PROGRESS REPORT
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 Goals
- Project Update
- Schedule

Project Scope

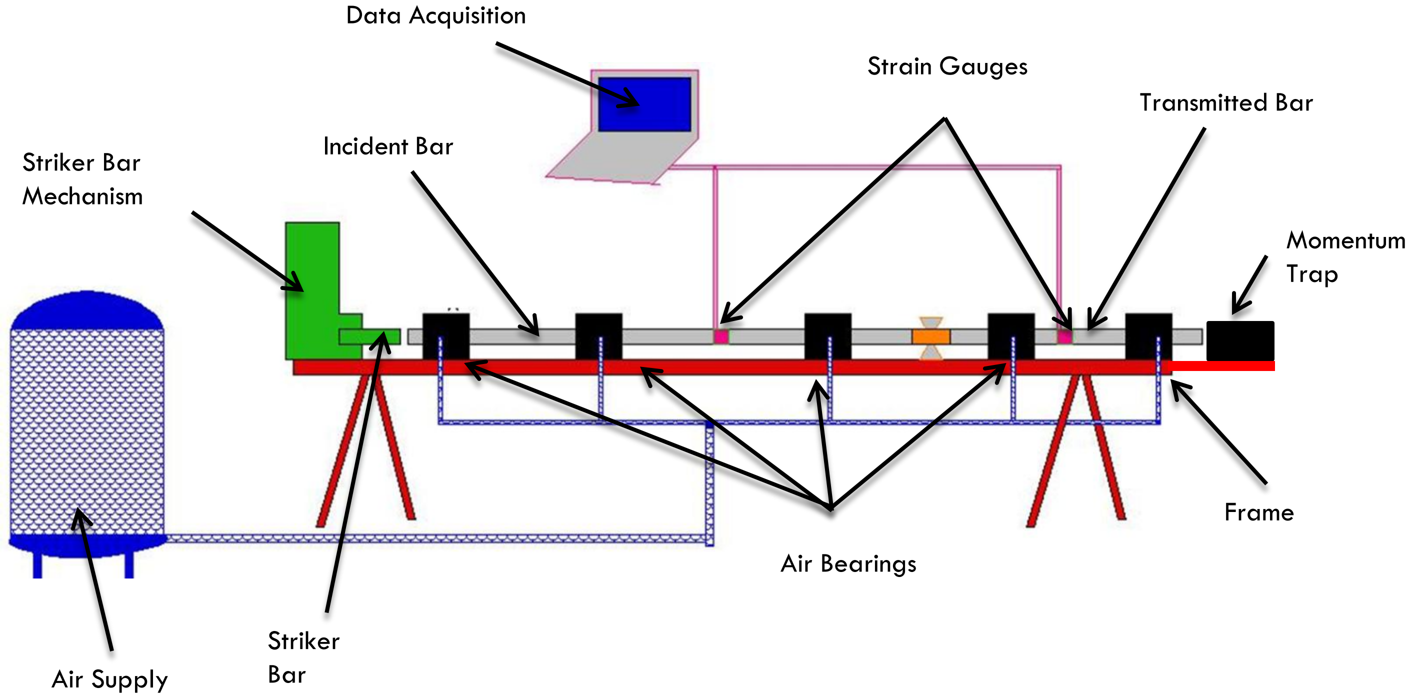
- Design a small scale Split-Hopkinson Pressure Bar Experiment
- Analyze SHPB design based on use of air bearings
- Provide analysis of:
  - Hardware cost
  - Interface requirements
  - Installation procedures
  - Impact on bar geometry

