The environmental regulations: brake or accelerator of innovation in the space sector?

Research paper

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Abstract:
Innovation within the space sector is often confidential for governmental reasons. The sector is highly strategic and involves both public and private actors in Europe. Furthermore, there is no European environmental regulation which is directly addressing the space sector, some of them like REACH and ROHS are still affecting it regarding the usage restriction of chemical components for the production of space engines.
The question this paper addresses is what innovation effect can be expected from introducing European environmental regulations which are affecting an advanced technology sector like the space one.
In this research paper we will focus on the space activity that concerns especially space engines for commercial purposes.
The innovations treated in the third part of this research paper are all responding to the European Regulations REACH and ROHS. The production, quality and the ways of working are affected and it is in this context that we can talk about innovations in the space sector that resulted from environmental regulations.
REACH and ROHS may not have fully reached one of their goal: to promote essentially strictly new innovations. However, they manage to reach space companies' awareness about the need to produce space engines taking into account the environmental externalities.
If we could point out one thing that is reducing the impact on innovation of REACH and ROHS, it would be the lack of compliance assessment and controls. But this requires additional financial investments from European governments.
In order to achieve the objectives expected by environmental regulations in the space sector, consideration should perhaps be given to provide legal support for the understanding of laws and environmental constraints to the engineering teams.

L'innovation au sein du secteur spatial est souvent gardée confidentielle pour des raisons gouvernementales. Ce secteur est très stratégique et concerne aussi bien des acteurs publics que privés en Europe. De plus, il n'existe pas de régulations environnementales européennes qui s'adressent directement au secteur spatial, quelques unes comme REACH et ROHS l'affectent quand même en ce qui concerne l'usage de composants chimiques pour la production d'engins spatiaux.
La problématique soulevée par ce mémoire est : Les régulations environnementales européennes ont-elles eu comme effet d'encourager ou de freiner l'innovation dans un secteur très avancé technologiquement comme celui du spatial ? Dans ce mémoire de recherche, nous allons nous concentrer sur l'activité spatiale qui concerne essentiellement les engins spatiaux construits à des fins commerciales.
Les innovations traitées dans la troisième partie de ce mémoire répondent toutes aux régulations européennes REACH et ROHS. La production, la qualité ainsi que les

façons de travailler sont visées et c’est dans ce contexte que nous pouvons parler d’innovations dans le secteur spatial résultant de régulations environnementales.
REACH et ROHS n’ont probablement pas atteint un de leurs objectifs de manière satisfaisante : promouvoir purement de nouvelles innovations. Cependant, ces régulations européennes ont réussi à faire réagir les entreprises du secteur spatial sur le besoin de produire des engins spatiaux en prenant en compte les externalités environnementales. Un des points qui selon nous est à souligner et qui réduit l’impact de REACH et ROHS sur l’innovation serait le manque d’évaluations de conformité et de contrôles. Mais ceci demande des investissements financiers supplémentaires de la part des gouvernements européens.
Pour atteindre les objectifs attendus par les réglementations environnementales dans le secteur spatial, il serait judicieux de fournir aux équipes d’ingénieurs une assistance et une aide légale à même de les informer judicieusement sur les contraintes juridiques et environnementales liées aux régulations environnementales.

Key words: space sector, innovation, European environmental regulations, REACH, ROHS, Technology Readiness Level (TRL), Chrome VI, Cadmium, Nickel

Mots-clés : secteur spatial, innovation, réglementations européennes environnementales, REACH, ROHS, l’échelle TRL, Chrome VI, Cadmium, Nickel

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Introduction

Innovation within the space sector is often confidential for governmental reasons. The sector is highly strategic and involves both public and private actors in Europe. Environmental innovations seem to be less known by the general public in the space sector than in others like the aeronautics or the automotive one.
So we were wondering if this impression was linked to the fact that a lot of innovations within the space sector remain confidential or if it was the sign that there were less environmental innovations within the space sector than in other sectors whose activities have also negative externalities on the environment.
Although there is no European environmental regulation which is directly addressing the space sector, some of them like REACH and ROHS are still affecting it regarding the usage restriction of chemical components for the production of space engines.

The question this paper addresses is what innovation effect can be expected from introducing European environmental regulations which are affecting an advanced technology sector like the space one.

In his article entitled “The tragedy of the commons” (1968), Garrett Hardin argues that in the absence of regulation and usage controls of a common resource, it can be overexploited as a negative externality.
This vulnerability of the common resource requires the creation of regulations and restrictions involving all the actors that use the resource. In the long term, if we want to protect common resources, we need to consider justice, intergenerational and intragenerational issues. Finding solutions to fight this tragedy of the commons is one of the governmental mission worldwide.
Our paper is referring to environmental regulations which aim to reduce the negative impact of industrial activity on the environment, and so the hypothesis of Garrett Hardin makes sense for our research work and reminds us that sectors like the spatial one are facing environmental issues that affect not only companies from one specific sector, but also the overall population.

In our research paper, we are focusing on the space sector. Although it’s difficult to study only the space sector, because it is much related to the aeronautics sector since the main actors of both industries are common. As the space sector is also related to the military and defence industry – a very confidential sector – it’s difficult to have access to all the information. Therefore, in this research paper we will focus on the space activity that concerns especially space engines for commercial purposes.

In our research paper, in the first part we have defined some general concepts of innovation and the concept of TRL, which is the innovation method applying in the space sector. We have also in the first part highlighted that in the innovation literature, there is no consensus within the economic theory whether environmental regulations do enhance innovation or not.
Then, in the second part, we are focusing on the specificities of the space sector in terms of technical constraints and innovation founding processes. Plus, we have introduced the two European environmental regulations REACH and ROHS that are affecting the space sector.

In order to address the question of our research paper, we have decided to use a method based on several business cases in the third part. The business case method is an empirical method to determine if REACH and ROHS have lead to more innovations and if these innovations were the one these two regulations were trying to enhance at the first place.
Although we are aware that we were not able to have access to the all ranges of innovation within the space sector, we have found and chosen several examples of innovations that we could linked to REACH and ROHS.

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1. Innovation: Economical theories and the specificity of the space sector

1.1. General concepts of innovation

1.1.1. Typology of innovations

According to the Oslo Manual which gathers guidelines aimed to collect and properly use data on industrial innovation, there are four types of innovation:

- Product innovation: Introduction of a new product (or service) including new characteristics, specificities, components or materials.
- Process innovation: Implementation of a new way of production or distribution. It implies deep changes in techniques, materials and softwares.
- Organizational innovation: Implementation of a new organizational way in the work practices, in the workplace organization or in the firm’s external relationships.
- Position innovation: Implementation of a new way of commercialization. It implies changes in design, packaging, placement, promotion and pricing.

1.1.2. The Porter Hypothesis

According to Porter (1991), pollution consists in a waste of resources. Thus, reducing pollution lead to a better productivity as resources are fully used. He argues that “strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it”.
The basic principle of the Porter Hypothesis, developed by Porter (1991) and Van Der Linde (1995) is that a well-designed, strict but flexible environmental regulation will drive companies to review their production processes or the product’s features and therefore to innovate. The outcome of this innovation will cover the compliance costs (technological standards, cap-and-trade emissions allowances/tradable permits, capital investments seen as unproductive by the firm) and will trigger additional profits. Resulting innovation will lead to a better competitiveness and profitability for the company.

See in appendix, Figure 1. a diagram illustrating the Porter hypothesis.

The two authors explain five reasons that support the Porter Hypothesis:

- First, environmental regulations are considered like signals which inform or alarm a company about likely resource inefficiencies and potential needs of improvement.
- Second, regulations can be an important source of information for raising corporate awareness about technological improvements to set up.
- Third, regulations reduce uncertainty companies may have concerning the potential benefits resulting from investments in innovation.
- Fourth, environmental regulations can generate pressure on companies that hence are motivated to innovate and make progress.
- Fifth, “regulation levels the transitional playing field”.

The Porter Theory has known fewer new developments, in particular one about managerial biases. Here the notion of time is underlined because the compliance costs resulting from the environmental regulations incurred on the short term are perceived as higher than the benefits resulting from the innovation reaped on the long-term. This lag between expenditures and innovation has been pointed out by Lanjouw and Mody (1996).

