DEVELOPMENT OF CONSUMER GRADE LEVITATING HOVERBOARD

TEAM 20 - MIDTERM II PRESENTATION

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PRESENTATION OVERVIEW

- Background and Objectives
- Final Design Concept
- Calculations
- FMEA
- Materials
- Manufacturing
- Business Aspect
- Scheduling
- Conclusion

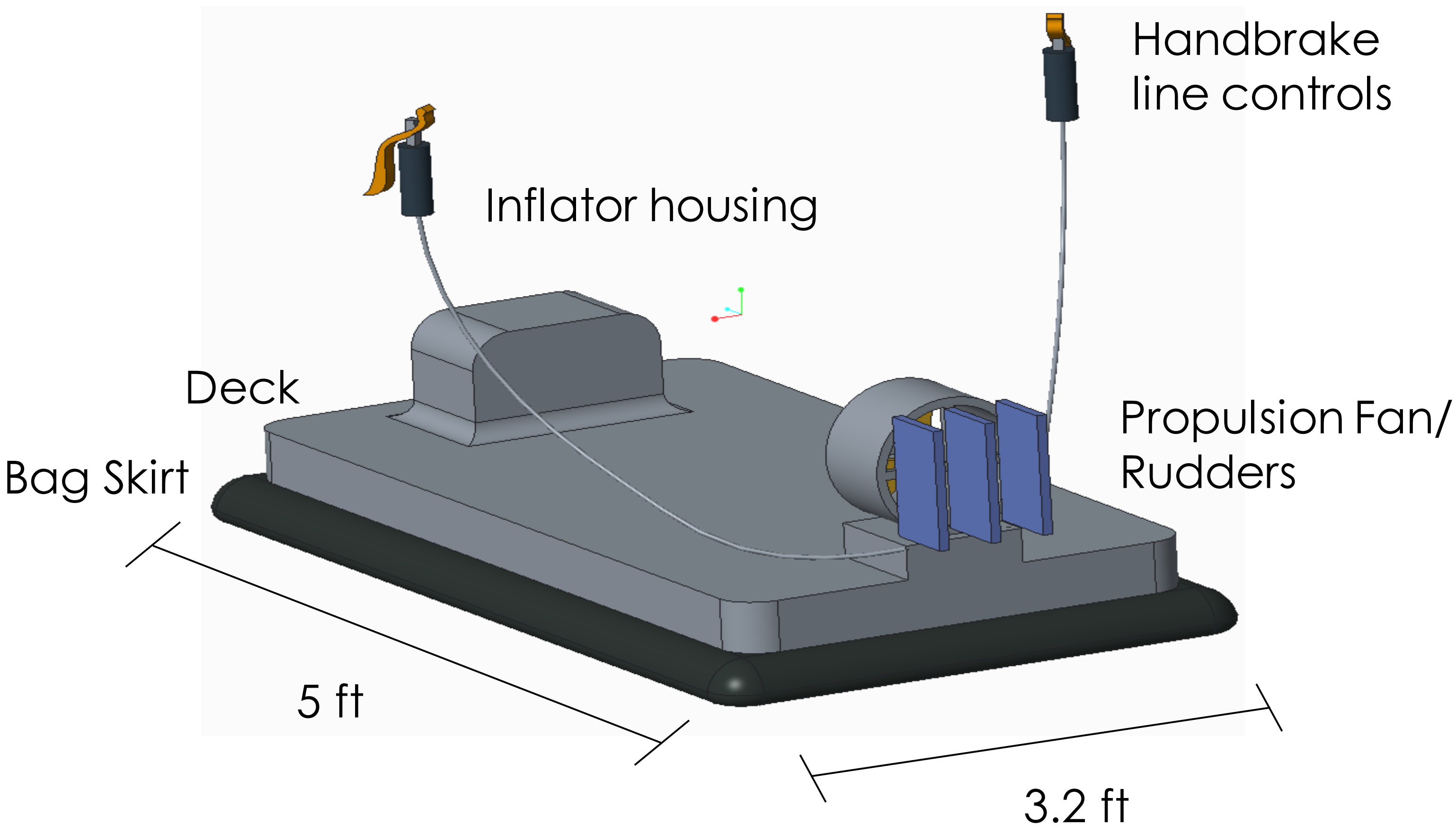
BACKGROUND AND OBJECTIVES

- **<u>NEED</u>:** Advanced hoverboards are very expensive and basic homemade attempts lack practical mechanics (e.g. steering) that make them viable.
- **<u>GOAL</u>:** Create a controllable hoverboard that can be used for recreation and/or short-range transportation. This hoverboard will use air as the levitating medium
- **<u>CONSTRAINTS</u>:** Balance, noise, and cost of production.

