
e.Deorbit Symposium
WE LOOK AFTER THE EARTH BEAT
6 May 2014
gmv
INNOVATING SOLUTIONS
MDA
elecnor
deimos
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Ref.:
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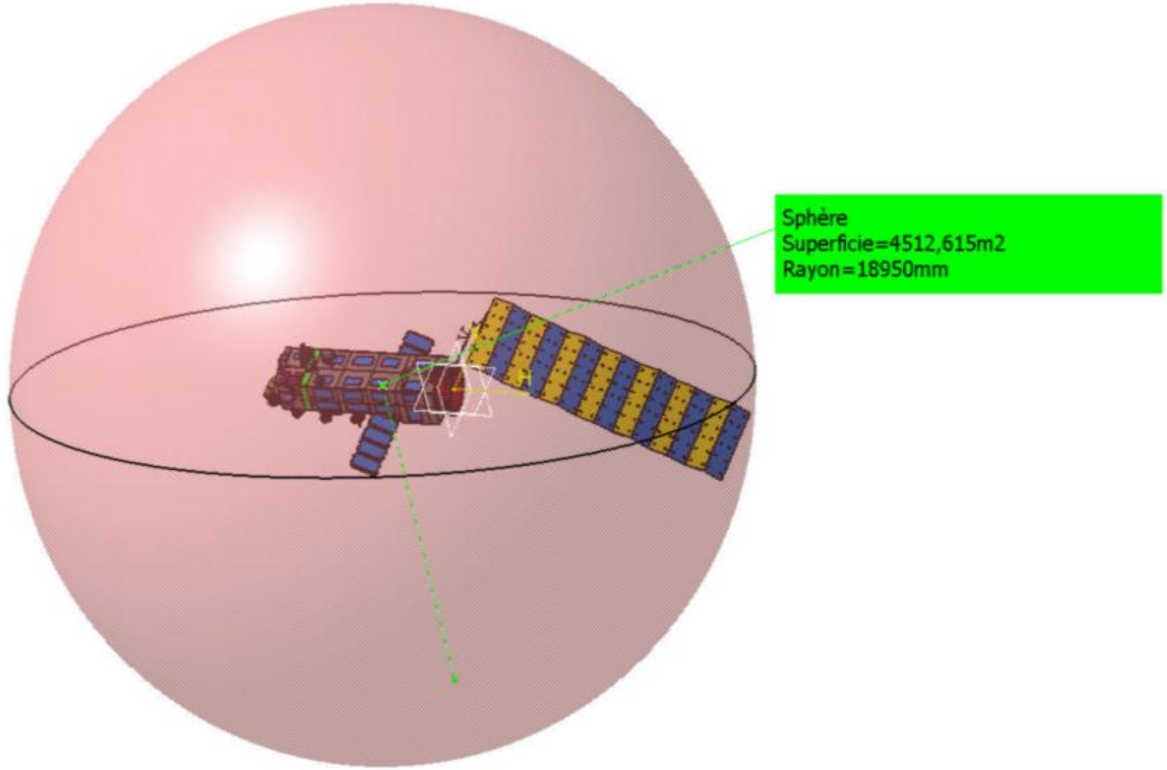
ThalesAlenia
A Thales / Finmeccanica Company
Space

Agenda

- Key points & Mission Configurations
- Capture Trade-Off for the 3 scenarios
  - Concept #1 [Flexible Link & direct Re-entry] capture Trade-off
  - Concept #2 [Rigid Link & direct Re-entry] capture Trade-off
  - Concept #3 [Reorbiting to Graveyard orbit] capture Trade-off
- Mission analysis
- Rendez-vous
- Satellite concepts
- ADR Mission technology actions
- Conclusion

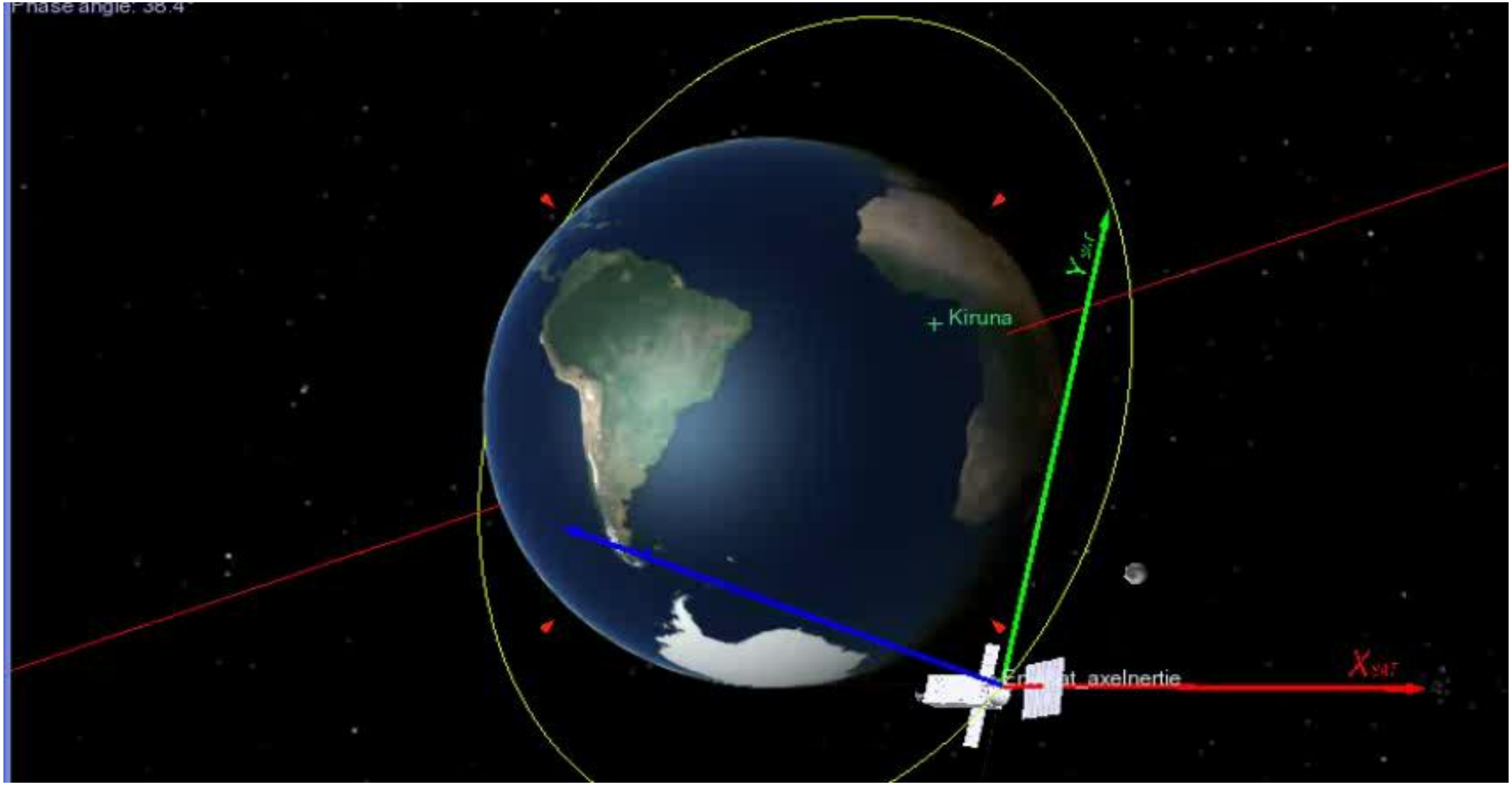
Key points

- Rendezvous strategy
- Capture of a tumbling debris at 3.5°/s
- To ensure compatibility with a VEGA launch of the chaser
  - Providing the ΔV for a direct re-entry
- To control the composite up to re-entry (or re-orbiting)
  - With rigid capture
  - With flexible link



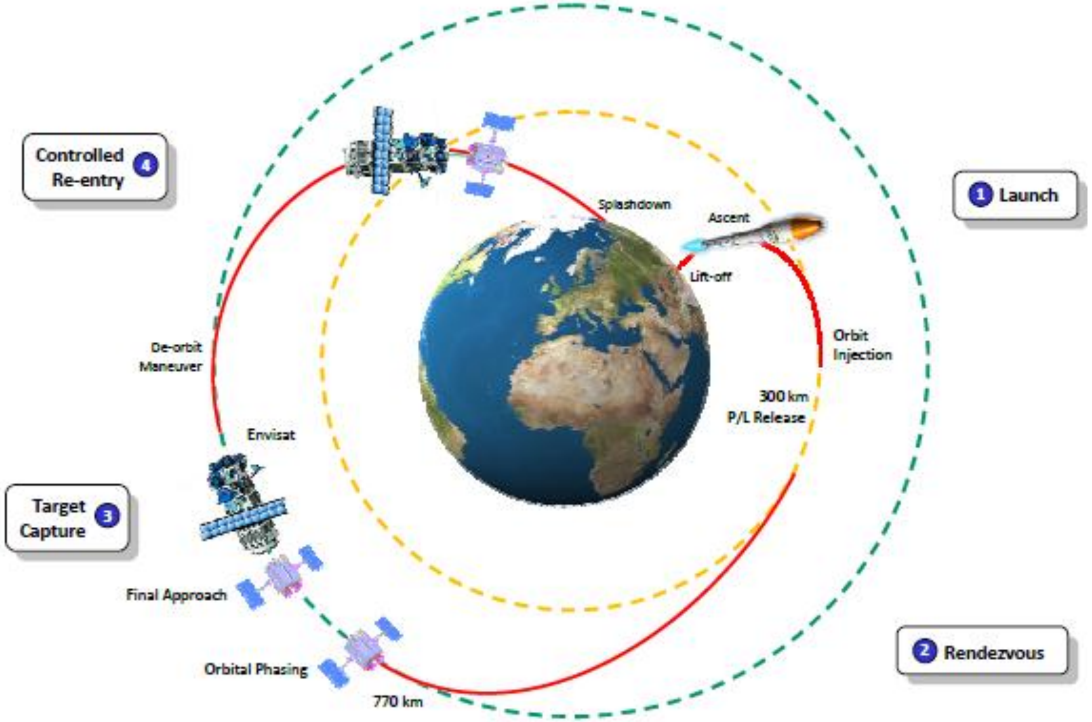
The capture system of the massive & tumbling debris is a major challenge

