International Conference on Environmental Systems

Actively Controlled Louver for Human Spacecraft Radiator Ultraviolet (UV), Dust, and Freeze Protection

Authors:

Darnell Cowan - NASA Johnson Space Center (JSC)

Presented By:

Darnell Cowan

52nd International Conference on Environmental Systems (ICES)

16–20 July 2023, Calgary, Canada

ICES-2023-60

Agenda

- Background
- Problem Definition
- Louver Solution
- Results
- Conclusion

Background

- NASA plans to develop infrastructure on the lunar surface and orbit to enable a sustaining human presence on the Moon as part of the Artemis Program
- The current Lunar Surface Habitat concept incorporates conventional single-phase radiators coated with Z-93 white paint like used the ISS to reject heat

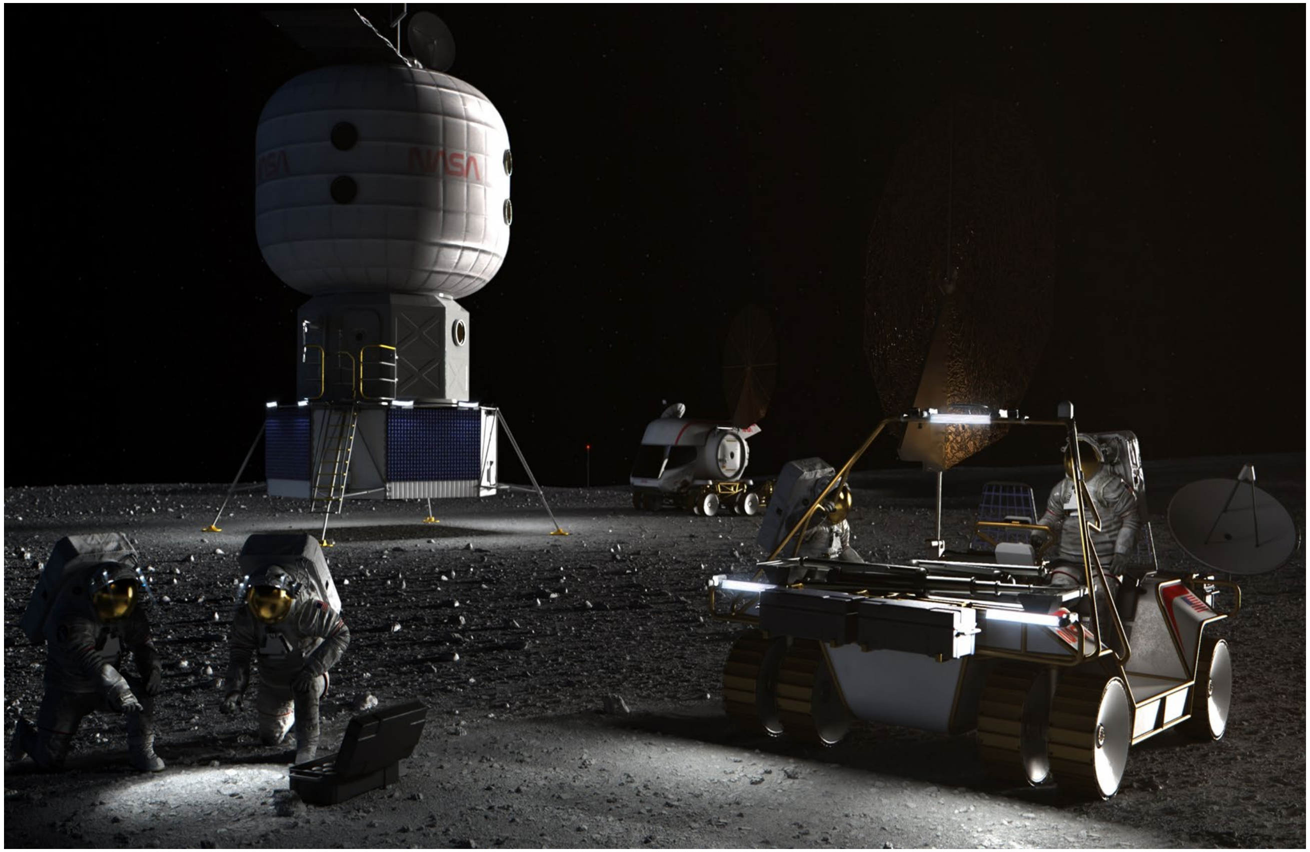

Figure: Lunar Surface Infrastructure Concept

Problem Definition

- During transit and on the lunar surface, the Lunar Surface Habitat Z-93 coated radiators will be exposed to high energy Ultraviolet (UV) radiation and lunar dust, which can significantly degrade the Z-93 absorptivity
- In addition, the environmental temperatures are below the coolant (HFE 7200) freezing point and can last for up to 14-days
- Actively controlled louvers is a solution to attenuate UV, dust and mitigate freezing concerns

