NASA's LunaRecycle Challenge
Phase 2 Official Challenge Rules, Revision 2
December 2, 2025

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Revision Log

Date	Revision #	Section	Description
08/11/2025	0	Original document	Original document
09/12/2025	1	Technical Requirements (Digital Twin Solution)	In Table 5. Planetary Environmental Conditions for Planetary Surface Operations Scenario, the Martian Environmental Conditions were updated with the correct unit of measurement for atmospheric pressure outside on the surface; the correct gravity for inside a pressurized habitat; and the atmospheric composition.
12/2/2025	2	Technical Requirements (Prototype Solution); Eligible Trash Items	Information for Zotek F30 has been updated in Table 4. Specifically, the name for Zotek F30 (now referred to as Zotek F30 Aviation) and link to the commercially available equivalent for Zotek F30 Aviation have been updated. In addition, the original link to the commercially available equivalent for the Rehydratable Pouch has been removed because it is no longer available. A new link will be provided soon in another revision of the challenge rules.

Definition of Legal Terms for this Challenge

Proof of Incorporation: Documentation showing that an entity is incorporated in and maintains a primary place of business in the United States.

Proof of Insurance or Financial Responsibility: Documentation showing a team's insurance coverage or financial assets in the specified amounts for each round of the challenge.

Proof of Nationality: Documentation proving the nationality of a team leader and/or team members.

Team: An individual, group of individuals, or a group of individuals represented by an entity that have officially registered and are eligible to compete in the challenge.

Team Agreement: A legal contract between a team and University of Alabama that describes the legal conditions of participating in the challenge.

Team Leader: A representative of the team that is responsible for compliance with the challenge rules by all members of the team and will serve as the primary point of contact for administrative matters related to the challenge.

Team Member: An individual who participates on a team in the challenge.

Definition of Technical Terms for this Challenge

Cleaning of Trash Items: In this challenge, cleaning refers to a process where a used trash item is cleaned prior to being recycled. Cleaning of Trash Items is not included in the scope of this challenge. Teams may assume that all trash items are already clean and free of contamination.

Digital Twin Solution: A set of virtual information constructs that mimics the structure, context, and behavior of a team's Prototype Solution. A digital twin has the potential to be dynamically updated with data from its physical twin; has a predictive capability; and informs decisions that realize value.

Eligible Trash Items: The trash items that teams are permitted to recycle in Phase 2 of the challenge. There are eight (8) eligible trash items, as described in TABLE 4.

Energy Efficiency: Energy Efficiency (kg/kWh) is equal to the mass (kg) of the usable output(s) divided by the energy consumed (kWh) to produce those usable outputs.

Judging Panel: A panel of professionals and subject matter experts from government, academia, and industry who will evaluate and score submissions and demonstrations.

Mass Efficiency: Mass efficiency (%) is equal to the mass of the usable output(s) divided by the sum of the mass of the trash item inputs and other inputs, excluding energy consumed and simulated regolith.

Minimum Batch Requirements: The requirements for batches of eligible trash items used in the Final Round Demonstration, as outlined in the Minimum Batch Requirements section.

Pre-Processing of Trash Items: In this challenge, pre-processing refers to a process where trash items are prepared for recycling and may include processes such as shredding, heating, or melting. Teams must address any necessary Pre-Processing of Trash Items in their Milestone Round design and their Final Round design, and teams are encouraged but not required to build and demonstrate Pre-Processing of Trash Items during the Final Round Demonstration.

Prototype Solution: Hardware systems, sub-systems, and components for Recycling of Trash Items.

Recycling of Trash Items: In this challenge, Recycling of Trash Items refers to a process for transforming trash items into a useful feedstock or end product. In this challenge, Recycling of Trash Items includes both pre-processing and transformation of trash items.

Usable Outputs: A usable output is either a useful feedstock or useful end product.

Useful End Product: A usable output that has the potential to be useful in a future mission to the lunar surface or martian surface. Teams will be responsible for defining the usefulness of any end product that they produce.

Useful Feedstock: A usable output that is capable of being used in additive manufacturing or another process to make a useful end product. Teams will be responsible for characterizing and verifying the characterization of any feedstock they produce.

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Challenge Problem Statement

During missions to the Moon and Mars, common trash items made of fabrics, plastics, foam, composites, and metals will accumulate as a result of crew activities, system operations, industrial activities, and the establishment of habitats. Without new solutions for efficient management, trash items will either need to be consolidated on the planetary surface at a controlled disposal site that may incur significant costs or be transported away from the planetary surface for processing or disposal, also incurring significant costs and complexity for NASA and other entities. In addition, addressing trash in these ways represents lost potential for cost recuperation and will result in the need to continually bring new supplies from Earth.

Challenge Goals

The LunaRecycle Challenge seeks to incentivize the design and rapid prototyping of innovative and effective solutions that can transform eligible trash items into useful feedstocks and/or end products. NASA is seeking solutions that will help minimize the need to transport trash away from the Moon or Mars or dispose of trash on either planetary surface and demonstrate the potential to enable the most efficient use of materials sent to the Moon or Mars.

The LunaRecycle Challenge seeks Prototype Solutions that optimize Energy Efficiency, Mass Efficiency, and the crew time required for operations. The challenge also seeks creative and technically sound Digital Twin Solutions that demonstrate how a machine learning-driven virtual model of a team's Prototype Solution can support future space operations.

Challenge Background

About Centennial Challenges

Centennial Challenges strive to be audacious and inspirational with a focus on long-range NASA goals while addressing complex mission needs. Challenges also identify new sources of expertise and stimulate current and new markets for government and commercial collaboration. The competitions ensure NASA's needs are met and provide terrestrial applications and opportunities for the betterment of humanity.

Trash in Space

As NASA prepares to establish longer-term human operations beyond Earth, recycling and trash management will play a critical role in reducing the need for frequent resupply and in making the most of what is already on board. The ability to convert trash into useful resources can also support broader goals like in-situ manufacturing and crew self-sufficiency, helping enable missions that are more efficient, cost-effective, and less reliant on Earth-based logistics.

NASA's Moon to Mars Architecture highlights reuse and responsible use as key tenets of long-term mission success. It includes specific goals like demonstrating the ability to use materials from the mission environment or from previously shipped goods and minimizing the disposal of trash and the need to bring new materials from Earth.

NASA's Space Technology Mission Directorate (STMD), Science Mission Directorate (SMD), and Exploration Systems Development Mission Directorate (ESDMD) have taken an interest in economically sustainable practices for long-duration missions to the Moon and Mars. Recycling has been called out specifically in publicly released documents such as the STMD Shortfalls and the SMD Biological and Physical Sciences Decadal Survey. Initial investments to address these interests have been made to enable the analysis of available waste streams for recyclability, determine near-term approaches for waste down-cycling, and demonstrate a standalone recycling and additive manufacturing system. These, and other similar efforts internal to NASA, only constitute a small part of the problem that may be solved through in-space recycling systems, and this challenge targets identifying novel approaches and partnerships to help address this need.

LunaRecycle Challenge Phase 1

In Phase 1, the challenge was divided into two competition tracks, one focused on designing a Digital Twin of a recycling system and one focused on designing a Prototype of a recycling system. NASA awarded a total of $850,000 in Phase 1—$250,000 to five (5) teams in the Digital Twin Track and $600,000 to eight (8) teams in the Prototype Track. NASA also recognized four top international teams across both tracks.

Challenge Overview

The LunaRecycle Challenge is a $3 million, two-phase competition focused on the development of solutions that can transform trash items into useful feedstocks and/or end products on the surface of the Moon and Mars.

In Phase 1, the challenge was divided into two competition tracks, one focused on designing a Digital Twin and one focused on designing a Prototype. Phase 2 will still seek both types of solutions—Prototype Solutions and Digital Twin Solutions. However, in Phase 2, the competition will be combined into a single competition track where the Prototype Solution will be required, and a Digital Twin Solution will be optional. In Phase 2, a team's Digital Twin Solution (if they choose to develop one) should be a digital model of the team's Prototype Solution, not an entirely different system or approach.

In Phase 2, the challenge will have two rounds of competition, a Milestone Round and a Final Round. In the Milestone Round, all teams are required to submit a preliminary design for their Prototype Solution. Teams invited to compete in the Final Round are required to submit a final design for their Prototype Solution and build and demonstrate their Prototype Solution hardware at a TBD demonstration location. Teams will have the option of also submitting a Digital Twin Solution in the Milestone Round and in the Final Round (if they are invited to participate in the Final Round).

NASA will offer prizes for both Prototype Solutions and Digital Twin Solutions. Teams may choose to compete for Prototype prizes alone or for both Prototype and Digital Twin prizes. However, teams may not compete for only the Digital Twin prizes.

The challenge will run for a total of 13 months, from August 2025 until August 2026. Winners are expected to be announced in August 2026.

Eligibility

Phase 1 of the challenge was open to both U.S. teams and international teams. However, in Phase 2, the challenge will be open only to U.S. teams. U.S. teams may, in some cases, include team members that are foreign nationals, as outlined in the Legal Requirements section below.

Any eligible team may compete in Phase 2. Teams are not required to have competed in Phase 1 in order to compete in Phase 2.

Additional legal requirements related to eligibility can be found in the Legal Requirements section below.

Multiple Submissions Not Allowed

Each team may only submit one (1) Prototype Solution and up to one (1) Digital Twin Solution (if the team is competing for the Digital Twin prizes). Multiple submissions by the same team are not allowed in Phase 2.

Two Rounds

In Phase 2, there will be two rounds of competition—a Milestone Round and a Final Round.

In each round, all teams are required to submit a Prototype Solution. Details about the submission requirements and deadlines for the Prototype Solution can be found in the Registration and Submissions section below.

In each round, each team also has the option of submitting a Digital Twin Solution. Details about the submission requirements and deadlines for the Digital Twin Solution can be found in the Registration and Submissions section below.

