Advanced Solar Arrays

Space Technology Mission Directorate

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NASA Glenn Research Center

Planetary Science Division Discovery Technology Workshop

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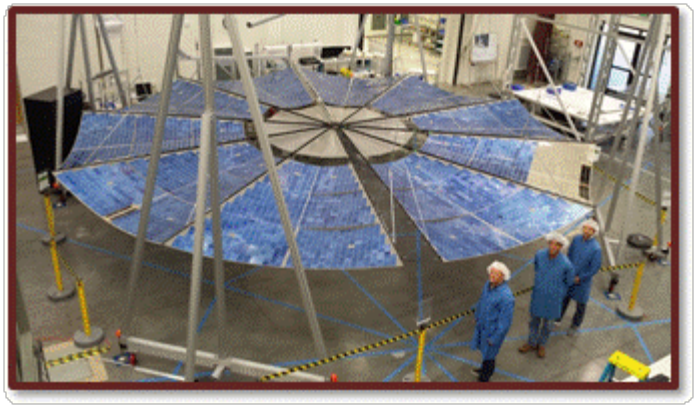
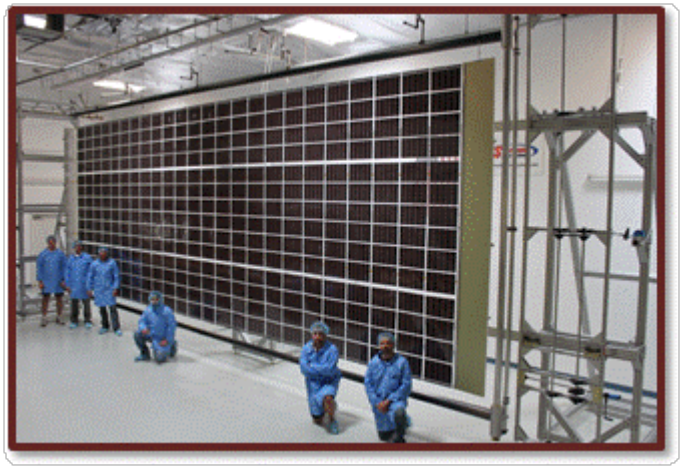
STMD Solar Electric Propulsion Project
Solar Power Element Overview

- **OBJECTIVE:** **Design and build a 20-kW-class solar array wing to meet mass, volume, strength, stiffness, and environmental requirements anticipated for human exploration missions**
- **APPROACH:** **Two contracts: a fan-fold design from ATK and a roll-out design from DSS. Both use flexible blankets to dramatically reduce mass and stowed volume compared to rigid panel structures.**
- **RECENT ACCOMPLISHMENTS:**
  - ✓ **Brought concepts from idea to hardware: Passed SRR, MDR, MRR, and TRR reviews**
  - ✓ **Conducted structural, thermal, and environmental tests on key subsystems**
  - ✓ **Characterized PV coupons in plasma environment and single event radiation effects on high power, high voltage electronic parts**
- **FY14 PLANS:**
  - – **Demonstrate TRL 5/6 with thermal vac deployment tests and stowed/deployment structural tests**
  - – **Demonstrate extensibility to 250kW-class systems analytically**



MegaFlex Engineering Development Unit (EDU) employs an innovative spar hinge to reduce stowed volume. Alliant Technical Systems (ATK)



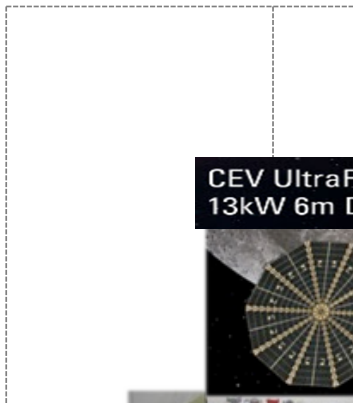
ROSA Engineering Development Unit (EDU) employs an innovative stored strain energy deployment to reduce the number of mechanisms and parts. Deployable Space Systems (DSS)

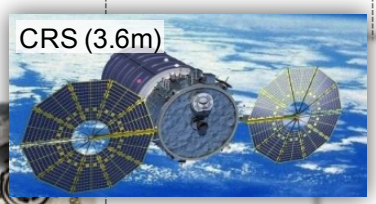
Contact: Carolyn.R.Mercer@nasa.gov NASA GRC

