The (successful) experience of the Maiden Flight of Vega, in parallel to the worth mission to lift Lares

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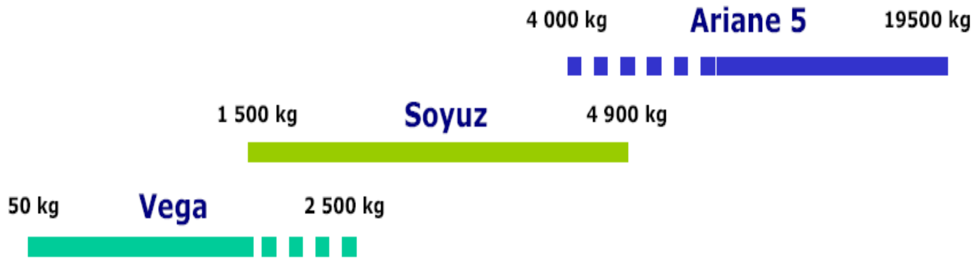
Vega Launch System at a Glance

Vega is intended to complement the European family of launchers and to target the small payload in low Earth orb



Typical mission capability

1 430 kg at 700 km in circular polar orbit

Flexibility of the Vega launcher
A wide mission range

Mass	Altitude	Azimuth
From 50 kg to 2,500 kg	From 300 km to 1,500 km	From equatorial to polar & SSO orbits (5.2 deg - 102 deg)

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Vega LV at a Glance

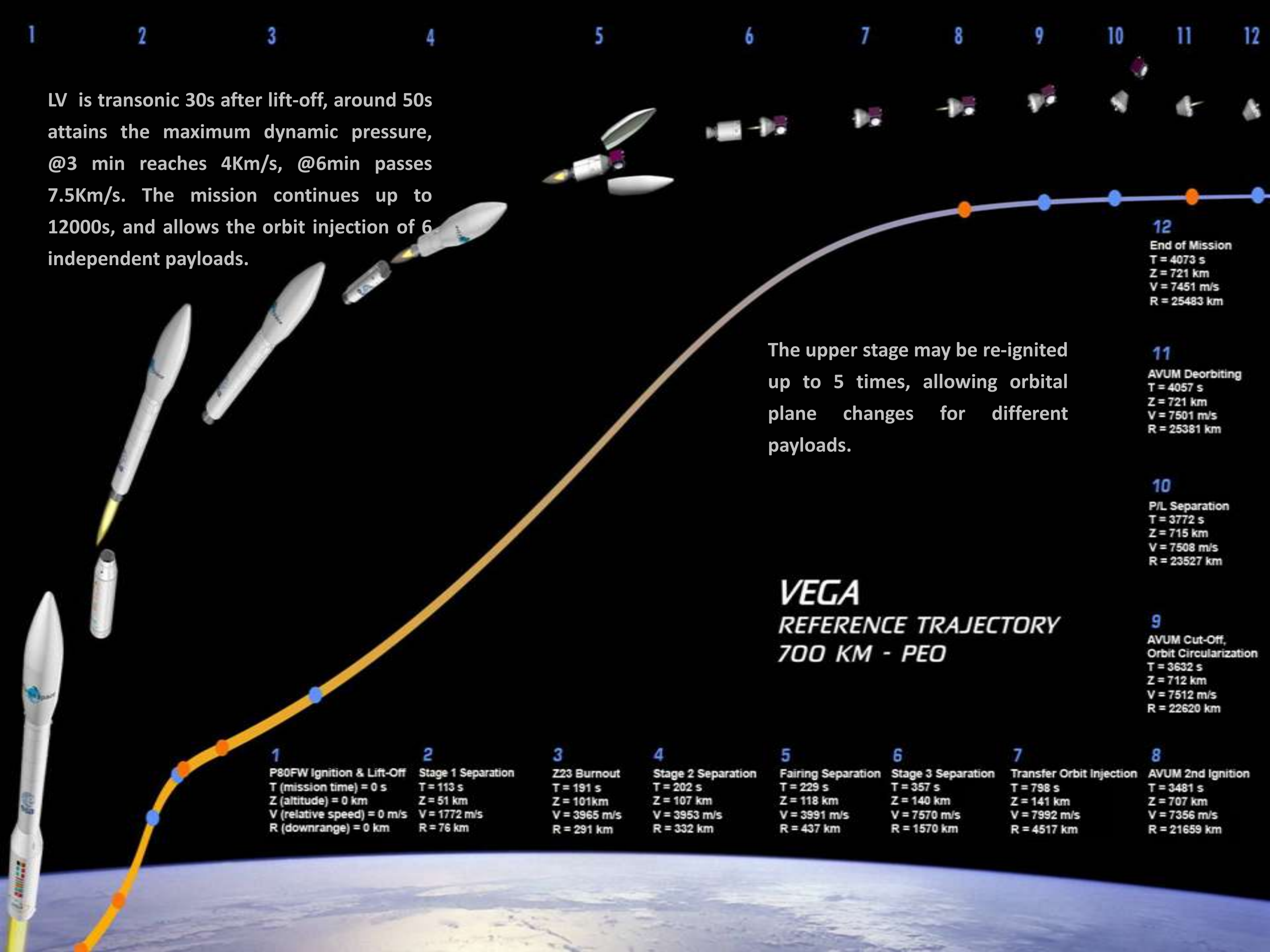
Despite its relatively low lift off mass (137 ton) Vega is the ***largest*** *launch vehicle mostly based on solid propulsion (solid stages assure as much as 95% of its ΔV).*