A company’s rationality is driven by its managers’ one. Ambec and Barla (2007) add that managers might miss some costly or risky investments opportunities, called “low-hanging fruits”. They do not go outside of comfort zones and tend to postpone any investments in innovation. According to these authors, environmental regulations are built to help the managers overcoming this problem by making these investments essential (and sometimes compulsory), more cost-effective and worthwhile.

Blind (2011) confirms the Porter Hypothesis by working on a linear regression with the data of 21 OECD’ countries from 1998 to 2004. To do so, he used different measurement parameters of innovation, such as the number of patents registered in OECD’s countries, the level of competitiveness within these countries and the variation in R&D expenditure intensity. In order to assess the regulations, he used governmental data and experts’ opinions on already completed studies.

According to him, on the short term, companies can be reluctant to innovate but the benefits come out on the long term. Environmental regulations enhance international competitiveness if and only if the developed environmental technologies are adopted in other countries as well, which would imply that the environmental regulations concern several countries.

Jaffe and Palmer (1997) developed three versions of Porter Hypothesis.

- The “weak” version tells that environmental regulations effectively spur environmental innovations.
- The “narrow” version claims that flexible regulations gives greater incentives to companies than technology-based standards.
- The “strong” version affirms that correctly designed environmental regulations lead to significant cost saving innovation which largely compensates for the cost of compliance.

Although Lanoie and al. (2011) respect the “weak” and “narrow” versions of the Porter Hypothesis, they find no support for the “strong” version. Indeed, as they explain, “a large part of the investments necessary to comply with regulations represent additional production costs”. Thus, innovation can only partly offset the compliance costs with no additional benefits. However, Lanoie and al. (2011) point out that investing in environmental R&D appears to be essential because more and more businesses are sensitive to the environmental performance of their suppliers. Therefore, this aspect of B2B relationships should not be overlooked.

1.2. Environmental regulations and innovation: the divergence of opinions within the economic literature

1.2.1. The limits of the Porter and Van Der Linde analysis

Ambec, Cohen, Elgie and Lanoie (2011) point out that Porter analysis does not say that in any case profit made thanks to innovation will cover the compliance costs of the environmental regulation. Furthermore, they affirm that Porter insists on the fact that not all the environmental regulations foster innovation and competitivity but only the well-designed ones. Although often in the economic literature, authors criticize Porter hypothesis for these points. That's why we have decided to focus on the following critics of the Porter hypothesis that are answering Porter’s arguments directly.

The first limit for Ambec, Cohen, Elgie and Lanoie (2011) might be the fact that Porter is minimising too much the rationality of companies. Porter is calling the missed business opportunities by the general term "Low Hanging Fruits", as previously mentioned, and the latter are existing because of the lack of information or organizational errors. Yet, governments or regulators do not have necessarily a high expertise to spot these missed opportunities and then to orientate the law to push companies towards these missed business opportunities. Generally, companies have got more information about the market conditions and business opportunities to maximise their profits than lawmakers.

For Bontemps and Rotillon (2003), the second limit is the fact that without proper sanction from the government in case where companies are not complying to regulations, the Porter and Van Der Linde hypothesis cannot really work. However, if the cost of the industrial controls is too high, this will discourage governments to conduct such audits.

The third limit is that the strategic behaviour of companies are not taken into account in the Porter and Van Der Linde analysis. In the Porter and Van Der Linde analysis, regulation is seen as an external factor that leaves companies with no choice but to respect it, yet companies can manipulate regulation through lobbying actions and can influence directly regulators.

The fourth limit is that the Porter and Van Der Linde analysis forgot one thing: the implementation of strict environmental regulation can often lead to innovation. But innovation will be driven from the new players of one sector, which have less economical difficulties than the existing companies. In fact, existing companies will need to change deeply their processes, production devices and or hire qualified human resources.

Finally, Porter and Van Der Linde are focused only on technical innovation while as described previously, innovation can take several form as defined in the Oslo manual.

1.2.2. Palmer, Oates and Portney theory

Palmer, Oates and Portney (1995) are not completely refuting Porter and Van Der Linde's arguments. In fact, they agree that companies are sometimes not vigilant enough when it comes to try reaching the best effectiveness level.
Even if environmental regulations are prone to create incentive for innovation, at the end of the day they create also new technological and economic constraints that represent additive costs for companies. These new costs are reducing their expected profits, while according to the authors the main goal of a private company is to maximize their profit. Environmental regulations make the implementation of eco-friendly technologies or processes necessary. As a result, some of the productive factors are allocated to less productive tasks. The environmental regulation reduces the choice available for firms and as a result their profit.
For them, the company is likely to invest in R&D until the cost of the tax for non-compliance becomes less expensive than adding R&D budget for innovation. In that case, companies will be willing to pay taxes rather than to invest in eco-friendly technology.
To conclude, they highlight that all the success stories in the Porter hypothesis are only exceptions not the rule and that we could always find failed stories that show how environmental regulations have caused the bankruptcy of companies by decreasing their profitability and increasing their production costs.

1.2.3. The classical theory as a counter argument of the Porter analysis: the environment as an economical constraint

For classic authors, environmental issues are seen as a constraint that can affect the longevity and durability of firms. The classical theory is based on negative externalities and depollution costs.
The environmental regulation and norms/standards have for consequences the fact that companies have to face the negative externalities resulting from the overall industrial activities. For example, the purchase of clean up engines like purifiers and the operating expenses (workers, maintenance) add financial charges or burdens supporting by firms that will certainly refrain them to innovate.

1.3. The innovation process in the space sector: a technology push strategy

There are two strategies for developing an innovation:

- The Market Pull strategy consists in using the demand to create the innovation. The demand creates the supply. This strategy is more carried by the Marketing function and the front office.
- The Technology Push strategy consists in using the technology to create the innovation. This strategy is more carried by the R&D function and the back office.

In the aerospace sector, the innovation process is often divided by various programs and by technology. We are in a process of innovation called Technology Push and more particularly based on the Technology Readiness Level (TRL) scale.

1.3.1. The Technology Push process

In this process, innovative ideas are driven by technology. Sources of ideas stem from technological and scientific opportunities. The means used are the Research and

Development (R&D). The level of innovation is high and innovations are difficult to imitate. As a result, the competitive advantage that these innovations confer on the company is solid and sustainable. This strategy is supported by technical profiles. A technological opportunity is, for example, the miniaturization of electronic components.

1.3.2. The Technology Readiness Level (TRL) scale

The TRL is a scale that evaluates the level of maturity of a technology from its design to its integration into a complete system including its industrialization.

This scale was designed by NASA for space projects. NASA introduced it in order to have a more effective evaluation and communication on the maturity of new technologies. Initially, the scale had seven levels and was improved in the 1990s. It has now nine levels (which have been widely accepted by the aerospace industry and government).

In the mid-first decade after 2000, the scale was widely adopted as a system for defining the availability of technology across the international space development community.

The TRL scale has therefore been developed to allow the evaluation of the maturity of a particular technology and the constant comparison of the maturity between the different types of technologies. Although several other management tools were already available for more business-oriented preparations, no tools were available to assess the stage of development of a technology. This turned out to be problematic for planning the development and construction of space shuttles for example. When the Space Exploration Initiative was announced in 1981, it became even more necessary to adopt a systematic approach to communicate the availability of technology and the forecast of its implementation between technological research and the space community responsible for mission planning. And as hundreds of people participate in the research, development, manufacture and use of space technologies, establishing a clear mode of communication was therefore necessary and indispensable for managing these technology-based activities.
See in appendix, Figure 2. a table showing the different levels of the TRL scale.

<u>Levels 1 to 3: BASIC AND APPLIED SEARCH</u>
Here, we move from the principle to the proof of concept for the application: scientific or even fundamental researches will be translated into applied researches: study "on paper" of the basic properties of a technology, around a speculative concept, in order to consider applications possibilities. This is followed by active laboratory R&D to validate the hypotheses and provide experimental evidence of the concept.
Actors involved in this step: Level 1 to 3 activities are often carried out by the public sector actors (Research organizations and Universities).

<u>Levels 4 to 5: ADVANCED RESEARCH AND TECHNOLOGY DEMONSTRATION</u>
From components to the prototype: In the laboratory, the basic technological components are integrated in order to verify their functioning together. If necessary, they are integrated into a realistic system using technological platform equipment.
This leads to the realization of a prototype which must be demonstrated in a representative environment of the application and then optimized in accordance with an operational environment on semi-industrial pilot lines.