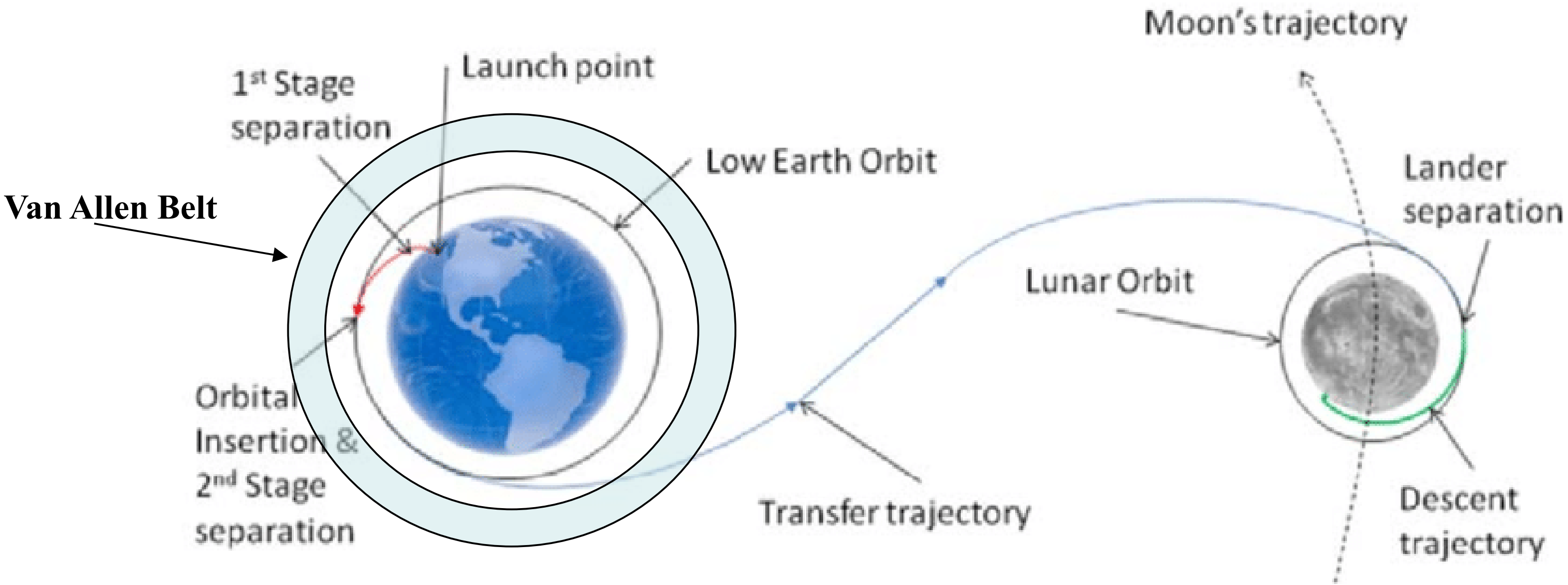

Figure. Simplified Artemis Spacecraft Flight Path

High Energy UV Radiation Impacts

- The Lunar Surface Habitat will travel through and dwell in the Van Allen Belts for days, and expose the radiator to high energy, or ionized, UV radiation
- Experiments have shown exposure to more than 500 Equivalent Sun Hours (ESH) in the Van Allen Belts can degrade the Z-93 absorptivity from 0.16 to 0.24, or 50%
- Thus, the radiator heat rejection capability will reduce from approximately 9 kW to 3 kW, or 60% reduction, based on conservation of energy

