Analysis for Lithium-Combustion Power Systems for Extreme Environment Spacecraft

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A longer duration mission to the surface of Venus will require a different power system

**Venus Surface:**
- 740 K
- 92 Bar
- ~1-2 m/s wind speeds
- 96.5% CO₂, 3.5% N₂, other trace gases

**Venera 13:**
- Battery powered lander
- Planned duration: 32 minutes
- Actual duration: 127 minutes
ALIVE mission concept could enable a 5 day surface mission without high temperature electronics

Power plant requirements:
- 13.3 kW$_{th}$ at 850°C
- 120 hour duration
- Total 213 kg
- Duplex Stirling engine for cooling (2.0 kW$_{pv}$) & power (0.33 kW$_{e}$)

Lithium combustion systems provide greater energy density systems than alternative options.

Combustion Reaction [2] [3]:

\[ 5\text{Li} + \text{CO}_2 \rightarrow 2\text{Li}_2\text{O} + 0.5\text{Li}_2\text{C}_2 + \text{Heat} \]

\[ \text{Li}_2 + \text{CO}_2 \rightarrow \text{Li}_2\text{CO}_3 + \text{Heat} \]

Energy Density [3]:

- **Li/CO\textsubscript{2} Burner**
  - 650 kW-hr/m\textsuperscript{3} system energy density

- **NaS Battery**:
  - 350 kW-hr/m\textsuperscript{3} system energy density
Computational analysis were performed for the energy/mass balance and natural convection in the reactor.

EES: Control Volume Analysis

COMSOL: Natural Convection Model

Acta Astronautica Publication Link [4]:
https://doi.org/10.1016/j.actaastro.2018.05.039
Experimental testing was performed to validate model data and to prove the concept.
Reactor 1.0: Controlled burn of lithium and carbon dioxide while removing heat
Reactor 2.0: Controlled burn of lithium and carbon dioxide producing electricity with a TEG
Reactor 3.0: The next reactor test will require a new injector mechanism

Injector test with chamber at vacuum pressure

Injector test with chamber at 30 psig
Future Work: Selected proposal for NASA SMD’s Hot Operating Temperature Technology (HOTTCH)

- HOTLINE project (Hot Operating Temperature Lithium combustion for IN situ Energy and Power)

- Designing a lithium combustion reactor driven mercury vapor turbine power cycle with an integrated cooling system
Thanks To:

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- NASA SMD for selecting the HOTLINE project (Award # 80NSSC17K0591)

- CU Boulder for hosting IPPW-15

- IPPW for supporting me with a student scholarship
References


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Valve Access:
- Control Room: Manual
- Control Room: Remote Electrical
- Test Cell: Manual