BFS

« Back From Space »

An atmospheric reentry kit
for Newspace applications

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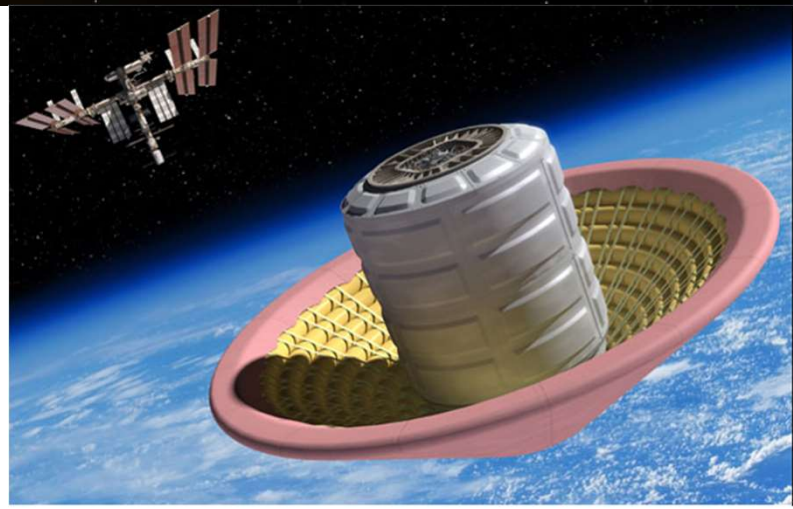
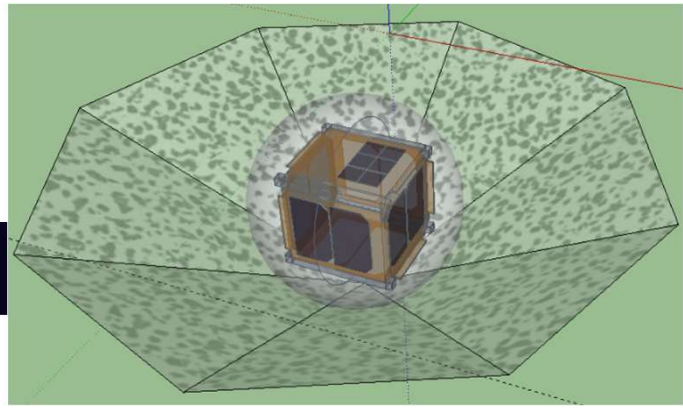
Context



- Increased need to bring products back to Earth
  - Scientific sample
    - Asteroid Samples
    - ISS experiments
    - Other in-orbit experiments
  - In-orbit manufacturing
    - Medical sector
- Development of reentry vehicles
  - E.g. HIAD of NASA



- Creation of BFS project to address CubeSat market
  - ESA ITT 2020
  - CNES R&T 2021 & 2022
  - CNES AAP (Call for Proposals) 2021 & 2022

nimesis ifth Institut Français du Textile et de l'Habillement NITREO

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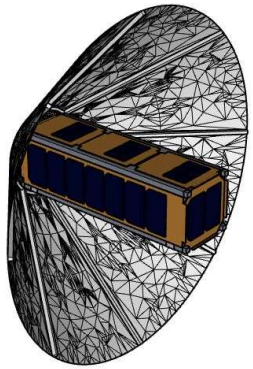
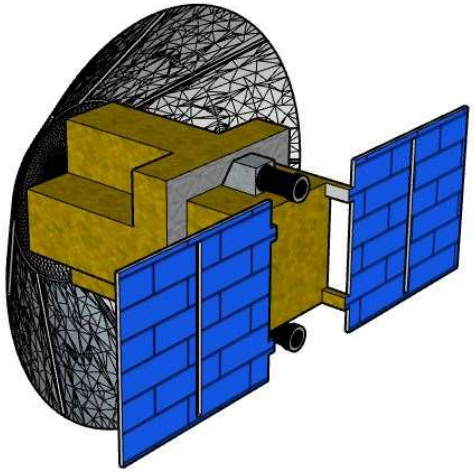
Potential Uses

- Scientific Payloads
  - Small experiments
  - Human intervention (ISS launched) or autonomous (rideshare)
  - Different conditions
    - LEO (ISS, suborbital)
    - Radiation belts exposure (rideshare on GTO orbit)
- Commercial Payloads
  - High added-value Payloads
  - Medical Bio Pharma Payloads
    - Microgravity molecules production
    - 3D printing of organs
  - “Space Warehouse”
    - Quick access to any point in the world
  - In-Orbit Manufacturing / Space Lab





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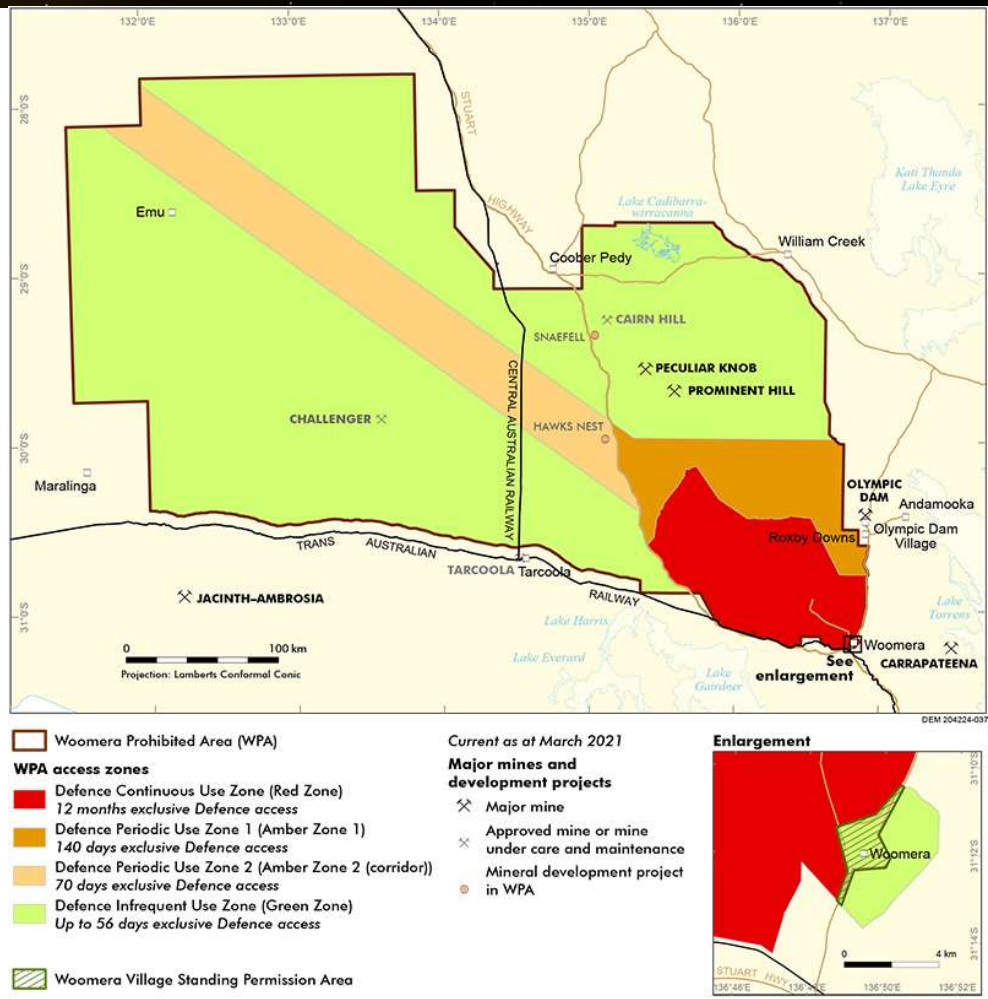
Choice of landing site