Vega LV architecture is as simple as possible: three monolithic CFRP solid propulsion stages, an upper storable liquid Vernier that contains most of the avionic equipment and the roll and attitude control system, a standard CFRP Payload Adapter and a Φ2.6m Payload Fairing. Four Al alloy interstage structures complete the airframe.

Height [m]	30.162
Maximum diameter [m]	3.005
Fairing diameter [m]	2.600
Mass at Lift-off [kg]	136740
Reference mission performance [kg]	1451
Structural Ratio	10.2%

LV is transonic 30s after lift-off, around 50s attains the maximum dynamic pressure, @3 min reaches 4Km/s, @6min passes 7.5Km/s. The mission continues up to 12000s, and allows the orbit injection of 6 independent payloads.

The upper stage may be re-ignited up to 5 times, allowing orbital plane changes for different payloads.



The challenge of the Maiden Flight

At the beginning of Vega LV development, the Maiden Flight was intended exclusively to collect test data for Launch Vehicle qualification and verify during the mission what was not possible on ground. In example, motors behavior in altitude, environment at payload, stage separation phases. The mission identified was an equatorial (relatively safe from trajectory and timeline point of view), the payload was represented by a structural dummy, without any functional system. This is a common practice, considering that, from historical records, first flights have a success probability bound between 32% (new launcher and new industrial organization) and 65% (i.e. consolidated industrial team for an evolutionary approach). Moreover, European space community , was sensible to the shocking lesson from Ariane 5 501 mishap.

Yet, the positive achievements of the critical design and qualification phase contributed to build-up the confidence of the community (customer, safety authorities and design office) on the vehicle sound design and robustness.

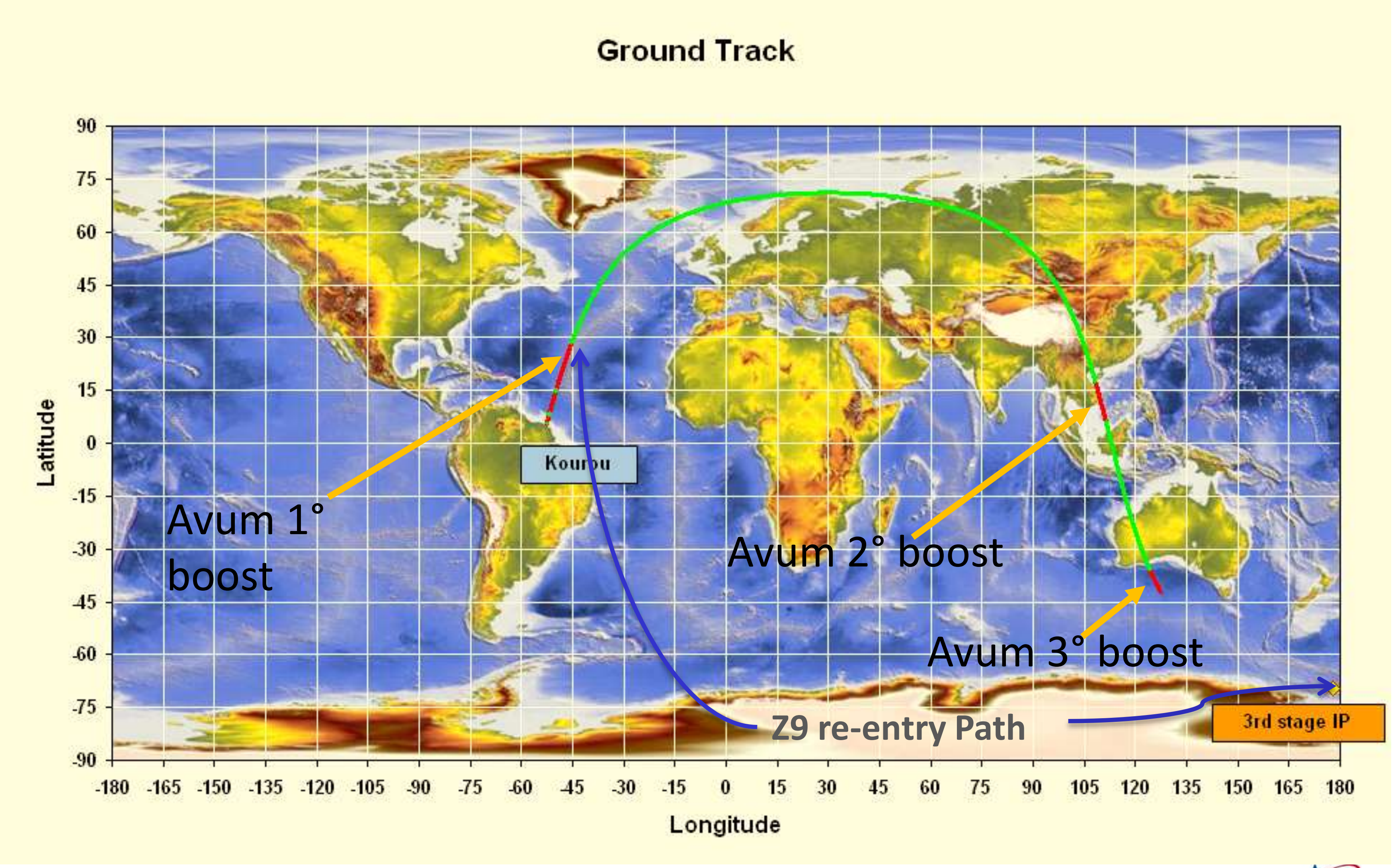
This led to the decision to associate to Vega System qualification objectives, a true exploitation mission , with real Payloads and a dimensioning trajectory.

