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VULCAIN®2.1, the European reference for Ariane 6 Lower stage cryogenic propulsive system

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Abstract

The intent of this publication is to provide an overview of the development progress of the Vulcain®2.1 propulsive system and its adaptation to Ariane 6 launcher.

The Vulcain®2.1 engine is a cryogenic gas generator cycle engine with two independent turbopumps. This engine is an evolution of the flight proven Vulcain®2 engine used on Ariane 5E, with the same performances but introducing cost effective new technologies aiming at a global recurring cost reduction including launcher and ground operations. In particular, this includes the implementation of a new nozzle extension using sandwich technology, the removal of some expendable pyrotechnic devices, the introduction of Additive Layer Manufacturing (ALM)

At the end of 2014, ESA Ministerial Council gave priority to the Ariane 6 program as Europe future launcher. In the framework of this decision, Vulcain®2.1 engine was confirmed as the engine to equip Ariane 6 cryogenic lower stage. Year 2015 has been dedicated to engine and propulsive system trade-offs to comply with Ariane 6 launcher different configurations, with as main objectives recurring cost reduction, performance, reliability and simplification of operations
Years 2016 & 2017 have been focused on the detailed design phase concluded by the delivery of the first development engine for test. Engine Vulcain®2.1 tests have started since beginning 2018. Years 2018 was focused on engine test execution as well as first semester 2019

Vulcain®2.1 will provide thrust to the lower cryogenic stage of the future Ariane 6 European Launcher for both configurations, the heaviest one dedicated to single / double payloads for classical GTO/GTO+ orbits Ariane64 (i.e. lift from the ground by 4 Solid Rocket Motors), and the lightest one dedicated to a large panel of single institutional payload missions Ariane62 (lift-off by 2 Solid Rocket Motors) which could use all the capacities of the engine.

This publication shows how the Vulcain®2.1 engine development is progressing toward qualification while incorporating the requirements of the new Ariane 6 configuration.

Keywords: Ariane 6, Vulcain®2.1, development, cryogenic propulsion

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Acronyms/Abbreviations

Acronyms/Abbreviations	Definition
AFD	Anti- flood device valve
ALM	Additive layer manufacturing
ARTA	Acompagnement Recherche et Technologie Ariane
ATV	Advance Transfert Vehicle
BEVE	Electrovalves box
CNES	Centre National d'Etudes Spatiales
DLR	The German Aerospace Center (DLR) Lampoldshausen
ECA-UPA	Ariane 5E performance adaptation program
ELA 4	Ariane6 Launch pad
EPC	A5 lower liquid propulsive system
ESA	European space agency
EV	Electrovalve
FCE	Fluid Control Equipments
FPS	Functional propulsive system
LBS	A5 ground board connection
LLPM	A6 Lower liquid propulsive module
LLPS	A6 Lower liquid propulsive system
LL-Vax	LLPM Main feeding Valves
MANG	A6 Ground / board connection (module d'avitaillement….)
MG x	Maturity Gate
MQD	Dynamic qualification model
MV	Vibration model
PAKC	Fuse part of the MANG
PCP	A5 pneumatic connection
PGD	Pressure gas regulator
PHH	Ariane6 with powder first stage and two liquid modules
PPDL	Production Pull development logic
PPH	Hydrogen pressurization Plate
PPO	Oxygen pressurization Plate
QM	Qualification model
RCS	Roll control system
SCP	POGO corrector system
SSHEL	A5 Helium liquid system
SWAN	Sandwich Nozzle extension
VAO/H	Feeding valves
VGO/ VGH	Engine gas generator valves
VMF/O	Chill down valves
TPS-lean	Turbopump starter lean

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1 INTRODUCTION

In December 2014, an ESA Ministerial Council gave priority to the Ariane 6 program as Europe future launcher. As one of the main constraints, Ariane 6 is to be designed exploiting as much as possible qualified components and technologies developed in the frame of previous launcher development programs or other frames, such as Research and Technology programs funded by ESA or national agencies.

ESA is the Development Contracting Authority for the Ariane 6 Launcher System and Ariane 6 Launch Base.

The Ariane 6 Launcher concept is PHH type and is based on a cryogenic main stage (LOX/LH2) powered by an evolution of the Vulcain®2 Engine.

The Lower Liquid Propulsion Module (LLPM) propulsive system uses one Vulcain®2.1 engine with the same performances as the current Vulcain®2. Vulcain®2.1 benefits from the results of cost reduction actions developed through previous full scale demonstration programmes or feasibility studies carried-out in 2012 aiming at a global recurring cost reduction including launcher and ground operations.