FINAL DESIGN CONCEPT

- **Performance Goals**
  - Must support a total load of 300 lbs or 164 kg
    - Assumed craft weight: under 60 lbs
    - Assumed rider weight: 200 lbs max
    - Safety factor: 1.2
  - Designed air gap of 0.25" or 0.625 cm
  - Must generate acceleration of 0.5 m/s

FINAL DESIGN CONCEPT



CALCULATIONS

- **Lift Calculations for a Hovercraft:**

The force needed to support the weight (W):

$$\boldsymbol{W = P \times A_C}$$

Where P is the cushion pressure and A_C is the effective cushion area. For most current designs, the cushion pressure varies in the range 1.2-3.3 kPa (25-70 lb/ft^2).

The required Volumetric flow rate (VFR) is then:

$$\boldsymbol{VFR = A \times V_d}$$

with the values A, and V_d being area of the vessel, and velocity of air discharge, respectively.

Comparing this to our supplier's lift calculator, the final VFR needed to maintain the 0.25" air gap was found to be 1606 CFM.

CALCULATIONS

- **Lift Calculations for a Hovercraft:**

The power (Pa) required to sustain the air cushion at the peripheral gap is given by:

$$P_a = h_C \times I_{CU} \times D_C \times \frac{W}{A_C}^{3/2} \times \frac{2}{d}^{1/2}$$

Where h_C is the clearance height, I_{CU} is the cushion perimeter, d is the density of air and D_C is the discharge coefficient (it varies from 0.5-1.0 depending on wall design but assume it is equal to 0.611 for a skirt with a straight wall).

This power was then simulated by two smaller 800 cfm air blowers attached at the front of the base for lift allowing our 0.25" gap.

CALCULATIONS

- **Axial thrust calculations for ducted fan:**

$a = 0.5 \, {}^{m}/_{s^2}$, $m = 136 \, kg$, $p = 1.225 \, {}^{kg}/_{m^3}$

$Axial\ Thrust\ (T) = mass(m) \times acceleration(a)$

Thrust Needed: approx. 18 pounds.

Supplier Fan Blade Specifications: 24 inch diameter, Type 3, 4 blades in 8-blade hub, 3600 rpm, at stated blade pitch produces:

25 degrees, 9480 CFM, 17.5 pounds, using 3.5 HP

Reference Equations for these Specs:

$Duct\ Area(A) = \pi \times radius(r)^2 \quad A = 1.167m^2$

$T = CT \times DischargeVelocity(V_d)^2 \times A \times p$

Coefficient of thrust(CT) for small Ducted Fans: typically around 0.03

MAJOR DESIGN CHALLENGES

- Multitude of factors affecting hovering performance. Many that depend on each other.
- There is a delicate balance that must be achieved between battery power and battery weight in order to supply enough CFM to lift the craft.
- Few conventional electric motors can supply the necessary kW in order to achieve a desirable thrust using a single propeller. Many that do require high voltages, around 230V, in order to power them. These motors are also very heavy.
- Achieving this voltage without a cord gets expensive very quickly. If you were to use standard 12V golf cart batteries in a series, each approximately $65 and 20lbs. You would need 19 batteries, totaling $1,235 and 380lbs in order to reach that voltage.

Failure Mode and Effects Analysis

Table 1 – Failure Mode and Effects Analysis (FMEA)

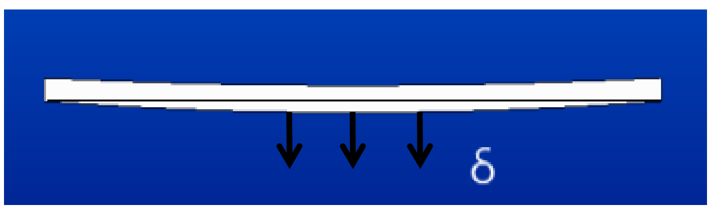
Component/Function	Failure Mode	Cause	Effect	Severity
Skirt	Broken Seal	• Improper assembly • Damaged	• Hoverboard will not inflate	High – Will not be able to operate if skirt is flat
Air Blower	Insufficient flow rate	• Low power supply • Product defect	• Hoverboard will not inflate	High –Board will not be able to operate if skirt is flat
Board	Cracks, Dents	• Too much weight • Improper use	• Unsafe to ride	High – will not be able to support customer weight.
Power Supply	Dead battery/insufficient supply	• Uncharged • Faulty battery	• Blower will not work • Thrust will not work	High – the whole operation depends on power supply
Propeller Fans	Unable to rotate and provide thrust	• Faulty Assembly • Dead Battery	• Hoverboard will have no thrust	Medium – Board will still float, but will not move deliberately
Steering Lines	Unable to control fans	• Faulty wiring / assembly	• Unable to steer the hoverboard	Medium – Board will float, but will be uncontrollable

