An Advanced Packaging Approach for a High Performance Deployable Photovoltaic System rHaWK

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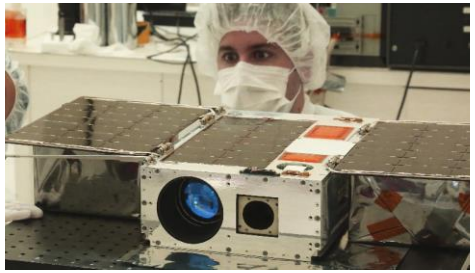
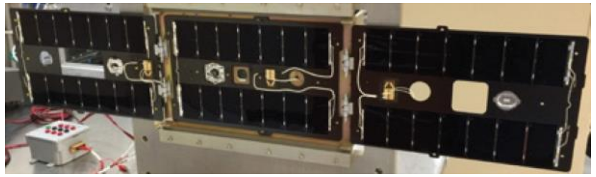
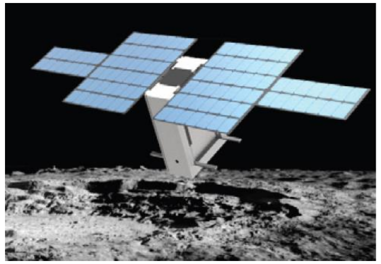
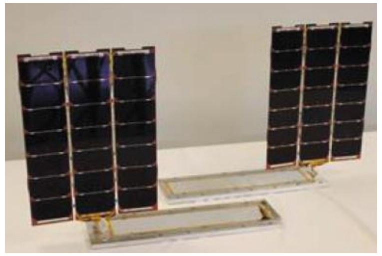
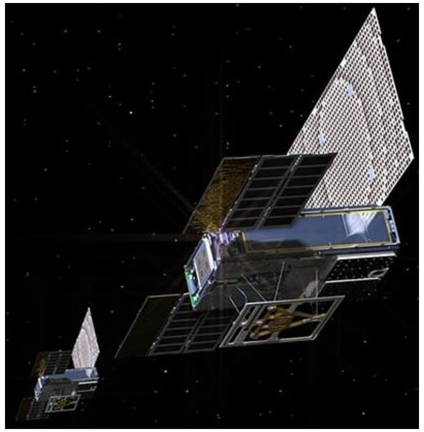
MMA's "HaWK" Solar Arrays

- MMA provides solar arrays for CubeSats for 10 years +
- Emphasis on "High Watts per Kilogram" (HaWK) and packing efficiency (Watts per m^3)
- Power requirements have ranged from 36W to 100+ W
- Single-axis SADA available for 1U- and 2U-width bus
- Flight heritage on Asteria, SHARC and MarCO with many soon to follow (6x arrays on EM1 missions 2019, 5x DoD and commercial 2018/2019)

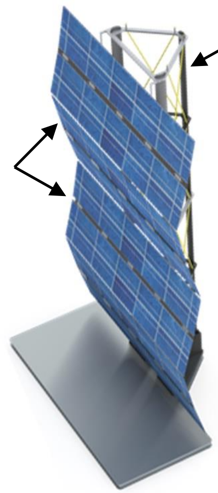



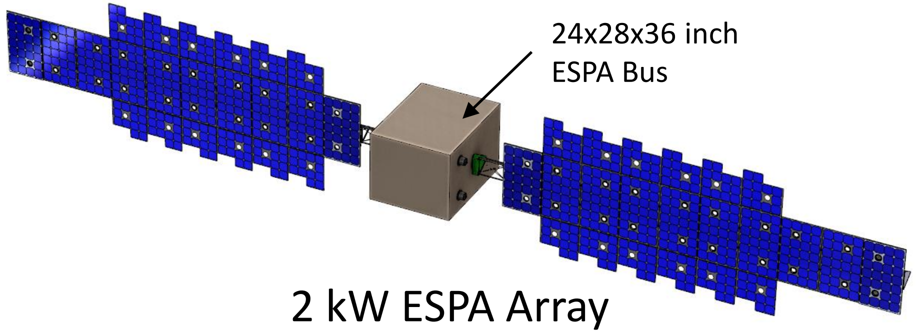





Advanced Packaging Approach for SmallSat Solar Arrays

- MMA's rHaWK technology is targeted for ESPA-class small satellites and larger
- Architecture is efficient at power levels greater than 500 watts up to several kilowatts
- Concept combines features of MMA's lightweight HaWK solar panels and deployable tape-boom technologies (high TRL)
- Multiple HaWK panels, and deployable side panels, are deployed and supported by a deployable tape-spring truss
- The assembly can be attached to a SADA

