Nammo

SECURING THE FUTURE

NAMMO IRELAND

INTRODUCTION AND PRODUCTS

DEDICATION
PRECISION
CARE

Derek Harris
Business Development Manager
Nammo Ireland Limited

+353 87 211 9010

derek.harris@nammo.com

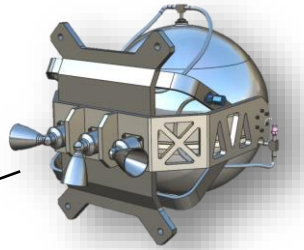
www.nammo.com

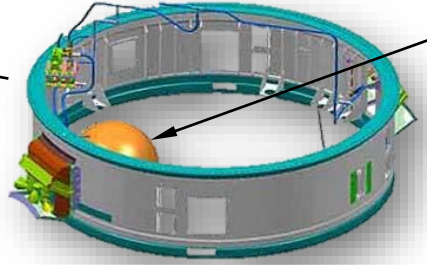
NAMMO SPACE

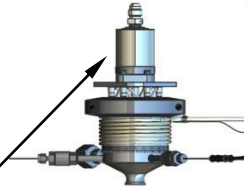
4 Sites	€19.6m	Product Areas: Solid Rockets, Hybrid Rockets, Igniters, Launcher Engine Structures, Valves, Pressure Regulators, Mono- and Bi-propellant Thrusters and Engines
3 Countries	145 People	
Dublin [Ireland], Raufoss [Norway], Westcott/Cheltenham [UK]	Customers: France, Germany, Italy, Israel, Japan, UK, USA	Extensive Test Facilities

NAMMO SPACE ON VEGA

Nammo Raufoss is responsible for the development of the Hydrogen Peroxide Propulsion System on the Vega-C/E upper stage [AVUM].







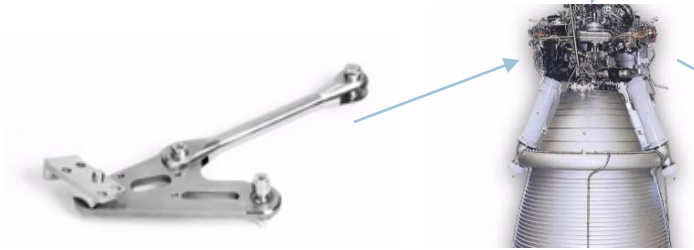
Nammo Ireland is responsible for the flow control valves in the Vega RACS system

NAMMO SPACE – ARIANE 5 and 6

V2.1 Engine Structures
- Standard Vulcain hardware qualified for Ariane 5
- Designed, manufactured and tested by Nammo Ireland
- Production contract for PC being negotiated

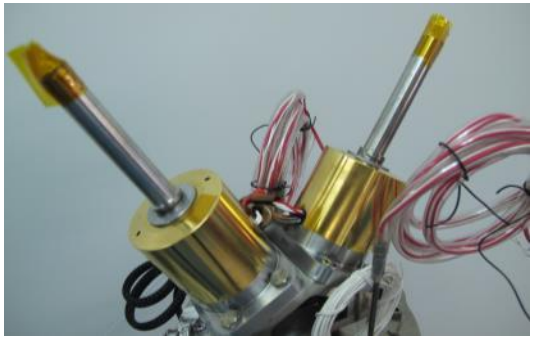
New Vulcain structures for Ariane 6
- 2 New structures for Vulcain 2.1 engine
- Analysis complete and hardware being produced for test

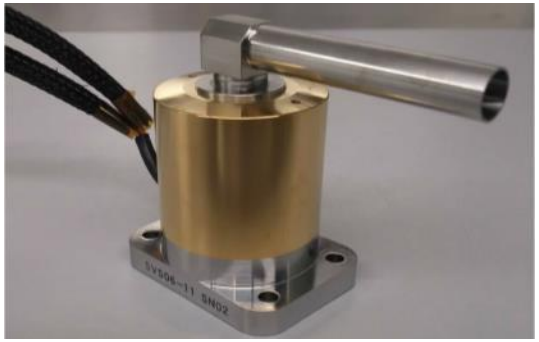
Vinci Engine Structures
- Structures have successfully passed qualification review