Project Scope

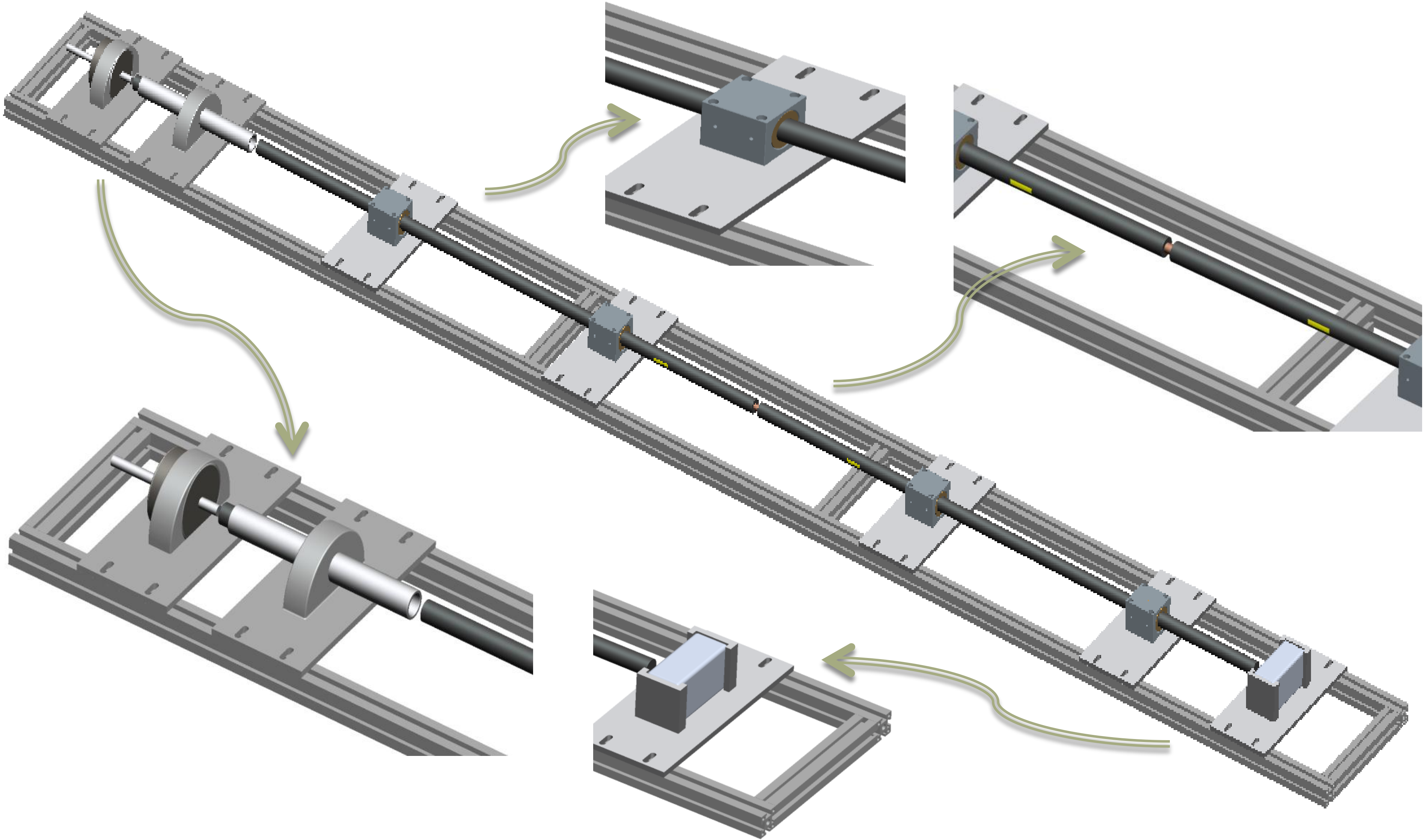
- Provide assessment of strain gauge technology
- Develop procedure to align bars
- Design a working prototype to show knowledge of system

Introduction - Overall Design

- Design small scale SHPB system



Introduction - Final Concept Model



Current Goals

- Locate data acquisition system
- Finalize air supply system
- Receive all materials
- Begin Construction

