

# Electrified Space Tug Hanging by a Thread

Tom Bryan, Emma Jaynes  
Space Systems Department

## Introduction

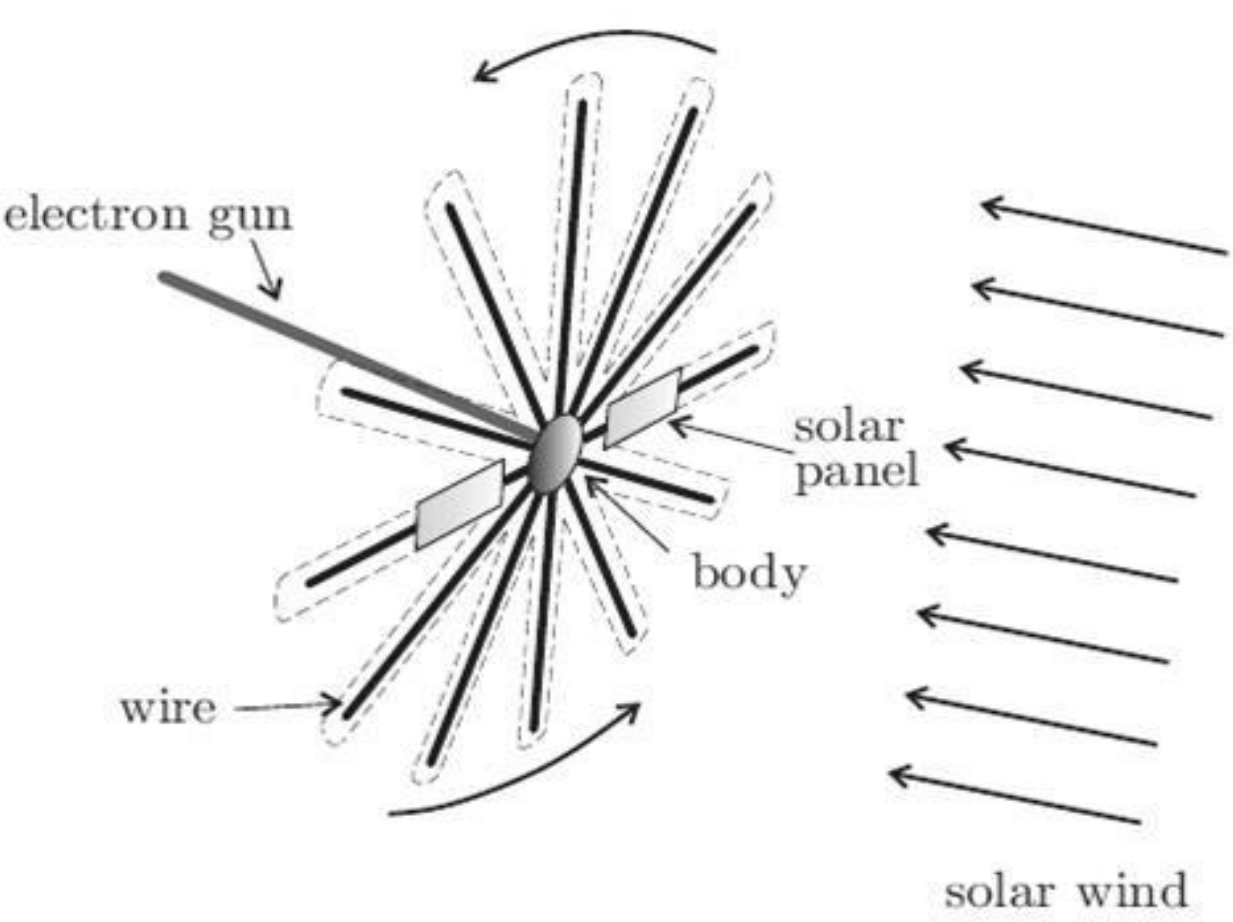
### Composite Conductor Power Tether Cable (CIF)

