DEMISEABLE PROPELLANT TANKS

Design and Test of Materials and Technologies

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Scope of Technology

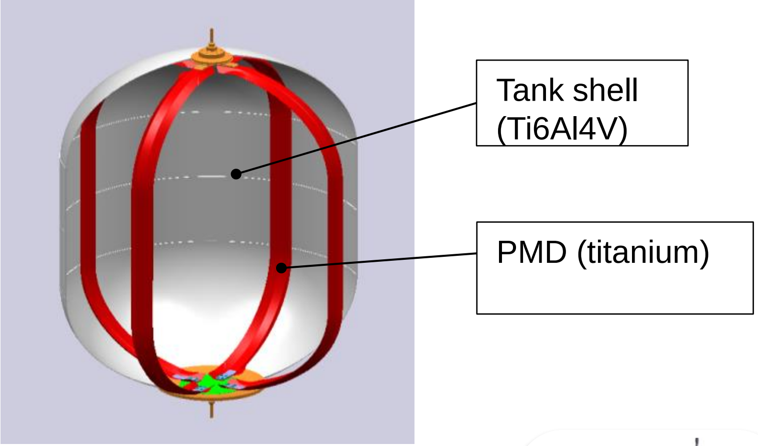
DEMISEABLE PROPELLANT TANK - Scope of Technology

- **Applicability range**
  - **Priority 1: LEO platform medium size**
    (100-200L, < Ø600mm)
  - Priority 2: LEO platform small size
    (37-50L, < Ø420mm)

- **Actual Technology**
  - Titanium tank (melting point ~ 1600°C)
  - Surface Tension PMD or membrane

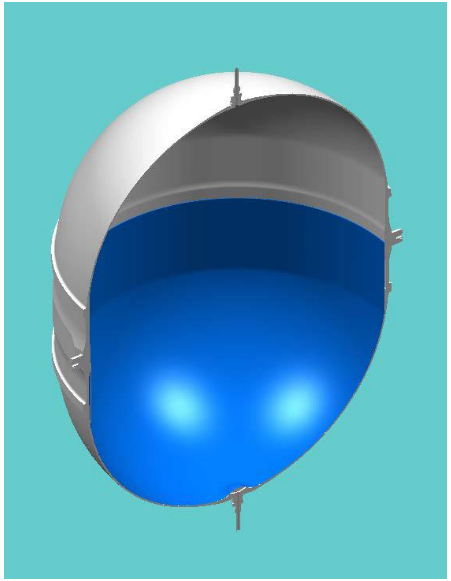
  ➔ **Non-demiseable**

- **Proposed Demiseable Technology**
  - Material: aluminium alloy (melting point ~ 600°C)
  - Surface Tension PMD or membrane



DEMISEABLE PROPELLANT TANK - Scope of Technology

- **Tank Main Requirements**
  - Tank family: 100 to 200 litres
  - Geometry: spherical/cylindrical (< Ø600mm)
  - MEOP: 24bar
  - Blowdown mode
  - Propellant: Hydrazine (optional: green ADN/H_2O_2)



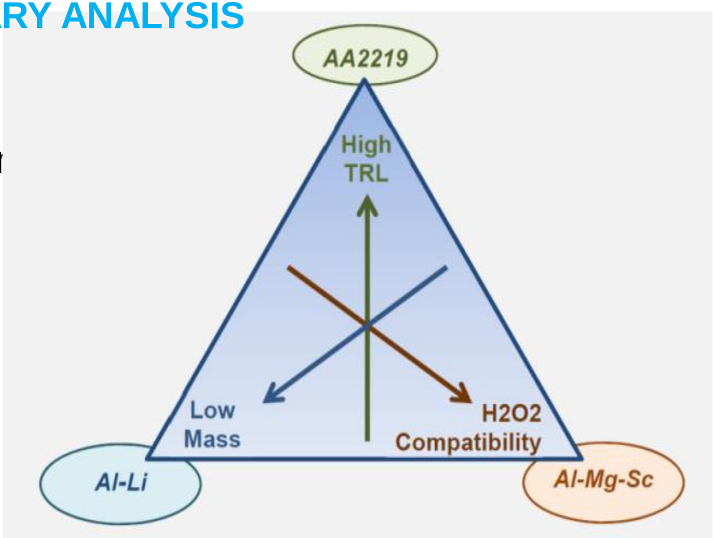
- **System level impacts**
  - Slight increase of tank mass (aluminum vs. titanium)
  - In case of membrane tank, to allow passivation pyro-valves to vent gas and propellant into space or thruster firing for consuming the residuals.
  - **Tank demiseability assumes early tank separation from satellite structure** (break-up altitude at 78km).

