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Current status of Pre-Qualification of Aluminium-Free Solid Propellant

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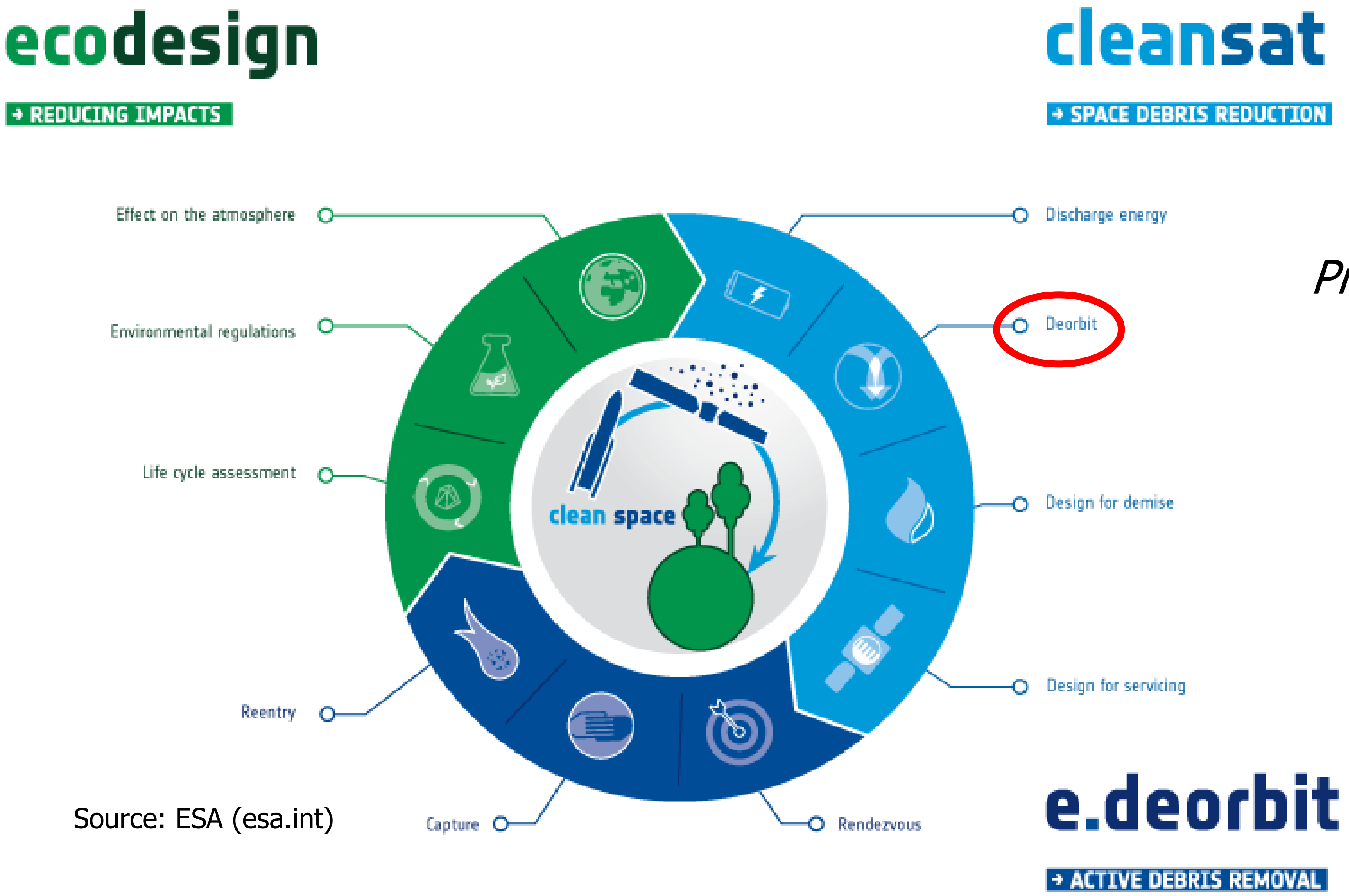

Source: ESA (esa.int)

