論文

IDENTITY, ORGANIZATION AND FUNCTIONING OF A FRENCH PHOTONICS CLUSTER: THE CASE OF OPTX(1)

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Abstract: The work of producing knowledge and skills cannot be done by professionals alone. How are knowledge, technology, or management systems established? This research focuses on various actors who work in industrial clusters in the knowledge creation process, by observing the "space" in which they are involved. This paper is a monography on the functioning of a 'competitive cluster', namely OPTX, a photonics technology-based cluster located in the South of France. The survey was carried out with qualitative methods such as fieldworks and personal interviews during 2017-2018. The OPTX cluster is a community composed by companies, labs, institutions of higher education and innovation partners. Considered as one of the European top class competitive clusters, it plays a key role both in industrial development and in technological advancement in the field of optics/photonics and image processing. To forge an 'ecosystem' favorable for the development of SMEs (Small and Medium-sized Enterprises), the cluster works in different fields of strategic activities (science-industry collaboration, patenting, marketing etc.), targeting high-potential growth markets. It was found that for SMEs, OPTX plays the role of interface with the major groups and outsourcers in the photonics sector.

Keywords: Cluster, Pole of competitiveness, University-industry collaboration, Knowledge transfer, Collective competence

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1. The community of practice: the interactive processes of building collective competence within a group of SMEs

1-1 How is the competence of a company, an organization or a collective fabricated from the multiple skills and knowledge of individuals? And how can one ensure that this process continues thanks to the widening and / or deepening of the knowledge and skills of individuals induced by their belonging to this collective? It is a question of understanding how, on the one hand, a common collective competence attributable to the organization from the qualifications of the members of the same collective can emerge and on the other hand, how this knowledge renews the knowledge of the individuals engaged in the process of creating new products, new services or new processes.

In general, we consider that the sum of individual competence naturally leads to the existence of a collective competence that they form. Also, we tend to consider it normal that these individuals enrich themselves from it, and this type of interaction as obvious or self-evident. However, we intuitively recognize that these processes are a well-organized construction which is only possible if the qualifications of the individuals are compatible and complementary with each other for a given activity, that such coordination requires a positive learning attitude and the confrontation of varied knowledge, and finally that the cooperation between these individuals is essential. It is also obvious that the collective learning interactions are

only possible if the objectives, the organization, and the strategy of the collective are well established from the outset.

1-2 In our present survey, we place ourselves in a position to observe how the general objective of these interactive processes is to aim at accelerating technological innovations, that is to say the collective action of putting, successfully, new products or new services on the market.

1-3 Our main observation field is on a so-called “pole of competitiveness”. This French policy mainly targets SMEs and aims at grouping SMEs and academic organisms in a local site, called a “cluster” (M. Porter 1998)[(2)]. Many observations made in the past show that such an organization would allow the SMEs to absorb more easily and more quickly new technological knowledge and skills and to get access to new markets. Networking in such a “cluster” is therefore considered to be an effective way of developing synergies between the different institutions, organizations or individuals, by disseminating innovative practices and thus improving the competitiveness of partner companies.

1-4 We then seek to know what the leadership of a “cluster” concretely does in order to create this type of virtuous cycle. How does it make use of the existing individual skills or coordinate them in a collective way, to make the SMEs innovative? This question also refers to that of a ‘community of practice’ (E. Wenger 1998)[(3)] that emerges through the interactions between the SMEs that make up the competitiveness cluster. For this purpose, we undertook an empirical approach to organize the direct interviews with the persons involved. During the period of 2018-2019, we visited this OPTX site twice and arranged two collective meetings with the members of the leadership that were followed by several telephone conversations. Materials for the redaction of this paper are made up of annual reports, collected documents and interview notes.

In this monograph, we will successively 1) deal with the general features of this competitiveness cluster, OPTX, 2) present a short history of this agglomeration of various actors (SMEs and research organizations, large groups, etc.), 3) describe the objectives, strategies and resources they possess, 4) present the financial contribution of the partners 5) detail the governance of the cluster and the skills of the managing team and 6) depict the concrete actions within the cluster, and in particular, the coordination of platforms.

2. Definition of the pole, some characteristics and its environment

Located on the northern academic campus of Marseille, OPTX is presented as "a competitiveness cluster dedicated to "deep tech" in photonics and imaging. For more than 15 years, OPTX has led an ecosystem of 220 players, made up of industrial partners, research and university establishments and training organizations. Its first ambition is to encourage and support breakthrough innovations, sources of wealth and job creation on this site." (presentation of the cluster's handbook)

2-1. Definition of French cluster

OPTX is more than a "cluster" that spontaneously emerged in a given locality; it is what the French economic policy calls a "competitive pole". Based on Michael Porter's work, we would say that a "cluster" corresponds to "a group of companies and institutions sharing the same area of expertise, geographically nearby, interconnected and complementary".

In our opinion, the French term "pole" adds one more dimension in the sense that "there is within it a **main actor**—designated by the public authorities—who has an animation function of all participants" (Director's interview).

The poles of competitiveness in France are indeed the result of the policy of the French State, promulgated in 2004, which had three simultaneous objectives: 1) industrial development based on research-industry cooperation, 2) support for SMEs and 3) development of the territory. They are defined by the 2005 finance law as "the regrouping on the same territory of firms, higher education institutions and public or private research organizations which are intended to work in synergy to implement innovation projects for economic development".

The law NOTRe (2015)[4] on the new territorial organization has given new powers to Regions, which are increasingly main stakeholders in the fields of economy and innovation. This law reinforced the role of regions in defining the economic strategy and the local development. They become in charge of drawing up a regional plan for economic development, and innovation; coordination on their territory of all actions in favor of the economy (public aids to businesses); the animation of competitiveness clusters. The new systems based on the law NOTRe allow the creation of public subsidies and a specific tax regime for a group of activities or industry grouped together as the pole of competitiveness.

"The poles are officially recognized by the State and are jointly commissioned by the State and the local authorities (communes, regions etc.). In particular, the pole has a labeling role for the ANR (national research agency)[5] and FUI (single inter-ministerial fund)[6] projects. In fact, we have an expert role on behalf of the State. Some State funding is subject to "labelization" by the clusters: the clusters therefore work upstream to assess the quality of the projects submitted. We evaluate projects both on their innovative character, but also on their economic viability. We have somehow public service missions". (Director's interview)

Unlike other clusters in the sense of M. Porter, the French competitiveness clusters therefore have a strong link with public actors, as shown by the citation above and also by the skills of certain members of the managing team in "public action". The capacity to have relationships with these various public actors to understand their requests is a skill sought by the cluster, as we will see below.

2-2. The environment of the OPTX cluster

From the scientific point of view, the region of South-France concentrates 20% of French R &D activities in the optical sector. A number of universities and engineering schools, including Centrale Marseille, produce each year an average of 150 engineers and PhD students in this field. Several renowned laboratories (Fresnel Institute, Marseille Astrophysics Laboratory, Inria, Onera, CEA, Cemagref, Ifremer, among others) employ nearly 1,500 scientists often involved in several major international scientific programs: Iter (experimental reactor for controlled fusion), ELT (giant space observatories), Antares (underwater telescope on the neutrino and dark matter track), Virgo (interferometer listening to the curvature of space-time).

