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CENTRE NATIONAL
D'ÉTUDES SPATIALES

MICRO MINI LANCEURS

JOURNÉE JEUNES CHERCHEURS

12 octobre 2023

Toulouse

Paolo BAIOCCO – Senior project manager of the MLCG project, project Team, directorates working on the project: DTS and CSG

CURRENT CONTEXT SATELLITES, LAUNCH VEHICLES, NEWSPACE

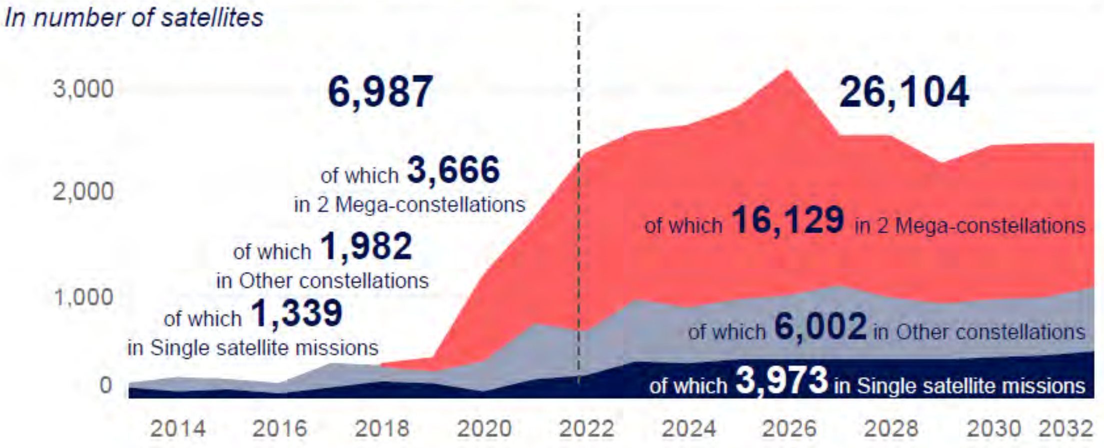
Un marché commercial en pleine mutation

- **Baisse du marché GEO commercial historique**
- **Euroconsult anticipates that about <u>26104 smallsats (<500 kg) will launch over 2023-2032</u>, or about 543 tons per year, i.e. one and a half ton per day on average over the next 10 years.**
- **The next decade will be defined primarily by the rollout of <u>multiple constellations, which will account for 85% of smallsats</u>, mainly for commercial operators.**

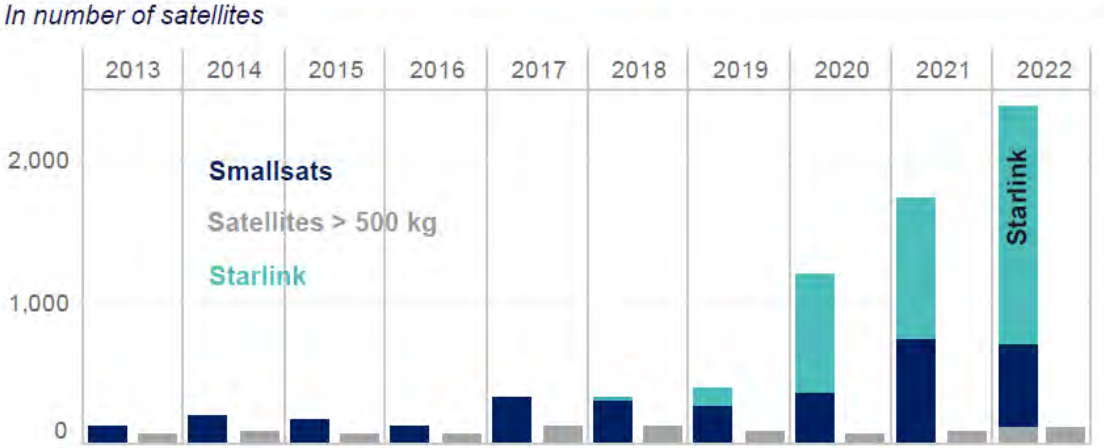
	STARLINK	OneWeb	TELESAT	amazon	Satnet – Guowang
Nombre de satellites prévus (% lancés)	4,408 satellites (>75%)	650 satellites (66%)	198 satellites (0%)	3,236 satellites (0%)	~2,000 satellites (0%)
Constructeur	Interne	OneWeb Satellites	Thales Alenia Space	Interne	Interne
Opérateur de lancement	Interne	Arianespace, SpaceX, ISRO	TBD	Arianespace, ULA, Blue Origin	CGWIC

NB: min Starlink mass 300 kg, raising up to 2 t

Euroconsult's 2023 smallsat launch forecast



Smallsats launched over 2013-2022 vs. non-smallsats

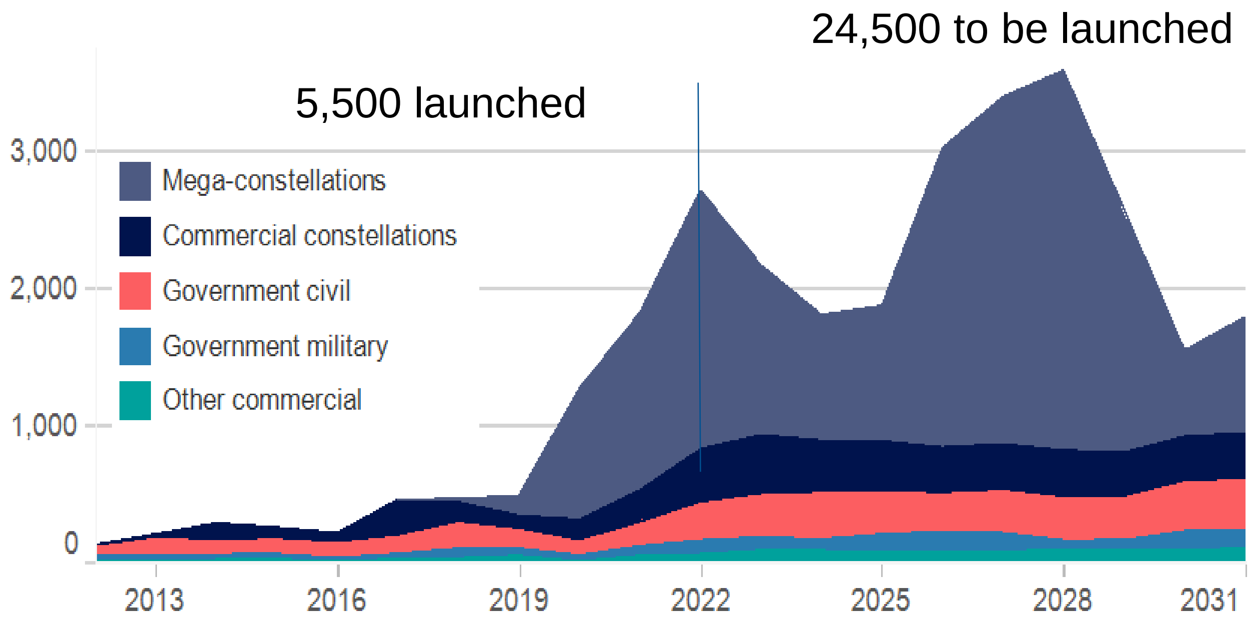


Source Euroconsult pour le CNES – July 2023

LES SMALLSATS & LES MICRO-LANCEURS

Lancement des smallsats en 2022
(hors Starlink & Oneweb):

- ***~566 t. lancé (55%)***
- ***#2372 smallsats (95 %)***



Source Euroconsult - 2022 forecast

Micro-lanceurs dans le monde:

- Principalement USA et Chine
- Une trentaine de projets ayant dépassé la phase papier
- Une douzaine a effectué au moins 1 vol
- 4 pleinement opérationnels dont (Electron, Kuaizhou-1A, Ceres-1,CZ-11)
- 16 projets Européens

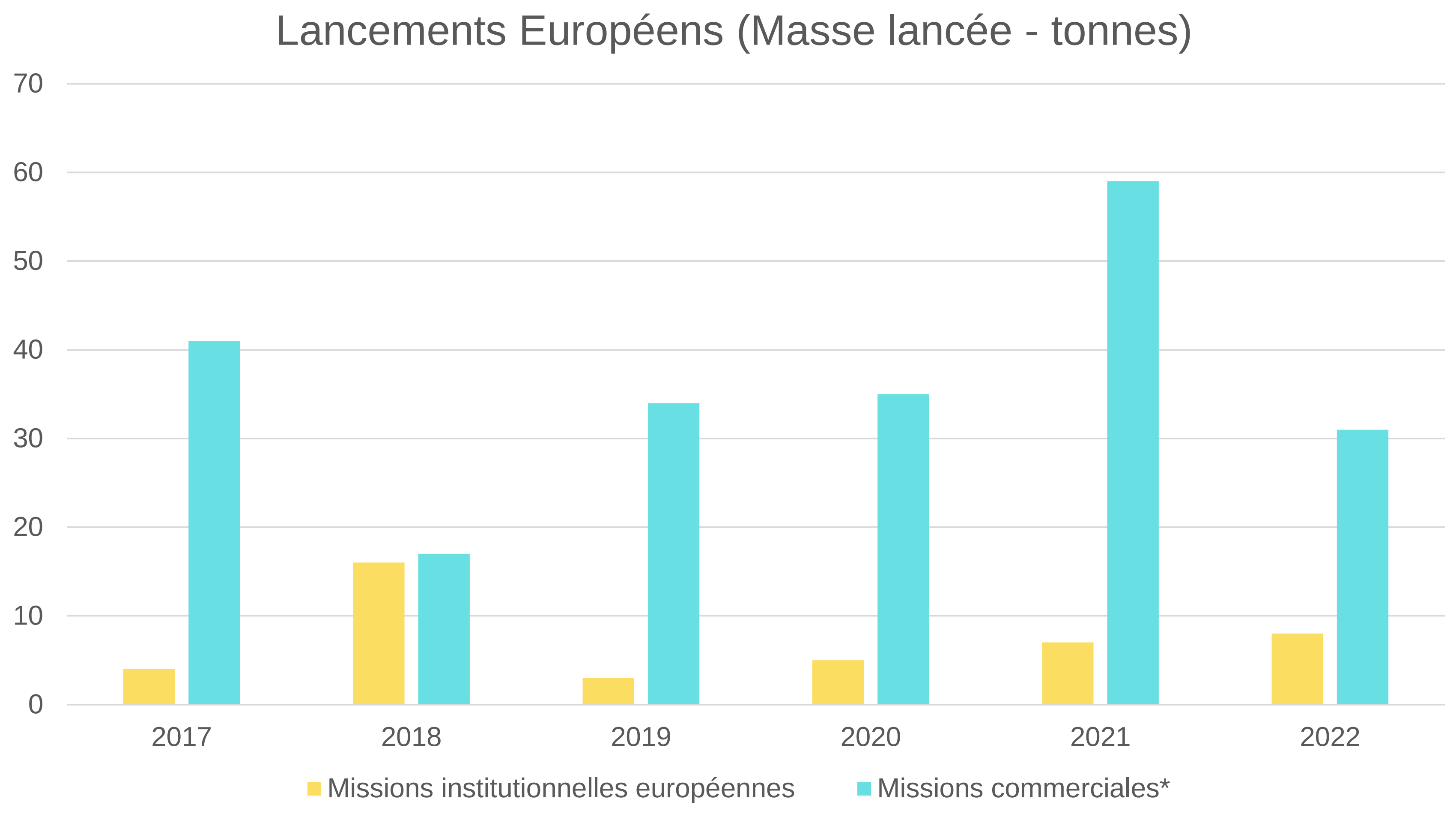
  (stade <= essais moteurs)