Mission Configuration

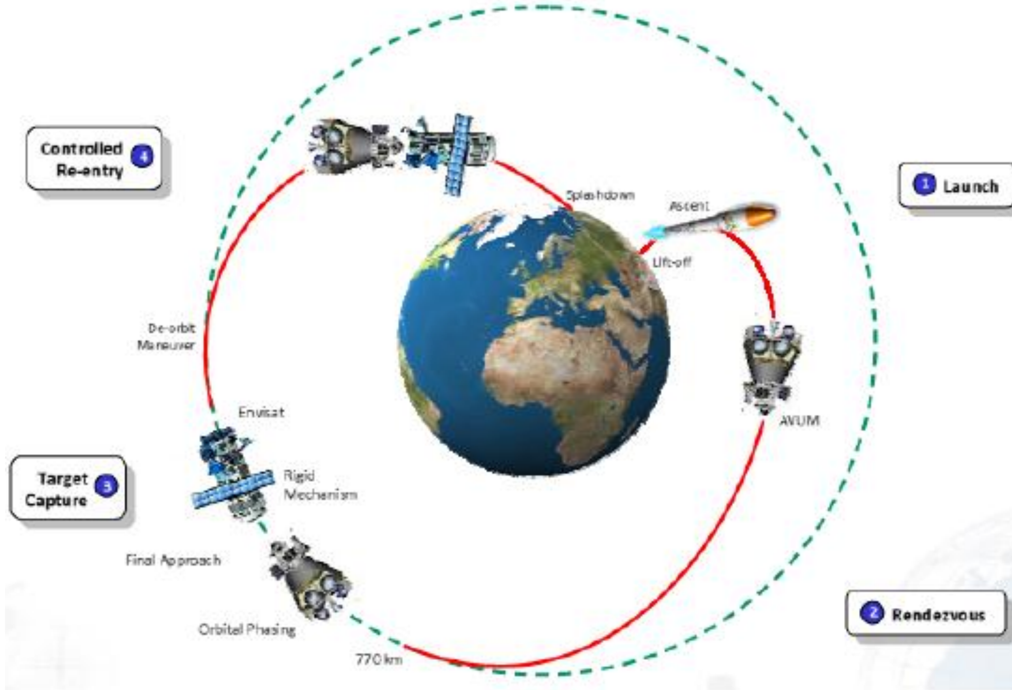


Mission Baselines

- Mission configurations for 3 concepts (1/2):
  - Concept 1 & 2 ensure a direct re-entry



Concept #1 : flexible solution



Concept #2 : Rigid solution

Direct Re-Entry lead to a capture / connection system compatible with a high thrust (last burn) and several kN

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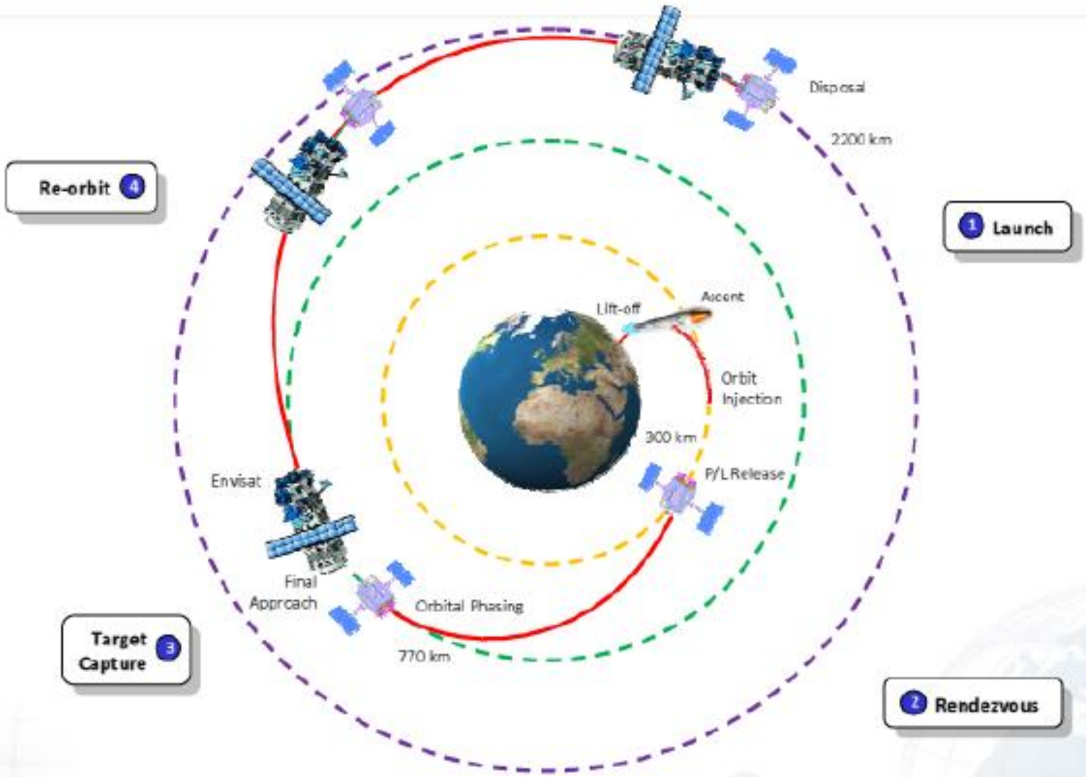
Mission Baselines

- Mission configurations for 3 concepts (2/2):
  - Re-Orbitation



Concept #3 : Reorbiting strategy - flexible or rigid solution

Re-Orbitation can be performed with a low thrust (but more ΔV). The requirements on the connection are relaxed.

Mission Baselines

- Capture trade-off
  - Major criteria :
    - Technical feasibility & TRL
    - System performance
    - Mission risk
    - Cost at completion

Score definition is :	Weight are applied :
0= unacceptable (fail) 1= critical 2 = acceptable 3 = slight advantage 4 = big advantage	1 = low priority 2 = medium priority 3 = high priority

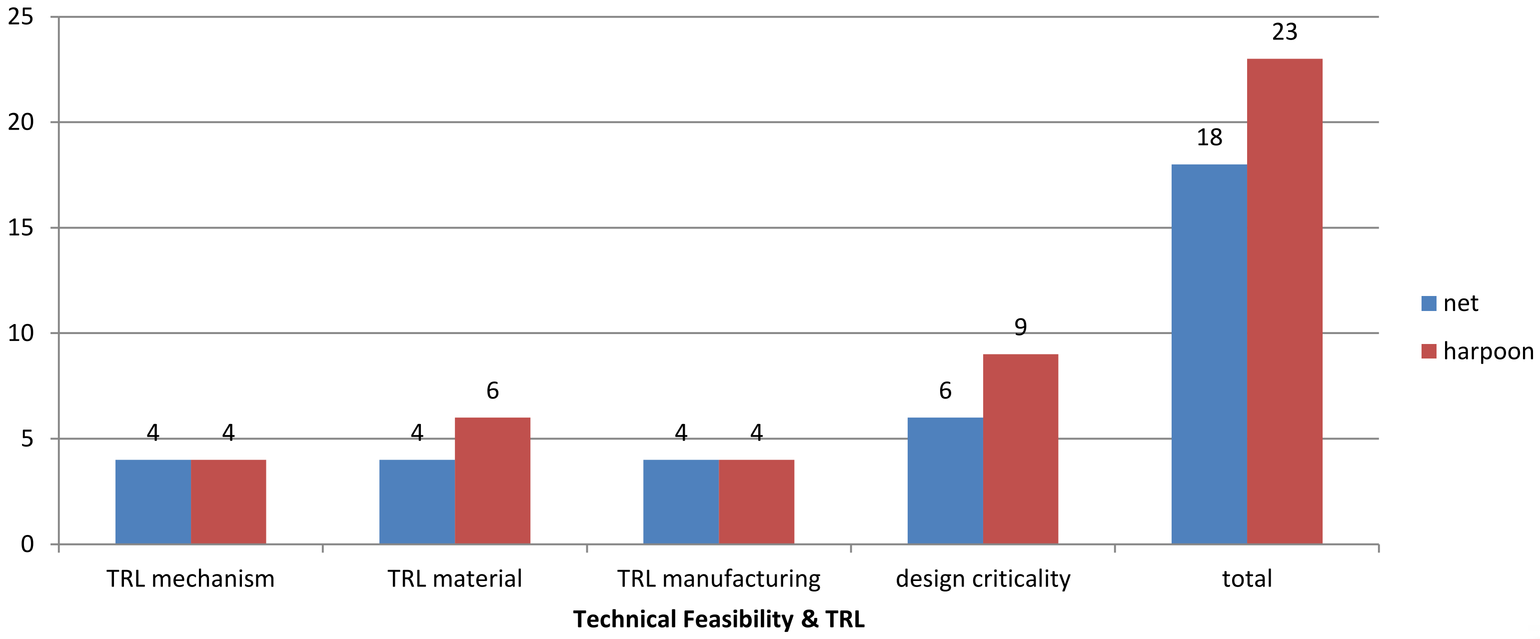
- Flexible Link ➔ 2 main candidates:
  - Harpoon vs. Net

- Rigid Link ➔ 3 main candidates
  - Tentacles
  - Robotic Arm
  - Robotic Arm + Clamping Mechanism

