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List of abbreviations

AI	Artificial Intelligence
AMR	Adaptive Mesh Refinement
AR	Augmented reality
ASCS	American Sprint Car Series
bn.	billion
CAE	Computer Aided Engineering
CAGR	Compound Annual Growth Rate
CFD	Computational Fluid Dynamics
CoE	Centre of Excellence
CPU	Central Processing Unit
EC	European Commission
EIBIS	EIB Group Survey on Investment and Investment Finance
EOSC	European Open Science Cloud
EPI	European Processor Initiative
ETP4HPC	European Technology Platform for High Performance Computing
EU	Europe
EuroCC	European Competence Centres
GENCI	Grand Équipement National de Calcul Intensif France
HPC	High Performance Computing
HPDA	High performance data analytics
HPL-AI	the High Performance LINPACK for Accelerator Introspection
IaaS	Infrastructure as a service
IEA	International Energy Agency
IoT	Internet of Things
IP	Intellectual property
ISV(s)	Independent Software Vendor(s)
IT	Information Technology
KERs	Key Exploitable Results
MEEP	MareNostrum Experimental Exascale Platform
Mio	million
ML	Machine learning
MPI	Message Passing Interface

OEM	Original equipment manufacturer
PRACE	Partnership for Advanced Computing in Europe
R&D	Research and development
RIKEN	Japan's research institution
SaaS	Software as a service
SME	Small and Medium Enterprises
TPs	Technology Providers
USA	United States of America
UQ	Uncertainty quantification
VDE	The VDE Testing and Certification Institute
VDI	Virtual desktop infrastructure
VR	Virtual Reality

Executive Summary

The main goal of the T6.1 Task Market assessment was to understand the market context in which EXCELLERAT operates in accordance to develop the appropriate business model and support direction in which the Centre of Excellence will develop. During the project lifetime, three deliverables were prepared: in the first deliverable, D6.1 Market Assessment, the initial data on the services that the Centre of Excellence might offer beyond the project were gathered. The second deliverable, D6.3 Market Assessment Update, was focused on the analysis of the potential EXCELLERAT Service Portal target users and provided the overview on the European and global HPC ecosystem and main markets trends. Comprehensive research of services, which are already available on the engineering markets, was done as well and SWOT analysis on engineering communities was developed. The final document, D6.5 Final Market Assessment, supports WP5, WP6, WP7 and includes the information collected through in-depth research on EXCELLERAT Service Portal target users and service portfolio offered within EXCELLERAT Service Portal with the aim to develop and finalise the business model, marketing strategies and plan the future evolvement of the Portal.

The document starts by presenting the HPC ecosystem: the current state in the EU and other World-leading countries. The next chapter focuses on engineering trends and innovations on the main markets. It is important to know in what direction innovation and research is going, what technologies are requested, what experts will be needed for demanding engineering tasks.

In chapter 4, the analysis of the Value proposition canvas is presented. This method helped us to better understand users' needs and pains, and find the proposition value offered on the EXCELLERAT Service Portal. Furthermore, the analysis of the EXCELLERAT Service Portal feedback is presented. The chapter is concluded by EXCELLERAT engineering communities SWOT analysis, providing the information about possible competitors that are providing services for Exascale engineering, but also on communities that could become future collaborators, when considering that they could provide some of the services on the EXCELLERAT Service Portal.

In conclusion, the recommendations for the future EXCELLERAT service portfolio and CoE development are given.

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1 Introduction

EXCELLERAT brought together the necessary expertise to set up a Centre of Excellence and boost the competitiveness of European engineering. The aim is to support the engineering community and to pave the way for the evolution of applications towards Exascale by offering an excellent service portfolio to the main engineering sectors: manufacturing, energy, aerospace and automotive. To be able to create a sustainable setup of the centre that will bring added value to its users, it is extremely important to understand the market context in which EXCELLERAT operates. This includes all stakeholders of such a market: code developers, HPC resource providers, software developers (who can offer services to complete the EXCELLERAT services portfolio), hardware companies and HPC expert users as well as the potential industrial users (that might benefit from the centres' expertise to become HPC users). Additionally, the Covid-19 Pandemic stroke at the beginning of 2020 and shook up the engineering world. In the field of engineering, HPC has established itself in a wide variety of application options. Large companies and high technology SMEs working in above mentioned industries rely heavily on the use of HPC-based simulations. Big data are playing an important role in innovation and, consequently, technologies such as AI and ML are coming to the forefront and will more and more demand state-of-the-art Exascale technologies.

To develop the most suitable service portfolio, CoE operation and business model, it is crucial to know the market context. What services are requested? What services will bring our users added value or value proposition? What services will be unique? How will EXCELLERAT services relieve users' pains and challenges? For this purpose, the market context was analysed:

• Target users that already use HPC extensively today, that might have a need for more resources or more capable Exascale systems soon. They will appreciate any activity and product that helps them to improve their efficiency, product development, and especially expert support for solving the most demanding engineering tasks.

• Each target market has its own specifics when talking about engineering tasks and challenges, technological trends that are expected in the near future, and new technologies adoption.

• Competitors are already offering some similar services and products. For instance, when coming to codes, EXCELLERAT´s biggest rival are Ansys and Dassault Systems with a very large set of tools going far beyond CFD. A competitor of co-design developers could be any organisation or CoE that offers this kind of service (port to new hardware) but specifically for engineering applications (HPE, Intel, EPI, ...). When talking about services and platforms, some CoEs already offer trainings, consulting, and platform (E-CAM). If we would like to develop services carrying in mind boosting European competitiveness and innovation, the right way is to turn competitors into collaborators and invite them to present their services jointly on the EXCELLERAT Service Portal. Knowing the services they already provide can avoid duplicating similar services in the EXCELLERAT portfolio, and rather building new, strong partnerships, create a strong community with all stakeholders and make easier for the stakeholders to find correct services, products and partnerships

HPC is an indispensable tool, and AI, ML, Industry 5.0 are not any science fiction anymore. Organisations and factories are transforming into IoT-enabled smart facilities, connected to clouds and using novel technologies that will support workers with AI and ML processes [1]. These technologies are vital for the advancement in research and science. Smart machines and robots, self-driving cars and airplanes and IoT networks demand intensive support systems such as Exascale, as new technologies will require massive data analytics, complex simulations and

huge data sets for ML training. The Exascale future is now, but some fine-tuning on co-design, big data analytics and security issues is needed. Thus, EXCELLERAT partners are working hard to lay the foundations for the engineering at Exascale level. As they did in the last three years of the project lifetime. Those foundations should be in the future continuously developed and optimised, that the EXCELLERAT experts could in the future support the engineering community to take advantage of Exascale computing power and launch a new era of technological innovations and scientific discoveries.

2 The HPC ecosystem

Many world countries: EU, USA, Japan, Russia, China, Brazil, and India are highly encouraged today to enter the HPC race to release the first Exascale system and dominate at the top world HPC position. All these countries have announced ambitious plans to build the next generation of HPC with Exascale performance and deploy state-of-the-art supercomputers a few years ago. We have been witnessing dramatic turns– the race between China and the USA, who have been holding the leading position by owning the most powerful HPC system in the last decade, was taken over Japan, when the Fugaku supercomputer was ranked no. 1 on Top500 List in June 2020 and still dominates up to date (June 2021).

The last update of the TOP500 list [1] in June 2021 shows that the highest number of supercomputer systems are owned by China (38%), which has 118 supercomputers (out of 500). By performance, China (19%) holds third place and is behind the USA (31%) and Japan (23%). The USA is still ahead of China in terms of installed performance. The USA is following China by owning 122 supercomputers in total (24%). Japan is settled on third place with 34 systems in total.

HPC leaders would like to would like to increase their sovereignty across the technologies to become less dependent on big technology suppliers from competitive countries. For instance, China´s most supercomputers are built by Lenovo, Inspur and Sugon are following [3], meanwhile the USA are building their Exascale machines in partnerships with Intel, IBM, HPE and Nvidia [4], [5], [6]. Lenovo is also the main supplier covering European market [3], Atos, the French-based company, is the second one. Fugaku, World´s fastest supercomputer was developed jointly by RIKEN and Fujitsu Limited and based on Arm technology [7].

2.1 Current state: The European HPC Ecosystem

In Europe, 29 European countries are joint under EuroHPC JU with the aim to fund world-class integrated European HPC and data infrastructure and support a highly competitive and innovative HPC and Big Data ecosystem [8]. Europe could be in a first position on the global HPC market as the European market is composed of several countries, financially supported by the EU, meanwhile, the USA, China or Japan stand as single countries alone. Steve Conway, expert of Hyperion Research explained Europe is already a main player on the world scale as about around 30% of the global HPC market is in Europe [9].

The EU aims to become one of the world leaders in the field of HPC. To date, Europe has two HPC systems in the world´s top 10 List. Since June 2021, the most powerful European system is JUWELS Booster Module (44.1 PFlops), built by Atos and located in Forschungszentrum Juelich in Germany. The second most powerful European system is HPC5, (35.5 PFlops), built

by Dell and installed by the Italian energy firm Eni S.p.A. On the Top500 List, 111 European supercomputers are placed recently, located in 18 countries (the most: Germany 23 systems, France 16 systems, the Netherlands 16 systems, Ireland 14 systems) [4].