Actors involved in this step: Public-private partnerships, Technological Research Institutes (IRT) and private R&D.

Levels 4 to 7: VALLEY OF DEATH
These levels represent the transition from the "concept to the product", that is to say the development of a technology until its validation in a real environment. An essential step in transmitting innovation to manufacturers, it is based on very expensive technological platforms and pilot lines. Crossing this valley of death implies pooling resources (public-private partnerships) and being financially supported.

Levels 7 to 9: TECHNOLOGICAL QUALIFICATION AND OPERATION
From the prototype product to the standard product: The technology, as validated in the form of its prototype, works under the predicted conditions. Its real application is implemented on industrial pilot lines to undergo ultimate tests. The complete system is then validated by successful missions in real environment.
Actors involved in this step: Private sector and Industries.

See in appendix, Figure 3. a diagram explaining the sequence of the TRL steps.

After introducing the general concepts necessary to grasp the notion of innovation in the space sector and the theoretical debates dealing with regulation and innovation raised in the economic literature as well, we will now get more into details by presenting the different constraints specific to the space sector which are able to influence the innovation process.

2. Space industry: Introduction to its specificities and REACH/ROHS regulations

2.1. The constraints within the space industry

2.1.1. Economical specificities

International space activity can be split up into three distinct markets: military and defence, scientific and commercial. Not all segments are open to competition as shown in the appendix, Figure 4. The commercial market remains the only one really open to competition. Thus the design is shared by major European and American groups (Airbus, Boeing, Safran, Lockeed, Eutelsat, Thales,). The launcher manufacturing and orbiting segment is now one and same market. In Europe, the launch of satellites (telecommunications, telephony, television, etc.) is shared between two private companies: Arianespace and Space-X, which each hold 50% of the market.

2.1.2 Manufacturing specificities

The manufacturing space segment is characterized by a high cycle length, coupled with very high product complexity and small batch. All of this make the space sector an area with a high technological barrier that requires working in a logic of network with the whole sector (SMEs, equipment manufacturers, laboratories, national agencies and prime contractors) in order to enable SMEs to participate effectively in technological innovation.

2.1.3 Technical specificities and constraints

When a satellite is launched in space, it encounters physical conditions that differ radically from those on earth. It is important to know them in the most precise way, in order to anticipate the degradations that can undergo the spacecraft. Therefore, engineers must adapt its accordingly, which causes difficulties in technical and financial terms. Below we expose the mains constraints that engineer have to take into account in satellites' fabrication.

2.1.3.1 Energy constraints

The first constraints encountered are of an energy nature. The satellite uses electric energy to function. Therefore, satellites must produce electric energy so that: On the one hands platform' subsystems in charge of secondary tasks, can keep the satellites in working order. On the other hand, payload equipment can function.
The success of a mission depends on the reliability of the electrical power subsystem (EPS), and more specifically on the reliability of the power supply. The amount of electrical energy required for the satellite varies according to the type of mission between 3 400 W for an observation satellite and 2 500 W for a telecommunications satellite. An electrical voltage must be delivered continuously throughout the life of the mission, sometimes 15 years. Therefore, the EPS must among others be able to store energy for the satellite, controlling and distributing electrical power and to deal with large variations in consumption.

2.1.3.2 Thermal constraints

The satellites are subjected to numerous thermal stresses. It is for this reason that each spacecraft embarks on the platform a thermal regulation system called Thermal Control Subsystem (TCS). TCS 'objective is to regulate the temperature of each equipment, in order to ensure the smooth operation of the machine. Indeed, some components must be kept below a limit temperature. But different elements external to the satellites complicate this such as for example the sun that generates in the vicinity of the Earth streams varying according to the seasons (approximately 1500 W / m²) which can change the temperature of the exposed parts to + 100 ° C.

2.1.3.3 Electrostatic and magnetic constraints

The electrostatic stresses are in other words the stresses due to the different radiations coming into contact with the satellite. These constraints are felt far into space, since in 2003, NASA's Mars Odyssey probe lost one of its instruments after receiving large doses of radiation from the Sun.

After a general overview of the specific characteristics and constraints of the space sector, we will now introduce the particularity of the innovation funding in the sector. In fact, contrary to other sectors, the effort in Research and Development is a mix of public & private and national & European investments.

2.2. Funding and organisation specificities of innovation in the space sector

2.2.1 The funding of innovations in the space sector

There are two types of public budgets related to the space area:

- Budgets allocated to the space sector: Credits are allocated on an annual basis by the state to public organizations in order to achieve objectives in the space sector. But their published amounts are to be carefully taken because some information are hidden for national or commercial security reasons. The space public budgets allocated to civil and military applications are increasing.

See in appendix, Figure 5. a graph illustrating the military spending in the world.

- Budgets allocated to the research and development in the space sector:

In Europe, these public budgets are the highest in France (1 587M$ in 2004), Germany (924M$ in 2005) and Italy (902M$ in 2005).

2.2.2 The funding of innovative projects and allocation of budgets

At the European level, the budgets allocated by the states are increasing more and more.

Each state finances its national space agency. Each national space agency finances the European Space Agency (ESA). The contribution of each agency's member state to the ESA's general budget is computed regarding each country's gross national product. Furthermore, each member state can contribute financially to ESA's optional programmes and chooses the amount. See the definition of ESA in the appendix, Figure 14.

Then all national space agencies and the ESA redistribute the funding to the firms.

Let's take the example of France: The French state gives funding to the Centre National d'Etudes Spatiales (CNES) and to the ESA. See the definition of CNES in the appendix, Figure 14.

The budget allocated to the CNES is rising for years. The French State invests increasingly in the CNES. In 2014, the French State allocated 1982M€ to the CNES (763M€ go to the ESA) and 2126M€ in 2015, therefore an increase of 8%.

Other French agencies are worth being highlighted:

- The Agence Nationale de la Recherche (ANR) is responsible for financing research projects in France. A part of its funding (3,3% in 2015, 17,4M€) come from other organizations working in partnership with the ANR. Therefore, there are some opportunities of co-funding that complete the ANR budgets. For instance, the ANR and the Fondation de Recherche pour l'Aéronautique et l'Espace (FRAE) created a partnership aimed to co-fund up to 50% some research projects in the aerospace and space sector.
- The Centre Français de Recherche Aérospatiale (ONERA) is considered as the French Aerospace Lab and is also administered and financed by the Department of National Defence. Its budget was 225M€ in 2014.

The Research and Development Programs in the space sector are more space exploration-related than environmental-related. For example, « Appel Espace 2016 » developed within the « Horizon 2020 », the funding program for Research and Innovation, is aimed to improve the European Space Sector competitiveness, the nondependence of the space sector and the research and development about the miniaturization of satellites. The total budget of the program « Horizon 2020 » is 79 billion €. A major part of this budget is dedicated to the robotics sector in order to explore other planets of our solar system. No budget is particularly allocated to the environmental research and development.

2.2.3 Hierarchy between the actors and project decision-making

It is generally the states which propel numerous aerospace programmes. But the main project managers are the ESA and the national space agencies.
Some programmes can also be propelled by private operators. For example, the construction of civil satellites mostly come from firms specialized in telecommunications and imagery.
See in appendix, Figure 6. the hierarchy of the main operator categories intervening in the aeronautics and space industries.

The CNRS (Centre National de la Recherche Scientifique) has built a partnership with the CNES. By the complementarity of their respective competencies, the CNES ensures the construction project and the direct funding of the project. For its part, the CNRS is responsible of providing the human and technical resources to the project. It also ensures a scientific support.

The phenomenon of coopetition is quite common in the space sector. It helps to meet the technological innovation challenges. Two companies can raise the need to mutualize some of their resources and competencies. The goal of the coopetition is not to appropriate the competitor's resources but to work hardly with him in order to develop new ideas, resources and competencies later on. For instance, Airbus and Thales Alenia Space, two major competitors in the European Space sector have led a kind of coopetition. Their common project was about creating Alphabus, a telecommunication satellites hub. The CNES and the ESA formed an institutional project team, which drawn the project. Astrium (Airbus) and Thales Alenia Space mutualized their respective human, technological and financial resources to constitute a unique industrial project team which stands as a project ownership.
See in appendix, Figure 7. the organizational structure of the Alphabus project.

