DEORBIT MOTORS FOR ACTIVE DEORBITING

U. Gotzig

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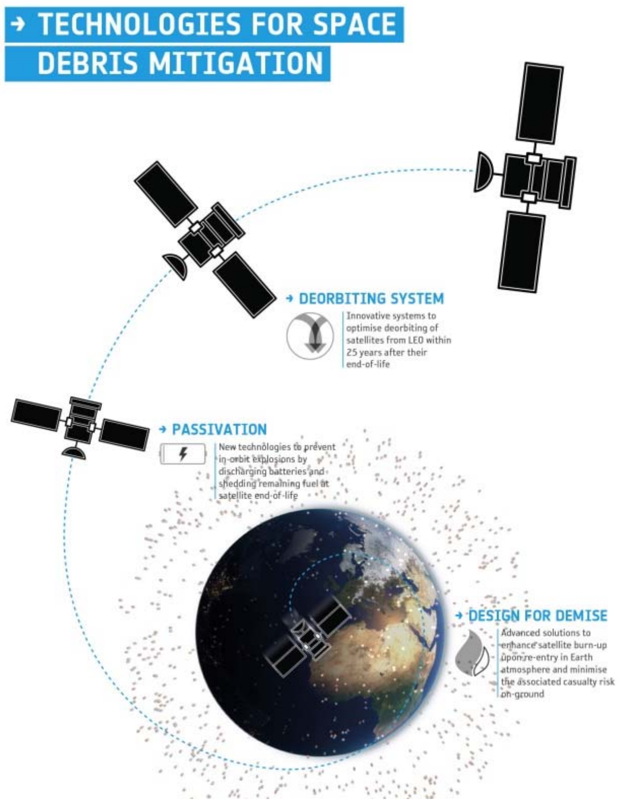
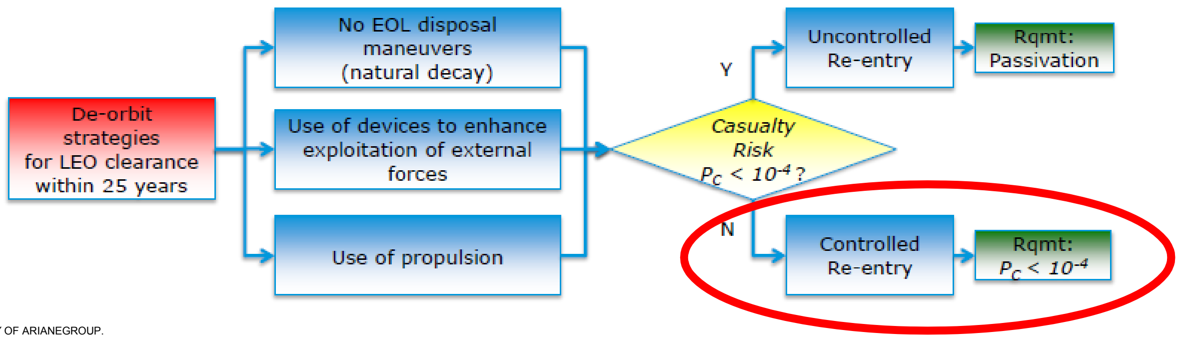
ESA Clean Space Industrial Days 2017

MOTIVATION AND MARKET FOR ACTIVE DEORBITING



Space Debris Mitigation and subsequent propulsion requirements

- **Design for Demise**
- **Passivation**
- **Active Deorbit Systems**
  - High Thrust, high Δv capability
  - Re-pressurization



