



Acceptance Testing of the Advanced Electric Propulsion System Qualification and Flight Thrusters

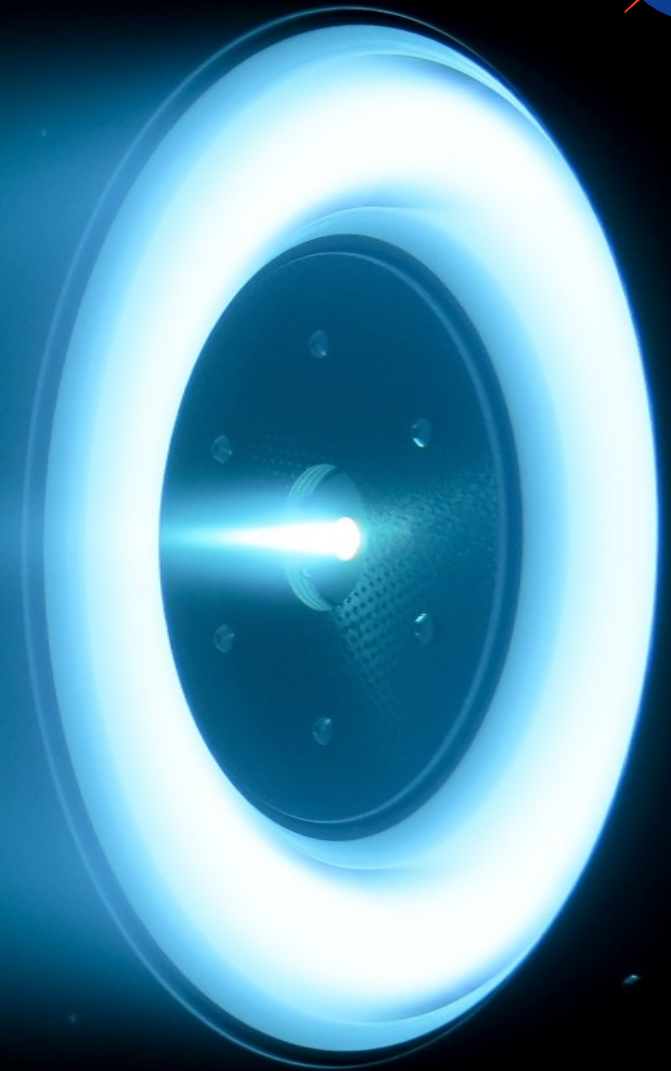
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