FORTISSIMO

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Impact Report

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Executive Summary

The vision of Fortissimo is to enable European manufacturing industries to benefit from the competitive advantages inherent in the use of advanced simulation based on High Performance Computing (HPC). Towards the realisation of this vision, Fortissimo has created a sustainable ecosystem where actors at all levels in the value chain can realise significant commercial benefit. This ecosystem is the Fortissimo Marketplace where end-user requirements can be matched against expertise, codes and compute cycles in a one-stop-shop. The development of this ecosystem has been informed by a set of 53 end-user driven experiments each involving partners across the value chain from end-users to HPC experts.

The major impact from Fortissimo comprises:

- The development of the Marketplace;
- The outcomes of the experiments;
- The outcomes of the dissemination activities;
- The development of relevant business models.

The principal objectives of this report are to demonstrate:

- The potential and actual benefits to European industry through the early adoption of Cloud-based HPC, with particular emphasis on the manufacturing sector.
- How Cloud-based HPC can overcome the barriers to advanced HPC-based simulation thus giving European SMEs a significant competitive advantage.

Participants in Fortissimo comprise all players in the value chain from end-users through to HPC centres. The dynamic of the interaction of these players is as follows:

- End-user requirements have informed the development of the Fortissimo Marketplace;
- Domain and HPC experts have supported the feedback loop between the Marketplace developers and the experiments;
- Experiments have resulted in direct business benefits to the end-user companies involved and dissemination material including the success stories, the Fortissimo brochure, flyers and the industry-facing Fortissimo website.

The gathering and presentation of data for this report as a set of KPIs, focused on demonstrating impact, has concentrated on information from the partners in the Fortissimo experiments. This represents a significant body of diverse experience and expertise.

The following conclusions can be drawn from Fortissimo:

- The Fortissimo approach is effective at transferring business-led technology enabled solutions to end-users. The collaboration of technology experts, technology providers and end-users has worked well. Fortissimo has demonstrated a clear value to the participating organisations as discussed in section 3. It is recommended that this model be followed in further calls for proposals.
- Experiments are an effective vehicle for benefitting SMEs, creating new business opportunities and creating awareness. Experiments which focused most closely on end-user requirements created the best outcomes.
- Success stories are a highly effective means of demonstrating benefits across the value chain and creating awareness of the benefits of advanced Cloud-based-HPC simulation. In Fortissimo, success stories have been complemented by a significant dissemination activity.
- Open calls are an effective way of way of setting up end-user driven projects to demonstrate the benefits of new technology.
- The Fortissimo vision of a one-stop-shop is now moving forward.

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1 Introduction

1.1 Objectives of the Fortissimo Project

The importance of advanced simulation to increased competitiveness for both large and small companies is well established. The vision of Fortissimo is to enable European manufacturing industries to benefit from the efficiency and competitive advantages inherent in the use of advanced simulation based on High Performance Computing (HPC), as practised, successfully and for some time now, by numerous high-tech industries. The mechanism adopted by Fortissimo to realise this vision is the provision of simulation services running on a Cloud of HPC resources. Towards the realisation of this vision, Fortissimo has addressed the following goals:

- Making advanced simulation accessible to industrial users, particularly SMEs, through the creation of a "one-stop-shop" where hardware, expertise, applications and visualisation and other tools are easily available and affordable on a pay-per-use basis;
- Creating and demonstrating a sustainable commercial ecosystem where actors at all levels in the value chain can realise sufficient commercial benefit to enable that commercial ecosystem to persist independently of European Commission funding, providing services to manufacturing industry, particularly SMEs.

The focus in Fortissimo has been on business-relevant application experiments to develop, test, refine and demonstrate this "one-stop-shop" and to confirm its economic viability to all participants in the value chain. A key objective has been to overcome the barriers to the development and exploitation of HPC enabled simulation services available as Cloud of resources. This has been done through the development, testing, evaluation and demonstration of HPC enabled simulations, complemented by the creation of a working Fortissimo Marketplace infrastructure.