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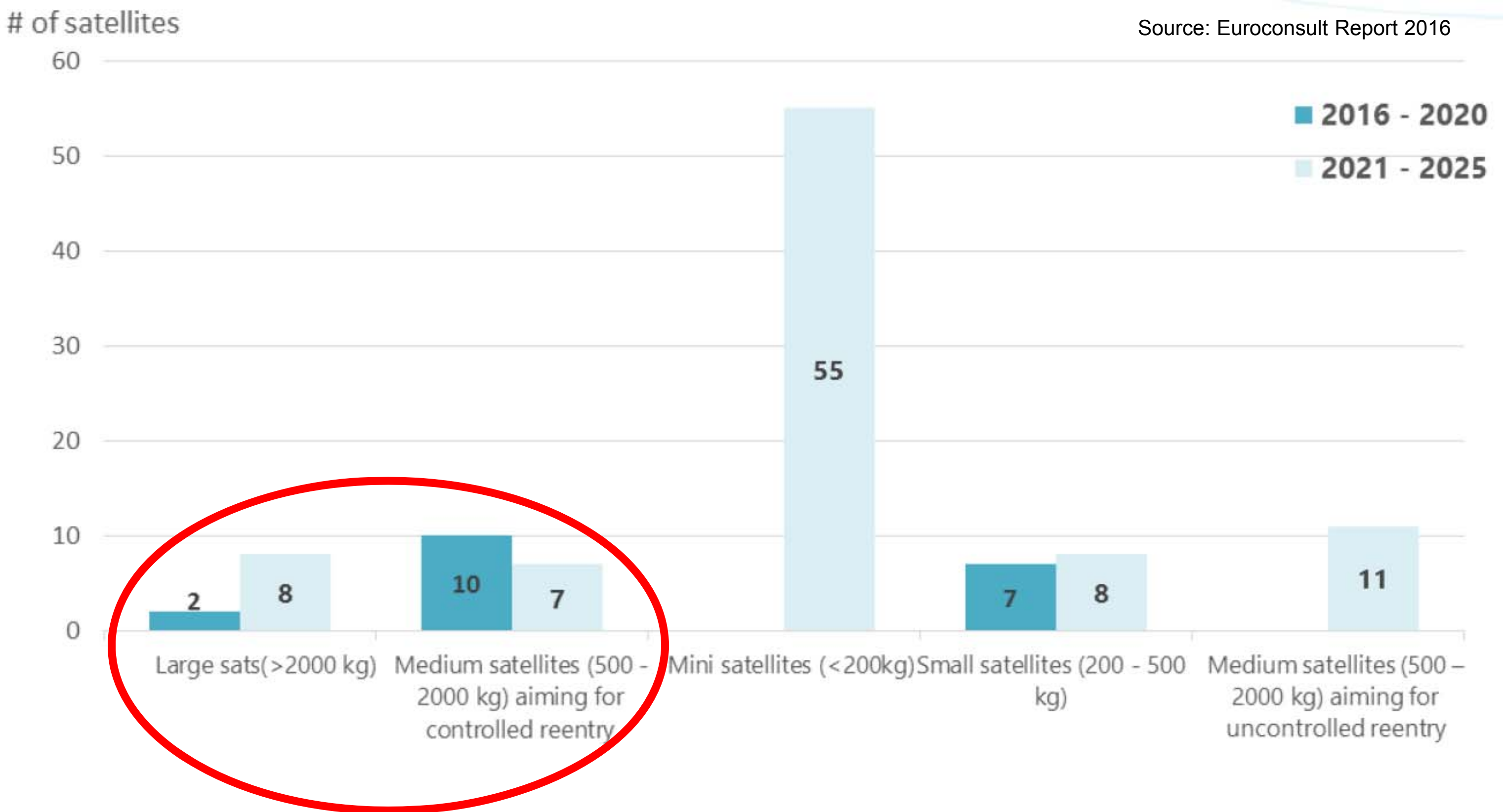