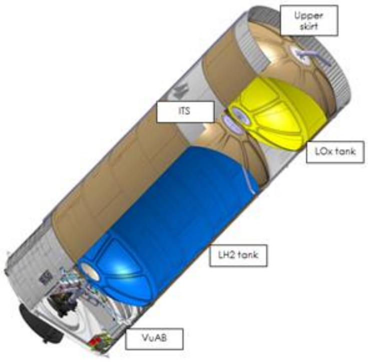

Figure 1: Lower Liquid Propulsion Module

The main functions of the Lower Liquid Propulsive System (also called "LLPS or Vulcain®2.1 Propulsive System") are:

- To produce a propulsive force, vectorable in both pitch and yaw, from liquid hydrogen and oxygen stored in the LLPM tanks,
- To pressurize the hydrogen tank with hydrogen gas flow supply by the engine ,
- To pressurize the oxygen tank with helium gas flow supply by liquid helium vessels ,
- To provide hydrogen gas flow for the Roll Control System activations.

In this System, the main functions of the Vulcain®2.1 Engine are:

- To produce a propulsive force,
- To provide hydrogen gas flow for the liquid hydrogen tank pressurization and for the Roll Control System activations.
- To heat the liquid helium coming from the liquid helium vessels for Lox tank pressurization

The Vulcain®2.1 propulsive system includes all the products and systems required to operate the engine, such as the feeding system, the tank pressurization system, the command system, and the tank loading / outgassing system.

Main products associated to the LLPS are:

- The Vulcain®2.1 engine,
- The FCE (Fluid Control Equipments): Feed-valves (VAO/H), Pressurization plates (PPO/H), Platine Gonflage-Détente (PGD), Electro-Valves box (BEVE), POGO corrector system (SCP), Roll Control System (RCS),
- The 8 MANGs (ground board connection on LLPM)

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Vulcain®2.1 engine is derived from Vulcain®2 engine and inherits from the past developments and the current qualification status, the main drivers for Vulcain®2.1 development being the targeted recurring cost, the time to market and its demonstrated reliability.

To reach the Recurring Cost and Time-to-Market targets, the development has implemented the so-called Production Pull Development Logic (PPDL) approach, taking into account the specificities of the Lower Liquid Propulsive System and with the objective to reach the capability to produce, the quality of the product and the need to prepare a robust industrialization phase. This PPDL is applied at Ariane Group, architect of the Launcher System, but also at the level of its Industrial Partners, for many of them Design Definition Authority of their products.

The design and testing of the Vulcain®2.1 propulsive system are conducted by Ariane Group and involve numerous companies and organizations across Europe as shown in Figures 2 and 3.

Figure 2: Ariane Group company

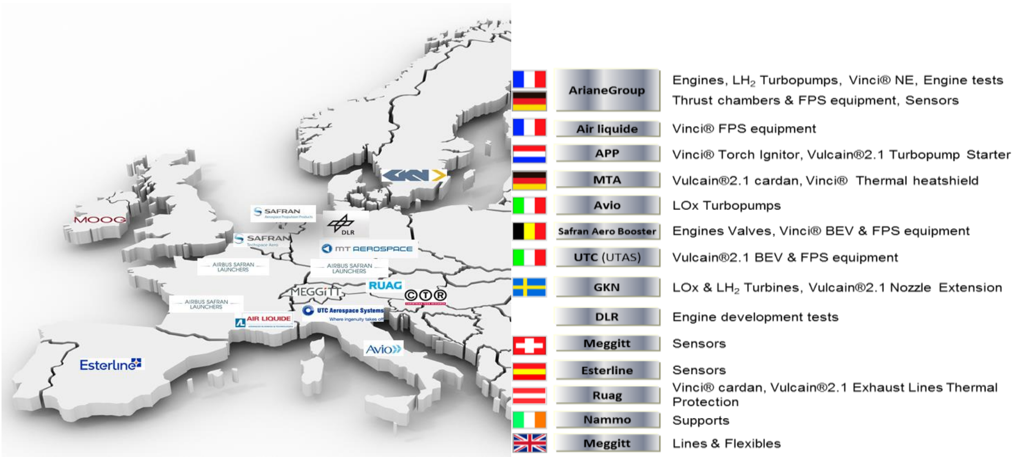

Figure 3: Liquid Propulsion Systems industrial organization

This paper focuses on Vulcain®2.1 propulsive system, especially regarding the Ariane 6 architecture evolution compared to the current Ariane 5 configuration, and how its development is progressing toward qualification.

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2 ENGINE ARCHITECTURE AND SPECIFICATION

2.1 SPECIFICATION

The main hypothesis is that the LLPM propulsive system uses one Vulcain®2.1 engine considered as a “building block”, with the same performances as the current Vulcain®2 engine. That means that Vulcain®2.1 operating envelopes shall remain within the current specified domains and environment.