Microsats and micro-launchers sandbox of Newspace

Ceres 1 – Galactic Energy

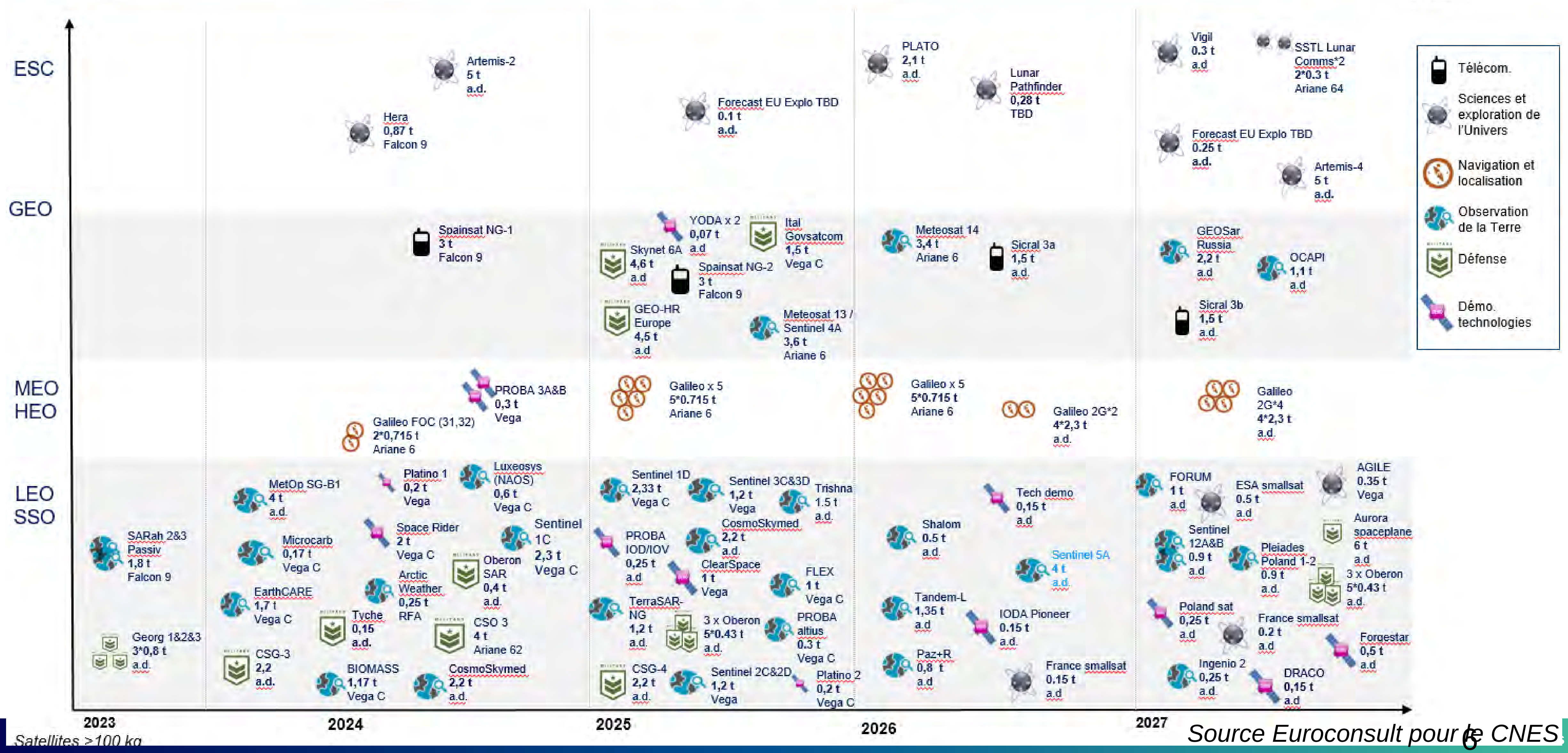
Electron - RocketLab

Un marché de lancement européen limité & principalement commercial



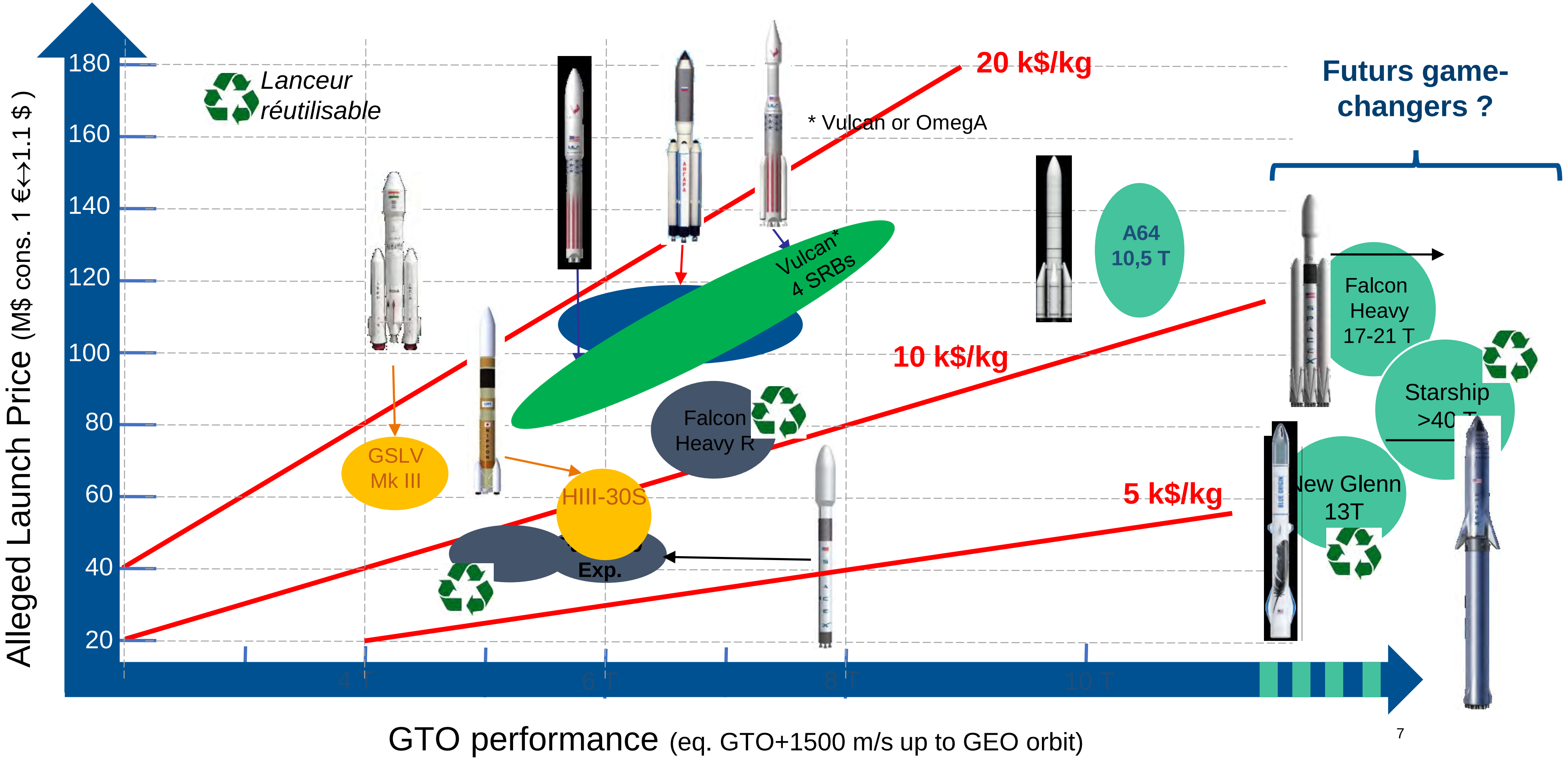
(*) dont lancements Soyouz à Baïkonur par Arianespace (OneWeb)

Un panel de missions institutionnelles prévisible et assez stable



Source Euroconsult pour le CNES

UNE TENDANCE VERS 5 k$/kg (GTO) ET DE FUTURS GAME-CHANGERS À L'HORIZON 2025



Newspace: Transformation or Disruption?

[…] a movement and philosophy encompassing a globally emerging, commercialy minded private spaceflight industry […]

[…] from an industrial organization perspective, NewSpace is nominally a fundamentally disruptive force vis-à-vis Old Space. […]

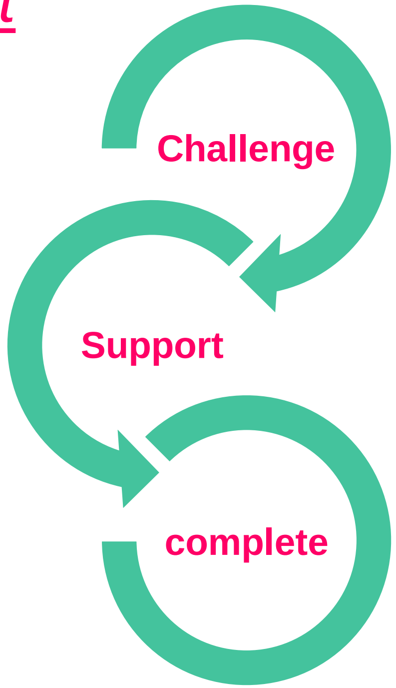
WIKIPEDIA

Legacy players:

- ✓ Public fundings mainly
- ✓ Linear development

Newspace players

- ✓ Public & private fundings
- ✓ Agile approach



… ET DES SPACEPORTS

Upgrading existing suborbital ranges:

- **Norway's Andøya**
- **Sweden's ESRANGE**

New Spaceports for light launchers:

- **UK's new spaceport Sutherland/Saxavord**
- **UK's Cornwall airport upgrading to spaceport for HTHL orbital missions (Virgin Orbit)**

Others:

- **Italy's Grottaglie airport upgrading to spaceport for suborbital launches**
- **Portugal's plans for an Atlantic Spaceport Center on the Azores**
- **Spain Canarias project?**

