Bowman Dynamics
MESKO ZPS Gamrat Sp. z o.o.

Institute of Aviation
Warsaw, Poland, since 1926

DEVELOPMENT OF ALUMINIUM-FREE PROPELLANTS AND SOLID ROCKET MOTORS FOR DEORBITING APPLICATIONS IN POLAND

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CST Center of Space Technologies

Center of Space Technologies
Institute of Aviation

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KEY ISSUES

INTRODUCTION

- CleanSpace-related activities
- Consortium
- Problem definition

PROPELLANT AND MOTOR DEVELOPMENT

- Propellant development
- Solid rocket motor concept
- System level aspects

SUMMARY

- Future work
- Conclusions

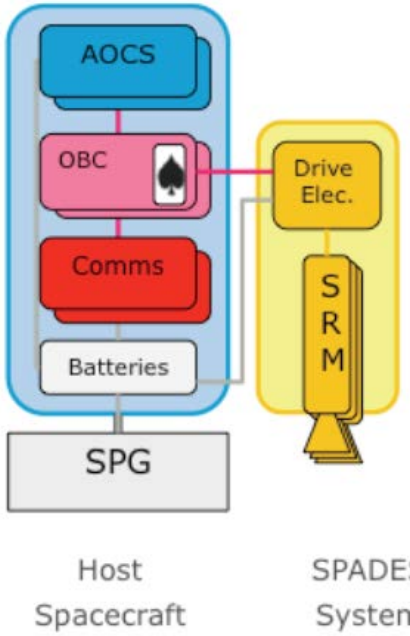
INTRODUCTION

e.deorbit
→ ACTIVE DEBRIS REMOVAL

ecodesign
→ ENVIRONMENTAL IMPACTS

cleansat
→ SPACE DEBRIS REDUCTION

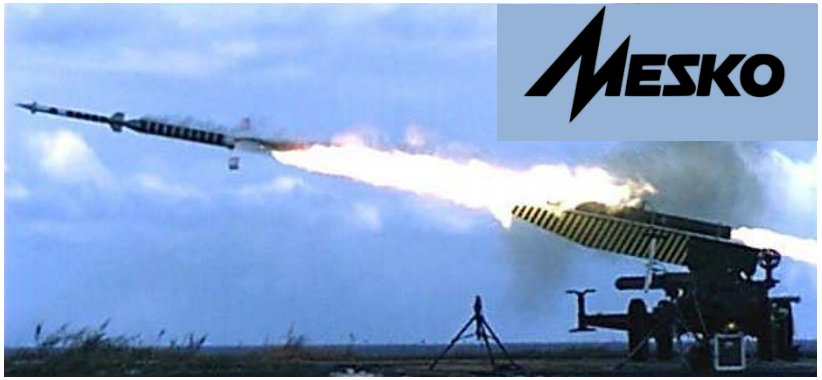
Clean Space Days 2016, ESTEC



Clean Space Workshop 2015, ESTEC

INTEREST IN SRM WITH ALUMINIUM-FREE PROPELLANTS

CONSORTIUM



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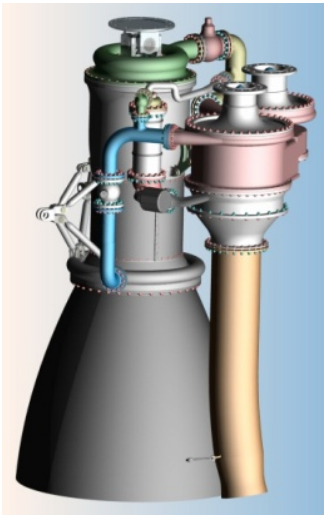
research for future