EuroHPC JU exposed two key issues on the EU HPC domain: One of the challenges Europe is facing is that all European supercomputers depend on non-European technology as the main hardware and software providers are based in the USA or China. EU thus depends on their supply chains, rules, and some European policies are not aligned with the policies from non-EU countries. Europe is mostly buyer but it works hard to become a builder of the HPC systems to offer the European stakeholders services and products according to European policies. The second one is the fact that Europe consumes 33% of global HPC resources, but supplies only 5% of global computing power [11]. To deploy the autonomous world-class supercomputing infrastructure and a competitive innovation ecosystem in supercomputing technologies, applications and skills, several projects are running under EUR 1 bn. joint initiative EuroHPC JU [10]. To make Europe a leader in a high-technology sector, in the mid- 2019, eight locations have been selected across the EU to host the first (pre-) Exascale EuroHPC founded supercomputers. Five are petascale systems, and were deployed in 2021 in Sofia (Bulgaria), Ostrava (Czechia), Bissen (Luxembourg), Minho (Portugal), Maribor (Slovenia). Three systems will be pre-Exascale and will be implemented by the end of 2021 in Kajaani (Finland), Bologna (Italy) and in Barcelona (Spain) [11]. Europe is striving for self-sufficiency. As microprocessors remain a short supply, the first low-power central processing unit based on European technology is being developed and will be delivered by EPI [12], under the H2020 funding programme. Furthermore, MEEP project explores hardware/software co-design for Exascale supercomputers and other hardware targets that are based on European-developed intellectual property (IP) [13].

Supercomputing will play a key role in the recovery era and will encourage innovation.

EU research and development policies are encouraging the development of supercomputing market as the EU top priority. According to the Digital Europe programme, EUR 2.7 bn. budget was proposed to found supercomputing in Europe during the 2021-2027 period [14]. At the end of June 2020, 19 projects were selected during evaluation with a total budget of EUR 55 Mio: the 9 selected projects are expected to develop energy-efficient hardware in European low-power processing technologies, the 5 selected projects will focus on the development of energy-efficient HPC Software and the 5 selected projects are expected to further develop, adapt and optimize HPC Software for applications in the European industry [15].

Within FocusCoE, fifteen Centres of excellence for supercomputing applications have been identified. Every CoE develops services offered to their target users: training, support to Code Optimization, offering Code and Software packages, presenting data catalogues, providing access to repository and success stories and offering expert consulting [16]. EXCELLERAT is one of the CoEs, serving as a key single access point for engineering applications [17].

Within ETP4HPC, the 2021 European HPC Handbook [18] with a description of 68 on-going HPC projects was released, proving that EU countries are doing great progress in the HPC landscape. At the beginning of 2020, the Strategic Research Agenda, number 4 was issued. This is a strategic document that outlines a roadmap for the achievement of Exascale capabilities by the European HPC ecosystem. The last edition focused on the most important research challenges for Work Programmes 2021-2022 and beyond.

To provide a high level of expertise in HPC and related domains, such as HPDA and AI, the EC supported 33 partners to establish national HPC competence centers, called EuroCC [19]. The aim is that the NCCs become national resources for identifying and coordinating technical knowledge, training resources, industrial outreach, and HPC services and tools for all computing centres in their home countries. Parallelly, the support activity, named CASTIEL (Coordination and Support for National Competence Centres on a European Level), is running with the goal to promote interaction and the exchange of expertise across the entire EuroCC network. EXCELLERAT will support EuroCC project and collaborate further with NCCs.

2.2 International HPC Ecosystems Overview

The most advanced actors in the Exascale computing world are the United States of America, China, Japan and Europe. The USA and China Exascale ecosystems are particularly interesting, since both countries predicted the first Exascale installations already in late 2020 to 2021, and will probably be deploying the largest number of these systems over the next years.

USA

Most prominent Exascale projects in the USA are funded through the $1.8 bn. investment by The U.S. *Department of Energy*. The Exascale Computing Project was set up to build up the Exascale ecosystem [20]. Aurora was expected to be the first Exascale supercomputer, set into operation in 2018, but the project was postponed a few times and finally delayed with a planned delivery date in Q1 2022 [21]. The first Exascale supercomputer will be Frontier, scheduled for delivery in 2021 and dedicated to research in science and technology. It will operate at a computation performance of 1.5 ExaFlops, and will be located at the Oak Ridge Leadership Computing Facility [6]. World-class supercomputer with AI capabilities, Perlmutter, will be used for complex scientific research in different applications, and will be delivered by the end of 2021 at the Energy Department's National Energy Research Scientific Computing Center [22]. According to the Top500 List [4], five most powerful system out of ten are in the USA. The USA holds a 24.4% share of all supercomputers on the Top500 List (122 systems).

China

A large part of the last decade China has been the leading player in the development and deployment of HPC installations. Regarding List Top500 [4], China is the World leader in the number of HPCs. China owns two supercomputers in the World´s top 10 list: Sunway TaihuLight at National Supercomputing Center in Wuxi in 4th place and Tianhe-2A at National Super Computer Center in Guangzhou in 7th place. Currently, first three Exascale systems under production in China are all built around CPUs, manufactured in home country. However, China's program for the period 2020-2025 was similar to the USA: two pre-Exascale machines should be installed by 2021, and five to six Exascale machines will be put in operation by 2025 [23], but by to date, it has not happened yet.

Japan

Japan's Exascale machine, Fugaku, is being jointly developed by Fujitsu and RIKEN Center for Computational Science and put in the public service in March 2021 [24]. Fugaku became the fastest World´s supercomputer in June 2020, and since it has been ranked nr. 1. With the distribution of 34 HPCs on the Top500 list, Japan is ranked on 3rd place among World countries

(behind China and the USA) [4]. In spring 2021, Japan presented Wisteria/BDEC-01, the first system of Japan's big data and extreme computing platforms. Project will be led by University of Tokyo/Riken R-CCS [25].

The race for Exascale is not over yet. The leading countries are preparing tools and resources for the Exascale level mainly to support research, science and industrial sectors. To step on the path of the sustainability and independency, Europe needs to shift from buyer to builder. EXCELLERAT will contribute its part by offering services and expert support for further Exascale development and thus creating added value in the European HPC ecosystem.

3 Engineering trends and innovation on main markets during the Pandemic

Pandemic hit the World in many ways. Due to Covid-19 restrictions, many sectors were affected severely. But the Pandemic has also shown that digitalisation can help to keep organisations alive and to address future challenges, less-digitised organisations will need to step forward to innovation and digital transformation. EU prepared the updated European industrial strategy [30] that will guide the European industry on the road to more sustainable, digital, resilient and globally competitive economy. The European Commission has released EUR 2.018 trillion stimulus package, that consists of the EU's long-term budget for 2021 to 2027 (EUR 1.211 trillion) and NextGenerationEU, a temporary instrument to power the recovery (EUR 806.9 billion) [31]; a EUR 8.2 bn budget for Digital Europe Programme, that is a part of Multiannual Financial Framework 2021-2027 [32]; and Horizon Europe, EUR 95.5 bn. funding programme for research and innovation [33] to encourage European organisations to invest in research and innovation and set the Union on the path to a sustainable and resilient recovery. EU Member States offered support to national organisations, mainly in fiscal nature [34]. People thought that organisations will stop their R&D expenses and lower innovation budgets, but the data show the opposite [35]. In some sectors, EU still contributes the highest share to global R&D investments – in the automotive and health sectors, EU contributes to 45% and 20% of total R&D[36].

In the next subsections, the results of Covid-19 impact on main markets are briefly presented. Additionally, R&D investments and innovation trends on main markets are highlighted to get an overview in what areas and technologies will be the focus put for further digital transformation and research.

3.1 Digital trends and Covid-19 impact on R&D on main markets

3.1.1 Automotive

The automotive industry is being a key GDP driver in many countries and is crucial for Europe´s prosperity. The automotive sector employs 13.8 Mio. Europeans and the sector represent the largest private investor in research and development (R&D) [38].

The Pandemic hit this industry heavily in 2019 and 2020 as it affected the whole automotive value chain. Car sales worldwide shrank for the first time in eight years in 2019 when the Pandemic hit for the first time, and bounced back well in the first quarter of 2021. Automotive industry has been already triggered by new trends in mobility, digitalisation and applying

sustainability policies that requested shift to new products and business models. Nowadays, the greatest emphasis in development is given to electric, connected and autonomous vehicles, which require a comprehensive investment budget. The study on carmakers R&D costs prediction show that the companies that will cut investments in electric, autonomous, shared and connected technologies during the Covid-19 times could face issues of falling behind their competitors. Carmakers in Europe spent far more on R&D than their competitors in the USA and Asia - between 2011 and 2019 R&D spent in Europe increased for 75% (to EUR 42 bn.) [39]. Despite the predictions shows car sales will be in decline, electric vehicles are expected to gain shares driven by higher-driven demand [40]. According to BBC report, the prediction shows that by 2025, 20% of all new cars sold will be electric, and the share will rise on 40% by 2030 and to 100% to 2040 [41]. On the other hand, according to the HIS Markit research [44],e-mobility technology (battery, e-motor and power electronics) is the area that will be the most negatively impacted by Covid-19.

OEMs can make their R&D operations more cost-effective by using novel technologies such as AI, VR/AR, blockchain, product lifecycle management and additive manufacturing [39]. To support novel technologies, the request for Exascale and hi-capable hardware will rise significantly. These technologies request talents – mainly software developers and engineers - as rising importance of in-vehicle software and connected and autonomous cars increases the need for full digital skills. Despite R&D costs shrinking, OEMs and suppliers are focusing on software development in the immediate-term, followed by electrified vehicle-architecture development [42]. The predictions show growing importance of software – areas with the strongest growth will be software functions (CAGR 11%) and integration testing (CAGR 12%) [43].

The automotive industry was also affected by the global microprocessor shortage. It affected chip prices and availability for crucial components which forced them to change supply chains and slow down production rates [44]. This has not only affected car manufacturers, but the whole industry, since most car manufacturers rely on third parties to develop systems which need computer chips, like infotainment systems.

