Vega Consolidation and Evolution

Work in Progress on Propulsion

Avio

Vega Workshop 2015

ASI April 1st 2015

Paolo Bellomi

P120C SRM: the first *true* common block in European Launcher Families

The reasons and the hassles for commonality:

Solid propulsion is inherently investment intensive, it is sensible to raw material availability and only large production rates are compatible with otherwise overwhelming fixed costs. A synergy within European Launcher Family is mandatory to make the technology affordable both in terms of recurring costs and investments.

From the other side, defining a common workhorse for launchers very different in terms of architecture obliged to a careful blending and tuning of requirements, including standards and general norms flowing down from Vega and Ariane 6: finding out a point of equilibrium was a complex (*sometimes distressing*) task that required an intense co-engineering phase at industrial level, involving for 6 months, teamwork from Avio, ASL, ELV and SABCA.

P120C SRM: the first *true* common block in European Launcher Families

The extent of commonality:

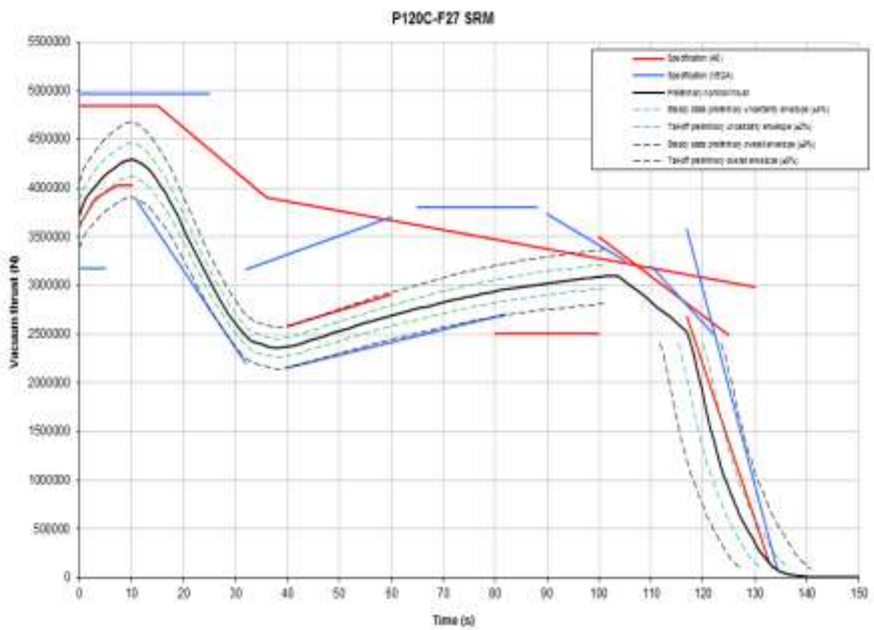
In recent years, commonality was more an ideal target than a practical achievement. PCV and P145 were sharing at most architecture, materials and technologies but not a single part. From the other side, the CSPM (the solid propellant stage proposed for A6 PPH and Vega) was judged too extreme in terms of commonality, mainly because avionics and pyrotechnics of the two launcher families resulted quite different.

