



Edible Astronaut Utensils (EAU): A Replacement for Astronaut Vitamins

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Abstract

Historically, astronauts have suffered from vitamin deficiencies as a result of prolonged space travel [1]; previous research proves that these deficiencies contribute to bone deterioration, vision loss, and other long-term health issues [2]. Aligning a solution to this problem with ongoing efforts to reduce waste and water consumption, this paper proposes a novel method of combining edible utensils with essential vitamins. A unique formula has been developed to maximize durability and strength of the utensil while also providing an infusion of vitamins that astronauts have trouble incorporating into their daily diet or producing naturally. Manufacturing of these utensils has been streamlined into a simple process that involves injection molding and high-temperature baking, all of which is highly repeatable and relatively inexpensive. The implementation of these edible utensils will be an improvement over current practices, as it will reduce plastic waste used in packaging of conventional vitamin pills and eliminate the need to clean reusable utensils, all while having a per-unit weight that is 0.2% of a standard metal utensil's weight. Data collected through research provides evidence that supplementing astronauts with a few key vitamins and minerals can lead to better overall health and mental wellbeing.

Introduction

The Edible Astronaut Utensil (EAU) is a strong competitor to current space sustainability practices. It addresses two important aspects of astronaut and environmental health: nutrition and sustainability. This product is suitable for both short term and long term manned missions and will provide a long lasting, environmentally-friendly solution to current astronaut nutritional deficiencies. The edible utensils can be used during meals to reduce waste from the current metal silverware used and improve overall nutritional content of the daily astronaut diet. The utensils are durable and extremely lightweight, as they will be made of flour and oat base tightly packed with Vitamin D3 powder. Edible utensils are a pre-existing technology, however the novelty of our technology is in the integration of Vitamin D3 into the utensils' grain base, as well as manipulating that base recipe to maximize the viability of the utensils in a spacecraft environment. EAUs will ensure better sustainability practices and increase performance and durability in space conditions.

The safety and success of space missions are dependent on the mental and physical health of the astronauts leading them. Therefore the caloric and nutritional profile of astronaut diets is a vital aspect of every manned mission. This technology will provide astronauts with a pleasant eating experience while also combatting the major threat that vitamin deficiencies pose to their overall well being.

The end goal for this new technology would be waste-free, edible utensils with a calculated mix of vitamins and minerals to target the deficiencies that astronauts usually experience in space, as well as a low-cost manufacturing plan for efficient production. In the future of long-duration missions and space colonization, the EAU will be a sustainable and health conscious alternative to current nutritional deficiencies and food consumption practices.

Methods

One major goal of this technology is to address the current shortage in innovative and sustainable solutions to the common nutritional deficiencies that astronauts experience while living in space. Research shows that Vitamin D is the nutrient that astronauts are most susceptible to deficiencies in [3]. Deficiencies in this essential nutrient are directly linked to loss of bone density, muscular weakness, and excessive bruising in astronauts [4]. Vitamin D deficiency is also widely understood to result in decreased mood and energy levels as well as impair cognitive function [5]. The overall quality of mental health and tactical performance of astronauts in space is therefore directly dependent on the intake of sufficient levels of Vitamin D.

As manned space missions continue to increase in duration and human energy exertion, solutions to the current nutritional deficits will be all the more vital. Difficulties in incorporating these nutrients into daily astronaut health are the result of lack of exposure to UV light and inability to sustainably package foods for spaceflight that naturally contain these nutrients [6]. Astronaut Utensil decreases the material waste associated with the current vitamin supplements that accompany astronauts on missions.

Enriched, all-purpose flour serves as the structure of the utensil while also being low-cost. Oat flour provides much needed fiber to support a healthy gut microbiome; it also provides protein, magnesium, and iron, all of which are lacking in an astronaut's diet due to their highly-processed menu items. Soy flour provides these same benefits as well as calcium to counteract an astronaut's degrading bone structure, and all essential amino acids needed to maintain muscle mass. Soy also contains fat which helps digest vitamin D, since it is a fat-soluble vitamin. Both oat and soy contain other beneficial vitamins and minerals as well, such as vitamin B6 and thiamine (B1) [7]. Salt preserves the edible utensil for a longer shelf life, as well as enhancing the flavor of the three flours. Vitamin D3 was chosen because it is more potent and absorbs in the body better than D2. 200 IU of Vitamin D3 per utensil matches the recommended daily amount of 600 IU per day, assuming an astronaut eats three meals a day [8]. The dosage is far below the risk of overdosing, so it will not be a problem unless an astronaut decides to eat the entire supply. The edible utensils will be made with a proportion of 37.6% enriched, all-purpose flour; 22% water; 20% oat flour; 20% soy flour; 0.4% salt; and 200 IU of vitamin D3. The ingredients will be mixed, poured into a mold, and baked at a temperature of 375°F for 30 minutes. These ingredients are mild in flavour and will therefore not interfere with the flavour or consistency of the food they are used to consume. Modifications such as flavoring can be incorporated into the mixture to accommodate the flavor preferences of each astronaut.

The second major goal of this technology is to address the environmental sustainability of the utensils currently used by astronauts. Traditional utensils are problematic as they need to be wiped down or be washed, either creating unnecessary waste or squandering valuable resources such as running water. This technology, on the other hand, is a zero-waste solution. As the utensils are eaten after use, there is no need to clean the utensils nor dispose of them, making them both more hygienic and sustainable than their traditional counterparts. Additionally, the packaging for the vitamin pills currently being sent to astronauts consists of a large amount of plastic. Since the utensils provide sufficient replacement for these vitamin pills, their implementation will cut down on plastic wastage. The edible utensils double as a vitamin supplement and a tool, meaning there is less to send to astronauts, in terms of mass and space.

