## S25 Design Description

The ArianeGroup S25 thruster is a bipropellant rocket engine delivering a nominal 23N (5lbf) thrust using the storable propellants monomethyl-hydrazine (MMH) as fuel and nitrogen tetroxide ($N_2O_4$, MON-1, MON-3) as oxidizer

The current **S25 design** includes all features which make ArianeGroup's bipropellant thrusters outstanding since decades:

- **Flight proven, from the shelf components:** Due to a common thruster interface, the S25 engine shares its flow control valve portfolio with the 4N and the 10N thrusters. This includes the metallic sealing and trimming components.
- **Double cone vortex injection:** As derived from ArianeGroup's bipropellant thruster family up to 400N, the S25 thruster implements an injector where the two propellant components are sprayed by two coaxial swirl atomizers into the combustion chamber. This guarantees for a very well balanced coolant distribution and thus balanced temperature distribution throughout the entire chamber and an optimum propellant atomization and mixing and thus optimum reaction and thruster performance.
- **Super-alloy heat barrier:** In order to minimise dribble volumes, hence maximise the pulse mode performances, the injector thermal isolation/decoupling is performed with a fuel film cooled conduction barrier made of a high resistant NiCr based super-alloy. The current engine is designed without an additional bird cage heat barrier.
- **Uncoated Platinum Alloy Chamber and Nozzle:** Because ArianeGroup is following the strategy of not using coated materials since the very beginning of its space propulsion activities, the thruster employs a platinum-based alloy for the hotter throat area. Protective coating of high temperature resistant but oxidizing materials have always been deemed as solving one problem by creating a new one. Defective coating may rapidly lead to failure of a thruster. Thermal cycles of a million of thruster pulses during a satellite life can cause coating defects, as can improper thruster handling during AIT. Application of thermal sensors on chamber and nozzle during ground tests are considered to be prohibitive. All those potential constraints of a coated chamber material are not encountered in conjunction with ArianeGroup’s Pt chamber approach.

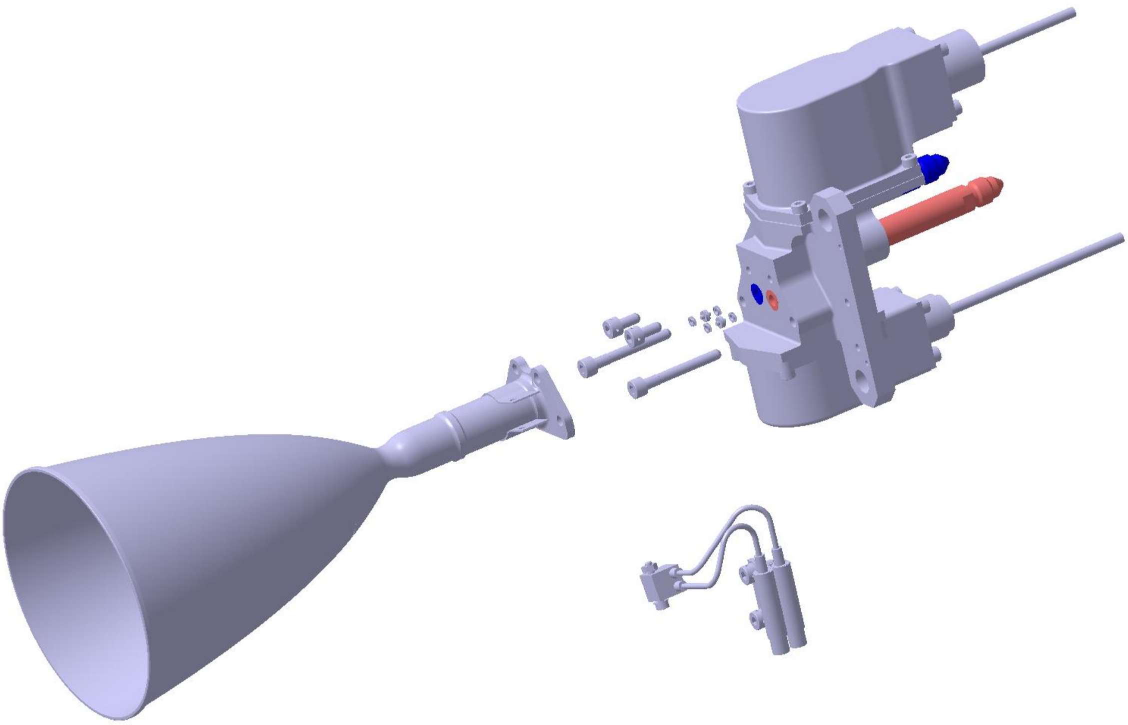

**Figure 1:** S25-1 PQM thruster

The S25-1 EM1 is the first Engineering Model of a 22N bipropellant RCT family equipped with a dual seat valve (Moog Inc.), designed for both, long steady state and pulse mode operation, operating in both pressure regulated and blow-down mode. The S25-1 design remains free from ITAR restrictions (EAR compliance rules and regulation applied for the torque motor valves from Moog Inc.).

