Section I. Proposal Cover Page

Proposal Title: Mealworm Development in Microgravity

Grade Level(s) of Submitting Student Team: 8

Submitting School: Citadel Middle School

Submitting School District: School District 43

Submitting Teacher Facilitator: Pam Hughes.

Name: Pam Hughes
Position: Teacher / Facilitator
Address: Citadel Middle School 1265 Citadel Drive, Port Coquitlam, BC
Daytime phone: 604-945-6187
Cell phone:
Email: pamhughes@sd43.bc.ca

Proposal Summary:

The purpose of this proposal is to send mealworms into space. If mealworms can develop into the next stage in their life cycle, they will be able to lay eggs and reproduce. The mealworms will be sent onto the ISS. Then the mealworms return, the mealworms can measure their dry weight to see if mealworms can grow and if their growth is hindered, enhanced, or will not be changed by microgravity. Astronauts are constantly losing muscle mass and bone density; insects are a reliable source of protein and vitamins. By measuring the growth of the mealworms, insect farming in microgravity can be optimized which will help astronauts stay in space for longer periods of time. If mealworms can grow in microgravity, less food and resources will be required to be sent onto the ISS.

Section II. Student Team Members and Professional Advisors

Co-Principal Investigators) (Not required\)

Name: Denzel Li
Grade Level: 8

Name: Jack Zhao
Grade Level: 8

Name: Kevin Mou
Grade Level: 8

Name: Rayyan Ali
Grade Level: 8

Name: Sam Brownsey
Grade Level: 8

Professional Advisors

Emmanuel Hung
Organization: Simon Fraser University
Contribution to Team: Professional Advisor.

Emma Kovacs
Organization: Simon Fraser University
Contribution to Team: Professional Advisor.

Section III. Experiment Materials and Handling Requirements

1. Fluids Mixing Enclosure (FME) Mini laboratory Proposed to be Used:

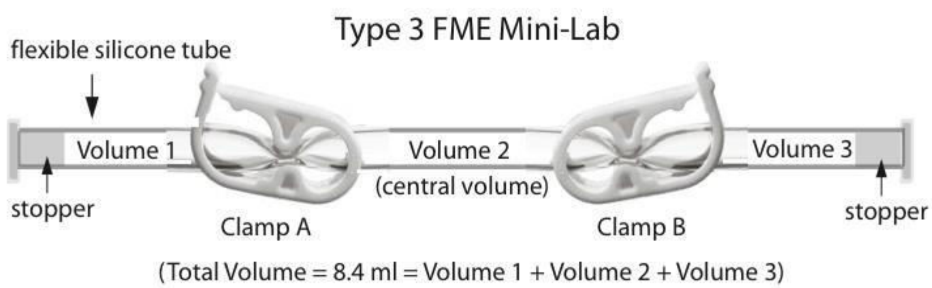
☐ Type 3 FME Mini lab (3 experiment volumes: two clamps used)

2. List of Proposed Experiment Samples (Fluids and Solids to be Used)

- Our experiment has no prohibited samples included in the Flight Experiment Proposal Guide.
- We also have no technology in our experiment.
- We are not proposing to use any of the Hazardous or Problematic Samples from the list on the SSEP website.

a) We have no fluids or solids that are hazardous.
b) None of these fluids or solids are mixing on the ISS and cannot result in excess heat, light, or pressure and will not impact other FME mini labs on the shuttle or ISS.
c) Nothing is a BioSafety level 2 in our experiment.
d) There are no problematic samples in our experiment from the list NanoRacks List of Problematic Samples.
e) Our experiment needs to be handled gently because there are lifeforms in the mini lab that could be crushed by shaking too hard.

Type 3 Mini Lab



Volume 1: 2 mealworms.
Volume 2: 1/8 crushed potato mixed in 5mL of water.
Volume 3: Ethanol.
None of the proposed samples are of human origin.

IMPORTANT: Are any of the proposed samples human in origin? (Check one):

☐ No

3. Special Handling Requirements During Transportation

Table 1: Requesting Thermal Control for Your Experiment

		Refrigeration	**Ambient Conditions**
PRE-FLIGHT	Shipping from your Community to NanoRacks in Houston	x	
	At NanoRacks until Handover to NASA	x	
FLIGHT	Handover to NASA Until Arrival at ISS	**x**	
	Onboard ISS		**X (required)**
POST-FLIGHT	From ISS until Arrival at NanoRacks		**X (required)**
	At NanoRacks through Return Shipping to Community		

4. Proposed Timeline of Crew Interactions

Table 2: Allowed Crew Interaction Days

1	on arrival at ISS (day payload is transferred from ferry vehicle to ISS)	A=0
2	during first week (2 days after transfer from ferry vehicle to ISS)	A+2
3	2 weeks prior to undock (14 days before undocking)	U-14
4	in week prior to undock (5 days before undocking)	U-5
5	in week prior to undock (2 days before undocking)	U-2