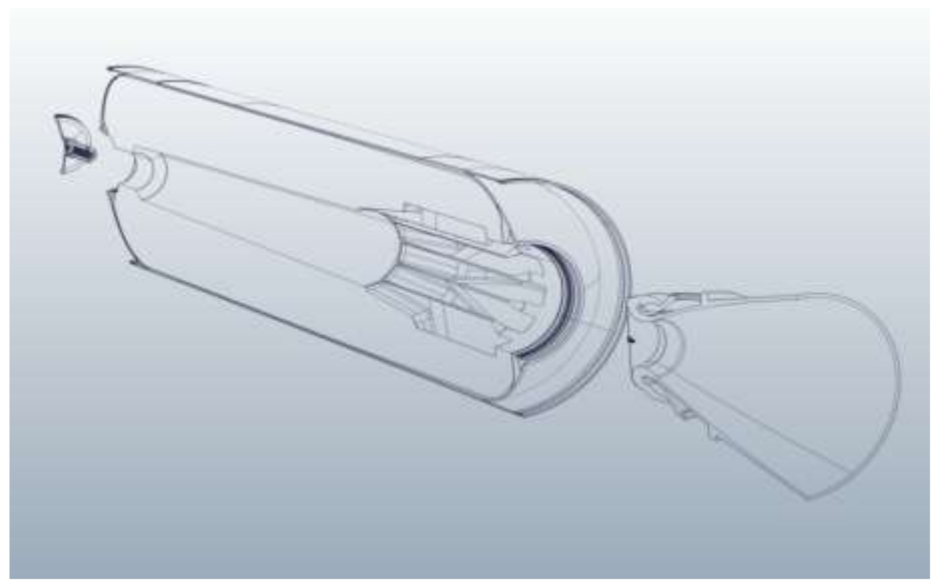
However, Cost & Value trade-off, performed at system and motor level during the co-engineering phase ended-out with a fairly large level of commonality: apart of the SRM, *external thermal protections, raceways mounts and Thrust Vector Control* will be eventually common, with obvious advantages in terms of development, industrialization and operations.

P120C SRM: the first *true* common block in European Launcher Families

The trade-off:

Defining a common requirement baseline, that at the same time would allow a sound motor technical and program feasibility was achieved in the co-engineering phase by a systematic trade-off approach. Recently a TRS was agreed among Launcher Systems primes and Avio, ASL as motor Design Authority. This allows a quick progressing phase B.





Avio

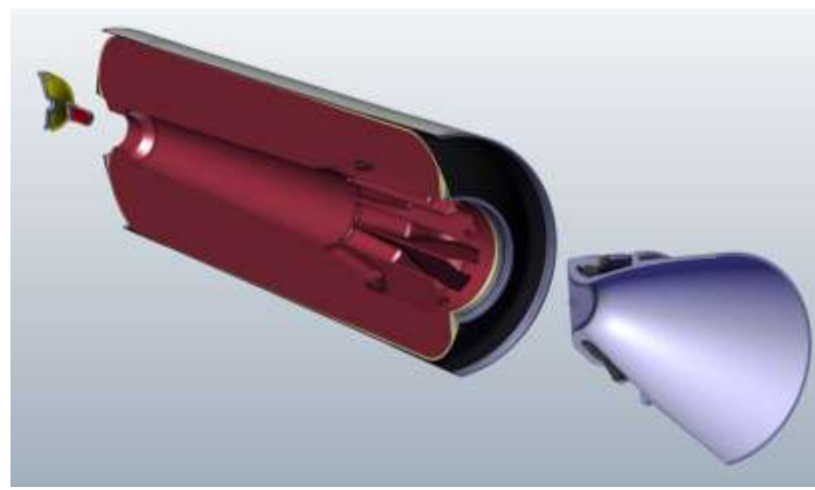
P120C SRM The first *true* common block in European Launcher Families

The SRM configuration at the onset of Phase B:

Establishment of Requirement Baseline was supported by a feasibility analysis with more than 30 variants studied, with diameters ranging from 3.2 to 3.5m and loadings from 125 to 136 tons of propellants. F27 configuration (based on HTPB-2013 propellant) is compliant to both Ariane 6 and Vega requirements. It is the current baseline for interface definition and LLI procurement. It will possibly evolve up to PDR to consolidate and optimize design.

PRELIMINARY SIZING CHARACTERISTICS	Unit	P120C F27
Propellant mass (LMC + igniter)	kg	135860
Total inert mass	kg	11100
Maximum expected operative pressure (MEOP)	bar	105
External diameter	m	3,4
Boss to boss length		11,7
Fwd polar boss interface diameter		1,0
Aft polar boss interface di	m	1,6
Nozzle throat initial dia	m	0,570
Nozzle exit diameter	m	2,175
Nozzle exit area	m²	3,715
Initial nozzle expansion ratio	-	14,56
Combustion time (F=150 kN)	s	132,9
Vacuum thrust total impulse (F=150 kN)	MN*s	368,9
Vacuum Isp at F=150 kN	s	277,5

Structural Index = 8,17%



Avio

P120C SRM: the challenges for a development

The absolute Design Driver is Target Cost.

