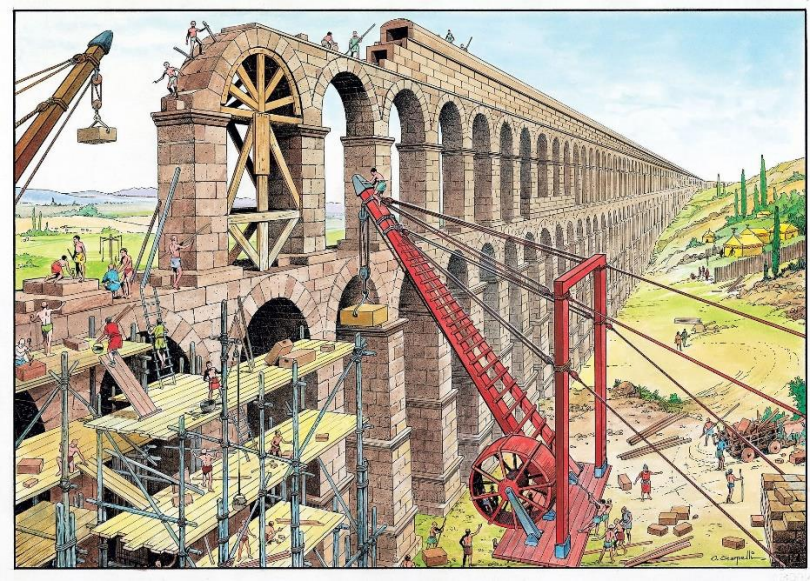


Water Where You Need It!

Background

Water is required for human survival and the transport of water has been occurring for thousands of years. Modern water transport systems are designed and built by engineers, using some of the ideas developed through the ages. Water may be transported with aqueducts, pipelines, canals, tunnels and various other means. Transporting water is very energy intensive, so engineers who create water-moving systems are always concerned about efficiency.

Water for cities, towns, and villages is general obtained from underground aquifers or surface reservoirs. Access to aquifers generally requires wells and pumping technologies. Water can be distributed from a reservoir if the reservoir is at a higher elevation than the end-users via a gravity-fed system, that can be designed without access to external energy. In most cases, water piping systems have to go through (tunnels) or around (bends) obstacles. They may also have to go across valleys, which is what lead to the aqueduct technology developed by the Romans. In poor and developing regions of the world, access to water requires low-cost systems, often making gravity-fed designs more cost effective than pump-driven methods that require external sources of energy. In addition, reliance on elevation and geography lessens the chances for mechanical failures due to faulty pumps or loss of power.

In this Engineering Design Challenge, student teams will be asked to engineer a piping system to get water where it is needed. They will focus on the needs in a specific region or village in the Spanish-speaking world. This challenge focuses on a range of disciplines and concepts. Teachers should feel free to modify and adjust the focus based on learning targets and their level of expertise. Some of the background concepts are as follows.

Science:

In gravity-fed piping systems, several ***fluid dynamics*** phenomena affect the efficient flow of water:

- The initial height of the stored water creates the ***hydrostatic head***, which is the pressure caused by elevation that either helps or hinders the flow. Water that is stored at a higher elevation has ***potential energy*** that will transfer to ***kinetic energy*** as it moves downward. The greater the change in elevation, the higher the velocity of the water (high flow rate). If water moves upward it will lose some velocity, resulting in a decreased flow rate. This is due to the ***Conservation of Mechanical Energy***, which is stated in the form of ***Bernoulli's Principle*** for moving fluids.
- ***Friction between the fluid and the walls of the pipe*** hinders the flow because friction results in a loss of energy. There will always be some friction between the walls of the pipe and the moving water. The amount of energy lost will be directly related to the length of the pipe. Lost energy means decreased velocity and a loss of flow rate.
- ***Friction between adjacent fluid particles*** as they move relative to one another hinders the flow. For this reason, ***laminar flow*** (smooth, organized movement) is always better than ***turbulent flow***.
- ***Turbulence*** is caused whenever the water direction is altered. The resulting friction causes a loss of velocity that hinders the flow.
- ***Pipe diameter*** has an inverse effect on the velocity of the fluid. Decreasing diameter causes increased velocity. This is known as the ***Principle of Continuity.***
- ***Valves*** generally create some friction losses. Different designs have different impacts and some losses can be minimized by a smaller outlet diameter.

