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ROSAs for New Space: Maxar Roll Out Solar Arrays on Three Different Spacecraft

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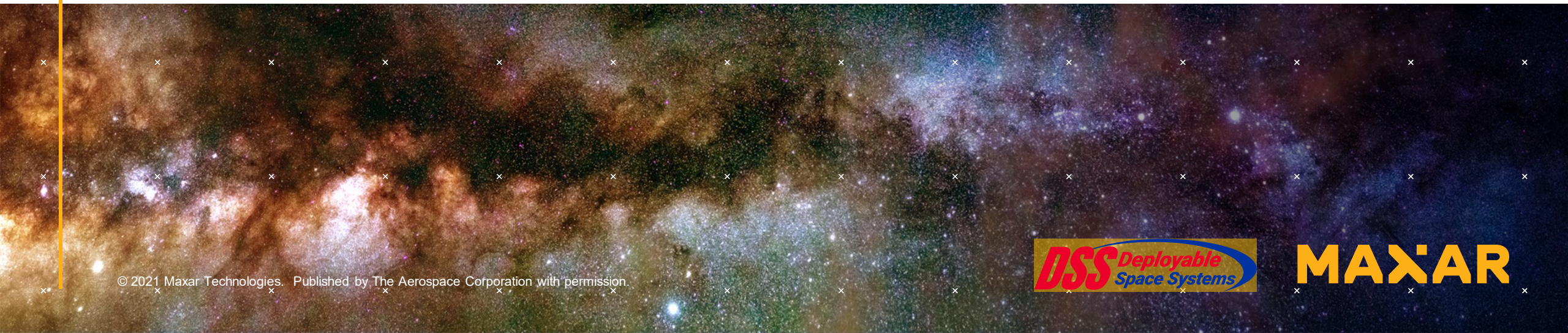


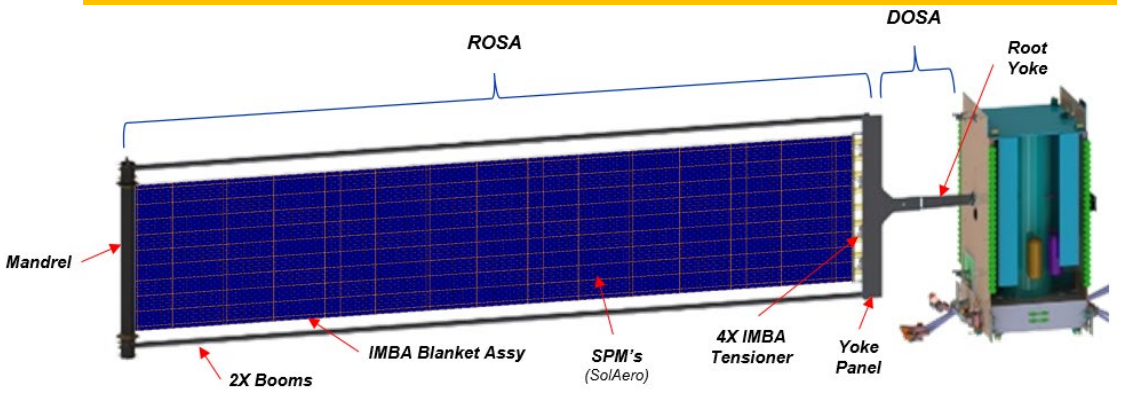
Maxar ROSA Experience

"Semper Gumby"

Evolution of ROSA at Maxar from 2014 - Present

- 2014 – 2018
  - IRAD contract with Deployable Space Systems (DSS)
  - Design and qualification of ROSA for 1300 Bus
  - 14 kW BOL, targeting >100 W/kg
  - Characterization and risk reduction testing
- 2018 - 2019
  - Awarded NASA Power and Propulsion Element
    - 70 kW BOL large dual-blanket ROSA
  - Awarded contract for small commercial GEO mission
    - Sub-10 kW ROSA
- 2020 – 2021
  - Awarded study contract for Dynetics Human Lander System
    - Sub-10 kW ROSA, retractable

Maxar ROSA for 1300 Bus

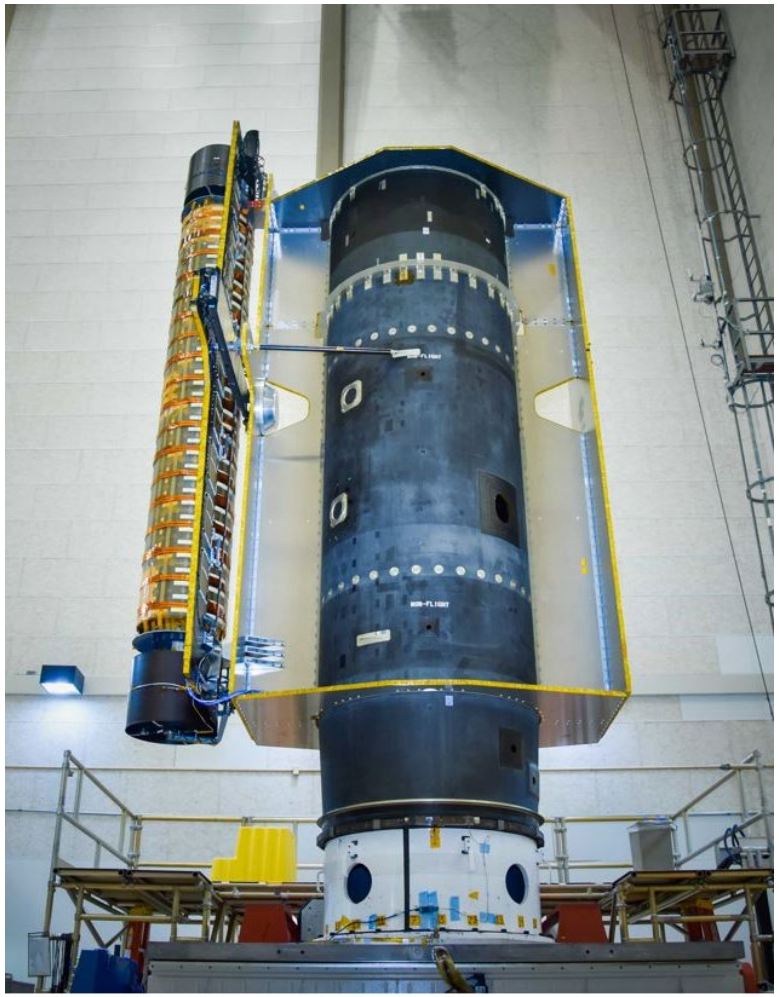


Source: "SSL ROSA Qualification Status", 2018 Space Power Workshop

Changes in the market and customer mix are driving a bifurcation of the product line