The OPTX pole is also located on a site that concentrates a strong industrial potential. The South of France is indeed the second region of optics-related industries, behind Ile-de-France (Paris region), and employs approximately 10,500 people in a large industrial sector including SMEs of few employees, start-ups born from the spin-off technology of university laboratories (Silos Technologies, Realviz, Lumilog, Light Technologies etc.), but also international groups (Thalès-Alenia Space, Dassault Systemes, ST Microelectronics, Gemalto etc.) and some world leaders in the niche markets (Seso in optical components for X-rays, Cybernetix in robotics, Optis in optical calculation …). The whole has already locally reached the level of almost 735 million euros in economic outcome in the early 2010s. Given that by 2017, OPTX is still expanding to the Occitanie region (notably Toulouse), this will improve industrial attractiveness and business opportunities for the SMEs of the cluster.

“The idea was not to expand for the sake of expansion, but to meet the needs of businesses in the Toulouse area. And in fact, synergies and crossovers between what was done in the PACA region (Provence-Alpes-Côte-d’Azur) and the Occitanie region have been already well identified. The goal is to create a Mediterranean arc of photonics. In Europe, the competitor is Germany. Our ambition is to create a large space which could become a major competitor to the regions as they exist in England or Germany.” (Director’s interview)

In total, the consolidated turnover of the sector covered by OPTX will rise to almost 1.6 billion euros.

The choice of Toulouse appeared as the “coherent extension” to expand a network of synergies and crossovers that could unite large groups (Essilor International S.A[7], Spherea[8]), innovative start-ups (Epsiline, Innovsys, T. Waves, Wynsep), and expert laboratories from optical field. In this regard, this physical set-up in Toulouse seals a series of collaborations and partnerships already engaged with CNES[9], ONERA, LAAS-CNRS (Robotics lab) and the École de Sup’Aéro[10].

In addition to the advantage of proximity with these regional institutions, OPTX especially sees in Toulouse “an industrial and academic richness” which will allow it to aggregate new partners as part of a development strategy, on the one hand, and on the other hand, to consolidate and enrich its competitive potential to compete on the international arena. Furthermore, the choice of Toulouse was also determined by the density of its scientific and entrepreneurial fabric in terms of optics relating to embedded systems in the space and airborne sectors, detection and monitoring for constrained environments, and photonic instrumentation for biotechnology and medical imagery.

2-3. OPTX as a competitiveness cluster with a European dimension

“Recognized by Europe as key technologies, alongside micro and nanotechnologies, photonics and imagery open up tremendous growth prospects for the industry: estimated at 447 billion euros in 2015, the market shows a forecast of 8% growth for 2018. OPTX is the major French pole in photonics and imagery and 5 th European photonics cluster. It aims to consolidate its international positioning, via:

- enhanced cooperation with European clusters and players (Spain, Germany, Italy, Netherlands, United Kingdom, Sweden, Finland, etc.),
- the creation of a network of international experts in areas with strong market and growth potential (United States, Russia, Israel and Asia: India, China, South Korea, Singapore).

The OPTX Cluster strengthens its European influence through:

- the presence of a full-time person in Brussels to actively monitor and guide SMEs on the Horizon 2020 programs,
- piloting European projects like EPRISE (see below),
- the launch of a collective action "Optx 2 Bruxelles" in order to help innovative SMEs in the field of photonics and imagery in their orientation and positioning approach at European level, in order to maximize their chances of participating in European projects.

2-4. History of the OPTX cluster

The OPTX cluster is supported by the PoPsud association. PoPsud is an association created in 2000 (under the regime of the association law of 1901) at the initiative of manufacturers and researchers in the fields of optics and photonics. Located in the Provence-Alpes-Côte d'Azur (PACA) and Languedoc Roussillon regions, OPTX, also labeled by PRIDES[(11)] (Regional program for Innovation in Solidary Economic Development), represents the optical and photonics sector in the south of France.

"In 2000, an industrial district was born in Marseille: the Pôle Optique-Photonique Sud association (PoPsud). Its objective: to bring industry, research and universities closer together by creating at least three shared R&D platforms.[(12)]"

"Research and industry already knew each other through the creation of prototypes, but small innovative companies had trouble capturing growth in very narrow niche markets. They were therefore ready for regrouping strategies to gain visibility," explains astrophysicist Jacques Boulesteix, at the origin of the association with an entrepreneur, Gilbert Dahan, the CEO of Seso[(13)], and an academic, Dr. François Flory.

In 2000, PoPsud brought together 75 companies and around thirty laboratories. It now coordinates 17 lots of shared equipment (7.5 million euros invested) in optical micro-components, aspherical mirrors for large telescopes, micro-technologies for optical instrumentation of the future (MOEMS) … Since 2003, the association has been granted an official national recognition from the French state, for its "technological anticipation" project. This national recognition was reinforced in 2005, when it received the "OPTX competitiveness cluster" label. In the meantime, others members have come from Languedoc-Roussillon, Rhône-Alpes, Ile-de-France …" (op. cit)

"PoPsud has broken our industrial isolation in photonics by bringing us closer to the networks that strengthen our credibility on the European scene", underlines Paul Coudray, CEO

of the integrated optics company Kloé[14], in Montpellier. (op. cit)

"By opening up to skills that we did not own ourselves in the city, PoPsud made it possible to obtain the coming location in Marseille of the European Center of Excellence for R&D in medical imagery (otherwise known as Cerimed)[15], argues Professor Claude Lecoq, one of the promoters of this case at CERN[16] in Geneva.

The project, which represented an investment of 22.5 million euros, finally came to a successful end in 2008-2009. About fifteen researchers from all over Europe were assigned to the opening of the center on Timone medical campus in Marseille, then around thirty others afterwards.

Another major project, bringing together 150 researchers and representing a cost of 21 million euros, will be set up on the 9,000 square meters space of the Château-Gombert technopole in 2008: the Marseille Astronomical Observatory[17].

"For PoPsud, we started from the needs of the actors to build projects together. The OPTX cluster pursues this logic, explains Jacques Boulesteix.

"It aims to demonstrate that Southern France offers more chances than elsewhere to work on new scientific themes and innovate in optics-photonics for the space industry, energy, ocean, health, environment, telecoms or microelectronics. Over the first three years, the OPTX competitiveness cluster aimed to generate 20 million euros in investment in industry-research cooperation.[18]"

"To sum it up, the cluster was created in 2000, before becoming a "competitiveness pole". There have been very strong links between the industry and academics for a long time. So it was actually a "pole" before poles formally existed. The first call for projects took place in 2006, and we naturally positioned ourselves and we were logically chosen as the pole. "(Director interview)

2-5. Some key figures

This cluster works on the basis of partnership between companies (around 60% of members), research laboratories and higher education establishments (25% of members) and its institutional partners (15% of members). It aims to create a linkage between fundamental research and industrial R&D around certain shared tools. In 2010, OPTX counted 115 companies of which 88 were SMEs with less than 50 employees. And 56 companies were very small companies with less than 10 employees, often created in the 2000s. The majority of them was positioned on niche markets and rarely exceeded the turnover of a few hundred thousand Euros. Between 2005 and 2010, the cluster nevertheless recorded the creation of more than

650 jobs within the sector.

