#space**enablers**

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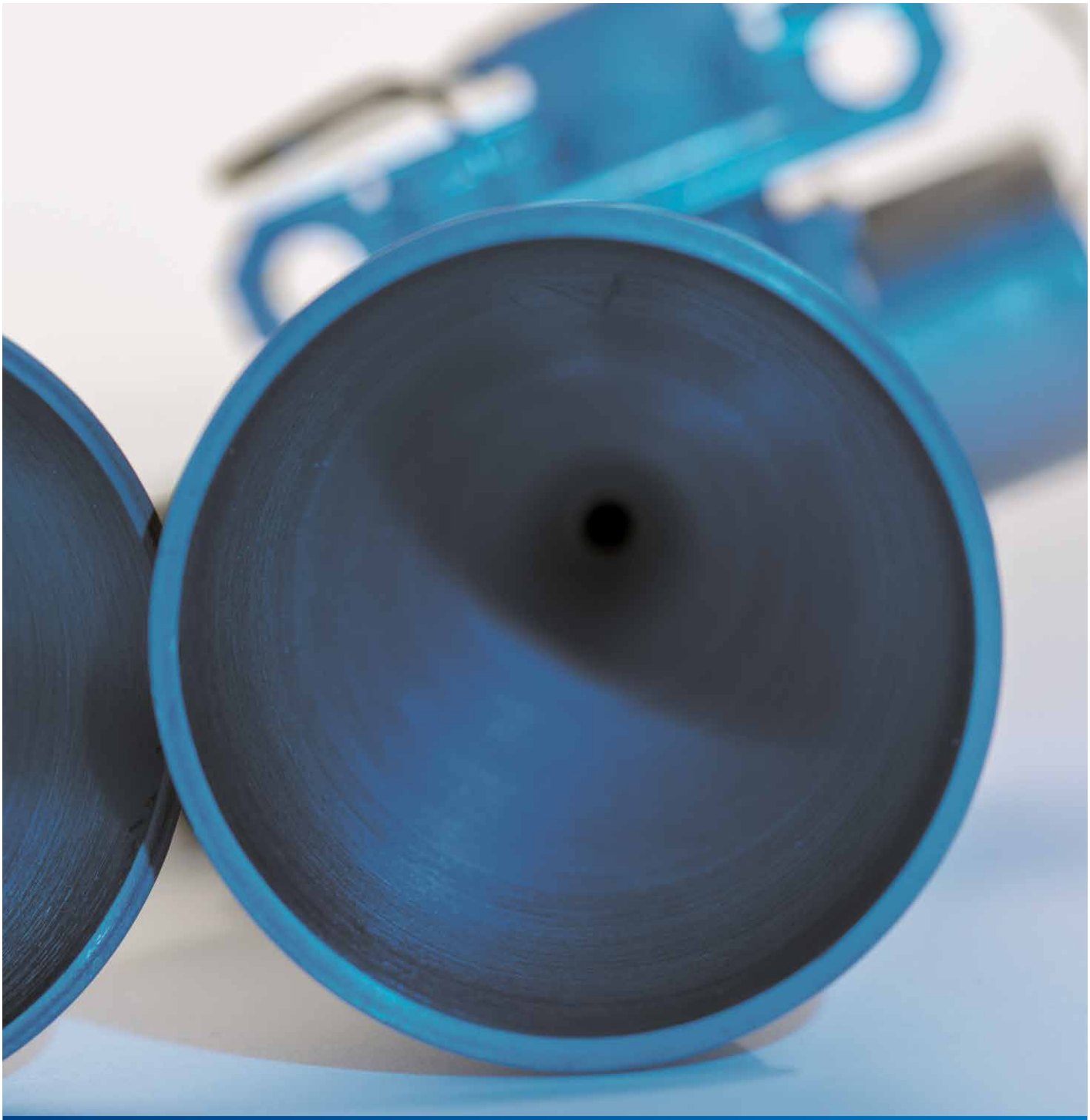


10N, 200N, 400N

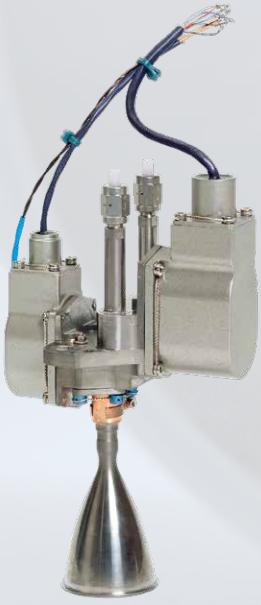
CHEMICAL BI-PROPELLANT THRUSTER FAMILY

CHEMICAL BIPROPELLANT THRUSTER FAMILY

For over 40 years, our bipropellant thrusters have been used in a diverse range of missions, including boost and on-orbit maneuvering of geostationary satellites and deep space probes. The provided thrust ranges from 10N up to 400N.