New materials, technologies and automated process for better dependability and lower MAIT cost. Among the others:

Low SRM Recurring Cost

- New High Perfo Prepreg
- Braggs Fibre for health monitoring and acceptance
- Full automated winding and lay-up of composite

- Integrated External Thermal Protection and raceways mounts

- Low Nozzle Inertia, to allow TVC based on EMA
- Low Part count Nozzle design.
- New low cost Nozzle Ablators

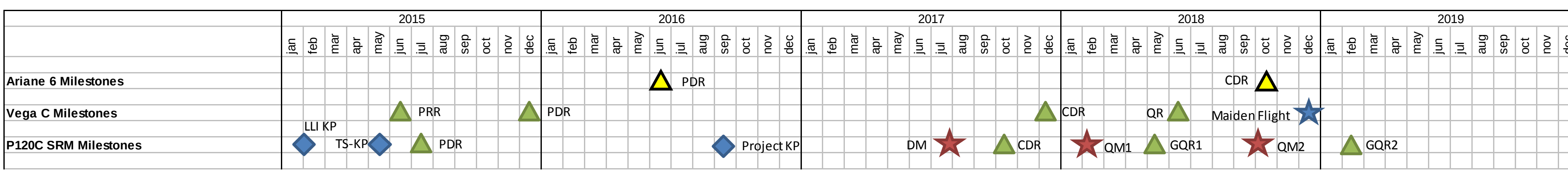
- Low raw material cost propellant.
- Propellant formulation optimized vs process
- Large grain structural margins.

