

Mission Performance of a Solar- and Microwave-Powered Aircraft

Adam Wickenheiser^{*a}, Ephraim Garcia^a

^aSibley School of Mechanical and Aerospace Engineering, Cornell University Laboratory for Intelligent Machine Systems, Ithaca, New York 14853

ABSTRACT

Unmanned aerial vehicles typically have limited flight time due to their reconnaissance payload requirements and their restricted scale. A microwave/solar powered flight vehicle, on the other hand, can remain in-theater continuously by harvesting electromagnetic radiation using on-board antennas and solar panels. A rectifying antenna is used to harvest power and rectify it into a form usable by the on-board electric motors and other electronics, while photovoltaic cells harness incoming solar radiation. Discussed is the design of the fuel-less air vehicle and its sensitivity to several key performance metrics for this class of aircraft. New metrics are presented that are unique to microwave-powered aircraft and are useful in the design of its missions. Of critical importance is the strong coupling among the aircraft's flight performance, power harvesting abilities, and its mission capabilities. Traditional and non-traditional wing shapes are presented in order to motivate a discussion of some of the key parameters in the design of a fuel-less air vehicle.

Keywords: power harvesting, microwave power, solar power, aircraft, performance

1. INTRODUCTION

Wireless power transmission has been considered as a highly advantageous alternative to wired transmission since the pioneering work of Heinrich Hertz; however, practical methods of focusing high-power electromagnetic energy have only existed since the 1930s. Furthermore, efficient means for converting this energy into usable DC current did not exist before the development of the rectenna (or rectifying antenna) in the 1960s.¹ Landmark experiments on microwave-powered airborne platforms were conducted by Brown on a tethered helicopter platform² and by DeLaurier on a free-flying, fixed-wing aircraft.³ Both of these experiments used large external rectenna arrays that degraded the performance of the aircraft. Flexible rectennas,⁴ however, may provide a solution to integrate the antenna into the structure of the airframe as well as conform it to its aerodynamic surfaces. This will provide a more practical solution to the fuel-less aircraft design problem.

Several aspects of fuel-less aircraft design, mission profile, and trajectory optimization have been considered. These mainly fall under the categories of sizing and weight requirements⁵⁻⁶ and station-keeping trajectory optimization in the presence of wind or measurement uncertainty.⁷⁻⁹ These studies, however, do not consider the coupling between the aerodynamic performance and the energy harvesting performance. Indeed, the wing shape and size can be designed to strike an optimal balance between aerodynamics and harvesting capabilities. Furthermore, the mission profile has a large impact on the optimal design. For example, an aircraft design for perpetual station-keeping over the microwave transmitter will not have the same aerodynamic capabilities as a long-range surveillance aircraft.

This paper focuses on several of the key metrics to consider when designing a fuel-less aircraft and its mission profile. These include traditional measures – such as endurance, range, and required power – and several new metrics that describe the aircraft's capabilities as a function of distance from the transmitting power source. The sensitivity of each of these metrics to design parameters and the physical basis for maximizing them will be discussed

* amw30@cornell.edu; phone 1 607 255-5457; fax 1 607 255-1222