Cloudflow

SUCCESS STORIES

Computational Cloud Services and Workflows for Agile Engineering

TABLE OF CONTENTS

MOTIVATION

In engineering, computers and software are used in different phases and stages of the product lifecycle. Starting with styling, covering the design and simulation of many domains, e.g. durability, safety, emissions, etc., and spanning the optimization of the manufacturing resources and processes. Many computer-aided tools (CAx tools) are compute-heavy and too expensive to be affordable for small and medium-sized enterprises (SME). Additionally, data sets are huge and typically sensitive with respect to Security issues. Cloud computing is known for data-centred tasks, thus well suited for running heavy simulations on scalable high-performance computing (HPC) resources, which themselves are hard to access and require a lot of skills typically also not available in SMEs. However, engineering applications do not only require software and hardware resources as engineers often think in workflows.

ABOUT CLOWDFLOW

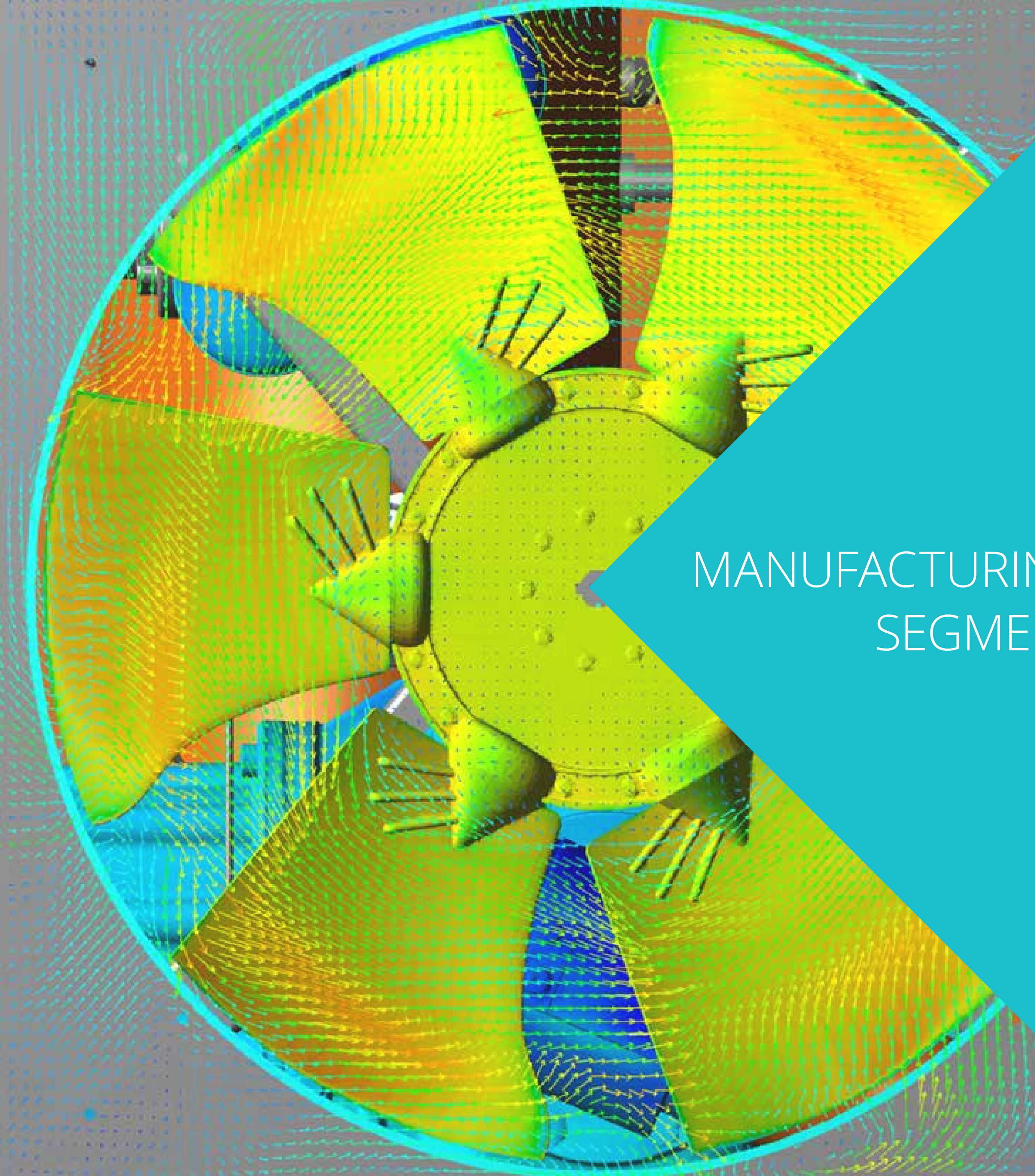
CloudFlow has recognized the importance of supporting workflows as engineers do not work in isolated cells but always use different tools and tool chains – in automating tool chains there is a similar amount of benefits not yet exploited by others as there is in accelerating simulations on HPC clusters – CloudFlow is supporting both.

CloudFlow is a project, co-funded by the European Commission (EC), with its unique proposition being the provision of a set of independent heterogeneous software services coming from different commercial software vendors which can be composed to workflows (chains of tools) by the end user and executed in cloud and HPC environments via its portal – the CloudFlow portal is becoming publicly available in summer 2017.

APPLICATION EXPERIMENTS

WHAT ARE THE EXPERIMENTS ABOUT?

Application experiments have been an integral concept of the project. They are SME-driven use cases for the CloudFlow platform that is being developed. CloudFlow is designed to execute application experiments in three waves, generating a total number of **twenty experiments**. They each have their own success story which we want to present in this brochure.



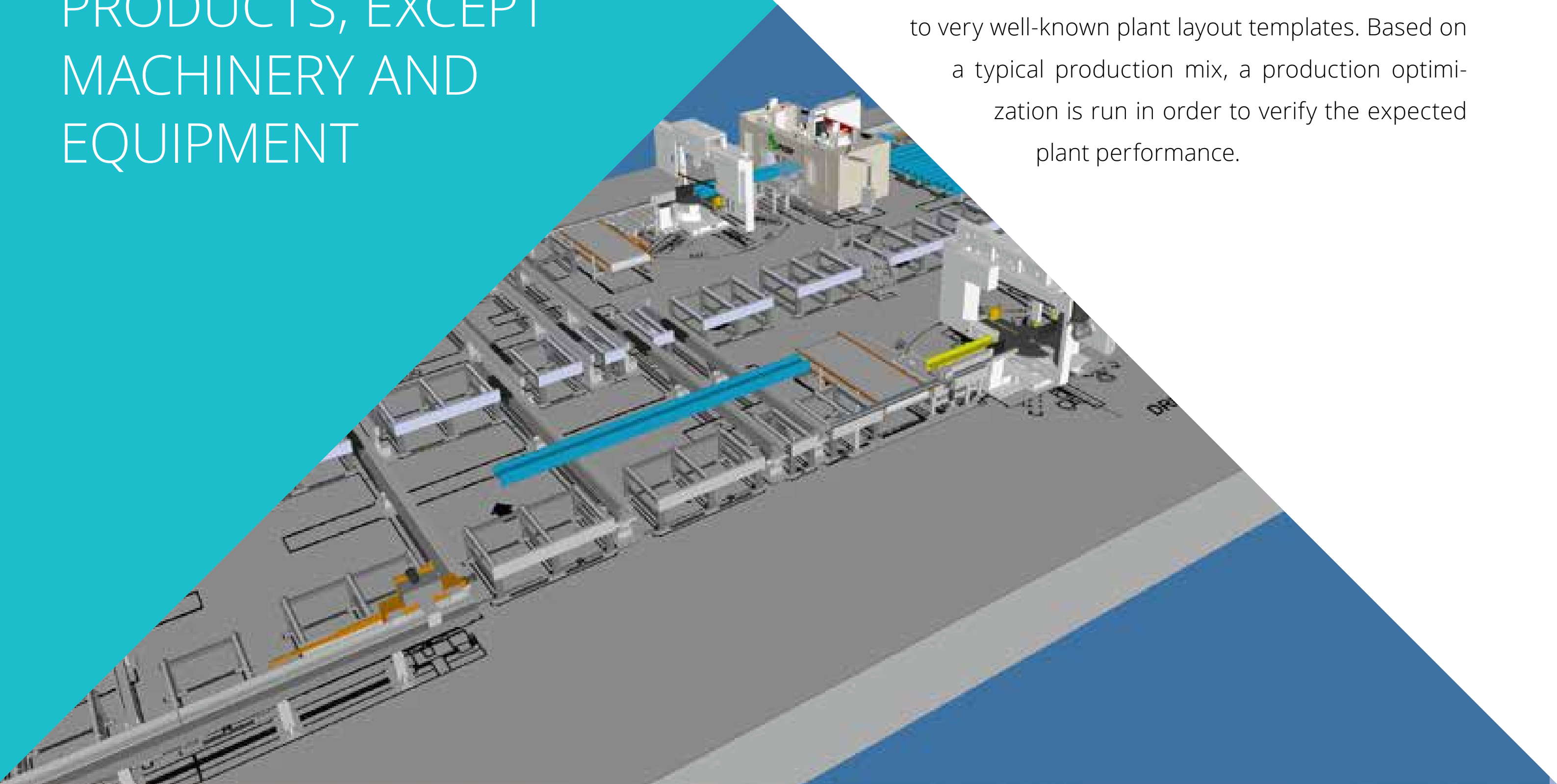
MANUFACTURING SEGMENT

OPTIMIZATION OF STEEL STRUCTURE MANUFACTURING

MANUFACTURE OF FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT

MOTIVATION

The current process of designing a new steel fabrication plant encompasses several steps and involves personnel with different competencies. At the beginning, the commercial crew interacts with the customer, in order to gather the plant requirements. Subsequently, the technical team prepares a first draft plant layout, based both on the customer requirements and on the previous experiences related to very well-known plant layout templates. Based on a typical production mix, a production optimization is run in order to verify the expected plant performance.



Since the needed simulation and optimization tools require powerful hardware, this task has to be done by the technical office and cannot be executed at the customer premises.

Therefore, a video of the simulation run is recorded by the technical office and sent to the customer. By watching the video, the customer develops a better understanding of the process and, typically, he wants to apply several changes to the layout or to the machines used. Those changes are sent back to the technical team, where a new simulation and optimization task is executed and a new video is generated. This loop is usually repeated until the required level of maturity of the solution is achieved.

Thus, the **existing process is time consuming and inefficient** because of many iterations, where only the technical team can run simulations and assess the plant productivity, using dedicated workstations. Each production optimization of a typical plant of medium complexity (composed of 4 machining stations, 2 loading bays, 2 unloading bays and the automatic handling system) requires approximately 8 minutes on a high-end, 8 cores desktop PC, while it requires 30 minutes on a normal laptop. Clearly, a 30 minutes window for each optimization is prohibitive in a negotiation with the customer. Each month, at least 10 requests for early design modifications and simulation are sent to the technical office, to start and carry on the negotiation phase and the mentioned iterations (within the average of 20 new negotiations per year).

The experiment is meant to optimize this process and to enable quicker and faster simulation and optimization even at the customers' site. This vision requires the implementation of two could-based services to simulate and optimize the production of a complex manufacturing system, composed of several machines and conveyors. The two services are coupled with a client application meant to streamline the access and the steps required to successfully simulate and optimize a production plant (i.e. upload of the simulation model, customization of the layout, selection of the production mix and visualization of the results). The technical objective of this experiment is thus to provide the functionalities of the simulation and optimization tools as cloud-based HPC services, in order to achieve the main business goal to **empower a wider range of user** (i.e. the commercial crew) with **quicker simulation and optimization** solutions to be deployed at the customer's premises.

TECHNICAL IMPACT

The implementation of the experiment **was successful in reducing the time** needed to perform an optimization for a layout of medium complexity **from 30 minutes to approximately 3 minutes** on portable devices, blowing away the barrier that made impractical the use of such tools during the negotiation phase, at the customer's premises. Modifications can now be applied showing directly the effects of the changes, streamlining the interaction towards the best configuration. With the achieved implementation of the experiment, several direct economic benefits are expected over a short to mid-term period.

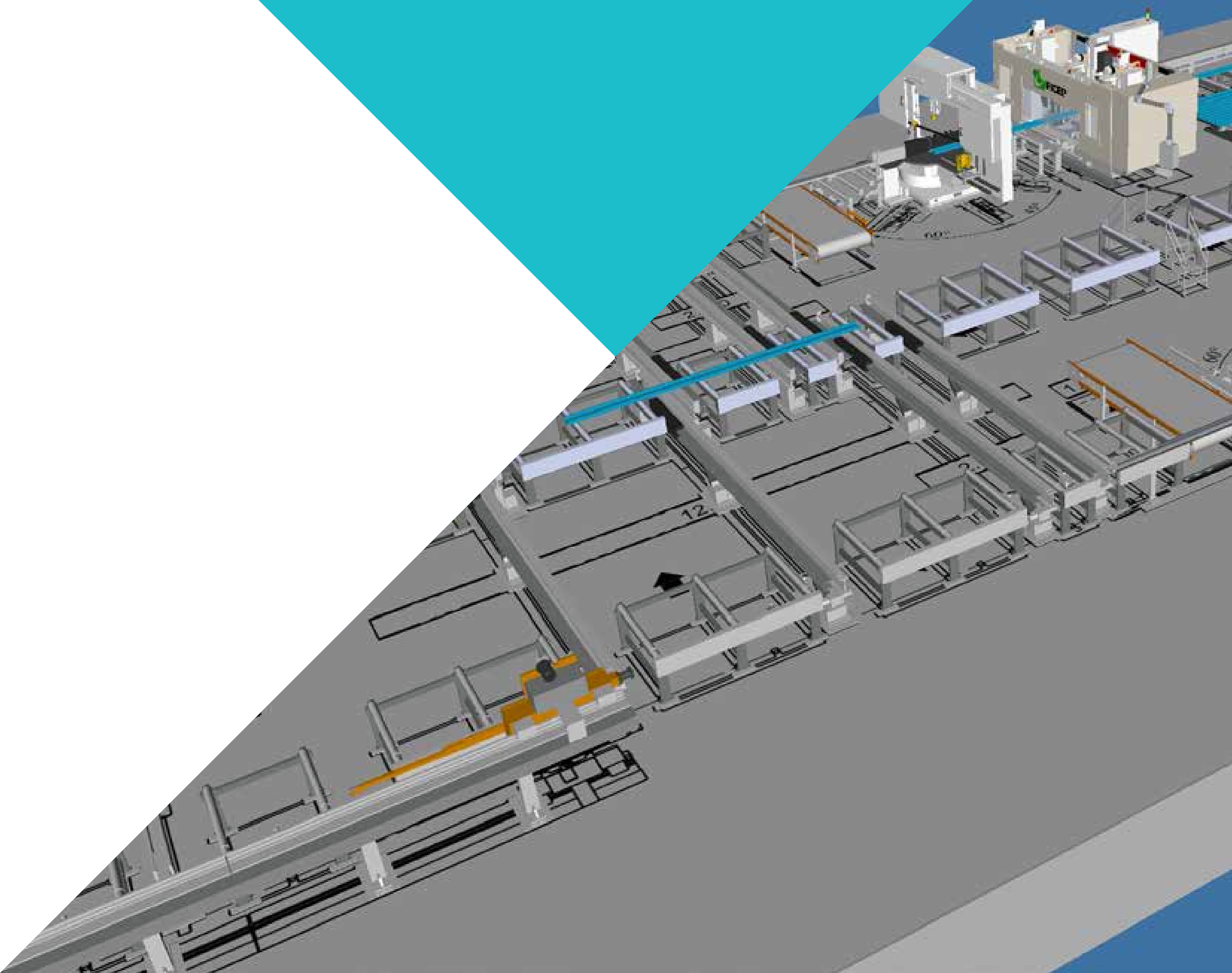
ECONOMIC IMPACT

FICEP benefits from a more **efficient proposal phase** due to the streamlined interaction between the technical team and the commercial crew, now endowed by **quick-everywhere simulation and optimization** capabilities (for the average plant afore mentioned, the number of iterations is reduced from a minimum of 6 – where each iteration takes 4 man-days – to 2, quantifiable in € 4,800 savings, not taking into account the improved quality of the service offered). Taking into account the number of negotiations processes initiated per year, which were estimated before in 20 negotiations, this lead to an estimation of **96,000 €/year savings**. Furthermore, collaboration between different FICEP teams located worldwide is boosted, as the results of different layout simulation are stored in the cloud, further increasing the capability to properly address the customer's needs.

The cloud-based configuration also allowed TTS to develop a new business (and pricing) model: a monthly € 100 fee in a pay-per-use model allows to reach a wider number of SMEs having a limited expenditure capacity but a strong necessity of simulation functionalities especially during the machine design phase. These companies would **benefit from** a usage of the platform purchased as a **service on demand**. Such SMEs usually operate in niche markets providing speciality high-performing machines in small (also one-of) lots. This will result in an increased number of active customers for TTS, with more than **20 additional machine manufacturers** using TTS cloud-based solutions, resulting in **€ 80,000 of additional sales** over a 3 years time horizon starting from the project conclusion, with the creation of **2 new jobs** over the same time period.

Partners:

- **FICEP S.p.a.** – Industrial company, end-user, Italy
- **SUPSI** – R&D institution, Italy
- **TTS S.r.l.** – SME, ISV, Italy


12

OPTIMIZATION OF WELDING LINES

MOTIVATION

Discrete event simulation (DES) of production and logistics processes is a well-established method to support engineering throughout a variety of manufacturing industries all over Europe, today. However, the process of conducting a simulation project and conducting simulation experiments is still a **very individual and rather handcraft-like activity** with the software residing on rich clients at the desk of each simulation engineer. The overall process and the outcome of simulation projects are highly dependent on the skills and the experience of the involved simulation experts and planning engineers.

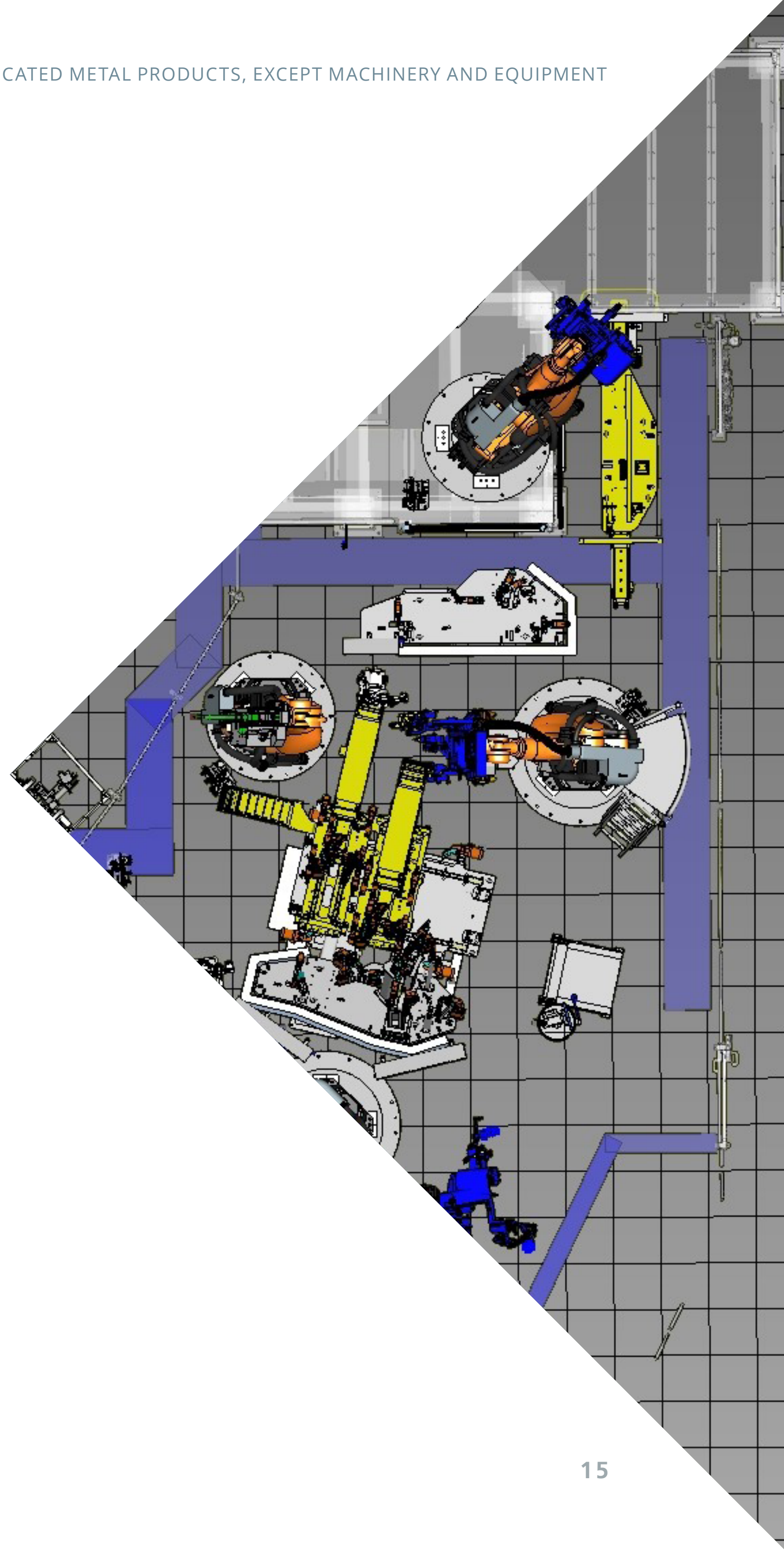
The SIMCASE experiment allows engineering companies (mainly in the automotive sector but with a high potential for other industries, too) to search for improved factory layouts **far more efficiently** than before. This is achieved by deploying discrete-event simulation (DES) models into the cloud. The use of Cloud resources for the simulation runs significantly **increases the number of evaluated configurations**, ending up with better manufacturing solutions (e.g. less buffer space and less investment in buffers; **better utilization of robots**).