The activities of these companies are strongly focused on high-tech engineering service activities on "optical and photonic" technologies applied to environment, health and defense /security/aerospace (see below). The activities of the companies in the OPTX cluster are centered on industry and services, and very little on commerce.

Here we should point out a major aspect in this configuration by highlighting the role of what is qualified as 'large companies', that is companies with more than 500 employees. There are only 5 groups (Thalès group[19]- the President of the OPTX cluster is also the CEO of Thalès—; Aliéna Space[20]; Naval Group[21]; Essilor International SA; Bertin technologies)

"The lack of presence of 'industrial locomotives' in photonic is evident in the region… These large companies are users of optical technologies and are not creative themselves. SMEs appear as first-tier subcontractors in charge of developing core optical technologies for large groups specializing in aeronautics, space and health." (Director's interview)

In 2018, the cluster regroups 225 members and partners whose distribution is as follows: 130 industrial companies, 40 academic laboratories, 9 higher education institutions and 46 institutional partners. Among 130 companies, there are still only 5 large groups and the majority remains very small with less than 10 employees. They all represent a turnover of € 1.3 billion and 10,000 employees.

As for its scientific activity, OPTX has labeled more than 170 collaborative projects for an amount of € 465 million (of which € 100 million funded in public grants) in six years since its beginning in 2006. Then between 2013 and 2017, it labeled 120 more research projects (€ 100 million) including 49 projects funded for 34 million €.

All of these companies have succeeded in bringing 43 new products and services to the market over the past 4 years.

Opening up to new markets by diversifying its activity is essential for the survival of companies. Corporate financing therefore appears to be a decisive need that has to be met. On average, young member companies of OPTX were able to raise €4 million in their first five years of existence. One of the cluster's objectives is now to help SMEs access to new European funding from the "Horizon 2020" program.

International development is another essential factor for their growth. One of the key objectives is now to strengthen the international positioning of these companies, in particular by building a network of international counterparts in high-potential market areas (United States, Russia, Asia, India and Israel) and by stimulating funding for international collaborative pro-

jects.

"60% of the turnover of our members is made in export… and more and more companies are going towards private fundraising…we have to help them doing so."(Director's interview)

3. The objectives assigned to the OPTX cluster, its resources and its strategies

3-1. the objectives and the scope

The OPTX cluster participates, as a 'competitiveness cluster', in supporting the innovation dynamic of the photonics industry, so that the region has an engine for its growth. It brings together industrial companies, research establishments and training organizations in a network ("ecosystem") that coordinates technological transfers for the benefit of SMEs. Thus, the pole promotes breakthrough innovations by offering these SMEs services such as R&D facilities, funding aid, intellectual property management, marketing strategies, etc. It stimulates the entire value chain in order to transform research results into industrial and economic outcomes for these companies.

"The cluster has a triple mission: to contribute to the growth of VSMEs/SMEs, to stimulate regional industrial dynamics in order to transform R&D (Research and Development) into value creation and to promote photonics technologies" (Director's interview)

—The cluster was mainly located in the Provence-Alpes-Côte-d'Azur region (PACA) and in Nîmes/Monpellier city during the first ten years. Since 2017, it has expanded its scope to Toulouse, in particular to the Space valley where space industries are developed with Arianspace[22] and AirBus Industry. The cluster is therefore now established in the PACA and Occitanie regions.

－It offers a global solution in photonics and image processing: Photonics is the use of light for industrial and scientific purposes. Identified as one of the 6 key technologies by the European Commission, photonics is a transversal sector, which concerns various fields with high tech potential. This technology is in fact applied in many everyday applications such as photovoltaic systems (using light to make energy), LED technologies (which create light), cameras (which detect and capture light) for security or in laser technologies (which amplify light) with medical applications. Information and communication technologies, on which the digital culture is based, are also strongly impacted by photonics.

This photonics technology is applied by the member companies of the OPTX cluster to 4 main areas of strategic activity associated with the growing markets:

1) Defense and security:

The development of photonics-embedded surveillance technologies (imagery, sensors, transmissions) improves the security of people and goods overall.

The prevention of assaults against people is today the subject of increased political measures, which calls for the development of effective surveillance systems: airport security, security of industrial sites, and surveillance in private places.

The automobile market, public transport, and railroad intersections also require high-performance security systems (maintenance, intersection monitoring, object detection, driver monitoring) which are linked to photonic technologies: imagery, sensors, optical surface treatments, adapted lighting.

Defense and Security is a historic market that represents a total turnover of 2,442 million euros for 27 OPTX companies.

2) Health and medical field:

Photonics and imagery are also used in many fields of health and medicine: biological analysis, diagnosis, and therapy, areas in which the precision, the speed of intervention of the light and its non-invasive nature are valuable properties.

Photonic tools (microscopy, tomography, and endoscopy) occupy a strategic position in the field of healthcare for elder people, with new perspectives for diagnosis, therapy and monitoring. Medical image processing, biochips, laser therapies and LEDs therapeutics are to play a major role in the early prevention of cancer, the implementation of non-invasive surgical methods, and the improvement of treatments. Faced with public health challenges, it is crucial to develop new technologies, methods and processes to help people stay healthy and to diagnose and treat diseases more effectively at lower cost.

Photonics and imagery can play a key role in solving these problems. Optical diagnostics and endoscopy, minimally invasive surgery and medical lasers are already used for the diagnosis or treatment of serious illnesses. Furthermore, the potential of photonic solutions in terms of reducing the costs of prevention, early diagnosis and personalized medicine is not yet fully exploited.

Within the network of the OPTX cluster, the health and medical fields represented in 2017, a total turnover of 117 million euros for 14 companies including 10 million for SMEs exclusively positioned in this area.

3) Clean cities:

The challenge of reducing energy consumption, developing renewable energies and climate change can only be met with the aid of photonic technologies. The first examples are LED

technologies, photovoltaic panels and automatic waste sorting machines. Photonics has many advantages for detecting, controlling, processing or even measuring. The quality of the sensors and the miniaturization of the systems now allow optical analyzers to control the environment of cities—water, soil, and air.

At the same time, these analytical technologies make it possible to adapt and optimize energy consumption, such as automobile fuel consumption or that of buildings, by proposing new solutions, absorbent surfaces and even diagnostic systems for thermal insulation.

4) Industry of the future:

Through industrial image processing, or spectroscopy etc., photonics represents a tool to improve the productivity for companies trying to introduce these new technologies into their manufacturing process.

It makes it possible both to increase the speed of production by automating global productive processes or by preventing bottlenecks in the production, but also to make production more reliable by introducing non-invasive control solutions in real time which are capable of integrating continuous control loops in the process.

