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Overview of Light Weight Radioisotope Heater Unit (LWRHU) Users Guide

May 2022

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Overview of Light Weight Radioisotope Heater Unit (LWRHU) User's Guide

NETS 2022, Cleveland, OH

Summary

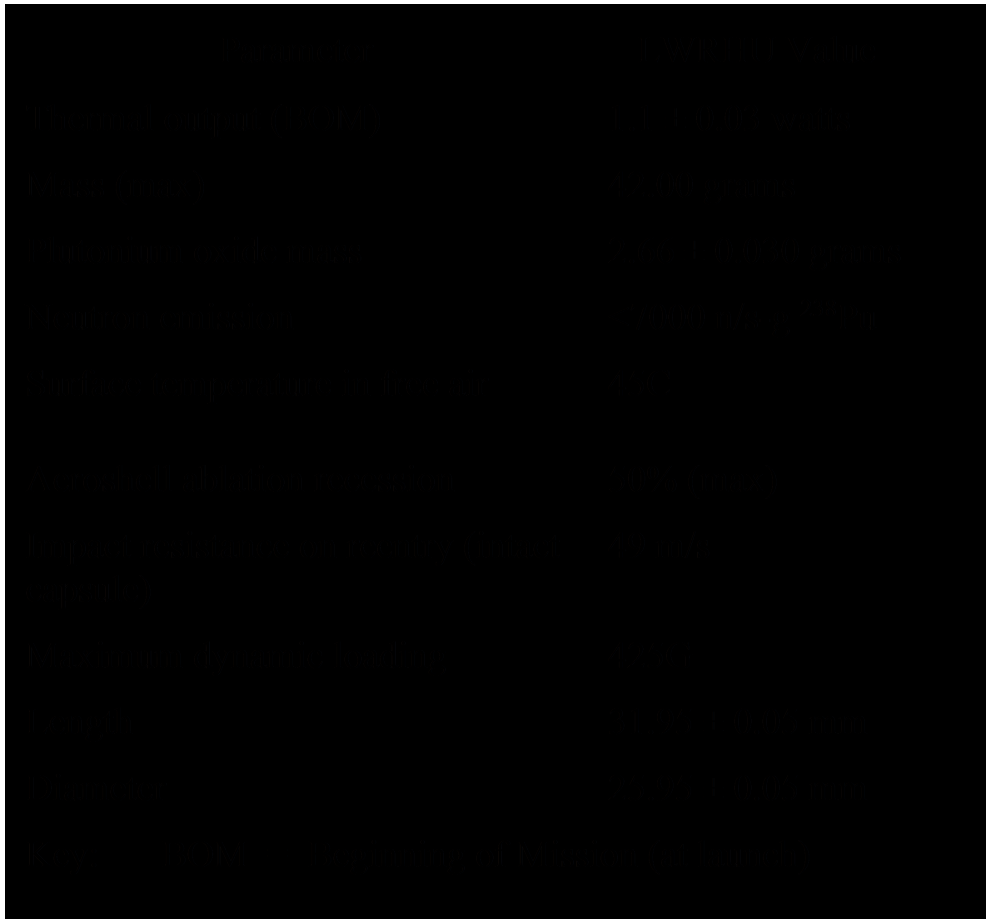
- Lightweight Radioisotope Heater Unit (LWRHU) User's Guide Purpose
- LWRHU Overview
- LWRHU History
- LWRHU Major Components

Purpose and Scope of LWRHU User's Guide

- Purpose:
  - Provides a general description of the physical characteristics, system interfaces, and performance characteristics of the LWRHU.
  - Provides to the mission proposer sufficient detail on the LWRHU and an understanding of the interfaces and support needed to utilize in a NASA RHU enabled mission.
- Scope
  - Provide a general description of the physical characteristics and system interfaces of the Light Weight Radioisotope Heater Unit (LWRHU)
  - Describe the physical and analytical models available to a mission design team
  - Identify the planning and execution involved in launching a nuclear payload, including National Environmental Policy Act (NEPA) activities.