ECONOMIC AND TECHNICAL IMPACT

These improved solutions directly lead to cost benefits: reduced size of required buffers and equipment result in a **decrease of investment for about 4-8 percent which translates to more than € 50,000 per manufacturing system**. Costs for engineering hours are saved to an extent of 10-20 percent compared to a conventional approach by being able to share data in an easier way and by parallelizing modelling and model execution (i.e. simulation). A major benefit for the end users, specifically for engineering SMEs, is also the distributed world-wide access to very costly software on a per-use part time basis.

Companies' **direct costs in software and hardware can be reduced up to 80 percent** considering that a simple notebook can run the client application and allow users to input parameters for simulations to be calculated and executed at a remote HPC provider, whether the simulation is conducted as one experiment or hundreds of experiments (variant simulation – design of experiments, DoE).

For SimPlan as independent software vendor (ISV), a Cloud-based offering leads to new revenue channels not only for software but also for engineering services and also to higher market coverage. The results of the experiment did exceed SimPlans initial expectations by far: the implemented solution fits nicely with existing offerings and will lead to



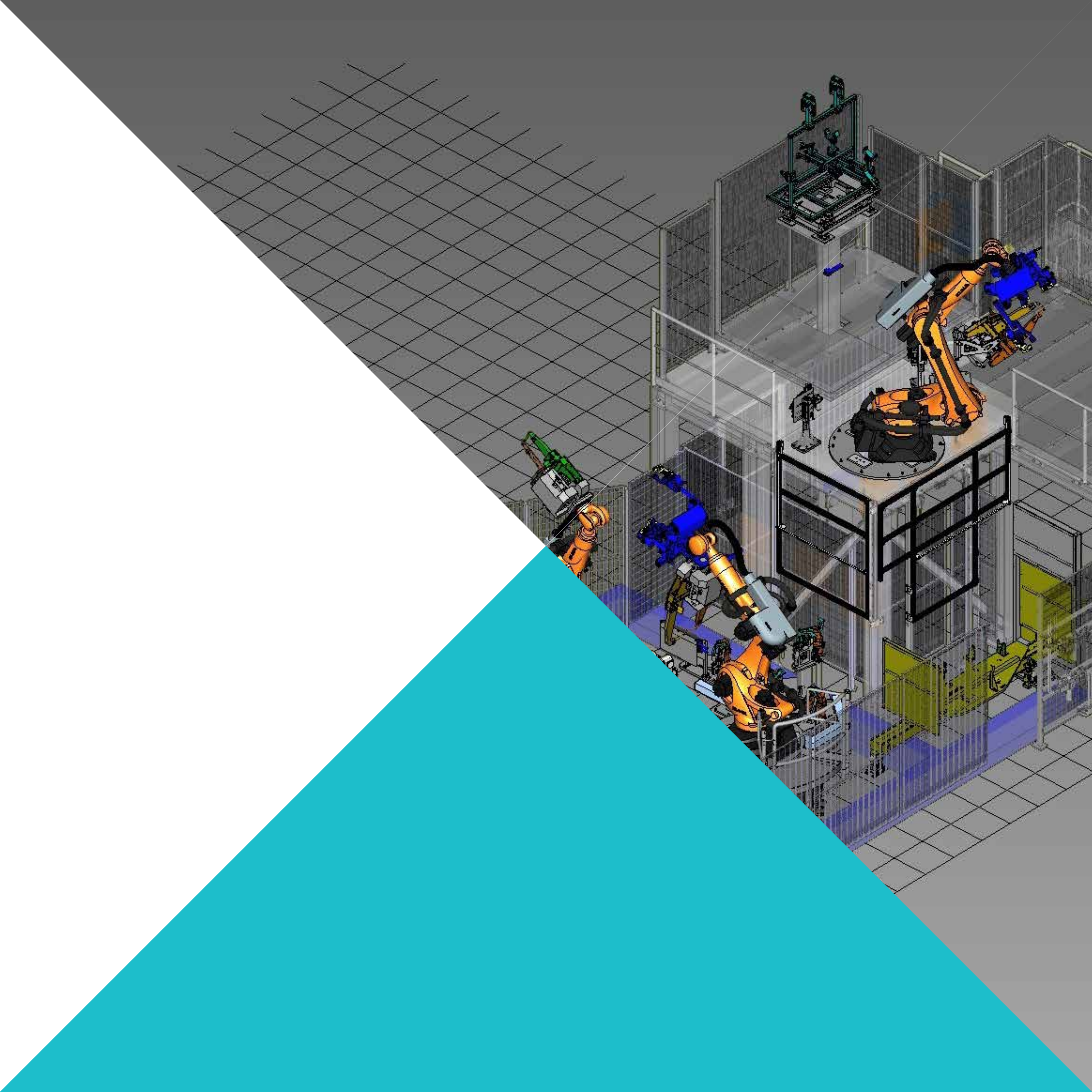
approximately € 300,000 additional revenue within the next 5 years resulting in about 1.5 additonal full time equivalents. It also turned out that the results are a door opener for in-depth discussions with major German automotive OEMs about them adapting the solution.

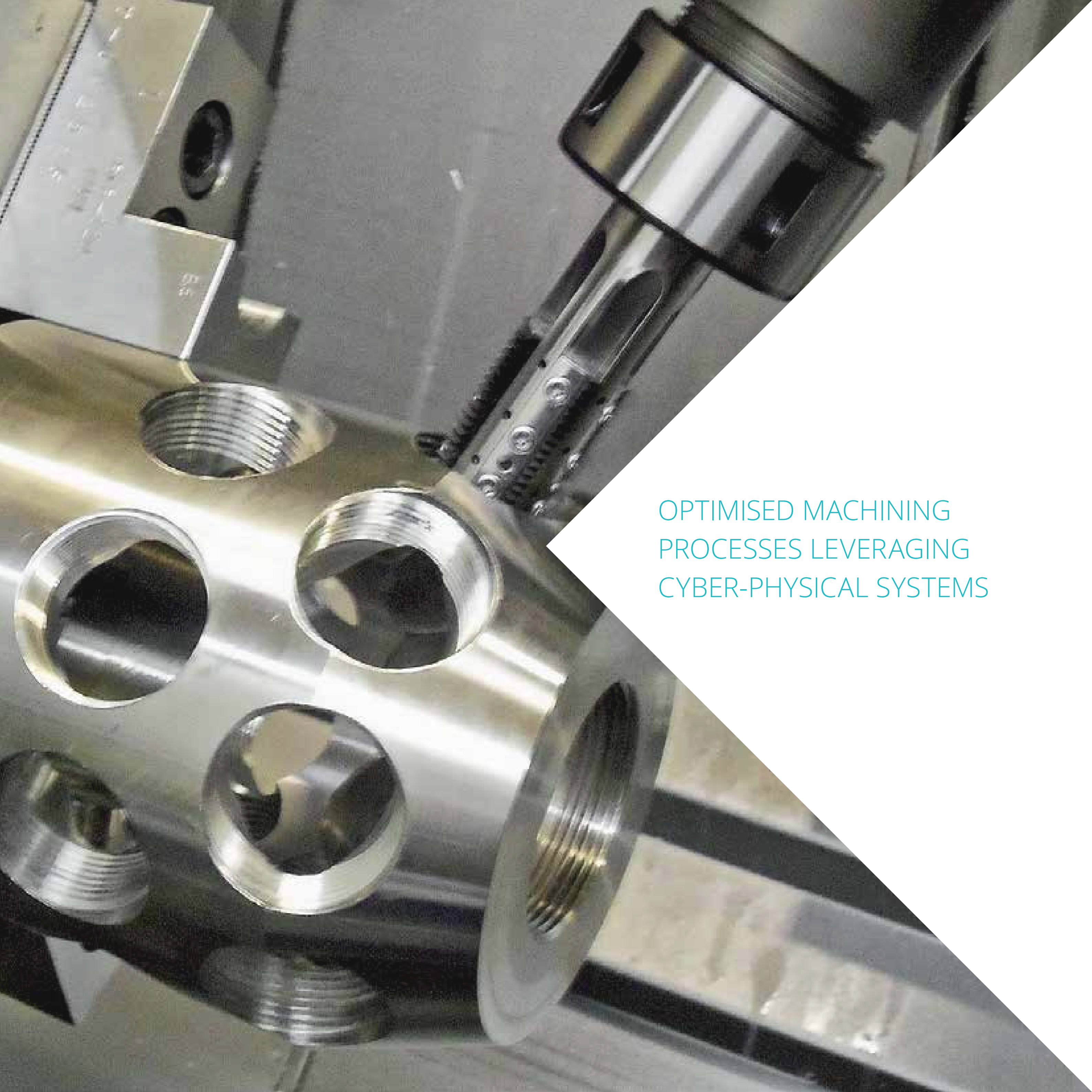
For Introsys as engineering SME, the offering leads to reduced engineering and software costs and improved offerings (engineering solutions) for their customers.

Introsys intends to provide better and innovative service to its clients. With a more cost effective work processes using Simcase Introsys can assure more quality to its clients (machine builders). This machine builders (first tier suppliers of the automotive industry) assures better production processes and products with lower costs. With Simcase Introsys maintains itself in a competitive edge relative to their competitors because they can **reduce 90 percent of the software license costs for a team with 10 robot programmers**. The Cloud solution also improves the software process quality in 10 percent. Addressing a customer segment defined by the Automation/Automotive/Logistic (OEM and Machine Builders) industry, in a three-year horizon INTROSYS estimates to face a market size of around $ 42 billion, with a potential share reaching 0.05 percent **and leading to incomes of € 17 million and about 20 additional employees**.

Partners:

- **Introsys-Integration for Robotic Systems** – SME, end-user, Portugal
- **SimPlan AG** – SME, ISV, Germany
- **University of Kassel** – Department of Organization of Production and Factory Planning – R&D institution, Germany





OPTIMISED MACHINING
PROCESSES LEVERAGING
CYBER-PHYSICAL SYSTEMS

MOTIVATION

Machining industry in Europe is a large market that accounted for 16.6 billion € in turnover in 2013. Computer Aided Process Planning systems providing simulation for machining process optimisation have been increasingly adopted by European SMEs, still they do not leverage cyber-physical systems information to a large extend.

The goal of this Application Experiment is to cloudify a Process Planning System as a CloudFlow-enabled service, hence offering cost-effective and flexible Process Planning to machining companies, especially SMEs. Technically, the dynamics of machining processes challenge the CloudFlow infrastructure with respect to reliability and integration of streamed data. The experiment is expected to lead to improved product quality, productivity and sustainability, shorter and more accurate quotations. Economically, the experiment will enhance the productivity, quality and sustainability of Powerkut – the end user in this experiment. The estimated targets are: a) cost savings in production: 20 percent - 30 percent (it is expected to save about € 200,000 per year for Powerkut when the system has been fully implemented in the company) and b) time reduction for process planning: 3-4 times faster (e.g., from 2 hours to about 30 mins for a reference part) (Powerkut is mainly for customised production and its current capacity is to process 300 customised orders per year. Using the CUSTOMISE solution, the capacity will be increased to over 1,000 orders per year).

This experiment is rooted in the traditional 'subtractive' manufacturing field – in contrast to experiment 131. In the current process for a part to be produced by milling etc., key machining parameters such as spindle speed, depth of cut, depth of width, etc. have to be calculated for better production quality, shorter production time and lower waste. In this process experienced based decisions need to be taken to achieve best possible part quality in minimum time with optimized costs. This requires a lot of experience on the side of the manufacturing engineers. Depended on cloud-enabled High Performance Computing (HPC) services, the CUSTOMISE approach of this experiment automates this process in a more efficient means. The functional services of CUSTOMISE deployed in a cloud-based architecture to a CloudFlow workflow, i.e., automatic feature recognition, optimisation of machining feature sequencing and multi-objective optimization of machining parameters, optimization targets of energy saving (30 percent), productivity improvement (20 percent) and precision improvement (10 percent) are achieved.

TECHNICAL IMPACT

Powerkut will reduce time, save costs and improve profit margin, and contribute to job creation. Coventry expects a technical impact related to new knowledge generation on sustainable machining processes by using real-world industrial case studies. Arctur (HPC provider) expects more machining SME end users and wider adoption of Cloud-HPC services.

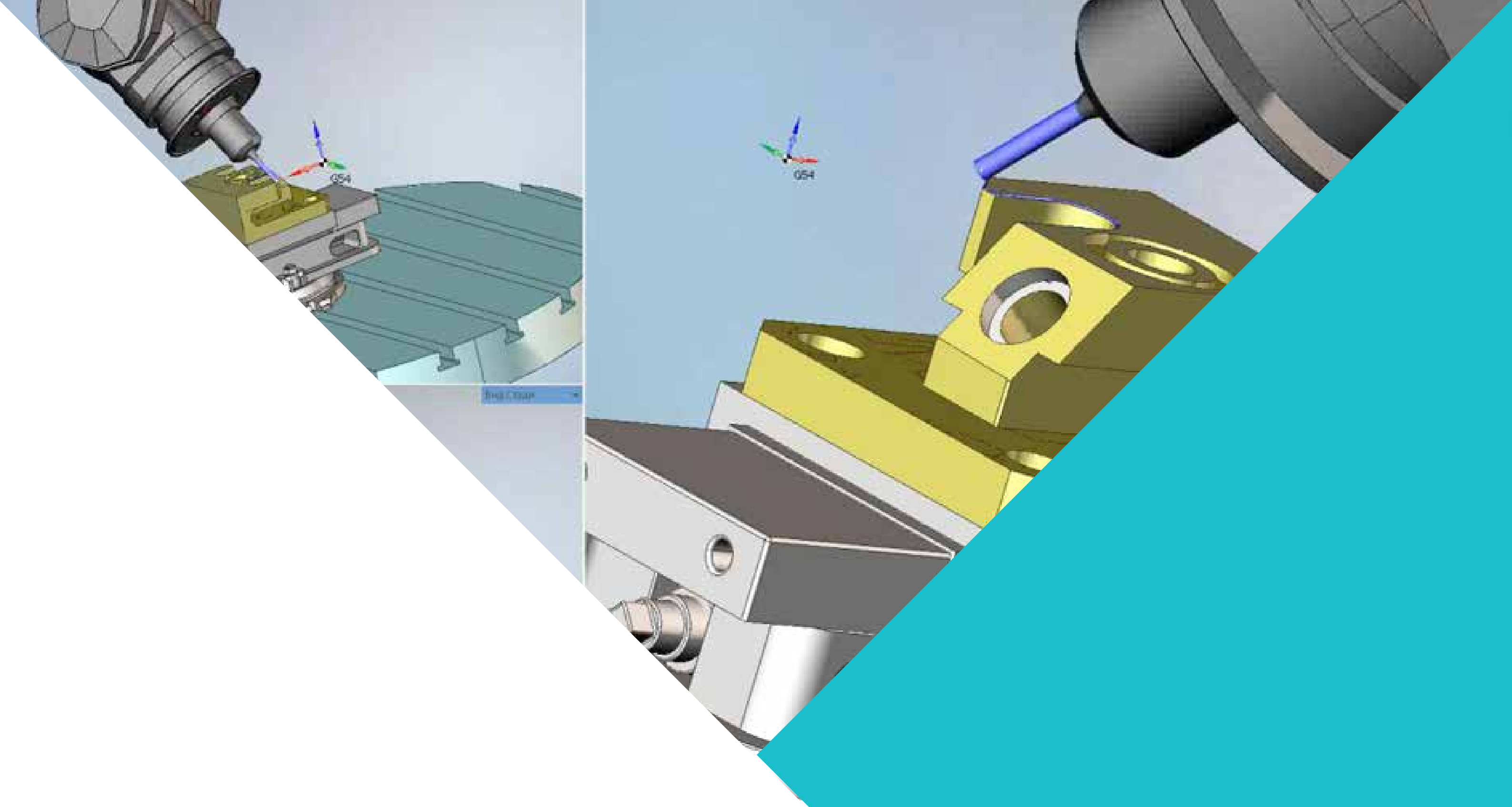
ECONOMIC IMPACT

Powerkut is expecting cost savings in the production in the range of 20 - 30 percent (e.g., energy saving, less scrap material, etc.). It is anticipated that € 200,000 will be saved per year for Powerkut when the system has been fully implemented in the company. The time for process planning is expected to be shrunk by more than 70 percent (3-4 times faster than today). Powerkut is mainly for customised production and its current capacity is to process 300 customised orders per year. The process plan for each order will be 2 hours in the current practices. With the CUSOTMISE solution, the efficiency will be increased 3-4 times higher to be within 30 mins for planning each order. As thus, the capacity will be increased to over 1,000 orders per year. Meanwhile, the quality of the produced orders will be improved from minimum 20 micro level to 5 micro level, and 20 percent-30percent of production cost will be reduced for each order, it should to motivate higher numbers of items sold/produced in markets. For the services developed by University of Coventry a commercial solution shall be brought to the market offering these CloudFlow services especially to machining companies in aerospace and automotive sectors. 5 years after the experiment more than 100 new customers (>400 licenses) shall be acquired resulting in a revenue stream of more than 1 Mio. €.

Arctur being an infrastructure provider expects to have mostly an economic impact from this experiment. This is reflected through the increased sale of Cloud and HPC resources. The increase of the sales follows the increase of new users using the services at offer. The secondary beneficial impact for Arctur is the widening of the service portfolio and references. With the addition of new services is able to offer more services to a wider audience of engineering customers. The service is of course always on offer in collaboration with the specialist knowledge of the field specialist or the individual ISV that contributed to the developments of this experiment.

Partners:

- **Powerkut Ltd.** – SME, end-user, U.K.
- **Coventry University** – R&D institution, U.K.
- **Arctur d.o.o.** – SME, HPC Provider, Slovenia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OPTIMIZING MOULDS AND STAMPING PROCESSES FOR BIPOLAR PLATES USED IN FUEL CELLS

MOTIVATION

Optimizing tools for stamping processes, finding the right process parameters and ramp-up forming production of sheet metals is a big topic in manufacturing industry, especially for those segments heavily handling sheet metals. This experiment is specifically looking into bipolar plates for fuel cells, an emerging market contributing to renewable greener energy supply, e.g. for Fuel Cell Electric Vehicles (FCEV). However, to gain market share, fuel cell production costs need to decrease.

The goal of this Application Experiment is to reduce development cost and time-to-market for new bipolar plates for fuel cells by accelerating engineering and manufacturing processes through cloud-based optimization technology. Technically, it is expected to lower barriers for SMEs to access engineering design workflows and computational resources. Economically, Borit – the end user in this experiment - expects 5 to 10 percent cost reduction. This cost reduction will mainly be achieved in the design and test phase for new products and can be translated in a reduction of total design time for the forming tool and the number of iterations required on the press (= less test tooling and press time) before a product which is up-to its specification is achieved. On average this would reduce the design time by several weeks and the testing time 'on press' by several days. This equals to approx. € 30,000 to 40,000 per new product (designer, less tools, les press depreciation and operator costs). If five new products are introduced each year, this could save up to € 200,000 per year and faster time-to-market; in a best-case scenario up to 3 months. This might also increase the employment rate by 1 or 2 operators in 2 to 3 years. The ISV Noesis will gain access to new markets and market segments by offering cloud-based services on an affordable pay-per-use model.

The process at Borit currently implemented does not involve simulation software for the forming process. Borit starts with creating the geometry of the bipolar plates in CAD. The corresponding tool geometry is also created using CAD software. The tool is then manufactured based on the CAD design. The mould is tested 'on press' and the design is iteratively altered until the plates have the intended nominal shape. This iterative process can take up to 6 to 8 weeks for just one plate depending on the plate complexity.

The manufacturing challenges are related to the quality of the resulting bipolar plates, e.g. not fully formed plate features and/or local rupture of the plate material. The simulation challenges are related to the accuracy of the model. A high fidelity simulation tool that can cut down the number of iterations needs to be found that responds in reasonable time using affordable compute resources. In addition, a simulation model needs to be defined that captures the plate behaviour with high enough resolution representing features like small radii and narrow channels.

The approach in this experiment is to introduce a combination of forming simulation software and the optimization tool Optimus by Noesis using HPC resources. Optimus defines the simulation strategy and launches the HPC service. Optimus acquires the results and builds a surrogate model from these simulation results using machine learning. The surrogate model is returned to the user to be implemented as process control.

TECHNICAL IMPACT

The experiment result is expected to close the loop between the Design Engineering Process and Manufacturing Life Cycle by the development of surrogate models based on high-fidelity simulation with approximately **30 percent of time reduction for the trial-and-error process (2 to 3 weeks faster than the current 6 to 8 weeks)** and significant improvements to the manufacturing quality. Moreover, it is expected to reduce the scrap rate from 5 to 2 percent; **potentially € 10,000 per year of avoided scrap**. With the introduction of simulation and optimization tools **more complex and challenging designs can be handled** thus motivating Borit to come up with innovative shapes for their bipolar plates that further improve product performance.

