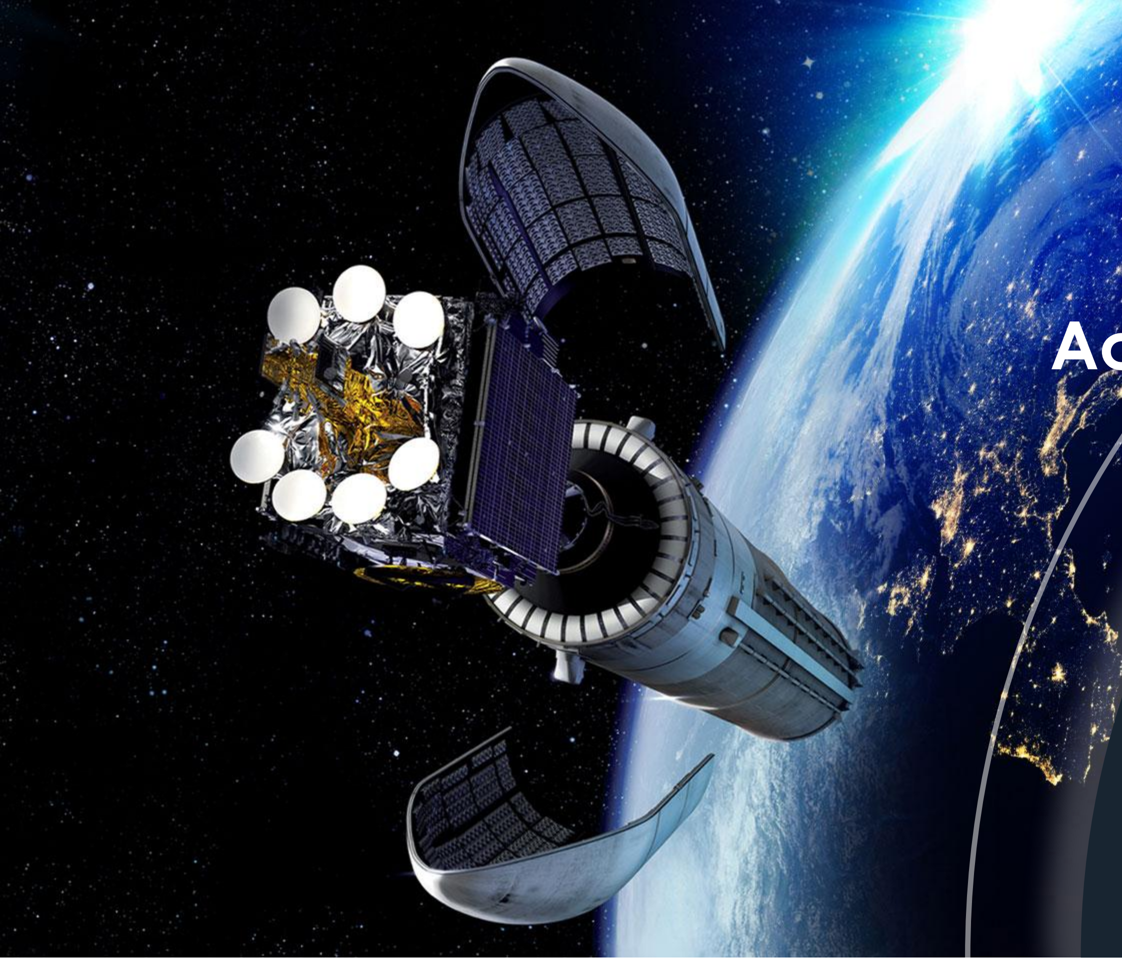

Active Debris Removal : a possible solution for mega constellations

CleanSpace Industrial days

C. Billot, R. Hache, M. Pasquinelli
S. Ferraris, L. Grassi, MV Catullo

ThalesAlenia Space
a Thales / Leonardo company

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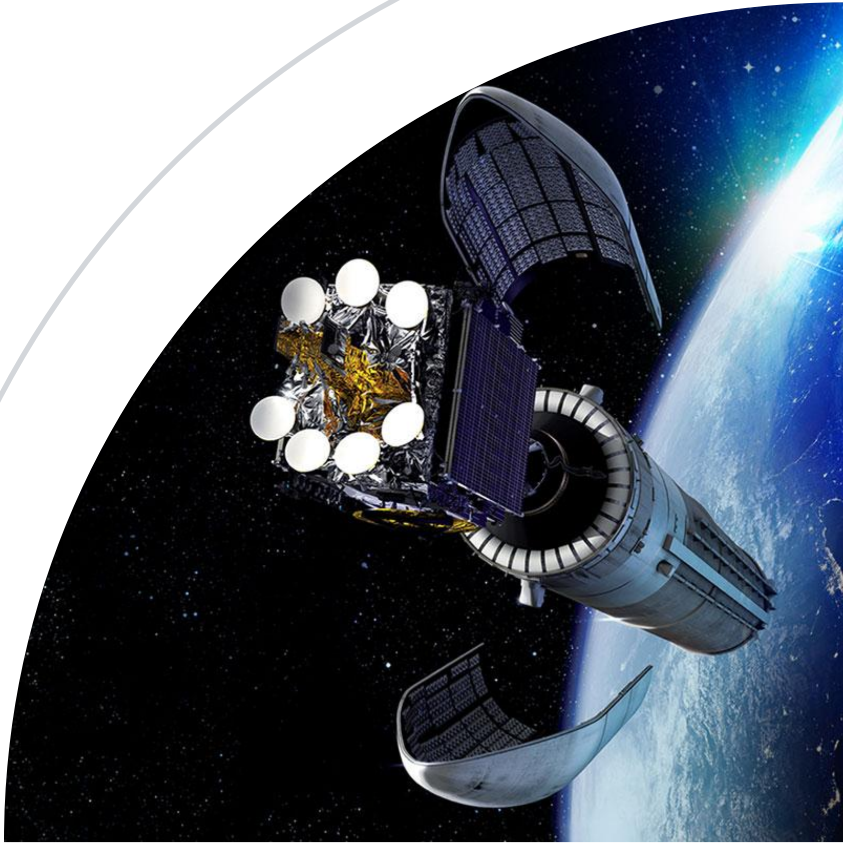
