Institute of Aviation
Warsaw, Poland, since 1926

CONCEPTUAL DESIGN OF SOLID ROCKET MOTOR FOR DEORBITATION AND ADVANCES IN THE DEVELOPMENT OF AN ALUMINIUM-FREE SOLID PROPELLANT

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KEY ISSUES

INTRODUCTION

- Institute of Aviation
- CleanSpace – IoA
- Problem definition

SRM FOR DEORBITATION

- Concept
- CleanSat Building Block outcomes
- Current work

SUMMARY

- Challanges
- Conclusions

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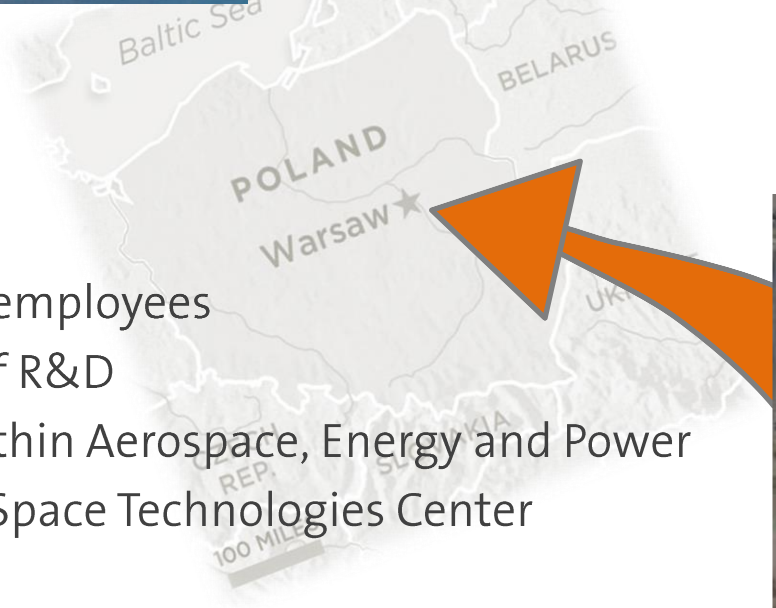
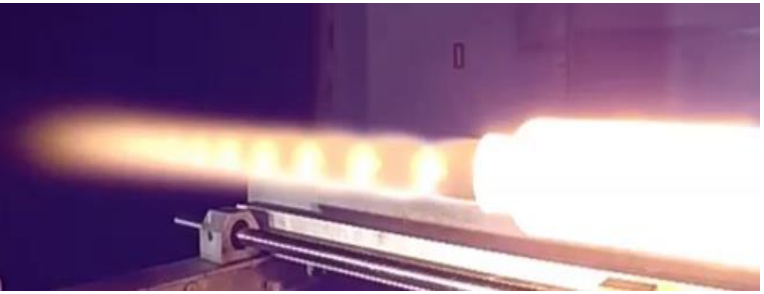


- Over 2300 employees
- **90 years** of R&D
- Projects within Aerospace, Energy and Power
- Dedicated Space Technologies Center