The Fortissimo Marketplace is an ecosystem where end-user requirements can be matched against expertise, codes and compute cycles as a one-stop-shop. This one-stop-shop provides all that is needed to improve the end-user's product or service offering. Furthermore, this one-stop-shop offers a viable ecosystem where all participants in the value chain can see a return on their contribution to the improvements made.

1.2 Objectives of this Report

The objectives of this report are to:

- Demonstrate the potential and actual benefits to European industry through the early adoption of HPC provided as a Cloud of resources with a particular emphasis on the manufacturing sector. These benefits are presented below in section 3 using a set of KPIs determined from the Fortissimo success stories[1]. These success stories comprise a significant body of material addressing many of the aspects of turning advanced simulation capabilities into competitive advantage and profit;
- Demonstrate how on-demand HPC can overcome the barriers to its adoption thus giving European SMEs a significant competitive advantage. This again is addressed in the presentation of the KPIs in section 3, particularly in sub-sections 3.1 and 3.2.
- Demonstrate the outcome of dissemination activities aimed a widely promoting the use of on-demand HPC to the target audience from the manufacturing sector. This is discussed in detail in section 4 below, Dissemination and Awareness Creation.

[1] https://www.fortissimo-project.eu

1.3 Structure of this Report

This report is structured into 6 sections comprising:

- This introduction;
- How the data underpinning this document was gathered;
- A discussion of that data;
- Dissemination and creation of awareness of Fortissimo's results;
- The development of business models;
- Conclusions and lessons learned.

1.4 Background

This section presents the structure of Fortissimo, the dynamics of the participants in Fortissimo, its funding and budget.

1.4.1 Structure of Fortissimo

In order to address its objectives and the associated challenges, Fortissimo was structured as a set of activities addressing:

- The development and operation of the Fortissimo Marketplace where end-users are able to find ways in which advanced simulation can improve their products via a one-stop-shop where they will have access to expertise, applications and computer cycles on a pay-per-use basis;
- Experiments which demonstrate the benefits of using Cloud-based-HPC solutions and provide important feedback to the developers and operators of the Fortissimo Marketplace;
- Dissemination which is creating awareness across manufacturing industry of the solutions Fortissimo is promoting and of their value;
- The development of business models to ensure the effective and viable operation of the Fortissimo Marketplace, including the involvement of Independent Software Vendors (ISVs);
- An overall management structure to ensure the effective operation and cooperation of all the activities in Fortissimo.

Orthogonal to this, the participants in Fortissimo comprise:

- Computer centres with access to high-performance computers, HPC-based expertise, domain expertise such as computational fluid dynamics (CFD), and open-source and commercially available software;
- Domain and HPC experts;
- Independent Software Vendors (ISVs);
- Domain-specific consultancies;
- End-users.

1.4.2 Project Dynamics

Participants in Fortissimo comprise all players in the value chain from end-users through to HPC computer centres. The dynamic of these players collaborating is as follows:

- Experiments indicate end-user requirements as input to the development of the Fortissimo Marketplace;
- Domain and HPC experts support the development feedback loop between the Marketplace developers and the experiments;

- At its heart, Fortissimo solves the business challenges posed by the Experiment end-users delivering business advantage and demonstrating the efficacy of HPC-enabled modelling and simulation;
- Experiments produce dissemination material including the success stories, the Fortissimo Brochure, flyers and the industry-facing Fortissimo website. This activity supports the creation of a critical mass of interest and an awareness across industry of Fortissimo and of the benefits of advanced simulation using Cloud-based HPC;
- Establishing a critical mass of activity results is essential towards a growing and viable Fortissimo Marketplace and helping new companies get over the hurdle of initial adoption.

1.4.3 Funding

Fortissimo had an overall funding of €16 million from the European Commission and a total budget of €22 million with a contribution from the partners of €6 million.

2 Gathering of Data for this Report

2.1 Overview

The gathering of data for this report has concentrated on information from the partners in the Fortissimo experiments. This represents a significant body of diverse experience and expertise. These partners are computer centres, companies and research organisations which fall roughly into the following categories:

- Providers of high-performance computer cycles;
- Independent Software Vendors (ISVs);
- Providers of software including open-source and in-house codes;
- Domain (such as CFD) experts;
- HPC experts;
- Industrial end-users.