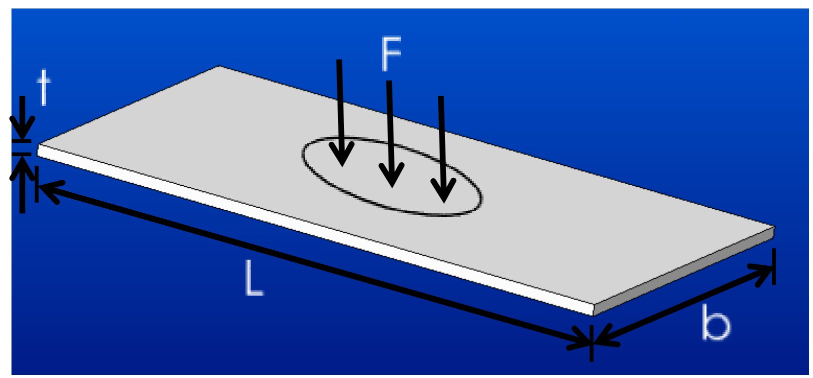
MATERIALS SELECTION

- FCOFV
  - Function
    - Light, inexpensive, stiff, strong rectangular plate
  - Constraints
    - Length (L)
    - Can not plastically deform under a load (F)
    - Width (b)
    - Deflection (δ)
  - Objectives
    - Minimize the mass and cost
  - Free Variables
    - Material
    - Thickness (t)

MATERIALS SELECTION

- Constraints
  - Length (L)
  - Can not plastically deform under a load (F)
  - Width (b)
  - Deflection (δ)





MATERIALS SELECTION

- Analysis for objectives in regards to the strength constraint:

$$m = (V)(\rho) = (A)(t)(\rho) = (L)(b)(t)(\rho)$$

$$\sigma = \frac{(0.75)(F)(b^2)}{(t^2)\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)} \rightarrow F = \frac{(\sigma)(t^2)\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)}{(0.75)(b^2)}$$

$$t = \frac{(m)}{(L)(b)(\rho)}$$

$$F = \frac{(\sigma)\left(\frac{(m)}{(L)(b)(\rho)}\right)^2\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)}{(0.75)(b^2)}$$

