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From Handicrafts to Habitat: Investigating Terite's Applications in Space

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ABSTRACT

The challenges associated with prolonged human space exploration missions require sustainable and innovative approaches to ensure the health and well-being of astronauts. Many indigenous plants around the world can potentially serve as valuable resources for long-duration space missions. The raw material, Ischnosiphon obliquus, commonly known as "Terite," is indigenous to the island of Trinidad. Before the 15th century, terite was used in weaving by the island's indigenous inhabitants to make household items such as baskets for fishing, jewellery, and utensils that lasted a lifetime. Over time, the strands have been known to produce eco-friendly craft items such as; tabletops, lampshades, book covers, plates, teacup holders, and more. In this paper, a design thinking approach is outlined to help us identify and evaluate potential experiments involving terite that could yield innovative solutions to the challenges of space habitation. It also identifies the areas of study and the considerations that are necessary for long-duration space travel and the potential for the development of space tourism within the Caribbean region. In this paper, we propose potential experiments in the areas of (1) cultivation and processing; (2) construction application; and (3) reinforced 3D printing to begin to explore terite as a sustainable and multifunctional resource in space.

Keywords: Terite, Space exploration, Long-duration missions, Design thinking, Innovation, Sustainable, User-centred, Cultivation, Processing, Construction, 3D printing

INTRODUCTION

Space exploration over prolonged periods presents a multitude of challenges, including the necessity for innovative and viable approaches to safeguard the well-being and medical necessities of astronauts. These missions are heavily criticized for their high risk, high expense, and low return characteristics (Piantadosi, 2012). The manifestation of empirical evidence and thorough investigation attests to the paramount importance of prioritizing human space exploration. Creating sustainable solutions is necessary. Space missions require careful management of resources, including food, water, and air; thus, sustainable approaches can help conserve these resources, making them last longer and reducing the need for resupply missions. By utilizing locally accessible resources and lowering the requirement for expensive materials and equipment, these novel ideas have the potential to lower the cost of space missions. It is within the realm of possibility that this effort could also enhance the prolonged viability of human space exploration by reducing the impact on natural resources and promoting the use of renewable resources.

Indigenous plants are a significant potential source of renewable and sustainable benefits. Primarily, the flora in question can confer a self-sufficient sustenance reserve for astronauts; an indispensable factor during prolonged expeditions where resupply from Earth is unfeasible. Some plants possess the ability to generate life-sustaining oxygen via photosynthesis, a vital function in maintaining human existence within an enclosed setting. Additional flora could potentially serve as sources for organic pigments or textile materials, which may be fashioned into garments and other essential goods required within a given environment. Moreover, certain vegetation may possess therapeutic attributes that have the potential to be advantageous in treating illness or injury. An inherent benefit of utilizing native vegetation lies in their intrinsic adaptation to the surrounding landscape, affording them the ability to flourish with minimal human influence. This means that they require less energy, water, and other resources than other plants. It is possible to utilize the unrepeatable qualities of these plants and adjust them according to spatial parameters in order to construct effective, sustainable resolutions that guarantee human life in space while minimizing the impact on the environment.

DESIGN THINKING APPROACH

As we explore the potential of Terite as a multi-functional resource for space exploration, a design thinking approach can help us identify and evaluate potential experiments that could yield innovative solutions to the challenges of space habitation. As a practical approach to creativity and innovation in design, our design approach begins by identifying the user's needs and understanding the problem that needs to be solved (Meinel & Leifer, 2018). The astronaut has many physical and psychological challenges with long-duration space missions. The role of the astronaut, the user in question, pertains to addressing a pressing issue, namely, developing resource options that are both forward-thinking and reliable for extensive expeditions into space.

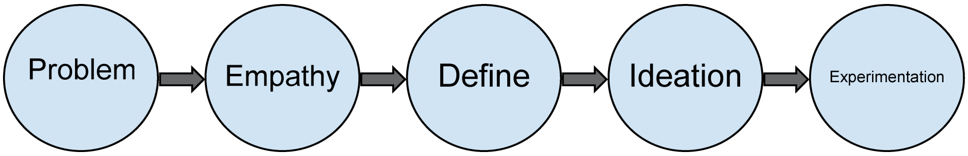

Figure 1: Design thinking approach applied to investigating Terite (adapted from Cuffie et al., 2018).

From the information gathered from the empathy phase, it was identified that there is a need for sustainable and innovative approaches to ensure the health and well-being of astronauts on long-duration space missions.