Pre-Qualification of Aluminium Free Solid Propellant

(GSTP, ESA contract no. 4000120120/17/NL/LvH)

esa

European Space Agency

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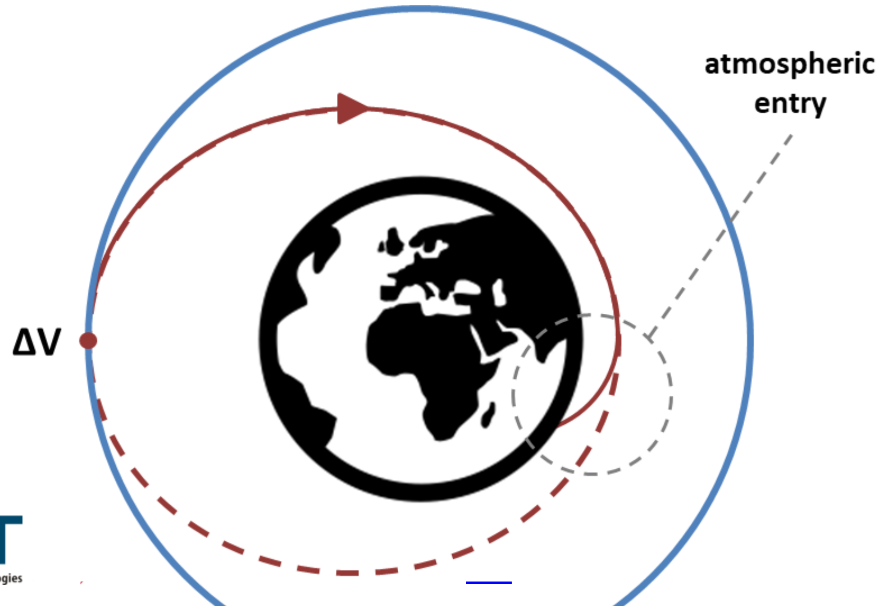
Solid propulsion for deorbitation

- Simple construction
  - Low dry mass
  - Compact size
  - High reliability

- Direct deorbitation capabilities
- Wide range of thrust levels and profiles possible
- Relatively high performance
- No temptation to expand mission duration
- Good storability

Mission definition

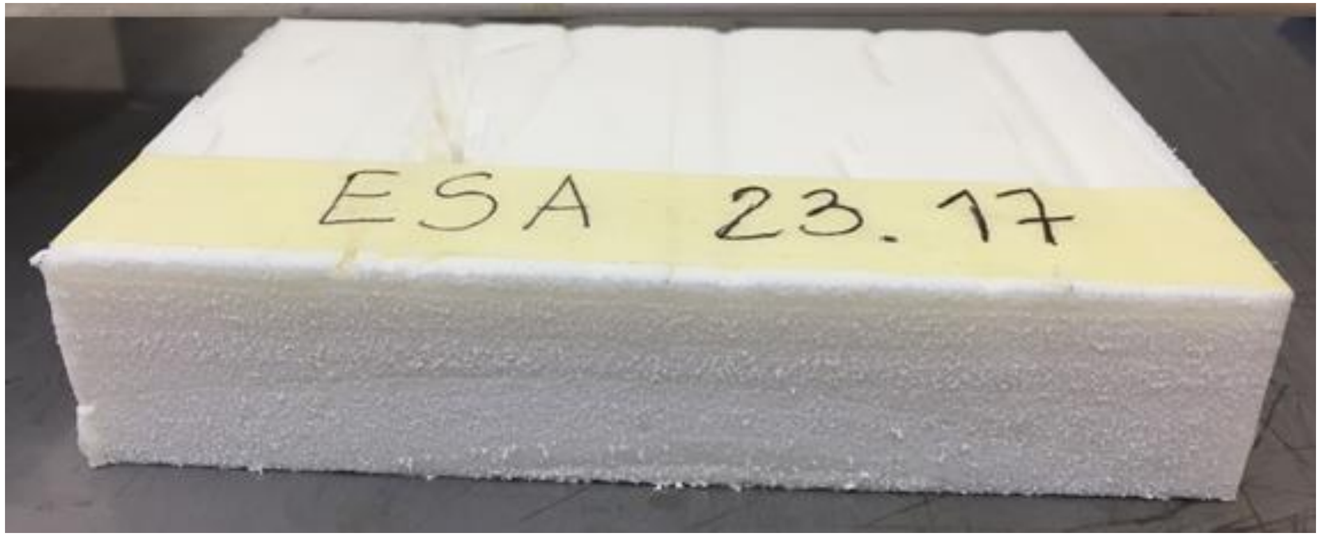
- Flexibility
- Basic configuration
  - Satellite mass – 1 500 kg
  - Initial orbit – SSO
  - Final orbit – 800 x 80 km