This will also cut down on the need for packaging, further reducing the amount of waste produced.

The prospective design for the utensils is a thin, spoon shaped body with fork-like prongs at the end and angled knife edge. This will eliminate the need to bring spoons, forks, and knives for astronauts meal time therefore reducing the weight allocated to food consumption. The 3D CAD model of the utensil design is demonstrated in Fig. A2 of the Appendix. Our carefully formulated ingredient mixture will ensure that the product is durable, lightweight, and safe to use for both hot and cold foods. Astronauts are advised to consume up to three utensils per day to ensure they intake an adequate dosage of Vitamin D in accordance with the recommended daily dose of 400-800 IU. Vitamin D has an extremely high upper consumption threshold limit of about 4,000 IU per day, therefore the product is also viable in an emergency setting as a source of caloric and nutritional intake. Our standardized design and ingredient formula will allow the technology to be easily mass produced at a low cost.

Our comprehensive product manufacturing plan entails an outsourcing of the majority of the manufacturing process to a well established edible cutlery manufacturing company called Mede Cutlery Manufacturer [9]. Outsourcing the manufacturing process will result in reduced cost per unit and eliminate the time, money, and resources required to research and develop an individualized manufacturing process. Subsequently, the EAU's can move more efficiently through the testing and prototyping phases of development and can reach astronaut hands within months rather than years. We plan to work closely with the manufacturer to make slight adjustments to the general manufacturing process to best suit the needs of our novel edible utensil recipe. The leading edible utensil manufacturing layout utilizes a 3 step process to create the utensils. First the ingredients are mixed and extruded into a die mold, then the material is pressed to conform to the mold shape, and lastly the utensil is baked in an industrial oven at 375 degrees for 30 minutes. The high-temperature high-pressure baking process produces a compact, lightweight, and durable final product while also retaining the nutritional integrity of the ingredients. This process is extremely efficient and cost effective, allowing Mede Cutlery to produce about 800,000 individual utensils daily at a cost of about \$0.13 per unit. This inexpensive and efficient process is highly conducive to the needs of long duration manned space exploration missions where a relatively large supply of EAU's will be required. Furthermore, the estimated shelf life of the EAU's is approximately 2-3 years. The estimated weight per unit is 0.05 grams; through continued innovation and testing, however, this weight can be decreased. The high pressure and temperature manufacturing process will also ensure that the consumption of the product results in minimal crumbs and debris. Our team has

developed a 3D model of a mold that will be machined from aluminum and given to the manufacturer so that the unique design of this utensil is perfected and manufactured correctly.

Post manufacturing, the utensils will be bundled into stacks which can then be packaged and vacuum sealed using NASA's prior radiation proof packaging technology [10]. This process will ensure the longevity of the product and allow for the most compact packing method.

Discussion

Providing astronauts with the vitamins they need at every meal will pay dividends for any space mission, as it will improve the physical and mental health of those aboard the spacecraft. Implementing these edible utensils into an astronaut's daily life will reduce bone deterioration, help preserve muscle mass, and increase energy levels. In addition, it will save astronauts from having to clean their reusable utensils, which consumes water and other resources. This innovation will also eliminate the need to send vitamin packages to astronauts, which will cut down on packaging waste and shipping costs.

The implementation of this innovation is not excessively costly and will be completed comfortably within the allotted budget of \$10,000. All ingredients in the batter for the utensil are inexpensive and easy to acquire. Manufacturing the mold for the utensil will be done quickly and easily at a machine shop. Outsourcing the rest of the manufacturing process to an experienced, well-established company will minimize error and produce inexpensive prototypes. These utensils can be immediately adopted by NASA for testing and eventual full-time use with minimal effort.

This design has immense potential to expand beyond a single utensil and revolutionize astronaut nutrition and sustainability. With further research, our ingredient formula and manufacturing plan can be expanded to produce a more diverse selection of sustainable designs such as edible food containers and plates designed for astronauts. One future goal we have for this product is to develop the concept further to address the major packaging waste issues that are currently hindering the sustainability of both manned and unmanned space missions. Our novel edible formula could be tweaked and molded into the shape of packing material to address current non-edible packing needs such as resealable bags, void fillers, and corner protectors. Furthermore, a revolutionary edible utensil and packaging 3D printing process could be developed to ensure that an in situ supply of edible vitamin utensils could be produced.

Technology Merit and Work Plan

The EAU is a utensil that is made out of edible ingredients and is also fortified with vitamins to ensure that astronauts are getting the vitamins that they need to survive and to be healthy. The utensil is made up of ingredients that will allow for a long shelf life and can be used like a regular, metal utensil in order to eat certain foods with but then can be eaten itself. This method eliminates waste that is produced from cleaning the regular utensil. Not only that but since the edible utensils are lighter than metal utensils, more can be transported on a spaceship and thus becoming cost efficient. Therefore, this technology promotes good health in astronauts while also being sustainable and cost efficient.

