



Plant the Moon Plant Mars CHALLENGE

Fundamental Experiment



Fundamental Experiment

Embarking on the Plant the Moon & Plant Mars Experimental Design is the start to the adventure of your contributions in this global science experiment. The experimental design is the choice of the team and some may choose to use this Fundamental Experiment as a launching point for making the choices that customize the experiment to their own unique research.

The basic question for every PTMC experiment is "How well is your plant growing?" – how can you do this fundamental part well and what else can you study beyond this? For some teams, this can be daunting without some ideas for a starting point.

TABLE OF CONTENTS

Experiment Components.....	pg 3
Sample Fundamental Experiment	pg 4
Choose Your Own Experiment.....	pg 6
Experiment Design Checklist.....	pg 7

Every experiment is defined by the independent variables, dependent variables, controls, and experimental protocols. In this Fundamental Experiment walk-through we will help you make the decisions needed to design your own experiment.



DESIGNING WITH BEST IN SHOW IN MIND

Many teams will set out with a goal in mind: to be recognized with a PTMC Best in Show Award. The overarching goal of the PTMC is to ultimately learn what the best conditions are for growing crops in Lunar or Martian simulant while minimizing what amendments we need from earth. Teams with Best in Show in mind should consider some of the following questions when designing their experiment on what will differentiate their experiment from others in their division (Elementary, Middle School, High School, or Undergraduate/Professional).

- **Best Experimental Design**
 - What can be done to isolate the variables and best test the hypothesis? Is this design replicable, clearly communicated, and valid?
- **Best Crop Growth**
 - What can be done with experimental design, amendments, or care to focus on crop growth?
- **Best Evaluation of Results**
 - What can be done with data collection and analysis that will lead to a robust evaluation of experiment results that draws valid conclusions from the research?
- **Most Innovative Experiment**
 - What is a unique approach in materials, equipment, design, or protocols that increases the effectiveness of growth in an innovative way?



Experiment Components

No two PTMC experiments will be the same—every team customizes the experimental design through four components: the independent variables, the dependent variables, the constants, and the protocols of the experiment. Even if a team studies and manipulates strikingly similar variables, the protocols (procedures) with which they handle them tailors the design.

Deciding on these four components are essential for every PTMC Experiment.

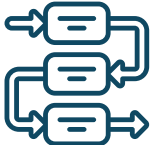
Independent Variable



Also known as predictor variable(s), this is the variable that the team deliberately manipulates or controls.

- It is the variable believed to have an effect on the outcome variable. The independent variable is often denoted as "X" and is chosen by the team to determine its impact on the dependent variable.
- In some cases, there can be multiple independent variables.

Dependent Variable



Also known as outcome variable(s), this is the variable that is observed, measured, or recorded by the researcher.

- It is the variable that researchers believe may be influenced by changes in the independent variable(s). The dependent variable is often denoted as "Y" and represents the outcome or response that is being studied or predicted.
- There can be multiple dependent variables that are measured.

Controls / Constants



The controls (or constants) are factors that are intentionally kept constant or unchanged throughout the experiment.

- Controls are not the main focus of study, but rather, they are used to provide a baseline for comparison and to isolate the effects of the independent variable(s) on the dependent variable.
- By controlling variables, teams can establish a cause-and-effect relationship between the independent and dependent variables, as they minimize the potential influence of confounding factors.

Protocols



Protocols refer to a set of predefined procedures and guidelines that outline the steps and methods to be followed during the experiment.

- The protocols are unique to each team's experimental design and can be an innovative factor in the design.
- These protocols ensure consistency, accuracy, and reproducibility of the experimental process.
- The decision of each independent variable, dependent variable, and control also includes developing and deciding on a specific protocol determining how that factor will be handled and implemented within the entire experiment.

The following outlines a sample "Fundamental Experiment" testing the effectiveness of soil mixtures on crop growth that teams could use as a starting point for their experimental design & customize if they choose.

Independent Variable



The soil composition of the pots will be deliberately varied to evaluate the optimal composition that minimizes the limited access to earth soil and maximizes the use of readily available regolith (the simulant).