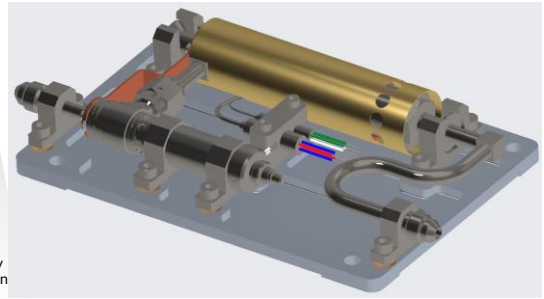


FLUID CONTROLS FOR SPACE

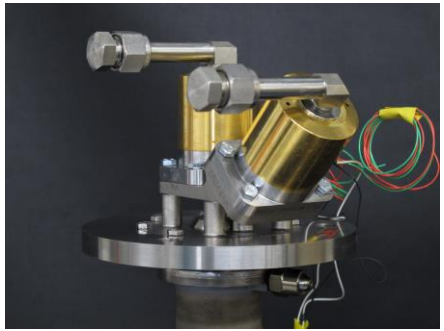
- Flow Control Valve for Chemical Rocket Engine
- Flow Control Valve for Launcher Subsystems e.g. Vega upper stage Roll and Attitude Control System
- Cold Gas Thruster Valve
- Cold Gas Pressure Regulator
- Fill and Drain Valves
- Non-Return Valves
- Electronic Pressure Regulator
- Propellant Flow Control Valve
- CubeSAT Propellant Storage Tank

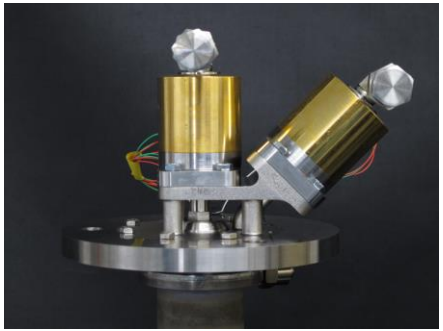


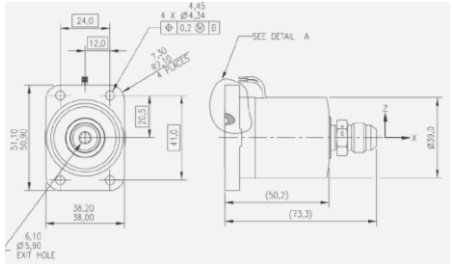




NAMMO SPACE–AEV/HTAEV FLOW CONTROL VALVE







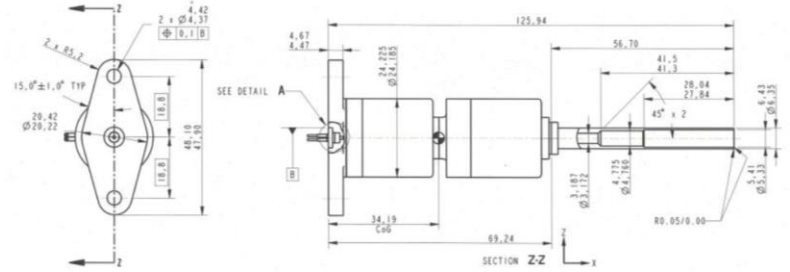
The Apogee Engine Valve (AEV) range has been developed and qualified to be compatible with a wide range of propellants used in chemical propulsion including Hydrazine/MMH/MON/Cold Gases. The valves are a normally-closed, non-sliding fit, dual coil design which features both internal filter and internal heater installation. The High Thrust AEV is the baseline for the 1kN LEROS 4 Apogee Engine (HTAE) being supported by ESA for its planetary science and exploration mission programmes.

Performance Characteristics			
Operating Media	MMH, MON, Hydrazine, IPA, GN_2 , GHe, H_2O_2		
Maximum Operating Pressure	22BarA		
Surge Pressure	140Bar for 2s		
Proof / Burst Pressure	42Bar / 82Bar		
Operational Temperature	-5˚C to 102˚C [Non-Operational -54˚C to 130˚C]		
Flow Rate / Pressure Drop	2.4Bar @ 190 g/s water		
Internal Leakage	1 x 10^{-4} scc/s GHe		
External Leakage	1 x 10^{-6} scc/s GHe		
Response	< 30ms open/close under all conditions		
Electrical Interface	Flying leads or standard DIN Connectors		
Operating Cycle Life	9,000 cycles		
Filter Rating	25 microns abs		
Wetted Materials	AISI316L, AISI304L, AISI430, PTFE		
Hardware Mass	420 gram		
Envelope	52mm x 38.1mm x 74mm		
Options			
Input Voltages	18-27 Vdc	26-36Vdc	18-27Vdc
Coil Power	38W	31.5W	40W
Fluidic Interface	3/8" tube stub or threaded AS4395 fitting		
Structural Interface	Metallic Flange with M4 bolt holes [can be customised]		
Internal Heater	2 W at 35V		
Technology Readiness Level	TRL8		

NAMMO SPACE–CTV-D FLOW CONTROL VALVE

The Nammo CTV-D Dual In-line Chemical Thruster Valve is a totally European 2-stage normally-closed solenoid actuated non-sliding fit flow control valve specifically designed for use with spacecraft chemical thrusters.