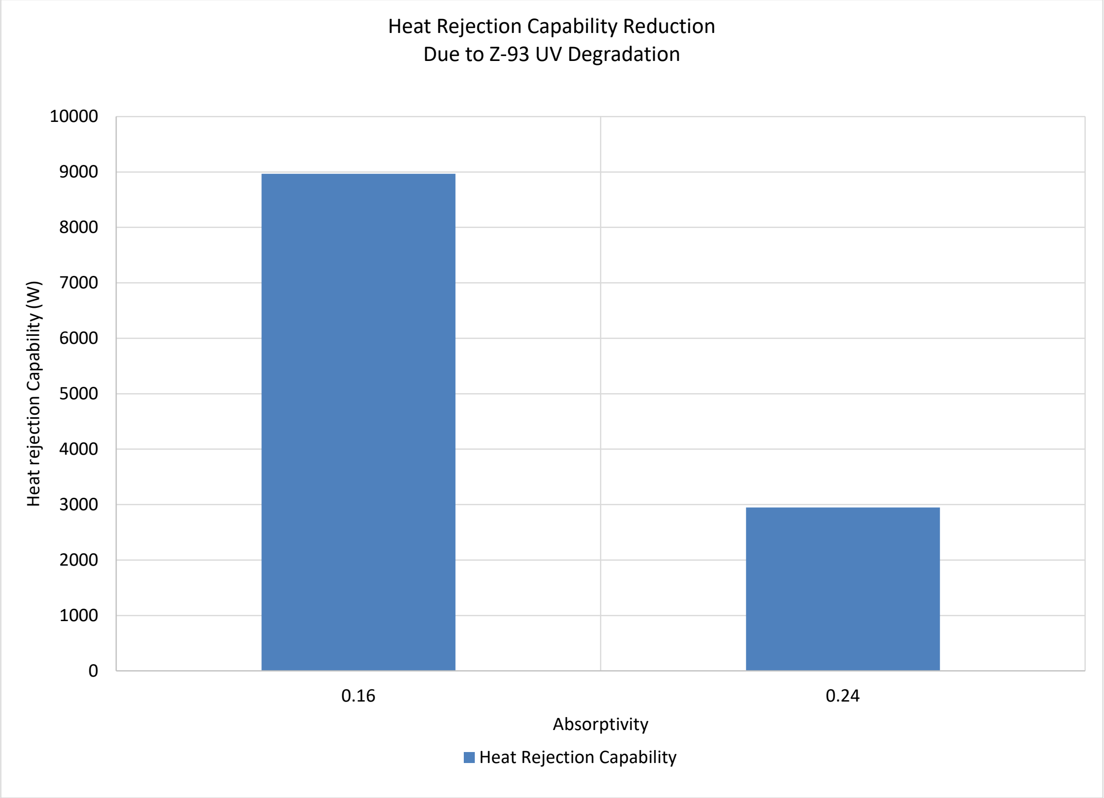

Figure. Change to Z-93 Absorptivity and Heat Rejection Capability due to Ionized UV

Lunar Dust Impacts

- Lunar dust is copious, highly adhesive, and tests have shown Z-93 absorptivity linearly degrades with the amount of dust coverage
- As little as 20% dust coverage can increase the absorptivity and decrease the heat rejection capability by 75% and 30%, respectively