This technology is different from current developmental efforts in NASA in that astronauts use metal knives, spoons, and forks that still need to be cleaned. Another option that astronauts utilize in order to eat is by not using utensils at all and instead sucking the food right out of the package which does not require any cleaning. However, this method doesn't allow normalcy for these astronauts and is not suitable for all food types. There are no efforts that are known of NASA developing edible utensils that are also sustainable and nutritious. The EAU is similar to other developmental efforts that are occurring on Earth. For example, edible utensils have already been developed by other companies. However, these utensils are not fortified with vitamins and minerals since it is not that much of a concern for the average citizen living on Earth while it is for an astronaut in space. This technology is also unique in the sense that the utensil can be used as an emergency nutritional and caloric ration in the case of emergency, whereas current astronaut utensils and vitamin supplements cannot provide this security.

Since astronauts still use metal utensils that need to be cleaned by a wet rag or wipes, these methods are very wasteful and lead to large amounts of trash stored in areas where astronauts eat, sleep, and work. Thus, our technology addresses these limitations. With this utensil, it can be eaten instead of cleaned, thus limiting trash and the need to find ways to eliminate this trash. Furthermore, this utensil guarantees that astronauts are getting the vitamins they need for proper health and body growth while they are completing rigorous activities in space. Additionally, individual metal utensils have a significant weight, averaging about 25 grams. In contrast, the EAUs weigh about 0.05 grams per unit, allowing about 500 edible utensils to replace a single metal utensil.

The two current technologies that the product aims to combine and replace are Vitamin D supplements and non-edible utensils (metal or plastic). nutritional benefits to the user. The utensils need to have certain characteristics (which will be referred to as "key performance

parameters”) for them to be a viable option to replace both Vitamin D supplements and traditional utensils. As they are meant to replace traditional utensils, they need to be usable as standalone utensils. They must have structural integrity so they do not break down when being used and should not dissolve when they come into contact with food, nor should they break if a reasonable force is applied. This utensil’s cost of manufacturing and packaging should not exceed that of a traditional utensil. Convenience is a factor; utensils should be ready to eat right out of the packaging or should require minimum packaging. Flavor is a minor factor to make eating the utensils more enjoyable.

The traditional utensils currently being used work well as utensils as they are stable. However, they need to be washed and do not provide a secondary benefit such as supplementing vitamin intake. They either need to be washed or wiped down, creating unnecessary waste. Vitamin pills need a large amount of packaging to be transported to astronauts. Like the traditional utensils, they do not serve a secondary purpose.

To fulfill the key performance parameters that were set, some challenges must be overcome. The predominant issue is determining the appropriate composition for the edible utensil since the ingredients’ combined nutritional value should be high enough to be considered a viable option. Several of the key performance parameters depend on the composition of the utensil. Additionally, the structural integrity of the utensil will depend on the ingredients it is composed of and the binding material that keeps it intact. The manufacturing process of these utensils should be carefully designed to satisfy the key performance parameters. The process should not damage any of the ingredients such that their nutritional value is impacted. Additionally, the process, along with the composition and the binding material, should help create a structurally sound utensil that is able to withstand the tasks it will go through. The packaging of the utensils should protect them from physical impact or extreme temperatures while in transit, while keeping them uncontaminated. To tackle the challenge of having a nutritional utensil, the utensil will be a replacement to vitamin D supplements. The structural integrity of the utensil will be maintained by baking the utensil at a high enough temperature and testing appropriate ingredient compositions’ relative stabilities. Most of the risks listed above can be mitigated through repeated testing and changing the composition of the utensils appropriately according to the results. The manufacturing process will be outsourced for an economic and practical benefit. The utensils will use already existing NASA-issued packaging, which will ensure the utensils survive the extremities of space.

Project Management Approach

The project management approach chosen for this proposal will be conducted by task. Task 1 would be the inception of the concept and development of cost basis analysis for the product. Key deliverables for task 1 would consist of a trade study to determine the current state of the edible utensil market and applicability to space missions and a prototype of the product. In addition to the trade study a cost basis report will be produced to quantitatively determine the total potential cost savings and cost avoidances from implementation of edible utensils with nutritional supplements within human flight missions. Task 2 will consist of prototype development; fabrication of molding dies will be produced followed by establishing agreements with co-manufactures to use previously fabricated die molds for prototype fabrication. The following project schedule shown below in Table 1 consists of tasks to be performed, level of effort (or full time equivalent, FTE).

Table 1. Project schedule.

Task		Full time equivalent (FTE)*	Schedule				
1	Trade Study		1	2	3	4	5
	- Identify current best in class for the edible utensil market - Determine advantages and challenges for utensil compositions - Determine current cost of nutrition delivery and develop model for nutritional delivery supply chain	2.4					
	Milestone: Trade study report						
2	Prototyping - Fabricate press molding die for co-manufacture - Establish agreements with co-manufactures	2.6					
	Milestone: Create prototype						
3	Preparation of final report and deliver prototype	0.5					

*Fulltime equivalent (FTE); 1-FTE = 40 hours/week, 1200 hours/(30day month)

Teaming and Workforce Development

Ferdusy Akthar: Contributed to the research, completion, and organization of the “Technology Merit and Work Plan” portion of the proposal. Also contributed to online conversations on what specific topics would be discussed in the proposal. Experience includes knowledge in relevant courses and knowledge in operations run by NASA. Time Spent: 6 hours

Charles Thorpe Barbier: Conducted research on the astronauts nutrition and investigated vitamin deficiencies. Did a rough CAD drawing of one of the proposed utensils. Estimated work time: 4 hours

Trey Barnes: Served as Project Manager, scheduled meetings, and provided project schedule and project management approach. Applicable experience consists of professional certifications (certified Lean Six Sigma Green belt, and ASQ Certified Quality Engineer), and work experience leading and coordinating technical projects in high speed manufacturing facilities. Time spent: 8hrs.