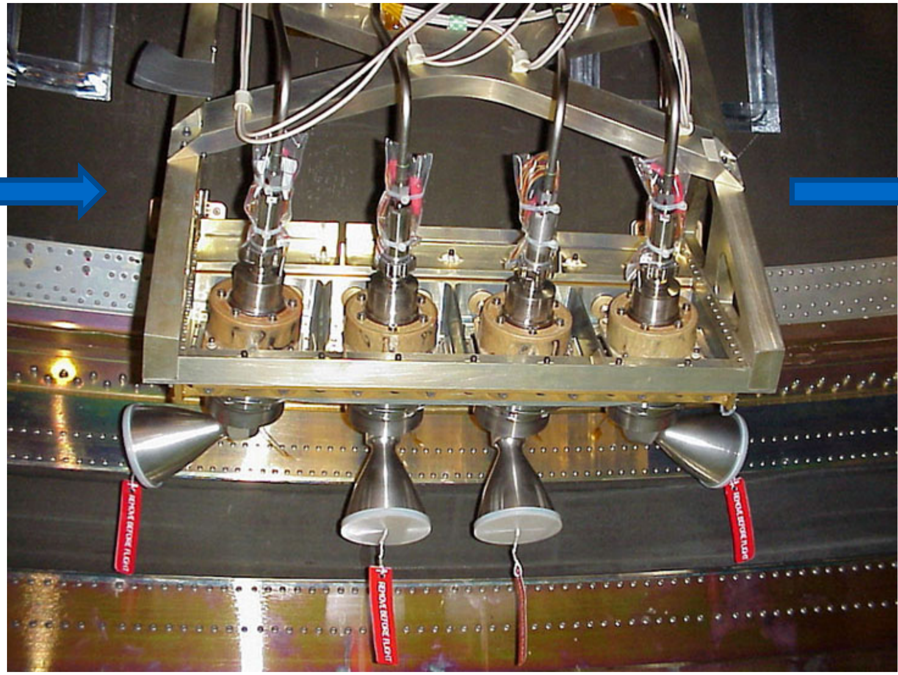
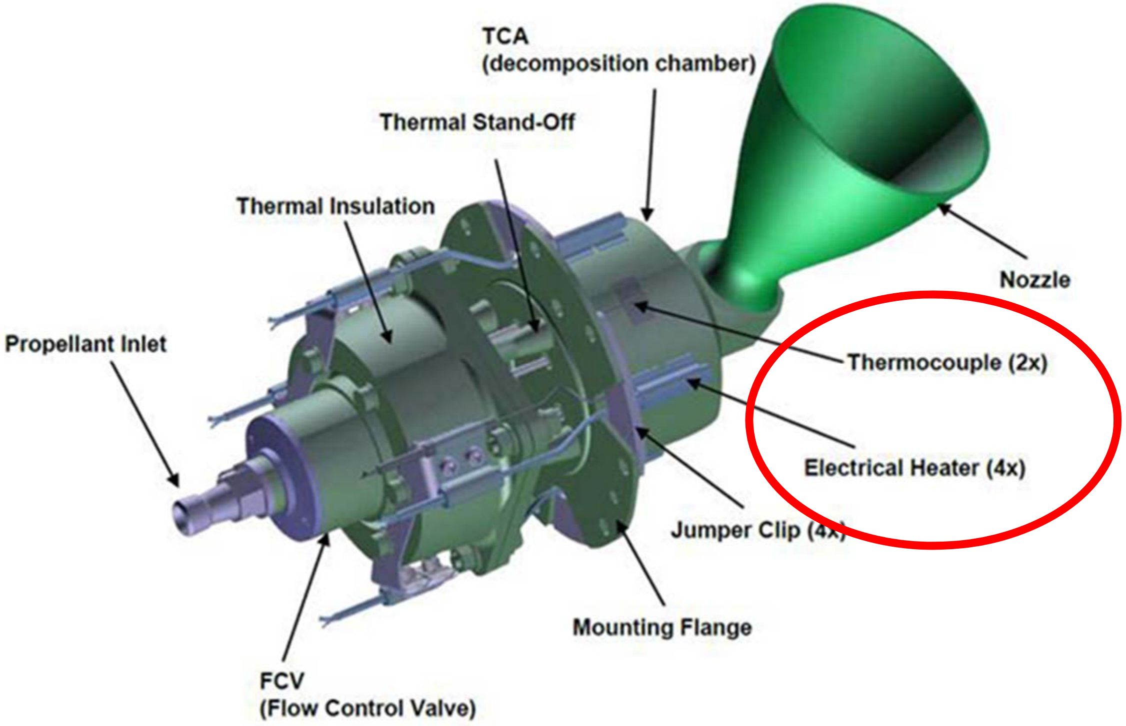


