

**Technical Overview  
LaserMotive's Winning Entry  
2009 Space Elevator Games  
Power Beaming Competition**

**I. Overview of the LaserMotive Laser Power Beaming System**

LaserMotive constructed a complete laser power beaming system for the competition, including:

- A compact, efficient multi-kilowatt laser transmitter based on laser diode arrays provided by DILAS Diode Laser Inc. of Tucson, AZ
- An optical system and beam director to focus and aim the beam at a roughly two-foot-square target at a range of 1 km (1100 yards).
- Both manual and automated tracking systems, although only the manual system was used in the 2009 competition.
- A lightweight (nominally 5 kg (11 lb)) "climber" designed to ascend and descend a 1 km (0.6 mile) long 5 mm (3/16") diameter steel cable

**II. The LaserMotive Climber**

The LaserMotive climber, nicknamed "Otis", included:

- A proprietary receiver array made from custom photovoltaic cells ("solar cells") designed specifically for converting intense laser light to electricity. The cells were provided by our industrial partner, The Boeing Company, via their subsidiary Spectrolab of Sylmar CA.
- A sophisticated electronic power conversion and motor drive system, using both off-the-shelf and custom components. For example, we used a high-performance 920-watt (approximately 1.2 horsepower) electric motor designed for model aircraft, weighing less than 300 grams (10.6 oz.) and a little larger than a "D" battery (36mm diameter, 60mm length), but added a LaserMotive-designed optical encoder and cooling fan assembly to enable the motor to operate at full torque over its entire speed range. The actual cable drive wheels were made of ultrahigh-durability polyurethane, most commonly used for skateboard wheels.
- A structural frame of carbon-fiber tubing and CNC-machined aluminum.

**III. The LaserMotive Laser System**

LaserMotive was the only entrant in the Power Beaming competition to develop its own laser system; other competitors made use of a much larger and more expensive industrial welding laser made available by a contest sponsor. This enabled LaserMotive to optimize the laser properties for maximum efficiency, and to perform end-to-end system tests in its own facilities; we believe such testing was crucial to our competition success.

#### **IV. LaserMotive's Power Beaming Records Set at the 2009 Space Elevator Games**

LaserMotive set several records at the Power Beaming competition, including:

- Greatest distance for laser power beaming: 1 km
- Most power transferred to a receiver at range: over 1000 watts of electrical power delivered at 175 m, and over 500 watts at 1 km. We also delivered over 500 watts of mechanical climb power ("horsepower at the wheels")
- Highest efficiency power beaming -- Over 10% efficiency from DC power into the lasers to DC power out of the receiver.
- Fastest average climb speed to 1 km: 3.97 m/s

#### **V. Next Steps**

Due to a series of minor problems, we were not able to achieve our goal – and the final competition goal – of climbing 1 km at greater than 5 meters per second.

The primary cause of failure during our final climb window was a mechanical fault which caused our climber to remain attached to the "bottom stop" which normally supports the climber before power is applied, and "catches" the climber as it descends. As a result, the climber dragged the bottom stop with it, slowing the climb and imposing an excessive load on the motor drive. This load caused a part in our power electronics to fail at 1,050 watts, well above its design power of 800 watts. We were able to install a replacement circuit board within our 45-minute climb window, but the replacement board proved to be defective, and we did not have time to install our second spare.

LaserMotive collected extensive data from both our successful and unsuccessful climb attempts during the contest, and based on preliminary analysis, we anticipate no difficulty in reaching 5 meters per second at a future NASA Power Beaming competition.

Although LaserMotive LLC will remain the primary sponsor of the LaserMotive competition team, we welcome contacts from potential sponsors and technology partners who would be interested in supporting the team.