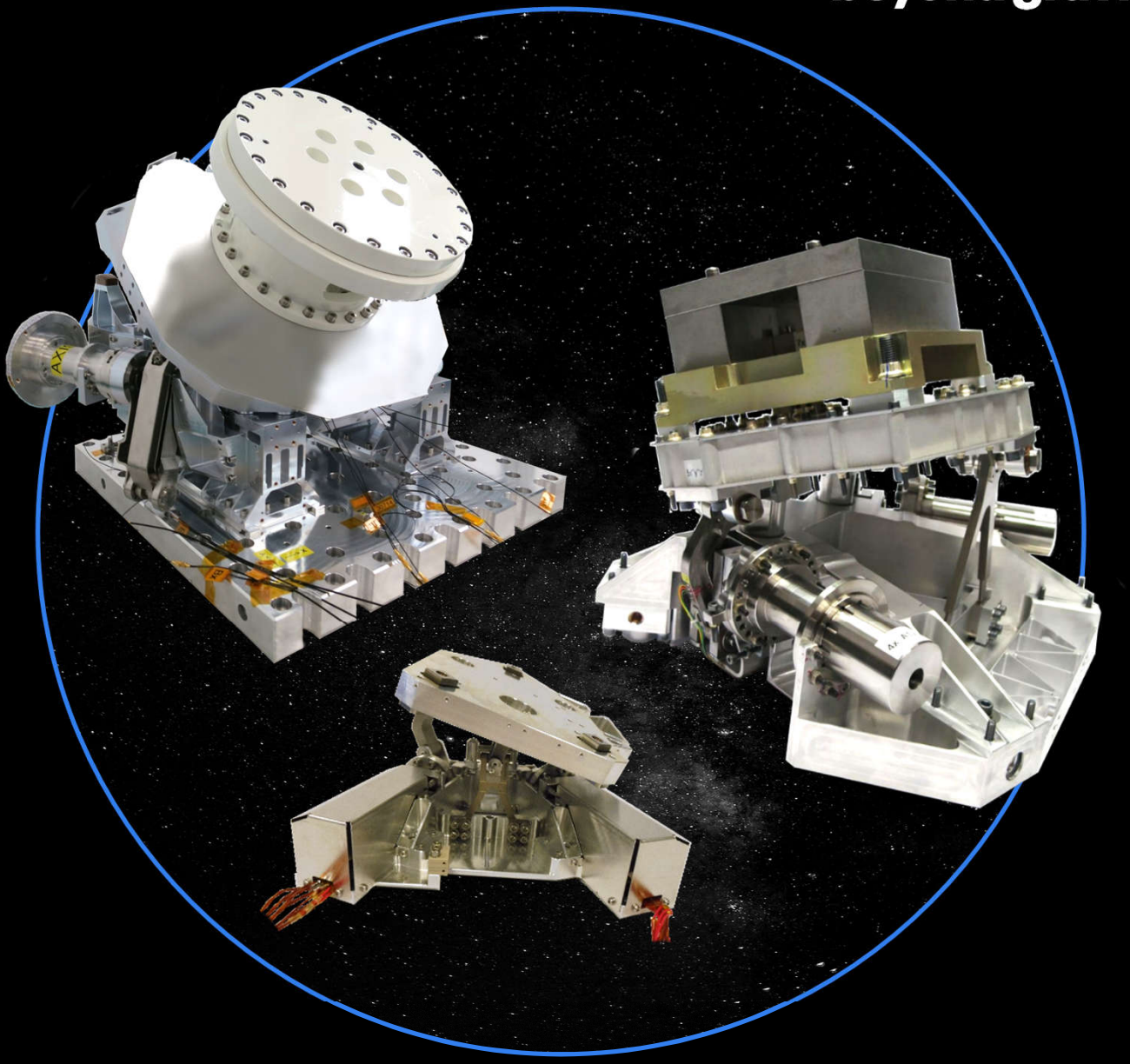
beyond gravity



APPMAX Family

Advanced Electric Propulsion Pointing Mechanism
2 Axis or 3 Axis

North/South respective East/West Station Keeping | Compensation of Center of Gravity Shift | Orbit Raising/Dropping | Momentum Wheel Off-Loading | Grave Yarding at S/C End of Life | Interplanetary Travel

The Beyond Gravity APPMAX Family is developed to provide low cost standardized, modular and scalable 2-axis and 3-axis Pointing Mechanisms for Electric Propulsion. A wide range of Thruster Types and Sizes can be implemented.