The practices between the different links in the space sector chain encourage the innovation: The state gives its support to the Research and Development by funding many programmes. The coopetition used by major actors of the space sector and a collaboration developed with national research institutes also led companies to innovate more and more.

After seeing that the public funds contribute largely to the Research and Development process in the space sector, we will now see that European public regulations can have a direct impact on the space business and its innovations.

2.3. European environmental regulations impacting the space industry

2.3.1 Regulation, Evaluation, Authorization and restriction of Chemicals (REACH)

2.3.1.1 General overview

REACH is a regulation that has been implemented in 2007 by the European Union. This European directive concerns all the countries within the European Union plus Iceland, Norway and Liechtenstein. REACH is gathering more than 40 previous directives to simplify the regulation regarding chemical substances and secure their usage.

It has 3 main focuses:

- To extend the knowledge regarding environmental and health risks of chemical substances and particularly the oldest one introduced into the European market before 1981. From now until 2008, the aim is to obtain risk information for almost 30 000 chemical substances.
- To make the companies be responsible of the assessment and risks management of using or manufacturing dangerous chemical materials. The administration used to be in charge of proving the dangerous impacts of chemical components. Thanks to REACH, this duty does not belong to the administration anymore but to companies directly; and this principle is called a "reverse burden of proof ".
- To promote an innovation and substitution policy.

REACH has got 3 processes:
(1) All European industrials have to register, evaluate, control and take inventory of chemical components with their properties that there are imported or manufactured in the European Union if the quantity is above 1 ton per year. In France, companies have the possibility to contact a Free Help Desk in case they have questions about specific parts within REACH. Then, the administration decides whether the substance is dangerous for the health or the environment or not.
(2) If the risk level of the substance is low or can be managed by precautious usage, it can still be used.
(3) If there are major risk level that cannot be managed, it can either still be used under strict conditions or the substance can be banned and companies have to create a substitute.
Since 2007, the list of chemical substances is growing and the initial threshold is decreasing. In fact, in 2007 companies had to declare the use of one component only if this component was imported or manufactured from 100 tons per year, now the threshold is from 1 ton per year.

2.3.1.2 The impact on the space industry

Companies of the aerospace sector in Europe are impacted by REACH since they are using chemical components to manufacture satellites. The aerospace industry uses more than 5000 chemical components and mixes of chemical substances manufactured by several suppliers. A lot of these mixes are made from 1 to 5 substances.

So the aerospace companies need to comply to REACH or they can face charges. In France, the Environmental Public Department of each region can proceed to a control directly in site to be sure REACH is applied.

2.3.2 Restriction Of the use of certain Hazardous Substance (ROHS)

2.3.2.1 General overview

ROHS is a European directive "2002/95/EC" that is implemented in all the countries part of the European Union.
In ROHS, there are 6 substances whose usage has been restricted like lead, mercury, cadmium or chrome.
The threshold for these substances within ROHS is 0,1% per material unit weight for all except for cadmium whose threshold is 0,01%.
The aim of ROHS is to promote the collection and recycling of hazardous electronic and chemical materials to reduce the impact on the environment. Plus, ROHS is uniformizing the rules within the European Union regarding hazardous material recycling standards that used to be different depends on the country. The manufacturer is now responsible for the risk of the dangerous components used in its production and their recycling.

As ROHS and REACH are both chemical components-related, we could say that there are redundant but while REACH is only concerning chemical components, ROHS has also a focus on electronic material and their traceability.

2.3.2.2 The impact on the space industry

As for REACH, ROHS affects the aerospace sector because companies such as ASTRIUM and THALES are using electrical equipment to manufacture satellites or space rocket.

To conclude, we notice that the space sector is subject to high technical and organizational constraints. The strong interaction between the private and public actors within the space sector expresses itself on the funding of innovations, on the coordination of the projects, and on the regulations that impact the space sector as well. The sector must adapt and comply to these European regulations. The European scope is a good one to understand the specific constraints in the innovation processes within the space sector because major actors of this industry are located in the European Union.

In order to better understand the impact of regulations on the innovation in this particular sector, we have decided to study some concrete innovation cases that we have gathered under two distinct parts: the product innovations and the process innovations.
These innovations have been selected because we have estimated that they were responding to the REACH and ROHS regulations.

3. Innovations arising from REACH and ROHS regulations: Business case examples

As mentioned earlier since the enforcement of the European ‘regulation REACH, many chemical substances have been restricted and eventually should no longer be used. And since the implementation of ROHS, companies must also put in place a method for recycling these chemicals in order to reduce their emissions.
As a result, aerospace companies that are strongly affected by this regulation find themselves obliged to find alternatives, substitutes for these chemicals substances and thus innovate to replace and/or recycle them to limit their impact on the environment.
Among the substances concerned, are cadmium and chromium. These substances are mainly used for the surface treatment of metals in order to make them more resistant. Indeed, by immersing metals in aqueous baths containing cadmium or chromium (this is called cadmium and chromium plating), that gives metals resistance properties regarding oxidation and corrosion and ensures good electrical conductivity. See the definition of a surface treatment in the appendix, Figure 14.

3.1. The Chrome VI also known as Chrome Hexavalent

3.1.1 General overview

This substance is used to make baths which reinforce aluminium components and give them an anticorrosive power and a conduction of electricity. The components are immersed in these baths and the process is called the chrome anodic oxidation. It is mostly used in the surface treatment chain.
However, the Chrome VI is very dangerous for human health. It is polluting, allergen and carcinogenic. It is already forbidden in the cosmetic and food industry but benefits from a suspension in the construction, aeronautics and aerospace sectors. In September 2017, the European directive REACH will ban the utilization of chrome VI. For now, many chrome components are subjected to a permission under the annex XIV of REACH.

For the surface treatments, the aerospace sector represents 5% of the user sectors. For the chrome VI-using processes, the aeronautics sector represents 15% of the user sectors. In the aeronautics and aerospace sectors, the components concerned by the using of chrome VI are safety components subjected to strong mechanical and thermal constraints.
See in appendix, Figure 8. the distribution of the industrial sectors using the chrome VI in their processes.

3.1.2 The surface treatment processes are going “green”

In order to anticipate the regulations effects, but also to acquire a “green” brand image, the industrials work on substitution solutions for many years.
As we can see in the following table, many substitutes have been found in the aeronautics sector. They are mainly Surface Treatment Process Innovations, as we have decided to call them.
As the materials produced in the aeronautics and aerospace sectors are likely similar and the production methods closely linked, one can consider the use of these process and product substitutes for the aerospace sector.

Sector	Process substitutes	Product substitutes	Details
Aeronautics	Surface Electro Initiated Emulsion Polymerization (SEEP)		Formation of an electro grafted polymer film on the product's surface, compatible with the used paint on metals (titanium, aluminium and its alloys, stainless steels, ...).
Aeronautics	Cobalt salt baths		Boeing often makes use of this process and has got patents about this technique.
Aeronautics/ Space	Anodizing, especially the Tartaric sulphuric acid anodizing (TSA)		Technique used by Airbus : a thin oxide layer on the component's surface, with good properties and corrosion resistance.
Aeronautics/ Space/ Nuclear	Electrolytic deposits of zinc-nickel		It procures a good corrosion resistance to the component. It enables the suppression of acid-chromium-containing passivation.
Aeronautics/ Space/ Nuclear	The Physical Vapour Deposition (PVD) method		A dry process used to make thin layer on component's surface. The German airline company Lufthansa uses this technique.
Aeronautics		Chrome	It can easily be hardened by thermal treatment but can't replace the chrome VI for all the applications. The Chrome III constitutes only a transition stage before the chrome-free stage. But it is an attractive solution for companies : they make savings (low energy consumption, in terms of discharge treatment processes, security measures and staff protection).
Aeronautics		Combinations between nickel, tungsten, bore and cobalt	On a case-by-case basis.

Other sectors are using chrome VI also. The automotive industry, which also uses chrome IV, is more advanced in terms of processes industrialization and product substitutes: Chrome III-based passivation (less efficient but acceptable quality), fluoride and titanium-based salts, coating with a combination of zincs such as zinc-nickel or zinc-cobalt (more corrosion-resistant but the biggest inconvenient is the cost), galvanized-steel passivation, and so on.