Milestone Round

In the Milestone Round, teams will submit a preliminary design of their Prototype Solution and (if they are competing for the Digital Twin prize) a preliminary Digital Twin Solution.

The Milestone Round will determine which teams are invited to compete in the Final Round. Up to 20 teams will be invited to compete in the Final Round.

To receive an invitation to compete in the Final Round, teams must: 1) Achieve a minimum score of 50 points for their Prototype Solution; AND 2) achieve at least one of the following:

- Rank among the top 20 Prototype Solutions, as determined by the Judging Panel
- Achieve a minimum score of at least 70 points for their Digital Twin Solution

The distribution of prizes to teams in the Milestone Round is discussed in the Prize Purse section below.

Teams may choose to defer submitting a preliminary Digital Twin solution in the Milestone Round and still present their final Digital Twin Solution and compete for the Digital Twin prizes in the Final Round (if they are invited to participate in the Final Round).

Final Round

In the Final Round, teams will develop, build, and demonstrate hardware systems, sub-systems and components for their Prototype Solution. Teams will submit a final design of their Prototype Solution and conduct a demonstration of their Prototype Solution at a TBD demonstration site. Teams may also develop, submit, and demonstrate a Digital Twin Solution in the Final Round.

Preliminary details regarding the demonstration are included in the Final Round Demonstration section below. Additional details about the dates, timing, expectations, and other logistics related to demonstrations will be provided to teams invited to compete in the Final Round.

Prize Purse

In Phase 2, the LunaRecycle challenge will have a total prize purse of up to $2,000,000. Teams must meet all Legal Requirements in order to receive a prize from NASA.

Prizes will be available for each type of solution (Prototype and Digital Twin) in both a Milestone Round and Final Round. Prizes are expected to be distributed as explained in TABLE 1. Teams are permitted to win multiple prizes.

Up to ten (10) Milestone prizes for each type of solution will be available. As discussed in the Milestone Round section above, up to 20 teams may be invited to compete in the Final Round. That means that up to ten (10) teams may be invited to compete in the Final Round but will not receive a Milestone prize. All teams invited to compete in the Final Round will be eligible for Final Round prizes, even if they did not receive a Milestone prize.

In the Final Round, there are three types of prizes available, Best Overall Prizes (1st and 2nd place); Technical Achievement Prizes; and the People's Choice Award. Each type is explained in more detail in TABLE 2.

TABLE 1. Prize Purse Distribution

Round	Number of Prizes	Prototype Solution Prize	Digital Twin Solution Prize	Total Prizes
Milestone Round	Up to 10 per type of solution (Prototypes and Digital Twins)	$50,000	$25,000	**Up to $750,000**
Final Round	Up to 6 for Prototypes and up to 4 for Digital Twins	Best Overall 1st Place: $400,000 Best Overall 2nd Place: $200,000 Technical Achievement Prizes (4): $50,000 each	Best Overall 1st Place: $250,000 Best Overall 2nd Place: $125,000 Technical Achievement Prizes (2): $25,000 each	**Up to $1,225,000**
Final Round (Bonus)	Up to 1	People's Choice Award: $25,000		**Up to $25,000**
TOTALS		**$1,300,000+ one People's Choice across both types of solutions**	**$675,000+ one People's Choice across both types of solutions**	**$2,000,000**

TABLE 2. Types of Prizes in the Final Round

Type	Description	Judging Criteria	How Prize is Determined
Best Overall Prizes	Overall winners of the challenge (1st place and 2nd place)	See TABLE 8 (Prototype) and TABLE 10 (Digital Twin)	Determined by the Judging Panel
Technical Achievement Prizes	Most Innovative Prize (Prototype)	See TABLE 9	Determined by the Judging Panel
	Highest Energy Efficiency Prize (Prototype)	See TABLE 9	Calculated at the Final Round Demonstration
	Highest Mass Efficiency Prize (Prototype)	See TABLE 9	Calculated at the Final Round Demonstration
	Most Trash Types Recycled Prize (Prototype)	See TABLE 9	Determined by the Judging Panel
	Most Innovative Prize (Digital Twin)	See TABLE 11	Determined by the Judging Panel
	Best Visualization Prize (Digital Twin)	See TABLE 11	Determined by the Judging Panel
People's Choice Award	Favorite Solution and Demonstration	Assessment by attendees of the day/portion of the Final Round Demonstration that is open to the public	Voting by attendees of the day/portion of the Final Round Demonstration that is open to the public. See Final Round Demonstration section for more details.

Competition Calendar

Phase 2 is expected to last 13 months. An expected competition calendar is summarized in TABLE 3. Updates to the competition calendar will be provided at: https://lunarecycle.competitionsciences.org/.

TABLE 3. Competition Calendar

Expected Dates	Activity
August 11, 2025	Phase 2 Launch Registration Opens
August – November/ December 2025	Webinars focused on: -Phase 2 Challenge Rules -Team Formation and Matchmaking -NASA Needs and Goals -Milestone Submission Tutorial
By October 1, 2025	Institute of Competition Sciences website opens to Milestone Round Submissions
January 22, 2026 4:00 PM Eastern Standard Time (EST)	Deadline for Registration Deadline for the Milestone Round Submissions
February 25, 2026	NASA announces Milestone Winners and additional teams invited to compete in the Final Round
By May 31, 2026	Institute of Competition Sciences website opens to Final Round Submissions
July 22, 2026 4:00 PM Eastern Daylight Time (EDT)	Deadline for Final Round Submissions
No earlier than August 17, 2026	Deadline for Prototype Solution hardware to arrive at demonstration site
No earlier than Week of August 17, 2026	Final Round Demonstration
No later than August 28, 2026	NASA announces Final Round winners

Technical Requirements (Prototype Solution)

Prototype Solutions are Required

In Phase 2, all teams are required to submit a Prototype Solution.

Scope of the Prototype Solution

Prototype Solutions must be focused on the recycling of eligible trash items.

Sorting of trash items and cleaning of trash items are not in the scope of this challenge. Teams may assume that all trash items are already sorted and clean and free of contamination.

Any required pre-processing of trash items (such as shredding, heating, or melting) must be included in the Prototype Solution design and is encouraged but not required to be included in the Prototype Solution demonstration.

For the demonstration, teams that are not demonstrating pre-processing as part of their solution may use any alternative method to prepare their trash items for recycling. For example, if a team's solution requires fabric to be shredded before it can be recycled, the team may shred the material on site using any method, including a very basic method like cutting it up with scissors.

The recycling of trash items must result in one or more usable outputs. A usable output may be either a feedstock that is capable of being used in additive manufacturing or another process to make a useful end product; or an end product that has the potential to be useful in a future mission to the lunar surface or martian surface. Teams will be responsible for characterizing and verifying the characterization of any feedstock they produce. Teams will also be responsible for defining the usefulness of any end product that they produce.

The challenge is not seeking solutions that only burn or incinerate trash. However, teams may submit solutions that use heat, melting, molding, shredding, gasification, or other similar approaches as part of a recycling system.

Scale of the Prototype Solution

Teams must design and demonstrate a solution at a scale appropriate to recycle at least one batch of eligible trash items. The minimum requirements for a batch are explained in the Minimum Batch Requirements section below.

In Phase 1, the challenge included 6 eligible trash categories and 17 eligible trash items. In Phase 2, the challenge will focus on eight (8) eligible trash items, as described in TABLE 4 below. These items represent trash that is both likely to accumulate in large quantities during planetary surface operations and considered difficult to address with current technologies.

In the Final Round Demonstration, NASA expects that there will inevitably be some constraints on the amount of space each team is allocated for the demonstration, based on the size of the

facility or site. NASA will work with partners and teams to ensure that the space available for demonstration is congruent with the requirements of the challenge.

Eligible Trash Items

In Phase 2, teams must recycle at least one and up to three batches of eligible trash items described in TABLE 4. Minimum requirements for batches containing a single eligible trash item and for batches containing multiple eligible trash items are explained in the Minimum Batch Requirements section below.

TABLE 4 provides details about the eight (8) eligible trash items and links to a commercially available equivalent item that teams must use for the Final Round Demonstration (see Final Round Demonstration section below). If there is a need to update or change any of these commercially available equivalents, teams will be notified at the beginning of the Final Round, or as soon as possible.

TABLE 4. Eligible Trash Items

Type of Eligible Trash Item	Approximate Materials	Form Factor	Approximate Moisture Content (%)	Commercially Available Equivalent
Aluminum structure/struts	Aluminum >90%	Aluminum 6061 Pipe, size ½" OD x 12"	~0%	Standard-Wall Aluminum Pipe https://www.mcmaster.com/5038K182/
Clothing	Cotton 100%	White cotton undershirt, size Large	~0%	Hanes Undershirt https://www.hanes.com/products/hanes-men-s-undershirt-pack-v-neck-moisture-wicking-100-cotton-with-odor-control-6-pack/777vp6
Drink Pouch	Aluminum 24% Polyethylene 65% Polyethylene Terephthalate 11%	Empty foil bag, size 3 ⅜" x 2 ½" x 13"	3%	Uline Gusseted Foil Coffee Bags https://www.uline.com/Product/Detail/S-18228SIL/Food-Bags/Gusseted-Foil-Coffee-Bags-3-3-8-x-2-1-2-x-13-Silver
Gloves	Nitrile 100%	Nitrile glove, size Medium	2%	Med Pride Medical Examination Nitrile Gloves https://www.medpride.com/product/nitrile-gloves/
Nomex Bag	Nomex 100%	Nomex White Hood	~0%	Nomex White Hood https://www.magidglove.com/magid-nom10-nomex-white-hood-nom10
Reclosable Bag	Polyethylene 100%	Reclosable Bag, size 5"x10"	~0%	Uline Reclosable Bag https://www.uline.com/Product/Detail/S-3121/Reclosable-Poly-Bags/5-x-10-4-Mil-Reclosable-Bags
Rehydratable Pouch	Nylon 41% Polyethylene 33% Ethylene vinyl alcohol (EVOH) 11%	Empty rehydratable pouch	4%	Original item is no longer available. A new link will be provided soon in another revision of the challenge rules.
Zotek F30 Aviation	Zotek F30 Aviation 100%	Zotek F30 Aviation foam, 12"x12"x1"	~0%	Zotek F30 Aviation https://www.zotefoams.com/wp-content/uploads/2025/03/PIS-Z001-ZOTEK-F30-Aviation-r1.pdf

No Lunar Environmental Conditions Required for Prototype Solution

In Phase 2, teams are not required to address any lunar environmental conditions in their Prototype Solution design or demonstration. In the Final Round, Prototype Solution hardware demonstrations will be conducted in Earth ambient conditions.