Most companies shrank R&D investments during the Pandemic. To keep European automotive sector competitive, the EU supported this sector with financial funds and state aids [45]. According to the Volkswagen annual report [46], in 2020 company spent EUR 13.8 bn. for R&D activities (driver assistance systems and automation, lightweight construction, connectivity, and alternative drive systems). These costs were 2.9% lower than in the previous year due to the fall in sales revenue because of the Covid-19 pandemic. Porsche did not tighten their budget for R&D, even more, in 2020 company presented several innovations for their sport electric and hybrid cars [47] and built in Germany three new state-of-the-art buildings worth $200 Mio. - a design studio, a concept car construction facility, an aero-acoustic wind tunnel and an electronics integration center [48]. BMW Group R&D expenses in 2020 decreased to EUR 5.7 Mio. (in 2019 EUR 5.9 Mio.) due to benefiting future-oriented mobility technologies, such as vehicle connectivity, highly autonomous driving and electric mobility as well as the new vehicle projects [49], [50]. By 2025, BMW group plans to invest more than EUR 30 bn. in R&D activities to keep its position as innovation leader [51]. Renault invested in the R&D in the first half-year of 2021 EUR 1.247 Mio. (H1 2020: EUR 1.310 Mio.). The decrease in R&D expenses over the first half-year of 2021 is explained by the

end of an initial cycle of upgrades to the product range, the lower level of business, and actions to reduce fixed costs, which focused particularly on subcontracting and purchases of prototypes. This decrease was accentuated by the Covid-19 pandemic [52]. Daimler significantly decreased the level of investment in R&D activities to EUR 8.6 bn. in 2020 (2019: EUR 9.7 bn.) [53].

3.1.2 Aeronautics

The Covid-19 crisis has not spared the aeronautics sector either. Globally, more than 60% of aircraft stayed grounded as there was less demand for air travelling. Due to less maintenance, demand for spare parts dropped, and customers cancelled delivery of new aircrafts. The analysis on the aeroplanes suppliers estimates a 20-50% reduction in OE demand in period 2020-2028, depending on the future market scenario [55]. Aerospace industry continually makes improvements and innovate technology trends. We need to take into consideration that aeronautics sector has wide spectrum of subsectors – civil and military aviation, helicopter aviation, spacecraft and space systems, unmanned aerial systems– that cover all areas from research, design, manufacturing, operating and maintenance and request reliable hi-end technologies, bug-free software and exceptional software engineers. In the next years, engineers will focus on development of the zero-fuel aircrafts to meet global environmental sustainability policies. Airbus step ahead and already presented concepts for the world's first zero-emission hydrogen commercial aircraft [56]. Engineers will put their effort also in observation and analysis of a system to monitor structures (structural health monitoring - SHM) with the help of SHM sensors, developing hardware and software for demanding analysis. The low-cost computational hardware, as for instance GPUs, are enabling engineers to run complex workflows for advanced data analytics using AI and ML. A big progress in development of a new, advanced materials is expected. Another area that requires an intense engineering approach is the thermal design of aerospace equipment. With the help of blockchains and smart automation data exchange between manufacturers and customers remain secured. Priority will be also given to additive manufacturing. The usage of novel technologies will rise: Aircraft maintenance companies already use IoT for predictive maintenance of aircraft parts and equipment meanwhile researchers will implement AI more and more to gain new insights (into materials, engine work, security). One of the most exciting innovation is developing autonomous flight systems (Airbus is also building autonomy systems and programmes [57]), and supersonic aircrafts – an aircraft that travels faster than the speed of sound [58]. . Engineers working in harsh, complex environments such as air and space, must develop precise technologies where no mistake is acceptable.

European demand for aerospace manufacturing decreased overall by 43% in 2020 [60]. During the Pandemic aerospace companies had to tighten their R&D budgets as well. In comparison to 2019, the 2020 Airbus R&D expenses decreased for 15% (2020: EUR 2.858 Mio., 2019: EUR 3.358 Mio.) [61]. Dassault Aviation decreased its budget by 5% (H1-2021: EUR 250 Mio., H1-2020: EUR 262 Mio.). The priority of the company remained project Falcon 6x, and at the beginning of this year, the first three development aircraft were delivered [62]. Dassault Aviation is investing in high-performance information system, they set up a single 3D experience platform for all their programmes and adapted the collaborative system engineering model to coordinate everybody involved in the development of large airborne systems [63]. The priority of Safran Group is to contribute to the decarbonization of aviation. Safran Group received a EUR 500 Mio. loan that will be used for development of propulsion systems for the next generation of single-aisle commercial aircraft. One of the first steps was signed agreement with GE Aviation to launch a technology development program with the aim to lower fuel

consumption and CO_2 emissions compared to today's engines for more than 20%. Safran´s R&D expenses were decreased by 5% (H1-2021: EUR 426 Mio.) [64].

3.1.3 Energy

Energy sector has been severely affected by Pandemic crisis. IEA´s data show that the energy demand in countries in full lockdown was on average 25% in decline, while in countries in partial lockdown the demand was lower for 18% per week. Due to lockdowns and more uncertain expectations in the years ahead, the investment in energy sector in 2020 was decreased for 20% [65]. While the demand on oil, gas and electricity decreased during pandemic, the statistics show that renewable markets, especially electricity-generating technologies, are more resilient to the crisis. In 2019, the renewable energy increased for 7%, but the IEA forecasts the decline by 13% in 2020 (compared to 2019) [66] as a result of lower investments, projects decline or cancellation, supply chain disruptions, delays in construction activities and Pandemic restrictions. Again, while the public spending on energy R&D continued to rise, private sector decreased their budget for R&D for 2% in 2020 [67].

Implementing HPC technologies into energy industry is needed and can significantly aid in the improvement of energy sector: development of new energy resources, maximising the potential of existing resources, forecast electricity demand, development of robots for dangerous situations and providing electricity smart trade platforms. The near future trends show further implementing AI, blockchains and data analytics that will help transforming energy sector [69]. The future belongs to renewable energy (sun and wind energy, geothermal sources) – building renewable energy infrastructure, new power systems and energy platforms. The main challenge remains building cost-effective energy storage that will occupy engineers in the next years [70]. The EC outlines in the revised Renewable Energy Directive that target for the share of renewables in the EU energy will be 40% by 2030 [71].

- The Internet of Energy is another term that is coming in front of future innovation to optimise the efficiency of energy infrastructure and reduce wastage [72]. Not only energy generation, but also development of cost-effective energy storage solutions with the help of AI, uniting all energy stakeholders with the use of blockchains, providing energy-as-a-service (EaaS) solutions, development of Vehicles-to-grid, and emerging Power-to-X technologies by industry that convert energy and carbon dioxide into new materials and innovative products will significantly change the energy industries we know today [73]. Future trends require Exascale methodologies / technologies. If we list just some from the HPC4E project and EoCoE2 [77], [78]:
- multiphase flows simulation in pipelines with heavy oil;
- molecular modelling of catalysts for heavy oil refining;
- combustion simulation tools to optimize fuel-biofuel design and performance towards more sustainable and greener transport systems;
- methodologies development to understand and predict the multi-scale atmospheric motion relevant for the operation and performance of wind farms in complex wind situations;
- farm design and short-term micro-scale wind simulations to forecast daily power production;
- simulate a wind power plant to optimise its production;

- use of high-end numerical tools to determine the properties of new materials for photo-voltaic power panels, or for batteries and super-capacitors,
- multi-scale simulation methods (molecular dynamics, kinetic Monte Carlo, quantum Monte Carlo, ...) for materials modelling (solar cells, batteries, supercapacitors....);
- geothermal and heat reservoir modelling;
- predictive hydropower capacity modelling; high-fidelity simulations for providing further understanding on the combustion process and emissions characteristics;
- massive data simulations: exploration data processing requires fine meshes to capture small geological features in areas of several square kilometers, exploitation relies heavily on hydrocarbon flow forecast at reservoir scale which needs robust simulations Application for uncertainty quantification in seismic imaging.

The simulations and visualisations in the energy sector have become far from simple, requesting state-of-the-art software systems and parallel processing on a vast scale [75]. Energy companies have insufficient software engineering resources, they do not have software developers skilled in solutions dedicated to their sector [76].

3.1.4 Manufacturing

Manufacturing has been one of the sectors that were struggling most in 2019 and 2020 due to Pandemic, trying to survive all disruptions. In 2021, manufacturing is coming back on track and is striving to become more innovative and digital. We are not talking about Industry 4.0 anymore, but can already focus on Industry 5.0. – from using high-end technologies to optimise the processes to connecting smart machines and people. In the next years, manufacturing will "become smarter" with the help of AI, 3D printing and 5G/6G networks. The quality issues, costs and production processes will be decreased by digital twins' replacements (e.g. IoTwins project aims to build reference architecture for the development and deployment of distributed and edge-enabled digital twins of production plants and processes [82]). Digital connectivity will become one of the major trends as business will rely on IoT. Also, manufacturing is following SDG goals for sustainable future that will lead to green innovations (switching to renewable energies, lessen waste, shorten supply chains, optimising manufacturing processes, use of smart machines for predictive maintenance, real-time communication for dispersed workforce) [77]. Manufacturers will integrate AI to innovate operations and improve productivity. AI in the combination with Computer-Aided Engineering (CAE) software will support demanding simulations that generates tonnes of data. With the help of powerful Exascale computers, companies could accelerate compute-intensive CFD and computer-aided design and engineering workloads [78]. Exascale systems, powered with AI will enable to train predictive models using the massive amounts of data, derived from actual laboratory experiments. AI in combination with ML will be applied in manufacturing robots. [79].

Manufacturing industry relates to different sectors, thus the R&D investments in 2020 varied significantly. In 2020 industry spent 6.2% more than in 2019, but if we look through sectors, software and technology companies invested more in R&D than in 2019, meanwhile the automotive industry cut their R&D budgets, the same cuts were done also by airliner manufacturers [81]. With the help of powerful Exascale systems, engineers will run advanced simulations, build innovative models and make better predictions based on big data inputs.