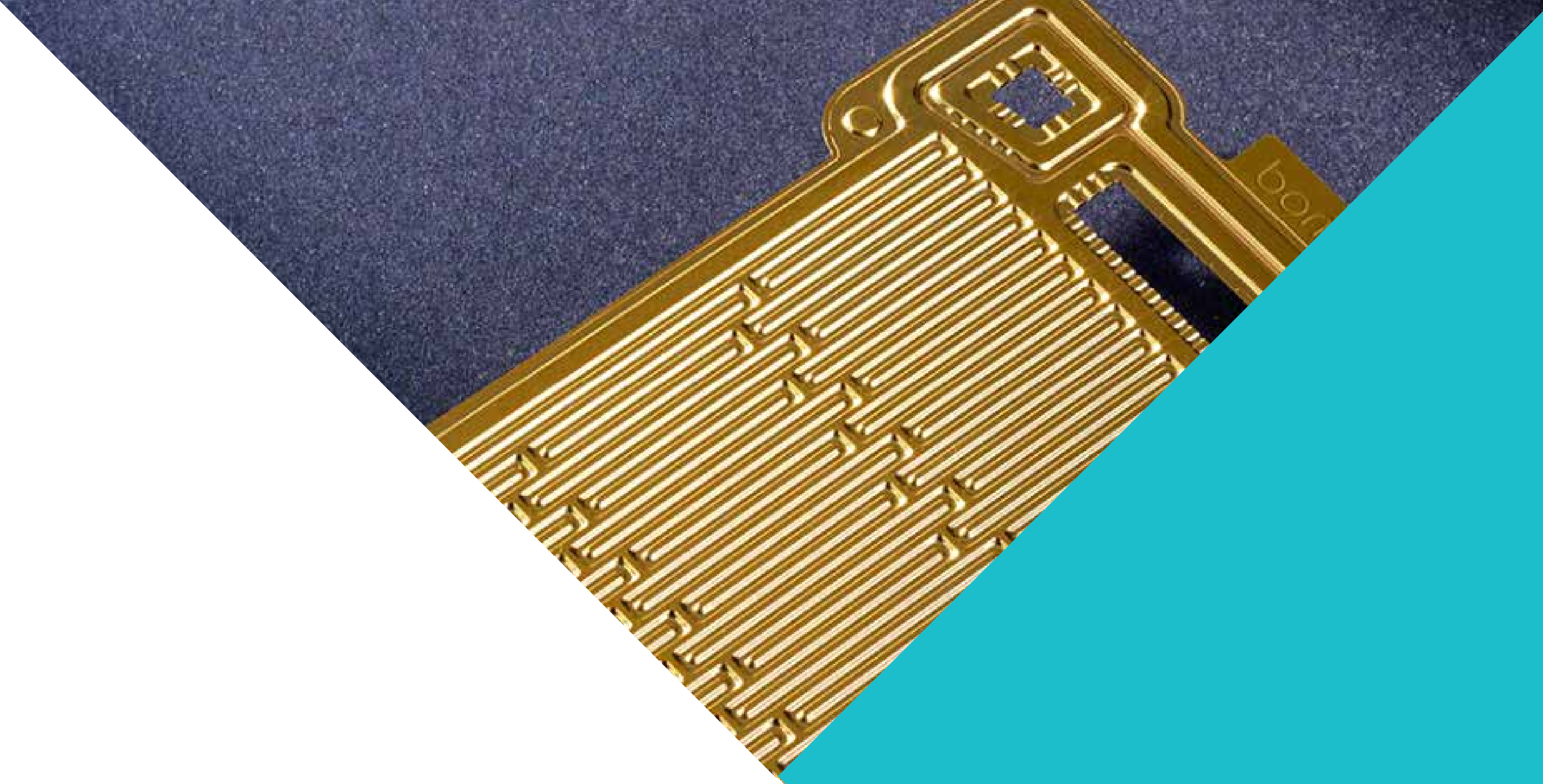
Technical impact for Noesis as ISV comprises **lowering access barrier to computational resource** and advanced engineering workflows, **supplying a general platform** for providing engineering and computational services in different contexts without sharing confidential IP or methodologies and providing a tool allowing workflow developers to offer customers tailored solutions on the cloud.

ECONOMIC IMPACT

Faster engineering based on better simulations will allow the end user Borit to reduce the design time (value 10 k€/iteration). Based on the product complexity, up to 8 iterations can are required for a new product. **Reducing this by 25 percent, adds up to € 70,000 to € 100,000 per year for five new products**, to reduce the amount of non-productive (test-)time on the press (100 €/h). **Virtual testing can reduce the test hours on press** (8 hours/test) **also by 25 percent** - a total reduction of 7 to 10 days can be achieved which equals € 6,000 to €8,000 per year, to reduce the number of tools to be produced (value up to € 20,000 per tool). For five new products (average complexity) Borit expects a reduction of 5 to 7 test tools and to reduce time to market (value for the fuel cell manufacturer). Moreover, **quality-improved forming capabilities and increased customer satisfaction** will attract additional customers. This may **create additional revenue of several hundreds of thousands of € per year**. The reduction in design time and total time to market will **allow the existing employees to handle more projects per year.**

For Noesis, the ISV, the CloudFlow-powered engineering workflows are expected to lead to 2-3 users to join the platform during the first year: this quantifies to about to about **€ 120,000 per year initially and increase with time to € 400,000 per year as the user-base grows**. These revenues accounts for all the items in the ManuCloud service subscription, that includes the Optimus optimizer deployed on the CloudFlow infrastructure as well as the tools for the workflow preparation and post-processing that are made available to the user.

On top of these estimates, there is the possibility to add engineering services offered to meet specific customer needs in terms of workflow complexity, specific optimization routines to be implemented, ad-hoc deployments on their production machines. **These services could produce about € 30,000 to € 40,000 in the first year to € 200,000 in the 3rd year after the end of the application experiment.** Since these are not recurring revenues, the sustainability of the engineering services business is supported by the continuous innovation of the end-user products and the increasing expertise of the end users with **new and more sophisticated analyses** done with Optimus. Eventually this expected volume of business



could translate to 4 new FTEs in the first 3 years (1 in the first year and the others as soon as the business takes off) as well as in the consolidation of the current jobs against adverse market conditions.

Partners:

- **Borit** – SME, end-user, Belgium
- **Noesis Solutions N.V.** – Industrial company, ISV, Belgium
- **Arctur d.o.o.** – SME, HPC provider, Slovenia

MANUFACTURE OF MACHINERY AND EQUIPMENT

OPTIMIZING ENERGY CONSUMPTION AND NOISE EMISSION OF THE COOLING AIRFLOW FOR COMPRESSORS

MOTIVATION

Noise emission and **energy consumption** are two decisive factors for worker safety as well as human-compliant workplaces and resource-efficient factories, respectively. This CloudFlow application experiment aims at minimizing energy consumption and noise emissions created by the fan and the cooling airflow for the reference case of compressors. This goal is achieved through introducing simulation, more specifically computational fluid dynamics (CFD), to the design and development process at BOGE and derive acoustics information from the flow simulation results to influence fan selection and noise-reducing enclosure design. The resource-demanding CFD simulations have been carried out with FlowVision from Capvidia which has been cloudified and adapted to the CloudFlow Infrastructure within the course of the experiment.

The experiment was an opportunity for BOGE to gain experience with CFD simulations and to introduce them to their development process that – so far – was based on building physical mock-ups and experimentation taking approx. 3-5 months of development time for one design variant of an enclosure-fan combination.

Product innovation: **improving the 'quality' of the compressor**–enclosure–fan combination based on the simulation results, quality here means:

- optimized design for the shape of the enclosure
- cooling-fan with lowest possible noise emission and power consumption
- **reducing development time** from 3-5 months to 1-2 months
- lowering costs due to shortened development cycles

TECHNICAL IMPACT

The cloudified CFD software FlowVision by Capvidia enabled BOGE to economically predict the effects of enclosure design and fan selection more accurately than with the physical experimentally based approach formerly used. Some of the quantifiable technical/physical improvements are:

- **reduced** fan **power consumption** from 4 kWel to 2.75 kWel (> 30 percent)
- **reduced fan noise** (just fan, without compressor block) from 82.1 dB(A) to 75 dB(A) (almost 10 percent - for our noise perception a reduction of 7 db(A) means that the new fan is almost **only half as loud as the previous one**)
- **reduced noise** of the whole **compressor** by 0.9 dB(A) (15 percent reduction of noise energy)

These **noise reduction** levels have been validated by physical experiments and measurements. These improvements have been possible due to the efficient HPC/Cloud-based simulations which have 4 provided insight into physical effects (air pressure, air flow) which is invisible in physical experiments. These insights revealed that some of the measures taken in the past to reduce noise of compressors where actually only addressing the symptoms, negatively affecting other performance parameters, instead of tackling the cause, e.g. noise reduction was compromising energy efficiency making the compressor less environmental-friendly than possible now after he experiment.

Simulation time could have been reduced by a factor close to 4 by using HPC resources. The affordability of the HPC resources and simulation services could have been improved by a factor close to 4, too, in the reference case due to a pay-per-use model.

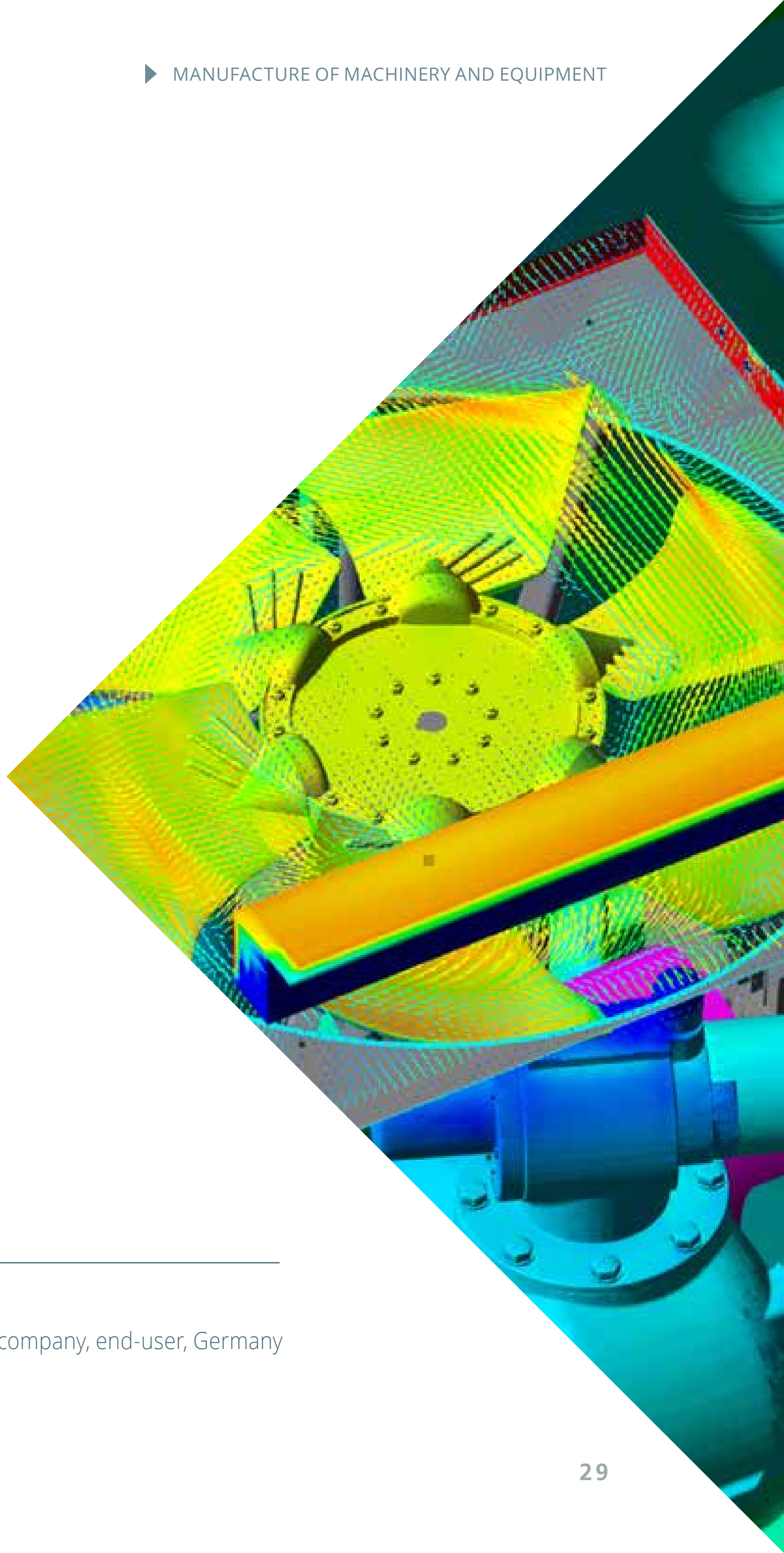
This all contributes to reduced design and engineering time and costs. Yet alone, the design and **layout of the splitter-type silencer can be calculated within hours instead of days** that were needed before for the physical experiment. This allows for simulating more alternatives than physical ones can be built economically, finding better solutions for the product more likely.

Putting it all together, the design cycle can be accelerated by a factor of 5 roughly, because not only individual experiments can be accelerated by virtualising them, e.g. the splitter-type silencer from a week to a few hours, but also some of the **physical mock-ups can be rendered superfluous** by replacing them with digital ones on which virtual simulations can be performed. Thus, the experiment also contributes to better time-to-market.

ECONOMIC IMPACT

Predicting noise emission and power consumption of a compressor more accurately in the development phase thereby avoiding physical validation steps has considerable economic advantages for BOGE in terms of development cost and time-to-market. Furthermore and based on the current number of delivered compressor systems existing BOGE clients will save electricity cost **that amounts to about € 350,000 per year.** Finally, the important noise and power consumption reduction offers potential to increase the BOGE market share in particular in those markets in which either very silent or ultra-energy-efficient compressors are required. Taking the development cost reduction and the competitive advantage through better products and a faster time-to market into account, it is conservatively estimated that BOGE can **increase their revenues by about € 2 million over the next 5 years.**

Having demonstrated the successful application of its FlowVision CFD analysis software, Capvidia expects a twofold economic impact of the experiments results. Using the software using cloud HPC resources on a pay-per-use base makes CFD and therefore this software attractive and affordable for many more companies. This will increase the sales of SW licences considerably. Moreover, the combination of the CFD specific knowledge of Capvidia with HPC resources in a package provides the company with a new business model selling all-inclusive CFD simulation services where customers get a turnkey simulation result for a fixed price in a given short time. **Capvidia expects to increase revenues by € 5 million over the next 5 years** thanks to the experiment´s results.



Partners:

- **BOGE KOMPRESSOREN Otto Boge GmbH & Co. KG** – Industrial company, end-user, Germany
- **Capvidia NV** – SME, ISV, Belgium

OPTIMIZING HEAT EXCHANGER DESIGN OF BIOMASS BOILERS THROUGH CFD SIMULATION

MOTIVATION

Biocurve manufactures condensing biomass boilers for central heating and hot water systems for domestic users. The design of such boilers is currently based on the experience of the Biocurve technical staff. A prototype is designed, and then the original design is improved through trial-and-error cycles. The only software used in the design process is computer-aided design (CAD) software (viz SolidWorks) and spreadsheets. Currently, the time needed to design a prototype of a condensing biomass boiler is close to 6 months. An additional 6 months are necessary to bring the prototype boiler to the market (construction, refinement, testing and official approval). With this current methodology, the capability of Biocurve to develop new boiler models or improve existing ones is very limited.

The objective of this experiment has been the introduction of computational fluid dynamics (CFD) tools, integrated in a cloud environment, in the design cycle for the condensing biomass boilers of Biocurve. The CFD tools (automatic mesh generator, CFD solver and CFD post-processing) have been applied to the simulation of the heat exchanger, one of the main components of the boilers manufactured by Biocurve. One of the challenges of the experiment has been the creation of a user-friendly interface and workflow. This has been a main requirement of the experiment, since Biocurve staff has never employed CFD tools previously.

TECHNICAL IMPACT

The resulting CloudFlow application allows Biocurve to design a heat exchanger not only in terms of thermal performance but also in terms of material use (fewer tubes or shorter tubes). This was not possible with the previously existing workflow. Also, this application enables Biocurve to research the performance of a number of possible modifications or improvements that, up to now, was also unfeasible because it would have required building physical prototypes. As a result, in terms of the product design and innovation, the design of the heat exchangers can be optimized, both in the flue gas side (number, total length, diameter, curvature and slope of flue gas pipes) and in the water side (water tank geometry).

During the experiment, the following technical improvements have been achieved:

- Development of a virtual model of the current 25 kW boiler model in which the **number of pipes has been reduced from 10 to 3.** The reduction of the number of pipes in this model represents a **saving of 18 kg of stainless steel** (a 32 percent of the original weight of the pipes of this boiler). This lower number of pipes implies **savings of raw material**, but also, savings in fabrication costs (lower hours of workforce required, smaller insulation needed, less paint) and transport costs (lower volume of the boiler). The total cost saved estimated for this model is around € 400 per unit.
- Adapting an elliptical geometry for the tubes (currently the pipes have a circular geometry)
- The water side has been modified in order to get a more homogenous distribution of the water mass flow throughout the water tank
- As a result of these modifications, the **volume** of the 25 kW boiler model has been **reduced by 30 percent**. This reduction saves material costs and, also, **allows the installation of these boilers in a greater number of houses,** since space is often of essence.

Also, the CloudFlow application contributes to reduce the time (and costs) to bring a new boiler to the market.

Thus, the time-to-market for a new boiler can be reduced from currently 1 year to 8 months (a **time reduction of 33 percent**).

ECONOMIC IMPACT

The use of the CloudFlow application can save Biocurve around € 23,000 in the design of a new boiler model, taking into account the reduction of the number of prototypes should be built and, as a consequence, the lower time-to-market required. The Cloud application would allow Biocurve to increase the number of new models developed per year (currently, Biocurve is able to design 1 new model per year). The reduction of the size of the boilers due to a better design can **save around 15 percent of the total costs** of a boiler.

This product (condensing biomass boilers) is positioned in the residential/commercial pellet boilers market. According to the European Bioenergy Outlook, edited by AEBIOM (http://www.aebiom.org/blog/category/publications/statistics/), the European potential market for residential pellet boiler (up to 50 kW) is expected to grow up to 2020 in more than 500,000 units, as well as some 30,000 commercial pellet boilers (more than 50 kW). Biocurve analyses Europe as a whole market and their boilers comply not only with European legislation, but also with local regulations (particularly British, German, French, Austrian, Italian and, of course, Spanish legislations). With the CloudFlow application, Biocurve will be enabled to speed up the maturity of some products (15 kW, 25 kW or 100 kW) even 1 year in advance and **enter in some currently unaffordable markets thanks to reducing costs** (that is, low outputs markets and Eastern Europe market). It is estimated that sales of current boilers will be increased by 80-100 units/year, new sales of lower output range boilers will reach 100-150 units/year and of higher output boilers, 50-80 units/year. Addressing a customer segment defined by the domestic and commercial (tertiary) heating sector, in a three-year horizon **Biocurve estimates to face a market around 600,000 potential buyers,** with a potential share reaching 0.05 percent and **leading to incomes of € 2.55 million.** Between **3 to 6 new jobs** would be created if this volume of sales will be reached.

From the point of view of nablaDot, this experiment has provided nablaDot with a new business model, through the development of CFD tools on the cloud. This business model can be offered both to SMEs and large companies. Currently, nablaDot's business (approximately 90 percent of the turnover) is based on CFD consultancy using commercial CFD software and in-house computational resources. In the long term (5 years from now), it is **expected that 40-50 percent of the turnover (around € 150,000) will be related to ad-hoc development** and supporting of CFD tools used in the cloud. 3 new engineers are expected to be hired thanks to this line of business.

UNIZAR-BIFI provides computing power to mainly local manufacturing companies. In the medium term (3 years), the market size of HPC centers (companies demanding power computing) is expected to be twentyfold. This experiment will help to expand its services to a wider geographical range and to maintain its remarkable position as a HPC center. According to the expectations, this will represent an **increase of incomes between € 30,000 and € 150,000 in the next 3 years and the creation of new jobs (between 2 and 5).**

The results of this CloudFlow experiment are an excellent proof of the advantages of the cloud-based simulations. The access to HPC resources through the Cloud offers relevant benefits: obviously, simulations are run faster, more complex models can be implemented or alternative designs can be calculated in parallel; as a result, the design process is not only improved but accelerated, since best solutions can be find sooner. Thus, the tool developed in this experiment is expected **to be offered to at least 15 manufacturers of heat exchangers** (from different sectors, such as oil and gas industry, food industry, power sector or automotive sector).

Partners:

- **BioCurve, S.L.** – SME, end-user, Spain
- **nablaDot S.L.** – SME, ISV, Spain
- **Universidad de Zaragoza** – R&D institution, HPC provider, Spain

SIMULATION AND OPTIMIZATION OF ADDITIVE MANUFACTURING FOR IMPROVING GEARBOX PRODUCTION

MOTIVATION

Mastering Additive Manufacturing (AM) processes is rather an artisan art than a straight-forward engineering process, requiring a lot of experience to avoid trial-and-error-loops and to get it first-time-right, starting from design, covering the manufacturing engineering stages and ending with finding the appropriate AM machine process parameters for optimum product quality.

In this Application Experiment new simulation models for the Additive Manufacturing process of gearboxes are developed and cloudified to enable AM-based produc-

tion of cycloidal gearboxes whose production costs are limiting its widespread use in automation, manufacturing machines and many other products.

Thus, the **industrial relevance** is twofold:

- improved simulation technology for the huge field of AM-based production of metal objects / parts (estimated market size for AM simulation technology: € 1 billion) and
- affordable AM-based production of cycloidal gearboxes with a multitude of applications (estimated market size for cycloidal gearboxes: € 600 million).

Currently, the complete engineering and production process of cycloidal gearboxes is based on subtractive manufacturing techniques and takes about four to six months and approximately € 10,000 of labour and material costs. The **envisioned process** uses cloud-based simulation and Additive Manufacturing techniques. While Additive Manufacturing will decrease the machining time including its preparation, the simulation of the additive process and especially the thermal effects will prevent costly trial-and-error-loops before usable AM-parts are produced. Thus, reducing the overall duration and render the production more flexibly and 'real-time'.

The challenges of this experiment are manifold: the thermal effects of the AM process need to be understood, modelled into a simulation model which then is to be executed in reasonable time leveraging Cloud/HPC resources. The approach to master these challenges is to use existing simulation technology (FEMPAR - a multiscale, multilevel and multi-physics finite element solver), cloudify it to run on HPC resources via a Cloud-middleware-based interface to exploit the full power of scalable resources and augmenting it with a simulation model that captures the physics of the thermal process of a metal printing machine.

