The Built EnvIRONment

By:
Aaron Boucher (ARCE ‘16)
Emmanuel Castaño (ARCE ‘17)
Leesa Choy (ARCH ‘19)
Kevin Church (ARCE ‘16)
Nathaniel Hall (ARCE ‘16)
Alejandro Lopez (ARCE ‘16)
Nicholas Petrarca (ARCE ‘16)
Habib Placencia, Exhibit Design (Art & Design ‘17)
Nicholas Reindel (ARCE ‘16)
Emily Setoudeh (ARCE ‘16)
Sean Westphal (ARCE ‘16)
Lacy Williams (ARCE ‘16)

Faculty Advisor
Craig Baltimore, PhD, SE

Curatorial Advisor
Catherine J. Trujillo, Kennedy Library
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1.0 Introduction

At 25 percent taller than the world’s tallest horse, this mustang sculpture stands over ten feet tall and weighs approximately 800 pounds. This mustang is a sculpture made entirely of scavenged and donated recycled steel and went from conception to erection in 10 weeks, remarkably quick project-sequencing! Allan was the result of a sustainability exhibit, The Living Library, requiring the use of recycled material and held by the Kennedy Library from April 12, 2016 through June 3, 2016. The sustainability exhibit, which also showcased Cal Poly’s learn-by-doing student education, was a collaboration of students from the College of Architecture and Environmental Design, College of Liberal Arts, and the College of Agriculture, Food, and Environmental Sciences. Allan was designed, fabricated, transported and erected by a group of Architectural Engineering(ARCE) and Architecture(ARCH) students within the College of Architecture and Environmental Design. The student’s involvement ranged from volunteering, to satisfying senior project requirements. Other exhibit contributions, such as storyboards and landscaping, were organized by students studying Graphic Arts and Agricultural and Environmental Plant Sciences within the College of Liberal Arts and College of Agriculture, Food, and Environmental Sciences.

1.1 Motivation For the Project and Formation of Team

The motivation for student participation started with the desire of professional artist, Ivan Mclean, to work with students on a Cal Poly campus sculpture. Ivan Mclean, a Cal Poly Farm Management alumni, is a sculptor and best known locally for the Cal Poly Performing Arts Center sphere sculptures. In response to Mclean’s proposal, Kennedy Library Curator, Catherine Trujillo, put forth the Living Library exhibit as an opportunity for Ivan to work with Students. Trujillo approached Dr. Craig Baltimore, a full professor within the Architectural Engineering Department, regarding the upcoming sustainability exhibit opportunity. Trujillo’s positive recent experience of exhibiting Baltimore’s third-year ARCE 306 course project, a 20 foot K’Nex scale model of the Willis Tower, had compelled her to reach out to him. The team originated in the Architectural Engineering department as an alternate senior project to the department’s standard senior project course (ARCE 415). A requirement of an ARCE senior project is for the student to have an interdisciplinary experience, which was satisfied through collaboration with an Architecture student, Graphic Arts student, two Agricultural and Environmental Plant Sciences students, the Kennedy Library Curator and staff, and a professional artist. The group of ARCE and ARCH students saw the project as an opportunity to potentially leave a lasting legacy with the university, while earning credit
towards graduation. Motivation for the sculpture was especially high due to the unique nature of being able to build a large-scale, physical object under the department.

1.2 Final Product Goals
Final product goals for the Built Environment were established early in the project timeline. The primary goal was having a safe sculpture installed on the 2nd floor of the Kennedy Library by April 11th. This translated to call for all students on the project to clear their schedule from April 7th – 11th to ensure the readiness of the deliverables. The goal of the majority of ARCE students was to satisfy their senior project requirements. It was made clear that senior project reports, held to a rigorous standard, would commence shortly after the sculpture installation and would be completed by the week of May 23rd. Product goals also included maintaining professionalism and accountability of all persons throughout the duration of the project.

1.3 Design Process Overview
The extensive design process was a key component to the success of the Built Environment project. Roughly half of the ten-week-long period between the team’s first meeting and the sculpture’s installation was devoted to design. It was agreed upon quickly that the sculpture should be a Mustang, to represent the university’s mascot. The iterative-focused process began at the individual level with each team member proposing rough mustang schematics. The design developed in combining the best of each previous iteration until two radically different designs emerged. Public safety and constructability was then heavily considered, and allowed for a unanimous decision of constructing two different horses, with one considerably superior in size to the other. After calculations were performed, construction documents and a scaled construction model were then made.

1.4 Report Overview
The Built Environment project offered a large spectrum of different types of student learning. The students were introduced to a time-impacted project-delivery. In the construction industry, a high-impact project-delivery is the name given to projects where an untypical factor considerably impacts the project course. This concept was relevant to the mustang project due to the 10-week time frame to design, fabricate, transport, and erect the sculpture. Exposure to an interdisciplinary team that had to communicate together effectively to be successful was a new experience for the
students. Constant communication was maintained through weekly meetings and shared file storage. Meetings acted as a means of coming to a team-by-in on matters because of every team member’s presence. A level of professionalism was required among the students, largely because of the accountability for each other required to complete the many different tasks. One main task was ensuring successful transportation of the sculpture into the library, in which erection could then occur. This required complete assembly and disassembly of major sculpture components. Bolts, washers, and nuts were strategically used to splice the sculpture into smaller segments. Throughout the duration of the project, processes of grinding, cutting and welding the recycled steel, invoked feelings among the team members. Phases such as “…0hhh, what if…” and “… now picture that but crossed with-”, shows that emotions of pride that were felt among team members. The following paragraphs include in-depth detail to high-impact project-delivery requirements, the design process of the sculpture, instructions for assembly and disassembly of the sculpture, and the experiences felt through working with the recycled material.
2.0 The Design Process of the Mustang

Each profession has its own language to describe the steps of a design process. This project used the Engineering Design Process for the Built Environment, which typically is categorized as follows:

- **Inspiration:** the owner or professional (e.g. architect or engineer)
- **Schematic Design:** first pass - placing the inspiration into a possible solution
- **Design Development:** second pass - refining solution for constructability
- **Construction Documents:** communicating how to construct including the engineering and details (how the pieces fit). Many times hidden issues arise.
- **Field Service:** a fancy name for actual construction. During construction unforeseen issues/challenges arise and require quick and workable solutions.

2.1 Inspiration: Getting Started

This initial step in starting the Design Process required establishing a starting point among the team. Experience and knowledge base often varies amongst group members. In this particular project, the subject was a sculpture - a horse. As engineers, architects, graphic artist, and horticulturist; a horse was not a well known or common subject. Many of the group members were unfamiliar with horses, not only in body parts and movements, but also the history of the horse and how they fit into society. Therefore, the initial common ground was for all team members to understand “What is a horse?” This process of discovery and learning of the equine world came in many forms; not only did the group research different aspects of the horse, they also got some in person experience with a trip to Cal Poly’s Equine Center.

2.1.1 Research and Presentations

To better understand “What is a horse?” the team split into two groups. Each group put together a presentation focusing on aspects of the horse with the goal of educating our fellow team members. The two topics of research were:

- physical characteristics of a horse and
- how horses have been and are used - social impact.

The physical group researched different common types of breeds in the United States, such as the American Quarter Horse, Arabian, and Thoroughbred. They also researched the anatomy and proportions of a horse seen in Figure 1.1, as well as studied the different movements that a horse makes, such as the walk, trot and canter.
The social group went back in history and researched the development of horses utilization over the years, from farming and war, to sports and leisure. In addition to this, the group also researched Cal Poly’s history with the horse, and how we became to be Mustangs (vs. Mules, according to the Polygram article from October 22, 1925, see Figure 1.2).