Sohaib Bhatti: Co-wrote the Technology Merit and Work Plan and the body and helped with the brainstorming process. Time spent: 5 hours.

Emily Bracchitta: Wrote the introduction and reviewed the proposal for concision and clarity. Time spent: 3 hours.

Ayesha Kashif:

Proposed solutions, alternatives and modifying the proposals, which involved development and planning mission completion Aided in the prototype design including technical analysis and formulated biological research for mission concept designs.

Max Huber: Served as the lead Manufacturing Engineer to determine the design of the die used to mold our utensils. Developed and researched possible manufacturing methods and drafted CAD models for each utensil. Also served as the final editor; wrote the abstract, edited the final proposal's grammar, and contributed to the Discussion. Has extensive experience in Manufacturing Engineering through time working at a machine shop and an aerospace engineering company, supplemented by relevant coursework as a Mechanical Engineering major with an Aerospace Engineering minor. Time Spent: 10 hours.

Donaven Lee: Researched the ingredients that will be used for the utensils and assisted with nutritional information. Experience includes 4 years self studying culinary arts, and 2 self studying physical fitness and nutrition. Time spent: 6 hours.

Chi Nnoka: Served as the quality manager for the team and its submissions throughout the program's different phases. Formatting of the proposal, references, appendix, cover page, and contributed to the discussions regarding the EAUs ingredients. Strong background in undergraduate research spanning topics of robotics, additive manufacturing, aircraft subsystem design, and space debris mitigation. Troubleshoot and assessed the feasibility of proposed ideas. Time spent: 8 hours.

Maria Tagliaferri: Served as the Principal Investigator for the project team and worked to develop and communicate project goals. Researched related technologies and industry standard utensil manufacturing processes to develop a comprehensive manufacturing plan in accordance with the needs and goal of the technology. Strong background in manufacturing engineering developed through internships and academic courses. Strong knowledge of environmental science and sustainability developed through academic coursework and personal research. Time Spent: 10 hours.

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Appendix

Quad Chart

The quad chart that provides an overview of the project is shown in Fig. A1.

Edible Astronaut Utensils PI: Maria Tagliaferri , Team 21 	
Goal/Objective Edible spoons and knives for astronauts can be used during meals to reduce waste and improve overall nutritional intake in the typical astronaut diet. These utensils are very durable and extremely lightweight. The rice, millet, and sorghum base can be packed with vitamins and other nutrients that astronauts struggle to incorporate in their diet, such as vitamin D. Edible utensils are a prior invention, but the idea to integrate vitamins and nutrients into the utensils' grain base as well as to manipulate the grain base recipe to maximize the viability of edible utensils on spacecrafts qualifies for an NTR. The final products of an investment in this product would be waste-free edible utensils with a calculated amount of vitamins to target deficiencies astronauts usually experience, as well as a manufacturing plan for efficient production.	 Strong, durable, 100% edible and compostable, made of rice, millets, sorghum, and vitamin and mineral powders.
Team Overview - TX06.1.4 Habitation Systems - This project will utilize a diverse array of skills and is well suited to the skills of the team. Chemistry, health sciences, and aerospace engineering will be utilized to determine the optimal ingredients to produce the edible base to maximize the product's nutritional value and cater its characteristics to a spacecraft environment. Mechanical and industrial engineering knowledge will allow the team to improve the manufacturing methods for the utensils as well as the structural integrity. Environmental sciences are essential to ensure the sustainability of all aspects of the production and use of this product.	Metrics and Key Performance Parameters - Utensils can be packed with nutrients and vitamins to solve nutritional deficiency problems for astronauts. - Reduce waste to zero, long shelf life. - Can experiment with materials besides grains to improve the utensil performance in space. - The high temperature baking process retains the nutritional components of both the grains and the added powders. - Highly moisture resistant, high density to reduce crumbs and debris. - The technology can be expanded into other edible and biodegradable packaging and meal preparation products. - Approximately 20 grams lighter than the average traditional metal utensil. - Can be easily mass produced at costs as low as 20 cents per unit. - In the future of space colonization this could be a sustainable and health conscious alternative to current eating habits and nutritional deficiencies.

Fig. A1: Project Quad Chart

Design Model

The 3D modeled shape and design of the utensil is shown in Fig. A2.

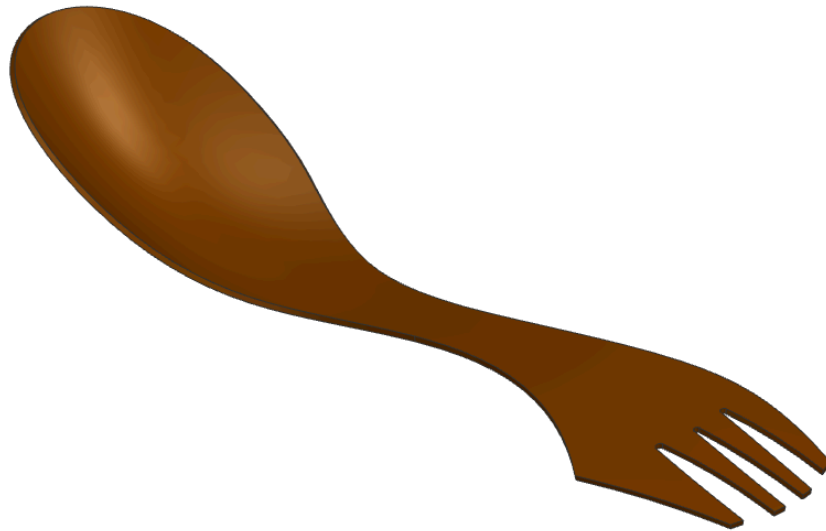


Fig. A2: CAD Model of Utensil Design

New Technology Report

A new technology report was submitted through the NASA NTR system and the NASA Form

1679 is shown on the following pages.