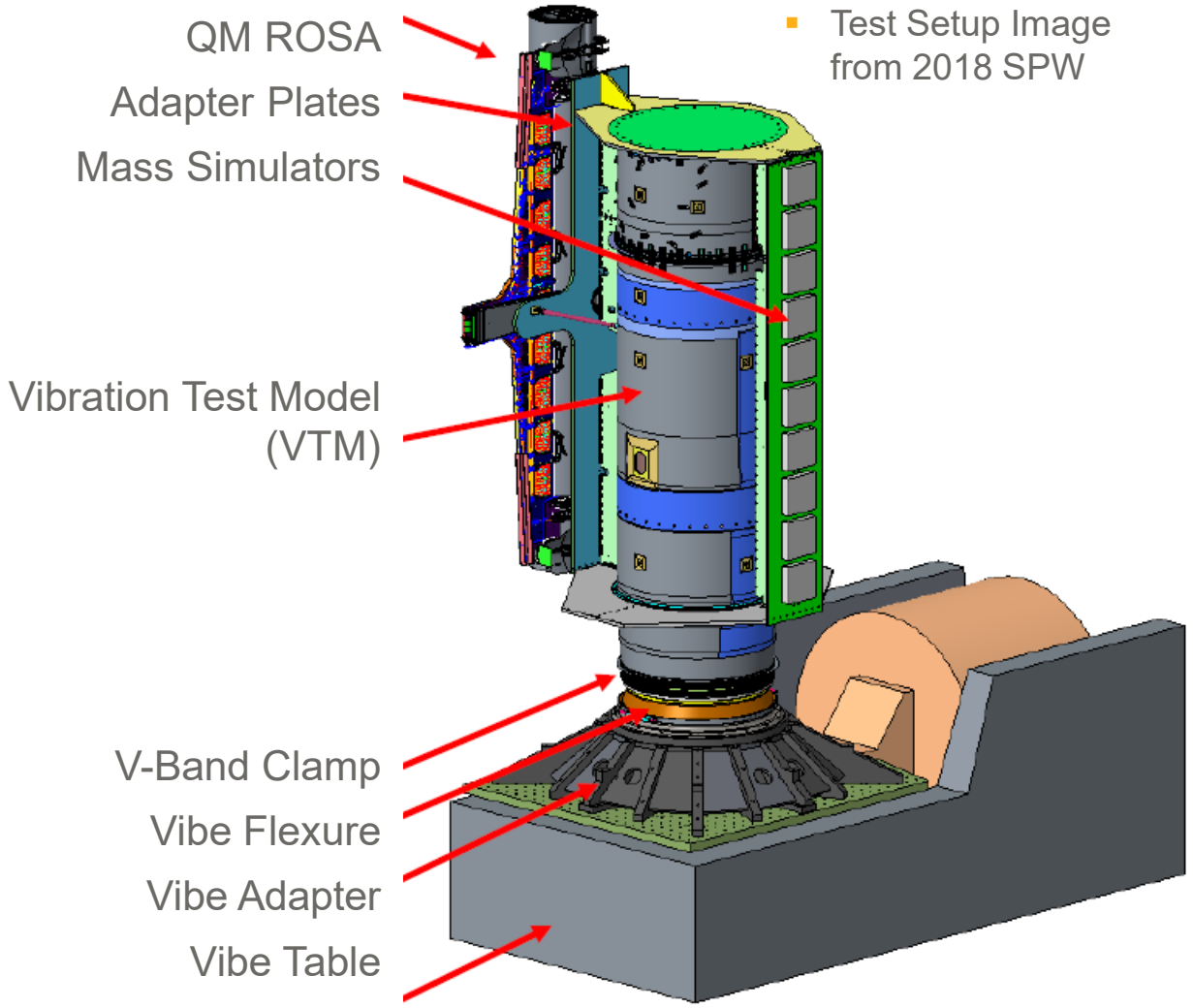
Update: Maxar GEO ROSA Qualification Wing Sine Vibe Completed

- Test Setup on Vibe Table at Maxar



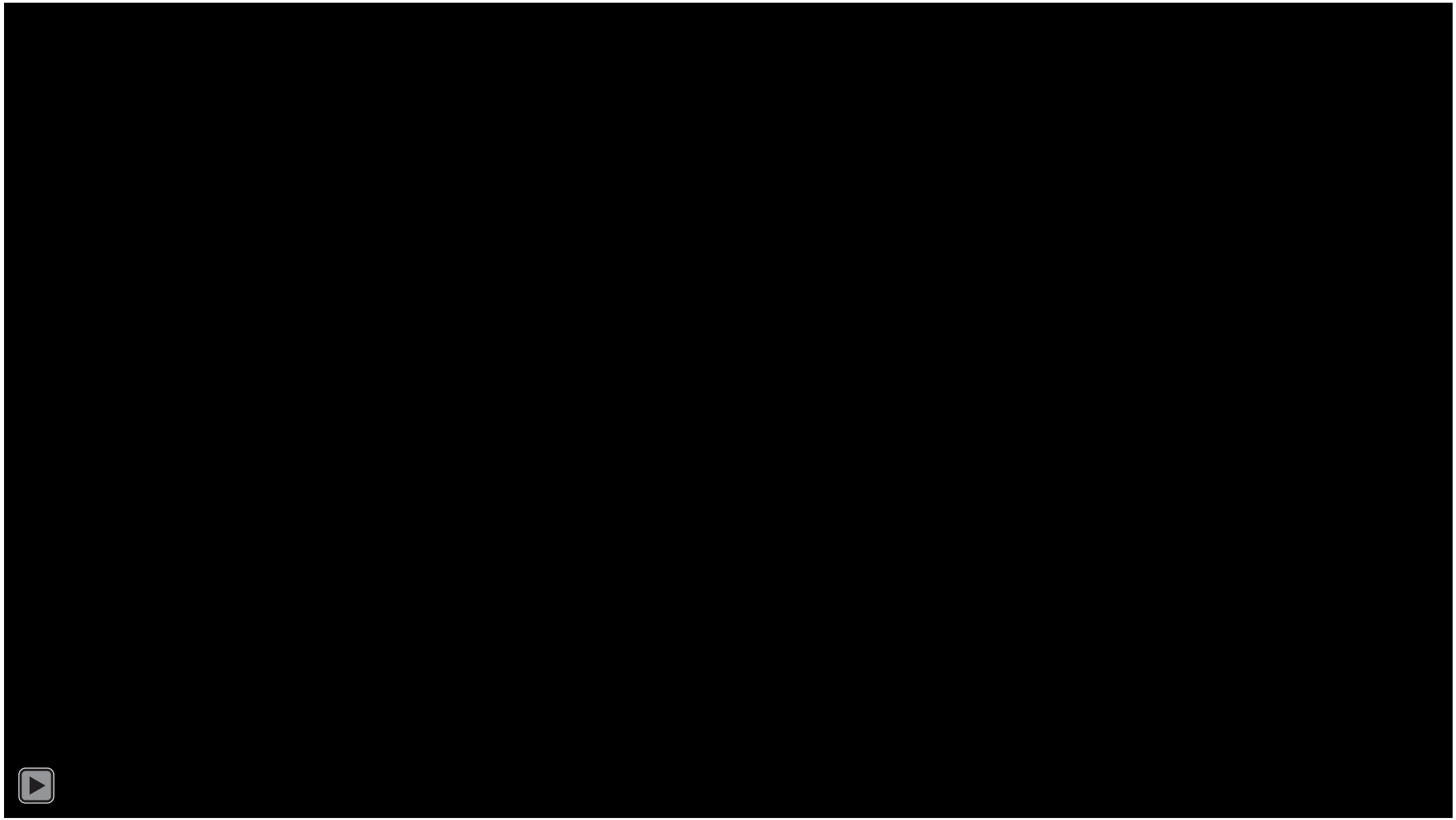
Credit: Maxar Photographic Services

- Test Setup Image from 2018 SPW



Test results to inform ongoing activities across ROSA programs at Maxar

Video of Maxar GEO Qual Wing Sine Vibe (X-Axis, Full)



Maxar Programs and ROSAs

"Three for three"

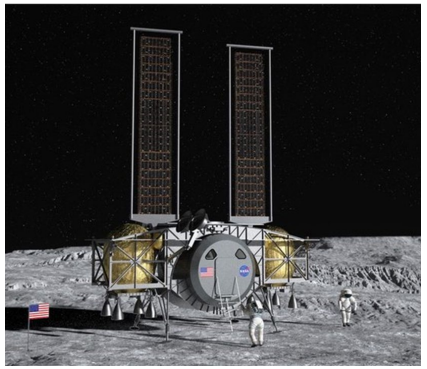
Three Maxar Programs, Three ROSAs

- **The Power and Propulsion Element (PPE) for Gateway, a part of NASA's Artemis Program**
  - 70 kW Beginning of Life (BOL)
  - Electric Orbit Raising (EOR)
  - Lunar Near-Rectilinear Halo Orbit (NRHO)
- **Modular Architecture-Class Commercial GEO Communications Mission**
  - 8 kW BOL
  - Electric Orbit Raising (EOR)
  - Standard GEO Orbit
- **Dynetics Human Lander System (DHLS)***
  - 5-10 kW BOL – Deployable and Retractable
  - Lunar Surface Operations
  - NRHO (at Gateway)

