Airbus Defence and Space Additive Manufacturing strategy implementation and development for space applications

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Abstract

Additive manufacturing technologies is, without any doubts, considered as an enabling and game changing technology. Benefits and industrial impacts associated to this quite new technological approach are so numerous that we can legitimately wonder if its impact will be as great as the composite was for the aeronautic and space domains?

Airbus defence and Space is being developed numerous applications involving Additive layer manufacturing from ground applications to flight ones. Once the benefit of ALM clearly

evidenced on the targeted parts, and the feasibility demonstration completed, comes the industrial phase where supply chain maturity readiness needs to be clearly addressed before entering in the “series” production.
This paper describes how within Airbus Defence and Space and more largely within Airbus Group, ALM is considered and commonly developed. Example of parts ready to be implemented in flight condition will be illustrated and the key element of the supply chain as well as the qualification logic will be discussed.

1. Introduction

The Airbus Defence and Space technology roadmap for materials and structures addresses technology development strategy and priorities required for both enabling the development of new generation of launchers as a prime position and supporting our capacity to be technological provider of parts and structures for all the scope our activities: civil and military launchers, planet exploration probes, space platform, robotic exploration and propulsion. When addressing such a list of applications and projects we can imagine the number of technical challenges to face.

Performance for sure remains the main requirement, but regarding the cost and the expectations of such missions, reliability comes out immediately. We have moved from performance requirement toward a more cost effective and sustainable approaches. Competition over the world with new economic models obliges to reconsider our model of development and technological choices. One of our main goals today is to accelerate and mature technologies for our next applications which is for the launcher market Ariane 6 and its increments.
Nevertheless this approach consisting in identifying technical capabilities and technologies required to support mission needs, needs to be completed by another approach consisting in proposing advanced technology at architecture level, integrated in a system. These new technologies, considered as game changing technologies, will permit to enhance the mission capabilities if developed sufficiently earlier before the decision to launch the mission.

To succeed in proposing the right technology for both approaches we are convinced that a multidisciplinary approach is mandatory. Multidisciplinary means integrate in a same team people from the systems, lab, design and stress offices but also manufacturing and control, supported by a network of fundamental researchers. By the way it will produce in each domain, including materials, structures, advanced engineering, manufacturing and transverses disciplines (control, certification…) technological roadmaps.

These roadmaps identify requirements in term of performances, competitiveness, robustness, environmental impact, and milestones in order to establish the maturation logic and associated time frame.

1.2 Technology roadmaping

With composite materials and new advanced metallic processes it is possible to play with a numbers of parameters to create the most optimized and efficient structure for dedicated

applications. These technologies rely on the development of new materials (organic resins, metallic alloys…) with the integration of multifunctional characteristics. Multi-functionality is key as it provides a game changing obliging the integration of materials and structure in a system view and reducing the number of interfaces. Such integrated structures offer an optimized efficiency in term of mass and cost.
To be able to optimize the cost and get the good level of competitiveness these materials need to be associated with cost effective manufacturing processes. Depending the topology/design of parts to be produced the selection of the technology could be different. Is this a complex stiffened part, or a very large tank? The key parameters influencing the cost are totally different.

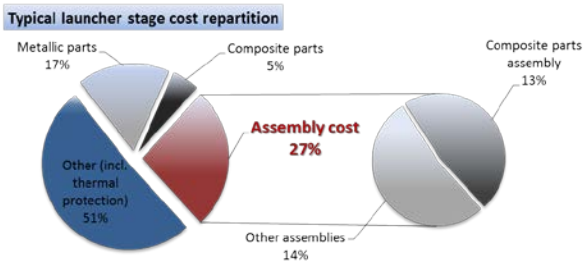


Figure 1. Typical launcher stage cost repartition

Globally, the more complex will be the design and the requested performance high, the higher will be the cost. It is of importance to develop process which limit huge and costly installations, like autoclave, and allow simplified, light tooling or even suppress its.
Fig1 shows the repartition of cost of a typical launcher structure. We can see that assembly and manufacturing represent an important part of the cost, justifying focusing our efforts on these two items.