 National Aeronautics and Space Administration Disclosure of Invention and New Technology (Including Software)	Form Approved O.M.B. NO. 2700-0009	DATE 06/30/21
	CONTRACTOR CASE NO.	
	NASA CASE NO. (OFFICIAL USE ONLY)	
This is an important legal document. Carefully complete and forward to the Patent Representative (NASA in-house innovation) or New Technology Representative (contractor/grantee innovation) at NASA. Use of this report form by contractor alternative format must at a minimum contain the information required herein. NASA in-house disclosures should be read, understood and signed by a witness in the witness signature block at the end of this form. In completing each section, use whatever detail deemed appropriate for a "full and complete" description. Contractors/Grantees please refer to the New Technology or Patent Rights – Retention by the Contractor clauses. When necessary, attach a full, detailed description.		
1. DESCRIPTIVE TITLE Edible Vitamin Enriched Utensils Designed for Astronaut Use and Consumption		
2. INNOVATOR(S) <i>(For each innovator provide: Name, Title, Work Address, Work Phone Number, and Work E-mail Address. If multiple innovators, number each to match Box 5.)</i> 1. Sohaib Bhatti; Innovator; 42840 Cedar Hedge Street, South Riding, VA 20152; 202-844-9081; sohaibbhatti192@gmail.com 2. Emily Bracchitta, 300 W. Hackney Rd., Greer, SC 29650, 864-430-0868, ebracch@g.clemson.edu 3. Max Huber, Innovator, 6010 Stoney Hill Road, New Hope, PA, 18938, Phone: 267-370-1459, khuber5@villanova.edu 4. Donaven Lee; Innovator; 7515 Doral Dr Ypsilanti, MI; 734-957-6810; donavenl@umich.edu 5. Chi Nnoka, Innovator, 804 Furnas Hall, Buffalo, NY 14228, +1-716-445-2486, chinnoka@buffalo.edu 6. Maria Tagliaferri, Innovator, 20 Canterbury Street Andover MA, 978-886-5117, mtaglia1@villanova.edu 7. Ferdusy Akthar; Innovator; 172 Hamilton St, New Brunswick, NJ 08901; 609-665-3586; ferdusy1162@gmail.com		
3. INNOVATOR'S EMPLOYER WHEN INNOVATION WAS MADE <i>(For each innovator provide: Name, Division and Address of Employer, Organizational Code/Mail Code, and Contract/Grant Number if applicable. If multiple innovators, number each to match Box 5.)</i> 1.-13. L'Space NASA Proposal Writing & Evaluation Experience Academy, Arizona State University.		
4. PLACE OF PERFORMANCE <i>(Address(es) where innovation made)</i> Virtual		
5. EMPLOYER STATUS <i>(choose one for each innovator)</i> All Innovators: CU GE = Government CU = College or University NP = Non-Profit Organization SB = Small Business Firm LE = Large Entity	6. ORIGIN <i>(Check all that apply and provide all applicable Contract/Grant Numbers and employer information.)</i> Grant/Cooperative Agreement No: 80NSSC19M0186	