Avio

P120C SRM: the challenges for a development

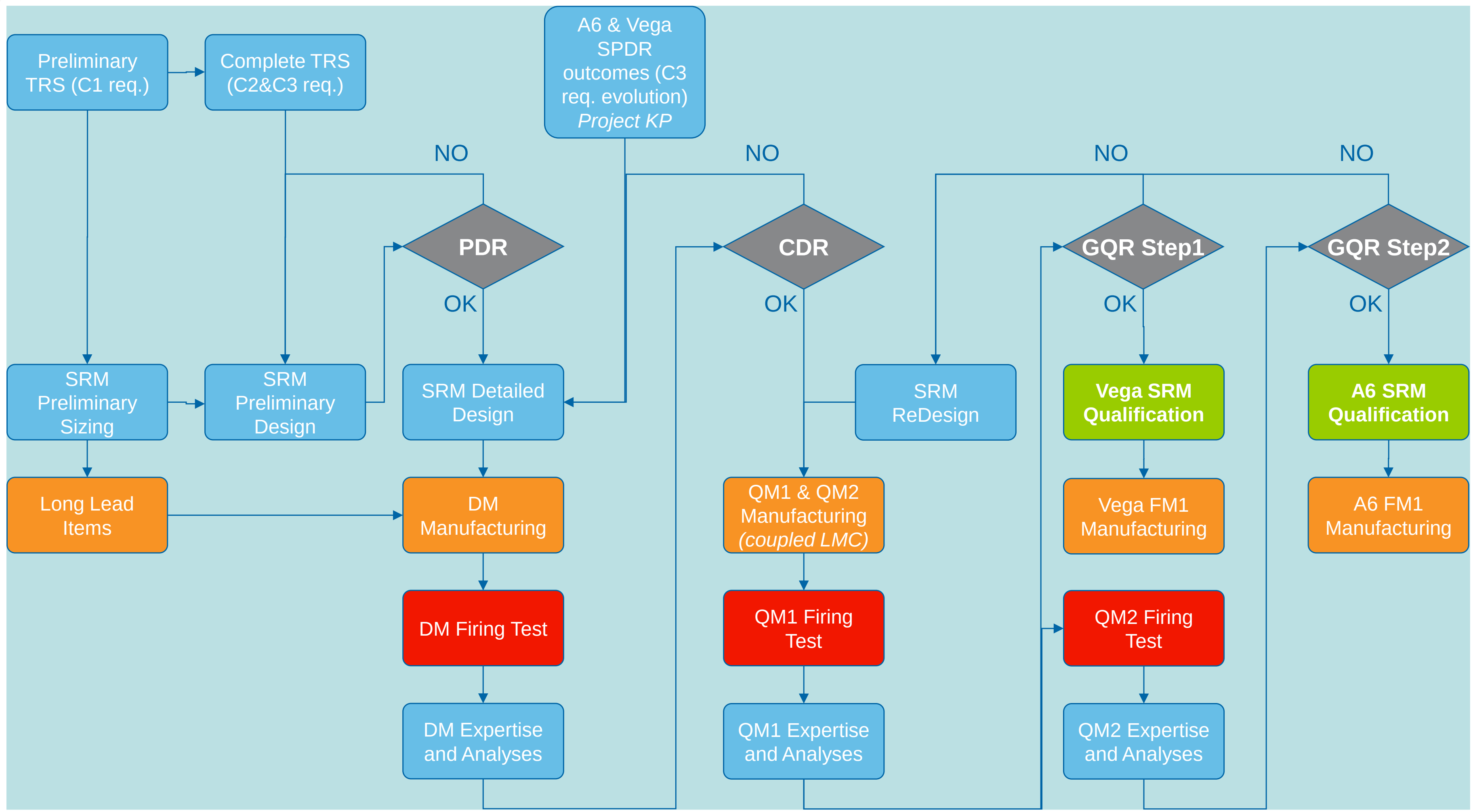
The logic adopted in setting the P120C Development and Qualification Logic is inherited by the experience earned during VEGA and VEGA Evolution SRM's D&Q phases. This reduces risks and uncertainties linked to architectural and detailed design phase; at the same time it allows many requirements to be verified by similarity approach. As first consequence, the firing test campaign is constituted, at motor level, by only one firing test (**DM**) during development phase C;

- the qualification and flight for Vega, through a single development firing test and a single qualification test (**QM1**)
- the qualification and flight for Ariane 6 through a second qualification firing test (**QM2**), for which the same propellant raw materials lots and tuning will be adopted in order to achieve a first experimental verification of performance reproducibility (thrust imbalance issue)



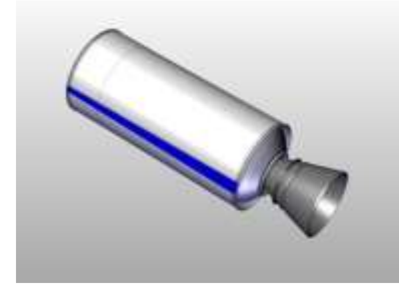
Avio

P120C SRM: the challenges for a development



Avio

Z40 SRM – A Multipurpose second stage Motor

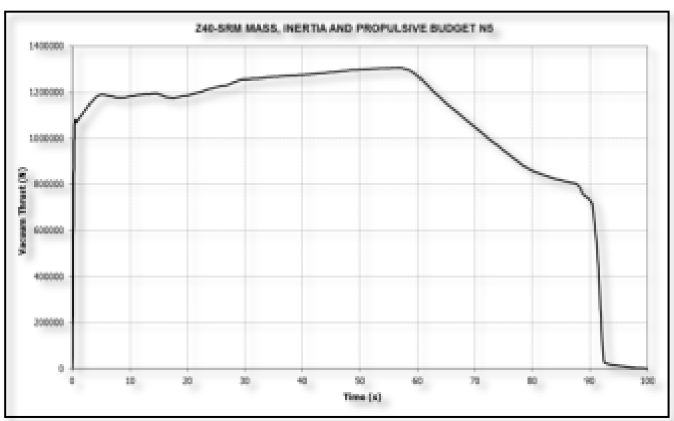


Z40 the choice:

Z40 has been conceived to get rid of limitations intrinsic to Z23, that jeopardizes the evolution of Vega, by bounding it in terms of performance and structural fluxes.