4 EXCELLERAT Service Portfolio and competitors analysis

4.1 Key Exploitable Results

A campaign of identification and update of the results issued from the developments conducted by EXCELERAT teams was performed. The objective was to refine the results planned at the beginning of the project and to prioritise the most relevant ones based on the following criterion: identify significant results which could potentially represent a new business or research activity to satisfy market expectations: Key Exploitable results (KERs). Characterisation tables were filled-in by all partners for each identified result. A characterisation tables describe in a simple way each component of the result, providing data / facts and identifying alternative available solutions to addressed target. The IPR and risk management aspects are also considered in the characterisation tables.

EXCELLERAT partners have provided 16 technical KERs. A short description of the identified KERs is presented in the Table 1. More detailed KERs analysis will be provided in the Deliverable 6.6 Final Report on Business Development and Sustainability Strategy.

This campaign enabled the identification that the percentage of completion of the planned developments is between 70% and 100%.

Some of the assets development planned at the beginning of the project were replaced by others. This is the case of **Fluidity** and **COVISE**. Other developments are introduced after the beginning of the project, we can refer to **Runcrawler**, **Lemmings** and **Flinter**.

For each KER, additional items were identified. We can mention the "target market", the "alternative solutions", The "Unique Value Proposition", The "go to market use model", the early adopters, the competitors and the IPR background and foreground.

KER	Short description
TPLS - code	Multiphase CFD code, Modelling the interface between flows of different fluids
Vistle	A tool for visualisation of large-scale simulations with huge amounts of data. Enabling debugging and providing accessible visualisation tools for non-experts
Alya: code optimisation	System-level and node-level code optimisations for extreme scale applications
Alya: Mesh refinement	Dynamic mesh adaptation in order to reduce the cost of numerical simulations
Modal decomposition toolkit	Efficient and user-friendly modal decomposition toolkit for large scale numerical simulation data sets
CODA - code	Full simulation of equipped aeroplanes to help the design process

BigHoop	Compression library to provide efficient data handling and storage strategies
NEK5000 - code	High fidelity simulation of turbulent flow in relatively complex geometries
FEniCs - code	Mesh generation of complex geometries. Automated error estimation and adaptivity
UQiT	UQ tool to evaluate the reliability of the simulations or to choose the controlling parameters to improve the accuracy of the results
AVBP - code	Automatic mesh refinement for high fidelity simulations with application to safety applications using AMR
Flinter	A tool to help contributor to stick to the standards
Lemmings	A tool to ship ready-to-use customisable workflows, featuring pre-run checklists and on-the fly sanity-checks
Runcrawler	A tool to mine data on runs logs from an HPC machine and build insights on the ways resources were used
SWAN	Secure data transfer platform. Remove of HPC entry barriers for industry Ease of use for inexperienced users by providing a GUI

Table 1 : Short description of collected KERs

4.2 Value Proposition Canvas

In order to better understand our potential customers and the value that our EXCELLERAT products and services could bring them, we have chosen to use the Value Proposition Design method, popularised by the renowned business theorist Alex Osterwalder[1]. This method helps to optimise the classification of EXCELLERAT products and services by stakeholder, industry and application and covers all the activities required to develop a sustainable business model and complete the business plan. An introduction to the use of the ground canvas made for applying the method can be found on [82].

1 [1] Value Proposition Design: How to Create Products and Services Customers Want, Osterwalder et al. (2015)

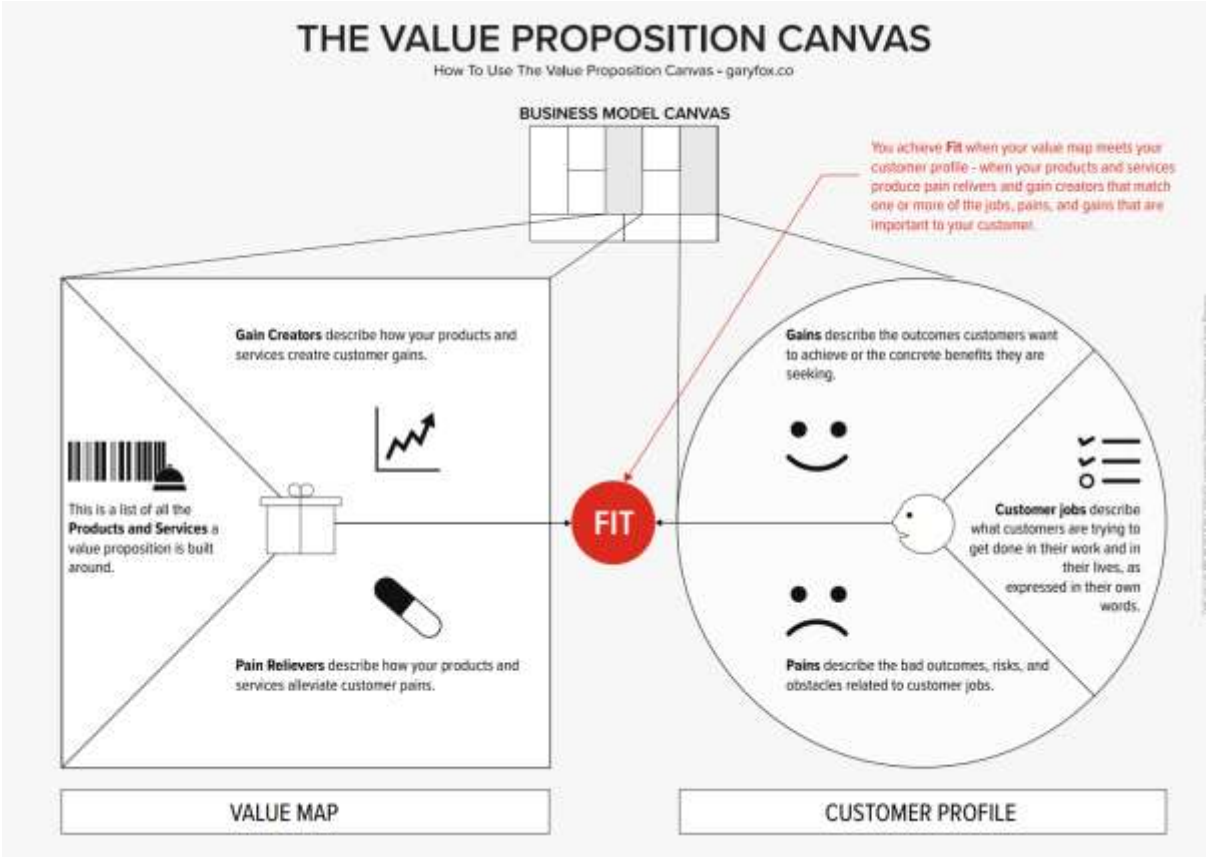

Figure 1: The Value Proposition Canvas explanation [82]

The primary market for EXCELLERAT communities interested in large-scale / high-fidelity CAE applications. The core codes improved by the project serve as a showcase for the CoE's capabilities, but the actual service would be tailored to the individual needs of the customer. The key selling point is actual expertise in the particular area. The sectors to be targeted first are automotive, aerospace, energy and manufacturing.

Since EXCELLERAT provides services to five defined target groups, we developed our analysis on five Value Proposition Canvases for the following target groups: (1) industrial end-users, (2) ISVs, (3) HPC providers, (4) HPC technology providers and (5) academic experts and research code developers. They were completed using information collected through questionnaires sent to the target groups in the second year of the project, online interviews with representatives of EXCELLERAT interest groups conducted in the third year of the project and basic research in publications, reports and presentations. The main results are presented in the next paragraphs.

While the discussion on the services fit is indeed mostly dependent from the targeted segments, a few commonalities may be observed. In particular, a common partial fit between requests and present offering is observed:

- **Events and funding opportunities information:** information on such topics is considered to be valuable for target end-users and thus chosen to be presented on the EXCELLERAT Service Portal since its first version. While the usage statistics of the service portal are not yet very large, the interest in this section of the service portal

seems not very high. This is probably due to the existence of other better-known initiatives. Instead of replicating those existing services, a better strategy could be to link the service portal to those in an effective way.

1. Industrial end-users

When addressing industrial end-users, we are certainly aware that there is a correlation between company size and awareness of (Exascale) HPC technologies applied to engineering challenges and innovation. Moreover, each of the markets covered - automotive, energy, aerospace and manufacturing - has specificities and therefore requires specific solutions and services. The sample of industries contacted for the questionnaires and interviews was quite limited (about 30), but since they were identified through the extensive network of the project partners, built over decades of activity, we think that the quality of the interviewees could overcome this limitation. We found that some challenges and barriers seem common to all users.

When it comes to challenges and blockers, most SMEs report problems with managing large datasets, checking the validity of simulation results, and engaging with research projects. They also have problems with access to expertise and computing resources, and report difficulties in finding appropriate software tools and ISVs to address their challenges as well. Large companies tend to employ many experts and rarely seek external help, and usually have their own HPC infrastructure that largely meets their needs. Enterprises of all sizes primarily use specialised commercial software codes, some of which lack high scalability and whose licensing models often penalise high numbers of parallel threads. A common pain point, therefore, is dealing with expensive and inflexible software licensing, which – in some cases is mitigated by moving to the cloud, where some ISVs offer pay-per-use licensing options. In addition, some users state that they have problems achieving the software performance promised by the ISVs with their hardware.

The second most reported problematic area relates to data privacy and security. Data security and data privacy are often perceived as problematic when accessing cloud services, fearing loss of control of their IP, especially when providers are international big players (Google, Amazon, etc.). Some of the end-users reported that they are not allowed to move data outside the company due to their security policy. Transferring huge amounts of data in the cloud is also often problematic performance-wise. Some end-users state also difficulties in renting HPC resources from external providers, due to long administrative procedures, unreasonable queuing systems and policies that differ from provider to provider. The common desire is for an easier, more user-friendly and more standardised access.

