Nano-THOR
And
PowerCube

Low-Cost Launch of CubeSats to Deep Space

Jeff Slostad
Tethers Unlimited, Inc.
11711 N. Creek Pkwy S., Suite D113
Bothell, WA 98011
www.tethers.com
About Tethers Unlimited, Inc.

• Founded in 1994 by Robert L. Forward & Robert Hoyt
• NASA SBIR & NIAC funding fueled initial growth
  – 2005 NASA SBIR “Success Story” Selection
• Successfully completed >70 contracts for NASA, DARPA, Navy, AFRL, Army, & industry primes
• Designed, built, launched, & operated a 3-picosecond satellite space flight mission in 2007, for less than $1M
• 7 Patents on space tether technologies
• Core Technologies:
  – Tether Propulsion & De-Orbit Technologies
  – Software Defined Radio Comm. and Nav Solutions
  – Nanosatellite Components
  – Deployable Apertures and Structures
  – Optical Fiber Tether Dispensers for Mobile Robots
  – RF-Based Relative Navigation for Satellites & UAVs
  – Towed Sensor Systems for UAVs

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NanoTHOR will deliver nanosatellites beyond Earth orbit using secondary ride shares on GEO launches.

1. **Launch & Checkout:** NanoTHOR and NanoSat launched to GTO as secondary payloads.
2. **Tether Deployment & Initial Spin-Up:** NanoTHOR deploys NanoSat at end of tether, modulating deployment over one orbit to set tether spinning.
3. **Residual Propellant Spin-Up:** Upper stage uses residual propellant to increase tether spin rate.
4. **Payload Toss:** NanoSat releases from tether, at GTO perigee, injecting NanoSat into Earth Escape Trajectory.
5. **Tether Disposal:** NanoTHOR releases tether at apogee; tether re-enters half an orbit later.

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The rotating tether ‘multiplies’ the ΔV provided by the stage

Enable thrusting with residual propellant to accelerate the nanosatellite by hundreds of meters per second.

Could boost dozens of nanosats with the same 2.9 kg tether.
Case Example

- Falcon 9 second stage massing 3,100 kg
- 10 kg nanosatellite
- A 1.9 m/s $\Delta V$ maneuver by the rocket will accelerate the nanosatellite by 586 m/s
  - Sufficient to toss the payload to escape from the perigee of a 35,786 x 200 km GTO trajectory
  - A 5 km tether results in only 7g’s of centripetal acceleration
  - Using currently available tether materials, the tether would mass just 2.9 kg
PowerCube provides an enabling set of capabilities:
Power, Propulsion and Pointing Control for CubeSats

PowerCube is a 1U module that provides:
- 300 Ns impulse, 300 s Isp propulsion (readily scalable)
- 80 W Peak, 50 W OAP
- Precision pointing of payloads using gimbal and PowerCube as reaction mass
to support a 2U payload, enabling high-performance, agile CubeSat missions in Earth orbit and beyond
**Propulsion**

- On-orbit electrolysis of water into gO₂ and gH₂ enables high-Isp propulsion while avoiding stored energy on launch to conform to P-POD requirements
- Modular, stand-alone propulsion module
- 300 Ns of impulse (100 m/s ΔV for a 3 kg CubeSat)
  - readily scalable to larger ΔV (Just add water!)
- 500 μNs bit-impulse, appropriate for attitude control
SunMill™ Deployable, Steerable Solar Array
For 3U Cubesat Structures

High power, highly capable missions: Enabled

- 0.45U system volume (incl. controller)
- Spectrolab CIC laydown heritage
- Fully customizable panel length
- Available for order Oct. 2013
- Full hemispherical pointing
SWIFT-RelNav for CubeSats

- **SDR-based Relative Navigation, Inter-Sat Communications, and Synchronization**
  - Ranging to ≤ 0.1m, heading to ≤ 1°, sync to ≤0.1 ppb & ≤1ns
    - Enables pointing for optical communications
  - 12 Mbps
  - ≤ 4W average power

- **No reliance on GPS**

**SWIFT-RelNav enables coordination & formation flight of clusters of CubeSats in Earth Orbit & Deep Space**

**SWIFT™ CubeSat Radios**
- SWIFT-RelNav – relative nav, x-link
- SWIFT-AFSCN – SGLS/USB
- SWIFT-TacComm - UHF&S-band

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Grapple, Retrieve & Secure Payload (GRASP)

- Simple inflatable booms used to deploy a high-strength net
- Net collapsed around target to securely capture it
- Target’s angular momentum can be dissipated using deployment of a tether under controlled tension
- Tolerance to positional and relative velocity errors
- No dependence on target configuration – captures anything that fits in the net
GRASP Zero-G Test

- 18 experiments conducted during Zero-G parabolas
- 3/3 deployments successful
- Tolerance to target tumble & positional error
- Tolerance of ~ several meters/sec relative velocity when aligned along net axis
- Release of “smooth” targets feasible

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• NanoThor can get you on your way
• PowerCube can give you propulsion, power, and pointing during your mission
• GRASP can provide a grapple when you arrive!