We also recognized the potential for indigenous plants, such as *Ischnosiphon obliquus*, to serve as valuable resources in space habitats.

The crucial questions of "What is a possible solution?" and "What to test?" were answered based on the synthesis of empathizing. and the problem statement. Based on our ideation brainstorming sessions and research, an assortment of ideas and solutions were considered to optimize the cultivation and processing of Ischnosiphon obliquus in space habitats and on other planets. Terite was also considered for its potential applications as a material for construction in space habitats and its suitability as a reinforcement for 3D printing.

TERITE AS A SUSTAINABLE RESOURCE

One plant that, from initial observations, has shown potential for space exploration is Ischnosiphon obliquus, commonly known as Terite (Nielson, 1966). It is an indigenous plant to the island of Trinidad. It has been used for centuries by the island's early inhabitants for weaving handicrafts

It typically grows to a height of two to three meters and has long, narrow leaves and a cylindrical stem or rod (Figure 2). The terite plants grow in clusters, and you can harvest fully grown plants at any time of the year (Fern, 2022). The plants to be harvested are selected if they have seven or more leaves. The plant is known for its strong and durable fibres, which have been used for centuries to create a variety of woven items, including baskets, mats, and clothing.

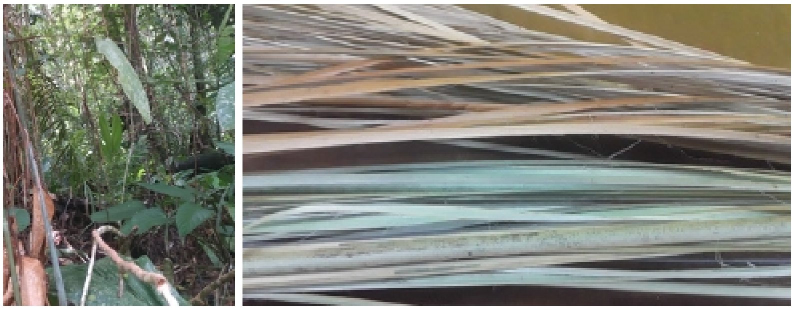

Figure 2: (LEFT) a Terite stem (rod) with leaves found in the forest; (RIGHT) Terite strands after cultivation, drying, and preparation for weaving.

The raw material is extracted by cutting the stalk and splitting it into equal widths to obtain strands that can be used for weaving. They are then placed in the sun to dry for three to four days to get brown; the terite rods were originally green (Figure 2). The roots are left intact to ensure continuous growth, making it a sustainable resource. The strands are then woven into different items such as cabinets, lamps, and shades, even a coffee table (Figure 3); basically, anything that can be imagined.

Additionally, the leaves have the potential to be used to make sanitary plates and bowls, and the inner part of the stalk is used as a natural fertilizer for plants, making it a multifunctional resource with minimum waste.

Figure 3: (LEFT) a coffee table made from terite strands; (RIGHT) a coffee table and serving tray made from terite.

Moreover, terite exhibits immense promise as an eco-friendly alternative for space expeditions. Its fibres possess the capability to produce a range of essentials required during long-duration missions, such as housing components and personalized articles utilized by astronauts. Terite is a resilient and eco-friendly plant that also has the possibility to thrive in various environmental conditions, making it a very promising candidate for use in space habitats or on other planets

PROPOSED EXPERIMENTS

A. Cultivation and Processing

For long-duration missions, astronauts want to bring plants for both aesthetic and practical reasons (Growing Plants in Space, 2021). They are good for psychological well-being while being critical for keeping astronauts healthy. It will be important for the crew to reliably grow plants in altered microgravity conditions.

To optimize the cultivation and processing of Terite in different conditions, we can design experiments that focus on determining the ideal growth conditions for the plant, such as lighting and temperature settings, and soil compositions. This could involve testing the growth of Terite in different simulated environments that mimic conditions found in space habitats or other planets.

Additionally, to investigate processing methods for maximizing Terite's usefulness as a resource, we can conduct experiments to test the best ways to extract and process the plant's weavable fibres. This could include testing diverse drying methods to determine the optimal moisture content for the fibres. Similarly, examining different techniques and tools (either current or to be designed) for extracting fibres can be conducted to ensure that they are of the highest quality and strength. A similar approach can be taken for all functional parts of the plant, including the leaves and interior stalk fibres.

Table 1. List of experiments and procedures that can be developed for cultivation and processing.

