D4OP

Demisability for Optical Payloads

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ThalesAlenia Space
a Thales / Leonardo company

Consortium & Team

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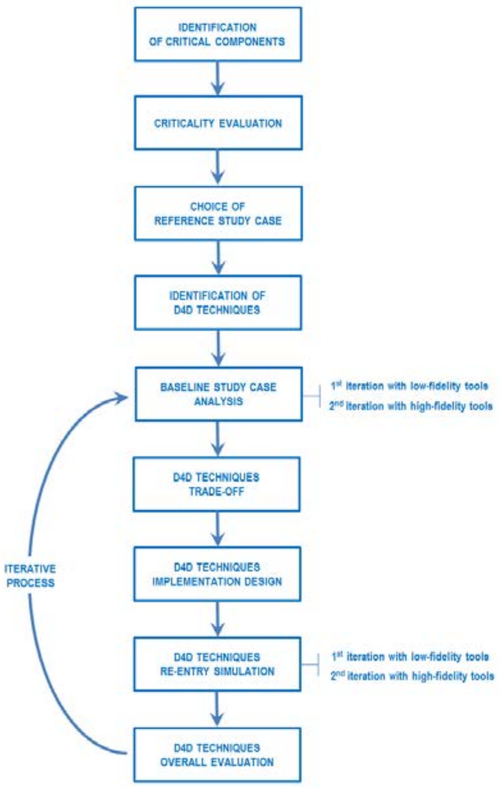
Study Goals & Main Tasks

Identify design solutions to improve the ***demisability*** *of optical payloads carried by satellites flying in LEO*
without impacting the payload ***performances***

Methodology & Achievments

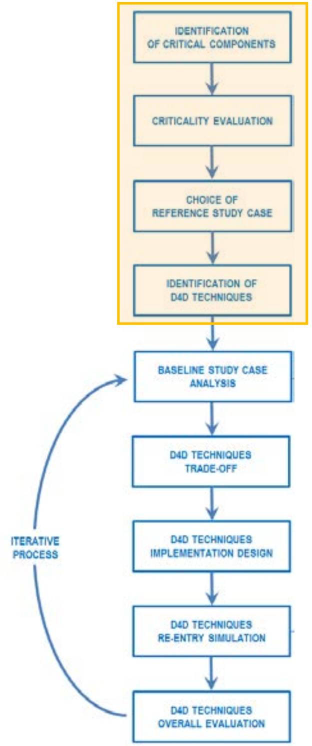
Methodology



Achievments

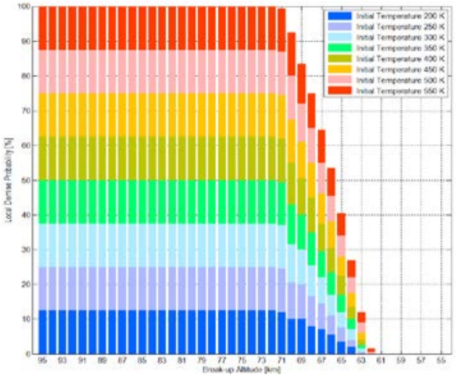
- CRITICAL ELEMENTS AND CRITICALITY
- D4D TECHNIQUES IDENTIFICATION
- LF ANALYSIS MODELLING AND RESULTS
- HF ANALYSIS MODELLING AND RESULTS
- DEMISE RESULTS AND D4D TECHNIQUES RANK
- ROADMAPS AND TEST PLANS
- OPEN POINTS

Methodology

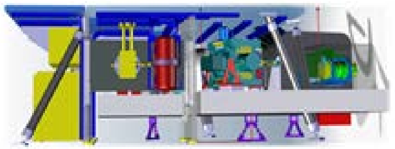


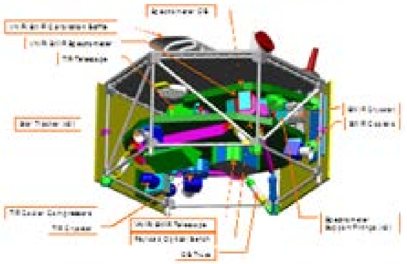
O/P P/L survey

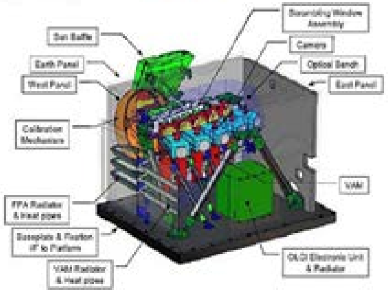
TADAP preliminary simulations



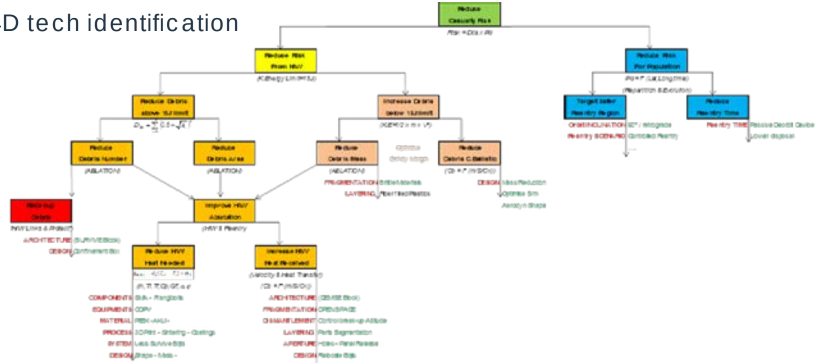
RSC selection







D4D tech identification



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Ref.: Clean Space Industrial Days & ATD3 Workshop
Template : 83230347-DOC-TAS-EN-005
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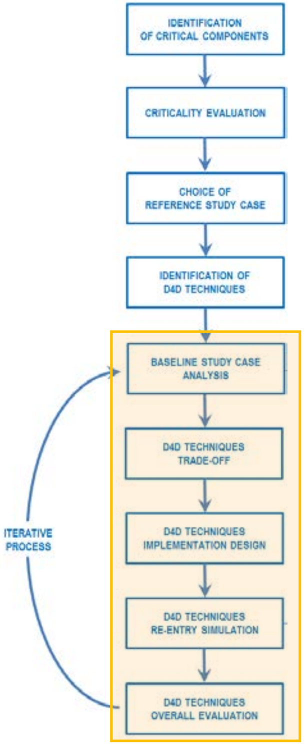
Methodology