THE 400N SCA THRUSTER WAS QUALIFIED FOR DEORBITING



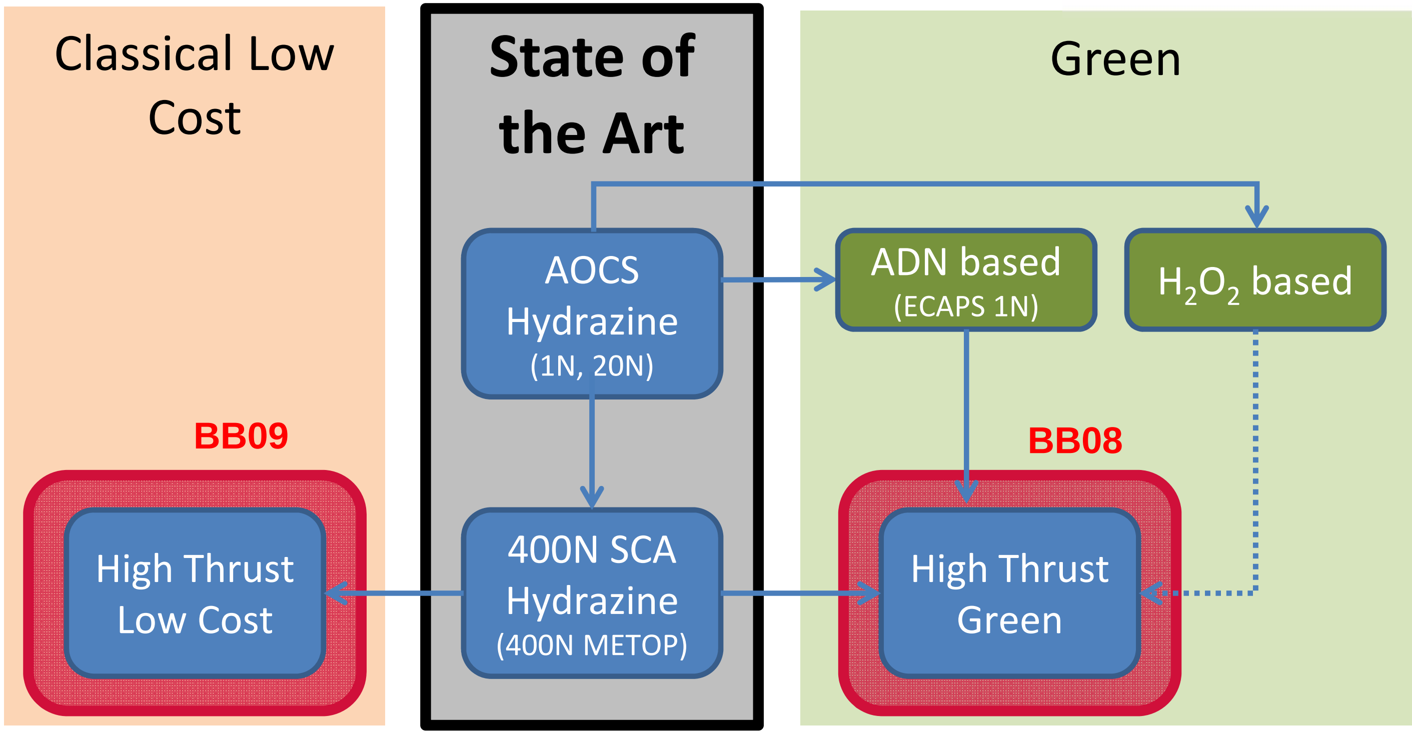
STATE OF THE ART EUROPEAN DEORBIT MOTORS



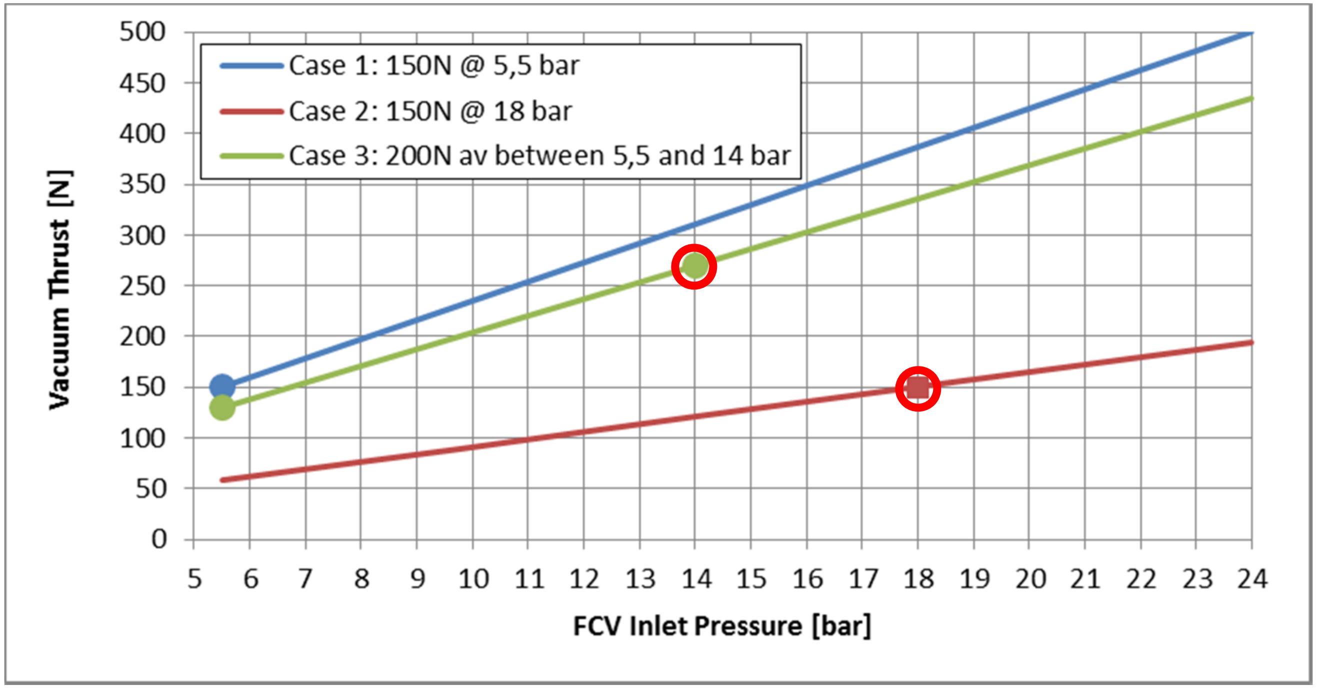
Standard 20N Hydrazine thruster can also be used for deorbiting