- Candidates
  - Woomera Range Complex (Australia)
  - Utah Test and Training Range (USA)
  - Las Bardenas Reales ? (Spain)
  - Camp de Canjuers ? (France)
  - Hammaguir ? Algerian/Moroccan desert ?
- Factors
  - Orientation relative to ISS plane
    - ±51.2° latitude
  - Practicable ranges
- Chosen Site: Woomera Range Complex



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Mission: Landing Accuracy

- Use of DEBRISK (CNES software)
  - Results plotted with MATLAB and Google Earth Pro

- Landing in the centre of Woomera
  - Max allowed error downrange: 235 km
  - Max allowed error in dV: 0.7 m/s
    - Propulsion accuracy: ±0.1 m/s

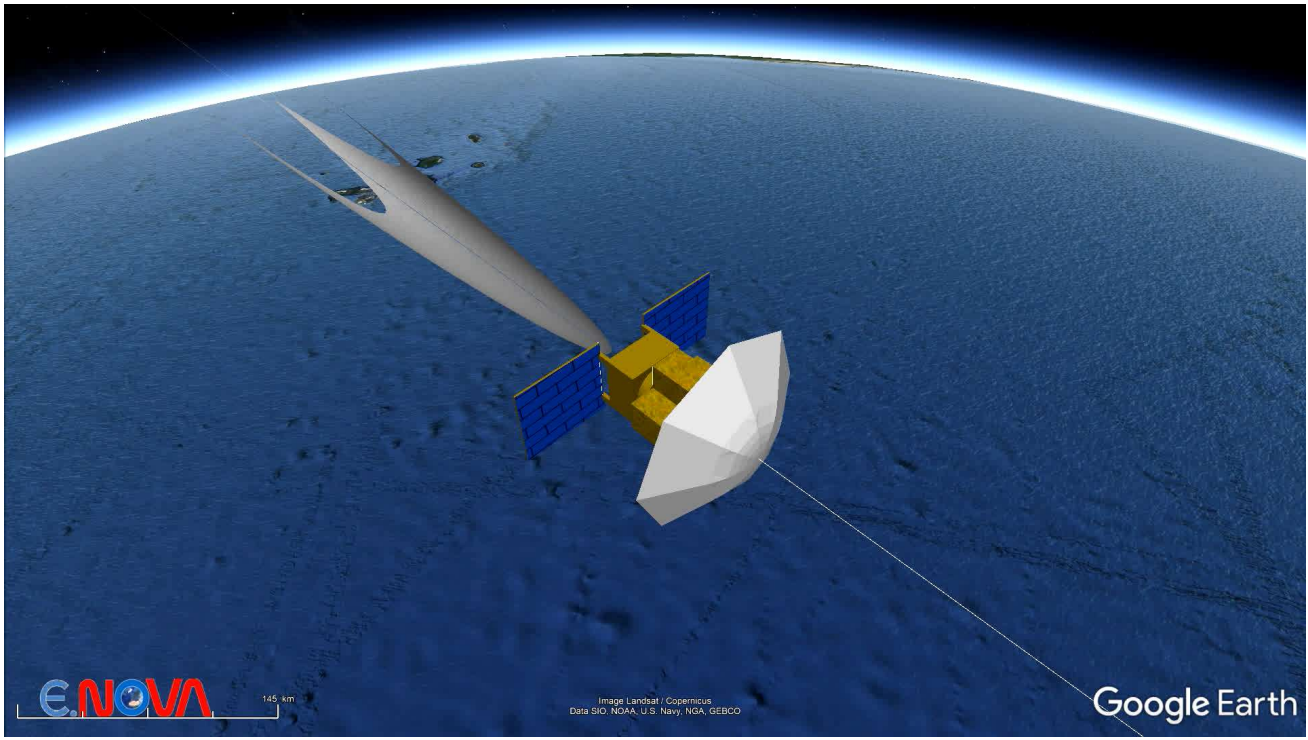
Parameter	Value
a	6615.636 km
e	0.024563
h_a	400 km
h_p	75 km
ω	236.3°
i	51.2°
Ω	356.23°

Proposed worst case scenarios			
Parameter	Max. variation	Worst case scenario 1	Worst case scenario 2
Δm	$\pm 0.2\ kg$	$4.3\ kg$	$4.7\ kg$
ΔD	$\pm 3\ cm$	$53\ cm$	$47\ cm$
Δh_p	$\pm 1\ km$	$74\ km$	$76\ km$
$\Delta \omega$	$\pm 0.5°$	$235.8°$	$236.8°$

https://youtu.be/ENNSJOiprZM

Mission: Deorbit boost

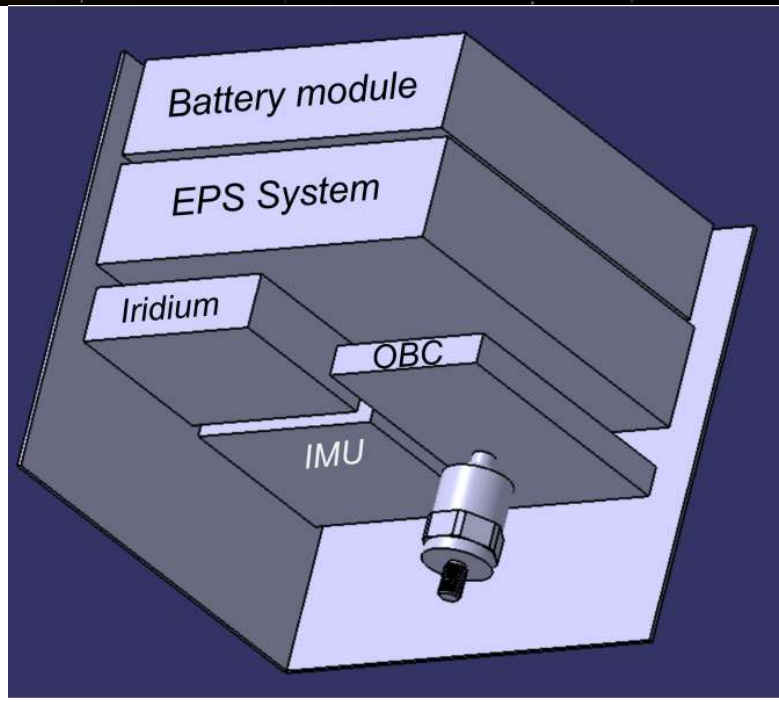
https://youtu.be/m5_PHDM7azg



- Nominal descent
  - Boost: 94.77 m/s
  - Perigee: 75 km
- Error of 1.3% in boost
  - Boost: 96 m/s
  - Perigee: 71 km
  - Downrange error: 407 km
- Error of 5° in pointing
  - Boost error: 0.35 m/s
  - Inclination change: 0.065°
  - Downrange error: 123 km straight, 14.9 km transversal

Mission Specifications & Requirements

- Nominal lifetime: 6 months
- Manoeuvre capabilities: 150 m/s
- ISS safety compliant
- Temperature measurement
- Pressure measurement
- 6 degrees acceleration measurement
- GPS position & velocity
- Datalink to ground