LWRHU Overview

- Designed to operate in planetary atmospheres and vacuum environments
- Previous missions have been in Mars atmosphere and vacuum of space
- Performance and material combability may need do be tested and understood for specific environments



LWRHU History

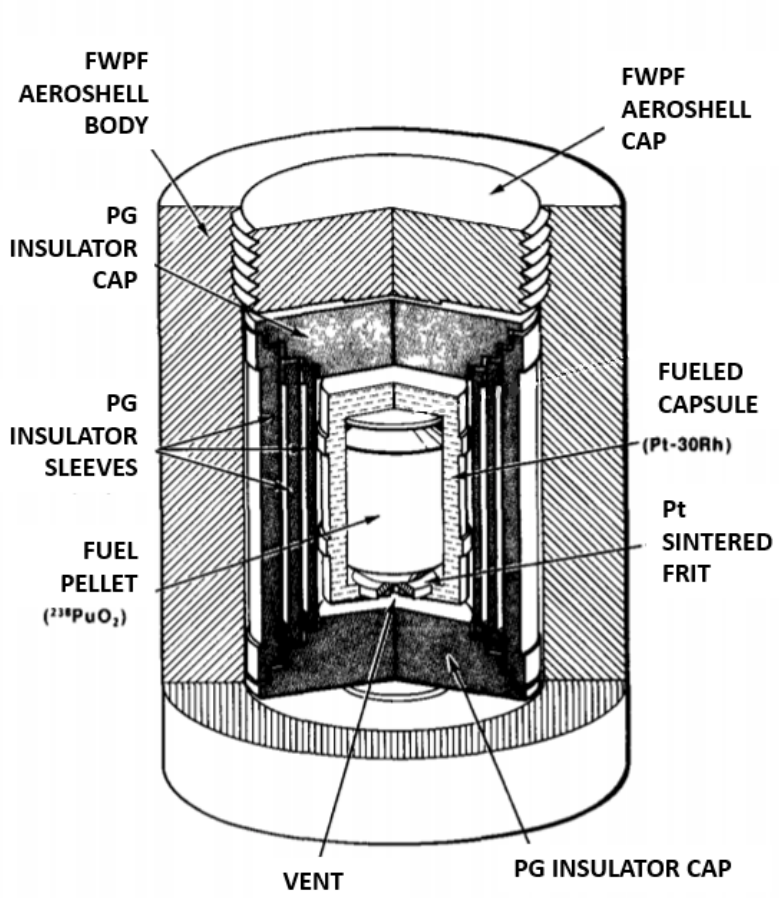
- Used on NASA missions since initial lunar landing
- Initial purpose was to provide heat to keep components and system warm in the cold space environment
  - No moving parts
  - No electrical components
- RHU design has evolved over time
  - Apollo 11 – 15 Watts
  - Pioneer and Voyager – 1 Watt
  - LWRHU – 1 Watt

LWRHU History

- Missions that used a slightly different and older design heater unit are:
  - Apollo 11 – contained two 15 Watt RHUs
  - Pioneer 10 – 12 RHUs
  - Pioneer 11 – 12 RHUs
  - Voyager 1 – 9 RHUs
  - Voyager 2 – 9 RHUs
- Missions that have used the current LWRHU design are:
  - Galileo – 120 LWRHUs (103 on orbiter, 17 on atmospheric probe)
  - Mars Rover Sojourner Pathfinder – 3 LWRHUs
  - Cassini – 117 LWRHUs (82 on orbiter, 35 on Huygens Titan probe)
  - Mars Rover Spirit – 8 LWRHUs
  - Mars Rover Opportunity – 8 LWRHUs