*Maxar proposed Electrical Power System as a supplier under Dynetics HLS Study Contract

Credit: NASA

Maxar Artist's Rendering



Credit: Dynetics

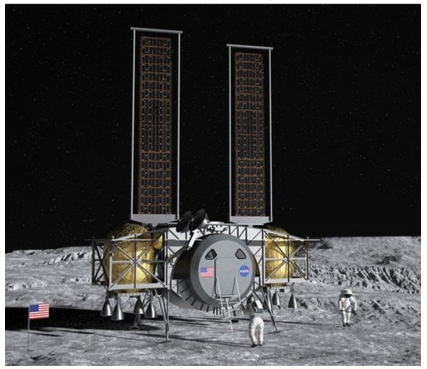
DSS Deployable Space Systems MAXAR

Maxar ROSA Qualification Approach Varies by Program

- **PPE**
  - Mechanically same solar cell as GEO Qual
  - Some mechanical components like GEO Qual
  - Dedicated Life Cycle and Combined Effects coupons
  - Modest component re-use from iROSA
  - Testing at assembly and sub-assembly level (e.g. 1/2 wing)
- **MAC**
  - ~ 80 % component re-use from DART (APL's Dual Asteroid Redirect Test)
  - Extended mission-specific testing of IRAD and PPE coupons
  - Protoflight testing of flight wings
- **DHLS**
  - Maximize component re-use from MAC
  - Development effort for 1/6 G, dust abatement, and deployment / retraction operation

Credit: NASA

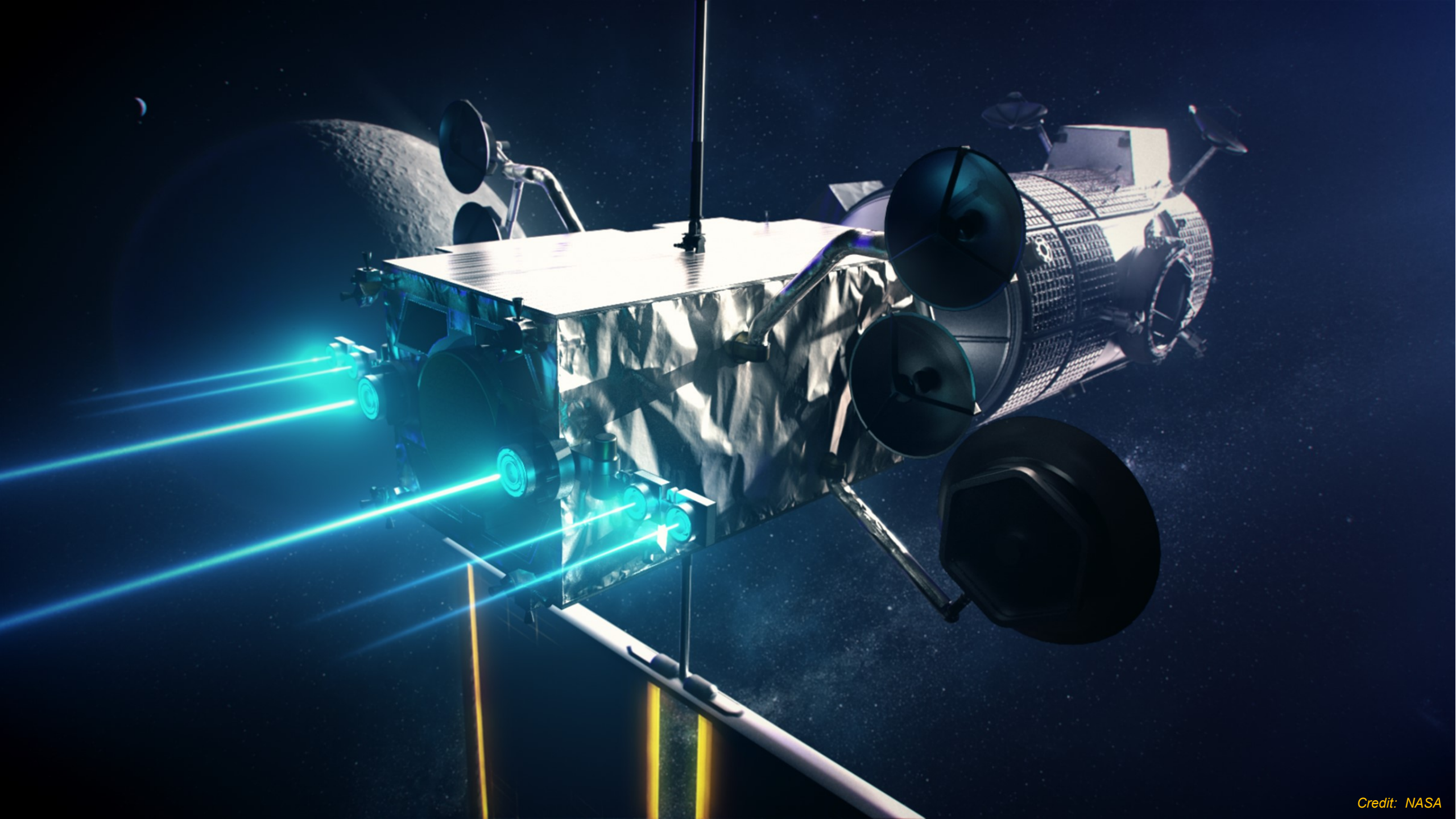
Maxar Artist's Rendering



Credit: Dynetics

PPE ROSA

“We may need a bigger building.”



Credit: NASA

Power and Propulsion Element (PPE) ROSAs

- Driving requirements and unique considerations / observations
  - At 70 kw everything is “super sized”
  - From day one, plan to “max out” design capabilities
  - Scale drives need for early decisions on key long lead items
  - Test program is complex and must be thought through
  - Scale of GSE and infrastructure cannot be under-estimated

- Other
  - Difficult to “stay out of the way” with wings this large
  - Additional protective measures needed for thermal, other
    - EP and Bi-prop plume impingement
  - Such large gossamer-like structures require a re-think of testing and verification approach
    - Need a dedicated AIAA spec for blanket solar arrays