Through its reduced thruster dribble volumes and high combustion efficiency, the thruster is also designed to achieve high efficient on-mode pulse capabilities and a reduced plume contaminant production.

**S25-1; -2 and -3 series**

The S25-1; -2 and -3 series are only to be distinguished by the valves coil designs, i.e. nominal command voltage, which can be adapted from nominal 28 to 51 VDC. The thrust chamber remains identical for all versions. The valve assembly (except coils) remains identical as well.

| Req. Description | S25-1 | S25-2 | S25-3 |
|---|---|---|---|
| Valve denomination | Moog 051-457 | Moog 051-215B | Moog 051-219B |
| Nominal command voltage | 28VDC | 42VDC | 51VDC |
| Qualification status (valve) | Qual by sim | Flight proven | Flight proven |
| Flight heritage (valve) | | e.g. Rosetta, Alphabus | e.g. JUICE |

**Table 1:** S25 with dual seat torque motor valve options

**Flight monitoring**

The upper combustion chamber temperature can be monitored in flight via a PT200 or PT1000 sensors. The baseline design can accommodate two sensors (primary and redundant) in a same bracket, welded on the combustion chamber wall.

As an alternative a flange thermistor, and additional FCV thermistors can be accommodated on customers demand in a later stage of the development program (an easily be taken from the established 10N stock).

**Maiden Qual Frame**

| **Maiden Specification** | **Thruster characteristics (PQM)** |
|---|---|
| Nominal thrust | 23 N |
| Thrust range | 18... 29 N |
| Minimum SSF ISP | 295s (at nominal thrust) / development target is 300 ± 3s |
| Minimum (unrestricted) impulse bit | 100 mNs |
| Nominal flow rate | 7,81 g/s |
| Inlet pressure range | 9 … 24 bar (trimming related) |
| Flow rate range | 5 … 9,5 g/s |
| Nominal mixture ratio | 1,625 |
| Mixture ratio range | 1,5 ... 2,2 |
| Nominal chamber pressure | 8,5 bar |
| Dimensions<br>- overall length<br>- throat diameter<br>- nozzle exit diameter | <br>< 230 mm<br>4,3 mm<br>74,4 mm |
| Nozzle expansion ratio | 300:1 |
| Mass | < 680 g (dual seat torque motor valve configuration) |
| Feed line connection | per SAE AS4395E02 or ¼'' weld interface |
| Mounting flange | screwed 3 x M6 alignment studs |
| Injector / chamber and nozzle material | Stainless steel / NiCr superalloy and Pt-alloy |
| Injector type | Built-in double cone vortex injector (all welded design) |
| Cooling concept<br>- Chamber<br>- Nozzle | <br>Fuel-film and radiative cooling<br>Radiative cooling |
| Valve concept<br>- Seat material<br>- Body, manifold, fittings and bending tubes material | Dual seat series redundant bipropellant valve (torque motor)<br>PTFE<br>CRES |
| Insert sealing | Gold plated stainless steel omega seals |
| Propellants (fuel/oxidizer) | MMH / N2O4; MON-1 ; MON-3 or MON-25 (tbc) |

*Extract from LAM internal specification as per 22N-ASLLAM-DVM-0001.*

| ***Maiden Specification*** | ***Thruster characteristics (PQM)*** |
|---|---|
| *Unconstrained MIB* | *100 mNs* |
| *IBIT std deviation* | *< 15% (3 sigma)* |
| *Centroid delay* | *5 ms < tc-del < 30 ms* |
| *Raise time 90% $RT_{90}$* | *$RT_{90}$ < 20 ms* |
| *Decay time 10% $DT_{10}$* | *$DT_{10}$ < 13 ms* |
| *PMF capabilities:*<br>· *Pulse train*<br>· *Single pulse*<br>· *Duty cycles [s]* | <br>*5 ms < ton < 5.5 hours*<br>*MIB ≤ 100 mNs*<br>*0.1 s < Command period < 600 s* |
| *SSF capability (single burn)* | *> 5.5 hours* |
| *Total propellant throughput* | *> 900 kg* |
| *Total number of pulses* | *> 500 000 pulses* |
| *Total number of thermal cycling* | *≥ 600* |

**Validation against vibration loads**

*Extract from LAM internal specification as per 22N-ASLLAM-DVM-0001 (Environmental loads – as per S10-18)*

