To: Dr. Oman

From: Nathan Fisher, Leann Hernandez, Trevor Scott

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Subject: Implementation Memo

In 2019 the Navajo Generating station, located near Page, AZ, was shut down. Benefits to the environment aside, this is an issue for the local Native American tribes on the surrounding reservation. Many of the residents of the reservation were receiving coal for highly discounted prices from the local coal mine that supplied the power plant and using that to heat their homes. When the Navajo Generating Station closed, so did the mining operations. With a lack of electricity in many of the homes on the reservation, this poses many issues for heating, especially in the winter months. This, in addition to the health effects of burning coal indoors, has led to a need for a cheap, reliable, and renewable heating source. One solution to this need comes in the form of a solar furnace. Many commercial options exist and are already being implemented however they can be expensive. Red Feather, a nonprofit working with residents of the reservation to satisfy their housing needs, has tasked this NAU capstone team with creating a more affordable solar furnace that competes with commercial models in terms of heating output. This memo outlines the progress made thus far in designing and constructing a competitive solar furnace.

1 Customer Requirements (CRs)

If a design does not meet the needs of the customer, then essentially, it is a failure. By developing clear communication and understanding the requirements of a design, as dictated by a customer, it is much easier to ensure a quality design that meets those requirements. The customer requirements laid out by Red Feather are all defined below:

- Low cost: the cheapest commercial option is $750, and as low as $450 if bought unassembled.
- Needs to heat an entire home.
- Must be scalable for different size homes
- Needs to be built with standard power tools and welding equipment.
- Low weight: needs to be installable by 2 people.
- Must be durable: for outdoor use in all seasons.
- Low noise level.
- Wall or roof mountable.

The manufacturability of the design has been highlighted since Red Feather will be building the furnaces themselves. The manufacturing plan may also be used for unassembled commercial options.

2 Engineering Requirements (ERs)

The team formulated engineering requirements to quantify the customer needs. The engineering requirements are made to set an achievable standard of performance. Each engineering requirements has a targeted amount and a tolerance. All the engineering requirements have not changed this semester except for cost.

2.1 ER #1: Cost

2.1.1 ER #1: New Cost Target = $400

The original cost target was $350 agreed upon by the team and the client. Red Feather currently pays

$750 for their solar furnaces. This engineering requirement is important so that the client can recreate the solar furnaces at an affordable price.

2.1.2 ER #1: Cost Tolerance = $50

The cost tolerance is $50. Ideally the solar furnace would cost as low as possible. Ordering materials in bulk often decreases the overall price of the materials.

2.2 ER #2: Heat Generation

2.2.1 ER #2: Heat Generation Target = 1500 W

The Heat Generation target is still 1500 W. This is important because this is what is needed to heat a home comfortably for 2 hours. After 2 hours, the home would continue to stay warm. This is comparable to what space heaters produce.

2.2.2 ER #2: Heat Generation Tolerance = 100 W

The solar furnace should be as close to 1500 W as possible to compete with other solar furnaces and space heaters. There is a 100 W tolerance.

2.3 ER #3: Heat Capacity

2.3.1 ER #3: Heat Capacity Target = 2 hours

The targeted heat capacity is 2 hours. This is important because this is the standard of the client's current solar furnaces. The room would continue to stay warm after the solar furnace was been shut off. This is important once the sun goes down.

2.3.2 ER #3: Heat Capacity Tolerance = 15 minutes

The Solar Furnace heat capacity tolerance is 15 minutes. Ideally the solar furnace will have a heat capacity of 2 hours or more.

2.4 ER #4: Weight

2.4.1 ER #4: Weight Target = 45 kg

The targeted weight is 45 kg. This is important so that the device can be easily installed by two people. This keeps install easy and saves time and money for Red Feather, allowing them to install more furnaces.

2.5 ER #5: Durability

2.5.1 ER #3: Life Span of at least 20 years

To match the advertised lifespan of commercial products, 20 years was chosen as the goal of the product. While this is difficult to test directly, only materials with this lifespan will be used. Furthermore, the team plans to use common parts, available at most hardware stores so that the design is repairable. Special consideration was given to the choice of acrylic for the window to prevent the chance of glass breaking and being expensive to replace. The parts with the shortest lifespans will ultimately be the fan and photovoltaic solar panel and may need to be replace at the 20-year mark, otherwise the rest of the design is static and has a much longer lifespan with proper care.

2.6 ER #6: Noise Level

2.6.1 ER #6: Noise Level under 40 dBa

40 decibels were determined to be the ideal noise level for a customer to experience inside the home while fan on the furnace is running. This is the noise level typically attributed to a quiet office.