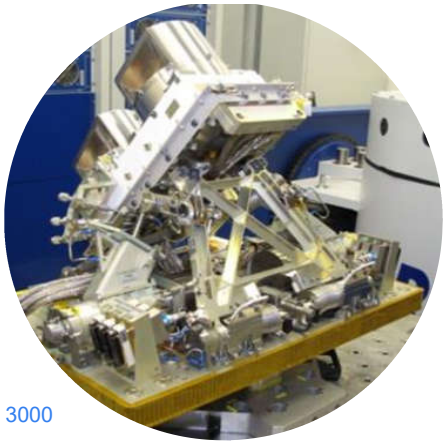
Contact: bert.menhardt@beyondgravity.com

Beyond Gravity delivers qualified Pointing Mechanisms for Electric Propulsion Thrusters, which are increasingly used on commercial satellite platforms and scientific spacecraft due to their advantage in fuel mass efficiency for the spacecraft.
The Beyond Gravity Pointing Mechanisms support Electric Propulsion Thrusters in their nominal position during launch, by means of a dedicated Hold-Down and Release Mechanism if necessary, and reduce the mechanical loads on the thrusters via dedicated damper elements. Upon its release, the Thrusters can be tilted around two axis. This motion is facilitated by two actuators, which drive the platform either via a strut-linkage around a spherical joint or a cross gimbal type arrangement. A third axis can be realized with a robotic arm. This provides larger pointing and deployment range, e.g. for off-loading the momentum wheels needed for spacecraft stabilization.

Experience

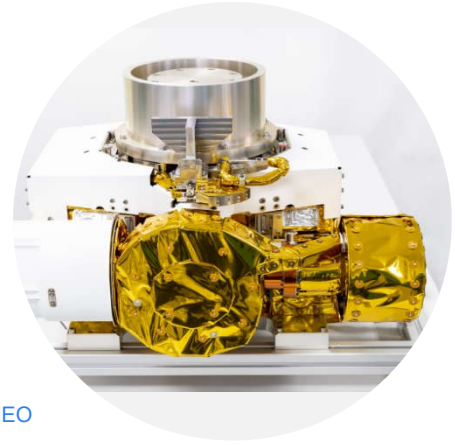
- 10+ different Mechanisms developed
- 10+ sizes/types of Thrusters (Hall Effect & Ion)
- 21 Models delivered
- 17 Flight Models in Orbit
- 31 Mechanisms in Production
- 24+ Years of Development and Engineering

Heritage Examples



TPM
EUROSTAR 3000

6 Flight Models with each two twin Thruster 2-axis pointing mechanism are in orbit, first launch in 2017.
Pointing range: 6.5° half cone Thrusters: Safran PPS®1350, Fakel SPT100, or T5/RIT10 Ion Thrusters

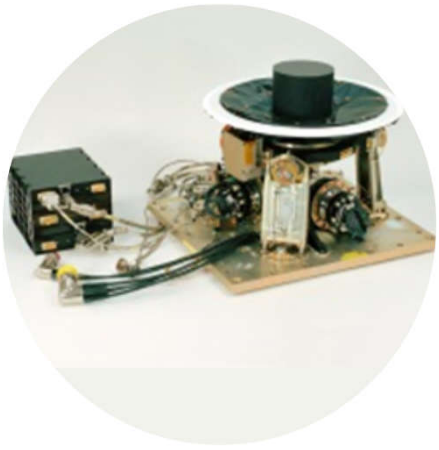


EPPM
Spacebus NEO

4 Flight Models are in orbit, first launch in 2017.
Pointing range: first axis can point to +120° the second axis to +/- 35°
Thrusters: Fakel SPT-140 or Safran PPS®5000

BepiColombo TPA
ESA/JAXA

Ion Thrusters first fire on 20th November 2018, arrival at Mercury scheduled end 2025.
Pointing range: 15° half cone.
Thrusters: 4x QinetiQ T6