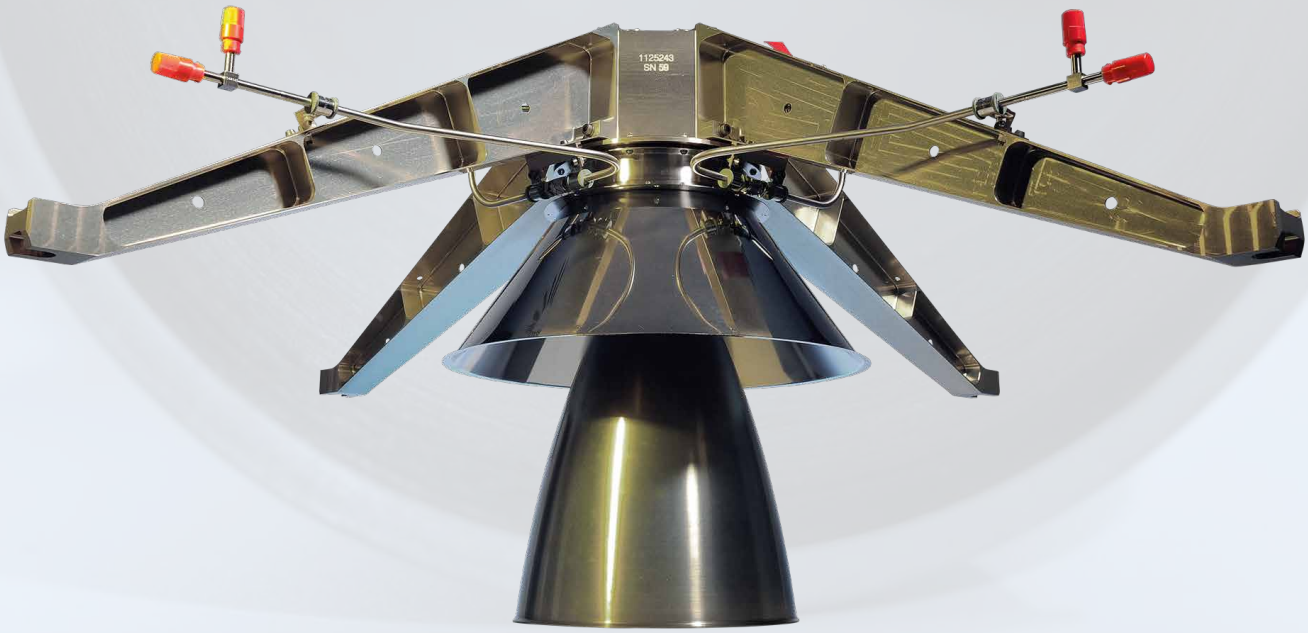
The 10N and the 400N thrusters are part of our chemical propulsion systems mainly flying in commercial GEO program. Also recent science missions like Rosetta and Gaia and future challenging missions like Bepi Colombo, Lisa Pathfinder and Solar Orbiter rely on our 10N and 400N workhorse thrusters.

The 200N thruster was developed for the Automated Transfer Vehicle (ATV) where it demonstrated flawlessly its performance on several missions. It has been selected to fly in the future Multi Purpose Crew Vehicle (MPCV).



10N

200N



400N

10N BI-PROPELLANT THRUSTER

DESIGNED FOR PRECISION ATTITUDE, TRAJECTORY AND ORBIT CONTROL OF SATELLITES.