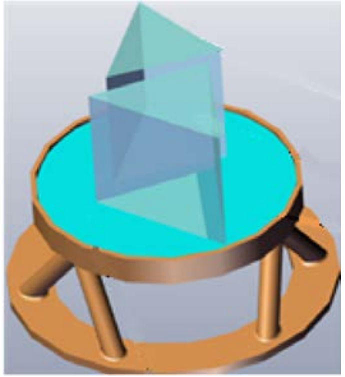


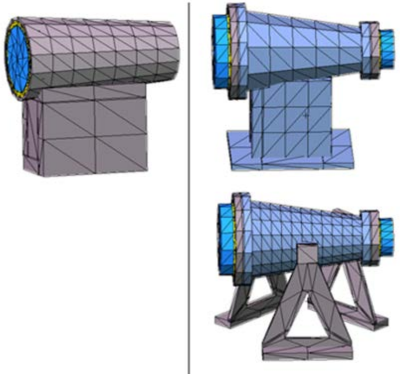
D4D tech trade-off

Quotation \ Contributor	Mass	Re-evaluation	Optical performance	Demisability	TRL	Cost
0	Mass increase unacceptable (> fuel reserve for controlled re-entry)	Technic not compatible with optical arrangement	Technic not compatible with optical requirements	No demise or limited demise (residual parts) => unacceptable	Immature or unrealistic concept	Cost increase out of the scope small to medium OP/L
2	Mass increase leads to a better efficiency of demise vs controlled reentry	Requests a full re-fundation of optical arrangement & instrument architecture	Such technics decrease very much the performances and impose a full rework with a high risk to not recover it	Secondary technic: insufficient but slightly improved demisability (requests, at least, the use of another main demise technic)	Prototype demonstra-tion	Cost increase could jeopardize the mission & interest of demise vs control reentry is questionable
5	Significant mass increase	Requests limited modifications of the instrument architecture & some optical layout optimization	Decreases significantly the performances and imposes important to full rework (active optics use for example)	Important demise impact (small residual parts, could be solved by association with another technic)	Demonstrator for validation	Increases significantly the OP/L cost & could be envisaged through sharing of optimization and/or development costs
8	Limited mass increase	Null or very limited impact on architecture	Null or very limited impact on the performance	Quasi full demise (very small residual parts, could be easily solved by design optimization of the elements)	Flight qualifica-tion	Increases the OP/L cost but remains competitive vs controlled rentry
10	Null of very limited mass increase			Total demise	Flight proven	Limited cost impact

D4D tech implementation

D4D tech LF & HF simulation





D4D tech rank

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
A-frame	Ti	Mass reduction 3D print	10	20	10	10	10	45	5	22.5	5	10	8	8	7.7	3 (not simulated)
		Invar 3D print	8	16	10	10	10	45	10	36	5	16	8	8	8.9	2 (not simulated)
		Invar	8	16	10	10	10	45	8	36	8	16	8	8	8.7	3
		Al	10	20	8	8	8	36	10	45	10	20	5	5	8.9	1

Achievments: Critical elements and criticality level

CRITICAL ELEMENTS AND CRITICALITY

D4D TECHNIQUES IDENTIFICATION

LF ANALYSIS MODELLING AND RESULTS

HF ANALYSIS MODELLING AND RESULTS

DEMISE RESULTS AND D4D TECHNIQUES RANK

ROADMAPS AND TEST PLANS

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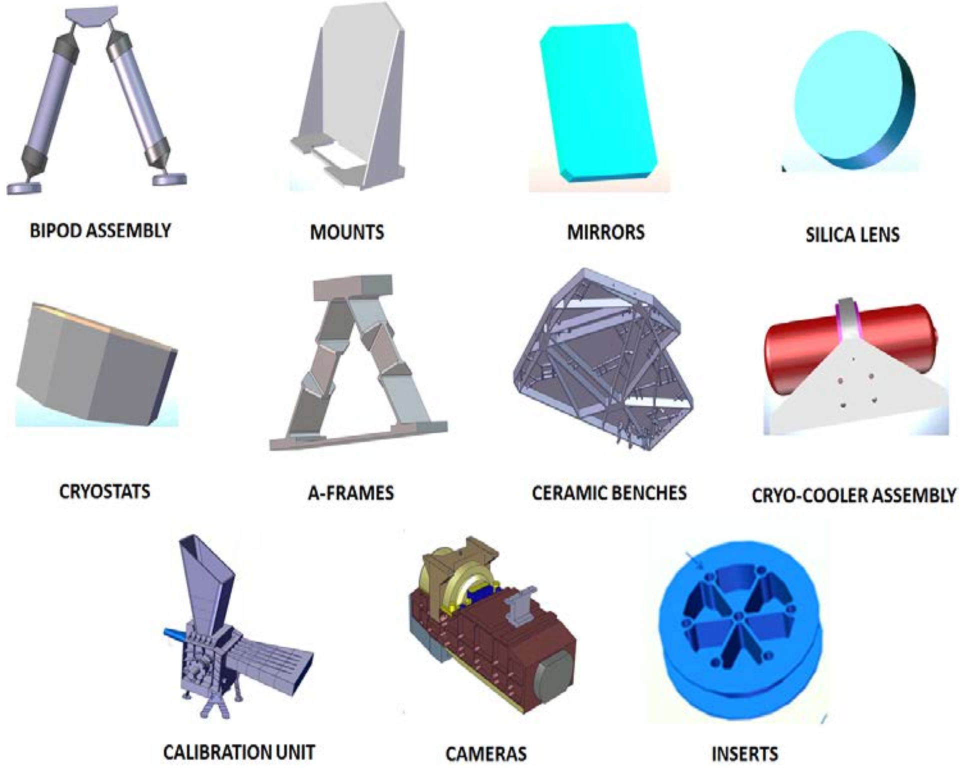
In general different reasons of criticality, can be identified as:

- Material
- Mass
- Shielding
- Configuration

Depending on the item, there can be a combination of such factors with different weighting.