- New space stations and space tugs to move vehicles from one orbit to another are being built by private companies. Even the Shuttle Tethered Satellite’s electrified Tether has been re-imagined and flown for generating power, orbital transfers,, and de-orbiting space debris.
- But the most ambitious new tether is the Electro-Static Sail or E-Sail, that will harness the energy of the Protons in the Solar Wind to push E-Sails through space by **repelling protons electro-statically**. But E-Sail tethers require tiny Space Tugs to deploy & control the tethers.
- A tiny Tethered Space Tug on a multi-kilometer tether must use power from the “Mothership” and data transfer across the **Composite Power Tether** to avoid solar arrays and RF antennas and a tether winch to enable the mothership to retrieve the attached tiny space tug.
- To increase fuel efficiency by using the Mothership’s power, the Tether Space Tug can use electrified thrusters on four 2-axis gimbals and a gimbaled tether boom for added attitude control.
- Other applications of conductive tethers include:**

➤ **Power transfer for lunar surface activities**



➤ **Deployment, stabilization, and control of Electrostatic Sail tethers**



- Marshall’s technical background with TSS, SEDs 1&2, ProSEDs and the existing expertise and research on flown & new E-Sail tethers and other composite structures provides a technical basis for a transition from fiber reinforced metal conductor cables to a radically new tether structure.

## Objectives

- As a TRL 1 technology development for composite conductive tethers we are researching and developing:
  - Manufacturers’ products and fabrication capabilities
  - Splicing & connection capabilities and problems
  - Find Critical key performance parameters based on planned use

## State of the Art

- Currently the only standardized tethers being sold and flown are ribbon style tether developed to decelerate & de-orbit CubeSats and Mini-Sats
- Most previous tethers for satellite have been specially designed and built for each individual mission

KPP	SOA	Target	Goal
Weight Per Length	Single wire Cu+	Two conductor, comp	1 kV + 10 kV bias
Tensile Strength	Fibers 7x Steel	Tether 4x Steel	
Data Rate	<40 Kbps	Video and commands	HD video + Lidar

Key Performance Parameters (KPPs) for Composite Conductor Power Tethers

## Materials & Methods

- New conductors (including metal clad SS and metal clad composite cores) are being developed along with new insulator coatings.
- Amberstrand** is a composite electrical conductor, originally funded by a NASA SBIR. Amberstrand:
  - Is a metal clad, high temperature Zylon fiber
  - Has 7 times the tensile strength of steel.
  - It is commercially woven into sleeves of various diameters and used as Mil-Spec EMI sheathing with superior high frequency performance at elevated temperatures
  - Has comparable shielding performance to copper braid while up to 85% lighter than nickel-copper braid.
- Tests have shown that Amberstrand has similar electrical and corrosion resistance as Stainless Steel in high voltage vacuum plasma testing for E-Sail
- A cable configuration with a strong flexible outer conductor of a metal clad composite that provides both tether tensile strength & a conductive sheath with an insulated center conductor can support many different applications

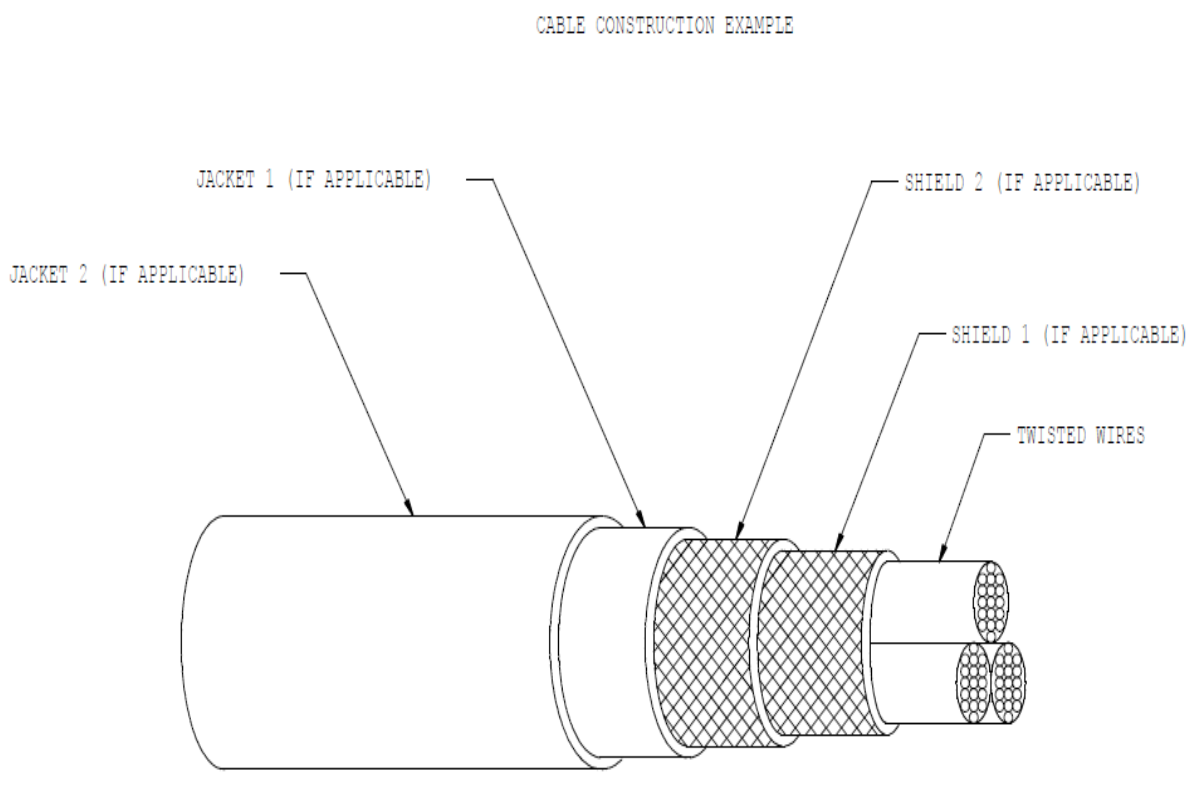
The Composite Conductor Power (& Data) Tether cable CIF was proposed to buy composite conductor sheathing and assembling a cable in-house, but found out that:

- Glenair** sells Amberstrand shielding and builds custom shielded twisted pair conductors. They are currently preparing part drawings and price quotes for **Space Grade Composite Conductor Power Tether Cables**.
- Analog Devices** builds and sells single line Ethernet chipset development boards that support the new standards for Power over Data Lines and Single Pair Ethernet, new technology and standards that are expanding rapidly.

## Results

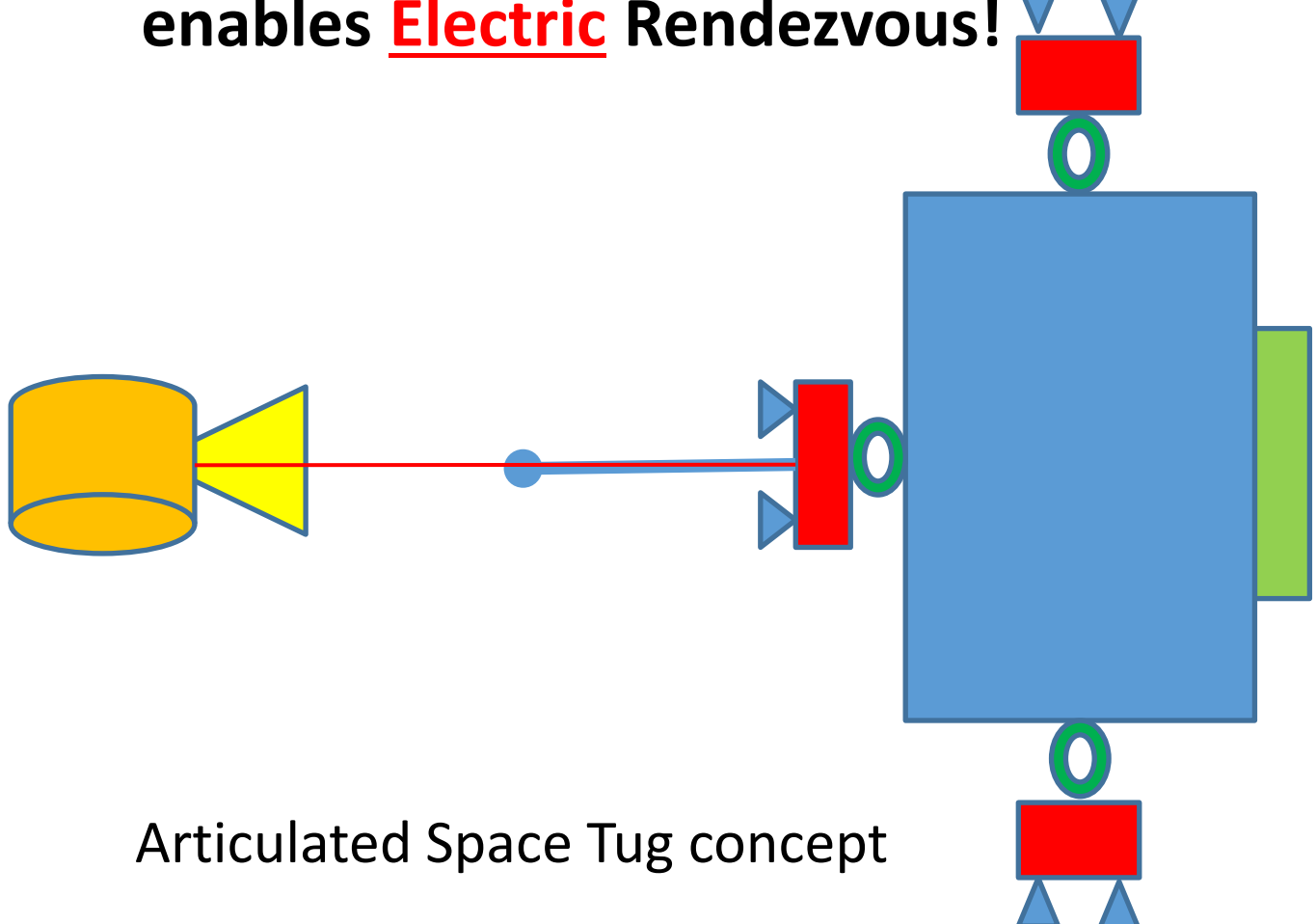
### Breakthrough!!