7. NASA CONTRACTING OFFICER'S TECHNICAL REPRESENTATIVE (COTR) John Dankanich	8.CONTRACTOR/GRANTEE NEW TECHNOLOGY REPRESENTATIVE (POC)
9. BRIEF ABSTRACT (A general description of the innovation which describes its capabilities, but does not reveal details that would enable duplication or imitation of the innovation.) Historically, astronauts have suffered from vitamin deficiencies as a result of prolonged space travel [1]; previous research proves that these deficiencies contribute to bone deterioration, vision loss, and other long-term health issues [2]. Aligning a solution to this problem with ongoing efforts to reduce waste and water consumption, this paper proposes a novel method of combining edible utensils with essential vitamins. A unique formula has been developed to maximize durability and strength of the utensil while also providing an infusion of vitamins that astronauts have trouble incorporating into their daily diet or producing naturally. Manufacturing of these utensils has been streamlined into a simple process that involves injection molding and high-temperature baking, all of which is highly repeatable and relatively inexpensive. The implementation of these edible utensils will be an improvement over current practices, as it will reduce plastic waste used in packaging of conventional vitamin pills and eliminate the need to clean reusable utensils, all while having a per-unit weight of 0.2% of that of a standard metal utensil. Data collected through research provides evidence that supplementing astronauts with a few key vitamins and minerals can lead to better overall health and mental wellbeing.	
SECTION I – DESCRIPTION OF THE PROBLEM OR OBJECTIVE THAT MOTIVATED THE INNOVATION'S DEVELOPMENT (Enter as appropriate: A. – General description of problem/objective; B. – Key or unique problem characteristics; C. – Prior art, i.e., prior techniques, methods, materials, or devices performing function of the innovation, or previous means for performing function of software; and D. – Disadvantages or limitation of prior art.) A. – General description of problem/objective; Currently, there isn't a very economical way of feeding astronauts while also making sure that they get the vitamins and nutritional supplements they need. Sustainability practices for future long-term space missions are lacking in creativity, in terms of food and dietary supplements. The Edible Astronaut Utensil is a strong competitor to current space sustainability practices. Edible utensils can be used during meals to reduce waste and improve overall nutrient intake in the day-to-day astronaut diet. B. – Key or unique problem characteristics; The main problem is ensuring astronauts are provided with the vitamins they need compacted into a durable utensil that does not crumble. This is unique as it requires research into how vitamins could react with other ingredients that compose the utensil. Another key to this project will be to ensure that the process is indeed sustainable and uses less waste than the current convention. C. – Prior art, i.e., prior techniques, methods, materials, or devices performing function of the innovation, or previous means for performing function of software; Currently, astronauts aboard the ISS use metal utensils to eat their food with; sterilizing them after every, or every other, meal. Vitamins and dietary supplements are consumed separately - apart from their daily meals. D. – Disadvantages or limitation of prior art; The packaging of vitamins is a disadvantage because of the extensive use of plastic which would be wasteful while in space. Plastic packaging for vitamins are unnecessary because there is radiation proof packaging. Metals will not be used as the material for the utensils because it will affect the weight of the utensils.	
SECTION II – TECHNICALLY COMPLETE AND EASILY UNDERSTANDABLE DESCRIPTION OF INNOVATION DEVELOPED TO SOLVE THE PROBLEM OR MEET THE OBJECTIVE (Enter as appropriate; existing reports, if available, may form a part of the disclosure, and reference thereto can be made to complete this description: A. – Purpose and description of innovation/software; B. – Identification of component parts or steps, and explanation of mode of operation of innovation/software preferably referring to drawings, sketches, photographs, graphs, flow charts, and/or parts or ingredient lists illustrating the components; C. – Functional operation; D. – Alternate embodiments of the innovation/software; E. – Supportive theory; F. – Engineering specifications; G. – Peripheral equipment; and H. – Maintenance, reliability, safety factors.)	

A. – Purpose and description of innovation/software; This innovation is meant to introduce a healthy way of reducing waste and resource consumption by incorporating essential vitamins into a commonly used utensil. This is a new technology as edible utensils have never been developed to specifically target the vitamin deficiencies that astronauts commonly experience. The overall purpose of this proposal is to provide a replacement for vitamin pills that are wasteful and use plastic packaging, as well as eliminate the need to clean reusable silverware with water or wet wipes.

B. – Identification of component parts or steps, and explanation of mode of operation of innovation/software preferably referring to drawings, sketches, photographs, graphs, flow charts, and/or parts or ingredient lists illustrating the components;

The full manufacturing process is as follows:

1. A CAD model is created and revised to reflect our final design for the utensil. This CAD model can be found below in Section 10.
2. A mold is machined and fabricated to contain a cavity that takes the shape of the utensil as determined by the CAD model.
3. This mold is given to a manufacturer with the ancillary equipment necessary to complete the production of the utensil (industrial ovens, etc.).
4. A batter is created with the ingredients mentioned in the Ingredients List below in Section 10. This batter is given to the outsourced manufacturer.
5. The manufacturer completes the production process by filling the molds and baking the batter at 375°F for 30 minutes.
6. The completed utensils are packaged and shipped to NASA for use.

C. – Functional operation; A single utensil is to be used by each astronaut at each meal time to consume food in the manner that conventional metal silverware is used. Upon completion of a meal, the astronauts can then consume the entire utensil.

D. – Alternate embodiments of the innovation/software; This technology can be further developed into edible or biodegradable packaging in the future. Through future research, methods to further extend the shelflife of this technology as well as the shelflife of other astronauts foods will improve the success and viability of long term manned missions to the lunar and mars surfaces. A wider variety of vitamins such as calcium and vitamin K can also be incorporated in the ingredients to adapt the utensil to be a multivitamin project.

E. – Supportive theory; Nutritional science was utilized to determine the ideal ingredient formula for the utensil as well as the ideal amount of vitamin D3 to pack into each utensil. Oat flour was chosen for its high fiber, protein, magnesium, and iron content all of which are lacking in an astronaut's diet due to their highly-processed menu items. Soy flour was chosen for its high calcium content which will healthy bone structure and production of amino acids in muscles. Soy also provides the utensil with the necessary fats to increase the efficiency of the digestion of Vitamin D within the utensil since it is a fat-soluble vitamin. Salt is used as a natural preservative in the edible utensil to extend the shelflife of the technology. Environmental science and waste management sciences also motivate this technology. The accumulation of waste on manned spacecraft poses a risk to both environmental and human health. Plastic and electronic waste have the potential to leak toxins into the spacecraft environment. Furthermore, the current limitation of waste management technology is that any accumulated waste must either be burned up in the atmosphere or is returned to Earth for disposal. Therefore, technology that can reduce accumulated waste by even a small amount can have a strong economic and environmental impact on future missions.