Experiment	Procedure	Data Collection
Cultivation of terite under different light conditions	Terite plantlings (or seeds) will be transplanted into different containers, and each container will be placed under different light conditions (low, medium, and high). The containers will be placed in a controlled environment with the same temperature and humidity level.	The growth rate, plant height, and weight of Terite plants will be measured regularly to compare the effects of different light conditions on terite growth.
Cultivation of Terite under different temperature conditions	Terite plantlings (or seeds) will be transplanted into different containers, and each container will be placed under different temperature conditions (low, medium, and high). The containers will be placed in a controlled environment with the same light and humidity levels	The growth rate, plant height, and weight of Terite plants will be measured regularly to compare the effects of different temperature conditions on Terite growth.
Investigation of processing methods for maximizing Terite's usefulness as a resource	Different processing methods for terite will be investigated, including drying and extracting its weavable fibres. Terite plants will be harvested and processed using different methods, and the resulting materials will be tested for their quality and usefulness in different applications.	The quality of terite fibres and materials produced using different processing methods will be assessed based on factors such as strength, durability, and suitability for various applications.

B. Construction Application

Advancements in technology and construction methods are making it possible to accomplish more space development than ever before (NASA Technology Innovation 17.1, n.d.). NASA has been developing technologies and practices to build structures on the surface of other planets using "in-situ" or on-site resources (Leach, 2014), Thus, to overcome the challenges of space construction, it's important to use the right materials and tools, which are achieved with rapidly developing tools and technology ("Space Construction: The Industry's New Frontier," 2020).

As we explore the multifunctional potential of terite for long-duration space missions, it is crucial to assess its mechanical properties and compatibility with other materials commonly used in space habitats. This would begin with the examination of terite's mechanical properties for different engineering applications and astronaut personal items. These applications require a series of tests to determine the material's tensile strength, elasticity, and toughness.

The second series of tests would set out to determine how terite interacts with other materials, such as metals and plastics, commonly used in space habitats.

The data collected from the first tests can be used to assess the suitability of terite for different engineering applications. These include building structures, personal equipment, and protective gear for astronauts. Additionally, the data can inform the development of standards and guidelines for using terite in space missions.

Table 2. A list of experiments and procedures that can be developed for construction applications.

Experiment	Procedure	Data Collection
Examination of Terite's mechanical properties for different engineering applications and astronaut personal items	Prepare a sample of terite with standard size and shape. Conduct tensile testing to determine the material's tensile strength. Conduct bending testing to determine the material's elasticity. Conduct impact testing to determine the material's toughness. Repeat the above tests under different conditions, such as temperature and humidity variations. Analyze the test results and determine the material's mechanical properties for different engineering applications and personal items.	Tensile strength data (in units of force per unit area) Elasticity data (in units of strain per unit stress) Toughness data (in units of energy absorbed per unit volume) Variations in mechanical properties with temperature and humidity changes
Investigation of compatibility with other materials used in space habitats	Prepare a sample of terite and other common space habitat materials, such as metals and plastics. Conduct compatibility testing by exposing the materials to different conditions, such as temperature and humidity variations. Observe and record any physical changes, such as warping or cracking. Conduct material analysis, such as chemical composition and surface morphology, to determine any chemical reactions or adhesion between materials. Repeat the above tests with different combinations of materials. Analyze the test results and determine the compatibility of terite with other materials used in space habitats.	Observation of physical changes Chemical composition and surface morphology analysis Compatibility assessment with other space habitat materials under different conditions.

The data collected from the second set of tests can be used to determine the optimal conditions for using terite in conjunction with other materials in space habitats. Also, the data can be used in the development of guidelines for the use and storage of terite in space habitats to minimize any potential interactions or negative effects.

C. Reinforced 3D Printing

Fiber-reinforced polymer (FRP) composites have been widely used in various industrial fields, such as building materials, auto parts, and electronic components, due to their superior properties and versatility (Yuchao et al., 2022). FRP products are usually required to be dedicated and customized in practical applications.

To determine terite strands' or fibres' usefulness and sustainability as a reinforcement for 3D printing in space, the fibres will be tested for their compatibility with other materials used in space habitats, such as polymers and metals.

Table 3. A list of experiments and procedures that can be developed for use in reinforced 3D printing.