TECHNICAL IMPACT

At the end of the experiment, the end user STAM has achieved the following technical impact:

STAM has now the possibility to take into consideration AM as a possible manufacturing approach for gearboxes, since the experiment results have demonstrated that the **simulation time can be reduced by around 65 percent** (18.5 hours for the simulation of a single part on standard workstation vs. 5.5 hours for simulating the same part using HPC), then **the huge obstacle of long simulation time for the non-cloudified software is overcome**.

The scrap material reduction was calculated via CAD model. It strongly depends from the shape of the object to be manufactured. Referring to the cycloidal gearbox parts (the case study), it was calculated that **averagely**

more than 30 percent of scrap material is saved (e.g., 66 percent for the input shaft, 25 percent for the output shaft).

- The torque density can be increased thanks to AM approach, which allows the adoption of some solutions such as printing the output shaft as a one piece (the cost of such a method with trade¬tional SM techniques would be huge). Indeed, reinforced connection between the pin and the plate can be printed, and the **transmittable torque increased by 20 percent.** This result was calculated via analytical formulas, taking into account the connection radius and the pin section radius.

- **The Time-to-Market of a new gearbox can be reduced by 30 percent:** in the baseline situation, this time is around 6 months. The experiment showed how this can be reduced to by 2 months, mainly thanks to the engineering workflow time reduction (thanks to avoiding the trial-and-error approach) and production time reduction through AM.

Summarizing all the technical impacts, **STAM can increase its competitiveness in the transmission systems industry** for high tech applications due to the fact that **STAM can become the number one source of mechanisms for special applications** at a more affordable price in the cycloidal gearboxes market.

The ISV CIMNE will further advance FAMPAR-AM for additional industrial applications. The ambition is **to become the reference simulation software provider for Additive Manufacturing.** The experiment progresses FEMPAR-AM to become a Software-as-a-Service. Experience gathered in this process can be used to **bring additional software tools to the CloudFlow infrastructure.** CSUC as the HPC provider will benefit from the experiment by **simplifying HPC usage, increasing the flexibility of solutions, acquiring new knowledge** with respect to remote visualization and management of graphical nodes and provide them as powerful solutions to additional customers.

ECONOMIC IMPACT

The total costs of engineering and production of a new gearbox can be reduced thanks to CloudFlow method by 30 percent. This was calculated taking into account **the engineering time reduction (33 percent), the material reduction (30 percent), the avoidance of trial-and-error approach.** Given that the € 10,000 cost of the baseline solution is mainly due to the heavy engineering workflow, the 33 percent time reduction is estimated in € 2,000 of cost saving. The remainder € 1,000 is due to the material saving and the avoided discarded parts thanks to the optimized production. **This reduction will allow for lowering the price of the innovative cycloidal gearboxes,** consequently increasing the competitiveness of STAM. Increased flexibility provided by AM as the manufacturing method will allow for opening new markets. Market expansion and new manufacturing opportunities will contribute to creating new jobs to support the growth brought by these opportunities. Existing resources will work to foster the follow-up activities of the project and allow STAM to use AM and simulation as the standard manufacturing workflow for cycloid gearboxes. **Three years after the experiment completion it is expected to increase number of jobs by three employees** (1 person hired as AM manufacturing and simulation specialist, 1 person hired as application manager and 1 person hired as sales and business development specialist).

The typical customer of cycloidal gearboxes is an SME or Large Enterprise developing machines for industrial automation, robotics and space. The market size of such companies is estimated € 600 Mio. One year after the experiment STAM aims at having 10 companies as customers in this market (approx. 0,015 percent of the market size), **three years after experiment completion, STAM wants to triple their market share from 10 to 30 companies** (approx. 0,05 percent of the market size). The type of product and associated service STAM provides in the field of cycloidal gearboxes is for special high-tech applications that cannot rely on series production suppliers. For this reason, each client usually requires the production of 1 to 2 gearboxes so we expect to sell roughly 12 to 15 gearboxes after one year and 35 to 40 after 3 years. **STAM estimates the additional revenues of the company due to exploiting the experiment's results to be € 100,000 after one year and € 320,000 after 3 years,** allowing them to create **three new jobs** in the focus area of the experiment.

From STAM's customers' perspective, cycloidal gearboxes are a key technology for a number of applications, since such devices allow them to obtain a

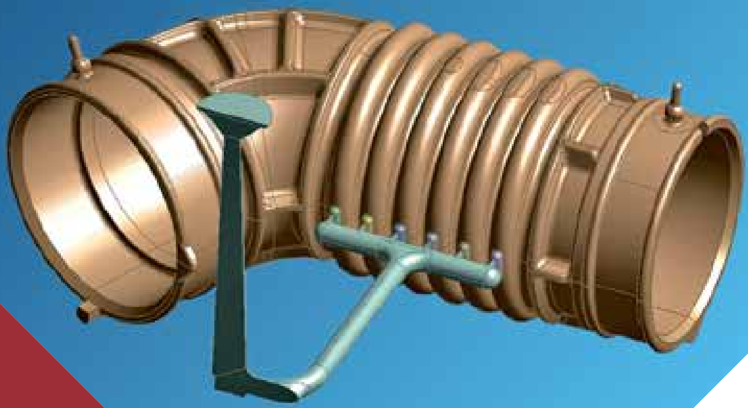
high ratio between the input speed (e.g., an electric motor) and output (e.g., an end effector), which is translated into **a high in-crease of the transmitted torque.** Moreover, the high efficiency and compactness of cycloidal gearboxes make them suitable for some particular applications, such as aerospace and robotics, while the resistance to torque peaks and shocks makes them appealing for heavy industries such as wood working and steel making. **If AM is successfully adopted thanks to CF simulation, the customers of STAM will benefit from a higher product quality** (see increased rated torque), which is sold at a lower price (see cost savings).

The software provider CIMNE will offer virtualization of the manufacturing process **permitting lower design costs through numerical simulation.** The exploitation of parallel computing resources of HPC providers in a **user-friendly and flexible way reduces computing time for users** who cannot afford buying such resources otherwise. CINME wants to increase their user community and become the reference as software providers for AM (increased market share, by 20 percent in the first year after the experiment and by to 50 percent after 3 years). The expected total income is € 14,000 for the first year and € 64,000 on a 3-year perspective which is enough to cover the production and commercial related costs estimated in € 12,000 for the first year (0,25 person) and € 40,000 on a 3-year perspective.

CSUC as being the HPC centre in this experiment **will offer new and better services** contributing to the strategic goal of CSUC to increase the use of HPC by SMEs. Easy access via the CloudFlow portal allow CSUC to **implement fast pay-per-use access to their HPC services** with an expanded service portfolio thanks to the remote visualization service implemented in this experiment. CSUC is estimating the local (Catalonia) market size for the experiment results to be 10 customers (one year after the project) and 20 customers 3 years after the experiment, when (a) market is more mature in terms of HPC simulation services usage and (2) developed tools have been improved through the use by industrial customers, who at those first stages will help to increase the usability of the platform, to make it easier for **new customers that therefore will have less barriers to become users of HPC simulation services.** After 1 year, CSUC estimates to **gather 3 new companies (30 percent of the market) and growing up to 10 companies (50 percent of the market) after three years.** The income (revenue) is estimated to be € 90,000 after 1 year and € 180,000 after 3 years: the envisioned income per customer at first stages is higher than on late stages, as the services need to be automatized and so the cost will become more affordable (and attractive) for users. This will allow for creating **one additional job position after 3 years.**

Partners:

- **STAM** – SME, end-user, Italy
- **CIMNE** – R&D institution, ISV, Spain
- **CSUC** – R&D institution , HPC provider, Spain



MANUFACTURE OF RUBBER AND PLASTIC PRODUCTS

OPTIMAL RUBBER INJECTION MOULDS THROUGH CLOUD-BASED SIMULATION

MOTIVATION

Rubber parts are present in a multitude of components used in a wide variety of industrial sectors of which transportation is the most relevant one. The market size in Europe for rubber parts amounts to approx. € 18 billion per year.

The objective of this application experiment is to improve the quality of the parts aiming at zero-defect (i.e. scotch, flash, weld lines and air-trapped) design while minimising injection time. The methodology applied for achieving this goal is based on a lean definition of the app to be running on the cloud. This means that user interaction is kept to a minimum, no visual interface is needed and reporting is done by automatically created reports.

Technically, it is expected to reduce the complexity of the rubber injection design process to allow rubber component manufacturers to optimise mould designs and accelerate ramp-up processes through user-friendly access to computational cloud services. Economically, the time and cost savings due to a simulation-based process are estimated to amount to 10 to 15 percent of the profit margin.

Currently, the end-user starts with a 3D CAD model of the rubber part to be produced. Based on their experience they design a preliminary mould and its heating system. Then, based on few optimization loops (typically from zero to five loops) the mould design and operation parameters are optimized. In this step, specialised CFD commercial software (imported from the plastic manufacturing sector) is used. After that, the mould is built and a start-up phase is needed to optimize the operation parameters by trial and error using the manufacturing machine. Typical lengths of these phases are: 1 month for mould and process design and optimization, 2-3 months for mould manufacturing and 1 month for start-up. Typical cost distribution is: 50 percent raw material, 5 percent energy consumption, 15 percent manufacturing equipment amortization and 30 percent personnel.

As described above, the current process already involves different simulations varying parameters such as mass flow rate, heat flux distributions, etc. However, due to the number of parameters and their value ranges, a full simulation of all parameter combinations, requires HPC resources, which are not available to the end user today. Thus, the mould design, mould manufacture and ramp-up of the manufacturing take 4 – 5 months, not guaranteeing zero defects with the first moulds manufactured.

The approach of this Application Experiment is to run a design-of-experiments suite of simulations on an HPC cluster, derive a meta-model from it that can then be used and evaluated for different parameter combinations guiding the engineers to much better starting positions, and ultimately allow for achieving zero-defect manufacturing with the first mould produced. This promises a 25 percent time reduction for the design and optimization cycle, as well as for the start-up phase and quality inspection. The latter time reduction is because one side-result is the area where a defect can be found. Therefore, visual quality inspection can be focused in analysing these areas in detail and not the whole part.

TECHNICAL IMPACT

The two end users in this Application Experiment see the main technical impact in the process innovation: **from a trial-and-error approach based on specialists' experience to an explicit knowledge-based approach** using meta-models that capture deep insight into the rubber injection process and optimised parameters. **This leads to an improvement of final product quality due to the minimization of part defects.** A better quality means **reduction of inspection time, reduction of start-up time and reduction of rejected parts.**

For the ISV the technical impact is on **making their tools available via a Cloud-based solution,** easily accessible via the CloudFlow Portal. This enables ITAINNOVA to **address** all members of the Spanish cluster of rubber industries (ASICE with more than **80 companies) via a unified cloud solution.**

ECONOMIC IMPACT

Economically, the novel approach translates into an improvement from 10 percent to 15 percent of the profit margin obtained for each mould. Half of this margin is attributed to time reduction during start-up and optimization stages (i.e. **less energy, less workforce, less rubber)** and the other half to the reduction of part rejections (i.e. less wasted rubber, less time for quality inspection). More importantly, it is expected **to produce almost no defect parts anymore,** thus also reducing scrap. Plus, productivity will increase considerably not only due to shortened design and start-up phases but also due to minimized filling time – thus **more parts can be produced in the same amount of time with higher quality.** The improved competitiveness is expected to **show increasing sales figures and to create new jobs** (expected 5 percent in three years, which means one new job for a SME like MIJU).

ITAINNOVA as ISV will increase in the number of projects for existing and new customers through the offer of the new service and the development of new workflows in different industrial fields. For example, since the workflow is also valid for non-Newtonian materials injection (i.e. plastics or die casting in addition to rubber) to overall market that can be addressed with this solution amounts to € 180 billion per year in Europe, ten times bigger than the rubber market alone. This will contribute to additional revenue of € 150,000 per year for the next five years and the creation of three new jobs at ITAINNOVA. The HPC resources needed for carrying out the simulations will be provided by UNIZAR-BIFI with a revenue forecast of € 40,000 per year. This will allow the creation of two new jobs in the next three years.

Partners:

- **MIJU S.A** – SME, end-user, Spain
- **STANDARD PROFIL S.A.** – mid-cap industry, end-user, Spain
- **ITAINNOVA** – R&D institution, ISV, Spain
- **UNIZAR-BIFI** – R&D institution, HPC provider, Spain

CLOUD-BASED OPTIMIZATION OF EXTRUSION DIES

MOTIVATION

Many products surrounding us in our everyday life are created by polymer extrusion: foils, sheets, pipes, window profiles, etc. The market volume for polymer extrusion processing industry is € 900 Mio. (foils and sheet will be approx. € 250 Mio.).

The aim of the experiment is to optimize the production process with optimized extrusion dies. A particular extrusion die – a flat slit die – is being optimized in this application experiment. Flat slit dies are particularly complex due to structural expansion. The simulation of the interaction of melted plastics with the geometry of the flat slit extrusion die is computationally expensive and technically demanding as fluid-structure interaction appears and need to be

coupled in the simulation – actually two simulators need to be coupled to solve for these physical phenomena.
The expected technical impact is savings in energy and raw material consumption, reductions in production down time, improvements on the final product quality and avoidance of recall actions for imperfect products. Economically, it is expected that EMO, the manufacturing SME, doubles their market share for flat slit dies from 5 percent to 10 percent in a € 100 Mio. market, INO enlarges their customer base by 50 SMEs and DHCAE extends their HPC portfolio with Infiniband-based cluster and online post-processing services.

After the design and manufacturing of an extrusion die, a tool must be put into operation, which is a complex process in itself. During the commissioning, iterative tests with the tool are conducted to detect necessary changes of the flow channel design. This very time consuming and cost-intensive process has not changed for decades. The manufacturing and commissioning of a flat slit die can take more than three months. Depending on the die size, costs of more than € 400,000 can occur, e.g. for quality steel, hours of work, commissioning material, etc.

The main challenge in plastic mold extrusion is to generate a uniform flow field across the exit plane of an extrusion die. To simulate this process fluid-structure interaction needs to be put in place accounting also for thermal effects. Coupled simulations are especially demanding as for each time step the result of the fluid solver has to be exchanged with the result of the structure solver, so that the bi-directional influences (forces) can be taken into account for the next solver step. This application experiment approaches this challenge by coupling two cost-efficient, scalable Open Source solvers with a highly customized simulation model for non-Newtonian polymer flow. This will be integrated into an extremely user-friendly workflow within the CloudFlow environment. Due to the HPC cluster an outstanding improvement of the process is expected both in terms of runtime and in process quality.

TECHNICAL IMPACT

DHCAE can provide low-latency HPC-based workflows to customers **(significantly reduce computational times for large problems:** before CloudFlow – max 72 cores, with CloudFlow – several 100 cores). Large computational problems can be calculated in 10 percent of the time that typical CFD workstations need. Customers will be able **to use FSI coupling for steady state simulations without the necessity to struggle with installing all the required libraries, setting up the HPC back-end,** etc. The experiment provides a template so that the other solvers from DHCAE can be offered as a Cloud service in the future as well.

INO can provide new simulation and optimization services based on Fluid-Structure-Interaction simulations and significantly increase computational power available due to the Arctur HPC Cluster to solve customer problems more rapidly or approach problem complexity which was not possible to be solved efficiently before – without HPC resources.

EMO will use the optimized extrusion die flow channel designs **to produce better and cheaper products.** The advanced CFD and CSM technology is planned to be introduced for in-house **usage without the need of buying hardware resources and the corresponding administrative effort to maintain them.**

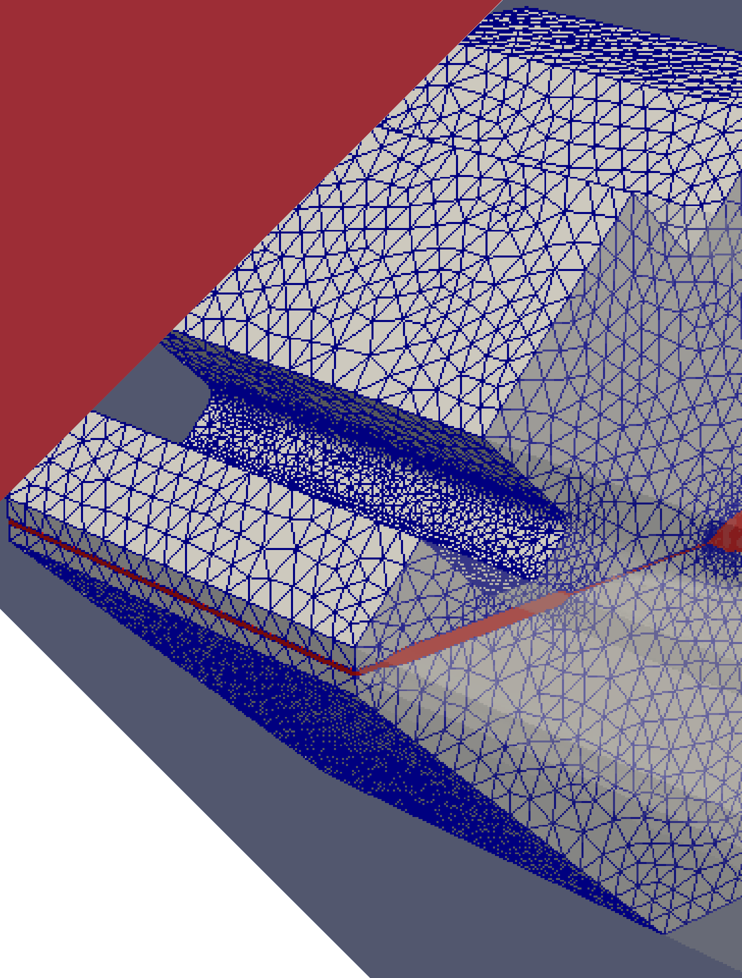
ECONOMIC IMPACT

The experiment can show that the **simulation times for large problems can be speed up by a factor of 10** compared to in-house hardware and by a factor of 3 compared to existing Amazon-based HPC architecture. The CloudFlow platform gives new sales opportunities to DHCAE, in particular **selling own CFD solvers with a pay-per-use approach,** and with no installation trouble on the customers side (new services, rare users with temporary demand). The existing software, in particular the pre-processing system CastNet, will get more attractiveness and this will result in **10+ additional soft licenses to be sold.** DHCAE expects three **new SME customers within 1 year and 10 new SME customers within three years.** The revenue is expected to be increase by 20 percent, which is € 70,000, and one additional engineer will be employed.

Within the next three years INO is expecting that **two new full-time equivalents (FTEs) can be hired** to join the company. With the increased possibilities of workflows and HPC power, **INO will address 500 new customers in the next three years and expects to triple their sales of € 80,000.**

EMO can avoid recall actions for each manufactured extrusion die. One recall actions implies costs of approx. € 100,000 for transportation (17 tons weight), modification and commissioning. The recall actions represent up to 30 percent of the production costs. Due to **a long-time average of 12 recalls per year this will save € 1.2 Mio. per year.** Commissioning time will be reduced down to 70 percent and equals a time-to-market reduction of several weeks. General **production costs can be reduced by 30 percent, particularly due to savings of energy, raw materials and personal costs.** Right now EMO has too less experience with this tool, but we expect to have a cost reduction of about 20-25 percent.

Arctur being an infrastructure provider expects that the economic impact form this experiment will be reflected through the increased sale of Cloud and HPC resources. The **increase of the sales follows the increase of new users** using the services at offer. The secondary beneficial impact for Arctur is the widening of the service portfolio and references. The service will be on offer in collaboration with the specialist knowledge of the field specialist of this experiment.



Partners:

- **EMO** – SME, end-user, Austria
- **DHCAE** – SME, ISV, Germany
- **INO** – SME, ISV, Germany
- **Arctur** – SME, HPC provider, Slovenia

MANUFACTURE OF ELECTRICAL EQUIPMENT

SYSTEM SIMULATION IN THE CLOUD

MOTIVATION

Complex systems consist of components from various domains, such as mechanics, fluidics and control engineering. The interplay of these components should be analysed already during the design phase – long before any prototypes are built – to ensure not only that they work individually as expected but especially that they work together as a system. Systems simulation allows engineers to find optimal solutions in order to ensure functionality and safety for complete multi-domain systems long before they can be tested in real life.

In the past, the end user of this case Stellba used an external engineering service provider which created a simulation model for the main components of a whole water energy plant, executed the simulation calculation and analysed the simulation results. Stellba paid approx. € 10.000 per project for these external engineering services. Stellba did not build up local simulation resources (know-how, hardware and software), because the frequency of such a systems simulation was too low compared to the expected costs. Not being able to perform these simulations in-house has the negative effect of depending on a third party in terms of quality and delivery time. The goal in this study is to enable Stellba to apply a systems simulation service developed by ITI for hydropower plants for cost-effective simulation calculation and results analysis based on adapting existing models, thus reducing the turn-around times in comparison to outsourcing to a third party.

TECHNICAL IMPACT

With the help of Fraunhofer EAS and ITI, Stellba can now run simulations themselves and **is independent from external engineering consultancy services.** No simulation software or hardware resources are needed on local computers. **Simulations can be started from every device at every point in the world** supporting Stellba in its commercial activities around the globe. The main cost benefit of Cloud resources lies in the missing initial costs for hard- and software.

The used subscription business model enables Stellba to use Cloud resources on demand. The cost-effective scalable HPC resources in the Cloud provide the possibility to run parameter studies in parallel within a reasonable time frame.

ECONOMIC IMPACT

The services and applications provided by ITI have been packaged as an **easily accessible, usable and affordable workflow.** The new approach of providing software to end users as Cloud services has enriched ITI's software functionality in terms of parallelization and accessibility, with the exploitation of Cloud resources also enabling ITI to offer a worldwide accessible service for simulation calculation and simulation data management. The new product is expected to create additional revenue through a subscription model. The expected additional revenue can enable ITI to hire up to two developers for optimizing and maintaining the simulation service.