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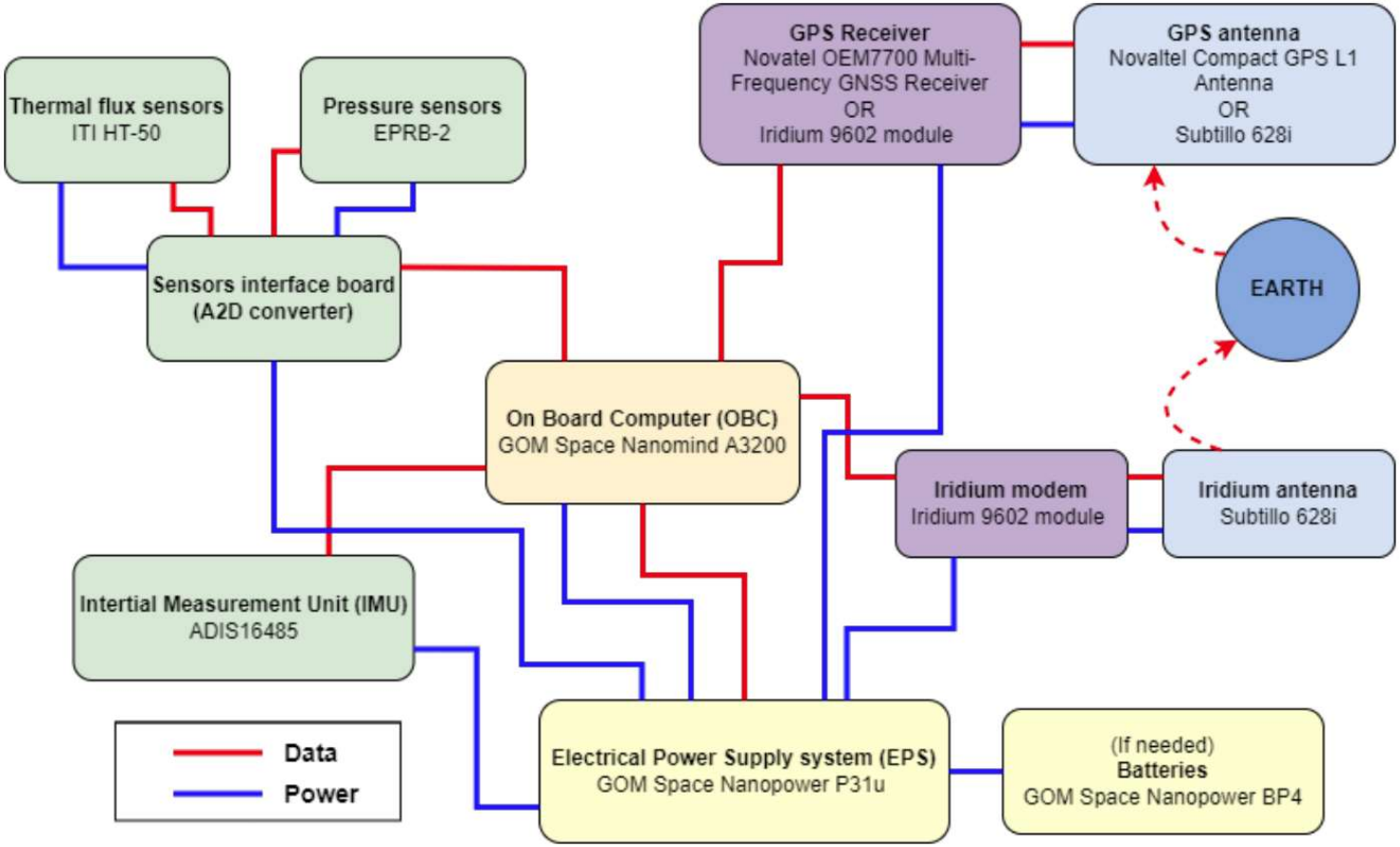
Platform Components

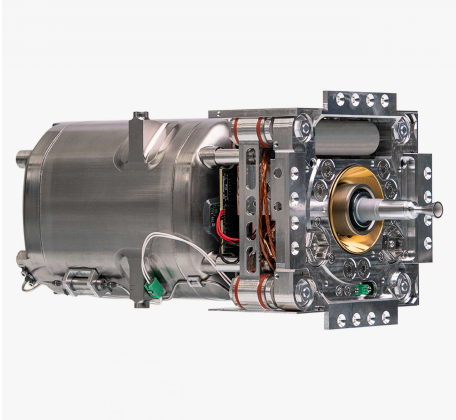
- Based on payload requirements for initial testing



Propulsion Module

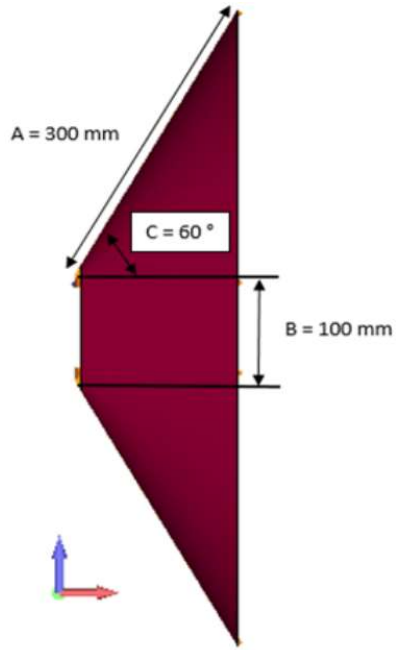
- Main considerations
  - Thrust
  - dV at equivalent mass
  - Power consumption

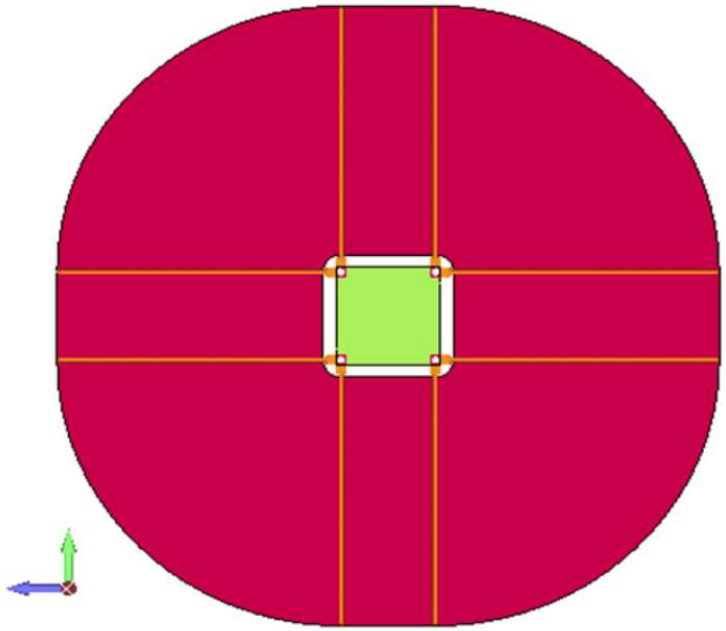
- 60 candidates considered
  - PM200 by Hyperion selected
    - Isp = 285 s
    - Thrust = 0.5 N
    - Power consumption = 12 W
    - dV @ kg = 230 m/s
  - EPSS C1 by NanoAvionics kept as alternative
  - Dawn Aerospace



Thermal Aspects

- Protection of:
  - payload from atmospheric entry
    - Temperature < 60 °C
  - heatshield to allow landing
    - Internal face temperature < 600 °C





- Materials chosen:
  - F-TPS: 3M Nextel 312
  - MLI
  - Payload: aluminium

- 3 cases studied:
  - 1500 °C during 60 s
  - 1000 °C during 300 s
  - 650 °C during 700 s

