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“LV-CTA” for NASA’s Lunar Vertical Solar Array Technology (LVSAT)

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Northrop Grumman's LV-CTA for NASA's Lunar Vertical Solar Array Technology (LVSAT)

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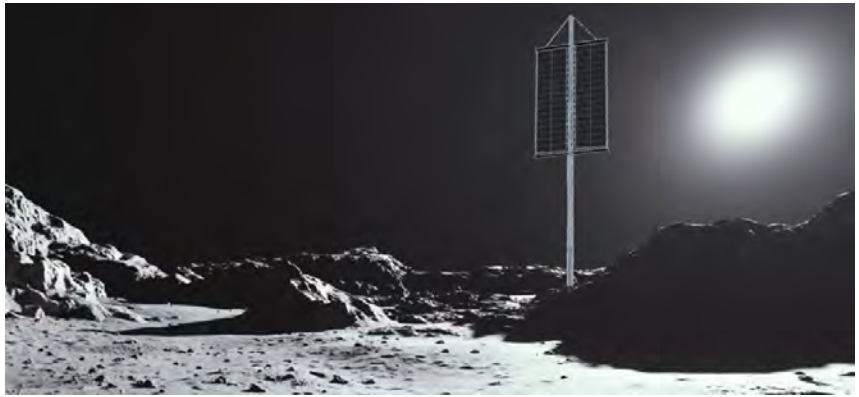


Project Overview

Base Phase:

- Develop "point design" baseline for all key elements of LV-CTA by performing trade studies, preliminary design and analysis, and subsystem prototyping to validate goals and objectives
- Determine limitations and drivers associated with Point Design
- Develop detailed plans for Option Phase

Option Phase:

- Perform detailed design, culminating in design review, with piece-part drawings and analysis.
- Complete assembly and comprehensive test campaign to validate LV-CTA operation in relevant lunar landed environment.

Technology Overview

The basic CTA architecture was originally conceived by NASA, then quickly developed by NG under NASA and AFRL funding, and NG is now under contract to Airbus to provide CTA for its revolutionary OneSat GEO communications satellites.

CTA incorporates high-TRL deployable structures and mechanisms in a novel configuration to provide compact stowage, stiffness and strength previously unachievable for solar arrays.

For LVSAT, CTA will include unique enhancements, notably:

- Strength for deployment in Lunar gravity
- Mechanisms for automatic retraction/stowage
- Mitigation against Lunar-specific environment (esp. dust)
- Avionics for autonomous, remote operation

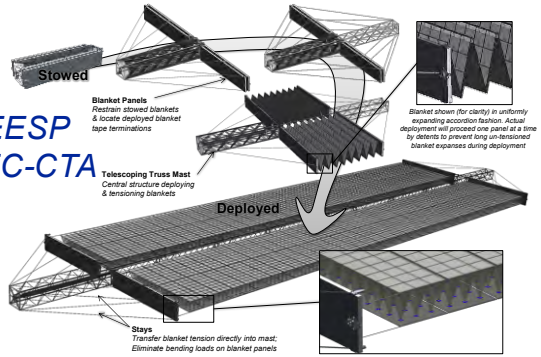
Company Overview

Northrop Grumman Corporation's (NGC) Goleta, CA operation (NG-G), is a recognized industry leader in designing and building mission-enabling, innovative deployable systems for spacecraft. NG-G consists of approx. 200 of the total 95,000 employees of NGC. NG-G has vast experience designing and building high-performance solar arrays and deployables, including the ISS solar array masts, and the 1-g self-supporting, 100+ W/kg UltraFlex wings for both the Mars Phoenix and Mars Insight landed missions. NG-G understands the challenges of building solar arrays for remote, autonomous deployment and operation in partial gravity and dusty conditions.

CTA Background and Status

Since its initial conception (by NASA) ca. 2015, CTA has advanced rapidly:

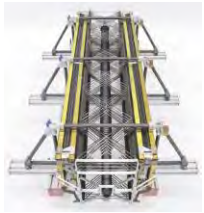
- SBIR development (two generations of high-fidelity prototypes, culminating in ~TRL 5 testing)
- Multiple offshoot SBIRs and funded studies, including
  - EESP PFC-CTA (~100:1 optical concentration for deep-space Solar Electric Propulsion)
  - AFRL ASSISTT (mast and SPM development)
- Award for Airbus' "OneSat" constellation of GEO communications satellites
  - Flight NRE and system qualification program + 24 ship sets initial production
    - CDR completed January 2021



EESP PFC-CTA

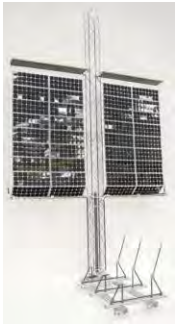
Airbus OneSat

CTA SBIRs



Stowed

Root and blankets staged



Blankets unfurling

Deployed

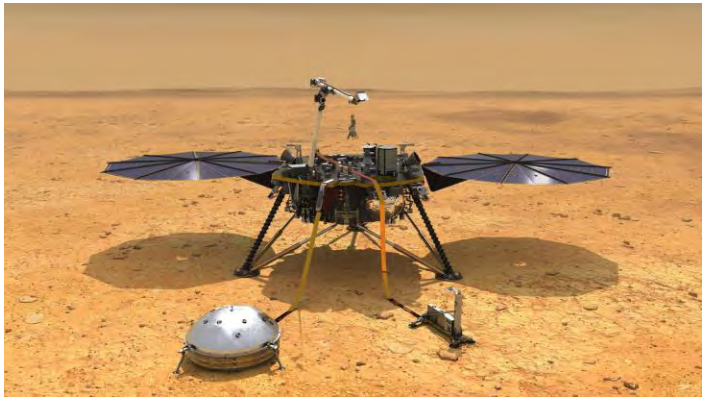
NG's Landed Solar Array Heritage

NG has unrivaled experience with landed deployable solar arrays, with UltraFlex

- 2001 Mars Surveyer Lander (2 flight units delivered; mission cancelled)
- Mars Phoenix (2008, 100% success)
- Mars InSight (2018, 100% success)