All these substitutes solutions can hardly be applied on the short-term to the aerospace sector given its specifications as shown in the second part of our research paper. The requirements are higher and more technical in the space sector. The products' performance needs to be the same whatever the process used. Moreover, the process' substitution is entirely linked to the customer's will towards its subcontractors. These latter have to convince them of the introduction of a new chrome-free-production process for key components.

3.2. The Cadmium

3.2.1 General overview

In the area of metal surface treatments, it is estimated that industries using cadmium are 90% aeronautics and 10% are aerospace. But the cadmium waiver (implemented in 1994) which has conferred a reprieve to the actors of these industries, comes to an end. This is why the companies involved in this sector are mobilizing and actively seeking solutions to replace cadmium. Like for the Chrome VI, we consider that materials produced by the aeronautics and aerospace sectors are similar in terms of technical requirements. That's why one can also consider the following substitutes as belonging to the aerospace sector, so the space sector.

3.2.2 Substitution solutions

If for a long time substitutes appeared utopian, nowadays the resolution of the cadmium case approaches. But it seems that there is not only one "best" solution but several ones.
In fact, several solutions are at the development phase or even already patented by different companies. These so-called substitute solutions consist in replacing cadmium with other chemical elements in the aqueous baths in which the materials are soaked.

3.2.2.1 The alkaline zinc-nickel solution

It is the most developed substitute by the aerospace companies. For example, this is the case for SAFRAN which, in its aqueous baths, has replaced cadmium by an alkaline (pH of the water is between seven and fourteen) zinc-nickel process. And the company has already delivered the first parts treated by this new bath to Dassault aviation for the front axle of the Falcon 8X. But this solution is not unanimous. The aviation sector, and even more so the space sector as shown in the second part of our research paper, is subjected to strong technical constraints. It is therefore necessary to convince customers that this new process is just as effective as the old one. And also make the suppliers and subcontractors adhere to this new procedure in order to have uniformity in the surface treatment of parts. But this will not be long, since SAFRAN has the ambition of no longer using cadmium for the treatment of surfaces of all the parts produced by the companies.

3.2.2.2. The solution of an aluminium zinc coating

Another solution developed by some players in the sector is to replace cadmium by an aluminum zinc process. The positive points of this substitute are that the zinc aluminium mixture seems to possess the same properties as cadmium, i.e. a high resistance to corrosion as well as good rigidity. In addition, zinc has excellent conductivity and costs are lower than with cadmium. However, for the moment this process is not used regularly on an industrial scale, which may be due to the fact that the aluminium, according to specialists, seems to be less resistant to hydrogen Space / interstellar medium. This process has not yet been patented, it is nevertheless referenced by the site sponsored by ANSES (National Agency for Food Safety and Food) which identifies the substitutes existing for the chemical agents that are carcinogenic, mutagenic and toxic to reproduction (CMR). However, companies in less technical binding sectors are beginning to use this solution to replace cadmium.

All these above-mentioned innovations, concerning both Chrome VI and Cadmium, can be designated as surface treatment process innovation. As seen in our first part, this is because those solutions possess all the characteristics of a process innovation. Indeed, these innovations all consist in an implementation of a new way to do surface treatment. Furthermore, they imply a deep changes of material used instead of using cadmium now one will use a mixture of different chemical agents in the surface treatment process.

3.2.3 Techniques for limiting releases of harmful cadmium compounds

With ROHS regulations, in addition to restricting the use of cadmium for surface treatment, companies in the aerospace industry must also innovate in terms of recycling this substance in order to limit the emissions of harmful compounds into the environment. A lot of solutions are in study but for now none are still used on an industrial scale. Here are some examples of the most promising techniques.

3.2.3.1 Use of hyper-accumulative plants

A hyper accumulator plant is a plant capable of storing in its tissues a high or even very high quantity of one or more elements, generally using bioaccumulation. In the case of cadmium, a plant is said to be hyper-accumulative since it has a cadmium content greater than 0.1 mg per gram of dry matter. There are three kinds of hyper-accumulating plants for cadmium:

- Thiapsis caerulescens
- Arabidopsis halleri
- Solanum nigrum

The method will consist in using the bark of the accumulating plants at the end of the cadmium process, that is to say when the cadmium is discharged into the waste water. To allow more cadmium to be accumulated, chemical modifications can be applied to tree bark. In order to obtain maximum absorption, special conditions must be met. For example, in an acid medium (higher pH) the plants absorb more cadmium, as shown in the table in appendix, Figure 9. The positive point of this method is that these plants have good absorptive capacity and can accumulate up to 116 micrograms of cadmium per gram of dry matter.

3.2.3.2 The use of fungus

Fungus aspergillus fumigatus plant makes it possible to decontaminate the waste water polluted by cadmium. The positive point of this fungus is that it has 5 cycles of regeneration and is effective for high concentration of cadmium. It also has a capacity of absorption of the product close to the 100%.

These two new techniques can be designated as recycling process innovations. and organizational innovation because it will implement a new step in the production: the recycling part is a new way to produce with new materials and also a new way to organize the production scheme.

3.3. The Nickel

3.3.1 General overview

Like cadmium and chromium, nickel is one of the chemicals covered by REACH and also by ROHS. Nickel, like the two other chemicals mentioned above, is used mainly for the surface treatment of metals. Nickel plating provides corrosion resistance properties. The nickel is deposited by electrolytic treatment using the redox principle. The metal to be treated is in fact immersed in a bath containing the nickel in the form of salts. An electric current is then imposed in order to force the reaction where the nickel is depositing in solid form on the metal.

This method and the use of nickel is called into question by REACH because of the harmfulness of the nickel salts. Indeed, the most used nickel salts such as nickel sulphate and nickel chloride are categorized as carcinogenic and dangerous for the environment.
There are currently few substitution technologies for nickel plating, as nickel plating is not widely used in the aerospace industry for scientific research in its own right. However, we found two alternative techniques.

3.3.1.1 Kanigen's chemical nickel platin

It is a method of chemical nickel plating according to a particular process and patented by the company Kanigen. The method consists in using a nickel-phosphorous mixture which is applied by a self-catalytic process, called the Kanigen process. This process, patented by Kanigen, is therefore the property of the group and complies with the REACH regulations. See the definition of an autocatalytic process in the appendix, Figure 14.

3.3.1.2 Replacement of NiP (Nickel Phosphorus) by FeB (Iron and Boron Mixture) in Chemicals Electrolysis

This technique is still under development and will only apply to copper. This process to replace NiP by FeB in the chemical process of copper protection. The tests found properties equivalent to those provided by NiP. The crystal structure would be similar as well as resistance to corrosion.

Like for the substitution solutions for the cadmium, these innovations can be named as surface treatment process innovation.

To summarize the results of these first business cases, the innovations are due to the fact that diverse basic parameters in the process have changed, like the pH, the temperature, the chemical components, the stay duration in the bath and so on. But the aim of REACH and ROHS regulations is to promote radical change and strictly new innovations. In these first business cases, often, companies are replacing one dangerous substance by other materials.

3.4. Process Innovation within Airbus Defence and Space

3.4.1 New quality and security processes

In 2007, Airbus Defence and Space (previously Astrium), known as a leader in the spatial sector for the manufacturing of space engines like satellites, has officially integrated new processes following the implementation of REACH regarding its supplier relationship management.

Within these new processes, it’s mandatory for the suppliers to join a security form for the forbidden components.
We have decided to classify these new quality guarantee requirements for the authorized suppliers of Airbus Defence and Space, that did not exist before REACH, as process innovation given the Oslo manual. In fact, these mandatory requirements have an impact on production and purchase processes. The materials bought from Airbus Defence and Space to its suppliers are used in the satellites and other space engines manufacture.
The forbidden substances like mercury, zinc or cadmium are often used in the space sector. The company has taken into account the REACH regulation and has changed its supplier relationship management to comply to REACH regarding quality issue. In order to go more in details, we have decided to define the new requirements as a quality process innovation.

In case where suppliers are using forbidden or dangerous materials listed in REACH, they will have to provide complementary documents. These documents are mandatory to justify that the risk level is low as shown in the appendix Figure 10., about Astrium Quality insurance requirements for the suppliers related to REACH.

3.4.2 An organizational and managerial response

Airbus Defence and Space has created a section within its Advanced Protections Material & Processes Laboratory in order to respond quickly to the new challenges that the company is facing because of REACH. The aim behind this new section is to anticipate the new requirements of the environmental regulations and not only react to it when there are already effective.
The company wants to promote eco conception, that is to say, to produce its space engines with the smallest environmental impact as possible from the beginning of the design and conception phases.