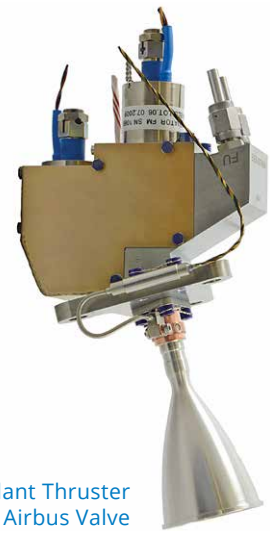
The 10N bipropellant thruster is a small rocket engine that uses the storable propellants monomethylhydrazine MMH as fuel and pure di-nitrogen-tetroxide N2O4, or mixed oxides of nitrogen (MON-1, MON-3) as oxidizer. It is designed for both, long term steady state and pulse mode operation. It operates in a wide pressure range at regulated pressure as well as in system blow down mode with flight heritage down to 6 bar inlet condition. Combustion chamber and nozzle are made of platinum alloy that does not need any surface coating. It allows operational temperatures up to 1.500°C (2700°F) and thus maximum thruster performance.

The uncoated surface is absolutely resistant against oxidization and thus is invulnerable to mishandling, micrometeoroid impact as well as to application of test sensors and to millions of pulse cycles. Trimming orifices between valve and injector provide for individual adjustment of the propellant flow according to the designed system pressure. Two types of propellant flow control valves may be applied: single seat or dual seat equipped with torque or linear motors.

10N Bi-Propellant Thruster Key Technical Characteristics	
Thrust Nominal	10 N (2.2 lbf)
Thrust Range	6.0 ... 12.5 N
Specific Impulse at Nominal Point	292 s
Flow Rate Nominal	3.50 g/s
Flow Rate Range	2.30 ... 4.20 g/s
Mixture Ratio Nominal	1.60 ... 1.65
Mixture Ratio Range	1.20 ... 2.10
Chamber Pressure Nominal	9 bar
Inlet Pressure Range	10 ... 23 bar
Throat Diameter (inner)	2.85 mm
Nozzle End Diameter (inner)	35 mm
Nozzle Expansion Ratio (by area)	150
Mass, Thruster with Valve	350 g (single seat) 650 g (dual seat)
Chamber Nozzle Material	Platinum/Rhodium Alloy
Fuel	MMH
Oxidizer	N_2O_4, MON-1, MON-3
Valve Single Seat	Bi-propellant torque motor valve
Valve Dual Seat	Bi-propellant torque or linear motor valves
Mounting I/F to S/C	Valve flange with 3 through-holes of 6.4 mm (1/4“) diameter
Tubing I/F	Per SAE AS4395E02 or welded
Valve Lead Wires	24 AWG per MIL-W-81381
Thruster Heater and Thermal Sensor	On request
Qualified longest single burn	8 hours
Qualified accumulated burn life	69 hours
Qualified cycle life	1.100.000 cycles