- Glenair (Manufacturer) has decided to develop new product (Twisted Pair or Triple conductors with 2 layers of Amberstrand shielding that they can manufacture in Continuous 3000m to 4000m lengths with Space Grade Materials & Process) (COTS) (3 phase AC can deliver three times the power on three wires as one phase on two wires)

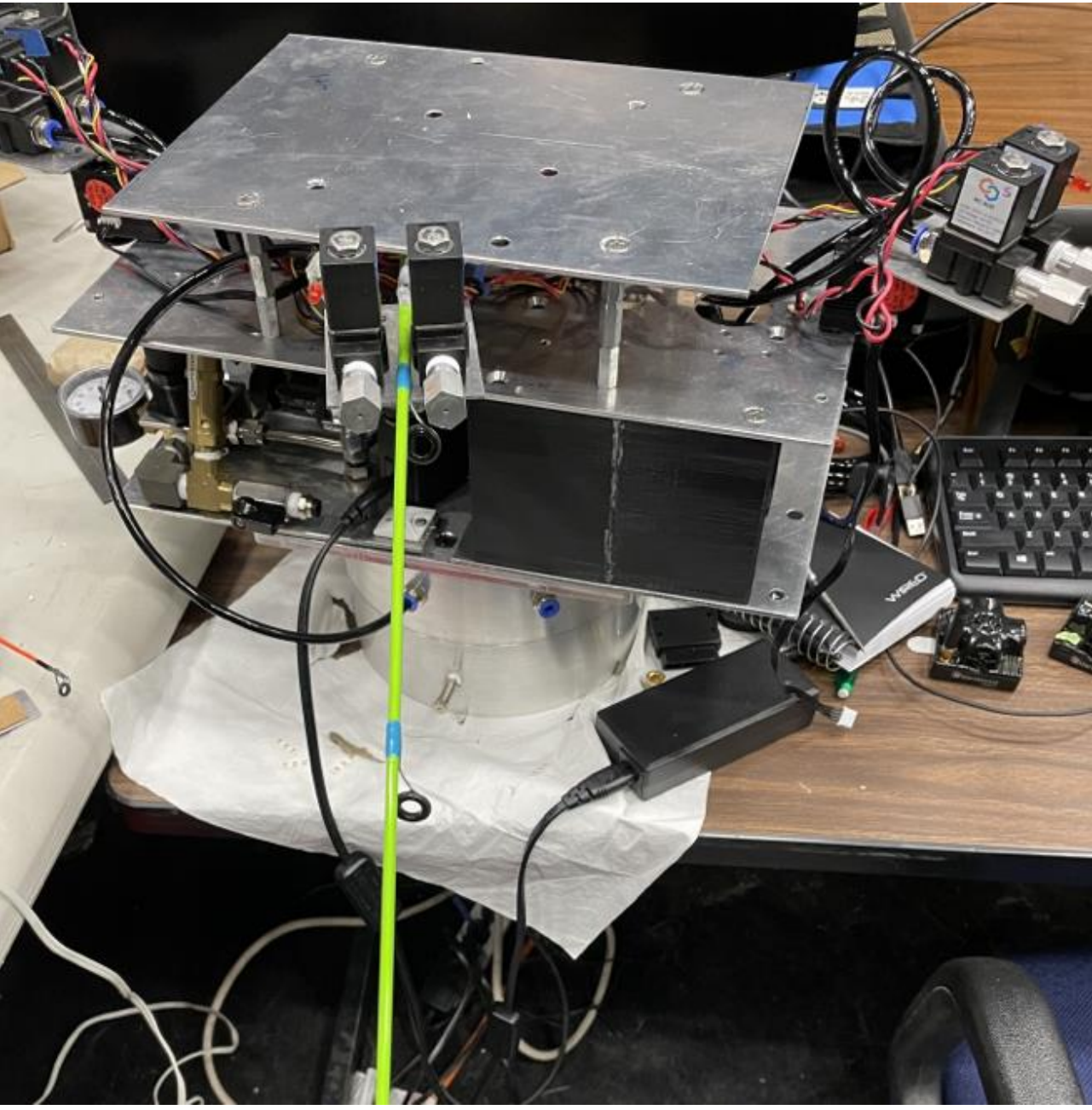


## Articulated E-Tether Space Tug (& Simulator)

- Side thrusters mounted on +/- 90° Servo mounts that can be pointed and fired independently
- Tether Tension thruster pair on +/- 90° Servo mount that points the Tether Yaw Attitude Boom
- Tether Retrieval Reel can pull the Tug Simulator, maintain tension, or reverse to provide Slack
- On-board Arduino CPU can drive the 3 Servos and fire the independent Thrusters or in Pair
- Pointing the Side Mounted thrusters in Parallel produce more thrust than from canted corner thrusters
- Gimbaled Thrusters can Push and Pull Captured Cargo or Modules Harder or Aligned
- Yaw Att. Boom uses Tension to stabilize Tug Attitude, drastically reducing fuel
- E-Tether provides Tension, Power, & Data Link to Tug from Reel Controller, OTV/Platform
- Yaw Att. Boom can “wobble” Tug & Tether and align Tug at Retrieval
- With E-Tether power, Tug can use Electric Augmented thrusters for better fuel efficiency & reduce re-fueling**
- Flight Tether Tug would use Hemispherical Gimbals on four sides of Tug and 5<sup>th</sup> gimbal for Boom &Thrusters**