Given the Oslo Manual, we can define this new section as an organizational innovation. The new section within Airbus Defence and Space has got the mission to anticipate the future impacts on the business of environmental regulations.

Moreover, within the Airbus and Safran joint venture, they are looking to hire dedicated human resources, with a high level of expertise in chemistry and environmental regulation such as REACH. So we could go further in our analysis and define this section as a managerial organizational innovation. As the appendix Figure 11. highlights in the position offer within Airbus Safran Launchers Issac, we can see how cross functional the mission is. In fact, the "REACh & Obsolescence Materials & Processes" Engineer will work with different departments such as Health and Safety, Design and even with suppliers and subcontractors. That proves that it represents a new way of anticipating environmental regulations.

Moreover, at Airbus UK, one has created cross functional projects resulted from REACH regulation under the CARMEN (Corporate Advanced REACH Management and Efficient Networking) designation, which aim is to gather people from different departments like Procurement, Communication, Health and Safety, IT, Legal departments. The targets of these projects are to reduce the negative impact of REACH in terms of costs and product obsolescence. We have defined these new way of dealing with REACH regulation as managerial organizational innovation also because the company tries to reduce the boundaries between each department to work on projects that will reduce the impact of REACH within the group.
See in appendix, Figures 12. and 13. two extracts of a presentation of Airbus UK.

In this third part, the organizational innovations that resulted from REACH highlights that companies within the space sector like Airbus Defence and Space or Safran want to comply to the regulation and its standards. But they are also looking for the reduction of the risk impact on their organization in terms of cost and profitability.
Given the confidential nature of the innovations treated by the subject, it may exist other product or process innovations that could be relevant as well, but for which it is very difficult to find information.

4. Conclusions

4.1. Results versus Expectations

In conclusion, the innovations treated in the third part of this research paper are all responding to the European Regulations REACH and ROHS - as previously mentioned. The production, quality and the ways of working are affected and it is in this context that we can talk about innovations in the space sector that resulted from environmental regulations.

The studied innovations are more process (Surface Treatment Process, Quality) and organizational (Managerial Organizational) focused.
On the one hand, we have noticed that the process-focus innovations were borrowed from more advanced-sectors like automotive or aeronautics ones. The organizational-focus innovations are designed as “rules of conduct” to comply with REACH and ROHS requirements whereby the company is responsible of the risks management of using dangerous elements.

On the other hand, the subcontractors of the aerospace sector have applied several substitution solutions but more researches have to be done to completely satisfy their supply and be in line with REACH. Space sector's actors have found substitutes to Chrome VI and Cadmium, two dangerous substances listed by REACH and ROHS.
Given the technicality of the products produced by the space sector, it is hard to find product innovations strictly speaking. Indeed, companies generally find alternative raw materials or substances to use for the production of space engines.
In that sense, we could say that REACH and ROHS may not have fully reached one of their goal: to promote essentially strictly new innovations. But we consider that we are lacking of technical knowledge to conclude if the innovations in our business case are radical (strictly new) or incremental (improvements) one.
But REACH and ROHS have managed to inform companies about environmental and health risks of some chemical substances. Plus, they have succeeded in reducing the usage of dangerous chemical components that have a negative impact on Environment. These two points are also two other targets of REACH and ROHS.

As the space sector is rather a secret one and all information are not fully disclosed, we may not be aware of the achieved results above-mentioned and of other types of innovation that might have arisen. Therefore, it is important to highlight that our results described in this research paper must be nuanced given the limited knowledge of the space sector that we have and our limited capacity to evaluate the degree of novelty of innovations.

4.2. REACH and ROHS: some improvements in terms of compliance assessment

Concerning REACH and ROHS regulation, there are some positive points that show that there are well-designed. REACH is banning gradually dangerous chemistry substances and that might in the long term encourage radical innovations. By banning chemical components, the aim of REACH is clearly to enhance radical innovation. Companies will have no choice but to find new substitutes.

Plus, REACH is gathering more than 40 previous directives, that is easier for companies that need to comply only to one European regulation and not to several ones.
For Knut Blind (2012), efficient environmental regulations have to concern several countries in order to enhance in the long term innovation and international competitivity, and it's the case with REACH and ROHS as there are applied within the European Union.

Finally, as Stefan Ambec, Mark A. Cohen, Stewart Elgie, and Paul Lanoie (2011) highlight in their article, an efficient environmental regulation must be gathering relevant information in order to share the best practices technologies. Companies could inspire them from what the others have done to reduce their negative impact on the environment. With REACH, information is gathered about how dangerous a chemistry material can be, so the other companies can anticipate and invest in substitute solutions.

With ROHS the recycling responsibility is on the manufacturer, which is responsible for its own waste. The notion of responsibility is for the first time addresses toward companies and that's a first step to make companies be aware of their duties.

If we could point out one thing that is reducing the impact on innovation of REACH and ROHS, it would be the lack of compliance assessment and controls. If companies were under strict audit and had to pay taxes, if they did not respect the regulation, it would be more efficient. There is already an audit system but we are aware that providing a regular control in every company concerned by REACH and ROHS requires additional financial investments from governments.

4.3. Some recommendations

Through our research we have found that the space sector has to respond to many technical and organizational constraints and that does not necessarily promote "green" innovation to comply and anticipate the environmental regulations. This is why we believe that it would be wise to review the communication between each actor and the way in which innovation is financing. Indeed, we found that once the money is allocated to companies or to research institutes, there is no upstream monitoring and downstream evaluation to verify whether space companies have integrated in their research and development all the requirements set up by environmental regulations like REACH and ROHS.
This is probably due to the fact that space agencies, such as CNES for example, which deal with the reallocation of state funds to the various players in the industry, are very oriented towards the conquest of space. Consequently, they do not necessarily have the competences (legal in particular) necessary to understand environmental regulations issued by the European community.

In order to achieve the objectives expected by environmental regulations in the space sector, consideration should perhaps be given to provide legal support for the understanding of laws and environmental constraints to the engineering teams.
It might be worthwhile to create an audit system at each stage of the innovation process that would ensure that engineers and researchers conduct actions that are consistent with legislators' expectations.

Appendix

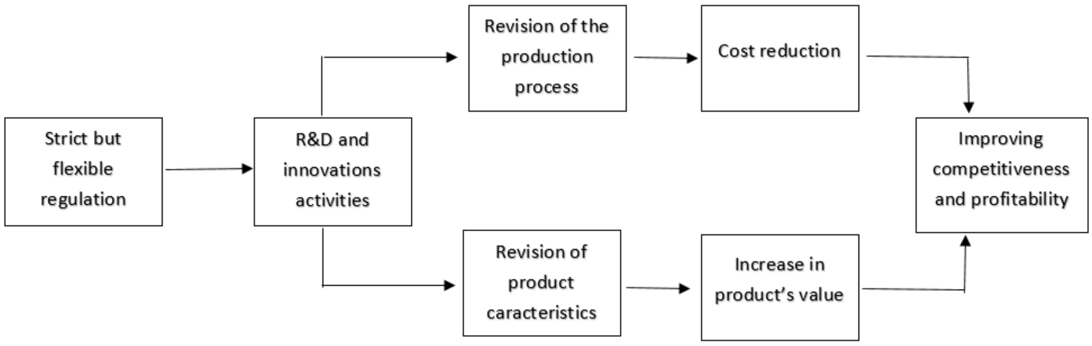

Figure 1. A schematic representation of the Porter Hypothesis.

ISO Technology Readiness Level Summary	
TRL	**Level Description**
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof-of-concept
4	Component and/or breadboard functional verification in laboratory environment
5	Component and/or breadboard critical function verification in relevant environment
6	Model demonstrating the critical functions of the element in a relevant environment
7	Model demonstrating the element performance for the operational environment
8	Actual system completed and accepted for flight ("flight qualified")
9	Actual system "flight proven" through successful mission operations

Figure 2. The different levels of the TRL scale.

Figure 3. The sequence of the TRL scale.

	Military & Defence Market	Scientific Market	Commercial Market
Satellites' manufacture	Institutional & Strategic	Strategic	Open to competition
Launcher's manufacture	Institutional	Strategic	Open to competition
Satellites orbiting	Institutional	Open to competition	Open to competition

Figure 4. International space activity segments.

