
Fast Actuating Rectum Transfer Exit Device (FARTED)

NASA's Lunar Loo Challenge

Members:

Daniel Card^{*}, dcard@umich.edu

Cell: (810)728-6754

Linkedin: [linkedin.com/in/dan-card](https://www.linkedin.com/in/dan-card)

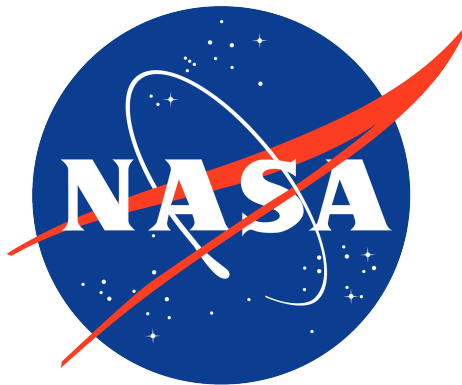
Portfolio: <http://www-personal.umich.edu/~dcard/home.html>

Drake Rundell[†], drundel@umich.edu

Cell: (810)772-9656

Linkedin: [linkedin.com/in/drrundel](https://www.linkedin.com/in/drrundel)

Portfolio: <http://www-personal.umich.edu/~drrundel/>



^{*}Graduate Student at The University of Michigan Rackham, Aerospace Honors Society, AIAA Student Member.

[†]Rotational Engineer at Williams International, University of Michigan BSE 20' Aerospace Engineering.

Contents

1	Introduction	4
1.1	Space Waste Collection Systems	5
1.1.1	Apollo Waste Collection System	5
1.1.2	Space Shuttle's Waste Collection System	7
1.1.3	Soyuz Waste Collection System	7
1.1.4	International Space Station Waste Collection System	7
2	Lunar Loo Challenge	9
2.1	Challenge Overview	10
2.2	Lunar Loo Requirements	10
2.2.1	Toilet Design Specifications	10
2.2.2	Toilet Performance Specifications	11
3	Fast Actuating Rectum Transfer Exit Device (FARTED)	12
3.1	Overview of Design	13
3.1.1	Working in Microgravity	13
3.1.2	Implementation for All Genders	13
3.1.3	Design Versatility	13
3.1.4	Transferring Collected Waste to Storage	13
3.2	Accommodations	14
3.2.1	Waste Containment	14
3.2.2	Stabilizing Urination	14
3.2.3	Functionality of Waste Containment System	14
3.2.4	Lifetime	14
3.2.5	Integration with Hygiene Products	14
3.2.6	Time of Turn Around	14
3.2.7	Mission Lifetime	15
3.3	Safety	16
3.3.1	Minimizing Contact with Waste	16
3.3.2	Isolating System from Vacuum	16
3.4	Technical Maturity	17
3.5	Technical Judging	18

List of Figures

1.1	Apollo Urine Transfer System	6
1.2	Apollo Fecal Bag	6

Chapter 1

Introduction

As NASA prepares to return to the Moon, innumerable activities to equip, shelter, and otherwise support future astronauts are underway. These astronauts will be eating and drinking, and subsequently urinating and defecating in microgravity and lunar gravity. While astronauts are in the cabin and out of their spacesuits, they will need a toilet that has all the same capabilities as ones here on Earth. NASA is calling on the global community for their novel design concepts for compact toilets that can operate in both microgravity and lunar gravity. These designs may be adapted for use in the Artemis lunar landers that take us back to the Moon. Although space toilets already exist and are in use (at the International Space Station, for example), they are designed for microgravity only. NASA's Human Landing System Program is looking for a next-generation device that is smaller, more efficient, and capable of working in both microgravity and lunar gravity. This challenge includes a Technical category and Junior category.

It is in this calling of this unique challenge that we wish to provide a solution that is both functional and innovative. This document will provide our design rationale, the functionality of the product, and how this design has innovated prior designs.

1.1 Overview of Space Waste Collection Systems

Space Waste Collection Systems(WCS) are the implementation of Earth toilets in a microgravity environment. However, easier said than done while in microgravity there poses a challenge of transporting and storing human waste. While in microgravity, fluids are pulled together through its surface tension causing the mundane task of transporting anything through a fluid system a non-trivial task. As a result of this non-trivial task, this seemingly simple task on Earth becomes a very intensive engineering project that cannot be overlooked.