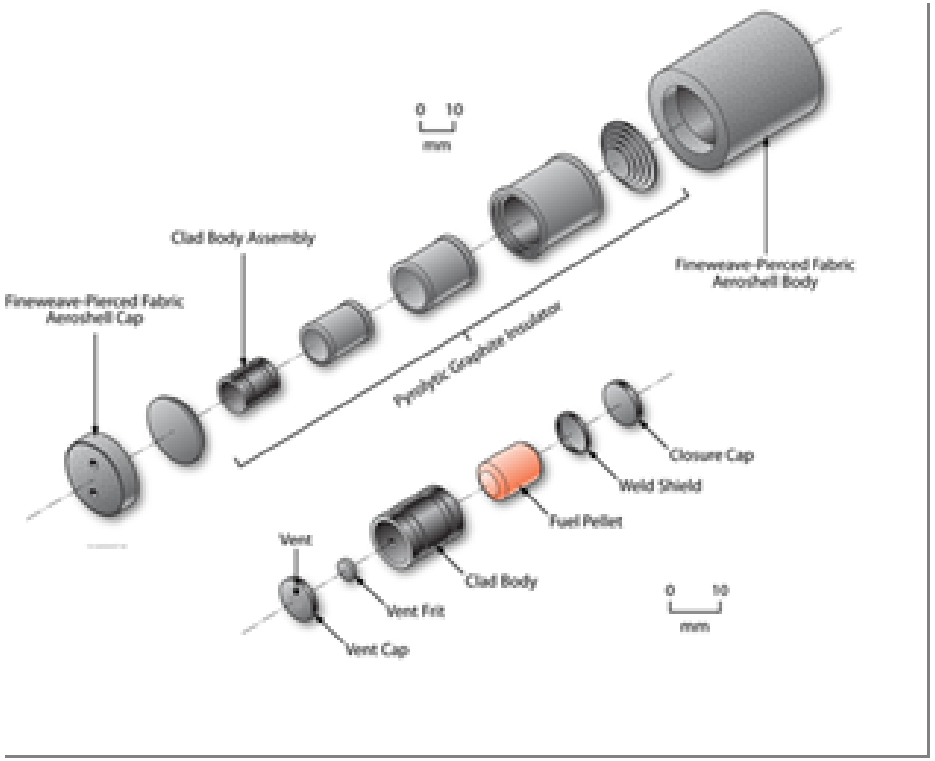
LWRHU Description

- One fuel pellet containing >80% $^{238}PuO_2$ fuel pellet encapsulated in platinum-30 rhodium (Pt-30 Rh) alloy cladding
- Cladding provides primary fuel containment
- Clad contains a frit vent to allow He to escape
  - He released from natural decay of plutonium dioxide
  - Avoids clad distortion from pressure build up



LWRHU Description

- Fueled capsule is surrounded by three concentric pyrolytic graphite insulator sleeves
  - Capped on the ends
  - Provide protection to the fueled capsule during re-entry and divert heat around the capsule
- Fine Weave Pierced Fabric (FWPF) aeroshell and cap provides for fueled capsule during reentry and launch accident events
- Overall dimensions
  - Overall diameter of 25.95 ± 0.05-mm
  - Length of 31.95 ± 0.05-mm
- Once fueled the LWRHU is thermally hot



LWRHU Management

- Interface working agreement will define detailed roles and responsibilities of participating agencies
  - Prepared early in each project
- Nuclear missions have added complexities compared typical NASA missions
- Missions should be aware of additional activities when developing overall plan