Use of Simulated Regolith

Teams are permitted to use simulated lunar regolith in Phase 2 of the challenge. However, if a team chooses to use simulated lunar regolith, they are responsible for procuring it, transporting it to the Final Round Demonstration, and disposing of it after the demonstrations, following safe handling procedures at each step.

Teams that would like to use simulated lunar regolith, should use LHS-1 Lunar Highlands Simulant, the specifications for which can be found at: https://sciences.ucf.edu/class/wp-content/uploads/sites/23/2019/02/Spec_LHS-1.pdf.

Use and Disclosure of Artificial Intelligence

Artificial Intelligence (AI) is permitted in this challenge. Teams may use AI to develop their solutions and prepare their submissions.

However, if a team uses AI tools or models (such as ChatGPT, Copilot, or others) to help create any part of their submission or solution (e.g., text, images, analysis, code, or design), they must clearly state that use and briefly describe how the AI was used.

In addition, teams are strongly encouraged to carefully review any AI-generated text or graphics to ensure accuracy, credibility, and alignment with the high technical standards of this challenge.

Technical Requirements (Digital Twin Solution)

In Phase 2, all teams also have the option of developing a Digital Twin Solution. Teams are not required to develop a Digital Twin Solution.

A team's Digital Twin Solution must be a digital model of the team's Prototype Solution. The Digital Twin Solution should not be an entirely different system or approach.

Digital Twin Scenarios

In the Milestone Round, a team's digital twin must address a total of two (2) scenarios: one (1) nominal scenario and one (1) off-nominal scenario. In the Final Round, a team's digital twin must address a total of three (3) scenarios: one (1) nominal scenario and two (2) off-nominal scenarios.

A team's digital twin must address:

- **Nominal Scenario**: In this scenario, the digital twin will mimic the conditions of the demonstration that the team will conduct with their Prototype Solution in the Final Round Demonstration.

In addition, a team's digital twin must address off-nominal scenarios from the following list:

- **Expanded Capabilities Scenario**: In this scenario, the digital twin must show an expanded capability compared to the demonstration that the team will conduct with their Prototype Solution in the Final Round Demonstration. Expanded capabilities may include any of the following: recycling of additional eligible trash items; recycling process that results in additional or different usable outputs; higher efficiency recycling process; faster recycling rate for the same mass of trash items; and/or increased automation that reduces the number of crew or amount of crew time required for operation of the system.

- **Power Outage Scenario**: In this scenario, the digital twin must address the interruption of power during one cycle of the recycling process. The power outage will occur at the point in the recycling process when the process is 50% complete. The power will remain out for 5 minutes. Upon the return of power, the digital twin should address a restart of the system and completion of the recycling system through the end of the cycle.

- **Planetary Surface Operations Scenario**: In this scenario the digital twin must address operation of the Prototype Solution on either the Moon or Mars (not both). The operation may be either inside a pressurized habitat, outside on the surface, or a combination of both inside and outside. In this scenario, the digital twin must incorporate the Planetary Environmental Conditions listed in TABLE 5 below for the location they choose.

- **A different off-nominal scenario defined by the team**: The team may propose a different off-nominal scenario that their digital twin will address instead of one of the three NASA-defined off-nominal scenarios above.

TABLE 5. Planetary Environmental Conditions for Planetary Surface Operations Scenario

Location	Outside on the Surface	Inside a Pressurized Habitat
Lunar Environmental Conditions	-Gravity is 1.625 m/s^2 -Atmospheric pressure is 0.3 nanopascals (nPa) -Temperatures range from: -223°C to -23°C	-Gravity is 1.625 m/s^2 -Atmospheric pressure is 57.2 kilopascals (kPa) -Temperatures range from approximately 18°C to 27°C -Air composition is approximately 34% oxygen and 66% nitrogen and water vapor
Martian Environmental Conditions	-Gravity is 3.73 m/s^2 -Atmospheric pressure is 636 pascals (Pa) -Temperatures range from: -153°C to 20°C -Atmospheric composition is approximately 95% carbon dioxide and trace amounts of other gases including oxygen	-Gravity is 3.73 m/s^2 -Atmospheric pressure is 57.2 kilopascals (kPa) -Temperatures range from approximately 18°C to 27°C -Air composition is approximately 34% oxygen and 66% nitrogen and water vapor

No Recommendations or Limitations for Software

There are no specific software tools recommended for developing a Digital Twin Solution. Teams may use whatever software, programs, models, or digital tools they would like to use to develop their digital twin.

Use and Disclosure of Artificial Intelligence

Artificial Intelligence (AI) is permitted in this challenge. Teams may use AI to develop their solutions and prepare their submissions.

However, if a team uses AI tools or models (such as ChatGPT, Copilot, or others) to help create any part of their submission or solution (e.g., text, images, analysis, code, or design), they must clearly state that use and briefly describe how the AI was used.

In addition, teams are strongly encouraged to carefully review any AI-generated text or graphics to ensure accuracy, credibility, and alignment with the high technical standards of this challenge.

Finally, the team's Digital Twin Solution presentation (in the Milestone Round Submission, in the Final Round Submission, and at the Final Round Demonstration) should be made by the team leader and/or team members, not by an AI.

Registration and Submissions

Phase 2 Registration

Registration will open when the challenge opens.

All teams must register for the challenge by January 22, 2026, 4:00PM Eastern Standard Time (EST).

Teams are strongly encouraged to begin the registration process as soon as possible and well before the deadline.

NASA has contracted with the Institute of Competition Sciences (ICS) to help administer Phase 2 of the challenge.

In order to register, all teams must:

- Create an account at the ICS website: https://lunarecycle.competitionsciences.org/. If you already have an account from Phase 1 of the challenge, you may use the same account with the same username and password or create a new account with a new username and password.
- Complete the Registration Form to create a team, designating a team name and team leader. All teams in Phase 2 must create a new team, even if the team name and team leader are the same as in your Phase 1 team. You must create a new team even if you are using the same account that you used in Phase 1.
- Download the Team Agreement template.
- Upload a completed and signed Team Agreement.
- Provide Proof of Citizenship for the Team Leader and each Team Member
- If the team is competing as an Entity, provide Proof of Incorporation showing that the entity is incorporated in and maintains a primary place of business in the United States.
- Provide Proof of Insurance or Financial Responsibility for the Milestone Round in the amount of USD $5,000.
- Affirm that, if the team is invited to compete in the Final Round, the team leader understands that the team will be required to provide Proof of Insurance or Financial Responsibility for the Final Round in an amount up to USD $250,000.

Once a team has completed all of these items, they will receive a communication explaining whether: 1) their registration has been verified; 2) their registration has not been verified because additional information is required; or 3) their registration has not been verified because they are not eligible.

If a team is invited to participate in the Final Round, they will be required to provide the following additional documentation to re-verify their eligibility:

- Proof of Insurance or Financial Responsibility for the Final Round in an amount up to USD $250,000

Further instructions for providing this documentation will be provided to teams invited to participate in the Final Round.

Milestone Round Submissions

The ICS website will be open to Milestone Round Submissions by October 1, 2025.

All Milestone Round Submissions must be uploaded to the ICS website https://lunarecycle.competitionsciences.org/ by the deadline, January 22, 2026, 4:00PM Eastern Standard Time (EST).

All teams must submit a Prototype Solution, including the following:

- A completed **Milestone Round Submission Template for Prototype Solutions** (see Appendix A: Milestone Round Submission Template for details and instructions);

- **Link to a publicly accessible video** (no longer than 5 minutes) showing progress to date, such as any materials, components, subsystems, or testing that the team has conducted. This is intended to demonstrate the team's capabilities and progress and help determine the team's expected readiness to demonstrate in the Final Round.

- A **Preliminary Demonstration Proposal** saved as a PDF document that addresses the questions in Appendix E: Preliminary Demonstration Proposal; this proposal will be for informational purposes only and will not be judged.

Teams that choose to also compete for the digital twin prizes must submit the following:

- A **presentation** addressing details about the team's preliminary Digital Twin Solution, as outlined in Appendix B: Milestone Round Submission Requirements for Digital Twin Solutions

- **Link to a publicly accessible video** recording of the presentation (no longer than 30 minutes) that includes a demonstration of at least a portion of a preliminary digital twin visualization for 1) the nominal scenario and 2) one (1) of the off-nominal scenarios. The recorded presentation should be given by the team leader and/or team members, not by an AI.

- A completed **Preliminary Demonstration Proposal** saved as a PDF document that addresses the questions in Appendix E: Preliminary Demonstration Proposal; this form will be for informational purposes only and will not be judged. The Preliminary Demonstration Proposal for the Prototype Solution and for the Digital Twin Solution should be in a single PDF document.

Final Round Submissions

The ICS website will be open to Final Round Submissions by May 31, 2026.

All Final Round Submissions must be uploaded to the ICS website https://lunarecycle.competitionsciences.org/ by the deadline, July 22, 2026 at 4:00 PM Eastern Daylight Time (EDT).