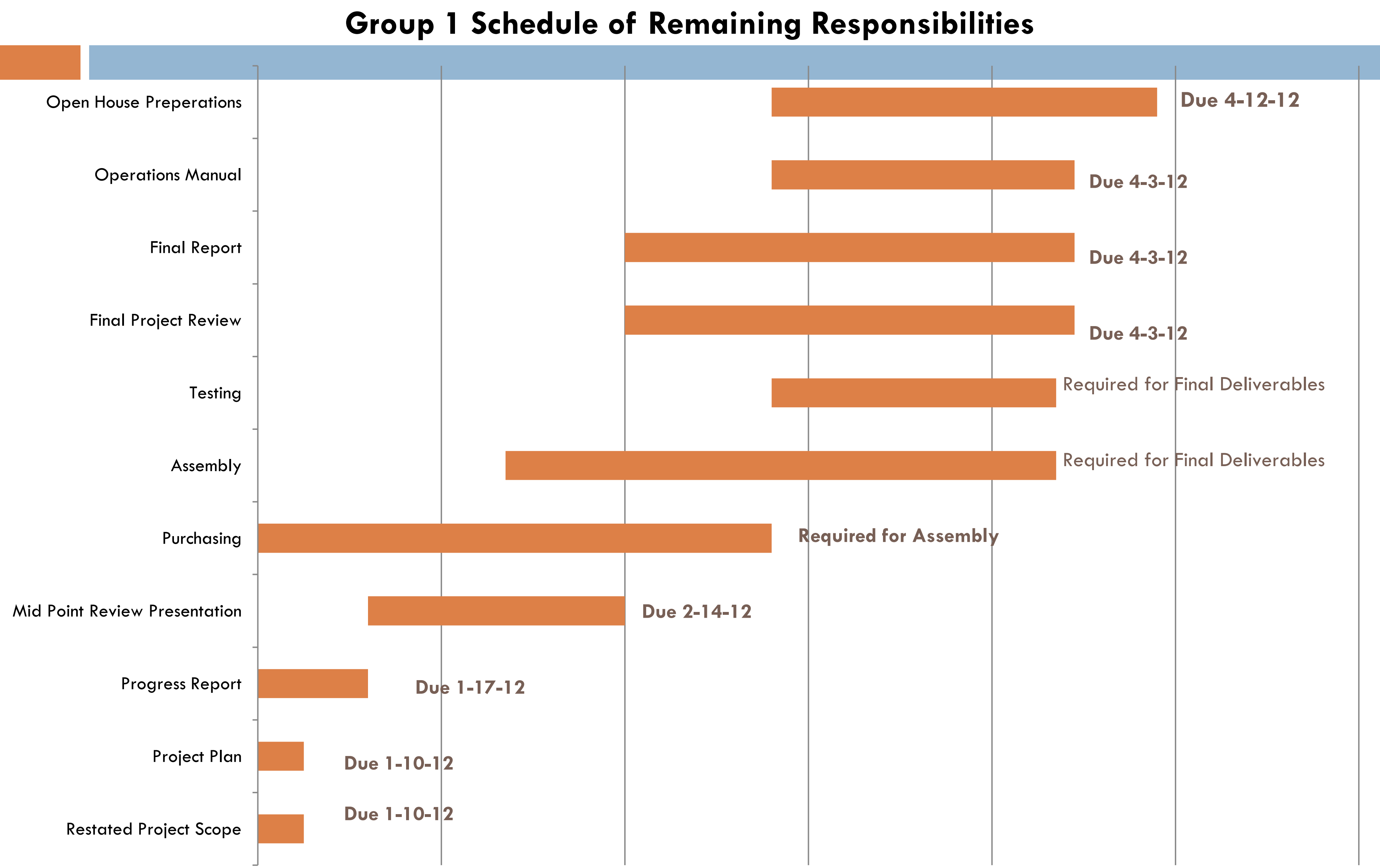
Project Update

- Background Research Completed
- Mathematical Analysis Completed
- Material Selection Completed
- Materials Ordered
  - McMaster-Carr order received
- Construction Site Located

Project Update

- Finalizing Testing Location / Equipment
- LabView Program Under Construction
- Operations Manual Started
- Initial Budget - $2,500
- Remaining Budget - $500

Schedule


Group 1 Schedule of Remaining Responsibilities
Open House Preperations
Due 4-12-12
Operations Manual
Due 4-3-12
Final Report
Due 4-3-12
Final Project Review
Due 4-3-12
Testing
Required for Final Deliverables
Assembly
Required for Final Deliverables
Purchasing
Required for Assembly
Mid Point Review Presentation
Due 2-14-12
Progress Report
Due 1-17-12
Project Plan
Due 1-10-12
Restated Project Scope
Due 1-10-12

End Goals

- Prove / Disprove usefulness of Air Bushings
- Provide a working SHPB
  - Provide test data
  - Test low strength copper
    - Not required

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 inch 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

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

Derived time, from previous equation

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

Calculated velocity from given solenoid

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

Maximum force transfered from solenoid

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

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

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

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