Harmony Mission – Designed to Demise

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12/10/2022

Harmony within ESA's EO missions landscape

THE EUROPEAN SPACE AGENCY

Harmony is ESA's Earth Explorer 10 mission, comprised of two companion satellites in a loose convoy with Sentinel-1D (along-track separation ~350 km).

- Its payload suite consists of a passive SAR and a multi-view TIR instrument
- Launch in 2029
- Multi-faceted mission (solid Earth, land ice and ocean)

APPLICATIONS

Latest news (22/9):

ESA selects Harmony as tenth Earth Explorer mission

A multi-domain "Earth System" mission

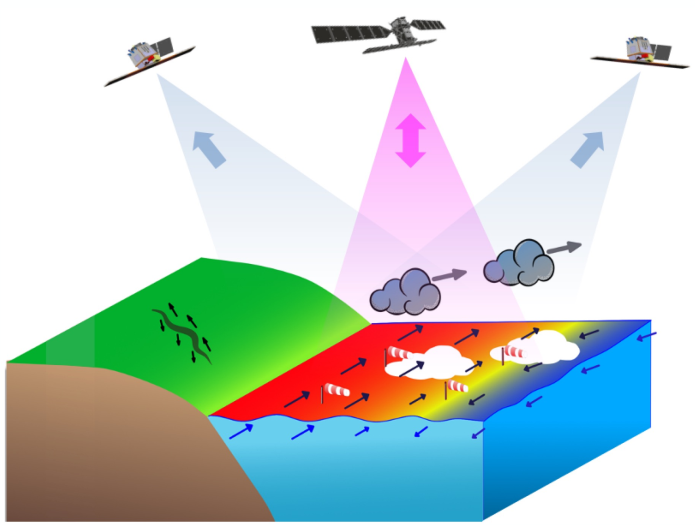
Upper oceans and ocean-atmosphere interactions

Land ice and sea ice

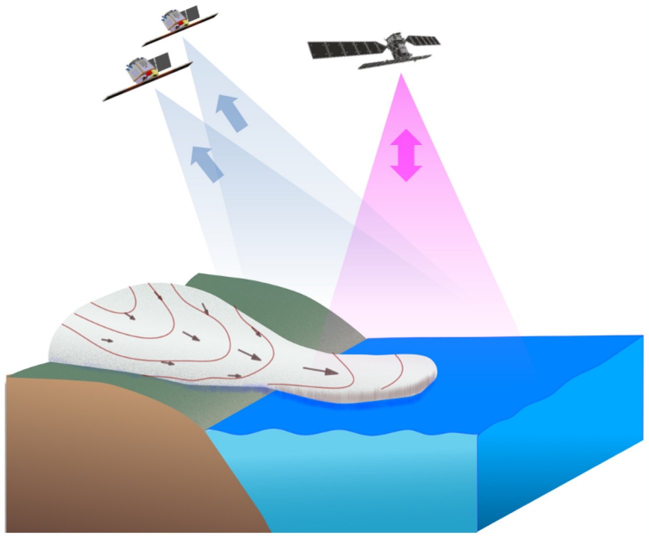
Tectonic strain and volcanic processes

Observation Concept

Yr1 (XTI) → Yr2 (Stereo) → Yr3 (Stereo) → Yr4 (Stereo) → Yr5 (XTI)