F. – Engineering specifications; ANSI/NSF 2: Food Equipment, ANSI/NSF 51: Food Equipment Materials, NSF/ANSI 169: Special Purpose Food Equipment and Devices

G. – Peripheral equipment; N/A

H. – Maintenance, reliability, safety factors; This technology will be submitted to the FDA to provide assurance that it is suitable for continued consumption. Due to the low risk nature of the base ingredients in the novel edible utensil recipe as well as the extremely high threshold of overdose for Vitamin D, this technology does not pose any significant health or safety risks to the user.

SECTION III – UNIQUE OR NOVEL FEATURES OF THE INNOVATION AND THE RESULTS OR BENEFITS OF ITS APPLICATION

(Enter as

appropriate: A. – Novel or unique features; B. – Advantages of innovation/software; C. – Development or new conceptual problems; D. – Test data and source of error; E. – Analysis of capabilities; and F. – For software, any re-use or re-engineering of existing code, use of shareware, or use of code owned by a non-federal entity.) is

A. – Novel or unique features; The formulated ingredient mixture outlined below in part 10. “Ingredients List and Justification” is the novel aspect of this technology. The specific shape of our utensil design is also unique to this technology compared to previous edible utensils. This technology is also novel in that it was specifically designed for use in space by astronauts.

B. – Advantages of innovation/software; The two major advantages of this innovation are it's high nutritional value and. An additional advantage is that this product can be used as an emergency caloric and nutrient supply for astronauts whereas traditional vitamin supplement pills do not provide any calories. This technology also decreases the weight associated with astronaut utensils as each unit weighs about 0.2% of the weight of a metal utensil.

C. – Development or new conceptual problems; One limitation of this new technology is in the operational use of the product. The success of the technology is dependent not only on the scientific background, but also on user feedback and enjoyment. If the majority of astronauts are not willing to incorporate this technology into their meal routine or simply do not enjoy using and consuming the utensils, the technology is not likely to be utilized to its fullest extent. Without active participation from the user, the product cannot provide the nutritional and environmental benefits that it is designed to. During the prototyping and phase of this technology, astronauts should be consulted to ensure that the taste, texture, and design of the product meets their needs in addition to general health and environmental standards.

D. – Test data and source of error; N/A

E. – Analysis of capabilities; N/A

SECTION IV – SPECULATION REGARDING POTENTIAL COMMERCIAL APPLICATIONS AND POINTS OF CONTACT (*Including names of companies producing or using similar products.*)

The major companies producing edible utensils are EdiblePro which can be contacted at info@ediblepro.com or +91-7760890320, Mede Cutlery Manufacturers which can be contacted at sale@cutlery-manufacturers.com or +86 18868944843, and Bakey's which does not have a current public point of contact.

10. ADDITIONAL DOCUMENTATION (*Include copies or list below any pertinent documentation which aids in the understanding or application of the innovation (e.g., articles, contractor reports, engineering specs, assembly/manufacturing drawings, parts or ingredients list, operating manuals, test data, assembly/manufacturing procedures, etc.).*)

TITLE	PAGE	DATE
Ingredients List and Justification: Enriched, all-purpose flour serves as the structure of the utensil. Wheat is the ideal material for this technology because it is abundant, low cost, and requires minimal water to process into flour. Oat flour provides the necessary fiber to support a healthy gut microbiome, protein, magnesium, and iron all of which are lacking in an astronaut's diet due to their highly-processed menu items. Soy flour also provides those benefits as well as calcium to counteract an astronaut's degrading bone structure, and all essential amino acids needed to maintain muscles. Soy also contains some fat which helps digest the Vitamin D within the utensil since it is a fat-soluble vitamin. Both oat and soy contain other beneficial vitamins and minerals as well. Salt preserves the edible utensil for a longer shelf life. Additionally, it enhances the flavor of the three flours. Vitamin D3 was chosen because it is more potent and absorbs in the body better than D2. 200 IU of Vitamin D3 fits the recommended daily amount of 400-800 IU per day if an astronaut eats an edible utensil with each meal for three meals a day. The dosage is far below the risk of overdosing (4,000 IU), so there is very low risk of danger in the event that a large supply is consumed in an emergency. The edible utensils will be made with a proportion of 37.6% enriched, all-purpose flour; 22% water; 20% oat flour; 20% soy flour; 0.4% salt; and 200 IU of Vitamin D3. The ingredients will be mixed, poured into the mold, and baked at a temperature of 375°F for 30 minutes.		
Manufacturing procedure:		

The manufacturing process will be outsourced to a vendor that specializes in the manufacturing of edible utensils to reduce time and costs associated with the research and development phase of manufacturing design. To determine the estimated cost per unit of manufacturing, quotes from several major manufacturers will be compared to determine the minimum cost and maximum attainable efficiency possible to produce the technology. The manufacturing process is divided into three main steps. First the ingredients are mixed and extruded into a die mold, then the material is pressed to conform to the mold shape, and lastly the utensil is baked in an industrial oven at 375°F for 30 minutes. To reduce cost and testing time, the manufacturing of our novel vitamin utensils will be outsourced to a current manufacturer until we can develop a manufacturing process that can be completed in space.		
CAD Model of Prototype: 		
11. DEGREE OF TECHNOLOGY SIGNIFICANCE (<i>Which best expresses the degree of technological significance of this innovation?</i>): Modification to Existing Technology		
12. STATE OF DEVELOPMENT Concept Only Design		
13. PATENT STATUS (Prior patent on/or related to this innovation.) None		
14. INDICATE THE DATE OR THE APPROXIMATE TIME PERIOD WHICH THIS INNOVATION WAS DEVELOPED (<i>i.e., conceived, constructed, tested, etc.</i>) June 2021		