Capture technique trade-off impacts satellite design

Concept #1 Flexible Link capture Trade-off

- Technical feasibility & TRL

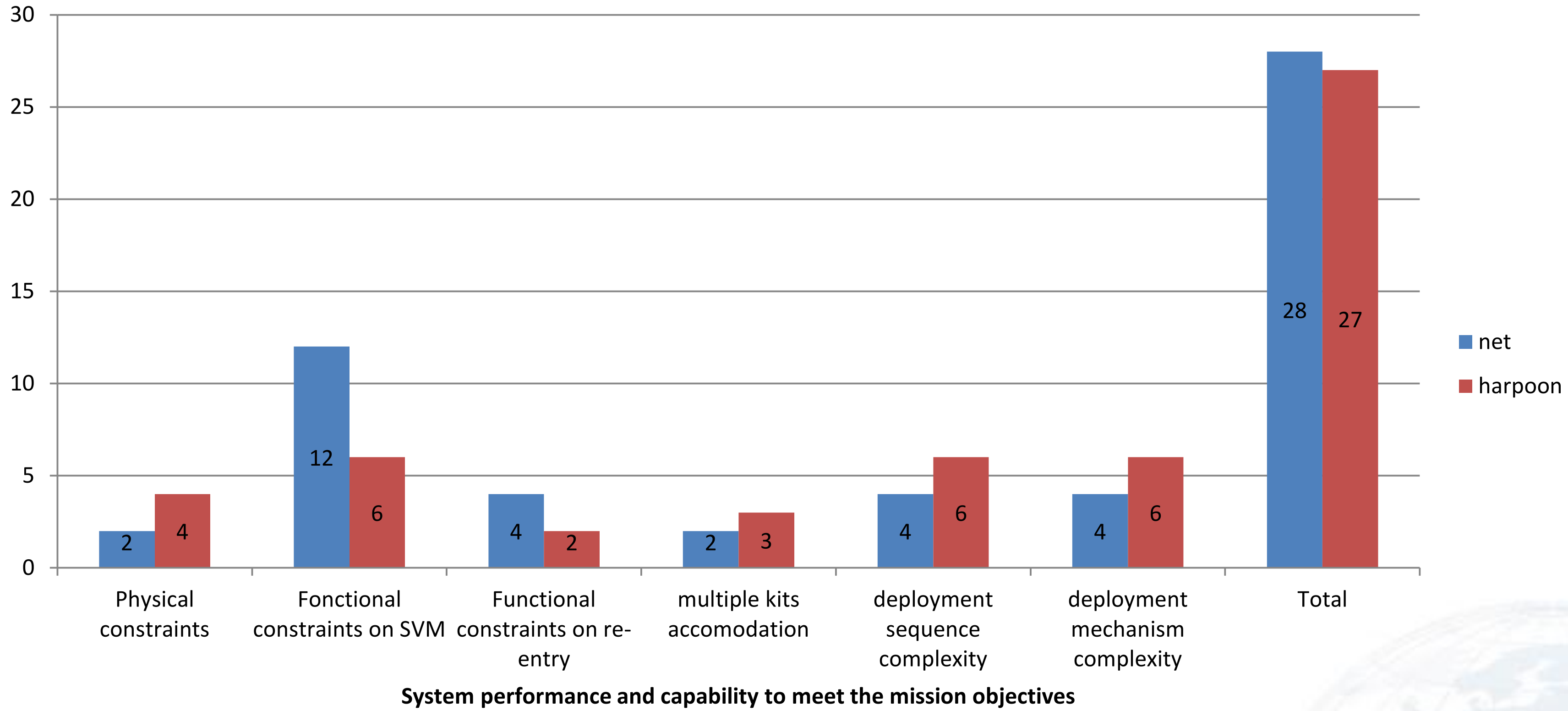


Harpoon is slightly ahead.

Deployment mechanim complexity is lower

Concept #1 Flexible Link capture Trade-off

- System performance



Capture distance is higher for Net with less GNC constraint on SVM

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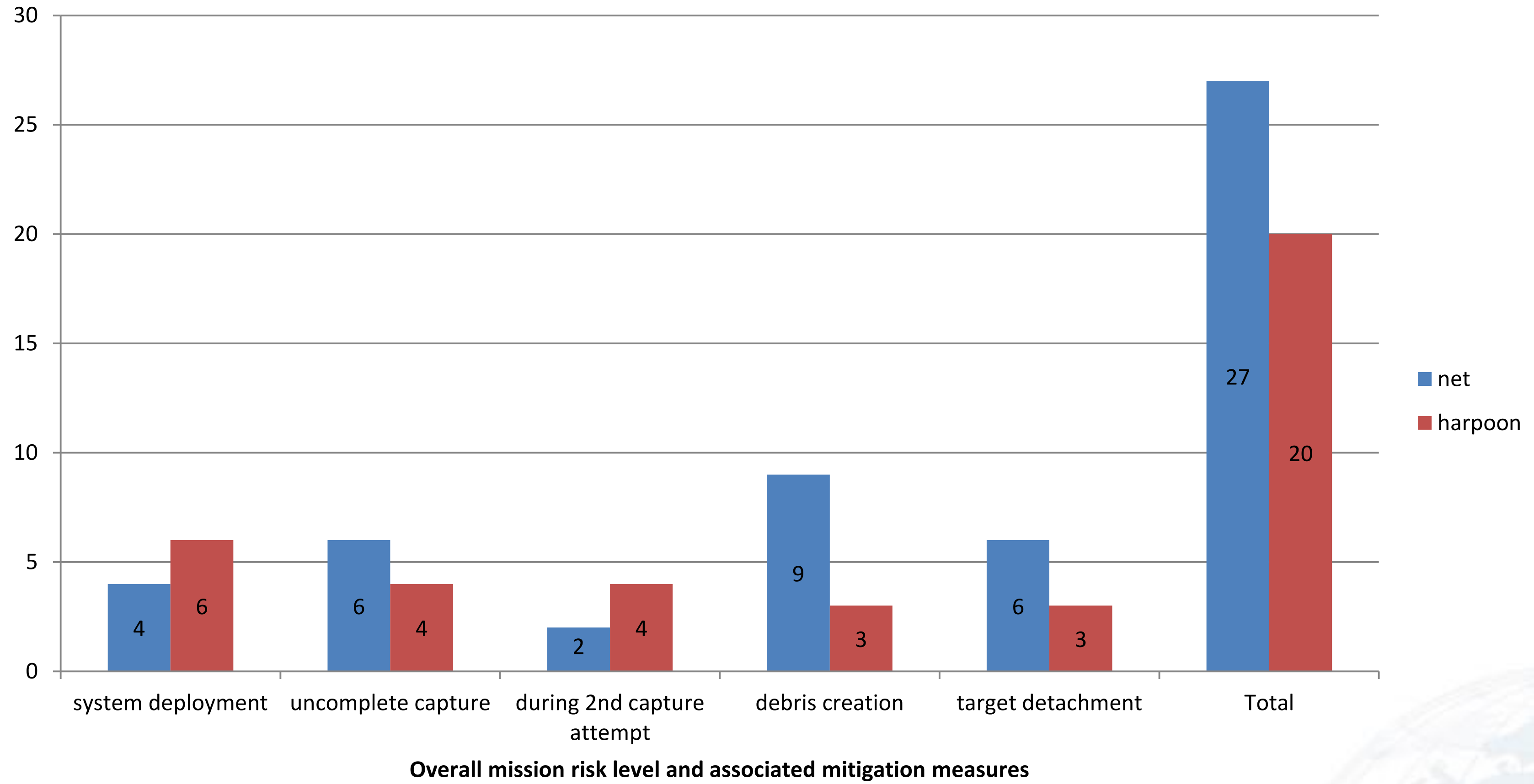
Concept #1 Flexible Link capture Trade-off

