SPACE TETHERS: Lessons from Developing “Revolutionary” Technologies

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Agenda

• What’s a Space Tether?
• History & Status of Tethers
• 10 Lessons from the Development of “High-Risk/High-Payoff” Technologies
Space Tethers

- Long, thin cable or wire deployed from a spacecraft
- High strength tethers can enable momentum transfer from one spacecraft to another
- Conducting tethers can create propulsive forces through Lorentz force interactions with the Earth’s magnetic field
Space Tethers for Propellantless Propulsion

Propellantless propulsion enables large $\Delta V$ missions with low mass impact.

- Orbit-Raising and Repositioning of LEO Spacecraft
- Launch-Assist & LEO to GTO Payload Transfer
- Capture & Deorbit of Space Debris
- Drag-Makeup Stationkeeping for LEO Assets
- Formation Flying for Long-Baseline SAR & Interferometry
Momentum Exchange

- Rotating tether picks payload up from low-LEO or a suborbital launch vehicle & tosses it to GTO
- Reduces the $\Delta V$ the launch vehicle must give to the payload
  - Greatly reduces launch vehicle size and cost, or
  - Increases payload capacity of launch vehicle
- MXER Launch Assist could make single-stage RLV system viable

Graph showing payload capacity scaling with $\Delta V$ provided by tether.
Momentum-Exchange/Electrodynamic-Reboost (MXER) Tether

- Rotating tether rapidly boosts payloads to higher orbits
- Tether uses electrodynamic thrusting to restore its orbital energy
- ED reboost eliminates need for propellant
  - High-Specific Impulse & High-Thrust propulsion
  - Short transfer times, lower launch costs

1. Rotating tether picks payload up from suborbital launch and tosses it into orbit
2. Tether's orbit drops as it transfers energy & momentum to the payload
3. Tether current pushes against Earth's magnetic field
4. Electrodynamic thrusting restores tether's orbit
MXER Tether Serves Multiple Exploration Missions

- **Reusable In-Space “Upper Stage”**
  - LEO to GEO
  - Lunar Base Supplies
  - Interplanetary Injection

- 2-5 fold reduction in launch costs
- MXER Tether launch assist may enable single-stage to orbit
NASA MXER Tether Video
Bootstrap Development of a Tether Transport System

• A Tether Transport System is an ambitious goal
• Key challenges:
  • Rendezvous & Capture
  • Traffic control & collision avoidance
  • Tether survivability in space environment
  • Perception as “high risk”
    • SEDS-1, SEDS-2, Plasma Motor Generator, TiPS
      • Worked perfectly, cost very little, and thus got little press
    • TSS-1 & TSS-1R Shuttle Missions
      • Big & expensive, highly publicized problems
      • BUT: Failures due to design process, not inherent physics issues

⇒ Start small, building technology capabilities & technology confidence
⇒ Develop incremental products to help fund development of tether transport systems
MXER Tether Development

- NASA/MSFC In-Space Propulsion program to develop technologies for MXER tethers
  - High-strength, space-survivable tethers - Tethers Unlimited & LMCO
  - Capture mechanisms - LMCO & Tenn. Tech
Demonstrating Survivable Tethers

- MAST Tether Experiment
  - NASA/MSFC STTR Project
  - TUI/Stanford CubeSat Mission
- Will obtain on-orbit data on survivability of tethers in space
Zero-G testing validated TUI’s “nanosat” tether deployer to be used on MAST experiment
Tether Propulsion Products

- **Terminator Tether™:**
  - Autonomous end of mission disposal of spacecraft to mitigate the growth of space debris

- **PET™:**
  - Propellantless Electrodynamic Tether for propulsion of LEO spacecraft
Remediating Space Radiation

- Van Allen Radiation Belts limit lifetime of spacecraft and present risk to manned missions
- High voltage tether structures can remove trapped radiation

DARPA-funded experiments & simulation indicate that 10 satellites with 20 kW could remediate inner belt to 1% of current flux within 6 months
Founded in 1994 by Robert Hoyt & Robert L. Forward
10 staff members (4 Ph.D., 3 MS, 3 BA) with >30 years combine space flight hardware experience
7 Patents on survivable tethers & ED tether control
Core expertise areas:
- Space Tether Technologies
- Innovative Space Propulsion Design/Analysis
- Planetary Sensors & Robotic Systems
- Nanosatellite Components, Platforms, & Architectures
- Grappling & Capture Technologies
- Electric Propulsion & Plasma Physics
- Simulation & Algorithm Development
10 Lessons on Developing Revolutionary Concepts
I. FAIL

- Missteps, rejection, & downright embarrassing failures are inevitable when developing & marketing a truly revolutionary concept

- No failure = no risk = no jackpot

- Failure is the sharpest tool for shaping your concept
2. Give Your Idea Away

- To survive & thrive, the Great Idea must be bigger than you
- NASA needs “Ownership”
- You need other smart people to work on it with you
- But be sure you get a patent on it...
3.

NASA is Your Enemy
NASA is Your Best Friend

• You will encounter resistance to your idea
• Remember: NASA is the CUSTOMER
• The Customer needs your help to discover that there’s a better way to solve his/her problem
4.

Learn How to Dance with Elephants

- Revolutionary Ideas threaten established juggernauts
- Sometimes you need the elephant to help push your idea forward
5a. Cultivate Champions

A Great Idea will go nowhere without an internal NASA champion
5b. Cultivate Squires

- NASA & the USA need to attract the best students into aerospace
- Your Duty, as a Champion of the Great Idea, is to use it to get young engineers excited
- One of those ‘pesky students’ may become your NASA customer
6. Face Up To Your Warts

- Your Great Idea has Problems, Big Problems
  *(otherwise, someone would already have built it!)*

- Admitting your problems sometimes gets your program cancelled

- Admitting your problems sometimes gets you more funding

- Hiding or ignoring Warts only leads to bigger Problems down the road
7a. You Need a “Boffo” Acronym*

- Half of your job is to successfully market your Great Idea

* Dr. Grant Swinger, aka Dr. Robert L. Forward
And “Sweet” Graphics

- Don’t underestimate the importance of communicating your ideas effectively and memorably
- And not just to NASA/DoD, but to the public as well
8.

But It’s Really all about the Hardware

- Ideas in the “powerpoint” phase have a limited lifetime
- Do everything you can to get beyond the powerpoint stage as quickly as possible
- 1 Piece of Hardware or Experimental Data Point is worth a thousand powerpoint slides
9. Go Broke

er, I mean

Go For Broke

- “You ain’t gonna make any money at this, son. Maybe you should go to law school.”

- You need to take the long view when developing technologies for 2020

- If you aren’t willing to take big chances to see your Great Idea succeed, who will?

- CARPE ASTRA!
It’s Only Science Fiction Until You Do It!

- Your Great Idea will remain just that unless you bust your hump to bring it into being
- You have the opportunity to turn science fiction into reality

And that’s what’s so cool about our jobs!