# StarTram: The Key to a Robust, Low Cost Earth/Lunar Transport System

by
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Developing permanent manned bases and colonies on the Moon will require a robust Earth/Moon transport system. It is increasingly clear that conventional launch systems, whether expendable rockets, the shuttle, single stage to orbit, scamjets, combined cycle, and other concepts, cannot provide the low cost, ultra reliable, safe transport that will be needed for significant and permanent human presence on the Moon. Thirty-four years after the first Moon landing, the cost of reaching orbit has decreased only marginally. It still costs about $10,000 per kilogram of payload to LEO and much more to the Moon. While some small reduction in launch cost appears likely, a large reduction, e.g., a factor of 10 or so, appears impossible.

A revolutionary new launch system, termed StarTram is described. StarTram has the potential to greatly reduce launch cost, e.g., down to ~$20 per kilogram, while delivering very large launch volumes, e.g., a million tons per year compared to the present volume of ~1000 tons per year. In StarTram, spacecraft are magnetically levitated and accelerated in an evacuated tunnel to orbital speed, i.e., 8 km/sec or greater, using the superconducting Maglev technology invented by Powell and Danby in the 1960's and 70's. Based on their inventions, Japan Railways is presently operating Maglev trains at up to 350 mph in the atmosphere with the speed limited only by air drag. In StarTram, no propellant is required to reach orbital speeds, and the energy cost is extremely low. At 5 cents per KWH, energy cost is only 50 cents per kg to reach 8 km/sec, and 75 cents/kg to reach 10 km/sec. If, however, the spacecraft were to enter the normal atmosphere at the end of the acceleration tunnel at such speeds, it would be destroyed by air drag forces and atmospheric heating. StarTram avoids this by having the spacecraft transition into a magnetically levitated launch tube that curves upwards from ground level to a high altitude (e.g., 20 km) where the air density is sufficiently low that atmospheric heating and air drag forces are acceptable when it enters the atmosphere. The launch tube is levitated by the magnetic repulsive force between a set of high current superconducting (SC) cables attached to it, and a second set of parallel SC cables on the ground that carry current in the opposite direction. Using the multi-megamp capability of presently available commercial superconductors, large levitation forces can be generated on the launch tube, e.g., 4 metric tons per meter of length, at 20 km altitude. The net upwards force on the launch tube (magnetic force minus launch tube weight) is restrained by a network of Kevlar tethers that anchored to the ground beneath. The tethers also stabilize the launch tube against lateral wind forces. The spacecraft enters the atmosphere through the open end of the evacuated launch tube. Atmospheric leakage into the tube is kept very low by a combination of gas jet ejectors and a MHD (Magneto Hydro Dynamic) pump that ionizes and expels air in-leakage.

The design of the StarTram system, including the Maglev acceleration tunnel, levitated launch tube, superconducting cables, tethers, and spacecraft, is described in detail. StarTram could launch at a rate of up to 1 spacecraft per hour, with a 200 ton gross takeoff weight that includes 70 tons of cargo launch. Speed would be 10 km/sec for spacecraft traveling to the Moon, with somewhat lower speeds for insertion into Earth orbit. StarTram could deliver hundreds of thousands of tons of supplies per year to the Moon, along with many thousands of passengers. The projected capital cost of a StarTram launch facility is approximately 60 billion dollars. Total launch cost, including energy, amoritization of the launch facility and spacecraft, and operating cost, is approximately $20 per kilogram of cargo. Almost all of the technology components needed for StarTram now exist in commercial form, including Maglev superconductors, tethers, cryogenic insulation and refrigerators, vacuum systems, etc. The StarTram spacecraft would require development and testing; however, in contrast to spacecraft like the Shuttle, StarTram spacecraft can be made much more rugged structurally and with much better thermal protection systems since the extra takeoff weight for these purposes costs very little. With a vigorous development program, StarTram could begin operation within 15 years from now.