Another approach, which is quite new, is to use, in the selection criteria list, the environmental impact of the different contributors of the technology to be chosen.

1.3 ALM Roadmap

For metallic materials and processes the logic for selecting materials and processes rely on different criteria:

- sustainability,
- robustness,
- environmental impact assessment
- cost reduction.

Three axes are followed. For light alloys the family of Aluminium / Lithium and Aluminium / Magnesium / Scandium are preferred for the opportunity in term of performance. The reduction of cost is there more introduced by new manufacturing processes as new forming process and new assembly process like Friction Stir Welding.

Additive layer manufacturing occupies an important place in the metallic roadmap. The purpose of this paper is not to explain why it seems so obvious to invest in this route, Airbus Defence and Space being probably the first company to have produced an ALM part in space with Atlantic

Bird 7 fitting (see fig 1). A lot of bricks need to be addressed and matured before to introduce this technology. These points have been addressed and discussed during the Harmonization conference organized by ESA. From the discussion it was evident that a European coordinated plan should be advantageously proposed. A link between maturity level of ALM materials and technology and program objectives must be identified in order to define the right level of effort to produce.

2. Additive Layer Manufacturing Generalities

2.1 Different technologies with pros and cons

Additive Layer Manufacturing is covering in fact a family of different processes with their own pros and cons with regard to the application. The main technologies targeted in space systems applications are:

- Powder bed processes with Laser or Electron Beam source
- Powder feed system with Laser source
- Wire feed system with Laser but also Arc or Plasma sources

The different technologies can be compared within several technical aspects as presented in the table 1.

++++ => best	Powder bed (laser)	Powder bed (EB)	Powder feed	Wire feed
Beam thickness	++++	+++	++	+
Layer thickness	+++	+++	++	+
Construction speed	+	++	+++	++++
Roughness	++++	+++	++	+
Internal stress level (less deformation)	+++	++++	++	++
Shape complexity	++++	+++	++	+
Repair capability	0	0	+++	+++
Multi material capability	0	0	++	0
Size of the part	++	+	+++	++++
Hollow and lattice structure capability	++++	++	0	0

Table 1: Comparison between the main technologies targeted

This table shows that the different technics are not really in competition but are actually very complementary. Each specific application with its own needs will be achieved using the most appropriate technology.

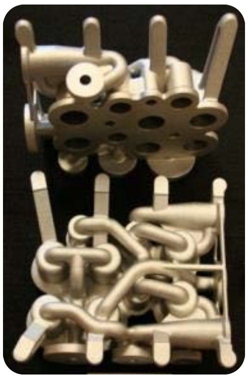
2.2 ALM at Airbus DS Space Sytems

Since several years, Airbus DS and especially Space System has identified ALM as a key technology for Space Applications. The first example is the Atlantic Bird 7 fitting manufactured in Titanium Ti64 by EBM and which is flying since 2011 (see fig2).

Figure 2 : Ti64 Atlantic Bird 7 fitting developed in 2009 and flying since 2011

This first application was designed as “black metal” in the sense where machined design was used to produce the part by ALM in order to limit the risk. Today a wide range of other applications are in development addressing:

- Wave guides
- Thermal and fluid control equipment

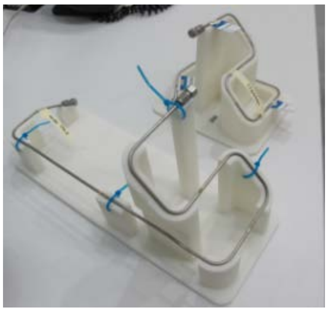


- Combustion chamber and injectors

- Thrusters

- Brackets and fittings

- Tooling



In order to face the exponential increasing demand and projects raising everywhere, Space Systems has implemented a transnational common roadmap grouping launchers, propulsion and satellite applications in order to rationalize efforts and to increase the knowledge share by the different teams. This roadmap is in a second step included in a more global Airbus Group roadmap

2. ALM for which benefits in Space applications

The different advantages brought by ALM are widely described in the literature and are summarized in fig 3.