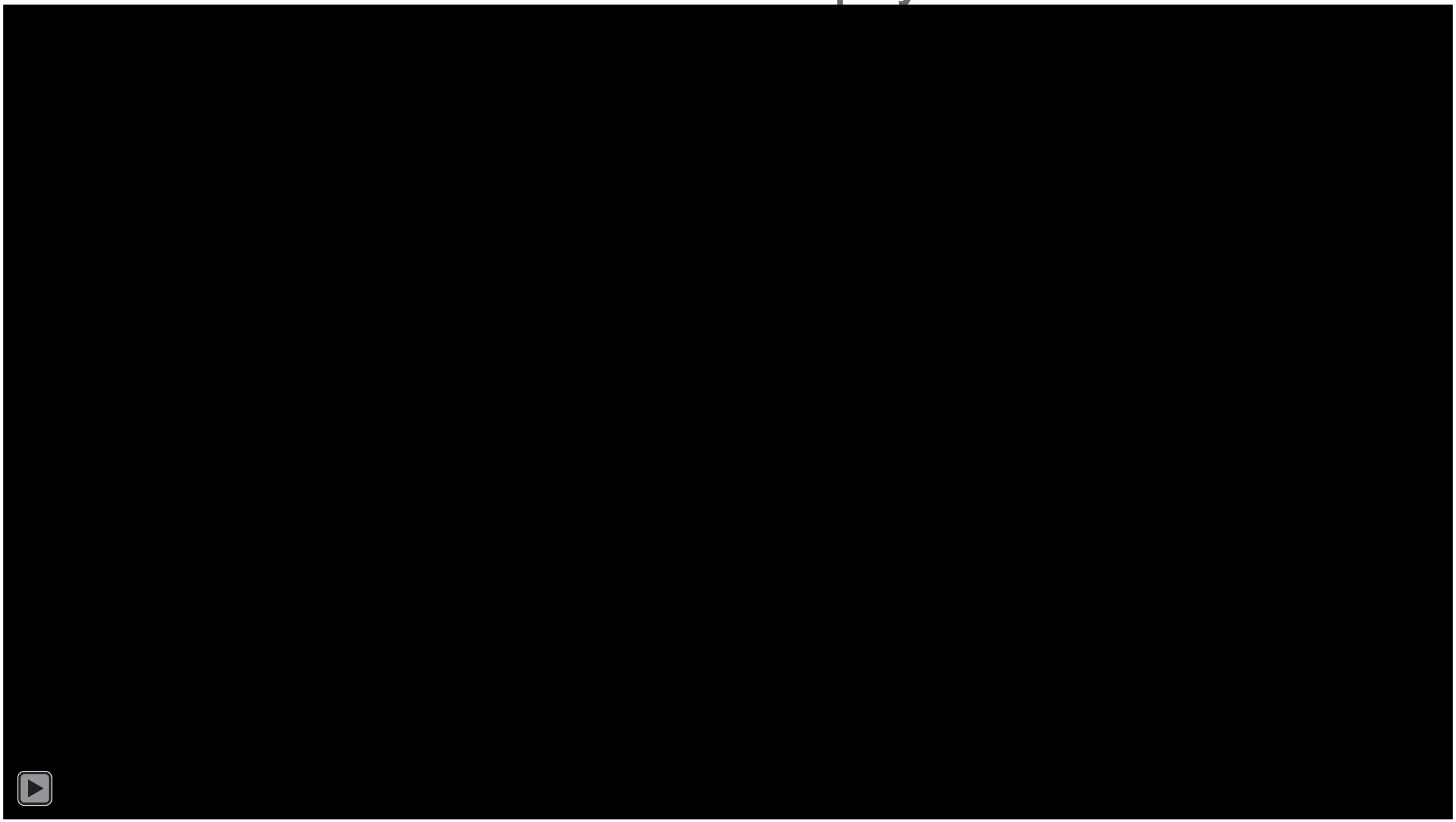
Credit: NASA

Large ROSAs: Single and Dual-blanket

Credit: Deployable Space Systems

PPE Double Blanket will be ~ 2X the Maxar GEO Qual Wing on the left

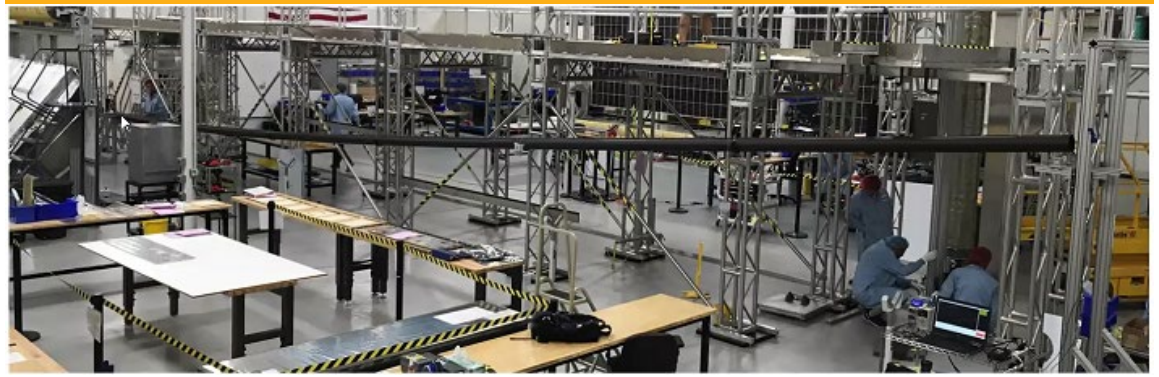
Video of PPE / HALO Deployments



PPE ROSA Status

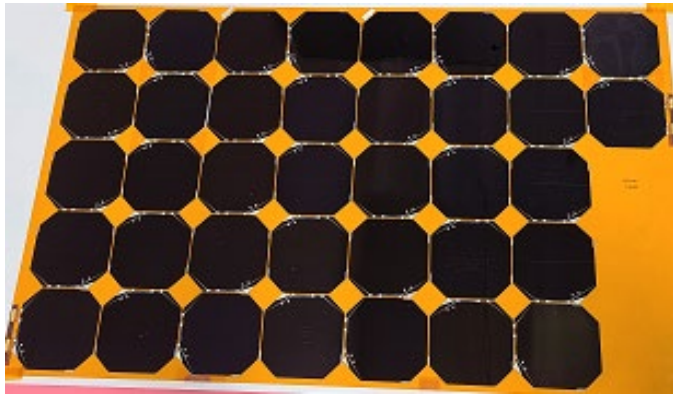
- Co-manifest with HALO uses every watt for EOR
- ROSA CDR in Q2 2021
- Long lead items
  - Booms fabricated and delivered
    - EDU boom strength testing underway
    - First flight SPMs delivered to DSS
  - Harness and diode boards on order
- End-to-end test plan being formalized
  - Baseline plan is to test each half-blanket like a single wing
  - Evaluation option to include full (double) blanket deployment – like iROSA
  - Evaluating use of pLEDss for wing-level electrical testing
  - Working with DSS and NASA on assessment
- Extensive coupon test program underway
  - Supplemental to GEO IRAD