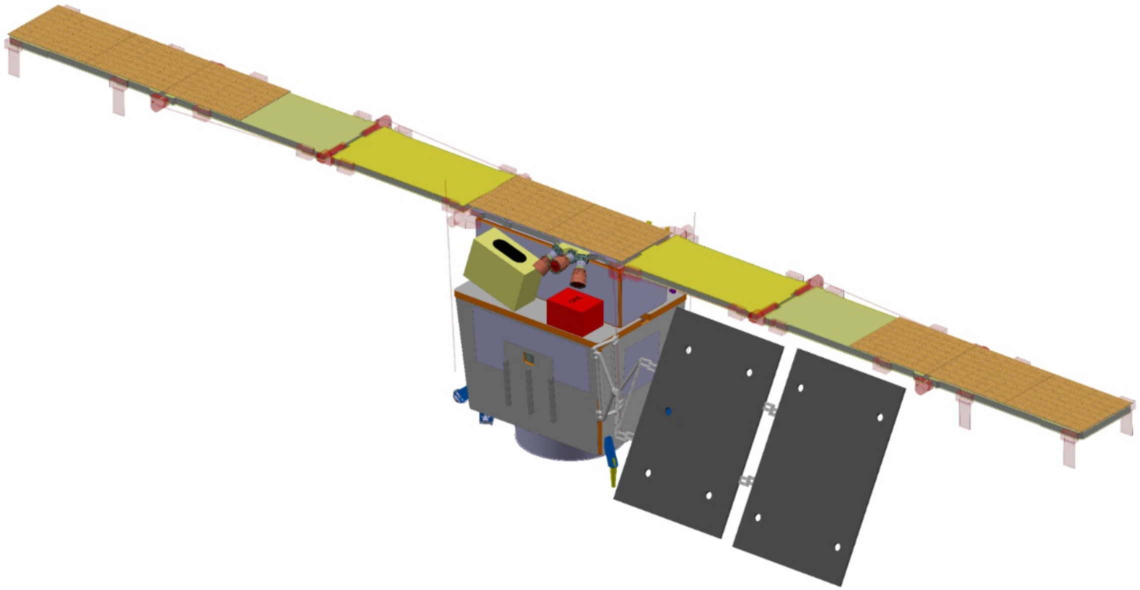
STEREO

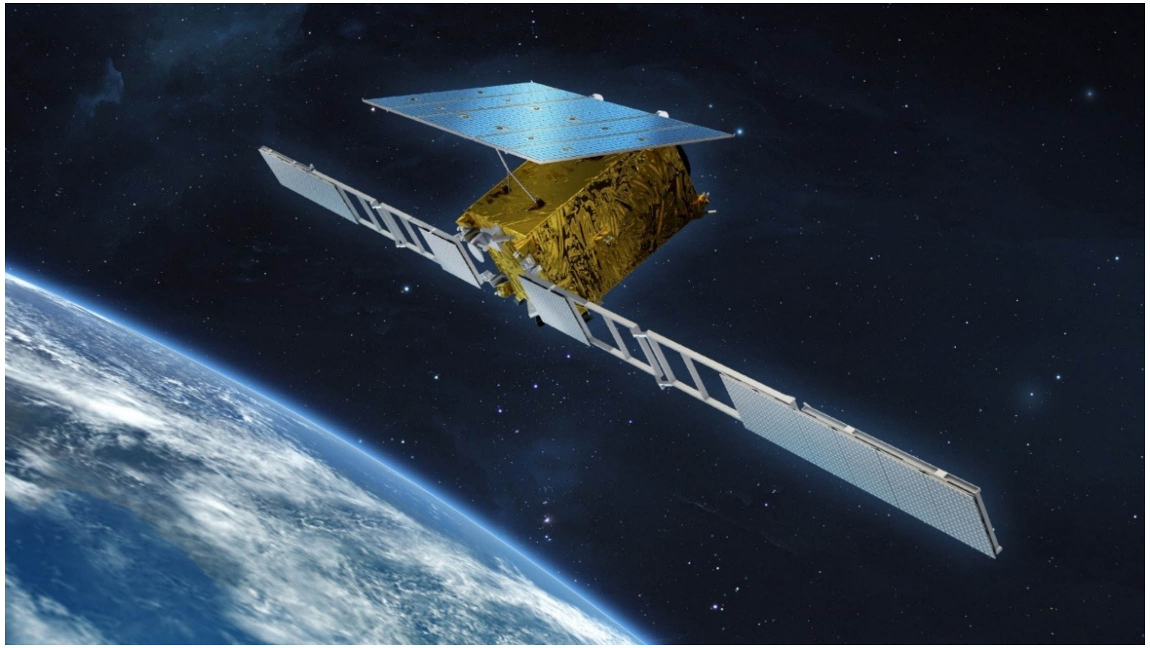


Across-Track Interferometry
XTI

Harmony can reconfigure itself in two different configurations, Stereo and XTI, each optimised for different observation techniques, to address different science goals.