The challenge of the Maiden Flight

The selected mission was demanding

1. **Injection of the main passenger LARES:**
   - Following two AVUM upper stage boosts
   - **Into a circular 1,450 km-orbit, inclined at 69.5 deg to the equator**
   - With a longitudinal spin of 30 deg/s
2. **Injection of the AVUM into a disposal elliptic o**
   - After LARES separation
   - Following a third AVUM boost
   - With a perigee altitude decreased down to 300 km compared to the circular LA
3. **Separation of the auxiliary passengers, ALMASat-1 and the seven CubeSats, on the AVUM disposal orbit**
4. **Passivation of the AVUM and end of mission**

The challenge of the Maiden Flight



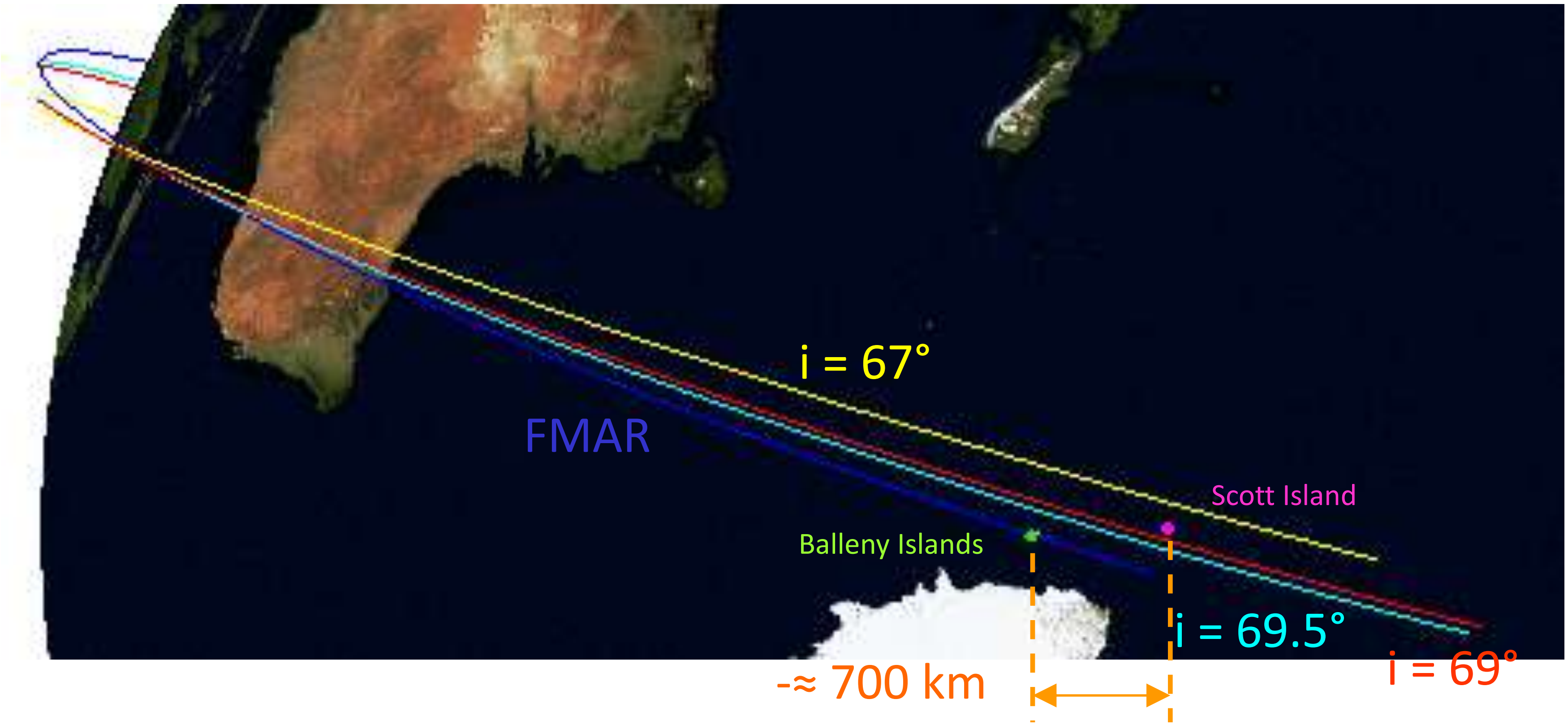
The challenge of the Maiden Flight

The decision taken had the obvious consequence to raise the LV readiness level necessary for the first flight.

The challenge implied further work on both Launch Vehicle and Ground , especially as far as, mission analysis, payload interface and safety clearance was concerned. It, undoubtedly, induced some delay on the schedule. However it resulted in:

- A full formal qualification of LV on ground, with all qualification certificates for the lower tier available and deeply reviewed, the completion of all system tests and system coherence verification;
- A validation of Payload Interface and environment on an actual payload;
- The validation of the complex missionization process and tools as well as the identification on the real life case of the impact of Space Regulation evolution.

The challenge of the Maiden Flight



During the missionization ELV, Lares P/L team, ESA, safeguard and range authorities had to join forces to solve unexpected problem as the fly-by over densely inhabited region and the impact point of the third stage in its reentry, close to Balleny Islands, a desert Antarctic rock, whose possession claims risked to raises of a complex international dispute, on the Antarctic Treaties.

The outcomes from the qualification flight