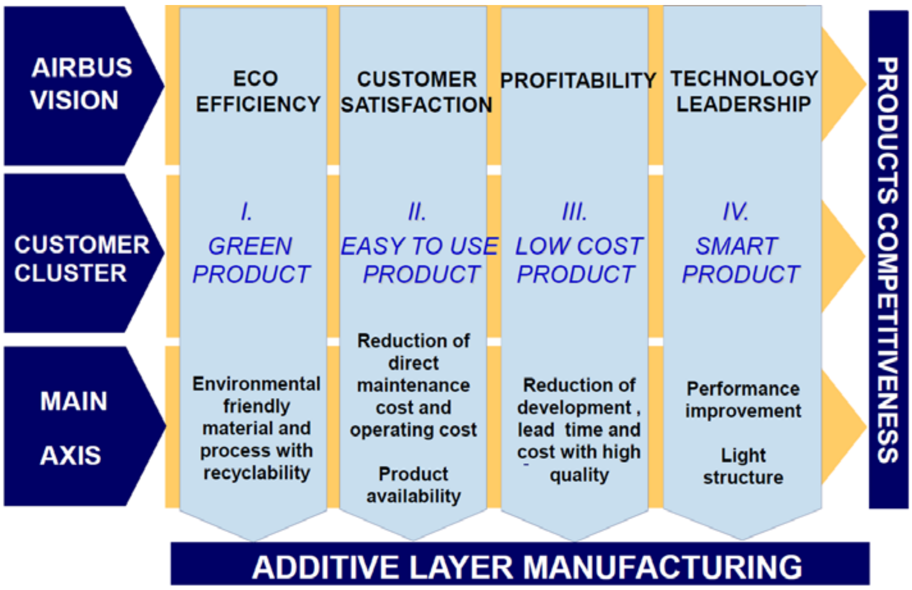


Fig 3: ALM domain of interest

Example of how these different benefits could be achieved are reported in fig 4&5

Weight reduction	• Topology optimisation for part under static loading
Cost reduction and lead time reduction	• One process instead of multiple manufacturing process • Manufacturing Flexibilty (direct link between cadcam and manufacturing) • No tooling
Performances improvement	• Bio mimetisum • New design

Fig 4 : General advantages for the aeronautic domain

For Space applications, specific points (see fig 5) need to be addressed to take benefit of ALM:

Cleanness	• Surface preparation
Outgassing	• Pore gas trapped • Hipping not efficient • Plastic compliant
High temperature & High stability needs	• Propulsion system - Thruster - combustion chamber • Ceramic mirrors

Fig 5 Specific space interest of ALM

3.1. Cost Savings + function integration

A good example of capabilities of ALM in reducing mass by function integration is illustrated by an Ariane 5 ME application. The upper stage bracket and support of A5 ME has, for example, been redesigned by topologic optimization approach (fig 6&7) integrating cryogenic cable support as well as stiffness and load requirements.

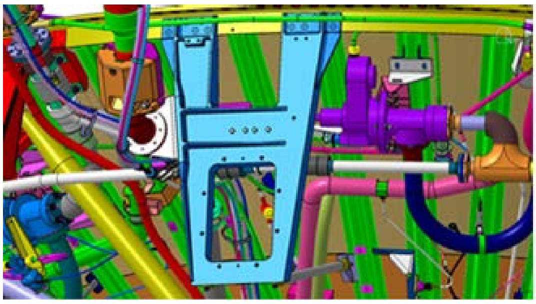


Fig 6 Previous design by classical process

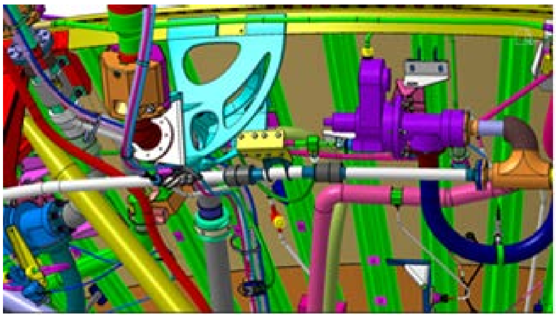
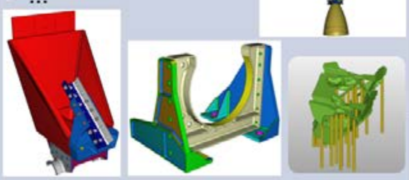


Fig 7 Redesign of ISCAR bracket with ALM

By doing that, important savings, in term of cost and mass, can be achieved as described in fig 8.