Performances	Vulcain®2.1
Pump inlet mixture ratio	6.030
Pump inlet total mass flow	326 kg/s
Gas Generator mixture ratio	0.900
Vacuum thrust	137 t
Specific impulse	431 s
Mass	2150 kg

LLPM Flight duration < 500 seconds
LLPM propellant loading: 154 tons

2.2 ARCHITECTURE

2.2.1 LLPM Propulsive system

The modifications on the main stage impact all the different LLPM subsystems. The major modifications of the LLPM propulsive system compared to the Ariane 5 lower liquid propulsive system are:

- Ground-board interfaces:

Development of new ground-board interfaces, in commonality with the Ariane 6 upper stage: MANG (Module d’Avitaillement Nouvelle Génération)

The MANGs replace the EPC LBS (Liaison Bord-sol), the PCP (Prise Culot Pneumatique) and the isolation valves. It is an interface device in between the launcher and the ground facility in KOUROU. It can be divided in two parts (see Figure 4, where the On-board and ground parts are respectively in the left and right sides):

- An on-board subassembly, also called the on-board or vehicle part;
- A ground subassembly, also called the ground or jettisonable part, which separates from the launcher after lift-off.

The on-board subassembly is bolted to the launcher. The ground part is fixed to the umbilical. Before lift-off, the on-board and ground parts are connected together by two fuse parts named PAKC (see Figure 4). During the sequence lift-off, pyro-actuator creates the adjusted force to pull the arms, inducing a torque to break the PAKC.

A MANG is composed of:
One main orifice of large diameter for propellant with a poppet which is mechanically closed at the disconnection and which can be actuated for closing when connected. The disconnection can occur just at lift-off, in positive time.
Additional gas functions up to 400 bar without poppet.

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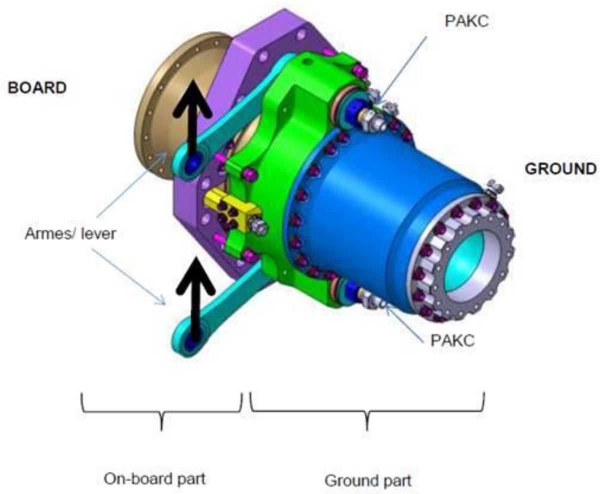

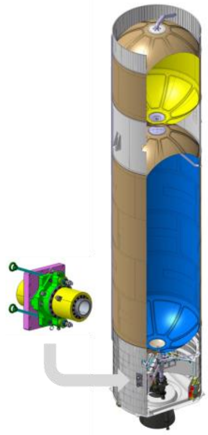

Figure 4: Ground board connection

MANG concept enables an optimization of Launcher and Ground architectures, with Recurring Cost reduction and simplification of operations for flight. This has led to look for optimization including all aspects: Launcher, Ground pad (ELA4), safety, lines.

The LLPM needs 8 MANGs in reference, distributed in 4 high diameters dedicated to the tanks for filling and pressurization purposes and 2 small diameters for the engine purging. The last two small diameters MANGs (with poppet) are considered for the chill-down, which allow the removal of the chill-down valves present on Ariane 5 (VMFO/H).

- Functional Propulsive Equipment:
  - Simplification of the Lox tank feeding line leading to significant tank pressure modifications and simplification of tank filling procedures.
  - Feed Valves (VAO/H) improved from Ariane 5 and commanded by the ground.
  - New Hydrogen and Oxygen Pressurization Plates (PRCPH and PPO), and simplified LLPM Roll Control System (RCS) integrated in the Hydrogen pressurization plate.
  - Command system simplifications: the new architecture permits to decrease by about 30% the number of Electro-valves.

2.2.2 Vulcain®2.1 Engine

Vulcain®2.1 engine is derived from Vulcain®2 engine and inherits from the past developments and the current qualification status. In particular, the Vulcain®2.1 development benefits:

- From the Vulcain®2 development campaigns (M201 to M209), and ARTA campaigns,
- From consolidation / exploitation programs (including ATV, Galileo and ECA-UPA programs),
- From 78 consecutive nominal ignitions of the Vulcain® 2 engine with successful flights on Ariane 5ECA and ATV after flight VA247 (103rd launch of an Ariane 5).