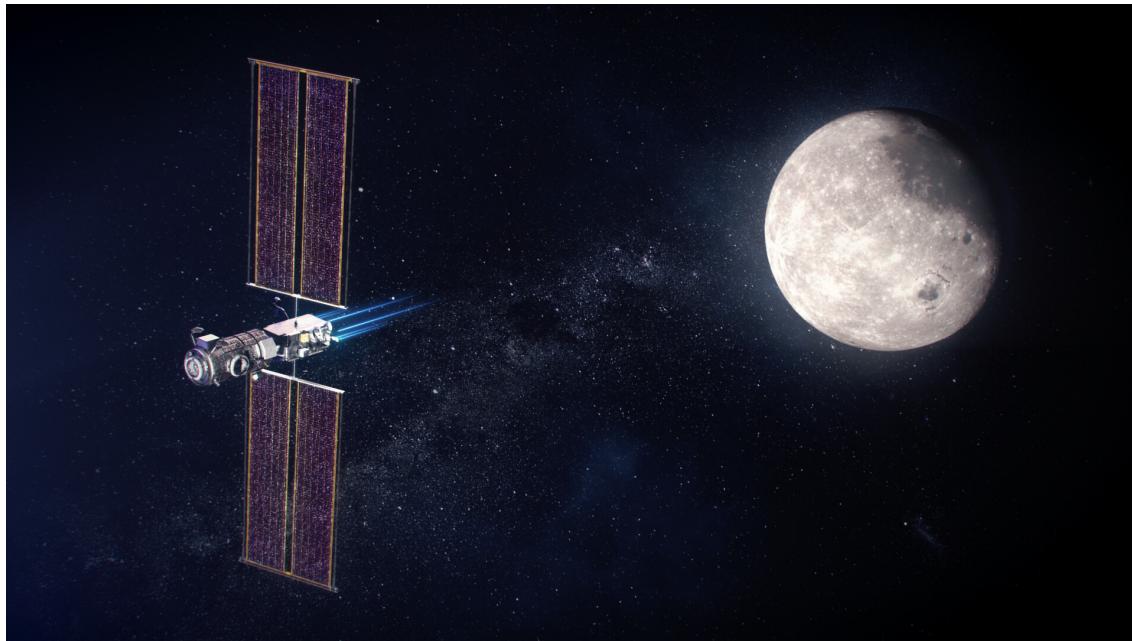
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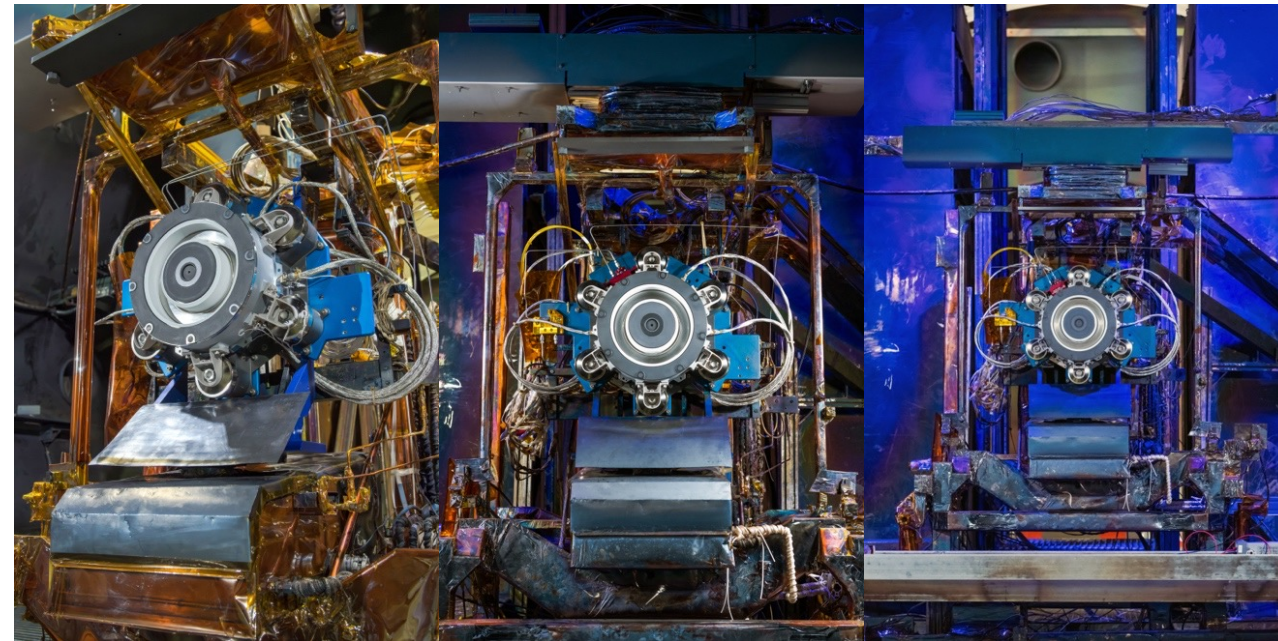
Aerojet Rocketdyne an L3Harris Company