Nominal thrust / thrust range	**400N 120 .. 420N**
Specific Impulse	225 s
Total throughput	861 kg
Total pulses	11.852

WITHIN ESA CLEANSAT PROGRAM 2 DIFFERENT TECHNOLOGIES WERE INVESTIGATED



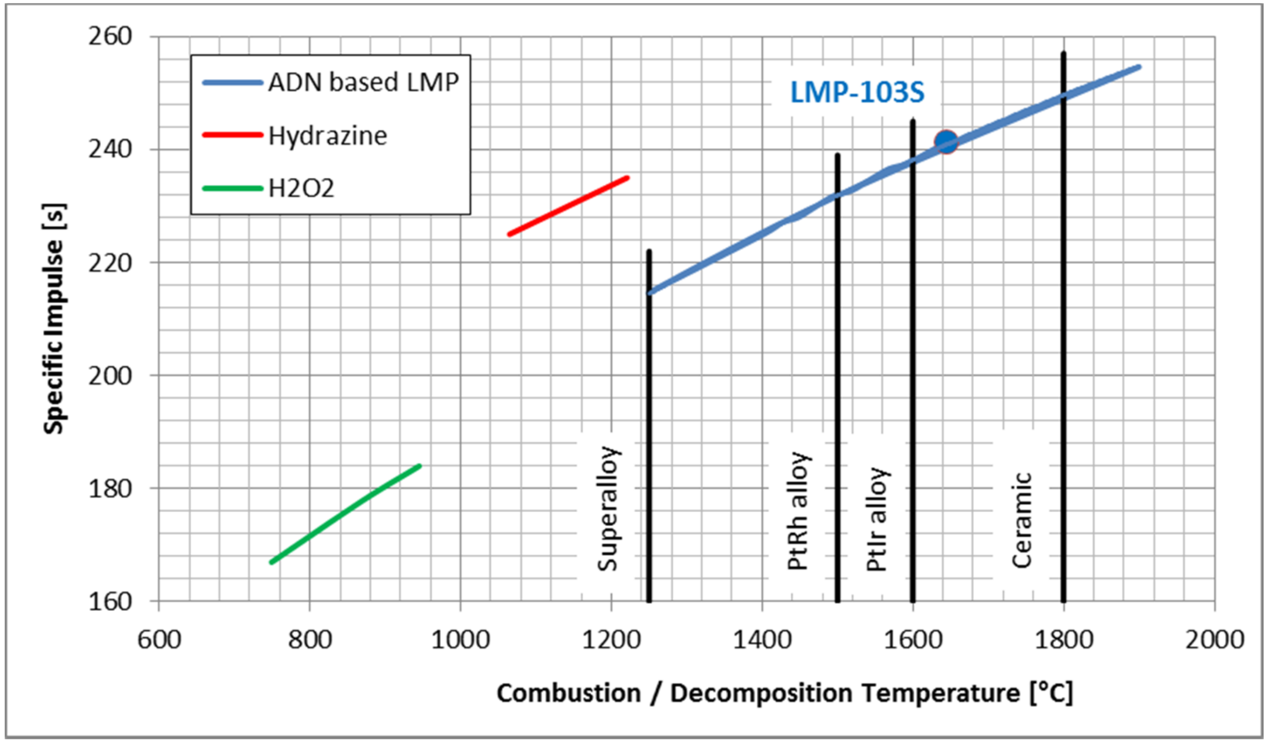
THE REQUIREMENTS OF EUROPEAN SYSTEM PRIMES WERE CONSOLIDATED



Case Design Point	Case 1 min. 150N @ 5,5 bar	Case 2 150N @ 18 bar regulated	Case 3 200N average over blow-down
Operation mode	Blow down	Regulated	Blow down
Operating pressure	24 - 5,5 bar	18 bar	14 - 5,5 bar
Design Pressure	24 - 5,5 bar	24 - 5,5 bar	24 - 5,5 bar
Design point @ 24 bar	500 N	194 N	434 N

