**NASA’s LunaRecycle Challenge**

**Phase 1 Submission Instructions and Template**

**(Digital Twin Track)**

## Instructions

In General:

* The submission must address each required section and topic described below. Teams should maintain all numbered section headings in their submission. PLEASE NOTE: Any submission that does not address all of the requirements will receive a “Fail” score for completeness, will not be judged, and will not be eligible for a prize.

Presentation:

* The presentation must be a PDF file and may include no more than 30 slides. Judges will not review any materials beyond 30 slides. This instruction section does not count toward the page limit and may be deleted prior to submission.
* The text on slides must be no smaller than 16-point font (Arial or Times New Roman recommended). Teams should use a standard size slide with 4:3 aspect ratio.
* Each section includes a recommended length for the answer. These recommendations are intended to provide guidance on NASA’s expectations for the length and quality of the answer, but teams are not required to adhere to these recommendations. Teams may allocate space to different sections as they see fit.
* The recorded presentation may be no longer than 30 minutes. Judges will not review the presentation beyond 30 minutes.

Visualization File:

* The animated visualization must be submitted as a separate file and may not be longer than 10 minutes. Judges will not review the visualization beyond 10 minutes.

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## Required Sections and Topics

1. Team Information (*1 slide suggested*)

1.1 Team Name: (Teams are encouraged to use a creative team name. This name may be used in promotional materials related to the challenge.)

1.2 Team Lead:

1.3 Team Affiliations/Organizations (if applicable):

1.4 Relevant Past Work (if applicable):

1.5 Geographic Location (City and State/Territory):

1.6 One Sentence Description: (Provide a one-sentence description of your solution that may be used in promotional materials related to the challenge. Do not reference any confidential elements of your solution in this description.)

2. Vision and Innovation *(3-4 slides suggested)*

2.1 What specifically is innovative about your approach?

2.2 How is it different from and/or better than recycling approaches currently used terrestrially?

2.3 How is it different from and/or better than recycling approaches currently contemplated for space applications?

2.4 How does your approach leverage advanced technologies or advanced manufacturing methods?

2.5 How does it address the conditions and activities of the hypothetical lunar settlement described in the Mission Scenario? Please specifically address: a) whether your system will be located outside on the lunar surface and/or inside a pressurized habitat; and b) how your system will be designed for the lunar conditions relevant to its location (as described in the Mission Scenario).

2.6 Teams are not required to design solutions to operate in lunar dust conditions. However, please describe how your solution might be adapted to operate in lunar dust conditions in the future and/or whether/how it might be inherently dust resistant.

2.7 This challenge is focused on recycling systems for the lunar surface. However, please describe how your solution might have application, or be adapted to have application, to recycling systems on Earth.

3. Recycling and Manufacturing Process (*8-9 slides suggested*)

3.1 What **waste category/categories** will your process address? Within each waste category, what waste items will your process address? Please provide details about the estimated amounts (% by mass and % by volume) and materials that will be recycled.

3.2 Describe the **usable outputs** produced from your process, including the types and amounts (kg) of feedstocks and any finished end products (kg or number).

3.3 What are the **systems and components** that make up your process? Please provide detailed descriptions, schematics, and other relevant data for these systems and components.

3.4 What is your **concept of operations**? Please describe: a) a full production cycle of your process, including the duration; and b) how many full production cycles will be required to recycle the estimated amounts and materials that you described in question 3.1 and produce the usable outputs that you described in question 3.2. In addition, please note whether operation of your system will require crew, and if so, what operational activities they will need to perform.

3.5 What **maintenance** for your system will be needed during your process or after your process has completed one or more full production cycles? Please describe any maintenance activities and whether the activities require crew.

3.6 Describe the **resource inputs** needed for your process (consistent with sections 3.1, 3.2, 3.3, and 3.4 above) including the total electricity, water, chemicals, minerals, and any other inputs, including crew time. Include the following RESOURCE INPUTS TABLE in your presentation for each waste category that you are addressing. If your recycling process addresses more than one waste category simultaneously, you may provide one table for multiple waste categories.