MATERIALS SELECTION

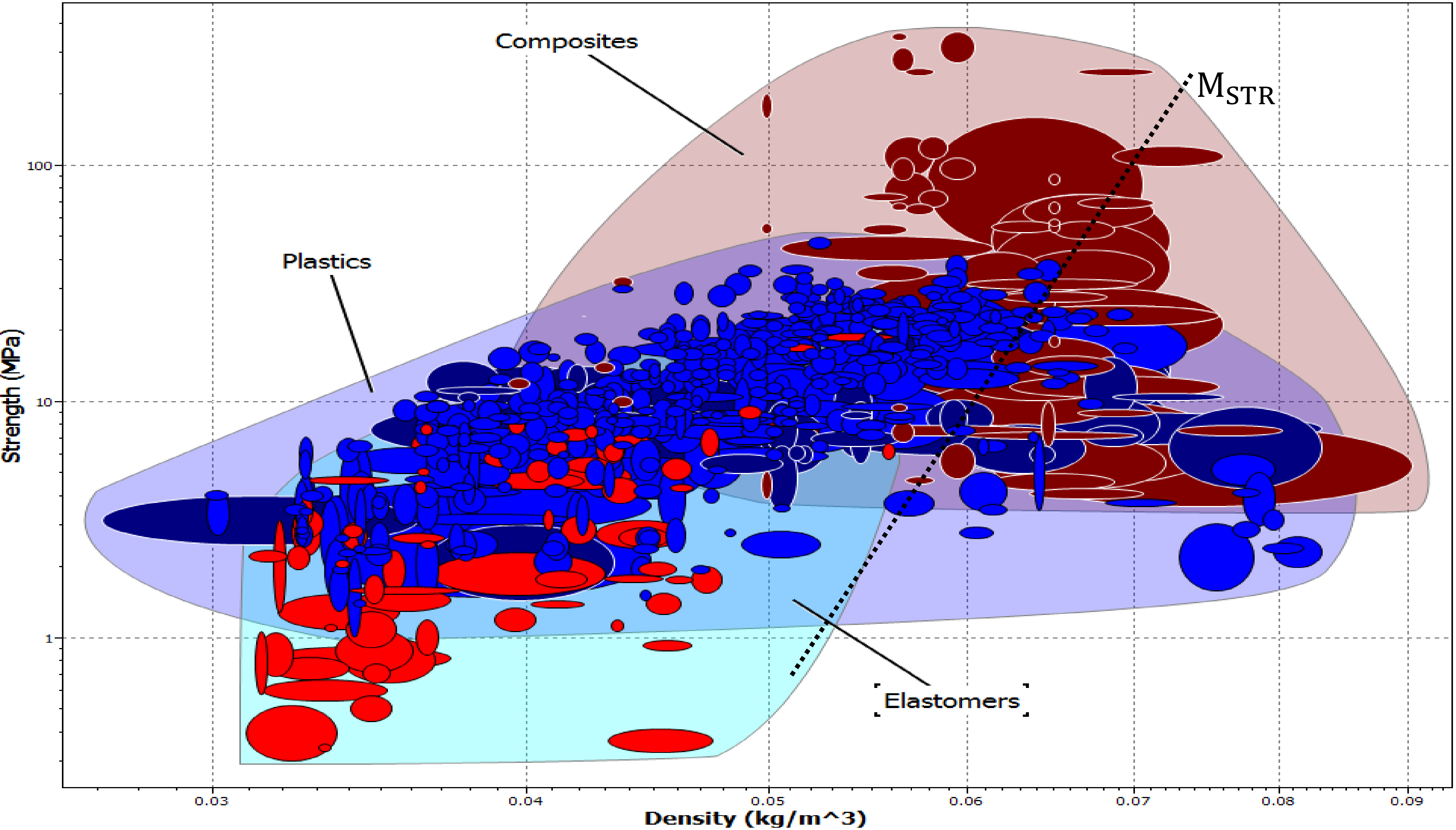
$$F = \frac{(\sigma)\left(\frac{(m)}{(L)(b)(\rho)}\right)^2\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)}{(0.75)(b^2)}$$

$$m = \frac{(0.75)^{\frac{1}{2}}(b)^2(F)^{\frac{1}{2}}(L)(\rho)}{\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)^{\frac{1}{2}}(\sigma)^{\frac{1}{2}}}$$

- Material Index (M) is the inverse of the material properties

$$M_{STR} = \frac{(\sigma)^{\frac{1}{2}}}{\rho}$$

MATERIALS SELECTION



MATERIALS SELECTION

- Analysis for objectives in regards to the stiffness constraint:

$$m = (V)(\rho) = (A)(t)(\rho) = (L)(b)(t)(\rho)$$

$$\delta = \frac{(0.142)(F)(b)^4}{(E)(t)^3\left(2.21\left(\frac{b^3}{L^3}\right)+1\right)}$$

$$t = \frac{(m)}{(L)(b)(\rho)}$$

$$\delta = \frac{(0.142)(F)(b)^4}{(E)\left(\frac{(m)}{(L)(b)(\rho)}\right)^3\left(2.21\left(\frac{b^3}{L^3}\right)+1\right)}$$