Shipping the LWRHU

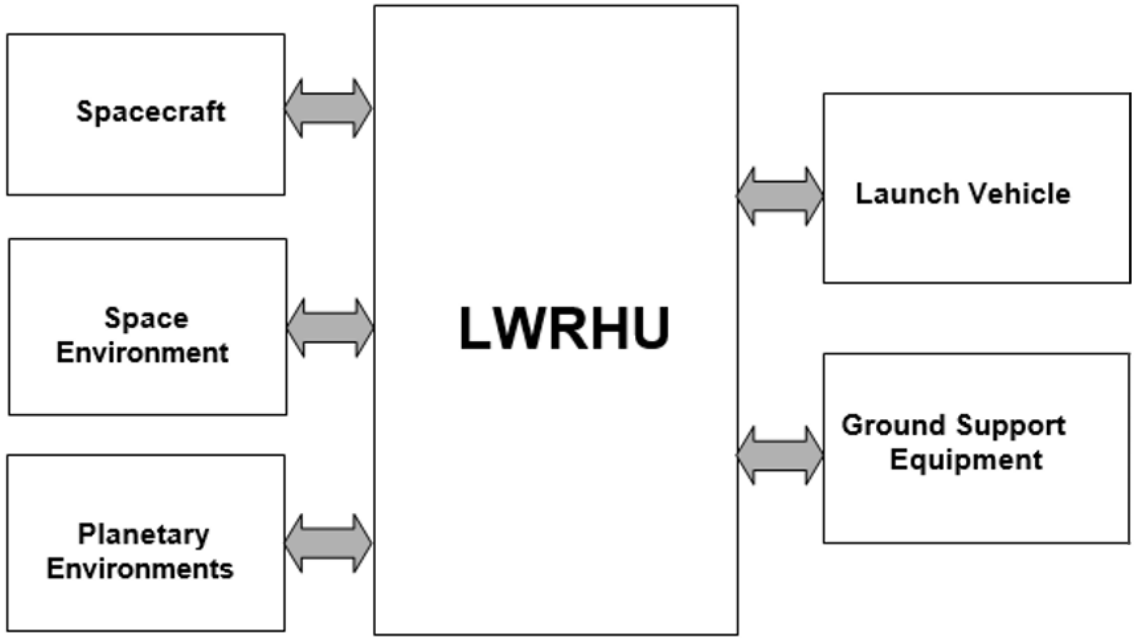
- Shipped to KSC after fueling and testing
- Cask options include 9975 or 9516 casks
  - 9975 cask
    - Can hold up to 19 watts
    - Bolted for easy use
  - 9516 cask
    - Can hold up to 500 watts
    - Welded container
- Cask is unloaded upon arrival at KSC
- Storage time at KSC is minimized to reduce resources required for managing a DOE Category 3 Nuclear Facility

Integration with Spacecraft

- LWRHU are delivered and stores in a safe prior to integration
- Personnel handle LWHRU with terry cloth gloves during integration
- Final checks are made to ensure successful integration with spacecraft
- INL personnel are responsible for material safety and security oversight

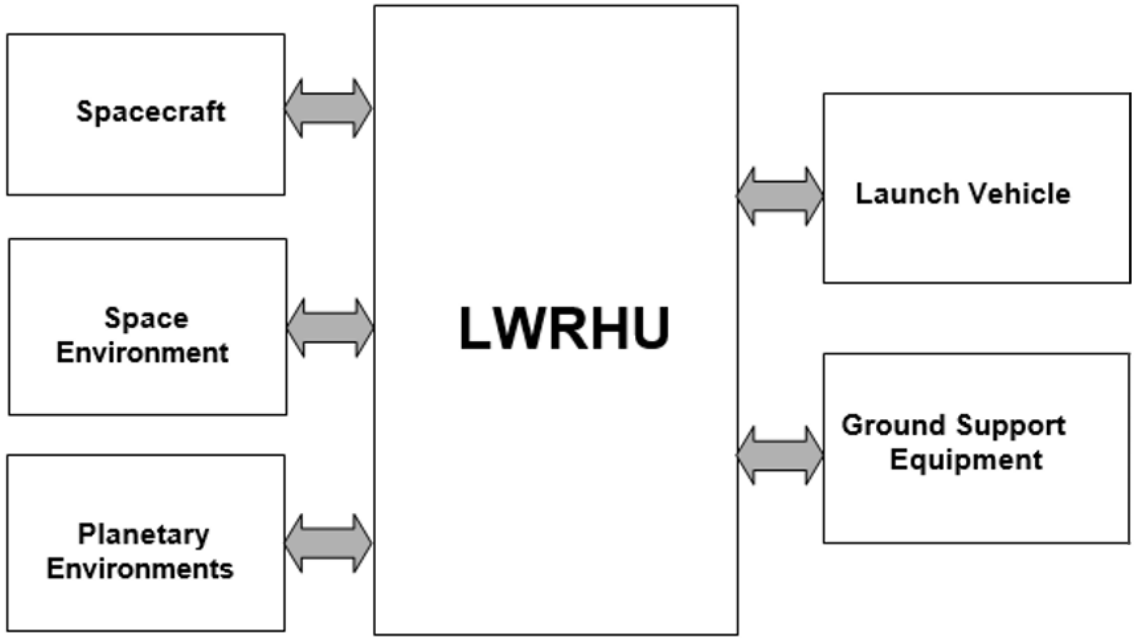
Interfaces

- Interfaces will be mission specific
- Spacecraft interfaces
  - mechanical interface with the LWRHU
  - thermal interfaces with the LWRHU
- Space-environment interface.
  - space vacuum environment
  - radiation environment
  - thermal environment,
  - mission load environment.