GENERIC DESIGN CONSIDERATIONS – CLASSICAL AND GREEN PROPELLANTS

ISP as a function of combustion temperature for various propellants pc=10bar; ε=40

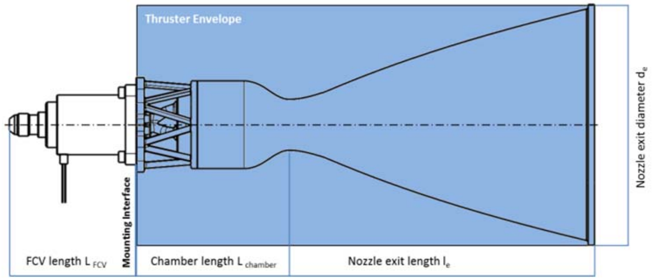


- **ADN based LMP:** variation of water content
- **Hydrazine:** variation of ammonia dissociation rate
- **Hydrogen Peroxide:** variation of concentration

GENERIC DESIGN CONSIDERATIONS – NOZZLE

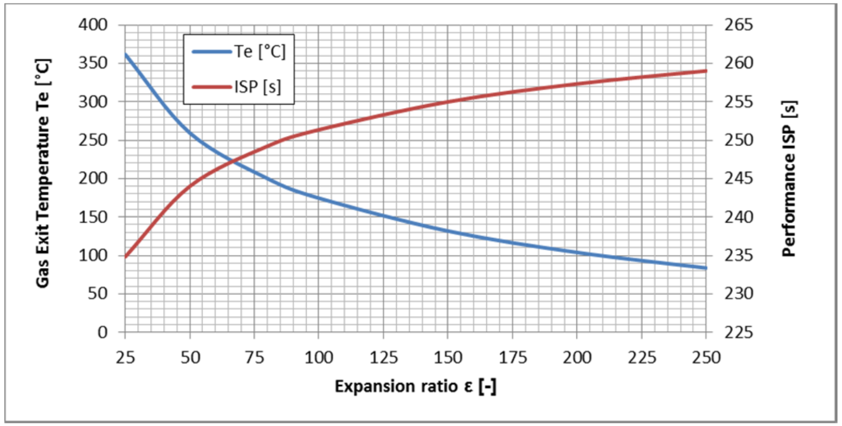
Nozzle expansion ratio determines

- the achievable ISP (ε → cf → ISP)
- The required envelope and also mechanical stress at the throat

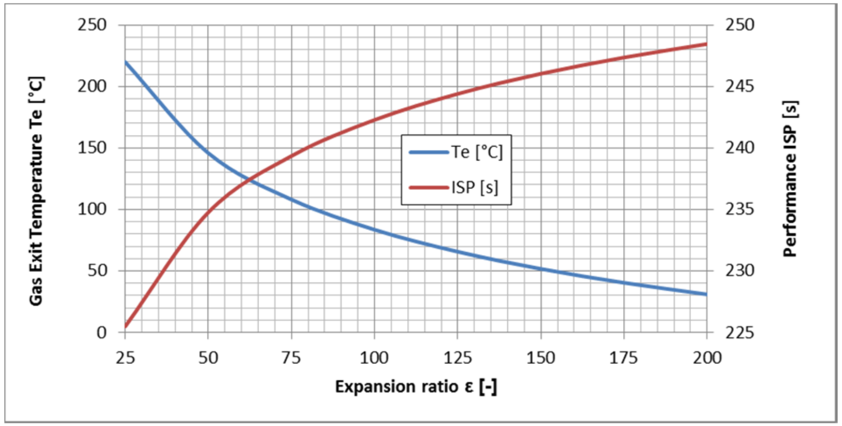


Gas temperature in supersonic part of the nozzle is determined by initial combustion / decomposition temperature

Propellant: LMP-103S



Propellant: Hydrazine



GENERIC DESIGN CONSIDERATIONS – CHAMBER MATERIAL FOR “COMBUSTING” THRUSTERS

- **ISP is a function of combustion temperature**

$$ISP_{theo} = c_f \cdot c_{e,theo} = c_f \cdot \sqrt{\frac{2\cdot\kappa}{\kappa-1} \cdot \Re \cdot \frac{T_C}{M}}$$