System	
Number of motors / fried simultaneously	4 / 2
Maximum acceleration	0.04 g
Total required ΔV	200 m/s
Total required propellant mass	116 kg
Motor	
Maximum thrust	250 N
Minimum propellant mass	29 kg
Minimum total impulse	78.5 kNs
Nozzle expansion ratio	220

Challenges	*Solutions*	*Implementations*
• High total impulse	• State of the art propellant • High Isp	• AP/HTPB system • Optimized oxidizer-fuel ratio
• Limited thrust (long burn time)	• Low burn rate	• End-burning grain • Low chamber pressure • Burn rate suppressant • Multimodal AP
• Solid particles generation	• No metalized compounds	• Aluminium-free propellant
• Storability	• Storability analysis and testing	• Vacuum, accelerated aging, radiation testing

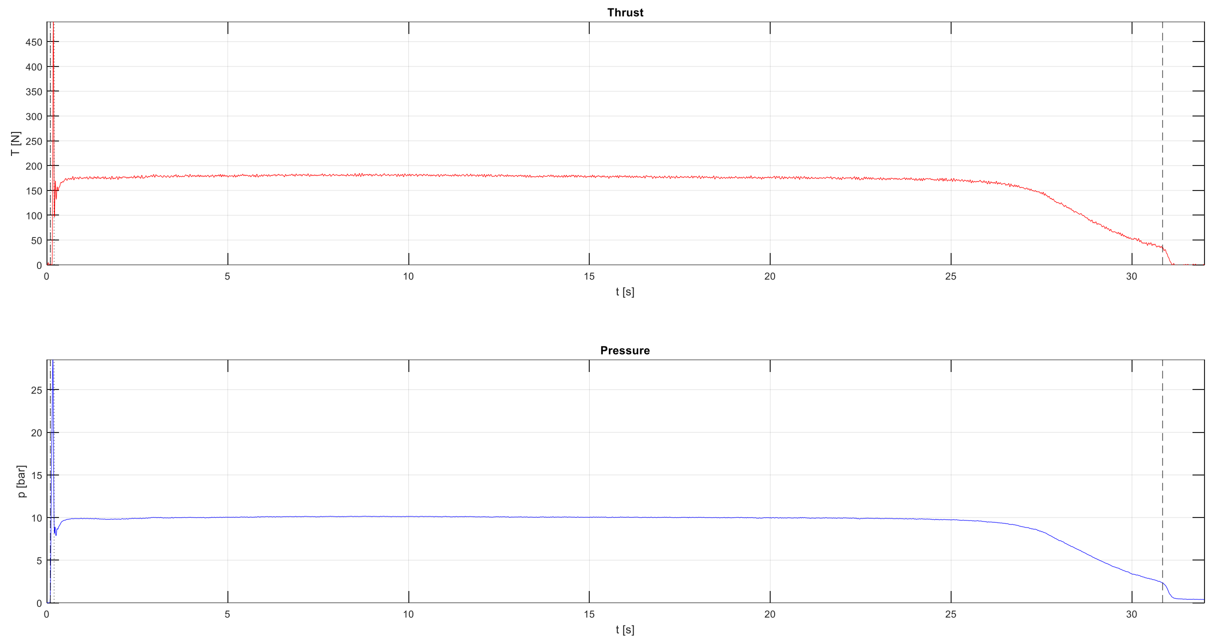
Propellant composition



- Burn rate suppressants
  - Explosives
  - Metalized compounds
  - Suppressants
  - Flame retardants

Initial composition (theoretical) → AP content optimization → Suppressant selection (tests) → Selection of final composition