10N Bi-Propellant Thruster with Single Seat Valve

10N Bi-Propellant Thruster with Dual Seat Valve



10N Bi-Propellant Thruster with Dual Seat Airbus Valve

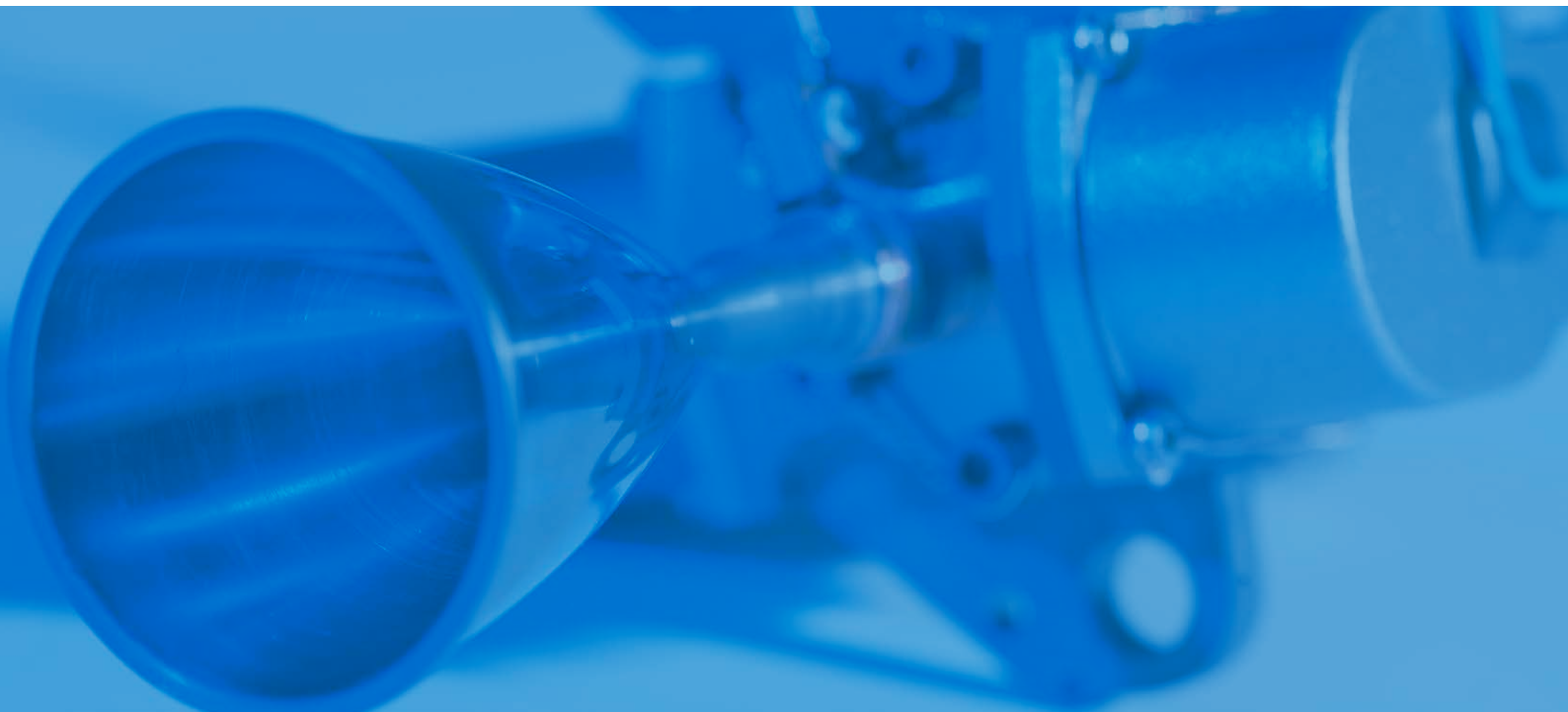
10N Bi-Propellant Thruster Heritage and Future Missions

Our 10N Thrusters are flying since 1974. The Table below starts with launch year 2010. For earlier satellites please contact ArianeGroup (contact details on last page).

Spacecraft	Launch Year
Arabsat 5A	2010
Arabsat 5B	2010
Astra 3B	2010
COMS	2010
KA-SAT	2010
MILSAT-B	2010
Nilesat 201	2010
Rascom-2	2010
W3B	2010
Arabsat 5C	2011
Astra 1N	2011
Atlantic Bird 7	2011
Ekspress AM4	2011
W3C	2011
Yahsat 1A	2011
Apstar7	2012
Astra 2F	2012
MSG FM3	2012
SK5D	2012
W5A	2012
W6A	2012

Spacecraft	Launch Year
YAHSAT 1B	2012
AMOS 4	2013
Alphasat PFM	2013
Astra 2E	2013
W3D	2013
SES-6	2013
GAIA	2013
AthenaFidus	2014
Astra 2G	2014
Astra 5B	2014
ARSAT 1	2014
Ekspress-AM4R	2014
Eutelsat 3B	2014
MEASAT 3B	2014
Arabsat 6B	2015
ARSAT 2	2015
Eutelsat 9B	2015
LISA-Pathfinder	2015
MSG FM4	2015
Ekspress-AM7	2015
Sicral2	2015

Spacecraft	Launch Year
DirecTV 15	2015
Hispasat 1 AG	2015
TELSTAR 12V	2015
AMU-1	2015
Eutelsat 8WB	2015
AMOS 6	2015
SkyBrasil	2015
AMOS 6 R	2016
Bepi Colombo	2016
EDRS-C	2016
SES-10	2016
SGDC	2016
Koreasat 7	2016
Exomars Orbiter	2016
Echostar 105	2017
Eutelsat 172B	2017
SES-12	2017
Solar Orbiter	2017
MTG	2019



200N BI-PROPELLANT THRUSTER

DESIGNED FOR ATTITUDE, ORBIT CONTROL AND RE-ENTRY MANEUVRES OF MAN-RATED HEAVY SPACECRAFT.