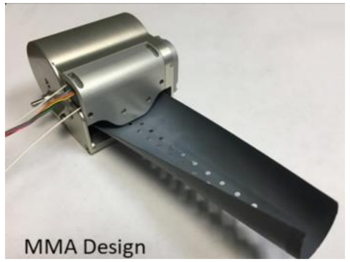




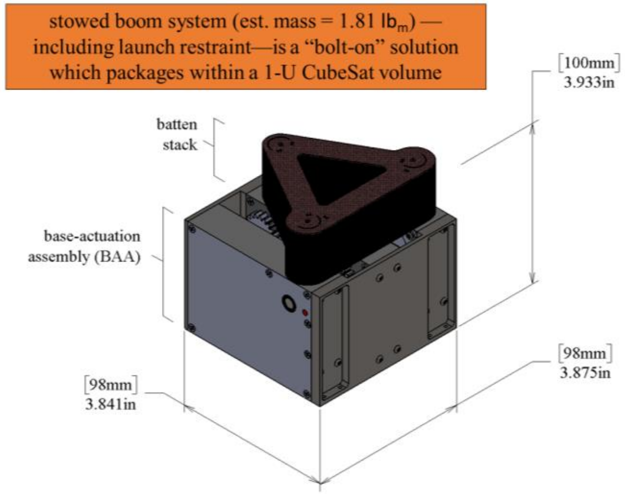
2 kW ESPA Array
(BOL, AM0, 28°C)

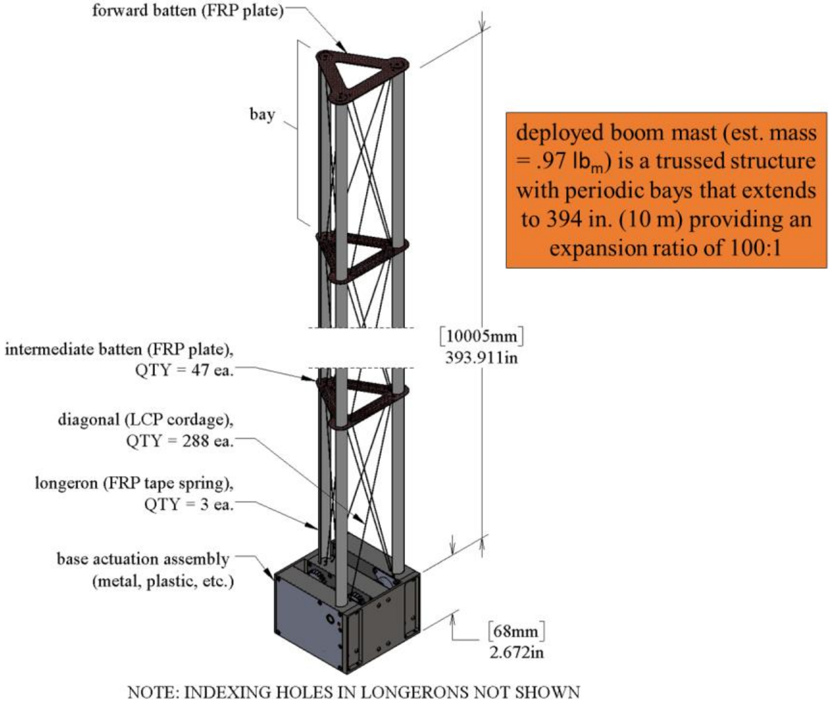
Nanosat Deployable Truss

- Developed at MMA and under SBIR support, the Nanosat Deployable Truss (NDT) architecture offers a 100:1 expansion ratio and is scalable to fit within a 1U volume
- Multiple tape springs form the longerons of a traditional truss-boom architecture
- Canister-free, linearly-deploying architecture enables full payload access to the truss batten frames
- Comparable stiffness and improved packaging efficiency compared to coiled-longeron booms
- Scalable to larger diameters and lengths