All teams must submit a Prototype Solution, including the following:

- A completed **Final Round Submission Template for Prototype Solutions** (see Appendix C: Final Round Submission Template for Prototype Solutions for details and instructions)

Teams that choose to also compete for the digital twin prizes should submit the following:

- A **presentation** addressing details about the team's complete Digital Twin Solution (see Appendix D: Final Round Submission Requirements for Digital Twin Solutions for details and instructions)

- **Link to a publicly accessible video** recording (no longer than 60 minutes) of the presentation, that includes a demonstration of the complete digital twin visualization for 1) the nominal scenario and 2) two (2) off-nominal scenarios. The recorded presentation should be given by the team leader and/or team members, not by an AI.

Final Round Demonstration

Location and Timing

All teams invited to compete in the Final Round Demonstration will deliver, assemble, and demonstrate their solutions at a TBD demonstration site in mid- to late August 2026.

The demonstration site is expected to be located in the South/Southeast or Northeast region of the United States. The demonstration location may be a NASA facility, an academic facility, or a commercial facility. Additional details will be provided to teams at the beginning of the Final Round, or sooner if possible.

All teams must deliver their hardware to the demonstration site by a TBD date in mid to late August 2026. Teams that are shipping their hardware must ensure that it will arrive by this deadline. NASA and/or its partners will arrange a place to receive and store hardware that arrives before the deadline, for at least seven (7) days prior to the deadline. Additional details will be provided to teams invited to compete in the Final Round.

Demonstrations, including unpacking and assembly of solutions, review of the demonstrations by judges, and disassembly of hardware is expected to be conducted over approximately one week (Monday through Friday) in mid to late August 2026.

Teams are expected to have up to two days to unpack and assemble their hardware in preparation for the demonstrations. Teams that are also competing for a digital twin prize will also use this time to set up any equipment that is necessary to demonstrate their digital twin.

Demonstrations are expected to be conducted over two to three days. Demonstrations may be divided into morning and afternoon shifts and/or specific time slots, and each team will be assigned a window of time (up to TBD hours) for their demonstration.

During the demonstrations, performance data from the demonstration will be compiled, and afterwards, made available to all judges for review.

Following the end of all demonstrations, teams will disassemble and re-pack hardware for shipping or another method of return to the team.

Additional logistics and a more detailed schedule related to demonstrations will be provided to teams invited to compete in the Final Round.

Resources at the Demonstration Site

NASA will define the resources available to teams at the demonstration site in detail once the demonstration site has been confirmed. The demonstration site is expected to be confirmed by the beginning of the Final Round, or sooner if possible.

NASA and/or its partners expect to provide at least the following resources:

- Electricity and electrical outlets (at a minimum, 120V AC)
- Water to be used in the recycling process (amounts and specifications TBD)
- A scale for verifying the mass of inputs and outputs
- Tables where teams will set up their hardware for demonstration
- Chairs to accommodate team members at the tables
- Screen for showing the digital twin demonstrations

In addition, NASA and/or its partners expect to provide all eligible trash items for the demonstrations. NASA will confirm or update this responsibility by the beginning of the Final Round, or sooner if possible.

Prototype Demonstration Requirements

During the demonstration, teams must complete at least one and up to three cycles of their recycling process during their demonstration window. Teams will recycle one batch of eligible trash items per cycle.

All demonstrations will be conducted in Earth ambient conditions.

During the demonstration, all teams will be expected to do the following:

- Verify the mass (kg) of their hardware
- Verify that their batches of eligible trash items meet the Minimum Batch Requirements, see next section

- Verify the mass (g or kg) of at least one and up to three batches of eligible trash item(s) to be used in the demonstration
- Transform at least one and up to three batches of eligible trash item(s) into at least one useful feedstock or end product
- Measure the amounts of all inputs used in the demonstration
- Show evidence that the feedstock(s) or end product(s) meet the characterization and quality standards that the team outlined in their final design

Additional details will be provided to teams invited to participate in the Final Round.

Minimum Batch Requirements

Each team must demonstrate recycling of at least one and up to three batches of eligible trash items. A batch may include a single trash item or multiple trash items. If a team is demonstrating more than one batch, all batches must be identical.

If a batch contains a single eligible trash item, it must:

- Contain at least 500 grams of the item.

If a batch contains multiple eligible trash items, it must:

- Have a total mass of at least 500 grams; AND
- Each item must represent at least 10% of the total mass.

For example:

- Team A's batch contains 550 grams of Clothing. The total mass is more than 500 grams, therefore Team A meets the minimum batch requirements.

- Team B's batch contains 400 grams of Aluminum and 100 grams of Drink Pouches. The total mass is 500 grams, with Aluminum representing 80% and Drink Pouches representing 20%. Therefore, Team B meets the minimum batch requirements.

- Team C's batch contains 400 grams of Aluminum, 80 grams of Drink Pouches and 20 grams of Reclosable Bags. The total mass is 500 grams, with Aluminum representing 80% and Drink Pouches representing 16%, but Reclosable Bags represent only 4%, which is below the 10% minimum. Therefore, Team C does not meet the minimum batch requirements and cannot use this batch in the demonstration.

Performance Data and Scoring

In order to receive a score for their Prototype Solution demonstration, teams must successfully complete at least one cycle of their recycling process. If a team cannot successfully complete at least one cycle of their recycling process, they will not be eligible for a prize.

During the Final Round Demonstration, teams will be judged on performance data from one cycle of their recycling process, as described in the Judging Criteria (Final Round) section. If a

team successfully completes more than one cycle of their recycling process, they may choose the cycle with the best performance for consideration by the judges.

Additional details regarding collection of performance data during the demonstrations will be provided to teams invited to participate in the Final Round.

Crew Limitations During Demonstrations

During the Final Round Demonstration, teams demonstrating only a Prototype Solution may bring up to four (4) team members, including the team leader. Teams demonstrating both a Prototype Solution and a Digital Twin Solution may bring up to six (6) team members, including the team leader.

All team members in attendance may participate in unpacking, assembling, and dissembling their solutions. However, only up to four (4) team members may participate at a time in the operation of the Prototype Solution or Digital Twin Solution.

Teams are encouraged to minimize the number of team members required to operate the Prototype Solution during the demonstration. Teams will be judged and scored on the number of team members and minutes per team member required for Prototype Solution operations, as described in the Judging Criteria (Final Round) section.

All team members attending and participating in the demonstrations must be an eligible team leader or team member listed on the Team Agreement. Teams will have an opportunity to update their Team Agreement prior to the Final Round Demonstration. The team leader is expected to attend and participate in the Final Round Demonstration.

Digital Twin Demonstrations

Teams that are also demonstrating a Digital Twin Solution will present and operate their digital twin at a demonstration session. Each team will have no more than a combined 60 minutes for their presentation and demonstration. If teams cannot complete their presentation and demonstration in 60 minutes, they will not receive additional time; rather they will be judged on the portion that was completed in 60 minutes.

Teams are encouraged to structure their presentation and demonstration as follows. However, teams may allocate time as they see fit, as long as they fit within the 60-minute requirement.

- Overview Presentation (15 minutes)
    - How the digital twin was developed and validated
    - Key assumptions, parameters, and system logic
    - An explanation of how the model connects to and communicates with the physical prototype

- Live Model Operation of Scenarios (45 minutes)
    - Teams will demonstrate how their digital twin addresses the nominal scenario and two (2) off-nominal scenarios.

Following the 60-minute presentation, the Judging Panel will have an additional 15 minutes to ask questions of the team. It is up to the Judging Panel to decide what questions to ask and how much of this time to use.

People's Choice Award Voting

The People's Choice Award in the amount of $25,000 will be awarded to the team that receives the most votes from attendees during the Final Round Demonstration.

The Final Round Demonstration is expected to be open to the public on a final "industry day" or similar event during the demonstration week. All attendees of the public event that are not team leaders or team members will be eligible to vote for their favorite solution/demonstration. Each attendee will receive one vote.

Attendees may cast their vote for whichever team they personally find the most impressive, compelling, innovative, or based on any other criteria they choose. There is no specific Judging Criteria for the People's Choice Award—voting is entirely based on attendees' opinions.

Voting will close at a designated time prior to the beginning of the winners' announcement and closing ceremony. The team with the most votes will be the winner of the People's Choice Award. In the event of a tie, the teams with the most votes will split the prize equally.

Winners' Announcement and Closing Ceremony

All winners are expected to be announced at a closing ceremony on the last day of the demonstration week. The awards ceremony may be livestreamed and/or recorded.

Judging Criteria (Milestone Round)

In the Milestone Round, a Judging Panel will evaluate teams on their Milestone Round Submissions. TABLE 6 summarizes the Milestone Round Judging Criteria for Prototype Solutions, and TABLE 7 summarizes the Milestone Round Judging Criteria for Digital Twin Solutions.

A total of 100 points is available for each type of solution. In order to be eligible for a Milestone Prize, teams must achieve a minimum score of 60 points.