The Fortissimo project is very close to the market because it directly addresses the stimulation of European industry through the adoption of Cloud-based-HPC computing. Its business-relevant experiments have placed a particular emphasis on the use of advanced simulation in manufacturing. Such simulation, involving the development of new products and services, is very close to the core businesses of most of the experiment partners in Fortissimo. Details of the outcomes of these experiments and their impact on the products and services sold by these partners are, in many cases, closely guarded information. This has introduced a level of abstraction, anonymisation and consolidation into the gathering of data and the information in that data. This necessarily implies that a document such as this deals with imprecise data which have, to varying degrees, been filtered and redacted by the partners concerned. Of course, Fortissimo itself has access to more detailed, but confidential data which cannot be presented here.

To compound this imprecision, much of the data provided deals with new products, services and markets. This means that we are dealing with imprecise market data and predicted deployments and revenues. In such cases, it is possible for a single datum to give a distorted picture of a wider market which renders any interpretation of such statistics uncertain or pointless. Rather than pursue a path of optimistically consolidating data and presenting meaningless averages and other statistics, we have chosen to present the data gathered in a qualitative way drawing on the information presented both by the Fortissimo success stories augmented by further information from the Fortissimo computer centres.

In total the results from 53 experiments and data from the partners involved have been used as the basis for this report. The gathering of data has involved interactions between the authors of this document, the Fortissimo computer centres and the other partners in the experiments. Much of this information is encapsulated in the success stories and the Experiments available via the Fortissimo Webpages, https://www.fortissimo-project.eu. The partners providing information for this report, can be roughly broken down as follows:

- Industrial end-users (58);
- ISVs (34)
- Code Owners (2)
- Domain experts (34)
- HPC experts (43)
- High Performance Computing Centres (8)

In total 120 partners were involved in the experiments broken down as above. It should be noted that some partners took multiple roles e.g. a partner might be both an ISV and a domain expert. Equally, there might be multiple end-users in a particular experiment.

The data underpinning this report was gathered from the HPC Centres and from the individual partners in the experiments. This data was captured directly from the HPC Centres, from the Experiment Final Reports and from the success stories and associated templates. In many cases the data were subject to refinement and clarification involving significant interaction between the experiment partners, the HPC-Centres and the participants in the Dissemination and Training work package responsible for the development of the Fortissimo success stories.

3 Impact

It should be noted that out of the 53 experiments conducted in Fortissimo, 44 resulted in success stories published on the Fortissimo Website, the Fortissimo Brochure These 44 experiments have been used in the development of the KPIs below. Following the gathering of data from these experiments, the following KPIs were identified.

3.1 Affordability

The availability of HPC systems as a Cloud of HPC resources, on a pay-per-use basis, opens up the use of such systems to companies which otherwise would only have access via an expensive in-house system. In many cases, such a system would not be financially viable because it would represent too great a capital investment. Furthermore, the cost of ownership of such a system would be much greater than pay-per-use access to a remote HPC system. This is because a shared access HPC system generally has a much greater utilisation than an in-house one.

16 experiments reported affordability as being a key issue in the use of on-demand HPC.

3.2 Feasibility

Feasibility is the complement to affordability. Some industrial applications are not feasible using an in-house system because it would have to be so big as to render it financially unviable. The elasticity of the Cloud of HPC resources-based approach can overcome this by making very large systems available on a pay-per-use basis at an affordable cost. In other words, the availability of very powerful systems enables large simulations to be undertaken which otherwise would not be possible on a smaller system or which would take too long to be consistent with the timescales of the design process.

Furthermore, simulations could reveal properties which physical experiments could not. The experiment entitled HPC-Cloud-based Simulation of Steel Casting is an example where simulation can reveal features not amenable to physical inspection.

22 experiments reported feasibility as being a key issue in the use of HPC-enabled simulations.