MATERIALS SELECTION

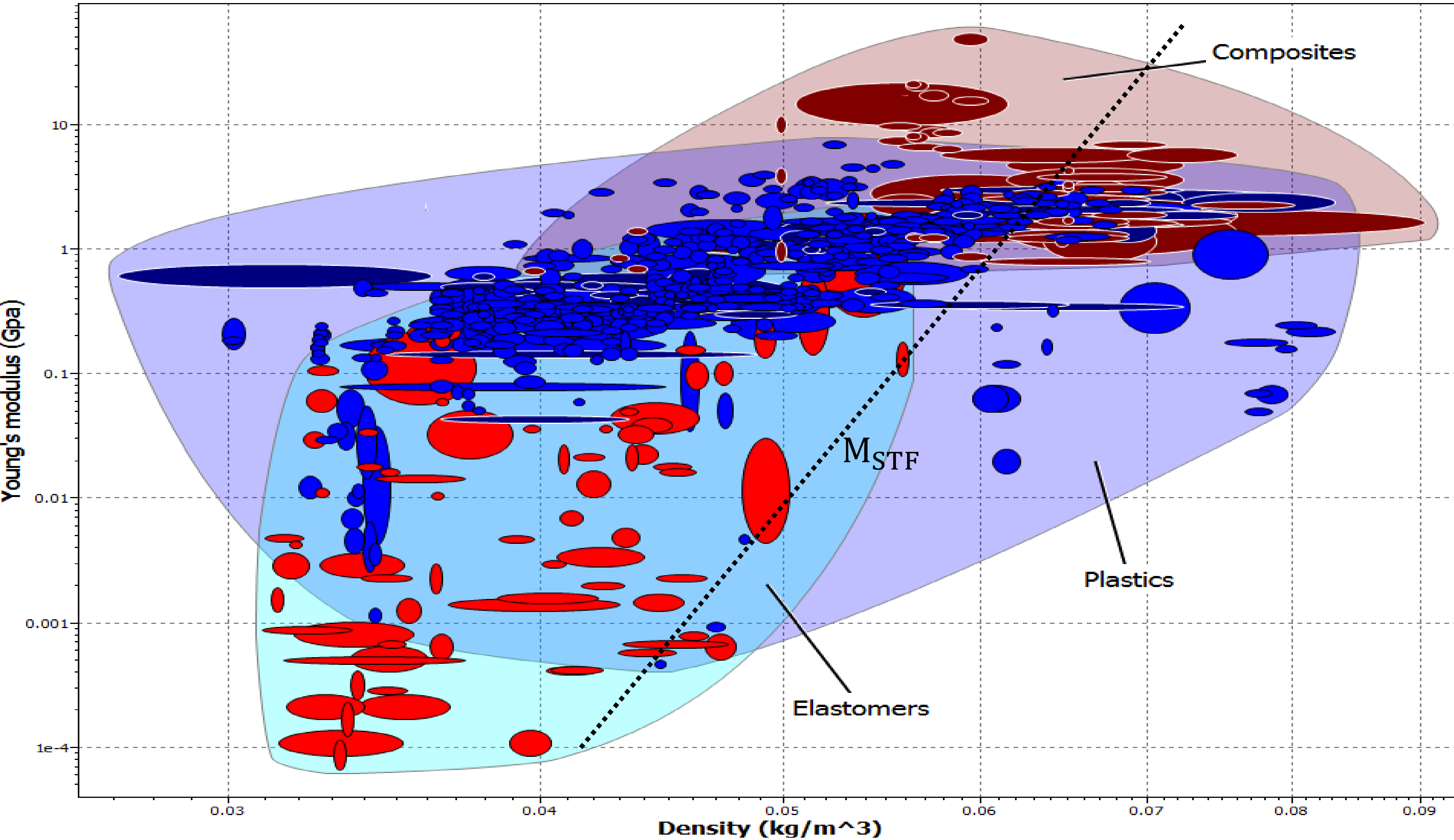
$$\delta = \frac{(0.142)(F)(b)^4}{(E)\left(\frac{(m)}{(L)(b)(\rho)}\right)^3\left(2.21\left(\frac{b^3}{L^3}\right)+1\right)}$$

$$m = \frac{(0.142)^{\frac{1}{3}}(F)^{\frac{1}{3}}(b)^{\frac{7}{3}}(\rho)(L)}{(\delta)^{\frac{1}{3}}(E)^{\frac{1}{3}}\left(2.21\left(\frac{b^3}{L^3}\right)+1\right)^{\frac{1}{3}}}$$

- Material Index (M) is the inverse of the material properties

$$M_{STF} = \frac{(E)^{\frac{1}{3}}}{\rho}$$

MATERIALS SELECTION



MATERIALS SELECTION

- Due to multiple constraints and multiple objectives, material indices must include cost and coupling constants for a decision to be made on only one material.

$$C_{tot} = (m)(C_m)$$

$$M_{COST-STR} = \frac{(\sigma)^{\frac{1}{2}}}{(\rho)(C_m)}$$

$$M_{COST-STF} = \frac{(E)^{\frac{1}{3}}}{(\rho)(C_m)}$$

MATERIALS SELECTION

- Coupling constant

$$C_{tot-STR} = \frac{(0.75)^{\frac{1}{2}}(b)^2(F)^{\frac{1}{2}}(L)}{\left(1.61\left(\frac{b^3}{L^3}\right)+1\right)^{\frac{1}{2}}(M_{COST-STR})}$$

$$C_{tot-STF} = \frac{(0.142)^{\frac{1}{3}}(F)^{\frac{1}{3}}(b)^{\frac{7}{3}}(L)}{(\delta)^{\frac{1}{3}}\left(2.21\left(\frac{b^3}{L^3}\right)+1\right)^{\frac{1}{3}}(M_{COST-STF})}$$