Gateway

- Gateway is NASA's first step towards sustained human operations in lunar orbit
- Gateway's first two elements (PPE and HALO) will launch as a co-manifested mission
- PPE will use high-power solar electric propulsion for transport of these elements to lunar orbit
 - 3 x 12-kW AEPS thrusters
 - 4 x 6-kW commercial Hall current thrusters



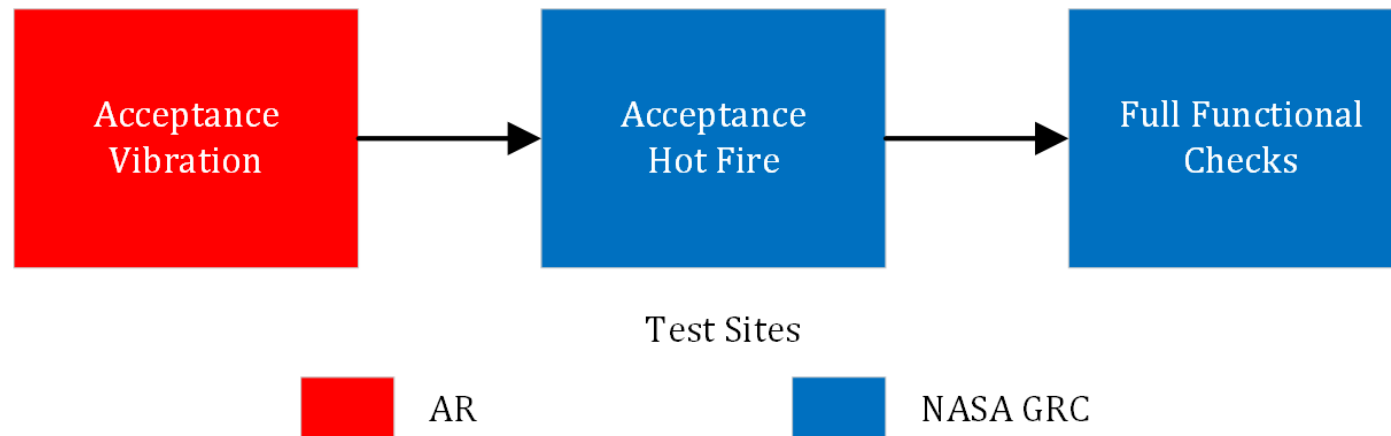
Advanced Electric Propulsion System (AEPS)

- Developed by Aerojet Rocketdyne (AR) based on NASA's Hall Effect Rocket with Magnetic Shielding (HERMeS)
- Critical Design Review completed in March 2022
 - Preceded by extensive testing of two AEPS Engineering Test Unit (ETU) thrusters
- Since CDR, AR has completed assembly of:
 - 1 x Qualification Model thruster (QM-1)
 - 3 x Flight Model thrusters (FM-1, FM-2, and FM-3)