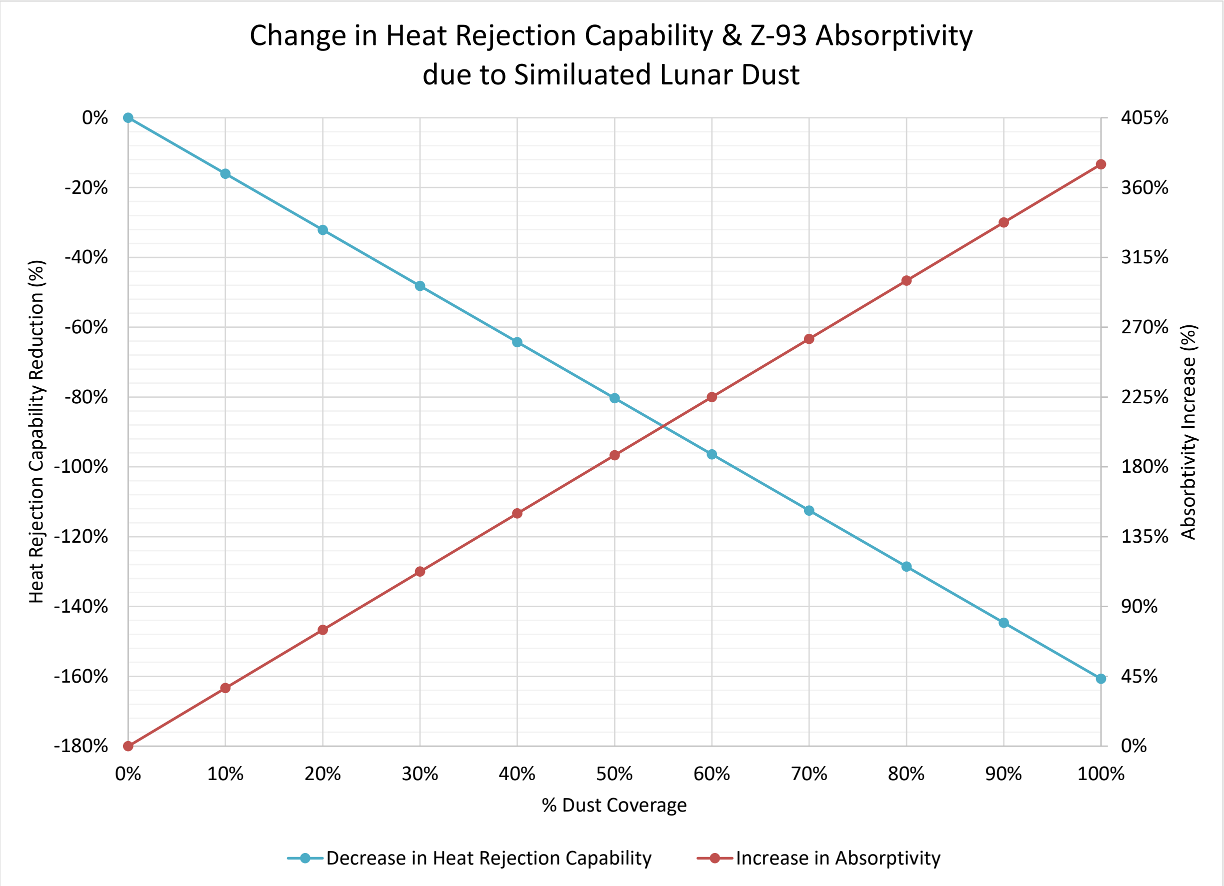

Figure. Z-93 Absorptivity and Heat Rejection Capability Degradation due to Lunar Dust

Freezing Impacts

- The environmental, or sink, temperatures during transit to lunar orbit and the 14-day lunar nights near the south pole can drop below the HFE freezing point and working limit

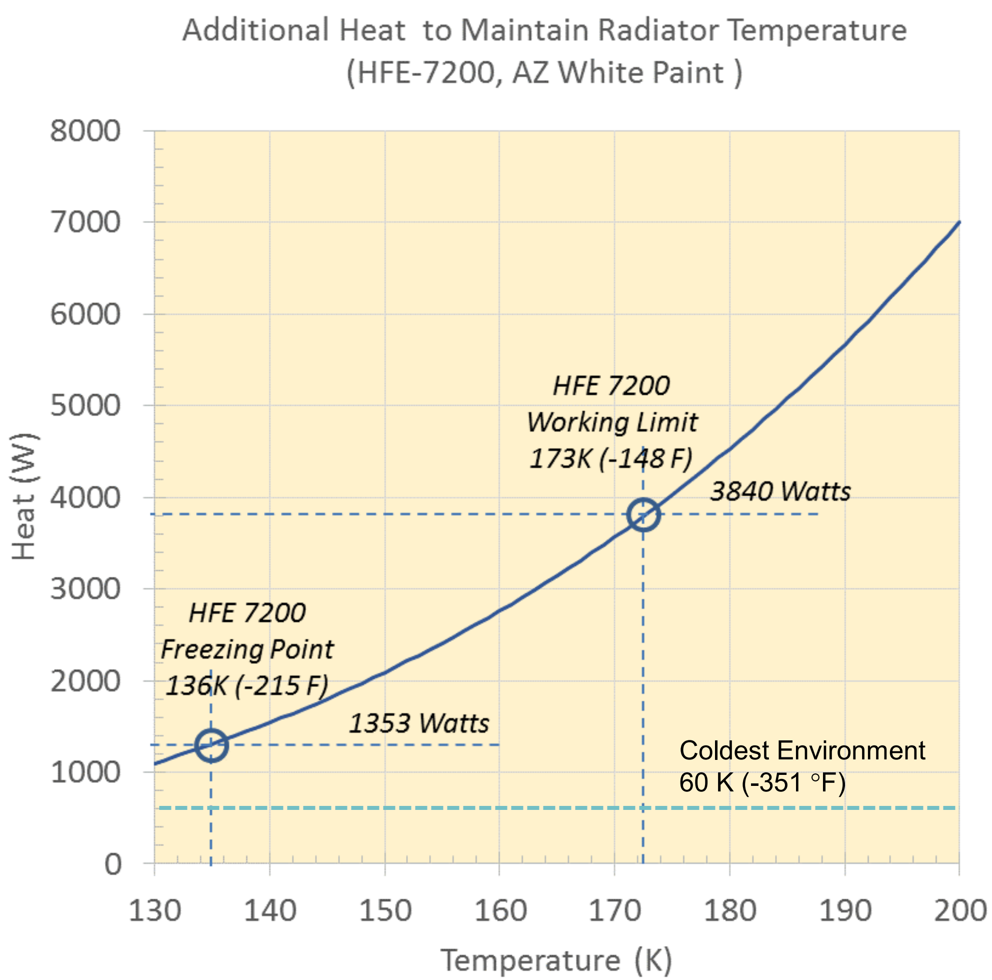

Figure. Heater Power Needs (reference TFAWS2021-AT-04)

Louver Solution

- A possible solution to reduce Z-93 absorptivity degradation and mitigate coolant freezing concerns is equipping a radiator with actively controlled louvers