In order to be eligible to receive an invitation to compete in the Final Round, teams must: 1) Achieve a minimum score of 50 points for their Prototype Solution; AND 2) achieve at least one of the following:

- Rank among the top 20 Prototype Solutions, as determined by the Judging Panel
- Achieve a minimum score of at least 70 points for their Digital Twin Solution

TABLE 6. Milestone Round Judging Criteria (Prototype Solutions)

Criteria	Description	Points
Completeness of the Submission	Did the team address all of the requirements listed in the submission template?	Pass/Fail
Vision and Innovation	-How well has the team articulated the vision and innovation for the solution? -How does the solution build or improve upon the current state of the art? -How does it leverage advanced technologies? -What is the commercial potential of the solution (terrestrial and/or in space)?	Up to 25 points
Feasibility	-How feasible will the design be to build and implement during the challenge? -How feasible will the design be to build and implement for a future NASA mission? -How well does the team understand and articulate potential technical risks and how they could be mitigated?	Up to 25 points
System Operating Requirements	-How well has the team minimized the mass and volume of the system? -What is the Energy Efficiency of the system? -What is the Mass Efficiency of the system? -How well has the team minimized the crew time necessary to operate the solution? -How well has the team minimized the production of hazardous byproducts, including particulate matter such as microplastics or metal shreds?	Up to 25 points
Usefulness of Outputs	-How useful are the outputs from the recycling process (feedstocks and/or end products)? -How well has the team described their method of characterizing and ensuring the quality of outputs?	Up to 10 points
Development Plan for Final Round	-How well has the team planned for actually developing, building, and testing hardware in the Final Round? -How well have they planned for the necessary personnel, budget, travel, and other development needs? -Does the team's video credibly demonstrate their capabilities, progress, and expected readiness to demonstrate in the Final Round?	Up to 15 points
TOTAL		**Up to 100 points**

TABLE 7. Milestone Round Judging Criteria (Digital Twin Solutions)

Criteria	Description	Points
Completeness	Did the team address all of the requirements listed in the submission requirements document?	Pass/Fail
Vision and Innovation	-How innovative is the approach? -How does the digital twin build or improve upon current state of the art digital twins? -How does the digital twin leverage advanced technologies?	Up to 20 points
Digital Twin Architecture	-Is the design approach technically sound? -Does it address all the necessary elements and characteristics of a digital twin? -Does it address all of the necessary engineering data and information?	Up to 30 points
Digital Twin Fidelity to the Prototype Solution	-Does it share the same dimensional attributes as the Prototype Solution? -Can it accept the same parameters as the Prototype Solution as inputs? -How accurately does it predict the form of the output with respect to the Prototype Solution?	Up to 20 points
Digital Twin Fidelity to the Off-Nominal Scenarios	-Does the preliminary digital twin address and visualize one off-nominal scenario? -How well are the conditions of the off-nominal scenario understood and represented?	Up to 20 points
Quality of the Preliminary Visualization	-What is the quality of the preliminary digital twin visualization (look and feel)? -What is the credibility of the preliminary digital twin visualization (how well does it represent the Prototype Solution and potential enhancements to the Prototype Solution)?	Up to 10 points
TOTAL		**Up to 100 points**

Judging Criteria (Final Round)

In the Final Round, a Judging Panel will evaluate teams on their Final Round Submissions and their demonstrations.

The following TABLES summarize the Judging Criteria for each of the Prototype Solution Prizes:

- TABLE 8 summarizes the Judging Criteria for the Best Overall Prizes (Prototype Solutions), which include 1st place and 2nd place. A total of 100 points is available. A total of up to 50 points will be awarded based on the Final Round Submission. A total of up to 50 points will be awarded for performance in the Final Round Demonstration. In order to be eligible for a prize, teams must achieve a minimum score of 60 points and successfully complete at least one cycle of their recycling process in the Final Round Demonstration. Teams that cannot successfully complete at least one cycle in the demonstration will not be eligible for a prize.

- TABLE 9 summarizes the Judging Criteria for the four Technical Achievement Prizes (Prototype Solutions).

The following TABLES summarize the Judging Criteria for each of the Digital Twin Solution Prizes:

- TABLE 10 summarizes the Judging Criteria for the Best Overall Prizes (Digital Twin Solutions), which include 1st place and 2nd place. A total of 100 points is available. A total of up to 50 points will be awarded based on the Final Round Submission. A total of up to 50 points will be awarded for performance in the Final Round Demonstration. In order to be eligible for a prize, teams must achieve a minimum score of 60 points and address all required digital twin scenarios in the demonstration.

- TABLE 11 summarizes the Judging Criteria for the two Technical Achievement Prizes (Digital Twin Solutions).

TABLE 8. Final Round Judging Criteria for Best Overall Prizes (Prototype Solutions)

Criteria	Description	Points
Completeness of the Submission	Did the team address all of the requirements listed in the submission template?	Pass/Fail
Vision and Innovation	-How well has the team articulated the vision and innovation for the solution? -How does the solution build or improve upon the current state of the art? -How does it leverage advanced technologies? -What is the commercial potential of the solution (terrestrial and/or in space)?	Up to 15 points
Feasibility	-How feasible will the design be to build and implement for a future NASA mission? -How well does the team understand and articulate potential technical risks and how they could be mitigated?	Up to 15 points
System Operating Requirements	-How well has the team minimized the mass and volume of the system? -What is the Energy Efficiency of the system? -What is the Mass Efficiency of the system? -How well has the team minimized the crew time necessary to operate and maintain the solution? -How well has the team minimized the production of hazardous byproducts, including particulate matter such as microplastics or metal shreds?	Up to 15 points
Net Outputs	-How useful are the outputs from the recycling process (feedstocks and/or end products)? -How well has the team described their method of characterizing and ensuring the quality of outputs?	Up to 5 points
Performance in the Demonstration	-How many types of eligible trash items (from one to eight, see TABLE 4) did the team recycle? -What is the Energy Efficiency of the system? -What is the Mass Efficiency of the system? -How many team members were required? How many minutes of time per team member were required? -Did the usable outputs meet characterization or quality standards, as defined by the teams?	Up to 50 points
TOTAL		**Up to 100 points**

TABLE 9. Final Round Judging Criteria for Technical Achievement Prizes (Prototype Solutions)

Prize	Judging Criteria	Teams Eligible to be Considered for the Prize
Most Innovative	Judges will review teams with the highest scores on the Vision and Innovation Judging Criteria and determine the winner.	Teams with top five (5) scores on the Vision and Innovation Judging Criteria (see TABLE 8) will be considered
Highest Energy Efficiency	Energy Efficiency will be measured during the Final Round Demonstration. The team with the highest Energy Efficiency will be the winner. In the event of a tie, the Judging Panel will break the tie.	Teams with highest Energy Efficiency will be considered
Highest Mass Efficiency	Mass Efficiency will be measured during the Final Round Demonstration. The team with the highest Mass Efficiency will be the winner. In the event of a tie, the Judging Panel will break the tie.	Teams with highest Mass Efficiency will be considered
Most Trash Types Recycled	Most Trash Types Recycled will be based on how many types of eligible trash items (see TABLE 4) each team recycles and the team's Mass Efficiency at the Final Round Demonstration. The Judging Panel will review these variables and determine the winner.	Teams that recycle at least two and up to all eight types of eligible trash items (see TABLE 4) will be considered

TABLE 10. Final Round Judging Criteria for Best Overall Prizes (Digital Twin Solutions)

Criteria	Description	Points
Completeness	Did the team address all of the requirements listed in the submission template?	Pass/Fail
Vision and Innovation	-How innovative is the approach? -How does the digital twin build or improve upon current state of the art digital twins? -How does the digital twin leverage advanced technologies?	Up to 20 points
Digital Twin Architecture	-Is the design approach technically sound? -Does it address and visualize all the necessary elements and characteristics of a digital twin? -Does it integrate all of the necessary engineering data and information?	Up to 20 points
Quality of the Visualization	-What is the quality of the digital twin visualization (look and feel)? -What is the credibility of the digital twin visualization (how well does it represent the Prototype Solution and potential enhancements to the Prototype Solution)?	Up to 10 points
Performance in the Demonstration	-How well did the team explain the digital twin architecture and engineering data in their presentation? -What were the levels of accuracy, cohesion, and predictive capabilities for the nominal scenario? -What were the levels of accuracy, cohesion, and predictive capabilities for the two off-nominal scenarios? -What was the quality of the visualization? -How well did the team address questions from the Judging Panel?	Up to 50 points
TOTAL		**Up to 100 points**

TABLE 11. Final Round Judging Criteria for Technical Achievement Prizes (Digital Twin Solutions)

Prize	Judging Criteria	Teams Eligible to be Considered for the Prize
Most Innovative	Judges will review teams with the highest scores on the Vision and Innovation Judging Criteria and determine the winner.	Teams with top five (5) scores on the Vision and Innovation Judging Criteria (see TABLE 10) will be considered
Best Visualization	Judges will review teams with the highest scores on the Quality of Visualization Judging Criteria and assess the quality of the visualization at the demonstration to determine the winner.	All teams that demonstrate a Digital Twin Solution at the Final Round Demonstration will be considered

Legal Requirements

In General

Teams are responsible for understanding and complying with these Legal Requirements.

Competition Eligibility Requirements

NASA welcomes applications from individuals, groups of individuals, and/or organizations or entities that meet the Eligibility Requirements provided below.

In order to participate in the challenge, each individual, whether acting alone or as part of a Team must identify their nationality.

No Team member shall be a citizen of a country on the NASA Export Control Program list of Designated Countries List Category II: Countries determined by the Department of State to support terrorism. The current list of designated countries can be found at http://oiir.hq.nasa.gov/nasaecp. Please check the link for the latest updates. This includes individuals with dual citizenship unless they are a U.S. citizen or a lawful permanent U.S. resident (green card holder).

While China is not a Category II designated country, pursuant to Public Law 116-6, Section 530, NASA is prohibited from participating, collaborating, or coordinating bilaterally in any way with China or any Chinese-owned entity. Team members who are citizens of China but not affiliated with a Chinese entity may be permitted to participate as a member of a Team but not as the Team Leader.

Subject to the conditions set forth herein, foreign nationals can participate as a member of a Team in the Challenge. However, foreign nationals are not eligible for a cash prize and must acknowledge acceptance of this by signing and submitting a Foreign Participant Acknowledgement Form in the Team Agreement.

Eligibility to Compete and Win Prizes from NASA

In order to compete and be eligible to win a prize from NASA:

- Individuals must be U.S. citizens OR permanent residents of the United States, AND over the age of 18.
- Organizations must be an entity incorporated in AND maintaining a primary place of business in the United States.
- Teams must be comprised of otherwise eligible individuals or organizations AND led by an otherwise eligible individual or organization.
- Team Leader must be a U.S. citizen or permanent resident.