Vega Maiden Flight on February 13th 2012, was excellent. All the qualification objectives were met, the vehicle successfully completed the full mission and behaved exactly as predicted, with very limited need to recalibrate tuning or prediction tools for the commercial phase.

What is more, the nine scientific payloads, among them Lares was the principal, were injected exactly where they needed.

A part of Lares, the Vega V01 Qualification Flight orbited other passengers:

- LARES
- ALMASat-1
- 7 CubeSats dispatched in 3 dispensers

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The outcomes from the qualification flight

The Vega Maiden Flight was a success

- The final countdown was run on time without interruption
- The lift-off occurred at the opening of the launch window, 10h00’00’’ UTC

The flight was comprehensively instrumented in with three separate TLM subsystems to:

- State on the flight qualification of the launch system
- Monitor the payload environment

The flight analysis has been conducted in line with the usual standards:

- Real time monitoring of critical measurements
- Presentation of the preliminary results the day following the launch)
- Level 0 analyses on 28, 29 February & 01 March
- Level 1 analyses meetings on 29-31 May with a Steering Board on 07 June

The outcomes from the qualification flight

Post-flight analyses of VV01 flight have confirmed the qualification of Vega Launch System. In particular:

- the performance capabilities was well centered on the expectations,
- timeline and transient events were remarkably as predicted,
- Payload injection accuracy was very good,
- the environments at Payload (high frequency and low frequency dynamics, thermal loads…) were generally mild, well below the dimensioning case and fit to market competitors, thus confirming the compatibility of the vehicle for the commercial exploitation

What is more, the flight prediction resulted generally very accurate, and the main performance parameters were centered (in example propulsion Isp), with no need of recalibration or changes in the Vehicle configuration.