- **ADN based propellants require exotic high temperature materials due to their high combustion temperature**
- **Classical cooling (one propellant acts as a cooling film) is not possible because propellants are premixed. Therefore chamber material has to sustain the full combustion temperature**
- **Current ADN based solutions (LMP-103S) or HAN based solutions (AF315-ME) use ReIr chambers from the US**
- **European Chamber Materials are investigated in the frame of H2020 RHEFORM Project**

High Temperature Chamber Materials

Material family	Type	Temperature limitation	Cost	Notes
Cr		1600°C tbc (melting point is 1900°C)	low	▪ Sintered, no conventional machining possible, brittle (thermal stress)
Mo		1800°C tbc (melting point is > 2500°C)	low	▪ Surface protection required
Noble metals	PtRh	< 1500…1600°C tbc	high	▪ more robust against oxidation ▪ heritage from ArianeGroup S10 and S22 thruster with PtRh 90/10 (1500°C limit); 80/20 ▪ higher temperature limitation with 70/30
	PtIr	1600…1700°C tbc	high	▪ ArianeGroup S400 heritage with PtIr70/30 (1600°C), with all advantages described above for PtRh ▪ higher Temp limitation than PtRh ▪ Similar raw material cost than PtRh
	ReIr	1900° tbc	Very high	▪ Expensive PVD (ITAR), life limitation due to mat. diffusion tbd, flight hardware (HiPAT; HPGP) know > 1700°C
Ceramics composites	SiC; CMC (ceramic matrix composites)	< 1600°C	Very high	▪ Oxidation; exfoliation by layer ▪ Water content in exhaust
Monolithic ceramics	Carbide (SiC)	< 1200…1700°C	high	▪ Oxidation; Porosity (RSiC); Lowest costs within ceramics; low density; temperature limitation due to decomposition (crystal structure) e.g. BN limit wrt decomposition is ~900…1000°C in oxidizing atmosphere. Water content in exhaust

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GENERIC DESIGN CONSIDERATIONS – CHAMBER MATERIAL FOR "DECOMPOSING" THRUSTERS

- Hydrogen Peroxide and Hydrazine allow classical super alloys that can be ALM printed
- ALM printing offers significant cost reductions because number of parts with subsequent joining processes is reduced

ArianeGroup ALM printed H2O2 thruster with 10x less parts compared to classical manufacturing

Superalloys that can be ALM printed

		Cost [$/kg]	T_{melt} [°C]	T_{max} [°C]	UTS [MPa]	YS [Mpa]	Elongation [%]
Reference	HY 25		1329-1410	1093	1005	475	51%
Ni based	IN718	192	1210-1344	700	1380±100	1240±100	18±5%
	IN 625	192	1290-1350	1093	930±100	650±50	35±5%
	Hastelloy X	≈ 200	1260-1355	1177	772±24	595±28	20±6%
	HY 188	≈ 200	1315-1410	1150	945	465	53%
	HY 230		1290-1375	1150	860	390	48%
Co based	CoCr MP1	330	1350-1430	1150	1100±100	600±50	20%
	CoCr SP2	625	1380-1440		1350	850	3%
Steel	316L	180	1375-1400	925	540±55	470±90	50±20%

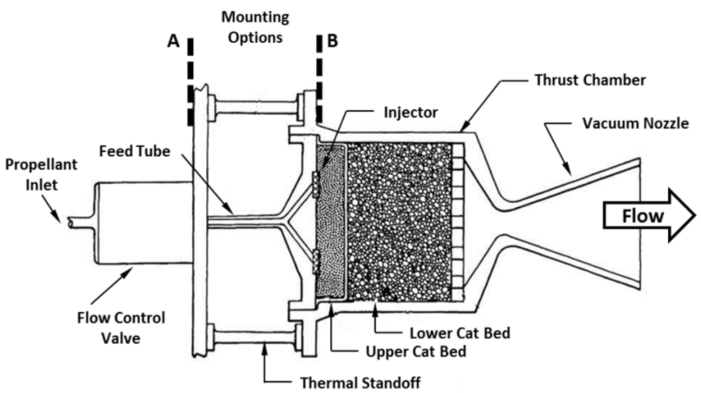
GENERIC DESIGN CONSIDERATIONS – OVERALL CHALLENGES

ADN Based Thruster

Due to high combustion temperatures high demands on

- thermal decoupling of hot chamber versus cold feed system
- Exotic chamber material necessary and subsequent high effort in manufacturing and assembly (joining)
- High temperature catalyst necessary