On-going ESA Phase 0 Study managed by Robin Biesbroek

Objective

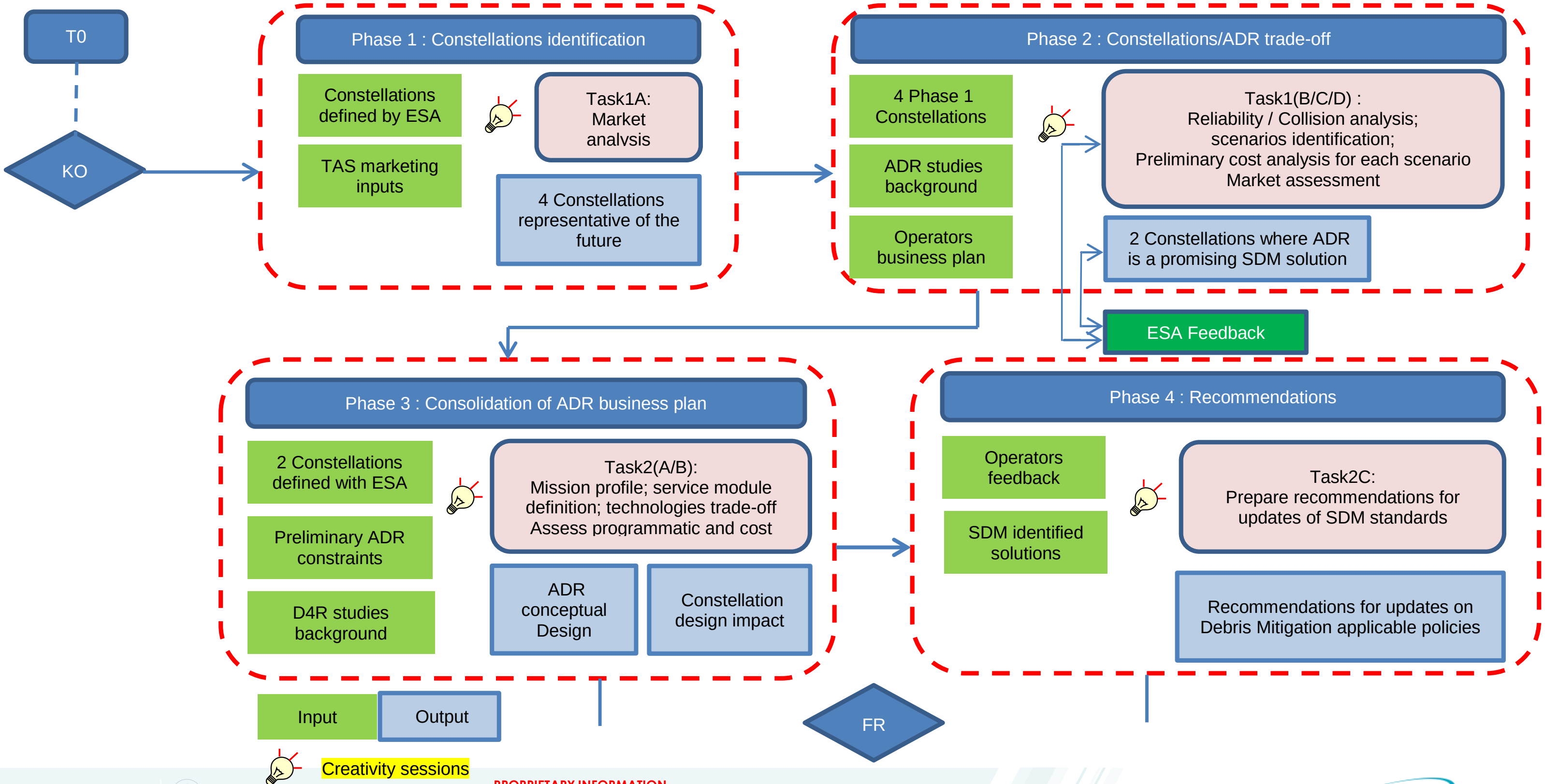
- Mega constellations operators have to address problem of removal failed satellite
- Compliance to Space Debris Mitigation requirement have to consider Collision risk & snow ball effect
- Solutions to trade
  - Reliability increase
  - In-orbit servicing
  - Removal