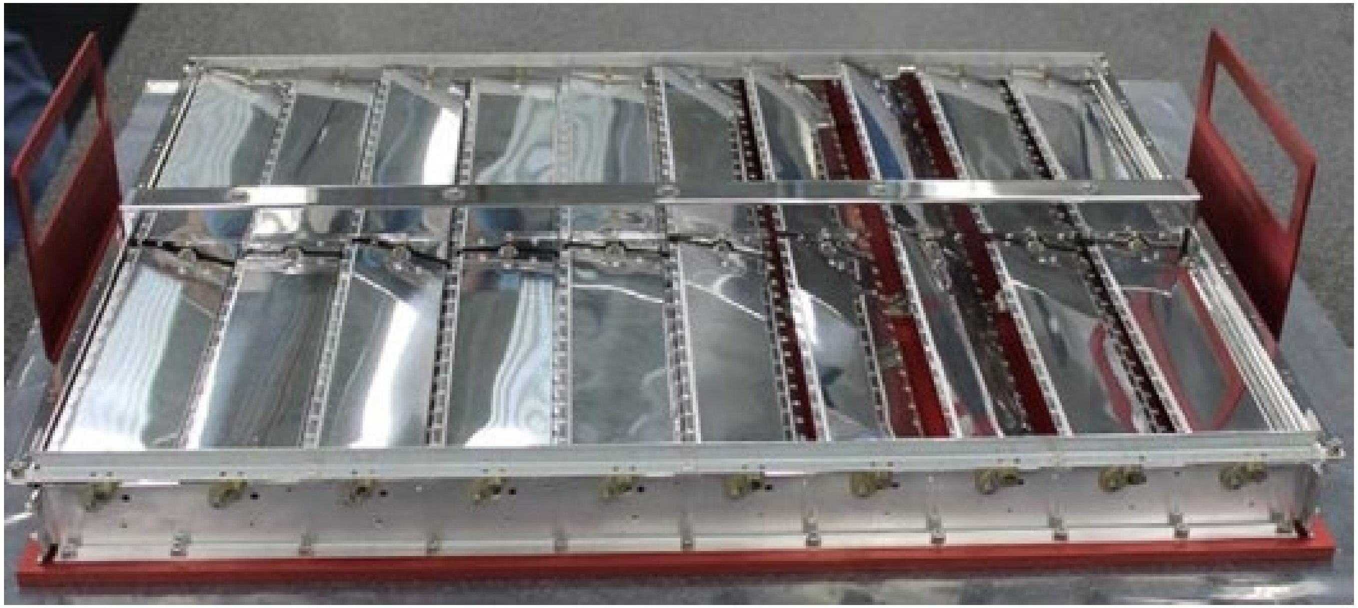

Figure. Sierra Nevada Corporation's (SNC) Passive Louver

UV Attenuation

- The louver blades can attenuate ionized UV from reaching the radiator coating while in the closed position
- Conventional aluminum louver blades are ~ 1.3 cm thick, and the UV intensity through the Van Allen Belts can be reduced from to 0 with this thickness based on Beer-Lamberts Law
- Thus, eliminating the Z-93 absorptivity degradation maintaining heat rejection capability upon arrival to lunar orbit or surface