Researching horses really helped the team build a solid fundamental foundation to lead us into the design process for this project. Many of the aspects the team researched were used later in the design process, especially the proportions and movements, which helped us give our statue a more lifelike feel in the end.
2.1.2 Trip to equine center
Along with research, the team also decided that it would be beneficial to see some horses in real life. The team was fortunate enough to be able to take a trip to Cal Poly’s Equine Center on campus. Here, we were able to fill our senses with what a horse is, from touching their muzzles, and smelling that distinct horse smell, to watching them move and interact in real life. Figure 1.3 (a) & (b) shows the team meeting several horses at the Equine Center.

![Team meeting several horses at the Equine Center](image)

The team was also able to see some of the new moms with their week old foals, which later helped inspire us to include the smaller “foal” sculpture. Being able to have that experience and see the horses in real life, and not just in pictures on the internet really helped to excite the team and gave us inspiration going into the design process.
2.1.3 Professional Inspiration

In order to expose us to the process of creating artwork, we made a visit to local artist, David Settino Scott. He invited us to come into his studio and ask questions about his pieces. Figure 1.4 is just one example of Mr. Settino Scott explaining his process to the team.

![Figure 1.4: Artist David Settino Scott explaining a series of sculptures that he did for a collection.](image)

He explained to us how he got inspiration for a piece, and how he was able to turn that inspiration into a reality by visualizing his end goal and then just “slapping shit together.” Mr. Scott was also able to provide many ideas on how to construct models, such as using cardboard and plaster with drywall tape as seen in Figure 1.5 (a). The team had a good time visiting the studio and were able to get some ideas from the tour.

![Figure 5 (a): David Settino Scott showing us how to use drywall tape, cardboard, and plaster to make a model, (b) a team member taking notes and sketching at the studio.](image)
2.1.4 Research of Other Artist
Once the team knew what a horse was, the next step was to investigate how we could manifest our vision. Different sculptures were researched in order to get an idea about what had been done before and to get inspiration for our own designs. We explored the works of artists like Deborah Butterfield, who casts bronze horse sculptures using driftwood as her forms, and John Lopez, who uses recycled metal to create strong animal forms.

2.1.5 Forms of the Horse
The research included looking at different forms that we could apply to our horse. The first main form focused on was the movement of the horse; did we want it to be a strong figure, such as a horse pulling agricultural equipment or rearing like in Figure 1.7, or more of a softer form, such as a horse grazing. The idea of how the horse should be covered and defined was also explored; did we want a full skin that detailed the horse's body, or did we want a minimal skin that created the illusion of the shape of a horse. After doing our research each team member presented their ideas about the direction of the design. The ideas ranged from focusing on proportions and the mass distribution of the sculpture, to incorporating plants and organic forms to the design illustrated in Figure 1.6 (a) and (b).

![Figure 1.6](image_url) (a), idea of concentrating the mass in the hind end of the horse, and (b) idea of incorporating the organic nature of plants.
After our initial ideas had been presented, the team paired up and worked together to develop ideas into something that could potentially be built.

### 2.2 Schematic Design: Design Iterations

The schematic design took the information and direction of the Inspiration phase and created an initial design concept through multiple iterations of model making. Each new phase of a model developed our ideas further until the final design was eventually decided on.

#### 2.2.1 Initial Models

The team broke into pairs to develop two ideas further and create initial models. The models ranged from cardboard and wire horses, to clay and even 3-D printed horses. The models all embodied different ideas that had been presented the week prior. All the models helped contribute to our development of the final design, but there were several models and concepts that stood out.

##### 2.2.1.1 Horse and Man: We are Mustangs

One of the group members was intrigued by the idea of forced perspective, so he created a computer model with the concept that from the side the model looked like a
horse, but from the front the model looked like a person. He even created his computer model with shapes of materials that the team had already collected to prove that it could be built. He then 3-D printed his computer model, seen in Figure 1.8, to see if the concept worked in three dimensions.

![Figure 1.8 (a) side view of the horse, (b) partial front view of the person.](image)

### 2.2.1.2 Plant Pony

Several of the team members liked the idea of incorporating the Living Library aspect into their models, and explored how plants could be incorporated into the design. One member created a clay model with the horse grazing, while plant life came up the horse and grew off of its back seen in Figure 1.9 (a). Other designs included placing succulents or other sources of greenery in the model in areas such as the mane and tail to provide some additional texture and color like in Figure 1.9 (b).

![Figure 8 (a) Clay model of a grazing horse with plant life coming up to its back, (b) metal horse model with hints of greenery incorporated.](image)
2.2.1.3 Coming to a Point
A couple designs focused on combining a strong movement in the horse with an interesting structural element, such as coming to a single point and having a moment connection. One of the designs was the horse leaping forward and having only the back legs touching while the rest of the body was suspended above the ground; a key aspect of this design was mass distribution. This model is shown in Figure 1.10. The other design emphasized the horse in a rearing position, but faded the back end of the horse to a single point over the hind legs. It was eventually decided that this concept would not be feasible for the scale of the large horse, but was adapted for the smaller “foal.”

Figure 1.10 (a) illustrates the single point connection, while (b) shows the horse suspended out above the ground.

2.2.1.4 Skin
Multiple designs focused on the different way skins could be applied (or not applied) in order to create the appearance of a defined horse body. Some ideas explored placing a full skin on one side of the horse’s body, while leaving the other side exposed so that the viewer could see the internal structure of the horse like the model in Figure 1.11 (a). Other ideas focused on covering the whole body with an open material so that there was still some visibility through the entire body of the horse, but that it also seemed defined as seen in Figure 1.11 (b).
Figure 1.11 (a) Example of a model with one side completely covered and the other side open, and (b) example of a skin that would cover the whole body but would have some transparency.

### 2.3 Design Development

After our initial ideas were presented, two concepts were picked that the team wanted to develop further. The team broke up into groups and the groups were divided by the basic design premise of abstract and realistic.

#### 2.3.1 Abstract Design

The abstract group wanted to develop the idea of a moment connection, creating an abstract form of the horse that wasn’t constrained by proper physique. They created a model out of metal conduit, cutting and bending the conduit to form the shape then bolting it together; this abstract horse form can be seen in Figure 1.12. The main driver of this concept was to have a strong base, such as concrete blocks, to develop the connection.

Figure 1.12. Abstract model with a temporary wood base.
2.3.2 Realistic Design

The realistic group wanted to focus on creating a model with the proper proportions that explored different methods of construction. Their first model, shown in Figure 1.13 (a), was made from plaster and resembled a walking horse, with the physical model highlighting the horse's head, legs, and barrel. Though this model did not turn out the way the group had hoped, it inspired them with a new idea. The group next used applicator sticks and hot glue to create a horse that was made from a series of trusses to form the model in Figure 1.13 (b). While the proportions were not quite right on this model, the entire team was intrigued by the idea of making the horse out of space trusses.

![Figure 1.13 (a) plaster model with wire mesh as a skin, (b) first applicator stick model.](image)

After the team decided that this was the direction that we wanted to go in for the large horse, another final model was created. The final model was crafted using a toy horse for reference. Figure 1.14 shows how this model more closely reflected the proportions and physique of a horse; the horse peaked at the withers and then sloped down at the back and then up to a peak at the hind quarters. The final model was also made with construction in mind. The majority of the pieces were based off a standard unit length, and this unit length formed most of the triangles within the truss. The rest of the pieces were based off of some fraction of the unit length. This model made construction of the horse much easier because it was essentially a 3D blueprint.
2.4 Construction Documents

2.4.1 Overturning
Our biggest concern with this project structurally was overturning, mainly caused by people leaning on the sculpture or by shaking. In order to make sure that it was designed for a satisfactory amount of loading, the team put together a mass distribution model, and from there we were able to perform calculations for overturning, with the emphasis being from several point loads of a couple hundred pounds each, replicating a human pushing or leaning on the sculpture. This was very helpful because allowed us to see where in our model need more mass in order to resist those forces.