The reliability of production system equipped by such photonics unit makes it possible to increase the safety of consumers, to guarantee compliance and to reduce negative environmental impacts.

3-2. financial resources of the OPTX cluster

The OPTX cluster has its own financial resources at its disposal, which support its actions and personnel costs. The collaborative projects and platforms are generally financed by specific programs from regional, national or European bodies. The following items concern only the managing cost of cluster:

1) Public resources account for a little bit more than 55% of the total financial resource:

They come from the Regions—more important than that of the State- of which 70% are from PACA, 20% from Occitanie and 10% from two other Regions.

State contributes up to almost 40% of public finances, of which 50% come from the DGE (General Direction of Companies) and 50% from the DGA (General Direction of Armaments)

“With us, there are many defense applications”; “the DGA is an important, reliable and precious partner” (Director’s interview)

Some resources also come from Metropolitan areas: “significant budget sum, if auditioned…” Aix-en-Provence, Marseille, Toulon, Casa Nice, Nîmes, Montpellier, Toulouse.

2) Private resources represent approximately 45% of all resources, of which one-third come from the contribution of private cluster members. This means that 225 members pay different tariffs following their status (Big groups, SMEs, start-ups, etc.), but observers/partners do not necessarily pay contributions.

   The other two-third of resources originate from a wide range of services (platform fees, marketing support, patent maintenance, technological consultancy, etc.)

"A recent rule requires that the sum of public funding will have to be less than or equal (at most) to the amount of private funding, therefore it pushes us to reach at least up to 50% of self-funding. It is a difficult transition, because until now the majority of funding came from public funds. We are in a transition phase where we must be trying to balance public funds-private funds." (Director's interview)

3-3. transition of strategies

As already seen, from the start, the OPTX cluster had the function of promoting the transfer of knowledge/technologies between big groups and SMEs or between academic research units and companies. Therefore, the cluster aimed at first to bring together several partners around common technological themes, to construct R&D projects with the partners sharing common interest, and to submit them to national or European funding institutions. In sum, the managing team was in charge of supporting the cluster members in the construction and finalization of these projects. In this first phase (2005-2009), the cluster naturally sought to employ project managers with scientific profiles or skills such as PhD or post-docs.

However, in the second phase (2010-2014), the cluster began to put more emphasis on the supportive role of SMEs for their growth strategy (financing, marketing, human resources management, etc.), although it continued to consider the creation of R&D projects as its main task. The awareness of its leadership started to shift to the market trends and looked for larger ranges of expertise and talent among its staffs.

In the most recent phase (2015-2019), the cluster is trying to position itself at the European or international level, either to seek scientific collaborations or for the markets prospection for products or services developed by the member companies. At the same time, it tries to reinforce its role as an 'intermediary agent', creating deeper connections between members by means of platform operations.

From the strategic management point of view, the managing team of the OPTX cluster is equipped with a management tool that consists in crossing domains of technology and fields

of its application or market. This tool named 'Technology/Market Matrix' is used in different strategic decision-making process. The individual skills of the team members seem to be divided, following the matrix between technological skills and "market" skills.

In 2019, the obtaining of the phase IV label[23] opened up new perspectives for action and projects all over Southern France (PACA and Occitanie regions), as already seen.

"As OPTX's application to the forth phase evaluation received strong support from the various public communities (Regions and Metropolitan areas such as Marseille, Toulouse, Aix etc.) located in PACA and Occitanie, the OPTX cluster intends to amplify the supportive offers to its member partners, in particular to facilitate their use of European innovation assistance programs and to improve access to international photonics markets… Also, in a context of declining public funding, we will have to develop an alternative economic model by increasing the share of European and private fundraising." (Director's interview)

4. The governance of the OPTX cluster, its managing team and their skills

4-1. Governance

"The operation of the OPTX cluster, an association under the regime of the 1901 law, is ensured by a governance made up of a board of directors, a strategic council and a steering committee."

1) The Board of Directors

Composed of 25 members elected at the General Assembly for a 3 years mandate, the Board of Directors is made up of academic and industrial members. Its role is to apply and implement the decisions made at the General Assembly. It is chaired by the president who is elected by the board of directors. Currently, the CEO of Thales group is in charge of the presidency.

2) The Strategic Council

Composed of at least 19 members, the Strategic Council has an advisory role to the Board of Directors. Its mission is to provide the prospective vision on the major scientific, technological and industrial challenges of the photonics and imagery sector.

3) The Steering Committee

Composed of members of the Bureau and institutional representatives of partners who participate in the financing of the cluster, the Steering Committee aims to discuss on the strategic policy lines decided by the Board of Directors and then to take in consideration concrete means for the implementation of these strategies. (Website of OPTX)

"The cluster is an association under the law of 1901. We have a strategic council that makes forward-looking studies, which establishes the major missions and orientations of the cluster. This council is seen as a force of proposals on the services offered by the cluster. It represents the diversity of its members and also of their geographical origins, even if it is not statutory… knowing that we have roughly 2/3 of academics and 1/3 of industrialists. Besides, there is an office… and a board of directors, which decide and validate the main orientations of the cluster proposed by the strategic council … "(Director's interview)

4-2. The managing team and the competence of each member

OPTX' organization chart is not mapped in a hierarchical way. It comes down to a list of names associated with a function. In addition to the Director General and a Deputy Director, there are "directors" of projects and platforms, of the business pool, the Europe/international poles, and a "project manager" of Europe EPRISE.

Under these managing staffs, there are 5 project managers in each domains; Occitanie, Communication, Marketing, Animation of events, Europe/International and 3 assistants in management, direction and secretariat. This list nonetheless covers implicit hierarchies, given that "team management, on the other hand, is clearly the role of the Director General" (Director's interview).

Three of these employees are university graduates with a doctorate and experience in academic research. One has prior engineering training, and another subsequently had industrial experience in a big business. The others hold a university title in the domain of "public policy", "management sciences" or "communication training". They have Bac + 2/Bac + 5 level diplomas. While young, majority of them had professional experience in the territorial public service, in associations or in companies. Only one person has a hybrid qualification (scientist/innovation management), while another person experienced both scientific research field and business world.

We can notice a notable difference between those who come from the scientific/technological field and those who come from backgrounds in public policy, management sciences, commercial marketing, etc.

Compared to the latter, the former value themselves, saying that "it is easier to learn management technics than to become familiar with technologies" and that "the transition in their professional career between the scientific field and innovation management took place naturally, without a lot of knowledge gaps. Once integrated into the management actions, they however tend to regret having moved away from the technology field, since they often think

"they have lost their qualification". On the contrary, the latter get the feeling of enriching themselves in contact with the technology field.

According to some these staff members, the OPTX managing team has a wide range of necessary skills, because they can benefit from the skills of a large network of members interior or exterior to the cluster. However, they sometimes feel a lack of "consistency" in their expertise between the scientific/technical knowledge and the skill of doing the real business. In addition, the team members are each competent in a single applied technology, but not necessarily in a given specific industrial case.