Engineers always try to minimize piping system components that hinder the flow. And they are constantly looking for new and innovative ways of increasing and using hydrostatic head to transport water with a minimum expenditure of energy.

Social Studies

The primary social studies components of this project are the history of water supply systems, primarily those of Roman design, and the social justice/global issue of easy access to clean water.

- The ***impact of water access on history*** and the success of the Roman Empire
- The ***challenges met by the designers*** of ancient aqueduct systems; going through and around mountains; over valleys; obtaining and moving materials
- Design ***inspiration*** from ancient systems; developing construction techniques; system maintenance; what did they know?
- ***Water needs and challenges in the developing world***; challenges of UN Sustainable Development Goal 6 – Clean Water and Sanitation
- ***Impact of manual transport of water on the lives of women and children***; hours lost to family time, outside employment, education; safety issues; health and orthopedic issues

- ***Modern infrastructure issues*** prevalent in cities and industrialized areas; challenges faced by increasing population and aging systems

World Languages

- Geography, culture, and daily life in chosen country or region; water needs
- Graphics and explanation of system design or maintenance in Spanish

Math

- Scaling to develop a model (*can be approximation*)
- Calculating increased flow rate based on diameter change (*worksheet would be provided*)
- Percent increase in efficiency after modification

Design Challenge:

Design a small scale model of gravity-fed supply system for a small village or town. The "reservoir" will be a two-liter bottle. There will a "mountain" and a "valley" in your way and you will need to have two outlets – one for irrigation and one for drinking water. Your system should work with both outlets open and with each of the outlets open separately.

Bonus:

- **How quickly can you empty your reservoir? (***Optimization; efficiency***)**
- **How much can you improve your flow rate? (***Modification***)**

Materials (per group)

- ½ -inch ID (inner diameter) PVC pipe, approx. 4 ft. length
- 1-inch ID (inner diameters) PVC pipe, approx. 4 ft. length
- 4 half-inch 90° PVC elbow
- 4 1-inch 90° PVC elbow
- 1 T- fitting
- 2 1-inch to ½- inch PVC reducers
- miscellaneous PVC valves (butterfly, ball, globe, etc.) (2-3 per group)
- miscellaneous sizes of flexible (vinyl) tubing (optional)
- duct tape

Shared materials

- PVC adhesive and primer
- water supply to
- 4-inch steel PVC (to be used by teacher, or under strict supervision)
- towels or mop to clean up water spills (if conducting activity inside)
- Extra chairs or desks to create “mountain” and “valley”
- Pieces of cardboard or foam core to create topographic features

OVERALL PROJECT PLAN

Water Where You Need It!	
Class 1 ***Hook***	Video concerning access to water – possibilities include Practical Action Water Pump Story of a Maasai Woman in Kenya Water Is - Unicef Access to Water (animated)
Class 2 ***Quick Build***	*In and Out* – (details attached) 20 minute challenge to get as much of a cup (3-5 oz) of water through a “pipe” system made of straws, tape, and binder clips; designed to focus on challenges of bends, obstructions, etc.
Class 3-5 ***Background Instruction*** *(Instructor supplied with additional resources being vetted by ProjectEngin)*	**General –** *Issues related to water access* **Science** – *Fluid mechanics, specifically Bernoulli’s and Continuity Principle; conservation of energy; resistance phenomena in pipes (connect to electricity); weight of water; water-borne disease and water quality 9if desried)* **History –** *Role and design principles of Roman aqueduct system; role of aqueducts in modern water supply (specifically NYC system)* **Math –** *Unit conversions, flow rates, scale factors* **World Languages – (TBD)** *Possible focus on Spanish-speaking regions; consider some “marketing” or instructions in Spanish*
Class 4-6 ***Background Research***	*Resources to be provided to groups for job-related research* • *Background of problem* • *Lifestyles* • *What has been tried* *Use jigsaw format by job description; allow one class to share results*

