The Lightweight Integrated Solar Array and anTenna (LISA-T) – Big Power for Small Spacecraft

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Abstract

NASA is developing a space power system using lightweight, flexible photovoltaic devices originally developed for use here on Earth to provide low cost power for spacecraft. The Lightweight Integrated Solar Array and anTenna (LISA-T) is a launch stowed, orbit deployed array on which thin-film photovoltaic and antenna elements are embedded. The LISA-T system is deployable, building upon NASA's expertise in developing thin-film deployable solar sails such the one being developed for the Near Earth Asteroid Scout project which will fly in 2018. One of the biggest challenges for the NEA Scout, and most other spacecraft, is power. There simply isn't enough of it available, thus limiting the range of operation of the spacecraft from the Sun (due to the small surface area available for using solar cells), the range of operation from the Earth (low available power with inherently small antenna sizes tightly constrain the bandwidth for communication), and the science (you can only power so many instruments with limited power). The LISA-T has the potential to mitigate each of these limitations, especially for small spacecraft. Inherently, small satellites are limited in surface area, volume, and mass allocation; driving competition between their need for power and robust communications with the requirements of the science or engineering payload they are developed to fly. LISA-T is addressing this issue, deploying large-area arrays from a reduced volume and mass envelope – greatly enhancing power generation and communications capabilities of small spacecraft and CubeSats. The problem is that these CubeSats can usually only generate between 7W and 50W of power. The power that can be generated by the LISA-T ranges from tens of watts to several hundred watts, at a much higher mass and stowage efficiency. A matrix of options are in development, including planar (pointed) and omnidirectional (non-pointed) arrays. The former is seeking the highest performance possible while the latter is seeking GN&C simplicity. Options for leveraging both high performance, 'typical cost' triple junction thin-film solar cells as well as moderate performance, low cost cells are being developed. Alongside, UHF (ultrahigh frequency), S-band, and X-band antennas are being integrated into the array to move their space claim away from the spacecraft and open the door for more capable multi-element antenna designs such as those needed for spherical coverage and electronically steered phase arrays.
Keywords: Solar Array, Antenna, Deployable Structures, CubeSat

Acronyms/Abbreviations

Beginning of Life (BOL)
Early Career Initiative (ECI)
End of Life (EOL)
Inflatable Torus Solar Array Technology (ITSAT)
Low Earth Orbit (LEO)
Lightweight Integrated Solar Array and anTenna
Marshall Space Flight Center (MSFC)
National Aeronautics and Space Administration (NASA)
Space Technology Mission Directorate (STMD)
Technology Readiness Level (TRL)
Ultra High Frequency (UHF)

1. Deployable Power Systems

Using thin-film based solar arrays for spacecraft applications is not a new idea. [1]. Only recently, however, has the technology matured to the point to make it feasible. Today's thin film materials yield a mass savings, leading to lighter power system mass and increased payload capability. Of interest to small spacecraft is their mechanical flexibility, which allows the use of innovative stowage and deployment methods.

Increased packing efficiency improves the specific power (W/kg) as well as stowed power density (W/m3), enabling higher power generation for small spacecraft. Advances in the terrestrial thin-film solar arrays have been dramatic. Several large-scale thin-film or partial thin-film arrays are in development, [2-4] though sub-kilowatt thin-film arrays remain scarce. The Lightweight Integrated Solar Array and anTenna (LISA-T) will meet this niche power need, both increasing as well as simplifying small spacecraft power generation.

LISA-T builds upon recent advances in solar sail propulsion for small spacecraft and the terrestrial photovoltaics community to create a combined thin-film array and antenna system. The technology is an evolution of previously described deployable power systems such as the PowerSphere, [5] Inflatable Torus Solar Array Technology (ITSAT), [6] and others [7,8]. Fig. 1 shows a conceptual rendering of the LISA-T stowed (a) and deployed in the omnidirectional (b) and planar (c) configurations.