Table 3: Allowed Crew Interactions

Allowed Crew Interactions	**Allowed Modifiers**
"Unclamp" (Open Clamp)	none
"Clamp" (means Re-clamp or Close Clamp)	none
"Shake"	type of shaking: "gently", "vigorously" duration required in units of 5 seconds*: e.g.*, "5 sec", "15 sec", "20 sec", "35 sec", "60 sec", "95 sec"
"Wait"	a team can request that the astronaut wait a specified number of seconds between two other requested interactions; wait duration (required to be in units of 5 seconds): "xx sec"

Table 5: Your Proposed Timeline of Crew Interactions

Allowed Crew Interaction Day	**Requested Interaction**

A=0	Unclamp Clamp A
A+2	
U-14	
U-5	
U-2	Unclamp Clamp B

Section IV. The Question to be Addressed by the Experiment

Our experiment is to send mealworms, or Tenebrio Molitor, into microgravity to see if they can develop into later stages of life. This experiment will add to scientific understanding since it will show us that they can survive without gravity and opens the possibility of creating a colony in the future. This colony will become a renewable source of food; therefore, we would not need to send up food as regularly for the astronauts. This experiment will pave the way for NASA to create colonies of mealworms in space, as well as prove life can adapt and change to their surroundings even with something key like gravity removed. If this experiment is a success, we would remove the need to have waste expulsion systems on the ISS because mealworms can eat all organic matter. mealworms would take up a small amount of space on the space station for a lot more gain.

We want to find out if mealworms will be able to grow in microgravity. There has been experiments like this one with fruit flies done by NASA in 2006, where they sent 15 fruit flies into orbit, and they were able to reproduce and grow. We want to test our hypothesis by comparing the mealworms that were on the ISS and the ones on Earth.

We can use our results to pioneer insect farming in space, and provide astronauts a more consistent supply of protein, which is harder to find in space than, for example carbohydrates. mealworms have higher ash content (1) than even beef and pork meat (2). Ash is a measurement of minerals in a food, the higher the ash content the more minerals that are valuable to human health and well-being, which would prove very beneficial to astronauts in space.

Insects are also very space efficient when it comes to farming, as they are small, don't need land to graze on, and the pens required to hold them could be built in a cube, which is a very space efficient shape.

Darkling beetles, which are the adult form of mealworms, are known to eat feces (3) of various animals. In future colonies, we could have separate sections for larvae mealworms and adult beetles. The adult Darkling beetles will eat human feces for sustenance and give birth to future generations. The mealworms that are going to be consumed will be cooked thoroughly to kill off all the bacteria.

Astronauts would be able to stay in space for extended periods of time in the future if insects are added to their diet.

It will be beneficial to do this experiment because we could apply the data, we collect to future mealworm colonies in space. This experiment will provide the answer to whether insects will be able to survive the increased exposure to radiation, lack of gravity, and being confined in a small space for extended periods of time. These findings may make insects farmable in space and reduce the effects of microgravity on the muscles of astronauts, which allows them to stay in space for longer periods of time in the future.

This experiment will add to the scientific understanding of how mealworms and insects develop in microgravity. It will help cultivate renewable food sources in space, and it will prove to be very beneficial for us as we do not have information about the growth of insects in microgravity. If mealworms can successfully develop and grow into the next stage of their lifecycle, then they can sustain a permanent colony in space. mealworms are a species that are very suitable to be launched to space since they feed on organic matter such as human waste. This adds to the understanding of mealworms, how they are affected by microgravity, and if they can also be used as a renewable food source for astronauts in space.

**In cases of more than 100g, round to nearest whole number.

Product	Water	Protein	Fat	Ash	Carbohydrate
Beef (Lean)	75	22.3	1.8	1.2	X
Pork (Lean)	75.1	22.8	1.2	1.0	X
Mealworm	64.1	17.6	13.8	1.5	3.1

Mealworm Ash Content:

https://www.mdpi.com/2304-8158/9/2/151/pdf

Information can be found on page 6.

Author contributions: Conceptualization, C.L. and J.Z.; methodology, C.L. and J.Z.; validation, J.M., V.P. and J.Z.; formal analysis, C.L.; investigation, J.M., V.P. and C.M.; resources, J.Z. and C.L.; data curation, J.Z. and C.L.; writing—original draft preparation, C.L. and J.M.; writing—review and editing, J.Z., V.P. and C.M.; visualization, C.L.; supervision, J.Z.; project administration, J.Z.; funding acquisition, C.L. and J.Z.