Mostly suitable for SSO or Polar orbits, missing equatorial launch capabilities

C'EST QUOI UN MICRO-MINI LANCEUR

A definition based on performance

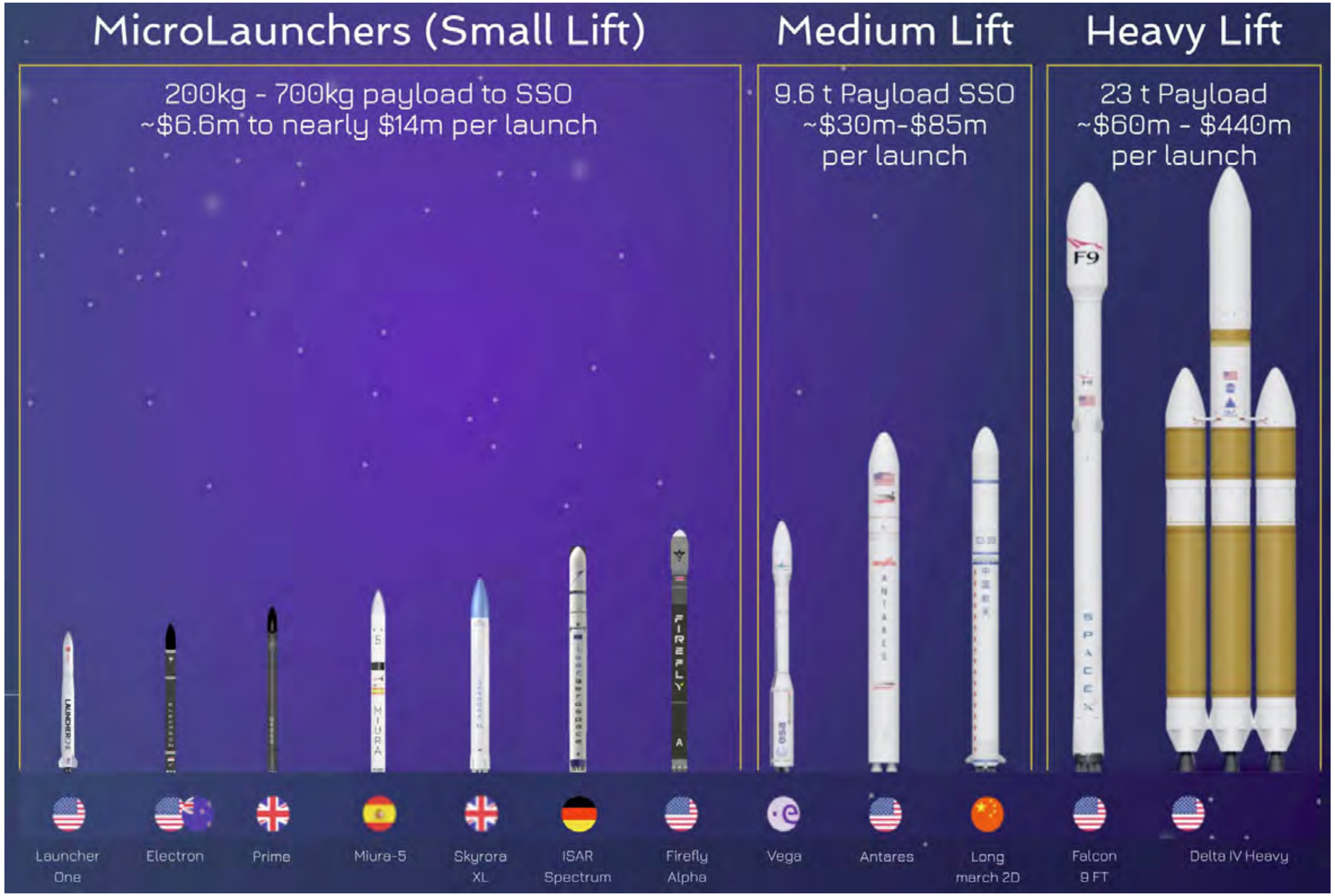
Payload in LEO (but which LEO?)

- Nanosat <100 kg
- Microsat 100 kg<mass<500 kg
- Minisat 500 kg <mass<1000 kg
- Smallsat 1000 kg< mass < 2000 kg

Usually a need in SSO between 600 and 800 km

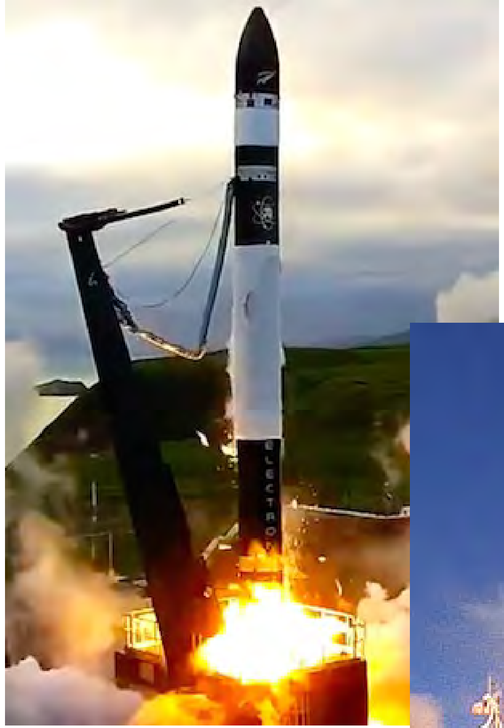
- Then a micro LV has a performance for a microsat
- And a mini LV has a performance of a minisat

However, there is no precise definition!

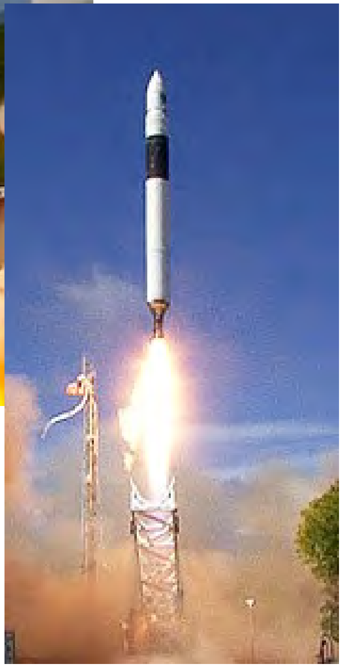


HISTORICAL MICRO MINI LV AND SMALL LV

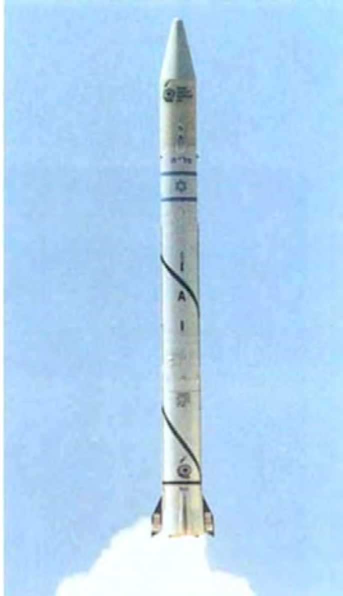
Mini/micro launch vehicles (Historical)



ELECTRON
150 kg SSO



FALCON 1
650 kg 200 km, i=28°



SHAVIT
290 kg 200x800 km, i=90°

F-15
50 kg LEO ?

PEGASUS XL
330 kg, 200 km, i=90°

SCOUT
220 kg, 550 km, i=2.9°

Diamant
105 kg, 300x1000 km, i=5.3°

Small launch vehicles (Historical)

VEGA
1500 kg LEO

ROCKOT
1950 kg, 200 km, i=63°

DNIEPR
3700 kg,
300 km, i=50.6°

TAURUS XL
1590 kg
200 km, i=28.5°

Scout (an acronym for Solid Controlled Orbital Utility Test system)

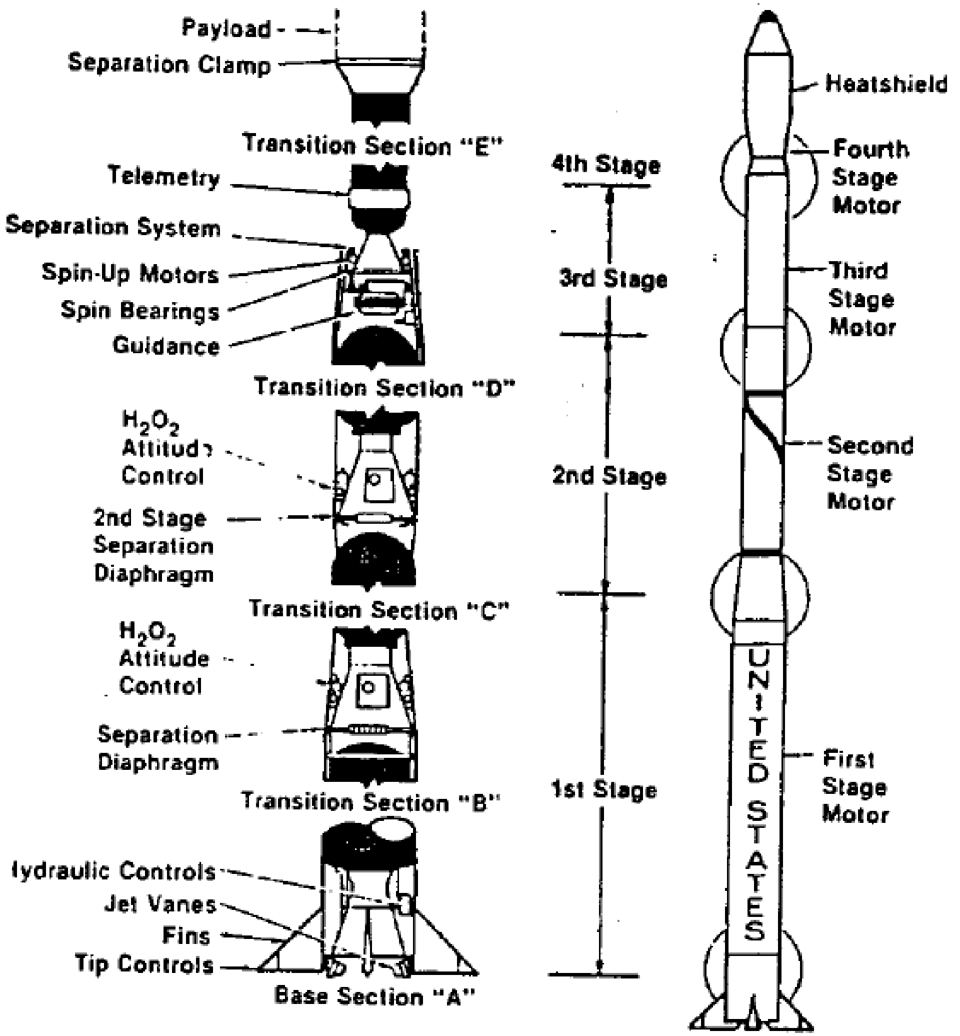
- Designed in 1957- USA
- Scout launch vehicles were used from 1961 until 1994
- Italian version: San Marco Scout launched from Malindi (Kenya)
- At the origin of VEGA

THE SCOUT LAUNCH VEHICLE SYSTEM

Pamela A. Tanck* and James L. Williams**

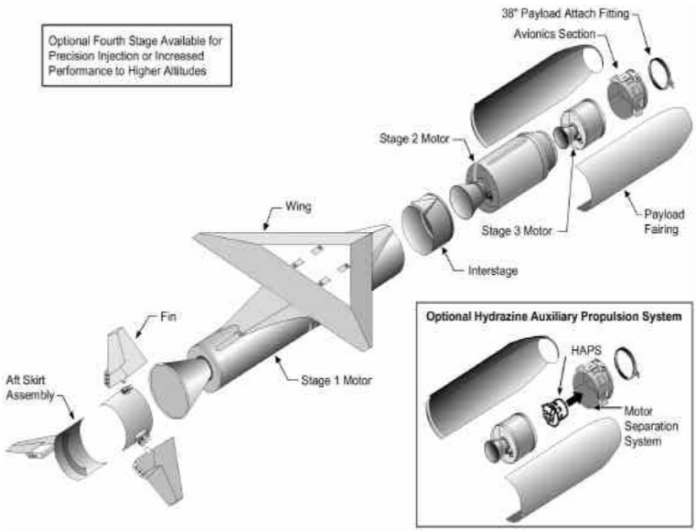
	Height (Meters)	Diameter (Meters)	Inert Mass (Kg)	Consumed Mass (Kg)
Heatshield	1.56	1.07	----	----
Stage 4	1.48	0.51	41	275
Stage 3	2.89	0.76	335	1,299
Stage 2	6.19	0.79	1,064	3,768
Stage 1	9.07	1.14	1,939	12,817