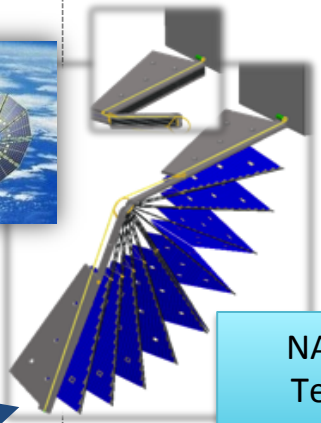
STMD SEP Solar Power Key Performance Parameters

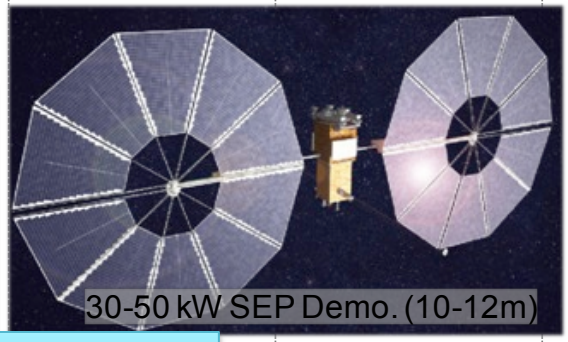
Parameter	SOA (Typical Large GEO)	Goal	Goal / SOA	Comment
Mission environment	$5x10^{14}$ 1MeV e^-/cm^2 with thin shielding	**$20x10^{14}$ 1Mev e^-/cm^2 with significant cell shielding**	4X	Radiation environment driven by 300 day LEO to GEO transfer
Solar Array Power	<20kW	**30kW – 50kW with extensibility to >250kW**	1.5X – 10X	Power requirement met with 2 wings and standard triple junction cells
Operating Voltage	32V to 105V	**160V – 300V**	1.5X – 3X	Must operate in dense plasma (thruster) environment
Specific Mass	60 W/kg	**>100 W/kg**	1.7X	End of life power; Mass and volume includes all mechanisms, structures, and power transfer up to and including the interface with the spacecraft.
Stowed Volume Efficiency	10 kW/m^3	**>40 kW/m^3**	4X	
Deployed Strength	0.005 g	**>0.1 g**	20X	Driven by on-orbit inertial loads, including docking and chemical thruster loads; Affects structural mass.
Deployed Frequency	>0.05 Hz	**>0.1 Hz**	2X	
Stowed Frequency	>25 Hz	**>25 Hz**	1X	Driven by launch loads; Affects structural mass.
Stowed Strength	20 g	**20 g**	1X	