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **ITI GmbH** – SME, ISV, Germany
- **Fraunhofer EAS** – R&D institution, Germany

CAD IN THE CLOUD

MOTIVATION

In the production process for any company, saving time during the design phase and optimizing the final product design are big challenges. Existing general-purpose CAD systems offer a way to create good designs for a multitude of products, but knowing the particular type of product in advance enables the development of dedicated functionality, thus minimizing design time and avoiding repetitive tasks and errors. Due to the complexity of the underlying free-form shape, the 3D design of a hydraulic turbine blade at the end-user Stellba is a long process. In the traditional CAD design approach it is necessary to use a lot of basic operations when modelling such a blade. These operations are mostly repetitive and similar for each design.

The goal of this case study is to reduce the amount of time needed to design a popular blade type called Kaplan blade. In Stellba's case, such a design process happens typically bi-weekly. An additional goal is to save, manage and share data by using the Cloud and a Cloud-based PLM system.

TECHNICAL IMPACT

To meet the challenge, the **CAD system Topsolid by Missler** and **product lifecycle management software by Jotne AS** were used in a new approach where the design process is accelerated and optimized by using dedicated functionalities specific to turbine blades. **These functionalities are added** to the base CAD system via the Cloud. Before – in an error-prone process – the end user's specialist had to perform 40 different operations on each surface to get the desired solid model. Now, the designer is smoothly guided through the process with **improved usability,** resulting in fewer errors and helping to achieve good results with a minimum number of operations.

Stellba's process to design a new blade is in fact running roughly **25 times faster than before, reducing the design time from eight hours to less than 20 minutes.** Consequently, Stellba is now able to create more designs in a given period and to try out more possibilities to improve the quality of their blades. In addition they can provide their design models to other applications via the Cloud-based PLM, e.g. for a successive simulation step.

ECONOMIC IMPACT

For Missler the case study has opened up the opportunity to develop **new "plug-ins" for other specific complex CAD design processes** of high importance to different end users and to provide such "plug-ins" through the Cloud. This is creating additional revenue for Missler while end users can increase their productivity for a reasonable price. Another benefit of the Cloud approach for Missler is to **simplify the process** of providing always the latest version of applications and making maintenance easier.

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **Missler Software** – SME, ISV, France
- **Jotne AS** – SME, ISV, Norway

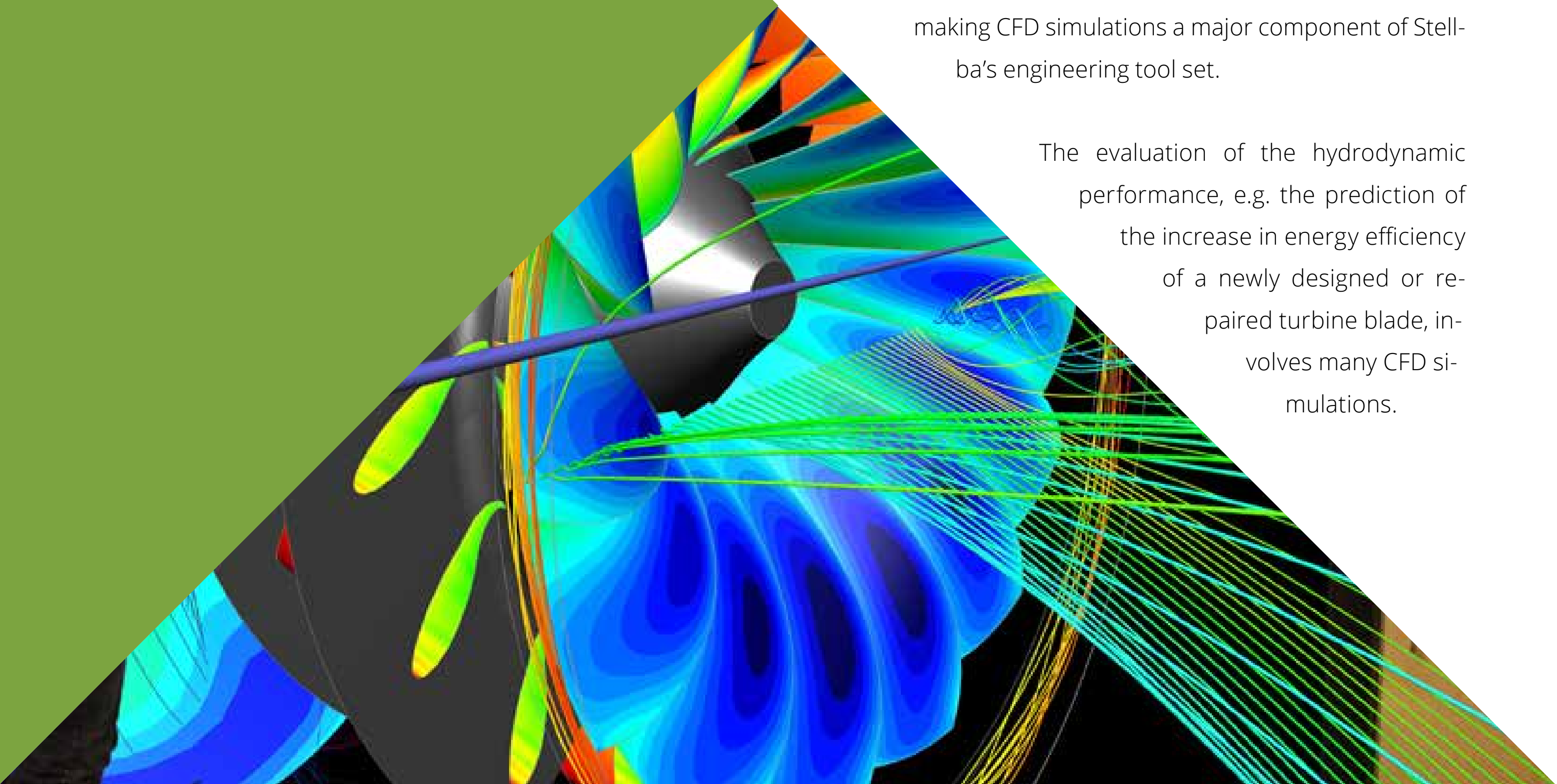
CFD IN THE CLOUD

MOTIVATION

Checking and assessing the aerodynamic or hydrodynamic performance of newly designed geometric parts by using Computational Fluid Dynamics (CFD) is a common practice in large(r) industry.

Every turbine they engineer and manufacture is different and tailored to the needs of a given specific power plant, which results in an extremely high development effort making CFD simulations a major component of Stellba's engineering tool set.

The evaluation of the hydrodynamic performance, e.g. the prediction of the increase in energy efficiency of a newly designed or repaired turbine blade, involves many CFD simulations.



The full characterisation (hill chart) of a complex hydraulic turbine may require several hundreds of such simulations, where each simulation can take several hours to several days, depending on the available computing resources. Such a complete calculation is time and cost prohibitive when using traditional desktop machines.

Thus, so far the turbine characteristics are only calculated (simulated) partially. By leveraging cloud-based HPC power in conjunction with an automated process chain, this case study aims at enabling Stellba to calculate the full turbine characteristics in an economic manner. The ambition is to perform ten times more calculations in a third of the time currently being used for just a sub-set of the problem, resulting in an overall performance benefit of a factor of 30.

TECHNICAL IMPACT

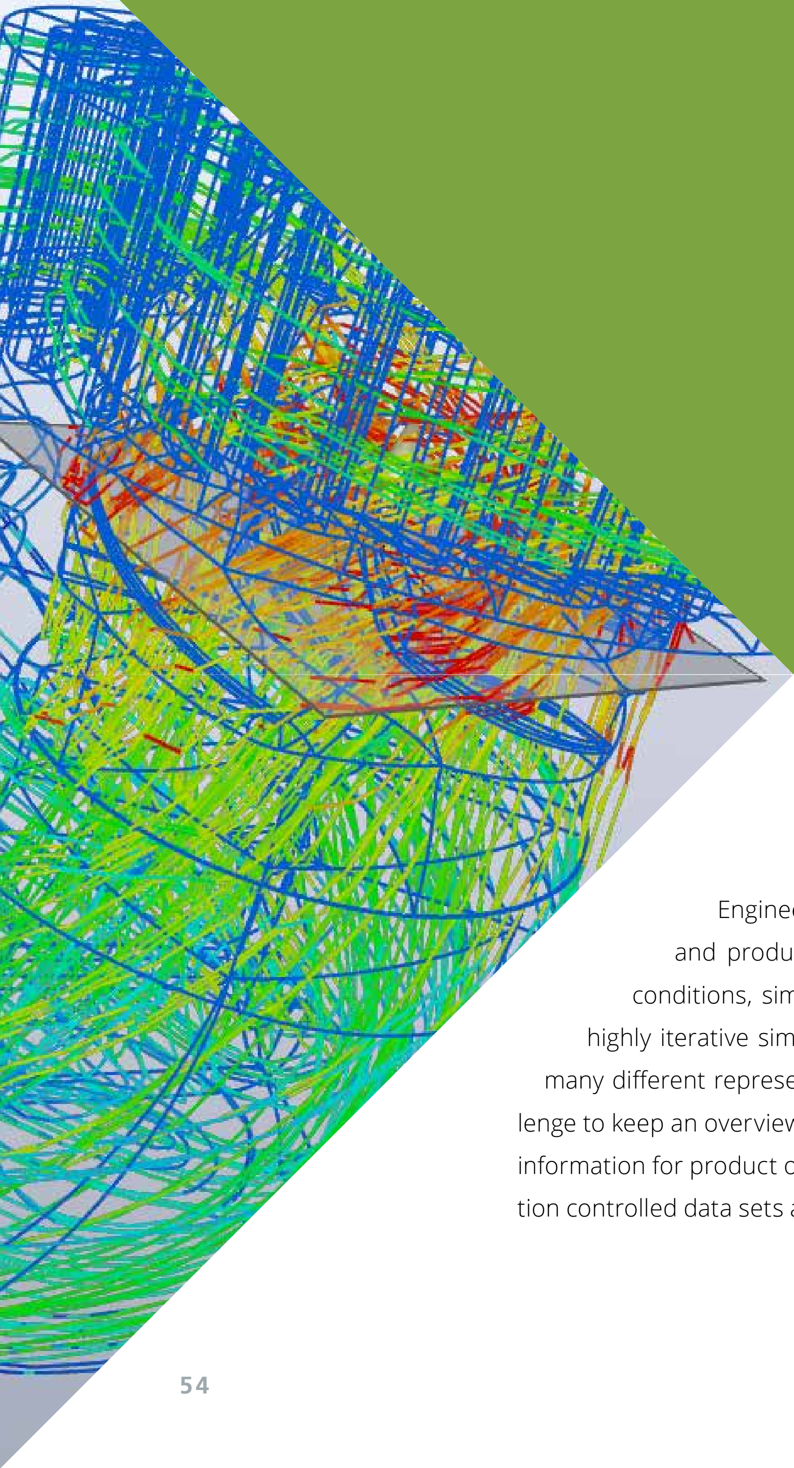
Using 'cloudified' CFD software of NUMECA and Product Lifecycle Management (PLM) software by Jotne AS, **speeds up and simplifies the CFD process,** thus reducing the development costs and **increasing the competitiveness of Stellba** by raising the product quality and reducing the development times (better time-to-market). By increasing the accuracy of the CFD, the end-user Stellba can reduce the security margin for their efficiency guarantees, which increases the competitiveness in the market. If the efficiency of a 40 MW turbine can be increased by two percent with the help of **efficient and sophisticated simulation**, the turbine owner will gain more electricity output from his water plant worth € 200.000 per year.

ECONOMIC IMPACT

For NUMECA, the **much higher accessibility of the cloud-based CFD solution**, from virtually anywhere, will largely enhance the end-user experience in evaluating and using CFD solutions in design processes. Consequently it is expected that the number of SMEs using CFD will increase largely in the short and medium term, resulting in **new customers for NUMECA**. Due to this increase one or two new jobs will be created in the short term.

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **NUMECA** – SME, ISV, Belgium
- **Jotne AS** – SME, ISV, Norway



PLM IN THE CLOUD

MOTIVATION

Engineering analysis processes include activities such as product design and product analysis, including mesh generation, definition of boundary conditions, simulation, and post-processing. In any engineering company the highly iterative simulation process results in huge amounts of files and data with many different representations of the 3D product model. For an engineer it is a challenge to keep an overview of related data (configuration control) and extract the essential information for product optimization, demanding a user-friendly overview over configuration controlled data sets and an easy and fast visual inspection.

For the process of managing evaluation results, the end user Stellba uses a multitude of different software packages with high license costs, training efforts and requirements towards human skills. The process is tedious and the locally installed software packages limit accessibility to the corresponding computers – there is no remote / web access. So, on average, Stellba spends four weeks on organizing and reviewing simulation results in parallel to running the simulations themselves. The goal of this case study is to reduce the amount of effort spent on reviewing and managing results by typically one week (i.e. by 25 percent), through the development of a dedicated solution with inter-application communication and by exploiting HPC resources for fast, accurate and optimized visualisation.

ECONOMIC IMPACT

With the help of Fraunhofer IGD and Jotne AS, the time for reviewing and managing simulation results at Stellba is being reduced by **saving about 40 person-hours of work** for a medium-sized turbine optimisation project. By shortening the elapsed time for handling projects, Stellba's capacity for new projects increases and **reduced product costs** lead to better competitiveness. The ownership of data by Stellba is also improved as project data are archived in a standard format (STEP, ISO 10303). The introduction of these processes will **help to preserve existing jobs.**

TECHNICAL IMPACT

The software components for analysis review and management are new HPC Cloud services provided by Fraunhofer IGD and Jotne AS, respectively, packaged into a workflow to be **easily accessible, usable and affordable.** With this new Cloud service approach, both software providers have **enriched their software functionality** for a more useful, usable and efficient presentation and analysis of simulation results. Since the topic of PLM and visualization addressed in this study is of high relevance for many manufacturing branches, in the future **hundreds or even thousands of new usages of this software per year have become possible.** The corresponding additional revenue can put Jotne AS into the position to **hire five new sales and support persons** for marketing the new solution and for supporting customers.

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **Jotne AS** – SME, ISV, Norway
- **Fraunhofer IGD** – R&D institution, Germany

CAM IN THE CLOUD

MOTIVATION

Simulating and optimizing the manufacturing process before the machines actually start making a new product is one of the key stages in manufacturing engineering. The aim is to minimize manufacturing time, to avoid wasting raw material (resources) and to safeguard the machines from being damaged. One has to compute many possible tool paths, assess them, select an optimum one and finally generate the Numerical Control (NC) code to actually run the machine. All these steps are very time-consuming and minimizing the time to find the best possible solution is crucial concerning the costs for the company.

The relevant process for the end-user Stellba in this study is the computation of the best tool path to machine a Kaplan turbine blade. To find an optimal tool path requires many selections and decisions by the engineer, e.g. material, methodology, and each chosen configuration requires a dedicated simulation run. As these simulations are basically independent from each other, using a parallel computing infrastructure should speed-up the iterative process and should allow computing more options to better explore the 'design space' and find 'uncommon' solutions.

TECHNICAL IMPACT

The GridWorker software tool by Fraunhofer EAS is being used to parallelize computations as much as possible to reduce the overall time used. Through GridWorker the available HPC resources are deployed on a number of virtual machines to exploit the power of many computational cores at the same time.

As a result, the HPC resources can **enable Stellba to simulate more complex machining tasks more quickly**. In fact, the time to compute a best possible toolpath is now only one third of what was necessary before. **This provides the opportunity to increase the quality of the machining**. Tool paths are now calculated in parallel. The CAM workflow allows the end user to **prepare all data sets at once** to produce a good machining plan and execute them at once and in parallel in the Cloud instead of having to wait for each individual result in front of his desktop before the next variant can be computed. **No high-end number crunchers are needed** locally by the end user since the computing power is provided in the Cloud.

ECONOMIC IMPACT

The Cloud with its HPC resources also improves the portfolio of the offers that the software vendor Missler can provide to the market. Deploying the CAM simulation engine as a Cloud service **ensures that users always work with the latest version**. The maintenance of the **application also becomes easier**: Missler has to update the application only once for all their users. The sales process is being **simplified with a pay-per-use approach** developed in the CloudFlow project from which Missler can expect more revenue and also potentially new customers. This will allow Missler to **hire new developers** to further improve their Cloud-based functionality and **also new technicians to provide training and support on the Cloud.**

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **Missler Software** – SME, end-user, France
- **Fraunhofer EAS** – R&D institution, Germany

COMPARING POINT CLOUDS AND CAD MODELS IN THE CLOUD

Checking the quality and accuracy of a manufactured part against the 'as-designed' status of the corresponding 'nominal' CAD model is a common process in industry. For this purpose, the machined part is scanned with a 3D acquisition device, e.g. a laser scanner, which results in several point clouds typically consisting of millions of measured, discrete 3D points. To determine where deviations between the CAD model and the point cloud exist, the two data sets need to be aligned and matched in a process called registration and distances between the closest points of both models need to be calculated.

For the manually quite tedious quality checks Stellba, the end user of this case, so far uses a multitude of different software packages, implying high license costs and high training efforts to be able to handle all the different user interfaces. This created the demand to reduce the amount of time needed (currently eight hours) by at least a factor of five by developing a dedicated solution exploiting HPC resources for fast, accurate and optimized matching of point clouds versus nominal CAD models improving both accuracy and usability.

TECHNICAL IMPACT

With the help of SINTEF and Jotne AS, the **processing time of quality checks** at Stellba is being reduced to less than 20 minutes **saving more than seven person-hours of work.** The ICT supported manual process containing error prone steps is being replaced by a validated software application that bridges domain barriers and **enhances the achieved quality** of the inspection. The operator at Stellba can now focus on the quality of the measurement and the produced parts while leaving most of the data processing to the new software application. In this particular case, **shortening the elapsed time for point comparison quality checks increases Stellba's capacity for taking on new projects.**

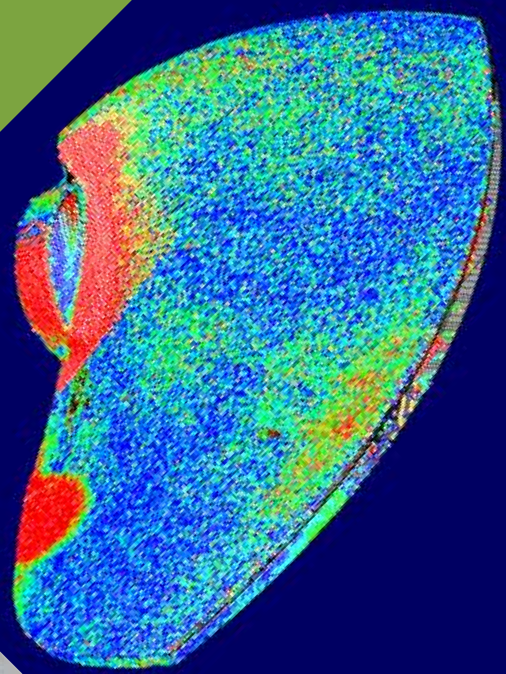
ECONOMIC IMPACT

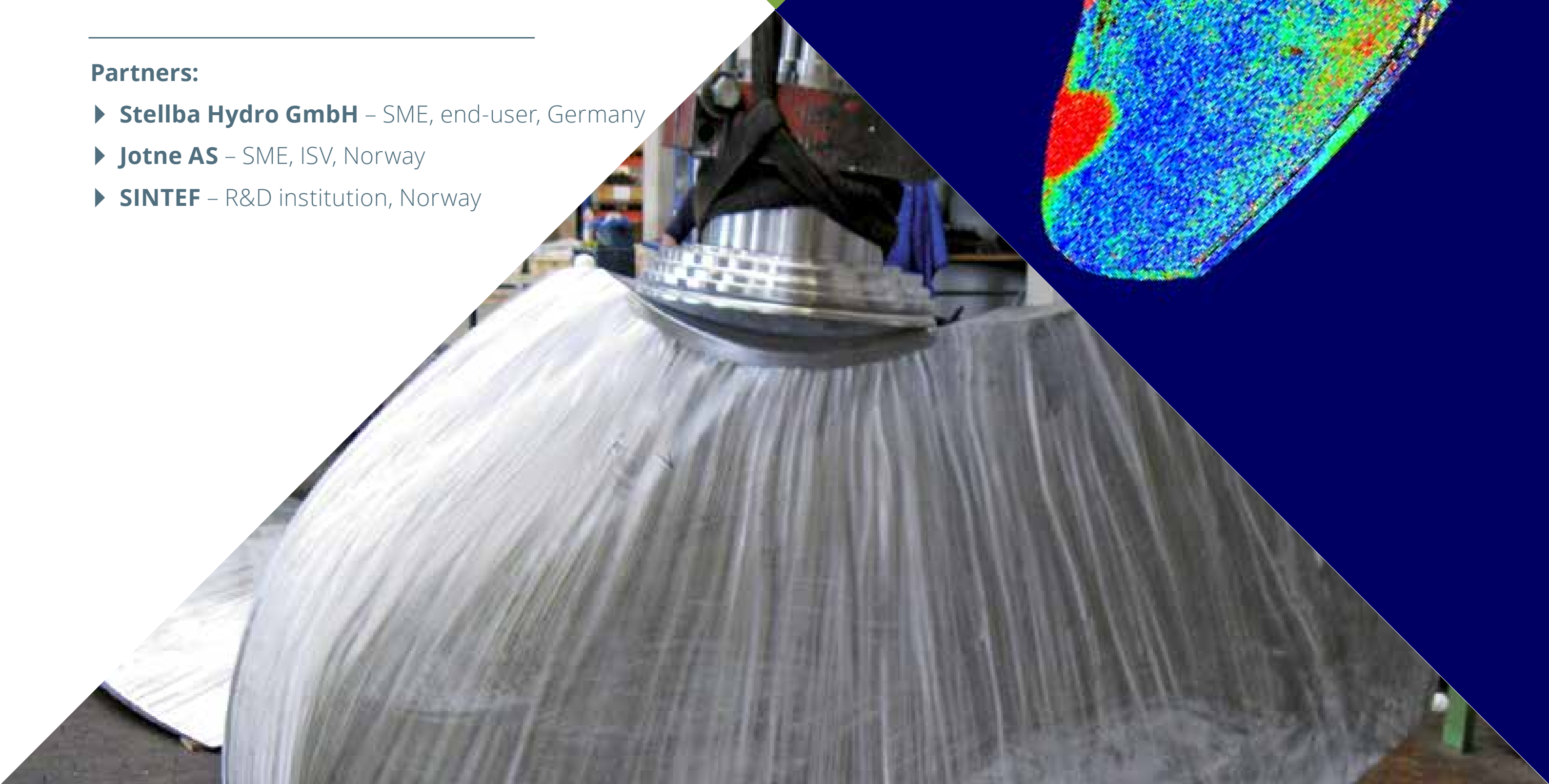
Since the addressed topic of accuracy checking is of high relevance for many manufacturing branches, hundreds or even thousands of other usages per year of the developed Cloud services are regarded as likely. The corresponding additional revenue can put SINTEF into the position **to hire one or two new researchers for porting even more functionality to the Cloud.**

Tackling the challenges of this experiment as a European endeavour **has brought together partners** from Norway (SINTEF, Jotne), Germany (Stellba) and Slovenia **(Arctur as the HPC/Cloud provider)** to **develop an effective and efficient software solution together** with the CloudFlow Competence Center that no single organization would have been able to offer on its own.