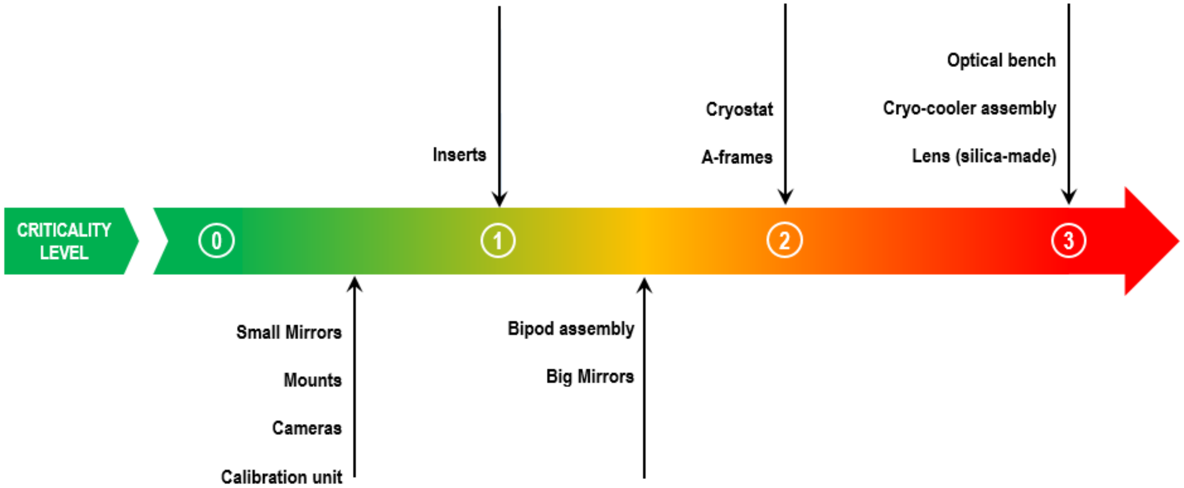


Achievments: Critical elements and criticality level

Concerning the criticality level as evaluated in D4OP, it can be noted that the have either a critical material assignation (ceramic bench, cryo-cooler assembly, etc.) or work as connector (bipods, a-frames) therefore influencing the separation of the whole P/L

On the other hand, components which have larger possibility of material swap and / or do not relevantly influence the separation –and then the demisability- of another components, have a lower criticality

Is to remark that the following ranks are affected by uncertainties if items of same typologies but very different characteristics are considered (e.g. Big Mirrors)



Achievments: Critical elements and criticality level

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- **Easy / Medium**: aluminum, copper, CFRP, GFRP, epo glues
- **Medium / Difficult**: steel, Inconel, invar, zerodur, ZnS, CFRP
- **Difficult**: titanium, silica
- **Impossible**: ceramics

Name [-]	Heat of Demise [kJ/kg]
AA7075	810
A316	1100
TiAl6V4	1594
Copper	701
Inconel	1164
Invar	980
Steel	1190
Silicon- Si	2783
Silica - SiO_2	3370
Zerodur	1486
Si_3N_4	4566
SiC	5040
GFRP	593
Pure Al	971
Task3 Glue	760
Task2 Glue	551
ZnS	986

Achievments: D4D techniques identification

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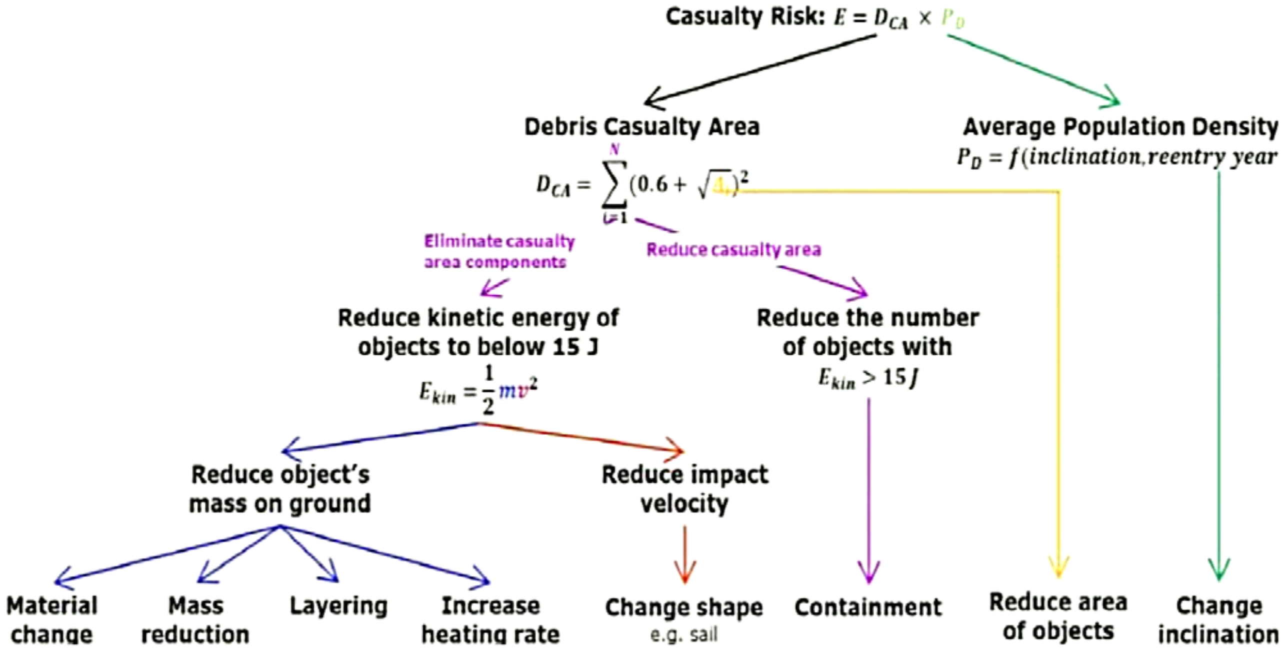