STMD Advanced Solar Arrays
ATK MegaFlex

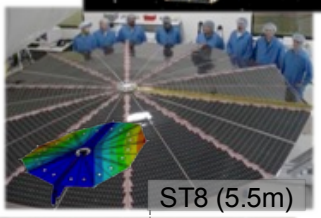


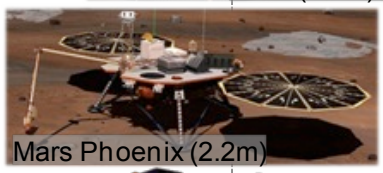


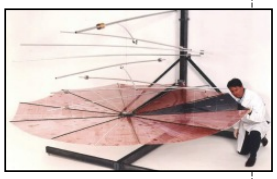




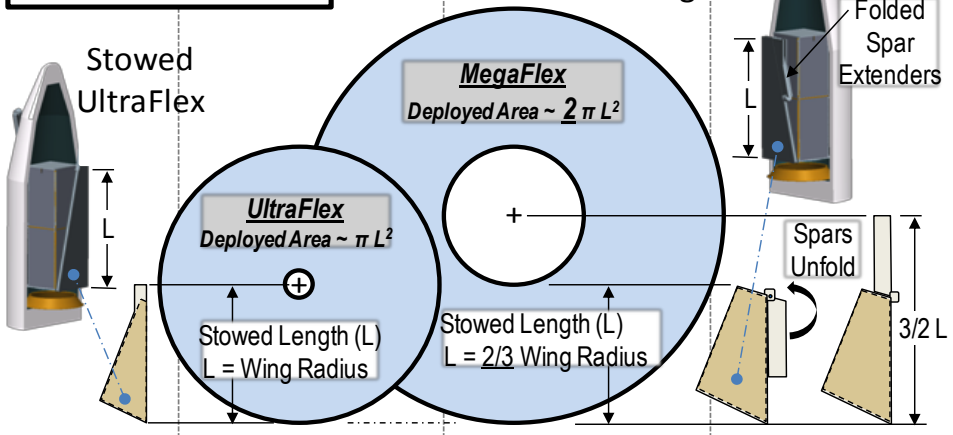
NASA STMD Technology Development







UltraFlex to MegaFlex Evolution



1995 — Time → — 2020

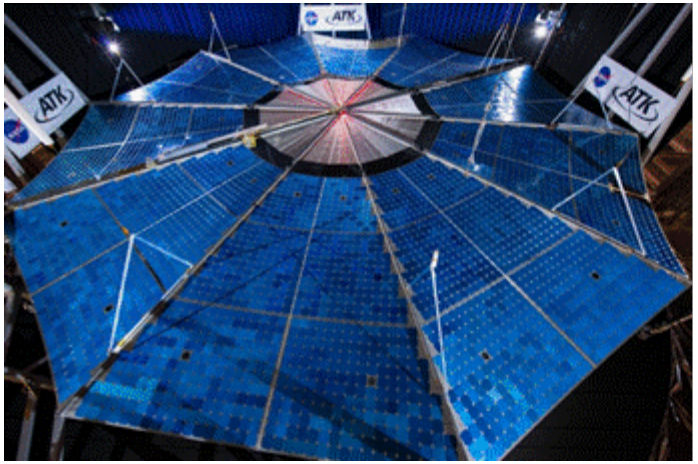
UltraFlex flights planned for Cygnus and Mars Insight

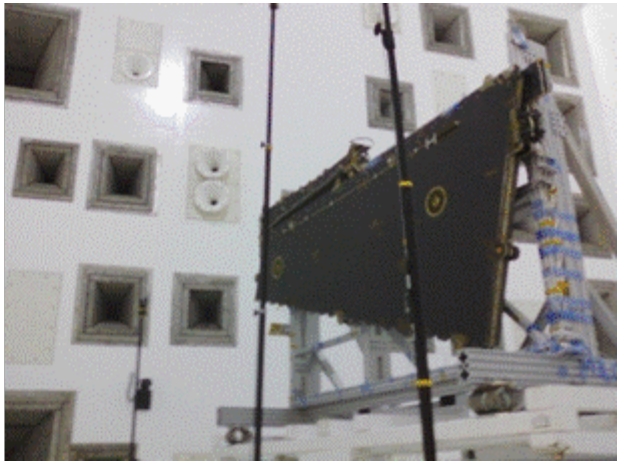
MegaFlex *is* UltraFlex *with* Improved Stowed Packaging

STMD Advanced Solar Arrays
ATK MegaFlex

20kW EDU Advancement	Date
Subsystem tests	✓
PV plasma testing	✓
EDU fabricated (sized for 20 kW)	✓
Stowed wing acoustic and random vibration equivalent exposure tests	✓
Thermal vacuum deployment tests (-60 C to +60 C)	✓
Vacuum structural dynamics and deployed strength testing	April 2014
TRL 5/6 (upon review of documentation)	May 2014

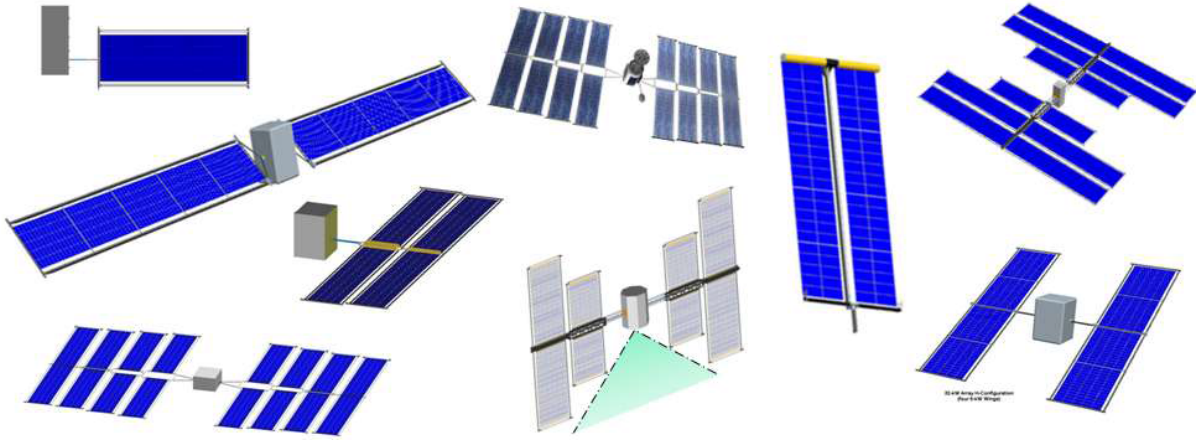
Deployed MegaFlex EDU (9.7 m diameter)