3.3 Access to Expertise

Many of the end-users were naïve users of simulation. Some might have no experience at all of the benefits of simulation and some might have tried elementary simulations using low-power in-house systems. In several cases access to domain expertise, such as CFD or the use of a particular software package, and to HPC expertise were seen as important.

12 experiments reported access to expertise as being a key issue in the use of advanced HPC-enabled simulations.

3.4 Increased Revenue

The success stories generally demonstrated an increase in revenue for the participants in the experiments through, for example, lower costs, more customers and shorter times to solution. This included small consultancies able to increase their turnover through the use of HPC, ISVs able to sell their codes, domain and HPC experts able to sell their skills and computer centres able to sell cycles. Interestingly, many participants in the value chain presented increases in revenue, but some presented more revealing figures by presenting increased profit. This is discussed in the section 3.5 below which deals with increased profit.

28 experiments reported increased revenue as being important drivers to the use of HPC. These figures should be considered together with those for cost savings below in section 3.7 and increased profit in section 3.5 below.

This was a highly variable indicator with indications of increased revenue in the millions of Euros while some partners reported increases in the low thousands. The experiments HPC-Cloud-based Design of High-Pressure vessels and the experiment HPC-Cloud-based Simulation of Flange Tightening are experiments reporting significant returns.

3.5 Increased Profit

The success stories generally demonstrated an increase in profit for the participants in the experiments. This included small consultancies able to increase their profit through the use of HPC, ISVs able to sell their codes, domain and HPC experts able to sell their skills and computer centres able to sell cycles. Interestingly, many participants in the value chain presented the more revealing increases in profit, but some presented less revealing figures by presenting increased revenue. These figures should be considered together with those for increased revenue in section 3.4 above and cost savings in section 3.7 below.

8 experiments reported increased profit as being important drivers to the use of on-demand HPC. Again, this indicator is variable with some experiments presenting increased profit in the thousands of Euros and other in the hundreds of thousands.

3.6 Job creation

6 experiments reported increased employment as a result of new capabilities through the use of on-demand HPC. One might expect the replacement of physical experiments with computer-based simulation to reduce employment, however in these cases it appears that the opening of new business areas contributed to the creation of new, highly skilled jobs.

3.7 Cost savings

Many partners reported cost savings for several reasons including:

- Cloud-based computer cycles are cheaper than in-house cycles;
- HPC-based simulation is cheaper than physical experiments;
- Design cycles are shorter with fewer physical prototypes needed;
- Improved industrial processes result in less wasted material and energy;
- Improved products result in cost savings;
- Favourable licensing arrangements;
- Mission critical simulations can be carried out more accurately and quickly, thus saving operational costs.

30 experiments saw cost savings as an important driver for the use of on-demand HPC simulations.

3.8 Quality of simulations

Partners from 4 experiments noted that the availability of on-demand HPC made it possible to carry out much more detailed simulations with the following benefits:

- Better products through high-fidelity simulation;
- Zero failure rates in statutory product inspection;
- Less waste in manufacture;
- Shorter design cycles involving fewer iterations and lower staff effort;
- Better industrial processes.

3.9 Shortened design cycles

Partners from 15 experiments noted shorter design cycles as an important driver for the use of on-demand HPC simulations. Benefits included:

- Shorter times to market;
- Lower design costs;
- Increased competitive advantage;

3.10 Improved competitive position

Partners from 10 experiments noted an improved competitive position as a result of using advanced simulation. This improvement resulted from faster design cycles, shorter time to market, better products and lower costs.

3.11 Improved industrial performance

Partners from 10 experiments noted improved performance of their products in industrial use. Examples of this can be seen in the experiments HPC-Cloud-based Design of High-pressure Vessels, HPC-Cloud-based Simulation of Flange Tightening and Advanced Simulation of Hydro-power Turbines.

3.12 Improved products

Partners from 9 experiments noted improved products as a result of using on-demand HPC. These products included: light aircraft; industrial manufacturing equipment; high-voltage cables; optimised aircraft wiring; more detailed chemical data; improved high-performance cars; better chimneys; better engine components; and better ships.