3D Printing Catalogue (Launcher 2ndary Structures)

2ndary Structures	Program(s)	PREPARE, INSIGEN, PROCEED PREPARE
Upper Stage brackets & supports: - SCAR support bracket - Vent line bracket - Cable bridge support - LH2 balancing nozzle - ISCAR Bracket - … - ETF brackets	Status /Due Date	ALM Design and Qualification Plan incl. ALM technology essentials - Design-for-ALM philosophy / methods - Process simulations & prediction (distortion & residual stresses) - Damage tolerance strategy - Quality assurance (process & quality control) - Qualification test case (→ALM ISCAR)
	Estimated savings	15-20 % (tbc)
	Quantity to be produced	dependent on no. of applications for A5/A6 up to 40/year
	Weight saving	up to 50 % (component dependent)
	Material / Technology	Generally material independent (Al and Ti engineering alloys)



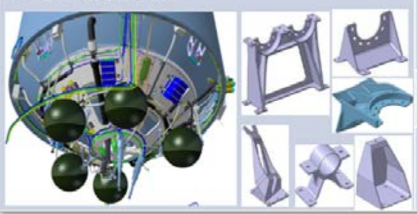


Fig 8: ISCAR product development and benefits

3.2. Lead time reduction

Lead time reduction is one of the most critical point for aeronautic and space applications. For space domain even if the production rate is low, the specificity rely on the non-generic definition of the parts to be produced, leading very often to important supply delay for molds or blanks…These delays obliged to freeze very early in the development phase the definition of the part, preventing design optimization or modifications. The possibility offered by ALM to achieve near net shape raw parts in few days is an incredible improvement on the procurement logic but also on the design logic.

The 3D printed components being developed by the UK team are part of a program that is now able to introduce components that cannot be manufactured using conventional technology. This includes a structural bracket for Eurostar E3000 telecommunications satellites manufactured from aluminum alloy. It is a single piece laser melted part (Fig 9&10) weighing 35% less than the previous bracket which comprises four parts and 44 rivets. The additive layer manufactured bracket is also 40% stiffer than the previous manufactured component, and does not result in waste generated by conventional machining (Fig 11).

The bracket is for mounting the telemetry and telecommand (TMTC) antennas onto the satellite, and has successfully completed flight qualification testing. It is ready to be flown on a forthcoming satellite.

The ALM bracket was manufactured for Airbus Defence and Space by 3T RPD Ltd, a leading production Additive Manufacturing company based in Newbury