The 200N bipropellant engine was developed and qualified for application as attitude control, maneuvering and braking thruster of ESA's ATV.

The engine is designed to be capable of both steady-state and pulse mode in a very broad regimes of inlet conditions and exhibits outstanding thermal and combustion stability even at extreme conditions. To meet the specific FDIR needs of man rated missions, the engine is equipped with several flight temperature sensors for e.g. in-flight leak detection and a combustion pressure transducer.

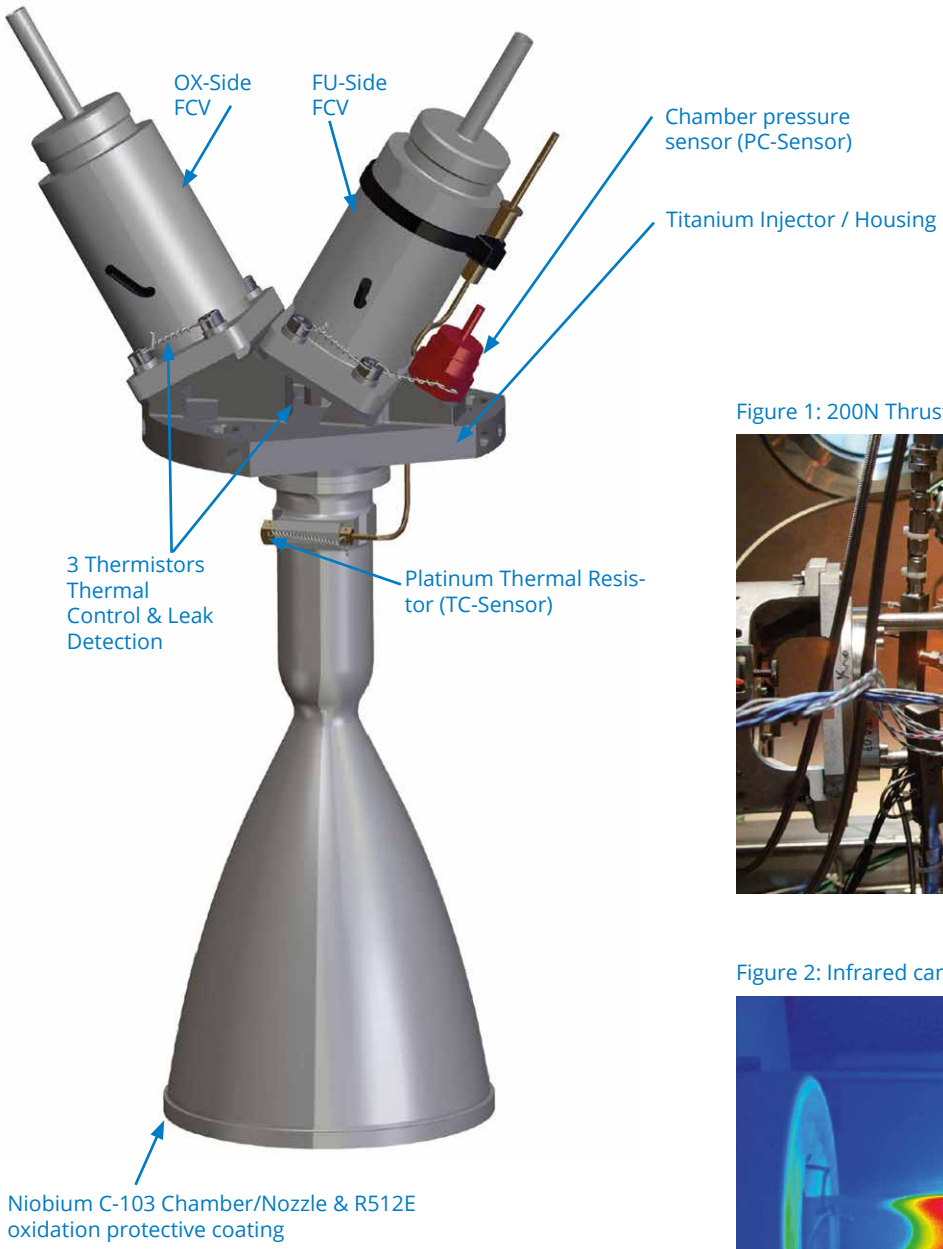


Figure 1: 200N Thruster firing test in high-altitude chamber

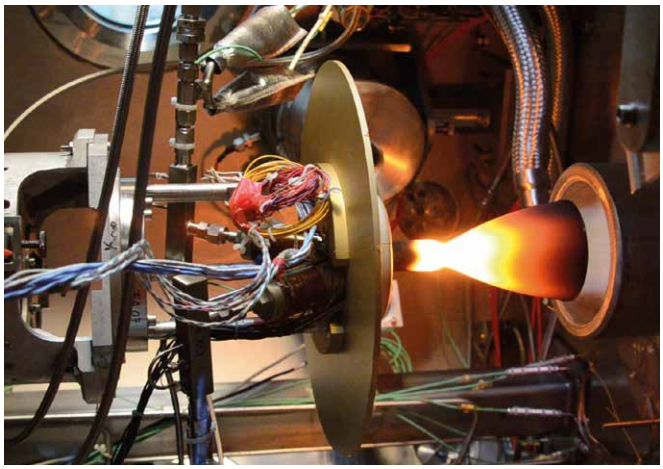
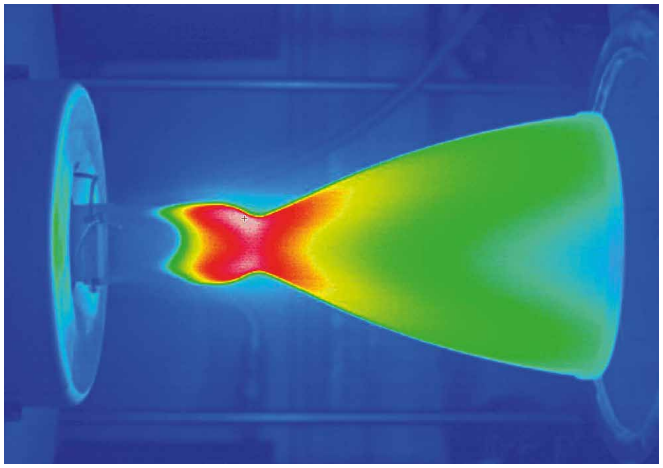


Figure 2: Infrared camera image



200N Bi-Propellant Thruster Key Technical Characteristics	
Thrust Nominal	216N ± 10N
Thrust Range	180N ± 15N to 270N ± 15N
Specific Impulse at Nominal Point	> 2650 Ns/kg (> 270s)
Flow Rate Nominal	78 g/s
Flow Rate Range	60 to 100 g/s
Mixture Ratio Nominal	1.65 ± 0.035
Mixture Ratio Range	1.2 - 1.9