02

Preliminary Analysis

DEMISEABLE PROPELLANT TANK – PRELIMINARY ANALYSIS

- **Tank shell material**
  - AA2219 provides the highest TRL for the application and a good specific strength
  - Al-Li alloys (e.g. 2195, 2055) provide the highest specific strength (lowest tank mass). The compatibility to propellants is still to be investigated
  - Al-Mg-Sc alloy (e.g. 5028) provide promising compatibility to H2O2 and a good specific strength



Propellant tank launcher heritage	Material	Weld technique	Propellant	TRL
• Ariane 5 EPS	2219-T8	TIG	NTO / MMH	TRL9
• Vega AVUM+	2219-T8	TIG	NTO / UDMH	TRL6

➔ Due to the heritage available in the launcher domain, the use of 2219 is recommended for LEO propellant tanks

DEMISEABLE PROPELLANT TANK - Preliminary Analysis

- **Piping Interface**

The specified pipe interface material is titanium. This means that a transition joint must be foreseen with the aluminium tank.

- Bolted joint: multiple seals needed to ensure tightness over 10 years

- Bimetallic transition joint: AA6082-to-Ti6Al4V being developed in Europe (~TRL6) using RFW joining technique.

- Rotary friction welded joint: applications of RFW of Al-Ti already developed in Europe (TWI and IWS) and feasibility of Al-Ti joints already performed at ESA.

➔ Due to its advantages in term of masses and tightness performance, the use of a bimetallic transition joint (RFW) is recommended

DEMISEABLE PROPELLANT TANK - Preliminary Analysis

- **Propellant Delivery System**
  - Elastomeric membrane: PTFE or EPDM (both materials possible). Qualification of PTFE for satellite environment (radiation, thermal) to be performed.
  - Surface tension device: Aluminium PMD (simple design assumed, as existing for titanium tanks).

➔ Both elastomeric membrane and surface tension PMD are deemed appropriate for LEO demiseable tank

DEMISEABLE PROPELLANT TANK - Preliminary Analysis

- **DRAMA Analyses**
  - **Material Assumptions:**
    - T(melting) = 866 K (nominal) / 916 K (worst case)
    - Cp (average) = 977 J/Kg-K *(variation of ±10% also evaluated)*
    - Emissivity = 0.5 *(ε = 0.3 also evaluated)*
    - Heat of melting = 385 kJ/kg *(variation of ±10% also evaluated)*
  - **Tank Masses:**
    - Volume 104L: varying between 5,7kg and 9,0kg*
    - Volume 200L: varying between 12,4kg and 19,7kg*

    ** Pending on safety factors and alloy considered*
  - **Re-entry Conditions**
    - Nominal: Break-up at 78km (V=7.58 km/s)
    - Worst case: Break-up at 65km (V=6.71 km/s)

DEMISEABLE PROPELLANT TANK - Preliminary Analysis

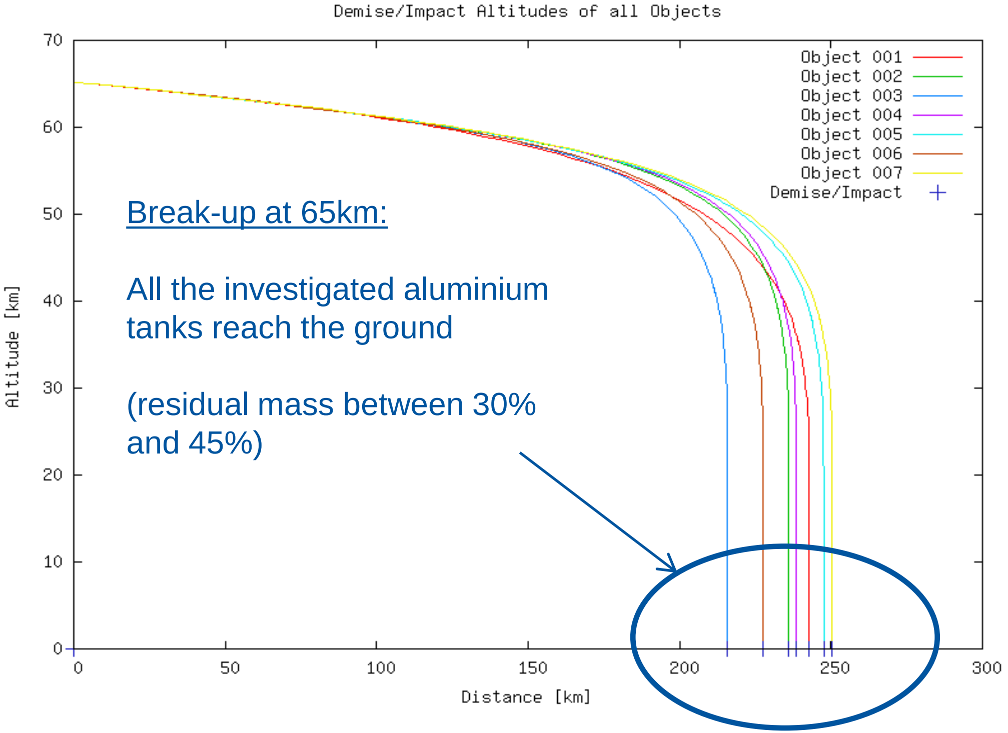
DRAMA Analyses

Results:

- The analysis performed with DRAMA indicates that the **aluminium tanks always demise for a break-up altitude of 78km, however none of the alloys is found to demise for break-up altitude of 65 km**.