- Objective to identify most cost effective solution

ADR for debris issue linked to Mega constellations



Study Logic



T0
KO
Phase 1 : Constellations identification
Constellations defined by ESA
TAS marketing inputs
Task1A: Market analysis
4 Constellations representative of the future
Phase 2 : Constellations/ADR trade-off
4 Phase 1 Constellations
ADR studies background
Operators business plan
Task1(B/C/D) : Reliability / Collision analysis; scenarios identification; Preliminary cost analysis for each scenario Market assessment
2 Constellations where ADR is a promising SDM solution
ESA Feedback
Phase 3 : Consolidation of ADR business plan
2 Constellations defined with ESA
Preliminary ADR constraints
D4R studies background
Task2(A/B): Mission profile; service module definition; technologies trade-off Assess programmatic and cost
ADR conceptual Design
Constellation design impact
Phase 4 : Recommendations
Operators feedback
SDM identified solutions
Task2C: Prepare recommendations for updates of SDM standards
Recommendations for updates on Debris Mitigation applicable policies
FR
Input
Output
Creativity sessions

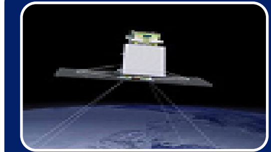
Study cases

Mega-1000

- 1080 sat / 200 kg / 1 m2 eff cross section
- 1100 km/ 85° - 20 planes with 54 SC
- Electric propulsion – 7y lifetime

Mega-200

- 200 sat / 1000 kg / 4 m2 eff cross section
- 1100 km/ 85° - 10 planes with 20 SC
- Chemical propulsion – 10y lifetime



Tas-3200

- 3200 sat / 380 kg / 2.6 m2 eff cross section
- 780 km/53° & 820 km / 53.8°
- Chemical propulsion – 5y lifetime

Tas-100

- 108 sat / 1200 kg / 1.8 m2 eff cross section
- 1400 km/ 90° - 6 planes
- Electric populsion – 10y lifetime