A Team may include foreign nationals and be eligible to win prize money as long as the foreign national signs and delivers a disclosure wherein they disclose their citizenship and acknowledge that they are not eligible to win a prize from NASA, AND the foreign national is:

- An employee of an otherwise eligible U.S. entity participating in the challenge,
- An owner of such entity, so long as foreign citizens own less than 50% of the interests in the entity,
- A contractor under written contract to such entity, OR
- A full-time student who, during the time of the challenge, (1) is enrolled in an accredited institution of higher learning, (2) has a valid student visa and (3) is otherwise in compliance with all local, state, and U.S. Government laws and regulations regarding the sale and export of technology.

Team Members must furnish proof of eligibility (including proof of citizenship or permanent resident status, for individuals, and proof of incorporation and primary place of business, for entities) which proof must be satisfactory to NASA in its sole discretion. A Team's failure to comply with any aspect of the eligibility requirements will result in the Team being disqualified from winning a Prize from NASA.

U.S. government employees may enter the competition, or be members of prize-eligible teams, so long as they are not acting within the scope of their Federal employment, and they rely on no facilities, personnel, hardware, access, knowledge, information previously developed, or other resources that are available to them as a result of their employment except for those resources available to all other Teams on an equal basis.

U.S. government employees participating as individuals, or who submit applications on behalf of an otherwise eligible organization, will be responsible for ensuring that their participation in the Challenge is permitted by the rules and regulations relevant to their position and that they have obtained any authorization that may be required by virtue of their government position. Failure to do so may result in the disqualification of them individually or of the entity which they represent or in which they are involved.
Teams will be ineligible to win the Prize if any Team Member is a U.S. Government entity or employee acting within the scope of their employment. This includes any U.S. Government organization or organization principally or substantially funded by the U.S. Government, including Federally Funded Research and Development Centers, Government-owned, contractor operated (GOCO) facilities, and University Affiliated Research Centers. Any such entity or individual will obtain prior written approval from their cognizant ethics officer that such participation does not violate federal personnel laws or applicable agency policy. A copy of this approval to participate in the Challenge will promptly be provided to the University of Alabama.

Participants may not use Federal funds from a grant award, cooperative agreement, or other transaction award to develop their challenge submissions or to fund efforts in support of their challenge submissions.

Current employees, consultants, and students of University of Alabama may not participate as Team Members on a Team. Participation of such parties as Team Members on a Team will make a Team ineligible for any Prize award from NASA.

Team Roles and Responsibilities

Each Team will designate a Team Leader. The Team Leader will be responsible for compliance with the rules, including prize eligibility rules, by all members of their Team. Prize funding will be released only to the Team Leader.

Intellectual Property Rights

Notwithstanding anything to the contrary in these rules, NASA and University of Alabama claim no intellectual property (IP) rights from the Team. All trade secrets, copyrights, patent rights, and software rights will remain with each respective Team.

To the extent the Team owns IP resulting from its participation in the Challenge, the Team agrees to negotiate in good faith with NASA for a grant of a nonexclusive, nontransferable, irrevocable license to practice or have practiced for or on behalf of the United States, the intellectual property throughout the world, at reasonable compensation, if NASA chooses to pursue such a license.

Insurance and Indemnification

Each Team Member agrees to assume any and all risks and waives claims against University of Alabama and the U.S. Government and its related entities, except in the case of willful misconduct, for any injury, death, damage, or loss of property, revenue, or profits, whether direct, indirect, or consequential, arising from each Team Member's participation in the Challenge, whether such injury, death, damage, or loss arises through negligence or otherwise. For the purposes of this section, the term "related entity" means a contractor or subcontractor at any tier, and a supplier, user, customer, cooperating party, grantee, investigator, or detailee.

Team agrees to obtain any and all insurance policies and coverage as stated in the Team Agreement and required by its local, state, or Federal governments to conduct any and all activities related to or required by participation of Team and the Team Members in the Challenge. In addition, Teams are required to obtain liability insurance in the amount of $5,000 USD minimum for the Milestone Round and in an amount up to $250,000 USD minimum for the Final Round that covers each Team Member or otherwise demonstrate financial responsibility for that amount. The Team's liability insurance will provide coverage for all claims by (A) a third party for death, bodily injury, or property damage, or loss resulting from an activity carried out in connection with participation in the Challenge, with the U.S. Government and University of Alabama named as an additional insured under the Team's insurance policies; and (B) the U.S. Government, University of Alabama, and its contractors for damage or loss to Government or University of Alabama property resulting from or related to Challenge activities. The Team and all Team Members jointly and severally agree to indemnify the U.S. Government and University of Alabama against third-party claims for damages arising from or related to Challenge activities. Should an onsite activity be held, all insurance requirements of University of Alabama and/or any other onsite partner must be met.

Proof of insurance in such form as reasonably required by University of Alabama shall be provided to University of Alabama as outlined in Exhibit C of the Team Agreement. Alternatively, if Team intends to fulfill this requirement by demonstrating financial responsibility in the requisite amount, Team shall submit to University of Alabama in writing such information as demonstrates to University of Alabama, in University of Alabama's reasonable discretion, that Team has sufficient financial responsibility to cover the potential claims cited in the requisite minimum amount as outlined in Exhibit C of the Team Agreement. **Proof of insurance or demonstration of financial responsibility for the Milestone Round must be provided by January 22, 2026, at 4:00 PM Eastern Standard Time (EST).**

Use of Names, Trademarks, and Insights

Team may not use the name, trademark or insignia of University of Alabama, its contractors, collaborators, or NASA on its printed materials related to the participation of Team in the Challenge without University of Alabama's or its contractor's, collaborator's, or NASA's prior written consent, whichever Party is applicable.

Team agrees that unauthorized use of such names, trademarks, and insignias shall result in elimination from participation in the Challenge if Team continues unauthorized use after being notified to cease and desist by University of Alabama or NASA, as applicable.

Delay, Cancellation or Termination

The Team acknowledges that circumstances may arise that require the Challenge to be delayed indefinitely or canceled. Such delay or cancellation, and/or the termination of the Challenge, shall be within the full discretion of NASA, and the Team accepts any risk of damage or loss due to such delay, cancellation, and/or termination.

Appendix A: Milestone Round Submission Template for Prototype Solutions

General Instructions:

- This template includes all of the required sections that your team should address for your Prototype Solution.
- In addition to this template, teams are also required to submit the following items, as described in the Milestone Round Submissions section:
    - A link to a publicly accessible video (no longer than 5 minutes) showing progress to date, such as any materials, components, subsystems, or testing that the team has conducted; and
    - A Preliminary Demonstration Proposal.
- If you are also submitting a Digital Twin Solution, please also submit the required items for a digital twin described in the Milestone Round Submissions section.
- Your submission must address each required section and topic described below. PLEASE NOTE: Any submission that does not address all of the requirements will receive a "Fail" score for completeness and will not be eligible for a prize.

Submission Document Instructions:

- All submissions must be in English; submissions in any other language will not be judged and will not be eligible for a prize.
- Teams should maintain all numbered section headings in their submission.
- The submission must be a PDF file and may include no more than 25 pages. Teams must adhere to this limit. Judges will not review any materials beyond 25 pages. This instruction section does not count toward the page limit and may be deleted prior to submission.
- A "page" is defined as Letter size paper (8½" X 11") with 11-point font (Arial or Times New Roman), 1-inch margins, single spaced. Any text included in tables, figures, captions, or footnotes may be as small as 10-point font.
- Each section includes a "Recommended length" for the answer. These recommendations are intended to provide guidance on the 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.

NAME/TITLE FOR YOUR SOLUTION

1. Vision and Innovation (*Recommended length: 1-2 pages*)

   1.1. Provide a brief overview of your solution, including eligible trash items that you will recycle (from TABLE 4); overview of the recycling system; and outputs (both usable and unusable).

   1.2. How does your solution use innovation to address the challenge?

   1.3. How does the solution build or improve upon the current state of the art?

   1.4. How does your solution leverage advanced technologies?

   1.5. Describe the commercial potential of your solution.

   1.6. How do you envision the anticipated maintenance needs and any expendables required for long term operation of the system (one year or longer)?

2. Milestone Round Solution Design

   2.1. Milestone Round Engineering Design *(Recommended length: 4-6 pages)*

      2.1.1. A rationale for your design approach

      2.1.2. Preliminary evidence and analysis predicting performance including mass, volume, and power requirements

      2.1.3. System-level and component-level design specifications for hardware and software, including bill of materials

   2.2. Milestone Round Operations, Analyses, and Testing *(Recommended length: 4-6 pages)*

      2.2.1. Concept of operations for one cycle and any related analyses or testing, including thermal analysis and structural analysis, if relevant to your solution

      2.2.2. Summary of the inputs**,** outputs, and efficiency of your recycling process**.** Please include the RECYCLING SUMMARY TABLE below to summarize these details.

      2.2.3. Plan for characterizing the usable outputs and finished products from the recycling process and verifying this characterization

RECYCLING SUMMARY TABLE

Question	Answer
Eligible trash item(s) from TABLE 4 that your solution will recycle	
Total mass of one batch of eligible trash items (expressed in kg). Please explain how the batch will meet Minimum Batch Requirements.	
Mass of each eligible trash item in one batch (expressed in kg). Please explain how the batch will meet Minimum Batch Requirements.	
Length of time (expressed in hours or minutes) to complete one cycle	
Electricity required for one cycle, including: –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)	
Amount of water (expressed in kg) required for one cycle.	
Types and amounts of other inputs required for one cycle. List each additional input and the mass required for one cycle (expressed in kg).	
Number of crew and time per crew member (expressed in minutes or hours) required to operate one cycle.	
Usable outputs produced by one cycle and amounts of each (expressed in kg).	
Unusable outputs produced by one cycle and amounts of each (expressed in kg).	
Calculate the Mass Efficiency (%) for one cycle. Mass Efficiency is equal to the mass of the usable output(s) divided by the sum of the mass of the trash item inputs and	

other inputs, excluding energy consumed. Simulated regolith does not count against Mass Efficiency. If your solution uses simulated regolith, you may exclude it from this calculation.	
Calculate the Energy Efficiency (%) for one cycle. Energy Efficiency (kg/kWh) is equal to the mass of the usable output(s) divided by the energy consumed to produce those usable outputs.	