4-3. The activities of the team and the task of each member

The team's work is organized into three types of activities:

1) Gathering information by observing technological and commercial trends and by making contacts with the experts both in the network and around the scientific and economic environment of photonics and imagery sectors.

The information collected relates to:

− Innovative technologies, their availability and possible uses, their experts and their market trends, etc.

− Networked companies (and research units), their characteristics in terms of products/services, the degree of technological advances, their instrumentation (the degree of openness to the private sector for academic units), their targeted markets, their human capacity, their eagerness for innovation, their needs, their expertise, etc.

− External opportunities for the member SMEs: funding organisms, technological or industrial regulations, response to calls for tenders, collaborative project programs, etc.

− Relations with other clusters and other companies in different fields.

2) Analyzing the whole data by entering it into databases which are fed along with the cycle of cluster's activities (projects, platforms, etc.); then cross-referencing all the data in a matrix (CRM type): technology/market; technology/companies; technology/experts; markets/companies, etc.

3) Evaluating the matrix analysis to identify possible actions vis-à-vis a company or groups of companies; then conceiving an action plan both for collective actions (trade fairs, seminar, visit to experts, organization of "B to B" meetings, etc.) and for individual incentives (project participation, collaboration or use of platforms, etc.)

The collection of information and the constitution and monitoring of data are to be managed

by each member of the team according to their specialty. However, from time to time, the analysis of matrix and the action plan organization requires a shared interest and a collective reflection and such collective action produces in return shared knowledge and collective competence. After such collective phase, everyone returns to his or her assigned task (projects, platform management, links with companies etc.) and offers collectively enriched expertise and services to the network partners.

The functions and skills of each member seem to be well defined and delimited by the organization. Yet, as we will see, the construction of various competences is not obvious (see below the description of EPPRISE and the Light 25 share).

Each member of the team is expected, beyond his/her specialization, to construct a general skill capable of understanding deeply the technological and management needs of SMEs and of identifying the business opportunity and the necessary resources in the network.

5. Concrete actions in the OPTX cluster

There are some typical actions the managing team undertakes in the framework of cluster policy. The first one is to favor the emergence of collaborative R&D projects among the network members. The second is the management of platforms. We will examine them below:

5-1. Support for research projects

This action consists of:

1) Help in defining the outline of the project
2) The search for partners
3) Support for setting up a project
4) Project labeling application
5) Lobbying with regional and national authorities

Above all, this action deals with the issue of how to accompany the member SMEs, and how to help them find research partners and collaborative skills in order to construct the coherent projects. This implies earlier negotiation with partners, project commission, assistance to project managers in drafting before the file deposit etc., in order to improve its chance to be admissible and eligible by funding organism. First, it is a matter of 'labeling' the R&D project: for this, OPTX organizes each time a project commission bringing together specialists and experts from its networks. Once "labeled" and funded, a project manager follows the projects over time until the end of the projects. This type of support appears sometime quite deli-

cate and complicated depending on the nature of projects or technological fields.

"One of the cluster's missions is to follow the project from the start until its completion. Our expertise or added value is judged above all on the basis of how well all of the operations are carried out or not. But in the course of project, there are often unforeseen events, for example, a change of interlocutor, a lack of equipment, a shortage of money, patent conflicts, etc.… "(Director's interview)

Many projects jointly constructed in the OPTX cluster most often targeted FUI (Single Inter -ministerial Fund: See the note 6), and sometimes the ANR's call for tender. For the experts of the cluster, it is above all a question of rereading/rewriting the scientific file and of forecasting the concrete outcomes—technological or commercial—of the project. "For the FUI, there are generally 1 to 3 tenders per year. Last year, we have only one project accepted… so we will have to work harder and harder…" (Director's interview)

5-2. Some examples of projects

The OPTX cluster has 'labeled' in 2017 twelve R&D projects of which five projects received funds from the ANR and 2 projects from the FUI.

Projects funded from the ANR;

- DUVET—Diode electroluminescence ultraviolet with tunnel effects
- METANIZO—Epsilon Near Zero anisotropic material for photodetection
- NANOSLIM—Designing nanoparticles during the drawing of optical fibers
- SEAFOOD—SEA-bottom Fiber-Optic Observatory for Distributed measurements
- WEEDELEC—Site-specific weeding robot using high electrical voltage actuator combined with UAV hyperspectral imagery for predictive management and post-assessment

Projects funded from FUI;

- FRELON—the development of a new long-range autonomous LiDAR complete system embeddable on a medium-sized drone, adapted to the market in the field of energy transport and rail transport
- IMAGAZ—The development of complex optical systems for monitoring and analyzing the atmosphere, environment.

Equally, in 2017 the OPTX cluster saw three 'labeled' projects completed with some tangible results;

- ECOVIGIDRIV—The project aimed to investigate new methods of human-computer interaction facilitating the perception of its environment, its own state and to minimize the driver's efforts to mobilize cognitive resources. The purpose of the project was to in-

crease the safety of the driver and passengers, while allowing the addition of new features such as energetically economic driving. This project produced 11 patents and 3 products and services.

- MAGNUM 2—This project, led by StakR, WIT company and the Mathematics Institute of Toulon, aimed to create a pilot allowing a portal for collecting, analyzing and managing pedestrian, vehicle, energy and environmental flows. This project has produced 3 patents and 10 prototypes and products.
- SERA—the 'Safety and Augmented Reality' project aimed to create a prototype vehicle in which will be displayed 'augmented reality driving assistance information from the processing of data from the vehicle, the road or even the position of the driver. This project included partners like PSA, Visteon Electronics, the Instar, the Heudiasyc laboratory, Mov'eo, Id 4 Car and iTrans.

5-3. A European project: EPRISE

The OPTX cluster is piloting a new European project named EPRISE. This took over the OASIS project that lasted for 4 years. Both two projects, funded with European funds, aims to establish collaborative networks with the European regions concerned, in order to promote and reinforce the European photonics industry.

The projects, based on the collaborative consortium, have almost the same partners:

－8 European clusters (Italy, two in France-OPTX and 'Photonique Bretagne'-, Spain, Germany, Netherlands, Sweden, Finland),

－1 British technical innovation center

The theme of the two projects is centered on photonics applied to the life sciences.

OASIS had a focus on life sciences in general and the access to health and medical markets. The objective was to try to allow a large range of SMEs to benefit from the platforms equipped with certain specialized technologies. Efforts were made to map the existing infrastructure and laboratories at the European level. In particular, the project manager tried to touch the academic labs, which are already used to allow their equipment to be used by external industrial customers with a tariffing system for their services, so that SMEs were able to get access. He also tried to select and map the SMEs that might be interested in such an opportunity. OASIS was funded by the European FP 7 program funds, which have now ended.

EPRISE is a confirmation of the OASIS project. The latter focuses on access of SMEs to 4 markets: medical technologies; agriculture; food industry; pharmaceutical industry.

The current project widens therefore the scientific fields and seeks to reach new SMEs involved in photonic application in the new fields. The EPRISE project, 'Empowering Photonics through Regional Innovation Strategies in Europe', has a budget of 1.4 M€.