Partners:

- **Stellba Hydro GmbH** – SME, end-user, Germany
- **Jotne AS** – SME, ISV, Norway
- **SINTEF** – R&D institution, Norway





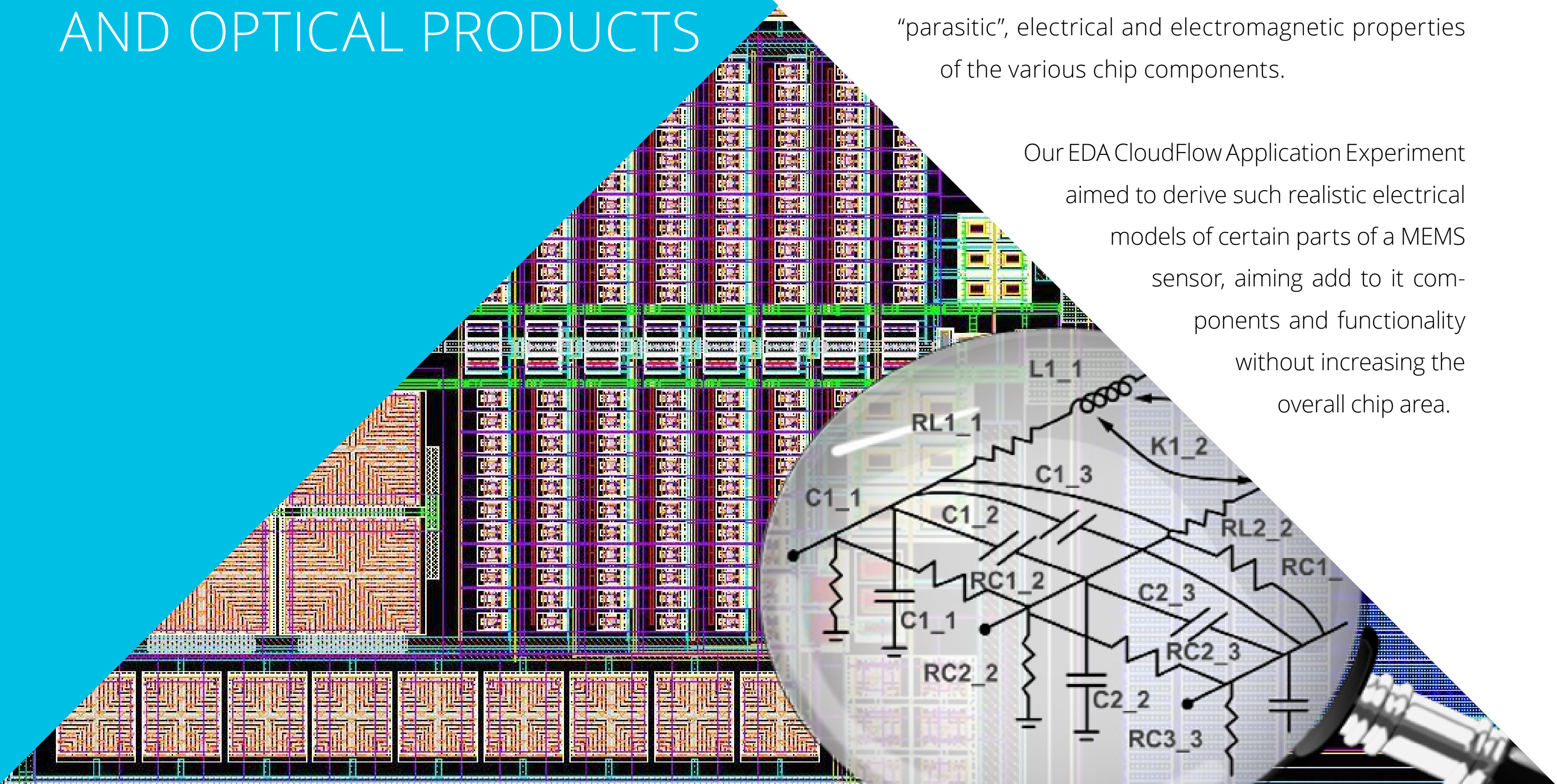
MANUFACTURE OF COMPUTER, ELECTRONIC AND OPTICAL PRODUCTS

ELECTRONICS DESIGN AUTOMATION (EDA): MODELLING OF MEMS SENSORS

MOTIVATION

Integrated circuits (microchips), are designed, modeled and simulated in more than 20 discrete design steps. Near the final steps where the design evolves to a physical layout, it is important that the models of the chip used in simulations are realistic, accounting for the electromagnetic behavior of the actual materials and geometries, so as to avoid performance shortcomings due to unforeseen, so called "parasitic", electrical and electromagnetic properties of the various chip components.

Our EDA CloudFlow Application Experiment aimed to derive such realistic electrical models of certain parts of a MEMS sensor, aiming add to it components and functionality without increasing the overall chip area.



The particular MEMS sensors are designed and manufactured by EUROPEAN SENSOR SYSTEMS (ESS).

- Product innovation:
  - use cloud version of Helic's modeling software to derive realistic chip models and free-up space on the chip
  - use the freed space to add new on-chip components and thus broaden the market opportunities for the chip
- Enable the particular innovation by using an on-cloud version of Helic's software
- Reduce chip de-risking time by 1.5 weeks for the particular 12 week exercise (10 percent time saving)

TECHNICAL IMPACT

In this particular experiment Helic's cloudified RaptorX parasitics extraction software, helped ESS modify its MEMS chip design and add interfaces for a broader range of devices, while maintaining the same chip dimensions and cost. In particular ESS:

- **freed 5 percent off the chip area**, by placing closer together certain on-chip transmission lines, whilst maintaining achieved levels of performance
- utilized the freed area to **add components** and extend the ASIC's ability to interface with all combinations of capacitive sensor structures
- ensure that is no crosstalk on the chip, without manually implementing pre-modeled generic foundry components

Further than the particular experiment and for more complex designs, IC designers have the following key benefits:

- Capture hard-to-discover crosstalk between blocks of different hierarchies
- Include all electromagnetic and substrate effects in the derived models
- Account for High-frequency resistance, self-inductance, mutual inductance, capacitance and substrate models in a single extracted file
- Quantify crosstalk between nets across multiple blocks
- Work on large circuits within realistic time scales

ECONOMIC IMPACT

End-User: Savings aspect

From the IC designer perspective, access to Helic's software over and HPC/cloud – enabled platform, provides a unique pay-per-user flexibility. Helic's software accepts generic format input (GDSII file of the physical design) and does not constrain the end user to the use of a specific hardware platform/OS or specific Electrical Design software suite. The time saving benefit from using Cloud Extraction services depends mainly on the complexity of the circuit that needs to be extracted and the capabilities of the cloud hardware. In the case of large designs, and considering that cloud hardware and optimized computing algorithms result in half the extraction time (conservative assumption) this could yield an overall project duration improvement of around 10 percent.

In the present demonstration, since only a small, but crucial, part of the chip was extracted, the improvement due to the small extraction time is negligible.

However, if one takes into account the time saved compared to the time needed to utilize alternative strategies to extraction (substitution of metal lines with pre-modeled METAL RESISTOR CELLS and utilization of conservative rules on physical design), then the overall **project's duration benefit is around 10 percent**. In terms of production costs reduction, were ESS to directly **reduce chip area by 5 percent** without adding the extra components, they would achieve a cost saving of approximately 5 percent on wafer costs. For an indicative cost of $ 0.8 /chip, savings would be in the order of $ 40,000 (€ 36,700) for 1 million pieces. It must be stressed however, that in this particular instance ESS **benefits** not from dollar savings on Si area, but **on added functionality!**

In terms of software license fees savings, should ESS decide to introduce the SaaS version of RaptorX in its design flow and employ it on crucial chip's blocks, the cost reduction for ESS's use of the cloud's extraction scheme vs the standard extraction scheme is in the order of whopping 80-90 percent. This would result in savings compared to the overall EDA tools licensing cost that ESS utilizes, of 25-30 percent, which may be up to € 40,000 per year.

Additional financial benefits for designers include (a) savings on expensive tape-outs (chip prototypes) and subsequent measurements which show chip misbehavior due to unaccounted parasitics in the model (b) avoiding losses incurred by getting into the market with underperforming and thus underpriced chips, in order to meet customer timescales. Such savings vary widely, depending on chip technology, volume and application area.

End-User: Market prospects

ESS products address a large market of micro-component solutions providers (for smart phones, tablets, ultra-books, and wearable devices). Currently estimated market size is at $ 3.7 billion whereas with current growth rates this market will have grown to $ 4.5 billion with ESS's potential share being at 0.2 percent generating **revenues**

of a ballpark $ 10 million. The Humidity sensors market alone, which is addressed by the improvements achieved in this experiment, is a fast growing segment, and was estimated at approximately $ 300 million for 2017, while a single customer alone can bring in a $ 2.5 million – 3 billion deal if their specification is met.

ISV: New market prospects

Helic, has developed from scratch and has successfully demonstrated a platform-agnostic web version of its RaptorX software, suitable for IP and Design Services SMEs as well as for the Academia. Security concerns over valuable IP leaking to the outside world, are not founded in the case of only partial chip processing, as long as any disclosing elements of the chip design, functionality, end application or customer do not leave the designer premises. Further security enhancements will depend upon the Cloud service provider and any additional security platform employed. Successful market take-up of the SaaS offering, could see Helic gaining revenues from the SME market where Helic's standard products version are normally outside most SMEs' budget limits.

The global SME IC designers' market targeted by Helic is estimated at $ 20-28 million and Helic could be looking at a 2 percent penetration in 3 years from now.

With Helic's currently envisaged **pricing model** this sort of penetration could **bring another $ 0.5 million in 3 years** from now.

In terms of new jobs, we estimate that **2 new job posts will be created to launch the SaaS product** and until a € 150,000 mark of additional revenue is achieved. Following that, it is estimated that another **1 job post will be created per € 100,000 of revenue**. More job posts may be created due to promotion effects (e.g. via academic usage).

ENVIRONMENTAL IMPACT

Amongst other things, Helic's software can be used to reduce a chip dimension, by allowing chip designers to bring closer together various on-chip components. The two main motivators behind reducing chip size are (a) smaller chips for smaller devices and (b) cost. The former has been an ongoing trend and market requirement from the very beginning of the electronics sector. Cost savings due to chip area reduction is a major driver, since (a) the cost of a printed Si wafer is the same regardless of how many chips have been printed on it and (b) yield improves a lot as chip area is reduced, because the same number of on-wafer defects produce less defective chips.

Raw material savings (Silicon, Si) are minuscule whilst also Si is abundant on the planet.However, there is a lot to be saved in terms of energy and water by reducing chip size.

Although it is extremely difficult and complex to accurately estimate such savings, we indicatively base our calculations on a 2002 estimation which stipulated that a 2 g (memory) chip requires:

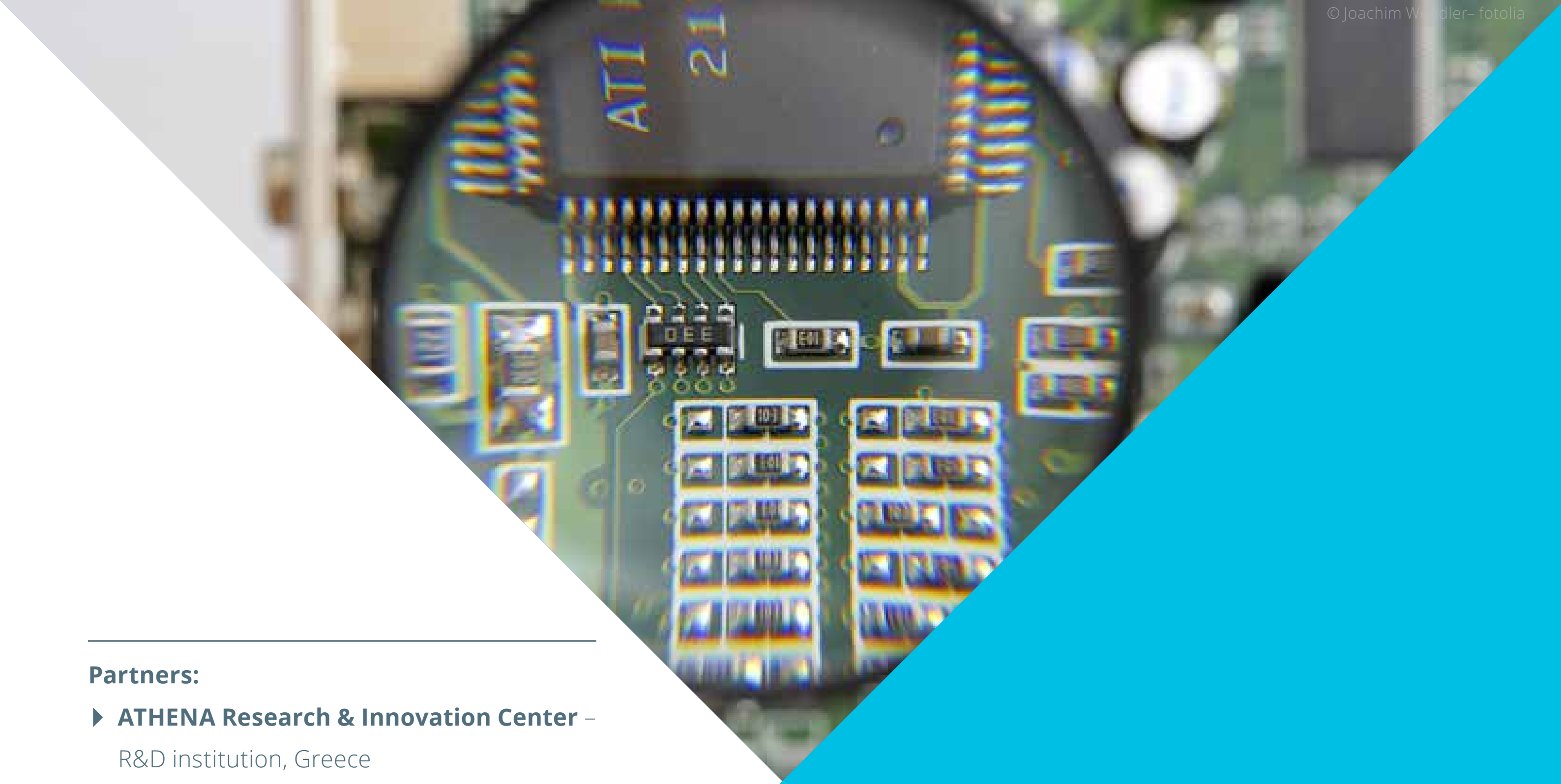
- 1.6 kg of fossil fuel
- 72 g of chemicals
- 32 kg of water

Adapting this gross approximation to our experiment and ESS's electronics (which, however are not memory chips), we have:

5 percent savings on a relatively small quantity of 1 million of ESS chips originally sized at 1640x1600 um each give approximately of savings in Si chips. Very roughly and not accounting for shrinkage effects in chip packaging, processes, yield and a large number of other parameters, we could obtain **savings of**:

- **188 kg of fossil fuel**
- **8.46 kg of chemicals**
- **3.76 tons of water**

If the above calculation gets the order of magnitude approximately right, and given that we live in a world with dozens of billions of microchips being produced every year, there is **certainly potential for massive savings on natural resources** by reducing the size of those chips.



Partners:

- **ATHENA Research & Innovation Center** – R&D institution, Greece
- **European Sensor Systems (ESS)** – SME, end-user, Greece
- **Helic S.A.** – SME, ISV, Greece

MANUFACTURE OF CHEMICALS AND CHEMICAL PRODUCTS / MANUFACTURE OF BASIC PHARMA CEUTICAL PRODUCTS AND PHARMACEUTICAL PREPARATIONS

MORE EFFICIENT DRUG PRODUCTION USING CLOUD-BASED CFD SIMULATION OF BIOREACTORS

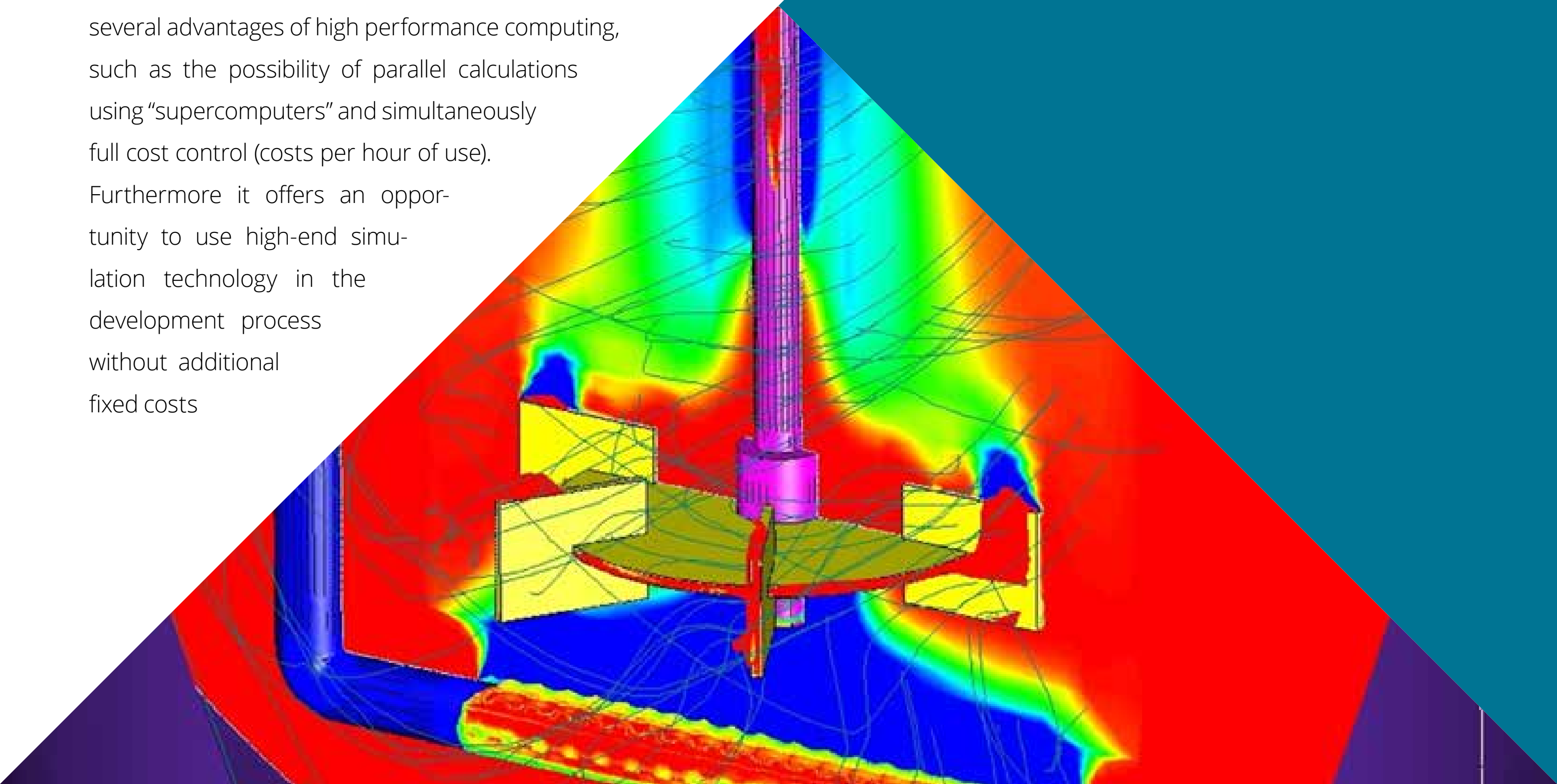
MOTIVATION

Aerated stirred reactors, the most common type of both small- and large-scale bioreactors, are used for performing microbial fermentation or mammalian cell culture unit operations for the production of biological therapeutics such as vaccines, hormones, proteins and antibodies. Usually, basic design criteria have been adapted in such a way as to meet the requirements of cells. In particular, the shear sensitivity requires consideration in impeller design, aspect ratio and aeration. Sufficient oxygen transfer and carbon dioxide removal are very important criteria in selecting a bioreactor system. Taking into account the process criteria, the scale-up process of bioreactors still presents a challenge and requires detailed knowledge about diverse fields such as the mixing processes, agitation, aeration, heat and mass transfer, etc.