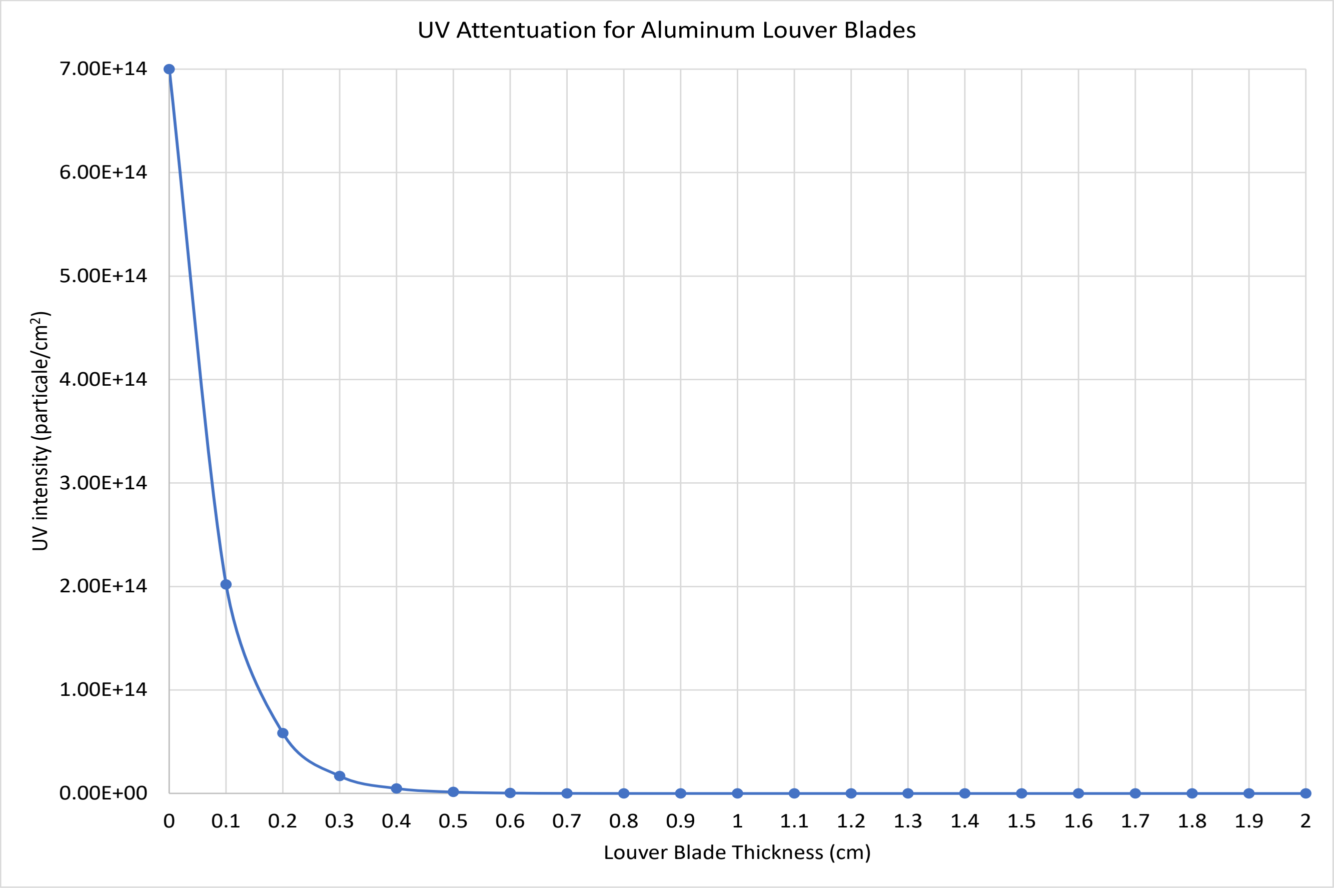

Figure. Aluminum Louver Blade Thicknesses Ionized UV Attenuation

Dust Protection

- Louvers can also block dust from settling on Lunar Surface Habitat (LSH) radiators while in the closed position, and limit Z-93 absorptivity and heat rejection capability degradation
- Currently, the amount of lunar dust adhering to a bare radiator without a louver for the LSH life cycle is undetermined, but assumptions can be made to assess the feasibility of using louvers for protection
- Assuming the bulk of the dust originates during landing while the radiator is stowed, total heat rejection capability of a four-panel radiator assembly will drop approximately 20%