Experiment	Procedure	Data Collection
Determining Terite fibres' usefulness and sustainability as a reinforcement for 3D printing in space	*Preparation of Terite fibres:* Terite stalks will be cut and split into equal widths to extract the raw material strands. The extracted strands will then be processed and dried to optimize their usefulness as a resource. *3D printing with Terite fibres*: The 3D printing experiment will aim to test Terite fibres' suitability as a reinforcement for 3D printing in space. The 3D printing process will be carried out with a 3D printer that can handle the Terite fibres. The printing will be done with different proportions of Terite fibres and other printing materials to determine the optimal ratio for maximum strength and durability.	The weight of the Terite fibres before and after processing will be recorded to determine the percentage of weight loss during processing. The strength and durability of the printed objects will be measured by subjecting them to mechanical testing. The data collected will include the maximum load the object can handle, the deformation under load, and the ultimate tensile strength. The compatibility of Terite fibres with other printing materials will be assessed by observing any changes in the physical and mechanical properties of the printed objects after exposure to different environmental conditions.
Potential for reducing the need for synthetic materials	*Identification of synthetic materials:* The synthetic materials commonly used in space habitats will be identified, and their properties will be recorded. These properties include the materials' strength, durability, and resistance to different types of stress. *Comparison of Terite fibres with synthetic materials*: The properties of Terite fibres will be compared to those of the synthetic materials commonly used in space habitats. This will be done by subjecting both materials to the same types of mechanical testing under different environmental conditions. *Experimentation:* The Terite fibres will be used as a reinforcement material for different types of objects commonly used in space habitats. These objects include utensils, personal items, and structural components. The performance of the Terite fibre-reinforced objects will be compared to that of similar objects made from synthetic materials.	The physical and mechanical properties of Terite fibres and the synthetic materials commonly used in space habitats will be recorded. The performance of Terite fibre-reinforced objects will be assessed by subjecting them to the same types of mechanical testing as the synthetic material objects. The amount of synthetic materials that can be replaced with Terite fibers in different types of objects will be recorded to determine the potential for reducing the need for synthetic materials in space habitats.

The potential for terite to reduce the need for synthetic materials in space exploration is significant. Synthetic materials are often costly to transport and difficult to recycle, making them an unsustainable option for prolonged space missions. In contrast, terite can be sustainably cultivated and processed, positioning it as an environmentally friendly alternative.

LIMITATIONS

Conducting these experiments may face challenges due to the limitations of resources, equipment, and the complexity of the space environment.

Table 4. A list of some limitations for each experiment group.

Experiment	Limitations
A. Cultivation and Processing:	• The availability of resources and equipment for the cultivation and processing of terite in space may be limited. • The impact of the space environment on the growth and development of Terite needs to be considered. • The experiment may be time-consuming and require frequent monitoring.
B. Construction Application:	• The mechanical properties of terite may not be suitable for all engineering applications in space. • The compatibility of terite with other materials used in space habitats needs to be thoroughly investigated before application. • The experiment may require sophisticated equipment and tools for testing mechanical properties.
C. Reinforced 3D Printing:	• The sustainability and long-term durability of Terite fibres as a reinforcement for 3D printing in space need to be evaluated. • The experiment may require special 3D printing equipment that can incorporate Terite fibres. • The effectiveness of Terite fibres as a reinforcement material needs to be compared to existing reinforcement materials.

Nonetheless, these limitations can be overcome with innovative solutions and interdisciplinary collaborations.

CONCLUSION

In conclusion, the design thinking approach is a valuable tool for exploring Terite's potential in space exploration. By identifying user needs and problems, researchers can ideate and develop experiments and procedures that optimize Terite's cultivation, processing, mechanical properties, and sustainability as a reinforcement for 3D printing. These experiments present opportunities for collaboration and innovation across fields and disciplines, bringing together experts in agriculture, engineering, materials science, and astronautics to create user-centred and sustainable space habitation solutions. In Table 5, we can observe several potential endeavours and investigations that will derive from the outcomes of these preliminary trials.

Table 5. Potential experiments that could be conducted with Terite.

#	Future Potential Experiments
1	Exploration of the potential of Terite as a resource for space tourism, including its use in handicrafts and other souvenirs for visitors.
2	Study of the effects of cosmic radiation and other space hazards on Terite fibers and their potential degradation over time.
3	Study of the effects of microgravity on Terite growth and processing.
4	Study of the potential of Terite as a source of medicine or other bioactive compounds in space.
5	Testing the biodegradability of Terite fibers in space and their potential use in composting systems.
6	Investigation of Terite's potential as a material for insulation in space habitats.

The triumphant development and implementation of terite in space could reduce our reliance on synthetic materials while facilitating more eco-friendly and efficient space exploration. With continued exploration and experimentation, Terite's potential as a versatile and sustainable resource for space exploration may hold exciting possibilities for the future.

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