Propellant composition

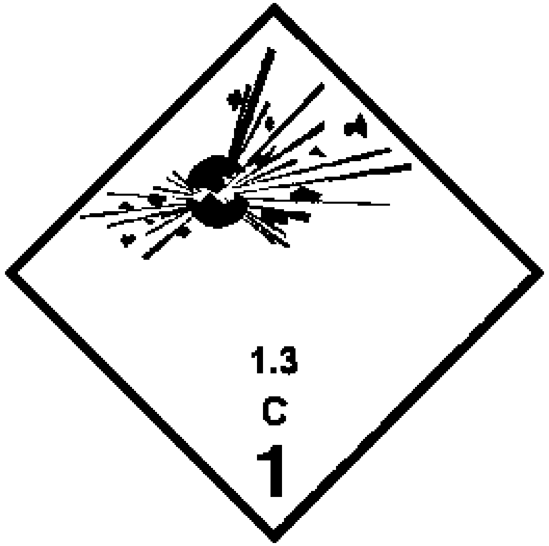


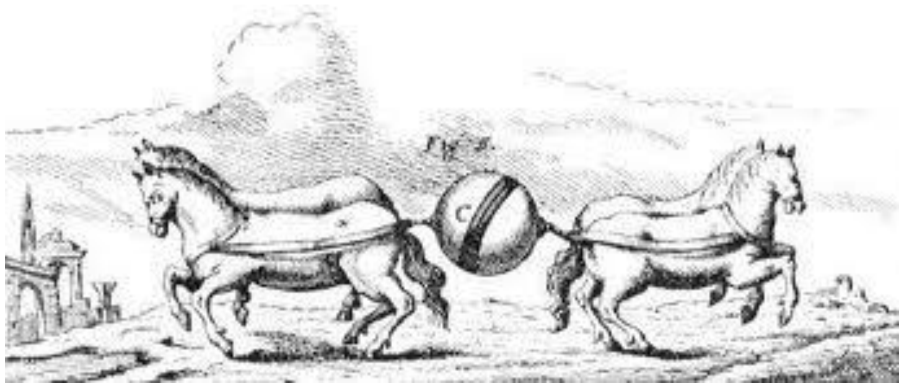
Final composition	
• Ammonium Perchlorate (bimodal)	
• HTPB system (binder, curing agent, plasicizer)	
• Oxamide	

Basic properties	
Density	1.71 g/cm^3
Burn rate (@ 10 bar)	2.85 mm/s
Theoretical I_{sp} (vacuum, 92% efficiency)	276.0 s
Demonstrated I_{sp} (static test, sea-level nozzle)	174.3 s
c* efficiency (static test)	89.9%

Propellant testing

- Safety assessment
  - Standardized test set: internal ignition, impact sensitivity, friction sensitivity, thermal stability, small-scale burning, decomposition temperature
  - Official ADR classification – 1.3C