1.1.1 Apollo Waste Collection System

During the age of Apollo, minimal work went into designing an effective waste collection system resulting from the difficulty of even obtaining a low Earth orbit. As a result the astronauts on-board would collect and dump urine overboard instead of storing the urine.

However, collecting urination from the astronauts was simple enough, collecting fecal matter is what proved to be most difficult. In order to avoid the troubles of defecating in space, many astronauts while in space would eat less of their rations to avoid the troubles of defecating in microgravity.

In the absence of a system providing positive means for the removal of feces from the body, an extremely basic system had to be relied upon for inflight fecal collection. The device used was a plastic bag which was taped to the buttocks to capture feces. After defecation, the crew member was required to seal the bag and knead it in order to mix a liquid bactericide with the contents to provide the desired degree of feces stabilization. Because this task was distasteful and required an inordinate amount of time, low residue foods and laxatives were generally used prior to launch. During flight, in addition to low residue foods, some use was also made of drugs to reduce intestinal motility.[[apollo_bathroom](#)]



Figure 1.1: Apollo urine transfer system.

Above in Figure 1.1 in which it had two main purposes: 1) dumping during time of voiding, and 2) dumping subsequent to voiding.



Figure 1.2: Apollo fecal bag for defecating in microgravity.

As shown above in Figure 1.2, the bag used to collect astronaut defecation's was rudimentary in design resulting in many of the astronauts being in great discomfort when defecating. This bag was placed over the anus of the astronaut, and would be sealed after use to prevent the spread of bacteria and pathogens.

1.1.2 Space Shuttle's Waste Collection System

1.1.3 Soyuz Waste Collection System

1.1.4 International Space Station Waste Collection System

Test [iss__background]

Chapter 2

Lunar Loo Challenge

Artemis is NASA's program to land the first woman and the next man on the Moon by 2024. Humanity is going back to the Moon to establish a presence that will enable eventual crewed journeys to Mars. As we prepare for our return to the Moon, innumerable activities to equip, shelter, and otherwise support future astronauts are underway. These astronauts will be eating and drinking, and subsequently urinating and defecating in microgravity and lunar gravity. While astronauts are in the cabin and out of their spacesuits, they will need a toilet that has all the same capabilities as ones here on Earth.

This challenge seeks to radically change current lunar space toilets to reflect the technological advances that NASA wishes to achieve throughout Artemis's mission timeline.

2.1 Challenge Overview

NASA is calling on the global community for their novel design concepts for compact toilets that can operate in both microgravity and lunar gravity. These designs may be adapted for use in the Artemis lunar landers that take us back to the Moon. Although space toilets already exist and are in use (at the International Space Station, for example), they are designed for microgravity only. NASA is looking for a next-generation device that is smaller, more efficient, and capable of working in both microgravity and lunar gravity. Getting back to the Moon by 2024 is an ambitious goal, and NASA is already working on approaches to miniaturize and streamline the existing toilets. But they are also inviting ideas from the global community, knowing that they will approach the problem with a mindset different from traditional aerospace engineering. This challenge hopes to attract radically new and different approaches to the problem of human waste capture and containment.

2.2 Lunar Loo Requirements

Driving new technological advances often times result from system requirements and the Lunar Loo challenge is no exception. Thought to be a trivial task, designing a toilet that offers services accommodating to many while in microgravity does indeed require attention to detail and knowledge of the microgravity environment.

2.2.1 Toilet Design Specifications

The specifications listed below represent the maximum allowed values. Proposed designs should at least meet them and will preferentially be lower than them. The toilet design should:

- Function in both microgravity and lunar gravity
- Have a mass of less than 15 Kg in Earth's gravity
- Occupy a volume no greater than 0.12 m³
- Consume less than 70 Watts of power
- Operate with a noise level less than 60 dB (an average bathroom fan)
- Accommodate both female and male users
- Accommodate users ranging from 58 to 77 inches tall and 107 to 290 lbs in weight

2.2.2 Toilet Performance Specifications

We are looking for a design that captures all the functionality of a toilet on Earth. At a minimum, crew using lunar toilets should not be exposed to vacuum during use, and toilet designs should be able to:

- Accommodate simultaneous urination and defecation
- Collect up to 1 liter of urine per use, with an average of 6 uses per crew per day
- Accommodate 500g of fecal matter per defecation, with an average of 2 uses per crew per day
- Accommodate 500g of diarrhea per event
- Accommodate an average of 114g of female menses, per crew per day
- Stabilize urine to avoid the generation of gas and particulates
- Accommodate crew use of toilet hygiene products, like toilet paper, wipes, and gloves
- Be clear of previous user's urine and feces in preparation for the next use
- Allow for transfer of collected waste to storage and/or provide for external vehicle disposal. Minimal Lander volume requires regularly minimizing waste storage or removing it from the vehicle
- Allow for easy cleaning and maintenance, with 5 minute turnaround time or less between uses

Additionally, in the event of system failure, the design will ensure that:

- All waste materials collected remain safely stored
- The crew is not exposed to urine, feces, or other collected materials
- The crew is not exposed to vacuum

Chapter 3

Fast Actuating Rectum Transfer Exit Device (FARTED)

Short description of design - edit edit edit

3.1 Overview of Waste Collection System

3.1.1 Working in Microgravity

Please discuss in detail how your design will work in both microgravity and lunar gravity

3.1.2 Implementation for All Genders

Please discuss in detail how your design will accommodate female and male crew

3.1.3 Design Versatility

Please discuss in detail how your design be easy to use and maintain, with low noise

3.1.4 Transferring Collected Waste to Storage

Please discuss in detail how your design allow for transfer of collected waste to storage or external vehicle disposal

3.2 Accommodations of Waste Collection System

3.2.1 Waste Containment

Please discuss in detail how your design will capture and contain urine, feces, vomit, diarrhea, and menses,

3.2.2 Stabilizing Urination

Please discuss in detail how your design will Stabilize urine

3.2.3 Functionality of Waste Containment System

Please discuss in detail how your design will accommodate simultaneous urination and defecation,

3.2.4 Lifetime

Please discuss in detail how your design will accommodate the needs of 2 crew members for 14 days,

3.2.5 Integration with Hygiene Products

Please discuss in detail how your design will accommodates the use of toilet hygiene products,

3.2.6 Time of Turn Around

Please discuss in detail how your design will clears previous waste content prior to next use,

3.2.7 Mission Lifetime

Please discuss in detail how your design will defines how often the collections system must be replaced or disposed of in the mission

3.3 Safety Measures of Design

3.3.1 Minimizing Contact with Waste

Please discuss the safety measures in place to ensure that during nominal use or in the event of a system failure crew handling of waste materials during maintenance or system use is minimized

3.3.2 Isolating System from Vacuum

Please discuss the safety measures in place to ensure that during nominal use or in the event of a system failure crew members are not exposed to vacuum

3.4 Technical Maturity

Please discuss the technical maturity of your proposed toilet design. What TRL would you assign it? Please provide a supporting rationale and/or evidence for this rating. Why do you believe this could be developed and integrated into a lunar rover in the next 2-3 years?

3.5 Technical Judging

- Proposal Quality Quality of proposal: clear, concise writing; thoughtful and complete explanations of how the proposed toilet design concept meets the specifications listed; accompanying CAD file (or other file format) is clear and complete. [10 pts]
 - Capabilities - Usage
 - Overall technical feasibility of the proposal toilet design.
 - Compatible for use by both female and male crew members.
 - How well does the design address issues like ease of use, odor control, noise, and turnaround time.
 - Likelihood that it will function in both microgravity and lunar gravity when prototyped.
 - How easy will it be to adapt the design for integration into a lunar rover. [20 pts]
 - Capabilities - Capacity Likelihood that it can successfully meet the performance specifications when prototyped, capturing:
 - Urine (and stabilizing it)
 - Feces (accommodating simultaneous urination and defecation)
 - Diarrhea
 - Vomit
 - Menses - Likelihood that it can accommodate the needs of 2 crew members for 14 days.
 - Defines how often the collections system must be replaced or disposed of in the mission [20 pts]
- Technical Maturity The likelihood that proposed toilet design can be developed and integrated in the next 2-3 years.
 - Quality of the explanation and supporting evidence for why a solution is designated at a particular maturity level. [20 pts]
- Safety Confidence that proposed design will minimize the crew handling of crew waste during maintenance or system use in all mission environments, and will not expose crew to vacuum in the event of a system failure. [20 pts]
- Innovation Novelty or creativity of proposed approach.
 - Elegance of design.
 - Describe how the innovation overcomes limitations and constraints of existing technologies or commercial products. [10 pts]