2.6.2 ER #6: Noise level under 40 dBa = +/- 10 dBa

While the team's goal is to have a "quiet" design, it is the second least important engineering requirement, and some tolerance has been deemed acceptable if it means achieving better heat output or fan quality. The team currently plans to test a boat bilge blower motor with an advertised noise level of around 44 dBa. This sound should be damped slightly in the home as the fan will be installed in line just outside the home bringing it in line with the target.

2.7 ER #7: Install Time

2.7.1 ER #7: Install time under 3 hours.

Install time will be based on the time to set up a prototype by two team members. This time can then be extrapolated for different sizes of the design and different tool capabilities.

2.7.2 ER #7: Install time tolerance = +/- 1 hour

The install time should be able to be accomplished in 1 continuous session without the need for breaks or to make multiple trips to the jobsite. Major activities include mounting the bracket for the panel, drilling the hole into the building and adding the duct, and mounting and wiring the solar panel and fan.

3 Design Changes

The main cause for design changes throughout the project has been cost driven. Due to the COVID-19 pandemic, the team lost much of the funding capability of the client. The primary result of this was to scale the prototype down and simplify some of the more complicated/costly elements.

3.1 Design Iteration 1: Change in furnace size discussion

The original plan was to try to match the heat output of the larger solar furnace used by Red Feather, the YourSolarHome. This model was to be 4' x 8' and be able to put out an ideal of 26,000 BTU over the course of a sunny day. Red Feather has begun partnering with Arctica Solar, whose product measures about 3' x 5' and advertises about 1/5 the heat energy of the larger model at about a quarter of the cost. Red Feather has found these smaller models to be effective and easy to install and has fostered a good relationship with the company. As a result of the lower funding and Red Feather's satisfaction with smaller furnaces, the team has decided to downsize their model to compare to the Arctica Solar's heating capability and size. The team plans for a 3' x 6' design to meet the same output of the Arctica Solar model.

3.2 Design Iteration 2: Change in fin design size discussion

Corrugated metal fins were originally planned for the design to increase surface area and maximize heat absorption by the fins while also being widely available. However, sourcing corrugated metal panels made of aluminum proved to be difficult for the team as most corrugated metal is used for roofing and is made of cheap metal without advertised heat properties or even alloy makeup. To solve this problem the team has moved to a fin design of a triangular profile. This design can be made using a sheet metal break which will allow the team to source plain sheet metal, which is widely available with proper specifications to ensure adequate heat transfer properties. These two profiles are shown in figure 1.

Figure 1. Corrugated vs Triangular Profiles

4 Future Work

The Gannt chart and schedule breakdown are shown below. The team is on schedule to complete all the deliverables for the semester. The team has built the frame of the solar furnace. The Scheduling Breakdown shown in figure 2 outlines all the tasks the team must complete. That Gannt chart is shown in figure 3 and corresponds to the scheduling breakdown. Each team member is represented by a different color as shown in the legend of the Gannt chart to show the task they are responsible for.

Post mortem(Reflection of first semes...	8/24/20	9/1/20
Self-Learning	8/17/20	8/25/20
Research Weldments	8/17/20	8/25/20
Research sheet metal	8/17/20	8/25/20
Research Arduino	8/17/20	8/25/20
Acquire Prototype and Testing Materi...	8/24/20	9/1/20
Send in PO	8/24/20	9/1/20
Research Sheet Metal Vendors	8/24/20	9/1/20
Research Arduino Materials	8/24/20	9/1/20
Start Building Final Project	9/7/20	9/15/20
Build Frame of Solar Furnace	9/7/20	9/15/20
Build Frame of Solar Furnace	9/7/20	9/15/20
Build Arduino and Program	9/7/20	9/15/20
Individual Anlaysis 2	9/14/20	10/5/20
Research Individual Topic	9/14/20	10/5/20
Research Individual Topic	9/14/20	10/5/20
Research Individual Topic	9/14/20	10/5/20
Midpoint Presentation	9/21/20	9/29/20
Testing Final Product: Procedure 1	10/5/20	10/9/20
Order all necessary materials for t...	10/5/20	10/9/20
Set up testing apparatus for testin...	10/5/20	10/9/20
Conduct Testing Procedure 1	10/5/20	10/9/20
Testing Procedure 2: Noise Level	10/5/20	10/9/20
Order necessary equipment for Pr...	10/5/20	10/9/20
Set up testing apparatus	10/5/20	10/9/20
Use decibel reader to conduct test...	10/5/20	10/9/20
Implementation Poster	10/19/20	10/27/20
Final Report	11/9/20	11/20/20
CAD package	11/9/20	11/20/20