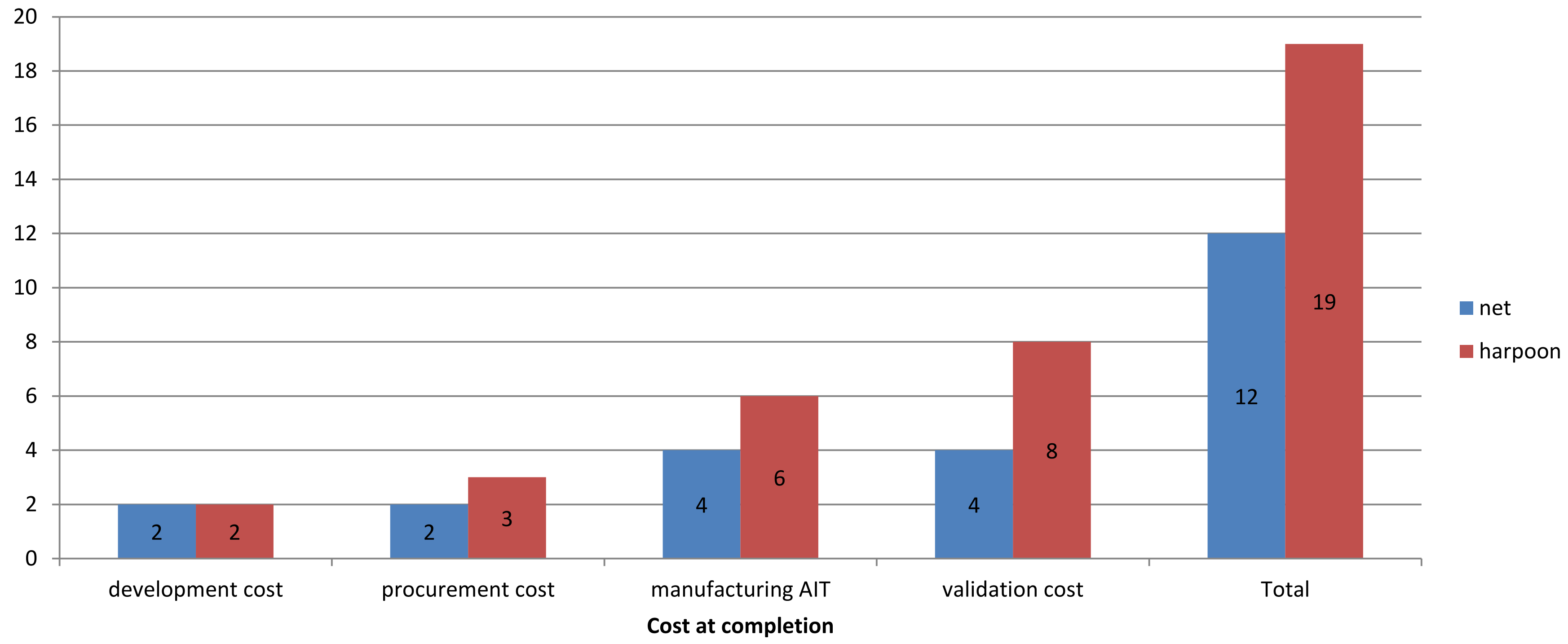
Mission risk



The risks of collision, failed capture have been carefully assessed for options

Concept #1 Flexible Link capture Trade-off

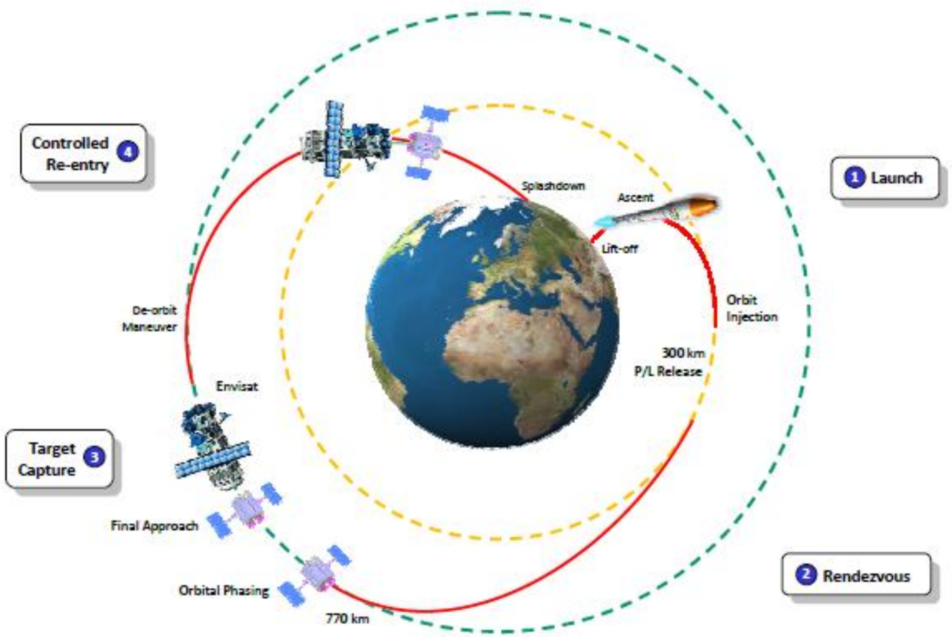
Cost

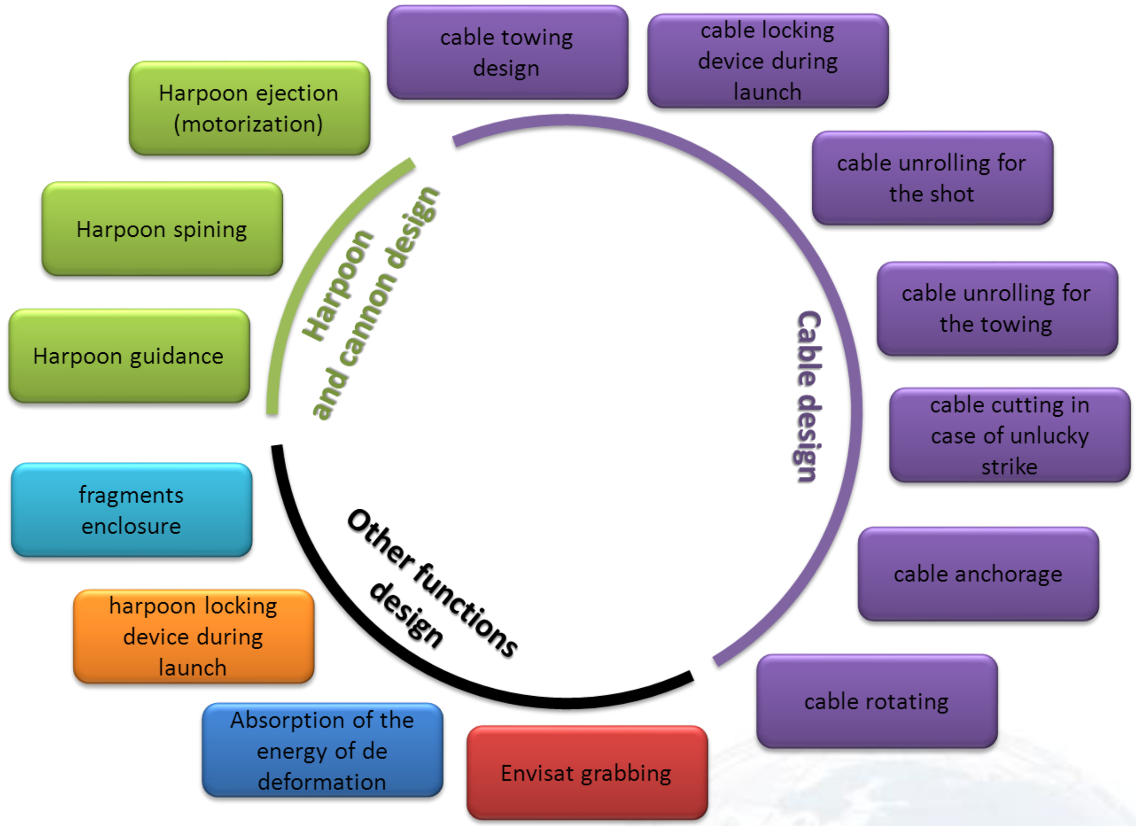


Total		Total weighted score Net	85	Total weighted score Harpoon	89

The Harpoon testability on ground @ full scale is much higher.