Engineering Design Process *ENB = Engineering Notebook form*	
Step	***Evidence***
CLASS 6-9 *Know Your Problem* • *Know Your End-User* • *Identify Constraints* • *Define Criteria*	Know Your End-User (Country) form; possibly "Day in the Life" format Identifying Constraints (ENB) Ranking Criteria (ENB)
CLASS 6-9 *Know Your Options* • *Research (see above; any additional country specific research can be done here)* • *Brainstorm*	Background Research Summary(ENB) and one page of research per job Brainstorming Summary (ENB) - Use SCAMPER/ paradigm shifts
CLASS 10 *Develop a Solution – Part 1* • *Choose a design* • *Identify needed materials*	Initial Design Plan (ENB) Materials List (ENB) - Need to decide if cost attached
Building Phase – allow 6-8 classes; includes testing and modification	
Develop a Solution – Part 2 • *Create a Plan/make a sketch* • *Build (3 classes)*	Sketch (to be included in ENB) - Note any changes on sketch Daily Summary Form (ENB)
Develop a Solution – Part 3 • *Testing/Feedback (1 class)* • *Plan some modifications to make it better (1-2 classes)*	Prototype Testing form (ENB) - Need to develop appropriate tests; Consider the following ✓ Flow rate (measure time to fill certain container) ✓ Ability to divert to different branch (use of valves) ✓ Flow rate with 2 outputs ✓ Acceptable "leak" factor

	Modification Form (ENB) - Allow 2 modifications to either improve flow or minimize leaks Final Design Summary (ENB)
Final Class *Develop a Solution – Part 4* • *Communicate Your Results* • *Reflection*	Present at "town" or "village" council meeting. Demonstrate working model. - Highlight flow rate - Ease of assembly/reliability - Cost (if considered)

Group Size: *4 students (groups formed in History class)*
Possible Jobs:

Project Manager	**Water Expert**
Civil Engineer	**Country/Regional Expert**

Materials Needed

Main Project

Materials (per group)

- ½ -inch ID (inner diameter) PVC pipe, approx. 4 ft. length
- 1-inch ID (inner diameters) PVC pipe, approx. 4 ft. length
- 4 half-inch 90° PVC elbow
- 4 1-inch 90° PVC elbow
- 1 T- fitting
- 2 1-inch to ½- inch PVC reducers
- miscellaneous PVC valves (butterfly, ball, globe, etc.) (2-3 per group)
- miscellaneous sizes of flexible (vinyl) tubing (optional)
- duct tape

Shared materials

- PVC adhesive and primer
- water supply to
- 4-inch steel PVC (to be used by teacher, or under strict supervision)
- towels or mop to clean up water spills (if conducting activity inside)
- Extra chairs or desks to create "mountain" and "valley"
- Pieces of cardboard or foam core to create topographic features

Quick Build (per group)

- 10 plastic straws ("pipes"); straws with a flexible section if possible
- 15 inches of duct tape (for joining "pipes")
- 4 small/medium size binder clips ("valves")
- 1 ruler (to help with planning and cutting; can be omitted)
- 2 pairs of scissors
- 2 sheets of graph paper
- 4 3-5 ounce paper cups
- 1 funnel
- 1 baking sheet or similar container to catch any leaks
- 1 set of student instructions

Miscellaneous:

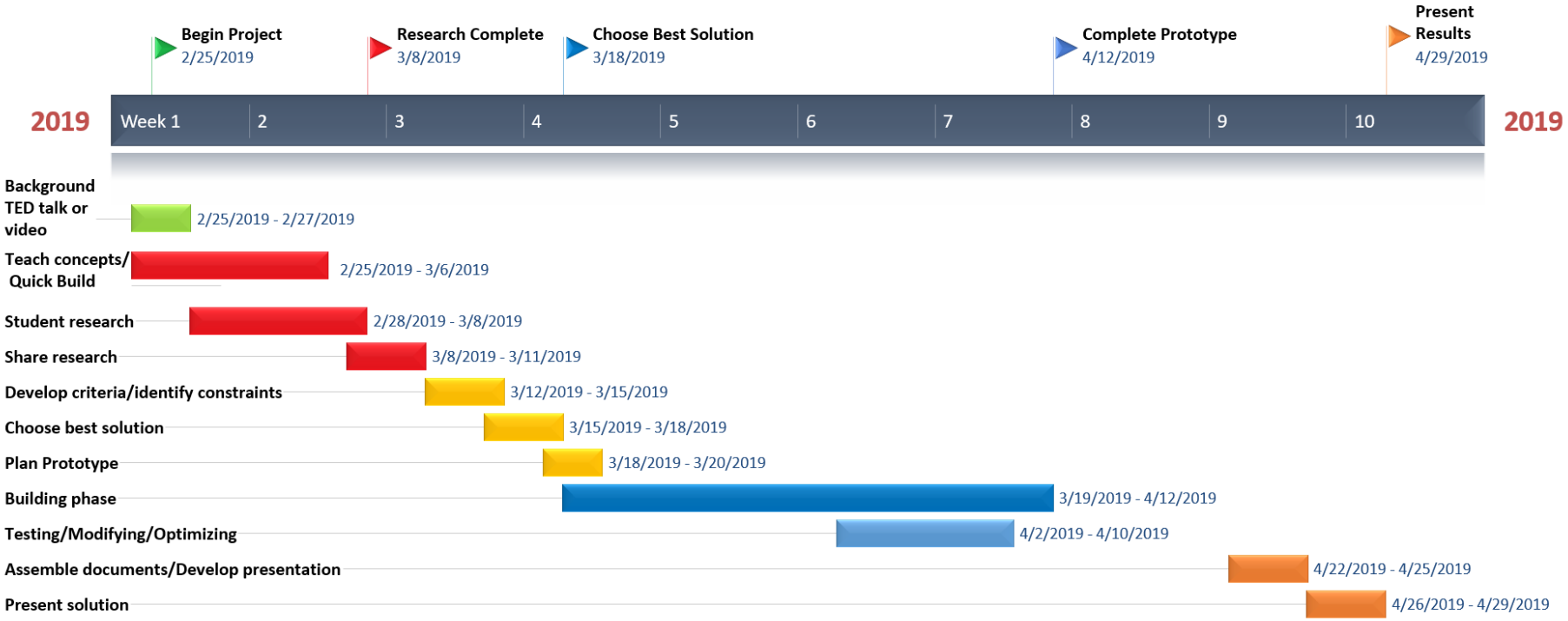
- One ½ inch binder per group
- Student forms – one set per group

ASSESSMENT*

INDIVIDUAL	GROUP
Skills *Assess for any of 21st Century Skills using Buck Institute Rubrics. Suggest Critical Thinking and Collaboration* *Peer and Self-Assessment*	**Skills** *Ongoing periodic self-assessment with the "How Are We Doing?" form*
Content *Instructor-developed; formative plus summative; generally most significant part of individual assessment in addition to "time on-task" classroom observations and peer assessment*	**Content** *Evidence of understanding and application of key curricular concepts in Engineering Notebook forms, specifically Initial and Final Design Plans and Modification Form.*
Process *Job-related evidence* *Classroom observations*	**Process** *Single-point rubric for Group Formative assessment* *Engineering Notebook for Group formative and summative assessment (primary evidence of both ongoing and completed process)*

Product *Typically group assessment component, unless issues with specific jobs/responsibilities*	**Product** *Identify key parameters for successful completion* *Meets criteria, constraints* *Modifications documented and explained*
Overall Assessment Components (approximate percentages**)** • *Group versus individual – 65/35* • *Process versus product – 70/30*	
NOTES: *Suggestions only; details to be determined in collaboration with classroom teachers **Estimated Timeline attached; based on non-consecutive classes	

Estimated Timeline
Getting Water Everywhere



Red – Research/Knowledge Acquisition
Yellow – Know your problem/ planning stage
Blue – Building
Orange – Final prep/presentation

In and Out Piping Plan

Teachers Instructions

Time: 40-60 minutes (explain, build, test, debrief)

Group Size: 3-4 students

Challenge: Students have 15 minutes to build a prototype piping system. They must meet the following criteria:

- ✓ All straws must be used. If they are cut – all pieces must be used.
- ✓ The piping system must have two points where pipes branch (branches can come back together or they can form two outlets).
- ✓ If you are using flexible straws there should be one bend in the system. If flexible straws are not available, a bend is not needed.