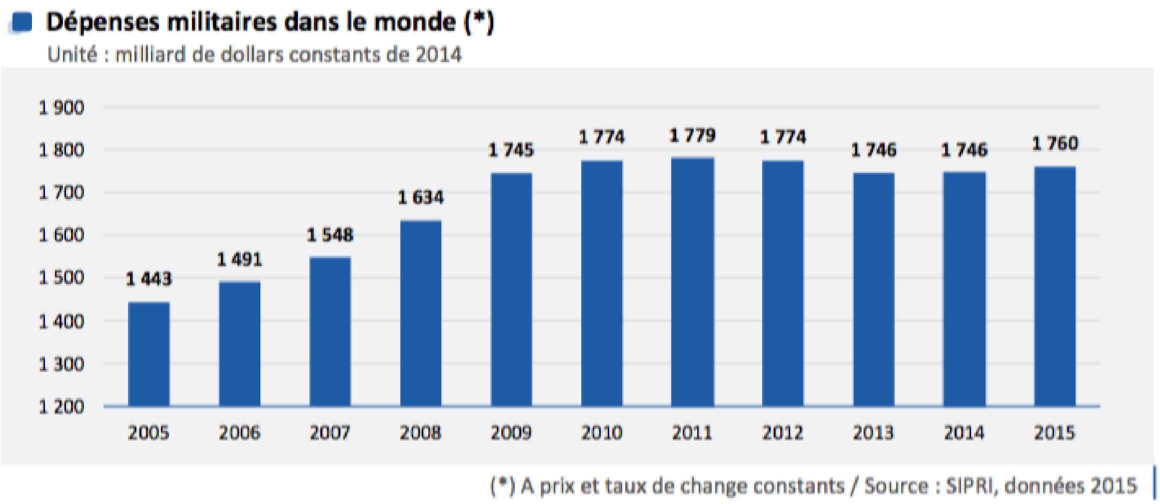

Figure 5. Military spending in the world. *Source : Xerfi*

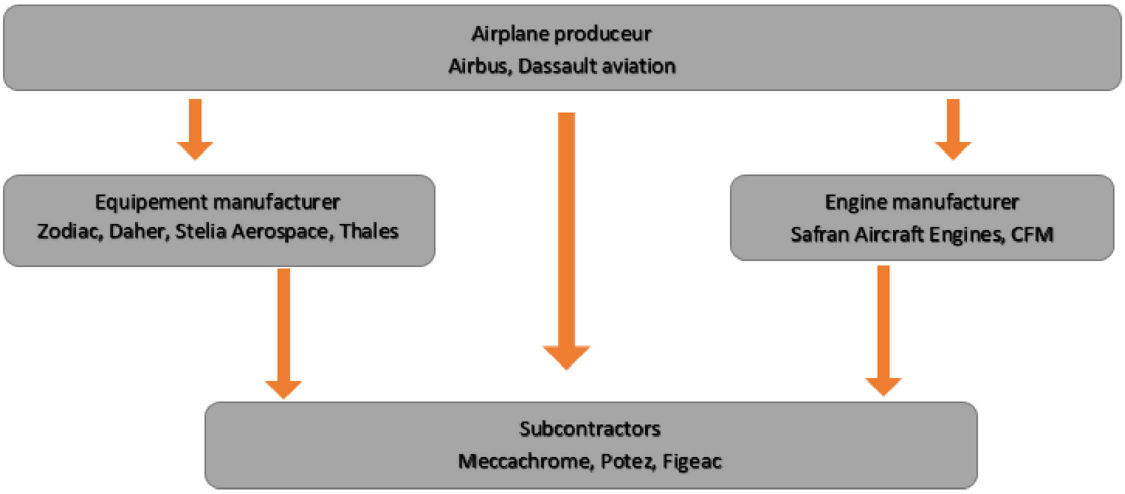

Figure 6. The hierarchy of the main operator categories intervening in the aeronautics and space industries.

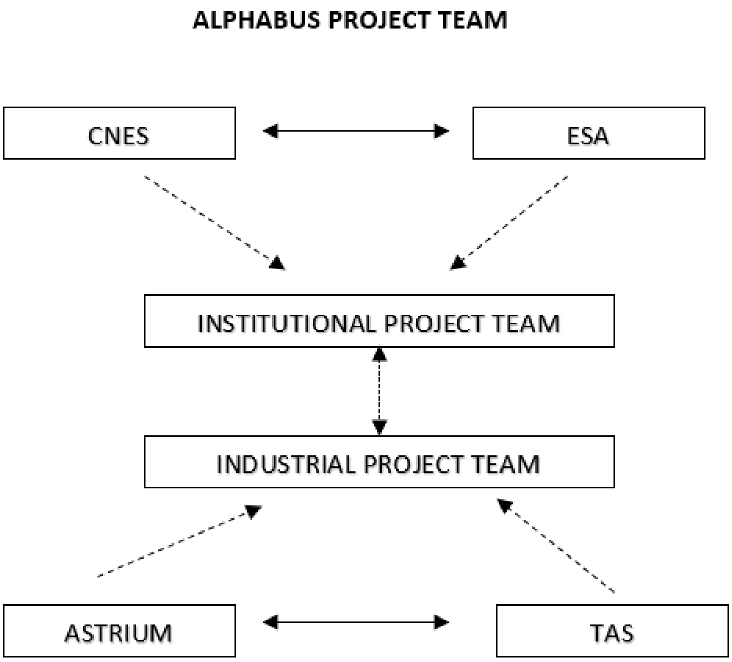

Figure 7. The organizational structure of the ALPHABUS project.

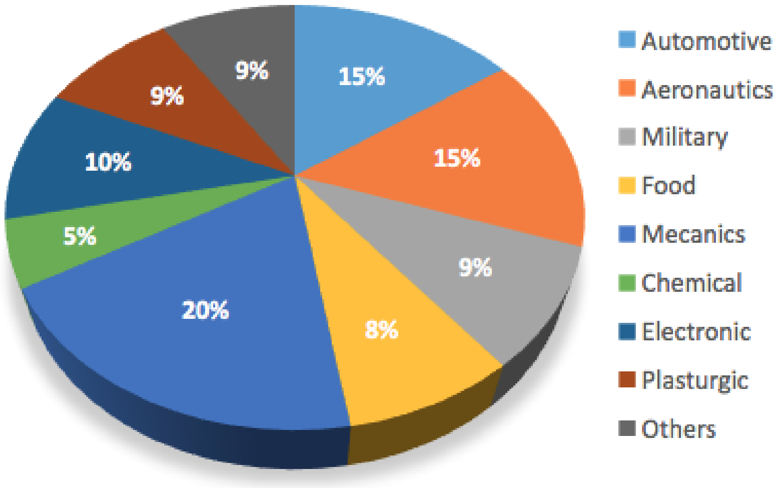

Figure 8. The distribution of the industrial sectors using the chrome VI in their processes. *Source: Traitement de surface: substituer ou à défaut, réduire et maîtriser l'exposition au chrome hexavalent.*

	Lead	**Cadmium**
pH	Maximum quantity absorbed (méq.g^{-1})	Maximum quantity absorbed (méq.g^{-1})
1	0,050	0,061
2	0,122	0,113
5	0,264	0,199
7	0,030	0,099

Figure 9. Influence of the pH on the maximum quantity of lead and cadmium absorbed by the Douglas' firs raw barks.

5.3 MATERIAUX INTERDITS
Les pièces et composants contenant les matériaux suivants, sous quelque forme que ce soit, sont interdits, excepté lorsqu'ils ont fait l'objet d'une autorisation formelle par le service qualité des Produits Industriels d'ASTRIUM Satellites, pour un cas précis :
- zinc et cadmium ;
- mercure ;
- substances radioactives ;
- étain pur (revêtement électrolytique ou fondu, défini comme matériau composé d'au moins 97 % d'étain) ;
- polychlorure de vinyle (PVC).

Pour les articles avec finition de surface métallique, le certificat de conformité doit comporter une mention certifiant que le matériau ou sa surface ne contient pas d'alliage composé à plus de 97 % d'étain, qu'il soit déposé à chaud ou électrolytiquement.
Toute proposition par le fournisseur de dévier de cette exigence doit faire l'objet d'une RFD pleinement justifiée et démontrant que le niveau de risque associé au matériau est acceptable (voir § 5.8.1).