Mitigation method

ADR multi missions

ADR among constellation

ADR single shot

Reliability increase

- Design
- Redundancy
- In-space maintenance
- EOL kit on-board

Deorbitation and natural re-entry

- 25 years
- 5 years

Reorbitation

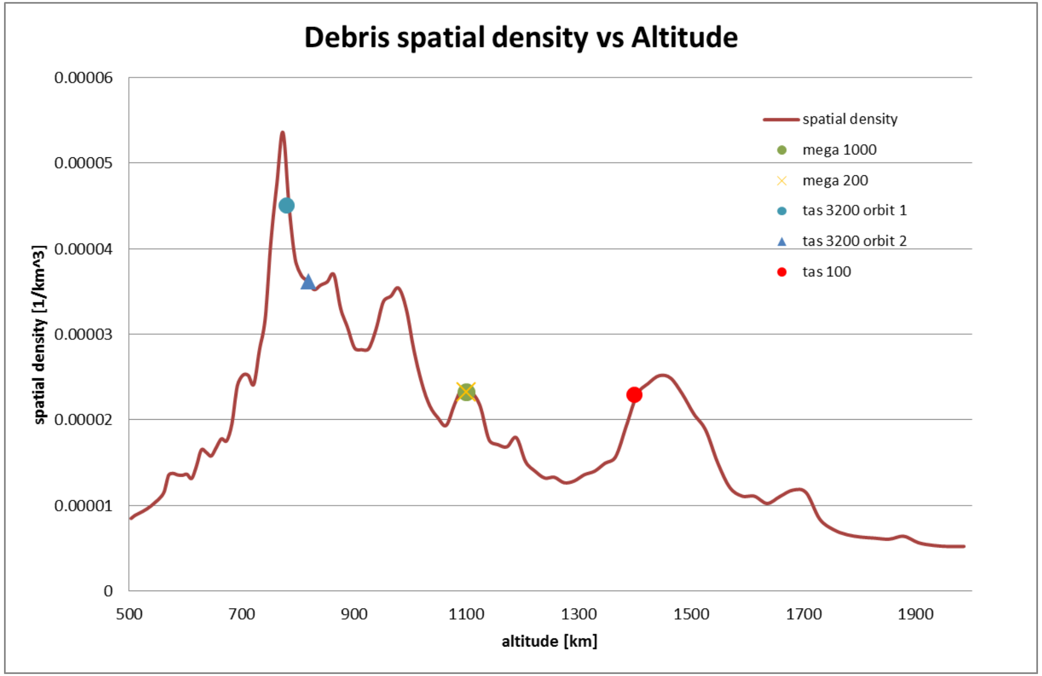
Deorbitation and controlled re-entry

Deorbit kit plugged by chaser/remover

Collision risk

- Debris environment is strongly dependent from the altitude

  - Risk evaluation of losing the satellites caused by an impact above the catastrophic threshold (40J/kg)
  - Smaller impacts possibly deactivating permanently a critical unit



20/06/2017
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Template : 83230347-DOC-TAS-EN-005