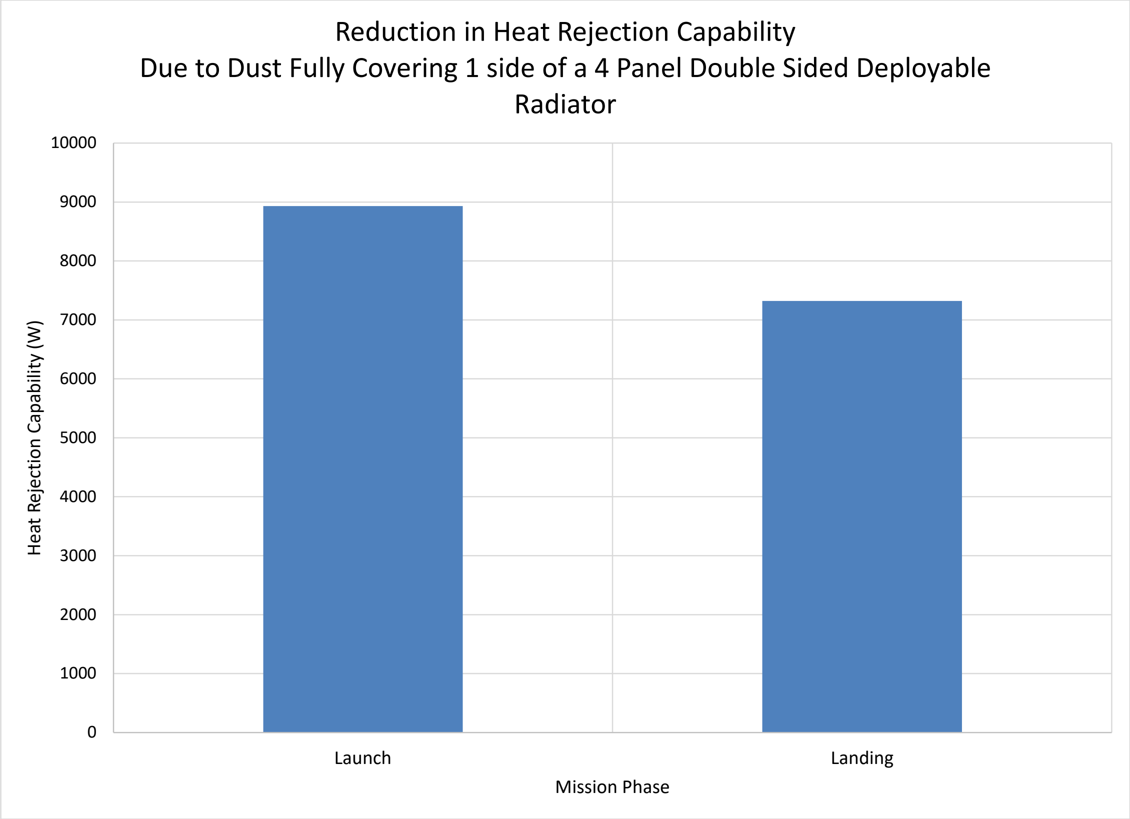

Figure. LSH Heat Rejection Capability Due to Dust on 1 Side of 1 Radiator Panel

Coolant Freeze Protection

- Louvers can reduce the radiator's effective emissivity to 0.14 while in the closed position and keep the radiator outlet temperature above the HFE 7200 working and freezing points
- This can be calculated using the first law of thermodynamics and assuming no environmental heat loads to bound the analysis (i.e., worst case cold conditions)

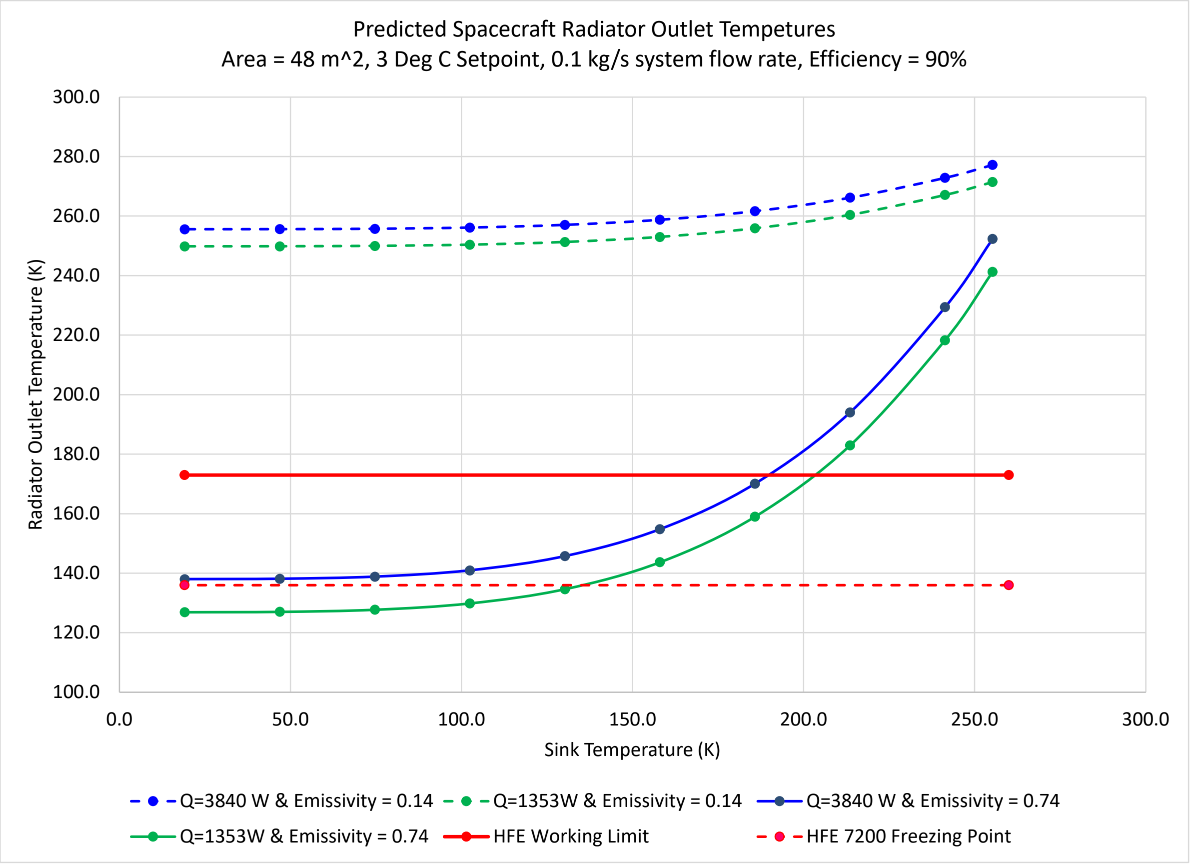

Figure. LSH Radiator Outlet Temperatures as a Function of Sink Temperature

Radiator Heat Rejection Capability with Open Louvers

- The louver will shunt some of the heat rejection capacity, and can be calculated by adding a view factor assuming blades mimic a rectangular-to-rectangular plate
- The results show a 13 to 7% reduction in heat rejection capability with the louvers, but the slight reduction in capability outweighs the reduction due to ionized UV and dust, which can range from 20 to 120%