Many applicable lessons learned from these programs to leverage for LVSAT

- Relevant environments: Self-supporting for deployment in partial (or full) gravity, dust, deployment conops and unusual thermal conditions



Credit NASA/JPL-Caltech

LV-CTA Team

- Photovoltaics (sample cells for coupon testing, consultation re. Lunar-specific qualification activities):
  - SolAero Technologies (STC)
  - Spectrolab (SPL)
  - Thin film PV (NG-SSD)
- Avionics (autonomous control and operation):
  - NG's Civil and Commercial Satellites business unit; leveraging capabilities from Space Station Resupply (CRS), Mission Extension Vehicles (MEV), etc.

NG Deployables' UltraFlex wings powering NG's CRS Cygnus

NG Deployables' Arrays and Capture Mechanism on MEV

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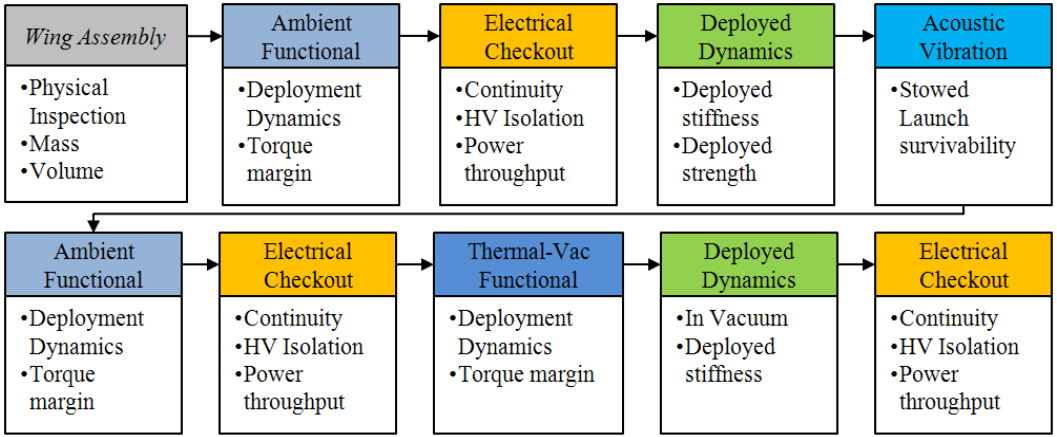
LV-CTA Base Phase Activities (summary SOW)

- 1-day **technical coordination meeting**
- Perform **design and analysis** in order to demonstrate the expected performance of the proposed Lunar VSAT system.
- Provide a design, analysis, and data (to include **Master Equipment List** (MEL), mass margin policy, trade studies, Power Equipment List (PEL), Concepts of Operation, etc.).
- Provide a detailed **technical description** of all major system components:
  - **Solar cell** materials, **blanket** design, and electrical **harness**;
  - Solar array **structure**, **mechanisms**, and deployment and **retraction** designs;
  - **Interface with rover** and concept of operations for transportation on the lunar surface;
  - **Avionics** required for deployment control, array pointing, and “keep alive” functionality;
  - Low data rate **communications** for monitoring and controlling the array;
  - **Power management** system for transferring power from the arrays to end users;
  - Expected **mass**, stowed **volume**, and **performance** characteristics.
- Quantify objective **system performance** based on test data and analysis.
- Develop the final **test plan** to include the finalized approach, test location, and finalized costs
- Present Base results as an **oral presentation**
- Provide a comprehensive Base **final report**

TRL 6 (System Prototype) Testing

Option Phase to include full system prototype build and TRL 6 (relevant environments) test campaign

- Ground (1-g) deployments will be performed vertically, with 5/6th of system weight offloaded from overhead
- Lunar Dust, a key "Relevant Environment," will be validated separately via sub-system level testing



Thermal deployments

- Full deployments at hot (+60°C)
  - Result: full deployment success
- Full deployments at cold (-50°C)
  - Result: full deployment success

THERMAL TEST CHAMBER
NGIS Goleta CA
16' x 16' x 28'

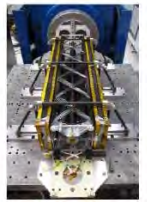
- *Full-system vertical deployment in NG-Goleta's high-bay by truncating "root standoff" portion of mast*
- *Complete mast tested horizontally (separately)*

Test details

sine sweep

Freq [Hz]	G's
5-60	6
60-100	4
Sweep	4 oct/min

- Full level sine sweep prior to random
- Random Spectrum per GEVS, with notching to limit response per MAC (18 g's)
- X-axis ~9 g's RMS
- Y-axis ~10 g's RMS
- Z-axis ~9 g's RMS
- 60 sec duration
- Increment loading, -12/-9/-6/-3/0 dB with inspections between
- 0.5g sine sweep before RV and after full level



NG is excited to join NASA in this work and to bring our corporate depth and experience, in particular with off-world solar arrays, to bear on the subject solar array challenge, to help turn Artemis plans into hardware to support lunar exploration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