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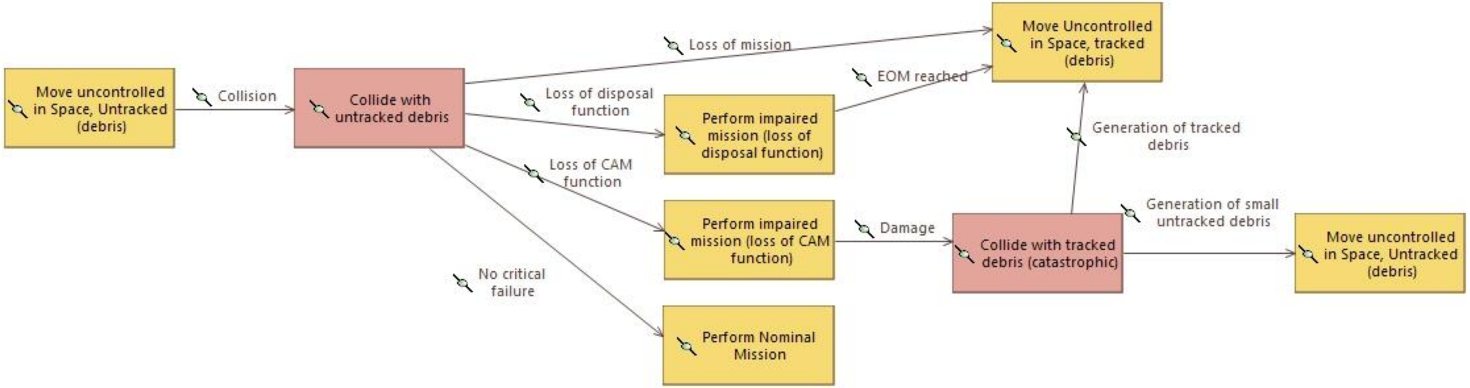
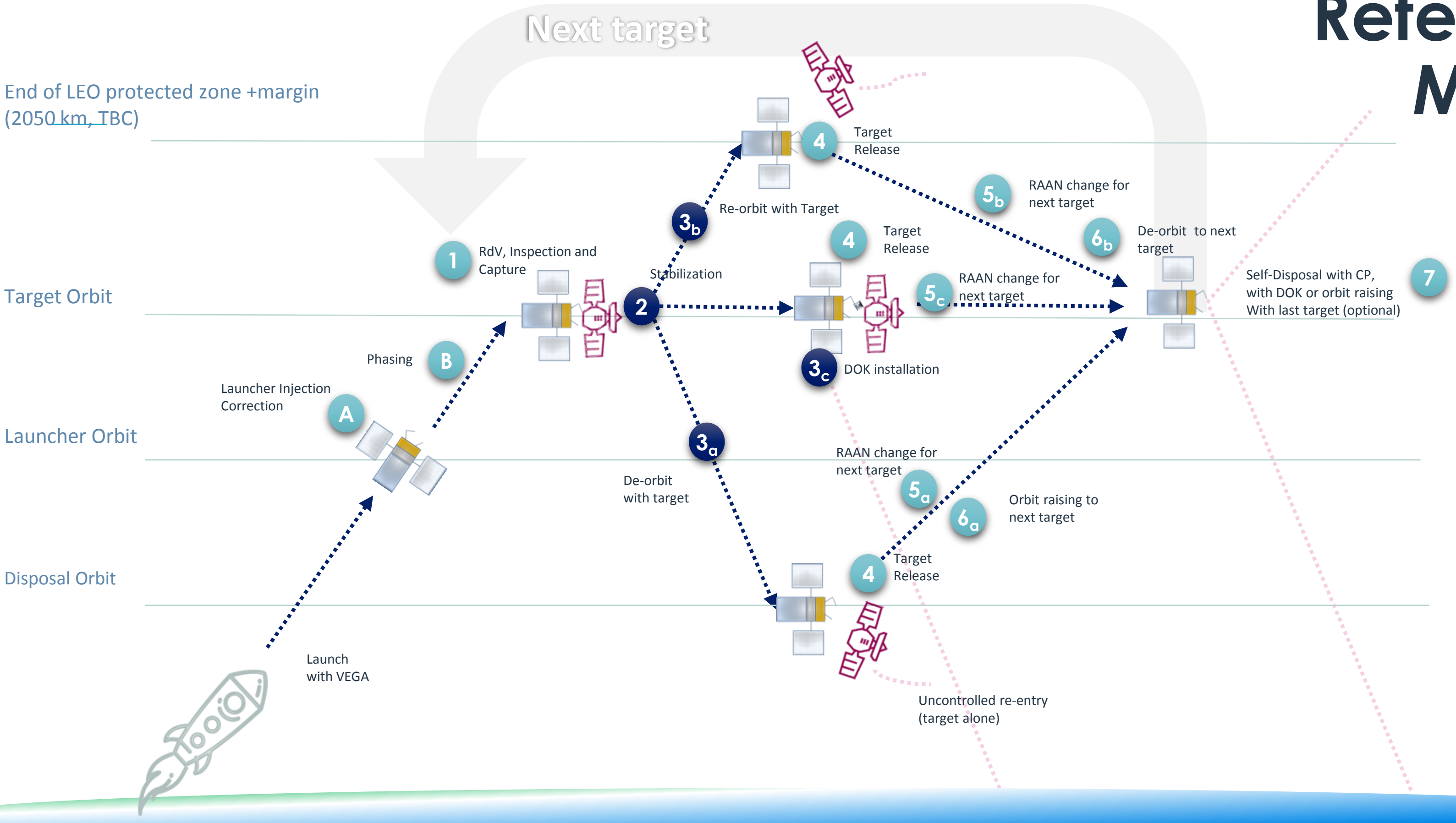
Collision risk

- Collision risk analysis
  - Risk of collision for the single satellite (during nominal mission) with an untracked debris
  - Risk of collision for a satellite inactive or with impaired Collision Avoidance Manoeuver (CAM) function with tracked debris
  - Debris generations through collisions