RESOURCE INPUTS TABLE

|  |  |  |
| --- | --- | --- |
| **Waste Category** | **Resource Input** | **Total amount required for your process** |
| (Name of the Waste Category, from Table 4 in the challenge rules) | Electricity | –Peak demand over a specific time period (kW)  –Total electricity consumed (kWh)  –Net electricity consumed, if any electricity is produced in the recycling process (kWh) |
| Water | kg |
| Chemicals/ Minerals/Other Resource Inputs | kg |
| Crew Time to Operate the System | # of crew and hours per crew member |
| Crew Time needed for Maintenance Activities | # of crew and hours per crew member |

3.7 Describe the types and amounts (kg) of any **unusable outputs** that will result from your process. Unusable outputs are defined in the Definitions section of the challenge rules.

3.8 Use the following NET WASTE RECYCLED TABLE to show the **net waste recycled**. In Phase 1 of the challenge, net waste recycled for each waste category is equal to the sum of the percentage recycled (by mass) of each waste item in a category.

For example, Team A has chosen the Fabrics category. Their process will recycle (by mass) 70% of the clothing, 80% of the towels, and none of the disinfectant wipes. Team A will multiply the percentage recycled by the total % by mass of each item, as listed in Table 4. Therefore, Team A’s net waste recycled is: (70% X 77%) + (80% X 21%) + (0% X 2%) = 71%.

Please use one row for each waste category that your process will address and one column for each waste item in the category. You may add additional rows and columns to this template as appropriate. Percentages should be rounded to whole numbers.

NET WASTE RECYCLED TABLE

| **Waste Category** | **Waste Item 1**  **(% recycled**  **by mass)** | **Waste Item 2**  **(% recycled**  **by mass)** | **Waste Item 3**  **(% recycled**  **by mass)** | **Net Waste Recycled**  **(%)** |
| --- | --- | --- | --- | --- |
| (Team A example)  Fabrics | 54% | 17% | 0% | **71%** |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

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4. Digital Twin Architecture (*8-10 slides suggested*)

4.1 Describe the architecture of your digital twin:

4.1.1 What is your design approach? Describe the physics-based models, simulation, and visualization you will use to create a virtual representation of an intended future physical system.

4.1.2 Describe the level of fidelity and resolution that demonstrates how closely the digital representation matches the real-world system.

4.1.3 Describe the sensors and observing systems and the data acquisition and data integration approaches.

4.1.4 Describe any automated control and decision-making capabilities.

4.1.5 Describe any artificial intelligence, machine learning, and empirical modeling capabilities.

4.1.6 Describe your expected approach to virtual prototyping and testing to test performance and functionality in a simulated environment.

4.1.7 Describe your validation approach for computer models (e.g., how accurately the model's predictions or outputs align with real-world intended future systems).

4.1.8 Describe how the digital twin would communicate with physical assets that would be part of the intended future physical system.

5. Digital Twin Key Characteristics (*4 slides suggested*)

5.1 Describe how your Digital Twin Prototype addresses the following key characteristics:

5.1.1 Accuracy, defined as the degree to which the digital representation reflects the real-world physical asset in data fidelity, model fidelity, and predictive capability.

5.1.2 Cohesion, defined as how closely coupled the different parts of the digital representation (e.g., model/simulation) are and how the model/simulation adheres to the laws of physics the same way the physical twin does.

5.1.3 Flexibility, defined as the ability of the digital representation to adapt and change to reflect the real-world physical asset and handle increasing complexity as the technologies or physical asset evolves.

5.1.4 Predictive Capabilities, defined as the ability of the digital model to anticipate the future behavior and performance of the physical asset.

5.1.5 Repeatability, defined as the ability to consistently create and operate digital twins that are reliable, can be replicated, and function as expected across multiple scenarios.

5.1.6 Usability, defined as the ease with which users can interact with, understand, and leverage the digital representation of a physical asset. NASA is seeking a digital twin that is user-friendly and enables efficient decision-making.

5.1.7 Verification and Validation, defined as how the digital twin meets specifications and requirements, including: a) How the various models will be assembled/integrated together; b) What are the analysis, demonstration, and test approaches for verification and validation; and c) What is the process for determining the degree to which a model is an accurate representation of the real-world asset.

6. Digital Twin Visualization (*2 slides suggested*)

6.1 Describe what is included or addressed in the visualization provided in your submission

6.1.1 How was the visualization created?

6.1.2 What engineering data does it incorporate?

6.1.3 What does it show?