Concept #1 selection after MBR



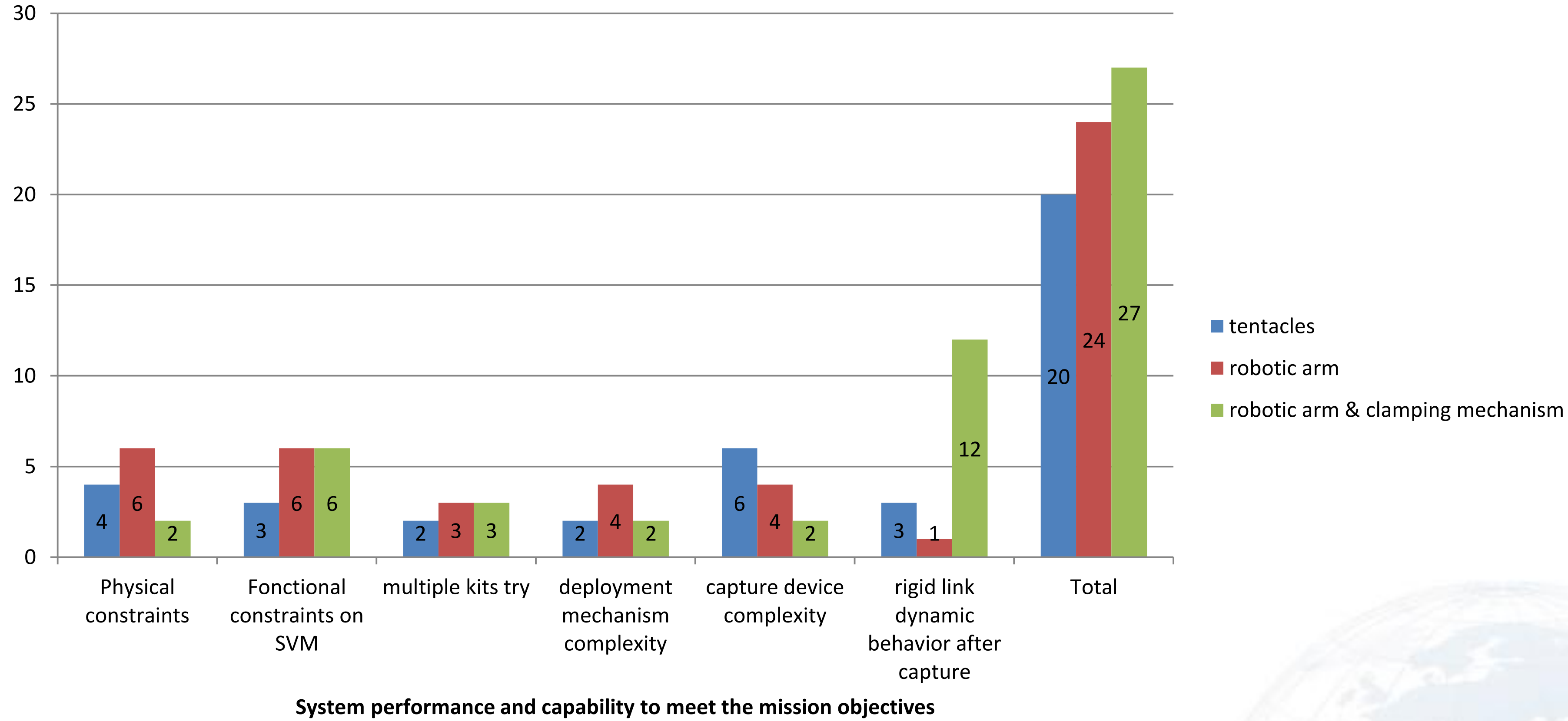


Concept #1 : flexible solution = Harpoon

Harpoon design focuses on risk mitigation

Concept #2 capture Trade-off

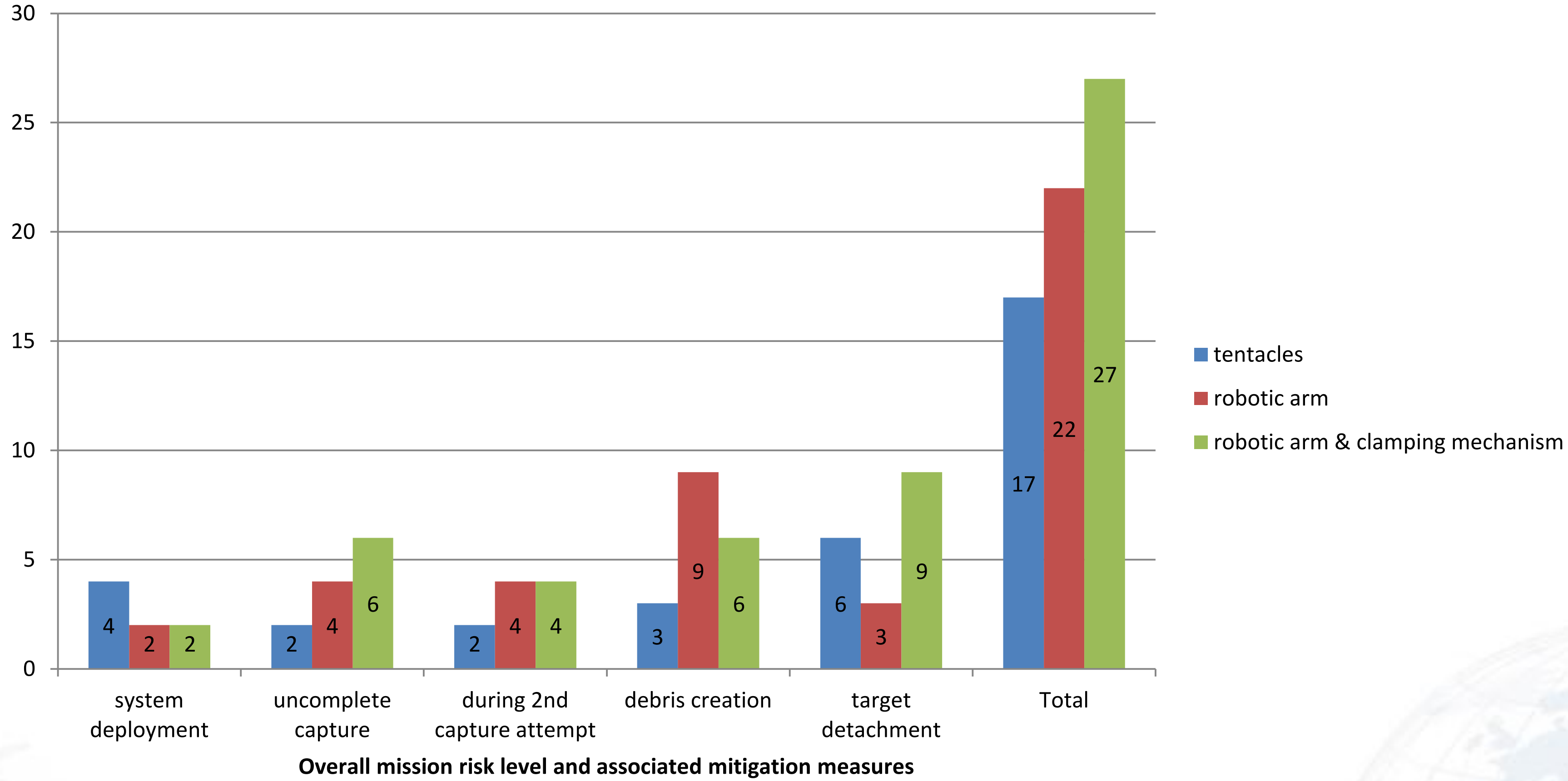
- Technical feasibility & TRL ➔ no significant difference
- System performances is the main driver



Clamping mechanism insures rigid link for re-entry with alignment of both Cog

Concept #2 capture Trade-off

Mission risk



Risk is mitigated by the two capture systems

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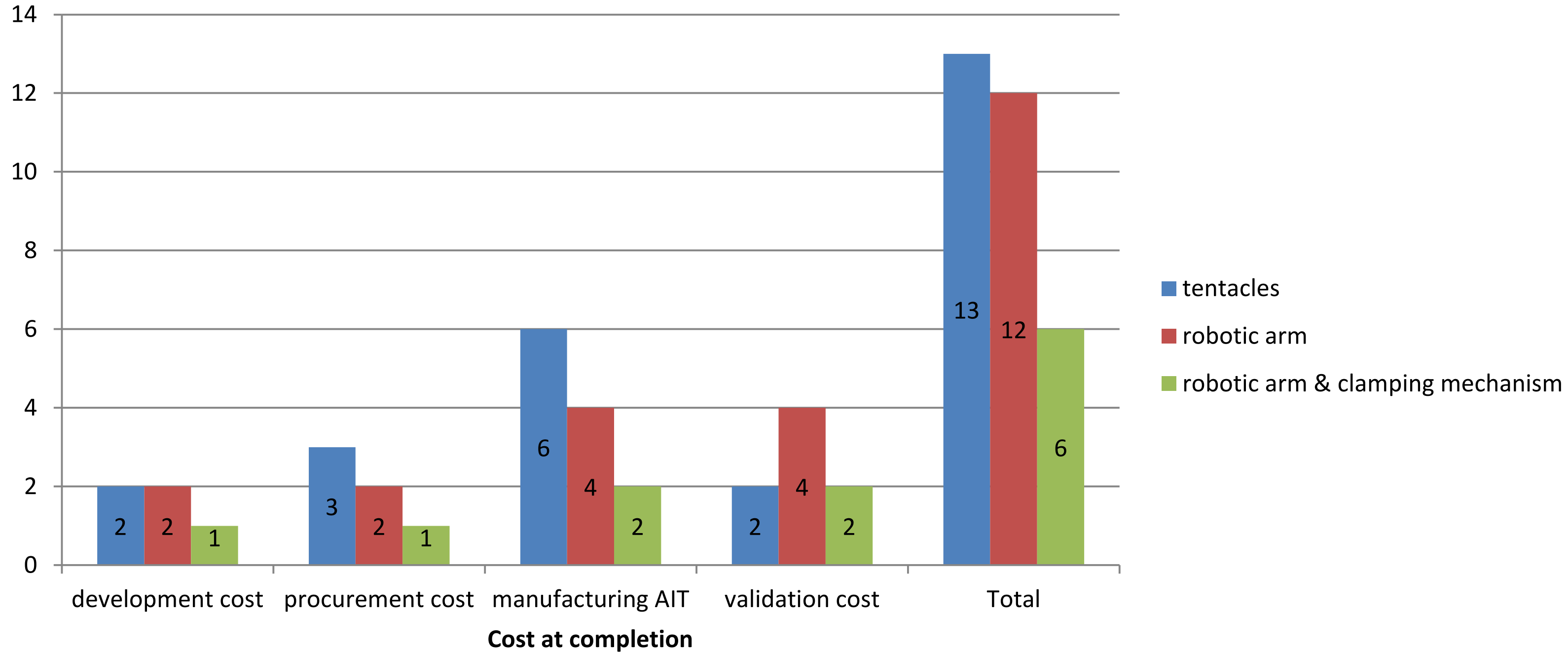
Concept #2 capture Trade-off

Cost



Total		Total weighted score Tentacles	70	Total weighted score Robotic arm	77	Total weighted score Robotic arm + clamping mechanism	80

Robotic arm & clamping mechanism is necessary to support high thrust controlled re-entry