2.4.2 Modeling in RISA
Since the final model was a series of trusses, it was able to be modeled in RISA 3D. This was done by assigning each node a 3D coordinate (x, y, z) and then connecting the appropriate nodes with members. From this we were able to apply loads as well as get images of what the structure would look like. Figure 1.15 shows different views from the RISA 3D model.
2.5 Field Service
During construction there were several design modifications made; all modifications came with group collaboration and discussion before making a final decision.

2.5.1 Deciding on Materials
The team had a wide variety of materials to choose from for this project, but the main structural component that was used were homemade angles made from steel plates that Simpson Strong-Tie donated.
However the angle pieces were fairly heavy, and we wanted to make the sculpture as light as possible with only an area of concentrated mass in the back. This led to the choice to make most of the upper triangle pieces out of conduit from the recycle yard, which was lighter than the steel angles. The team was also particular about what material were used for the skin and where it was placed on the sculpture. We tried to achieve a flowing pattern with the skin that left some cells open, while also defining the space. Two materials were chosen for the skin in order to provide different textures, solid sheet metal and an open mesh sheet metal.
2.5.2 Modifying the Head

One modification that was made to the actual form of the horse was turning its head. Initially the horse’s head was looking straight forward, with both side of the neck being symmetrical. The team decided to shorten one side of the horse’s neck in order to create the effect that the horse was looking in a particular direction, which can be seen in Figure 1.17. To pick which direction the horse should be looking, the way the legs were moving was compared to how a horse really moves and which direction the head naturally sways. This is probably one of the best design decisions made during construction because it gives the horse more expression.

![Figure 1.17. The tilt of the horse's head can be clearly seen in this photo.](image)

2.5.3 Bracing the Legs

Initially the design had cross-lateral bracing in every cell in order to create a true truss (triangles), but after completing the main structure of the legs the team thought they were starting to get congested. After much deliberation it was decided to not add cross braces to the two lowest levels of the legs (see Figure 1.18). This is a good example of how the team collaborated and compromised to come to a collective design agreement.
2.5.4 Base Plates
Continuing along with our problem of keeping mass low and towards the back, we decided that the best solution was to create large, heavy base plates. The idea came from artist Ivan McLean who had brought large sheets of thick gauge steel for the project. We were able to create aesthetically pleasing shapes for the base plates, and configure them in a manner that provided a toe to help resist overturning. Figure 1.19 (a) & (b) show the construction and layout of the base plates.

2.6 Conclusion
All in all, the design of the Mustang Sculpture never stopped, and was constantly a fluid movement of ideas. Eleven minds were successfully brought together and
collaborated on the design of a very large sculpture (see Figure 1.20). The diversity of the group played a key role in bringing ideas to the table, exploring concepts and pushing the limits on what people thought that we could do. The final product is a testament to how well the team worked together to achieve a common goal.
3.0 High Impact Construction Projects

3.1 History of the Construction Productivity Improvement Officer

The minute someone starts any project, the one thing that seems to be on their mind is when the project will be completed. This is especially true with construction and real estate, for revenue starts when the project ends. Time is money in every sense of the phrase when it comes to construction projects. Whether paying for materials, labor, or loss of income during the construction sequence, every contractor knows that projects bleed money until the day the keys are handed over. Having known this for many decades, many contractors and researchers have looked into what factors have the most influence on the timeliness and productivity on a jobsite, and have thought of ways to improve these methods in order to increase productivity, reduce the duration of the project, and ultimately save money. In today’s society with the push for everything to be faster and cheaper, highly-impacted projects have become the norm, and these improved methods are proving to be what is necessary to keep up with these demands.

Within a construction project, contractors act as the overhead to control all sub-parties and make sure everything is on track, so by nature they are most cognizant of what it takes for a project to be successful. Over the years when asked what the most time-influencing factors on a project are, contractors have listed buildability, management and leadership, knowledge of subcontractor’s work, relationships between the general contractor, subcontractor, and client, and the completeness of design information within the project (Nkado, 1994). Many also argue though that these factors can be prioritized so as to maximize productivity to keep up with a highly-impacted project timeline (Nkado, 1994). Through a survey conducted, it was found that of the factors listed above, the ones that were highest on the priority list were those that directly related to project information that the contractor could quantify, and those in which the impact on construction could be evaluated and predicted explicitly. (Nkado, 1994). This therefore made it much easier to analyze where mistakes were being made in the productivity of projects, and how improvements could be made.

As research continued into the 21st century on how to improve productivity, it was found that there were trade-offs between time, cost, and quality on every project, and that even an unlimited amount of resources would still result in compromises needed at some point. Genetic algorithms and optimizations were developed, which helped to revolutionize productivity since each project could be evaluated independently given all
of the specific factors of its construction sequence. These algorithms helped to produce specific results that would then tell contractors how to best optimize the use of their resources and complete a project in the most efficient way possible (Ozcan-Deniz, Zhu, Ceron, 2012). However, with all of the research conducted and cutting edge optimizations being performed, researchers and scholars ultimately knew that contractors would never sit down to perform such an optimization, no matter how much it would improve their project. Therefore results of this research needed to be streamlined so that information could be easily accessible in a new format or method that could be implemented on the jobsite.

The first proposed idea that researchers and scholars came up with was the need for a construction productivity improvement officer (henceforth referred to as the CPIO) as a crucial part of every general contractor’s office, who would be present on every job. The CPIO would be present from the bidding to the completion of a project, and would be responsible for overseeing productivity via the means and methods being used both on a daily basis and over the longevity of the project. Studies showed that the amount of pre-planning that goes into a project directly affected the overall cost and success of a project (Ranasinghe, Ruwanpura, 2012). By having the CPIO involved during the bidding stages, a realistic and predictable productivity plan can be developed to save time and ultimately money for both the contractor and the owner. During the execution of construction, the CPIO helps to increase the accountability the general contractor and all sub-parties, thus reducing the need for change orders or delays in the schedule. Upon completion of the project, the CPIO would be responsible for documenting the productivity improvement measures taken, how outcomes using these measures compare to standard practices, and how the success of these measures could be implemented into new industry standards. The hope was that the implementation of a CPIO would push the construction industry as a whole to move forward in implementing scholarly research on productivity in a practical manner in the field.

As with introducing any new idea, the concept of having a CPIO on site at all times was met with adversary from contractors. It took a lengthy amount of time and numerous projects before this idea was eventually adopted into the industry. Many contractors were reluctant to pay the cost to hire a CPIO without realizing the benefits that would come from it, and even those companies that accepted the idea often had trouble finding the ideal candidate who could optimize their performance under such high impacts. Eventually however CPIOs were gradually introduced to the construction process via partial implementation processes, and to the relief or researchers, this implementation proved to have great improvements in the productivity and efficiency
of projects. CPIOs recorded an increase in “tool time”, a decrease in the waste of materials which therefore eliminated unnecessary costs, and an overall compliance with the proposed schedules (Ranasinghe, Ruwanpura, 2012). The industry was moving in a direction towards increasing efficiency and eliminating the impact of highly constrained projects.