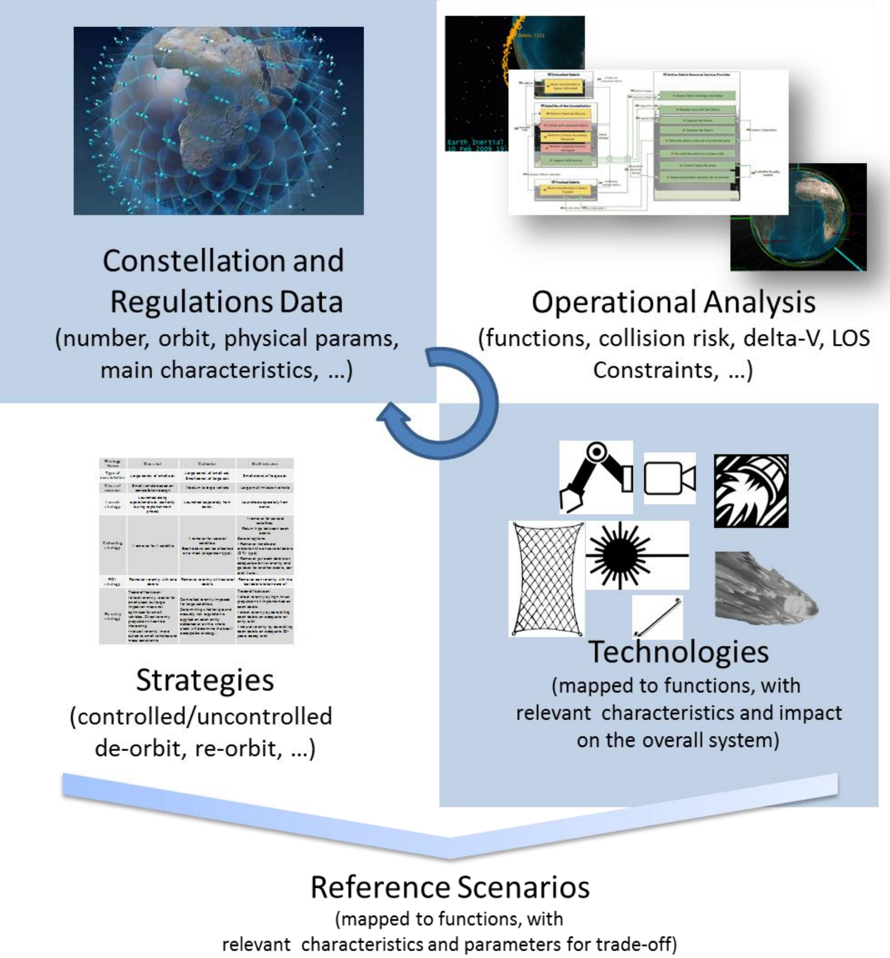


Reference Mission

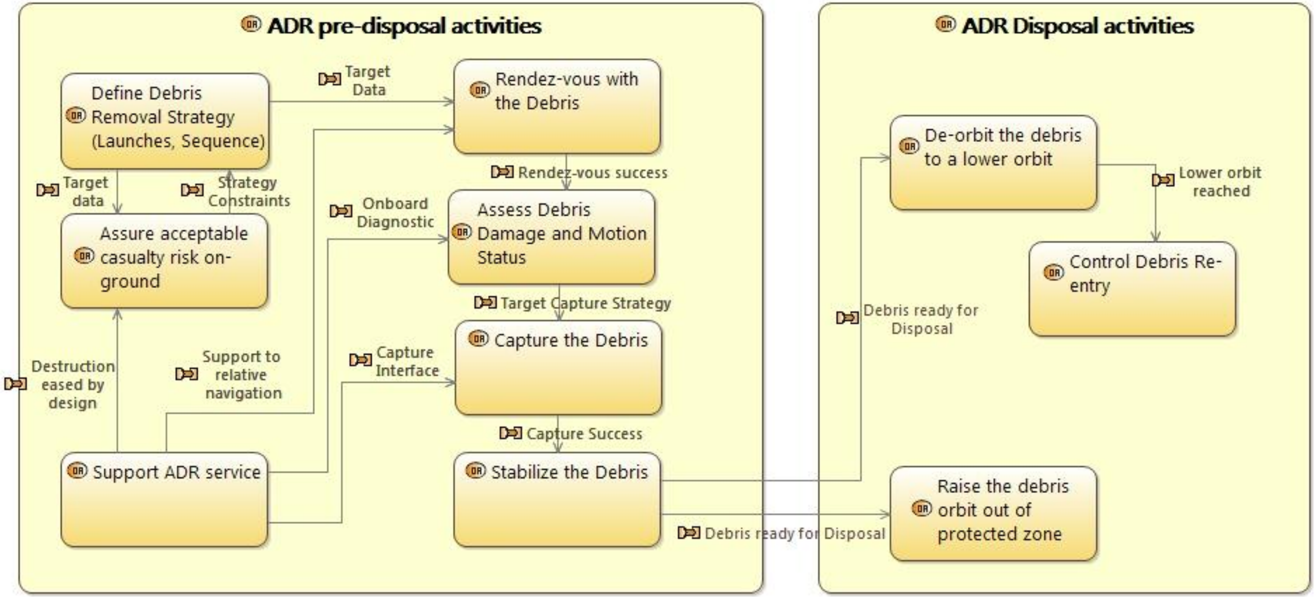


End Of Life operations analysis

- Scenarios defined by:
  - ADR Constraints
    - Constellation Data
    - Regulations
  - ADR Needs
    - Added value from the ADR service
  - ADR Architecture
    - Strategies
    - Architecture Components and Functions
    - Mission Analysis and Performances
    - Space Segment Technologies



EOL operations analysis



- technologies associated to this activities and related variability relevant for trade-off (e.g. IR or optical cameras not relevant, use of chemical or electrical propulsion is relevant)

