FREQUENTLY ASKED QUESTIONS ABOUT STARTRAM

1. Q: **<u>The magnetically levitated launch tube seems like the ultimate Indian Rope Trick. Is it really possible to levitate a launch tube at 70,000 feet?</u>**

   A: The Gen-1 StarTram cargo launch system does not use a levitated launch tube. Instead, the acceleration tunnel exits directly to the atmosphere from a high altitude surface point, e.g., on the order of 15,000 to 20,000 feet, on a mountain or mountainous terrain.

   The Gen-2 StarTram passenger/cargo launch system uses a magnetically levitated launch tube, to keep deceleration forces on the spacecraft when it enters the atmosphere low enough (e.g., ~2 g) so that passengers can tolerate them. With the Gen-1 cargo system, atmospheric deceleration is in the range of 10 to 20 g, too high for passengers.

   It is possible to magnetically levitate the launch tube to an altitude of 70,000 feet, with enough superconducting current. The magnetic interaction between a cable current of 100 Megamps (1 Megamp = 1 million Amps) on the ground and a cable current of 40 Megamps at 70,000 feet will produce a levitation force of 4 tons per meter of cable length. Superconducting cables can already carry a million amps in a square inch of cross section with zero power loss. The real trick is not levitating the launch tube, but getting the cost of the superconducting cables down to an acceptable level. This appears achievable with the large scale production of superconductors for StarTram.

2. Q: **<u>StarTram will cost 30 to 60 billion dollars to build, depending whether it is a cargo only or a cargo plus passenger system. It needs to launch hundreds of thousands of tons of cargo and tens of thousands of passengers annually to achieve a launch cost of $20 per pound. Is it reasonable that there will be that big a market?</u>**

   A: There potentially is a very large launch market. For example, a 1000 Megawatt(e) Space Solar Power Satellite would weigh ~10,000 tons, or 20 pounds per kilowatt(e). At a launch cost of $50 per pound, it would cost $1000 per kilowatt to launch, making it an attractive alternative to Earth based fossil and nuclear power plants. (Space Solar Plants in GEO orbit need no fuel, do not pollute, and beam full power 24 hours a day.) At the present launch cost of $5000 per pound, Space Solar Power Satellites will never get off the ground. World power generation is currently several million Megawatts (equivalent to thousands of plants of 1000 Megawatts(e) each) and growing several percent per year. Launching just 100 Space Solar Power Satellites per year at a launch cost of $20 per pound would yield a revenue of 40 billion dollars per year, enough to pay off the StarTram facility in a couple of years. 1 million space tourists per year – 1/30th of the visitors to Disneyland – at $5,000 per passenger, would bring in 5 billion dollars annually. Other large markets appear possible.

3. Q: **<u>Why doesn’t the outside atmosphere rush into the open end of the evacuated launch tube or acceleration tunnel?</u>**

A: There is an MHD (Magnetic Hydro Dynamic) “window” at the open end of the evacuated launch tube or acceleration tunnel. A RF power source ionizes any air that tries to enter the tube. An MHD pump, which consists of a transverse strong DC magnetic field at the end of the launch tube and an applied current, physically expels the ionized air from the tube.

4. Q: **<u>What is the main challenge to building StarTram?</u>**

A: For the Gen-1 StarTram system, the most difficult challenge is the storage and rapid delivery of large amounts of electrical energy used to accelerate the StarTram cargo craft to orbital speed. Peak power delivery rates reach a maximum of ~100 gigawatts. While the delivery time is only a few seconds, handling such power levels in a cost effective way is challenging, requiring sophisticated, high current/high voltage electronic switching.

For the Gen-2 StarTram system, the most difficult challenge is the erection of the levitated launch tube. There are two options: The first is to construct the launch tube on the surface, together with its superconducting cables and restraining tethers, and then slowly energize the cable, levitating it over a period of days. The second option is to erect the cable and tether system, and then lift the launch tube into place using additional lifting tethers. At this point, it is not clear which is the best approach.

5. Q: **<u>Where would StarTram be located?</u>**

A: StarTram would be located in a remote area with a low population density. Its main environmental effect would be high altitude sonic booms as spacecraft entered the upper atmosphere. High latitude regions appear promising, including Alaska, Northern Canada, Greenland, and Siberia. Launch would be into polar orbits, which cover all of the Earth’s surface. For GEO applications, such as Space Solar Power Satellites, equatorial orbits are required, which could be achieved by an electric thruster burn on the spacecraft. The Antarctic ice sheet is particularly attractive for StarTram. There are no native species on the interior of the ice sheet and the acceleration tunnel would be at about 10,000 feet altitude, reducing the levitated height requirement for the launch tube. Also, the acceleration tunnel could easily be constructed at low cost inside the thick ice sheet.