5.24 FICHE DE SECURITE
Pour les produits chimiques, la dernière version de la fiche de sécurité des matériaux (MSDS) doit être fournie à chaque livraison. Chaque mise à jour appliquée à la MSDS doit apparaître explicitement. La MSDS doit être rédigée dans la langue du destinataire et être conforme à la directive européenne REACH EN N°1907/2006, annexe II.

Figure 10. Astrium Quality insurance requirements for the suppliers, related to REACH

REACh & Obsolescence Materials & Processes Engineer (m/f)
Airbus Safran Launchers Issac
Tâches et missions principales, responsabilités
Within this context, your main tasks and responsibilities will include: Implying a permanent survey of constantly evolving regulations, Analysing in-depth our products and of substances either procured or implemented by Airbus Safran Launchers Defence and Space, Enabling design offices to account for associated design constraints in developments, Interfacing with various offices like procurement, quality assurance, health & safety, design, manufacturing and control as well as with suppliers and subcontractors.
This role will involve frequent travels for business (once a month) in France and Europe and as such you must be able to travel accordingly.
Compétences requises
We are looking for candidates with the following skills and experience: Educated to 5 years Degree level (or equivalent) in Materials and ideally in Chemistry, 3 years of experience in supply quality or process materials or chemical engineering, Ideally good knowledge of the REACH regulation and obsolescence treatment, Knowledge of SAP-EHS is a plus, Team spirit, Advanced level of English and negotiation level of French.

Figure 11. Airbus Safran Launchers Issac, REACh & Obsolescence Materials & Processes Engineer offer

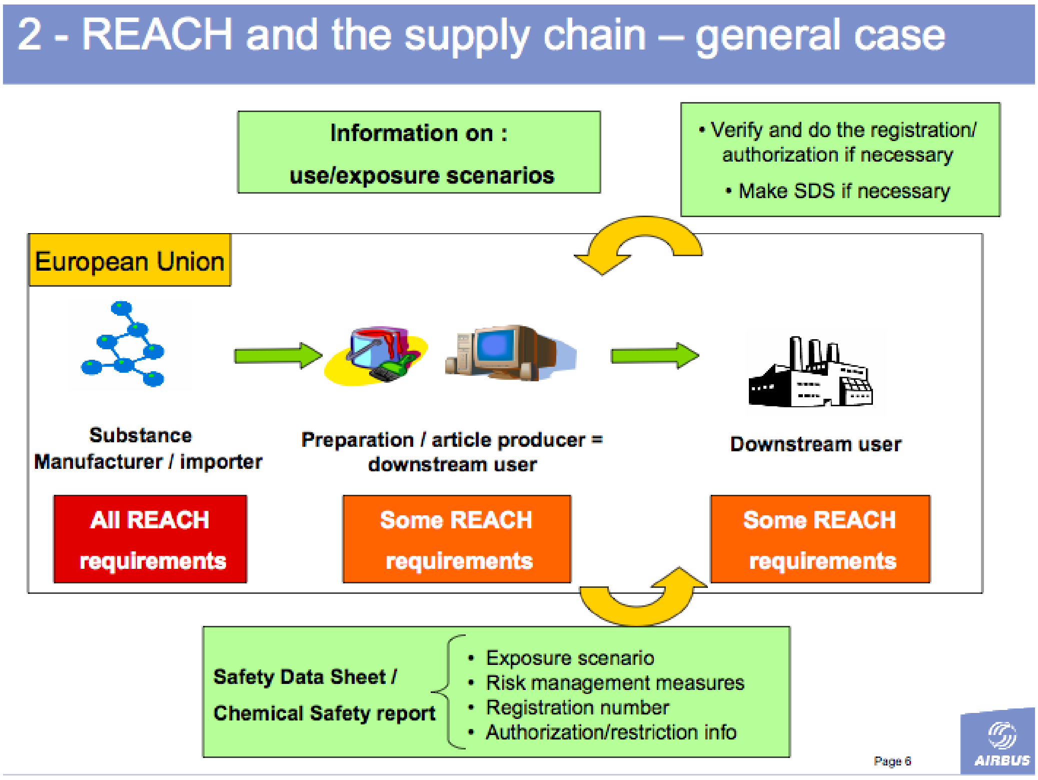

Figure 12. Presentation of Airbus UK (1). Source: Practical implementation of REACH (Airbus)

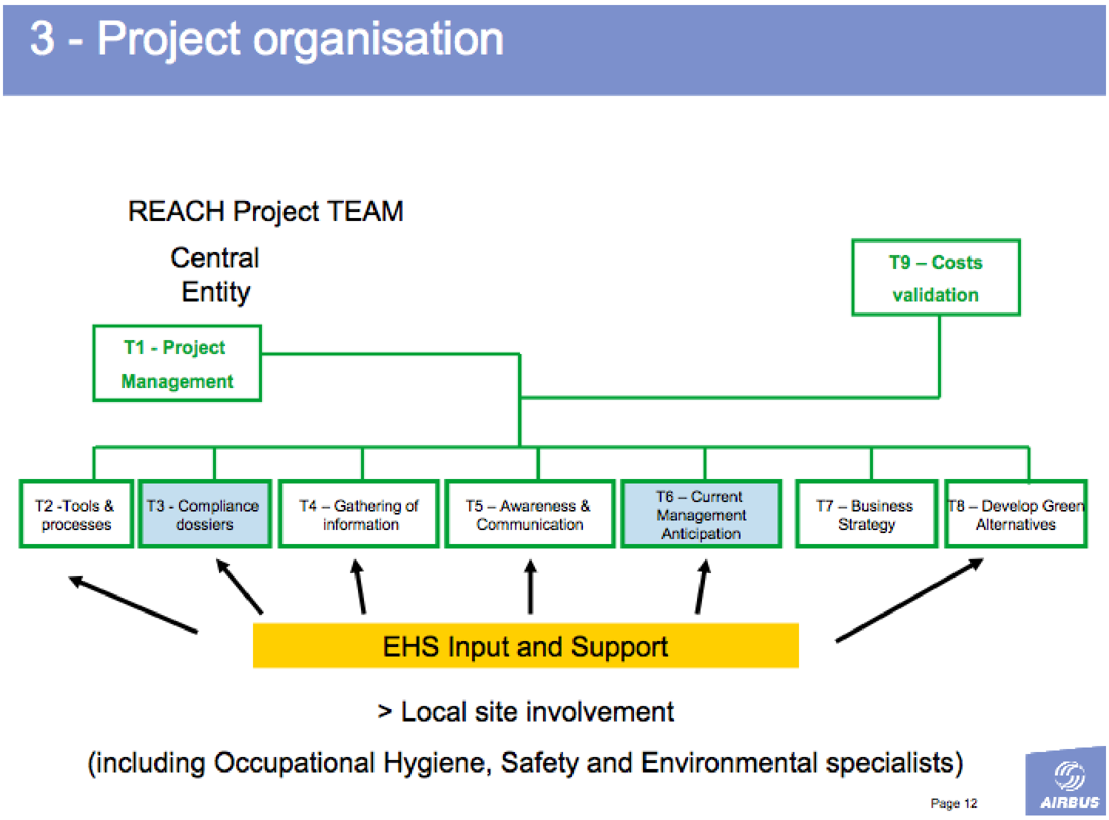

Figure 13. Presentation of Airbus UK (2). Source: Practical implementation of REACH (Airbus)

ESA: An international organization which enables the development of Europe's space capabilities. Its 22 member states coordinate their financial and intellectual resources to put in place important space-related programs and activities.

CNES: A French public organization in charge of the French space program development. Its 5 main strategic fields are: Ariane, Sciences, Observation, Telecommunications and Defence. The CNES is one of the most important space agencies in the European Union. Indeed, the French budget per inhabitant for the space sector is the second most important in the world (30€/year/inhabitant) after the United States' one (46€/year/inhabitant). The CNES is administered by the Department of National Defence.

Autocatalytic process: An autocatalytic process is a chemical reaction whose catalyst (here phosphorus) is among the products of the reaction.

Surface treatment: A mechanical, chemical, electrochemical or physical operation which has the consequence of modifying the appearance or the function of the surface of the materials in order to adapt it to given conditions of use.

Figure 14. Definitions

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