Tape Spring Deployer

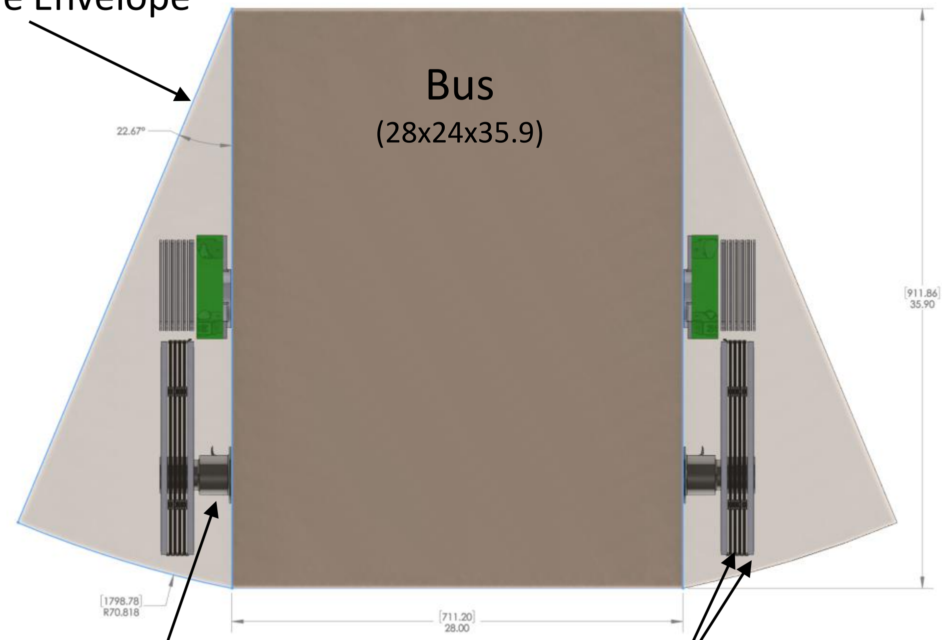


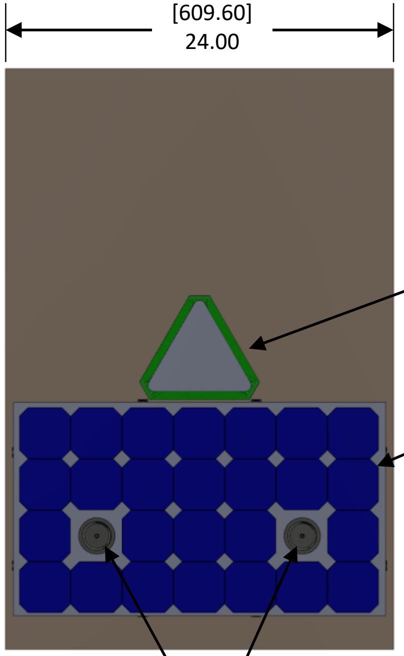


rHaWK Stowed Envelope

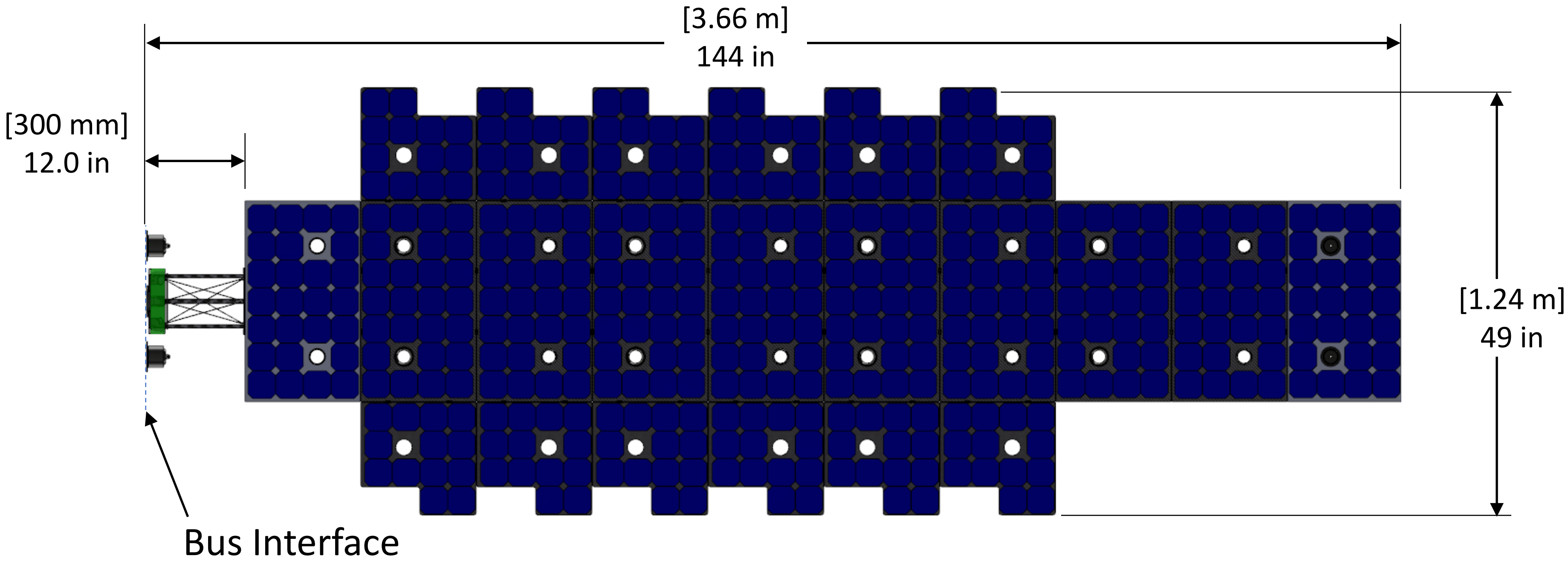
Typical high-performance array targets: 120 W/kg, 40 kW/m³