Although its first use is foreseen on Vega C3, it perfectly supports further evolutions, in example Vega E, Vega EH etc…

Development of Z40 has been started on Avio own funding since 2011. The program was aimed to mature the readiness level for a certain number of promising architectures and technologies, developing at the same time a flight standard motor. A PDR has been performed on September 2012 on a baseline requirement originated by ELV studies on Vega E1.



Avio

Z40 SRM – A Multipurpose second stage Motor

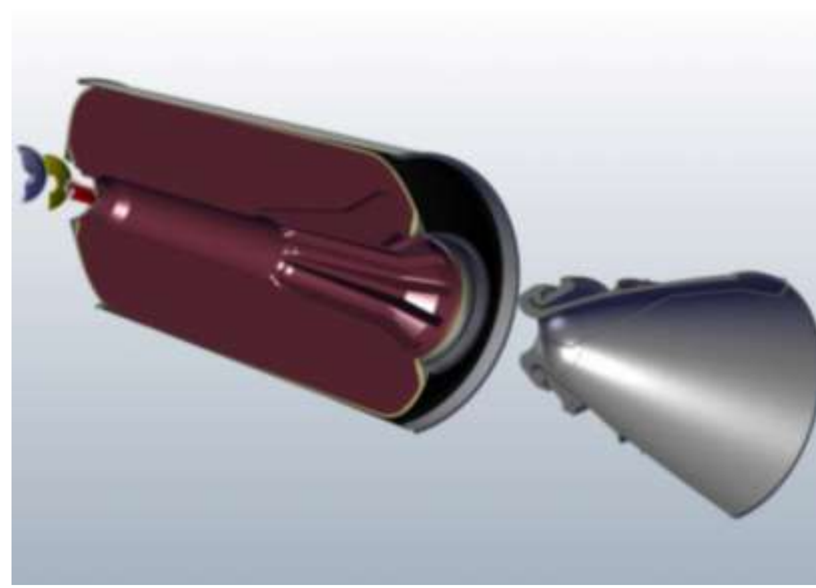
Z40 from the technology demonstration to the flight standard motor

Z40 configuration baseline DD1 as from 2012 PDR will evolve to DD1.1 for application to Vega C3, following the selection of technologies mature for motor qualification at the beginning of 2018. With regard to its predecessor Z23 the motor has an higher average pressure, total impulse 50% higher, sporting larger structural margins on the case and on propellant grain, low torque flexible joint.

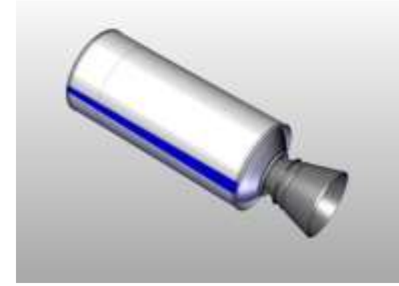
The development and industrial challenge is to fit the target cost of the Z23.

PRELIMINARY SIZING CHARACTERISTICS	Unit	Z40 N5
Propellant mass (LMC + igniter)	kg	**36239**
Total inert mass	kg	3028
Maximum expected operative pressure (MEOP)	bar	115
External diameter	m	**2,4**
Boss to boss length	m	6.1
Fwd polar boss interface diameter	m	0.60
Aft polar boss interface di	m	1,06
Nozzle throat initial d	m	0.28
Nozzle exit diameter	m	1,72
Nozzle exit area	m²	2,32
Initial nozzle expansion ratio	-	37
Combustion time T38 (Pi =1.5 bar)	S	92,9
Vacuum thrust total impulse T38 (Pi =1.5 bar)	MN*s	103,6
Vacuum Isp at T38 (Pi =1.5 bar)	s	293,5

Structural Index = 8,36%



Z40 SRM – A Multipurpose second stage Motor



Z40 from the technology demonstration to the flight standard motor

Z40 as a pathfinder for technology demonstration has allowed to develop and validate several processes. Few of them, mostly aimed to target cost have been retained as baseline for motor development (DD1.1).