Achievments: LF analysis modelling and results

CRITICAL ELEMENTS AND CRITICALITY

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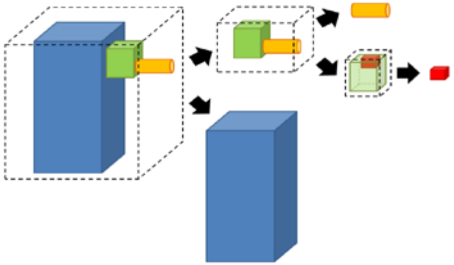
The modelling of the LF simulations, followed the below-mentioned rules. With TADAP a first iteration was performed about the demise rank then with SCARAB simulations the demise results and rank were refined.

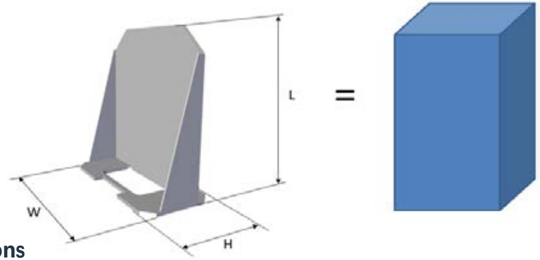
Initial orbit
- Possibility of set up different Trajectory Earth Fixed initial data

Fragmentation
- Possibility of simulating all the S/C as compound of simple shapes
- Possibility of simulating a progressive fragmentation



Aero-thermal model
- Randomly tumbling heating model - 3DoF model
- Implementation of simplified shielding between the objects (the mutual shielding is updated according to fragmentation process)
- Implementation of thermal conductivity between the objects

Geometrical
- Adoption of simplified primitives to model complex objects
- Shapes, dimensions and position close as-much-as-possible to the real objects



Connections
- Multiple connections are generally modelled
- The weakest connections are modelled with a glue layer:
  - o Mirrors / mounts
  - o A-frames (upper part) / benches

Materials
- Adoption of the most representative material for each shape

Masses
- The masses of single objects are close as-much-as-possible to the real objects.
- Mass balance (i.e. total masses almost equal at platform and payload level).
- Adoption on "thermic" masses to obtain the above-mentioned balance (i.e.: all the items that are not modelled in detail, and included in large aluminium masses to obtain the correct mass)

Granularity
- Almost all the critical objects (for each payload) are simulated, at least one for each typology
- Focus on Payloads: platform are model with an external cover with an internal "thermic"

Achievments: LF analysis modelling and results

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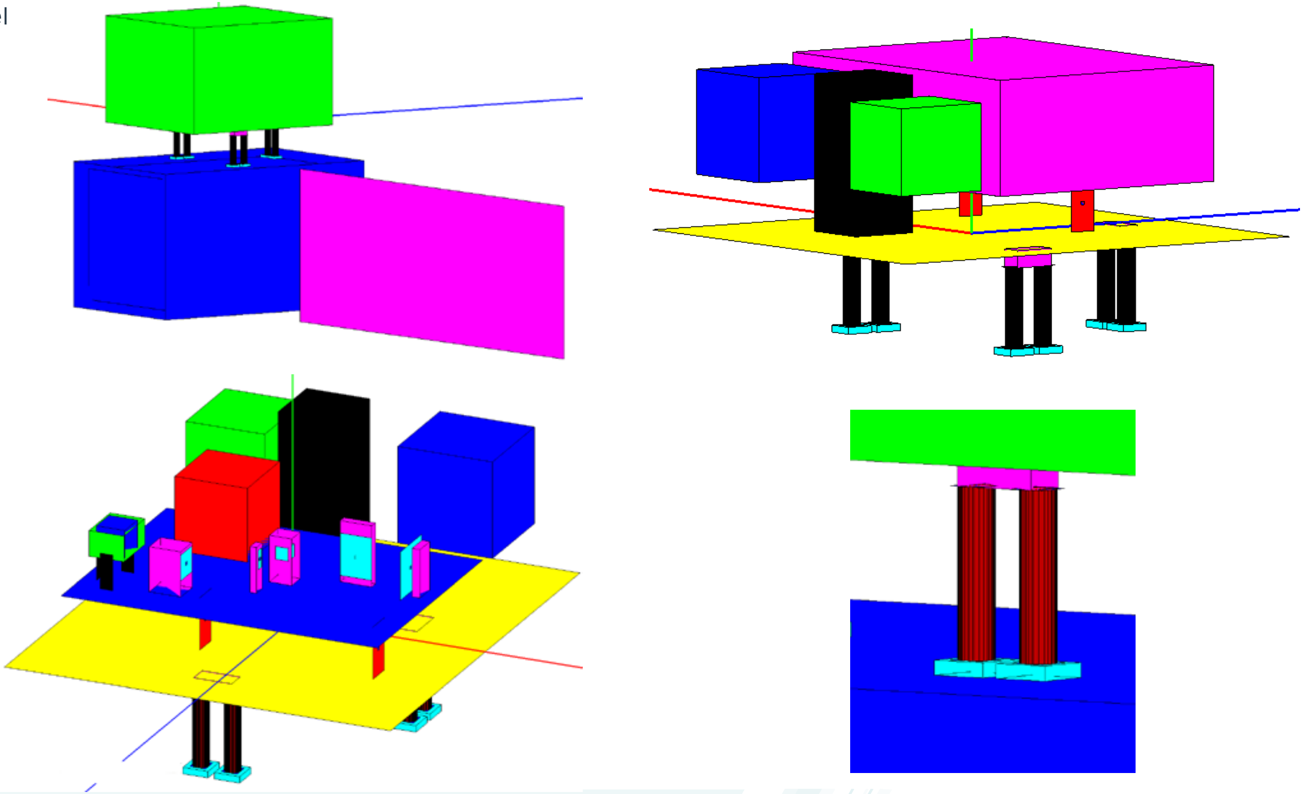
RSC TADAP model