3.13 New and Improved services

Partners from 10 experiments identified new and improved services available or to be made available via the Fortissimo Marketplace or otherwise. These included: prediction of drifting snow; molecular modelling; processing of cartographic data; electro-magnetic design; analysis of gears; drug discovery; manufacture of engine components; seismic processing; crowd monitoring; and the design of communication buoys.

3.14 New business opportunities

Partners from 8 experiments noted new business opportunities arising from the use of Cloud-based-HPC simulation. These included the areas of: composite material design; molecular modelling; electromagnetic design; environmental modelling; additive manufacture; superconductors; and ship design.

3.15 New licence models

New approaches to software licensing were noted in 9 experiments.

3.16 Service to be offered in the FF Marketplace

Partners from 9 experiments expressed an interest in placing services in the Fortissimo Marketplace. 24 services are currently available.

3.17 Service to be offered elsewhere.

Partners from16 experiments expressed an interest in offering HPC-based services via the Cloud.

3.18 Discussion

Whilst the principal aim of Fortissimo is to benefit SMEs in the manufacturing sector, it is clear that there need to be benefits across the value chain to support a thriving infrastructure supporting the use of advanced on-demand HPC simulations. The Fortissimo experiments carried out demonstrate, in the preceding sections, a wide range of benefits addressing all participants across the value chain. These participants include industrial end-users, HPC experts, domain experts, code owners, ISVs and computer centres. The Fortissimo Marketplace provides an ecosystem where all these participants have either a financial (i.e. they make money for their services) or commercial (they make better products more cheaply) or a competitive (time to market is reduced) benefit. Such benefits are clearly described and qualified above.

4 Dissemination and Awareness Creation

This section discusses the activities in Fortissimo to disseminate the results of its activities and to create awareness of the benefits of on-demand HPC simulation in the target audience of manufacturing SMEs. The sections below present these activities in outline. For further detail the reader is referred to the Fortissimo web pages[2], and to the collated success stories and experiments presented there.

4.1 Discussion

The activities undertaken in Fortissimo supporting dissemination and the creation of awareness and the broadening of its impact have included:

2 http://www.fortissimo-project.eu

- The development of the Fortissimo style;
- The development of the Fortissimo website linked to the Fortissimo Marketplace;
- The development and promotion of success stories and associated videos;
- The press campaign and supporting press releases;
- Promotion of the Open Calls;
- The development of appropriate public reports and documents[3];
- Attendance at conferences and exhibitions;
- Cooperation with other EU initiatives such as I4MS[4];
- The development and promotion of training material;

These activities and their impact on industry are discussed in the following sections.

4.2 Success Stories and their Effectiveness

One of the main goals of Fortissimo is to encourage European SMEs to use digital simulation for the development and optimisation of their products in order to stay competitive in a global market. However, for an SME the integration of new technologies into the development work flow or into production is of higher risk than for a large company. This is because the investment will be a much bigger fraction of the overall turnover. To mitigate this risk for SMEs, it is essential to demonstrate that the deployment of new technology can lead to increased business for other SMEs companies. This is one of the major goals of Fortissimo.

The Fortissimo project has developed 53 experiments aimed at demonstrating to SMEs the benefits of using advanced digital simulation. Moreover, these experiments show clearly how to integrate digital simulation and HPC technologies into current working practices while keeping the risk and necessary investment at a low level.

Creating and promoting success stories, derived from successful experiments, is a key factor in reaching the Fortissimo goal of promoting the use of digital simulation to SMEs. A wide range of industrial sectors and applications are represented in the experiments. This is essential for the effective demonstration of the flexibility of on-demand HPC simulation and how it can address the challenges facing individual SMEs.