Fig 9 : The Stevenage team in charge of the bracket development

Fig 10 : The final aluminum bracket

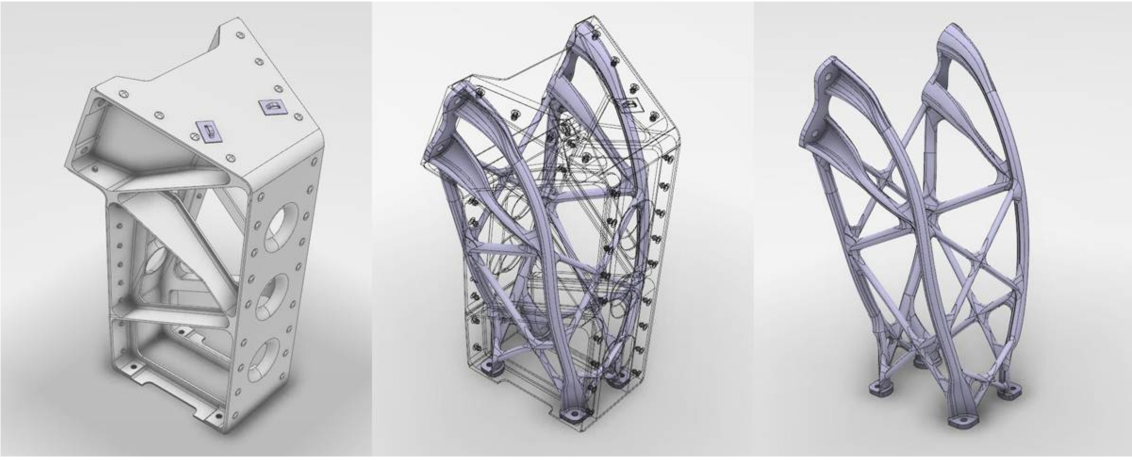
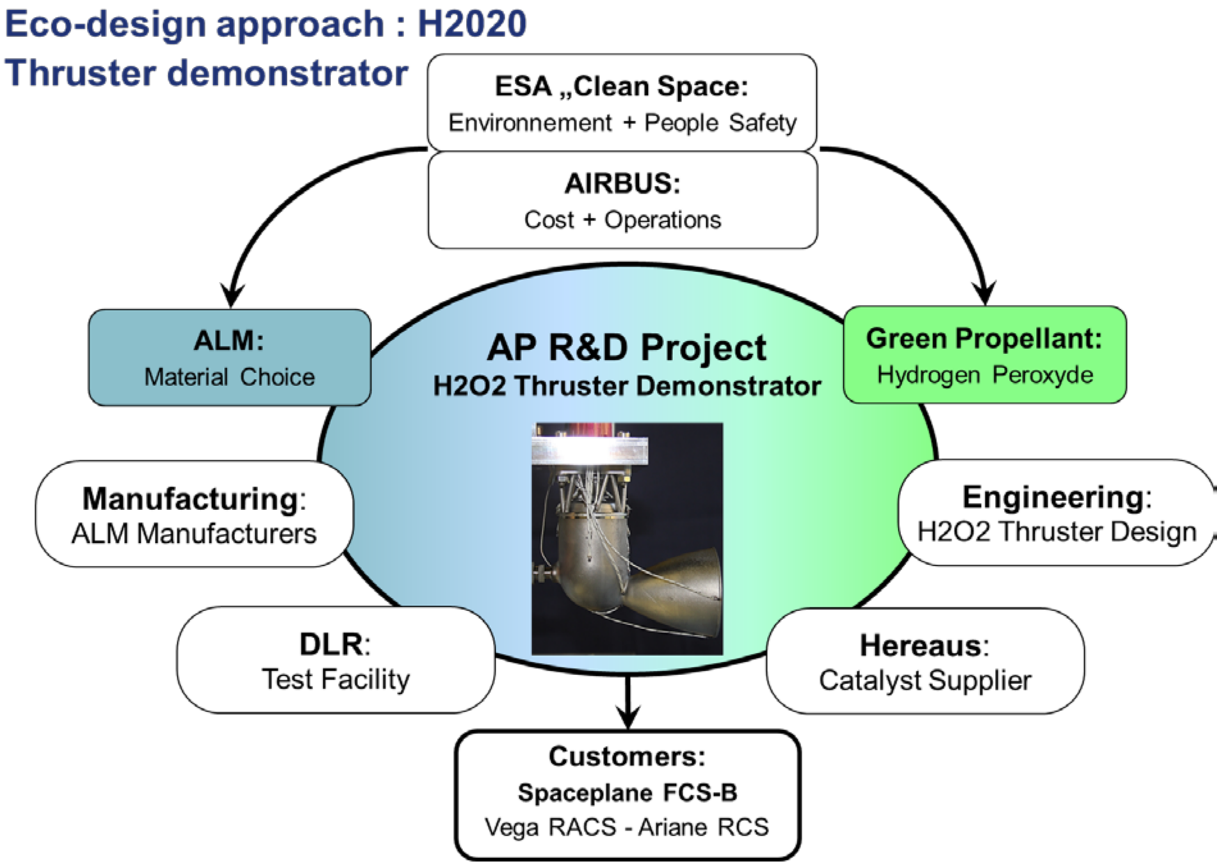


Fig 11 : design optimization of the bracket

3.3. Environmental impact

Arbus Defence and Space has developed and disseminated Eco-design approach in his design offices. One of the pillars of this methodology is the evaluation of the environmental impact by life cycle analysis. This criterion is used in the trade–off phase additionally to others like, mass, cost…

Example and illustration of this method and its result is given in the following picture [Ref 1]. The life cycle analysis study performed on thruster demonstrator has shown that the combination of new green propellant development and ALM technology allow, in addition to mass and cost advantages, to reduce the global environmental impact.