Computational Fluid Dynamics (CFD) is a simulation approach that can be successfully used for the characterization of bioreactors by evaluating process parameters. Useful processes can be obtained using CFD already in an early development stage of the devices without the need for building-up a prototype. Furthermore, CFD tools can be successfully used in the scale up/down process, in order to reduce the number of prototypes and therewith production costs.

The main challenge in the calculation is the treatment of multiphase systems and long process time of several hours which leads to long calculation time, which is not suitable for industrial application. In order to overcome these limitations and to apply CFD simulations in the development process, a highly optimized workflow and huge computational resources are required. For instance, an estimation of the oxygen mass transfer coefficient for only 1 variant takes about 1 week of computational time (using a single computer with 12 CPUs). This is mainly caused by the need to run transient simulations up to 20 seconds. The time must be completely simulated and in addition the simulation has to run with very small time steps caused by multiphase simulations (e.g. 0.01s).

Simulation is becoming more and more interesting for the industry in the case of comparing several simulation variants but only if the calculation takes no more than 1 week. There are several advantages of high performance computing, such as the possibility of parallel calculations using "supercomputers" and simultaneously full cost control (costs per hour of use). Furthermore it offers an opportunity to use high-end simulation technology in the development process without additional fixed costs



(such as licences and hardware costs). An optimized simulation workflow for the HPC/Cloud infrastructure offers SMEs a possibility to exploit the advantage of this technology directly for their own products, without huge investment costs and a long period of vocational adjustment.

The aim of the presented project was to adapt the virtual process for cloud-based multiphase simulations of a bioreactor in order to perform a DoE analysis (Design of Experiments). SES-Tec, as the end-user in the experiment, is planning to offer the obtained know-how and services to their customers with a significantly faster, automated and proven simulation workflow using the CloudFlow infrastructure. Obtained results during the project time will be used for demonstration, where DoE calculations will be shown as a state-of-the-art method for the bioreactor analysis already available for the complex multiphase simulations in pharmaceutical industry.

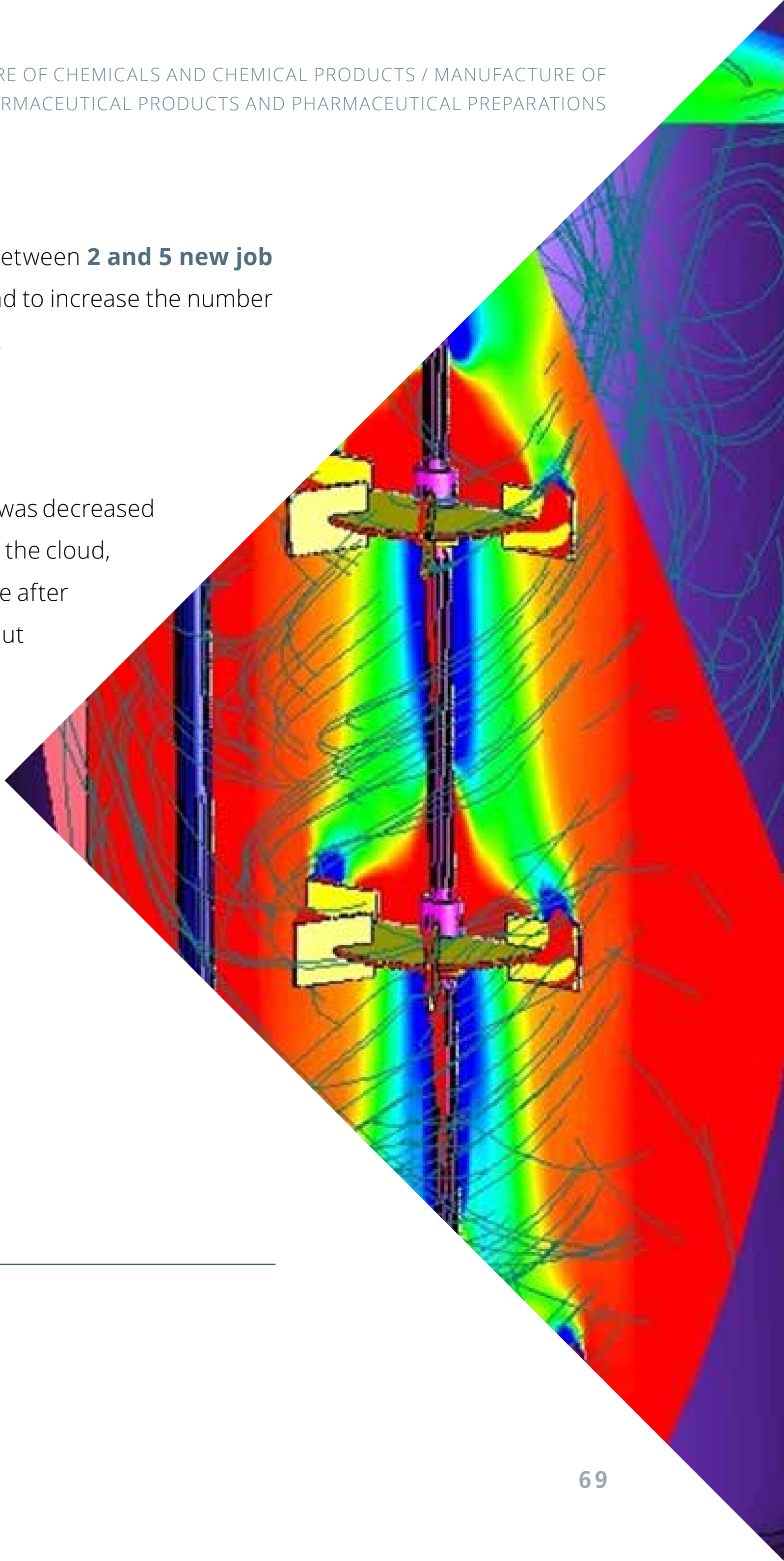
ECONOMIC IMPACT

Using the Cloud-based simulation technology it is possible to carry out analysis of bioreactors with **clearly reduced costs** due to reduced calculation time of parallel simulation variants and full cost control. Through the parallel calculation of a **huge number of variants in a very short calculation time** it enables the opportunity to get new customers. Addressing a customer segment defined by the pharma, biopharma, automotive and general engineering industries, in a three-year horizon SES-Tec estimates to face a market size of around $ 4.7 billion, with a potential share reaching 20,000-50,000 €/year and **leading to an increase of 15 percent of actual turnover** due to only Cloud computing. Furthermore, **SES-Tec is planning to hire a new employee,** which deals exclusively with cloud computation. AVL-List as independent software vendor in the experiment benefits by new customers or more sold licences. Moreover, a new Cloud-based business model was created as well. In the three-year perspective, AVL is expecting an **increase of the sold Cloud-based licences by 5-10 percent (about € 150,000 in three-year perspec-**

tive). Only for the Cloud computing, **AVL** is expecting to offer between **2 and 5 new job positions.** Furthermore, AVL also expects to gain new clients and to increase the number **of AVL-FIRE users up to 15 percent** in three-year perspective.

TECHNICAL IMPACT

The computational time for design of experiments (DoE) analysis was decreased from 5 weeks to 1 week. Due to huge computational resources in the cloud, **all 25 simulations variants can be run in parallel** and not one after the other. This number of variants are typical for DoE analysis, but are not limited anymore thanks to Cloud-based technology. Furthermore, the number of simulation variants is **no longer related to the in-house hardware resources** and therefore no investments are needed. Finally, each bioreactor manufacturer can benefit from proven and validated simulation technology and workflows for this kind of application.



Partners:

- **AVL List GmbH** – industrial company, ISV, Austria
- **SES-Tec OG** – SME, end-user, Austria

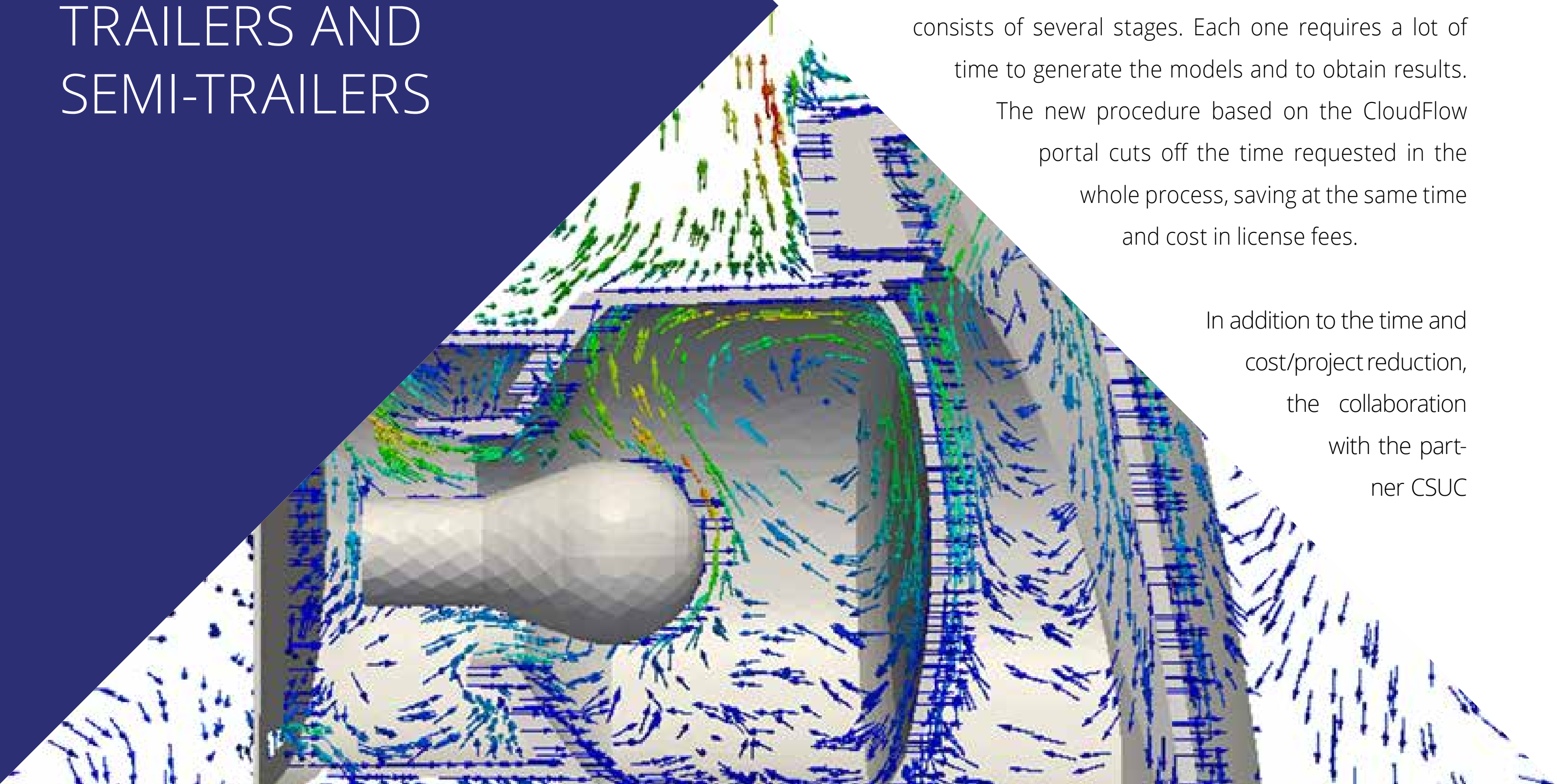
MANUFACTURE OF MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS

AUTOMOBILE LIGHT DESIGN: THERMAL SIMULATIONOF LIGHTING SYSTEMS

MOTIVATION

The development of head and rear lamps is totally conditioned by the outer style surfaces. Often this forces lamp designers to work with reduced spaces. Heat dissipation is very difficult in these conditions and the plastic material may degrade, losing its optical and esthetic properties. Simulation is a powerful tool to test virtually the thermal and mechanical performance of lighting systems. The simulation process consists of several stages. Each one requires a lot of time to generate the models and to obtain results. The new procedure based on the CloudFlow portal cuts off the time requested in the whole process, saving at the same time and cost in license fees.

In addition to the time and cost/project reduction, the collaboration with the partner CSUC



(HPC) has given to an SME like BTECHC the possibility to run bigger models improving the simulation quality and increasing the number of simulation rounds per project. This aspect is crucial to check more strategies for heat dissipation, to decide the convenience of using thermal shields and, to select materials and surface treatments properly.

- Improving the simulation process to speed up the product innovation in lighting systems. This means:
- Optimized design in terms of the material thermal performance.
- Optimized design in terms of the best strategy of thermal dissipation.
- Increasing the number of simulation rounds per project.
- Lowering costs due to savings in commercial license fees.

The new simulation methodology has been validated by comparison with previous simulated results and experimental measurements.

TECHNICAL IMPACT

Any CFD software to be used in thermal simulation of lighting systems is very demanding in computing resources. Robustness and reliability are strongly dependent on the number of cells used in models. The use of high performance computing is very convenient to run this kind of simulation. Although the computational cost provided by HPC is quite reasonable, the license fee of commercial CFD software depends on the number of cores to be used in the simulation and makes it unaffordable for an SME like BTECHC. The CloudFlow experiment has enabled BTECHC the chance of working with OpenFoam (CFD open source) after enhancing its capabilities of modeling properly the radiation phenomena. It has been estimated **savings of 80 percent in license fees and 38 percent in computing costs.**

In addition to the cost reduction, the cloudified process **reduces by 75 percent the workflow execution time** due to the use of supercomputing and the automatization of several stages in only one single workflow. This fact enables BTECHC **increasing the number of simulation rounds per project from 3 to 10** which allows better product optimization.

Another important advantage for BTECHC is being able to run the workflow via the CloudFlow portal from any place with Internet connection as well as using the remote post processing through the portal by means of a powerful graphical node. Now the simulation results can be discussed directly with the customer without investing time reporting or creating videos to support explanations.

ECONOMIC IMPACT

Every year the automotive industry starts near 500 new developments of head and rear lamps. It is estimated that the funds devoted to outsourcing CAD and CAE activities (BTECHC core business) are approximately € 360 million worldwide. BTECH began supporting the automotive lighting industry in 2009. One of the BTECHC strategies to win market share is offering services not covered by the competitors. Thermal simulation, due to its complexity, is one of these services. Until now, the simulation service had two main drawbacks: cost and number of loops per project. The CloudFlow experiment is a solution for BTECHC clients who claimed for time and cost reduction.

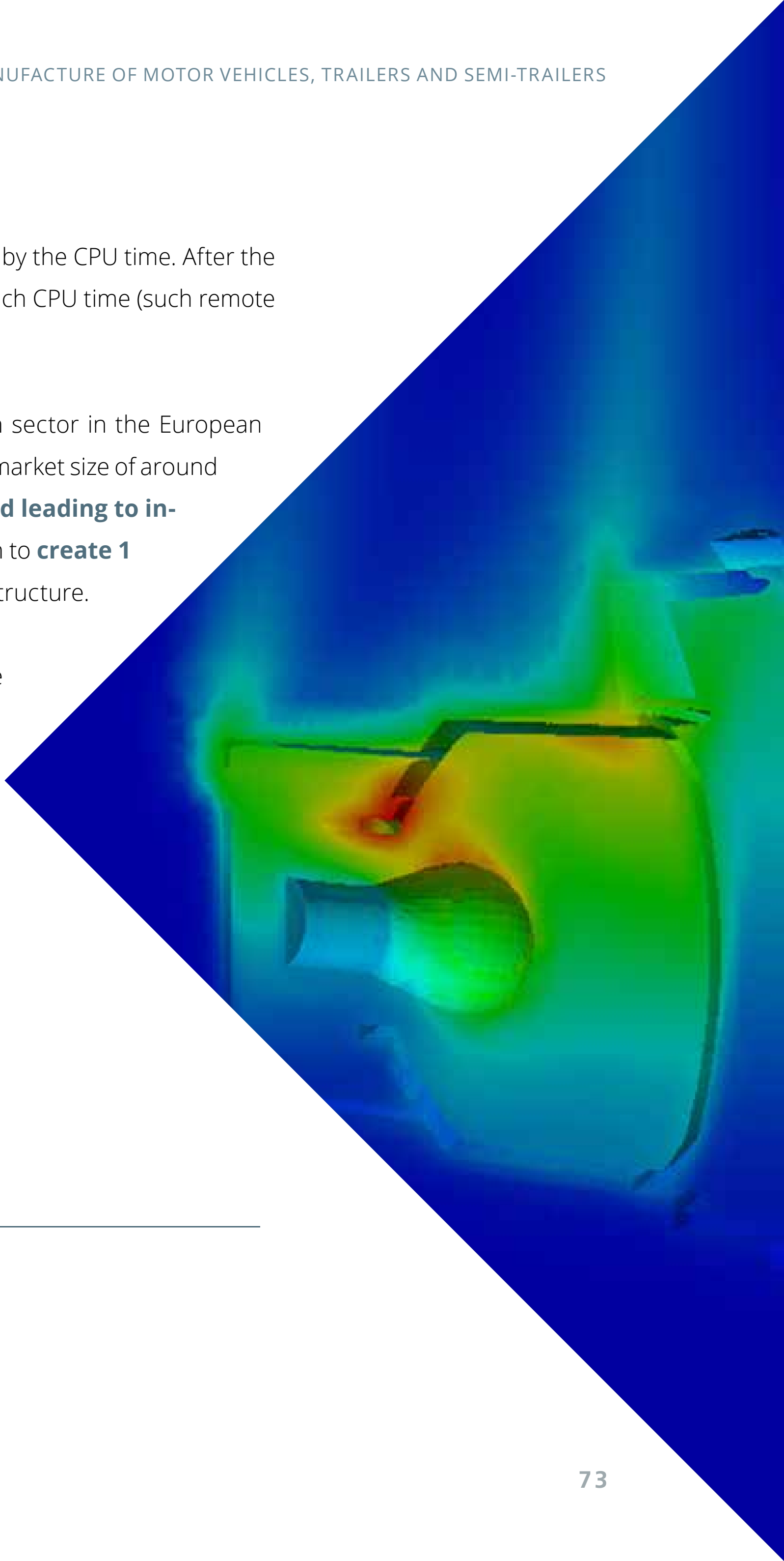
Summing up all cost/project involved in the project execution, the total cost difference between the **old and new procedure is approximately 76 percent. This huge cost reduction** should lead BTECH to a better position to win market share as provider of engineering services.

Taking the development cost reduction and the competitive advantage through better products and a faster time-to market into account, it is estimated that BTECHC can **increase their revenues in simulation services by about € 240,000** over the next 3 years. It is expected the **creation of 2 new jobs** allocated to the CAE&CFD department for this period of time. It is estimated that synergies with the CAD team would increase the **revenue in CAD services in two times reaching € 1.2 million.**

Regarding the CSUC activities as HPC, after the CloudFlow portal deployment CSUC users have easier ways to follow up their jobs. Before the experiment, a pay-per-use payment modality was in use and the value of each simulation was accounted by the CPU time. After the CloudFlow experiment other resource which do not consume much CPU time (such remote visualization) are properly accounted using the wall clock.

Addressing a customer segment defined by the CAE simulation sector in the European industry, in a three-year horizon CSUC estimates to face a global market size of around 100 customers, with a **potential share reaching 5 percent and leading to incomes of € 50,000.** With this new resources available CSUC plan to **create 1 new job** to support the new users and develop the existing infrastructure.

Another important advantage for BTECHC is being able to run the workflow via the CloudFlow portal from any place with Internet connection as well as using the remote post processing through the portal by means of a powerful graphical node. Now the simulation results can be discussed directly with the customer without investing time reporting or creating videos to support explanations.



Partners:

- **BTECHC** – SME, end-user, Spain
- **CSUC** – SME, HPC provider, Spain

OPTIMAL DESIGN OF SUSPENSION SYSTEMS

MOTIVATION

Suspension systems are present in many products in daily life: cars, motorbikes, etc. The automotive market for suspensions and its components (such as shock absorbers) is awfully significant for European industry. Automotive OEMs value vehicle safety and comfort, and so the technical specifications for components are high. This demand for safety and comfort is an outstanding characteristic in the EU5 market (France, Germany, Italy, Spain and United Kingdom).

Global market of shock absorbers was estimated in $220 billion in 2016. Companies like KYB and Showa reported in 2016 annual turnovers of $3.2 billion and $2.5 billion, respectively. The EU5 is a net exporter of shock absorbers with figures close to €2.1 billion in 2016. The International Monetary Fund (IMF) predicts a considerable rise in the Gross Domestic Product (GDP) of all of the EU5 countries between 2016 and 2021. Estimated GDPs range from 4.0 in Spain and Italy to an impressive 5.8 percent in UK.

Outside of the passenger car market, there are significant opportunities with respect to shock absorbers, such as the OEMs that manufacture commercial vehicles, agricultural equipment and trailers. Special attention must be paid to off-road and competition vehicles. Suspensions are key elements in this type of vehicles and have a big influence on handling and performance. For this reason there is an increasing interest on the R&D sector on vehicle competition championships to provide the best quality of suspension adapted for each type of vehicle and each racing category.

In this scenario, the goal of this experiment is to provide cloud-based tools that allow for finding an optimum design for a given use of suspension systems considering the application–specific requirements and constraints. The solution proposed is based on the use of a general-purpose software tool for multi-body simulation. Therefore the applicability of the experiment results is not limited to just suspension systems but after slight adaptation can be used in many practical problems arising in industry. Furthermore, this experiment is not just looking into the prediction of the behaviour of a mechanical system based on a set of design variables; it aims at finding the optimum values of the design variables in order to make the mechanical system achieve the desired behaviour. The challenge lies in finding the design variables efficiently using a “smart” optimization approach.