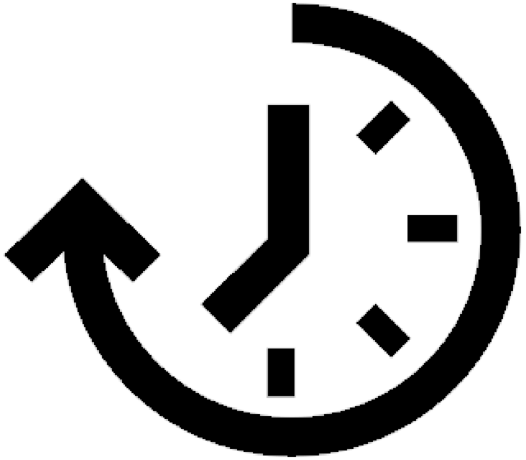




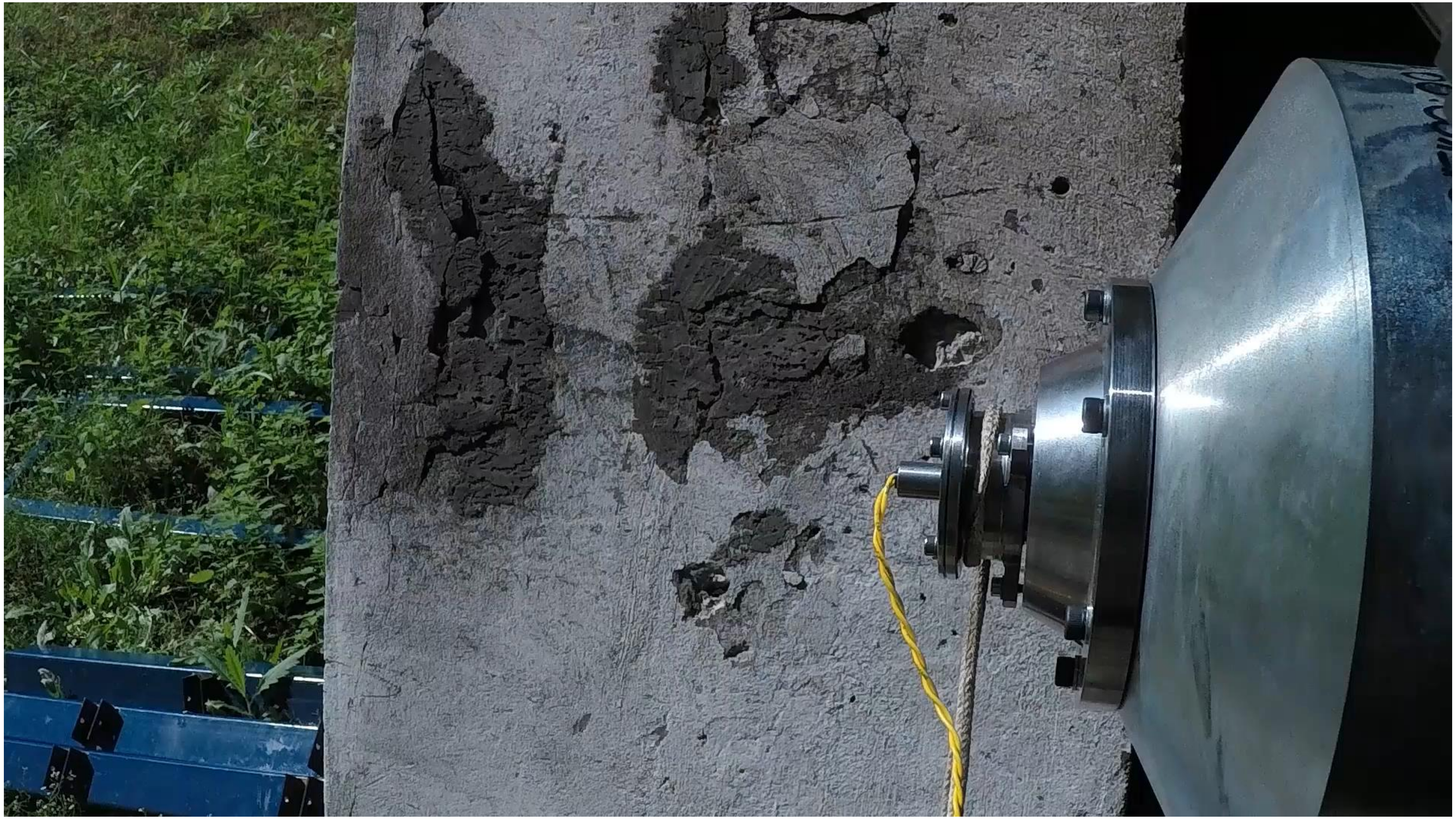
- Vacuum
  - No significant change in mass and properties observed