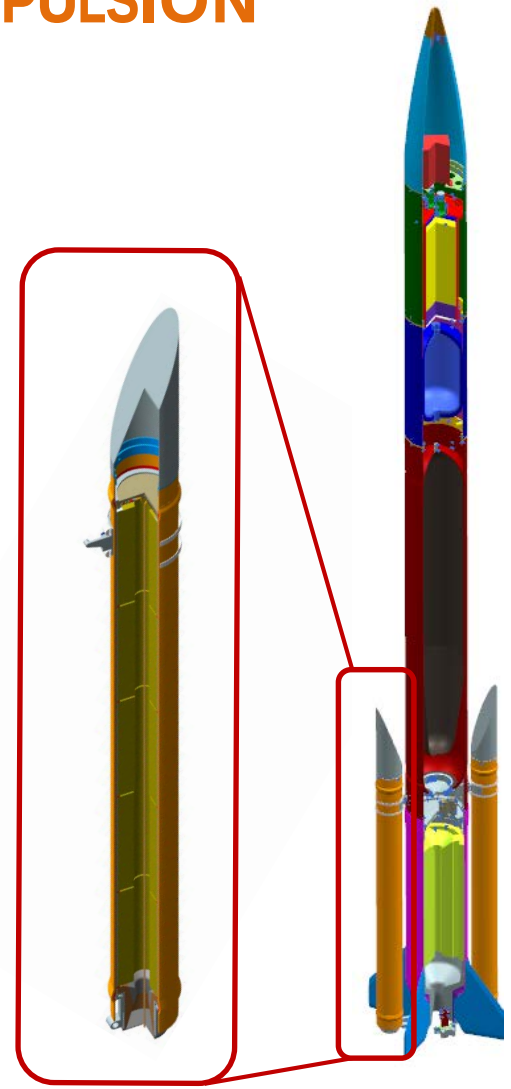
INSTITUTE OF AVIATION - EXPERTISE

- Sounding rocket and launcher projects
- Green **propellant development**
  (FP7, ESA PECS, GSTP, GSP, H2020)
- Hydrogen peroxide (+98%) manufacturing
- Hybrid and liquid rocket engines
- Satellite **flight hardware** experience



EXPERIENCE IN SOLID ROCKET PROPULSION

- Meteor sounding rocket program
- ILR-33 „Amber” sounding rocket
- Solid rocket propellant laboratory research
- Tactical ballistic missile



SOLID ROCKET MOTORS

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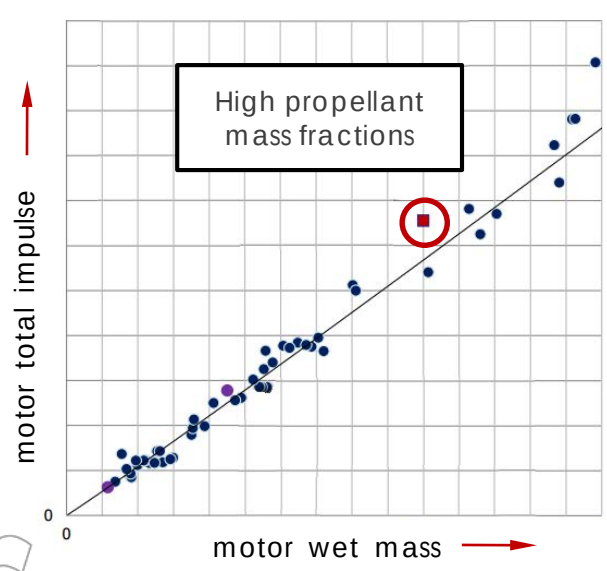
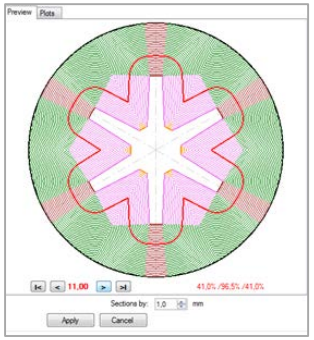
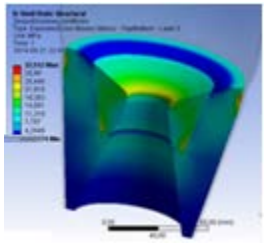
- Solid rocket motors
- Missile defence projects
- ESA ESERO rocket
- Analysis, design, software







