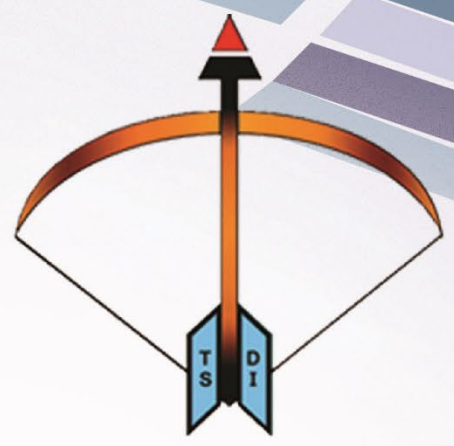




Temasek Defence Systems Institute

SUSTAINABLE ENERGY HARVESTING TECHNOLOGIES FOR PERPETUAL UAV OPERATIONS

Author: MAJ Koh An Song
Thesis advisor: Paul T. Beery
Co-advisors: Eugene P. Paulo

Background

Unmanned Aerial Vehicles (UAVs) operational endurance is constrained by reliance on lithium-polymer batteries. This limitation affects their effectiveness in long-duration missions, particularly in operations where uninterrupted surveillance and mission execution are critical. Renewable energy sources provide an opportunity to extend UAV flight times, potentially achieving near-perpetual flight.

Objective

This study aims to explore and evaluate the integration of renewable energy technologies—solar, kinetic, and RF energy harvesting—into UAV systems. By utilizing simulation models, the research seeks to determine the feasibility and performance of these technologies in extending UAV endurance, with a focus on enhancing operational efficiency for military applications, particularly naval missions.

Methodology

Simulation Software: ExtendSim 10 was used to model and analyze UAV systems with integrated energy harvesting technologies.

Energy Sources: Solar panels, kinetic energy harvesters (piezoelectric systems), and RF energy harvesters were incorporated into the UAV model.

Design of Experiments: A 2-level full factorial design was used, with 128 configurations tested. Each configuration was simulated 30 times for a total of 2,400 hours of simulation, representing 100 days of flight operations.

Data Analysis: Regression analysis and contour profiling were performed using Minitab and JMP Pro to evaluate the impact of different energy harvesting configurations on flight endurance.

Key Findings

Solar Energy Dominates: Solar energy harvesting showed the most significant improvement in UAV flight endurance, with larger solar panel areas and higher efficiency contributing the most.

Kinetic and RF Energy Harvesting: Kinetic and RF energy systems had a less significant impact, with kinetic energy harvesting even reducing efficiency due to its low power density.

Way Ahead

Prioritize Solar Energy: Future UAV designs should prioritize solar energy harvesting for maximizing endurance, with focus on enhancing solar panel efficiency and integration.

Improve Kinetic and RF Technologies: Additional research should explore ways to make kinetic and RF energy harvesting more efficient and viable for UAV operations.

Field Testing: Conduct extensive field testing under various environmental conditions to validate the performance of energy harvesting technologies in real-world scenarios, for military environment.

Date: Nov 2024