15. PREVIOUS OR CONTEMPLATED PUBLICATION OR PUBLIC DISCLOSURE INCLUDING DATES *(Provide as applicable: A. – Type of publication or disclosure, e.g., report, conference or seminar, oral presentation; B. – Disclosure by NASA or Contractor/Grantee; and C. – Title, volume no., page no., and date of publication.)*

None

16. QUESTIONS FOR SOFTWARE ONLY

- (a) Using non-NASA employees to beta-test the program? YES NO If Yes, done under a beta-test agreement? YES NO
- (b) Modification of this program continued by civil servant and/or contractual agreement? YES NO
- (c) Copyright registered? YES NO UNKNOWN If Yes, then by whom?
- (d) Has the latest version been distributed outside of NASA or contractor? YES NO UNKNOWN
If Yes, date of first disclosure:
- (e) Were prior versions distributed outside of NASA or Contractor? YES NO If Yes, supply NASA or contractor contract:
- (f) Contains or based on code not owned by U.S. Government or its contractors? YES NO UNKNOWN If Yes, name of code and code's owner:
- Has a license for use been obtained? YES NO UNKNOWN

17. DEVELOPMENT HISTORY

STAGE OF DEVELOPMENT	DATE (MM/YYYY)	LOCATION	IDENTIFY SUPPORTING WITNESSES (NASA in-house only)
a. First disclosure to others	06/03/21	Virtual	
b. First sketch, drawing, logic chart or code	06/25/21	Virtual	
c. First written description	06/25/21	Virtual	
d. Completion of first model of full size device (<i>invention</i>) or beta version (<i>software</i>)	N/A	N/A	
e. First successful operational test (<i>invention</i>) or alpha version (<i>software</i>)	N/A	N/A	

f. Contribution of innovators *(if jointly developed, provide the contribution of each innovator)*

Charles Thorpe Barbier: Did research on the astronauts nutritions and I also noted that Vitamin D was the astronauts main nutrition in space. Did a rough CAD drawing of one of the proposed utensils. Estimated work time: 6 hours.

Chi Nnoka: Served as the quality manager for the team and its submissions throughout the program's different phases. For this proposal, he did the formatting of the proposal, references, appendix, cover page, and contributed to the discussions regarding the EAU ingredients.

Maria Tagliaferri: Served as the principal investigator for the project team and worked to develop and communicate project goals. Researched related technologies and industry standard utensil manufacturing processes to develop a comprehensive manufacturing plan in accordance with the needs and goal of the technology.

Max Huber: Served as the lead Manufacturing Engineer to determine the design of the die used to mold our utensils. Developed and researched possible manufacturing methods and drafted CAD models for each utensil. Also served as the final editor; wrote the abstract, edited the final proposal's grammar. Has extensive experience in Manufacturing Engineering through time working at a machine shop and an aerospace engineering company, supplemented by relevant coursework as a Mechanical Engineering major with an Aerospace Engineering minor. Time Spent: 10 hours.

Donaven Lee: Researched the ingredients that will be used for the utensils and assisted with nutritional information. Experience includes 4 years self studying culinary arts, and 2 self studying physical fitness and nutrition. Spent 6 hours.

Sohaib Bhatti: Co-wrote Technology Merit and Work Plan

Jason Zou: Did research on feasibility on proposal aspects. Worked with others to modify and develop proposal.

g. Indicate any past, present, or contemplated government use of the innovation

None

18. SIGNATURES OF INNOVATOR(S), WITNESS(ES), AND NASA APPROVAL

TYPED NAME AND SIGNATURE (<i>Innovator #1</i>) Maria Tagliaferri MT	DATE 6/29/21	TYPED NAME AND SIGNATURE (<i>Innovator #2</i>) Chi Nnoka CN	DATE 06/29/21
TYPED NAME AND SIGNATURE (<i>Innovator #3</i>) Max Huber KMH	DATE 6/29/21	TYPED NAME AND SIGNATURE (<i>Innovator #4</i>) Donaven Lee DL	DATE 6/29/21
TYPED NAME AND SIGNATURE (<i>Innovator #5</i>) Charles Thorpe Barbier CTB	DATE 6/29/21	TYPED NAME AND SIGNATURE (<i>Innovator #6</i>) Sohaib Bhatti MSB	DATE 6/29/21
TYPED NAME AND SIGNATURE (<i>Innovator #7</i>) Faiza Sikandar FS	DATE	TYPED NAME AND SIGNATURE (<i>Innovator #8</i>) Jason Zou JZ	DATE 6/29/21
TYPED NAME AND SIGNATURE (<i>Innovator #9</i>)	DATE	TYPED NAME AND SIGNATURE (<i>Innovator #10</i>)	DATE
TYPED NAME AND SIGNATURE (<i>Innovator #11</i>)	DATE	TYPED NAME AND SIGNATURE (<i>Innovator #12</i>) Emily Bracchitta EB	DATE 6/30/21
TYPED NAME AND SIGNATURE (<i>Innovator #13</i>)	DATE	TYPED NAME AND SIGNATURE (<i>Innovator #14</i>)	DATE
TYPED NAME AND SIGNATURE (<i>Witness #1</i>)	DATE	TYPED NAME AND SIGNATURE (<i>Witness #2</i>)	DATE
NASA APPROVED	TYPED NAME	SIGNATURE	DATE