Fortissimo has created and published 44 success stories that demonstrate the business benefits of digital simulation for SMEs. These form the basis for a raft of communication and promotional activities in Fortissimo which will be continued in Fortissimo 2 and through the commercial activities of Fortissimo Marketplace Ltd, the legal entity of Fortissimo. Additional success stories will result from the nearly 40 additional experiments in Fortissimo 2. This set of success stories is a considerable asset. It will be an important component in realising Fortissimo's goal of stimulating the business of SMEs by bringing HPC-enabled simulation to them. The success stories are available from the Fortissimo web site. A brochure brings all success stories into a single document. Flyers have been developed to promote individual success stories.

Fortissimo has produced a series of industrial videos demonstrating the business impact of an experiment on the end-user. Their impact has been maximised by choosing different segments and using different success stories from different countries. All videos are short and to the point to give the main message of the success story without losing the attention of the audience. These videos are highlighted on the webpages namely the experiment and

3 This document, the collated success stories and the Fortissimo White Paper available on the Fortissimo website.

4 http://i4ms.eu/i4ms/i4ms.php

pressroom pages. These videos will also be used for general introduction to the Fortissimo Marketplace at events including presentations, workshops and conferences.

4.3 Effectiveness of the Press Campaigns

One of the main activities of Fortissimo has been the planning and execution of a communication and press campaign. Fortissimo contracted five different agencies in five countries (UK, France, Spain, Italy, and Germany) which were led by the German agency, Flutlicht.

The campaign was mainly based on highlighting the Fortissimo success stories picking one or two for each communication. The target was not only technical communication channels such as technical magazines, but also general everyday news channels such as newspapers and web portals. The goal was to promote the Fortissimo brand and the Fortissimo Marketplace together with the central message around the business benefits of digital simulation.

The press campaign has been successful with significant impact. More than 225 articles about Fortissimo, the Fortissimo Marketplace and business benefits of digital simulation as demonstrated in Fortissimo have been published in seven countries over a period of three months to the end of the project. The articles comprised online and printed articles in diverse media types including national daily newspapers, weekly news magazines, mainstream and technology media and horizontal media outlets such as production, engineering, and cloud computing.

4.4 The Fortissimo Web Site and its Effectiveness

The Fortissimo web site has been under continuous development since its inception. Its layout and structure have been developed to support service and solution offerings A central element of the web site is the success stories presented in an intuitive way so that users can easily and quickly identify success stories relevant to their business.

Analytics for web-page usage indicate a steadily increasing traffic to the web site. The number of sessions have gone up from about 200 per week in 2015 to 300 per week at the end of 2016. The average number of pages displayed per week has gone up from about 600 in 2015 to more than 1,300 pages per week at the end of 2016.

This is clearly the result of the very successful PR campaign undertaken during November and December 2016. Furthermore, the average number of pages shown per session has gone up from 3.3 to 4.4 pages. The Fortissimo Web site provides direct access to the Fortissimo Marketplace and so is an important component in its promotion. It should also be noted that the web site was an important tool used in the promotion of the Open Calls for Experiments described below in section 4.7.

4.5 Impact on Industry

Fortissimo's impact on industry is demonstrated in section 3 where the KPIs are presented. This impact has manifested itself across the value chain in the following ways:

- Affordability of superior design capabilities;
- Feasibility of previously infeasible simulations;
- Access to expertise – both HPC and domain specific;
- Increased revenue or profit either through the sale of services or product enhancements;
- The creation of new jobs;
- Cost savings;
- Better design through higher-fidelity simulations;

- Shortened design cycles;
- Improved competitiveness through a range of benefits;
- Better, more performant products;
- New and improved services;
- New licence models; and
- Access to new capabilities via the Fortissimo Marketplace.

4.6 Cooperation with other initiatives

Fortissimo has cooperated fully with other EU initiatives such as I4MS (see section 4.1) and related projects. This support has included:

- Direct liaison with EU officials;
- Participation and presentations at events;
- The organisation of workshops;
- The development of joint promotional material; and
- Participation in regular planning meetings.

4.7 The Open Calls for Experiments

The Open Calls both in Fortissimo and in Fortissimo 2, the follow-on project to Fortissimo with a total funding of more than €10 million, provide a good measure of awareness in industry of the potential benefits of on-demand HPC. In all four open calls, 2 in Fortissimo and 2 in Fortissimo 2, there was strong competition for funding and clearly a growing awareness of the industrial benefits of this technology.