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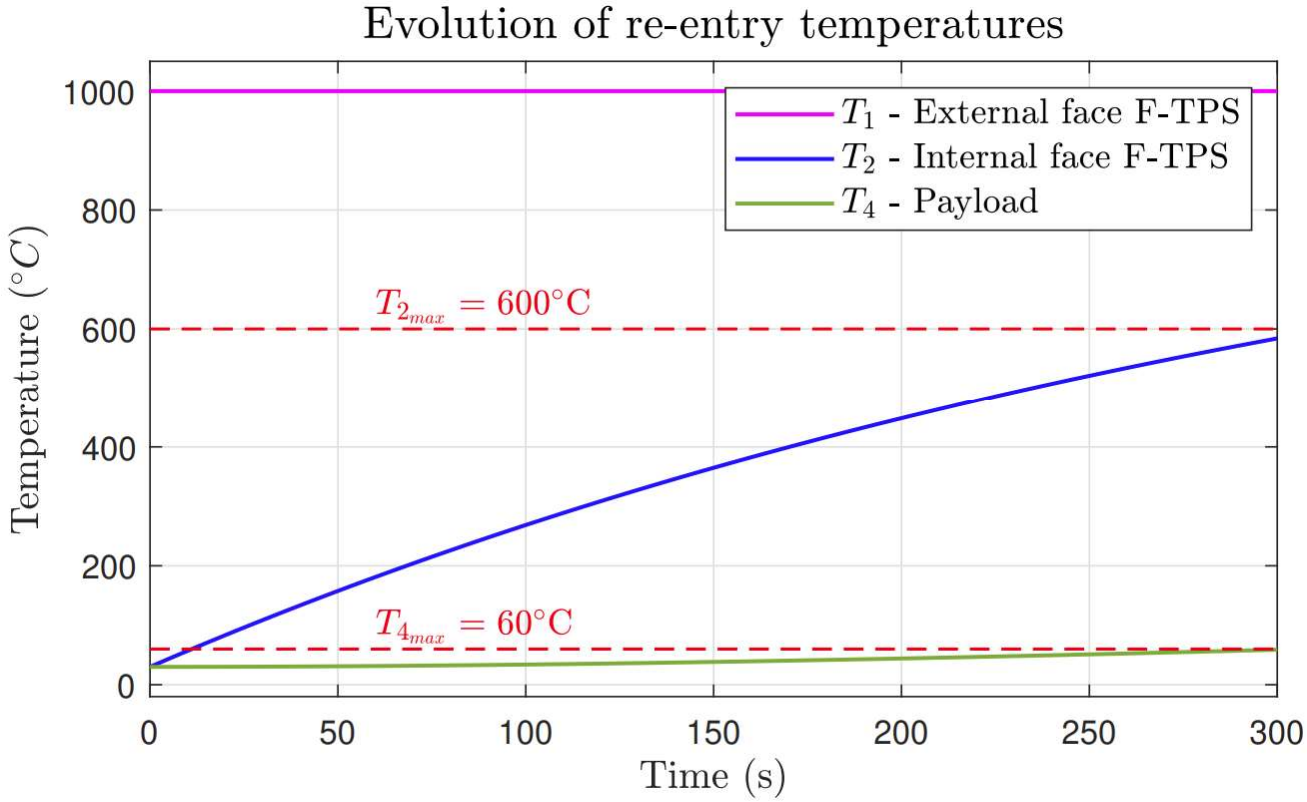
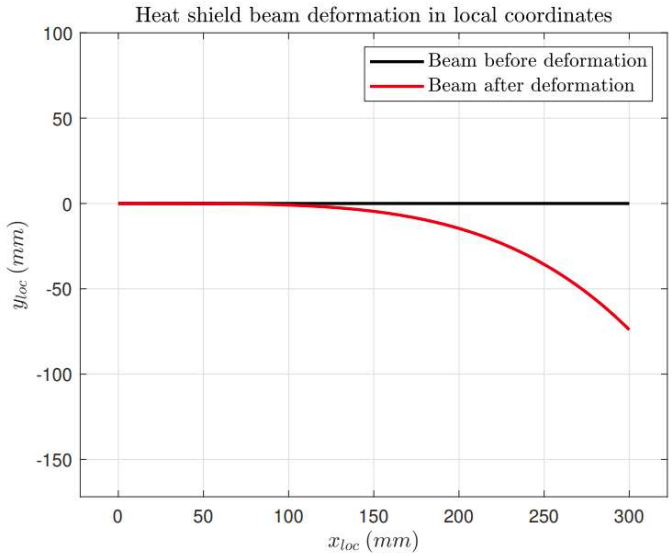
Thermal Aspects

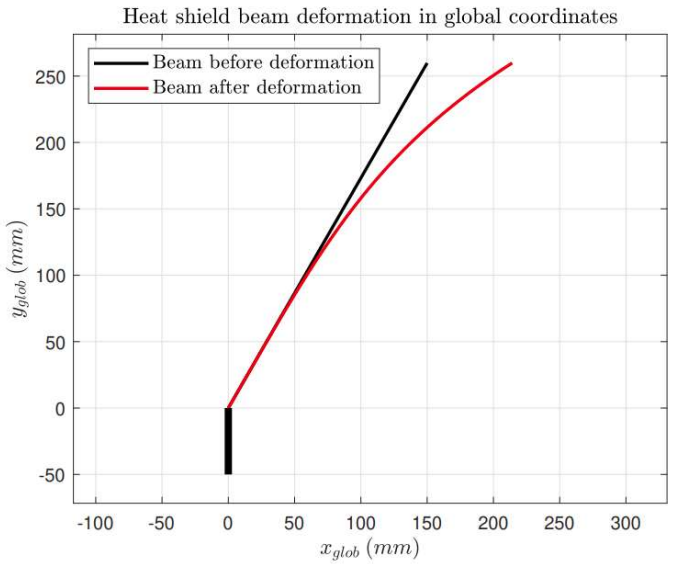
- Most demanding case:
  - 1000 °C during 300 s
    - Thickness of F-TPS: 3.6 mm
    - Internal face temperature: 584 °C
- MLI thickness: 4 mm
  - Payload temperature: 58.9 °C



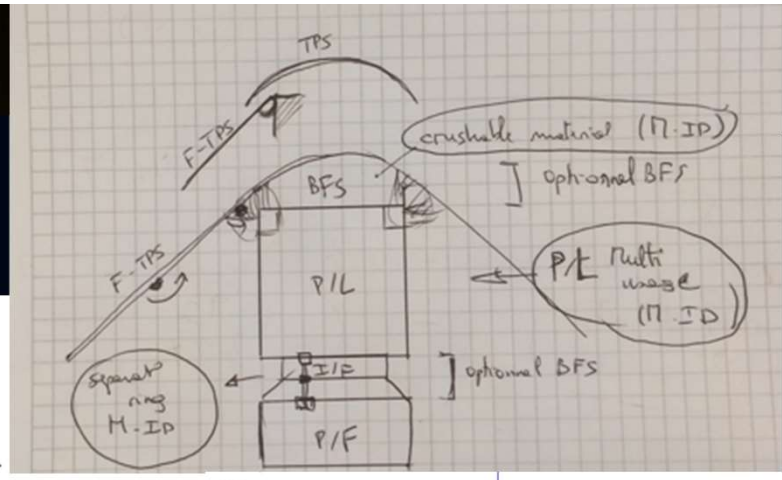
Mechanical Aspects

- Typical surface pressure: 4 kPa
- 8 beams to hold F-TPS
  - 300 mm long
  - Nitinol alloy (shape memory)
- Max tip displacement: 78 mm
- 6.5 mm diameter
  - 513.6 g
  - 74.01 mm displacement