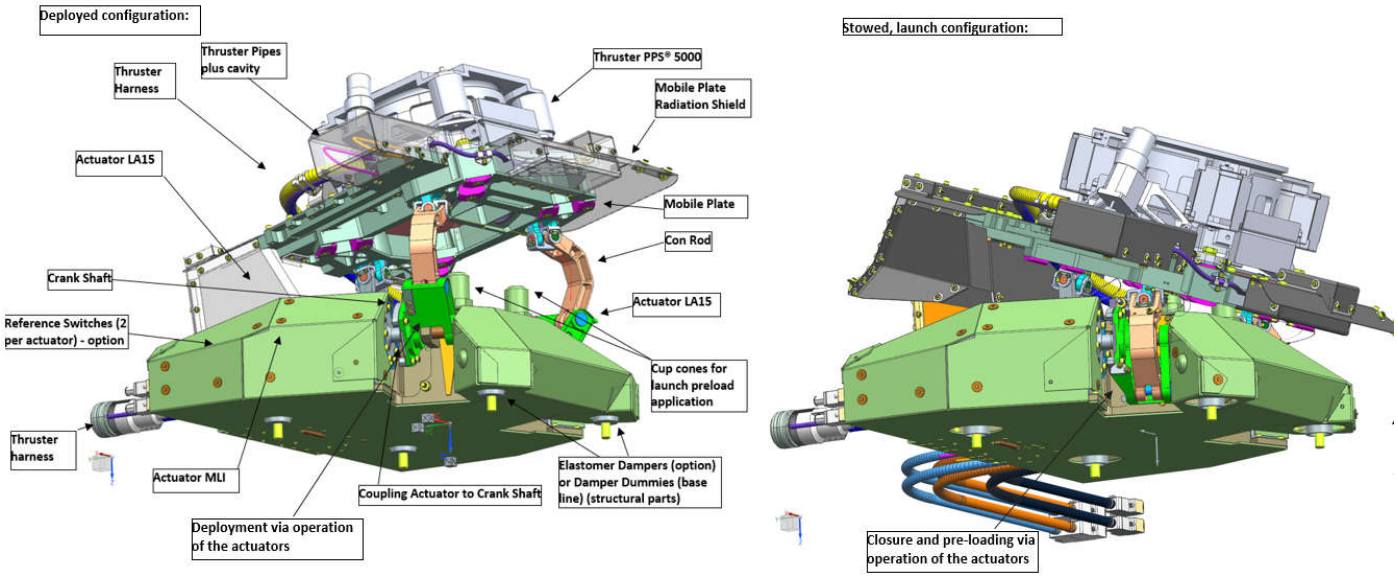


EPMEC
ESA

SMART-1 started 2003 with a Safran PPS®1350 Hall Effect Thruster and proved use of electrical propulsion with solar power as primary propulsion

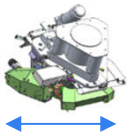
APPMAX2 – Advanced Electric Propulsion Pointing Mechanism 2 Axis

Concept and Features

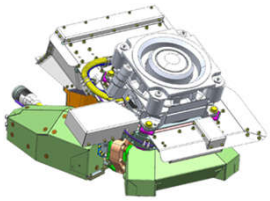


Thrusters	For different size of thrusters the mechanism can be up- or downscaled. The APPMAX2-Baseline is compatible to Electric Propulsion Thrusters like PPS®5000, BHT-6000 or SPT140.
Kinematics	Two stepper motor based actuators move independently, without restriction from launch position to the maximum operation angle limited by hard stops. They move individually via a conrod the mobile plate. The third moving point is held via cardan and flexible strut. The position is defined by step counting and can be referenced via hard stops or reference switches (optional).
Pointing Range	The mechanism executes a 15° half cone as standard. The pointing range can be extended, adaptive design and delta qualification is needed.
Actuators	The Beyond Gravity LA15, a low cost hybrid high detent torque stepper motor based actuator, is used. Smaller Beyond Gravity actuators are used for downscaled APPMAX2-XS. Loads on actuators are only torsional.
Launch Locks	The actuators move the Con Rods slightly over the kinematic dead center point of the crank drive. Their unpowered holding torque act as a Launch Lock. APPMAX2 for higher mass Thrusters will be equipped with a flight proven HDRM, a burn wire release actuator.
Piping	Piping is part of the mechanism and is designed in the form of a flexible helical routing on the fixed side of the mobile plate, protected by a micro meteorite shielding.
Flow Controller	The flow controller is mounted on S/C for thermal reasons.
Damping or no Damping	The baseline foresees hard, direct mounting of the mechanism at the I/F to the S/C. Depending on the Thruster allowed random and shock loads elastomer dampers are implemented.
Harness	The Thruster Harness (generally CFE) will be installed with the Thruster including connector without restrictions.
Switches and Positioning	As an option redundant switches for position reference are implemented.
No Zero-G device	No Zero-G device is needed. AIT effort is reduced. (Not for high mass Mechanism)
Thermal / Micrometeorite	The Actuators are equipped with heaters and MLI. Depending on the thermal analysis dedicated radiators, protective plates or MLI are mounted.