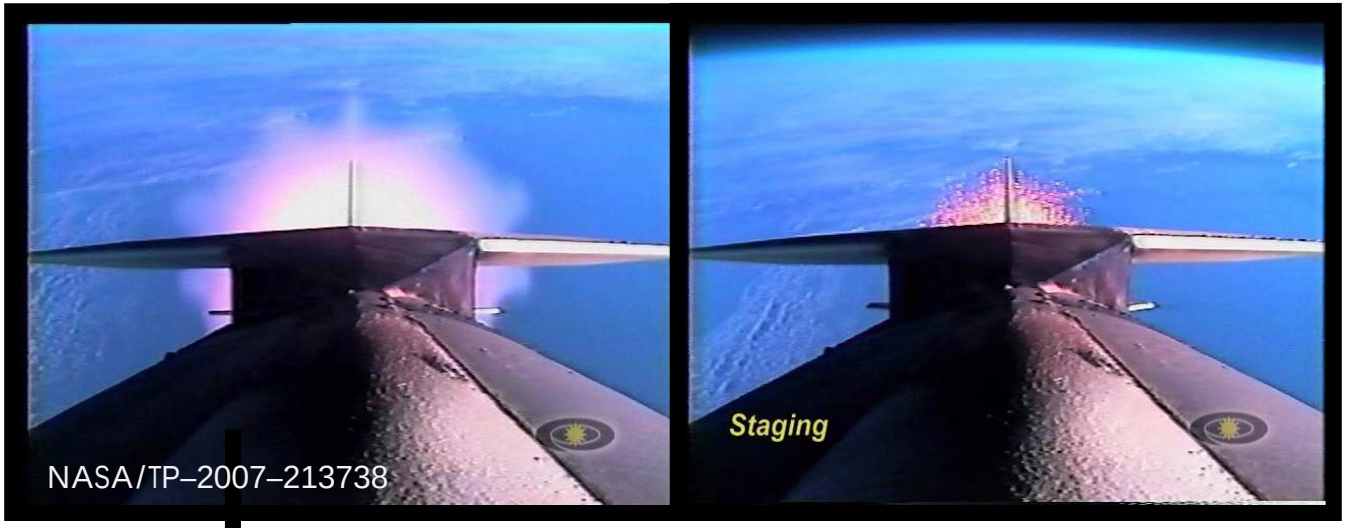
WHAT ARE THE **PROBLEMS** WITH EXISTING SOLID ROCKET MOTORS?

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

PARTICLE GENERATION → …

ALUMINISED PROPELLANTS

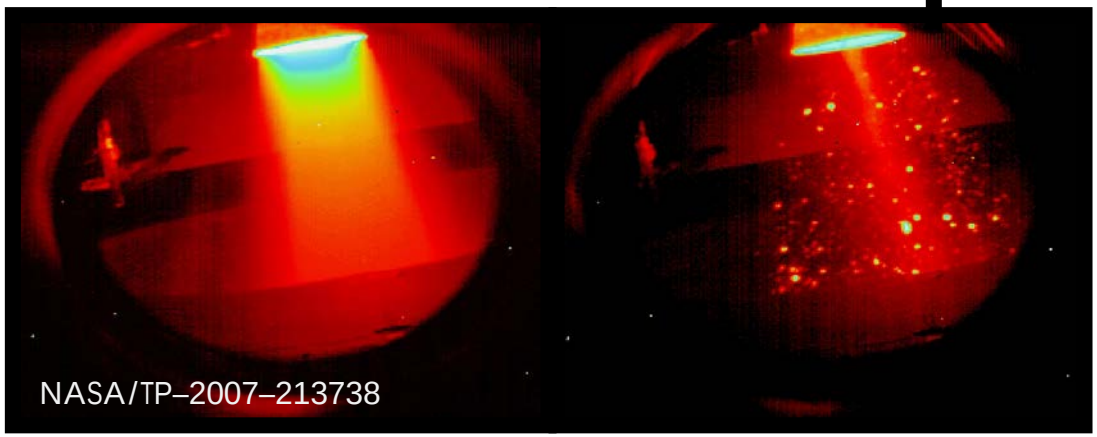
Problem definition



Pegasus first stage operation before seperation

- 5-10 µm Al_2O_3 particles during nominal firing
- At low pressure particles of 10 mm can be seen