With composition measured by volume and replicate pots set up in each iteration:

- 2 pots: 50% simulant + 50% earth soil
- 2 pots: 75% simulant + 25% earth soil
- 2 pots: 90% simulant + 10% earth soil
- 2 pots: 100% simulant
- 2 pots: 100% earth soil (for control comparison)

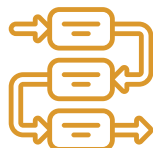


Sample Independent Variable Protocols

- To ensure consistency when measuring by volume, metric measurements of milliliters will be used on the household measuring cups used in the experiment.
- Prior to planting, the team will test the volume of the pots provided in the kit to establish how many milliliters (ie, cubic centimeters) of soil will be the total from which the percentages of soil composition will be established.
 - For example, if it is determined that the pot will hold 40 mL of soil:
 - 50%/50%: 20 mL of simulant + 20 mL of potting soil
 - 75%/25%: 30 mL of simulant + 10 mL of potting soil
 - 90%/10%: 36 mL of simulant + 4 mL of potting soil
- The mixtures will be made in a larger container before transferring to the grow pots to ensure that no volume is lost when mixing in too small of a container.

These protocols are listed as examples and are not exhaustive to the protocols that a team will need to establish.

Dependent Variable



The outcomes will be a mixture "Tier 1" and "Tier 2" outcomes as defined in PTMC Project Guide. These will serve as a metric by which we will assess how well our plants are growing.

A standardized procedure for the timing, method, and materials used for measuring each of these outcome variables needs to be established

The team will measure the following weekly:

- Plant height
- Stem diameter
- # of leaves and/or fruit

Sample Dependent Variable Protocols

- Measurements will be taken every Tuesday at the beginning of 3rd Period to ensure consistency in weekly readings.
- Sample plant height measurement protocol:
 - On a level surface, hold the ruler vertically alongside the plant, starting from the base or soil level and align straight until you reach the topmost point of the plant, which could be the terminal bud or the highest point of growth.
 - Note the height in centimeters and record in the weekly log for each pot (repeat the measurement process for each plant, ensuring consistency in the method and technique used). Include the time and date on the data log. .
 - If the plant has irregular growth patterns, such as sprawling branches or multiple stems, measure the height of the main central axis or the tallest stem.

These protocols are listed as examples and are not exhaustive to the protocols that a team will need to establish. Similar measurement protocols must be established for every outcome variable under study.

Controls / Constants



Since the fundamental experiment is testing the effect that soil composition has on the growth of the plants, all other factors needs to be kept the same (constant).

The following will be kept constant for this experiment:

- **Crop** - the same seed type, number of seeds, and starting point of germination in each pot for every pot.
- **Water** - the same amount and method to each pot in each watering
- **Lighting** - all pots will be kept under the same lighting conditions
- **Fertilizer/Amendment** - every pot will be given the same amount of the fertilizer/amendment



Sample Control Protocols

- **Crop** - Every pot will be planted with the same number of seeds at the same stage of germination.
- **Water** - Every pot will be spritzed with the same amount of water at the start of the experiment and watered with equal amounts in weekly intervals. Every watering will be recorded.
- **Lighting & environment** - to avoid confounding with lighting, temperature, and space, all pots will be kept in the same lighting conditions. Pots will be rotated each week to ensure that position in the grow space is not a confounding variable.
- **Fertilizer/Amendment** - Every pot will be administered the same fertilizer or amendment at the same interval.

Additional Protocols



As the experiment progresses, your team may note that changes in protocols or even design may be necessary due to the way that the plants are actually growing and responding to the experiment treatments. This is a normal part of science, however, teams should be careful to not disturb the experiment too soon (eg, replant as soon as it seems that plants are dying) and should always document any modifications made.

Some protocols will be used just for the initial planting or final harvest while other protocols will be ongoing. Any adjustments needed should be documented.