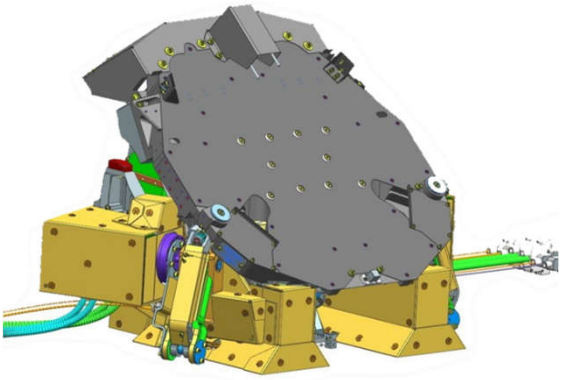
APPMAX2 – Family



230 mm
APPMAX2-XS



485 mm
APPMAX2-Baseline

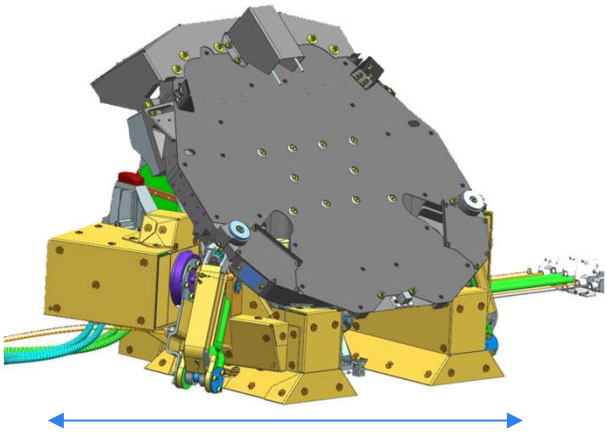


910 mm
APPMAX2-H

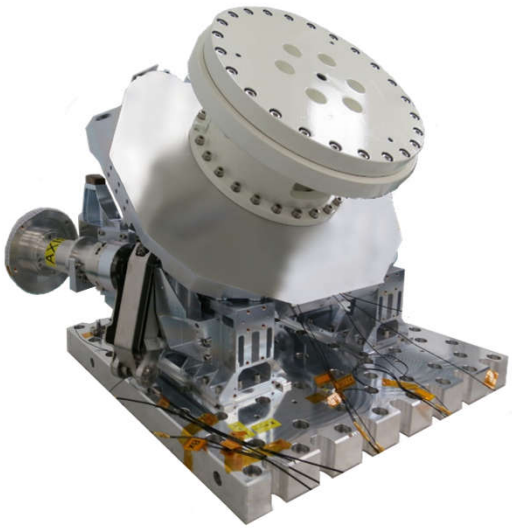
	APPMAX2-XS	APPMAX2-S	APPMAX2-Baseline	APPMAX2-L	APPMAX2-H
Motion Range	15° Half Cone, around vector perpendicular to S/C interface plane				
Repeatability	better than 0.1°				
Resistive Torque Capability	harness and piping (routing by BGA)				
Thruster Mass	1.3 kg e.g. SPT50, BHT-200/350	max. 5 kg e.g.. BHT-600 PPS®X00	8-15 kg e.g. PPS®5000, BHT-1500/6000 SPT140, RIT-2X, XR-5	max. 30 kg	50 kg
APPMAX2 Mass	2 kg	8.4 kg	13.8 kg	19.2 kg	29.5 kg
Main Dimensions LxWxH	170x150x95	344x342x199	486x484x281	493x593x385	493x765x497
Stiffness stowed	130 Hz	110 Hz	110 Hz	90 Hz	90 Hz
Stiffness stowed with opt. Damping	70 Hz	80 Hz	80 Hz	65 Hz	-
Stepper Motor Phase Resistance at 20°C	90 Ω		82 Ω		118 Ω
Actuator	Nemo + PG		LA15		SA15
HDRM	none (Launch Lock by Actuators)			Heritage EPPM HDRM: 2x burn wire Release Actuator	
HDRM I/F	N/A			5.2 A +/-1 A firing duration 40-100 ms	
Development Status	EM in production, internally funded development	conceptual design	TRL6 in Q3/2022 FMs ordered	conceptual design	CDR status FMs ordered

