Lightweight Integrated Solar Array and Transceiver (LISA-T)
NASA Marshall Space Flight Center (MSFC) and NeXolve

Small Satellite Conference 2016
Partnership and Current Funding

Technology development done in partnership with industry

NeXolve an industry leader in space deployable systems as well as space-rated polyimides

NeXolve has vast experience in space industry, recently involved in thin-film deployment systems for
- James Webb Space telescope sunshield
- NanoSail-D solar sail experiment
- NEAScout solar sail mission
- Nustar telescope

Currently funded through the Space Technology Development Early Career Initiative
LISA-T is a launch stowed, orbit deployed structure…

… on which lightweight, flexible photovoltaic and antenna elements are embedded.
Initially targeting ‘small-sat’ applications

- Surface area, internal volume and mass allocation are limited resources; often driving competition between power, communications, GN&C, and the payload.

- Most small-sats limited to 10’s of watts electrical power; what if we can increase this to 100’s of watts?

What if we can ‘create’ real-estate on orbit while using only limited stowage volume for launch?

- Thin-film, flexible assemblies
Enabling Technologies

LISA-T is building off solar sail work

Projects such as NanoSail-D and NEAScout have given advancements in:

- Support booms,
- Thin-film substrates, and
- Deployment mechanisms.

These are coupled with advancements in thin-film PV to form the basis for LISA-T

NanaSail-D benchtop test @ NeXolve (Huntsville, AL)

- 2.2 meter booms; 10m² <5µm thick CP1
Can we utilize ‘created’ real-estate with lightweight, small footprint deployable antennas?

- Create integrated array, using a shared space claim for both power and communications.

Also creates opportunity to enhance capabilities with an array of antennas:

- Multiple band communications
- Spherical coverage eliminating the need for pointing
- Phased arrays for beam steering and signal direction detection
The current emphasis of LISA-T is on *stowed power density* \((W/m^3)\) backed by a matrix of array options:

- Omnidirectional (non-pointed) configuration to generate power no matter satellite orientation.
- Planar (sun pointed) configuration to maximize performance.
- High performance thin-film solar cells
- Low cost thin-film solar cells
- UHF Dipole Antenna
- S and X-band Helical Antennas
## Current Performance Targets

<table>
<thead>
<tr>
<th>SOA</th>
<th>Generation Axes</th>
<th>BOL Power (W)</th>
<th>Stowed Power (kW/m³)</th>
<th>Specific Power (W/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Performance of Commercially Available Power Systems</td>
<td>2-axes</td>
<td>7.3</td>
<td>~33</td>
<td>~53</td>
</tr>
<tr>
<td></td>
<td>1-axis</td>
<td>36</td>
<td>~99.0</td>
<td>~130</td>
</tr>
<tr>
<td></td>
<td>1-axis</td>
<td>29</td>
<td></td>
<td>~54</td>
</tr>
<tr>
<td></td>
<td>1-axis</td>
<td>80</td>
<td>~83</td>
<td>~53</td>
</tr>
<tr>
<td></td>
<td>1-axis</td>
<td>56</td>
<td>~142</td>
<td>~89</td>
</tr>
<tr>
<td></td>
<td>1-axis</td>
<td>72</td>
<td>~45</td>
<td>~58</td>
</tr>
<tr>
<td><strong>LISA-T pointed</strong>*</td>
<td>1-axis</td>
<td>&gt;200</td>
<td>&gt;250</td>
<td>&gt;250</td>
</tr>
<tr>
<td><strong>LISA-T omnidirectional</strong>*</td>
<td>3-axes</td>
<td>&gt;125</td>
<td>&gt;125</td>
<td>&gt;125</td>
</tr>
</tbody>
</table>

*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.*
LISA-T Tech Development Map

2013

Omni TRL4 Demo

Flat TRL5 Demo || Alt. Flat Demo

2014

2015

Omni TRL6 Maturation

Flat TRL6 Maturation

2016

2017

Explore Alternate Flat Design Options
Kapton flat panel tested in vacuum with \textit{in situ} AM0 illumination (previously shown at PVSC 2015)

**Article Overview**

- 0.45m² deployed 25µm Kapton
  - Packaged into ~1/2U
  - Mass: ~145g

- 8 active solar cells
  - Uncovered and bonded via adhesive
  - ~125-150W if fully populated by 25% IMM

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LISA-T Electrical Deployment: TRL 5 Qualification

High Intensity Solar Environment Test (HISET)

Marshall Space Flight Center

May 21, 2015

COTS monopole, custom patch and custom dipole antenna incorporated
Scratches found after deployment

NeXolve’s CORIN XLS: an optically clear, radiation stable polyimide that is extremely resistant to AO erosion.