New High Tensile Strength Prepreg

Braggs Fibre for health monitoring and acceptance

Full automated windin lay-up of composite

Integrated External Thermal

Protection and raceways mounts

Low SRM Recurring Cost

Low Torque Self protec Nozzle Flexible Joint.

Low Part count Nozzle design.

New bias tape process for ablators.

Low raw material cost bimodal propellant.

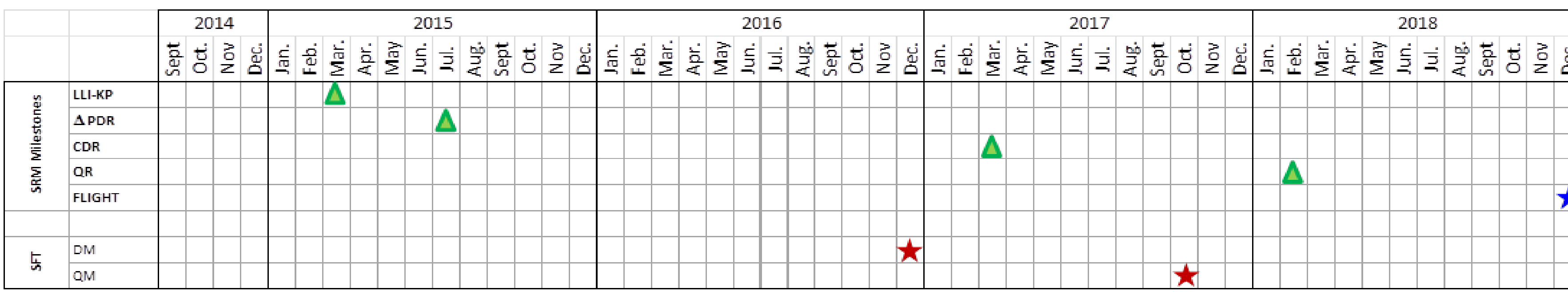
Propellant formulation optimized vs process and nozzle erosion.

Large Grain structural

Z40 SRM – A Multipurpose second stage Motor

The development cycle:

Quite similar to Z23, has been based for the first phase on the demonstration of technology and materials through the use of pathfinders and breadboards. In particular, the IMC new design has been demonstrated on a Z9 scale case for prepreg validation, three F1100 cases for high strength skirt, a full scale inert casting motor, a large number of flexible joint specimen and of CPh resin infusion as well as braiding samples and subscale specimen for nozzle. Automated Tape Lay-up has been validated on two full scale specimen, ending up to DM00 model currently under test.



Vega Upper Stage Engine

Vega Evolution get increased versatility by a large ΔV on upper stage.

CM 2014 proposes a trade-off work to identify the best choice for propulsion for Vega E Upper Stage (**VUS**). Trade-off whose participant are ELV, Arianespace, Avio, and ASL is expected to reach a selection point on September 2015.