"Europe's photonics industry is facing global market competition and has to cope with a very high speed of technological developments in the field. While scientists and researchers have made great strides in the application of photonics in these market sectors, there is still plenty of work to be done. Companies developing photonics-based products for these markets face highly specific Go 2 Market challenges such as long delays in market adoption, complex regulatory frameworks and high barriers to market entry. The EPRISE consortium will organize a series of European photonics workshops over the next 2 ½ years, with the aim of providing SMEs with solutions on how to overcome the market entry barriers. Advised by a panel of experts, the project consortium will gather together information about available public funding to aid SMEs in the process. Pre-arranged business to business meetings at these events will also boost collaboration between companies at both regional and national European levels." (Secpho-European union website[24])

This project has specific needs, in addition to those of other OPTX actions (identification of companies, markets, etc.), to match the possibilities and needs of SMEs:

- a precise assessment of the technological maturity of companies (the TRL criterion[25])
- technological expertise to enable SMEs to enter a targeted market.
- regulatory expertise in each national framework especially for the food and pharma sectors.

Each manager in his country makes a national analysis of the needs and potentials of SMEs, in coordination with the cluster companies, customers, and technology experts. From the report of each country, a global manager of OPTX makes a synthetic program and attempts to offer the organization of various events vis-à-vis the different partners.

- General workshops
- More local events for EPRISE: B to B meetings, possibilities to get access to an integrator or end users,
- Interaction sessions among SMEs at European level; this type of action allows SMEs to cooperatively develop collaborative projects or joint participation in export fairs, etc.

The global project manager, an OPTX female employee holding a PhD title in Astrophysics, coordinates this inter-county group and people with very different skill background within

the consortium.

"Faced with very different and specialized knowledge, she has to broaden her general scientific and technical competences. She is learning a big consortium management and a team leadership technique… Within the OPTX team, she works in collaboration with those in charge of SMEs doing the door-to-door survey. The latter has a business or innovation management background, so they complement each other. This type of collaboration allows us to build both a very efficient database and a collective skill." (Director's interview)

5-4. Platforms in the OPTX cluster

The platform is a collaborative tool privileged by all competitive clusters. The OPTX cluster has set up several platforms with mixed results:

1) PEMOA is the first platform built and managed by the cluster. It consists of a classic pooling of equipment. Led by the OPTITEC cluster in charge of its coordination and management, the consortium is made up of ONERA[26], LAM (Marseille Astronomical Observatory) and industrial partners who participated in the financing of equipment (ALPAO[27], SILAS[28], etc.). ONERA owns itself the equipment obtained with ERDF[29] credits. The objective of the platform is to find new applications for adaptive optics, for example in the field of ophthalmology or laser communication for defense. Originally (at the end of 2014), the available time for the use of equipment was divided between the LAM (25%), ONERA (25%) and the OPTITEC cluster (50%). But in fact, this activity has only partially developed. The Platform is only used for the training of engineering students of the École Centrale Marseille. The equipment appears too complex and too expensive for the use of SMEs. Interested SMEs are not competent enough to handle the devices, while the large groups already possess in-house equipment.

2) Olise® Lab is an academia-industry consortium. This includes the LNE (National Metrology and Testing Laboratory[30]), OPTITEC, a Nîmes-based medium size firm, Exavision[31], and Bertin Technologies. The LNE is the principal coordinator. OPTITEC has co-invested in the equipment and would have liked to present it in the Light 25 Share platform. This has been refused, as there were administrative conflicts with the LNE. This project was also co-funded by Nîmes Metropole.

Located in Nîmes in the LNE's building, Olise® Lab is a cutting-edge technological equipment for businesses with its test bench developed by Spherea Test & Services. Specialized in the quality control of cameras, the shared technological platform allows SMEs to gain a com-

petitive advantage, by providing unique expertise services in the production process. A real performance and competitiveness booster, this platform offers industrial companies and academic laboratories the opportunity to develop high-precision cameras using quality control equipment. This also leads to a reduction in R&D costs and an improvement of technical expertise at the service of product quality.

3) Light 2 Share is an online platform for the exchange of services and expertise, aiming to bring together SMEs users and suppliers of innovative technological solutions. Launched in November 2017, operational in January 2018, its main objective is to allow SMEs to get easy access to cutting-edge equipment at low cost or to technological experts in optics, photonics, and imagery. This on-line system helps any entrepreneur —user or supplier- to identify where the essential resources for an innovative project, skills, expertise and the materials are. For a moment, only business partners were interested, not academics.

To use it, there is a tariffing system where the services providers fix a price on the day-base, which is paid in return by the users. As the cluster is managing the system, OPTX takes a 10% commission (with a ceiling of 1100 euros). The entire financial flow passes through the cluster administration, which issues the bill to the users. This type of revenue allows the cluster to develop the platform and to improve the quality of services.

The platform manager is now working on 30 transaction offers, but up to now only one transaction has been finalized. Partners of the cluster mainly make the service offers, but the platform is open to all external companies. The manager told us that “my role in the system is that of a ‘moderator’ in the negotiation between suppliers and users.” This implies for example to check the quality of materials and to reassure the user (example, calibration certificate). She does not intervene directly in the service, only bridges suppliers and users.

Before the operation is launched, the administration is to organize a first “filter”, a three-way interview on the expertise of supplier, the equipment, and the time required for the operation. If supply and demand does not match, the manager continues the discussion and reformates the service package. Once the technical proposal and the tariff are accepted, the ‘contractualisation’ may be finalized between user and supplier. This is a bilateral contract excluding the cluster administration, though the cluster keeps an eye on the affair and if necessary, can play a role of financial intermediary or offer the training for the user.

For now, there is no partnership with academic labs despite OPTX’s wish. Some academic researchers are eager to be partners, but the university administrators do not agree with its economic model. The manager told us that “she was mainly responsible for the design of the system, and now the CRM (database tool based on technology/market) is taking an increas-

ingly important place." She has experienced in the past the innovation management, the R&D projects and the management of platforms. She is led to fully use all her competences accumulated up to now, in order to put in place this new tool based on a new economic model. Recently, a sales technician has been recruited to support the platform manager. Some colleagues of the cluster are very supportive to improve the functionality of the system.

5-5. An experience of platform and project management by a female manager

Originally, the manager of 'platforms' did not have any knowledge about the industry, nor about SMEs. She had to learn a whole knowledge and know-how on the job, by confronting many everyday constraints of this type of job. In particular, she gained a lot of know-how from one of her colleagues, the current deputy director of the cluster who had the experience of starting up a company.

She said that "I arrived at OPTX with sufficient scientific knowledge, after having accomplished the training of engineering school, my doctoral thesis, and the first experience of the post-doc in a laboratory or in innovative companies …My scientific and technical training (engineering school) was particularly useful to understand the different technologies offered by the cluster: imaging, sensors, lasers, detectors, etc."