Interfaces

- Planetary-environment interface.
  - the atmosphere
  - atmospheric pressure
  - radiation environment
  - thermal environment
  - mission load environment.
- Launch-vehicle interface
  - the atmosphere
  - atmospheric pressure
  - radiation environment
  - thermal environment
  - mission load environment.
- Ground Support Equipment



Planetary Protection

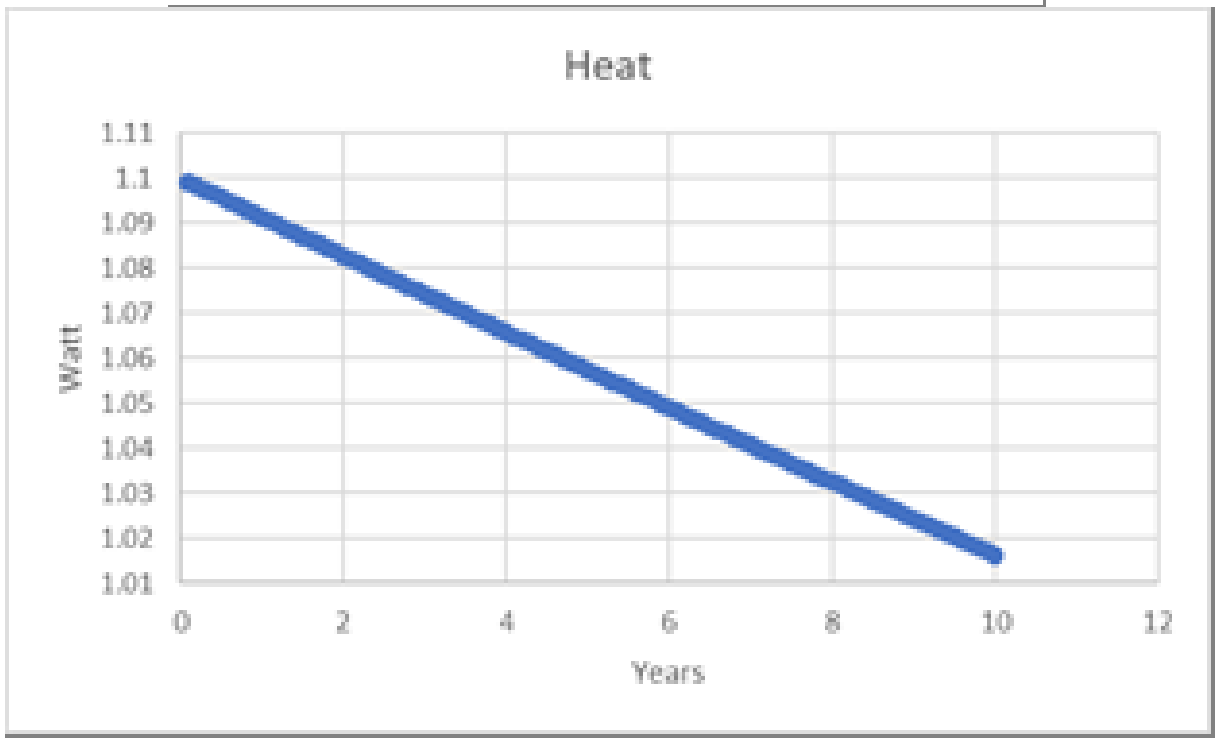
- LWRHU reaches surface temperature of 45 ℃
- Does not reach self sterilizing temperature of 110℃
- Additional sterilization methods may be needed if planetary protection is needed.
- Sterilization methods include but are not limited to:
  - acceptance via a cement curing process (150°C for 16 hours)
  - packaging and sealing LWRHUs inside sterile containers and shipping to KSC to be stored at PHSF and unpackaged and integrated into the spacecraft in a Clean Room
  - sterilizing LWRHUs at KSC via heat sterilization process