2.3. Milestone Round Schematics *(Recommended length: 3-5 pages)*

Provide schematics for key elements of your solution, including process design, mechanical and fluids schematics, electrical schematics, and assembly-level drawings showing envelopes and key dimensions.

2.4. Milestone Round Master Equipment List *(Recommended length: 1 page)*

Use the following EQUIPMENT TABLE to provide a master equipment list, including mass and volume estimates.

EQUIPMENT TABLE

Description of Equipment and Supplier	**Estimated mass (kg)**	**Estimated volume (cm^3)**

2.5. Milestone Round Safety Analysis *(Recommended length: 1 page)*

2.5.1. Identify any potentially hazardous materials or other safety concerns related to your design, concept of operations, or outputs.

2.5.2. Provide a safety analysis addressing pressure vessel systems and material compatibility (if relevant to your solution).

3. Development/Project Plan *(Recommended length: 2 pages)*

   Describe your plan for developing and building hardware for the Final Round Demonstration. Teams should address the technical steps necessary for hardware development and testing; success criteria for testing; personnel and other resources; and expected timeline/schedule in relation to the Final Round deadlines. Teams may also describe any past experience or future development plans that they believe is relevant to their expected readiness in the Final Round.

4. Risk Assessment *(Recommended length: 1 page)*

Describe the technical and other risks associated with developing your solution in the Final Round. Teams should address any potential supply chain management or long lead items that will be required to demonstrate your solution in the Final Round. For each risk, teams should include an assessment (such as high, medium, low) and your proposed risk mitigation strategy.

5. Development Budget *(Recommended length: 1 page)*

Use the following BUDGET TABLE to estimate the budget necessary to execute your Development Plan in the Final Round. You may add additional rows to the BUDGET TABLE as needed. Please Note: In this challenge, NASA is not focused on comparing the overall cost of solutions; rather this section is intended to assess how well the team has thought through the budget necessary to build their solution. In the Expected funding source(s) column, teams should address whether they will already have funds in place to support work during the Final Round, and if not, how they will secure the necessary funds. Teams may assume Milestone Round prizes in their budget.

BUDGET TABLE

Type of cost	**Description**	**Estimated budget for developing your solution in the Final Round**	**Expected funding source(s)**
Materials			
Equipment			
Lab/testing			
Personnel			
Travel			
Admin			
Other (as applicable)			

Appendix B: Milestone Round Submission Requirements for Digital Twin Solutions

General Instructions:

- The submission must address each required section and topic described below.
- In addition to this template, teams are also required to submit the following items, as described in the Milestone Round Submissions section:
    - A link to a publicly accessible video recording of the presentation (no longer than 30 minutes) that includes a demonstration of at least a portion of the preliminary digital twin visualization for 1) the nominal scenario and 2) one (1) of the off-nominal scenarios; and
    - A Preliminary Demonstration Proposal for your digital twin
- 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 and will not be eligible for a prize.

Presentation Instructions:

- The presentation must be a PDF file and may include no more than 20 slides. Judges will not review any materials beyond 20 slides.
- 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 the 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.
- The recorded presentation must include a demonstration of 1) a preliminary digital twin visualization for the nominal scenario and 2) a preliminary digital twin visualization for one (1) of the off-nominal scenarios.
- The recorded presentation should be given by the team leader and/or team members, not by an AI.

1. Vision and Innovation (*Recommended length: 1-2 slides*)

    1.1. Name/Title for your solution

    1.2. How does your solution use innovation in the Digital Twin?

    1.3. How does the solution build or improve upon current state of the art digital twins?

    1.4. How does your solution leverage advanced technologies?

    1.5. Describe the commercial potential of your digital twin.

2. Preliminary Digital Twin Architecture (*Recommended length: 5-6 slides*)

    2.1. Describe the architecture of your preliminary digital twin.

    2.2. What is your design approach? Describe the physics-based models, simulation, and visualization you will use to create a virtual representation of your team's Prototype Solution.

    2.3. Describe the level of fidelity and resolution that demonstrates how closely the digital representation matches your team's Prototype Solution.

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

    2.5. Describe any automated control and decision-making capabilities.

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

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

    2.8. Describe your validation approach for computer models (e.g., how accurately the model's predictions or outputs align with your team's Prototype Solution).

    2.9. Describe how the digital twin would communicate with physical assets that are part of your team's Prototype Solution.

3. How your preliminary Digital Twin addresses the Nominal Scenario (*Recommended length: 2-3 slides*)

    3.1. Describe how your digital twin will model the nominal scenario, including the engineering data, predictive capabilities, and bi-directional communication that will be incorporated into the model.

3.2. Describe any features or capabilities (such as thermal management, prediction of stress conditions, or any other capabilities) that your digital twin will demonstrate in the Nominal Scenario that would not otherwise be addressed by your team's Prototype Solution.

4. How your preliminary Digital Twin addresses one (1) Off-Nominal Scenario (*Recommended length: 2-5 slides*)

   4.1. Describe how your digital twin will model one (1) of the off-nominal scenarios, including the engineering data, predictive capabilities, and bi-directional communication that will be incorporated into the model of these scenarios.

      4.1.1. If you are designing your own off-nominal scenario, explain how your off-nominal scenario leverages the capabilities of your digital twin to deliver additional valuable insights into the design or operation of your team's Prototype Solution

   4.2. Describe the data or insights that your digital twin will provide that may help to improve the form, fit, and function of your team's Prototype Solution or a modification of your team's Prototype Solution that enables increased capability, reliability, or efficiency.

5. Digital Twin Characteristics (*Recommended length: 1-2 slides*)

   5.1. Describe how your preliminary digital twin addresses Accuracy, defined as the degree to which the digital representation reflects your team's Prototype Solution in data fidelity, model fidelity, and predictive capability.

   5.2. Describe how your preliminary digital twin addresses 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 your team's Prototype Solution does.

   5.3. Describe how your preliminary digital twin addresses Predictive Capabilities, defined as the ability of the digital model to anticipate the future behavior and performance of your team's Prototype Solution.

   5.4. Describe how your preliminary digital twin addresses Verification and Validation, defined as how you will determine the degree to which the digital twin is a true representation of your team's Prototype Solution.

6. Development/Project Plan *(Recommended length: 1-2 slides)*

   6.1. Describe your plan for developing your final and complete Digital Twin Solution for the Final Round Demonstration. Teams should address the technical steps necessary for development and testing; success criteria for testing; personnel and other resources; and expected timeline/schedule in relation to the Final Round deadlines.

Appendix C: Final Round Submission Template for Prototype Solutions

General Instructions:

- This template includes all of the required sections that your team should address for your Prototype Solution.
- If you are also submitting a Digital Twin Solution, please also submit the required items for a digital twin described in the Final Round Submissions section.
- Your submission must address each required section and topic described below. PLEASE NOTE: Any submission that does not address all of the requirements will receive a "Fail" score for completeness and will not be eligible for a prize.

Submission Document Instructions:

- All submissions must be in English; submissions in any other language will not be judged and will not be eligible for a prize.
- Teams should maintain all numbered section headings in their submission.
- The submission must be a PDF file and may include no more than 30 pages. Teams must adhere to this limit. Judges will not review any materials beyond 30 pages. This instruction section does not count toward the page limit and may be deleted prior to submission.
- A "page" is defined as Letter size paper (8½" X 11") with 11-point font (Arial or Times New Roman), 1-inch margins, single spaced. Any text included in tables, figures, captions, or footnotes may be as small as 10-point font.
- Each section includes a "Recommended Length" for the answer. These recommendations are intended to provide guidance on the 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.

NAME/TITLE FOR YOUR SOLUTION

1. Vision and Innovation (*Recommended length: 2 pages*)

    1.1. Provide a brief overview of your solution, including eligible trash items that you will recycle (from TABLE 4); overview of the recycling system; and outputs (both usable and unusable).

    1.2. How does your solution use innovation to address the challenge?

    1.3. How does the solution build or improve upon the current state of the art?

    1.4. How does your solution leverage advanced technologies?

    1.5. Describe the commercial potential of your solution.

    1.6. How do you envision the anticipated maintenance needs and any expendables required for long term operation of the system (one year or longer)?

2. Final Round Solution Design

    2.1. Final Round Engineering Design *(Recommended length: 6-8 pages)*

        2.1.1. A rationale for your design approach

        2.1.2. Preliminary evidence and analysis predicting performance including mass, volume, and power requirements

        2.1.3. System-level and component-level design specifications for hardware and software, including bill of materials

    2.2. Final Round Operations, Analyses and Test Results *(Recommended length: 6-8 pages)*

        2.2.1. Concept of operations for one cycle and any related analyses or testing, including thermal analysis and structural analysis, if relevant to your solution

        2.2.2. Summary of the inputs**,** outputs, and efficiency of your recycling process**.** Please include the RECYCLING SUMMARY TABLE below to summarize these details.