The valve inlet can be supplied with welded or threaded connections and incorporates a 25 micron particle filter. The thruster interface flange can be configured to match customer requirements



Performance Characteristics		
Operating Media	MMH, MON, Hydrazine, IPA, GN_2 , GHe, H_2O_2	
Maximum Operating Pressure	28Bar	
Surge Pressure	140Bar for 2s	
Proof Pressure	105Bar	
Burst Pressure	200Bar	
Flow Rate / Pressure Drop	< 2Bar @ 4g/s water	
Internal Leakage	8×10^{-4} scc/s GHe	
External Leakage	1×10^{-6} scc/s GHe	
Response	< 8ms open/close under all conditions	
Electrical Interface	Flying leads or standard DIN Connectors	
Operating Cycle Life	1,050,000 cycles	
Filter Rating	25 microns abs	
Wetted Materials	AISI316L, AISI304L, AISI430, PTFE	
Hardware Mass	100 gram	
Envelope	126mm x 48.1mm x 24.3mm	
Options		
Input Voltages	9.75 - 15.0 Vdc	19.5 - 38.0 Vdc
Coil Power	20.5 W	8.5 W
Fluidic Interface	1/4" tube stub or threaded AS4395 fitting	
Structural Interface	Metallic Flange with M4 bolt holes [can be customised]	
Internal Heater	2 W	
Technology Readiness Level	TRL6	

NAMMO SPACE–COLD GAS PRESSURE REGULAT0R

The **Cold Gas Mechanical Pressure Regulator** is a single stage passive flow control device, primarily intended for gaseous regulation in propulsion systems. The regulator will step down from the high pressure inlet, to a predefined outlet pressure for the customer.

The regulator is manufactured from lightweight Titanium, and the seal material is PCTFE. The regulator is all electron-beam welded construction, with tubing and mounting interfaces to customer requirements.

This single stage design regulator was used successfully on the PRISMA satellite mission.

Performance Characteristics	
Operating Media	GN2
Inlet Pressure	250 bar
Outlet Pressure	4 bar nominal
Set Point Accuracy	3.9 to 4.1 bar, set at max operating inlet pressure
Outlet Pressure Tolerance	+/- 0.4 bar over life
Lockup	<1.5 bar above set point
Outlet MEOP	6 bar maximum
External Leakage	< $1x10^{-6}$ GN_2 over pressure and temperature range
Internal Leakage at Lockup	<$1x10^{-4}$scc/s GN_2
Operating Temperature	+17°C to +60°C
Non-Operating Temperature	-20°C to +60°C
Mass Flow	10 mg/s GN_2
Life	1 year
Hardware Mass	0.25 kgs
Structural Connection	4 bolts, M5
Connection for Fluids	1/4” tube stub or screwed AS4395 fitting
Envelope	107mm x 60mm x 63mm
TRL	TRL9

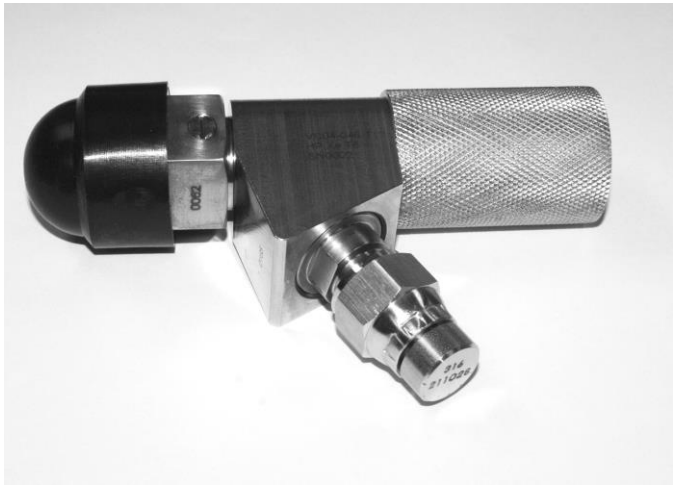
NAMMO SPACE–FILL and DRAIN VALVE

Fill and Drain Valve / Test Port

The Nammo Fill and Drain Valve (FDV) is a well established product which has flown on many European satellites. It is suitable for use on all categories of satellite propulsion currently in use.