The main drivers for choosing Vulcain®2 as the basis for complementary developments to build a new Vulcain®2.1 are the targeted recurring cost, the time to market and the reliability.

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For the Vulcain®2.1 Engine, the following main set of changes is considered as the reference in comparison with Vulcain®2:

- Reduction of the recurring cost of the current Vulcain®2 nozzle with a new nozzle design (SWAN):
    - Using the sandwich technology developed by GKN and tested on ARTA campaign at Vulcain®2 scale to reach TRL 6 (test readiness level). The sandwich technology replaces the tube wall technology.
    - Suppressing the re-injection Torus at mid height and using long exhaust lines similar to Vulcain 1.

SWAN tested on Vulcain®2 ARTA campaign

Swan implemented on M1 engine

Figure 5: Vulcain®2.1 Nozzle extension

- A new Engine Thermal Protection to protect the nozzle and exhaust lines from thermal environment at the launcher rear part. A tile concept has been chosen for the Nozzle extension (reinforced Inconel tiles covered by Prosial foam), and a soft thermal protection for the exhaust lines (multi-layer sheet, Nextel / Fibermax / Nextel).

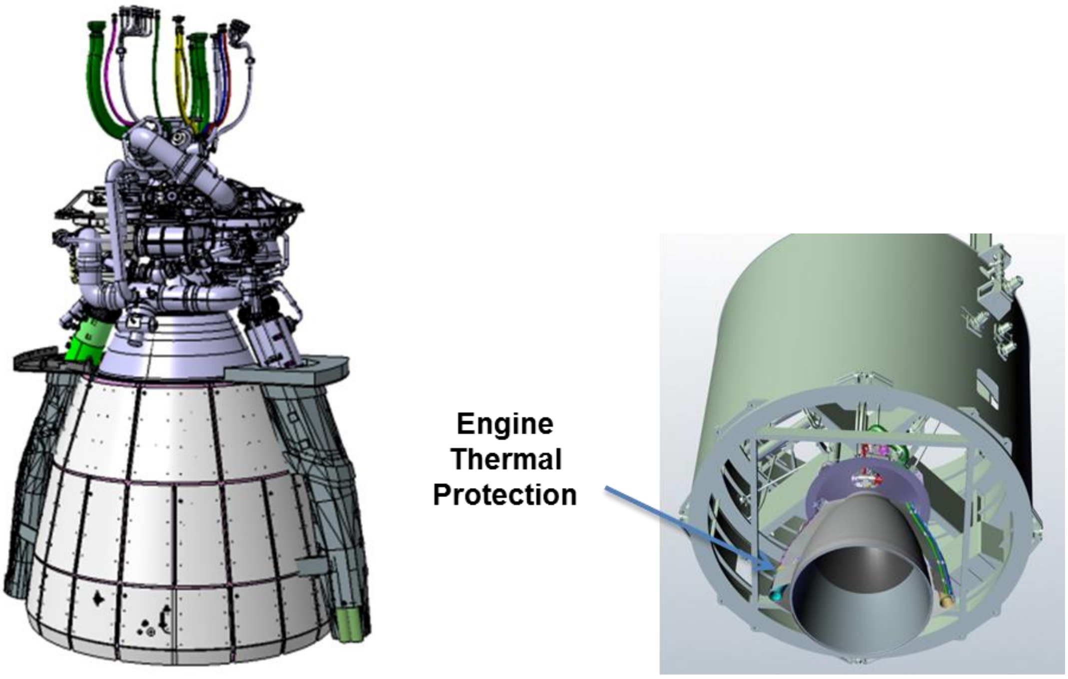

Figure 6: Vulcain®2.1 thermal protection

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- Vulcain®2 pyrotechnics partial removal, in particular with a ground ignition of the Thrust Chamber, and with the help of a reduced-cost Turbine Pyro Starter. Previous studies and tests have demonstrated the feasibility of such modifications.

- Thrust Chamber local design modifications (acoustic cavity removal, LOx dome pre-distributor removal, new LH2 mixer…) and process simplification (standardization and robustness improvement to intermediate galvanic pulse-plated nickel deposition…)

Figure 7: Vulcain®2.1 Thrust Chamber

- Gas Generator manufactured through a new technology, the Additive Layer Manufacturing (ALM) process developed within ArianeGroup with the support of CNES in the frame of research and technology studies.