Flight Sequence & Key Events

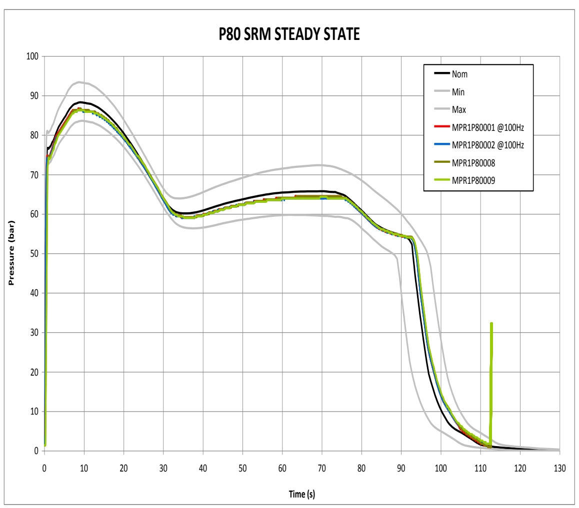
Mission Events	Prediction [s]	Measured [s]	Delta [s]
P80 Ignition	0.0	0.0	0.0
P80 Separation	114.5	112.5	-1.9
Z23 Ignition	115.1	113.5	-1.6
Z23 Separation	201.9	200.3	-1.6
Z9 Ignition	218.5	216.5	-2.0
Fairing Jettison	223.5	221.5	-2.0
Z9 Separation	347.0	349.2	+2.3
First AVUM Boost	From 354 for 180.9 s	From 357 for 185.4 s	+4.5
Second AVUM Boost	From 2,889 for 242.4 s	From 2,888 for 231.9 s	-10.5
LARES Separation	3,299.0	3,293.2	-5.8
Third AVUM Boost	From 4,092 for 138 s	From 4,091 for 134.8 s	- 3.2
CubeSats & ALMASat-1 Separation Sequence	From 4,231.0	From 4,225.3	-5.7

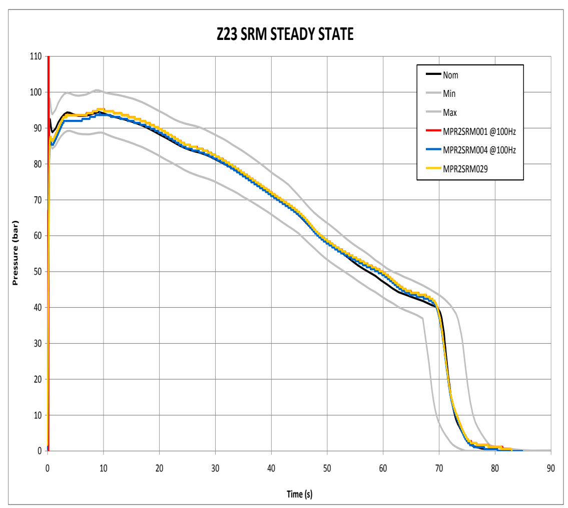
The VV01 actual timeline is fully consistent with the flight forecasts

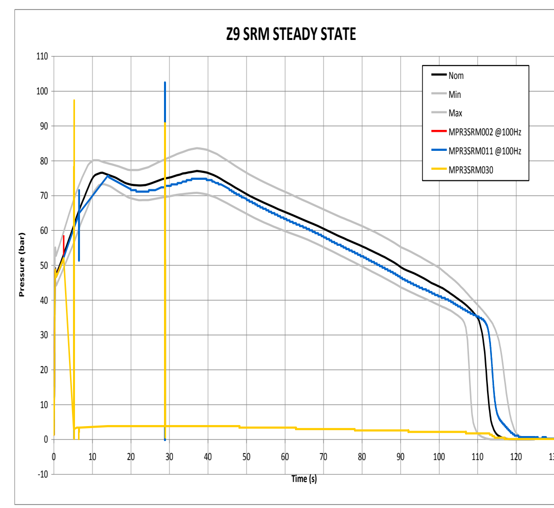
Performance & Propulsion (Mod)

Post-flight analyses of VV01 flight have confirmed Vega performance capabilities

All propulsion systems behaved very closely to the nominal predictions, except for a slight difference on Z9 tail-off:







Trajectory & Injection Accuracy

The trajectory is consistent with the specification taking into account the dispersions of the propulsion systems.

The in-orbit conditions are very good in terms of accuracy

Parameters	Lares Req	Prediction based on as build LV data	Inertial Reference System *	External Means**	VV01 PI Injection Accuracy***	VV01 PL Accuracy Requirement (3σ)
Semi-major axis (km)	7828.137	7828.280	7828.683	7827.638	-1.045	±30
Eccentricity	0.0	0.000186	0.000190	0.000229	0.000039	0.005
Inclination (deg)	69.5	69.4998	69.499	69.441	- 0.058	±0.15

*** The Inertial Reference System is the same one as on Ariane 5**

- * * Figures based on back propagation at PL separation time of TLE NORAD (13-04-2012) data by STK-9 tool

-* Separation system effect is included**

Payload Pointing - LARES-

Payload separation conditions confirm the very good accuracy provided by the Vega system and its flight program algorithms

	Achieved Accuracy	Accuracy Requirements at PL Separation
Transversal Angular Velocity	0.36 deg/s	± 0.6 deg/s
Delta Roll Angular Rate	0.18 deg/s	± 1.0 deg/s

Stage Separations occurred respecting Thrust Levels, Angular Kinematics Conditions and clearance