MATERIALS SELECTION

- Equating the two previous equations will then yield:

$$\frac{(0.75)^{\frac{1}{2}}(\mathrm{b})^{2}(\mathrm{F})^{\frac{1}{2}}(\mathrm{L})}{\left(1.61\left(\frac{\mathrm{b}^3}{\mathrm{L}^3}\right)+1\right)^{\frac{1}{2}}(\mathrm{M}_{\mathrm{COST-STR}})} = \frac{(0.142)^{\frac{1}{3}}(\mathrm{F})^{\frac{1}{3}}(\mathrm{b})^{\frac{7}{3}}(\mathrm{L})}{(\delta)^{\frac{1}{3}}\left(2.21\left(\frac{\mathrm{b}^3}{\mathrm{L}^3}\right)+1\right)^{\frac{1}{3}}(M_{COST-STF})}$$

- Rearranging variables in terms of y = mx + b

$$\mathrm{M}_{\mathrm{COST-STF}} = \frac{(0.142)^{\frac{1}{3}}(\mathrm{b})^{\frac{1}{3}}\left(1.61\left(\frac{\mathrm{b}^3}{\mathrm{L}^3}\right)+1\right)^{\frac{1}{2}}}{(\delta)^{\frac{1}{3}}\left(2.21\left(\frac{\mathrm{b}^3}{\mathrm{L}^3}\right)+1\right)^{\frac{1}{3}}(0.75)^{\frac{1}{2}}(\mathrm{F})^{\frac{1}{6}}}(\mathrm{M}_{\mathrm{COST-STR}})$$