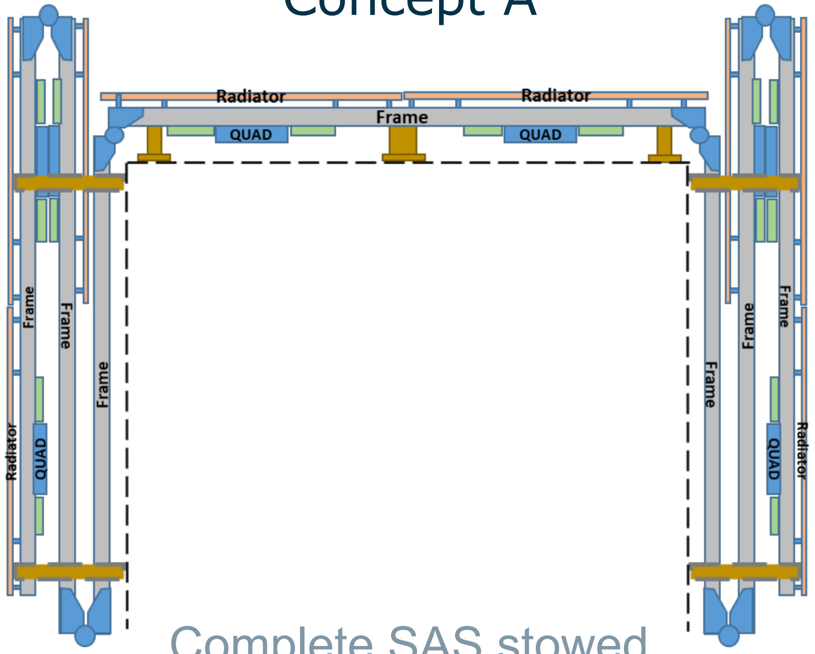
Harmony Concepts (PRR)