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RSC TADAP results

- **Case 1:** HC bench; Zer &Tit items optimiz
- **Case 2:** HC bench; Invar big mounts; Invar A-frames; I/F weakening
- **Case 3:** HC bench; Invar all mounts; Invar A-fra & steel fittings; I/F weakening
- **Case 4:** HC bench; Opt Invar all mounts; Opt Invar A-frames; Opt steel fittings
- **Case 5:** HC bench; AlSi all mounts; AlSi A-frames; AlSi fittings
- **Case 6:** Old ceramic bench; AlSi all mounts; AlSi A-frames; AlSi fittings

	CA Baseline [m²]	CA Case 1 [m²]	CA Case 2 [m²]	CA Case 3 [m²]	CA Case 4 [m²]	CA Case 5 [m²]	CA Case 6 [m²]
Bipods	0	0	0	0	0	0	0.00
Lower Bipod Fittings	0	2.64	0	2.64	2.64	0	0.00
Upper Bipod Fittings	1.39	1.39	1.39	1.39	1.39	1.45	1.39
Spectrometer Bench	1.25	0	0	0	0	0	1.32
Mount of Mirror 1	Att on bench	0.94	0	0	0	0	Att on bench
Mount of NIR Folding Mirror	Att on bench	0	0	0	0	0	Att on bench
Mount of SWIR 1 Imager	Att on bench	1.52	0	1.52	1.52	0	Att on bench
Mount of NIR/SWIR Dichroic	Att on bench	1.01	0	1.01	1.01	0	Att on bench
Mount of SWIR 1 PG Mirror	Att on bench	1.46	1.46	1.46	0	0	Att on bench
Mirror 1	1.13	1.13	1.13	0	0	1.13	1.13
NIR Folding Mirror	0	0	0	0	0	0	0
SWIR 1 Imager	Att on bench	0	0	0	0	0	Att on bench
NIR/SWIR Dichroic	Att on bench	0	0	0	0	0	Att on bench
SWIR 1 PG Mirror	Att on bench	0	0	0	0	0	Att on bench
SWIR 1 Cover	1.57	1.55	1.57	0	0	0	1.57
SWIR 1 Internal	Att on cover	Att on cover	Att on cover	0	0	0	0.00
A-Frames	1.53	1.53	1.53	1.53	1.53	0	1.53
Calibration Unit	0	0.81	0	0.81	0.81	0.81	0.00
Electronic Box	0	0.81	0	0.81	0.81	0.81	0.00
Telescope Mount	2.51	0.94	0	0	0	0	0.00
Telescope Mirror	1.13	1.13	1.13	0	0	1.13	1.13
Telescope A-Frames	1.15	1.15	1.15	1.15	1.15	0	1.15
TOTAL	*9.00*	*13.96*	*7.96*	*8.28*	*6.83*	*3.87*	*6.49*

Baseline

- The re-entry consists of progressive fragmentation, starting from outside to inside, as was already predicted by WP2120 simulations
- Spectrometer Bench survives entirely, with optical elements attached to it, except SWIR 1, Mirror 1 and NIR Folding Mirror, which separate from it
- Bipod assembly detaches from optical bench and SVM panels, eventually titanium end-fittings survive
- A-frames survive

D4D cases

- Spectrometer bench always demises when swapped from ceramic to aluminum sandwich
- Bipod Fittings remain in general hard-demisable in all simulations
- Each mount has a different behaviour for each case, only Case 5 shows a clear improvement
- Little mirrors usually demise, Mirror 1 demises only if in zerodur/CFRP sandwich
- Cryostat demises only in Case 3 and Case 4
- A-Frames only demise if in aluminium
- Calibration Unit and Electronic Box results are not much relevant / affordable due to the low granularity level of their models
- Telescope casualty area was deduced by applying the results of spectrometer mounts, mirrors and a-frames to the Telescope Assembly itself.

Main outcomes

- Baseline and Case 6 are two different scenarios, difficult to compare with the other D4D ones (Case 1 to Case 5)
- Case 5 is the best one
- Case 4 is better than Case 2
- Case 4 improves Case 3
- Case 6 shows improvements only not related to Spectrometer

Achievments: HF analysis modelling and results

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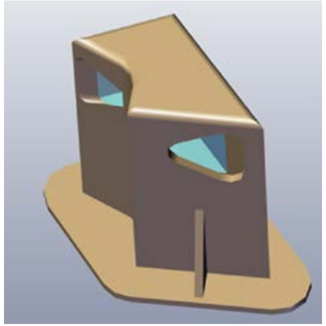
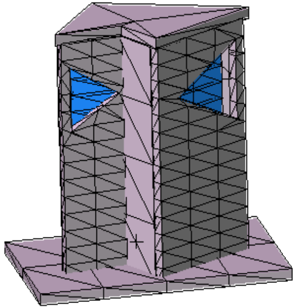
in both HF runs, a relevant amount of technique was considered, trying to develop implementative solutions which both increase demisability without impacting optical performances.