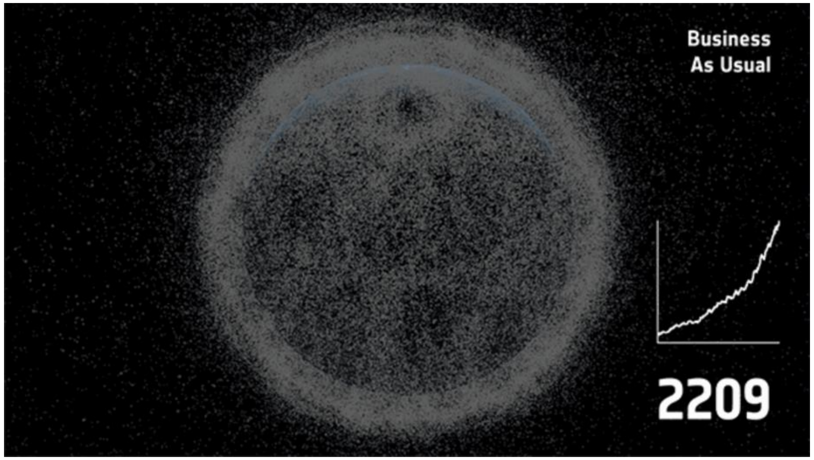


CST
Center of Space Technologies

- Sounding rocket project and launcher design
- Green **propellant development**
  (FP7, H2020, ESA PECS, ESA PLIIS, ESA TRP, ESA GSP, ESA GSTP)
- Hydrogen peroxide (98%+)
- Hybrid and liquid rocket engines,
  solid rocket motors
- Satellite **flight hardware**

INTRODUCTION

- Unresolved problem of space debris
- Future impact of mega-constelations
- End-of-life disposal
- The 25-year rule



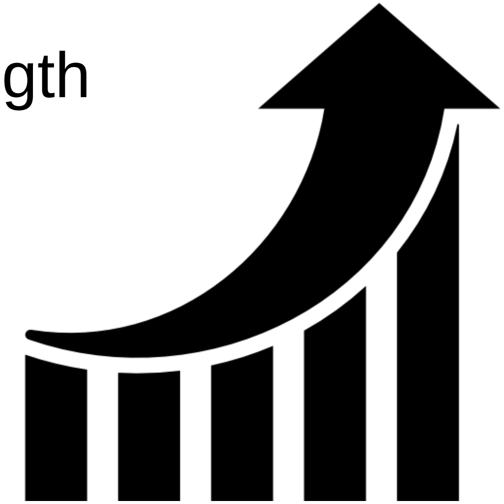
Source: ESA (esa.int)

cleansat

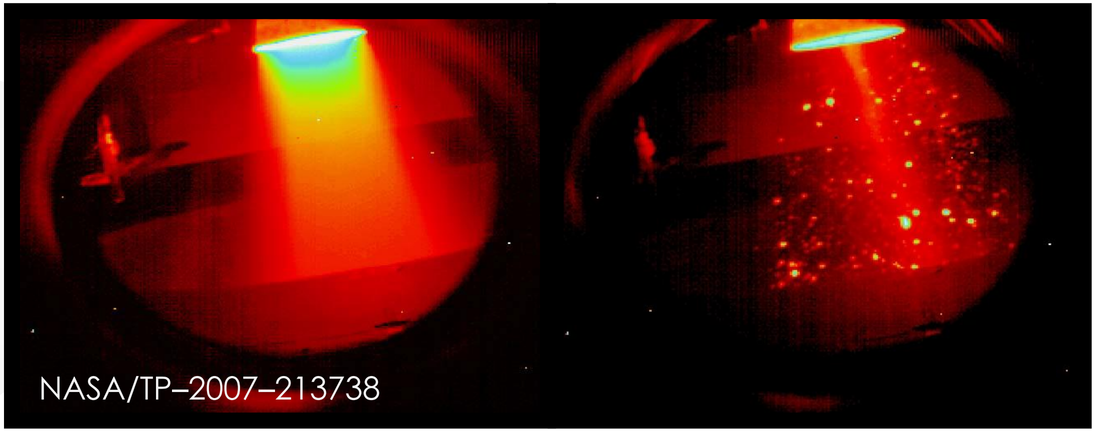
→ SPACE DEBRIS REDUCTION

ADVANTAGES
OF SOLID ROCKET MOTORS FOR DEORBITATION

- Compact size
- Autonomus system
- No temptation to expand mission length
- Direct deorbitation
- Near-to-constant thrust is possible
- Relatively high performance
- Storability
- No toxicity



