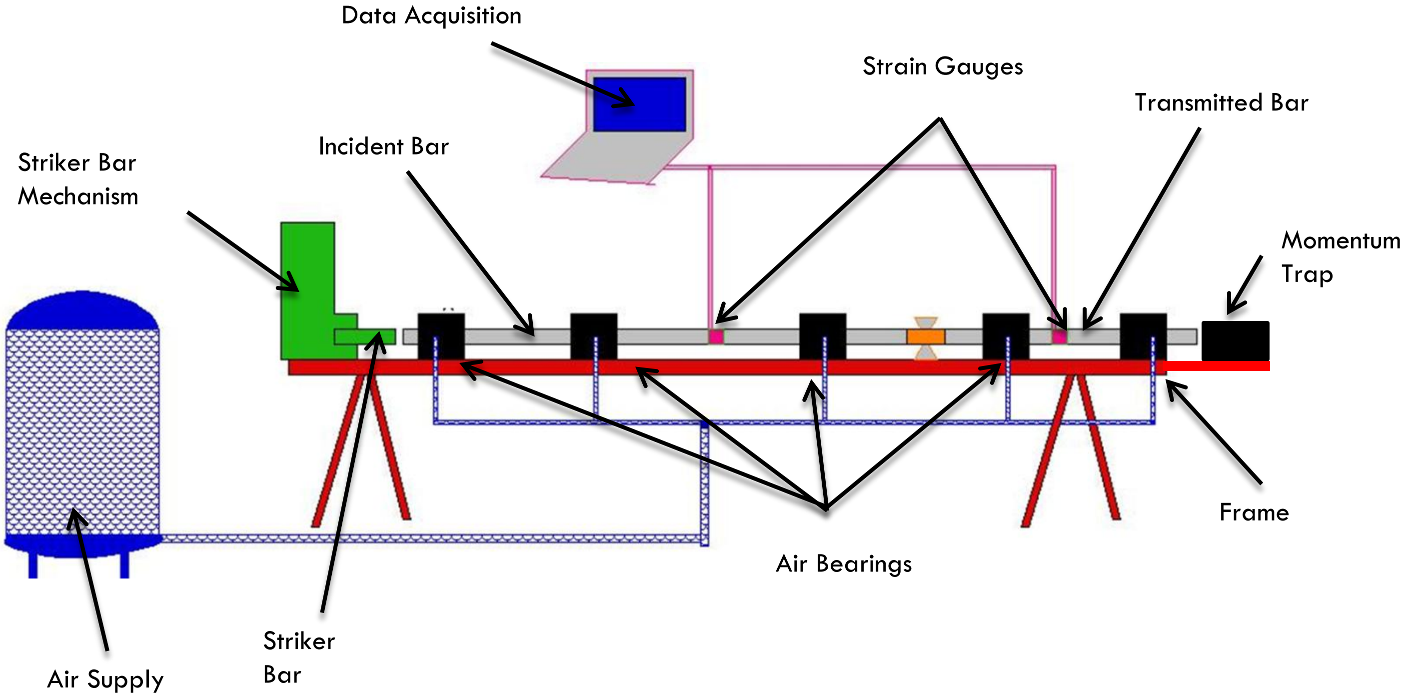
- Design a small scale Split-Hopkinson Pressure Bar Experiment
- Analyze SHPB design based on use of air bearings
- Provide analysis of:
  - Hardware cost
  - Interface requirements
  - Installation procedures
  - Impact on bar geometry