In Fortissimo Open Call 1, 65 proposals were submitted. These corresponded to a request for funding of €14.9 million. 22 proposals were selected for funding with a value of €5.1million.

In Fortissimo Open Call 2, 82 proposals were submitted. These corresponded to a request for funding of €18.3 million. 10 proposals were selected for funding with a value of €2.2 million.

In Fortissimo 2 Open Call 1, 73 proposals were submitted. These corresponded to a request for funding of €16.6 million. 22 proposals were selected for funding with a value of €5.1 million.

In Fortissimo 2 Open Call 2, 102 proposals were submitted. These corresponded to a request for funding of €17.2 million. 15 proposals were selected for funding with a value of €2.5 million.

5 The Development of Business Models

Business models, including the involvement of ISVs, have been developed to address the long-term sustainability and viability of the Fortissimo Marketplace. Significant emphasis has been placed on developing business models, with a broad scope, covering market expectations and pricing, which benefit all levels of the value chain enabling them to establish a viable business in the provision of services and leading to a sustainable Fortissimo Marketplace;

6 Overall Conclusions and Lessons Learned

6.1 Introduction

This section presents the conclusions and lessons learned from the activities of Fortissimo. It draws on the outcomes of the experiments, the success stories and the results of an extensive dissemination activity.

The following broad conclusions can be made about this type of initiative:

- Overall, it represents good value for money measured by several metrics including return-on-investment and cost of job creation. This calculation is difficult to make globally because of the very diverse nature of the experiments. However, where appropriate data exists, it is easy to see a positive return on investment on an experiment by experiment basis sufficient to support this conclusion;
- It is a good way of supporting SMEs which are the bedrock of the European economy. This is clear from the benefits presented by the experiments;
- It is effective at encouraging the early uptake of technology by industry with resultant competitive advantage;
- It constitutes an effective means of stimulating the economy and making industry more competitive;
- The focus on end-user involvement and resultant benefits is an easy message to support with resultant high impact.

6.2 The Experiments

All experiments (each effectively a small project) focused on real industrial problems. A typical experiment involved 35 staff months of effort, a cost of €250K and lasted for 18 months or more.

Based the outcomes and demonstrated benefits, the experiment approach is an effective vehicle for benefitting end-users. Furthermore, the collaboration of domain and HPC experts, ISVs, code owners, computer centres and end-users has been productive. End-users have been exposed to the benefits of Cloud-based-HPC. Domain and HPC experts, ISVs and computer centres have identified areas for new business. The experiments have demonstrated a clear value to all participating organisations across the value chain as described above.

In most experiments an economic return greater than the investment of public funding made by the EC was noted. However, not all benefits can or should be reduced to purely monetary returns: Improved products and services; improved reputation; faster design cycles; feasibility; environmental impact of less waste; and environmental and societal benefits should also be taken into account. These can result in even higher benefits in the long term.

It should also be noted that the use of on-demand HPC as a Cloud of resources made some problems feasible which were not previously possible. This applies both to the capacity of the available system and to problems which were not amenable to physical experiment, but could be effectively handled using advanced simulation.

Furthermore, the best success stories came from experiments with the clearest end use. For experiments, where the end use was not so well identified the success stories, were generally of a lesser quality. Success stories were developed in three tranches: The first tranche came from experiments in the initial Fortissimo proposal; the second and third tranches of success stories came from experiments selected in the open calls. Generally the scrutiny of proposals for experiments to be undertaken was greater in the open calls than in the initial proposal. This is mirrored in the experiments from the two open calls where the success stories were generally better at indicating benefits across the value chain.

The experiments involved both naïve and experienced end-users. The former would not otherwise have been involved in an activity capable of giving them a significant business benefit. The latter were looking to increase the scope of existing applications (bigger, faster, lower cost etc.).