MATERIALS SELECTION

- The coupling constant is simply the slope of the previous equation

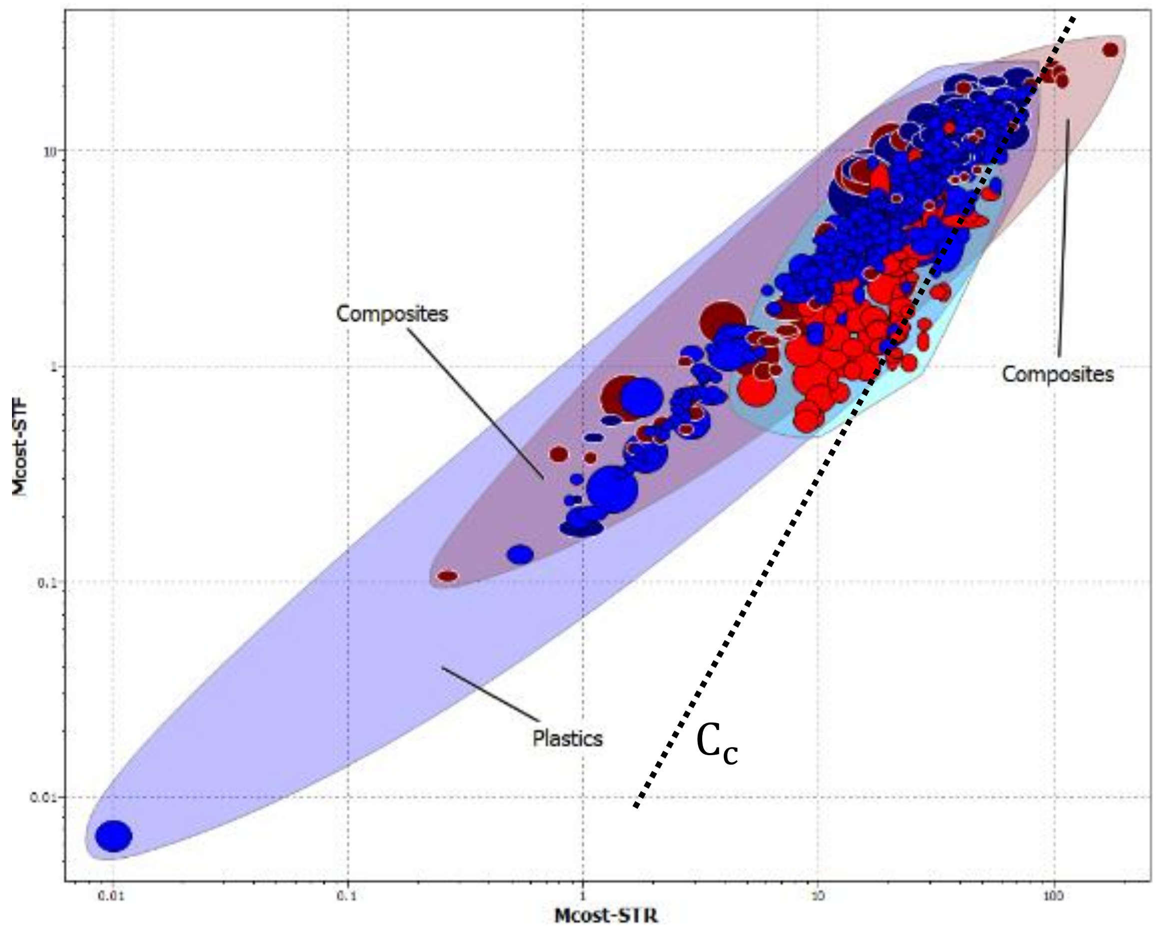
L = 5 ft= 1.524 m

b = 3.2 ft= 0.97536 m

δ = 5 mm

F = 1350 N

$$C_c \approx 2\left(\frac{1}{\mathrm{Pa}}\right)^{\frac{1}{6}}$$



MATERIALS SELECTION

- Best materials:
  - CFRP (Carbon Fiber Reinforced Plastic) (composite)
  - Parallel grain wood
  - PVC (thermoplastic polymer)
- Decision of material:
  - CFRP
- Yields a mass of:
  - 2.12 kg = 4.67 lbs
- Yields a thickness of:
  - 0.9 mm