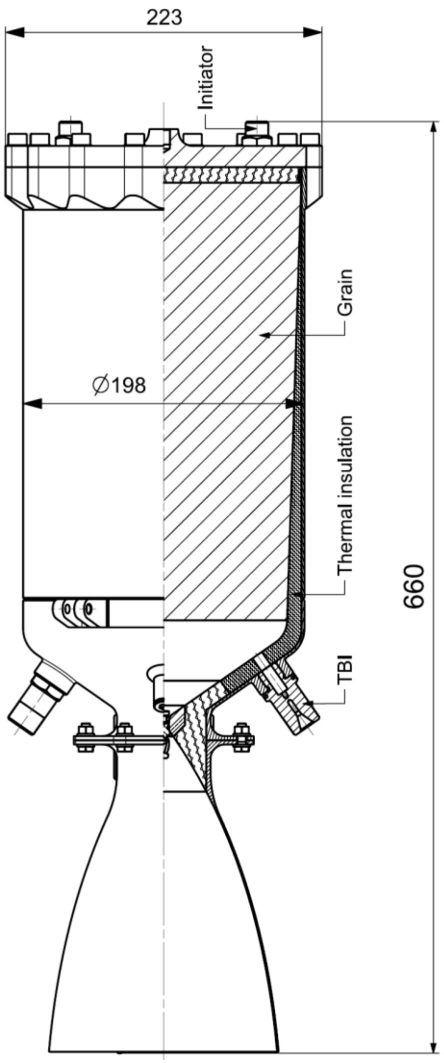
DESIGN ISSUES

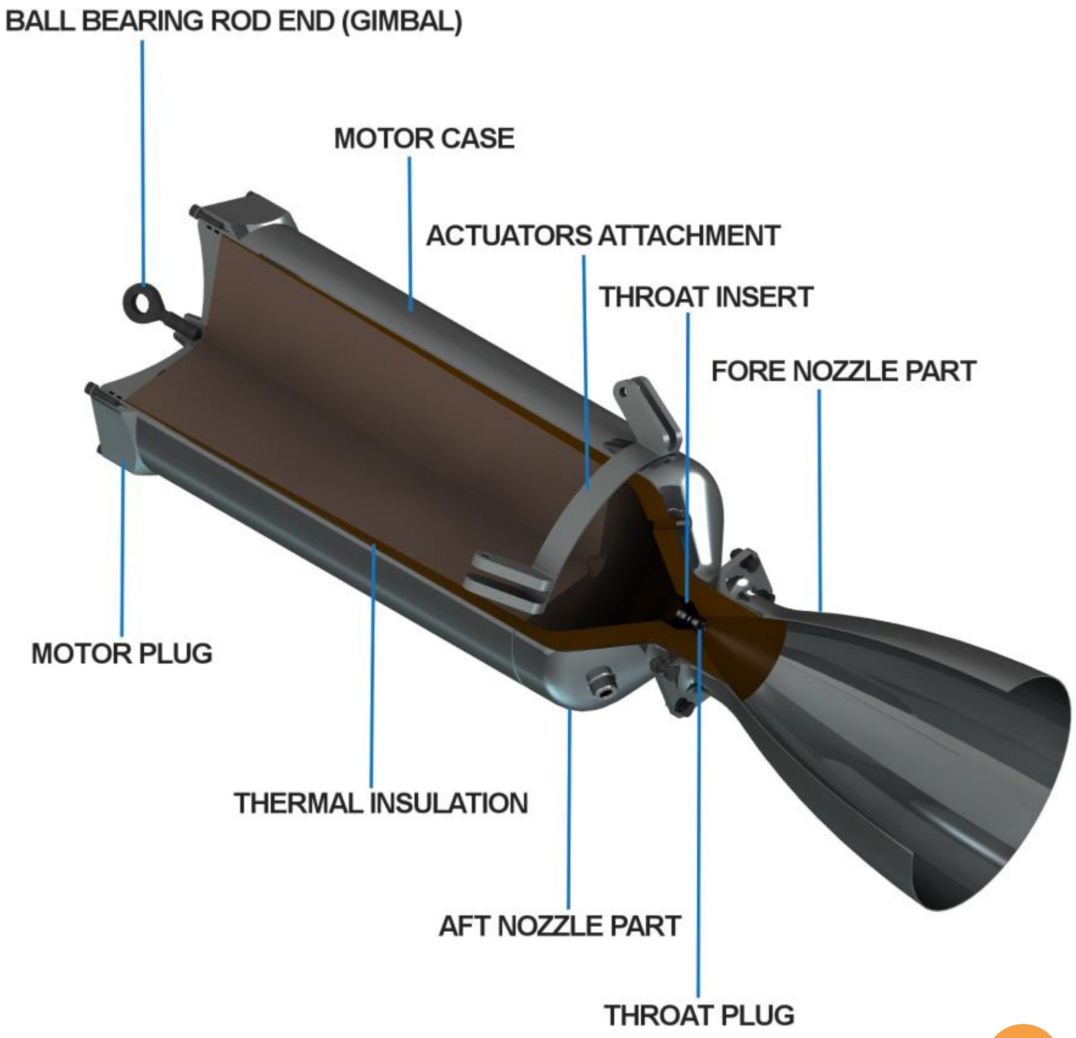

NASA/TP–2007–213738