Performance Characteristics	
Operating Media	GN2
Inlet Pressure	250 bar
Outlet Pressure	4 bar nominal
Set Point Accuracy	3.9 to 4.1 bar, set at max operating inlet pressure
Outlet Pressure Tolerance	+/- 0.4 bar over life
Lockup	<1.5 bar above set point
Outlet MEOP	6 bar maximum
External Leakage	< $1x10^{-6}$ GN_2 over pressure and temperature range
Internal Leakage at Lockup	<$1x10^{-4}$scc/s GN_2
Operating Temperature	+17°C to +60°C
Non-Operating Temperature	-20°C to +60°C
Mass Flow	10 mg/s GN_2
Life	1 year
Hardware Mass	0.25 kgs
Structural Connection	4 bolts, M5
Connection for Fluids	1/4” tube stub or screwed AS4395 fitting
Envelope	107mm x 60mm x 63mm
TRL	TRL9

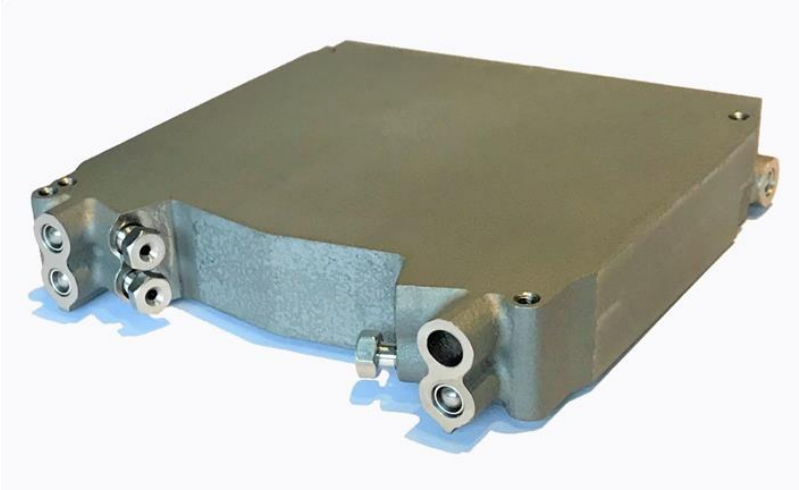
NAMMO SPACE–GROUND HALF COUPLING



The Ground Half Coupling (GHC) is a generic design for actuation of the VC03 Fill and Drain Valve. The unit is manufactured from stainless steel and is designed for use with liquid propellant or gas across a range of pressures.

Performance Characteristics	
Operating Media	GN2
Inlet Pressure	250 bar
Outlet Pressure	4 bar nominal
Set Point Accuracy	3.9 to 4.1 bar, set at max operating inlet pressure
Outlet Pressure Tolerance	+/- 0.4 bar over life
Lockup	<1.5 bar above set point
Outlet MEOP	6 bar maximum
External Leakage	< $1x10^{-6}$ GN_2 over pressure and temperature range
Internal Leakage at Lockup	<$1x10^{-4}$scc/s GN_2
Operating Temperature	+17°C to +60°C
Non-Operating Temperature	-20°C to +60°C
Mass Flow	10 mg/s GN_2
Life	1 year
Hardware Mass	0.25 kgs
Structural Connection	4 bolts, M5
Connection for Fluids	1/4” tube stub or screwed AS4395 fitting
Envelope	107mm x 60mm x 63mm
TRL	TRL9

NAMMO SPACE–CUBESAT PROPELLANT TANK



Nammo Ireland has developed a 3D printed metal tank that can be used on small spacecraft like CubeSATs.

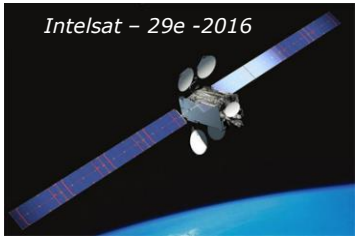
The Additive Manufacturing laser powder printing allows for the production of intrigue internal flow paths.