Ash Content of Pork, Beef, And Other Meats:

https://www.fao.org/ag/againfo/themes/en/meat/backgr_composition.html

By Food And Agriculture Organization of The United Nations

Darkling Beetle Consumption of Feces:

http://www.pestproducts.com/darkling-beetle.htm

By Lani Powell

Section V. Experiment Design

Experiment Rationale:

We will be measuring and comparing the dry weight between the mealworms that went to the ISS and the ones that stayed on earth. This will answer the question of whether mealworms will be able to grow and move on to further stages of their larval phase in microgravity. This will also provide insight to our other reason for performing this experiment being the possibility of creating large mealworm colonies in space for the purpose of a renewable source of protein. We reason that if mealworm larvae can grow and to move on to later stages of their larval phase, they should also be able to move on to their adult phase, given enough time. These adult beetles will then give birth to the next generation of mealworms.

Experiment Materials:

2 very early-stage mealworm larvae will be used for our experiment. We chose mealworm larvae due to their small sizes which can get down to 1/8th of an inch. Small sizes are required to be able to fit into the mini lab. mealworms are easily obtainable in pet shops all over the world, as they are often used feed other animals. If this experiment succeeds, the option of installing mealworm farms to future space missions opens and will provide astronauts with a renewable food source. It is important to have a renewable food source on future deep space missions as they will not need to carry as much food with them and will allow more space for scientific instruments. To keep the mealworms alive during the approximate 1-month time it takes to transport experiments to the ISS, we will make them go into a dormant state by restricting their access to food. While on the ISS, we will have a chamber dedicated to a mixture of crushed potatoes and water, which will be used as their food source for the rest of the mission. The potatoes will be supplied from a local grocer, and the water will be acquired through the tap. We'll be using 1/8th of an Ethanol will be used to end the experiment before it comes back to earth and to preserve the bodies. The Ethanol will be obtained from an online vendor. None of the materials originate from humans and will not be dangerous to the astronauts if they are contained inside of the FME mini lab.

Experimental Procedure:

Once on the space station, an astronaut will unclip one of the clips allowing the dormant, early-stage larvae to access the potato mixture and to become active. There will be no further contact with the experiment and the larvae will be allowed to access the food mixture. On the day the experiments are going to be sent back, the clip which holds back the Ethanol will be released. The Ethanol will kill the mealworms and prevent the bodies from decomposing on their way back.

Ground Elements:

The analysis will be carried out comparing the dry weight of mealworm larvae that went to the ISS and the ones that stayed at Earth. We will unclip the clips on earth at the same time as the ones on the ISS. We will make sure that the room temperature of both the mealworms on the

Earth and the mealworm on the ISS is the same to ensure that temperature is not a factor in their growth. This can be done by drying out the larvae and measuring it on a scale.

Experimental analysis:

We will wait for the Ethanol to evaporate into the air and measure the dry weight of the mealworms that went to the ISS and the ones that stayed on earth. We will then compare our results to determine whether being in microgravity hindered or enhanced their ability to grow. This will also determine whether the mealworms were able to move on to later stages of the larval phase in microgravity.

Section VI. List of Reference Publications

Nutritional composition:
https://link.springer.com/chapter/10.1007/978-3-030-32952-5_20
By Aguilar-Miranda ED, Lopez MG, Escamilla-Santana C, De La Rosa BAP, people mentioned at the bottom of the article.

Mealworm Care:
https://flukerfarms.com/reptile-u/care-sheets/mealworm-care-sheet#:~:text=Mealworms%20can%20be%20found%20almost,huge%20role%20in%20the%20ecosystem

Scientific Name:
https://en.wikipedia.org/wiki/Mealworm

Mealworm Survival:
http://www.geckosunlimited.com/community/leopard-geckos-food-and-feeding-issues-/73925-mealworms-survive-food-water.html

Section VII. REQUIRED Letter of Certification by the Teacher Facilitator

November 3, 2021

I certify that the student team designed the experiment described herein and authored this proposal, and not a teacher, parent, or other adult. I recognize that the purpose of this letter is to ensure that there was no adult serving to lead experiment definition and design, or write the proposal, and thereby provide content and/or professional expertise beyond that expected of a student-designed and student-proposed experiment.

I also understand that NCESSE recognizes that facilitation of thinking across the student team through advice and counsel by the team's Teacher Facilitator, other teachers, and local area and national researchers, is not only to be encouraged but is absolutely vital if students are to receive the necessary guidance on the process of scientific inquiry, experimental design, how to do background research in relevant science disciplines, and on writing the proposal. I also understand that it is appropriate for the Teacher Facilitator and other teachers to provide editorial comment to the student team on their proposal drafts before proposal submission.

I also certify that the samples list and the special handling requests listed in this proposal are accurate and conform to the requirements for SSEP Mission 16 to ISS. I confirm that the team, after reviewing their procedure and budget for obtaining the samples for the experiment, is certain that they will be able to obtain the necessary samples for their experiment in time to meet the deadline for shipping the flight-ready FME to NanoRacks. If using human samples, the team is aware that these samples must be tested for prohibited viruses before the experiment can be selected for flight.

Finally, I certify that the student team will have access to the proper facilities and equipment to prepare the FME mini-laboratory for flight and to analyze the samples after the flight.

Mrs. Pam Hughes
Teacher Facilitator