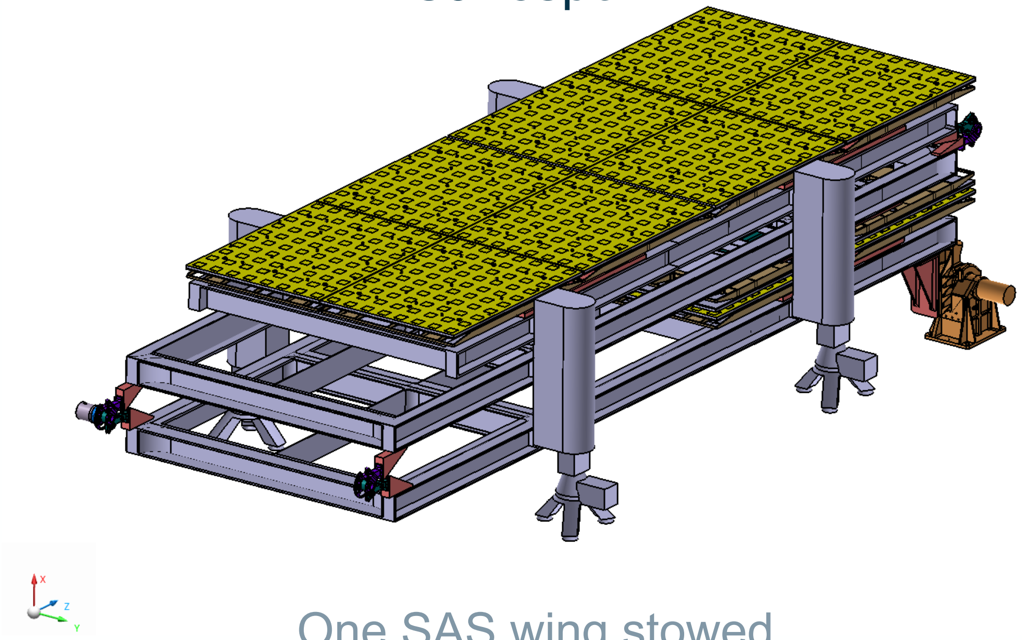
SAR Antenna in Stowed Configuration

Concept A



Complete SAS stowed

Concept B

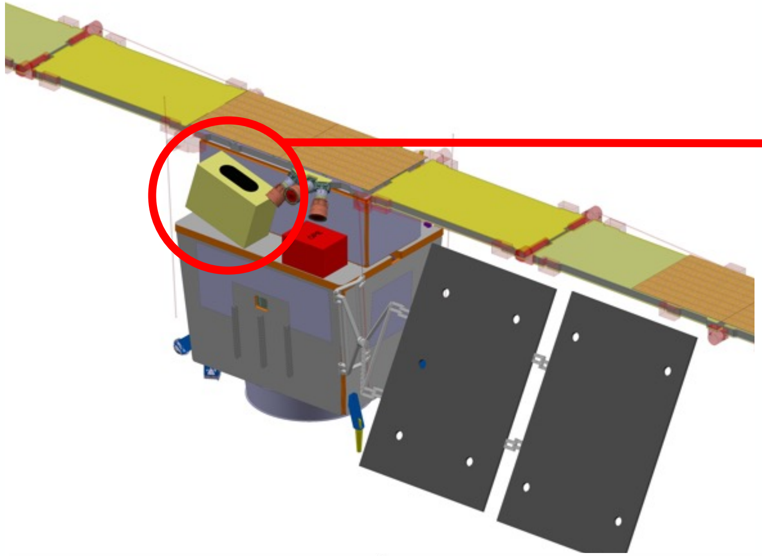


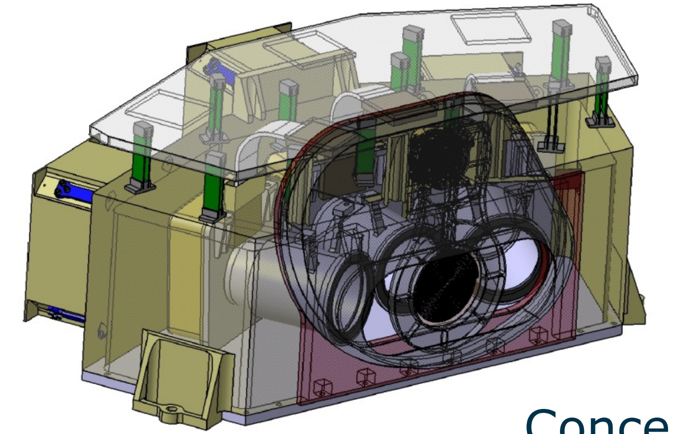
One SAS wing stowed

Two different mechanical concepts have been selected:

- The SAS in Concept A is a self standing structure that is folded around the spacecraft.
- In Concept B the SAS comprises of two wings that are mounted at the side of the spacecraft.