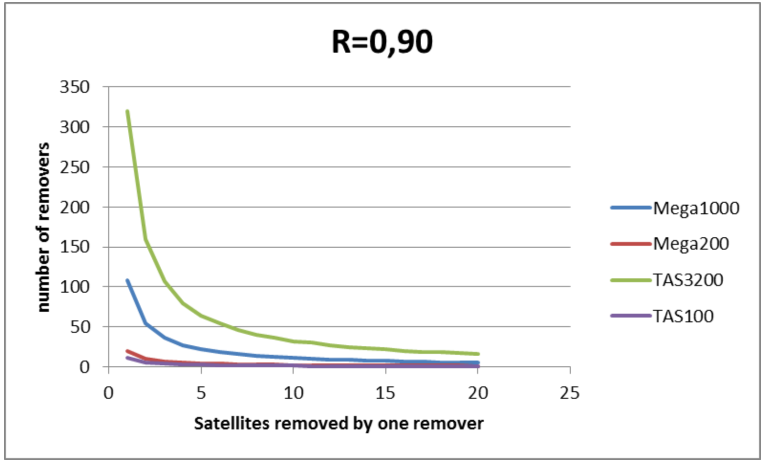
$$cost_{TOT} = cost_{constellation} + cost_{ADR}$$

$$cost_{ADR} = N_{removers} \cdot cost_{remover} + N_{launchers} \cdot cost_{launcher} + cost_{GS}$$

EOL operations analysis

$$N_{removers} = \left\lceil \frac{N_{failed\ satellites}(p_R) + N_{collisions}(p_{collision})}{N_{satellites/remover}} \right\rceil$$

- Number of satellites removed by each remover is one of the main factor for the overall evaluation
- One-shot or small size removers are not expected to be in larger constellations (impact on costs)