According to her, "the follow-up of FUI projects is very complicated, because one needs to understand "industrial downstream, since innovative products or services must be brought up to the final market, whether they are concerned with incremental innovations or ruptures". The manager is therefore led to understand all the process of industrialization.

The role of the OPTX cluster is to put its members and partners in connection. Her own skills and knowledge are built informally on the job: they come from CRM database but also from formal and informal information around her networks. "We often recreate network knowledge, of course from a matrix of keywords, technologies/markets, but also largely complemented by the quotidian news, oral speeches we capture in daily conversations…"

Knowledge and know-how accumulated in the course of projects or platforms management in contact with the various industrial, institutional and academic partners correspond to a collective competence of the cluster to embed the deep needs and skills of their partners in the collective action.

6. The start-ups from the OPTX cluster

The OPTX cluster witnessed the birth of around fifty start-ups over its past fifteen years of

existence. Contrary to many competitive clusters in France, OPTX does not, however, developed its own function in charge of creating start-ups. The incubator IMPULSE, the official PACA region incubator, located on the same campus as OPTX, assumes this function. Its operation will be described in a separate monograph. As an example, we present here a single case of a start-up.

Example 1: First Light Imaging

Revenue in 2019 1-2 M€

Number of employees 10-15

Subsidiaries First Light Imaging Corp.

First Light Imaging is a French company headquartered in Meyreuil near Aix-en-Provence, France. The company designs and manufactures scientific cameras for visible and infrared spectra based on EMCCD, e-APD, and InGaAs technologies.

First Light Imaging's products are used in high-end scientific application such as astronomy, adaptive optics, biological imaging and industry.

Company History

The company, founded in 2011, is a spin-off of 3 French laboratories: Laboratoire d'Astrophysique de Marseille (LAM), Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) and the Haute-Provence Observatory (OHP).

As part of the Horizon 2020 SME Instrument phase 2, the European Commission has supported First Light Imaging for the development of C-RED One, the world's fastest low noise Short-wavelength infrared commercial camera based on e-APD MCT technology.

First Light Imaging is a member of several French competitiveness clusters: Optx, Alpha-Route des Lasers and Optics Valley.

First Light Imaging is also a member of Aix-Marseille French Tech.

Since 2014, First Light Imaging also brings its expertise to the JPL NASA.

In January 2016, First Light Imaging created a US subsidiary located in San Francisco, California.

Products

First Light Imaging designs and manufactures high speed and low noise scientific cameras for both visible and infrared spectra.

− OCAM is the world's fastest low noise camera, coming from a transfer of know-how from French laboratories and leading to the creation of the company. OCAM is operating on the visible wavelength (from 400 to 900 nm) and based on an EMCCD sensor from E 2 V / Teledyne. A version with an electronic shutter embedded is also available.

− C-RED One is a scientific camera operating on the short-wave infrared wavelength (from 0.8 to 2.5 μm) based on an e-APD MCT sensor from LEONARDO.

− C-RED 2 is a scientific camera operating on the short-wave infrared wavelength (from 0.9 to 1.7 μm) based on an InGaAs sensor from SOFRADIR.

First Light Imaging's cameras are used at the Subaru Telescope in Hawaii, the GranTeCan telescope in the Canary Islands or the MIRC-X interferometry instrument on the CHARA Telescope.

7. Summary

This paper aims to study the functioning of a 'competitive cluster', namely OPTX, a photonics technology-based cluster located in the Southern France. We surveyed this cluster during 2017-2018 on a base of meetings and personal interviews.

The OPTX cluster is a community of 225 members with over 130 companies, 40 labs, 14 institutions of higher education and 30 innovation partners. Considered as one of European top class competitive clusters, it plays a key role in industrial development in the field of optics/photonics and image processing. Its first objective is to encourage the transfer of technologies from academic research to SMEs. Since its start in 2005, it has, in fact, awarded its 'label' to around 300 joint R&D projects worth a total of 550 million Euros for 130 million Euros of subsidies from several regional, national or European funding organisms.

In order to create an 'ecosystem' favorable for the development of SMEs, the cluster works hard in various domains ranging from patenting to marketing by passing the academia-industry collaboration, especially targeting high-potential growth markets. Photonics is a domain which is associated with a wide field of applications (telecoms, vision, imagery), related to energy (photovoltaic systems, ITER), health (medical imaging, therapy), Safety, Security and Space. For SMEs, OPTX plays the role of interface with the major groups and outsourcers in the photonics sector.

Notes

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(2) Michael E. Porter, “Clusters and the New Economics of Competition”, Harvard Business Review, Cambridge (Massachusetts), November-December 1998, p.77-90.

(3) Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. Cambridge University Press

(4) Promulgated in 2015, this law aims to reorganize and clarify the distribution of powers of local authorities between the municipality, the department and the region.

(5) ANR is a corresponding organism of JSPS in Japan.

(6) The Single Inter-ministerial Fund (or FUI) is a special program intended to support applied research, to help the development of new products and services which are likely to be put on the market in the short or medium term.

It makes it possible to finance so-called “collaborative” R&D projects (associating large companies, SMEs and laboratories) backed by competitiveness clusters.

(7) Essilor International S. A. is a French-based international ophthalmic optics company that designs, manufactures and markets lenses to correct or protect eyesight. Quoted on the Euronext Paris Stock Exchange, Essilor is responsible for creating Varilux, the world’s first progressive lens which corrects presbyopia and allows clear vision in the wearer’s near, intermediate and far vision. The company formed from the merger of ophthalmic firms Essel and Silor in 1972. Its activities are largely focused on research and development. It is the world’s largest manufacturer of ophthalmic lenses. Essilor invests over €200 m each year to research and innovation. In January 2017, Essilor merged with Italian eyewear giant Luxottica. On 1 October 2018, the new holding company Essilor Luxottica was born, resulting in combined market capitalization of approximately €57 billion. Essilor has about 450 researchers working at its four R&D facilities: one R&D Center in Ireland dedicated to photochromic lenses and three Innovation & Technologies Centers in Europe (France), the United States (Dallas) and Asia (Singapore). These facilities develop new products and work to identify and forge the best possible research partnerships.

(8) SPHEREA is a spin-out of the test divisions of Airbus. It’s origins stretch back over 50 years, to the involvement of Aerospatiale and Sextant in the development of Concorde and the Mirage F 1 fighter. In 1996 the test divisions of both companies merged to support France’s Rafale fighter and Leclerc tank programs. The new entity formed the basis of what was to become SPHEREA, when Airbus Group spun off its test and services division in 2014 as part of a wider reorganization.

(9) The National Centre for Space Studies (CNES) (French: Centre national d’études spatiales) is the French government space agency (administratively, a “public administration with industrial and commercial purpose”). Under the supervision of the French Ministries of Defense and Research, CNES operates from the Toulouse Space Center and Guiana Space Centre.

(10) The Institut supérieur de l’aéronautique et de l’espace (ISAE-SUPAERO, English: National Higher French Institute of Aeronautics and Space), is one of the prestigious French universities (grandes écoles) in engineering founded in 1909. It was the world’s first dedicated aerospace engineering school and is considered to be one of the best in Europe in that field.

