Since the problem we were presented with was to find a widespread use of aluminum on campus and improve its function, we decided there was no better place to look at than Beaver Stadium. The bleachers in the stadium are made of aluminum alloy and we sought out to strengthen them so the Penn State Football experience can be more enjoyable.
Definition of Needs:

The objective of this project is to identify opportunities across the campus that uses aluminum and our purpose is to find a system to increase the efficiency and sustainability of products and product systems. There are many uses of aluminum on the University Park campus of the Pennsylvania State University, which include electronics, construction, lockers, bookshelves, Chik-fil-A sandwich packaging, door handles, laboratory materials, baseball bats, Beaver Stadium bleachers, and pop/soda cans.

Possibly one of the most common use of aluminum here at State College, PA happens on football Saturdays at Beaver Stadium. Hundreds of thousands of fans fill the stadium and sit/stand on the aluminum bleachers. Aluminum is a viable option when trying to seat 106,000+ fans; it is cost-effective, yet durable.

In order to produce aluminum, bauxite is mined and then purified using the Bayer process. Purified aluminum oxide is then mixed with cryolite to melt the metal and then through electrolysis, aluminum ions are reduced to form aluminum metal. The aluminum can then be mixed with other metals to form an alloy that has certain properties, such as strength and cost. The alloy is then pressed into sheets and bent into its desired shape and cut to desired dimensions. The bleachers are then shipped to location where the supports and bleacher top are assembled and anchored into the foundation. The product is then used for as long as it can handle thousands of jumping and screaming fans. Once the bleachers have reached the end of their life, they are disassembled and sent to a foundry to be shredded and melted down so they can be reused.

Problems associated with the bleachers at Beaver Stadium:

1. Navy game: One set of bleachers in the student section broke and students passed it up through the crowd.
2. Almost every game you can feel the benches rocking back and forth as people jump around and dance during games.
3. Possible rusting and weathering due to natural environment.
4. Can become weakened by cracks continuing to grow from constant cycle of getting wet, freezing and expanding.
5. Get cold and wet making it miserable to sit on.

Detailed Description of Concepts:

Our two initial ideas were to change the alloy or the structure. Changing the alloy would allow for control over which properties are enhanced and uses the same amount of material that is presently used. Changing the structure only improves the stability and requires more material than is currently used. So, changing the alloy is more favorable than changing the structure. The university was also not able to reveal to us any information on the structure of the bleachers due to safety concerns.

Currently the bleachers would be made of 3000 series aluminum alloy. It is the most widespread use of aluminum and has moderate strength (only 20% higher than pure Al) and is not heat-treatable.
Idea #1:

5000 Series Aluminum Alloy – properties: (Mg principal alloy addition) less tendency to streak or discolor, resistance to corrosion, weldability, high strength, good fatigue properties, excellent formability.

Idea #2:

6000 Series Aluminum Alloy – properties: (Mg and Si major alloy addition) one of least expensive, excellent resistance to corrosion, spot and fusion welding, can be dyed, good fatigue properties, fabricated by virtually all methods.

Idea #3:

7000 Series Aluminum Alloy – properties: (Zinc primary alloy addition) spot welding, poor corrosion resistance, has to be protected, fracture toughness inferior to others, excellent fatigue properties.

Idea #4:

Clad Aluminum – properties: (pure Al bonded to both sides of alloy sheet) high strength, superb corrosion resistance, roll bond as strong as Al itself.

**Concept Option Analysis:**

In our selection matrix, we said that quality of life and economic viability were the most weighted factors followed by innovation and then human factors and implementation being least weighted.

Idea #1: Selection Matrix – 3.3

5000 Series Aluminum Alloy – How the human acts has the greatest influence on this option due to it being lower strength than other options. Implementation is the next greatest because it can be fabricated the easiest. Innovative, economic and quality of life are next, being relatively average because neither factor is good or bad for this option.

Idea #2: Selection Matrix – 4.5

6000 Series Aluminum Alloy – How the human acts, implementation, and economic have the greatest influence on this option due to it being another lower strength alloy than other options, it can be welded by several methods, and is the cheapest. Innovative and quality of life is the next greatest because it can be dyed and provides a new look and doesn’t fatigue easily.

Idea #3: Selection Matrix – 2.2

7000 Series Aluminum Alloy – How the human acts, implementation, and economic viability have greatest influence on this option but received average ratings because they are not as superior compared to other options. Innovative followed by quality of life got low ratings because it has to be protected and is easy to fracture and has poor corrosion resistance.
Idea #4: Selection Matrix – 3.3

Clad Aluminum – Quality of life has the greatest influence on this option because it is the highest strength option. Innovative is next because it uses pure aluminum to protect its core. Human factors, implementation, and economic received lower end ratings because there is more work put into this alloy, it is hard to weld, and is the most expensive.

<table>
<thead>
<tr>
<th>Criteria/Req</th>
<th>Human Factors</th>
<th>Innovative</th>
<th>Quality of Life</th>
<th>Implementation</th>
<th>Economic Viab.</th>
<th>Total of row</th>
<th>WF of row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Factors</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>.1</td>
</tr>
<tr>
<td>Innovative</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>.2</td>
</tr>
<tr>
<td>Quality of Life</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>.3</td>
</tr>
<tr>
<td>Implementation</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>.1</td>
</tr>
<tr>
<td>Economic Viab.</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>100%</strong></td>
<td><strong>3.3</strong></td>
<td><strong>2.2</strong></td>
<td><strong>3.3</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Detailed Description of Final Concept:**

After evaluating each option with the matrices, the 6000 series (idea 2) proved to be the best alloy option for our system. The 6000 series gives the best mix of all the parameters given and allows for possible change in the look of the stadium.

Human factors has a high rating because fans are not likely to have an impact in weakening the bleachers and it requires little maintenance. Implementation also has a high rating because of the alloy’s weldability and ease of fabrication, so it’s easier to install. Economic Viability’s high rating is due to the alloy being one of the least expensive options. Innovative has a fairly high rating as well because the 6000 series has the capability of being dyed, so it could provide a fresh new look for the stadium using blue and white bleachers. The Quality of Life is fairly high due to the alloy’s fatigue properties.

After looking at the problems we noticed with the bleachers (breaking during a game, rocking back and forth, weathering, and cracks freezing/expanding), implementing the 6000 series alloy as the material for the bleachers would almost completely solve these problems. Moreover, the 6000 series costs less than the 3000 series which is currently being used right now.
SolidWorks Model of Bleachers

(Dyed blue to show possible innovation in future)

- **Dirt**: Mined using explosives, shovels, etc.
- **Bauxite Ore**: Bayer Process removes impurities
- **Aluminum Oxide**: Electrolysis separates ions and reduces Al
- **Aluminum Metal**: Alloying Process mixes Al w/ Mg & Si
- **Aluminum Alloy**: Roll, Cut, Bend, Weld to form product
- **Bleacher Parts**: Shipping to deliver product to location
- **Bleachers**: Assembled using bolts, screws, drills, etc.
- **Heat**: Trucks, planes, trains
- **Aluminum Alloy**: Shredding, Melting to reuse the alloy