BFS " Back From Space "
Study Cases – NANOSAT



STATUS: NANOSAT Size => **27 U P/L Module**

20-45 Kg Max P/L Mass => **1-1.5m** Diameter (Cb<25)

50 kg Max SAT Max => compatible NANOSAT P/F

APPROACH & SOLUTION: Partner Legacy for **P/L Module**

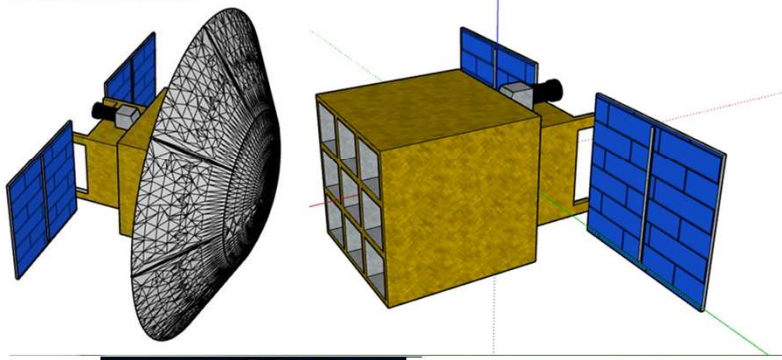
Multi service P/L Module (Cubesat & Experiment Dispenser)

Extra-terrestrial Sample Container / Crushable BPS – Crash landing

Separation Ring – Parachute – Ground Recovery Systems

Partner Legacy for **P/F Module and Operations**

(Propulsion Module :Nanoavionics EPSS-C1 or Dawn Aerospace)

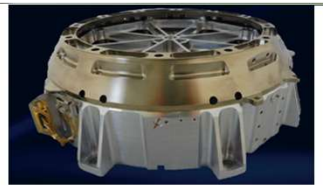


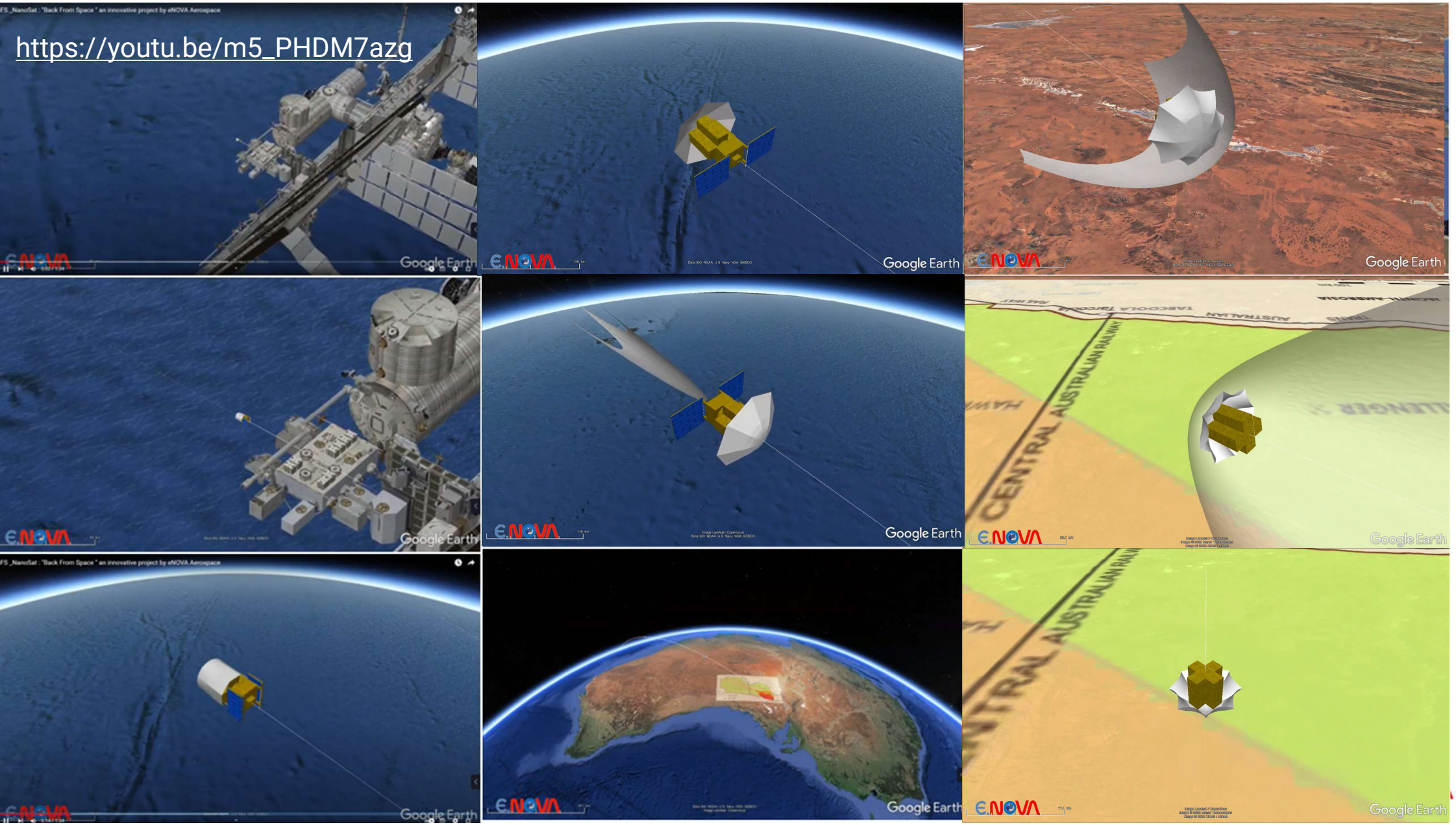
OUTCOMES & RESULTS : Capability of Market of such P/L Module

P/L Reentry (**NANORACKS** intention : **4SAT/yr ?)**

P/L Reentry (Loft Orbital intentions as a reentry service provider):

P/L Reentry (**Space Pharma** intentions of **1P/L/month**)




https://youtu.be/m5_PHDM7azg
Google Earth
Google Earth
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Google Earth

BFS : Fly your stuff
“Back From Space !!”

F-TPS: Flexible Thermal Protection

« NANOSAT Innovative Technologies »

MINISTÈRE DE L'ÉCONOMIE DES FINANCES ET DE LA RELANCE

Liberté Égalité Fraternité

FRANCE RELANCE

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

FAST

cnrs INSIS

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BFS “ Back From Space “
F-TPS Consortium (2022)

Management, Aerospace Network
Mission & System Engineering

E.NOVA AeroSpace

An **System Engineering**
& Entrepreneurship Company
leading **Technological SMEs**
in aerospace **innovative** business

RTech: Computed Fluid Dynamics (CFD)
AerothermoDynamics

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IFTH : Textile Expertise
(Flexible Thermal Protections)
Material & Process Expertise
Production & Tests

cnrs INSIS
FAST
Orléans ICARE

CNRS-INSIS :Aerothermal Tests
PHEDRA (*Soufflerie à **P**lasma **H**ors **E**quilibre **D**e **R**entrées **A**tmosphériques*).

