Combined Experimental and Numerical Investigations into Laser Propulsion Engineering Physics

by

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ABSTRACT

The RPI pulsed Laser Propulsion (LP) research effort focuses on the future application of launching nano- and micro-satellites (1-10 kg payloads) into Low Earth Orbit (LEO), using a remote Ground Based Laser (GBL) power station to supply the required energy for flight. This research program includes both experimental and numerical studies investigating the propulsive performance of several engine geometries (constituting a lightcraft family). Using the Lumonics twin K-922m TEA pulsed laser system, axial and lateral thrust, C_m, I_{sp}, and η measurements were made for these engine geometries, examining the effects of several critical factors including: engine orientation (e.g. lateral and angular offset), laser pulse energy, pulse repetition frequency, pulse duration, propellant type, and engine size-scaling effects. Investigation into the origins of lateral “beam riding” forces was of particular interest. Lateral impulse measurements and high speed Schlieren photography were utilized to provide an understanding of laser beam-riding/propulsive physics.

The acquired lightcraft database was used to further develop an existing 7-Degree Of Freedom (DOF) flight dynamics model extensively calibrated against 16 actual trajectories of small scale model lightcraft flown at White Sands Missile Range, NM on a 10 kW pulsed CO2 laser called PLVTS. The full system 7-DOF model is comprised of updated individual aerodynamics, engine, laser beam propagation, variable vehicle inertia, reaction controls system, and dynamics models, integrated to represent all major phenomena in a consistent framework. This flight dynamics model and associated 7-DOF code provide a physics-based predictive tool for basic research investigations into laser launched lightcraft for suborbital and orbital missions. Simulations were performed to demonstrate the flight capabilities of each engine geometry using the updated lightcraft propulsion database, the results of which further demonstrate that autonomous beam riding capability is an essential component for a stable launch to orbit and the future of LP.