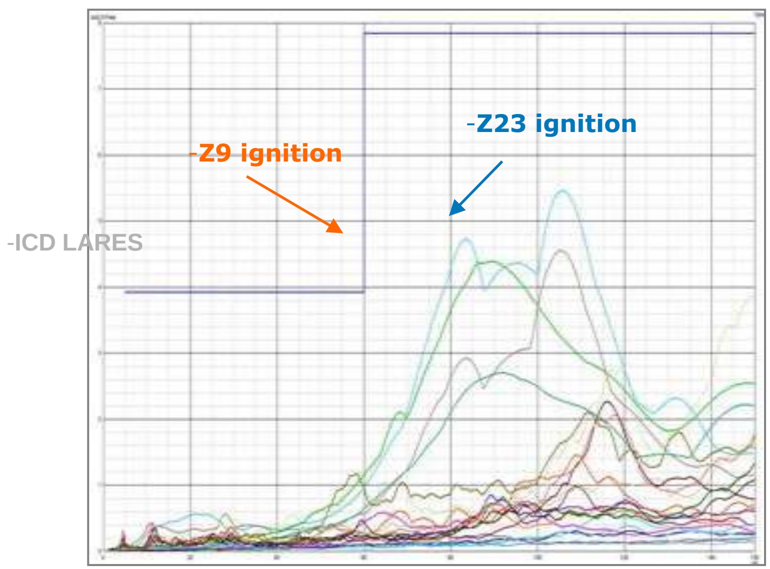
Separations	Thrust level [KN]	Transversal Angular Velocity [Deg/s]	Margins at sep for disengage ment
P80	< 27 (Req. 51)	0.2 (Req. 0.5)	> 95 %
Z23	< 0.8 (Req. 1.5)	0.09 (Req. 0.6)	> 95 %
Z9	< 4 (Req. 5)	0.002 (Req. 1)	> 99 %

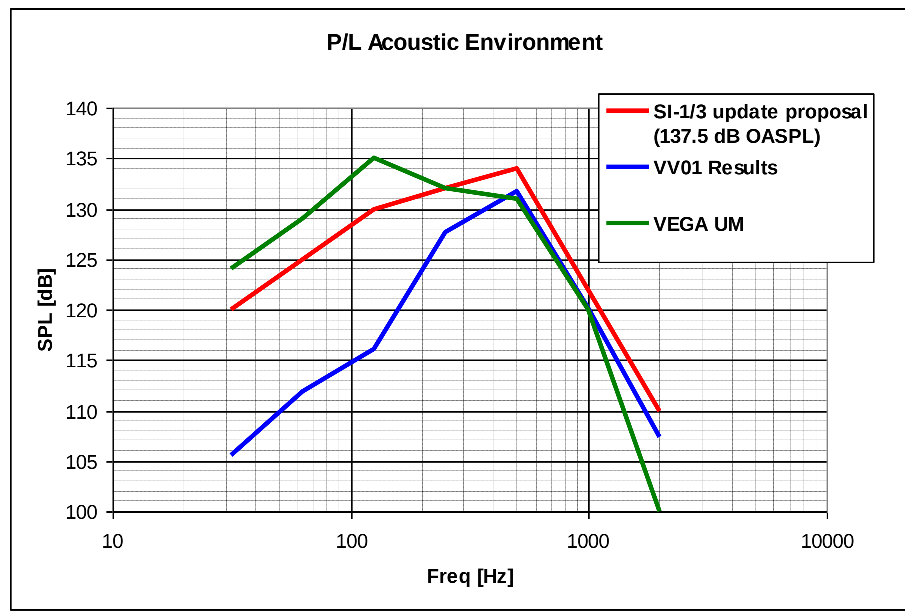
Payload Environment

Much better than the dimensioning case: Acoustic, Shock, Thermal Loads…

Large margins demonstrated, and room to improve Payload Comfort, thus simplifying design and qualification efforts of Payloads (say cost and infrastructure), to enlarge accessibility to space also to small players (i.e Universities, research centers…)

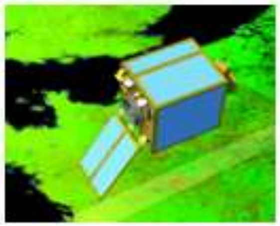
Sine-equivalent levels in lateral direction

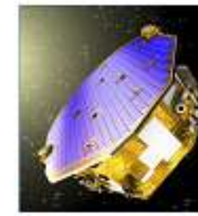




The market perspectives after the Maiden Flight

A part the Manifest already covered by contract, an average of three to four launch per years is envisaged, by ESA and Arianespace.





Global Vegetation Monitoring

Disaster monitoring and biosphere studies

Global wind-profile observation

Weather forecasting improvement

Re-enter technologies demonstration

Future robotic space exploration preparation

GMES Sentinels

GMES Space segment

Global Monitoring for Environment and Security

Testing of gravitational waves detection technologies

Fundamental physics studies

The Next Challenge

ELV, Avio and Vega industrial team visibly demonstrated, after Vega qualification and Maiden Flight, that even in European environment of harsh regulation and fractioned industrial organization, it is possible to approach a low cost access to space, with a high level of quality and service, through technical and business innovation, compliance, and design to cost.