- Using Gravity for LEO deployment and the electric tether winch for Retrieval enables **Electric** Rendezvous!**



## Space Tug Prototype



Hardware prototype constructed in the FFRL

## Alignment

Composite Conductor Power Tethers aligns to MSFC’s strategic **Areas of Propulsion & In-space transport and Habitat Systems**. Development of Composite Conductor Power Tethers aligns directly with MSFC’s traditional **Design, Development, Test, and Evaluation (DDT&E)** role in material and fabrication technology and multi-discipline space system development.

Development of lightweight, high-strength flexible power tethers that can be used between two or more space vehicles to Support “GO” and for power transfer from surface power generation landers to habitats, 3D construction printers, or resource processors to support “LIVE”. Two such technology gaps have been identified by STMD:

- Propulsion Gap STMD-Prop-022 or S5-G1 for “Unique Platforms: Sails & Tethers”
- Power Gap STMD-Power-002 for “>300V Power Transmission Cabling” supporting GCD Tethered Power Systems.

## Conclusions

With Existing:

- COTS Composite Power/Data Tether Cables (3000m-4000m)**
- COTS Thruster Gimbals (TUI)**
- COTS Electric High Isp Thrusters**
- Space Rated Arduino Processors**
- Space Qualified Electro-Permanent Magnetic Gripper / “MAGTAG” (Altius-Space)**

## An Articulated E-Tether Space Tug can be built for flight experiments

## Acknowledgements

This work is being funded under a Center Innovation Fund (CIF) award