  The Gas generator is composed of 3 main parts:
  - Injection head (ALM - Inconel 718)
  - Body (ALM - Inconel 718)
  - Acoustic cavity / thermal jacket (ALM - Hastelloy X)

  In particular, the use of 3-D printing significantly reduces the number of parts needed to manufacture and integrate the injection head (from hundreds to just five). Less manufacturing & integration processes mean lower costs.

ALM Gas Generator (head + body)

Figure 8: Vulcain®2.1 ALM Gas generator

- Hot Gas Valve: suppression of in-flight switch of engine operating point (a single operating point during the whole flight) in order to simplify the engine hot gas valve with the introduction of an off-the-shelf electrical actuator to set-up the engine during its acceptance test.

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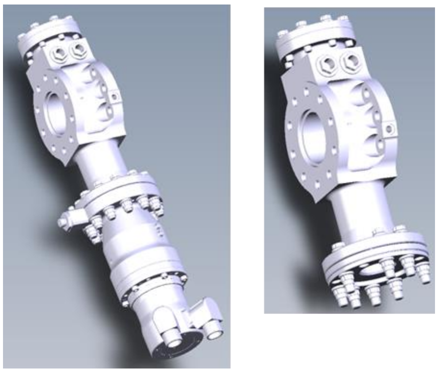

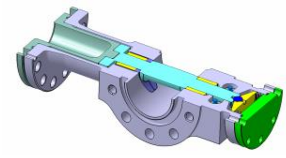

Figure 9: Vulcain®2.1 Hot Gas Valve

- Simplification of command and venting systems, as well as line routing (induced by some of the afore-mentioned changes).
- Hydrogen turbopump: industrialization modifications to ease the manufacturing and decrease the cost (removal of the volute casing double skin , coating removal , local design modifications …)
- Oxygen Turbopmp change of s suppliers for some parts (“farm out”).
- LHe/GHe heater slightly adapted to the long Oxygen exhaust line configuration.
- New engine attachment with a redesigned actuator support (linked to the introduction of new actuators).

3 SUMMARY OF THE VULCAIN®2.1 PROPULSIVE SYSTEM DEVELOPMENT

Overall logic

The main principle for Ariane 6 development is the reuse of some Ariane 5 products, taking the Vulcain®2 engine as a “building block”, with modifications to sustain the constraints of the Ariane 6 launcher environment and to decrease the recurring cost.

The qualification of the LLPS consists in several aspects to qualify: ground operations, LLPM performance, etc.

The overall goal is to perform the qualification of Vulcain®2.1 engine, engine subsystems and FCE by mid-2020. The full qualification of Vulcain®2.1 Propulsive System will be reached after the combined qualification tests first semester of 2020, which will permit to qualify the main functions of the Functional propulsive system (tanks filling, tanks pressurization, engine command, engine chilldown, venting, tanks de-loading, etc.).

The development objective of Ariane 6 focuses on a maiden flight within the second semester 2020.

The overall Vulcain®2.1 propulsive system development planning is presented hereafter:

Engine & FPS Feasibility Review	Jan. 2015
MG5	Mar. 2016
MG7	Oct 2018
MG11 (Qualification review)	June 2020
1st Flight	2nd semester 2020
MG15 (Full Operational Capability)	2023

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Ariane 6 Launch System development will end up with the demonstration of its Full Operational Capability, whose indicator will be its availability to perform 11 launches a year.

The overall development logic is to test as much as possible during the engine tests the critical items of the Functional Propulsive System (pressurization system, command system…).

The command system of the engine will obviously be tested in the Ariane 6 configuration. The engine part of the chill-down will also be tested at engine level.

The development of new ground-board interfaces called MANG (Module Avitaillement Nouvelle Génération) is performed in commonality with the upper liquid module.

The last main step for the Functional Propulsive System is the combined qualification tests which will be performed on ELA4 (new Ariane 6 launch pad).

During the combined tests, the complete Lower Liquid Propulsive Module will be tested while connected to the ELA4 ground installation. The following qualification steps will be performed:

- Full closed loop of the pressurization system,
- POGO system: first firing test with the flight structural model,
- Full command system: first firing test with a command fluid coming from PGD regulator plate,
- Ground validation: test of the ground operations in flight conditions, including failure cases,
- Flight Chill-down process.

4 ENGINE QUALIFICATION

The different engine modifications have been qualified through 3 engine tests campaigns (M1, M2 and M1R) performed between beginning 2017 and mid 2019 (Vulcain®2.1 has also taken benefit from passenger tests defined on Vulcain®2 tests campaign in 2015 to mitigate in advance some risks).