Perhaps one of the most pivotal changes that came about from productivity optimization research was the improvements made to project scheduling. Since the early 1900s, professionals in the construction industry have more often than not used Gantt charts to schedule their projects. Gantt charts identify which events within the execution of a project are critical to timely completion, and these events combine to make up the critical path. The use of this scheduling technique allows contractors to put more emphasis on those critical activities, and allows them to see how much leeway they have with non-critical activities. This method has been used for over a century and is still widely used in the industry today, however research in project optimization has come to find one major flaw with the Gantt chart method. Traditionally, Gantt charts are created during the planning and bidding stages of a project, using a one-step approach to set a schedule in place that all sub-parties are expected to adhere to for the duration of construction (Maylor, 2001). However, during high-impact projects, these schedules are not always perfectly met, thus altering the critical path and requiring the creation of a new updated schedule. The less efficient a project is in meeting deadlines, the more iterative this process is, thus wasting the time
and energy of project managers and those involved with the coordination of the project. Most recently, scholars have taken their research and implemented optimizations into the scheduling process, allowing for a smoother schedule that accounts for the possibility of making changes once the project has started (Maylor, 2001).

It is the lessons learned from the benefits of the CPIO that were used in the Mustang Sculpture to assure quality deliverables for the impacted timeline. As researchers noted, pre-planning that a CPIO brings to a project is essential to the overall success of the project. Similarly pre-planning for Mustang Sculpture was established by identifying intermediate goals in relation to the deliverable date, obtaining “buy-in” from team members for each goal, establishing communication chains (i.e. assigned tasks for team members), and agreeing to accountability standards. The implementation of the CPIO into the construction process has shown improvements in productivity and efficiency. The highly time impacted Mustang Sculpture relied heavily on efficiency of the process in order to produce the end product. Although the constraint of a tight timeline was always at the top of the weekly agenda, the benefits of the CPIO position in construction management allowed for a reduction of the impact of the tight timeline and a successful end product.

3.2 Project Timeline and Deliverables.

- **Phase I. Inspiration**
  - Visit to equine center
    - *Along with research, the team also decided that it would be beneficial to see some horses in real life.*
  - [OCCURRED: 1/27/16]
  - “What is a horse?” research and presentations
    - *The team split into two groups and presented on physical characteristics of a horse and the social impacts of how horses are used.*
  - [DUE: 2/2/16]
  - Visit to David Settino Scott’s studio
    - *In order to expose us to the process of creating artwork, the team made a visit to local artist, David Settino Scott.*
  - [OCCURRED: 2/9/16]
  - Research of other artists and horse forms
    - *Different sculptures were researched in order to get an idea about what had been done before and to get inspiration for our own designs. The research also included looking at different forms that we could apply to our horse.*
  - [DUE: 2/9/16]
Phase II. Schematic Design
- Initial models
  - Each team member created a scale model of their initial concept
  - [DUE: 2/19/16]
Phase III. Design Development
- Second pass models
  - Members formed into two groups to produce larger models of how their preferred designs would actually be constructed
  - [DUE: 2/26/16]
Phase IV. Construction Documents
- Hand calculations, drawings, and scheduling
  - The team produced overturning calculations, RISA models, drawings, lists of materials, and Gantt charts to document and explain their design
  - [DUE: 3/14/16]
Phase V. Final Exams and Spring Break
- Finals and the Singapore trip planning had effects on the availability of team members to work on the Mustang during this time period
  - [OCCURRED: 3/14/16 THROUGH 3/26/16]
Phase VI. Field Service
- Deciding on materials
- Modifying the head
- Bracing the legs
- Base plate construction
  - The bulk of construction took place during the first two weeks of Spring quarter in High Bay Lab with the help of artist Ivan McLean
  - [OCCURRED: 3/28/16 through 4/10/16]
Phase VII. Installation
- Moving day
  - The team moved the horse from High Bay Lab to the library with the help of artist Ivan McLean
  - [OCCURRED: 4/11/16]
3.3 How The Built Environment Mirrors a High-Impact Project

3.3.1 Constraints

The senior project, The Built Environment, which was a part of the Living Library Exhibit in the Robert E. Kennedy Library on Cal Poly’s campus, was an exemplary model of replicating a high-impact construction project on a college level. As mentioned in the previous section (History of the Construction Productivity Improvement Officer and Project Timeline and Deliverables), some constraints the team faced during design and construction were: time, budget, space, and communication. Each aspect of the process was integral in keeping the team on track to finish the project by the deadline.

3.3.2 Time

The first and biggest constraint on this project was time. From its inception, time was working against the team because their first meeting was less than three months before the installation date of the sculpture. The group members had to work through
the design process and perfect iterations of their computer model, which was used to calculate structural strength and stability. Additionally, a nodal model was created to give a three dimensional representation of the sculpture design concept. In order to fully develop the idea, the groups spent a month on concept drawings, which left little time once the team decided on a final design. This expedited schedule required a Gantt Chart to be made in order to plan out each milestone and its deadline. This schedule was updated weekly to reflect the most recent deadlines or new tasks that needed to be completed.

The time constraint has the most impact on construction, for the mustang sculpture had to be built and erected within two weeks. This impact resulted in 100% accountability, as each worker had to be present during his or her work shifts (much like an actual work site) in order to assure the necessary hours were put into the project. Similar to a real construction project, there is usually a final push where the last couple of weeks are rushed and every worker must be productive and efficient in order to maximize time. During the final push for the construction phase, the team members worked late and over the weekends in the High Bay Lab in order to finish the sculpture.

### 3.3.3 Budget

Another constraint for a project is budget, which the team also experienced. They were encouraged to fundraise and to reach out to Alumni, friends of the Architectural Engineering department, and the University as well. These efforts were necessary due to the sustainability aspect of the sculpture. The money gathered from different generous sources contributed to meals during construction and to material costs.

This resembles an actual high-impact project because every dollar counts towards materials, workmen's compensation, or to keeping the project on time. Contractors and project managers of these accelerated projects need to update their books constantly to make sure all expenses are included to ensure a balanced budget.

A real construction project’s high material budget is where it differs from this senior project. This senior project used reclaimed and recycled materials, so there were no material related expenses. Therefore, group members needed to gather recycled materials, so they gathered usable materials at the main recycle yard on campus because it housed unused pipe and metal from surrounding shops and buildings from the university.
3.3.4 Space
In highly developed cities such as San Francisco, Los Angeles, and New York, space is very limited so the demand for it is very high, which causes developers to build up instead of out. This increase in height of the skyline affects the people on the ground though. In a high impact project, one major impact is space because it requires organization between the different groups. Immediately, the restricted space on the construction site impacts the arrival of materials. Every material delivery must be coordinated by the contractor so it arrives without sitting at the site for too long because it will hinder productivity if it sits in the way of other workers.

The team experienced this phenomena as well because they were working in a confined space while building the sculpture. The laboratory used to construct the sculpture, a measly 2,869 sf, had to be shared between over 2,000 students of three departments in the College of Architecture and Environmental Design. Due to this, they could not have too many big materials in the shop or else it would get too crowded, leaving someone incapable of working efficiently. During the assembly of the sculpture in the library, the team also experienced this because they had to carefully plan out the construction sequence to prevent downtime. Every minute they blocked the hallways and entrances in the library meant an inconvenience for its patrons. Additionally, this impact occurs on real high-impact projects when big rigs carrying large materials require closed streets in order to make the tight turns, or a crane blocks off a lane from the main road, creating traffic and accidents for the public.

3.3.5 Communication
Notably the most important part of any project, high or low impact, is coordination and communication. The team had to coordinate between the Artist, the Client, and the Faculty Advisor. This coordination required twice-a-week meetings in order to guarantee all members were aware of the tasks that needed to be completed before the next meeting. In order to keep the team accountable, the Gantt Chart and meeting minutes helped to keep members up to date on necessary deadlines.