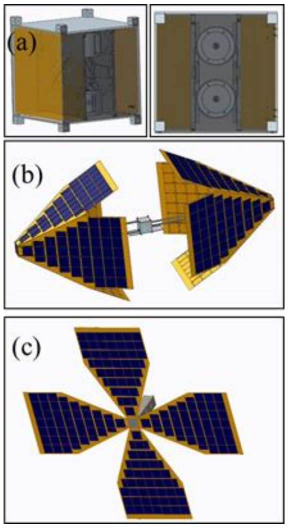

Fig. 1. Concept drawing of the LISA-T arrays (a) before deployment and after; (b) omnidirectional deployed and (c) planar deployed.

LISA-T embodies two separate configurations based on >99% common components: (i) the omnidirectional (non-pointed) and (ii) the planar (pointed). The omnidirectional array configuration stows into a 1U CubeSat (10 cm x 10 cm x 10 cm ‘unit, or U), while the planar array configuration stows into 1/2U. The omnidirectional array is three-dimensional; no matter how the spacecraft is orientated, power will be generated. Primarily for cost-conscious users, the omnidirectional system greatly simplifies the spacecraft’s attitude determination and control system requirements and is generally lower in cost.

The omnidirectional configuration can provide up to 125W at BOL. The planar array more of a traditional flat configuration. Though it requires the spacecraft to point it toward the sun, the planar array maximizes the number of solar cell actively generating power, increasing dramatically the available power – up to 300W BOL. Both a high performance (~28% efficient @ ~$250/W) triple junction thin-film solar cell as well as a low cost (~10% efficient @ ~$15/W) single junction may be used in either configuration, depending upon the needs of the user. Stowage efficiencies of nearly 400kW/m^3 with specific powers of 250W/kg are currently achievable. A comparison to various state-of-the-art power systems can be found in Table 1.

Table 1. Comparison of LISA-T performance metrics to other state-of-the-art spacecraft solar power systems.

	Axes	BOL Power (W)	Stowed Power (kW/m3)	Specific Power (W/kg)
Clyde Space 3U Body	2	7.3	~33	~53
MMA HaWK	1	36	~99	~130
Clyde Space 3U Deployable	1	29		~54
Tethers Unlimited SunMill	1	80	~83	~53
Pumpkin Turkey Tail	1	56	~142	~89
LISA-T Pointed	1	>225	>400	>300
LISA-T Omni	3	>100	>100	>75

Note: The LISA-T calculations assume a high efficiency >25% thin film cell; lower cost cells can also be used to generate >100W in the pointed and >50W in the omnidirectional configuration. Power levels are scalable.

Both configurations have been tested through Technology Readiness Level (TRL) 6 at the NASA George C. Marshall Space Flight Center. Ambient and thermal vacuum stowage and deployments tests have been conducted on both configurations and elements thereof. Fig. 2 shows the TRL5 omnidirectional prototype: a 60W array based on the low cost cell option. Further details on the array architecture and its evolution are published elsewhere. [9]

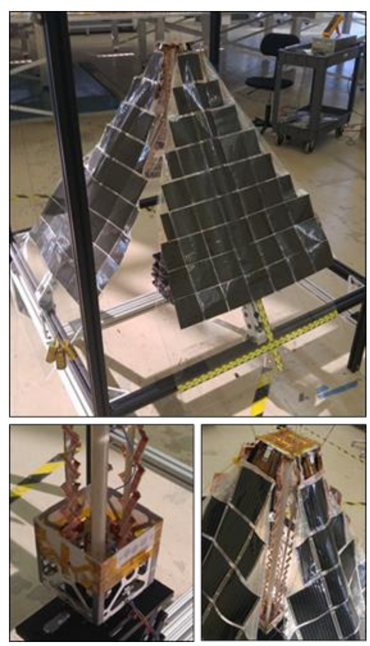

Fig. 2 The LISA-T arrays deployed in the omnidirectional configuration in TRL-5 testing.

2. Deployable Antennas

Non-pointed missions benefit from antenna system designs with customizable radiation patterns. Antenna arrays provide opportunities for custom radiation patterns, overall gain increases, multiband communication, directional interference cancelling or steering, and incoming signal direction determination. The created surface area of these deployable propulsion and power systems creates new opportunities for the inclusion and positioning of multiple lightweight deployable antennas.