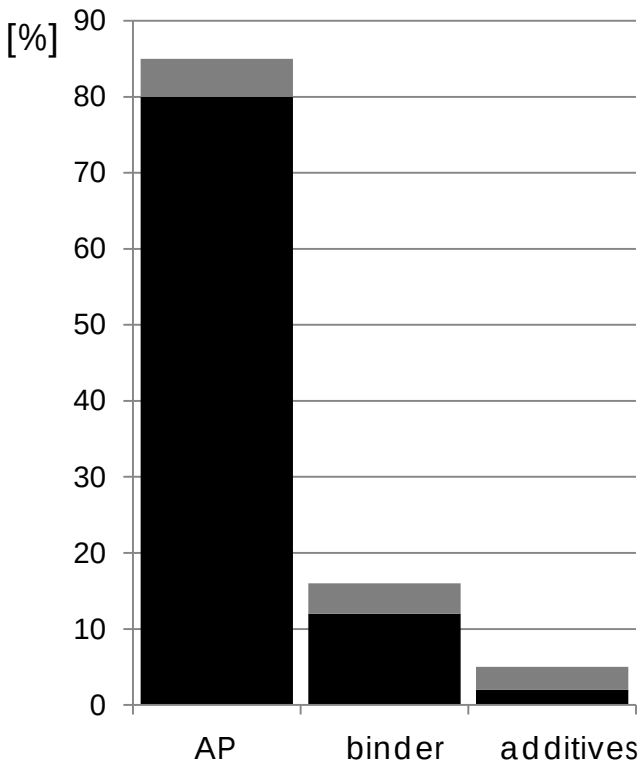
ATK STAR-37 test in vacuum chamber



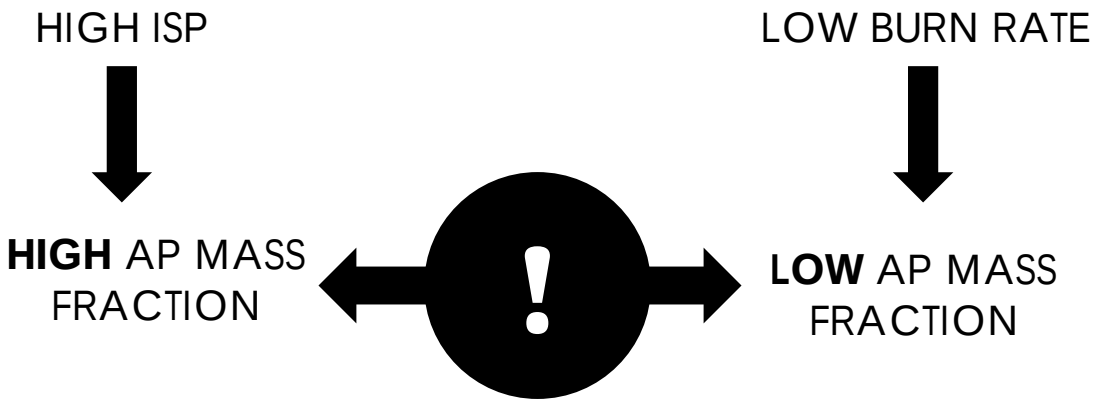
PROPELLANT SELECTION

- A **non-metalised** formulation
- **Bimodal AP** for good packing and **stability** of combustion (eliminating compounds like Al_2O_3, TiO_2)
- Lack of very fine fractions not to increase burn rate - well tuned bimodal compositions can have lower burn rates than unimodal ones!
- The vacuum **Isp** assuming a 92% efficiency is: **281.5 s**

(CEA: equilibrium flow, pc = 20 bar, $A_e/A_t = 450$)