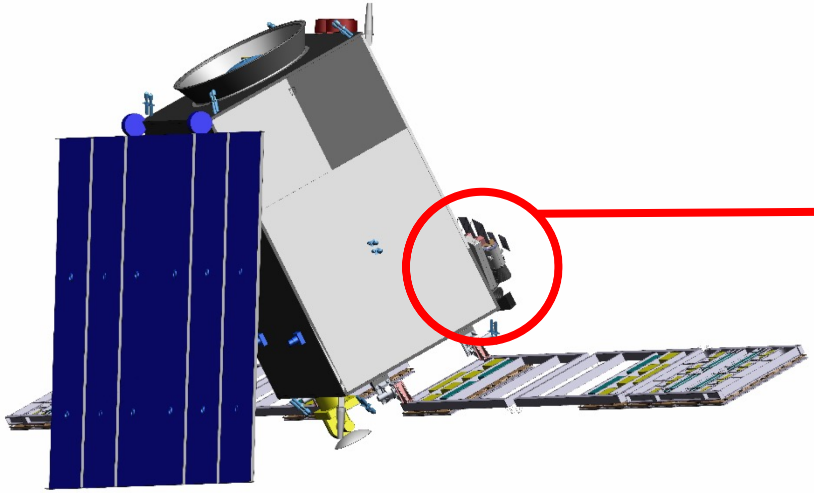
Thermal-Infrared Instrument

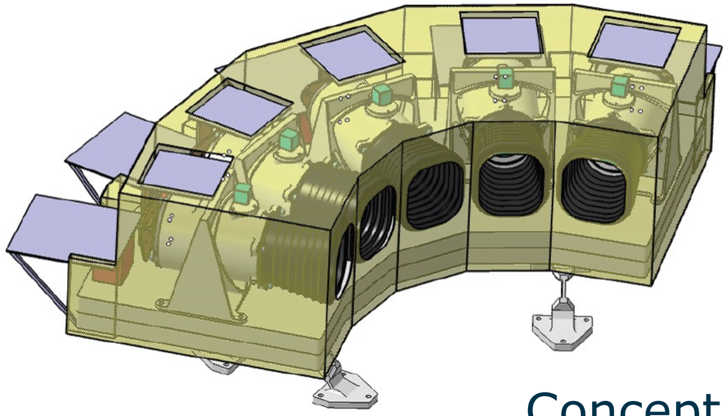




Concept A

Concept A



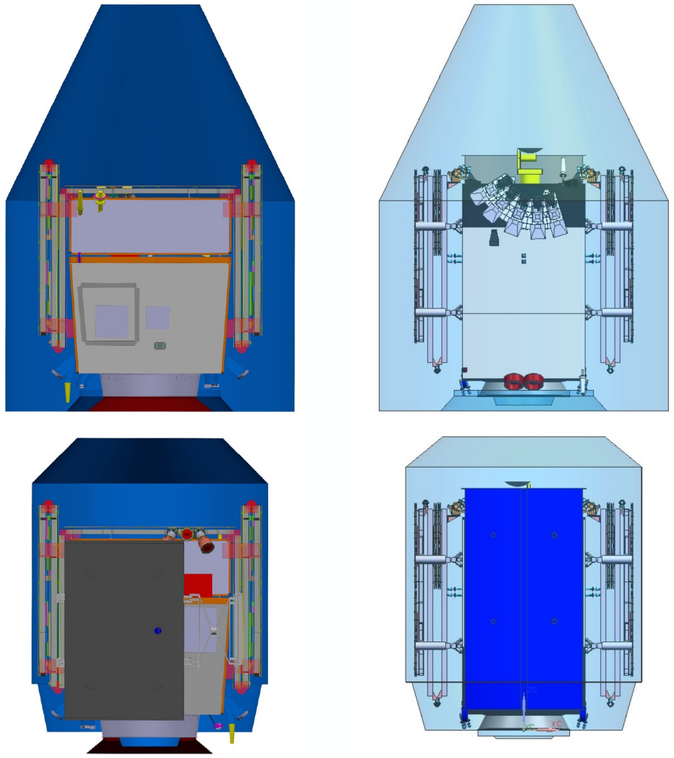


Concept B

Concept B

Dual-Launch on VEGA-C

Concept A   Concept B



	Concept A	Concept B
	[kg]	[kg]
Platform	468	441
SAR instrument	209	242
Optical instrument	50	51
Dry total	727	734
Dry inc. system margin	872	881
Propellant A+B	160	200
Total launch mass	**1904**	**1961**
Launch orbit [semi-minor axis x semi-major axis](*)	500km x 693km	400km x 693km
Launcher capability to target orbit (**)	1934	1964
Margin	30	3

(*) Both concepts assume an elliptical launch orbit with apogee near target orbit.
(**) Takes into account VESPA dual-launch adapter.

Both concepts are compatible with a dual launch on VEGA-C, both in terms of mass and volume.

