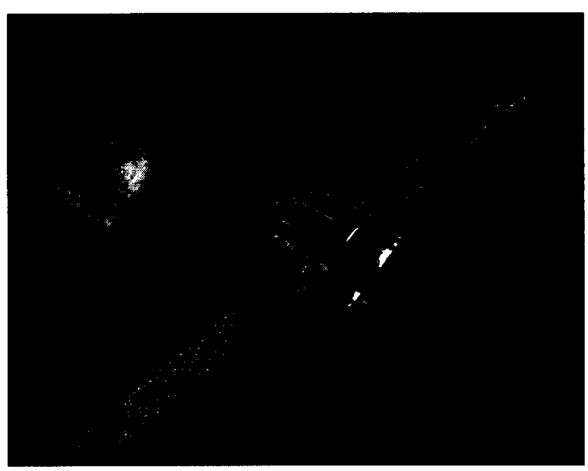
May 30, 2002

Life Test of the Deep Space 1 Ion Engine

John Brophy
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
John.R.Brophy@jpl.nasa.gov

Ion engines are the most fuel-efficient rockets used in space today. They are roughly ten times more fuel-efficient than conventional chemical rocket engines. High fuel efficiency is critical for missions to explore the solar system because the costs to launch anything into space and escape the Earth's gravity are so high. At a cost of roughly $30,000 per kilogram ($66,000 per pound) launching a lot of fuel into space that you're going to burn later is like burning money. Ion engines solve this problem and enable NASA to perform missions that would otherwise be too expensive.

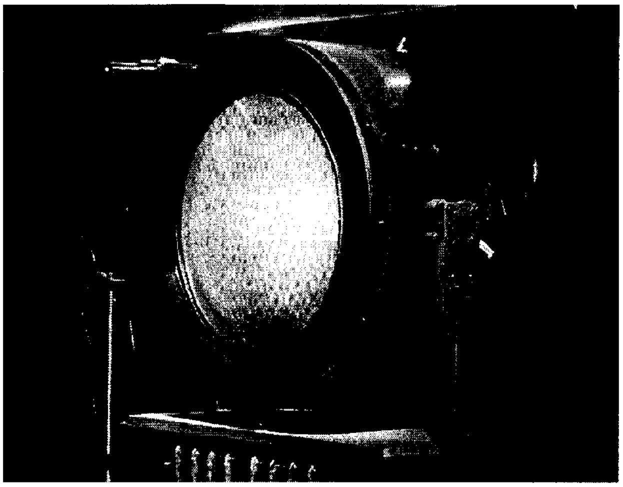
But this fuel-efficiency comes at a price. For ion engines the price is a very low thrust level. The ion engine that flew on the Deep Space 1 mission could produce a maximum thrust approximately equal to the weight of a single 8 ½ x 11 sheet of paper. If the ion engine on Deep Space 1 was operated at its maximum thrust level, the spacecraft would go from zero to 60 mph in about 40 hours. Not exactly a sports car. However, after a year of thrusting at this level the spacecraft would be going more than 10,000 mph (>4500 m/s). Slow, steady acceleration can really get you moving.



Deep Space 1 with ion engine firing.

The ion engine on Deep Space 1, jointly developed by NASA's Glenn Research Center, Boeing, and NASA's Jet Propulsion Laboratory was designed to operate for one year at its maximum power level of 2.5 kW (~3.4 horsepower). Over this time it will "burn" about 83 kg (163 lbs) of propellant. The propellant for ion engines is a noble gas called xenon. Xenon is found naturally in the Earth's atmosphere, is chemically inert and environmentally safe. Ion engines are not only highly fuel efficient, but are also "green" in the environmental sense. Even the engine's exhaust plume has a faint green glow characteristic of ionized xenon.

The low thrust level of ion engines means that they have to run for a long time to accelerate the spacecraft to its desired velocity. Several long tests were performed to make sure the ion engine for Deep Space 1 would last long enough to perform the mission. These included a 1,000-hr test, a 2,000-hr test, and an 8, 000-hr test, all performed at the engine's maximum power level. The maximum power level is believed to be the most stressing condition for the engine. Somewhat ironically, the ion engine on Deep Space 1 was actually operated for 16,265 hours, but with the majority of this time at the low power (< 1 kW) end of the engine's throttle range.



Deep Space 1 flight spare ion engine under long-duration test at NASA's Jet Propulsion

Beginning in the fall of 1998, the flight spare engine from Deep Space 1 was placed in a long duration test with the objective of demonstrating that the engine could be run for 150% of its design life. This goal was successfully achieved in December 2000, approximately two weeks ahead of schedule. Since that time the test has been continued with the goal redefined to determine the ultimate service life capability of this engine design. As of the end of May 2002, the engine has been operated for more than 23,000 hours and has processed more than 183 kg (403 lbs) of xenon. This is by far the longest any rocket engine has ever been operated and corresponds to 220% of its original design life. Significantly, the engine still appears to be in good health.

Advanced planning for future missions is now driving the need for improved ion engine performance. In particular longer engine life is the performance parameter of most interest for near-term missions.