APPMAX2-H

Advanced Electric Propulsion Pointing Mechanism 2 Axis – Heavy



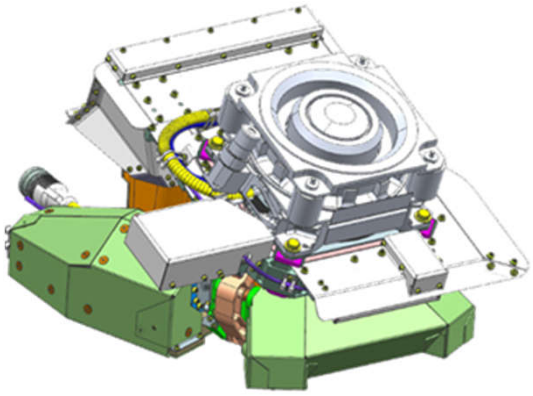
APPMAX2-H



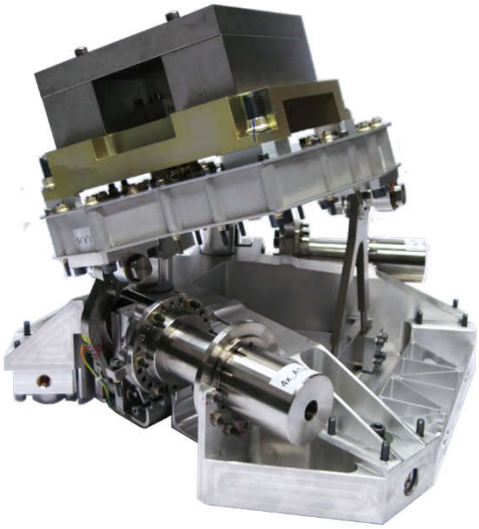
	APPMAX2-H
Motion Range	15° Half Cone, around vector perpendicular to S/C interface plane
Repeatability	better than 0.1°
Resistive Torque Capability	harness and piping (routing by BGA)
Thruster Mass	50 kg
APPMAX2 Mass	29.5 kg
Main Dimensions LxWxH	493x765x497
Stiffness stowed	90 Hz
Stiffness stowed, with opt. damping	-
Stepper Motor Phase Resistance at 20°C	118 Ω
Actuators	SA15
HDRM	HDRM - TRL 9 2x burn wire Release Actuator
HDRM I/F	5.2 A +/-1 A firing duration 40-100 ms
Development Status	CDR status FMs ordered

APPMAX2-Baseline

Advanced Electric Propulsion Pointing Mechanism 2 Axis – Baseline



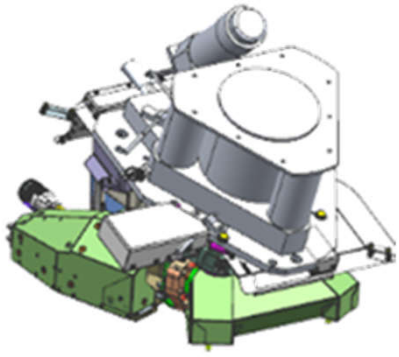
485 mm
APPMAX2-Baseline



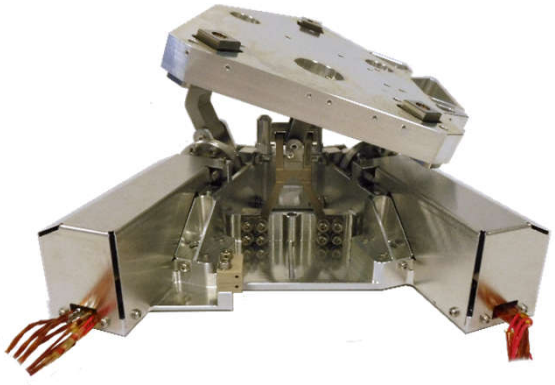
	APPMAX2-Baseline
Motion Range	15° Half Cone, around vector perpendicular to S/C interface plane
Repeatability	better than 0.1°
Resistive Torque Capability	harness and piping (routing by BGA)
Thruster Mass	8-15 kg e.g. PPS®5000, BHT-1500/6000 RIT 2X, SPT140
APPMAX2 Mass	13.8 kg
Main Dimensions LxWxH	486x484x281
Stiffness stowed	110 Hz
Stiffness stowed, with opt. Damping	80 Hz
Stepper Motor Phase Resistance at 20°C	82 Ω
Actuator	LA15
HDRM	none (Launch Lock by Actuators)
HDRM I/F	N/A
Development Status	TRL6 in Q3/2022 FMs ordered