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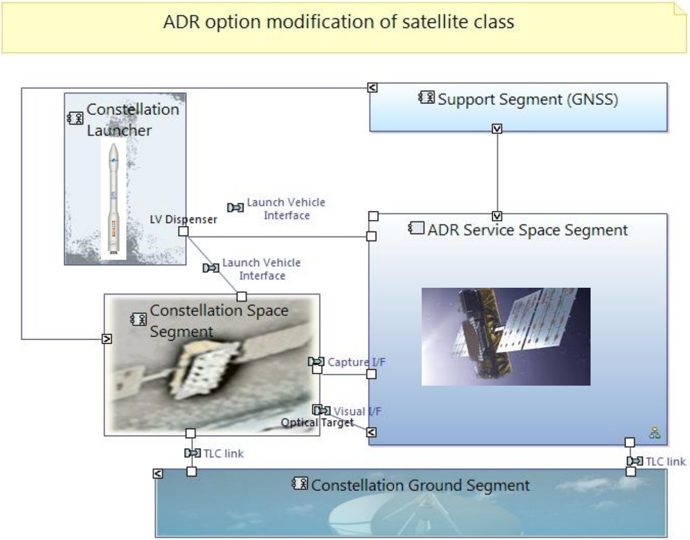
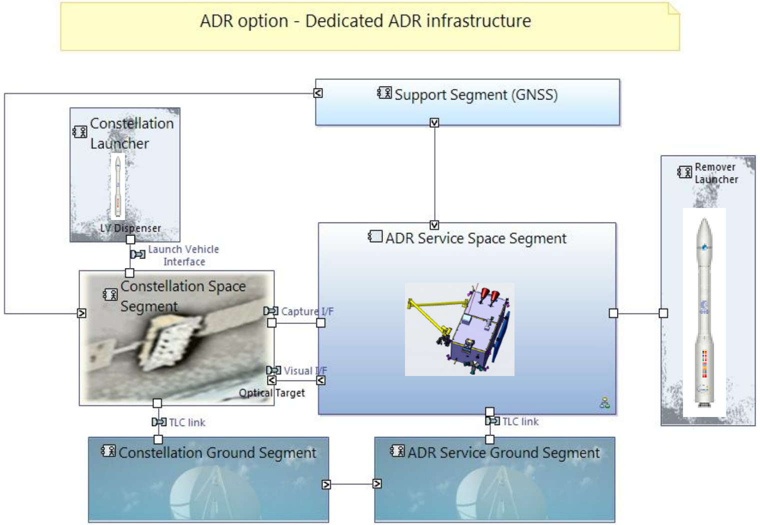
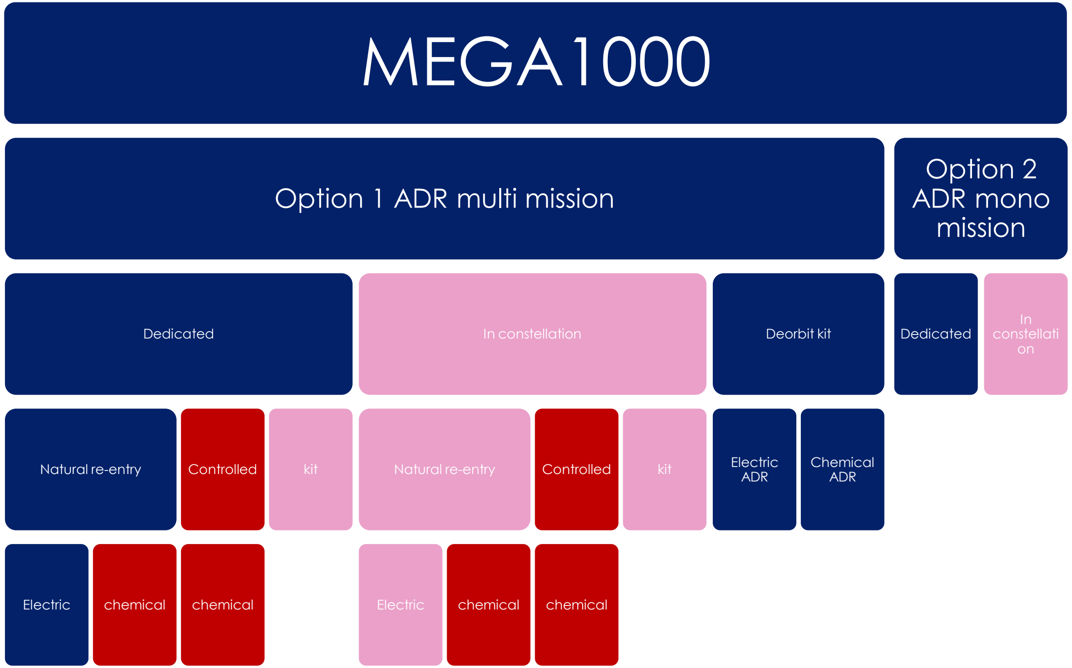




Simplification at first glance



Conclusion

Solution to highlight function of constellation

- **Failure case will happen**
- **Collision risk not neglectible**
- **ADR solution to be challenged**
- **Business model will drive orientation**