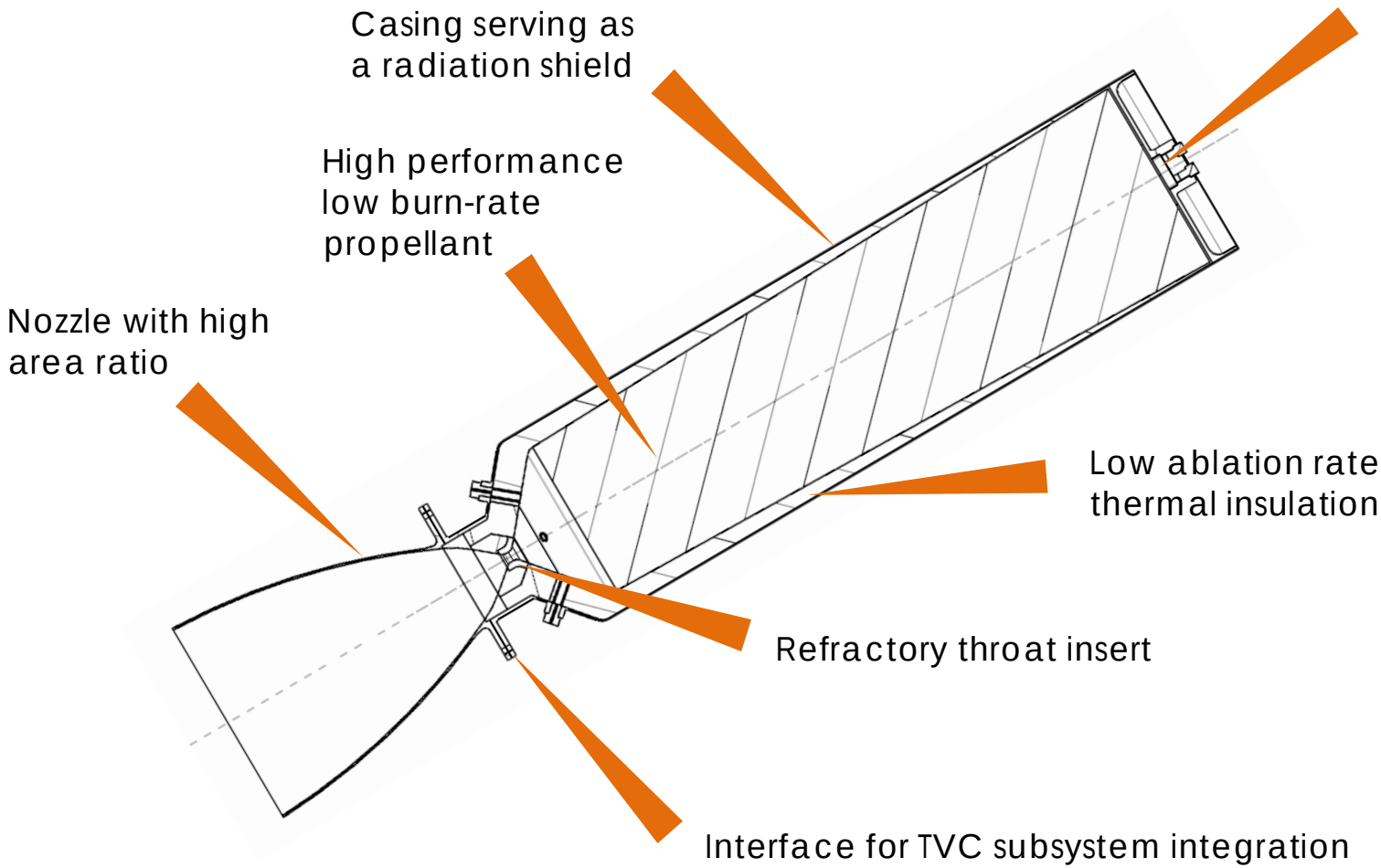
BURN RATE AND PERFORMANCE



SOLUTION: HIGH AP MASS FRACTION AND USE OF A BURN RATE SURPRESSANT

- There is an **upper limit** on AP content – due to increasing the viscosity of the propellant slurry during casting, what leads to **bubble contamination** of grains and the burn rate can not be controlled
- The upper limit of AP content can be incorporated in a propellant with decreasing particle size of AP. However, even for very corse AP the limit mass fraction is about **85 %**