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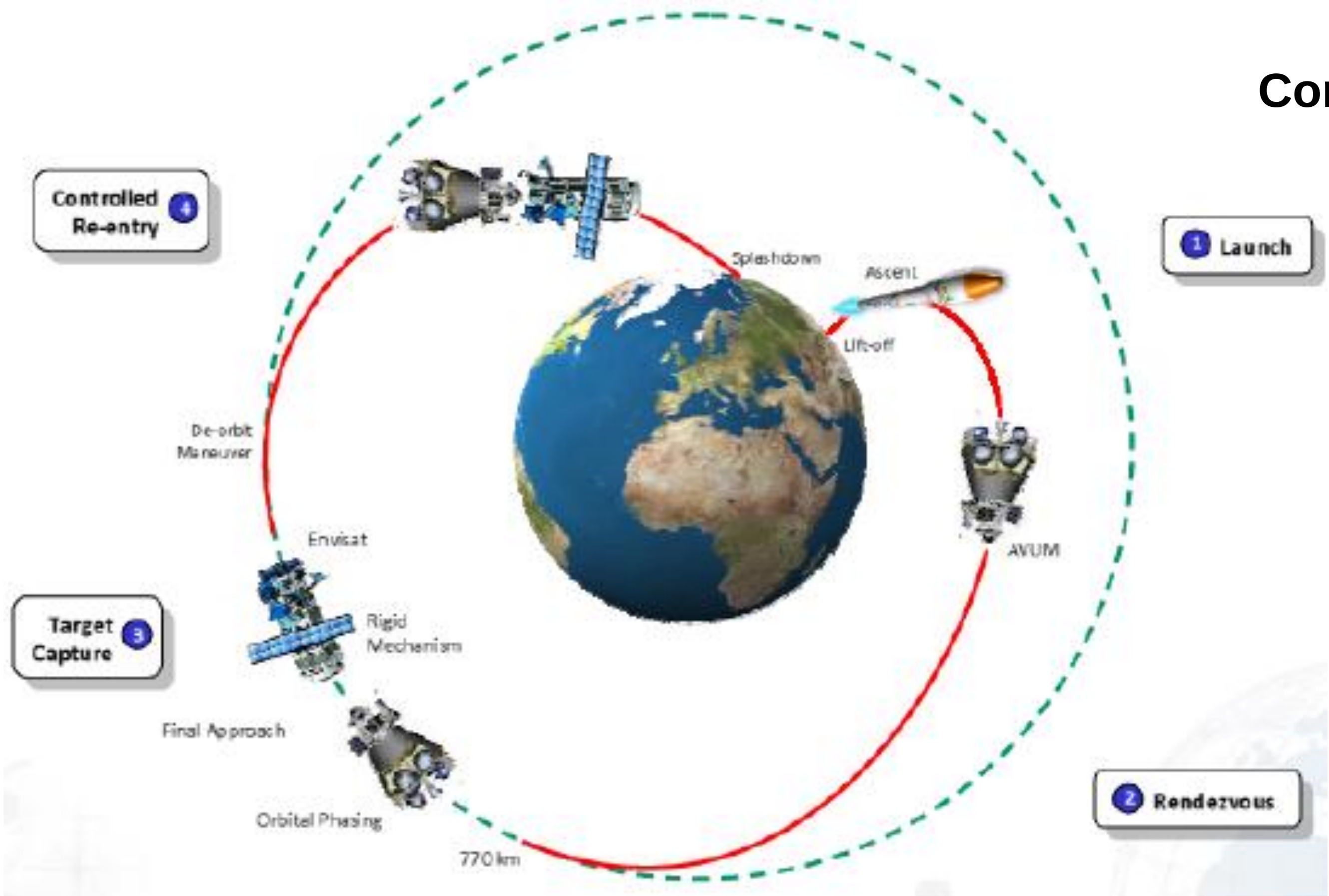
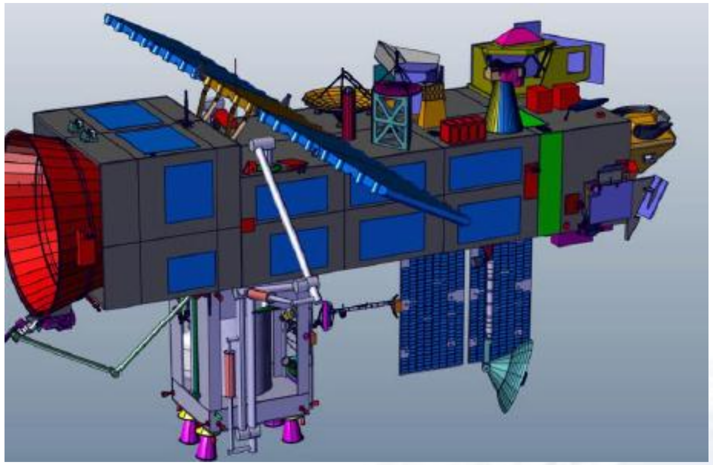
Concept #2 capture Trade-off

Concept #2 selection after MBR



Concept #2 : Rigid solution = robotic arm + clamping mechanism



Robotic arm will capture the debris. To insure controlled re-entry with high thrust, a clamping mechanism is necessary

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Concept #3 capture Trade-off

- 3 possible capture techniques
  - Contactless
  - Flexible link
  - Rigid link

- Mission re-orbitation
  - To reach 2100 km
  - Then reach own graveyard orbit

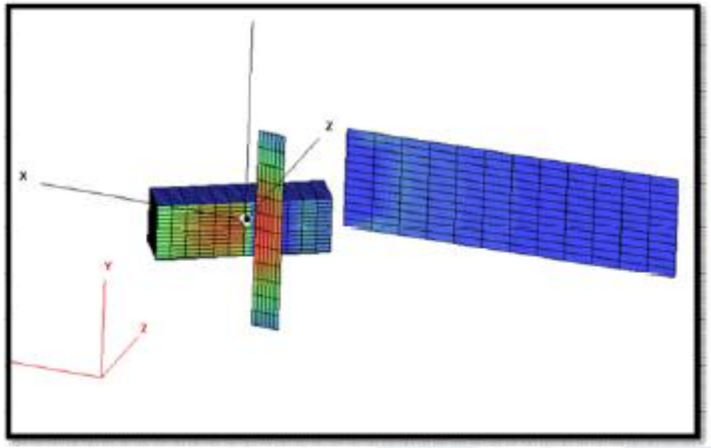
Re-Orbitation requires same mission phases: rendez-vous, capture, controlled of the stack

Concept #3 capture Trade-off

- Electric propulsion is mandatory to reach 2100 km altitude
  with a VEGA Launch

	M launch			1400 kg			
	Isp (s)	ΔV 1	Propellant mass	Mass before deorbiting	ΔV 2	Propellant mass	Total propellant mass
MON/MMH	320	62	27	9223	610	1629	1657
QT6	4120	62	38	9212	610	138	1224

  - Thrust stop during eclipse



- IBS solution not in line with Vega or Soyuz launch
  (IBS = Ion Beam Shepherd)
  - Required propellant mass > 1800 kg

Contactless solution is not possible for eDeorbit

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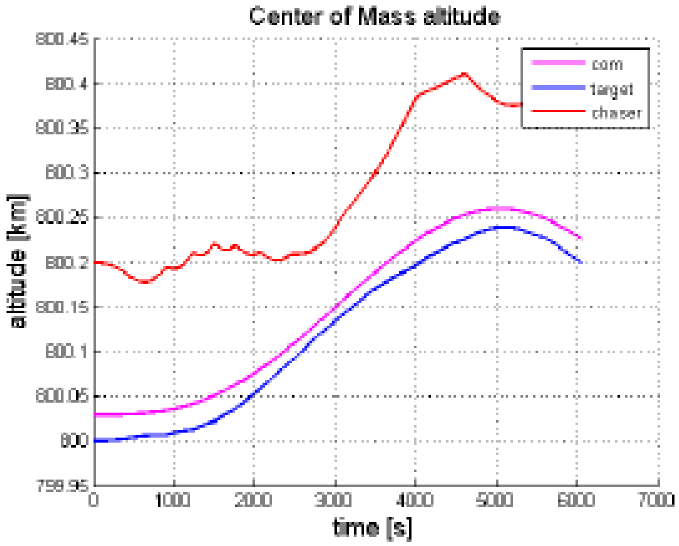
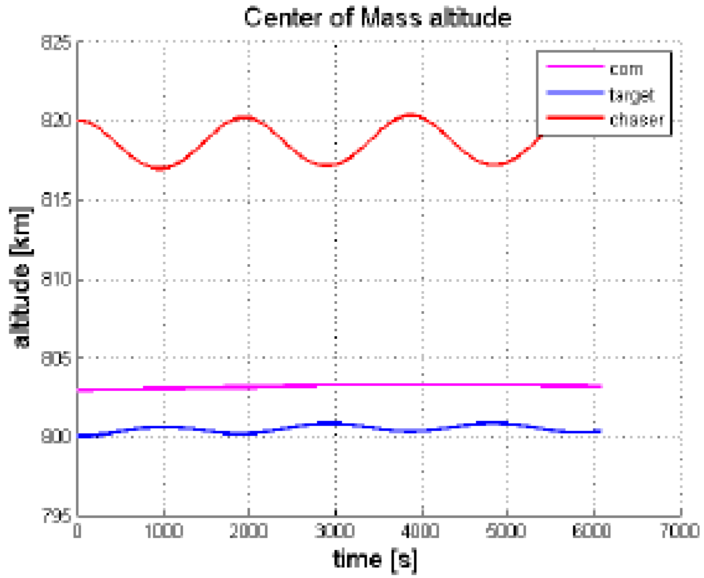
Concept #3 capture Trade-off

- Flexible link needs long cable to insure stability



Cable length 200 m



Cable length 20 km

- 330 days versus 4,7 years in high debris populated region

Mission duration is a key factor wrt collision risk during re-orbitation

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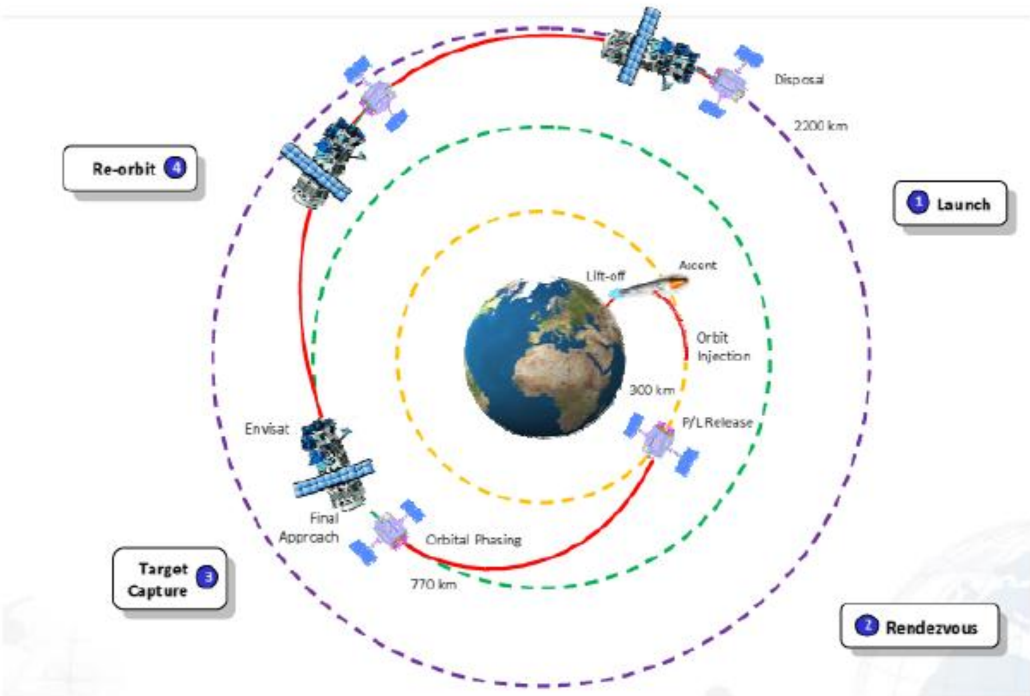
Concept #3 capture Trade-off

Concept #3 selection after MBR



Concept #3 : Rigid solution = robotic arm + clamping mechanism

Rigid Solution is selected for re-orbitation. Design will benefit from low thrust solution.