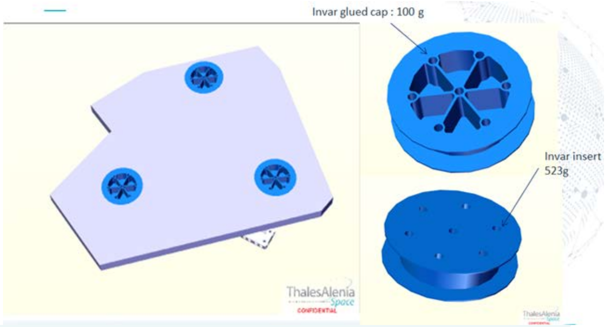
Most of the solutions can be summarized in the following typologies:

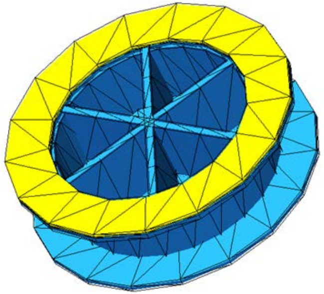
- Mass and dimensions update





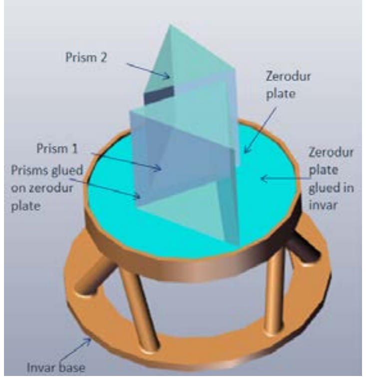
- Material swap (and following update of dimensions and mass)

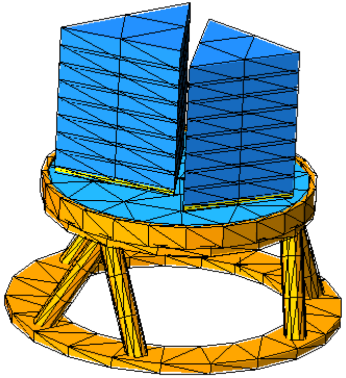




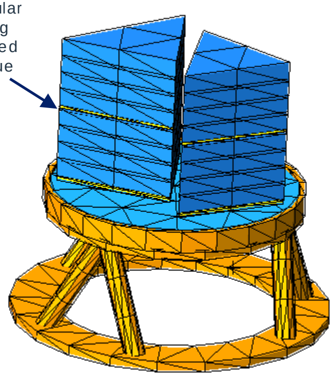
Achievments: HF analysis modelling and results

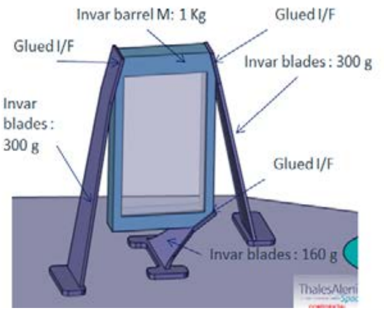
- Radical new design & splitting

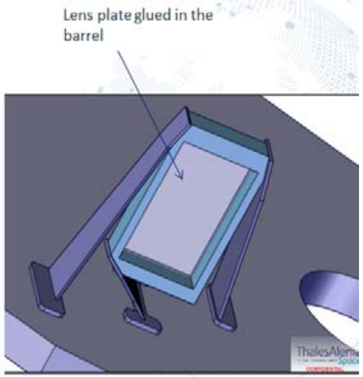




Molecular bonding simulated with glue layer

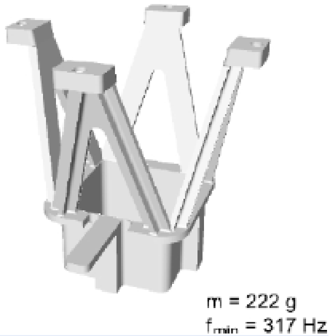




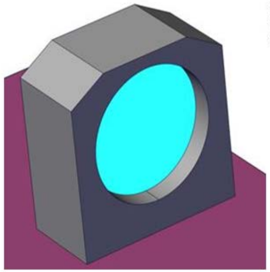


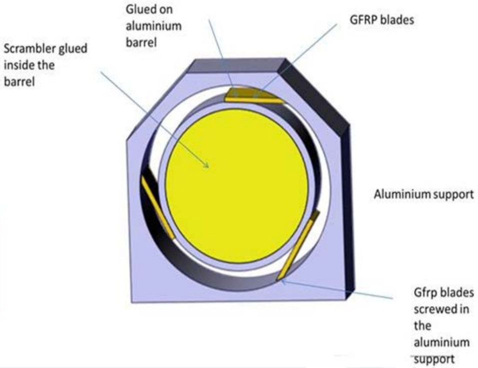
Achievments: HF analysis modelling and results

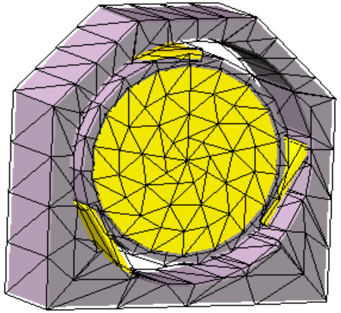
- Material swap (and following update of dimensions and mass)



- I/F weakening







Achievments: Demise results and D4D tech rank

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Optical Bench	ceramics	CFRP (Al HC)	10	20	10	10	5	22.5	10	45	10	20	8	8	8.4	1
		Zerodur (CFRP HC)	5	10	8	8	10	45	10	45	2	4	5	5	7.8	2 (not simulated)