MOTOR DESIGN



TRADE-OFFS TO BE DONE

- Aluminum alloy casing Vs. maraging steel
- Motor conditioning seal configuration
- Insulation geometry
- S/C mounting
- Nozzle submergence

GOALS

Cost minimisation
Performance optimisation

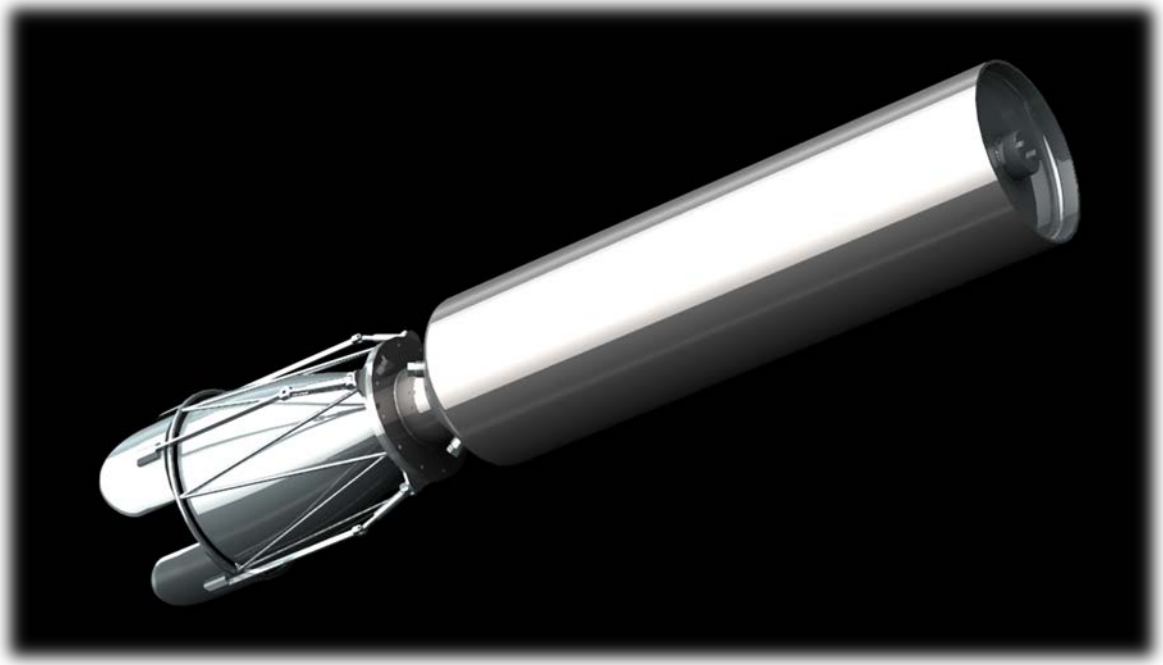
COMPLIANCE WITH REGULATIONS

- Low particle size in exhaust
  Elimination of Al_2O_3
  A non-classic burst disc
  Fully combustible thermal insulation
- Development using ECSS