TOTAL: Height= 22.90 M Mass= 21,543 Kg



Pegasus airborne system

- **Advantage of being airborne**
- **LV mass limited by aircraft performance**
- **Maneuver needed after drop off to reach suitable flight path angle and velocity**



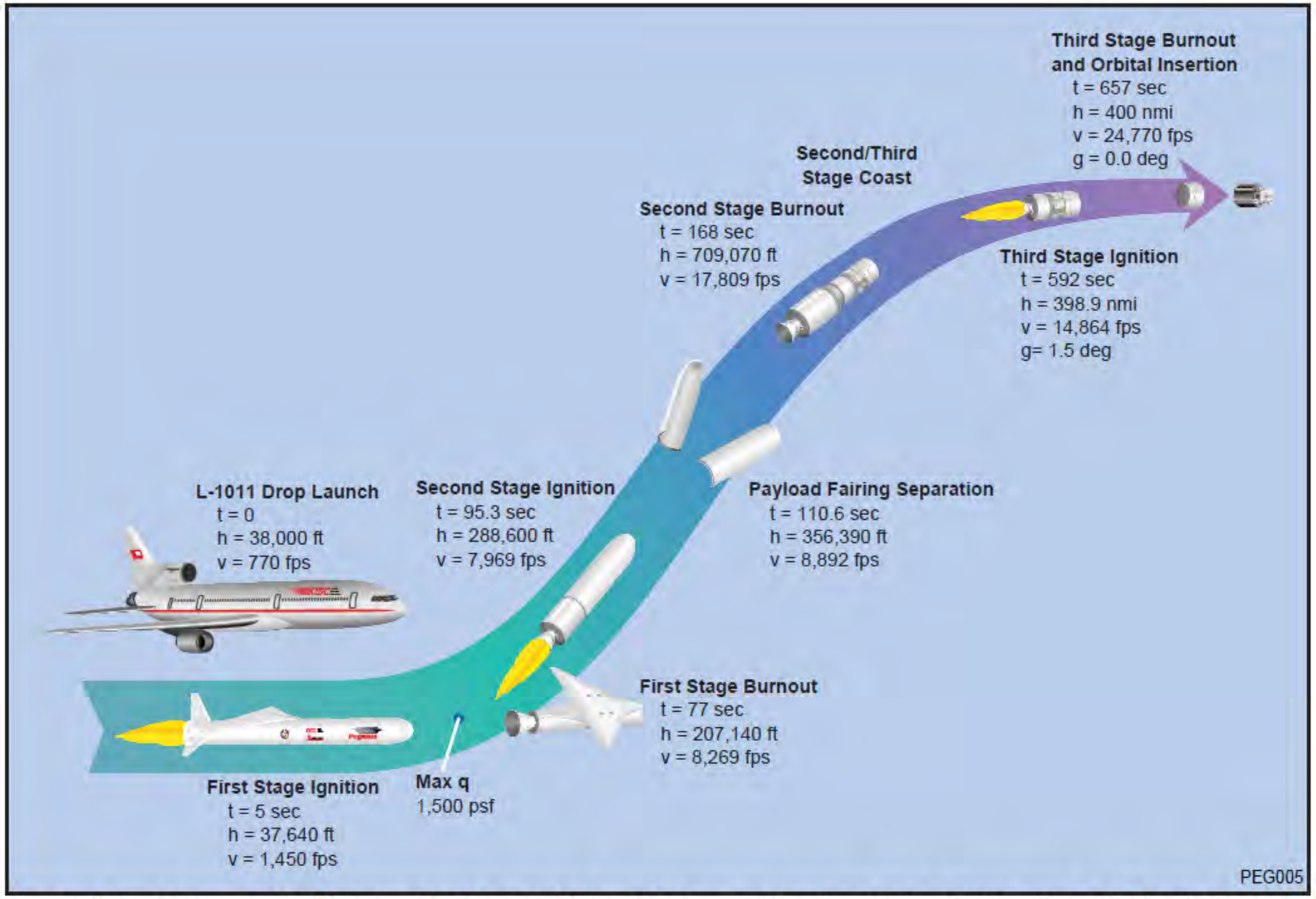
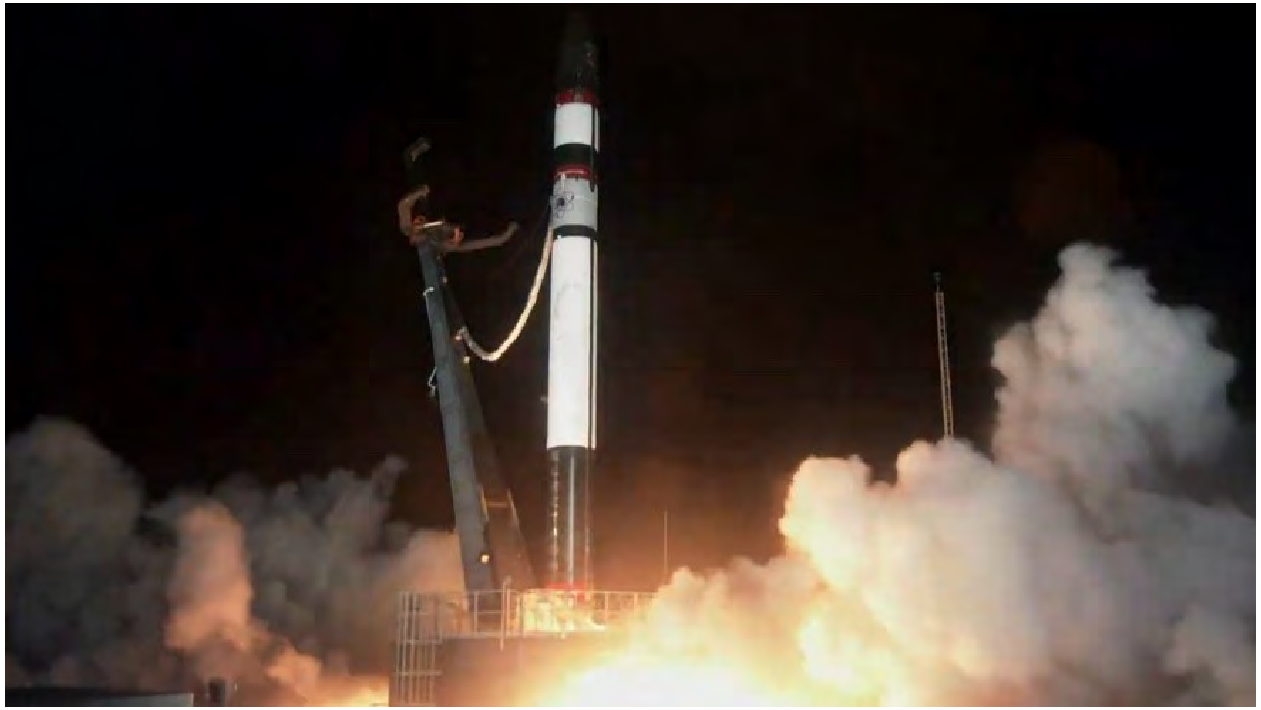


Figure 3-1. *Pegasus XL Mission Profile to 741 km (400 nmi) Circular, Polar Orbit with a 227 kg (501 lbm) Payload.*

MICRO MINI LV TODAY: EXAMPLES ABROAD

ELECTRON (Rocket Lab)



Electron is a two-stage orbital expendable launch vehicle (with an optional third stage) developed by the American aerospace company Rocket Lab to cover the commercial small satellite launch segment (CubeSats). Its Rutherford engines, manufactured in California, are the first electric-pump-fed engine to power an orbital rocket.

First stage	
Length	12.1 m (40 ft)
Diameter	1.2 m (3 ft 11 in)[6]
Engines	9 × Rutherford[6]
Thrust	**Sea level:** 162 kN (36,000 lb_f)[6] **Vacuum:** 192 kN (43,000 lb_f)[6]
Specific impulse	303 seconds (2.97 km/s)[6]
Fuel	RP-1/LOX[6]
Second stage	
Length	2.4 m (7 ft 10 in)
Diameter	1.2 m (3 ft 11 in)[6]
Engines	1 × Rutherford[6]
Thrust	**Vacuum:** 22 kN (4,900 lb_f)[6]
Specific impulse	333 seconds (3.27 km/s)[6]
Fuel	RP-1/LOX[

Rocket LAB's Electron booster stage recovery attempt

- The micro LV electron by rocket lab succeeded in retrieving the booster stage on May 3rd 2022, but then lost it.
- Recovery by helicopter hooking.
- First recovery by successful hooking and splashdown.

Rocket Lab launches 34 satellites, helicopter catches booster for 1st time! - YouTube

Electron rocket failed to reach orbit in a May 15, 2023, launch from Rocket Lab's Launch Complex 1 in New Zealand. Shortly after stage separation, the upper stage's single Rutherford engine ignited but appeared to shut down seconds later.

The launch is the second failure of the Electron in less than a year, and the third in 20 launches. An Electron launch failed in July 2020 because of what the company said was an "anomalous electrical connection" in the second stage that had evaded acceptance testing.