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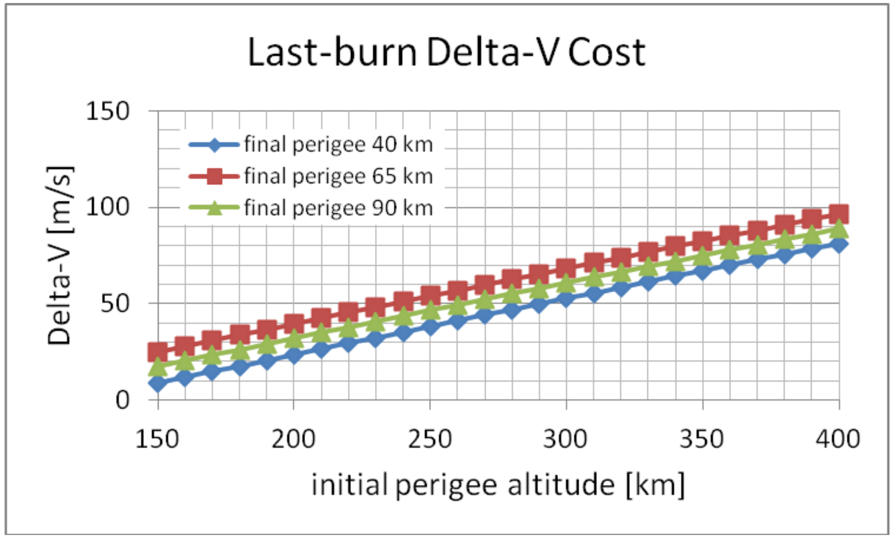
Mission analysis

- Optimal injection orbit Vega
  - Low Zp
- Soyuz only as back-up
- multiple burn strategy
  - *Performance optimization*
  - *re-entry slope for footprint area*



High thrust for last burn insures debris footprint into SPOUA

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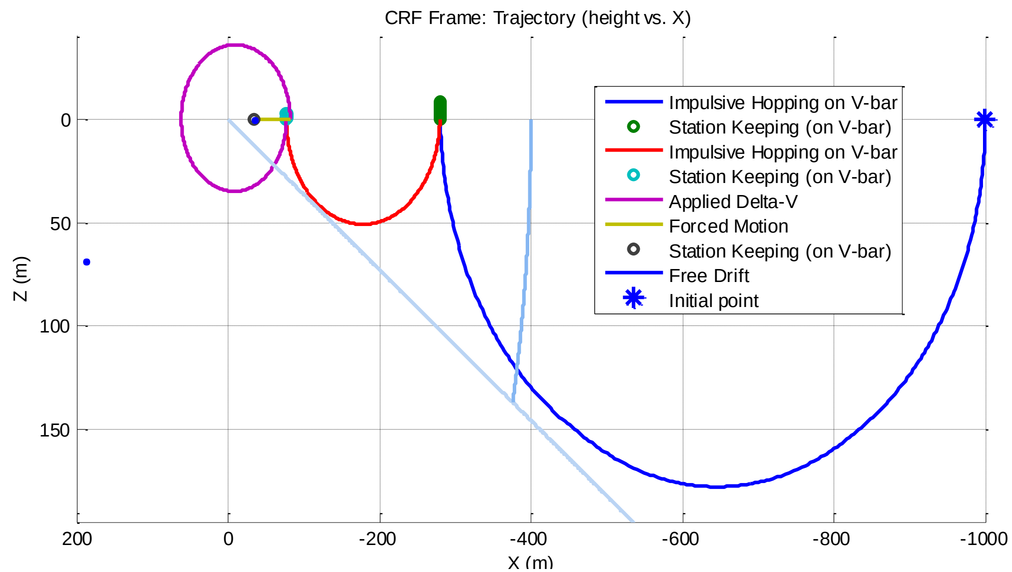
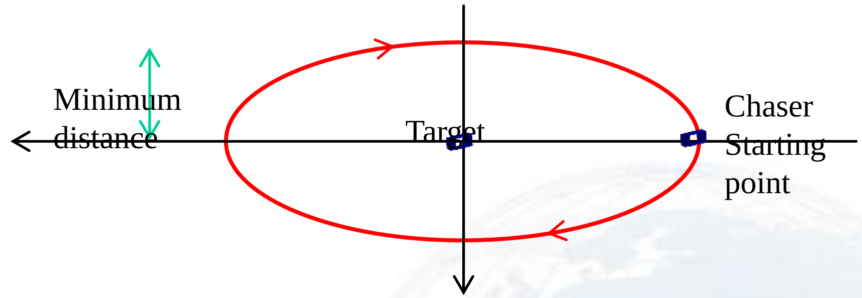
Rendez vous

- RdV strategy
  - V-bar impulsive hopping radial
  - Fly around
    - With target in FOV sensor
    - Restitution phase
  - Force motion



- Autonomous rendezvous strategy with non collaborative targets has a good TRL thanks to comprehensive R&D & testing



ADR specificity is to operate a large target

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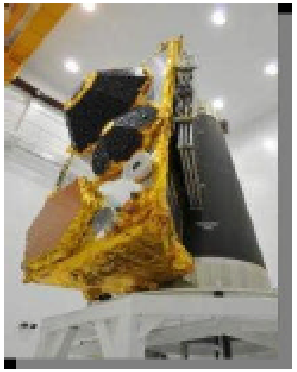
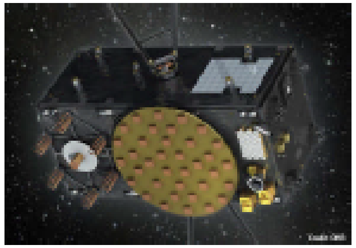
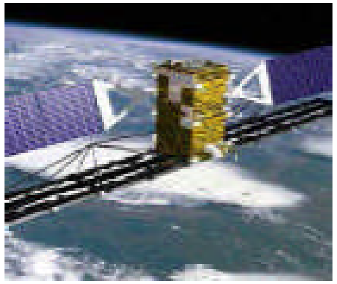
Satellite concept

ELiTe (Constellation) **PL <270 kg** SC <750 kg	Galileo IOV **PL <300 kg** SC <700 kg	PRIMA **PL < 1200 kg** SC <2000 kg	SPACEBUS **PL < 1500 kg** SC <3000 kg SB 3000B2
			
GBS-2 (2010) [Telecom, 24 SC] **O3B (2013)** [Telecom MEO – 8000km, 16 SC] **IRIDIUM** (2014) [Telecom LEO – 80 SC]	GALILEO PFM, FM2 2011, (ESA, EC) GALILEO FM3,FM4 2012 (ESA, EC)	**RADARSAT-2**(2008) [SAR, Canada CSA] **Cosmo Sky Med** (2010, 4 SC) [SAR, Italian MoD] **SENTINEL1** (2013) (SAR Land Environment, ESA) Cosmo Sky Med 2nd G (2017/18) [SAR, Italian MoD]	**Arabsat 3A, AB2, Eurobird, Eutelsat W2, W3, W4, W5, Hispasat 1C, 1D, Sirius 2**
Hydrazine propulsion	Hydrazine propulsion	Hydrazine propulsion	Bi-propellant

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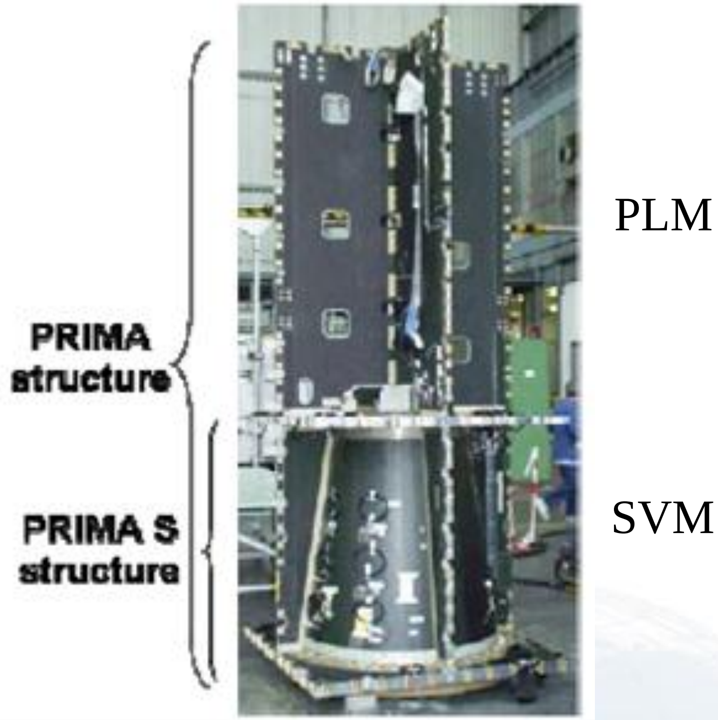
Satellite concept

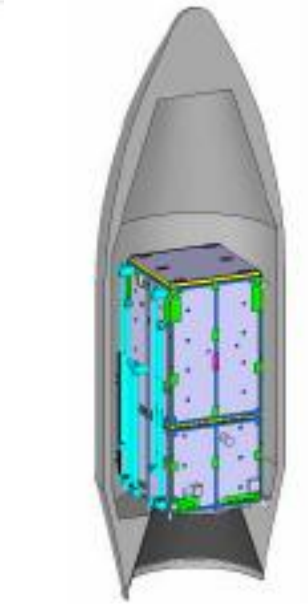
- SVM can rely on TAS LEO Platform product lines for
  - Avionics
  - Power subsystems
- Synergy with Spacebus propulsion
  - Bi-propellant & electric
- Derived from PRIMA platform:
  - Composed of PRIMA-S (SVM) structure & PLM structure
  - Central cone to guarantee the structural integrity of the central tube
  - PLM will support main propulsion
- Fits into Vega launcher