Chamber Pressure Nominal	8 bar
Inlet Pressure Range	17 ± 7 bar
Minimum on time	28 ms
Minimum off time	28 ms
Minimum impulse bit	< 8 Ns at 28 ms
Pulse frequency	1 to 5 Hz
Throat Diameter (inner)	12 mm
Nozzle End Diameter (inner)	95 mm
Nozzle Expansion Ratio (by area)	50
Injector type	Impingement with film cooling
Mass, Thruster with Valves and instrumentation	1,9 kg
Chamber / Nozzle Material	SiCrFe coated niobium alloy
Fuel	MMH (qualified) / UDMH (demonstrated)
Oxidizer	MON-3 (qualified) / N2O4 (demonstrated)
Valve	Monostable dual coil solenoids, 32 W
Cumulated on time	46500 s
Cumulated number of pulses	320.000
Number of full thermal cycles	250
Max. t_on (single burn)	7600 s

200N Bi-Propellant Thruster Heritage and Future Missions

Spacecraft	Launch Year
ATV - 1 Jules Verne	2008
ATV - 2 Johannes Kepler	2011
ATV - 3 Edoardo Amaldi	2012
ATV - 4 Albert Einstein	2013
ATV - 5 Georges Lemaître	2014
Orion MPCV-ESM „EM-1“	2018
Orion MPCV-ESM „EM-2“	2021

400N BI-PROPPELLANT APOGEE MOTOR

RELIABLE APOGEE AND DEEP SPACE MANEUVERS.