Generally speaking, industrial end-users would like to gain access to early released state-of-the-art hardware, technology experts and code developers (or providers), purchase only the services they need (with a pay-as-you-go format), with the aim of cutting their costs and lowering the investments.

EXCELLERAT Services FIT

After analysing the Value Proposition Canvas (VPC), the following services fit (that is, a match between customer needs and pains with the at the moment identified service offer) was

identified. Please note that how the project partners will provide those services is related to the business model and plan identified for the exploitation phase, and therefore not the object of this Deliverable, being the focus of a future report.

- **Consulting:** Consulting is the main service category offered by EXCELLERAT. EXCELLERAT could provide access to know-how and experts for specific domains/challenges in different ways and through different channels. For instance, an end-user might take benefit of use-cases, success stories and best-practices guides or request support in applying the same techniques or tools on his own design tasks. Consulting topics provided by the EXCELLERAT partners (as listed in D4.2 and D1.6):
  • Data Analytics for Engineering using Machine Learning [T2]
  • Data analytics in engineering [T3]
  • Data management for large scale simulation result and input data [T4]
  • Efficient and modern implementation of Exascale ready engineering software [T5]
  • Efficient execution of large-scale engineering simulation workflows [T6]
  • Holistic Testing and Validation for the Engineering Workflow [T7]
  • Modelling of Engineering Problems [T9]
  • Numerical Solution methods for Engineering Problems [T10]
  • Performance Engineering for the Complete Large-Scale Engineering Workflow [T11]
  • Strategies for Load-Balancing and Data-distribution [T12]
  • Strategies for in-situ visualization and data-analytics [T13]
  • Visualization methods and tools for large scale engineering simulation workflows [T14]

  Training: EXCELLERAT could provide training that will help users to get the skills to introduce new methodologies in the company. Training topics that are provided by the EXCELLERAT partners: training modules on data analysis and engineering simulation data, training modules for self-learning or complementary to training sessions (tutorials) published on portal, training on dataset use and applications - how to manage huge datasets, checking validity of results, training on Exascale engineering topics for end users.

  Tools access: EXCELLERAT could provide access to specific tools, developed or optimised by the project:

  For simulation: CODA, Alya, AVBP, Fenics, Nek 5000 and TPLS, For in-situ visualization: Vistle,

  For evaluation the reliability of the simulations the software (UQiT)

  For data transferring: secure data transfer platform the software (SWAN)

  Compression library: for efficient data handling the software (BigHoop)

Datasets access: EXCELLERAT could provide high performance hosting and access to specific datasets like Data Exchange Platform developed by SSC-Services GmbH within the EXCELLERAT project.

Prospect users will receive accurate information on the available hosting partners security and privacy measures, letting the user make an informed decision.

HPC resources: EXCELLERAT could provide support in accessing HPC resources and infrastructure owned by the available partners. This should make easier accessing high-end technologies (including pre-Exascale or future Exascale systems) possibly lowering costs, and speeding time to market..

Services that are requested by end-users but not yet provided by EXCELLERAT:

- Since some interviewees reported that they have issues to find an appropriate ISV for collaboration, especially when using open-source codes or tailored software, a match-making service could be proposed.
- Some interviewees reported problems arising from the need of software validation and certification, required in specific applications or value chains. EXCELLERAT might consider supporting software validation or certification processes, analysing ways of collaboration with specialised entities.

Services that fit partly:

- **Events and funding opportunities information:** information on such topics is considered to be valuable for target end-users and thus chosen to be presented on the EXCELLERAT Service Portal since its first version. While the usage statistics of the service portal are not yet very large, the interest in this section of the service portal seems not very high. This is probably due to the existence of other better-known initiatives. Instead of replicating those existing services, a better strategy could be to link the service portal to those in an effective way.

2. ISVs

ISVs are facing challenges with changing industries, aggressive competition, and need to find ways to recruit and retain talent to develop effective, secure and bug-free software. Emerging new technologies such as AI, ML, 5G, IoT request new scalable and well-secured software that will fulfil digital requirements. This target group could be divided into two types: small-sized ISVs companies and startups specialized in specific niche applications and large-sized ISVs offering a wide range of solutions and support. A second challenge comes from the communication between ISVs and their users/customers; ISVs won't develop or do research on a new direction/feature unless they perceive a promising market for that, but users are not always aware of all the possibilities innovation could bring to their business. For instance, ISVs are not likely to invest putting effort in developing and adapting their software to new available technologies not readily available on the market, even if very promising. This is especially true

for Exascale systems, where most of the components are at the bleeding edge of technology. To develop new software or adapt their own to these new technologies, ISVs need an environment where a tight collaboration with all target groups (end-users, technology providers, HPC providers, researchers and other code developers) is possible.

With the support of EXCELLERAT, ISVs could find easier to deploy software to HPC centres and Cloud providers, finding know-how and expertise for Exascale development, access to tools for data analytics and data management helping them to support novel technologies lowering investments and risks.

EXCELLERAT Services FIT

After analysing the Value Proposition Canvas, the following services fit was identified:

- **Consulting:** EXCELLERAT could provide access to know-how and experts for specific domains/challenges in different ways and through different channels. For instance, they could be interested in support for performance improvement, advanced visualization capabilities, data flow optimization, parallelisation etc. Since EXCELLERAT partners have a good overview of the HPC market, both from the perspective of HPC users and HPC providers. Partners can also recommend ISVs new features or improvements.

  Consulting topics provided by the EXCELLERAT partners (as listed in D4.2 and D1.6):

  • Co-Design Engineering Software- and System-Design [T1]

  • Efficient and modern implementation of Exascale ready engineering software [T5]

  • Meshing and re-meshing techniques, methodologies and Software [T8]

  •Data Analytics for Engineering using Machine Learning [T2]

  • Data analytics in engineering [T3]

  • Data management for large scale simulation result and input data [T4]

  • Strategies for Load-Balancing and Data-distribution [T12]

  • Strategies for in-situ visualization and data-analytics [T13]

- **Co-design:** EXCELLERAT could provide ISVs access to large infrastructures and specialized hardware (like specific GPUs or other accelerators, but also file systems and resource managers) which may not always be easy for them to gain access to.
- **Service portal:** Some small ISVs could eventually take benefit of the EXCELLERAT service portal to offer their solutions as services on it, as a way to have a better HPC integration and to reach more customers.

Services that are requested by ISVs but not provided by EXCELLERAT:

Since ISVs are sometimes not aware or unsure of the possibilities of novel hardware and how they can utilise it to gain an advantage over competitors, EXCELLERAT acting as a technology scout could offer research and insights into new possibilities. In case of dissemination events

or through its partner network, EXCELLERAT can also provide user feedback on ISVs software.

Services that fit partly:

- **Events, funding opportunities information –** the same considerations described in the end-users section apply.

3. HPC providers

The HPC field is constantly facing changes; moving to faster and more capable systems, from Petascale to Exascale (we are already talking about Zettascale), from providing services on-premises in data centers to cloud. Nevertheless, the demand for computing resources from old (like CAE) and new (like fintech) communities continues to rise and HPC providers need to fulfil ever-growing customer requests. The primary challenges HPC providers face are keeping operational costs under control and insuring the know-how to prepare the initial setup of new systems. HPC infrastructures require large investments and have long purchasing cycles (a year or more). Furthermore, HPC providers find it hard to evaluate the performance of new hardware; popular HPC benchmarks used in tenders and procurement processes often do not represent the real application-level performance. Most EXCELLERAT partners offering HPC resources are non-profit academic and research institutions supported by public funding, that for legal and administrative issues are often limited in their possibilities to interact with industry. Another challenge derives from high operational costs due mostly to energy consumption for powering and cooling such powerful systems.

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EXCELLERAT Services FIT

After analysing the Value Proposition Canvas, the following services fit was identified:

- **Consulting:** Since some partners are well-established HPC providers leading the domain, EXCELLERAT could support them to share their best practices and know-how when it comes to procurement process, hardware selection, data management, data security and HPC infrastructure setup at the Exascale level.

  Consulting topics provided by the EXCELLERAT partners (as listed in D4.2 and D1.6):

  • Co-Design Engineering Software- and System-Design [T1]

  • Data management for large scale simulation result and input data [T4]

  • Efficient and modern implementation of exascale ready engineering software [T5]

  • Holistic Testing and Validation for the Engineering Workflow [T7]

  • Meshing and re-meshing techniques, methodologies and Software [T8]

  • Strategies for Load-Balancing and Data-distribution [T12]

- **Training:** since some HPC providers have expressed the interest to participate in training on operating and utilizing HPC infrastructure for their own employees, EXCELLERAT could offer specific training on that. Sharing the best practices obtained by EXCELLERAT partners will not only help other HPC providers to stay on top of the new technologies, but also help them develop new talents in this area, as they expressed a lack of qualified people to employ.
- **Service Portal:** Some HPC provider could eventually take benefit of the EXCELLERAT service portal to offer their infrastructure services on it, as a way to have to boost industrial awareness.
- **Data Management:** Some interviewees expressed a clear interest in adopting secure and easy to use data management tools and solutions. The tools developed by SSC within the EXCELLERAT project could be a very promising solution for those needs.
- **Tools:** Data Exchange & Workflow Portal, SSC, is being tested at HLRS, but will be moved to other HPC centers as well. The advantages this Portal brings are: higher HPC customer retention due to less complex HPC environment, reduction of HPC complexity due to web frontend, shorter training phases for inexperienced users and reduced support effort for HPC centres, calculations can be started from anywhere with a secure connection, time and cost savings due to a high degree of automation that streamlines the process chain. Another tool HPC providers could access is compression library that allows for significant file size reduction while limiting compression induced artifacts, named BigWhoop. Another tools HPC providers will be offered are Lemmings - An open-source helper tool to ship ready-to-use customizable workflows, featuring pre-run checklists and on-the fly sanity-checks and Runcrawler, an open-source helper tool to mine data on runs logs from a HPC machine and build insights on the ways resources were consumed.
- **Codes:** Some of the codes EXCELLERAT partners are developing could be tested by technology providers (e.g. Alya, CODA, AVBP).