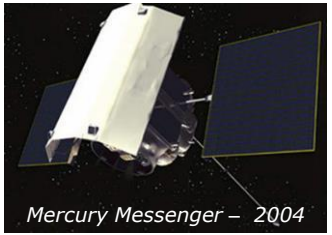
CubeSat Propellant Storage Tank	
Tank Materials	Titanium (Inconel, Aluminium, Stainless Steel also possible)
Fuel Volume	100cm^3 (Main + Plenum)
Fluids	Butane, Nitrogen
Dry Mass	180g
Pressure [MEOP]	10 bar
Proof Pressure	25 bar
Burst Pressure	40 bar
External Leakage	1x10^{-6} scc/s GHe
Temperature Range	-5°C to +50° (5)
Shock	100–500 Hz 12dB/Octave. 500–5000 Hz 2000g
Life	5 Years
Physical Envelope	1U x 1U x 0.2U
Filtration	15 - 40 micron
Cleanliness	ESA Spacecraft Propulsion Requirements ECSS-E-ST-35-06C
Heater	Plenum temperature controllable via external heater
Ports	10-32 UNF Coned or as required
Configuration	No-Welds, fully 3D printed
Insert Blowout	40,000 psi rated

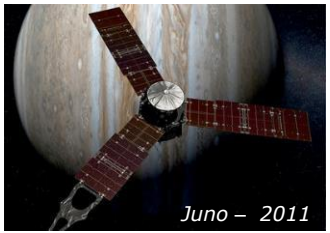
OTHER NAMMO PRODUCTS USING NAMMO IRELAND VALVE TECHNOLOGY

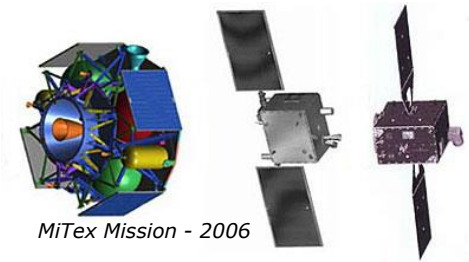
A BRIEF SUMMARY

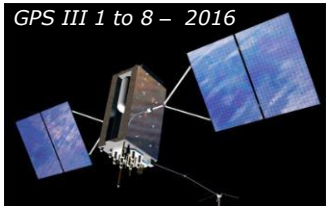
NAMMO LEROS APOGEE ENGINES –PRODUCT LINE HERITAGE









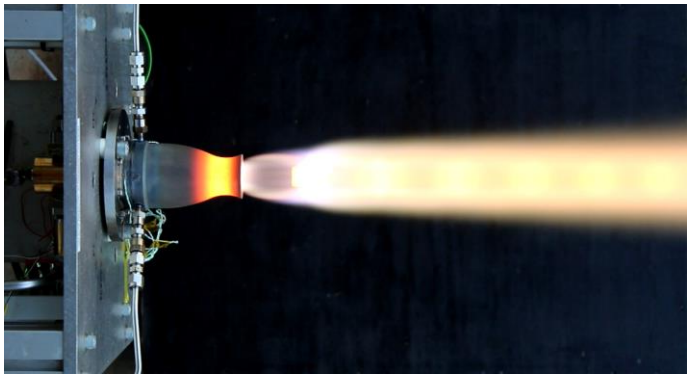


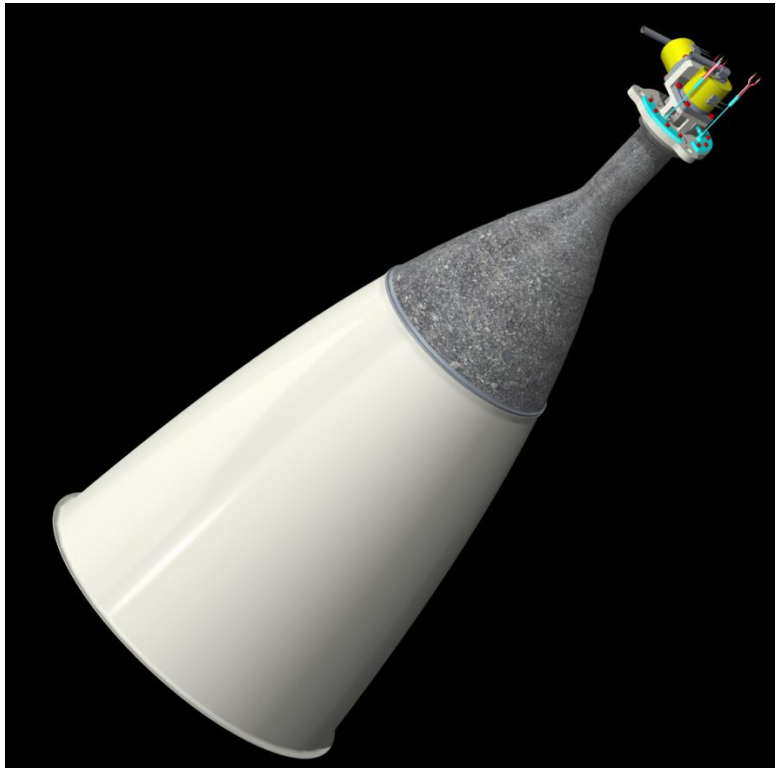
LEROS APOGEE Engines – Over 90 Engines around the Solar System