in line with ESA IPOL
Space Debris Mitigation requirements

SYSTEM INTEGRATION

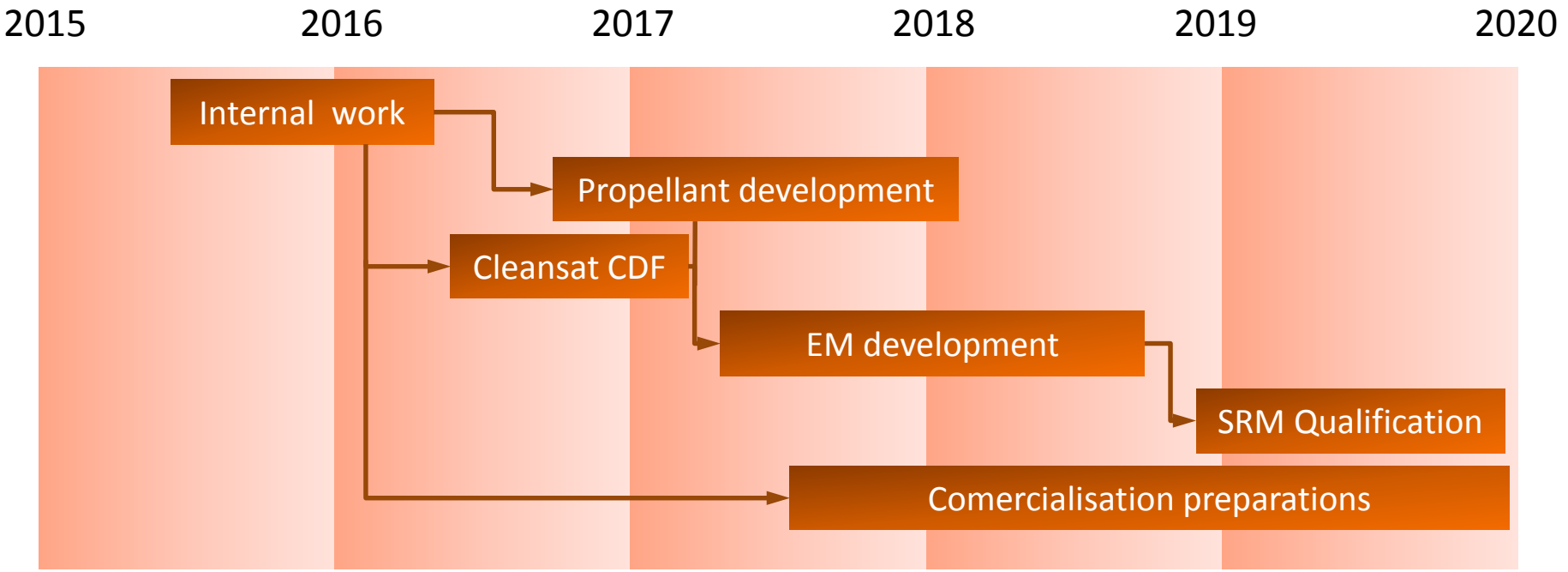
- Simple mounting on S/C
- Seperate TVC module
- Enhancing reliability
- Autonomous



Potential to develop TVC systems in Poland

DEVELOPMENT ROADMAP

Technology in-orbit-demonstration possible before 2020



SUMMARY

Experience with solid rocket motors ✓

Experience with flight hardware ✓

Experience with minimum-smoke propellants ✓

Development, testing and production capabilites ✓

Cost reduction perspective ✓

Bright prospects

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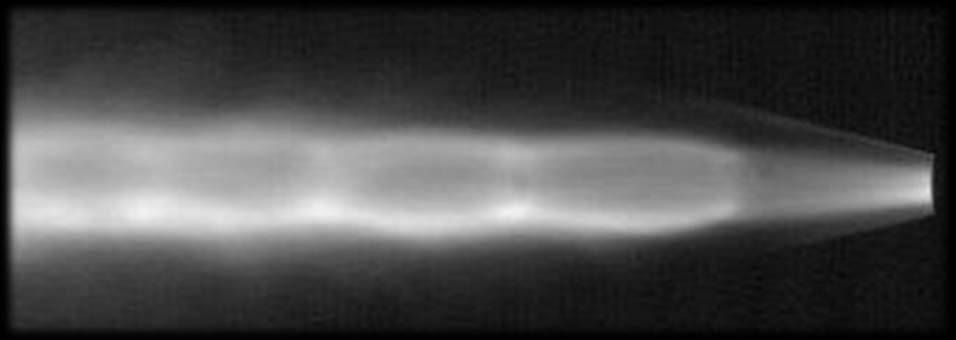

Thank you for your attention

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