HIGH THRUST → end-burning motors with low burn rate should be used

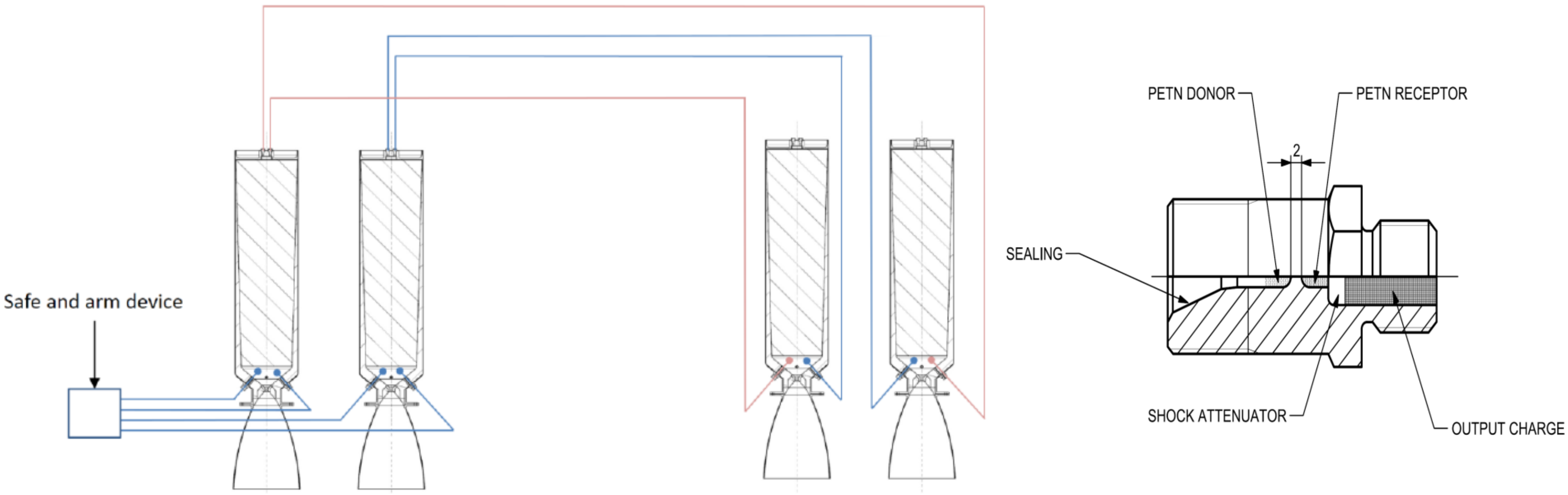
PARTICLE GENERATION → non-aluminised propellants