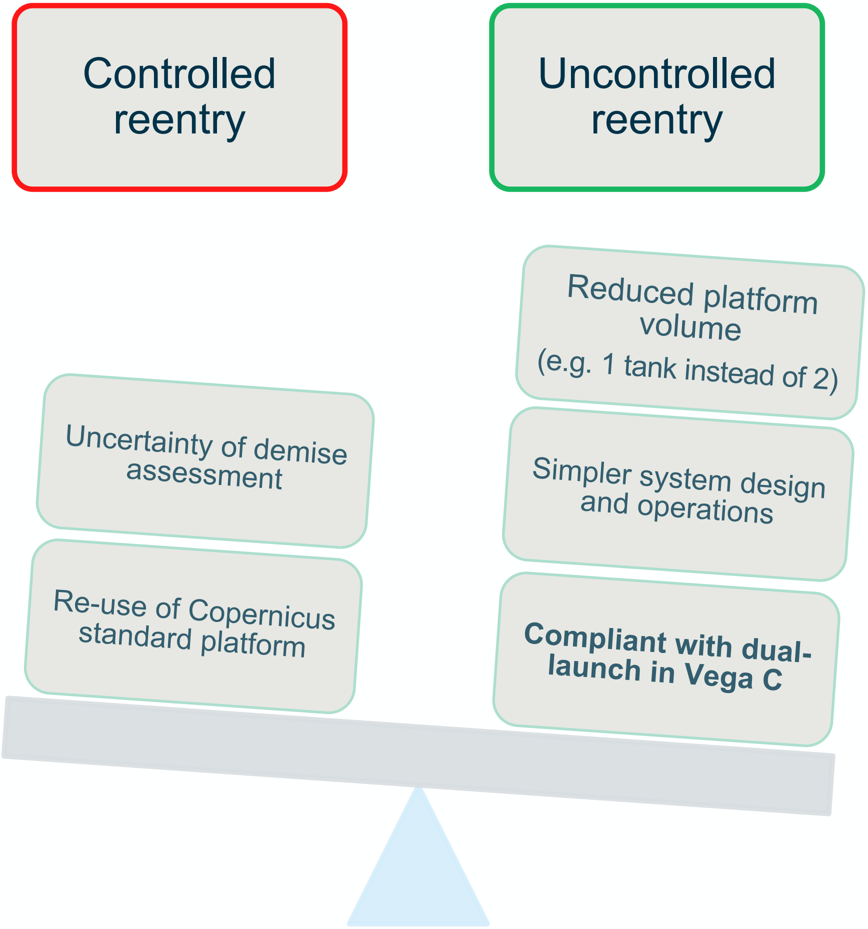
HARMONY Phase A design drivers for EOL

- Baseline shall be compatible with dual launch on Vega-C
  - Limited volume and mass
- Formation Flight with Sentinel-1
  - Fixed operational orbit
- Mission combining optical and radar payloads
  - Large deployable Radar antenna
  - High mechanical stability & tight pointing requirements
- Cost constrained
  - Non recurrent costs must be minimized
    - → Use of LEO standard platform product lines
    - → Limited possibility of adaptations of the platform

Major driver for the design!

- VESPA-C vs. Stacked Configuration
- Direct injection vs. Injection in low orbit
- Uncontrolled vs. Controlled re-entry

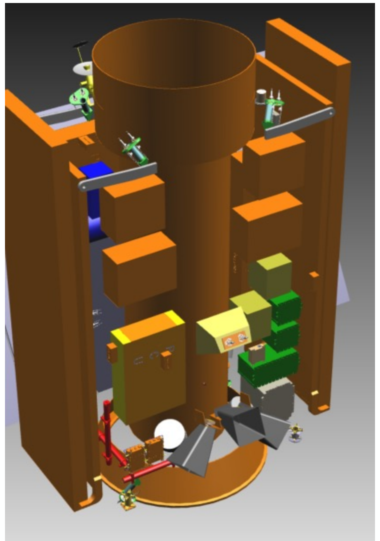
Controlled reentry vs. Uncontrolled reentry



Conclusion: Harmony shall meet the casualty risk requirement with uncontrolled re-entry.

Casualty risk – Critical components

Platform components



- CFRP internal structure
- RW mass
- Tank
- Star trackers
- Gyroscope
- Drain Valve
- Electronic units

- Platform itself close to 10^{-4} threshold
- No room for fragments from payload

Optical payload components

Bipods

Optical bench

Optical units brackets (Ti)

Lenses (ZnSe, Ge)

Lens barrels

Radar payload components

High stability support structure
(e.g. titanium brackets)

Design for Demise strategy

Fix from the beginning **applicable modelling approach** and assumptions :
- material modelling assumptions
- break-up modelling approach

Platform: Identify design for demise options with minimum non-recurrent cost

Payload: Design from the beginning for full demise

Avoid containment, unless it would not increase the severity/energy of a ground impact

Close collaboration between industrial consortium and re-entry simulation and design for demise experts is key

Platform

Main risks and uncertainties

- Break-up altitude
  - Fixed at 78 km

  more optimistic results from DRAMA melting of external structure but considered uncertain

- Modelling approach and materials
  - Guidelines for Demise Verification (DIVE) and material databases applicable

  Important for complex equipment STRs, RW, Gyros, etc.

- Modelling of electronic equipment
  - Agreed to use current DRAMA model

  Research on going, but decision taken in the absence of consensus on the best modelling approach

Design for Demise options

(limited modifications possible - standard platform)

- Trade-off of different Star-Trackers designs
  - Option without titanium parts identified
- Gyroscope without titanium housing baselined
  - Detailed modeling resulted in full demise
- Reaction Wheels with aluminum flywheel
  - Option to reduce footprint per RW, even if the Ball Bearing Unit may still survive

Optical payload

Main risks and uncertainties

- Performance requirements
  - Thermal stability requirements often contradictory to Demise
- Nested design with several small elements in materials hard to demise
  - Glass lenses, mirror motors, etc.