Source: SpaceNews

Virgin Orbit launcher one

LauncherOne rocket system

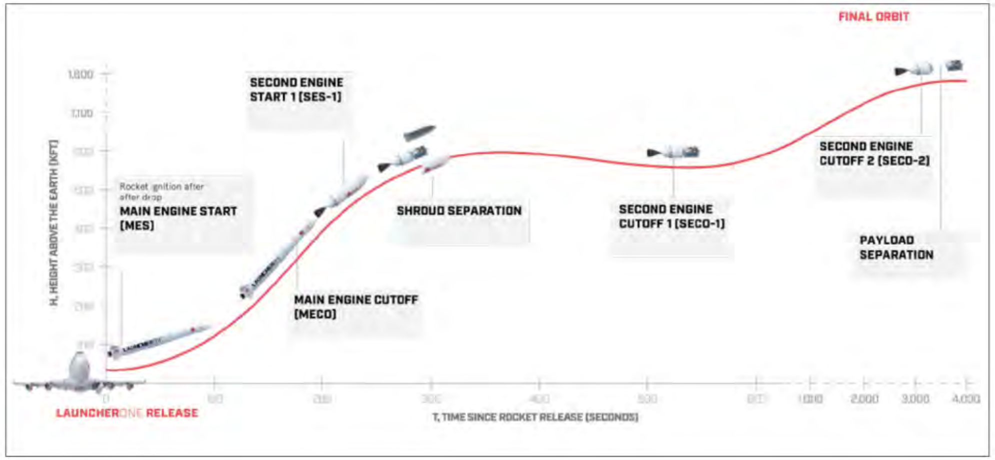
LOX/RP-1 pump fed stages

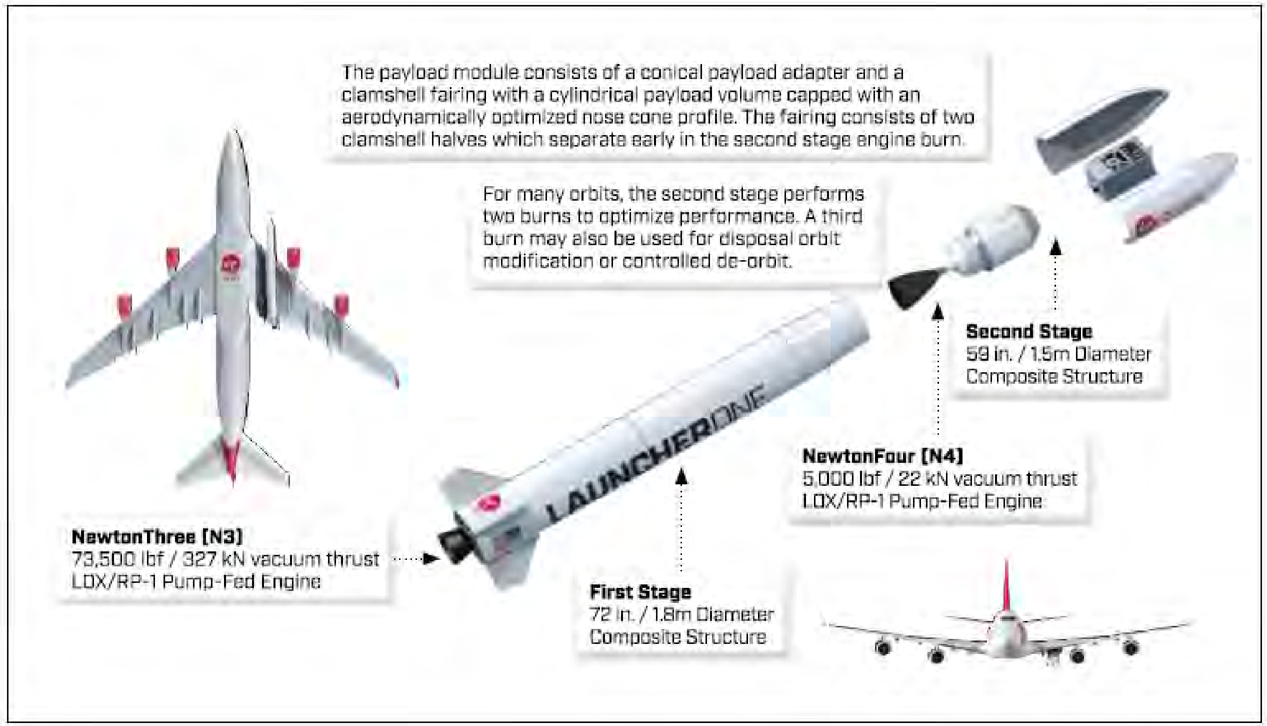
F_{V1}=327 kN, F_{v2}=22 kN

m_{PL}= 300 kg @ 500 km, SSO

Release @ 10600 km, FPA=27.5 deg.

Booster stage in composite





- <u>1st successful flight: January 17, 2021</u> with 10 cubesats
- 4 successful flights, 2 failures
- Final flight on 9 January 2023 failed to reach orbit

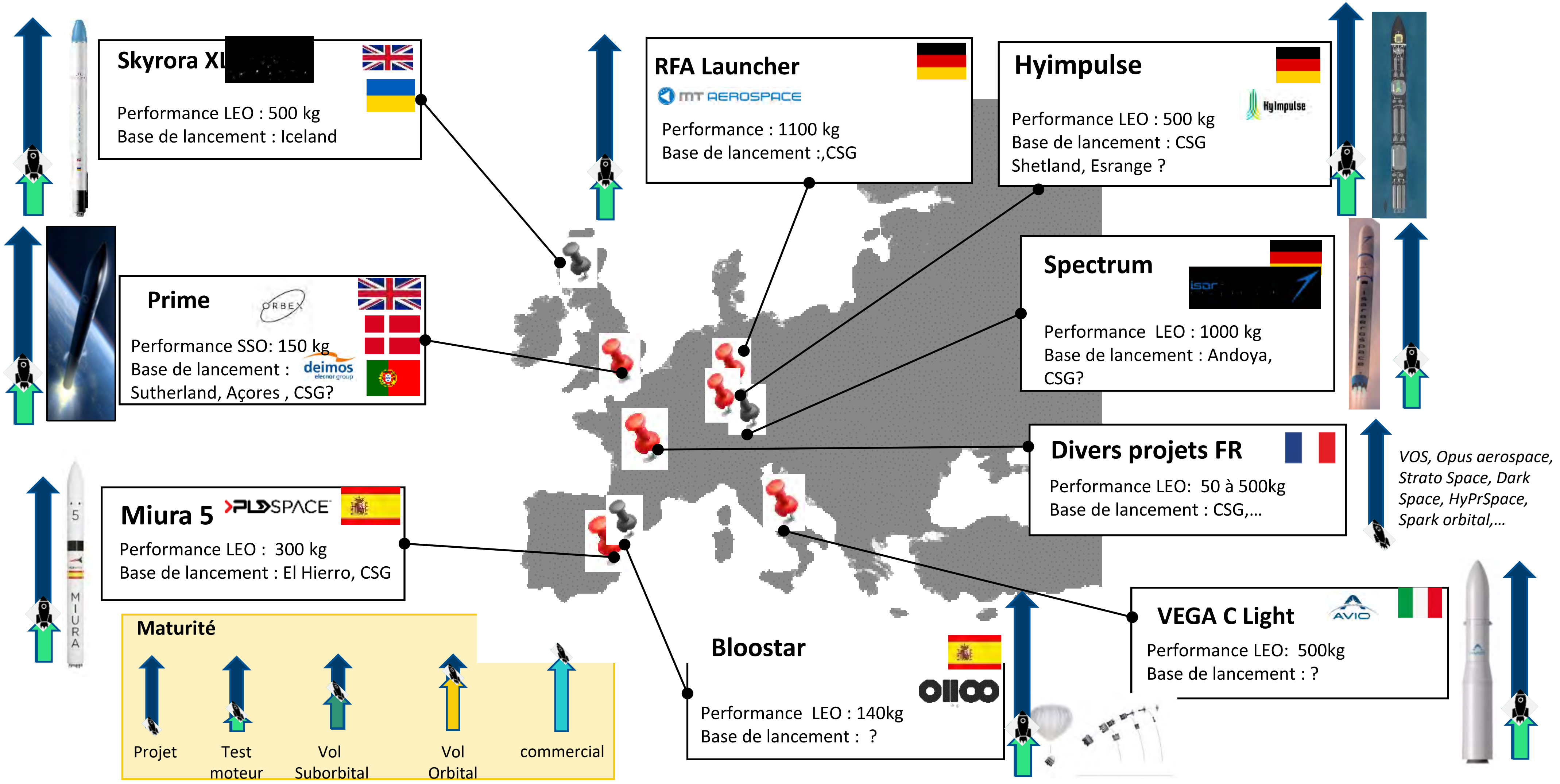
MICRO MINI LV TODAY:
IN EUROPE

Lanceurs légers européens développés durant la décennie 2020

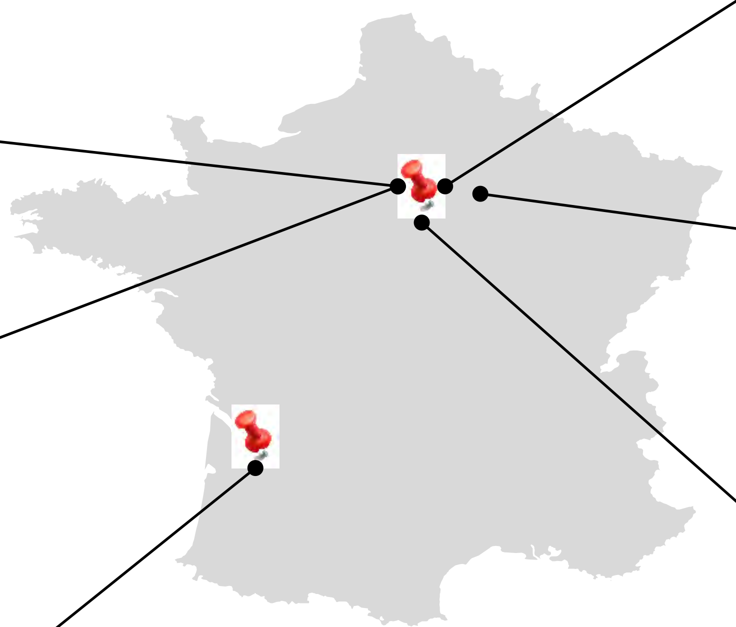
Principales caractéristiques des lanceurs légers européens en cours de développement (maj 11 janvier 2023)

Lanceur	Prime[7]	RFA One[8]	Spectrum[9]	Skyrora XL[10]	SL1[11]	Miura 5[12]	Zéphyr[13]
Constructeur	Orbex	RFA	Isar Aerospace	Skyrora	HyImpulse	PLD Space	Latitude
Dimensions Hauteur x diamètre	19 x 1,3 m	30 x 2 m	27 x 2 m	22,7 x 2,2 m	27 x 2,2 m	34 x 1,8 m	15 x 1,2 m
Étages	2	3	2	3	3	2	2
Masse	18 t			55,8 t	48 t		
Propulsion (1er étage) Poussée unitaire	6 ? ? kN	9 Helix 100 kN	9 Aquila 75 kN	9 Skyforce 80 kN	8 x 75 kN	5 Terrel-C 105 kN	6 Navier ? kN
Ergols	propane x oxygène liquide	kérosène x oxygène liquide	propane x oxygène liquide	kérosène x peroxyde d'hydrogène	oxygène liquide x paraffine	kérosène x oxygène liquide	kérosène x oxygène liquide
Charge utileorbite héliosynchrone	150 kg (500 km)	1 200 kg (700 km)	1 000 kg (700 km)	315 kg (500 km)	400 kg (500 km) 500 kg	300 kg (? km)	70 kg (600 km)
Autre caractéristique	Structure allégée de 30 % /ratio standard	Moteur à combustion étagée			Propulsion hybride	1er étage récupérable	
Base de lancement principale	Sutherland	SaxaVord	Andoya	SaxaVord	Kourou	Kourou	SaxaVord
Premier vol (prévision)	2023	2023	2023	2023	2023	2024	2025