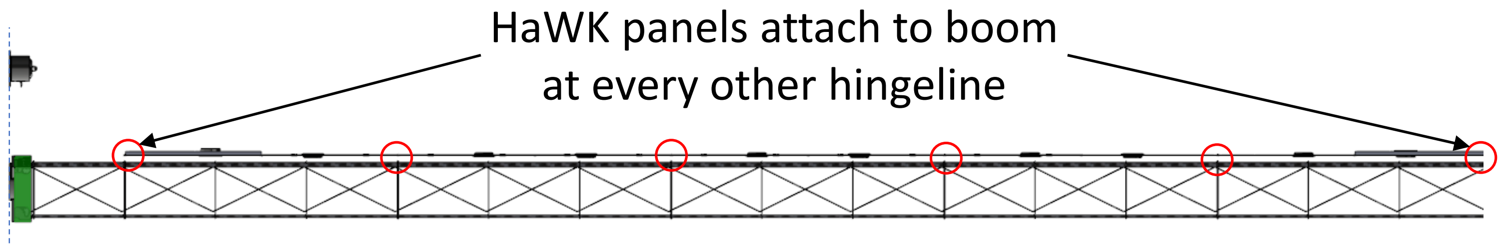
rHaWK: 130+ W/kg, ~93 kW/m³





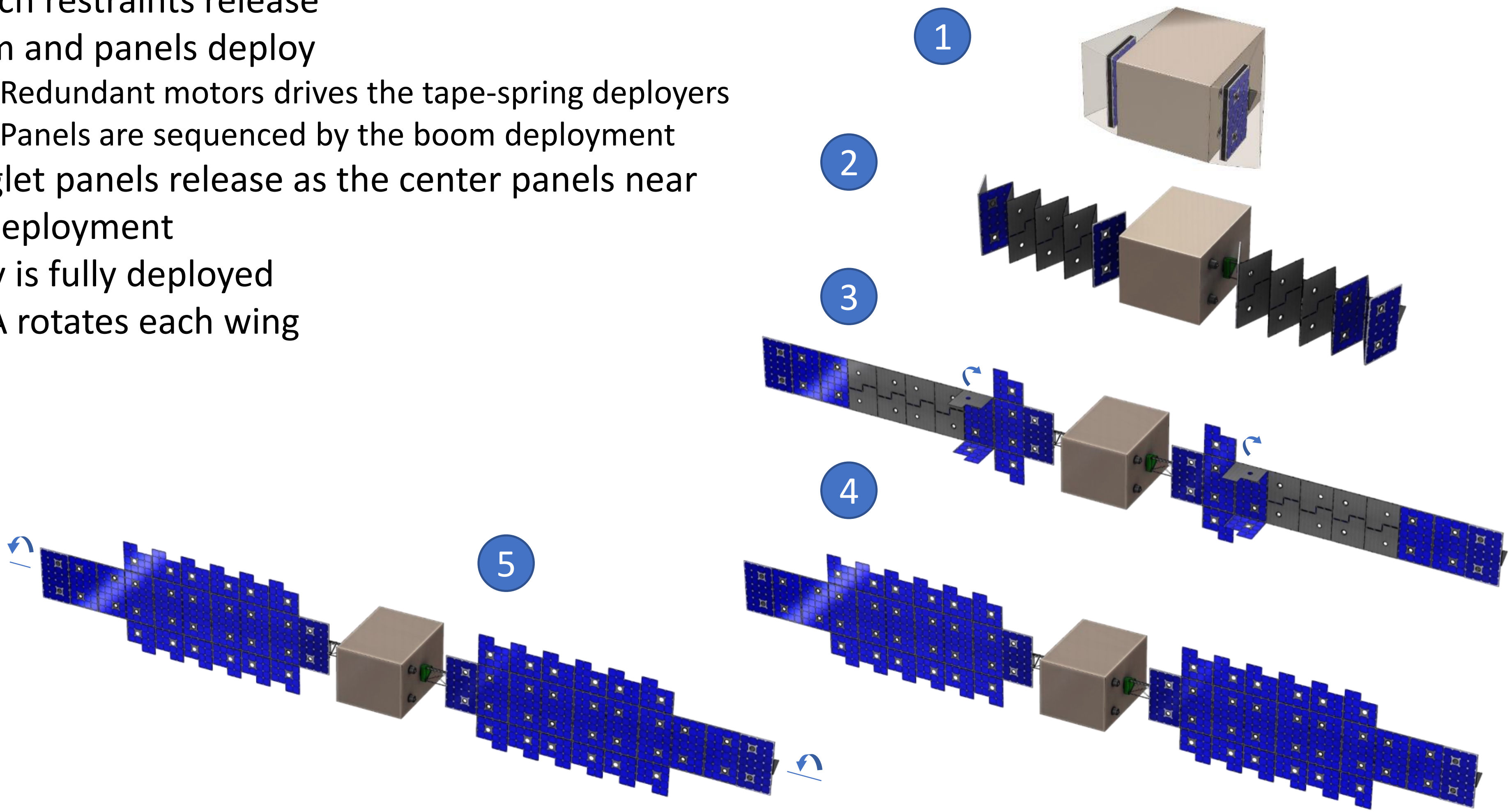
1 kW rHaWK Wing





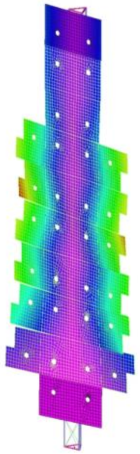
rHaWK Deployment Sequence

1. Launch restraints release
2. Boom and panels deploy
   - Redundant motors drives the tape-spring deployers
   - Panels are sequenced by the boom deployment