SRM DEVELOPMENT



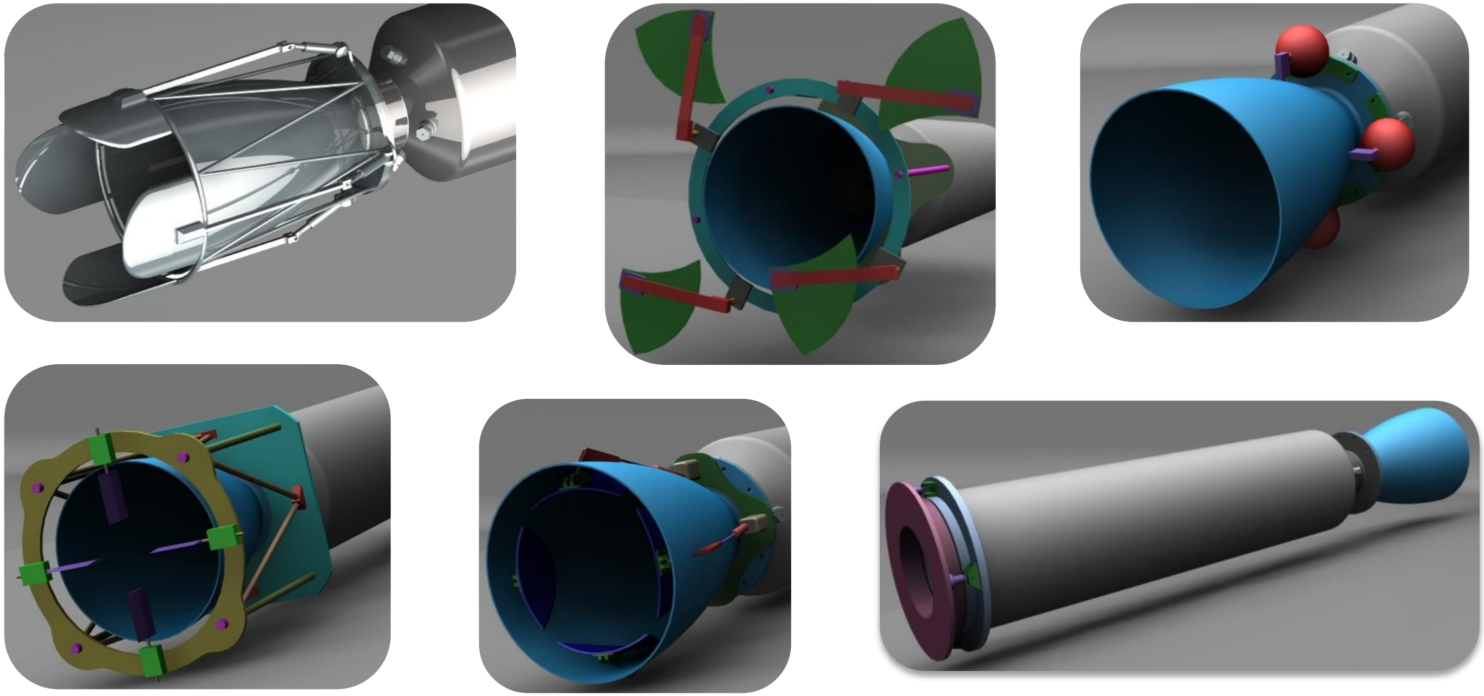


IGNITION CHAIN



- Clustering requires a reliable ignition system
- Shielded Mild Detonating Cords
- Redundant lines
- Thru-bulkhead Initiators

THRUST VECTOR CONTROL



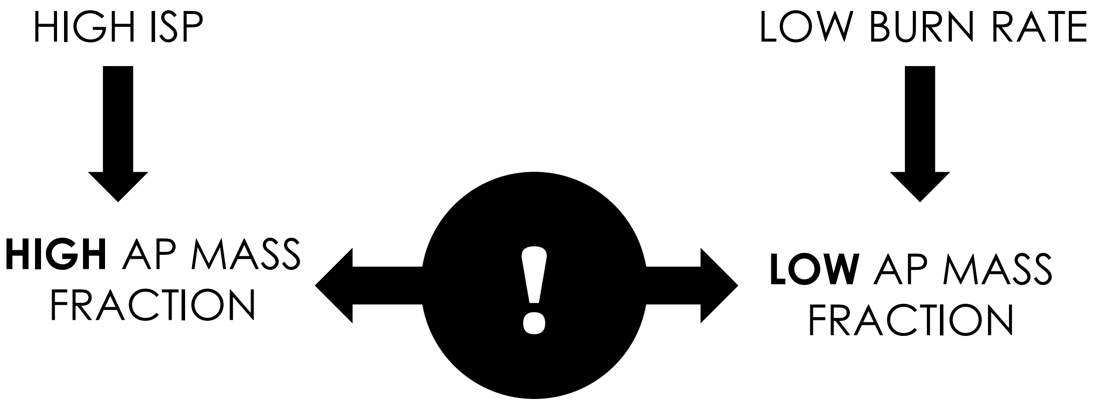
- Use of TVC is required
- Impact on SRM design
- Thrust vector must be alligned with S/C CoG