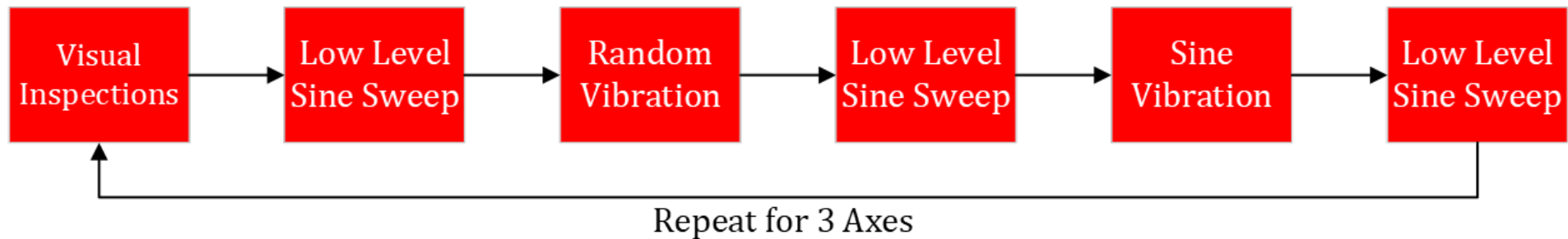
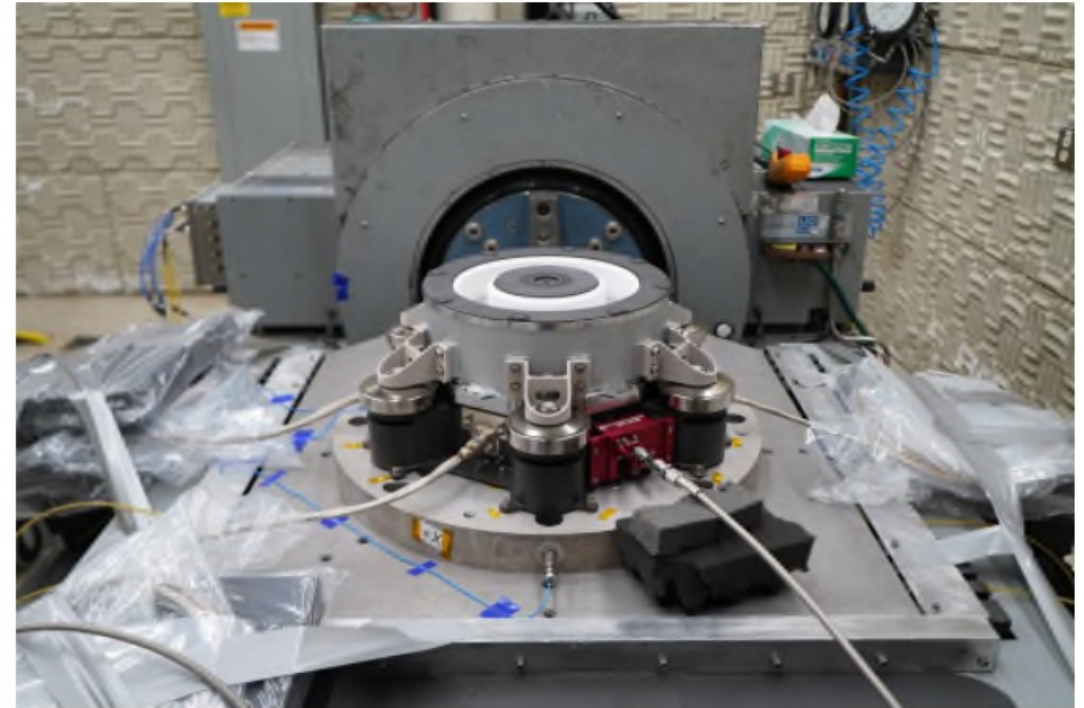
AEPS Acceptance Testing

- All AEPS QM and FM thrusters undergo the same acceptance test program (ATP) prior to either delivery to PPE (FMs) or entrance into their qualification campaign (QMs)
 - All ATP activities are led by AR with support and insight/oversight from NASA
- AEPS ATP has the following goals:
 - Determine whether each thruster meets expected workmanship standards
 - Confirm that each thruster is built to design
 - Screen each thruster for build defects
- AEPS ATP includes test sequences both at AR in Redmond, WA as well as at NASA GRC in Cleveland, OH
 - To date, 3 AEPS thrusters have undergone ATP: QM-1, FM-1, and FM-2