APPMAX2-XS

Advanced Electric Propulsion Pointing Mechanism 2 Axis – Extra Small



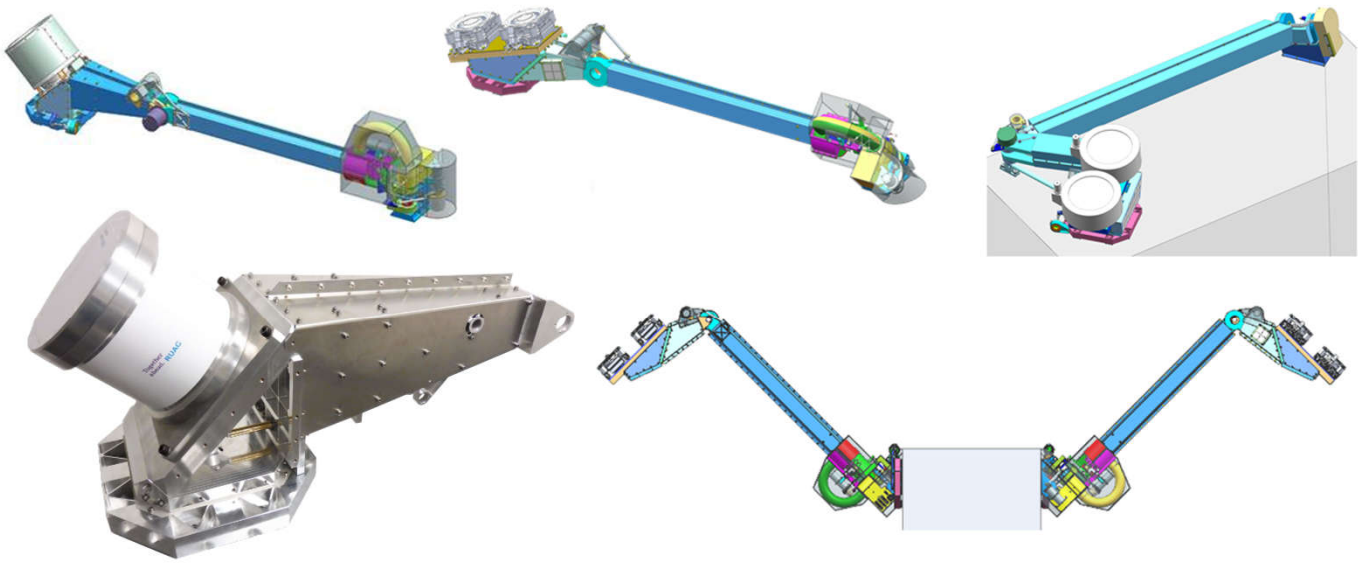
230 mm
APPMAX2-XS



	APPMAX2-XS
Motion Range	15° Half Cone, around vector perpendicular to S/C interface plane
Repeatability	better than 0,1°
Resistive Torque Capability	harness and piping (routing by BGA)
Thruster Mass	1.3 kg e.g. SPT50, BHT-200/350
APPMAX2 Mass	2 kg
Main Dimensions LxWxH	170x150x95
Stiffness stowed	130 Hz
Stiffness stowed, with opt. Damping	70 Hz
Stepper Motor Phase Resistance at 20°C	90 Ω
Actuator	Nemo + PG
HDRM	none (Launch Lock by Actuators)
HDRM I/F	N/A
Development Status	EM in production internal funding