Project Scope

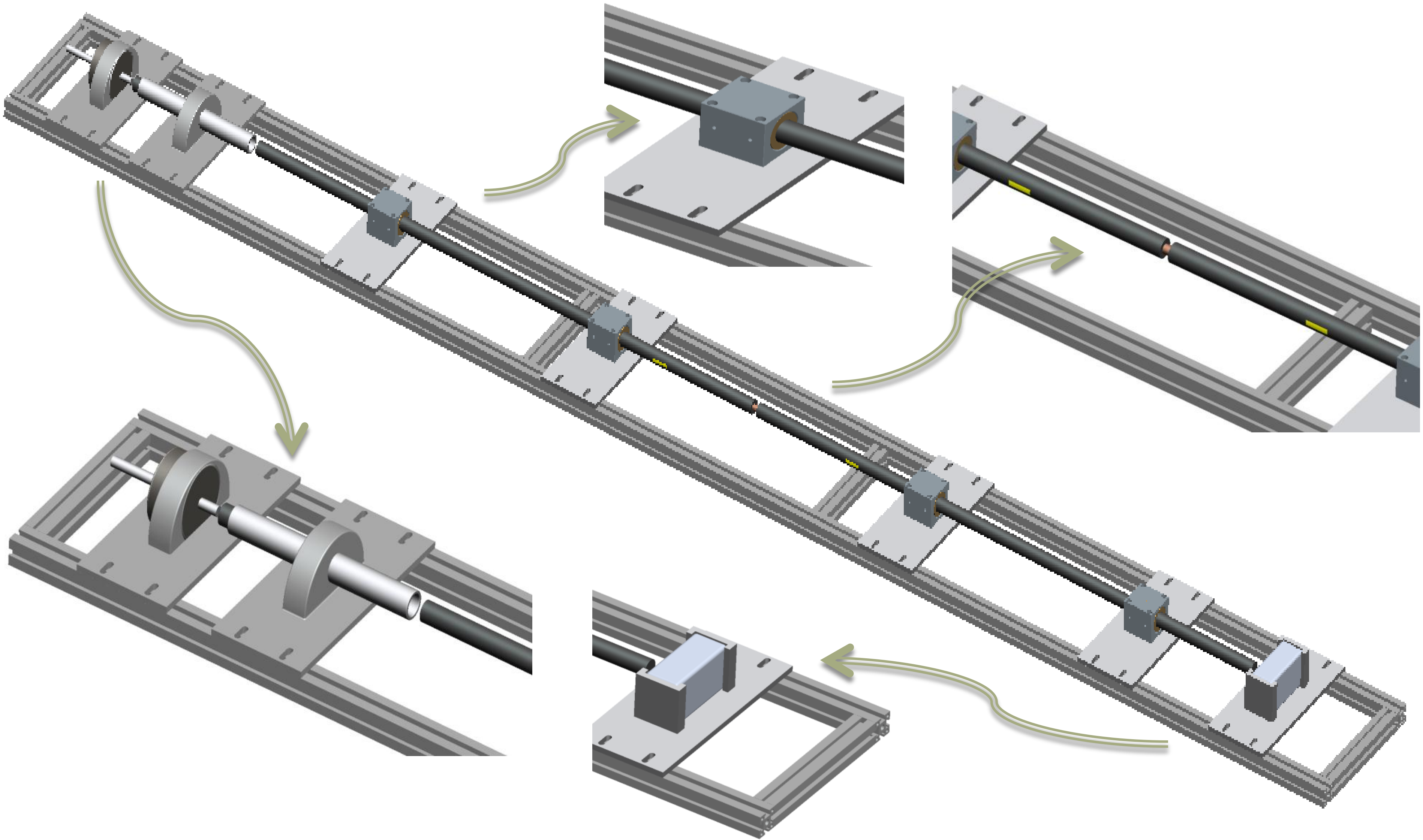
- Provide assessment of strain gauge technology
- Develop procedure to align bars
- Design a working prototype to show knowledge of system

Introduction - Overall Design

- Design small scale SHPB system

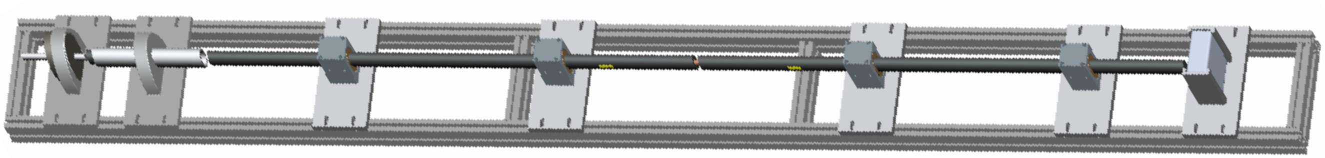


Introduction - Final Concept Model



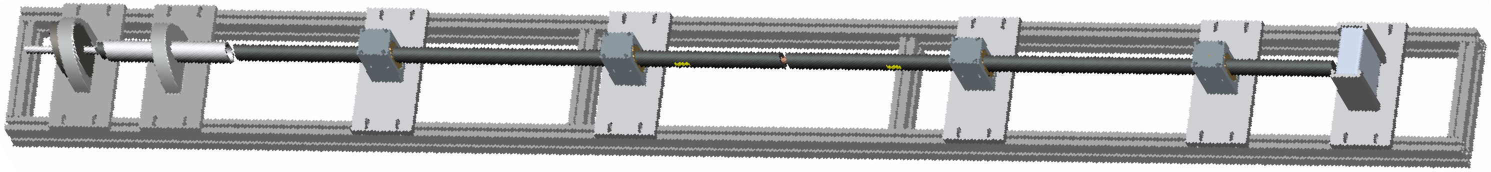
Current Status

- Materials received
- Part Machining Underway
- Construction Underway



Current Status

- LabView DAQ Program Under Construction
- Operations Manual Started
- Budget - $500 remaining of $2,500