Stowed MegaFlex EDU

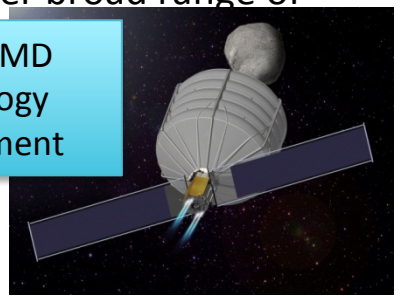
STMD Advanced Solar Arrays
DSS Roll-Out Solar Array (ROSA)



Rectangular design enables configuration flexibility –

- length/width can be adjusted to match deployed/stowed profiles
- Scalable over broad range of

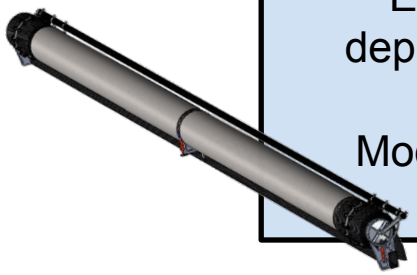
NASA STMD Technology Development



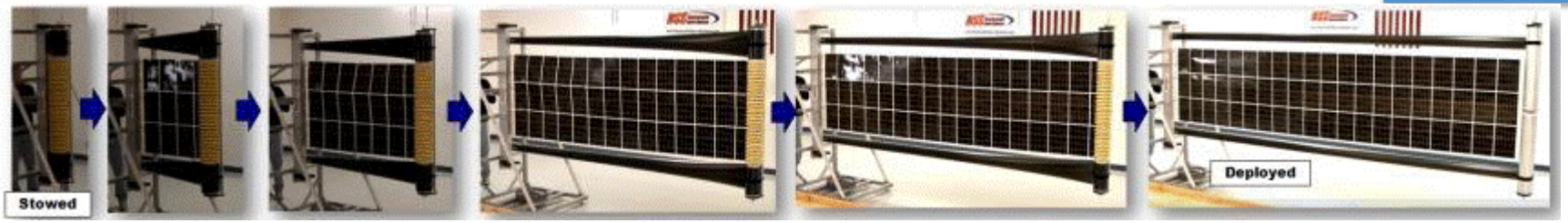
High margin, linear, elastically-actuated deployment – no motors required to deploy

Elastic structure maintains stiffness throughout deployment for partially-deployed power generation

Modular PV blanket assembly enables high-power affordability



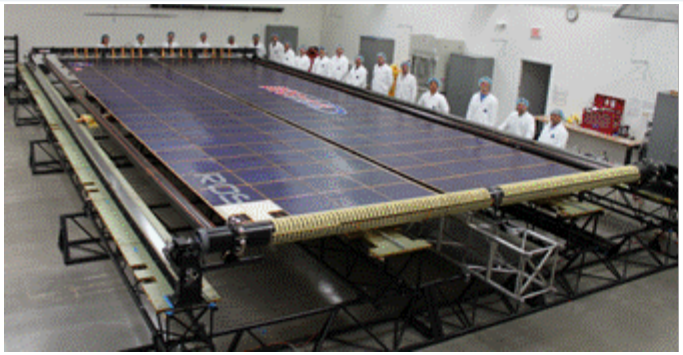
ROSA flight planned for ISS Demo



STMD Advanced Solar Arrays
DSS Roll-Out Solar Array (ROSA)

20kW EDU Advancement	Date
Pathfinder ROSA (sized for 15 kW) built and deployed 40+ times	✓
Pathfinder thermal and vacuum testing (subsystem tests)	✓
Component level vibration tests	✓
EDU structural deployment tests	✓
EDU fabricated and deployed (sized for 20 kW)	✓
Vacuum Structural Dynamics Testing	April 2014
PV plasma testing	April 2014
Thermal Vacuum Deployment Tests (-60 C to +60 C)	May 2014
Deployable backbone integration for Mega-ROSA demonstration	June 2014
TRL 5/6 (upon review of documentation)	June 2014

Deployed ROSA EDU
(13.6 m x 6.3 m)



Stowed
ROSA EDU

Flexible Blanket Solar Arrays can be Tested at NASA's Space Power and Reverberant Acoustic Test Facilities