NAMMO LIQUID APOGEE ENGINES – LEROS 4 (HTAE)

This 1000N (225 lbf) nominal thrust High Thrust Apogee Engine (often referred to as the HTAE) is currently under development at Nammo Westcott.

The HTAE is being designed as a mission enabling, propellant optimizing engine targeted at ESA deep-space Mars-return missions and has undergone extensive development and hotfire testing. Qualification is targeted for 2020.





NAMMO RCS/ACS THRUSTERS – LTT

LTT-*i*

UK designed, manufactured and tested at Nammo Westcott this high performance 10N (2.25 lbf) MMH/MON thruster, optimized for Isp, boasts 284 second Isp @13.9 bara (202 psia) inlet pressures and 290 seconds Isp at 17.4 bars (252 psia) inlet pressures. This thruster has been flown successfully on multiple USA Government missions. We are able to offer this high performance variant of our LTT range at a very competitive price and it can be delivered within a 6 month timescale.

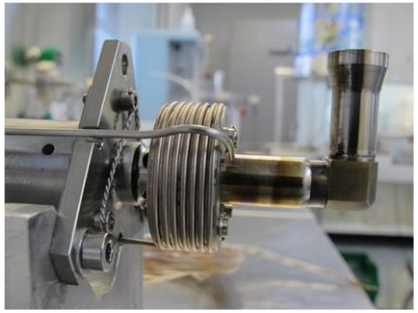
LTT

UK designed, manufactured and tested at Nammo Westcott 274 second Isp @ 13.9 bara (202 psia) 10N (2.25 lbf) MMH/MON thruster. We have sold this engine in vast numbers (500 deliveries) primarily into the US market. This low-cost RCS/ACS thruster has proven to be extremely reliable and can be delivered within a 6 month timescale.

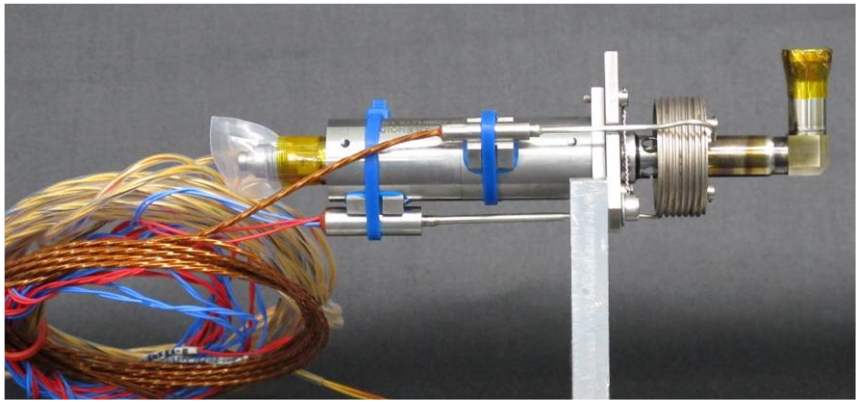
NAMMO RCS/ACS THRUSTERS – LEROS MHT-1N

This new high performance, low cost European high throughput 1N (0.225 lbf) hydrazine monopropellant thruster has been developed over the past 5 years at Nammo Westcott to meet the growing requirements for a 1N (0.225 lbf) thruster that can meet the high throughput capability being driven by de-orbit legislation.