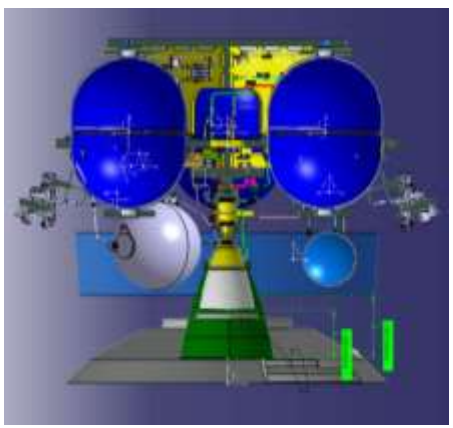
IV stage
a small storable propellant engine (2-7 KN) (i.e. Berta)

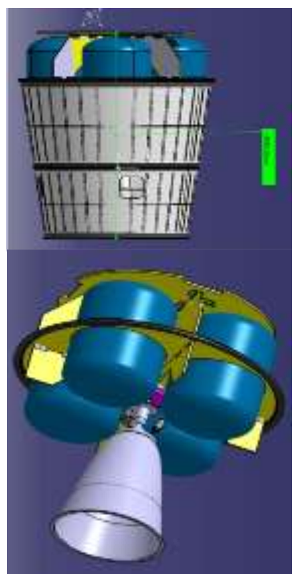
a storable propellant engine derived from Aestus (30KN)

a LOx-LNG engine derived from Mira (75-120 KN)

a LOx-LH2 engine (60 KN)

III stage



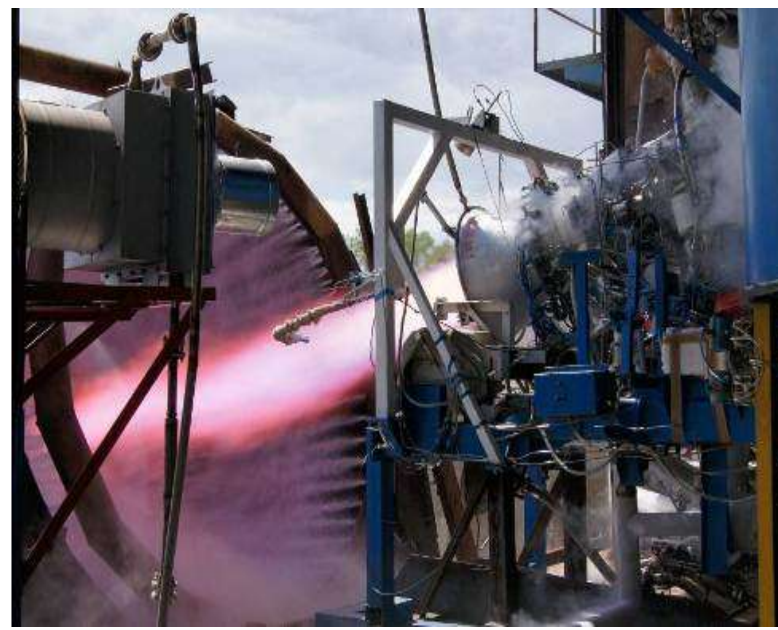


Vega Upper Stage Engine

MIRA engine: a serious option for Vega E upper stage

Mid 2014 Avio completed the successful demonstration of LOx-LNG technology through MIRA D engine within Lyra program, in partnership with the Russian firm KbKA.

A part of the fully satisfactory results from several test campaigns, the TRL achievement highlighted the robustness of the engine architecture and the advantages of the propellant pairs.



Avio

Vega Upper Stage Engine

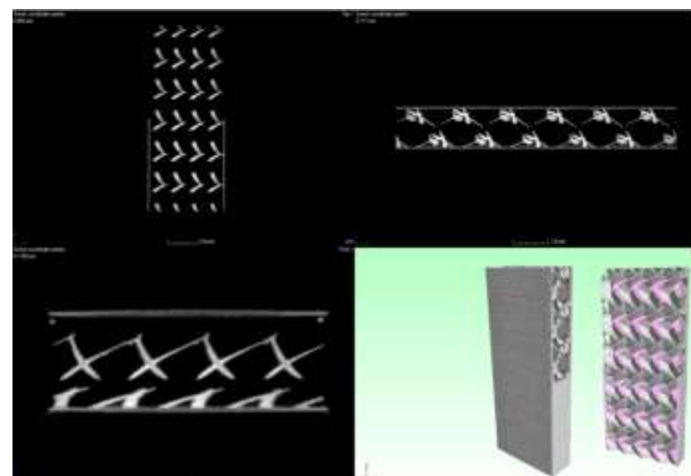
MIRA engine: a serious option for Vega E upper stage

