Current Status of Space Tether Experiments (December 2014)

STS-75 Tether Experiment

History

After the two very ambitious and operational daring Space Tether Experiments, conducted by an US-Italian cooperation on the US space shuttle in 1992 and 1996 it became quiet about tethered space systems. This article tries to assess the current activities of tethered satellite experiments and their future goals.

First, let's recall the two dramatic "tether" key events in 1992 and 1996 which influenced all further space-tether experiments. There were two major less than completely successful missions of the Italian-NASA joint Shuttle projects, TSS-1 in 1992 (STS-46) where the 20 km electro-dynamic tether was deployed to the length of only 268m and stopped by jam in the mechanism but then could be successfully retrieved by a couple of risky, time consuming maneuvers for a re-flight in 1996 (STS-75), the TSS-1R mission.

On February 25, 1996, TSS-1R (re-flight of TSS-1) began as planned, unreeling mile after mile of tether while the observed dynamo current grew at the predicted rate. The deployment was almost complete when the unexpected happened: the tether suddenly broke and its end whipped away into space in great wavy wiggles. The satellite payload at the far end of the tether remained linked by radio and was tracked for a while, but the tether experiment itself was over because the electrodynamic tether deployed to the length 19.6 km and was completely severed by an arc discharge caused by a breach in the tether insulation.[1]

The lessons were that tethers worked basically as predicted and expected, however the associated system engineering problems are severe and have to be overcome through applying even more robust system engineering processes.

Future Applications

Since the TSS experiments opened a new phase of space tether technology and possible applications, some of the more challenging projects possible in the future shall be mentioned here [2].

- Bare tether experiments such as the Japan/Europe/USA joint project employing a sounding rocket in suborbital flight using a 1km-long bare electro-dynamic tether;
- Space debris removal;
- Re-boost of the International Space Station (ISS) by an electro-dynamic tether with length more than 10km to elevate its altitude without expense of any fuel;
- A sample collector at an asteroid in a "Hayabusa-like" mission;
- Sun-tower solar power satellite proposed by NASA;
- Tethered Space Solar Power Satellite proposed by USEF, Japan;
- Rotating electro-dynamic tether application to enable simple entry into the atmosphere of the Jupiter; and
- A **space elevator** proposed by NASA in geo-synchronous earth orbit (GEO) with tether of length 100,000km to enable us electric transportation from the Earth to space.

Research Activities since 2000

Project	Date	Org	Goal	Remarks
ProSEDS	2003	NASA	Like SEDS (in 1993 and 1994, successful deployment of 20km tethers), ProSEDS was to have been deployed from a Delta II, but would have used a conductive tether, instead of a nonconductive one, to allow electromagnetic orbital adjustment. The ProSEDS tether would have been 15 km long, with 10 km insulated and the last five bare wires.	It was originally intended to be flown along with a launch of a Global Positioning System satellite in the spring of 2003, but was withdrawn at the last moment, due to concerns that the tether might collide with the International Space Station". For various reasons, ProSEDS was then cancelled.
YES-2	2007	ESA	Deploy a 30km 0.5mm thin tether and release a 35kg spherical reentry capsule (Fotino) into a predetermined trajectory. Student-designed project	Final deployment length could not be verified (31.7km?). Fotino was released, tether dynamics could be evaluated. "Longest artificial structure in space".
STARS-1	2009	JAXA	Short distance tethered mother/daughter satellites, dynamically handled as multi-body system. The daughter satellite is a tethered space robot (TSR), attitude control via tether tension and arm links, camera on daughter satellite.	Daughter could be deployed but not completely, robotic motion of the daughter satellite was confirmed, the arm link actuated by ground command. Since April 2009 deployment/retrieval stopped because of unstable conditions and power problems (daughter).
T-Rex	2010	JAXA	T-Rex is a Japanese - European/American/Australian/ international campaign The goal was to test a new type of "bare" electrodynamic tether (EDT) that my lead to a generation of propellant-less propulsion systems for LEO spacecraft or OTV's.	The 300 m bare tape tether was deployed successfully and video of the deployment was transmitted. EDT current "collection" with a "hollow cathode" ignition was demonstrated.[2]
TEPCE	2015	NRL	The Tether Electrodynamic Propulsion CubeSat Experiment (TEPCE) consists of two nearly identical end-masses with a stacer spring between them, which separate the end-mass and start deployment of a 1 km long braided-tape conducting tether. TEPCE will use a passive braking to reduce speed and hence recoil at the	NRL plans to use six of Thurn's deployment mechanisms for the TEPC mission slated to launch in early 2015, "TEPCE will hitch a ride to the International Space Station", says A. Thurn, "and then the dextre robotic arm on the ISS grabs it and we deploy from there. There's a stacer spring in the middle of the CubeSat and, when the cord is burned by the nichrome

			end of electrodynamic current in either direction. The main purpose of this mission is to raise or lower the orbit by several kilometers per day, to change liberation state, to change orbit plane, and to actively maneuver	mechanism, that spring shoots out and we deploy a one-kilometer tether between the two end masses of the satellite. So we split that satellite into two pieces [3].
STARS-2	2019	JAXA	Follow on of STARS-1 (see above).	According to researchers, the tether, measuring 300m in length when fully extended, will generate electricity along its entire length as it passes through Earth's magnetic field while in orbit. The electricity will reduce the speed of pieces of junk careering through space – everything from dead rockets to satellites that have ended their missions – and lure them closer to Earth. The cosmic cleanup ends when the clutter burns up harmlessly as it enters Earth's atmosphere.[4]

In summary, progress is being made, however it is a long way for practical applications and even a longer way to the realization of a "SpaceElevator" to GEO.

References:

[1] The Space Tether Experiment (TSS-1, TSS-1R), http://www-istp.gsfc.nasa.gov/Education/wtether.html

[2]Space Demonstration of Bare Electrodynamic TapeTether Technology on the Sounding Rocket s520-25, http://arc.aiaa.org/doi/abs/10.2514/6.2011-6503

[3] NRL Invents CubeSat Release Mechanism: To Deploy Solar Panels, Tethers, - http://www.nrl.navy.mil/media/news-releases/2014/nrl-invents-cubesat-release-mechanism-to-deploy-solar-panels-tethers#sthash.XjP5AkiM.em7otTWc.dpuf http://www.nrl.navy.mil/media/news-releases/2014/nrl-invents-cubesat-release-mechanism-to-deploy-solar-panels-tethers#sthash.XjP5AkiM.dpuf

[4] STARS-2 (Space Tethered Autonomous Robotic Satellite-2), https://directory.eoportal.org/web/eoportal/satellite-missions/s/stars-2

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