These meeting resemble the OAC (Owner, Architect and Contractor) meetings that take place consistently during a high-impact project to keep all parties alert to any upcoming problems. These meetings are very helpful in finding and fixing problems when they arise because they can be addressed quickly and efficiently. By resolving problems quickly during frequent meetings, they are less influential to the deadline than if it was fixed later.
3.4 Conclusion

As clients aspire to create a landmark structure, and structural engineers design buildings to be taller, contractors are burdened with keeping these behemoths on time and under budget. These projects are more and more often needed to implement high impact project delivery methods. The project challenges every member involved to communicate effectively in order to remain ahead of the accelerated deadline. The Built Environment, though not a skyscraper, was a project that simulated a high-impact project delivery in many of the aspects of the term, which made it all that rewarding upon completion.
4.0 The Story

INTRODUCTION [RIBBON-CUTTING REFLECTION]

On April 12th, 2016, the Reclaimed Mustang project, along with the entire Living Library exhibit, was received by a welcoming community of students, faculty, and staff. Those in attendance munched on carrot cake and Oreos and clapped as the team advisor, professional artist Ivan McLean, cut a springtime-green ribbon to welcome the display to the second floor of the Kennedy Library. The atmosphere livened up to an all-time high; amidst concrete pillars and study tables lay two grand metal mustangs, a succulent garden, two hanging shipping pallets full of fresh flowers, several-hundred library books, and a dozen enlightening written displays focused on sustainability practices and local efforts. The sculptures’ reception was a success; students on the team paced away steadily, grown and learned like never before, memories full of irreplaceable experiences. The following is a narrative from the students’ perspective, telling the short story of the Reclaimed Mustang project and highlighting the experiences that led to the project’s final ribbon-cutting…

TEAM FORMATION [BEGINNINGS]

Open on the Architectural Engineering (ARCE) building’s A-Lab on January 26th, 2016. The sun readied its setting behind the San Luis Obispo hills west of campus, and nine students gathered around the combined wooden lab tables awaiting an introduction by the senior project advisor, ARCE professor Dr. Craig Baltimore, as well as Cal Poly Campus Art Curator Catherine Trujillo. The leading duo gave a heavy project pitch: the Reclaimed Mustang sculpture project was to demand strong, nonstop communication and a large time commitment from each student. Dr. Baltimore stressed the time-impacted nature of the design, construction, and installation, and Trujillo highlighted the goals of the art piece aesthetically, introducing the work of the project’s professional advisor, sculpture artist Ivan McLean, and explaining the sustainable themes of the final exhibit “The Living Library”. The meeting ended with a long list of to-do deliverables and the promise of an extraordinary journey.

THE FIRST QUESTION [ WHAT IS A HORSE?]

The initial nine ARCE seniors, Aaron Boucher, Emmanuel Castano, Kevin Church, Nate Hall, Alejandro Lopez, Nick Petrarca, Emily Setoudeh, Sean Westphal,
and Lacy Williams, were soon joined by ARCE senior Nick Reindel and Architecture second-year Leesa Choy to complete the assembly of motivated try-hards. The first question of design: What is a horse? With a prompt as such, the students had no choice but to dive into research, some looking into the history of human-horse relationships, symbolism, basic anatomy, and movement types (gaits). A power-point presentation helped each organize their thoughts, and left them with a good start towards creation of an accurate horse sculpture. For the next few weeks, there were two major focus points: coming up with a schematic design, and gathering as much reclaimed or repurposed steel as possible.

ELEVEN-PERSON DESIGN [SPLIT SCHEMATICS]

Team members’ imagined horses of steel- such was the common ground- but each posed its own scale, inspiration, and focus. Each explored a different parameter. Each had its own flare, and that was how the schematic design process got rolling: two weeks of brainstorming a herd of steel horse sculptures with snowflake-like variety. While the pros of floating ideas and eleven student-driven design paths were evident in the breadth of boundaries defined, the harshness of decision-making came about slower than expected. Pushing direction-setting even further back was the sense that the team didn’t quite have what they needed to settle for the sculpture’s form, size, or an aesthetic. Materials were not yet scouted, artist Ivan McLean gave a generous amount of drawing-board freedom (unexpected to many), and a long list of limitations left each student concerned with different aspects. Petrarca and Church explored ways to get greenery into the project, Williams, Setoudeh, and Lopez showed interest in a form with motion, and the others dove into spectator-interaction and material use. The reality was that all sectors were going to need addressing eventually, and the task’s time restrictions cast a giant shadow on such a grand idea.

Nonetheless, progress ensued. Inspiration came from all around: a lovely visit to the Cal Poly horse stables, google images of steel horses that came before, and a wisdom-gathering day trip to the studio of San Miguel artist David Settino Scott. All gathered with their own slides to share on the evening of February 11th. The A-Lab schematic presentation that followed lent itself to a thousand new ideas; every new angle had advisors Trujillo and Baltimore increasing their speculations, giving the students more phrases like: “…0hhh, what if…” and “… now picture that but crossed with-”. There were clearly paths in sight, but the team had yet to choose a direction. The next bend promised more and more exercises in creative problem solving with an eleven-person team.

GATHERING MATERIALS [A CONSTANT FLOW]
Gather everything—poles, pipe, car parts, book shelves, old bikes, etc.—and bring them to high bay lab. The horse team was again and again reminded to be on the lookout. Early on, a solid grasp on available building materials meant a better idea of possible design choices. Weeks went by of having but a vague idea of what finish and structure was to make up the final horse. Alongside the initial schematic designs each student had to come up with, the whole team was challenged to find actual building material. Around the A-lab tables the students racked their brains for thoughts on connections and places to find available metal. While company phone calls, emails, and good timing eventually gave the new sculptors the collection of repurposed metal that they eventually put to final use, the very first stockpile was made up of campus-scavenged scrap, bike parts, and donated barrels.

This affected the design phases heavily; either the student would change their potential mustang altogether with acquisition of new pieces, or the student would hold back on material development of their design in hopes an answer would come from the scrap bins one of the coming days. Westphal led communication efforts with campus material recycler “Recycle Rich”, who showed the mustang team to the epitome of campus recycle yards- and gave the team open access to its wares. The time-scope pressed, but the material gathering did not falter. It became rather motivating to go out to the big campus scrap bins and wheelbarrow back some agricultural conduit, car parts, and rusted bolts. The notion that the students’ brainchild metal mustang was to actually exist in steel before their very eyes became more real as every next rusted assortment was piled by the concrete yard door.

ARTISTS AND ENGINEERS [SMALL MODELS, BIGGER MODELS]

With schematics phase past and the material hunt beginning to see its first gains, the eleven students were tasked with further design development. This meant models. This meant thoughtful drawings. This meant a surge in creative solutions and artistic exploration. In loose groups of two, each student was to develop their own schematic idea into a model, incorporate into it another student’s design elements, and present at the following week’s meeting. Concerns sprouted from the longtime artistic gap many held since freshman year studio ended in the spring of 2013, but students ran at the new challenge. Whether considering themselves artists yet or not, every member transformed an original imagining into a true-form model. Cardboard, model clay, wire mesh, hot glue, little leaves, basswood scraps, paper clips, applicator sticks, 3-D printed plastic, and horse dolls satisfied the prompt to an unexpected variety; the first development stage easily brought each student’s design to even greater uniqueness. The groups reconvened around A-lab table again the coming week, and
select ideas seemed to catch the eyes of advisor and student alike. Petrarca, Choy, and Westphal brought focus down on true-proportioned horses with a defined skeletal system and partially covered skin; these on display starkly contrasted the structurally-intriguing and abstract partial horses of Williams and Boucher. Hall, Church, and Petrarca boosted enthusiasm for an integration of greenery within the design for the structure itself, pushing for a layer of depth into the meaning of the sculpture’s Living Library environment. Taking center spotlight in modeling, Lopez’ 3-D printed horse-woman had those present in awe. No explanation necessary, the form itself communicated that a careful layout of collected parts may make it possible to create a single shape that looks like a horse and from another angle like a woman, hands outstretched. Good words were passed around and discussion of priorities ensued. Unto each model: Was it constructible? Did we have the material? Would it stand? Did it have a good form and meaning? What would it say to those who passed by? Questions were asked, the sun set, and by end of meeting, eleven artist-engineers funneled into two groups for the second design development phase.