Propellant testing

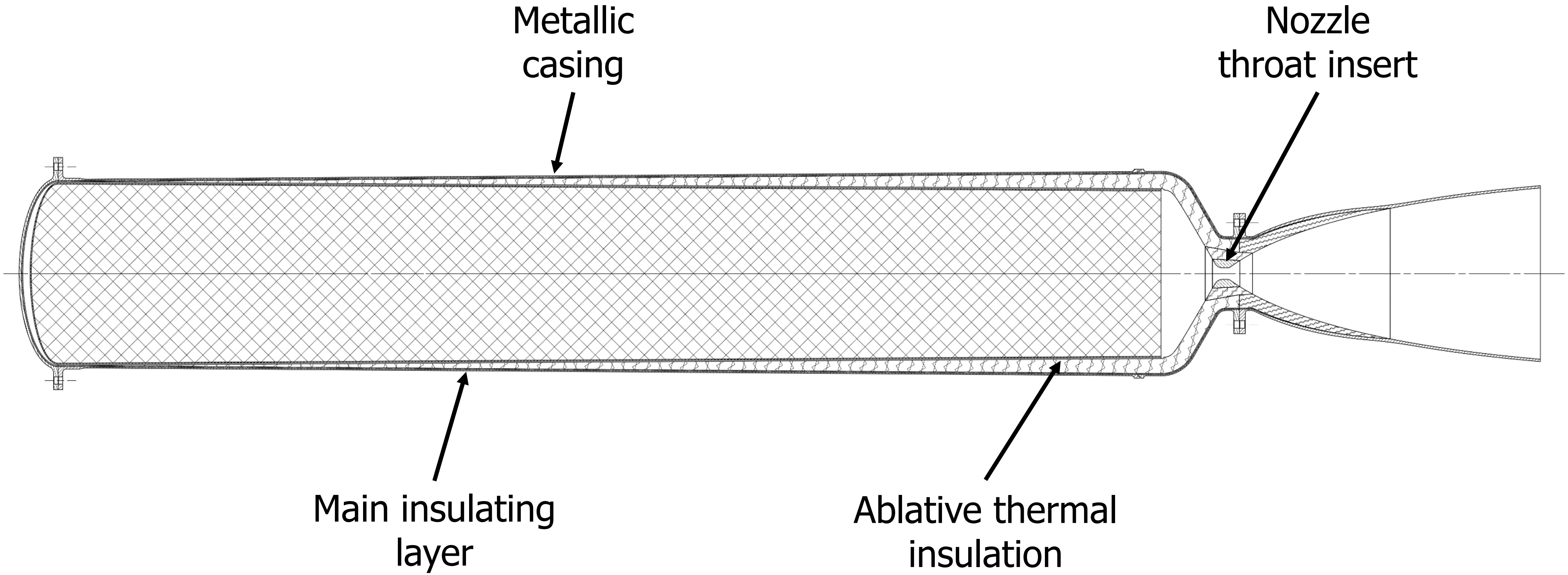
- Ageing
  - Accelerated aging up to 10 years storage equivalent
  - Marginal properties change but significant sensitivity drop



- Radiation
  - Total dose – 10 kGy (1 megarad)
  - No impact on burn rate and only minimum on strength



SRM outline

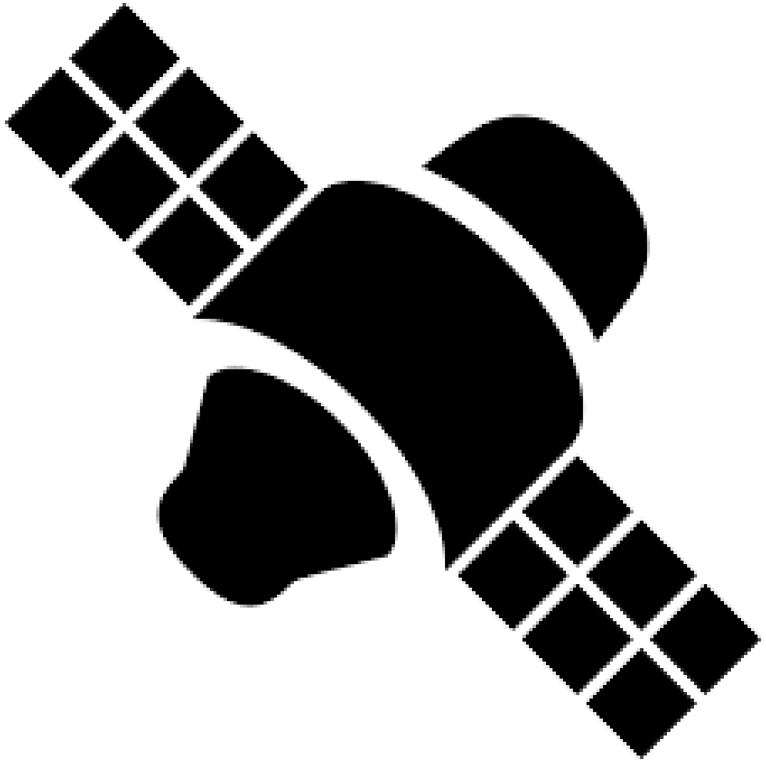

Metallic casing
Nozzle throat insert
Main insulating layer
Ablative thermal insulation