        2.2.3. Plan for characterizing the usable outputs and finished products from the recycling process and verifying this characterization

RECYCLING SUMMARY TABLE

Question	Answer
Eligible trash item(s) from TABLE 4 that your solution will recycle.	
Total mass of one batch of eligible trash items (expressed in kg). Please explain how the batch will meet Minimum Batch Requirements.	
Mass of each eligible trash item in one batch (expressed in kg). Please explain how the batch will meet Minimum Batch Requirements.	
Length of time (expressed in hours or minutes) to complete one cycle.	
Electricity required for one cycle, including: –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)	
Amount of water (expressed in kg) required for one cycle.	
Types and amounts of other inputs required for one cycle. List each additional input and the mass required for one cycle (expressed in kg).	
Number of team members and time per team member (expressed in minutes or hours) required to operate one cycle.	
Usable outputs produced by one cycle and amounts of each (expressed in kg).	
Unusable outputs produced by one cycle and amounts of each (expressed in kg).	
Calculate the Mass Efficiency (%) for one cycle. Mass Efficiency is equal to the mass of the usable output(s) divided by the sum of the mass of the trash item inputs and	

other inputs, excluding energy consumed. Simulated regolith does not count against Mass Efficiency. If your solution uses simulated regolith, you may exclude it from this calculation.	
Calculate the Energy Efficiency (%) for one cycle. Energy Efficiency (kg/kWh) is equal to the mass of the usable output(s) divided by the energy consumed to produce those usable outputs.	

2.3. Final Round Schematics *(Recommended length: 4-8 pages)*

Provide schematics for key elements of your solution, including process design, mechanical and fluids schematics, electrical schematics, and assembly-level drawings showing envelopes and key dimensions

2.4. Final Round Master Equipment List *(Recommended length: 1 page)*

Use the following EQUIPMENT TABLE to provide a complete master equipment list, including mass and volume estimates.

EQUIPMENT TABLE

Description of Equipment and Supplier	**Estimated mass (kg)**	**Estimated volume (cm^3)**

3. Pre-Processing of Trash *(Recommended length: 1-3 pages)*

3.1. Will you build and demonstrate all hardware related to pre-processing at the Final Round demonstration, or do you intend to use an alternative method at the demonstration site to address pre-processing? If you will build and demonstrate all hardware related to pre-processing, you may skip section 3.2.

3.2. If you are using an alternative method at the demonstration site to address pre-processing, please complete the PRE-PROCESSING INPUTS TABLE below.

PRE-PROCESSING INPUTS TABLE

Length of time (expressed in hours or minutes) to complete one cycle of any pre-processing included in your design that will not be built and demonstrated	
Electricity required for one cycle of any pre-processing included in your design that will not be built and demonstrated, including: –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)	
Amount of water (expressed in kg) required for one cycle of any pre-processing included in your design that will not be built and demonstrated.	
Amount of other inputs required for one cycle of any pre-processing included in your design that will not be built and demonstrated. List each additional input and the mass required for one cycle (expressed in kg).	
Number of team members and time per team member (expressed in minutes or hours) required to operate one cycle of any pre-processing included in your design that will not be built and demonstrated.	

Appendix D: Final Round Submission Requirements for Digital Twin Submissions

General Instructions:

- The submission must address each required section and topic described below.
- In addition to this template, teams are also required to submit the following, as described in the Final Round Submissions section:
    - A link to a publicly accessible video recording (no longer than 60 minutes) of the presentation, that includes a demonstration of the complete digital twin visualization for 1) the nominal scenario and 2) two (2) off-nominal scenarios.
- 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 and will not be eligible for a prize.

Presentation Instructions:

- The presentation must be a PDF file and may include no more than 20 slides. Judges will not review any materials beyond 20 slides.
- 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 the 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 60 minutes. Judges will not review the presentation beyond 60 minutes.
- The recorded presentation must include a demonstration of 1) a complete digital twin visualization for the nominal scenario and 2) a complete digital twin visualization for two (2) off-nominal scenarios.
- The recorded presentation should be given by the team leader and/or team members, not by an AI.

1. Vision and Innovation (*Recommended length: 1-2 slides*)

    1.1. Name/Title for your solution

    1.2. How does your solution use innovation in the Digital Twin?

    1.3. How does the solution build or improve upon current state of the art digital twins?

    1.4. How does your solution leverage advanced technologies?

    1.5. Describe the commercial potential of your digital twin.

2. Digital Twin Architecture (*Recommended length: 6-8 slides*)

    2.1. Describe the architecture of your complete digital twin

    2.2. What is your design approach? Describe the physics-based models, simulation, and visualization you will use to create a virtual representation of your team's Prototype Solution.

    2.3. Describe the level of fidelity and resolution that demonstrates how closely the digital representation matches your team's Prototype Solution.

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

    2.5. Describe any automated control and decision-making capabilities.

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

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

    2.8. Describe your validation approach for computer models (e.g., how accurately the model's predictions or outputs align with your team's Prototype Solution).

    2.9. Describe how the digital twin would communicate with physical assets that are part of your team's Prototype Solution.

3. How your Digital Twin addresses the Nominal Scenario (*Recommended length: 2-3 slides*)

    3.1. Describe how your digital twin models the nominal scenario, including the engineering data, predictive capabilities, and bi-directional communication that has been incorporated into the model.

3.2. Describe any features or capabilities (such as thermal management, prediction of stress conditions, or any other capabilities) that your digital twin will demonstrate in the Nominal Scenario that would not otherwise be addressed by your team's Prototype Solution.

4. How your Digital Twin addresses two (2) Off-Nominal Scenarios (*Recommended length: 4-6 slides*)

   4.1 Describe how your digital twin models two (2) off-nominal scenarios, including the engineering data, predictive capabilities, and bi-directional communication that has been incorporated into the model of these scenarios.

      4.1.1 If you are designing your own off-nominal scenario, explain how your off-nominal scenario leverages the capabilities of your digital twin to deliver additional valuable insights into the design or operation of your team's Prototype Solution

   4.2 Describe the data or insights that your digital twin will provide that may help to improve the form, fit, and function of your team's Prototype Solution or a modification of your team's Prototype Solution that enables increased capability, reliability, or efficiency.

5. Digital Twin Characteristics (*Recommended length: 1 slide*)

   5.1. Describe how your digital twin addresses Accuracy, defined as the degree to which the digital representation reflects your team's Prototype Solution in data fidelity, model fidelity, and predictive capability.

   5.2. Describe how your digital twin 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 your team's Prototype Solution does.

   5.3. Describe how your digital twin addresses Predictive Capabilities, defined as the ability of the digital model to anticipate the future behavior and performance of your team's Prototype Solution.

   5.4. Describe how your digital twin addresses Verification and Validation, defined as how you will determine the degree to which the digital twin is a true representation of your team's Prototype Solution.

Appendix E: Preliminary Demonstration Proposal

In the Milestone Round, all teams must submit a Preliminary Demonstration Proposal. The Preliminary Demonstration Proposal must be a single PDF document. This proposal is for informational purposes only and will not be judged.

Teams will have an opportunity to update this Preliminary Demonstration Proposal if they are invited to compete in the Final Round. A template and deadline for updating this Preliminary Demonstration Proposal will be provided to teams invited to compete in the Final Round.

Please address the following questions about your Prototype Solution:

- What specific hardware systems, subsystems, and components do you intend to demonstrate in the Final Round?
- What is the approximate mass (kg) and volume (cm^3) of the hardware that you intend to demonstrate in the Final Round?
- Please describe the internal and external interfaces of the hardware that you intend to demonstrate in the Final Round.
- What is the concept of operations for the demonstration, including how long (minutes or hours) it will take to demonstrate one cycle that recycles one batch of eligible trash items?
- Which eligible trash item(s) do you intend to recycle at the demonstration?
- How many batches do you expect to use for the demonstration? Teams may use up to three (3) batches, and all batches must be identical.
- If you are planning to recycle multiple eligible trash items, what is the expected mass (kg) of each eligible trash item in your batch? Please be sure that your batch meets the Minimum Batch Requirements.
- Do you intend to build and demonstrate any pre-processing, or do you intend to use an alternative method at the demonstration site to address pre-processing? If you intend to use an alternative method at the demonstration site to address pre-processing, please describe that method.
- How will you capture and handle outputs (usable outputs and unusable outputs) at the end of the recycling process?
- Will you require any unique resources to conduct the demonstration?
- Will your demonstration result in any potentially hazardous materials? Do you have any safety concerns related to the demonstration that should be mitigated prior to the demonstration?
- How many team members do you plan to bring to the demonstration? Teams demonstrating only a Prototype Solution may bring up to four (4) team members. Teams demonstrating both a Prototype Solution and a Digital Twin Solution may bring up to six (6) team members.

For teams that are also developing a Digital Twin Solution, please address the following questions:

- Which two off-nominal scenarios does the team intend to demonstrate?
- Will the team require any unique resources to conduct the demonstration?
- How many team members will present and demonstrate the Digital Twin Solution?

Appendix F: Additional Safety Considerations

Teams should recognize that the eligible trash items in this challenge, while mostly common consumer products, are actually complex materials and chemicals that may undergo phase change in vapor, solid, or liquid form during a recycling process. Heating, grinding, and other types of processing, especially of plastics and foams, could be associated with a variety of hazards.

During the Final Round, teams will be required to address in detail any potential hazards related to their Prototype Solution. Teams will likely need to complete a standard hazard and mitigation inventory that identifies all potential hazards, the cause of each hazard, the effect of each hazard, mitigation or controls for each hazard, and verification of those mitigations or controls. A simplified example of a hazard and mitigation inventory is shown below.

Hazards relating specifically to each team's Prototype Solution may be the responsibility of teams to address. Additional details and timing related to the hazard and mitigation inventory will be provided to teams that are invited to compete in the Final Round.

Simplified Example of Hazard Inventory and Mitigations

Hazard	Cause	Effect	Mitigation/ Controls	Verification	Responsibility
Compressed Gas	Gas may be asphyxiant, toxic, flammable, reactive, toxic and/or corrosive	May cause illness, injury, or death	Use factory set relief valves that are ASME compliant with correct flow capacity calculation	Check all equipment during set up and before beginning any demonstration activities	Team
Rotating equipment or moving machinery					
Electrical shock					
Smoke/Fire					
Additional Hazards TBD					