APPMAX3 – Advanced Electric Propulsion Pointing Mechanism 3 Axis

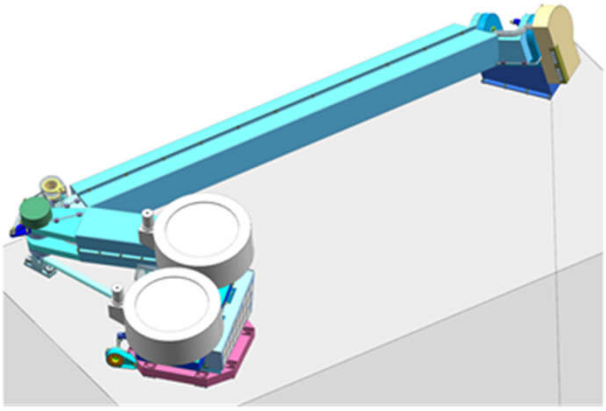
Concept and Features

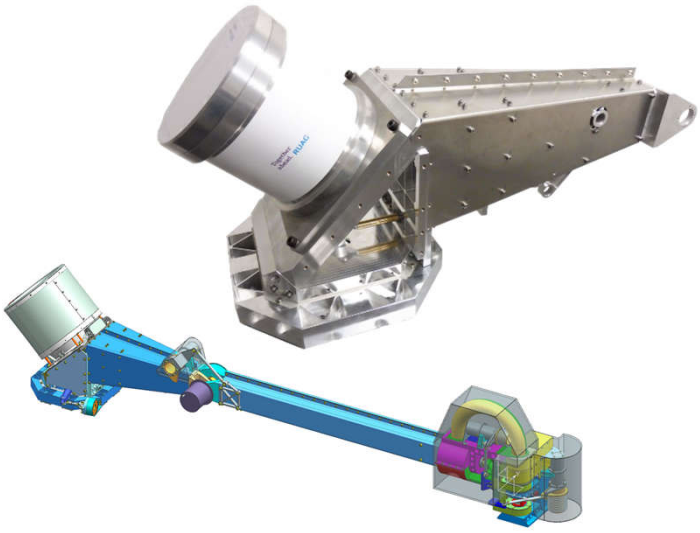


Thrusters	Single or Dual Electric Propulsion Thruster (T6, RIT 2X, PPS®5000, SPT140).
Interface / Space Craft	Only the HDRM and the root bracket are mounted to the S/C.
Kinematics	Three stepper motor based actuators move independently, without restriction from launch position to the maximum operation angle limited by hard stops. Segments are move individually via levers attached to the adjacent elements. Vespel bushings carry the main loads of each moveable element. The position of each element is defined by step counting and can be referenced via hard stops or reference switches (optional).
Pointing Range	The mechanism pointing range can be defined according the specification. Per axis, up to 230° angular range is possible, depending on launch configuration.
Actuators	The Beyond Gravity LA15, a low cost hybrid high detent torque stepper motor based actuator, is used. Loads on actuators are only torsional.
Hold Down Release Mechanism	The mobile plate is fixed to the S/C during launch by a clamp band like HDRM. The HDRM is unlimited resettable and generates no shock. Release is performed via electro magnetic field acting against a permanent magnet.
Piping	Piping is part of the mechanism. The piping is protected by a micro meteorite shielding. At the rotational axes a helical routing is foreseen.
Flow Controller	The flow controller can be mounted close to the mobile plate and is equipped with radiators and / or MLI according to thermal analysis.
Damping or no Damping	The baseline foresees hard, direct mounting of the mechanism at the I/F to the S/C. Depending on the Thruster allowed random and shock loads elastomer dampers are implemented.
Harness	The Thruster Harness (generally CFE) will be installed with the Thruster.
Switches and Positioning	Redundant switches for position reference are implemented.
Zero-G device	Zero-G device is provided.
Thermal / Micrometeorite	The Actuators are equipped with heaters and MLI. Depending on the thermal analysis radiators or MLI are mounted where necessary. Protective plates as applicable.

APPMAX3

Advanced Electric Propulsion Pointing Mechanism 3 Axis





	APPMAX3
Motion Range	Angular range per axis: up to 230°
Repeatability	+/- 0.1°
Resistive Torque Capability	harness and piping (routing by BGA)
Thruster Mass	1x 12 kg (single Thruster) 2x 12 kg (dual Thruster) e.g. PPS®5000, SPT140, RIT2X
APPMAX2 Mass	depends on design approx. 28 kg
Main Dimensions LxWxH	depends on design up to 2 m boom length
Stiffness stowed	> 100 Hz
Stiffness stowed, with opt. Damping	> 80 Hz
Stepper Motor Phase Resistance at 20°C	90 Ω
Actuator	LA15
HDRM	Clamping mechanism, electro magnetic field versus permanent magnet
HDRM I/F	8A at 26V ca. 200ms
Development Status	Individual Concept contracted Delivery end 2023