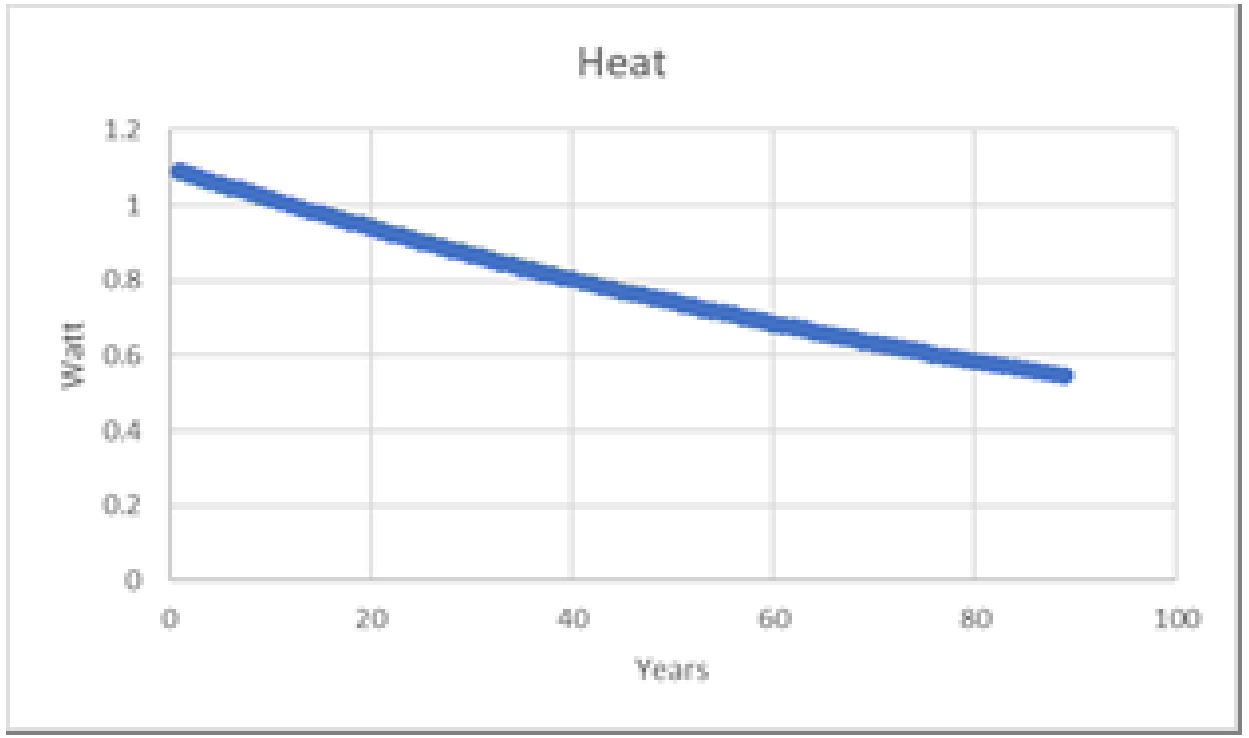
Launch Safety Requirements

- NASA missions planning to use a LWRHU must follow a number of NASA Procedural Requirements (NPR's) that includes:
  - NPR 8580.1, "Implementing the National Environmental Policy Act and Executive Order 12114,"
  - NPR 8715.3, "NASA General Safety Program Requirements,"
  - NPR 8715.2, "NASA Emergency Preparedness Plan Procedural Requirements—Revalidated,"
  - NPR 7120.5E, "NASA Space Flight Program and Project Management Requirements,"
- National Environmental Policy Act is required for NASA missions
- NSPM-20 establishes 3 tiers of launch authorization
  - Most LWRHU missions will be tier 1 or tier 2
  - Any tier of NSPM-20 will require a SAR

Simplified Power Prediction

$$W = W_I * e^{(-\ln(2)*(\frac{Decay\ Period}{Pu^{238}\ Half\ Life}))}$$





Conclusions

- INL has completed a user's guide for the LWRHU to assist potential users
  - Mission design
  - Scoping calculations
- Information includes
  - Mass properties
  - Design information
  - System interfaces
  - Launch Safety
- Form to request a copy of the LWRHU User's Guide can be obtained from J. Michael Newmann at j.m.newman@nasa.gov.

Acknowledgements

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Idaho National Laboratory

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