Preheating and control of preheating necessary



Some relaxation of classical requirements due to a controlled operation with a few steady state burns only

Low Cost Thruster

Due to low cost / high performance requirements

- Low cost components (valve, catalyst) necessary
- ALM printing offers significant simplification potential and less components / joining processes
- A simple (straight) nozzle with a high expansion ratio compatible with available envelope increases the performance
- A simplified catalyst bed is required due to cost reasons

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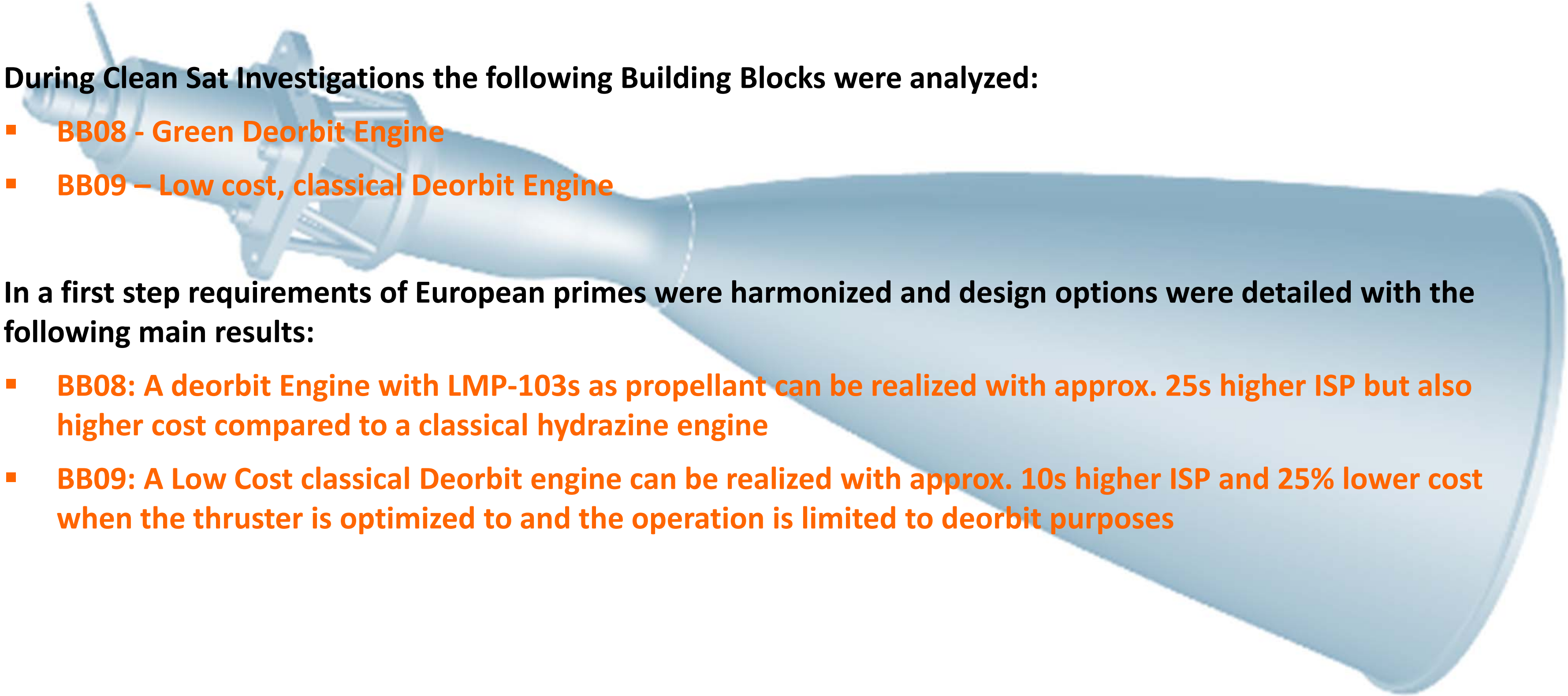
CONCLUSION



During Clean Sat Investigations the following Building Blocks were analyzed:

- **BB08 - Green Deorbit Engine**
- **BB09 – Low cost, classical Deorbit Engine**

In a first step requirements of European primes were harmonized and design options were detailed with the following main results:

- **BB08: A deorbit Engine with LMP-103s as propellant can be realized with approx. 25s higher ISP but also higher cost compared to a classical hydrazine engine**
- **BB09: A Low Cost classical Deorbit engine can be realized with approx. 10s higher ISP and 25% lower cost when the thruster is optimized to and the operation is limited to deorbit purposes**