Deployment Boom Strength Testing at DSS



Credit: DSS

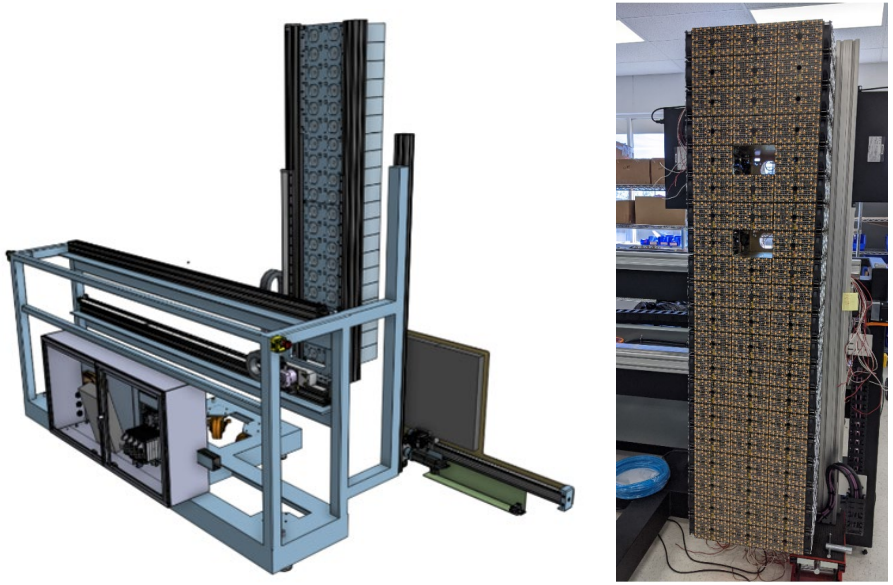
SPM with SolAero Z4J cells



PPE Wing-level Electrical Testing with LED-based Light Source

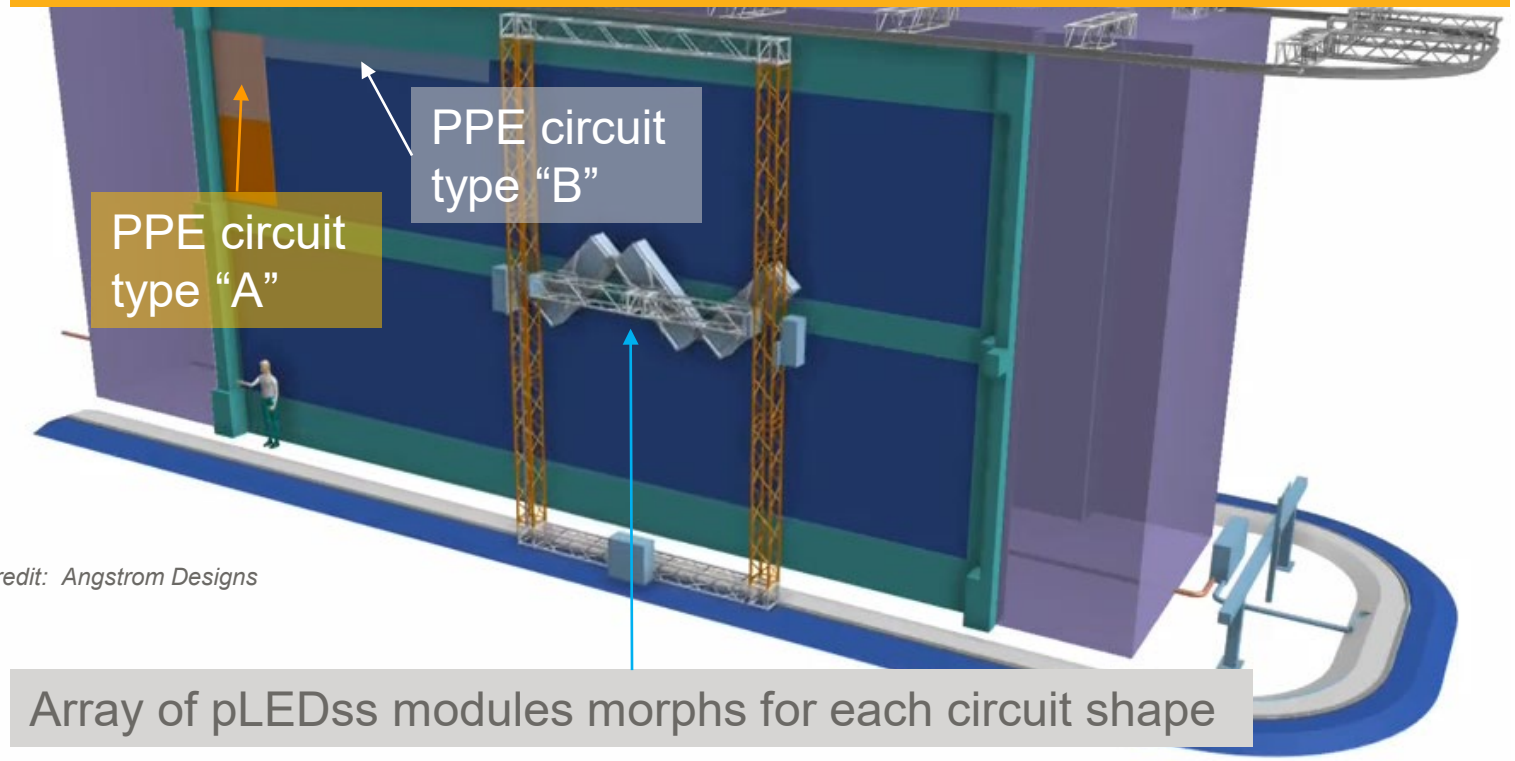
- Maxar is currently working with Angstrom Designs to demonstrate a small pLEDss system for testing 5-junction solar cells on a flight program
- In parallel, plans are in development between Maxar, DSS, NASA GRC and Angstrom, for implementing pLEDss on a larger scale for wing-level test of PPE

pLEDss Demonstration Unit



Currently undergoing calibration at Angstrom for evaluation at Maxar

Modular pLEDss concept for PPE wing-level test



Credit: Angstrom Designs

Array of pLEDss modules morphs for each circuit shape

Modular Architecture-class ROSA

"Wagging the dog."

Modular Architecture-Class ROSA

- Maxar's MA-class spacecraft is targeted at GEO missions in the 5-15 kW power range
  - First implementation is on a commercial GEO spacecraft
  - Full Electric Orbit Raising (EOR)
- Driving requirements and unique considerations / comments
  - Minimum specified time to GEO governs EOR duration
  - Business case means that EOR governs solar array sizing ("wagging the dog")
    - Sizing for EOR means payload EOL power margin is ~ 40%
  - EOR CONOPS require daily knowledge of expected array power output
    - Need specific daily (or near-daily) predicts
      - Orbital position, radiation exposure, and power output
  - Mounts to spacecraft using Maxar Redundant Release Devices (RRDs) in place of primary Frangibolts to reduce shock loads
  - ROSA allows this mission to use three different solar cell types