Alongside the hurdles of design, the team split into task- for construction preparation. Reindel looked to arrange welding lessons, Williams coordinated material storage and high-bay lab space usage with ARCE department technician Ray Ward, Setoudeh organized a check and update of safety kits and tools in the high-bay lab (including the addition of oxygen masks and several fire extinguishers to the space), and Hall laid out the project Gantt chart. Lopez and Church worked with some gathered scrap material in the shop in order to test applicability. Schedule-stuffed and time-short, individuals managed to divide work fairly well and communicated constantly as to when a task was to be delayed or responsibility changed.

A roll of progress transitioned the team into the second design development phase. Building products companies Verco Decking Inc. and Simpson Strong Tie both gave word to donate a hefty supply of test scraps, which meant a whole lot of like-sized steel plates and slates, both galvanized and ungalvanized. More conduit, thick and thin, were trucked into the high-bay lab from trips to the recycle yard to add to the heightening piles. The two groups worked on developing their models for the next phase, and motivation seemed to start off high; ideas flew from mind to mind and the brainstorming sessions were optimistic. Time between ARCE design labs, ARCH studios, and midterms challenged project dedication, and soon the models were due for presentation. Yes, each member of each development group could explain the plan- everyone could generally describe the proposal- but the models were a whole separate challenge. In a way this challenge represented the aspect of the project design which would eventually dictate final design direction: constructability and time-impacted deliverability. One group focused on a sculpture based on two
systems: a framed skeleton and a semi-permeable skin (to partially cover the skeleton). They chose to present this idea in a plaster model; the result was an organically shaped, thick skeleton of a horse and an imaginary and assumed skin system. Westphal, a member of the first group, also dedicated his time to an important “part 2” idea. He designed and built a space frame horse out of applicator sticks, aesthetically linked to triangles, and based on ease of constructability. The second group decidedly differed from the proportional horse. They came up with a structurally-interesting abstract horse design based off of one main element: the horse was to balance from a single pole, a cantilevered moment connection at the body, and a counter-weight in the back end, and all based into a small cubic volume of reinforced concrete. The second group’s model was shopped together last-minute from thin-walled conduit and demonstrated the structural system without having actual counter-weight system in place. Both groups scrambled to finish tall-ordered small-scale sculptures by the A-lab meeting on the first of March, 2016.

SUBMITTALS [TWO HORSES, TWO CALCULATION PACKETS]

The groups were sent back to the drawing boards after the Tuesday night meeting for a third design development phase. Project advisor Trujillo felt that the first group had lost what they had initially intended to express in their model, and so the plaster idea was tossed in lieu of Westphal’s more positively-received and form-flexible space truss horse. Group one spent the next week rebuilding a scaled model space truss horse out of applicator sticks. Keeping in mind constructability, they used as many like-sized triangles as possible, but still kept the pose interesting by keeping one leg off the ground. Group two received criticism for bringing concrete into the design as well as skeptical comments regarding overturning of a cantilever- the cantilever having, at that point, “exact geometry undecided.” Their time during the next week was not with the model, but with the pose and geometry. Both groups honed down on more detailed specifications in order to present a best-estimated list of material weights, footprint, and potential construction schedule. The first group had a scale model and the second had drawings and a material schedule. Both seemed doable and worthwhile. After discussion as to how they would decide, Baltimore and Trujillo revealed their decision for the reclaimed mustang project: “We are going to build both horses.”

From that moment the goal was there- decision made. With Westphal’s model, Church’s sketches, and the skin samples Petrarca and Lopez experimented with in the shop, the “big horse” was a set-in-stone final design. Group one took hold of the final drawing and calculation packet to be sent to the campus facilities engineer for permitting the big horse, while group two took responsibility of the “baby horse”
(though Boucher was to soon take lead of the “baby horse” altogether during construction). The packets’ seismic overturning calculations provided students the opportunity to use sections of ASCE 7-10 not previously studied, and solve a unique, small-scale structural problem. The sculptures also had to resist forces from passersby leaning against them. Taking the role of structural engineers cast upon their own imagined aesthetics, the students put together strength checks and final geometry into two packets for approval of the campus facilities engineer. A team-wide message was sent as soon as the packets went through and were passed (within it, many exclamation marks); construction was then a reality.

**THE RUSH [TWO WEEKS OF TIME-IMPACTED CONSTRUCTION]**

The quarter turned with great severity in mindset-shifts. Winter’s end saw the project stalled and just about ready to begin revealing its full form in construction. A cleaned and (mostly) supplied high-bay lab awaited the next phase; the ground longed for the metal dust, sparks, loud cuts, and red-sharpie measurements of progress. The team took welding lessons and scouted for tools in the last few weeks of the quarter, and Boucher, Church, and Williams managed to form and pour the concrete base for the baby horse during finals week. Then half the team left for Singapore, and the other to their hometowns for Spring break. Though the transition between tough school quarter, spring break, and new quarter would be cause enough to forget about academia for a little while, the reclaimed mustang project team anticipated the lag, and adjusted into the rushed-construction setting.

Two weeks were spent building the reclaimed mustang, resulting in the partially-exposed apace frame horse that was to liven the second-floor space of the library. Early framework welds and measurements revealed the struggle of scale that came with building each triangle making up the frame. Whenever a team member figured out a new strategy or solution, it was quickly passed around and shared. For example: there became standard assumptions for the side of an angle piece one would cut and measure, the applicator stick model was heavily edited and used to figure optimal geometry, and the process of making triangle modules and then connecting them with the conduit cross-braces was utilized to make use of the eleven-person team available to apply themselves. Division of labor also helped, but overlap kept each person available for aid to the other. Church and Choy spent the later hours of the nights working on the mustang head alone, but would essentially aid in torso work when needed. Lopez and Westphal became the go-to mig welders while Hall and Setoudeh grinded and cut with great efficiency. All hands came aboard to aid McLean with baseplate design and construction during the last weekend, and with the head and neck finally in-place by that time, Church and Choy transferred their focus to the
layered-steel mane and tail. Rush construction was full of all-day work days, but never once did the project seem in danger of incompletion. The scale-model-based design made for efficient assembly; cranking out the next leg or welding the skin plates would not fall behind unless the team failed show up. Eleven workers on a horse plus a highly-skilled and generous profession artist as advisor were plenty to tackle the challenge, and still result in the students put through a worthwhile challenge.

**INSTALLATION DAY [HEAVY LIFTING, FITTING SNUG, AND COMING ALIVE]**

On April 11th, 2016, a giant metal horse and a smaller counterpart were positioned by the information desk on the second floor of Cal Poly’s Kennedy Library. The big horse traveled across land in seven pieces: tail, mane, back end, front end, and three baseplates, all of which were loaded into McLean’s generous flatbed trailer before a slow drive from concrete yard to temporary parking out front of the library. The baby horse was dollied- concrete base and all- to the library elevator put to the side of the Living Library site on the second floor. Many a library-goer were redirected that day to “detour through the 24-hour room” in order to leave the library; Dr. Baltimore’s ARCE 223 class of over thirty students volunteered their time to being traffic cones for the morning, redirecting the public such that the seven parts of the mustang could be safely transported to the site. While the baseplates made it in no time- the largest of which barely scraping by within the dimensional confines of the service elevator- and the horse mane and tail joining the plates rather quickly, the two frame parts of the actual horse were another story altogether. Each end of the horse was hand-carried (at least eight people per trip) up the first flight of library stairs and around Julian’s Café to the back of the second floor Living Library Site. With McLean’s calm but directive instruction, the whole transportation ran incredibly smoothly. It was as if the limits of transportation were brushed and poked but not crossed, as if the team teased failure on purpose, and laughed on their way into the exhibit space.