3. Winglet panels release as the center panels near full deployment
4. Array is fully deployed
5. SADA rotates each wing

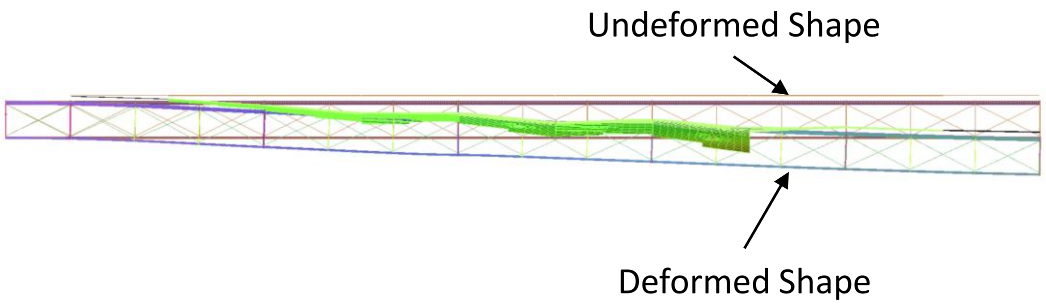


Deployed Modal Analysis Results

- Typical arrays of this size exhibit a first mode of ~ 0.25 Hz
- MMA's NDT offers comparable stiffness and improved packaging efficiency compared to coiled-longeron booms