Learning Goals: Working with constraints; planning before building; prototyping; value of small-scale version before larger model; testing; learning from failure; principles of fluid flow in pipes; challenges of creating strong joints

Materials:

Each group will need the following:

- ✓ 10 plastic straws ("pipes"); straws with a flexible section if possible
- ✓ 15 inches of duct tape (for joining "pipes")
- ✓ 4 small/medium size binder clips ("valves")
- ✓ 1 ruler (to help with planning and cutting; can be omitted)
- ✓ 2 pairs of scissors
- ✓ 2 sheets of graph paper
- ✓ 4 3-5 ounce paper cups
- ✓ 1 funnel
- ✓ 1 baking sheet or similar container to catch any leaks
- ✓ 1 set of student instructions

1. **Planning:** Allow groups to have a few minutes to plan before they take their materials. Let them see what is available, but no taking anything yet. Stress the **need to plan** and require a preliminary sketch on a piece of graph paper. No one obtains their materials until planning time is done for the class.

2. **Obtaining Materials:** Every group should designate 1-2 "materials procurement" people. If you can, it helps to have scissors, rulers, and graph paper on their tables in

advance. If you are unable to do that, have those in a different area from the other materials to cut down on traffic. Make sure students take 15 inches of duct or supply a pre-cut piece at their table. DO NOT let them take the entire roll!

3. **Building:** Let the building begin! Put a timer up using one of these fun Classroom Timers or by Googling "online timer" and using the first result. Depending on the age of the students, 15-20 minutes will be needed. Once time is up – time is up! This reinforces the idea of a **constraint** and makes failure more likely.

4. **Testing:** Once building is complete, it is time to test. Allow one student from each group to fill one cup with water. Instruct groups to position their system above the baking sheets, with an empty cup on the baking sheet at every outlet. *You can used larger cups at the outlets if you have them available; sturdier, larger cups or beakers will minimize spillage or tipping.*

   Instruct one student to slowly add the water to the system using the funnel. They should add half of the water at first. Stop at the halfway point and allow students to block off any leaking sections using the clips as valves. This will only be helpful if they have a branch that the water can continue to flow through.

All About the Country, Region, or Village We have Chosen

Location Information	
Continent	
Country	
Neighbors	
Terrain (coastal, mountains, desert, etc.	
Climate	
Natural Resources	
Possible Water Source	

Any extra notes:

About the People	
Average Income	
Typical Jobs	
Education – what grade do most people complete?	
Life Expectancy	
Health Issues	
Family Life	
Type of Housing	
Current Access/Lack of Access to Water (who gets it, how often, where is it located, etc.)	

Solutions		
What has been tried?	**Success or Failure**	**Reasons**

What will your biggest challenge be?

Summary of Background Research

What is the problem that is being considered? (Answer in one sentence.)

Scientific Principles: (What is known about the scientific principles that are relevant to this problem?)

Primary Researcher _____

Existing Solutions: (What solutions have already been developed to address this problem?)

Primary Researcher _____

Human Factors: (Who will benefit from a solution to this problem? In what way will those people benefit?)

Primary Researcher _____

Freestyle: (Conduct a broad sweep of the internet and record any information that is relevant to this project.)

Primary Researcher _____

Criteria Ranking Form

Directions:

- **Each team member** should **get a slip of paper** that will be **used to rank the criteria**.
- Complete the ranking slip by **writing each criteria** into the position **in order of importance** (***1*** *is the most important* or highest ranked! ***5*** *is the least important* or lowest ranked.)
- The **Project Manager** then collects each slip and **totals** them up *with help* from the team.
- **Fill in** both parts of **the chart below**. (The *most important criteria* will have the **lowest score** and should get *ranked #1*.)

Criteria: (In no particular order.)	**Total Points:**

Rank:	**Criteria:** (In the order voted upon based on total points.)
1	
2	
3	
4	
5	

Voting Slips:			
Use scissors to **cut out** the **six voting slips**. (There may be extra slips depending on team size.)			
Rank:	**Criteria:**	**Rank:**	**Criteria:**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	
Rank:	**Criteria:**	**Rank:**	**Criteria:**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	
Rank:	**Criteria:**	**Rank:**	**Criteria:**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	

BRAINSTORMING SUMMARY

Team Member Names	
What is the problem that is being considered in the brainstorm? (Answer in one sentence.)	
One member of the team should record notes from the Brainstorm in the space below.	