  Parent-Child feature in DRAMA used to guarantee a fair assessment of the shielding
- **Lack of material data**
  - In particular for glass materials

  Absence of test data, technical assessments done and agreed with safety office (e.g. modelling of ZnSe)

Design for Demise options

(goal: full demise)

- Optical bench in aluminium
- Replace of titanium lens barrel with aluminium
- Bipods designed as single-part components, and different options analysed:
  - Replacement titanium with invar
  - Bipods containment → discarded
  - Replacement titanium with aluminium

Baseline

Optical payload – zooming in into the ZnSe lenses

Zinc Selenide does not fit a ‘standard’ demise model → **No test data exists**

Several small lenses (<150 gr) deeply nested in the payload design → **driver for casualty risk**

→ Multi-disciplinary Panel of Experts put together, including Internal and external experts on optics, materials, safety and demise demise to agree on the modelling approach

Properties available, Zinc Selenide has a melt point of 1798K BUT…

In air, Zinc Selenide oxidises ~520K, deforms ~720K and decomposes ~920K
Sufficient oxygen should be available during reentry for decomposition

Decomposition is to hydrogen selenide (gas), selenium (melt 220C) and zinc oxide powder.

Contiguous zinc oxide could be a risk → high melt (2247K). However:

- Dynamic environment → promote the formation irregular-shaped/porous particles.
- fragment would be a fraction of the full lens (<< 150g).

MEETING

Meeting Date	28/01/2022	**Ref**	EOP-ΦMP/2022-01-2334
Meeting Place	webex	**Chairman**	Rosario Nasca Erik De Witte Digitally signed by Date:
Minute’s Date	28/01/2022 Erik De Witte Digitally signed by Erik De Witte Date: 2022.02.03 12:41:59 +01'00'	**Participants**	Benoit Bonvoisin TEC-MSP Bernardo Carnicero EOP-8MP Erik de Witte EOP-8MP Flavio Mariani EOP-8MO James Beck EXT: BELSTEAD Kevin Hall EOP-8MP Rosario Nasca TEC-QI Sergio Ventura TEC-QI Stijn Lemmens OPS-SD Tiago Soares TEC-SYE
Subject	ZnSe lenses demisability modelling for Harmony	**Copy**	

Decomposition based model agreed for HRMY
Recommendation for the future: Confirm this assumption by test

Radar Payload

Main risks and uncertainties

- Granularity of the modelling
  - Guidelines for Demise Verification (DIVE) applied → cut-off criteria per type of material
- Electronic elements modelling
  - As for platform: Agreed to use current DRAMA model
- Support structure design
  - High thermal stability needed

  e.g. Assessment of limit titanium size of brackets that would survive investigated but designs on the verge of demising discouraged → considered risky.

Design for Demise options

goal: full demise

- Detailed modelling of antenna resulted in full demise of antenna elements
  - Note: passive antenna, smaller than S1
- Support structures could have a critical impact high number of surviving fragments.
  - Replacement of titanium by CFRP

  Resin choice as well as fiber layout analysed to improve demise → Manufacturability of brackets with promising design was confirmed by manufacturer.

Conclusions / Lessons Learned

- Harmony will be the first ESA mission that has been **designed for demise** from phase A onwards.
- Combination of several Design for Demise techniques at platform and payload level

→ feasible and credible HARMONY design with uncontrolled reentry and dual-launch in VEGA-C.

Enablers:

- Adopting Design for Demise from the beginning of the project was key
- Multi-disciplinary approach, involving experts from various disciplines (TEC-QI, TEC-SY, OPS-SD, external,…)
- Focus on D4D in industrial engineering team (and clear Statement of Work)
- Buy-in from scientists (to allow the necessary compromises)
- Clear strategy from the outset to identify where to focus D4D efforts and where to relax, in order to prevent large cost impact on the mission
- Close collaboration between industry and ESA experts from an early stage allowed to fix the assumptions and to enforce modelling consistency

There are several areas that can be improved:

- Knowledge of demisability of glass and different CFRP materials
- Break-up modelling
- Database of equipment models