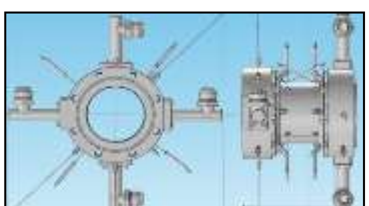
In recent times a large consensus on LOx-LNG propulsion is diffused in Space Transportation business: SpaceX Raptor, Samara, ASL for both expendable and reusable systems.

Since 15 years Avio, also in partnership with CIRA, has been pioneering the technology: taking profit on a use case (i.e. VUS), on new design and manufacturing technologies (i.e. ALM) and newly available materials developed an industrial mastership at engine system level as well as at component i.e.:

- Turbomachinery both for LOx and for LNG
- Injection Plate
- Combustion Chamber

Few patents applied for by Avio will eventually result in a breakthrough on propulsion recurring cost





Vega Upper Stage Engine

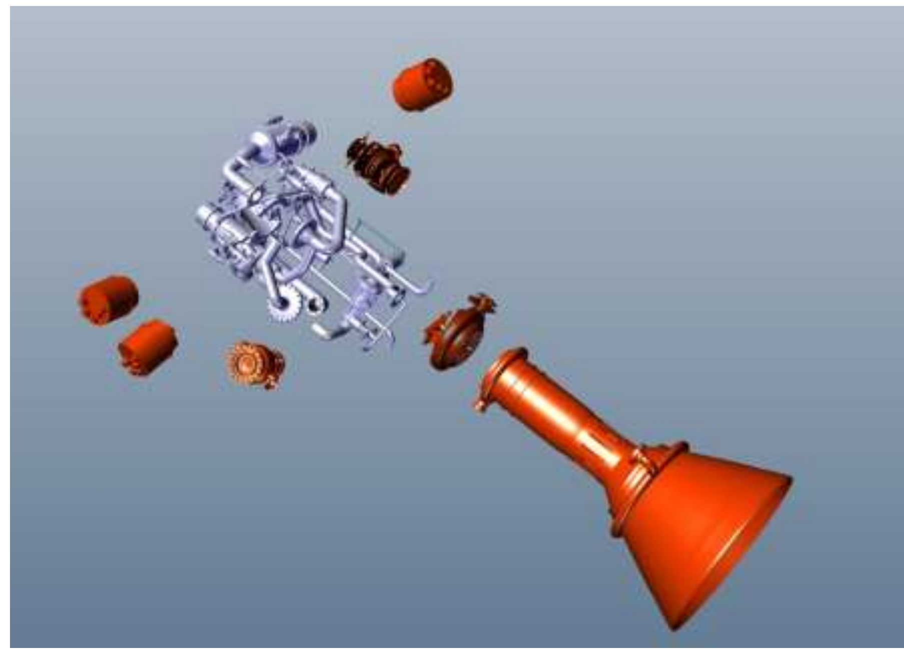
MIRA engine: a serious option for Vega E upper stage

Avio is currently working to find the optimal requirement baseline (in the range between 75 and 120KN) and an European industrial share for a LOx-LNG upper stage flight engine.

MIRA-F present baseline

Vacuum Thrust	98 KN
Vacuum Specific Impulse	364 s
Engine Mixture Ratio	3.4
Propellant inlet pressure	3 bar
LCH4 tank temperature	110 K
LOX tank temperature	90 K
Engine Mass	280 Kg
Engine Exit diameter	1.3 m
Engine Length retracted	<1.9m

Development and qualification plan aim to the engine qualification (prior the stage one) by 2023.



Following the success story of P80FW development, MIRA-F development can carry also objectives for reusability demonstration, to be applied on future generations of SRLV.

Avio