LISA-T integrates lightweight axial mode helical and/or patch antennas into the deployable system. These lightweight antennas are compact for stowage and can be positioned on either the center support of a panel package (blue lines) or on the panels themselves (red lines) as shown in Fig. 3. Antennas on the panels can be placed on either side of the panel as desired.

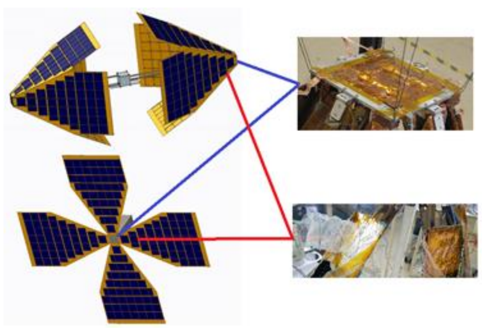

Fig. 3. Antennas can be integrated into either the LISA-T omnidirectional (top) or planar (bottom) configurations.

Custom lightweight helical and patch antennas have been created for S band and X band communications. Simulations show both S band and X band helical antennas to have a main beam gain greater than 10dbi. Simulations show custom patch antennas have a main beam gain around 7 dbi. Both helical and patch antennas have significantly less stowed thickness, volume, and mass than current state of the art. By placing multiple antennas in various positions on the structure, desired coverage patterns or phased array implementations can be achieved.

In addition to S and X bands, integrated UHF dipole antennas with a simulated gain of 1dbi have also been developed. These dipole antennas can be integrated into the panel between or beside solar cell elements. Further details on the antenna development are published elsewhere. [9]

3. Flight Demonstration

NASA is studying a potential Earth-orbital flight demonstration of the LISA-T in 2019 or 2020. The demo would consist of a CubeSat Class 1U power and antenna module attached to a 6U spacecraft bus. The current plan would have an 180W planar array built from both low cost and high performance solar cell packed in the 1U power module and deployed once the CubeSat is in low Earth orbit. An artist concept of the deployed LISA-T system in flight can be seen in Fig. 4. Because >99% of the hardware is shared between the planar and omnidirectional configurations, this demonstration will also show feasibility for the non-pointed, omnidirectional array. Both S- and X-band helical antennas will be integrated. The LISA-T antenna structure would demonstrate a deployable, multiple band system with low mass and volume. The demonstration will show feasibility for both high power and spherical coverage communications. It should be noted that several companies have expressed interest in the capabilities to be provided by LISA-T and NASA is currently negotiating a licensing agreement with one.

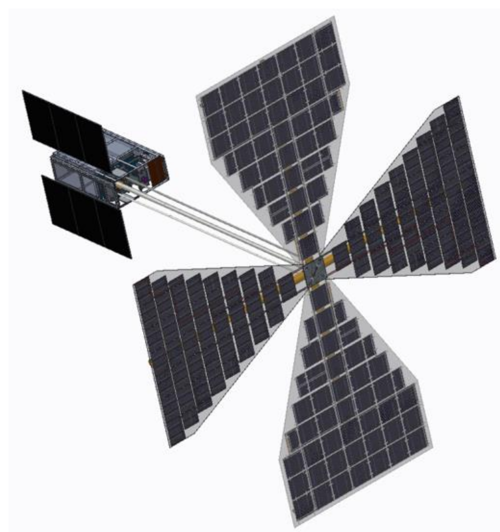

Fig. 4. The planar LISA-T configuration is shown deployed from a 6U CubeSat during flight.

4. Conclusions

Deployable structures for spacecraft is not a new idea. The technology to finally enable manufacturing, packaging and deploying them from very small spacecraft, including CubeSats, is finally mature. Innovative, multi-functional deployables may provide propulsion, power and communication, greatly increasing the capability of CubeSats for science and exploration and potentially enabling an entirely new class of deep space exploration and science missions..

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