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BFS “ Back From Space “
F-TPS : Objectifs

1. Analyses Systèmes et Mission **BFS orienté NANOSAT** (retour LEO)
   => Etablir **Cahier des Charges** Systèmes & I/F pour la F-TPS

2. Etat de l’Art et Matériaux / Procédés F-TPS **RoadMap industrielle**
Etat Art NEXTEL / Alternatives Européennes
   (Faisabilité BFS + F-TPS HP sur ces missions GTO-Extraterrestre)?

3. Etat Art Procédés F-TPS / **RoadMap industrielle**
   Orienté NEWSPACE / Approche Low Cost – Série

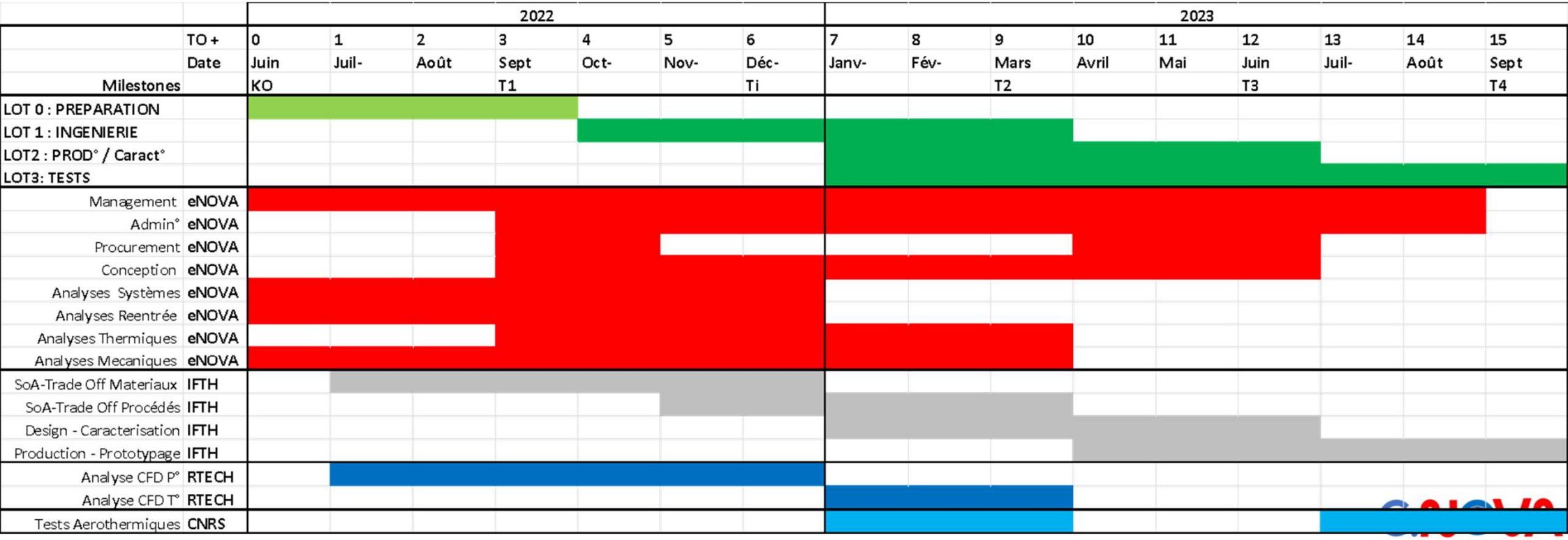
4. **Validations Technologiques** / Production Demonstrateur F-TPS
   Echantillons / Demonstrateur Ech 1 / Demonstrateur Vol

BFS “ Back From Space “
Study Cases – NANOSAT

TOPIC : F-TPS Progress

STATUS : WBS & Planning

CONCLUSION :



Nanosat Size

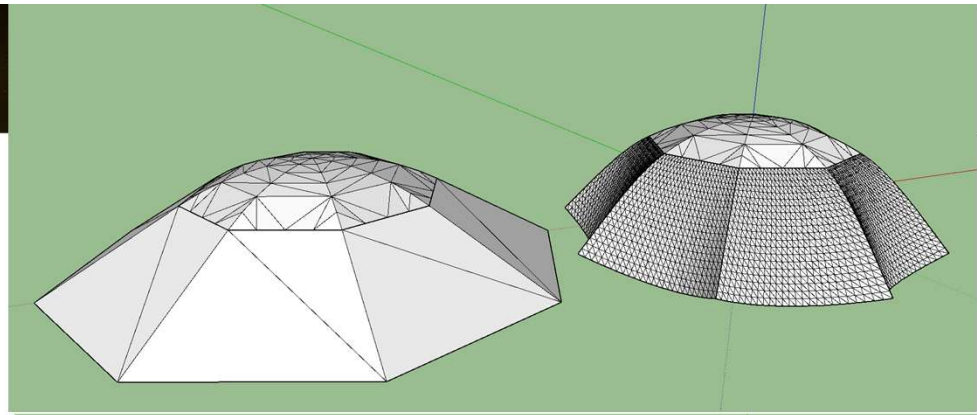
- Study of Aerothermal Shield

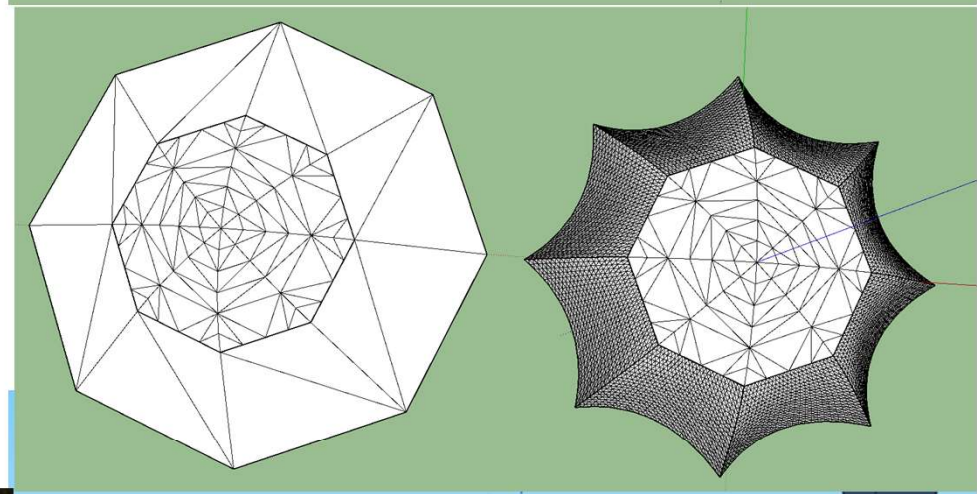
Model Assumptions:

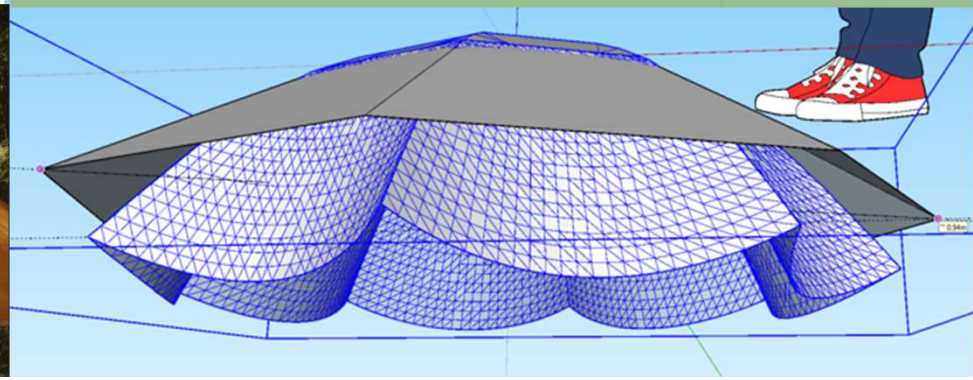
- Textile Not Extensible => Rib Deflexion Only
- Rib Design => Worst Case (no Optimisation)