In order to perform Vulcain®2.1 development / qualification tests and to prepare its future production, PF50/P5 engine test bench changes have been implemented to cope with the listed engine modifications. These test bench modifications have been implemented on P5 facility at DLR in Germany (burners implementation for Thrust chamber ground ignition…) in 2017, and the modification linked to new actuator angulation has been implemented end 2018. For the modifications of the PF50 facility in France, they have been implemented end 2018 with the objective of not constraining the Vulcain®2 production planning.

Modifications introduced in the LLPS directly impact the whole engine system. Thus the objective was to test M1 engine with the target to increase as soon as possible the maturity of the modifications:

- SWAN: nozzle design parameters as well as exhaust line attachments,
- High Frequency stability of the main combustion chamber with acoustic cavities closed,
- Ground ignition: set-up of the burners’ configuration (number, location, orientation) and validation of the associated load case,
- ALM Gas Generator characterization regarding head injection head loss, and stratification assessment and thermomechanical behaviour.
- Electrical actuation of the hot gas valve on the ground for engine tuning.

A second test campaign with the M2 engine is being performed to qualify all these modifications. M2 test campaign is the main qualification campaign of the Vulcain®2.1 development for the following reasons:

- The hardware configuration is the closest to the recurring flight one described
- The number of tests and their cumulated duration is compatible with the Qualification Rules

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These engine campaigns have been performed in 2018 and 2019 on the two test facilities, on the PF50 located in Vernon (France) and on the P5 located in Lampoldhausen at DLR (Germany).

In addition to the need for Vulcain®2.1 engine fire testing, development engines are planned to be delivered for upper level testing:

The first development engine M1 will be refurbished into M1R to be used for LLPM QM (Qualification Model) after its fire acceptance test. The combined tests are foreseen during the first semester of 2020 on the ELA4 launch pad in French Guyana.

The second development engine M2 will also serve as the MQD (Dynamic Qualification Model) after its fire tests. As a result, it will be the engine that would have undergone a complete life cycle, including dynamics.

Figure 10: Engine dynamic testing

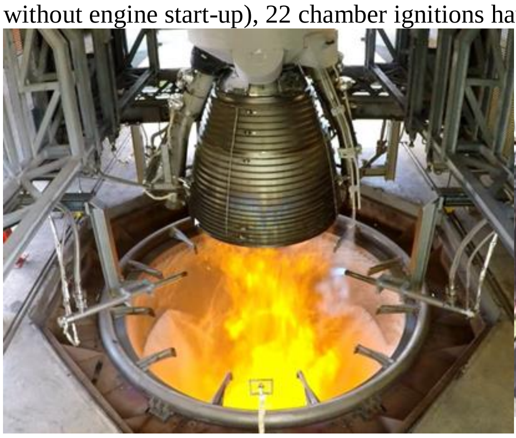
5 STATUS ON THE DEVELOPMENT OF VULCAIN®2.1 PROPULSIVE SYSTEM

The MG5 (PDR) and MG6 (Manufacturing Key Point) reviews of the engine and of the FPS and engine equipment were held in 2016 and 2017.

In 2018 all the MG7 reviews (Critical design Review) of all the equipment have been held, and the development tests have been performed in 2017 and 2018 for all the equipment.

Engine tests

The first V2.1 campaign, M1, has been performed from January up to mid of August 2018. 12 tests have been performed with a cumulated duration of 6315 seconds. Thanks to the “rafale” test process (thrust chamber ignition without engine start-up), 22 chamber ignitions have been performed, including 10 “rafale” ignitions.



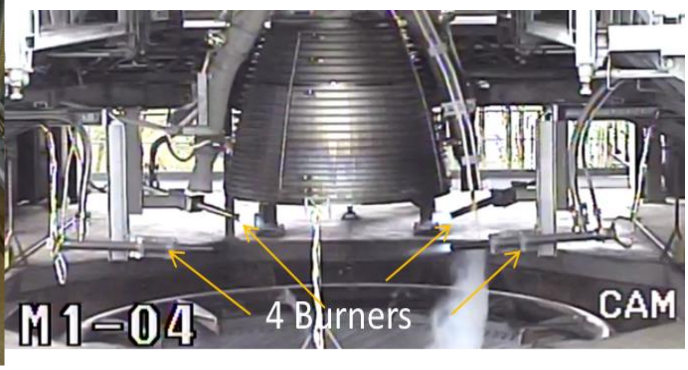


Figure 11: M1 firing engine test

Figure 12: Burners implementation

The quality of the thrust chamber ignition with ground burners is in accordance with the forecast (pressure peak and ignition delay coherent of the ignition with specific pyro igniter).