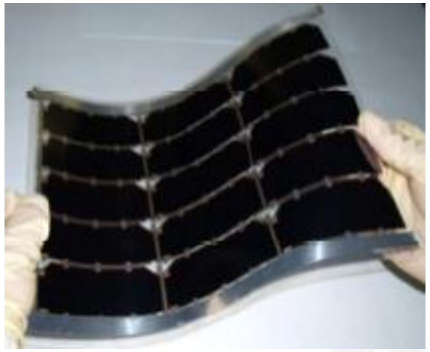
Building block from LEO platform product line enables to reduce risks & cost

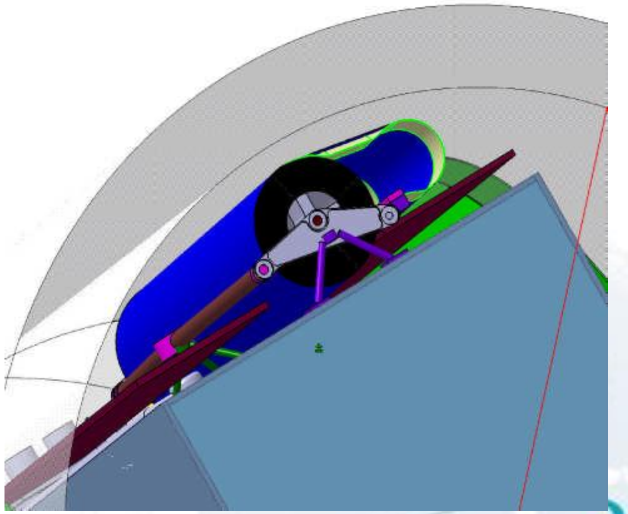
Satellite concept

- Concept 3 with electric propulsion
  - Composed of PRIMA-S (SVM) structure & PLM structure
  - High power need ~5 kW
  - Flexible solar array ease capture
- Fits into Vega launcher
- In line with the current development road map
  - Neosat 1st application



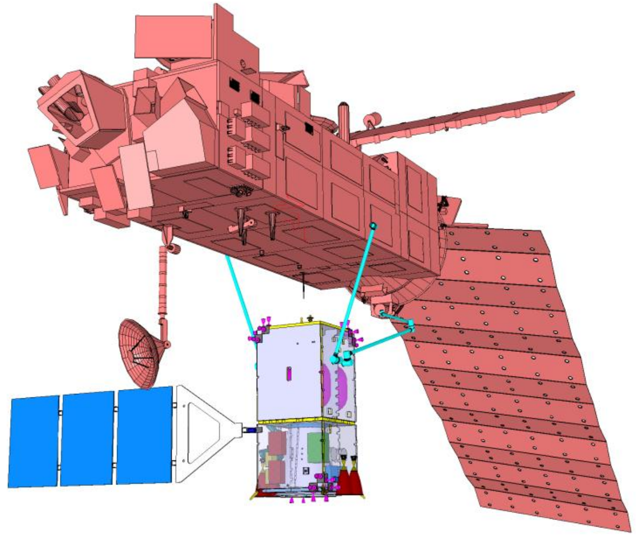
Flexible SA accommodated for low thrust propulsion

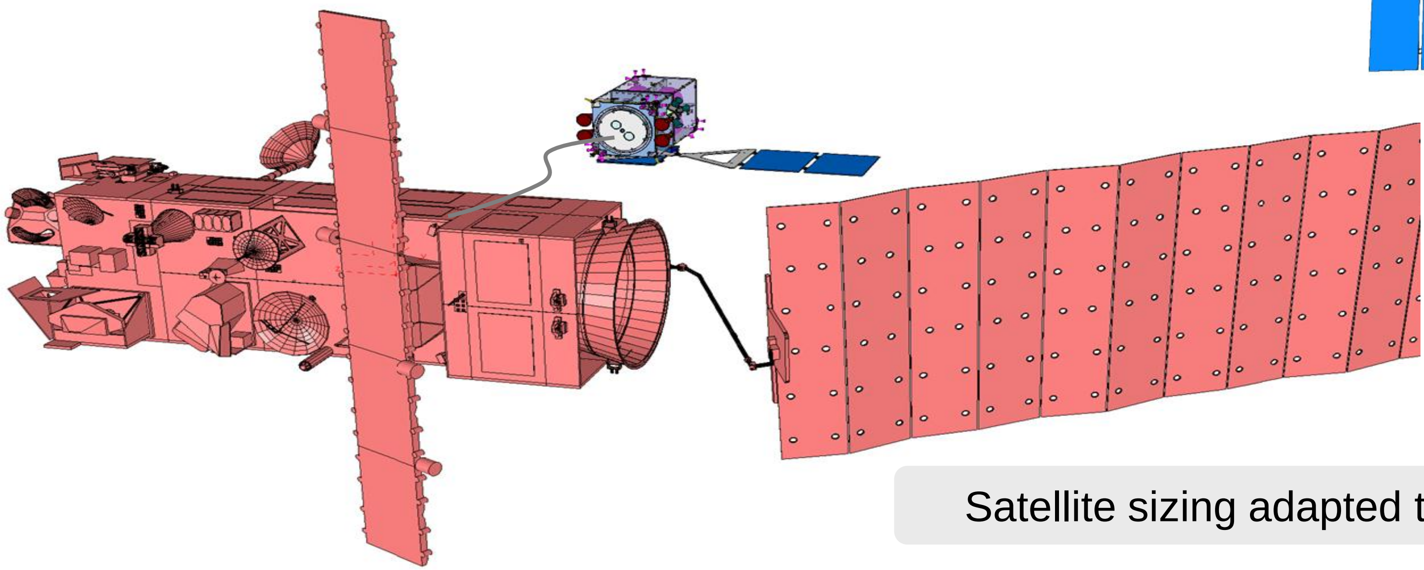




Satellite concept

- Adaptation of Prima Platform for each concept
  - *Harpoon*
  - *Tentacles & robotic arm*
  - *Electric propulsion*





Satellite sizing adapted to each concept

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Ref.:

ADR Mission technology actions

- Challenging mission

  - *RdV with non-collaborative target*
    - *Support also interplanetary mission with autonomous RdV*

  - *Technologies TRL are reasonable, step to reach TRL6 is needed*
    - *Flexible link controllability*
    - *Harpoon/net deployment & capture*
    - *Final approach & sensor processing*
    - *Control of the connected system, algorithms, FDIR*
    - *Tumbling reduction capacity*

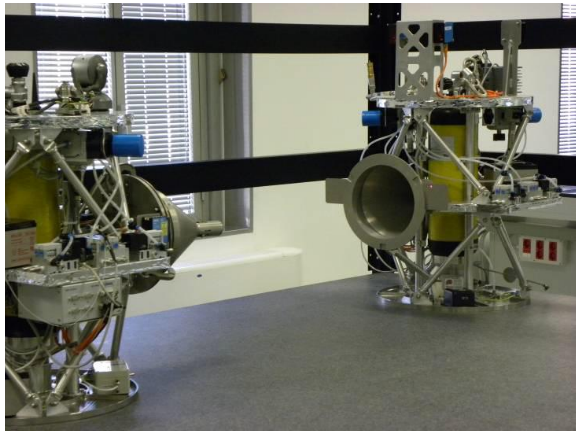
R&T needed to mature efficient technologies

Thales Alenia Space Technology Readiness

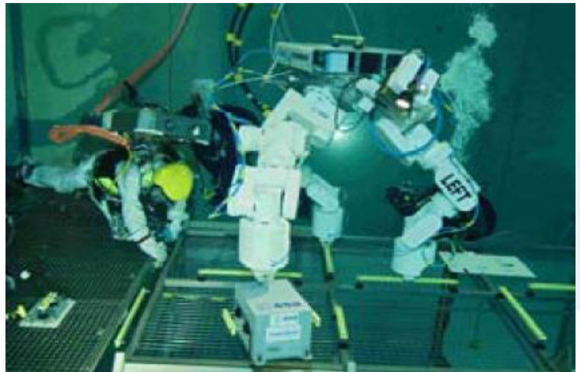
- Rendez-Vous GNC is a major development axis
  - Rendez-vous for non collaborative mission (with partners)
  - Robotic RdV Test Facilities
  - Optical sensor processing with large target.
  - Terminal Rendez-Vous Control with tumbling target
- Robotics
  - Technology Demonstator
  - Control & Dynamics
- Tether cables & Flexible system dynamics
- Mechanisms

TAS is preparing key technologies to enable ADR: Rendez-Vous, Robotics, Control, Mechanisms …
also involving key partners

RdV & FF Test Bed
TAS-F



RdV & FF Test Bed
TAS-I



Eurobot Demonstrator
TAS-I

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Conclusion

- The ADR of a large spacecraft is a challenge:
  - Increasing with the tumbling rate,
  - But can be foreseen with solutions with a reasonable TRL.

- Rigid connection with a robotic system has the higher maturity
  - As it takes benefit of development for exploration & manned flight.

- Flexible links are promising and will require technology & system development effort to achieve robustness, reduced risks and qualification:
  - Harpoon or net system (ejection, capture, failure management)
  - Control and FDIR of the system (controllability, anti-collision)

- The Service Module can rely on LEO platform product lines to optimises its cost completed with propulsive elements mostly used in GEO.

- THALES ALENIA SPACE is preparing the ADR solution:
  - Using synergies with exploration & Manflight technologies: RdV, Tethered, Robotics …
  - And system study at European and national level.