- The choice of aluminium alloys, the tank size (within 100L - 200L) and the safety factors used for dimensioning have little influence on the results. **Variations on material properties (melting point, Cp, heat of fusion, emissivity) and the different tank masses have a negligible impact on demiseability** when compared to the break-up altitude.

- Titanium tanks do not demise at all



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Proposed Tank Design

DEMISEABLE PROPELLANT TANK - Proposed Tank Design

Demiseable Tank - Master Trade-off	Tank 1a	Tank 1b	Tank 2a	Tank 2b	Tank 3a	Tank 3b
Material	**2219**	**2219**	**5028**	**5028**	**2060**	**2060**
Condition	T8	T8	H116	H116	T8	T8
Weld process	TIG	TIG	*tbd*	*tbd*	*tbd*	*tbd*
Forming process	forging	forging	*tbd*	*tbd*	*tbd*	*tbd*
Propellant Delivery System	PED	PMD	PED	PMD	PED	PMD
Mounting	equator	equator	equator	equator	equator	equator
Pipe I/F transition	bolted joint (*)	bolted joint (*)	bimetal	bimetal	bimetal	bimetal

Evaluation (Max: 5 / Min: 1)

Weight	Criteria	Tank 1a	Tank 1b	Tank 2a	Tank 2b	Tank 3a	Tank 3b
10	Demiseability	4	4	4	4	4	4
10	Metal propellant compatibility - hydrazine	4	4	2	2	3	3
6	Metal propellant compatibility - green ADN	2	2	2	2	2	2
4	Metal propellant compatibility - green H2O2	1	1	3	1	1	1
10	PMD wettability / PED compatibility - hydrazine	5	5	5	5	5	5
6	PMD wettability / PED compatibility - green ADN	2	3	2	3	2	3
4	PMD wettability / PED compatibility - green H2O2	2	1	2	1	2	1
5	Dry Mass	3	3	3	3	5	5
5	Development cost	4	4	2	2	2	2
5	Development time	4	4	2	2	2	2
5	Development risks	4	4	2	2	2	2
10	Recurring cost	4	4	3	3	3	3
5	Material procurement (lead time, etc.)	4	4	4	4	3	3
	Score	**301**	**303**	**249**	**243**	**256**	**258**

DEMISEABLE PROPELLANT TANK - Proposed Tank Design

The trade-off shows that the following areas require to be investigated:

- Long term compatibility (and SCC) of all Aluminium alloys with hydrazine
- Compatibility of Al-Mg-Sc alloy (5028) with hydrazine
- Compatibility of PED material with hydrazine and green propellants
- Wettability of PMD material with hydrazine and green propellants
- Aluminium pipe transition joint

→Therefore the next development activities regarding demiseable tank technologies should focus in priority on the above mentioned areas.

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On-going Tests (for Trade-off Consolidation)

DEMISEABLE PROPELLANT TANK - On-going tests (for trade-off consolidation)

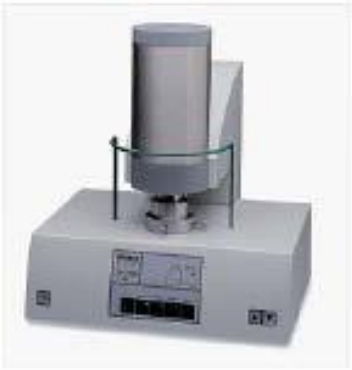
– Hydrazine Compatibility Test (1 month @ 71°C)

Material	Weld technique	Reference (w/o immersion)	Immersion in Hydrazine	Test: Compatibility test	Test: Additional test
5028	Base material	(5) tensile sample	(5) tensile sample	• Visual insp. • Mass change • Prop. analysis • Catalytic effect	• Tensile
6082 / 2219	Manual TIG	(7) welded pipe	(7) welded pipe		• Leak/proof • Tensile • Microsection
6082 / Ti6Al4V	RFW	(7) welded pipe	(7) welded pipe		
2219	Base material	(3) contact angle	(3) contact angle	• Visual inspection • Contact angle measurement	
2060	Base material	(3) contact angle	(3) contact angle		
5028	Base material	(3) contact angle	(3) contact angle		

DEMISEABLE PROPELLANT TANK- On-going tests (for trade-off consolidation)

— **Thermophysical Test**

Material	Weld technique	Test
2219	Base material	• Density • Specific heat Cp • T(melting) • Heat of Melting
2060	Base material	
5028	Base material	



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Conclusion

DEMISEABLE PROPELLANT TANK - Conclusions

- The replacement of Titanium with an Aluminium alloy is confirmed to be the most promising approach given the major impact in terms of tank demiseability.

- The break-up altitude was found to be the major parameter to drive demiseability, much more than the choice of the aluminium alloy.

- In order to minimize development risks and cost, the recommended approach is to use the **conventional 2219 alloy technologies**, available from launchers, **and to extend it to LEO platform application**. It is expected that the mass penalty (4kg heavier than titanium) is acceptable when compared to the necessity of a controlled re-entry.

- Innovative tank technologies, involving Al-Li or Al-Mg-Sc aluminium alloys, may be developed and introduced later on to optimize the performance.