The current process of finding an optimal design is an iterative procedure requiring several physical prototypes, testing them, varying design parameters, building and testing again and thus subsequently approaching an optimum – or at least a design, which fulfils the requirements. Maybe better designs exist but cannot be elaborated due to time and cost constraints. The current process strongly depends on designers’ experience and is slow and expensive. In the market of vehicles for competition, designing and testing a single modification of an existing shock absorber may take 3 to 4 weeks and the associated costs are from € 3,000 to € 5,000. In the case that modifications had to be performed in the vehicle and suspension geometry costs may rise up to € 50k. Costs and time for a single iteration are spent without certitude of getting the expected results. Rarely the optimum solution is found in the first attempt; therefore this process has to be repeated 3 or 4 times which in practice makes the process unfeasible due to budget and the competition calendar limitations. A complete new design may take 2 to 3 months and the total cost can amount to as much as € 500k. In this context, simulation promises to explore a wider design space and find better solutions in the same or shorter time with a fraction of the expenses associated to the current process.

The challenges of the approach conducted in this experiment is to efficiently use HPC resources for the compute-demanding multi-body-systems simulation and to implement an efficient automated optimization procedure which deducts design variables from many simulations' results. Thus, the use of this software tool will reduce the need and number of physical prototypes as well as will find better design solutions. This goal is achieved by a design of experiment (DoE) approach including sensitivity analysis of the goal function and constraints with respect to the design variables.

TECHNICAL IMPACT

The end user, Donerre is able: **a) to change and enhance the design process by using simulation tools, b) to reduce the time required for the design of new products, c) to allow the R&D team to test design alternatives that would be unfeasible in a typical methodology based on real ground test and d) to improve product quality.** The experiment results prove that the user is able to quickly introduce changes on the design parameters and rapidly analyse the effects in the vehicle behaviour with a **very short learning curve.** In the experiment the user devoted less than one training day to learn the use of the cloudified solution. These features lead to **outstanding reductions (5 to 10 percent) of the lapse time devoted by the engineer in the design of a new product** as well as to better understanding of vehicle dynamics. The new approach contributes to improve the quality of the final product. As far as simulation results are accurate (i.e., differences between simulation results and experimental measurements in a vehicle are lower than 10 percent), **the use of simulation will reduce the need for building physical prototypes and will allow exploring a large number of design options,** including modifications in the shock absorbers and the vehicle suspension.

STT contributes to the experiment with CMechStudio: a general-purpose multi-body simulation software. STT as ISV expected the following technical impact: a) **reduction of execution time** required by the parametric analysis between 10 to 50 percent, b) reduction of execution time required by an optimization problem by 10 percent to 20 percent, c) **new possibilities to run parallel simulations on Cloud/HPC infrastructures,** thus allowing solving more complex problems/models in less time. Within the experiment run tests were performed with three models: a simplified two-dof suspension model, the rear suspension system of a racing motorbike and the full model of a car boogie. The results obtained from these test cases proved that the **technical objectives have been fully achieved.**

ECONOMIC IMPACT

The simulation tool allows analysing a single modification in the design of an existing shock absorber in less than one week leading to **savings in man labour of about 1 to 2 weeks.** This time reduction is important especially if several iterations had to be performed. **The number of physical prototypes will also be reduced. Expected overall cost savings will be higher than 50 percent.**

Cost of simulation tools is also an important factor. In most cases SMEs cannot afford the use of simulation tools due to the price of the licenses.

For example, the price of buying a license of MSC Software Adams Car is € 50k plus 20 percent of mandatory maintenance for

1 year or € 10k/year per licence. This factor limits the access of SMEs to simulation software. The pay-per-use approach proposed in this experiment will make simulation tools affordable to SMEs.

Using simulation tools Donerre will solve some crucial issues of racing vehicles. This competence could motivate customers to select Donerre instead of another brand. Donerre expects to **create a new job for a design engineer in 2018.** Total income expected from the execution of this experiment in the next three years is € 70k approximately.

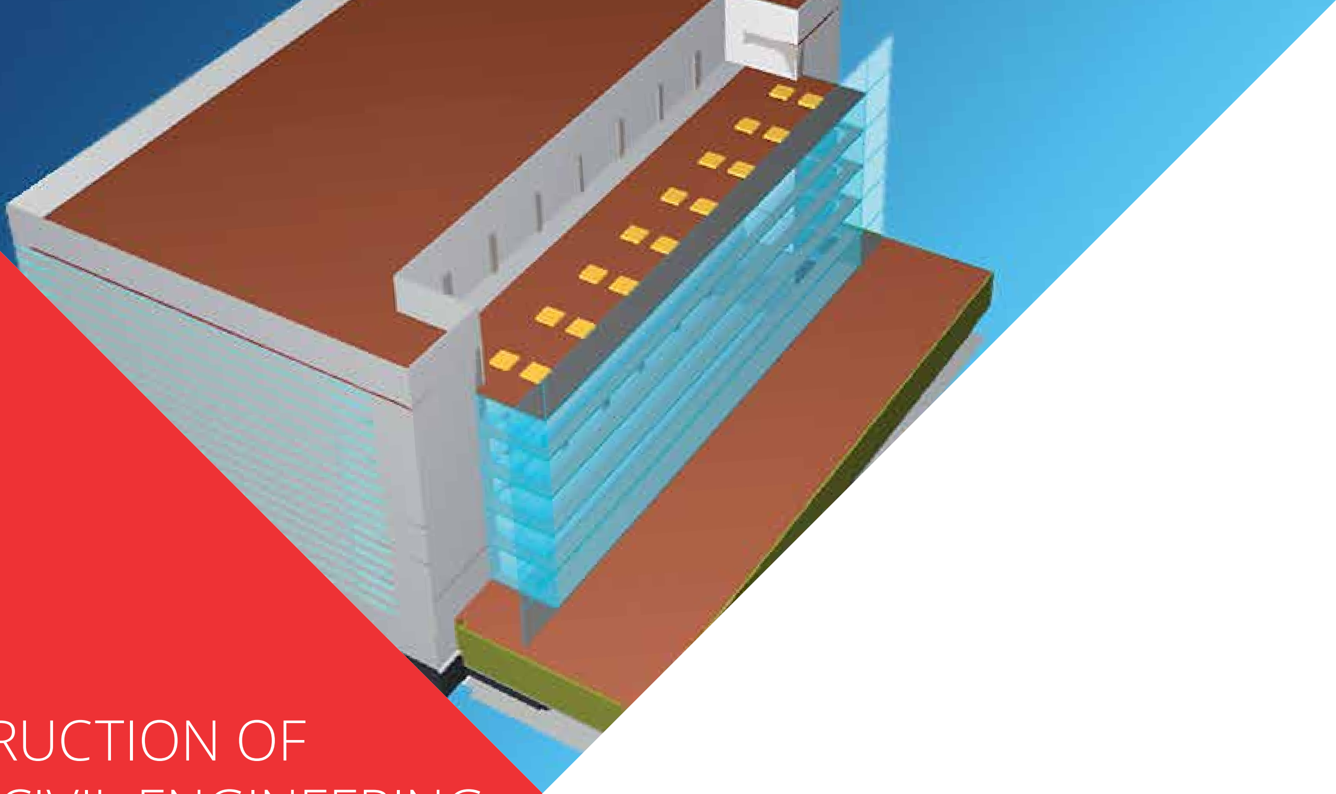
STT, the ISV, estimates to **increase in 2018 the turnover generated by the simulation tools in 2016 by a factor of 5 percent and 10 percent in the next three years to a total amount of € 145k.** It is expected to create a new job for a mechanical engineer in 2018.

From the perspective of the HPC provider, Bifi, this experiment has contributed to improve BIFI's HPC-Cloud infrastructure. The expertise acquired will help BIFI in obtaining new projects and contracts. Bifi expects increasing sales of HPC resources to users of simulation tools; **expected income accounts for € 30k in the next three years. It is expected creating 3 new jobs.**

Partners:

- **Donerre** – SME, end-user, France
- **STT** – SME, ISV, Spain
- **Unizar-Bifi** – R&D institution, HPC provider, Spain

CIVIL ENGINEERING SEGMENT



CONSTRUCTION OF OTHER CIVIL ENGINEERING PROJECTS

IMPROVING FIRE SAFETY OF BUILDINGS BY SIMULATION IN THE CLOUD

MOTIVATION

Fire safety of buildings is of relevance for each European citizen. Who does not want to feel save when shopping in a mall or visiting a theatre? In case of an emergency event, people have to get out of the building in a fast, streamlined but not chaotic manner, sprinklers have to be placed in the planning and construction phase so to keep fire under control or even extinct it, fire fighters have to have sufficient access routes and water supply, etc. This all should be simulated and optimized before starting the building process. The market size in Spain (Europe) for fire simulation tools and services is estimated to amount for € 1.5 million (€ 20 million).

The goal of this experiment is to improve fire safety designs in the building sector using CFD. Specifically this means to integrate a CFD tool called CYPE-FDS into the CloudFlow platform for detailed fire simulation scenarios focused on the building design industry. As a show case, a real shopping centre located in Spain will be used for a complete fire safety design process. The expected technical impact is an improvement of the complete workflow of the fire safety design stage, a reduction in time for the model preparation and results analysis, and higher accuracy in the prediction compared to the traditional process through leveraging the open source solver FDS.

Economically this will show the following effects: a) an increased number of fire-safety design projects, b) reduced costs of the fire-safety facilities due to optimization (30 percent cost reduction as an average, approximately € 80.000 in a case similar to the one solved in this experiment), and c) reduced costs for hardware and software for users applying fire simulation due to a per-per-use concept for HPC resources and open source software.

Currently, fire protection analysis and design is based on scalar and prescriptive models (simple and fast approach) according to codes like CTE DB SI 6 code, Eurocode (EN 1992-1-2:2004 and EN 1993-1-2:2005). But these models do not supply detailed information about the movement of smoke and the temperature evolution. Although the usage of CFD tools would be possible, the technology is not commonly used in industry because of the hardware and software costs, the limited number of CFD specialists and the time constraints for defining the fire safety design. In the reference case, this represents approximately 30 percent of the total time for the complete building design (structural and facilities). The complete fire safety design using CFD tools must be solved in no more than three weeks in order to be competitive with prescriptive models.

The challenges lie in providing a user-friendly tool with fast response times using HPC resources to facilitate fire simulations for AEC engineers that are not experts in fire simulation software. The approach is to cloudify the open source solver FDS to obtain the necessary accuracy for the fire protection analysis and design. CYPE-FDS, the pre-post tool, which facilitates the case definition, will be available in the workflow through a virtual machine. Several fire scenarios could be executed in parallel thanks to HPC resources inside CloudFlow. Finally, the results obtained in the case experiment will be summarized in a Best Practice Guideline for FDS use in building industry. This guide could be used to establish strategies for estimating a good balance between the cell size, the solving time, and the accuracy of results; HPC efficiency (number of cores, solving time reduction, simulation cost ratios); and numerical considerations in order to define subdomains.

TECHNICAL IMPACT

CYPE, the ISV partner, will be able to offer **new cloudified solutions for their software to new and existing clients.** Furthermore, improvements in the CYPE FDS workflow are realized due to the use of HPC resources. Adopting the same procedure for other software, e.g. structure analysis, energy efficiency and construction management, CYPE will be able to **increase the cloud-based product** offerings allowing not only for solving more complex problems in the domain of fire simulation but also other domains.

Cottés and Itecam, both end-users in the experiment, **profit from the user interface improvements,** especially for pre- and post-processing the model. **The training time for the CFD tool can be reduced significantly** by providing application-specific tailored functionality. Additionally, access to HPC resources is streamlined by the workflow and **does not require special know-how on the user side.**

Concerning the fire safety facilities design the end users benefits from the **increasing number of fire scenarios that could be simulated.** Finding the optimum design is **speed up by 30-40 percent due to the usage of the cloud solution because** it is accessible anytime, has no idle time and runs with good stability and low risk in simulation interruption.

ECONOMIC IMPACT

CYPE will address a bigger target market with **the expectation of 2,000 clients within one year after the experiment completion.** Furthermore it is likely to start **200 projects with existing clients,** one year after the experiment completion, **with a perspective of 400 projects in the third year.** Concerning new clients, CYPE expects 100 projects in the first year and 300 projects in the third year, respectively. The **financial benefit with a total income for the first year is estimated by € 57,000 and by € 192,000 in the third year** in software license sales. CYPE is planning to employ two new software developers.

At the moment only 20 percent of the Fire Safety Design Projects from the end user Cottés require the usage of CFD tools. This corresponds to € 350,000 - € 400,000 per year given a total revenue of € 3.5 -4.0 Mio. Using the cloudified solution of the experiment, Cottés expects **to double the**

number or projects resulting in a budget of approx. € 750,000 per year. Cottés is also expecting to reduce the costs of the active and passive mechanisms and gaining more probability of winning the tendering process. Today, Cottés trades only in the Spanish market, developing 20 fire safety design projects in 2016. Gaining competitiveness through the cloudified version, the **number of projects could be doubled.** Furthermore, Cottés customers would benefit from obtaining optimized solutions in shortened time period, **with a 30-40 percent cost reduction, as an average € 80,000 per project.**

Another benefit is the potential access to new markets like major civil engineering construction projects (airports, tunnels) and the forensic engineering sector. Another sector could be opened if insurance companies will ask for a CFD solution in order to know the origin of a fire. If 0.1 percent of these fire scenarios required a detailed analysis through CFD simulations, **Cottés would increase its number of projects in a range from 15 to 25.** After the CloudFlow Project, Cottés is planning to **employ two more CFD specialists** in fire simulation and one engineer expert in Fire Safety Codes.

In 2016 ITECAM has developed four CFD projects for private companies using commercial software such as ANSYS-CFX, Solidworks Flow, etc. focusing on CHT analysis, pressure drop simulations, and coupled multi-physics problems. Thanks to the "Fire in the Cloud" application experiment, ITECAM expects **to expand its CFD simulation capabilities to other areas, such as: HVAC analysis, FSI simulation under fire scenarios, human evacuation analysis,** etc. At the end of the third year, ITECAM is planning to **consolidate a specific CFD department with 2-3 engineers,** dedicating 50 percent of its activity to FDS simulations. In 2017, ITECAM expects **to achieve revenues close to € 50,000** through the use of "Fire in the Cloud", collaborating with Cottés and CYPE in consulting activities, benchmarking, and training some of our associated companies. In 2020 the CFD department is expected to **achieve revenues close to € 250,000,** approximately 45 percent of this amount would be generated through FDS activities.

Arctur being an infrastructure provider expects to have mostly an economic impact form this experiment. This is reflected through the increased sale of Cloud and HPC resources. The increase of the sales follows the increase of new users using the services at offer.

Partners:

- **Cottés Group** – SME, end-user, Spain
- **Cype Software** – SME, ISV, Spain
- **ITECAM** – R&D institution, Spain
- **Arctur** – SME, HPC provider, Slovenia

INFRASTRUCTURE

The whole CloudFlow Infrastructure is designed as a multilayer architecture to separate functionalities. It consists of six main layers, which may contain one or more system components. From the end-user perspective all the layers are seen as a whole, but the real interactions between system components are complex.

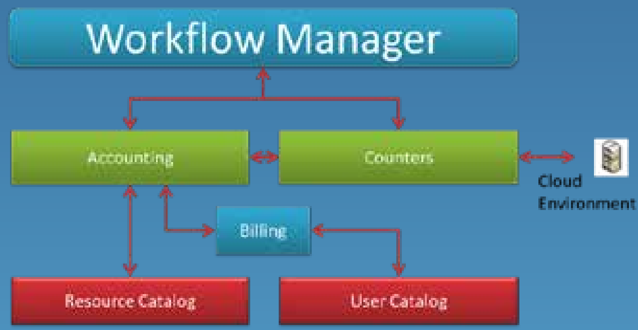
By using the CloudFlow Portal, the end user can easily choose one of the available workflows that best suits the actual needs. The CloudFlow Portal provides a graphical front-end that allows the user to configure, track and interact with design and engineering software. The end user does not need to know about implementation details of the software or the environment that he wants to use. The user can fully concentrate on performing his engineering task. The whole management of the workflow execution and of the connections between inputs and outputs of the chained services and applications from different vendors is done by the Workflow Manager. It uses semantic service and workflow descriptions to be able to execute workflows in the proper way and with correct connections between input and output parameters. The required services and applications are arranged in the desired order into a workflow and are executed accordingly. The single services and applications run on virtual machines, which renders the hardware allocation flexibly and relatively easy. The Cloud Management Service offers the possibility to launch new virtual machines (VMs) on demand as needed by the running.

Partners:

- **ARCTUR** – Arctur Računalniški inženiring d.o.o., Slovenia,
- **CARSA** – Consultores de Automatizacion y Robotica S.A.,Spain
- **CSUC** – Consorci de Serveis Universitaris de Catalunya, Spain
- **DFKI** – Deutsches Forschungszentrum für Kuenstliche Intelligenz GmbH, Germany
- **Fraunhofer** – Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., Germany
- **ITI** – ITI Gesellschaft für Ingenieurtechnische Informationsverarbeitung MBH, Germany
- **JOTNE** – Jotne EPM Technology AS, Norway
- **Missler** – Missler Software, France
- **NUMECA** – Numerical Mechanics Applications International SA, France
- **SINTEF** – Stiftelsen SINTEF, Norway
- **UNIZAR-BIFI** – Institute for Biocomputing and Physics of Complex Systems of the University of Zaragoza, Spain
- **UNott** - The University of Nottingham, U.K.

CLOUDFLOW PORTAL

The CloudFlow portal is the entry point for workflow execution in the CloudFlow infrastructure. The portal encapsulates the technical details and provides complete end-to-end solutions to the end user. Furthermore, the portal provides added value by enabling the symbiosis of key competencies and knowledge. The CloudFlow portal enables easy and straightforward access to the Cloud/HPC resources.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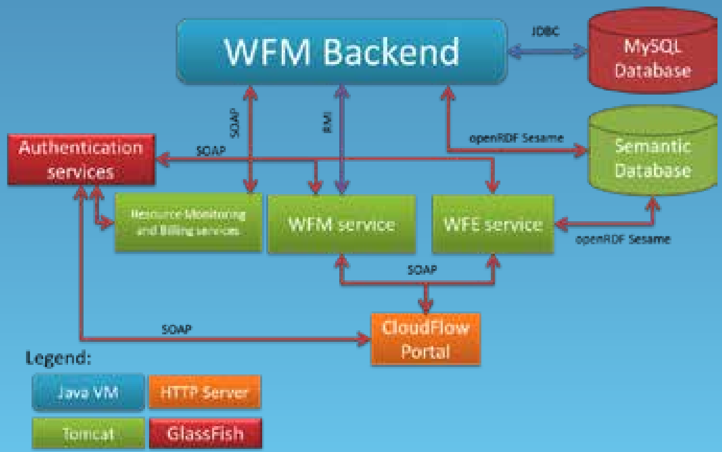
Counters
Cloud Environment
Billing
Resource Catalog
User Catalog


WFM Backend
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MySQL Database
SOAP
RMI
openRDF Sesame
Semantic Database
Authentication services
SOAP
Resource Monitoring and Billing services
WFM service
WFE service
openRDF Sesame
SOAP
SOAP
CloudFlow Portal
Legend:
Java VM
HTTP Server
Tomcat
GlassFish

FUTURE OF CLOUDFLOW

CLESGO - ENGINEERING APPS AS A SERVICE

WHAT IS CLESGO ABOUT?

clesgo is a technology-driven startup dedicated to the democratization of ICT-enabled solutions for the manufacturing industry. clesgo is being positioned as one of three Cloud Platforms in Europe and it is becoming the single point of access for cloud-based engineering and additive manufacturing tools. In order to achieve this, clesgo is building strategic alliances with different technology providers and domain experts. The first strategic alliance was established with the partners of the European project CloudFlow and the partners of the European project CAxMan followed the same strategy. Thus, clesgo is acting as commercial integrator for the technology providers and the domain experts, while also acting as innovation manager for the holistic solution and its long sustainability.

MISSION OF CLESGO

clesgo's mission is to boost the manufacturer's competitiveness and to strengthen the affordability and accessibility for manufacturing SMEs of ICT-enabled solutions. clesgo aims to foster the access to manufacturers of customized technology for the digitalization of their processes, rendering flexible, ubiquitous, and cost-effective orchestrating solutions, and leveraging trusted strategic alliances with world-class expert partners. clesgo does not limit itself to facilitating the affordable access to the technology, clesgo is also developing the customers, by means of understanding their needs and desires and by means of advising them in applying and profiting from the solutions in the most innovative and efficient way, maximizing the impact and added value for them and their customers.

VALUE PROPOSITION OF CLESGO

The democratization of engineering and simulation technologies has different perspectives. From a technological perspective, cloud interfaces, cloud-based HPC, and cloudified engineering tools enable the access to the technology. From a business perspective, unified pay-per-use models, web self-service models, and try-before-you-buy strategies make the technology affordable. Nevertheless, the lack of domain knowledge and the complex graphical interfaces of the engineering tools prevent many unexperienced end-users to apply and profit from the technology.

In order to lower the knowledge barrier for unexperienced end-users, clesgo is generalizing the concept of engineering applications (apps). An Engineering App is a design centric workflow that reproduces an engineering process for specific product types such as: pumps, structures, wings, etc. The Engineering App is easily employed by end-users without domain knowledge nor experience with dedicated software tools. In other words, an Engineering App already models the corresponding expert knowledge for the very concrete product type within a unified web-based user interface.

When an end-user employs an Engineering App, she only needs to configure it for her individual product. For instance, an Engineering App for a pump is already »parameterized«, in order to generate the suitable mesh according to the input geometry and the boundary conditions, considering the time and space discretizations, boundary layer conditions, and fluid properties, among others. In addition, the Engineering App also provides the corresponding validation criteria to assess the result based on convergence, residuals, pressure / velocity profiles, etc. clesgo empowers manufactures with Engineering Apps as a Service,

- leveraging Software as a Service,
- Computing as a Service,
- Integration as a Service, and
- Customization as a Service.

Clesgo aims to streamline the access of manufacturers to such technology and know-how, by means of developing, creating, and offering Engineering Apps.

CLOUDFLOW – THE CONSORTIUM

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www.eu-cloudflow.eu

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