The final bolt locked found the horse more a spectacle than ever. Her withers barely missed the lighting system above as she stretched her neck down, giving a subtle nod to the baby horse bouncing around its legs. The two forms breathed, immediately fulfilling the exhibit’s title alongside the horticulture club’s living wall and succulent garden. The mustangs’ presence had incredible effect on the onlookers- that much was undeniable. Green soon covered the middle baseplate in fake grass and around the horses in a boundary of old hardcover books. By 2:00pm the statues were in place, and the team left to rest for the reception to come. Hard hats in hand, the designers and builders of the reclaimed mustang walked away feeling a mix of artist’s pondering and engineer’s speculations.
5.0 The Baby Mustang Report

The Built Environment project split into two designs: a larger than life-size sculpture and a smaller, foal-sized sculpture. Although the initial project was planned to only include one sculpture, a second horse was added as the Team fully developed their design ideas. Throughout the design process, the Team analyzed numerous ideas, exploring different spatial relationships, forms, and structures. As we began to focus on a final design, two ideas came to the forefront. The first idea, inspired by an engineering focus, was a truss based design. Designing with an engineering mindset had several advantages: the sculpture would be light, easy to construct, and easy to fabricate. The second idea focused on an artistic, abstract design. The horse would have a single cantilevered back leg, and a flowing, abstract shape. This contrast in design ideas showcases the impact that an engineering design approach can have when compared to an artistic approach. When the Team discussed the merits of each concept, the issue of constructability was the deciding factor. The artistically inspired horse required a large concrete base to support the cantilevered leg, and the constraints of transporting the sculpture in and out of the library made this approach unfeasable. However, both design ideas were popular with the Team, and so the decision was made to continue forward with both concepts. The truss sculpture was constructed at a large scale, while the cantilever leg design idea was be scaled down to a constructible size. The smaller, abstract sculpture was named the Pony, and was the size of a foal when compared with the truss sculpture.

5.1 Summary of Construction Process

The Pony was built in two phases. Phase 1: this phase consisted of constructing the formwork for the concrete base, fabricating the cantilevered leg, and pouring the concrete. To complete this phase on time, a 2’ x 2’ x 6” concrete base with a cantilevered pipe was cast 3 weeks before the erection date to allow the base to cure. Phase 2: The body was built around a flowing spine that established the lines of the horse silhouette. After the body was fully constructed, the body and base were attached with a friction fit pipe and a single bolt. This design allowed for easy transportation into and out of the library.
5.1.1 Design Inspiration

The design of the Pony was based on an abstraction of a horse; the idea was to have the form of the horse fade away as you move from the front to the base. To achieve this, we decided to cantilever the back of the Pony from a small concrete base. This choice did two things: it brought energy into a static sculpture, and also achieved the abstraction that we were looking for in our design. To help inspire our design, the group examined previous artistic interpretations with this same theme. As you can see in figures 1 and 2, this concept of fading the form into abstraction has been done before with great success. Figure 2 in particular shows the type of
energy and motion we wished to capture in the Pony.

Figure 1.

![Figure 1]

5.2 Design Process
Design quickly moved from conceptual sketches to physical models. Several ideas and forms were developed, exploring both the single back leg and the level of detail used to define the shape. This process was essential to deciding on a final design. As shown in the photos below, the models utilized many different materials in an attempt to define the final form of the Pony. The final design borrowed concepts from all of the models shown below.

Figure 2.

![Figure 2]
5.3 Stability Calculations

The concrete base of the sculpture was carefully sized to ensure its stability and safety. By taking into account the weight of the concrete base in relation to the statue, an overturning calculation was used to determine the dimensions of the base, as shown below.

\[ \Sigma M = (F_p * 2) * (H_{statue}) - (W_{base}) * (1/2 * B) \]

- \( F_p = 200 \) Pounds
- \( H_{statue} = 4 \) Feet
- \( W_{base} = (\frac{1}{2})^2 * B^2 * (150 \text{ pcf}) \)

For stability, \( \Sigma M \) must = 0. Insert \( (\frac{1}{2} \text{ B}^2) \) for \( W_{base} \) and solve for \( B \):

\[ B = \sqrt[3]{(200 \text{ lb} * 2) * (4/ft)/(0.25 * 150 \text{ pcf})} \]

This is an example of the equation used to determine the necessary size of the base to achieve the required stability. Because the weight of concrete is known, a relation between the size of the base and the overturning moment could be established. This overturning moment was based on a design force of two point loads of 200 pounds, each applied at the top of the sculpture. This was to model a reasonable worst case scenario of several people attempting to knock the Pony over. After solving this equation, the group used a 2’ x 2’ x 6” base to achieve this level of stability.
5.4 Construction Sequence

Because the Pony utilizes concrete as well steel, the group had to take into consideration the curing time of concrete. The base was cast two weeks before the rest of the construction was begun to ensure that the concrete was fully set. Planning the construction sequence with a Gantt Chart was an essential part of the design process, and allowed for multiple separate elements of the project be completed on the correct schedule for installation.

5.4.1 Construction Team
To properly divide the labor and successfully deliver the project on time, the team decided that to have one member responsible for construction. Aaron Boucher volunteered to take this role. Additionally, Kevin Church and Leesa Choy designed and constructed the head of the Pony. They were also in charge of the head of the large mustang, which helped maintain a consistent design between both sculptures.

5.4.2 Materials
To maintain the design ethos that the Living Library promotes, the Pony was built entirely with recycled or donated materials. The base was constructed out of concrete, with rebar reinforcement, while the body consisted primarily of 1 ½” steel pipe. Additional skin materials included galvanized steel tabs and galvanized 16 gage steel sheets.

5.4.3 Acquiring materials
This project was a part of the Living Library exhibit, a showcase for the sustainability of the Cal Poly campus, and as such only recycled materials could be used to build the Pony. The College of Architecture and Environmental Design support shop had an extensive stockpile of metal scraps that were remnants from older projects. The pipe used to create the skeleton of the Pony was recycled from this stockpile. Along with providing materials, the CAED shop was an excellent resource for the construction of the entire Built Environment project. The concrete and rebar that formed the base of the Pony was donated from the Architectural Engineering Department from the excess material they had from their Concrete Design labs. Verco and Simpson Strong-Tie, two
construction companies with good relationships with the team and the Architectural Engineering department, donated the metal scraps that became the Pony’s skin.

5.4.4 Design Transportation Sequence
Because we had designed a connection that could easily separate the body and base, transportation presented few challenges. The Pony was constructed in the High Bay Laboratory of building 21, and had to be moved from the high bay into the second floor of Kennedy Library. The group had previously determined the best route to the library: after following College Avenue to California Boulevard, we used Dexter Road to arrive at Kennedy Library. The Pony was placed on a dolly, and then rolled into the Library elevator and onto the second floor.

From left: Aaron Boucher, Kevin Church, and Leesa Choy transporting the Pony.

5.4.5 Erection
Transporting the Pony to the Living Library exhibit on the second floor of the Kennedy Library went very smoothly. Ease of erection was a primary consideration during the preliminary design phase, and the extra thought and effort put into it payed off during erection. The connection between the phase one and phase two was designed with only one bolt; this allowed for a quick and easy construction process. Furthermore, the concrete base was placed on a dolly, and was easily rolled into the library elevator and onto the second floor.