MAKE IT YOUR OWN

If your team chooses to use this soil composition experiment as your fundamental starting point for your experiment, what would you need to do to actually implement it and customize to your team? See page 7 of this Fundamental Experiment for a full checklist, but to start:

- Identify the crop/seeds you'll use in your experiment
- Decide on a watering technique, lighting source, and grow space
- Identify any amendments to add to the simulant + earth soil mixtures (fertilizers, etc.)
- Create a hypothesis - what do you think the outcome will be?
- Identify the dependent variables you'll measure and establish protocols (recurring or otherwise).
- Begin writing up your Initial Experiment Design (Task #2) and planning for your planting day!



Questions? Teams are always welcome to reach out with questions about their experiment designs to ptmc@competitionsocieties.org.



Choose Your Own Adventure!

No two PTMC experiments will be the same—every team customizes the experimental design through four components: the independent variables, the dependent variables, the constants, and the protocols of the experiment. Even if a team studies and manipulates strikingly similar variables, the protocols (procedures) with which they handle them tailors the design. **Deciding on these four components are essential for every PTMC Experiment.**

Testing soil composition as outlined in the "Fundamental Experiment" is just one option out of many, many ways that you would design your experiment - many components to the experiment could be a predictor, outcome, or control, depending on the design. The following examples can provide inspiration for other experiments but are not meant to be prescriptive as teams are encouraged to consider in customizing their own experiment.



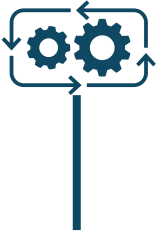
What are some other options for independent variables?

- **Water** - testing different watering techniques or water amounts
 - **Independent:** 2-3 different watering techniques assigned to 2-3 pots each, with control pots for comparison.
 - **Controls:** Soil composition, seeds, amendments, environment, lighting, etc. the same.
 - **Dependent** - at minimum, measure Tier 1 characteristics (page 43 of the PTMC Project Guide).
- **Crop type** - testing different crop types
 - **Independent:** 2-3 different crop types assigned to 2-3 pots each, with control pots for comparison
 - **Controls:** Watering method, amendments, environment, lighting, etc. the same.
 - **Dependent** - at minimum, measure Tier 1 characteristics (page 43 of the PTMC Project Guide).
- **Amendment** - testing the effect of a particular amendment or fertilizer
 - **Independent:** Testing 2-3 different amendments assigned to 2-3 pots each, with control pots for comparison
 - **Controls:** Watering method, crop, environment, lighting, etc. the same.
 - **Dependent** - at minimum, measure Tier 1 characteristics (page 43 of the PTMC Project Guide).



What are some other options for dependent variables?

- See the PTMC Project Guide (page 43) for ideas on other outcomes to measure.
- Many measurements of outcomes will depend on a team's grade or skill level, access to equipment and technical expertise, and time available.



What are some other options for controls?

- Controls will always depend on what is being studied as the independent variable.
- The ultimate goal is to be able to measure the effectiveness of your interventions and study in the independent variable to be able to test the hypothesis. Make sure that you do not have any confounding variables that could cast doubt on the effectiveness of the treatments you are testing.



Before You Plant Checklist: Decisions & Protocols

Note: These steps do not have to be decided in this order, but every experiment should at minimum consider each of these elements and account for them in Task #2: Initial Experiment Design.

-  • **Did you decide your team's team's experiment objective?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you decide what crop(s)/seed(s) you will plant?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you decide on the amendments, fertilizers, and soil that will be added to the pots alongside the simulant regolith?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you decide on the watering method?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you decide on the light source that will be used?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you decide on a location/dedicated grow space and adequate signage to indicate to the casual observer that an experiment is being conducted in that space?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?
-  • **Did you establish the method, timing, and manner in which experiment records are tracked and pictures or videos are taken and managed?**
 - Is this: an independent variable, dependent variable, or control?
 - What is your team's protocol for handling/incorporating this?



Note: Some protocols for the experiment will be just for the preparation, planting, and final harvest while others will be a recurring protocol for measurement, monitoring, and maintenance. It is normal for protocols to be tweaked as the experiment progresses to troubleshoot—just always record any changes made to increase the credibility and replicability of your experiment.