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
A-frame	Ti	Mass reduction 3D print	10	20	10	10	10	45	5	22.5	5	10	8	8	7.7	3 (not simulated)
		Invar 3D print	8	16	10	10	10	45	10	36	5	16	8	8	8.9	2 (not simulated)
		Invar	8	16	10	10	10	45	8	36	8	16	8	8	8.7	3
		Al	10	20	8	8	8	36	10	45	10	20	5	5	8.9	1
End-fittings	Ti	Mass reduction 3D print	10	20	10	10	10	45	5	36	5	10	8	8	7.7	3 (not simulated)
		steel	2	4	8	8	8	36	2	9	10	20	10	10	5.8	4 (not simulated)
		Al + Brass	10	20	5	5	8	36	10	45	10	20	5	5	8.7	1 (not simulated)
		AlSi + Brass	10	20	10	10	10	45	10	45	2	4	5	5	8.6	2

Achievments: Demise results and D4D tech rank

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Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Imager mounts	Ti	Mass reduction 3D print	10	20	10	10	8	36	6	27	5	10	8	8	7.4	4 (not simulated)
		Invar 3D print	10	20	10	10	10	45	8	36	5	10	8	8	8.6	2
		Invar (glued feet)	10	20	10	10	10	45	8	36	10	20	8	8	9.3	**1**
		AlSi	10	20	10	10	8	36	10	45	2	4	5	5	8.0	3
Mirror Mounts	Ti	Mass reduction 3D print	10	20	10	10	8	36	10	45	5	10	8	8	8.6	**1**
		Invar 3D print	10	20	10	10	10	45	8	36	5	10	8	8	8.6	**2**
		AlSi	10	20	10	10	8	36	10	45	2	4	5	5	8.0	3
Dichroïc Mounts	Ti	Mass reduction 3D print	10	20	8	8	8	36	5	10	5	10	8	8	7.0	3
		Invar 3D print	6	12	8	8	10	45	10	45	5	10	8	8	8.5	2 (not simulated)
		Invar (glued feet)	6	12	8	8	10	45	10	45	10	45	5	5	9.2	**1**
PG+P Mounts	Ti	Invar 3D print	8	16	8	8	10	45	7	31.5	5	10	8	8	7.9	2
		Invar (glued feet)	8	16	8	8	10	45	7	31.5	10	20	8	8	8.6	**1**
		AlSi	10	20	8	8	8	36	10	45	2	4	5	5	7.9	3

Achievments: Demise results and D4D tech rank

D4OP

- CRITICAL ELEMENTS AND CRITICALITY
- D4D TECHNIQUES IDENTIFICATION
- LF ANALYSIS MODELLING AND RESULTS
- HF ANALYSIS MODELLING AND RESULTS
- DEMISE RESULTS AND D4D TECHNIQUES RANK
- ROADMAPS AND TEST PLANS
- OPEN POINTS

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Cryostat	Ti	Ti Glued covers	6	12	10	10	10	45	7	31.5	10	20	10	10	8.6	2
		AlSi Screwed cover	8	16	10	10	10	45	8	36	2	4	5	5	7.7	3
		Al	10	20	8	8	8	36	10	45	10	20	8	8	9.1	1

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Polar. Scrambler Mount	Al	Al	10	20	10	10	10	45	6	27	10	20	10	10	8.8	2
		Al GFRP blades	10	20	8	8	10	45	10	45	10	20	8	8	9.7	1

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Achievments: Demise results and D4D tech rank

CRITICAL ELEMENTS AND CRITICALITY

D4D TECHNIQUES IDENTIFICATION

LF ANALYSIS MODELLING AND RESULTS

HF ANALYSIS MODELLING AND RESULTS

DEMISE RESULTS AND D4D TECHNIQUES RANK

ROADMAPS AND TEST PLANS

OPEN POINTS

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Cryostat	Ti	Ti Glued covers	6	12	10	10	10	45	7	31.5	10	20	10	10	8.6	2
		AlSi Screwed cover	8	16	10	10	10	45	8	36	2	4	5	5	7.7	3
		Al	10	20	8	8	8	36	10	45	10	20	8	8	9.1	1

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Polar. Scrambler Mount	Al	Al	10	20	10	10	10	45	6	27	10	20	10	10	8.8	2
		Al GFRP blades	10	20	8	8	10	45	10	45	10	20	8	8	9.7	1

Achievments: Demise results and D4D tech rank

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Mirrors	Zerodur	Light-weighting	10	20	10	20	8	36	10	45	5	10	8	8	8.6	1
		Zerodur (CFRP HC)	10	20	8	8	2	9	10	45	2	4	8	8	6.3	2

Critical element	Current material	Modification for demise	Impact												Trade-off /10	Rank
			Mass		Re-evaluation		Optical performance		Demise		TRL		Cost			
Inserts	Ti	Ti 3D print	10	20	10	10	10	45	7	31.5	5	10	8	8	8.3	2 (not simulated)
		Ti	8	16	10	10	10	45	5	22.5	10	20	10	10	8.2	3
		Invar	8	16	8	8	10	45	7	31.5	10	20	10	10	8.7	1
		CFRP short fiber	10	20	8	8	10	45	8	45	2	4	5	5	7.9	4 (not simulated)
I/F weakening	bolted	glued	5	10	8	8	8	36	5	45	10	20	10	10	7.1	1