Provides both mechanical and environmental protection

Kapton thick, risks tear propagation, yields bulky folds

Toughened CP1: a tear resistant, fluorinated polyimide manufactured by NeXolve.

~3.3 µm thick substrate @ 7.7 g/m²

Adhesive thick and risks creep during stowage

Adhesive-less method to bond cells to TCP1 substrate.
After implementing these improvements, maturing the omnidirectional became priority.

Quad pyramid:
- Fewer facets for simpler deployment
- Separate facets for simpler folding, modular fabrication, and rework possibility
- Symmetric deployment for orbital dynamics and kinematics
- Petal designed around unit cell size as opposed to specific PV dimension; flexibility to accommodate different solar cell and antenna options
- Quad Pyramid design directly convertible to planar pane (see slide 13)
1. Central bi-stable booms deploys central plate
2. Petals partially deployed by elgiloy c-booms
3. Petals unfolded by shape memory nitinol
4. Petals passively hold shape

LISA-T 4 petal mechanical deployment:

NASA and NeXolve
7/6/2016

Article Overview

- Packaged into ~0.6U
- Mass: ~750g
- 5µm CP1
- CORIN covered cells
- Adhesiveless bonded

- Each petal 30-40W with low cost cells; 60-80W with high performance.

Single deploy in nadir seeking satellite or double deploy in non-nadir for 50-60W (100-140W) omnidirectional power generation with low cost (high performance) solar cells
Extending to Planar Configuration

Quad Pyramid is directly extendable to a planar panel w/ small change to deployment plate angle [and shorter central boom]

Each petal capable of ~70W with high efficiency cells (~30W with low cost cells)
- Single deployed design: 250-280W high efficiency (100-120W low cost)
- Double deployed design: 500-560W high efficiency (200-240W low cost)
Integrated Antenna

- LISA-T antenna types
  - Embedded nitinol dipole antennas
  - Integrated S and X band patches
  - Integrated S and X band spirals
  - Integrated S and X band axial helical
- Spherical coverage vs. omnidirectional via array
  - Sphere vs. donut/torus
- SOA and current targets

<table>
<thead>
<tr>
<th>SOA</th>
<th>Band</th>
<th>Main Beam Gain</th>
<th>Type</th>
<th>Directionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Performance Of Commercially Available Antenna Systems</td>
<td>UHF/VHF</td>
<td>0 dbi</td>
<td>Monopole/Dipole</td>
<td>Near omni</td>
</tr>
<tr>
<td></td>
<td>UHF</td>
<td>1.5 dbi</td>
<td>Turnstile monopoles</td>
<td>Near omni</td>
</tr>
<tr>
<td></td>
<td>S-band</td>
<td>8 dbi</td>
<td>Patch</td>
<td>Pointed</td>
</tr>
<tr>
<td></td>
<td>S-band</td>
<td>2 dbi</td>
<td>Turnstile</td>
<td>Pointed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LISA-T Examples</th>
<th>Band</th>
<th>Main Beam Gain</th>
<th>Type</th>
<th>Directionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitinol Dipole Array</td>
<td>UHF</td>
<td>1 dbi</td>
<td>Dipole</td>
<td>Spherical w/array</td>
</tr>
<tr>
<td>Nitinol Helical Array</td>
<td>S or X</td>
<td>10 dbi</td>
<td>Axial taper helical</td>
<td>Spherical w/array</td>
</tr>
<tr>
<td>Planar Spiral Array</td>
<td>S</td>
<td>2 dbi</td>
<td>Planar spiral</td>
<td>Spherical w/array</td>
</tr>
<tr>
<td>Patch Array</td>
<td>S or X</td>
<td>8 dbi</td>
<td>Patch</td>
<td>Spherical w/array</td>
</tr>
</tbody>
</table>
Acknowledgments and Contact

• Les Johnson: Principal investigator*
• John Carr: Principal investigator *
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• Brandon Farmer: Director, Advanced Materials Group
• Joseph Smith: System Design and Fabrication
• Mark Johnson: Mechanical Design
• Barrett Robertson: Mechanical Design

*Contact Les Johnson (les.johnson@nasa.gov) and John Carr (john.a.carr@nasa.gov) for more information; cards available at display booth

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