MICROLAUNCHERS PROJECTS IN EUROPE



Principaux mini-micro lanceurs français en développement



MAIA

maiaspace

Performance SSO 500 kg with reuse
Spaceport : CSG
date 1er vol: 2026

SIRIUS-1

SIRIUS

Performance SSO : 175 kg @ 600
Spaceport : CSG
date 1er vol: 2025

OB-1

Hybrid Propulsion

Performance SSO : 200 kg
Spaceport : CSG / Kiruna / barge
date 1er vol: 2025

Dark space

Performance SSO : 300 kg @500
Spaceport : EU Airport
date 1er vol: 2028

ZEPHYR

Latitude

Performance SSO : 80kg @ 600
Spaceport : CSG, Saxavord
date 1er vol: 2025

STERNE

OPUS

Performance SSO : 150-250 kg @700
Spaceport : CSG
date 1er vol: 2025

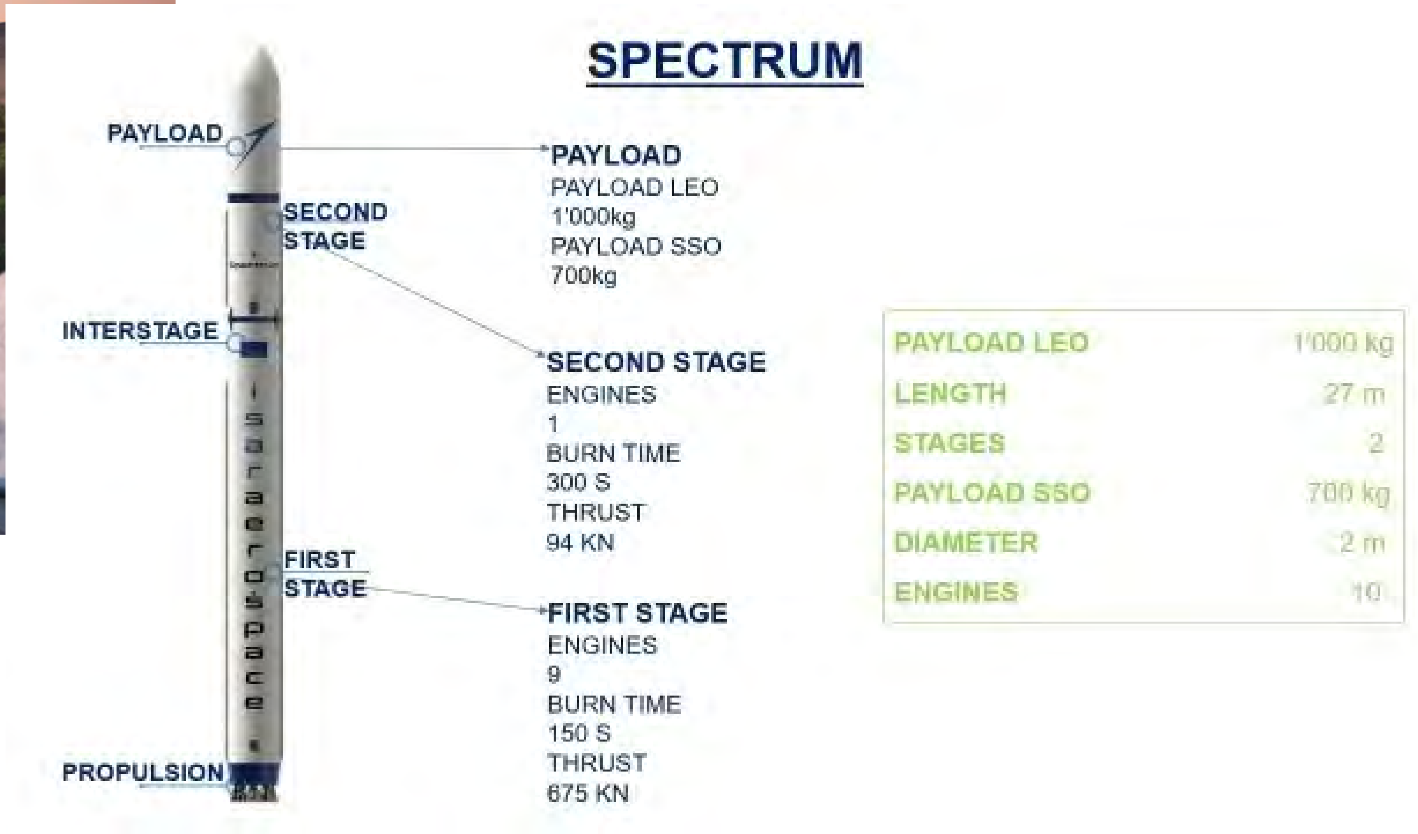
Maturité

Projet | tests | Sub-orbital | Orbital | commercial

Reuse

Sept 2023

Spectrum (ISAR Aerospace)



RFA One (Rocket Factory Augsbourg - RFA)

RFA One est une fusée à trois étages conçue pour lancer dans l'espace de petits satellites et des charges utiles d'un poids initial maximal de 1 300 kg.

Moteurs à combustion étagé, poussée de 100 kN
Les composants du moteur sont fabriqués par Rocket Factory Augsburg et s’appuie sur des techniques de fabrication additives par impression 3D, notamment en ce qui concerne les corps des turbopompes, les chambres de combustion et les injecteurs.

Le deuxième étage est propulsé par un unique moteur-fusée Helix dont la tuyère est optimisée pour fonctionner dans le vide.

MIURA-5 PLD Space

Miura 1 test flight – 6-Oct-2023

MIURA 5 CHARACTERISTICS

MIURA 5 is a **two-stage launch vehicle**. Its first stage is propelled by five regeneratively cooled liquid engines which are designed and built in-house by PLD Space. The second stage is propelled by a single engine of similar design.

Vehicle

Length:	25 m
Diameter:	1.8 m
Lift-Off Mass:	32.000 kg
Stages:	2 + optional kick-stage
Propellants:	LOX / Kerosene
Reusability:	First Stage

First Stage

Length:	17.7 m
Engines:	5
Total Thrust:	408 kN (sea level)

Second Stage

Length:	9 m
Engines:	1
Total Thrust:	65 kN (vacuum)

FLIGHT PHASES

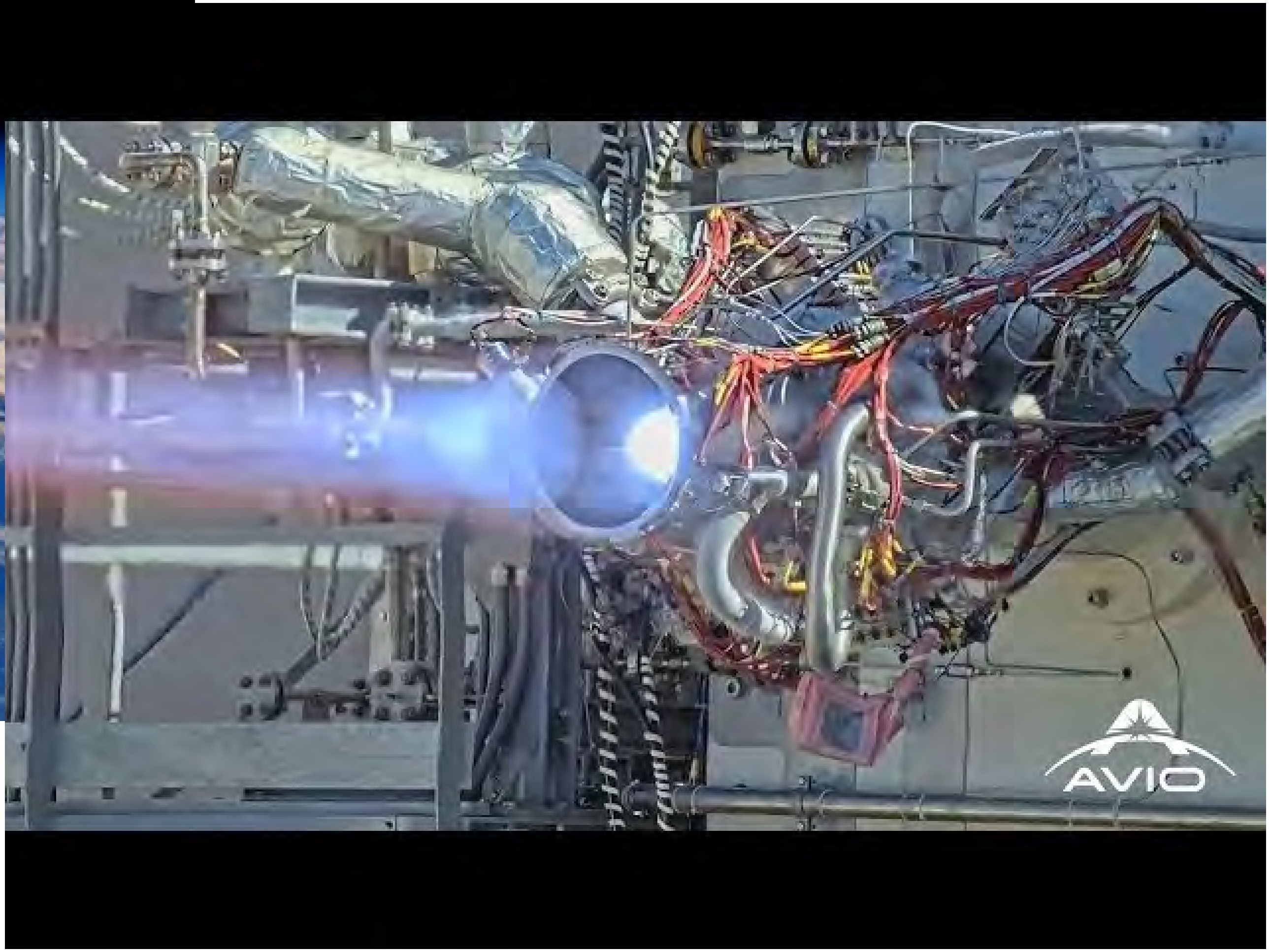
MaiaSpace


maiaspace
Vue d'artiste du lanceur Maia.