Acceptance Vibration

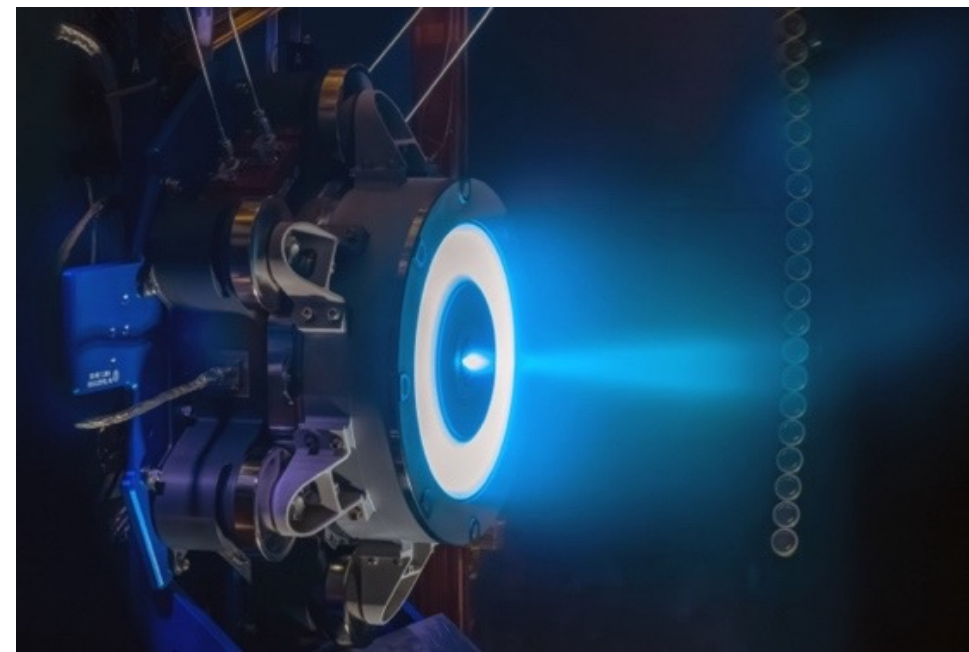
- The AEPS acceptance vibration test sequence consists of:
 - Photographic and visual inspections
 - Random and sinusoidal vibration separated by low-level sinusoidal sweeps to detect changes in thruster structural characteristics
 - Sequence repeated for all three thruster axes
- QM-1, FM-1, and FM-2 all successfully completed ATP vibration and proceeded into hotfire testing

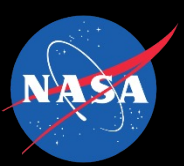




Acceptance Hot Fire

- The AEPS acceptance hot fire sequence consists of:
 - Thruster shipment to GRC
 - Installation into the test facility
 - Detailed functional checkouts of the thruster and all ground support equipment
 - Facility evacuation and initial conditioning of the magnets, cathode, and thruster
 - An acceptance thermal cycle
 - A series of reference firings to assess performance and stability at the 9 kW, 10 kW, 11 kW, and 12 kW operating conditions