The 400N bipropellant thruster is designed for apogee orbit injection of geostationary satellites and for trajectory and planetary orbit maneuvers of deep space probes.

The 400N engine uses the storable propellants Monomethyl-hydrazine MMH as fuel and pure Dinitrogen Tetroxide N2O4 or Mixed Oxides of Nitrogen (MON-1, MON-3) as oxidizer. It is designed for long term steady state operation. It operates in a wide pressure range at regulated pressure mode.

The combustion chamber and a part of the nozzle are made of platinum alloy. That does not require surface coating, thereby allowing operational wall temperature up to 1.600°C (2.900°F) and thus maximum engine performance.

The engine can be provided with supporting structure and thermal shield as completely assembled module on customer request.

400N Bi-Propellant Apogee Motor Key Technical Characteristics	
Thrust Nominal	425 N
Thrust Range	340 ... 450 N
Specific Impulse at Nominal Point	321 s
Flow Rate Nominal	135 g/s
Flow Rate Range	110 ... 142 g/s
Mixture Ratio Nominal	1.65
Mixture Ratio Range	1.50 ... 1.80
Chamber Pressure Nominal	10.35 bar
Inlet Pressure Range	12.5 ... 18.5 bar
Throat Diameter (inner)	16.45 mm
Nozzle End Diameter (inner)	296 mm
Nozzle Expansion Ratio (by area)	330
Mass, Thruster with Valve	4.30 kg
Chamber Throat Material	Platinum Alloy
Nozzle Material	Nimonic
Injector Type	Double Cone Vortex
Cooling Concept	Film & Radiative
Fuel	MMH
Oxidizer	N_2O_4, MON-1, MON-3
Valve	Solenoid Single Seat, Double Coil Voltage 21 to 27 V Power 35W per coil Bi-Stable

400N Bi-Propellant Apogee Motor Heritage and Future Missions

The 400N Apogee Engine can look back on more than 40 years use in space. The thruster has experienced multiple refinements in the course of its 40 years life. And innovation for further product improvement still continues. The Table below starts with launch year 2000. For earlier satellites please contact ArianeGroup (contact details on last page).

Spacecraft	Launch Year
AMSAT	2000
CLUSTER II	2000
EUTELSAT W4	2000
HISPASAT 1C	2000
ARTEMIS	2001
Atlantic Bird 2	2001
EURASIASAT	2001
Eurobird	2001
SICRAL	2001
ASTRA 1K	2002
Atlantic Bird 1	2002
EUTELSAT W5	2002
Hispasat 1D	2002
HOT BIRD 6	2002
MSG FM1	2002
Stellat	2002
STENTOR	2002
AMC-9, GE-12	2003
AMOS 2	2003
MARS EXPRESS	2003
Apstar 6	2005
FM01, GEi1	2005

Spacecraft	Launch Year
GEi2	2005
MSG FM2	2005
Syrakus 3A	2005
Venus Express	2005
HB7A, APA2	2006
Koreasat 5	2006
Syrakus 3B FM2	2006
THAICOM 5	2006
Chinasat 6B	2007
FM02, RC1	2007
Galaxy 17	2007
Star One C1	2007
Chinasat 9	2008
CIEL 2	2008
Star One C2	2008
Turksat 3A	2008
W2A	2009
MILSAT-A	2009
Palapa D	2009
SICRAL 1B	2009
Thor-6	2009
W7	2009

Spacecraft	Launch Year
MILSAT-B	2010
Nilesat 201	2010
RASCOM-2	2010
W3B	2010
W3C	2011
Apstar 7A	2012
Apstar 7B	2012
MSG FM3	2012
W6A	2012
Yamal 402	2012
Alphasat PFM	2013
AMOS 4	2013
W3D	2013
Athena Fidus	2014
ARSAT 1	2014
ARSAT 2	2015
Hispasat 1 AG	2015
MSG FM4	2015
Sicral 2	2015
Exomars Orbiter	2016

Apogee Motor with integrated heat shield and thrust frame

FUTURE SPACE AMBITIONS

ArianeGroup is pride of it's extensive and flawless heritage. Customers worldwide rely on the chemical bipropellant thruster family to achieve their missions. ArianeGroup is continuously improving it's product portfolio to support future space ambitions.