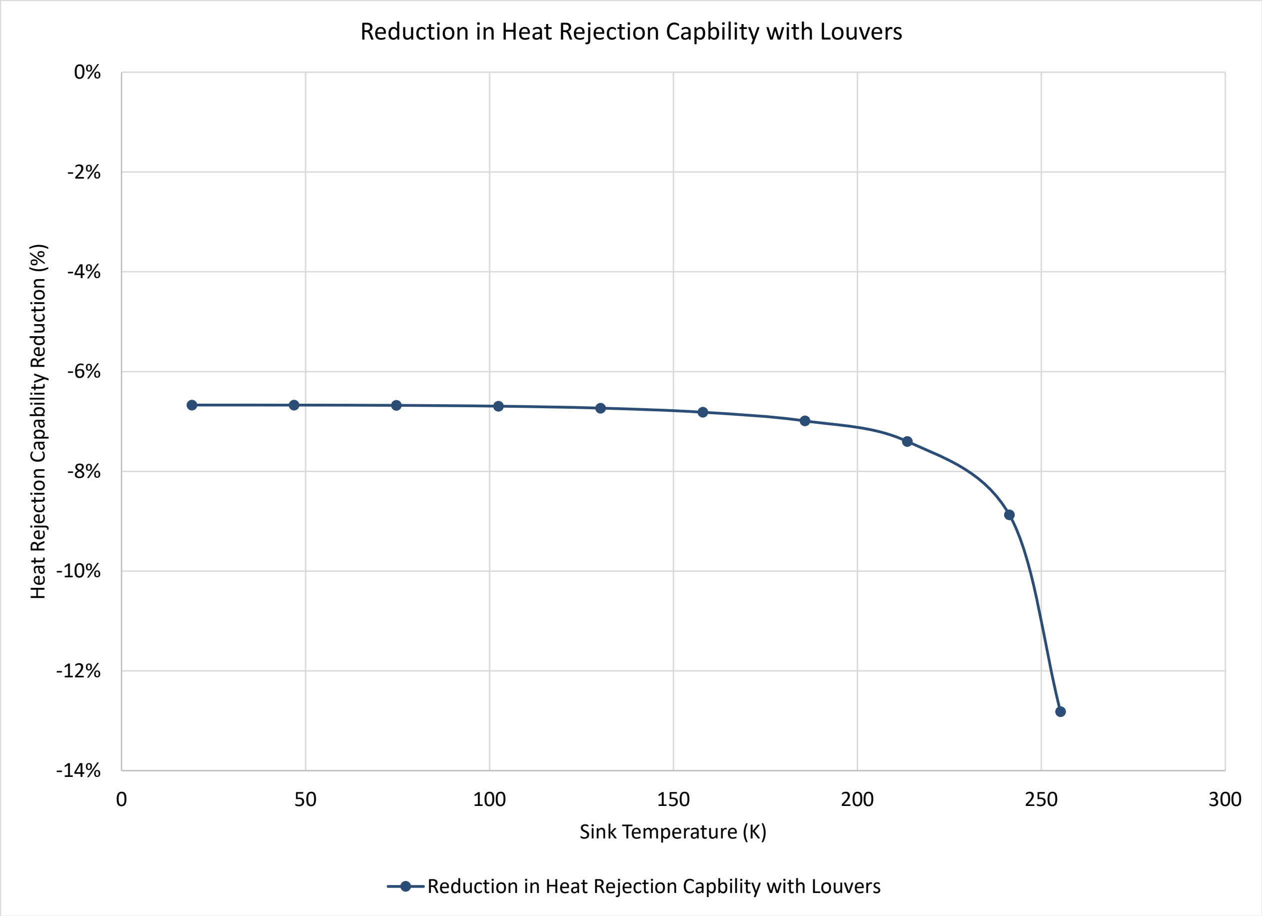

Figure. Heat Rejection Capability with a 14 Blade Louver and View Factor

Actively Controlled Louver Design Considerations

- Passively controlled louvers have been used on satellites like New Horizons Pluto and Rosetta12 for decades, but not on heritage human spacecrafts
- Advancement to active control (i.e., motorized) is necessary to improve thermal response times and allow ground control

Parameter	Passive Louver	Active Louver
Emissivity Range	0.14 to 0.74	0.14 to 0.74
Heater Power	4 kW	0
Power	0 kW	Less than 350 W
14-Blade Weight	1 kg (2.2 lb.)	0.5 kg (1 lb.)
Blade Thickness	Less than or equal to 1.3 cm (0.5 in)	Less than or equal to 1.3 cm (0.5 in)
Open to Close Response Time	1 to 2 hours	< 15 minutes

Table. Human Spacecraft Active Louver Design Considerations Compared to Passive Louvers

Conclusions

- Equipping human spacecraft radiators with louvers is a feasible solution to limit coating degradation due to ionized UV and lunar dust, as well as mitigate coolant freezing concerns during Artemis Missions

- Technology development is necessary to advance the louver from the conventional passive controlled to active control and the next step is to produce a proof of concept based on the design considerations

Questions?