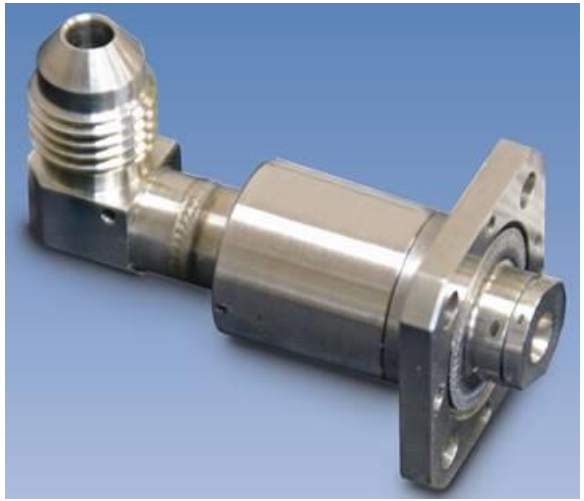
The thruster has been developed under joint Nammo UK/ESA funding and was qualified in 2016 to 44kg (97 lbs)throughput for Formosat-7. Isp is minimum 226 seconds at 24 bar (348 psia) inlet pressure making it one of the highest performers available. It had its first flight on the SSTL Telesat LEO-1 satellite in January 2018. The MHT-1N is under contract to be qualified for the Airbus Eurostar Neo telecoms platform and additionally for ESA, a total pulsed/steady state throughput of over 90kg (198 lbs) of hydrazine.



Telesat LEO-1



NAMMO SPACE – COLD GAS THRUSTER



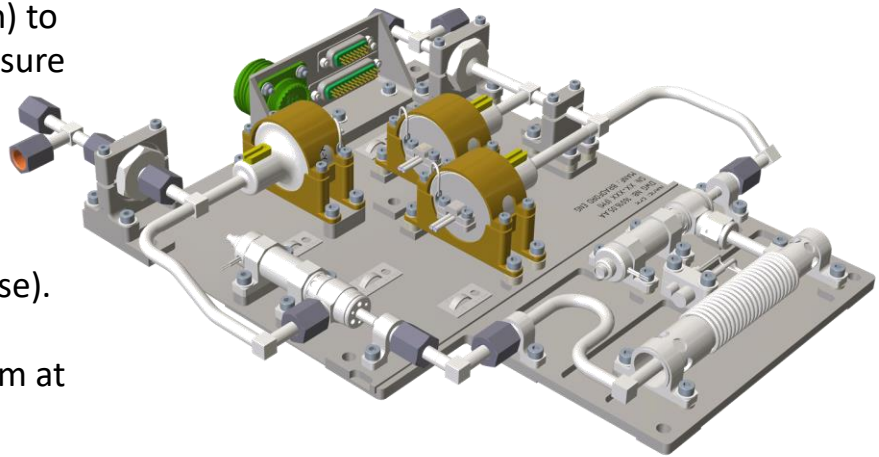
The Nammo SVT01 Series of Cold Gas Thrusters use a flat faced seal to reduce the risk associated with valve internal leakage due to a high cycle life. Variations in thrust levels are achieved by use of the different sized thruster nozzles which can be interchanged.

FLOWN

Performance Characteristics	
Operating Media	GN2, CF4, GXe
Max Operating Pressure	1.5 to 2.5Bar
Proof Pressure	16Bar
Operational Temperature	-35°C to +95°C
Vacuum Thrust	10mN (± 5%) to 50mN (± 5%)
ISP (Ambient Temperature)	GN2 - 72s (Nom); CF4 - 47s (Nom)
Thrust Vector Accuracy	<1°
Impulse Bit Repeatability	<5%
Electrical Interface	Flying leads or standard DIN Connector
Coil Resistance	110-115Ω @ 20°C (typical)
Response Time	<5.0ms (Opening and Closing)
Power Consumption	Coil and voltage dependant
Internal Leakage	1 x 10^{-4} scc/s GHe max at 1.5 Bar
External Leakage	1 x 10^{-6} scc/s GHe max at 1.5 Bar at EOL
Operating Cycle Life	1,500,000 cycles
Filter Rating	25 µm abs
Construction Materials	AISI304L, Radiometal 4550, EPDM Rubber, Silicone Rubber
Hardware Mass	60 gram
Envelope	15.85mm diameter, 52mm length
Fluidic Interface	Threaded AS4395 fitting
Structural Interface	Metallic Flange with M4 bolt holes [customisable]
Mounting	4 off M3 hole on 23mm PCD
Technology Readiness Level	TRL9

