PROGRESS ON THERMAL ENERGY CONVERSION TECHNOLOGIES FOR THE RADIOISOTOPE POWER SYSTEMS PROGRAM TECHNOLOGY MANAGEMENT ELEMENT. L.J. Evans[1] and S. K. Bux[2], [1]NASA Glenn Research Center, [2]Jet Propulsion Laboratory/California Institute of Technology.

Introduction: Radioisotope power systems (RPS) such as Radioisotope Thermoelectric Generators (RTGs) have been successfully used to power deep space missions for the past 60 years. Though reliable, rugged, and long-lived, the thermal to electric conversion efficiency for the state-of-the-art flight systems is only ~6%. The National Aeronautics and Space Administration (NASA) Radioisotope Power Systems (RPS) Program Technology Management (TM) Element is currently working to mature several research technologies for power generation enabling landers and rovers to survive through the lunar night. This abstract introduces the technologies that are under development by NASA's RPS Program TM Element.

Technology Management Element: The TM Element of the RPS Program Office manages and invests in developing promising thermal-to-electric conversion technologies. The technology readiness level (TRL) level of a system indicates how well-developed it is. TRL 1-4 involves proof-of-concept, modeling, and basic breadboard testing and progresses up to TRL 9 flight proven systems. The focus of the TM Element is maturing low-TRL (TRL 1-5) technologies for future RPS infusion.

While RTGs have proven to be reliable means of converting heat to electricity for space missions, other methods of thermal energy conversion are also being developed by TM. The TM element manages several radioisotope conversion technologies at various TRL levels including solid-state (thermoelectric), dynamic (Stirling), and electrochemical (Ericsson). The highest maturity task currently in the TM portfolio is the Skutterudite Technology Maturation Task (STM) which is currently at a TRL 4-5. The use of Skutterudites compounds ($CoSb_3$ based) as thermoelectric materials instead of lead-telluride as "drop in" replacement could enhance the current state-of-the-art MMRTG system end of design life (EODL) 17 yr power levels significantly [1]. Another supported task which is TRL 2 is developing segmented thermocouples that could upgrade the GPHS RTG restart currently invested in by the RPS Program (Next Gen Mod 1 Project) [2]. The task Group for the HOlistic Science of Thermoelectrics (GHOST) is TRL 1 and is focused on improving thermoelectric materials through the utilization of modeling and experimental validation [3]. The Small Stirling Technology Exploration Power (SmallSTEP, TRL 2) task is a Stirling cycle-based conversion system for low power applications [4]. Finally, the Radioisotope Johnson Thermo-Electrochemical Convertor (RJTEC, TRL 1-2) is a heat engine utilizing gaseous electrochemical cells and the principles of the Ericsson thermodynamic cycle for heat-to-electric conversion [5].

TM Task Key Performance Parameters: To highlight the trades for investments, key performance parameters (KPP) such as the specific power, efficiency, power output, technology readiness level, and system mass can be compared using an analytical hierarchy process (AHP) [6]. The AHP was utilized to create weighted values for each evaluation criteria and then combined with decision matrices to create table scores comparing past and present systems. Each task will be briefed in detail, outlining key performance parameters (KPPs), progress, AHP tables, comparison matrices, graphical visualizations, and path to infusion in future RPS. Six criteria will be highlighted: 1) TRL - The technology maturity level. This considers the time to maturation and cost of further development. 2) System Efficiency (%) - The system conversion efficiency at BOL. 3) Specific Power (W/kg) - The specific power (We/kg) of the system. It is not affected by the large (>300 W) or small (mW) scale of the system. 4) Power Output (We) - The electrical power output at beginning of life. This ignores potential mission requirements for a low or high-power system. 5) Mass (kg) - The mass of the system, accounting for the number of GPHS modules and Pu-238 (or alternative heat source.) 6) 17-yr Power Output (We) – The electrical power output at end-of-design life. Pairwise comparisons allow each criterion to receive a weighted value, and the effect of prioritizing different KPPs based on potential missions will be demonstrated.

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References:

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