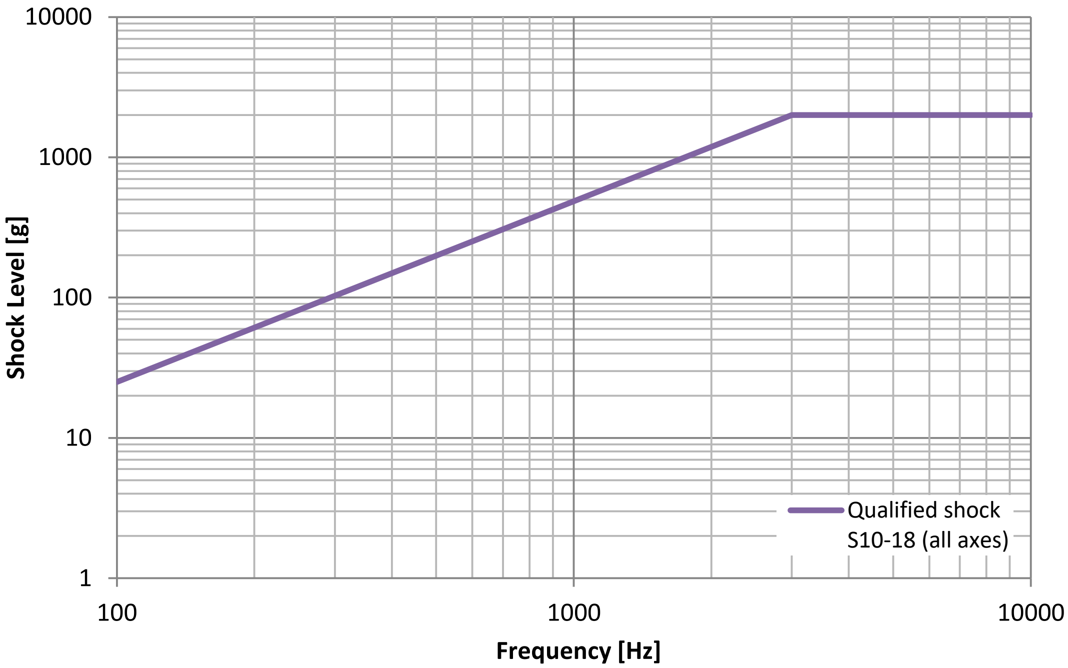


Figure 2: Shock specification

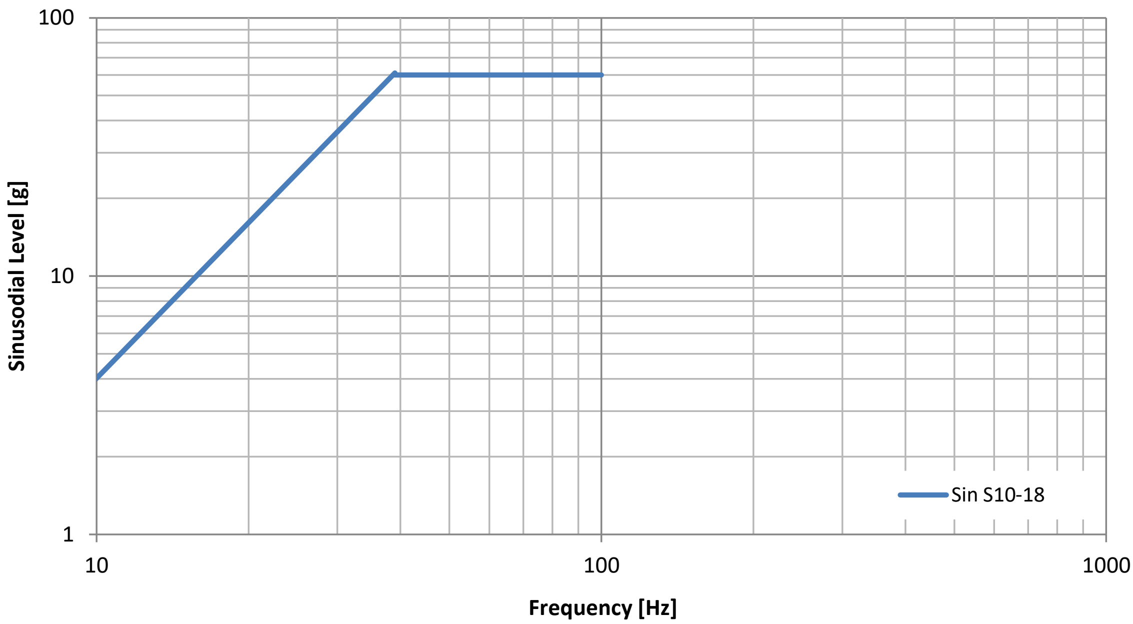


Figure 3: Sinus vibration specification

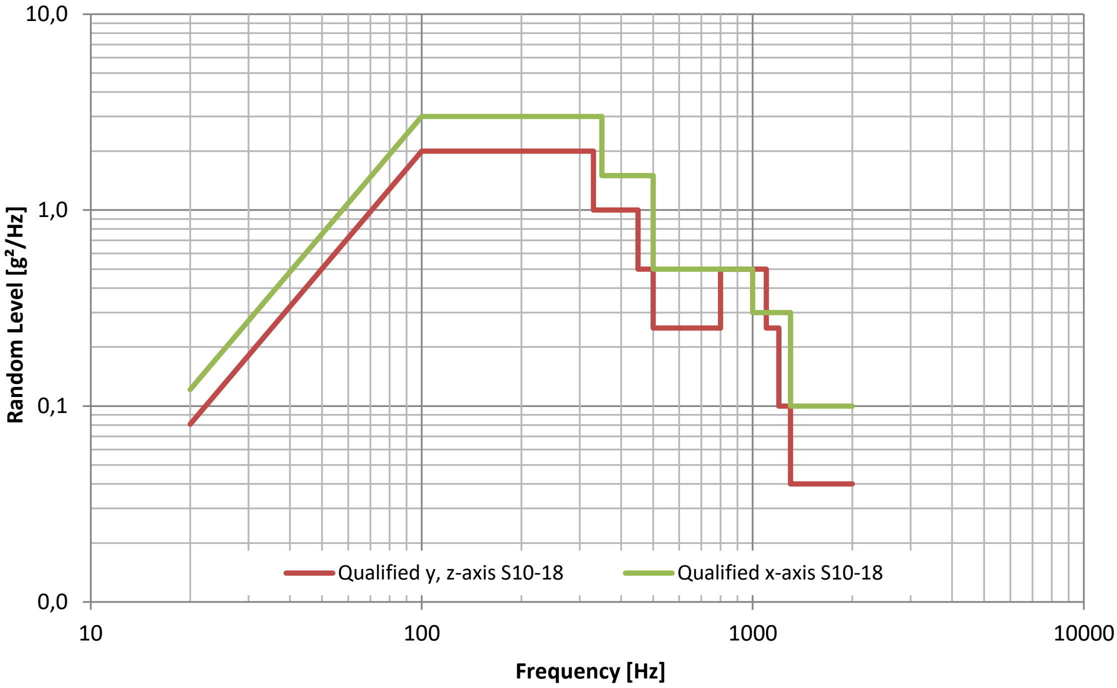


Figure 4: Random vibration specification - lateral and axial direction