(11) PRIDES is a system set up by the Region to support the development of SMEs in the territory. SME members of PRIDES can benefit, in addition to certain services (marketing, access to platforms, etc.), from direct individual financial assistance (zero-rate loan, subsidy).

(12) Newspaper Marseille 02/05/2005

(13) Aix-based company Seso, medium size firm (60 employees) designs, develops and manufactures optomechanic and optronic systems in the fields of astronomy, science, space and defense, nuclear and industry. It offers large mirrors, lighting, assembling and cementing technologies, as well as super polishing. Founded in 1979,

Seso has been merged by Thales in 2010.

(14) Kloé is an academic start-up from Monpellier University founded by two researchers, Dr Paul Coudray, expert in photonics, and Pascal Étienne, specialist in materials. This company a major global player in photolithographic technologies with mask and laser. Its expertise, for more than 15 years in the lithographic production systems and photo-sensitive resins are testimony of Kloé's unique know-how in the control of photon-matter interactions.

(15) The CERIMED project has been carried out in Marseille since 2005 by Aix-Marseille University in conjunction with numerous laboratories, institutions and national and European industries. It aims to offer on a single site a space for synergies and discussions between the different disciplines of the medical imagery sciences, in close collaboration with industry. The objective is to create a center of excellence in Europe bringing together competences and infrastructures to conduct an ambitious R&D program for the design and validation of the next generation of imaging systems, which could make a decisive contribution to the solution of major public health problems. The ambition is to give Europe a dominant position in the medical imagery market by strengthening the synergy between all the stakeholders, institutional and industrial. It is therefore a partnership and multidisciplinary service and research platform. It offers, on the Timone medical campus in Marseille, a space for synergies between the different disciplines of the preclinical and medical imaging sciences, in close collaboration with industry. The CERIMED set open to academic laboratories and companies specializing in biotechnology and instrumentation.

(16) The European Organization for Nuclear Research (French: Organisation européenne pour la recherche nucléaire), known as CERN, is a European research organization that operates the largest particle physics laboratory in the world in Geneva.

(17) This facility includes two major technology platforms for qualification of space instruments and for fabrication and metrology of optical mirrors. LAM astronomers specialize in cosmology and galaxy evolution, exoplanets and Solar System, and R&D in optics and instrumentation. In 2012, the Observatoire d'Astronomie Marseille merged with other earth-sciences research institutes from Aix-Marseille University and became a new entity called the Observatoire des Science de l'Univers Institut Pythéas (OSU-IP) which now includes 6 major labs for earth and universe sciences.

(18) Magazine: Usine Nouvelle 10/11/2005

(19) Thales Group is a French multinational company that designs and builds electrical systems and provides services for the aerospace, defense, transportation and security markets. The company is headquartered in Paris' business district, "La Défense" and its stock is listed on the Euronext Paris. The company changed its name to Thales from Thomson-CSF in December 2000 shortly after the acquisition of Racal Electronics plc, a UK defense electronics group. It is partially state-owned by the French government, and has operations in more than 56 countries. It has 80,000 employees and generated €18.4 billion in revenues in 2019. As of 2017, it is also the 8 th largest defense contractor in the world and 55% of its total sales are military sales.

(20) A joint venture between Thales (67%) and Leonardo (33%), Alenia Space also teams up with Telespazio to form the parent company 'Space Alliance', which offers a complete range of services and solutions. Alenia Space posted consolidated revenues of about 2.15 billion euros in 2019 and has around 7,700 employees in nine countries.

(21) The Naval Group (formerly known as Direction des Constructions Navales or DCNS) is a global and major French defense contractor and an industrial group that specialized in naval-based defense platform and the marine renewable energy. The group employs next to 13,000 people in 18 countries. The company is owned in part by the 'Agence des participations de l'État', a private company through which the French State holds a 62.49% stake, Thales holds 35% and the personnel a 1.64% stake.

(22) Arianespace SA is a multinational company founded in 1980 as the world's first commercial launch service provider. It undertakes the operation and marketing of the European Ariane program. The company offers a number of different launch vehicles.

(23) The competitiveness clusters have been already evaluated three times in the past after the phase I (2005-2009), the phase II (2010-2014) and the phase III (2015-2019). At each phase, some succeeded in obtaining 'labellization' (go sign) and others did not have (stop sign).

(24) http://www.secpho.org/en/noticias/eprise-a-leading-eu-photonics-consortium-for-life-science-markets-starts-with-secpho-collaboration/

(25) The TRL (technology readiness level) scale is a measurement system used to assess the level of maturity of a technology (hardware, components, peripherals, etc.), in particular with a view to funding research and its development or in the perspective to integrate this technology into an operational system or subsystem. The TRL level was first used by American government agencies, but this concept has since spread widely and has been adopted by many organizations, companies and public institutions around the world. The TRL is in particular an important criterion in the Horizon 2020 program of research funding by the European Commission.

(26) The Office National d'Etudes et de Recherches Aérospatiales (ONERA) is the French national aerospace research centre. It is a public establishment with industrial and commercial operations, and carries out application-oriented research to support enhanced innovation and competitiveness in the aerospace and defense sectors. ONERA was created in 1946 as "Office National d'Études et de Recherches Aéronautiques". Since 1963, its official name has been "Office National d'Études et de Recherches Aérospatiales". However, in January 2007, ONERA has been dubbed "The French Aerospace Lab" to improve its international visibility.

(27) ALPAO, a start-up company in 2006 based on the technology developed at Grenoble University and CNRS, manufactures a range of adaptive optics products for use in research and industry, including deformable mirrors with large strokes, wavefront sensors, and adaptive optics loops. These products are designed for astronomy, vision science, microscopy, wireless optical communications, and laser applications. Now it is a worldwide main player in the Astronomy and Space fields.

(28) CILAS is a French company, a subsidiary of Ariane Group, specialized in laser and optics technology, founded in 1966 by two companies: CGE (Compagnie Generale d'Électricité becoming Alcatel-Alsthom) and Saint-Gobain. The aim was to exploit industrially and commercially the work of laboratories working on laser sources and laser equipment. This high-technology engineering company was the inventor of the particle size analyzer. Today, it develops, manufactures and produces systems combining laser and precision optics in the field of high technology, accounting. Products for the military represent 50% of turnover against 50% civilian.

(29) The European Regional Development Fund (ERDF, in French FEDER) is a fund allocated by the European Union. Its purpose is to transfer money from richer regions (not countries), and invest it in the infrastructure and services of underdeveloped regions. This will allow those regions to start attracting private sector investments, and create jobs on their own.

(30) The Laboratoire national de métrologie et d'essais (National Laboratory of Metrology and Testing) is a French reference laboratory responsible for carrying out measurement and testing products of all kinds for their certification for placing them on the market. It also coordinates metrology activities in France.

(31) Specialized in the Defense and Nuclear sectors, Exvasion design and produce optronic systems resistant to high pressures (100 bars), extreme temperatures, shock and vibration, but also with strong ionizing radiation, acid vapors, etc.