National Aeronautics and Space Administration

Long Life, High Speed, Heaterless Mobility Actuators

Principal Investigator: Andrew Kennett (352); Co-Investigators: Duval Johnson (352), Robert Dillon (357), Jason Kempenaar (353)

Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Long Range Lunar/Mars Surface Mobility**

Overall Objectives:

Develop mobility actuators operable from -230ºC to +125ºC without preheating for day and night driving at 30 cm/s, at comparable mass & volume to the state of the art.

FY21 Objectives:

Develop design guidelines for dry lubricated gearing, that allows life greater than 4e19 cycles*MPa^5, for stresses between 200 and 800 megapascals.

- Rationale: Validated guidelines do not currently exist for dry lubricated gearing.
- Relevance: This performance enables a 100km traverse range at a similar mass and volume to the wet lubricated SOA.

Demonstrate heat management of a torque-dense, outer rotor motor, with >5x the specific torque density of the current Mars SOA.

- Rationale/relevance: Enables significantly less gearing, and proportionally lower input cycle requirements

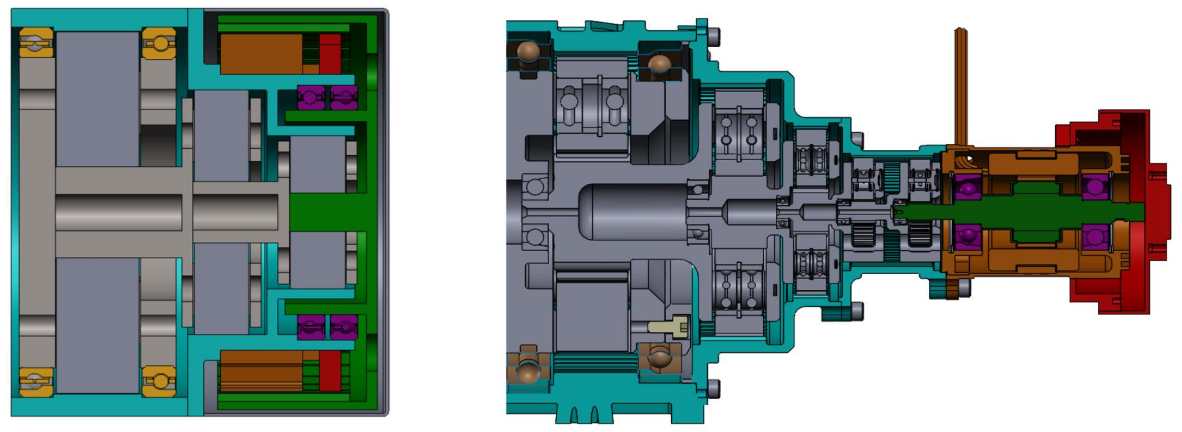
Background and motivation:

Lunar and Mars mission studies have identified highly demanding requirements for surface mobility, which far exceed that demonstrated by the current state of the art actuators in traverse speed, traverse distance, and energy allowed for heating (the current state of the art actuators require heating to at least -55ºC, in flight).

New mobility actuator technology that provides extremely long life, velocities up to 30 cm/s, and operation at -230°C without preheating would be enabling for the Endurance, Inspire, and Intrepid Lunar rover missions, which are highly likely to be referenced in the next Decadal Survey. It would also enable a Mars surface mission to visit multiple type localities for sampling the geological diversity of the planet, which could be proposed to New Frontiers 6.

Approach and Results

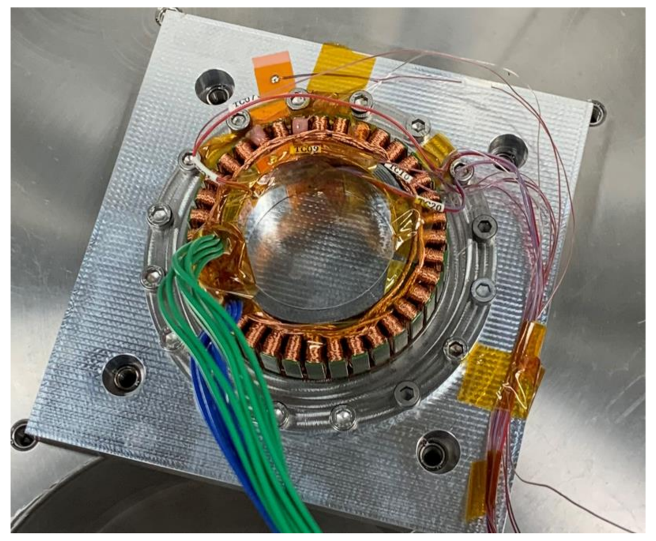
Concept Actuator:



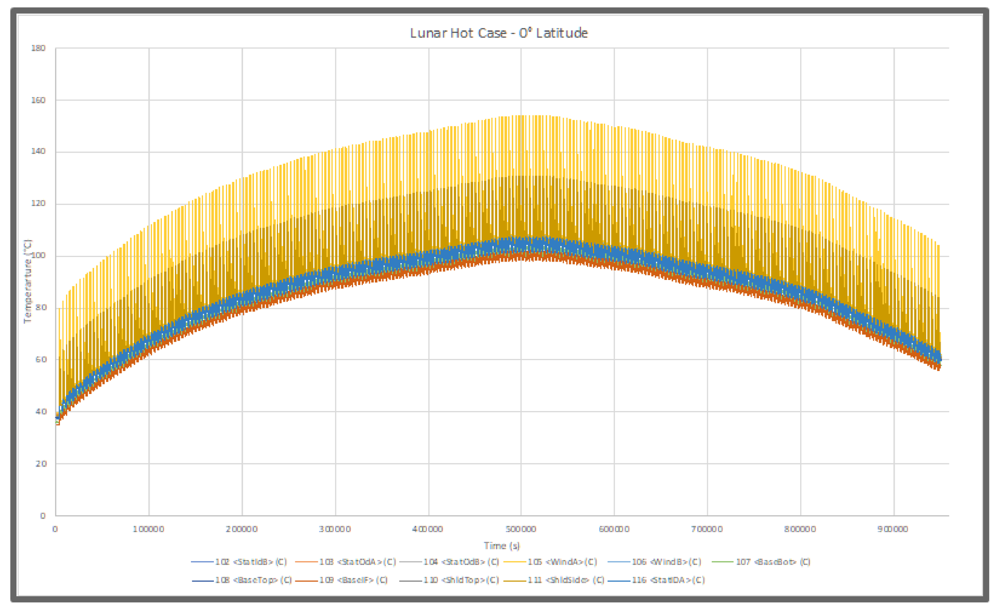
The concept actuator, left, uses a large diameter, torque dense, outer rotor motor to allow for a significantly reduced gear ratio, as compared to the current state of the art (right). This reduces the requirements on the motor bearings and input gearing, enabling the opportunity of replacing wet lubricants with dry lubricants that do not increase in drag at low temperature.

Outer rotor motor thermal demonstration:

To demonstrate that the proposed outer rotor motor could dissipate heat effectively, a representative motor was modeled and tested to characterize its performance in a vacuum environment. This testing and modeling demonstrated that continuous, high speed mobility is possible, and can enable future Mars and Moon missions, without overheating.



Instrumented motor in vacuum chamber

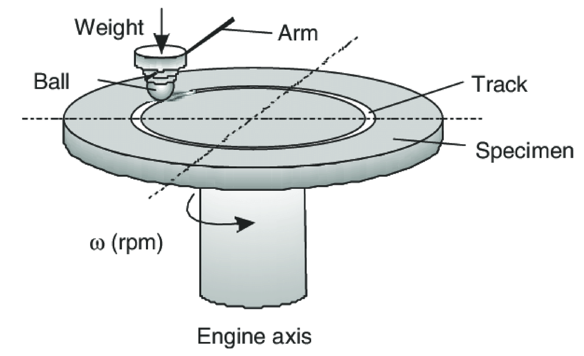


Correlated motor temperatures, showing safe, continuous operation in an Lunar, equatorial environment.

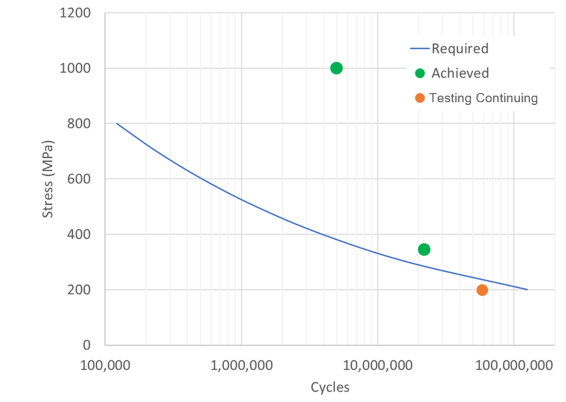
Dry lubricant down-selection:

A variety of lubricants were procured from two vendors, and tested using a pin-on-disk tribometer to evaluate performance. Coatings applied by vendor A (JPL's traditional vendor) performed significantly below that of vendor B, even for the same requested coating. Chemical analysis and other inspections identified inconsistencies with vendor A's coatings, which may explain the discrepancy in performance.

At the completion of the first year, one coating from vendor B has demonstrated consistent pin-on-disk performance, in excess of that required for the concept actuator, in an ambient gN2 environment. This testing will be extended to gearing, and to low temperatures in FY22.



Schematic view of a pin-on-disk test apparatus



Plot of stress vs. life for preferred coating, at three contact stresses.

Significance/Benefits to JPL and NASA

This task has demonstrated that JPL/NASA can take advantage of the high torque density of outer rotor motors, as long as they are used in a high aspect ratio configuration, with a large inner diameter to reject heat (as configured above). This allows for significantly reduced gear ratios, which reduces the life required for input gearing and allows for higher achievable output speeds. The former is enabling for dry lubricated actuators, meant for cold environments, while the latter is universally applicable to all rover missions.

While further developments are in progress, initial testing indicate that dry lubricants can reliably achieve the lifetimes necessary for long distance traverse, without the need for external heating.

These developments combined, will yield an actuator that is capable and enabling of the needs for future Mars and Lunar missions as describe to the left.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: Andrew.Kennett@jpl.nasa.gov

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