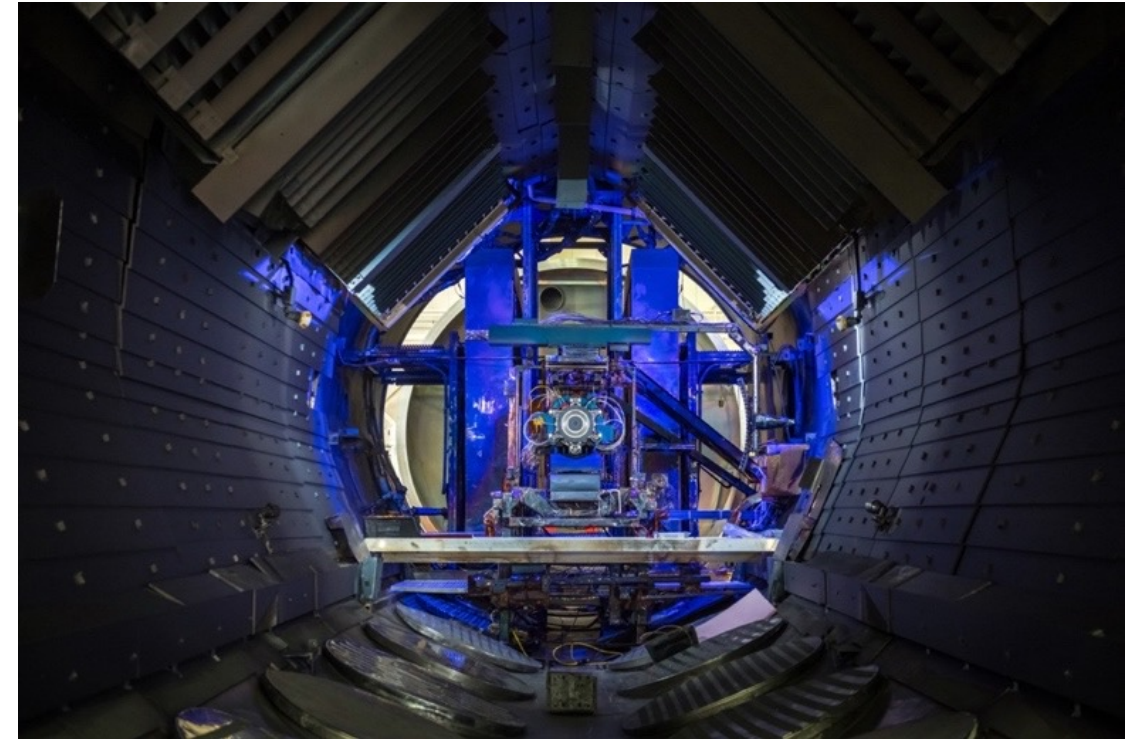
Facility and Ground Support Equipment

Vacuum Facility 5

- Nominal pumping speed: ~ 700 kl/s on xenon
- Operating pressure: ~ 4.0 μ Torr at 12 kW

Ground Support Equipment

- Power and propellant supplied using calibrated commercial laboratory systems
 - Flow rate uncertainty:
 - Anode: $\pm 1\%$ of the reading
 - Cathode: $\pm 0.35\%$ of full-scale (100 sccm)
 - Voltage uncertainty: $\pm 0.03\%$
 - Current uncertainty: $\pm 0.3\%$
- Thrust measured using an inverted pendulum thrust stand with $\pm 0.8\%$ uncertainty



**Facility and Ground Support Equipment have extensive heritage from
AEPS/HERMeS development**



Hot Fire Results

Performance

Discharge Power (kW)	Unit	Thrust (mN)	Specific Impulse (s)
9	QM-1	444	2605
	FM-1	446	2594
	FM-2	446	2607
10	QM-1	491	2651
	FM-1	494	2654
	FM-2	494	2670
11	QM-1	540	2704
	FM-1	542	2694
	FM-2	542	2710
12	QM-1	586	2737
	FM-1	589	2735
	FM-2	589	2747
Uncertainty		± 5	± 31