**Performance prediction**

SSF ISP > 295 s
PMF:

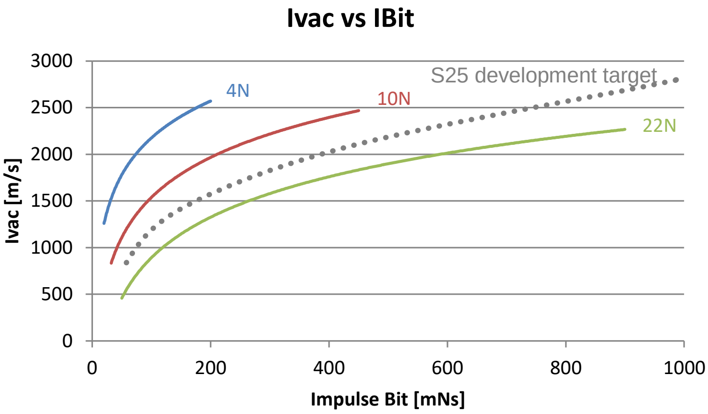


Figure 5: Performance prediction Ivac vs IBit

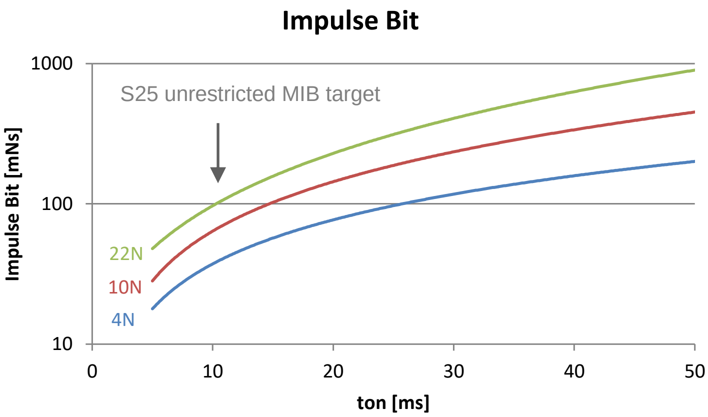


Figure 6: Performance prediction Impulse bit vs on-time

## Interface control drawing