NAMMO SPACE - ELECTRONIC PRESSURE REGULATOR

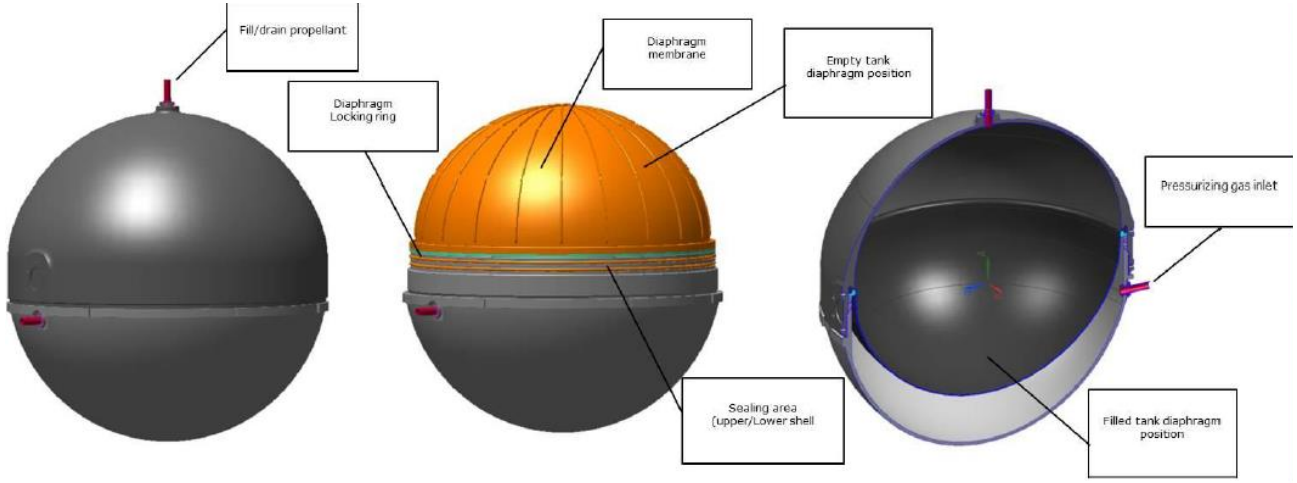
- EPR includes thermal conditioning of Xenon (or Nitrogen) to prevent Joule-Thompson issues and regulate outlet pressure and minimum temperature.
- In-flight pressure variation and control.
- Scalable design.
- Suitable for flow control of liquids and gases.
- No need for multiple regulators (as in the mechanical case).
- Low leak rate (<2 x 10^{-5} scc/sec Helium internal).
- High Flow capacity > 600mg/s Xenon at EoL, >2g/s Helium at EoL .
- Compatible with all heritage spacecraft propellants and pressurants.
- Up to 310 bara (4496 psia) MEOP.
- Pressure set point range is 0.5 to 22 bara (7.25 to 319 psia).
- Programmable by telecommand.
- In-orbit data logging.
- Regulation accuracy of 0.1 bar.
- Response to 90% of new level <1 second.



This state-of-the-art development features the Nammo advanced High Pressure Proportional Valve

NAMMO SPACE – ALUMINIUM ALLOY TANK MANUFACTURE

- High strength forged aluminium alloy hemispheres are cold forged to near net shape, followed by fine machining of the interfaces to final form.
- Heat treatments are integrated in the manufacturing process, to secure strength, exact dimensions and compatibility.
- Currently produce 54 litre tanks with a Viton diaphragm.
- Blow down ration 4:1
- Components for attaching the diaphragm membrane, sealing and external connections are all made of the same Aluminium Alloy or Viton compound.



SOUNDING ROCKET AND MICRO-LAUNCHER PROPULSION

Nammo has devoped a suborbital launcher based on the hybrid engine technology. The Nucleus maiden flight was from Andoya in September 2018.

Three versions of Nucleus will be available, which will be followed by the NorthStar Micro Launcher.

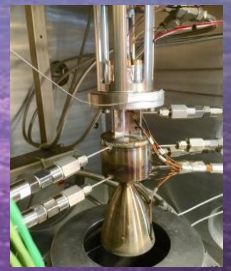


Image : Andøya Space Center

HYDROGEN PEROXIDE TEST FACILITIES AT NAMMO RAUFOSS

The Nammo Raufoss ground level thrust test stand is designed for engines of up to 500kN of thrust. The facility also includes class 1 storage for up to 40,000 litres of H2O2.

Here we see the 30kN hybrid Nucleus engine during development testing.

SPACE PROPULSION TEST FACILITIES AT NAMMO WESTCOTT

The Nammo Westcott spacecraft propulsion test facility includes ground level test and high altitude test capabilities.

The high altitude test stand is designed for engines up to 1500N thrust.