Oscillations

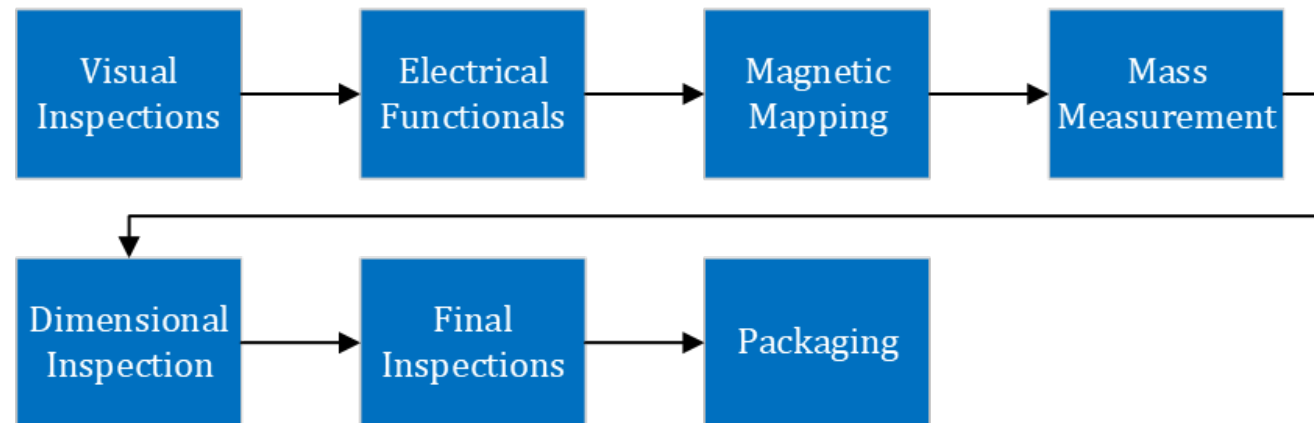
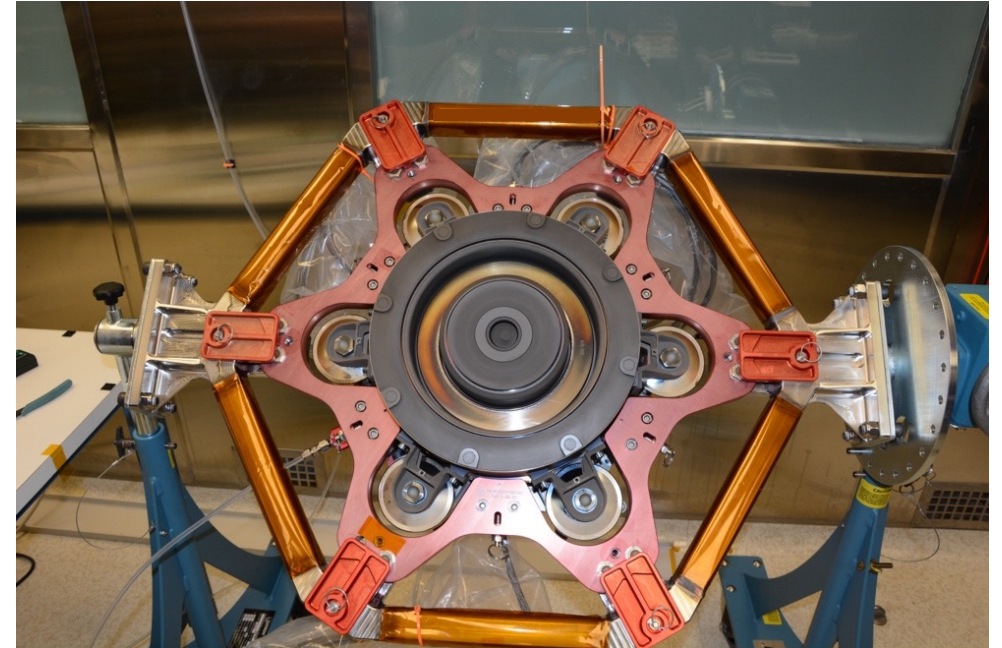
Discharge Power (kW)	Unit	ID, Pk-Pk (A)	ID, RMS (A)	VD, Pk-Pk (V)
9	QM-1	12.8	3.5	32
	FM-1	12.7	3.4	28
	FM-2	13.1	3.5	30
10	QM-1	12.8	3.7	31
	FM-1	13.2	3.7	29
	FM-2	13.0	3.7	30
11	QM-1	13.6	4.0	30
	FM-1	14.1	3.9	29
	FM-2	14.0	3.9	30
12	QM-1	15.2	4.2	31
	FM-1	14.9	4.1	31
	FM-2	14.7	4.2	31

No statistically significant variation in performance or oscillations between QM-1, FM-1, and FM-2



Full Functional Checks

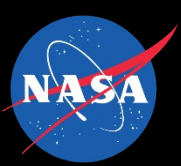
- After hot fire, all AEPS thrusters undergo the following functional checks:
 - Visual and photographic inspections
 - Thruster health verifications:
 - Electrical functionals (e.g., continuity, isolation, etc.)
 - Magnetic field measurements
 - Interface verifications:
 - Mass measurement
 - Dimensional inspections
 - Final visual and photographic inspections
 - Final packaging for delivery to PPE or qualification testing





Conclusion

- This work presents an overview of the AEPS acceptance test program, which is designed to:
 - Determine whether each thruster meets expected workmanship standards
 - Confirm that each thruster is built to design
 - Screen each thruster for build defects
- AEPS ATP consists of acceptance vibration, a hot fire sequence, and a final set of functional test and interface inspections
- To date, three AEPS units have undergone and successfully passed ATP: QM-1, FM-1, and FM-2
 - No statistically significant differences observed between these three units
- ATP of the remaining two AEPS units (FM-3 and QM-2) is either underway or planned for the near future



Questions?