6. Q: **<u>What if the superconducting cables fail? Would StarTram crash?</u>**

A: For the Gen-1 StarTram system, there is no magnetically levitated launch tube, so there is no issue of levitation failure. For the StarTram cargo craft, there are multiple independent and redundant superconducting loops. A substantial fraction of these loops could fail, and the cargo craft would still remain levitated and exit the acceleration tunnel. Because of the excellent reliability of superconducting windings, the very short operation time, and multiple, independent, and redundant design, the probability of loss of levitation for the cargo craft is negligible.

For the Gen-2 system with a levitated launch tube, the superconducting (SC) cables that levitate the launch tube contain a set of multiple independent SC circuits, each with their own refrigeration and coolant system. If some of these cables were to fail, their current would automatically transfer by magnetic induction to their closely coupled neighbor cables, with just a very minor reduction in total current. This could be quickly compensated for by increasing the current through the neighboring cables. There already is strong net upwards magnetic force on the launch tube, which is held in place by the restraining tethers, and the position of the launch tube will not change. There will be at least a dozen independent SC cables in both the levitated and ground SC cable arrays. The probability of enough failures to cause loss of levitation is virtually zero. The same principle applies to the superconducting loops on the StarTram spacecrafts.

7. Q: **Can StarTram withstand big storms and lightning strikes?**

A: The Gen-1 system, since the acceleration tunnel is completely underground, will not be affected by storms or lightning strikes.

For the Gen-2 system, with the magnetically levitated launch tube, the StarTram facility would be located in regions where the probability of hurricanes and tornadoes would be extremely low. While there are severe storms at high latitudes, the wind speeds are substantially lower than those in hurricanes and tornadoes. The launch tube and tether system is very strong, and the magnetic forces much greater than wind forces. Even in a 100 mph cross wind, for example, the wind force per meter of launch tube is only about 1% of the magnetic levitation force per meter (8 metric tons per meter at low altitude, with a 3 meter diameter launch tube, drag coefficient = 0.2). The StarTram launch tube and tethers would be protected against lightning strikes by electrically conducting cables that would carry the stroke current down to the ground.

8. Q: **How much would a trip into orbit cost for a passenger? How risky would it be?**

A: Present passengers to the ISS (International Space Station) have to pay 20 million dollars for the trip. The cost for a Gen-2 StarTram passenger trip will be on the order of $5,000. Present crash rates for commercial airlines are on the order of 1 per several million takeoffs and landings. StarTram accident rates should be comparably low.

9. Q: **When could StarTram begin operating?**

A: Assuming vigorous funding and a strong goal directed program, the Gen-1 cargo StarTram system could start operating within 10 to 15 years. A Gen-2 passenger/cargo system could start operation within 15 to 20 years.

10. Q: **Can StarTram defend the Earth from large asteroid impacts, like the one that destroyed the dinosaurs?**

A: Yes. This is probably the most important application of StarTram. The probability of collision with a large asteroid or comet is very low, but the consequences would be very great. In a Tsunga type event, which occurred in the early 20th Century, a 100 yard diameter object destroyed thousands of square miles of Siberian forest. The impact could have killed millions, if it had struck a populated region. A mile wide object, of which there are many thousands in the Solar System, could completely wipe out humanity. Tsunga type events happen roughly once each Century. Bigger events are rarer, but inevitable. Of particular concern is Chiron, a 200 kilometer size ice body that is in a chaotic orbit that extends beyond Saturn. At some point in the future, probably within the next 100,000 years, analyses project that Chiron will be flung out of its present orbit, with an 80% chance that it will cross the orbit of Earth. Conceivably, gravitational forces from Jupiter and other bodies could fracture Chiron into many pieces, each large enough to wipe out humanity if it were to collide with the Earth.

Today, we have no defense against asteroid or comet impacts. We probably would not even have a warning prior to impact. With present launch capabilities, this situation will not change. To really defend against impacts, we need a much more capable warning system, together with many large, high ΔV interceptors that are pre-positioned in orbit and ready to go the moment an incoming threat is detected. This will require launching many tons of mass into orbit, something not possible with today's high cost launch systems.