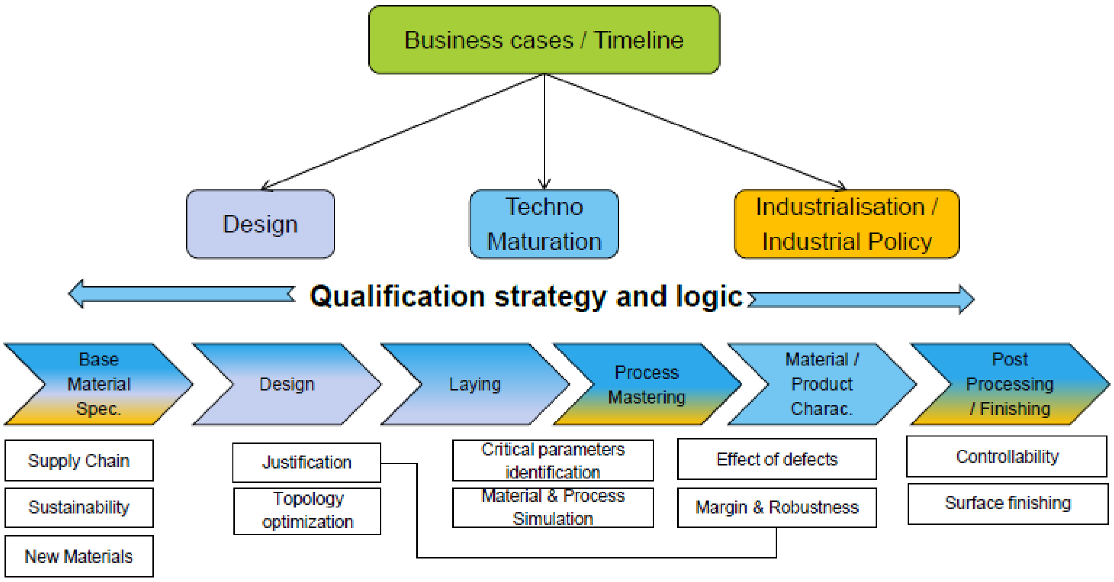


H2020 Thruster ENVIRONMENTAL BENEFITS = COST REDUCTION

Environmental indicators	Cost
ALM	
Raw materials depletion ↘	Raw materials use ↘
Energy&water consumption ↘	Energy & water use ↘
Waste production ↘	Waste treatment ↘
	Manufacturing cycle saving ↘
Green propellant	
Human toxicity ↘	Ground equipments ↘
Terrestrial ecotoxicity ↘	Safety operations ↘
	Transport conditions ↘

4. Conclusion, Challenges and Perspectives

Three main pillars support the industrial development of the ALM technology. The first is Design for ALM, as a new way of thinking the design has to be implemented in all design offices to take advantage of all new possibilities of the technology. The second is ALM Maturation, as a lot of work is still needed for a better understanding of the process parameters on the impact of parts properties. The last is ALM industrialization with the mastering of the entire supply chain from the raw material supplier (powder supplier) to the post processing and the control to be performed.



This strategy is shared at the Airbus Group level where a global ALM Roadmap and shared project is ongoing in order to achieve a complete qualification strategy and logic with common and transversal challenges addressed: powder quality or design but also more product specific orientated need as mechanical properties (fatigue or static loading) or surface finishing (waveguides, fatigue loaded parts).

Before ALM could be the technology which will allow the cost reduction of spacecraft and launcher by 50% as claimed on certain publications or web articles a lot of work need to be performed to master the critical parameters and the main element of the supply chain. At this condition we are convinced that ALM will contribute significantly in the product competitiveness.

References

[1] Fiot.D, Desagulier.C, Gotzig.U, Welberg.D and Saint-Amand.M 2015. Low cost and green small storable propulsion system. In: *6th european conference for aeronautics and space sciences (eucas).*