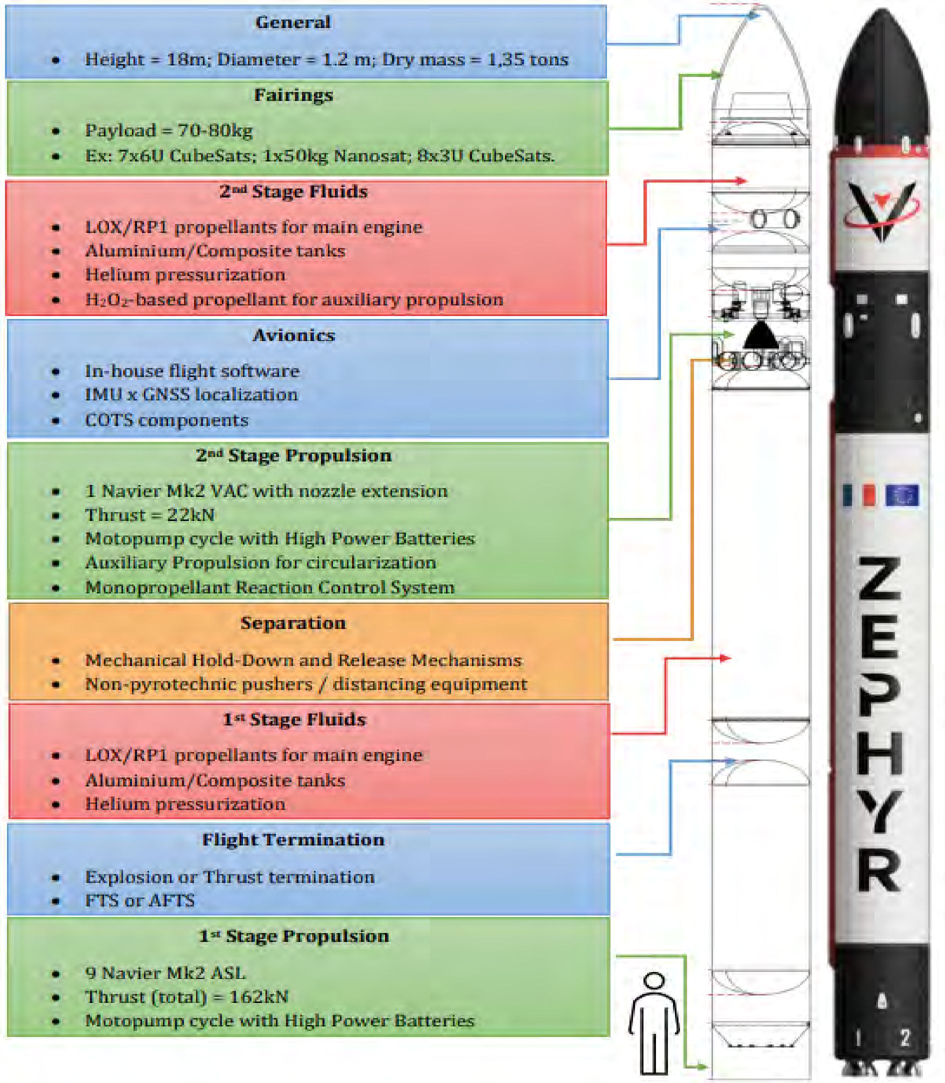

maiaspace
maiaspace

AVIO MLV

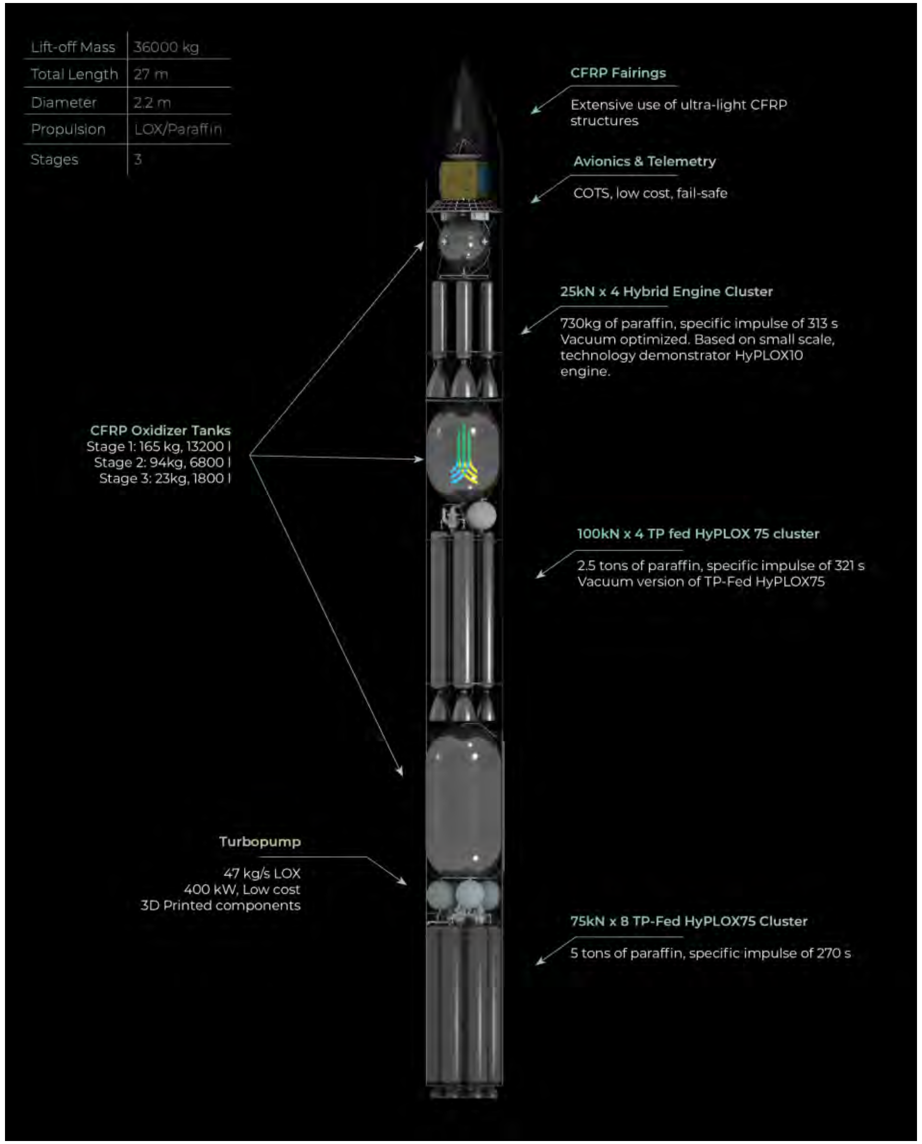
M10 firing test in Sardinia (LOX/LCH4)

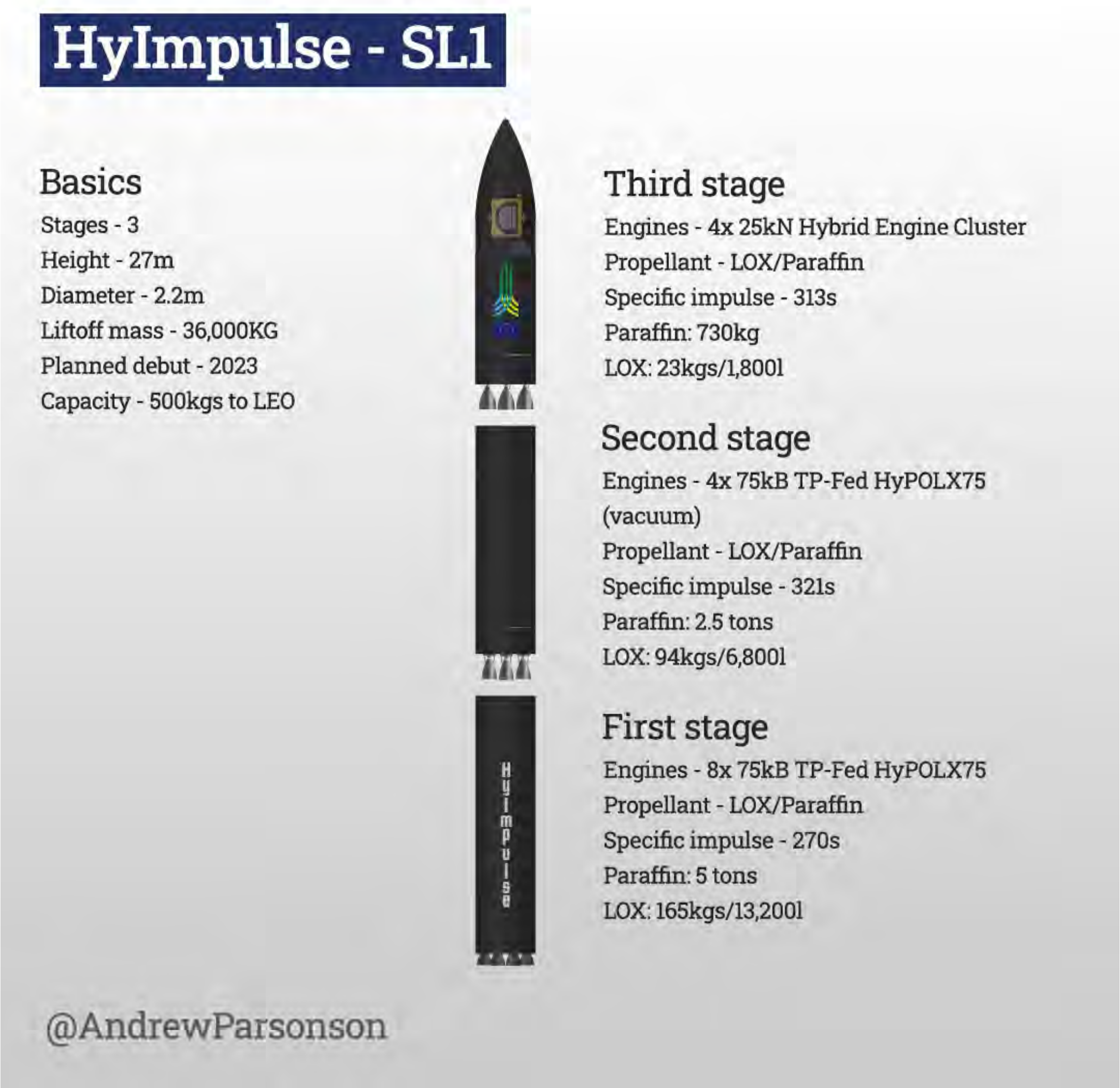


ZEPHYR (Latitude)



HyImpulse


Lift-off Mass 36000 kg
Total Length 27 m
Diameter 2.2 m
Propulsion LOX/Paraffin
Stages 3
CFRP Fairings
Extensive use of ultra-light CFRP structures
Avionics & Telemetry
COTS, low cost, fail-safe
25kN x 4 Hybrid Engine Cluster
730kg of paraffin, specific impulse of 313 s Vacuum optimized. Based on small scale, technology demonstrator HyPLOX10 engine.
CFRP Oxidizer Tanks
Stage 1: 165 kg, 13200 l
Stage 2: 94kg, 6800 l
Stage 3: 23kg, 1800 l
100kN x 4 TP fed HyPLOX 75 cluster
2.5 tons of paraffin, specific impulse of 321 s Vacuum version of TP-Fed HyPLOX75
Turbopump
47 kg/s LOX
400 kW, Low cost
3D Printed components
75kN x 8 TP-Fed HyPLOX75 Cluster
5 tons of paraffin, specific impulse of 270 s


HyImpulse - SL1
Basics
Stages - 3
Height - 27m
Diameter - 2.2m
Liftoff mass - 36,000KG
Planned debut - 2023
Capacity - 500kgs to LEO
Third stage
Engines - 4x 25kN Hybrid Engine Cluster
Propellant - LOX/Paraffin
Specific impulse - 313s
Paraffin: 730kg
LOX: 23kgs/1,800l
Second stage
Engines - 4x 75kB TP-Fed HyPOLX75 (vacuum)
Propellant - LOX/Paraffin
Specific impulse - 321s
Paraffin: 2.5 tons
LOX: 94kgs/6,800l
First stage
Engines - 8x 75kB TP-Fed HyPOLX75
Propellant - LOX/Paraffin
Specific impulse - 270s
Paraffin: 5 tons
LOX: 165kgs/13,200l
HyImpulse
@AndrewParsonson

HOSTING THE ML AT CSG: THE MLCG PROJECT

cnes

Compétition européenne du micro lancement : Accueil au CSG

Segment de perfo: 100-1500 kg LEO

RFA Rocket Factory

RFA-One

HyImpulse

SL1

isaraerospace technologies

SPECTRUM

PLDSPACE

MIURA 5

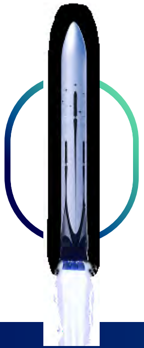
AVIO

VEGA Light

Latitude

Zephyr

Mais Space



Et d'autres encore....