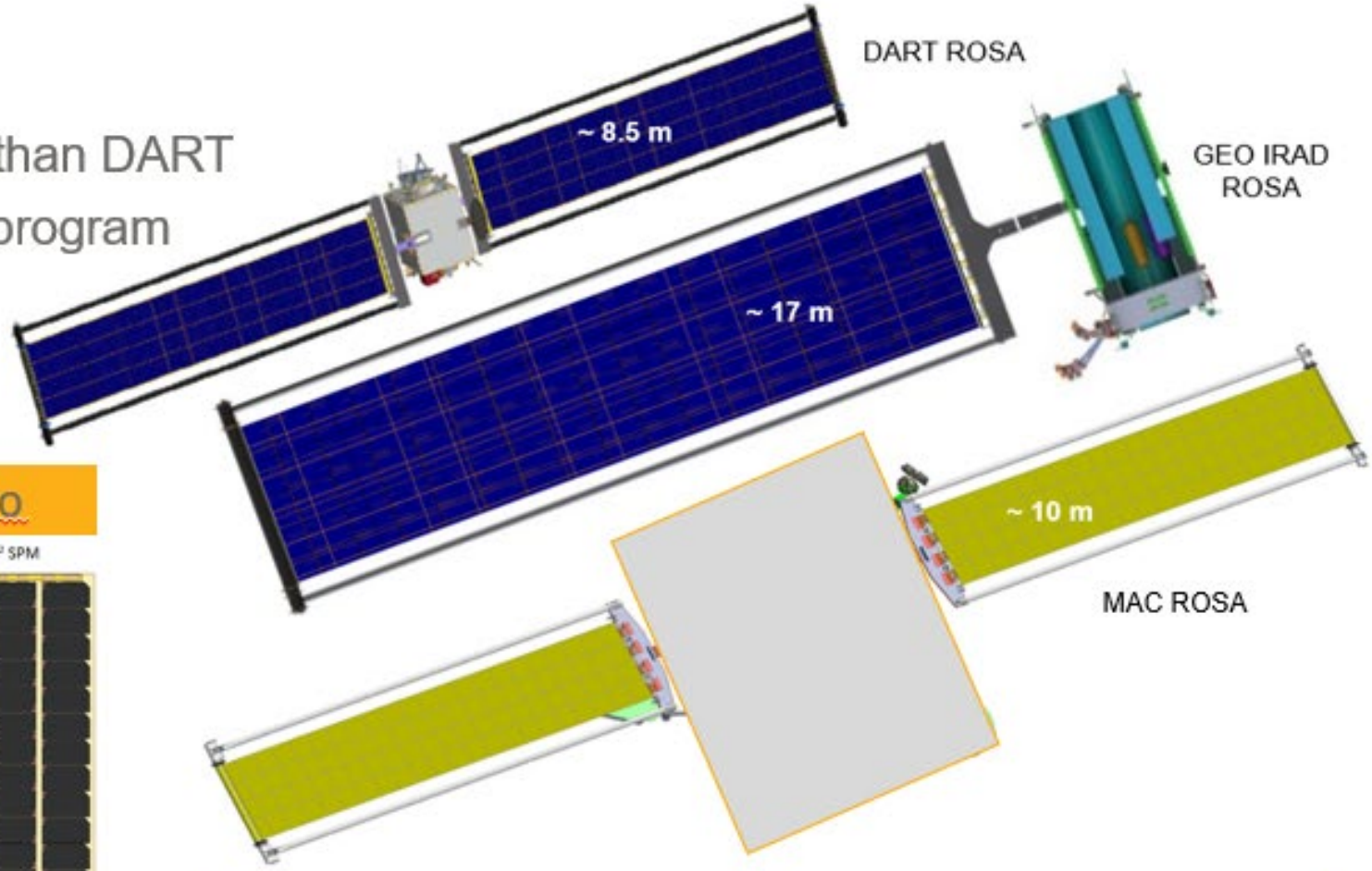
Maxar GEO Spacecraft

Maxar Artist's Rendering

Electric Orbit Raising Drives EPS Design and Solar Array Sizing

MAC ROSA is a scaled-up DART blanket with a scaled-down GEO Yoke

- ~ 80 % component re-use from DART
- MA is ~1.5 m longer and 0.35 m wider than DART
- Solar cells are 2-per 4” wafer for each program
- Random vibe loads are similar
  - Higher Sine vibe for Legion



Three different SPM types from SolAero

Parallel gap between CIC: 1.02 mm (0.04")
- Grout between Parallel CIC runs (not shown) for ESD arc mitigation

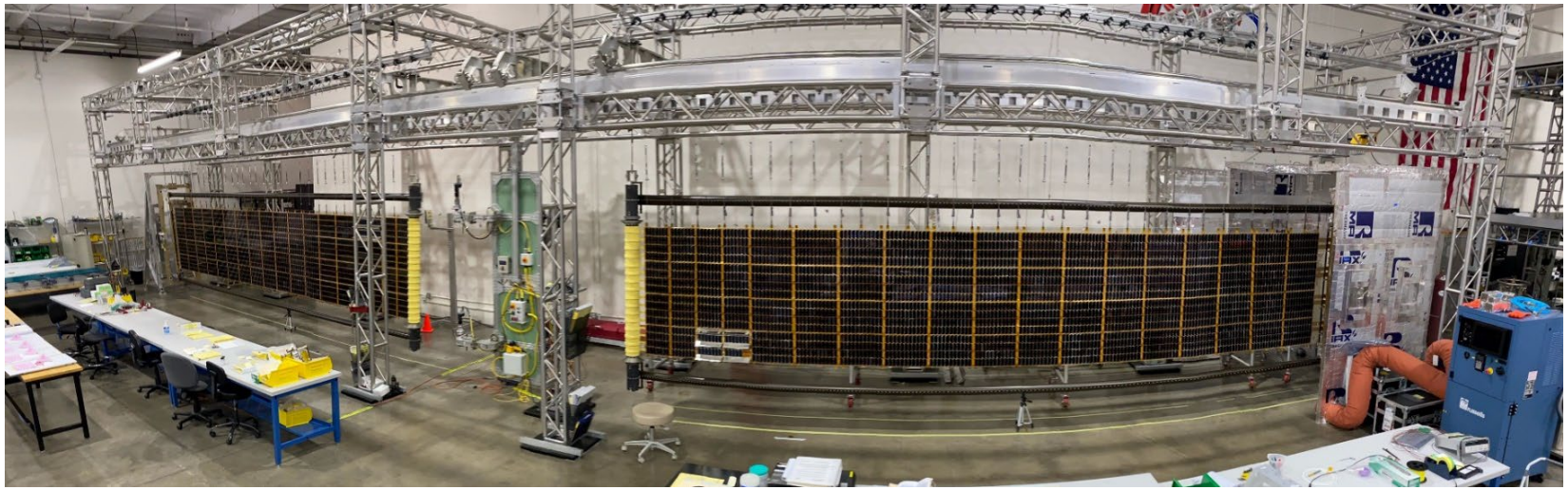
Parallel gap between CIC: 9.65 mm (0.38")
- No need to grout, bigger gap

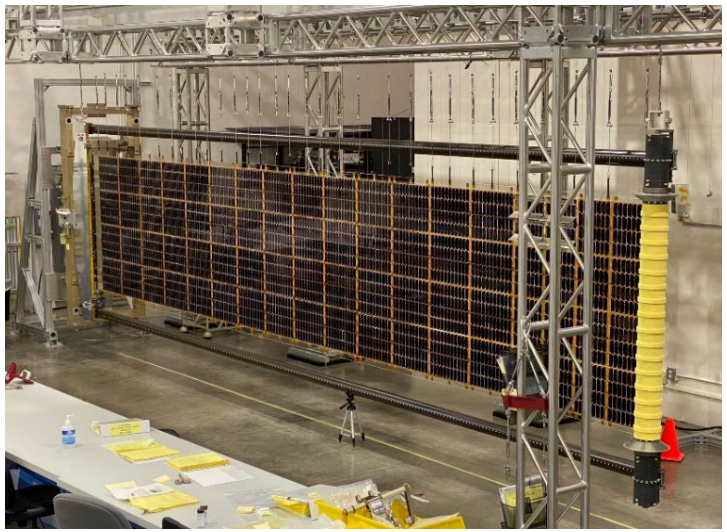
Parallel gap between CIC: 9.65 mm (0.38")
- No need to grout, bigger gap

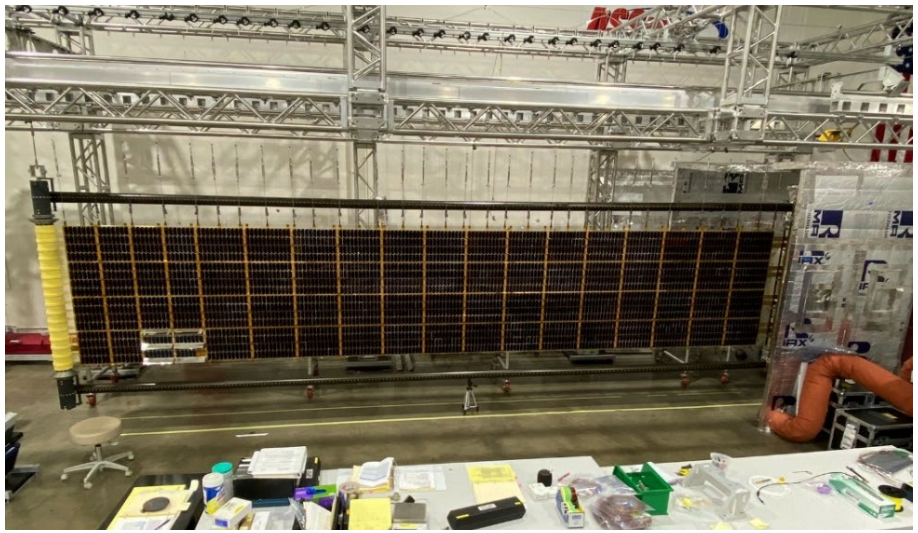
Credit: SolAero

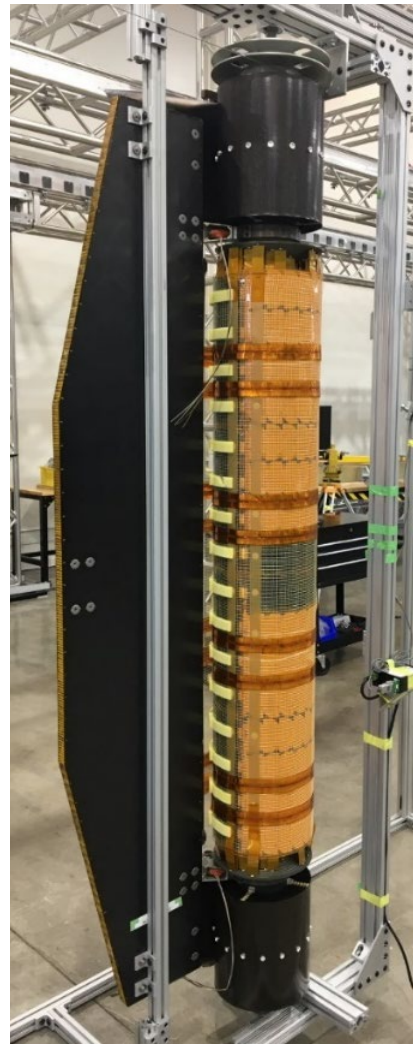
Scale of MAC ROSA falls in-between DART and Maxar GEO ROSAs