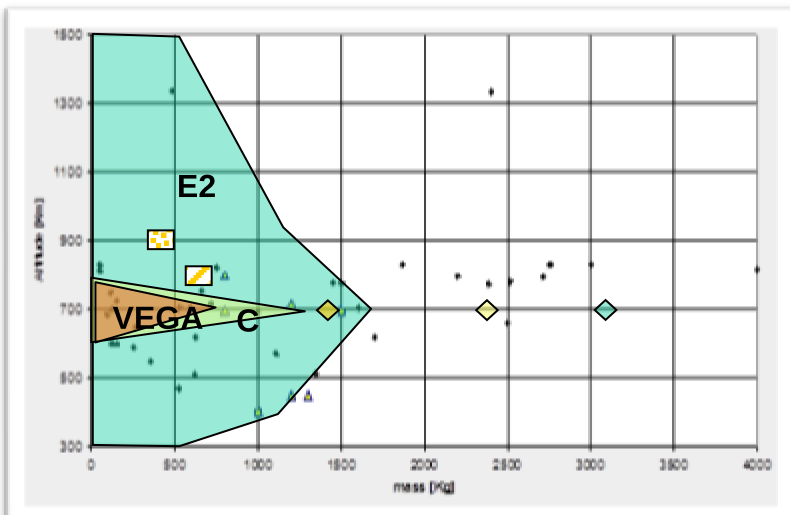
ELV as Vega LV prime, took the challenge in 2003 and achieved the result: what is more, built-up an original system culture, a know-how, an innovative infrastructure and solid industrial partnership both in European and extra European space business environment.

Vega Maiden Flight opens a true world of opportunities that ELV and Avio are committed to exploit:

- Of course the commercial market for LEO PL, but also,
- the consolidation and the evolution of the vehicle to suit the market opportunities.
- the extension of Vega capability to Space Exploration and in orbit servicing, through the development of Vega Electric Propulsion Module, integrated in the Vega Upper Composite

A World of Opportunities:
Vega Evolution

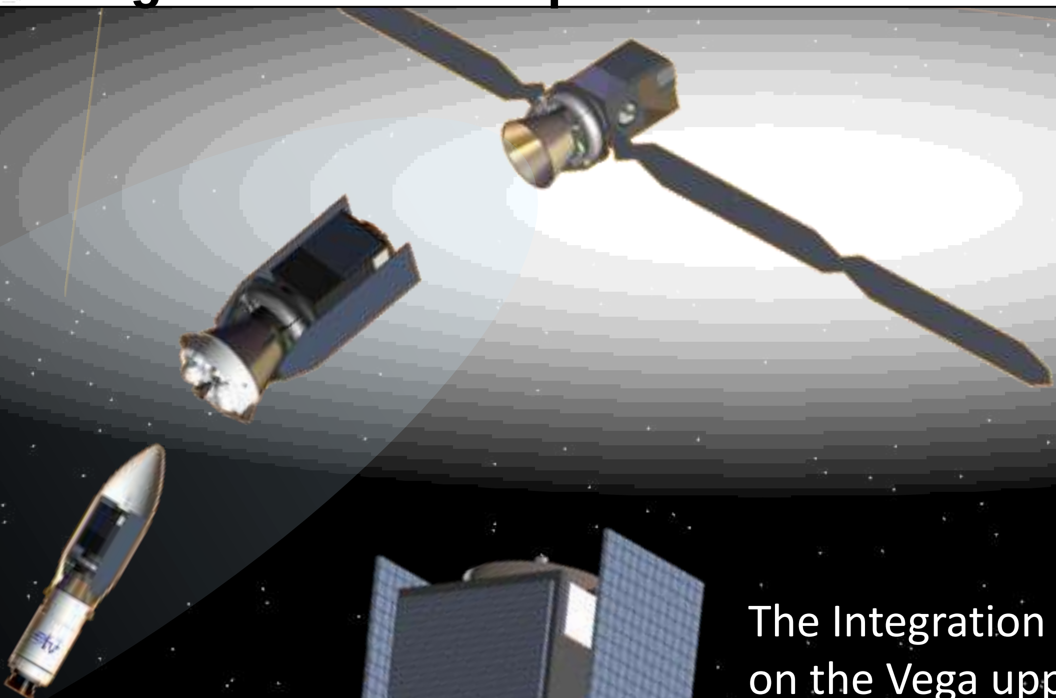
Vega shall improve its position as a LEO player through a phased process of consolidation and evolution. In ELV and Avio vision, this implies the qualification of a Vega C (incorporating cost driven improvements and performance retuned to match competitors) by 2017, and a Vega E which add versatility, i.e. the ability to exploit 65% of the market in dual P/L missions, by the dawn of 2020es.