Main goals MLCG (micro-mini launchers @CSG)

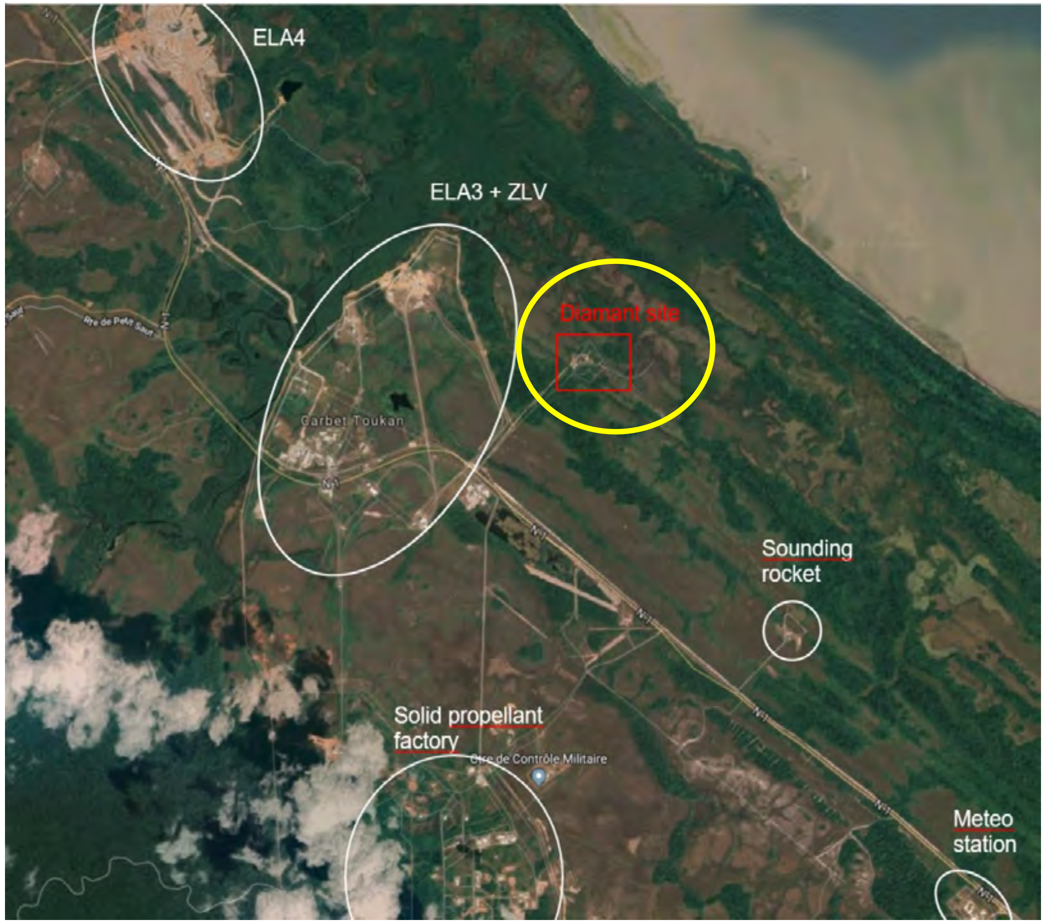
- Support the European newcomers in developing private space transportation systems
- Increase CSG spaceport activity for the benefit of all stakeholders
- Foster new satellite markets
- Provide a favorable geographical location for specific missions
- Provide a multi launcher complex for years to come
- Provide the 50 years launching experience and safety background of CSG

Requirements

- LEO performance <1500 kg for ≥10 years operations

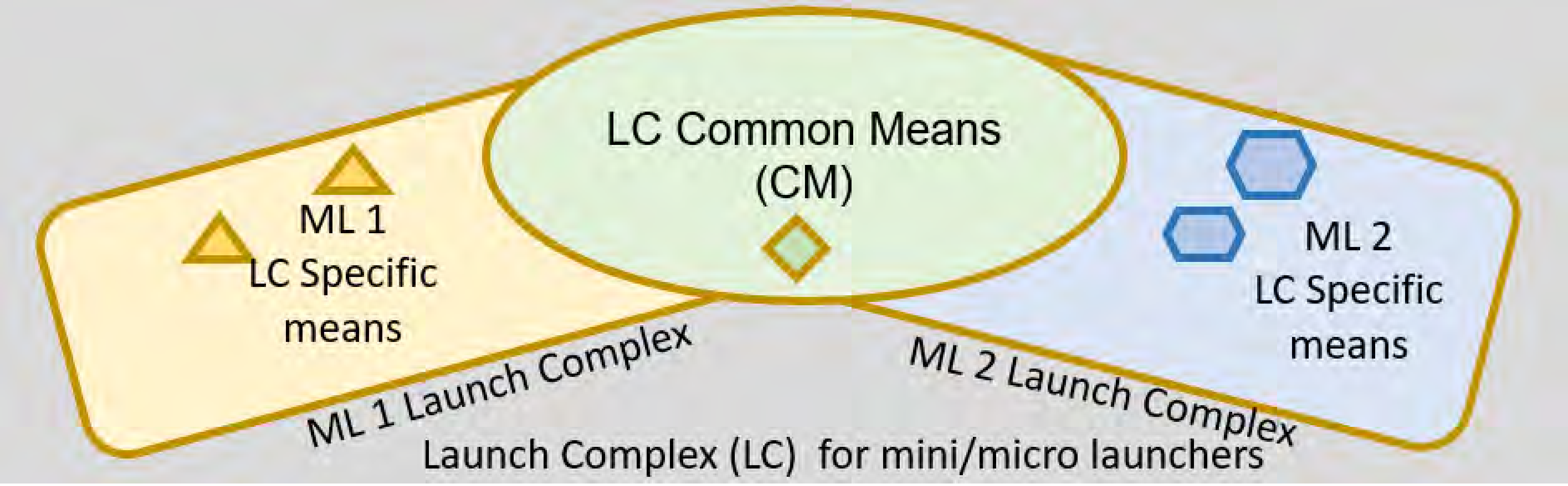
The ELM-Diamant launch site

- **Launch site used at the beginning of the French space adventure for launching the Diamant LV from French Guyana**
- **ELM-Diamant:**
  - A multi launch system ground segment founded by **France 2030** initiative
  - Using common systems developed by CNES
- **Using ESA CSG Range (EPCU, radar stations, TM…) under ESA authorization**



Micro-Mini launchers base concept in ELM

- **Common Means : facilities and functions maintained & operated by Launch Base for all Launch Operators**
- **Specific Means : facilities and functions maintained & operated by each launch operator of micro-mini launchers (MLO)**
- **Different launch operators in the same site**



The CNES MLCG project

- **The CNES MLCG project consists in developing the so-called Common Means necessary for all MLs for their operations on the ELM-Diamant.**

- **Common Means include, for the Ground part**
  - Area for propellant storages LIN and conventional fluids
  - Liquid oxygen reservoirs
  - Securities means, access controls, Diamant site perimeter fence
  - Nitrogen network
  - Energy supply network
  - Optical fiber network
  - Access roads to Common Means
  - …
- **Common means consist also of**
  - A ML in-flight neutralization system (FTS)
  - A ML Backup Kit (KSM), covering the localization, telemetry and neutralization aspects.

- **Support activities for the MLs for their use at the CSG**

Specific Means, Micro-mini LV Operators

- **Specific Means are specific to each ML and both their development and their operations are the responsibility of the MLO**

- **Possibility to delegate to CNES development of some Specific Means**

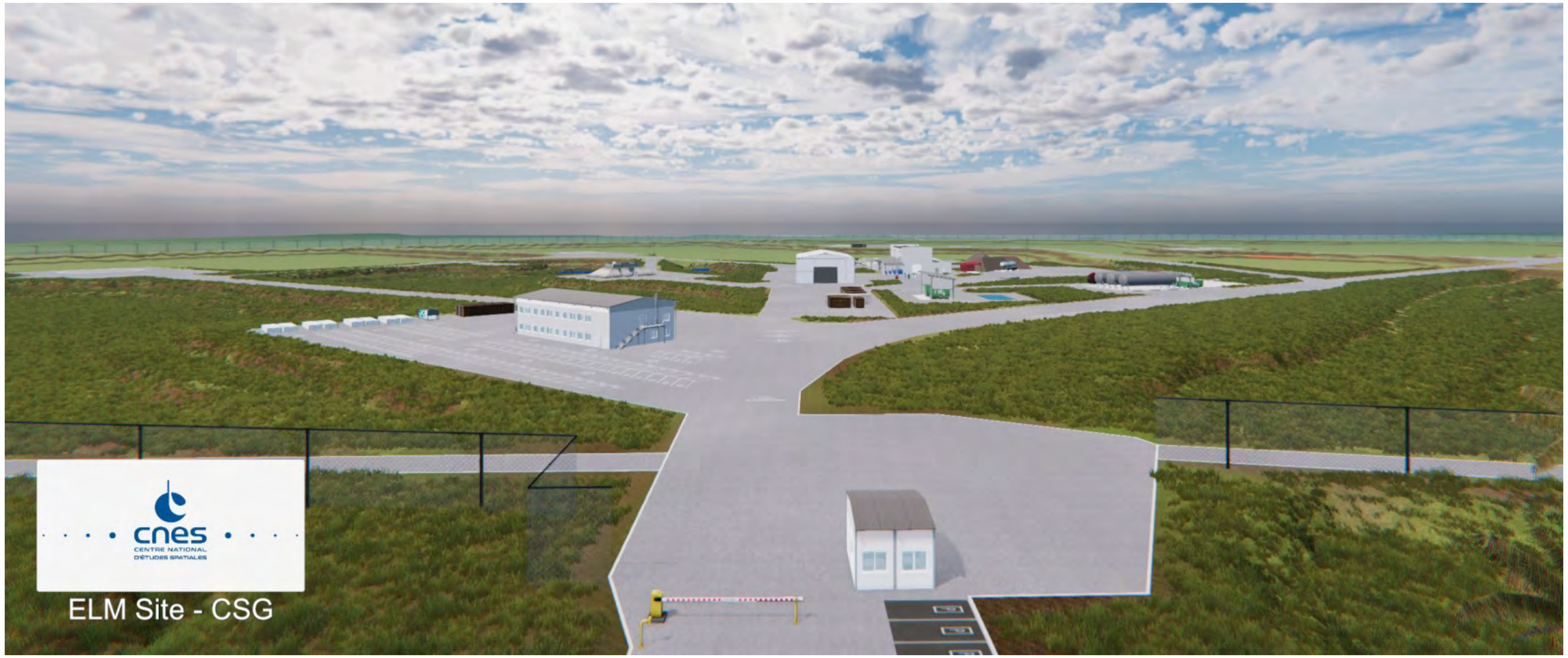
- **Specific means are typically**
  - Launch Pad including plume trench
  - Specific fixed storages for propellants in chronology
  - Concrete stand supporting launch table
  - Deluge system
  - Lightning protection
  - Launcher transport and verticalisation element
  - …

ELM overview – current project status

- **ELM-Diamant constituted by:**
  - A front area (with mainly the launch areas).
  - A rear area housing in particular the Assembly, Integration and Testing (AIT) facilities (not shown).

- **ELM-Diamant able to accommodate up to 6 ML maximum.**

- **Infrastructures activities : 2023-2025.**



Q/A