MANUFACTURING

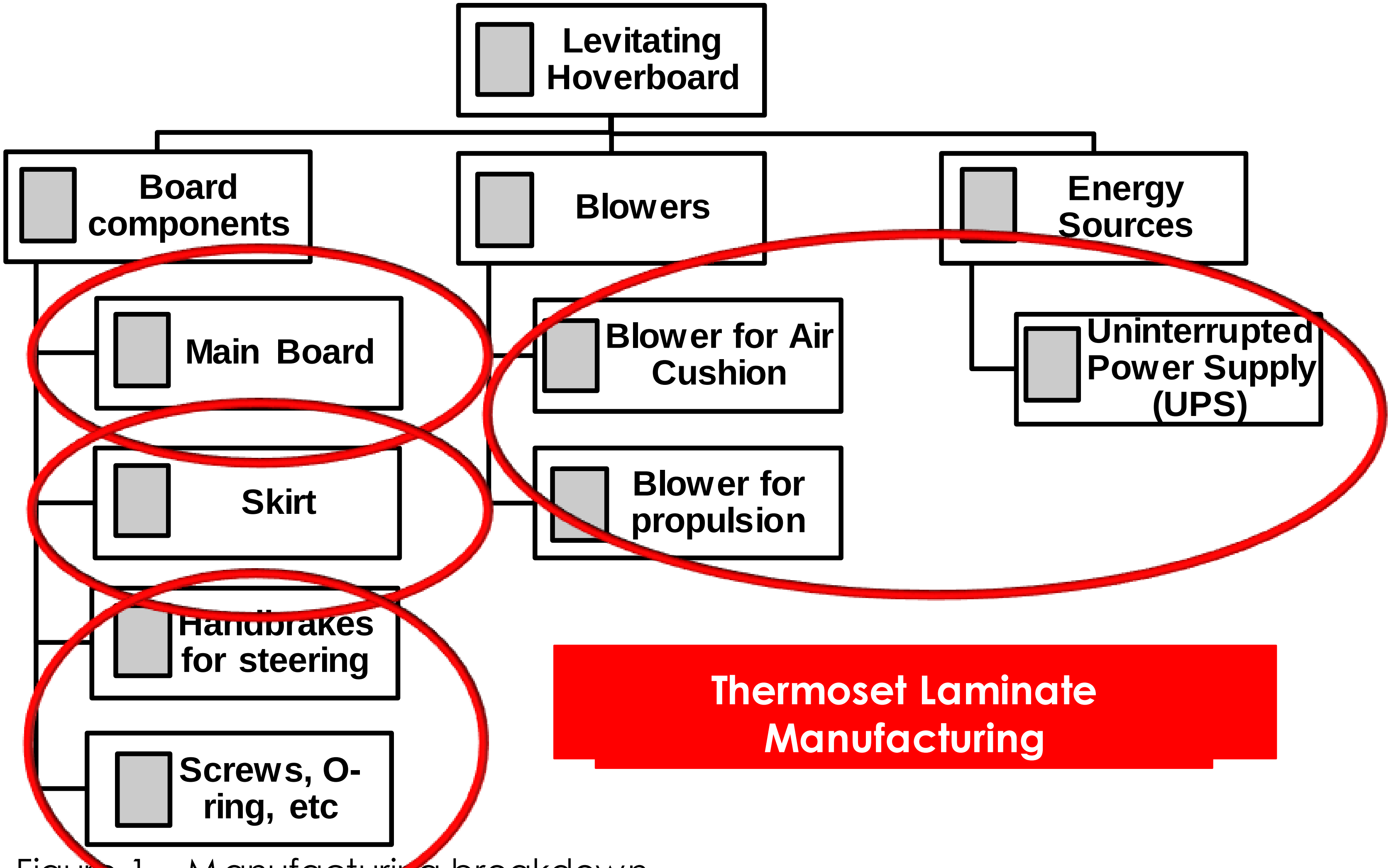


Figure 1 – Manufacturing breakdown

Thermoset Laminate Manufacturing

BUSINESS ASPECT

- **Name: HHBoards**

  Tag Line: "Let Us Lift You"

- **Customer problems:**
  - **Commercial existing hoverboards - $10,000.**
  - **Our product will be significantly less expensive.**

- **Intellectual Property**
  - **Trademark:**

    The name of brand

    Tagline

    LOGO
  - **Patent:**

    The Mechanical Design

BUSINESS MODEL CANVAS

Key Partners

FAMU-FSU College of Engineering

Common Vendors

Key Activities

Research and Development

Manufacturing

Logistics and Supply Chain

Key Resources

Intellectual Properties

- Trademark
- Patents

Value Propositions

Service
- Customer Convenience

Customer Needs
- Recreational aspect

Key Features
- Wireless
- Inexpensive
- Safe
- Mobile

Customer Relationships

Market Ambassador

Rentals at Park, Malls, and Technologic Conference

Keep open customer communications

Channels

Social Media
Posters
Commercials
Stores
Magazine

Customer Segments

Age 7 and older

Outdoor users

Revenue Streams

Google AdSense
Direct Sale
Rental Services

Cost Structure

Material Cost
Manufacturing Cost
Worker Compensation
Advertisement Cost

B.M.C. SEGMENTS

Customer Relationships

- Marketing Ambassadors
- Product Rentals at Parks, Malls, and Technological Conferences
- Open communication with customers

Customer Segments

- Age 7+
- Users
  - Commuters
  - Outdoor users

B.M.C. SEGMENTS

Revenue Streams

- Google AdSense
  - We provide space on our website
  - Works by matching text and image by the content on our website
  - We get paid from advertisers
- Direct Sales from Customers
  - HHBoards purchased through website
- Rental Services

B.M.C. SEGMENTS

Cost Structure

- Material Cost
- Manufacturing Cost
- Advertisement Cost

Product Key Features

- Wireless
- Inexpensive
- Safe
- Electric Powered

B.M.C SEGMENTS

Value Propositions

- Customer needs
  - Performance
  - Cost effectiveness
- Customer Convenience
  - Ease of Use
  - Broad age range

Channels

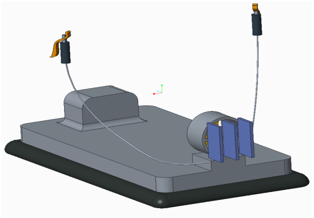
- Social Media
- Commercial
- Stores
- Magazines
- Posters
- Business Owned Website

SCHEDULING

Table2– Gantt Chart

Task Name	Duration	Start	Finish
Research	33 days	Sat 9/10/16	Tue 10/25/16
Identify Optimal Materials	11 days	Sat 10/1/16	Fri 10/14/16
Choose a Concept	12 days	Sat 10/15/16	Mon 10/31/16
Basic Prototype	7 days	Sat 10/22/16	Mon 10/31/16
Begin CAD Model	16 days	Mon 10/31/16	Mon 11/21/16
Calculations for Operation	12 days	Mon 10/31/16	Tue 11/15/16
Set final measurements	5 days	Tue 11/15/16	Mon 11/21/16
Final Parametized CAD Model	5 days	Tue 11/22/16	Mon 11/28/16
Create Purchase Order	5 days	Tue 11/29/16	Sat 12/3/16
Final Report and Presentation	6 days	Tue 11/29/16	Tue 12/6/16

CONCLUSION



- Final concept has been chosen
- Engineering challenges remain for the operation
- FMEA was defined for the product's operation
- Ideal materials for hull parts identified
- Business Model Canvas developed as part of InNOLEvation competition

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QUESTIONS?