EXAMPLE SYSTEM DESIGN

Name	Value [kg]
Propellant	14.82
Thermal insulation	1.83
Nozzle	1.08
SRM total mass	22.14
SRM dry mass	7.33
SRM structural coefficient	0.33
Frame mass	1.56
TVC system	2.88
Total	26.59

COMPOSITE PROPELLANT

- High Isp, long storability, low burn rate, no solid particles generation
- Rejection of a wide range of typical additives
- AP/HTPB are most beneficial in terms of performance

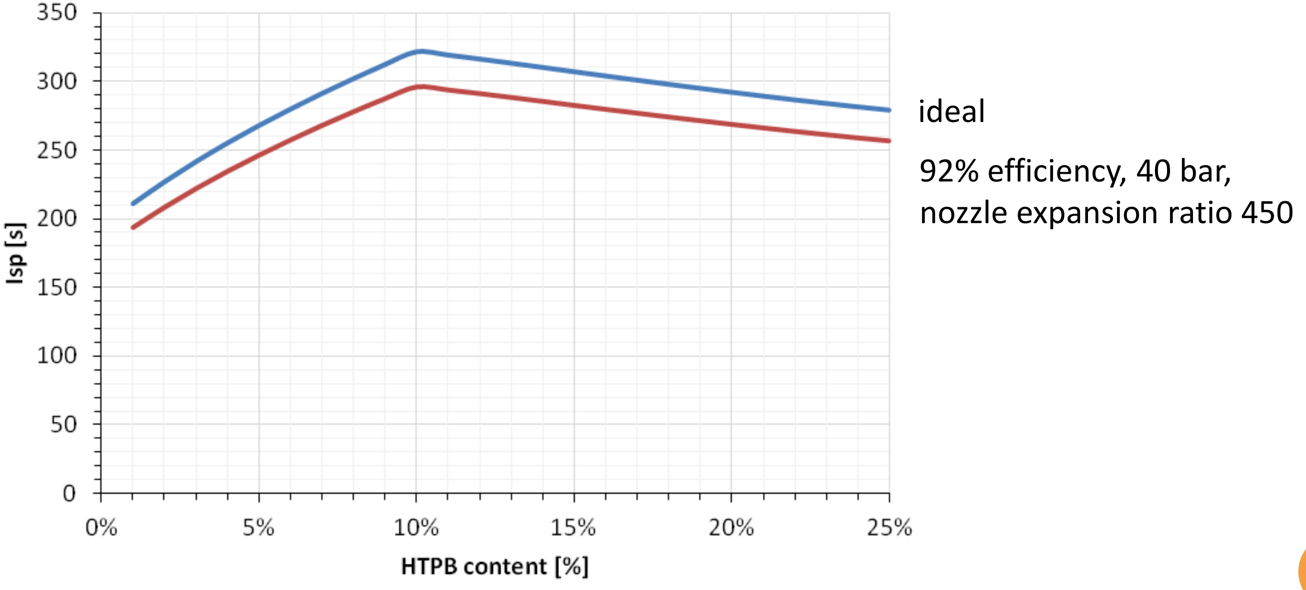


HIGH ISP

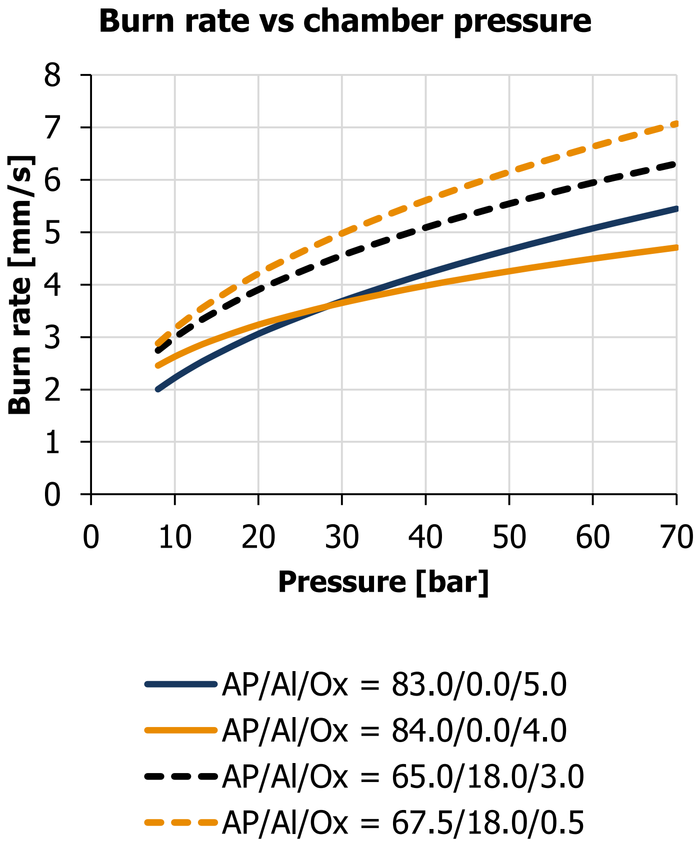
HIGH AP MASS FRACTION

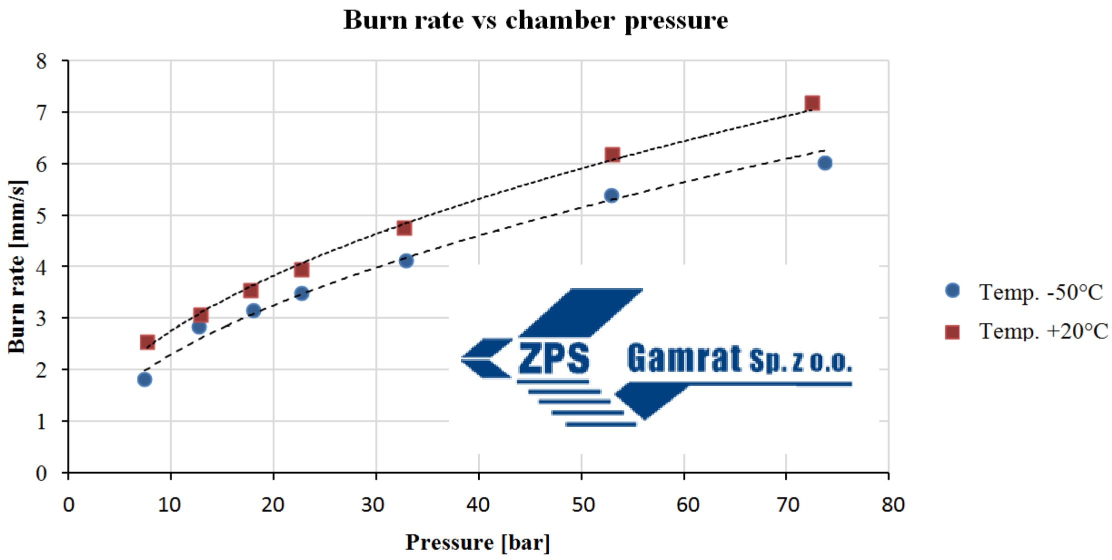
LOW BURN RATE

LOW AP MASS FRACTION



INITIAL PROPELLANT ACTIVITIES





- ➢ Proof of concept

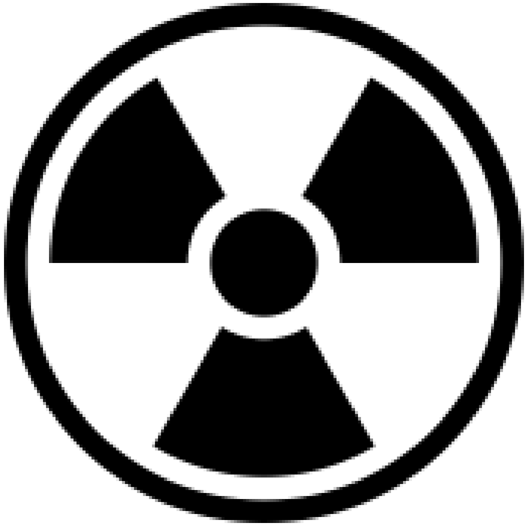
CURRENT PROPELLANT DEVELOPMENT

Component	Content
Ammonium Perchlorate (AP)	80-89%
Hydroxyl-terminated Polybutadiene (HTPB)	10-15%
Other, including various burn rate suppressants	1-7%

Explosives	Metalized compounds	Burn rate suppressants with insufficient literature data		Flame retardants