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The engine transient phases (start up and shut down) show a behaviour very similar to the Vulcain®2 engine transient, which confirms the acceptability of the modifications implemented:

- New turbopump starter (cost modification applied / Vulcain 2 starter)
- New hot gas valves (VGCe)
- ALM gas generator
- Modifications on the thrust chamber (distribution plate and acoustic cavity removal)

Several tests were performed without gas generator igniter, with a gas generator ignition only with the turbopump starter. As the quality of the ignition was not with enough margins regarding ignition delay and associated pressure peak, the gas generator igniter has been re-introduced to come back to the Vulcain®2 sequence.

The global operating domain has been explored with in particular an exploration at low thrust chamber pressure to identify the margins regarding flow separation at nozzle extension level, and the good behaviour of the new VGCe which is equipped with an electrical actuator.

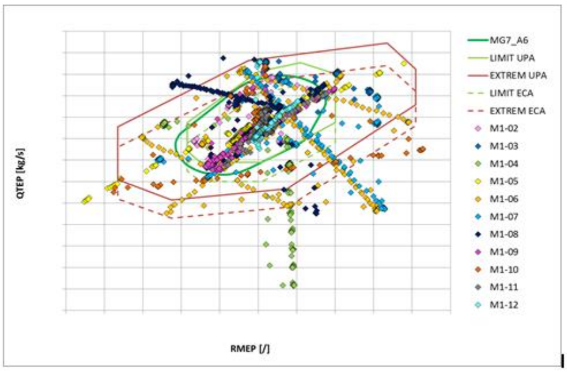

Figure 13: Engine operating domain

The first tests of the ALM GG have been performed with injection characteristics in line with the expected values (the shape of the gas generator injector had been adapted to ALM manufacturing), with a very good behaviour of all the parts made in ALM.

A good behaviour of the Nozzle extension SWAN was also observed, in particular regarding the cooling circuit (pressure and temperature in line with expected value).

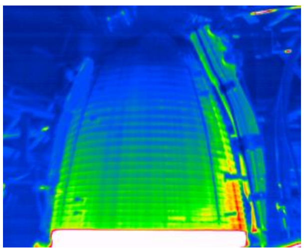

Figure 14: Nozzle extension thermal map during engine test

An optimization of the M2 engine campaign objectives has been performed, taking advantage of the approach presented in the reference [2]. This has led to reduce to 12 tests the campaign, instead of 16 tests initially.

The main objective of M2 campaign was to qualify in robustness all the modifications implemented, and to demonstrate for all the new hardware one main life cycle in the extreme operating domain and at least 3 main life cycles in the limit operating domain.

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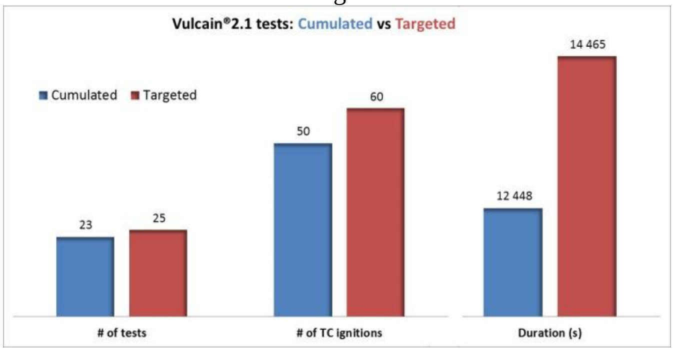
M2 test campaign has also served to determine and/or confirm the functional identification of the engine regarding all the modifications implemented on the engine, in particular with:

- o The Combustion Chamber w/o pre-distribution plate,
- o The ALM Gas generator injection head
- o The Hydrogen Turbopump w/o double-skin in its volute casing and with the full set of reindustrialization features,
- o The confirmation of the VGC hydraulic characteristics,
- o The TPS Lean+ profile and its anticipation within the sequence.

The first M2 test was performed in November 2018 and the end of the campaign is foreseen in July 2019.
The 2 last tests of the campaign will be performed with the flight actuators in order to test the engine gimballing.
So far, 9 tests have been performed with a cumulated duration of 5610 seconds on M2.

The Engine M1 has been refurbished in flight configuration M1R and has performed its acceptance test for the shipment to Les Mureaux and its integration onto CTM-L (LLPM module dedicated to combined tests in Kourou).

So far, 23 tests have been performed on the Vulcain®2.1 engine with a cumulated duration of 12448 seconds.



To complete the engine qualification, the engine qualification dynamic campaign (MQD) will be performed first quarter 2020 with refurbished M2 engine.

The first flight engine FM1 will perform its acceptance test before end 2019.

Equipment subsystems tests

The PMG7 (CDR review) for the MANG was held in July 2018 based on studies and development test results.