DART ROSA Solar Array Flight Wings, Stowed and Deployed









Credit: Deployable Space Systems

~ 80 % of MAC ROSA components are re-used from DART

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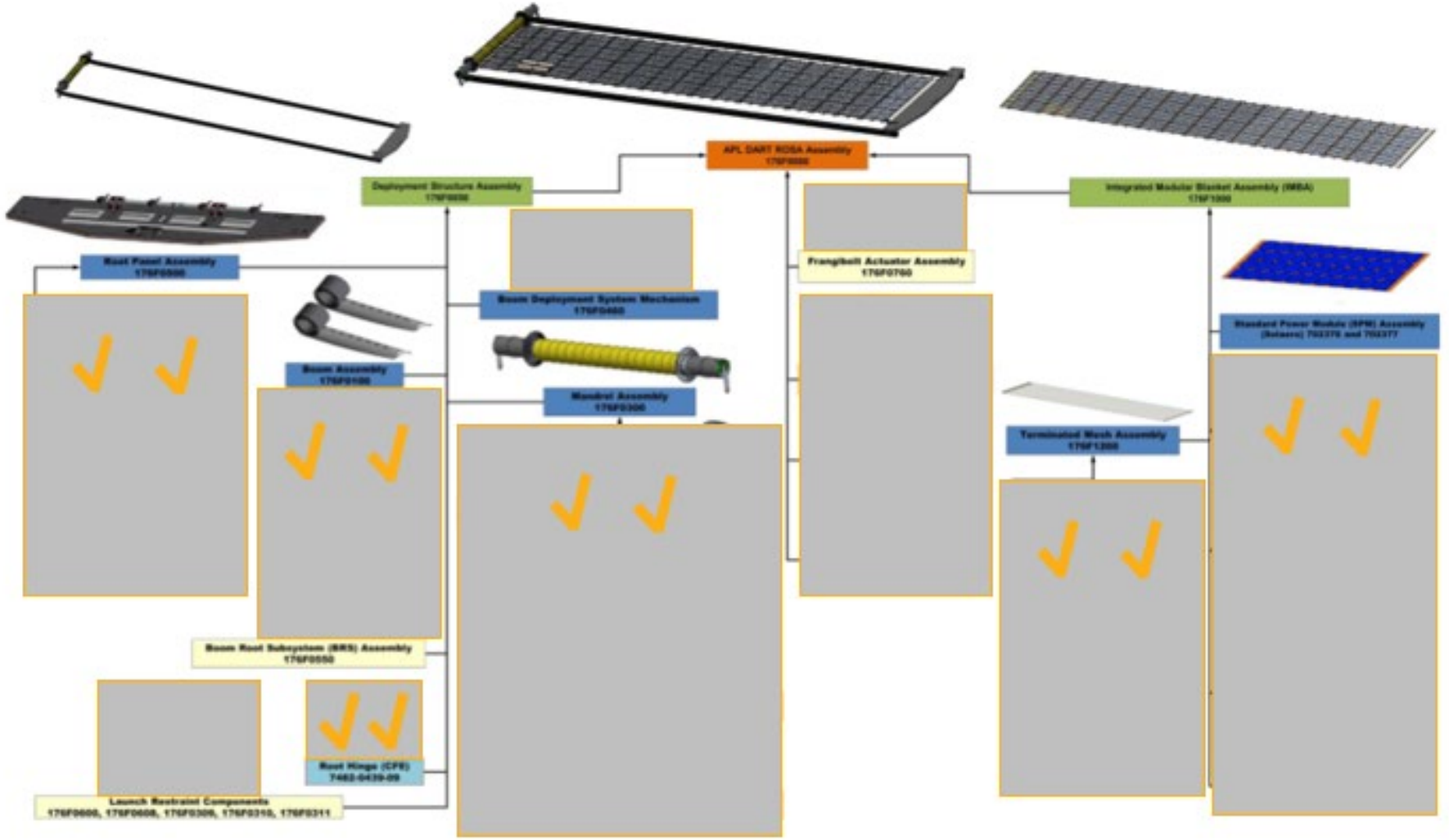
MAC ROSA Status

- First flight build is underway, all SPMs have been delivered by SolAero
- Blanket and component builds ongoing and on track for Q3 delivery and Q4 launch



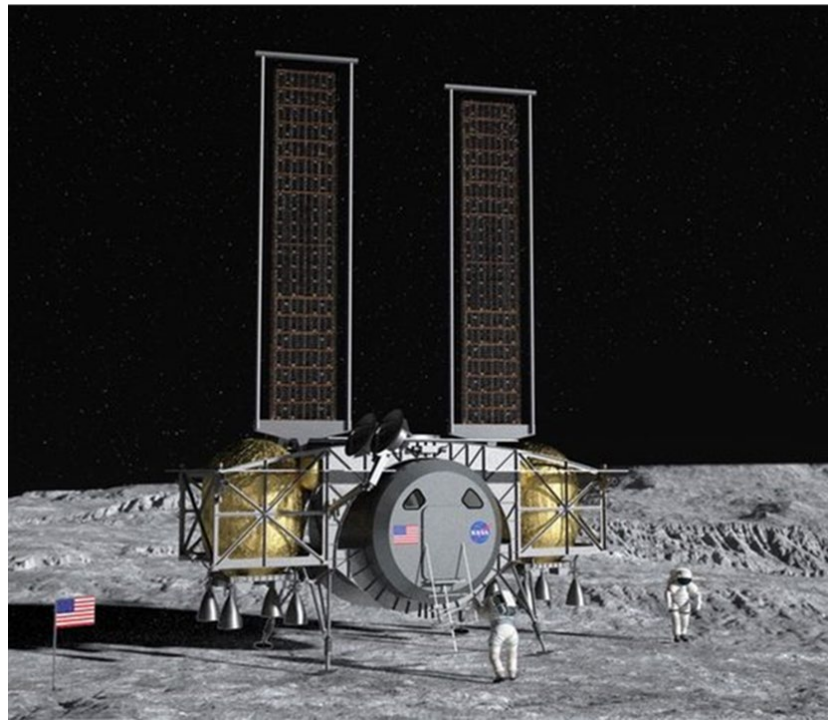
√ = completed for one wing

DHLS ROSA

"Shake, rattle and roll."