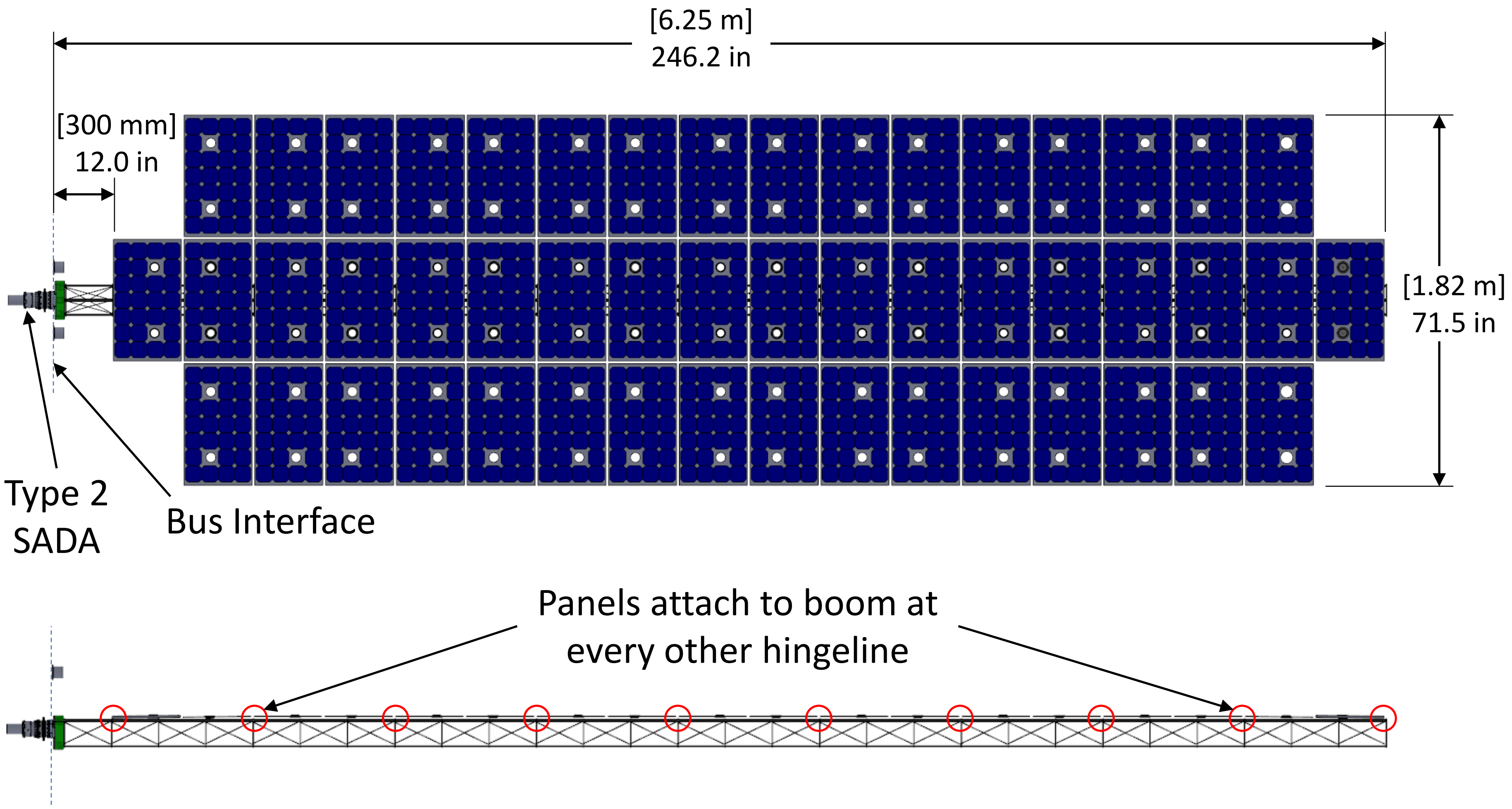


0.83 HZ
Torsional Mode



0.96 HZ
Bending Mode

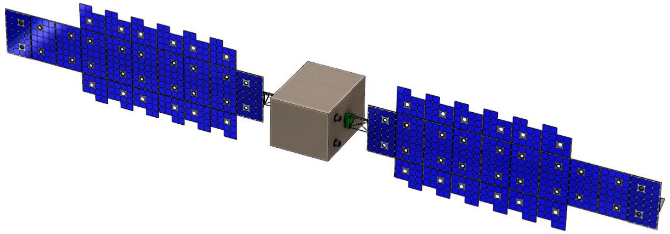
Scalability: 3.15 kW rHaWK Wing
(6.3 kW Array)

