Sunjammer
Solar Sail Project Overview

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L’ Garde

- Founded in 1971 in Orange County, CA,
- Historic provider to DoD of Inflatable RV Decoys
- World Leader in Deployable Space Structures

L’ Garde is a world leader in the development of inflatable and deployable structures for terrestrial and space applications.

L’ Garde is focused on providing agile and responsive research and development services to its customers.
What is a Solar Sail?

• Traveling through the heavens on starlight may sound like science fiction but that is what solar sailors aim to accomplish.
• Sunlight will create a pressure on a surface that is strikes.
• The solar pressure felt on earth is roughly 1,000,000 times weaker than the wind pressure from a gentle breeze (9mph).
• A solar sail is a spacecraft that harnesses the pressure provided by sunlight.
• In its simplest form, a solar sail spacecraft consists of a large area of reflective material, held in the “wind” of sunlight, joined to the spacecraft bus.
L’Garde Solar Sails

Design Features

- High Density Packagability
- Controlled Linear Deployment
- Structural Scalability
- Propellantless Operation
- Meets Current Needs
- Meets Future Desires

Key In-Space Propulsion (ISP) Sail Personnel Involved in TDM Project

Design Heritage

- Cold Rigidization Boom Technology
- Distributed Load Design
- Aluminized Sun Side
- High Emissivity Eclipse Surface
- Beam Tip Vane Control
- Spreader System Design

- 83 m² ISP Solar Sail 2004
- 318 m² ISP Solar Sail 2005
- 170 m² Ikaros 2010
- 1200 m² Sunjammer Launch 2014
What is Sunjammer?

- Sunjammer is an exciting project supported by NASA STMD’s Technology Demonstration Missions Program.
- Sunjammer will demonstrate the propellantless propulsion potential of solar sails through deployment and navigation of 1200m2 sail after launch as secondary payload.
- Sunjammer is the final solar sail demonstration before infusion.
Mission Overview

Demonstration Objectives

1. Demonstrate segmented deployment of a solar sail
2. Demonstrate attitude control plus passive stability and trim using beam-tip vanes.
3. Execute a navigation sequence with mission-capable accuracy.
4. Fly to and Possibly Maintain Position at sub-L1 and/or Pole Sitter Positions

Access to Space:
Manifested as Secondary on DSCOVR Launch to L1 (F9 1.1 in Q4 2014)
Demonstration is Not Enough - TDM Programs Need Infusion
Sunjammer is Being Planned, Designed, and Executed with an Eye Always on Infusion

<table>
<thead>
<tr>
<th>Partner</th>
<th>Contribution</th>
<th>Stakeholder Expectations</th>
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<tbody>
<tr>
<td>NOAA</td>
<td>• Ground Stations Website EPO</td>
<td>• NOAA expects to receive magnetometer data from the sensor suite.</td>
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<td></td>
<td>• Mag. Analysis</td>
<td>• NOAA has interest in continuing work after demo is complete.</td>
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<tr>
<td>Celestis</td>
<td>$1M (Project Reserve Funds)</td>
<td>• L’ Garde will accommodate a total of 4kg Celestis memorial payload on board the carrier</td>
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<td></td>
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<td>and sailcraft portions of the spacecraft. MOA is in place.</td>
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<td>SSHI</td>
<td>20% of Sponsorship Revenues</td>
<td>• L’ Garde will grant certain commercial rights to SSHI who will sell sponsorship of</td>
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<td></td>
<td></td>
<td>the mission to commercial entities. A portion of L’ Garde revenues will be directed</td>
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<td>to risk reduction cost offsetting efforts.</td>
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<tr>
<td>Imperial College</td>
<td>$500 k Magnetometer</td>
<td>• Imperial College London will develop and provide flight/science quality magnetometers</td>
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<tr>
<td>London</td>
<td></td>
<td>for Sunjammer. This work is funded by UK Space Agency. Data will shared with Imperial</td>
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<td></td>
<td>College. Flight qualification will be provided as well.</td>
</tr>
<tr>
<td>University College</td>
<td>$500 k Plasma Sensor</td>
<td>• University College London will develop and provide a flight/science quality plasma</td>
</tr>
<tr>
<td>London</td>
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<td>detector for Sunjammer. This work is funded by UK Space Agency. Data will shared with</td>
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<td>University College. Flight qualification will be provided.</td>
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<tr>
<td>NASA SMD</td>
<td>Ride Share!! &amp; Interest</td>
<td>• Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics) urged</td>
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<td></td>
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<td>development of a program very similar to Sunjammer.</td>
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The L’Garde Sail is a unique design well suited to very large (high performance) solar sails.