After finishing brainstorming, take a picture of the workspace or save your sticky notes, then answer the questions below.
What were 3 specific issues/aspects of the problem?
What were the 4-6 design ideas that appeared most often during your brainstorming session?
What are at least 4 key features of your design? (The may be described or sketched.)

Initial Design Summary

Team Members & Titles: (Who is on the team? What is each team member's job title?)	
Criteria: List the *top 5 things* that your team must keep in mind to develop a good solution. List them in order from most important to least. Use the ***Criteria Ranking Form*** to complete this.	
Most Important Features of the Solution: 1.	
2.	
3.	
4.	
Least Important Feature of the Solution: 5.	
Constraints: What are the *limitations and requirements* that the *solution must meet?* No more than 6.) Use the ***Identifying Design Constraints*** form to complete this.	

Design Statement: *What* will your team do to *develop a solution* for the problem? You may use a sketch, bullet points, or paragraphs to create a clear picture of your plan.

Meeting Criteria: How will your proposed solution (above) meet the identified criteria? Name the criteria **specifically** and the ways that they are being addressed. Use the list from the first page of this form.

Anticipated Issues/Problems: What *issues or roadblocks* will your team have to overcome in order to succeed?

(Example: How/Where will the materials be obtained? How may a scaled model not accurately represent the actual "product/solution"? How do you plan on getting the information or product to the end users?)

Materials List

Material Needed for Model	Dimensions or Size	Quantity	Purpose of Material

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Project Task Planner

Project Title:	**Company Name:**			
Group Members:				
Task: What needs to be done?	**Due Date:**	**Assigned To:** (Initials)	**Date Done:**	**Completed By:** (Initials)

Daily Summary Form

This form should be completed DAILY or as requested by instructor. (1 - 2 sentences per question.)	**Company Name/Logo:**
Form Completed by:	Date:
What work was done today?	
How did that work help to push your project closer to completion?	
What work needs to be done tomorrow?	
Form Completed by:	Date:
What work was done today?	
How did that work help to push your project closer to completion?	
What work needs to be done tomorrow?	
Form Completed by:	Date:
What work was done today?	
How did that work help to push your project closer to completion?	
What work needs to be done tomorrow?	

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Form Completed by:	Date:
What work was done today?	
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What work needs to be done tomorrow?	
Form Completed by:	Date:
What work was done today?	
How did that work help to push your project closer to completion?	
What work needs to be done tomorrow?	
Form Completed by:	Date:
What work was done today?	
How did that work help to push your project closer to completion?	
What work needs to be done tomorrow?	

Modification Form

Company Name:	
Team Member Authorizing Change:	
Job Title:	

Rationale for Modification: (How is this modification supposed improve your team's product?)

Sketch or Photo of Modified Area: (Label the areas that are being modified.)

(Before Modification)	**(After Modification)**

Results of Modification: (How did the product perform differently as a result of the modification?)

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Final Design Summary

Company Name & Company Logo:	
Team Member	**Title/Responsibilities**
Problem Statement: What was your challenge?	

MEETING CRITERIA: List the 3 top criteria that your team developed and listed on the **Initial Design Form**. Fill in the spaces on the right to show how you met each criterion.

CRITERIA	HOW WE MET IT

CONSTRAINTS: List 3 constraints that were listed on the **Initial Design Form**. Fill in the spaces on the right to show how you met each constraint.

CONSTRAINT	HOW WE MET IT

Detailed Description or Labeled Drawing of Final Design Product/Solution:
Drawings should be *labeled* to *highlight* the important *details*.

CHANGES OR MODIFICATIONS: List any significant changes from your Intial Plan. *How/Why* is your final version better at meeting you design goals?

CHANGE	WHY or HOW it is better

Most Significant Science Concepts: List the 2-3 science ideas that you used the most in designing your solution.

1.

2.

3.

Implementation Issues: Will there be any issues/problems to consider if you want to actually implement your solution? List any that you can think of.
Future improvements and additions to your solution: What would you do next to make your product better or to be able to help more people?