It is recommended that future initiatives should focus clearly on business relevant experiments. Business relevant means that the experiments would be able significantly to

improve a product or service or enable new products and services in an affordable way. All experiments need to make a clear contribution to the bottom line. The experiments need to make the case for business investment even to naïve users.

Finally, Fortissimo repeats the success of the HPCN-TTN network[5] which ran from 1997 to 2000 and which also demonstrated the benefits of HPC to industry through a series of mini-projects. Many of the conclusions from that initiative remain valid and still apply to initiatives such as Fortissimo.

6.3 The Success Stories

These encapsulate the positive outcomes of the experiments where the benefits of the results of the experiments can be clearly demonstrated. These form a diverse body of material. 44 such stories are available. It should be noted that, in general, success stories should focus on the end-user and his problem rather than on the technology. It also should be noted that the development of the success stories was in some cases hampered by commercial considerations. This was because some experiments were very close to the competitive heart of the end-users and other players in the value chain. This meant that figures relating to the business benefits of the experiments were confidential and could not be presented as fully and as effectively as desired in the success stories.

6.4 The Marketplace

The Fortissimo Marketplace is an ecosystem where end-user requirements can be matched against expertise, codes and compute cycles as a one-stop-shop. This one-stop-shop provides all that is needed to improve the end-users' product or service offering. Furthermore, this one-stop-shop offers a viable ecosystem where all participants in the value chain can see a return on their contribution to the improvements made. Actual returns across the value chain are clearly described in section 3.

The Fortissimo Marketplace has now been established as a legal entity, the Fortissimo Marketplace Limited, created. It now operates in a busy, crowded and competitive environment featuring several major players. In this environment, Fortissimo is concentrating on those areas where it has a well-defined competitive advantage

6.5 The Dissemination Activities

Extensive dissemination activities have been carried out. The cornerstone underpinning this dissemination has been the success stories. This has created considerable awareness in industry and beyond as evidenced by the press coverage, visits to the web site and the participation in the open calls. It is clear that the focus on the end-user and the demonstration of benefits across the value chain rather than a focus on technology has been a significant factor in the positive outcome of the dissemination activities.

6.6 The Effectiveness of the Fortissimo Management Structure

The Fortissimo structure was devised to manage a project with 122 partners. This structure comprised computer centres (8), a project management team, 16 core partners and 106 experiment partners. Altogether there were 53 experiments. The following management structure was used:

- The management team had direct oversight of the core financial, operational, technical development, business model development, open call and dissemination activities;

5 https://cordis.europa.eu/esprit/src/hpcnhome.htm

- Each of the three tranches of experiments was subject to the oversight its own dedicated activity; Each of these three activities was supported by the centres which liaised with the relevant experiments generally on a geographical basis.

This management structure worked well. It enabled the effective management of both the core activities and the experiments in a partially devolved fashion.

6.7 The Effectiveness of the Open Calls

The Open Calls have clearly demonstrated their effectiveness.

- They have been well publicised;
- They have been highly competitive
- They have been successful in attracting large numbers of good quality proposals;
- Resultant experiment outcomes and success stories have also been of a good quality.

Details of the outcomes of the calls are presented in section 4.7.

6.8 Overall Conclusions

The Fortissimo approach is an effective vehicle for knowledge exhange with end-users. The collaboration of technology experts, technology providers and end-users has worked well. Fortissimo has demonstrated a clear value to the participating organisations as discussed in section 3. It is recommended that this model be followed in further calls for proposals.

Experiments, that are small focused projects, are an effective vehicle for benefitting SMEs, creating new business opportunities and creating awareness. Experiments which focused most closely on end-user requirements created the best outcomes.

Success stories are a highly effective means of demonstrating benefits across the value chain and creating awareness of the benefits of technology, in this case advanced on-demand HPC simulation. In Fortissimo, success stories have been complemented by an active Dissemination activity and the creation of the Fortissimo Marketplace.

The Fortissimo management structure is an effective way of managing a project with a large number of partners.

Open calls are an effective way of way of setting up end-user driven projects to demonstrate the benefits of new technology to new users.

The Fortissimo vision of a one-stop-shop is now becoming a reality.