- **Vaness - Sail Control Surfaces**
- **Striped-Net Sail Architecture**
- **Unstressed Sail Material**
- **1200 m² Sail Area**
- **~40m on a Side**
- **5um Kapton Film (8.5kg)**

**L’Garde Patented Sub-Tg Conical Deployable Booms**

Sailcraft Bus

Sail Quadrant

Stowed

Deployed
**Secondary Payload Resume**

**Dim.:** 28in x 28in x 38in  
**Mass:** 153kg (wet)  
**CG:** 0.457m (18.7in)

**Primary Spacecraft Safeguards:**  
- Fully Welded Hydrazine System  
  (Tank to Pyro Iso Valve)  
- Full Bus Power Disconnect  
  (Two Switches on Lightband)  
- AFSPCMAN 91-710 Compliance  
- 0.3 m/s Separation Velocity  
  (Timer Delayed Power-Up)

**Hazards:**  
- Hydrazine System (57kg Fuel)  
  (May be Redundant with DSCOVR)  
- Pressurized Gas (31MPa (4500psi))  
  (2.7kg of Pressurant)  
- ~15 Energetic (Pyro) Actuators  
  (Cable Cutters, Pin Pullers, Iso Valves)  
- Lithium Ion Secondary Batteries  
  (COTS Battery System 30Wh)  
- Lithium FeS2 Primary Batteries  
  (250Wh Energizer COTS)

**Interface:**  
- 15in Lightband  
  (Separation Signal)  
- Unconditioned Power  
  (For Trickle Charger)  
- No Command  
- No Telemetry

ESPA Grande on F9H
Sunjammer Mechanical Design 1/2

PDR Renderings

Sailcraft + Carrier
Post-Burn

Sailcraft Post Deploy
**Sailcraft:**
- Quadrants, beams, 2-axis vanes
- "shelf" structure
- Jettison mounts and umbilical (upper)
- Canister = solar array

**Avionics:**
- Flight Computer
- Star tracker, sun sensor, IMU
- Radio, omni, helix antenna
- Sailcraft EPS & rechargeables
- Jettison & guidance cameras
- Magnetometer
- Remote firing board 1
- Boom & motor control boards
- Celestis payload / logos

**Carrier:**
- Launch support structure & brackets
- Lightband separation ring
- Spreader bar restraints
- Jettison mounts and umbilical (lower)
- Hydrazine tank and thrusters
- GN2 tanks, cold gas RCS, N2H4 pressure
- Inflation valve ganglion
- Camera boom

**Avionics:**
- Carrier PDU & primaries
- Remote valve controller
- Remote firing board 2
- Deployment controller
- Celestis payload
The Carrier Assembly is the Structural Part of the Sail Craft That Holds the Propulsion and Inflation System.

Once the Sail is Fully Inflated the Carrier is Jettisoned to Reduce Mass.
Sailcraft Mechanical Design

- Spreader
- Packaged Main Sail
- Stowed Vane Booms
- Packaged Main Sail Boom
- Sailcraft/Carrier Separation Plane
Demonstration Objectives Verified

1. Demonstrate segmented deployment of a solar sail
   • Verified with onboard imaging system
   • Data relayed to ground

2. Demonstrate attitude control plus passive stability and trim using beam-tip vanes.
   • Calibration effort will verify controllability and stability.

3. Execute a navigation sequence with mission-capable accuracy.
   • Sunjammer will be flown on a navigation sequence that future users are interested in.

4. Fly to and Possibly Maintain Position at sub-L1 and/or Pole Sitter Positions
   • Real time Infusion. This mission profile will demonstrate the validity of using solar sails to monitor space weather at pseudo Lagrange points.
   • Data will be relayed to the ground and analyzed by NOAA, UCL, and ICL.
Other Infusion Opportunities

- NASA
  - Heliophysics
  - Communication
  - ADR/ODR
- NOAA
  - Storm Warning
  - Communication
- DoD
  - STP
  - Communication
  - ADR/ODR
- SSHI (Commercial Entity)
  - Celestis Payloads
  - Advertising Rights
Other Near Term Tasks For Sails

Northern “polesitter” providing continuous polar coverage of the Earth and moon

Aerosols & clouds (Galileo)

Near Infrared Mapping Spectroscopy (Galileo)

Family of artificial Lagrange orbits

Wind vectors from polar imagery (LEO & GEO composite)

UV auroral imaging (NOAA)