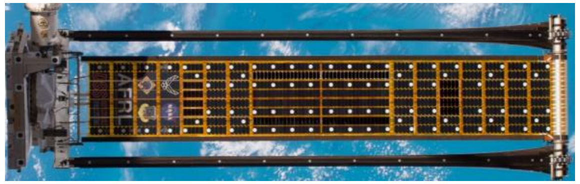


Comparison to Tensioned Blanket

The rHaWK architecture is similar to tensioned-blanket arrays but offers the following benefits and advantages:

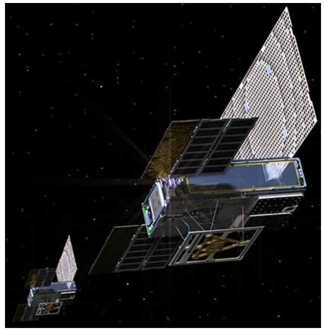
- Array does not require tension, relaxing the stiffness and strength requirements (and mass) of the boom
- Array has a reduced effective length (multiple attach points along the length), increasing the first mode compared to a blanket that is attached only at the tip and root.
- Rigid substrates offer improved radiation shielding and thermal distribution over flexible blanket substrates
- MMA boom does not use a canister (better mass and packaging efficiency, W/kg & kW/m^3)
- Stowed form factor is more friendly and flexible for smallsats and small launch vehicles
  - Array stows as a rectangular stack of rigid panels
  - Boom does not require a deployment canister

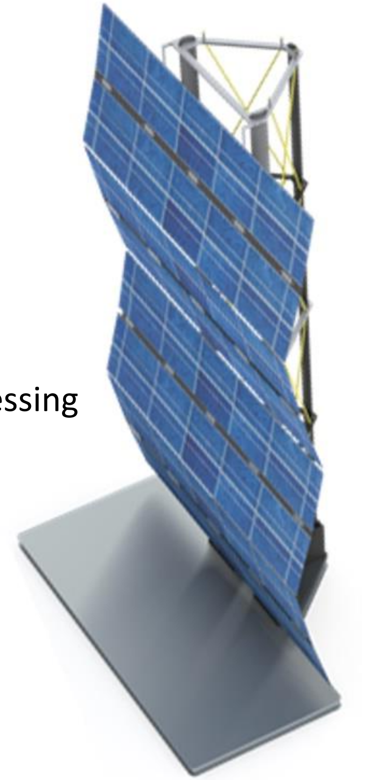




Technology Readiness Level

- Subsystems have up to TRL 9 maturity
- rHaWK system TRL is 3, anticipating TRL 6 in 2019



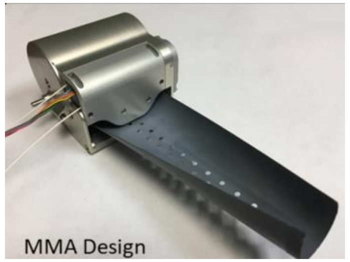


TRL 9
- Solar Panels
- Hinges
- Wiring / Harnessing

TRL 6
- Tape Springs
- Tape Spring Deployers
- Diagonals

TRL 9 in 2018 on an MMA antenna system

TRL 3
- rHaWK system



Tape-Spring Struts

Conclusions

rHaWK offers several benefits to interplanetary missions:

- Exceptional packaging efficiency. 93 kW/m^3 compared to 40 kW/m^3
- Exceeds state-of-the-art for power density at > 130 W/kg
- High reliability, industry-heritage rigid-panel array materials and processes
- Rigid substrates offer radiation shielding for long-duration missions
- System structural depth offers high stiffness and strength for delta-v maneuvers
- Canister-free, linearly-deploying boom structure is available for deploying or supporting other sensors
- Scalable architecture enabling up to 6+ kW on an ESPA bus

MMA Design

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