Achievments: Roadmaps and test planes

- CRITICAL ELEMENTS AND CRITICALITY
- D4D TECHNIQUES IDENTIFICATION
- LF ANALYSIS MODELLING AND RESULTS
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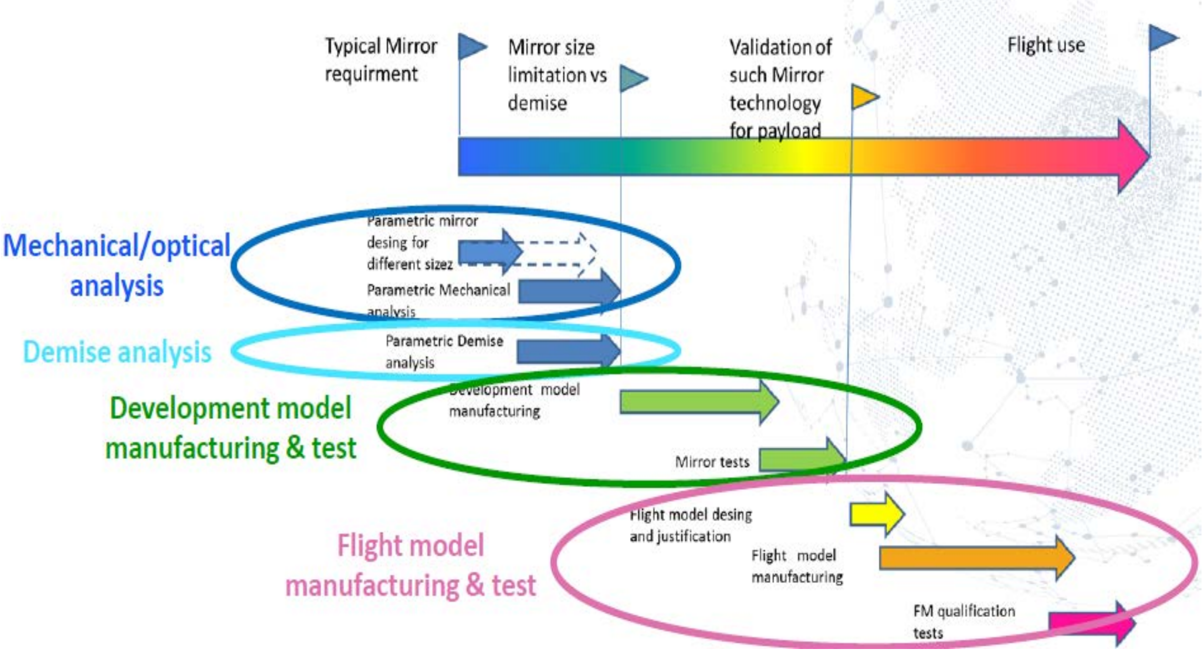
- DEMISE RESULTS AND D4D TECHNIQUES RANK
- ROADMAPS AND TEST PLANS
- OPEN POINTS

Critical design requirements:

- Materials
  - Avoid Titanium and ceramics (SiC, Si3N4, ...)
  - Invar can be a good replacement AlSi (CTE) or Aluminum
- Design & process
  - Avoid massive parts (Ti, ceramics, Invar)
  - Additive manufacturing: promising
- Interfaces
  - Glued links instead of screwed/bolted links
  - Solutions allowing an early separation of shadowing elements



Achievments: Open points

- CRITICAL ELEMENTS AND CRITICALITY
- D4D TECHNIQUES IDENTIFICATION
- LF ANALYSIS MODELLING AND RESULTS
- HF ANALYSIS MODELLING AND RESULTS
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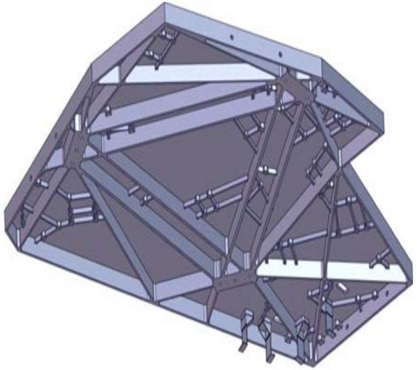
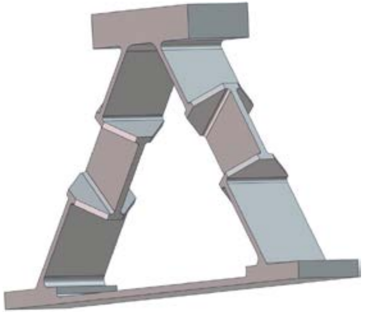
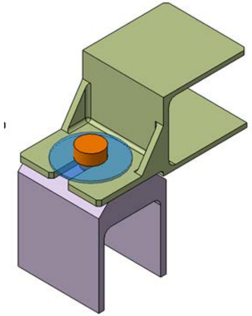
- ROADMAPS AND TEST PLANS
- OPEN POINTS

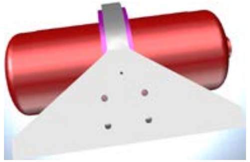
- *Replacement of ceramic bench*
- *Silica items*
- *A-frames*
- *Inserts*
- *Titanium 3D-manufactured mounts*
- *Early dismantlement of P/L external*
- *Other items*







m = 164 g
f_{min} = 301 Hz



Conclusions

- Different P/Ls were investigated, identifying the critical items and associated criticalities, eventually providing a significant knowledge of the different components and configurations
- Development of very complex LF (TADAP) and HF (SCARAB) models, in order to represent the specific feature to both baseline and D4D re-design components.
- Different D4D techniques were identified and simulated, by applying them to a large number of items via detailed re-designs, concerning demise, good results about:
  - HC bench
  - 3d-printed invar (imagers)
  - Invar monolithic (imagers)
  - 3d-printed titanium (mount 1)
  - Invar-blades mount (dichroic)
  - CFRP-zerodur mirror (mirror 1)
  - Reduced zerodur mirror (mirror 3)
  - Polarization scrambler
  - Bipod fittings
  - Aluminum and invar a-frames
  - Aluminum cold box
- Efficacy of the from-LF-to-HF approach: by first adopting LF and quick simulations is possible to have a first screening of the most promising choices, which are then refined with HF S/W, saving time in terms of modelling and computational costs
- Identified D4D techniques well investigated under demise and not-demise aspects to provide a fully preliminary evaluation about their applicability on O/P items
- Some but not trivial open points, which underline the difficulty of apply D4D techniques to optical P/Ls, finally remarking the importance of this Study and future potential activities on the same topics