4. HPC technology providers

Technology providers could be divided at least in two main groups: (1) hardware and middleware providers (providing different building components like storage components, processors, accelerators, disks) and (2) service providers (providing different services like SaaS, PaaS, IaaS and customer support). In today's challenging environment, technology providers are facing fast customer changes as a result of quickly onboarding new technologies and processes and rapid digital transformation. Moving to the cloud requests development of new scalable software and technologies. Furthermore, service providers need to assure highly secure systems to their customers. Outsourcing, hiring and collaborating with IT experts is the pain point of all TPs. The IT experts can namely aid in the improvements, assuring that TPs stay on top of the latest tools and techniques. for a common challenge they face is how to build reliable high-end systems from unreliable components.

On the other hand, technology providers create the "technologies of the future" and they are already striving to develop the next generation technology - zetta technology. Leading technology providers (e.g. Atos, HPE, NVIDIA, Intel) have all needed resources in-house and

offer expert help to users (their customers). For instance, NVIDIA owns Selene, World´s 6th most powerful supercomputer in the world and powers 342 systems on the TOP500 list, including 70 percent of all new systems and eight of the top 10 [83]. However, they are usually striving to connect with the user communities, in a process of ”co-creation” that aims to create a solid reputation among them and therefore to be seen as a reference vendor.

Some smaller technology providers stated their interest to gain access to some tools and datasets offered by EXCELLERAT, while the “big players” said that at the moment they are not interested in the services offered on the EXCELLERAT Service Portal. All of them in any case are interested in making new, valuable connections, finding new customers and experts for further collaboration. One way is to provide access to the software codes developed or optimized during the project.

EXCELLERAT Services FIT

After analysing the Value Proposition Canvas, the following services fit was identified:

- **Consulting:** same considerations apply as those described above in the end-users section.
- **Codes:** Some of the codes EXCELLERAT partners are developing could be tested by technology providers (e.g. Alya, CODA, NEK5000).

Services that are requested by HPC technology providers but not provided by EXCELLERAT:

- Since technology providers are using more and more AI, ML techniques and methodologies in several aspects of their business (software and hardware), a matchmaking service with competencies and experts in the EXCELLERAT partners stakeholders communities could be provided. .
- Since forecasts from leading experts (like Hyperion) indicate a rapid growing of the cloud services market even for HPC/HPDA workloads, EXCELLERAT could support those partners offering cloud services as an additional marketing channel.

Services that fit partly:

- **HPC / GPU resources:** while technology providers mainly use their own in-house Hardware and Software, they could benefit accessing EXCELLERAT partner's HPC resources for co-design purposes, and the Portal could offer a one-stop-shop access for that. Some technology providers also require access to large HPC infrastructure for product development and testing, to improve scalability and Exascale-enabling. EXCELLERAT could facilitate that access.

5. Academic experts and research code developers

Academic experts and research code developers are developing their own software, mainly for non-commercial purposes, and they collaborate with academic and industrial experts in different areas and applications. We interviewed a sample of reputed academicians, mostly working on simulations, data analytics and few with AI or ML. When talking about the challenges they face, the biggest one they reported was finding and retaining enough skilled and talented IT professionals., They are therefore interested to different types of collaborations and access to skilled professionals working in HPC or specific domains. Academic experts also claim they have problems accessing the HPC resources when needed, are facing hard times because lacking skills in using HPC infrastructure (queuing system, split jobs), must deal with long administrative times and poor user-support. They find renting HPC resources too costly, thus many of them own and use small departmental clusters.

When coming to software, they use open source codes or develop their own codes that are hardly scalable and are not designed for Exascale systems yet. They need to do some adaption of the codes when transferring them from in-house resources to external ones. Development and maintenance of in-house codes takes much effort and time.

Academic researchers and code developers would like to gain an access to the early released state-of-the-art processors and accelerators, technology experts and code developers (or providers), share their know-how in training and use-cases, collaborate on different research projects.

EXCELLERAT Services FIT

After analysing the Value Proposition Canvas, the following services fit was identified:

- **Consulting:** EXCELLERAT could provide access to know-how and experts for specific domains/challenges in different ways and through different channels. For instance, academics and code developers might take benefit of use-cases, success stories and best-practices guides and request support in applying the same techniques or tools on their own development tasks stance, a Academics and code developers can also use some of the application software or tools developed or optimised in the project (e.g. Efficient and modern implementation of Exascale ready engineering software). Therefore, all consulting topics, listed under industrial end-users and ISVs could be offered to academics and research code developers too.
- **Training:** EXCELLERAT could provide training that will help users to get the skills to introduce new methodologies in the faculty or research centre. Some proposals: training modules on data analysis and engineering simulation data, training modules for self-learning or complementary to training sessions (tutorials) , training on dataset use and applications - how to manage huge datasets, checking validity of results, training on Exascale engineering topics.
- **Tools access:** EXCELLERAT could provide access to specific tools, developed or optimised by the project, for instance, Vistle- a general visualization tool for large scale data sets, BigWhoop - compression library, UQiT - an open-source Python package for uncertainty quantification (UQ) in CFD, Modal decomposition toolkit for large scale numerical simulation data, Lemmings - An open-source helper tool to ship ready-to-use

customizable workflows, featuring pre-run checklists and on-the fly sanity-checks. How this will be made possible will depend on the IP owners of the tools and their licensing models.

- **Datasets access:** EXCELLERAT could provide high performance hosting and access to specific datasets, as the Data Exchange Platform was developed by SSC-Services GmbH within the EXCELLERAT project.
- **HPC resources:** EXCELLERAT could provide support in accessing HPC resources and infrastructure owned by the available partners. This should make easier accessing high-end technologies (including pre-Exascale or future Exascale systems) possibly boosting research results.
- Codes: Codes that EXCELLERAT partners are developing could be used by academics for research purposes: Alya, CODA, NEK5000, TPLS, FEniCs, AVBP.

The EXCELLERAT Service Portal and the support of the CoE will be further developed, monitored and improved according to the future customer´s needs. The full support to all target groups is needed, and EXCELLERAT partners, interest groups and invited collaborators could provide different services that are needed, in the framework of the EuroHPC initiative, to lift Europe as a main Exascale player, holding the competitive and innovation leading position.

4.3 Excellerat engineering communities SWOT analysis

In the engineering world, communities exist whose goal is to connect engineers, researchers and companies from various domains to share experiences, organise events and promote the advancement of engineering techniques. Some of those communities are fairly large, not restricted to a single domain, but most of them are focusing on a specific area of engineering, or even around a specific software solution. The goal of this analysis is to identify the relation between the EXCELLERAT project and these communities, what activities could EXCELLERAT undertake to become a part of these communities and what could be the benefits of collaboration. Within this SWOT analysis, we are going to focus on EXCELLERAT's features regarding other communities, possible collaboration opportunities, taking into consideration the EXCELLERAT Service Portal as well. Data for this analysis was gathered throughout the EXCELLERAT project and activities in WP6, including market research, questionnaires and interviews with stakeholders and interested parties.

EXCELLERAT in relation to other Engineering communities

The biggest and most active communities in engineering and technology are NAFEMS [90], IEEE [91] and ACM [92]. We have decided to group these communities together, as we believe they have similar goals and activities.

The NAFEMS mission is to provide knowledge, international collaboration and educational opportunities for use and validation of the engineering simulation. NAFEMS facilitates unbiased worldwide communication and collaboration between industries, academia, and

government organisations for the advancement of best practice in multidisciplinary engineering simulation expertise. They organize conferences and deliver training as well as personal educational opportunities that are aligned with the rapidly-advancing engineering simulation technologies. Inside NAFEMS there are many more subdivisions and communities, like regional groups, working groups, academics, technical communities and similar. We identified NAFEMS as the most ideal community for targeting Exascale usage. However, using market research in form of questionnaires and interviews with stakeholders, we have also identified that EXCELLERAT interest groups take part in IEEE, ACM, ASCS, VDI and VDE communities, which we have included in this analysis.

NAFEMS and ASCS are more focused on simulation technology, IEEE and VDE are focused around electronics and hardware engineering, VDI is a general engineers association, and ACM has a strong focus on computing, but it shows that a lot of AI/ML engineering companies are members.

All communities undertake similar activities; they organise events, conferences, training and workshops, foster communication between members, help members with projects, funding, access to infrastructure and offer various services and benefits to their members. As such, they have a large network of members with clear communication channels.

STRENGTHS	**WEAKNESSES**
EXCELLERAT combines the competences of all top HPC centres in Europe dealing with industrial users	Small user community
EXCELLERAT partners have already a wide customer base acquired over many years	Relies on partner activities
EXCELLERAT partners have top-class large-scale infrastructure	Does not organise events and conferences
No membership fee for community – interest groups	Does not publish own journals
EXCELLERAT Service PLatform is being developed	Active only for a couple of years
OPPORTUNITIES	**THREATS**
To collaborate with the communities in order to work on Exascale together and reach a wider user base	Communities often struggle to collaborate with EU-funded initiatives
Create use cases and success stories with community members	Excellerat can’t handle so many users from communities at once
Publish in journals and attend conferences,organized by engineering communities	Domain experts to work with users from communities may be hard to find

Exascale niche is not yet fulfilled in other communities	Exascale is still a newtechnology for many users in the engineering communities
Offer products/services like co-design, visualisation, engineering simulation at Exascale level	

Table 2: EXCELLERAT vs Engineering communities SWOT analysis

EXCELLERAT in regards to Code communities

Code communities are gathered around a certain software package or tool. Here we have found that we can differentiate communities, based on the licensing type of the software they are gathered around. Open source software tends to have a large community, mainly attracting academics, but can suffer from fragmentation when multiple communities form around different versions of the same software, the OpenFOAM community is a clear example. Proprietary software tools developed by commercial organisations such as Siemens, Dassault, Simclale, Altair and Ansys gather both industrial and academic members. Those communities may have fewer members, but have clearly defined communication channels, organise training events and provide commercial support.