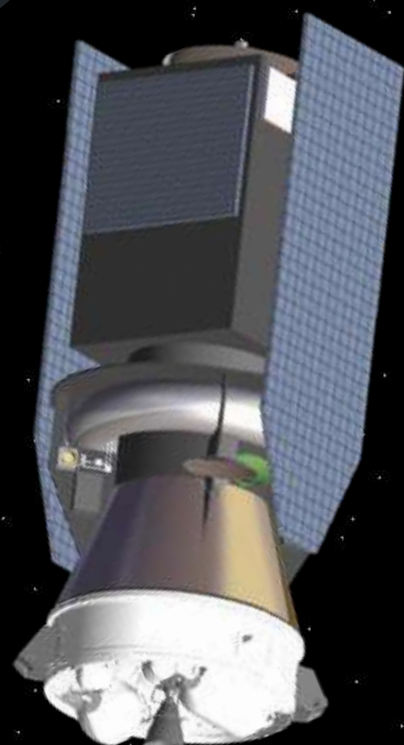
Vega E will allow non LEO mission capability, thus opening opportunities for new scientific exploration.

Vega Vega C Vega E

A World of Opportunities:
Vega Electrical Propulsion Module for Solar System Exploration



	Trip [days]	Payload [Kg]
Venus	1000	710
Mars	1000	620
Deimos	1000	650
Phobos	1000	650
NEO	1050	600
Moon	300	1460

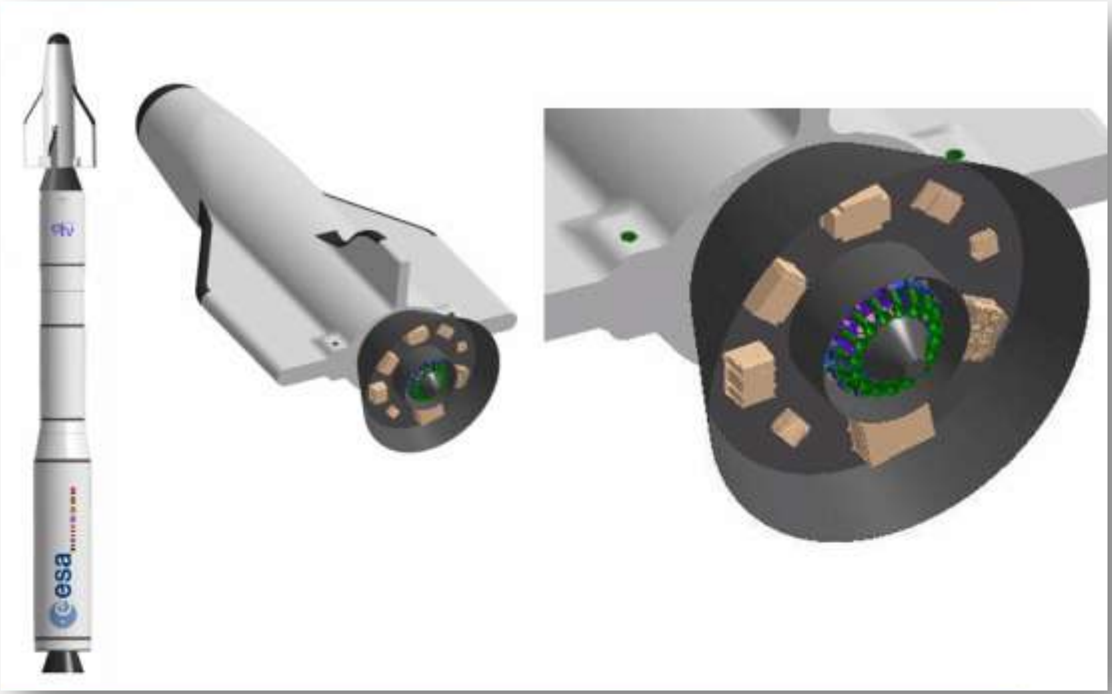


The Integration of an Electric Propulsion Module on the Vega upper stage, will make Solar System exploration missions feasible without huge budget. Scientific Payload will be placed where they need, making scientists free from the burden of engineering spacecraft and controlling the mission during the transfer flight.

GEO orbit may also be exploited for TLC payloads

A World of Opportunities:
In Orbit Servicing

Vega availability opens new perspectives for in orbit servicing applications, from re-entry test-bed (as IXV flying soon and USV-3), to Space Duster applications, ISS service.



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Conclusions

Lares team was visionary to the point of accepting the challenge of a first flight.

Facts demonstrated how they succeed.

Vega is now flight qualified and fully operational: it assures a flexible and low cost access to Low Earth Orbits. Plenty of opportunities for scientific missions, as a main or secondary payload are now available.