Figure 2: Schedule Breakdown

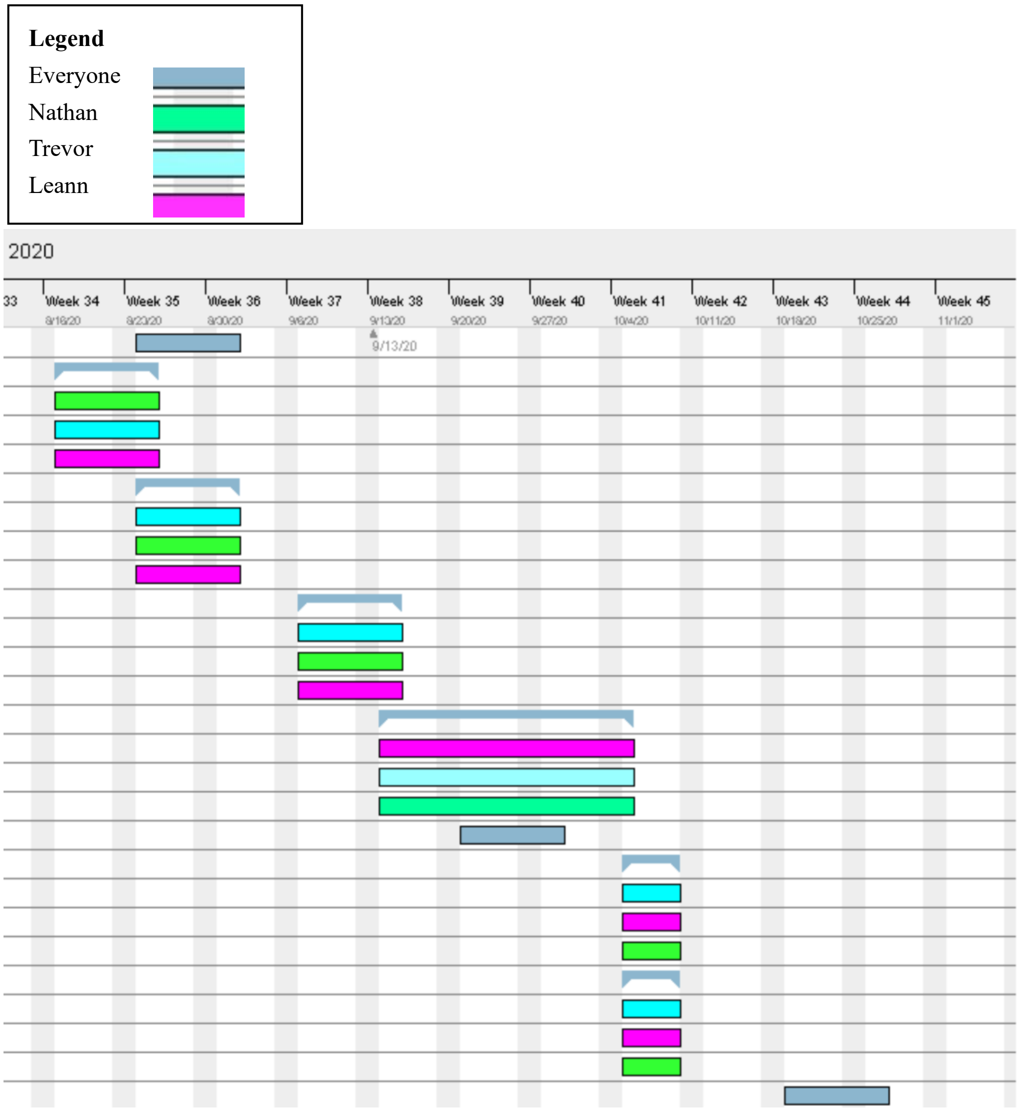

Figure 3: Gannt Chart

4.1 Further Design

For manufacturing, the team scaled down the prototype due to funding. The team is scheduled to complete the prototype soon and begin testing. The frame of the solar furnace has been completed. In addition, the programming of Arduino for testing is nearly finished. Originally the plan was to build a full-size model of 4' x 8' and be able to produce 26,000 BTU. Red Feather has purchased materials from Solar Arctica. Solar Arctica has a 3' x 5' solar furnace and produces about 1/5 the heat energy of the larger model at about a quarter of the cost. The team has scaled down the model due to funding and to compete with Solar Arctica.

4.2 Schedule Breakdown

The schedule is shown in figure 1 above. The team is on schedule to finish all tasks. Leann is in charge of programming and setting up the testing for the team. Nathan and Trevor are in charge of the main building of the prototype due to location. All team members are helping with research on the cost of the materials, such as plexiglass and sheet metal, and design.