For these reasons, commercial software vendors may seem to have an advantage, but reportedly, they will not pursue and develop new features in regard to scaling to Exascale levels if there is not a clear demand from their users, and if the required infrastructure is not readily available (Exascale HPC infrastructure and software libraries). This can lead to a situation where software vendors wait for Exascale infrastructure to become available for their users, and users will not invest in hardware infrastructure unless there is software support for it. Open source software communities are more likely to adapt new technologies faster. We can assume the reason for that is academic researchers being the main contributors to the code.

Because of that, EXCELLERAT could benefit from collaboration with both kinds of code communities. Proprietary code communities need help and persuasion to adopt Exascale technology, while open-source communities can serve as early adopters.

STRENGHTS	**WEAKNESSES**
EXCELLERAT already has domain experts developing some of those codes for Exascale	Community understands the code better and knows which parts of the code need optimising
EXCELLERAT partners know how to get funding for parallelizing codes and adapting them to Exascale	Code communities are usually not so open to outsiders
EXCELLERAT partners can provide access to HPC infrastructure and expert know -how	
OPPORTUNITIES	**THREATS**
First-mover advantage (Exascale-directed	Have to develop Exascale ready codes

services are still absent from market)	before we have access to Exascale resources
To collaborate with code communities on adapting codes to Exascale	Too much effort needed for adapting codes
Communication with the communities through established channels	In some cases there is no central authority in code communities which may be bad for collaboration
Create collaboration demand for exascale through exisiting use cases and success stories	Communities may not invest if there is not a clear demand from users, but users are not aware of the potential benefits

Table 3: EXCELLERAT vs Code communities SWOT analysis

EXCELLERAT in regards to other CoEs

There are 15 European Centres of Excellence (CoEs) focusing on High Performance Computing. Each of them is filling a specific niche and advancing that specific area with the use of HPC and Exascale technologies. Most of them undertake similar activities, they organize events, offer training and consulting, work on software and advanced simulations. One could argue that the CoE are competitors in this regard, but they are targeting different areas and users. We believe that there is more to gain from collaboration than competition. The CoEs already collaborate on training events, market research and share best practices. Very few CoEs have publicly expressed that they work on data management (only CompBioMed) and co-design (only HiDALGO). EXCELLERAT and BioExcel are currently the only ones offering services through it's a Service Portal. BioExcel has taken a different approach, developing and offering computing services on the ELIXIR compute platform, which uses other provides like AWS and Google Cloud for resources. Some CoEs like E-CAM and CompBioMed offer a training portal, with educational materials and training events. Most of the other CoE state that they offer services like training and consulting for specific expert areas, but little detail is provided online. CompBioMed even offers a HPC resource allocation program. Although EXCELLERAT has already established collaboration with some other CoEs, we believe the EXCELLERAT Service Portal presents an even better collaboration opportunity.

STRENGTHS	**WEAKNESSES**
Only one with Service Portal	Other CoEs have more expertise in other areas
Knowledge and expertise in engineering areas	Every CoE has their own approach to solving challenges
EXCELLERAT has strong network of HPC centres inside consortium – know how in simulation, co-design, data management and visualisation	Service portal still in development

Infrastructure available from partners inside consortium	
OPPORTUNITIES	**THREATS**
Collaboration on launching services on Excellerat Service Portal	Other service portals may emerge
Some areas of interest between CoEs overlap, especially regarding to Exascale simulation technology	Infrastructure requirements may differ than what Excellerat can offer
Similar event are organised, thus overlapping interests from users	Other CoEs may not have services suitable for our Service Portal
Collaborate and share best practices on IP, legal, sustainability, business	Other CoEs may not want to use our Service Portal due to IP and data security concerns
	Too much effort to coordinate collaboration of other CoEs on EXCELLERAT Service Portal

Table 4: EXCELLERAT vs CoE SWOT analysis

EXCELLERAT in regards to other service platforms

EXCELLERAT plans to offer some of the services, developed within the project through the EXCELLERAT Service Platform. Currently, there are some commercial solutions on the market that offer HPC computing services, and could soon be offering Exascale level services. Such platforms include AWS, Microsoft Azure and Rescale. Large commercial companies usually collaborate only with a couple of ISVs, and offer the codes on their platforms. EXCELLERAT, on the other hand, has a strong network of stakeholders and ISVs, and could take a similar approach to advancing the Service Platform.

STRENGTHS	**WEAKNESSES**
EXCELLERAT has expertise in a number of codes	Service platform is still in early stage
Only such service platform in the EU – focusing on engineering Exascale applications	Early stage of results cannot not offer at the moment a clear financing plan set for the platform
Strong stakeholder network	Market demand needs to be created
Strong academic network	
OPPORTUNITIES	**THREATS**
EXCELLERAT can collaborate with different stakeholder like ISVs, code developers, domain experts, HPC and HPC	Competitor platforms like AWS and Google Cloud could offer a better/cheaper

providers to offer their services on service platform	service in the future
Can offer unique services developed during the project	Exascale infrastructure won't be widely adopted
Stakeholders have expressed clear demand and interest	The platform depends on ISVs adapting their codes to support exascale

Table 5: EXCELLERAT vs other service platforms SWOT analysis

Data Management is an important part of the move towards Exascale computing. However, we couldn't identify any specific communities in this area. There are some private organizations in the EU that deal with these challenges, but that is out of the scope of this analysis.

5 EXCELLERAT in the Future

As presented in the deliverable, Exascale will be the driving force in the HPC world and market in the following years. Currently, the market is heavily involved in the development of the hardware resources and solutions of this scale, but it is undoubtedly clear that the push on the hardware side needs to be followed by the development in software and services field. After collecting a lot of information during almost three years project lifetime, and after all the analysis done so far, we can safely conclude that there is a clear need for the services that the EXCELLERAT CoE has been developing for engineers in automotive, airspace, energy and manufacturing industries. The world is becoming even more digital and more complex: Exascale systems will play a key role in advancing scientific research and engineering, and will have the capability to integrate critical technologies, including advanced computing, artificial intelligence, simulation for advanced 3D modelling, and data analytics. New technologies, such as AI, ML, Industry 5.0, 6G and smart IoT are already matter of today and request not only cutting-edge Exascale infrastructure, but also experts that know how to use novel technologies in the specific domain areas, how to address possible challenges with big data, how to run complex simulations parallelly or how to process flood of data in an appropriate way to use it efficiently in ML processes.

The D6.5 Final market assessment focuses on the insights and recommendations for the EXCELLERAT Service Platform and CoE future development. The task of this deliverable was not only to do a comprehensive market overview, but to prepare final recommendations for the future sustainable development of the CoE:

- In the industrial sector, big caps and high-tech SMEs are already using the HPC cloud to perform their simulation, modelling, visualisation and HPDA. Because of the Pandemic restrictions, their R&D budgets are currently reduced or even blocked. When the Pandemic restrictions will be removed, companies will continue to use the HPC cloud to optimise their product development, production process, validation in order to shorten time-to-market as much as possible, to reduce development and production costs. EXCELLERAT needs to integrate more of these companies into its community:
  - to inform companies about the current and future performance at Exascale level,
  - to inspire them with Exascale potentials to view, explore and prepare more efficient and innovative products and processes,
  - to enable them to find partners such as HPC providers, HPC technology providers, ISVs, code developers, academics, consultancy experts on a European level
  - to advise them, find solutions for their challenges,
  - to offer access to codes, software and other open source tools without preliminary big investments and encourage users to test the tools,
  - to offer training for engineers and provide the know-how on how to use new tools that will allow engineers to develop more innovative products and improve productivity,
  - to offer open call funding for particular applications of big caps and high-tech SMEs to offer them to test tools, training or consulting, developing new partnerships with different stakeholders (ISVs, code developers, academics, HPC providers, HPC technologies providers) and find new Exascale solutions for their respective applications.

- To achieve this, EXCELLERAT needs to further develop and optimise its services and products, such as:
- usability of products and services to make them easier to use without external support,
- workflow integration of codes and software to save time and cost of the (potential) users,
- to reduce the cost of HPC (cloud) use and help potential users to switch easier to HPC use to offer user friendly (interface, etc.) codes and software to make them easier to use (no additional external support),
- to standardise some processes to reduce time and improve cost for HPC use,
- to improve the reproducibility and scalability to target the usability of codes and software,
- to make the services and products more sustainable to improve the market sharing and give more economical and technical opportunities for potential users,
- SMEs that are not yet using the HPC cloud, through different regional, national and European projects e.g. EuroCC, have the opportunity to be informed about the possibilities of using the HPC cloud to improve their simulations and HPDA. A long-term joint work between Excellerat and EuroCC/Castiel could be very important for SMEs which do not have ready applications at Exascale levels yet, but can prepare visions, explorations and future experimentations for the use of simulation, visualisation, modelling, data analytics and management, digital twin, machine and deep learning in the HPC cloud at Exascale.
- New-coming ISVs, code developers and academics need to be integrated into the EXCELLERAT community so that they can benefit from the knowledge hub and be consulted by the EXCELLERAT consortium partners:
- to use the open source services and products developed and optimised by the EXCELLERAT partners, related to data analytics and data management, to improve their workflow integration;
- to share and use information, know-how and tools optimised and developed by EXCELLERAT consortium regarding the co-design for engineering applications to improve the performance of their HPC Cloud offering and create partnerships with HPC technologies providers to use future high performance software and codes;
- to be integrated in open call funding in order to encourage and enable them to try to develop new products and services and to optimise some products and services that meet the demand and expectations of the market in the future;
- to be able to exchange their knowledge and vision with the EXCELLERAT partners, with the companies of the industrial sector belonging to the EXCELLERAT community in order to understand their needs and to satisfy them through new partnership developments.
- Services and tools that are created or will be created in the EXCELLERAT Centre of Excellence should also be available to academics and expert advisors. Academics will have the possibility to access the latest Exascale tools and software. According to this, academics could participate in the future research activities collaboration with industrial sector.
- SWOT analysis shows that various engineering communities offer different services, some of which could be included in the EXCELLERAT Service Platform too, especially those offering Software and training. More effective collaboration should be made with

FocusCoE, as the MaX and ESiWACE2, as they develop and improve codes but do not have a service platform. By collaborating with engineering communities like NAFEMS or Code communities like the OpenFOAM community, EXCELLERAT could develop new services that are in line with the community requirements.