5.5 Design difficulties and lessons learned
Due to the abstract and free flowing nature of the Pony, fabrication of individual pieces did not follow a strict or predefined schedule of sizes. This type of construction worked well because the group had a single team member in charge of the design, but presented challenges when trying to communicate with team members about the shapes of specific pieces. This limited the amount of assistance team members could offer, and forced the group member in charge to micromanage the design. To avoid
this problem, in the future the team should spend a few more days in the design phase, and layout exactly what the Pony’s design will be, instead of beginning construction with only a form model. If the group had created a schedule with exact sizes and angles, fabrication could have been a lot faster. However, with the limited design time available to us, the approach used allowed construction to begin as soon as possible and enabled the project to be completed on schedule.

5.6 Conclusion
By splitting the Built Environment project into two separate designs, we were able to fully explore two competing design ideas. This choice also illustrated the importance that must be placed on constructability and design constraints when deciding upon a design scheme. While the cantilevered base design of the Pony was a great aesthetic design, it was ultimately impractical at a larger scale. But by pursuing both ideas, the team ultimately challenged themselves to improve the final project, and did not just take the easy way out of only designing one statue. This project involved all aspects of the construction process, and it will be an experience that the team will remember for the rest of their careers.
6.0 Installation and Disassembly Instructions

Section 1: Metal Mustang Sculpture Part Breakdown

Mustang Sculpture Itemized Parts List

- 2 red, quadrilateral metal foundation plates (smaller front and larger rear)
- 1 silver, pentagonal metal foundation connector plate
- Detachable metal tail
- Detachable mustang mane
- Rear section of mustang body
- Front section of mustang body
- 10 stainless steel ½” bolts (not including the 12 attached to the foundation plates)
- 3 stainless steel ¼” bolts
- 22 stainless steel ½” nuts
- 3 stainless steel ¼” nuts
- 12 stainless steel ½” washers
- 22 stainless steel ½” lock washers

Part Images

Image 1.1: Smaller front foundation plate (left) and larger rear foundation plate (right).
Image 1.2: Foundation connector plate.

Image 1.3: Detachable Metal Tail
Image 1.4: Detachable Mane

Image 1.5: Rear Section of Mustang Body
Section 2: Metal Mustang Sculpture Assembly Instructions

*Disassembly instructions are the same as assembly, just in reverse order.
*Be sure to read entire packet before beginning assembly/disassembly.
*Bolted connections: bolt-material-washer (if required)-lock washer (if required)-nut.

Step 1: Aligning Foundation Plates and Connector Plate

1. Be sure that installation will be on a level surface. The sculpture is not designed to be placed on a surface not meeting this criteria.
2. Place the two red foundation plates flat on the ground with the red side up.
3. Place the metal connector plate flat on the ground, between the two red foundation plates, with the triangular tab side up.
4. Align the three plates together so that the orientation matches that of Image 2.1.
5. Be sure that the triangular connection tabs are aligned as seen in Image 2.2.
6. Place ½” bolts through the holes of the triangular tabs, connecting each foundation plate to the connector plate.
7. Attach ½” lock washers and nuts to the back of foundation bolts. Hand tighten each bolt. See Image 2.3
8. Once all three bolts-connecting the foundations to the connector plate are hand tightened, tighten each bolt with a pair of wrenches.

Step 2: Instal Rear Section of Mustang Body
1. Take the rear section of the horse and orient it with its feet firmly flat on the floor.
2. Notice that the plate attached to the foot of each leg has four holes that correspond to four bolts attached to the foundation plate.
3. Lift rear section of the horse and translate it over the larger red foundation.
4. Lower rear section of horse so that bolts slide through the holes near each foot. Do not let horse self-weight rest on the bolts as they could be severely damaged. See Image 2.4 and 2.5
5. Hand tighten washers, lock washers, and nuts onto the bolts.
6. Once all 8 sets of fasteners have been hand tightened, fully tightened nuts with a wrench. The rear section of the mustang body should be able to stand by itself when all bolts are fully tightened. See image 2.6

Step 3: Installation of Front Section of Mustang Body
1. Take the front section of the horse and orient it with its front right foot lying firmly flat on the floor. See image 2.7
2. Notice that the plate attached to the foot of the front right leg has four holes that corresponding to four bolts attached to the smaller foundation plate. Also, notice the seven holes in the middle torso of both the front and rear sections of the horse.
3. Lift the front section of the horse and translate it over the smaller red foundation.
4. Lower front section of horse so that the bolts slide through the holes near the front right foot. Do not let horse self-weight to rest on the bolts as they could be severely damaged.
5. Hand tighten ½” washers, lock washers, and nuts onto the bolts, connecting the plate to the smaller foundation. Concurrently, hand tighten the seven ½” bolts, lock washers, and nuts attaching the middle two torsos together. See images 2.8 and 2.9
6. Once all bolts are hand tightened, fully tighten each bolt and nut with wrenches.

Step 4: Installation of Tail and Mane
1. With two ¼” bolts and nuts, attach the top of the tail to top of the rear of the horse. See Image 1.3 and 2.10.
2. With one ¼” bolt and nut, attach the bottom of the tail to the side of the rear of the horse. See Image 1.3 and 2.11
3. Attach the mane to neck of horse by hooking the mane over the top neck pipe. See Image 2.12.

Assembly Instruction Reference Images
Image 2.1: Foundation and connector plate orientation.

Image 2.2: Triangular connection tabs.

Image 2.3: Nut, lock washer, and bolt combination.
Image 2.4: Rear horse section placed on larger foundation.

Image 2.5: What to avoid.
Image 2.6: Rear horse section stands alone with tightened bolts at feet.
Image 2.7: Front horse section placed on smaller foundation.

Image 2.8: Bolts connecting the front and rear torsos together (view from rear to front).

Image 2.9: Reverse side side of Image 2.8.
Image 2.10: Attaching top of tail.

Image 2.11: Attaching bottom of tail.

Image 2.12: Hooking mane to the head of the horse.
Section 3: Potential Risks, Tips, Damages

Risks

- Most parts of the mustang sculpture are exceptionally heavy. The foundation and connector plate each weigh a few hundred pounds while each section of the horse weighs about 400 pounds.
- Hard hats must be worn when assembling the sculpture to avoid head injuries from moving parts or bumping into the statue during assembly.
- Be careful to avoid pinching fingers under foundations or in between connecting members.
- The ears of the horse are moderately sharp and could impale an individual if one was to fall onto them.

Tips

- Moving slowly is key. Be sure to fully understand where pieces are going before they are moved. Many of these pieces are large, awkward to carry, and heavy; be sure that the work area is as clear of clutter as possible.
- When resting the heavy pieces on the ground, be sure to rest them on top of mats, rugs, etc. to preserve the quality of the flooring.
- Eight or more bodies are recommended when moving the front and rear sections of the horse.
- Gloves greatly help lifting the sculpture’s parts.
- Flat moving dollies are advantageous for moving the parts around.
- When attaching the rear half of the horse to the foundation, one can use shoring to hold up the back half, instead of or in addition to, fully tightened ½” bolts. Shoring can also be used for supporting the front half of the horse during construction.
- The horse will rust when placed outside, exposed to the elements. This is to be expected and will not compromise the strength of the materials for decades to come. It is for this reason that stainless steel bolts should only be used.

Damages

- The worst damage that can occur is the punching of the foundation bolts backwards through the foundation. These bolts are welded on the underside of the foundation in order to facilitate installation. If these bolts become skewed or punched through the hole, they must be rewelded before assembly continues.
- Both the front and rear of the horse are thoroughly and redundantly welded. They should not break apart unless severe and intentional damage is afflicted. Denting of members is likely to occur if parts are dropped or impacted by other large and dense bodies. This would not significantly compromise the integrity of the sculpture.