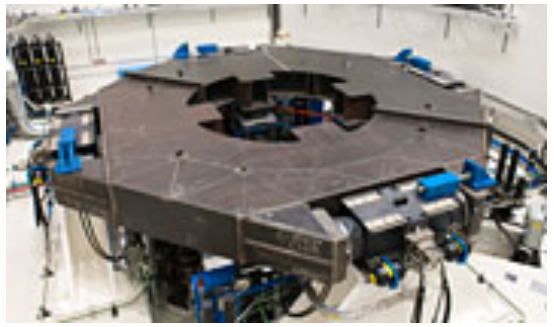
NASA Glenn's Space Power Facility

- Space Simulation Vacuum Chamber:
  - 30.48 m diameter by 37.18 m high
  - Thermal Vacuum (<2 x 10^{-6} torr)
  - 12 m diameter, 12 m high Cryogenic Shroud (-160 C to +65 C)
  - 256-channel data acquisition w/500 thermocouples

- Reverberant Acoustic Test Facility
  - 14.5 x 11.4 x 17.4 m chamber volume
  - 163 dB OASPL
  - 25 Hz to 10 kHz
  - 19 microphone closed-loop control
  - 1,024 channel high-speed data acquisition

- Mechanical Vibration Facility
  - 34 t max test article mass
  - 5 to 150 Hz
  - 24-channel analog abort
  - 64-channel closed-loop control
  - 1,024 channel high-speed data acquisition

http://facilities.grc.nasa.gov/spf/quick.html

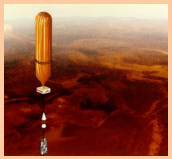


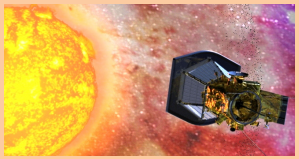
Solar Array Structures Can Accommodate SOA and Advanced Cell Technology to Support Unique NASA Science Mission Requirements

High Intensity / High Temperature (HIHT)

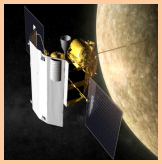
Venus surface

Venus atmosphere

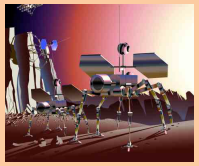




Solar Probe Plus



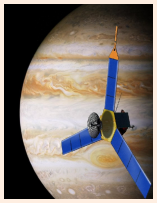
Mercury orbit



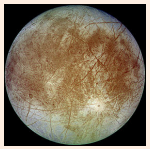
Mercury surface

Low Intensity / Low Temperature (LILT)

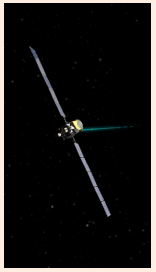
Juno



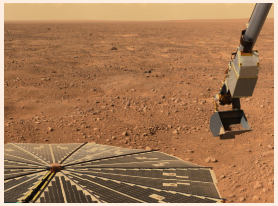
Europa



Missions to comets & asteroids



Dawn



Polar Regions of Mars

Extreme environment photovoltaic characterization testing and expertise is available at the NASA Glenn Research Center

- Triple Source Air Mass Zero Solar Simulator (modified X25) and Large Area Pulsed Solar Simulator (LAPSS)
  - Temperature dependence (-150 to +150°C)
  - Variable solar intensity (.002 suns to 1.3 suns)
  - High incidence angle measurements
  - Radiation damage performance degradation
- UV and atomic oxygen exposure evaluation
- Generation of primary and secondary AM0 solar cell calibration standards via high altitude spacecraft
- Monochrometer-based spectral response (350-27000 nm)
- Filter-based spectral response (350-1900 nm)
- Rapid thermal cycling cell/blanket coupon testing
- Thermal balance characterization of flexible blankets
- Plasma interaction and arcing characterization of cell/blanket technology under varying space environments

STMD Advanced Solar Arrays Summary

- **High performance solar arrays are being matured by STMD**
  - ROSA and MegaFlex engineering development units are expected to be at TRL 5/6 within the next few months
    - Designed to meet STMD performance goals
      - 0.1g in all axes; 0.1Hz; sized for 20 kW BOL per wing
      - GEO-like thermal design
      - Photovoltaic blankets designed to support 160 to 300 VDC power bus and operation near electric thruster plume
    - Expectation is that these arrays can go straight to flight qualification or protoflight units

  - **Both arrays can scale to different power levels and mission requirements**

- **Testing facilities and expertise are available at NASA GRC to support a wide range of science mission operational environments**

Planned AO Library Content And Contact Information

Planned AO Library Content

- Fact Sheets for ATK MegaFlex and DSS ROSA solar arrays
- NASA GRC's Test Capability Sheets
- These charts

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