- According to Hyperion research on HPC vertical markets 2020 [84] HPC systems went down for 7% (2020 vs 2019), and many users started to use cloud systems, moving projects into cloud. Moreover, the 6-year forecast shows cloud computing will continue to grow at over 30.7% CAGR, HPC at 7.5% CAGR, and Exascale computing 9.6% CAGR. Cloud is anticipated to be a critical component in future system designs for HPC, as well as overall resource capabilities for HPC application. Also, the border between Cloud and HPC is shrinking and there exist many hybrid solutions. Within EXCELLERAT Service Portal the Data Exchange & Workflow Portal, SSC, is already being developed and tested at HLRS. In case testing will be successful, the asset could be offer via other EXCELLERAT partners, that could provide HPC Cloud services. EXCELLERAT partners, interest group partners or vendors could offer on-demand, elastic Cloud resources that companies and existing HPC centers could use during peak usage, with resource management integration. Another potential opportunity is to create Cloud services that interact with HPC infrastructure, launching simulations with a few clicks onto Exascale resources. Industry users are interested in that approach, for that, collaboration with the ISVs and technology providers is vital. Data locality surpassed data security as the most-named barrier to exploiting cloud computing.
- Intermediaries (so called “translators”) between researchers and (end) users should be established in order to optimise the cooperation while allowing each side to focus on working tasks.
- AI plays a significant role in the engineering sectors as it is a key driver of economic development. According to Eurostat data [85], 7% of enterprises in the EU with at least 10 people employed used AI applications and 2% of the enterprises used machine learning to analyse big data internally in 2020. Europe is still lagging behind other world regions (China, India and USA) but The European Commission aims to invest EUR 1 bn. per year investment in AI under the Digital Europe and Horizon Europe programme and plans to attract more than €20 bn. a year in investments over this decade [86]. During our interviews, only HPC technology providers are using AI within their processes, and one of the largest European companies. Other respondents do not use any AI. As this is the technology that is becoming more and more important, the EXCELLERAT partners should add emphasis on AI services that could be offered to end-users. Partners should also tightly collaborate with AI experts, developing new use cases, codes and training models (e.g. use of AI methodologies to augment modelling and simulation applications, application of HPC techniques to enhance AI capabilities). Using AI in engineering tasks will open new challenges and questions that could be solved with the support of EXCELLERAT.
- EXCELLERAT interest groups were included in the project as the interaction with entities external to the consortium will enhance the success and sustainability potential

of the Centre, as well as ensure a multiplication of the available knowledge, thus widening the awareness and encouraging further use of HPC in Europe [17]. During the project lifetime, we have noticed the interest group members were not fully involved in the respective activities and were poorly responsive when inviting representatives to the interviews. EXCELLERAT partners must find an appropriate way for fruitful win-win collaboration. Within the interest groups, the most visible representatives of ISVs, Industrial End Users, Scientific Experts and Technology Providers are present, bringing to the EXCELLERAT priceless value of knowledge and experience.

- EXCELLERAT covers four main sectors: automotive, aerospace, energy and manufacturing. Due to the future technology evolution and knowledge that EXCELLERAT CoE unites under its roof, targeting the new sectors should be a way to go, for instance, these could be additive manufacturing, transportation and maritime.
- Special care has to be given also to the developments and achievements of the EuroHPC JU since this will certainly have a considerable impact on the developments of the CoE.

This document can also serve as the background for potential outcomes and exploitation of the technical WPs. Engineering applications will be among the first exploiting exascale, not only in academia but also industry. Within WP2 (Application Development), the reference applications were brought to the EXCELLERAT to support the aim to achieve EXASCALE performance in HPC for Engineering and thus to become candidates to be executed on the Exascale Demonstrators, Pre-Exascale Systems and Exascale Machines. New codes, presented in Table 1 were brought to the EXCELLERAT during the project lifetime, and even more areas requesting new software and codes (e.g. mesh refinement, new numerical methods, and exploiting new technology such as accelerators) were presented in Section 3.1. The topics listed, together with the individual technical priorities identified for each code, will drive the work of other Work Packages, notably WP3 (Driving Exa-HPC Methodologies and Technologies) and WP4 (Enhanced services), by providing requirements for work that will benefit not only the reference codes in EXCELLERAT, but that also be the basis for services that aimed at the wider engineering software community. Even more, the VPC analysis shows that new codes and open software is requested, so partners are encouraged to import more codes and establish new collaborations with ISVs to further develop and test new software, which will result further in new use cases production- another great asset EXCELLERAT could provide to different users to promote Exascale services. WP3 could further develop efficient implementation strategies for the new requirements in the application codes and identify the best mapping algorithms/architecture for the reference applications. Eight new pre-Exascale systems have been developed in Europe within EuroHPC JU so the future testing of use cases or kernels on those technologies could be done, representing the use cases on emerging technologies. This is also another opportunity to collaborate with European HPC Centres and allows bringing together experts, new know-how and use of the most powerful systems in Europe. EXCELLERAT as an engineering CoE should support application fields relevant for both industry and academia and thus has to offer a relevant services portfolio. Analysis of VPC, KERs presentation and SWOT analysis led to recommendations provided in this document, that

will help WP4 AND WP5 (Centre Implementation) to further develop and implement the defined services. New reference applications and related use-cases, that could cover a wide range of engineering applications fields, presented in Chapter 3, could be developed. Information collected in this document will also serve for finalising business plan and marketing strategy development within WP6 (Market Context and Sustainability). Finally, to advocate the advantages of the Exascale and to promote the EXCELLERAT CoE and its services offered via EXCELLERAT Service Portal, a strong communication and dissemination activities needs to be carried out. Information in this document about target markets, trends on markets, target groups and VPC can help for preparing effective communication and dissemination materials and strategies in WP7 (Awareness, Impact Creation and Outreach).

By the end of the project, the business model for the EXCELLERAT Service Portal and CoE operation will be developed, and clear guidelines for the EXCELLERAT service portfolio and CoE development will be set. Through the project lifetime, the foundation for the prospective CoE supporting engineering sectors and leading them across challenges and obstacles towards Exascale was laid. The first European pre-Exascale systems are nearly ready to be delivered and put in operation. Working with the Exascale system in practice will bring first results, that will show all advantages of the CoE support and will bring new opportunities to improve EXCELLERAT services. EXCELLERAT partners share Europe's vision to develop independent HPC ecosystem in Europe, and could continue with further successful activities on development and optimising services for engineering at Exascale level.

6 Conclusion

As presented in the deliverable, Exascale will be the driving force in the HPC world and market in the following years. Although the first Exascale systems were expected to see the light of day in late 2020 or early 2021, the release of the state-of-the-art machines has been postponed due to the Pandemic. Currently, the market is heavily involved in the development of the hardware resources and solutions of this scale, but it is undoubtably clear that the push on the hardware side will have to be followed by developments on the software and solution field and of course in the development of expertise and consulting.

A new valuable information that helped us developing services and business plan, was presented in three market assessments (D6.1, D6.3 and D6.5), done during the three-year research. The market analysis shows that "competitors" offer several services and some of them could be offered on EXCELLERAT Service Platform too, especially offering Software and trainings. More effective collaboration should be made with FocusCoE, as the MaX and ESiWACE2. Future service development should also put greater focus on HPC technology providers and AI experts, who hardly find appropriate services for their needs. Collaboration with Interest groups partners appears to have an added value for the EXCELLERAT CoE, better future integration of their expertise in the services is however needed.

We can safely conclude that there is a clear need for the services that the EXCELLERAT CoE has been developing and have been offered through the EXCELLERAT Service Portal on the market. The EXCELLERAT CoE will have to do a big push to prepare and promote Exascale infrastructure and services in the following year(s). EXCELLERAT CoE was established really early and is an early bird on the market offering services to the engineering sectors that are planning to work on Exascale level.

Before the project is concluded, some more activities need to be carried out: the business and marketing plan will be finalised, the EXCELLERAT Service portfolio should be further developed and improved, the appropriate promo materials will be designed for respective target group. Some additional codes will be available on the Portal. New use cases need to be produced and results have to be promoted widely to further advocate the Exascale systems and innovation they bring to target market sectors. In the last chapter of this document the recommendations for future EXCELLERAT Services and CoE development were provided.

The use of EXCELLERAT Service Portal and services requests monitoring will provide the first results that will bring further insights what improvements of the EXCELLERAT Service Portal could be done. It is assumed that a comprehensive implementation of AI technologies in different sectors in the near future would open additional collaborations and service development. Additionally, some KERs and assets are still under development and will be completed by the end of the project. To work towards long term center operation, Meanwhile, the CoE operation and EXCELLERAT Service Portal can be tested, and analysis will bring results for future improvements to offer to the target groups the most suitable services they need for innovation at Exascale level. The next phase of the EXCELLERAT project will be proposed, as the goal of the consortium is to further develop services and offer expert support to users to help Europe to develop World class supercomputing ecosystem at Exascale level for engineering applications

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