Upcoming Plans

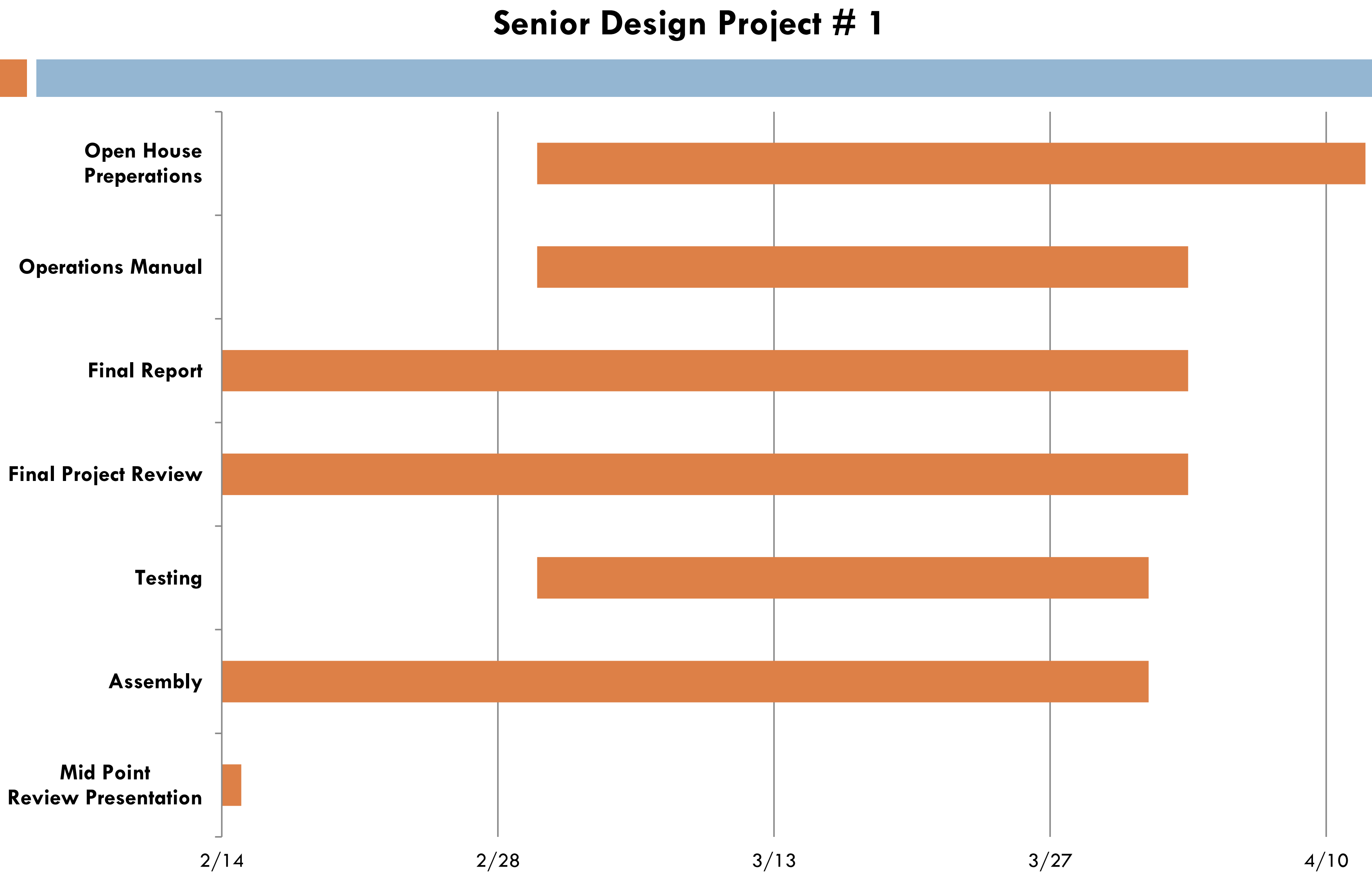
- Finalize testing location, February 21st
- Complete prototype: March 5th
- Complete LabView programming, March 5th
- Test apparatus, March 12th – 26th

Checks / Tests

- Construction Checks
  - Bar to bushing fit/tolerances
  - Bar alignments
  - Striker bar and momentum trap mechanisms

- Final Tests
  - Dry run with no sample
    - Check strain gages
  - Full run with sample
    - Obtain sample deformation data

Schedule


Senior Design Project # 1
Open House Preperations
Operations Manual
Final Report
Final Project Review
Testing
Assembly
Mid Point Review Presentation
2/14
2/28
3/13
3/27
4/10

Summary

- Machining & Construction Underway
- Finalizing Testing Location(s)
- Selecting Testing Dates
- LabView Code / Instruction Manuel Underway
- Schedule Updated

Questions?