Dynetics Human Lander System (DHLS) ROSA

- Ongoing competition for a lander to put the first woman and the next man on the moon in 2024
- Driving requirements and unique considerations / comments
  - Design for 10 years: polar, equator or in-between
    - First mission is 6 (Earth) day stay near southern pole
  - Reduced mass is critical
  - Retractable wing for landing and takeoff (loads and dust)
  - Wing tilt mechanism for alternate latitudes
  - Stowed volume is restricted
  - Active dust abatement measures are required
    - "Shake, rattle and roll"
  - Deployment under 1/6 G
- Other
  - Use of ROSA allows for later upgrades to lower-mass PVA with minimal delta qualification



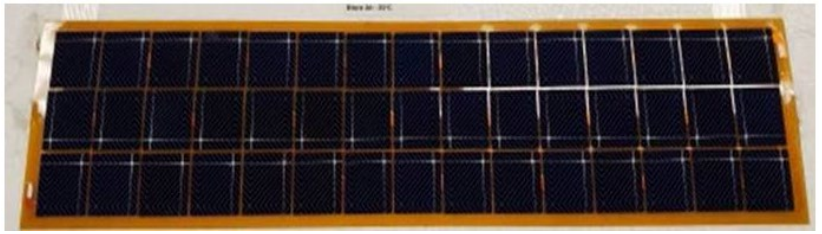
Dynetics Artist's Rendering

Key considerations are mass, and dust abatement

DHLS follows Legion ROSA design, based on Maxar's modular architecture

- General design
  - Mandrel, blanket, solar cell and associated mechanisms are enveloped by MAC ROSA
  - Slightly larger deployment boom to take lunar loads
  - Motor for retraction (adds torque margin also for deployment)
  - Thruster plume shields based on designs/materials in development for PPE
- Dust mitigation measures
  - Three different dust abatement methods in development
  - Two of these are the subject of an ongoing cooperative IRAD between Maxar and NASA
  - One is the subject to an ongoing GTA between Dynetics and NASA

mPower DragonSkin Module



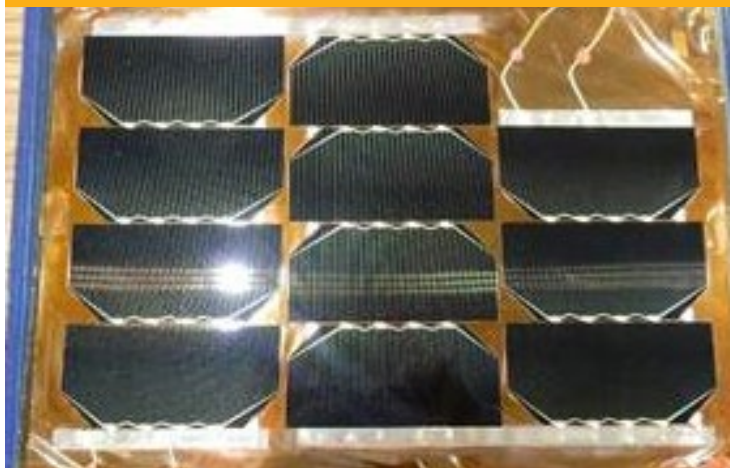
Credit: mPower Technologies

- Development and qualification approach
  - Early large/full scale wing prototyping to demonstrate deployment and some dust abatement
  - Parallel coupon testing to characterize / validate SPM-level dust abatement
  - Re-fit of large wing with SPMs featuring selected dust abatement features
  - Re-test of large wing in dust environment

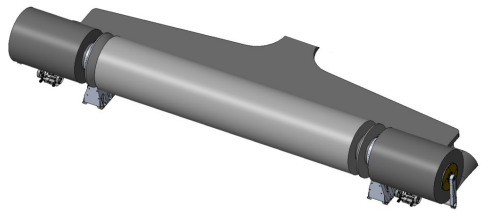
DHLS ROSA Status

- Initial study contract completed including spacecraft-level PDR
  - Wing sizing and packaging complete – approx. 2.5 m x 10 m
    - Stowed volume compliance is confirmed
    - Hold down locations and bolt pattern identified
    - Booms sized for >6X deployed strength margin
  - Three different cell and SPM solutions developed for same wing geometry
    - Continuing to evaluate additional mass-reduction options as new PVA technology matures

MELCO / Azur Space SPM Test Coupon



Credit: Mitsubishi Electric Company (MELCO)



Down-select for Next Phase Expected in Q2 2021

Dynetics A Leidos Company

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Conclusion

Conclusions

- Three different ROSA designs for three distinct missions have been presented
- Each takes advantage of ROSA's unique capabilities in a different way
- Designs of similar scale can build commonality and reduce qualification efforts
- The blanket design is inherently solar cell agnostic
- Conditions that lead to cell cracks in rigid panels are less prevalent
- Industry needs an AIAA standard for flex blankets with different tests

Acknowledgements

NASA Glenn Research Center
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SAVID LLC
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THANK YOU!

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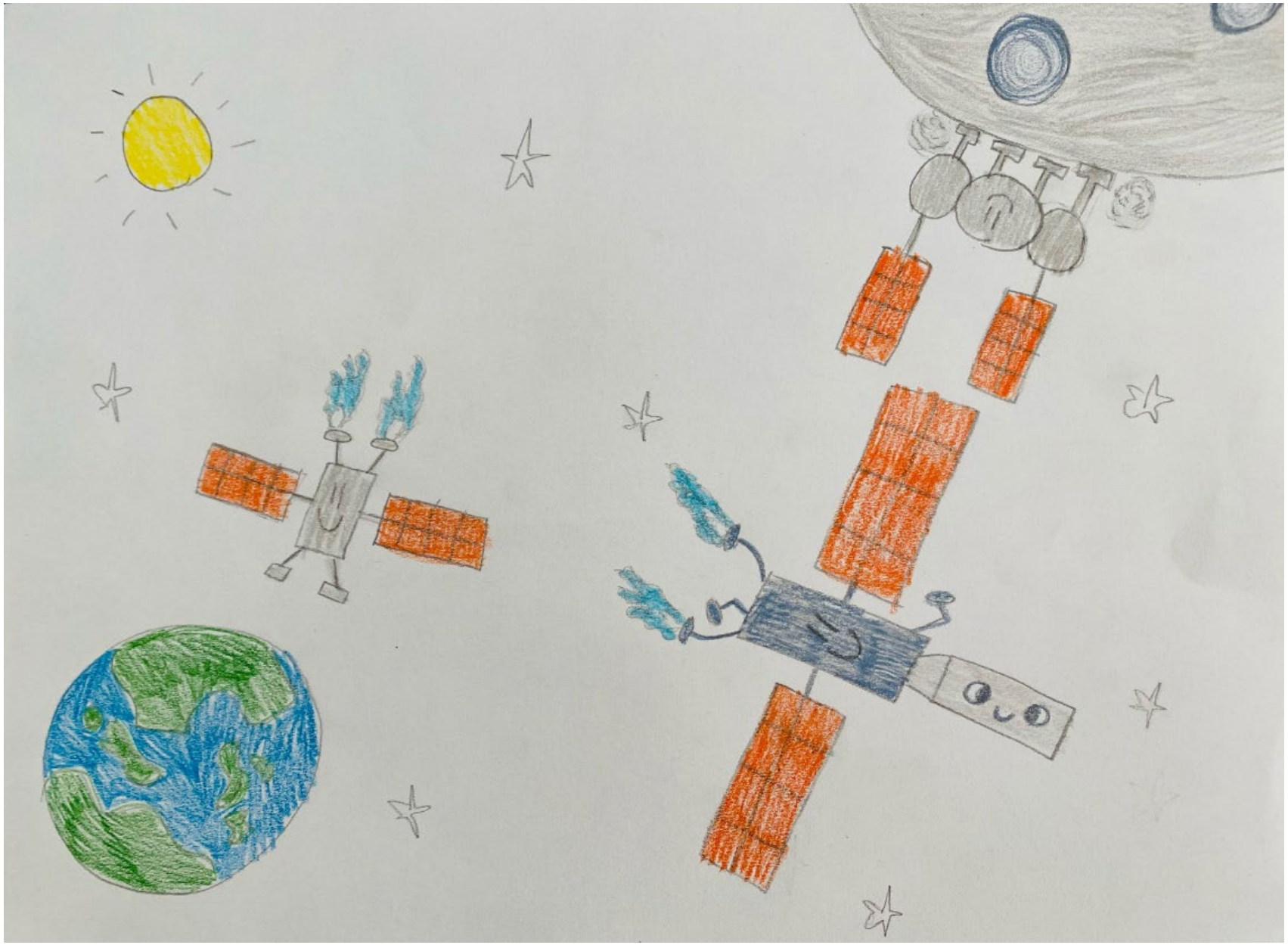
Art by Sloane Yates



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