Preliminary Results:

- Rib Deflexion : **7.5cm**
- Textile Displacement : **7cm**







BFS “ Back From Space “
Study Cases –DEMO Cubesat

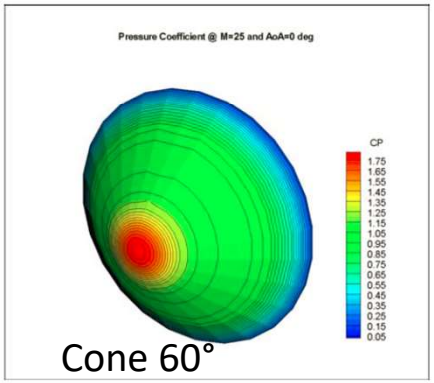
STATUS: BFS _ CFD

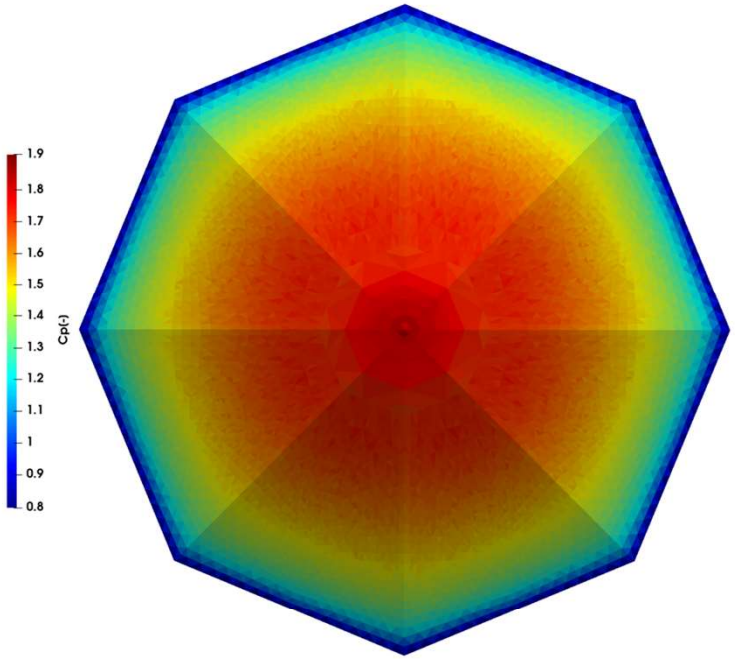
APPROACH & SOLUTION:

RTech CFD : S/W = **MISTRAL**

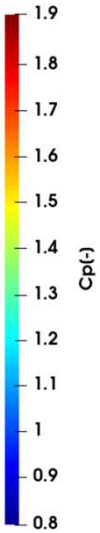
OUTCOMES & RESULTS

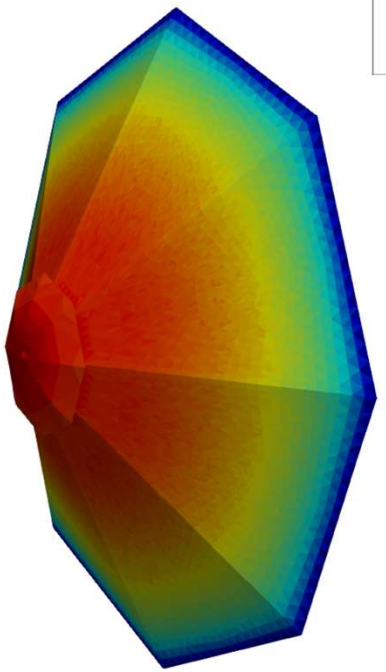
Cd =1.288 / S=.305m²

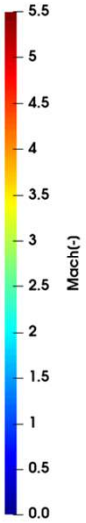


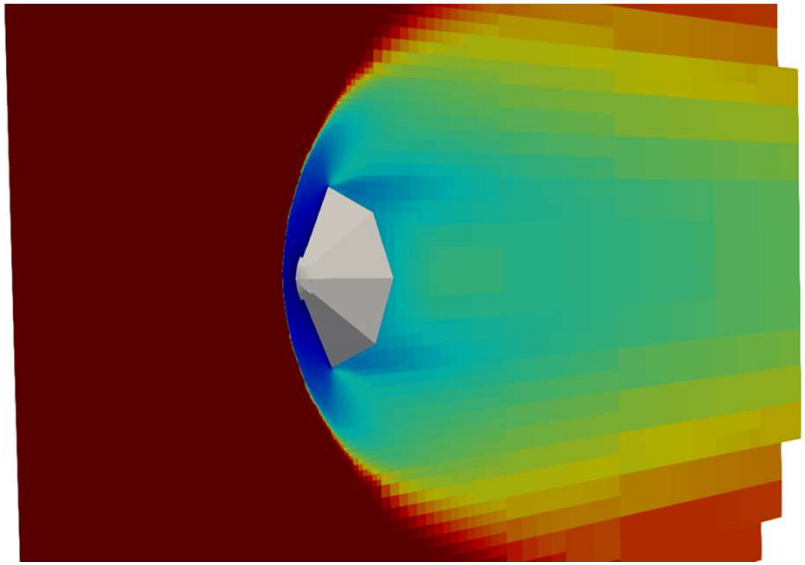


Cone 60°
8 pans
Petit Dome









Reentry Analysis Characterisation

Cd= 1.28 / 1.5 / 1 => CFD **DEBRISK v3**

DEBRISK v2 _ Nanosat N8_Nextel_ Thermal Mass 3 & 5Kg

BFS REENTRY	Max. DownRange(km)	Max. WallT° (K)	Final Velocity (m/s)	Max Acc° (m/s2)	Max. Qconv (W/m2)	Min. Cb (kg/m2)	Max. Cb (kg/m2)	Cb @ 70 km	Alt Qmax (km)	Alt Tmax (km)	Alt Gmax (km)	Alt Périgé (km)	Cd Cone Equ	material	Thermal mass (kg)	Debrisk version	Diamètre SPHR
M25_Cb15_D1.189	17 605	1 153	49.48	-66.37	309 421	10.58	178.55	24.90	74 746	73 586	59 217	75	1.5	Nextel	5	v3	1.518747306
M25_Cb20_D1.030	17 767	1 218	58.11	-65.15	380 531	14.12	239.59	33.24	72 847	71 673	56 599	75	1.5	Nextel	5	v3	1.315273749
M25_Cb25_D0.921	17 894	1 266	65.97	-64.07	445 250	17.62	298.73	41.48	71 822	70 658	53 626	75	1.5	Nextel	5	v3	1.176416604
M35_Cb15_D1.407	17 613	1 131	49.48	-65.93	286 488	10.58	179.83	24.90	74 560	73 393	60 567	75	1.5	Nextel	5	v3	1.797006046
M35_Cb20_D1.219	17 775	1 195	58.17	-65.30	352 031	14.14	239.40	33.27	71 936	71 936	58 263	75	1.5	Nextel	5	v3	1.556252887
M35_Cb25_D1.090	17 903	1 243	66.02	-64.63	411 985	17.65	299.84	41.55	70 703	70 703	55 176	75	1.5	Nextel	5	v3	1.391954898
M50_Cb15_D1.682	17 622	1 107	49.51	-66.28	263 746	10.59	179.75	24.93	74 753	73 559	59 929	75	1.5	Nextel	5	v3	2.147833037
M50_Cb20_D1.457	17 784	1 168	58.12	-65.20	323 649	14.13	238.86	33.26	71 873	71 873	57 587	75	1.5	Nextel	5	v3	1.860077973
M50_Cb25_D1.303	17 912	1 217	66.10	-64.60	378 566	17.67	300.17	41.60	70 269	70 269	55 885	75	1.5	Nextel	5	v3	1.663704317
M25_Cb15_D1.288	17 342	1 055	38.00	-68.06	218 308	6.50	109.79	15.30	77 091	77 091	62 912	75	1.28	Nextel	5	v3	1.518747306
M25_Cb20_D1.115	17 495	1 111	44.31	-66.88	267 922	8.65	146.22	20.36	75 915	74 759	60 624	75	1.28	Nextel	5	v3	1.315273749
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M35_Cb15_D1.523	17 348	1 034	37.96	-67.79	201 820	6.49	109.54	15.27	77 940	76 795	64 505	75	1.28	Nextel	5	v3	1.797006046
M35_Cb20_D1.319	17 504	1 090	44.35	-66.99	248 379	8.66	146.91	20.39	75 531	75 531	61 918	75	1.28	Nextel	5	v3	1.556252887
M35_Cb25_D1.180	17 626	1 135	50.11	-65.93	291 184	10.82	182.96	25.48	74 461	73 282	60 260	75	1.28	Nextel	5	v3	1.391954898
M50_Cb15_D1.821	17 356	1 013	37.97	-67.61	186 100	6.49	110.25	15.28	77 016	77 016	61 949	75	1.28	Nextel	5	v3	2.147833037
M50_Cb20_D1.577	17 511	1 067	44.34	-66.96	228 590	8.66	146.55	20.38	75 893	74 687	61 054	75	1.28	Nextel	5	v3	1.860077973
M50_Cb25_D1.410	17 634	1 112	50.08	-66.21	267 921	10.82	183.57	25.47	74 413	73 266	59 750	75	1.28	Nextel	5	v3	1.663704317
M25_Cb15_D1.457	17 387	1 071	39.75	-67.57	231 813	7.07	119.83	16.63	76 696	76 696	63 795	75	1	Nextel	5	v3	1.518747306
M25_Cb20_D1.262	17 541	1 129	46.38	-66.39	284 266	9.41	158.76	22.14	75 665	74 498	59 465	75	1	Nextel	5	v3	1.315273749
M25_Cb25_D1.128	17 665	1 177	52.48	-65.80	333 992	11.77	199.27	27.71	73 171	73 171	57 603	75	1	Nextel	5	v3	1.176416604
M35_Cb15_D1.724	17 393	1 050	39.69	-67.79	214 494	7.06	119.71	16.61	76 720	76 720	63 126	75	1	Nextel	5	v3	1.797006046
M35_Cb20_D1.493	17 549	1 107	46.43	-66.75	263 573	9.42	159.81	22.18	75 535	74 404	60 625	75	1	Nextel	5	v3	1.556252887
M35_Cb25_D1.335	17 671	1 153	52.44	-65.86	308 606	11.75	199.37	27.66	73 212	73 212	59 143	75	1	Nextel	5	v3	1.391954898
M50_Cb15_D2.060	17 401	1 028	39.70	-67.63	197 662	7.06	119.11	16.62	76 834	76 834	62 026	75	1	Nextel	5	v3	2.147833037
M50_Cb20_D1.784	17 557	1 084	46.42	-66.46	242 478	9.41	159.47	22.16	74 694	74 694	59 722	75	1	Nextel	5	v3	1.860077973
M50_Cb25_D1.596	17 680	1 129	52.91	-65.82	284 058	11.76	198.91	27.68	74 265	73 072	58 565	75	1	Nextel	5	v3	1.663704317

Q max < 400 - 445 KW/m²

T° < 1135 – 1265 K

G < 6.7

Nanosat Size

Impact DV error = 1m/s

NORM => **AOP = +/- 0.3°** => RANGE 30-40km

ACT => **INC = +/- 7.5 E-3 °** => RANGE = 0km

ALT => **PERI = +/-3.3 km** => RANGE = 300Km

NOTA : **1 km delta Perigée**

impacts downrange = **50/70/150-200 km**

(Pending Perigee Altitude)

SPEC : Accuracy Delta V (//Track) **<<100mm/s**

GOAL : Accuracy Delta V (//Track) **<30mm/s**

		NOM	NORM	NORM	ACT	ACT	ALT	ALT
(Rstar)	DV(m/s)	1	1	-1	1	-1	1	-1
	APO	400	400.002	400.002	400.000	400.000	400.000	400.000
	PERI	75	74.991	74.991	74.994	74.994	78.321	71.668
	ECC	0.02456	0.02456	0.02456	0.02456	0.02456	0.02431	0.02482
	SMA	6615.63	6615.63	6615.63	6615.63	6615.63	6617.3	6613.97
	INC	0.00001	1E-05	1E-05	**0.00756**	**0.00758**	1E-05	1E-05
	RAAN	0	0	0	180	0	360	0
	ECC	0.02456	0.02456	0.02456	0.02456	0.02456	0.02431	0.02482
	AOP	0	**359.7**	**0.30041**	180	360	360	0
	TA	-180	**180.3**	**179.7**	180	180	180	180
	MM	16.1341	16.1341	16.1341	16.1341	16.1341	16.128	16.1402
(Rstar)	X	-6778.1	-6778.1	-6778.1	-6778.1	-6778.1	-6778.1	-6778.1
(Rstar)	Y	-8E-13	-8E-13	-8E-13	-8E-13	-8E-13	-8E-13	-8E-13
(Rstar)	Z	-1E-19	-1E-19	-1E-19	-1E-19	-1E-19	-1E-19	-1E-19
(Rstar)	Vx	9.5E-16	0.001	-0.001	9.5E-16	9.5E-16	9.5E-16	9.5E-16
(Rstar)	Vy	-7.5738	-7.5738	-7.5738	-7.5738	-7.5738	-7.5748	-7.5728
(Rstar)	Vz	-1E-06	-1E-06	-1E-06	0.001	-0.001	-1E-06	-1E-06

H1 (km)	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
H2 (km)	100	95	90	85	80	74	74.9	75	75.1	76	70	65	60	55	50
INC1 (°)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SMA1 (km	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778	6778
INC2 (°)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SMA2 (KM	6628	6625.5	6623	6620.5	6618	6615	6615.45	6615.5	6615.55	6616	6613	6610.5	6608	6605.5	6603
Mu_km	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05	3.99E+05
DV (km/s)	0.086	0.088	0.089	0.091	0.092	0.094	0.094	0.094	0.094	0.093	0.095	0.097	0.098	0.099	0.101
DV (m/s)	86.287	87.750	89.214	90.678	92.144	93.903	93.639	93.610	93.581	93.317	95.077	96.545	98.014	99.483	100.953
								m/s							
						0.293	0.029	0.000	-0.029	-0.293					
								%							
						0.00312	0.00031	0	-0.0003	-0.0031					

E.NOVA AeroSpace

Thank you for your attention

Any question?

Luis GARCIA MOZOS: luis.garcia-mozos@student.isae-supaero.fr
Christian PIERONNE: christian.pieronne@estaca.eu
Stéphane HEINRICH: stephane.heinrich@enova-aerospace.com