TVC outline

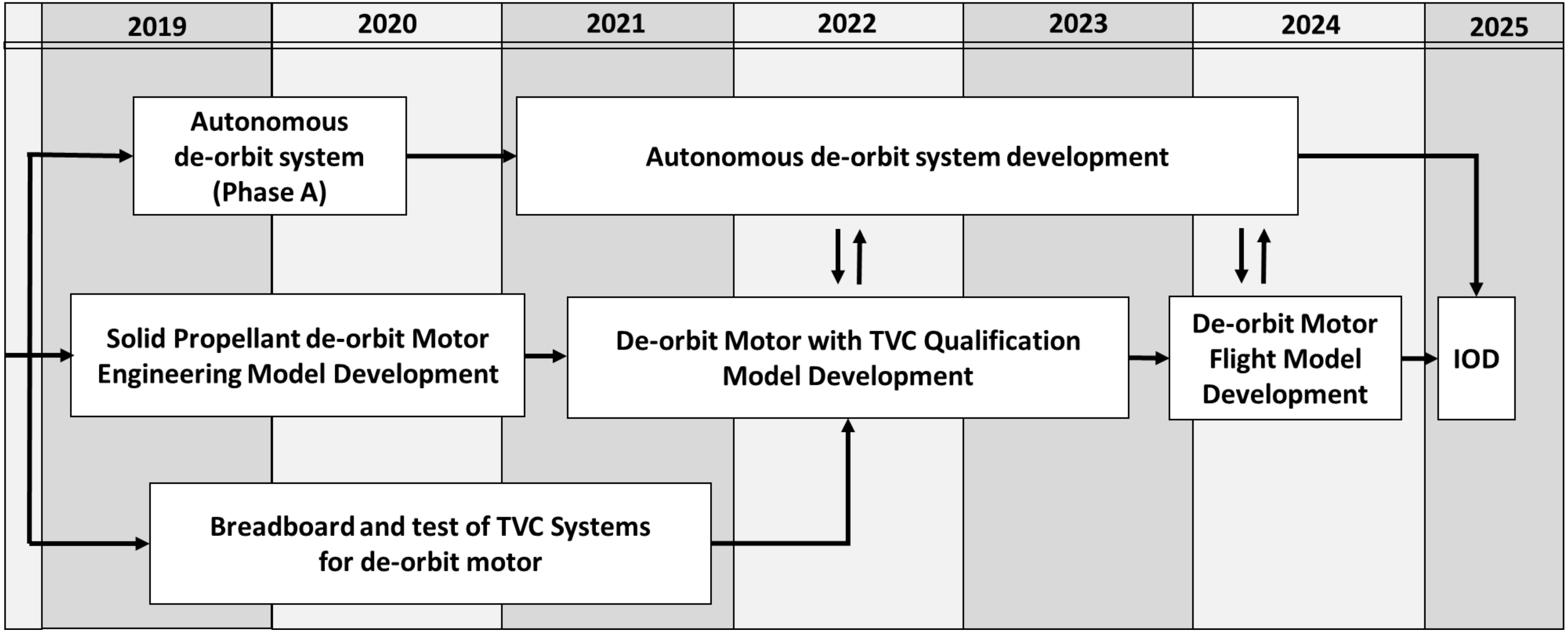
- Outside jet vanes configuration
- Subsystem elements
  - Rotary actuator
  - Planetary gearbox
  - Deflector flaps
  - Controller
  - Power supply
- Further mass improvement required

System-level integration

- Cluster configuration
- Integration with spacecraft
- Interfaces
- Thermal control and AOCS
- Considered mounting solutions:
  - Inside the satellite, to the side wall
  - Inside the satellite, to the bottom wall
  - Cluster mounted to the launch vehicle adapter
  - Mixed approach is also possible



Development roadmap



Conclusions

- Using solid rocket propulsion is advantageous for deorbitation
- Development of a dedicated propellant composition was required to meet the requirements
- Trade-off between specific impulse and burn rate was undertaken
- Propellant pre-qualifying tests are in progress
- Preliminary SRM design gives outlook for future work

Thank you for your attention

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