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MEMORANDUM FOR PRS (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO) 26 September 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-AB-2000-183**
Mead, Frank; Larson, Bill, "Review of Recent Progress During Laser-Powered Lightcraft Flights to Unlimited Altitudes"

Lasers 2000 (Albuquerque, NM, 4-8 December 2000) **(Statement A)**
(Deadline: 30 Nov 2000)

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REVIEW OF RECENT PROGRESS DURING LASER-POWERED LIGHTCRAFT FLIGHTS TO UNLIMITED ALTITUDES

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In 1996, the Air Force Research Laboratory's Propulsion Division at Edwards AFB initiated a project that had as its main objective to launch a laser-propelled Lightcraft into a suborbital trajectory within a period of five years in order to demonstrate the concept and its attractive features. The Lightcraft concept is a nanosatellite in which the laser propulsion engine and satellite hardware are intimately shared. The forebody aeroshell acts as an external compression surface (i.e., the airbreathing engine inlet). The afterbody has a dual function as a primary receptive optic (parabolic mirror) for the laser beam and as an external expansion surface (plug nozzle) during the laser rocket mode, which is used only outside the atmosphere. The primary thrust structure is the centrally located annular shroud. The shroud provides air through inlets and acts as a combustion chamber for plasma formation in the airbreathing mode. In the rocket mode, the air inlets are closed, and the afterbody and shroud combine to form the rocket thrust chamber and plug ("aerospike-type") nozzle. The full-scale vehicle has a focal diameter of 1 m and a dry mass of about 1 kg. Fully fueled, this vehicle would have an initial mass of about 2 kg (i.e., a mass fraction of 0.5), and would be launched into orbit with a megawatt-class infrared ground-based laser. It would be a single-stage-to-orbit (i.e., airbreathing (infinite I_{sp}) to M=5 and 30 km; a laser thermal rocket with its own on-board propellant at higher altitudes and in space) using a combined-cycle pulsed detonation engine. Once in space, the Lightcraft will use its 1 m diameter optical system to provide, for example, Earth surveys with 8 to 15 cm resolution in the visible light frequencies from Low Earth Orbit. Such a device is simple, reliable, safe, and environmentally clean, and could have a very high all-azimuth, on-demand launch rate. The current launch model under consideration would launch up to 1,000 vehicles per year for under $500 of electrical power. Production costs of about $3,000 for the spacecraft appear reasonable at present.

The Lightcraft Technology Demonstration Program was planned in five phases. Phase I, Lightcraft Concept Demonstration, was to demonstrate the feasibility of the basic concept. This phase ended in December 98. Under Phase I, performance was measured with pendulum impulse and piezoelectric thrust stands; shadowgraph and beam propagation studies to 90 m were accomplished; a pointing and tracking system was developed and demonstrated on horizontal wire-guided flights outdoors to 122 m, and outdoor vertical free-flights approaching 30 m were successfully conducted. Low Mach number wind tunnel tests were also accomplished with a 23-cm diameter model, and later reported. The basic conclusion of all this work was that the feasibility and basic physics of the Lightcraft concept had been adequately demonstrated, and that a much larger, 100 kW class, laser would be required to completely accomplish Phase II.

Phase II, Lightcraft Vertical Launches to Extreme Altitudes, was initiated in January 99, and is a five-year effort designed to extend Lightcraft flights in sounding rocket trajectories to 30 km with a 100 kW CO_2 laser. The objective of the current Phase II vertical flight test program is to extend Lightcraft vertical free-flights to significantly higher altitudes in the range of 150 to 300 m using the 10 kW Pulsed Laser Vulnerability Test System (PLVTS) laser. A subscale version of the Lightcraft vehicle is being used. This laser-powered Lightcraft is a 1/10th-scale model. Currently with this size vehicle, laser flight tests are being conducted at the High Energy Laser Systems Test Facility (HELSTF), White Sands Missile Range (WSMR), New Mexico, using the currently available PLVTS CO_2 electric discharge laser. This laser is a pulsed wave, closed cycle, 10 kW CO_2 laser with a pulse repetition rate of 1 to 30 pps (selectable), and a variable pulse width of 5 to 30 μs. For flight test experiments, the laser is being operated at 25 pps and 18 μs pulse widths. Details of the Lightcraft performance measurements and flitght test experimental results will be discussed. Video footage taken during the outdoor free flight tests will be shown during the presentation.

Phase III, Lightcraft Dual Mode Vehicle, is a two-year effort designed to launch the first laser-propelled vehicle, a fully functional Lightcraft, into space. Phase IV, a far-term effort to be conducted over the next 10 to 15 years, will develop a launch capability for Lightcraft weighing 100 kg and costing less than $1.5M to build and launch. Few details of these phases will be discussed or presented.