The tests performed were:

- Functional tightness tests (poppet tightness, actuations, On board poppet reverse opening pressure)
- Endurance performed with MANG_S1R
- Anti-icing with MANG_S1R
- Ground board tightness under load with MANG_S and MANG_L
- Disconnections tests performed with MANG_L and MANG_S
- 20K tests performed

Main tests results are compliant with expectations.

Tightness and manoeuvring tests have been performed in Air Liquide company at 20 K (LH2).

And the first MANG disconnection test has been performed in a new test cell PF8D in Vernon (France) in cold conditions.

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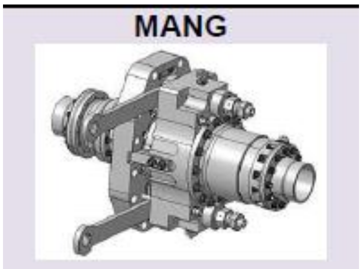

Figure 15: MANG

Figure 16: MANG disconnection test

Up to the Qualification, several category 1 tests have still to be performed in order to qualify the designs. The tests are detailed below and are the same for the 2 types of MANG:

- Functional tests: The MANG will be tested in order to check the tightness level and the overall good behaviour
- Endurance test: The goal will be to verify the capability of all elements of MANG to sustain the activations number defined in the requirements (integrating refurbishment logic constraint for ground part).

All these tests are planned at Ariane Group Vernon in the Group J area.

Then, other tests to be performed will be:

- Vibration tests on board part
- Pyroshock tests on board part of MANG_S and MANG_L
- Thermal vacuum tests (only MANG_S board part).

The MANG will be also tested during category 2 tests campaigns (Fluid connection box, Early combined tests and combined tests). It will be mainly disconnection test in different conditions, and use in real operational conditions LOX, LH2, with the environment of Fluid connection box).

In Ariane Group Ottobrunn (Germany), the following equipment PRCPH and PPO (with new Electro-Valves), LL-VAX (Feeding valves with actuator modification) have passed their PMG7 based on the results of the studies and of the following development tests:

- Life Cycle Actuations
- Thermal cycles by submerging in LN2
- Vibration in three axis with the EQF levels available at the time
- Mass flow checks for orifice dimensioning
- Actuations with real media

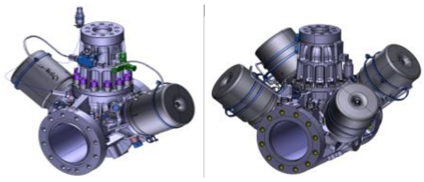

Figure 17 : PP0 + PRCPH

The plates' Electro-Valves and the Feeding valves fulfil all the requirements (manoeuvring time, tightness, massflowrate,…)

The final verification test campaigns are the on-going qualification campaigns at product level. In addition to the above mentioned tests, the following aspects are being verified:

- Vibration in three axis with the EQF levels on full assembly
- Pyro shock in one axis with the EQF levels
- Cycles according to the endurance factor of the qualification rules
- Full Flow tests on assembly

Figure 18: Main feeding valve

Following the qualification test campaign, PMG11s will be held

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The results of all these development tests make possible finalizing the qualification design which has been presented during the Critical Design Review (CDR / PMG7) of each equipment held in 2018.

During 2019, all the qualification tests of Vulcain®2.1 equipment will be performed to authorize the realization of the qualification Review of all the equipment up to first quarter 2020.

For the Vulcain®2.1 propulsive system, the qualification will be done after the combined tests scheduled in Kourou second quarter 2020.

6 CONCLUSION

A new configuration of the Vulcain®2.1 propulsive system has been defined with as main objectives recurring cost reduction, performance, reliability and simplification of operations.

The development of the Vulcain®2.1 propulsive system is well on track with a configuration that has been confirmed during the Maturity Gate 7 (CDR) of the engine held end 2018 and has been assessed as consistent with the Ariane 6 high level requirements issued by ESA.

For all the Vulcain®2.1 equipment, the development tests have been performed in 2017 and 2018, and their Maturity Gate 7 (CDR) has been held to authorize the qualification phase (qualification design and qualification tests).

In particular, the Vulcain®2.1 engine qualification firing tests shall be ended in July 2019 with in total more than 25 tests and 13000 seconds of duration demonstration.

The engine M1R has passed its acceptance test and will be delivered mid-2019 to Les Mureaux site to be assembled on the LLPM module dedicated to the combined tests in Kourou scheduled first semester 2020.

At Functional Propulsive System level, all the fluid equipment have passed their Maturity Gate 7 (CDR), and their Qualification Reviews are scheduled between mid-2019 and first quarter 2020.

The main Challenge to qualify this new Vulcain®2.1 propulsive system, in due time for Ariane6, is on track.
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7 REFERENCES

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