BTATz, DAAF, DHT, FOX-7, HMX, RDX, TATB	Aluminum Hydroxide, Ammonium Bromide, Ammonium Tetrafluoroborate, Antimony(III) Oxide, Bismuth(III) Oxide, Calcium Carbonate, Calcium Oxalate, Calcium Phosphate, Iron(III) Oxide, Lithium Fluoride, Neodymium(III) Oxide, Picrite, Sicomin-Rot K3130 S, Sodium Fluoride, Strontium Carbonate, Titanium(IV) Oxide, Trimethoxyboroxene, Triphenylantimony(III), Zinc Bromide, Zinc Fluoride,	2-Cyanoguanidine, 2-Nitrobenzoic Acid, 3-Aminobenzoic Acid, 4-Aminoazobenzene, 5-Aminotetrazole, 8-Orthooxyquinoline, Ammonium Chloride, Ammonium Fluoride, Ammonium Fluorosilicate, Ammonium Hexafluorophosphate, Ammonium Iodide, Ammonium Oxalate, Anthracene, Benzoic Acid, Biuret, Bromobenzoic Acid, Chrysoidine, Diaminobenzene, Diammonium Bitetrazole, Diethyl-N,N-Bis(2-Hydroxyethyl)-Aminoethylphosphonate,	Ethyl Ester of 4-Nitrobenzoic Acid, Hexachloroethane, Hexamethylenetetramine, Hydroxylammonium Chloride, Hydroxylammonium Oxalate, IDDP, N,N,N′,N′-Tetramethyl-1,3-Butanediamine, N-Bromosuccinimide, Oxalohydroxamic Acid, Phenyl Ester of Salicylic Acid, Polyvinyl Chloride, Pyrocatechol, Salicylamide, Salicylic Acid, Semicarbazide Hydrochloride, Urethane	Ammonium Dihydrogen Phosphate, Ammonium Polyphosphate, Ammonium Sulphate, Azodicarbonamide, Decabromodiphenyl Oxide, Dechlorane Plus (Occidental Chemical), Diammonium Phosphate, Diphenylamlne, Firemaster 836, Hexabromocyclododecane, Melamine, Oxamide, Pentabromodiphenyl Ether, TBPD, Urea

PROPELLANT STORABILITY

- Space radiation impact
- Oxidizer and binder decomposition
- Significant properties change for high doses (>25 Mrad)
- Modification of binder by introducing aromatic rings
- Further tests required
- Vacuum impact



CHALLENGES

Combining high performance and low burn rate

Low-mass thermal insulation

Nozzle throat insert for long duration firings

Burst disk with minimal element ejection

the developed concept is in line with ESA IPOL Space Debris Mitigation requirements ☑

CONCLUSIONS

- Consortium capabilities have been proved throughout initial activities (internal research + 2 ESA projects)
- Institute of Aviation has the goal of providing a new solution for the benefit of the European market
- Initial results show that SRM are promising for S/C deorbiting

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