Comments?

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

$$E_s = 2 * \delta S_E$$

Velocity Calculations

The velocity of the striker bar is needed
The only requirement is that the specimen plasticaly deform
while the incident and transmitter bars are only loaded elasticaly
The following equations show the process

$$\sigma_{yc} := 70MPa$$

Yield stress of copper

$$Area_c := \pi \cdot \left(\frac{.4}{2} in\right)^2 = \blacksquare \cdot in^2$$

Area of the copper

$$F := \sigma_{yc} \cdot Area_c = \blacksquare \cdot kN$$

Force Required to reach Yield

Next the mass of the steel bar is computed

$$\rho := 7.85 \frac{gm}{cm^3}$$

Density of steel

$$v := \pi \cdot \left(\frac{0.75}{2}\right)^2 in^2 \cdot 6in = \blacksquare \cdot in^3$$

Volume of the 3/4 inch diameter, 6 in striker bar

$$mass := v \cdot \rho = \blacksquare$$

Mass of the striker bar

Velocity Calculations

Next the amount of time the striker bar will impact the incident bar

$c := 6100\frac{m}{s}$ Speed of wave propogation in steel

$L := 6in$ Length of Striker bar

$t := 2\cdot\frac{L}{c} = \blacksquare\cdot s$

Pressure wave propogating down the strikerbar and returning
= 2 x length/speed

$t = \blacksquare\cdot\mu s$ Duration of impact

Finaly the minimum velocity of the striker bar needed to plasticaly deform the specimen

$V := \frac{F}{mass}\cdot t = \blacksquare$

$V = \blacksquare\cdot\frac{mi}{hr}$

Minimum velocity of striker bar needed to plasticaly deform the copper specimen

Velocity Calculations

$$Acc := \frac{310ozf}{mass} = ▮$$

Acceleration available from a chosen solenoid

$$L_{sol} := 1in$$

Length of piston with given force

$$D = D_o + V_o \cdot t + .5A_{cc} \cdot t^2$$

Generic dynamic position equation

$$time_{sol} := \left(\frac{L_{sol}}{0.5\,Acc}\right)^{.5} = ▮$$

Derived time, from previous equation

$$V_{stkr} := Acc \cdot time_{sol} = ▮ \cdot \frac{mi}{hr}$$

Calculated velocity from given solenoic

$$Force_{striker.sol} := \frac{V_{stkr} \cdot mass}{t} = ▮ \cdot kN$$

Maximum force transfered from solenc

Weak Formulation for FEA

$$\rho\cdot A\cdot\frac{d^2}{dt^2}T-\frac{d}{dx}\left[E\cdot A\cdot\left(\frac{d}{dx}u\right)\right]-f(x,t)=0$$

$$\int\left[w\cdot\rho\cdot A\cdot\frac{d^2}{dt^2}T-w\cdot\frac{d}{dx}\left[E\cdot A\cdot\left(\frac{d}{dx}u\right)\right]-w\,f(x,t)\right]d(x,t)=0$$

$$\int\left[-(\rho\cdot A)\cdot\left(\frac{d}{dt}w\right)\cdot\left(\frac{d}{dt}T\right)-w\,f(x,t)\right]d(x,t)+w\cdot A\cdot\rho\cdot\left(\frac{d}{dt}T\right)=0$$

Weak Formulation for FEA

$$[K]*\{u\} + [C]*\{\dot{u}\} + [M]*\{\ddot{u}\} = \{F\}$$

$$K_{ij} = \int_{xa}^{xb} \left[a(x) \cdot \left(\frac{d}{dx} \psi_i \right) \cdot \left(\frac{d}{dx} \psi_j \right) + c(x)\, \psi_i \cdot \psi_j \right] dx$$

$$M_{ij} = \int_{xa}^{xb} c_o(x) \cdot \psi_i \cdot \psi_j \, dx$$