Please check our wiki for help on navigating the form.

EuroHPC

Call: H2020-JTI-EuroHPC-2020-01

(ADVANCED PILOTS TOWARDS THE EUROPEAN EXASCALE SUPERCOMPUTERS)

Topic: EuroHPC-2020-01-b

Type of action: EuroHPC-RIA

Proposal number: 101018180

Proposal acronym: HPCQS

Deadline Id: H2020-JTI-EuroHPC-2020-2

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How to fill in the forms

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the steps in the submission wizard.

1 - General information

Topic	EuroHPC-2020-01-b	Type of Action	EuroHPC-RIA
Call Identifier	H2020-JTI-EuroHPC-2020-01	Deadline Id	H2020-JTI-EuroHPC-2020-2

Acronym	HPCQS
Proposal title	High Performance Computer and Quantum Simulator hybrid

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months	*48*
Fixed keyword 1	High-performance computing (HPC)
Fixed keyword 2	Quantum Technologies (e.g. computing and communication)
Free keywords	*quantum simulator, hybrid quantum-HPC computation, modular supercomputer architecture, cloud access, Tier-0, federated quantum-HPC infrastructure, co-design, use case, ATOS QLM, Pasqal Fresnel*

Abstract

The aim of HPCQS is to prepare European research, industry and society for the use and federal operation of quantum computers and simulators. These are future computing technologies that are promising to overcome the most difficult computational challenges. HPCQS is developing the programming platform for the quantum simulator, which is based on the European ATOS Quantum Learning Machine (QLM), and the deep, low-latency integration into modular HPC systems based on ParTec's European modular supercomputing concept. A twin pilot system, developed as a prototype by the European company Pasqal, will be implemented and integrated at CEA/TGCC (France) and FZJ/JSC (Germany), both hosts of European Tier-0 HPC systems. The pre-exascale sites BSC (Spain) and CINECA (Italy) as well as ICECH (Ireland) will be connected to the TGCC and JSC via the European data infrastructure FENIX. It is planned to offer quantum HPC hybrid resources to the public via the access channels of PRACE. To achieve these goals, HPCQS brings together leading quantum and supercomputer experts from science and industry, thus creating an incubator for practical quantum HPC hybrid computing that is unique in the world. The HPC-QS technology will be developed in a co-design process together with selected exemplary use cases from chemistry, physics, optimization and machine learning suitable for quantum HPC hybrid calculations. HPCQS fits squarely to the challenges and scope of the call by acquiring a quantum device with two times 100 + neutral atoms. HPCQS develops the connection between the classical supercomputer and the quantum simulator by deep integration in the modular supercomputing architecture and will provide cloud access and middleware for programming and execution of applications on the quantum simulator through the QLM, as well as a Jupyter-Hub platform with safe access guarantee through the European UNICORE system to its ecosystem of quantum programming facilities and application libraries.

Remaining characters 5

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under Horizon 2020 or any other EU programme(s)? ○ Yes ◉ No

Please give the proposal reference or contract number.	
xxxxxx-x	

Declarations

1) The coordinator declares to have the explicit consent of all applicants on their participation and on the content of this proposal.	☒
2) The information contained in this proposal is correct and complete.	☒
3) This proposal complies with ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct).	☒

4) The coordinator confirms:

- to have carried out the self-check of the financial capacity of the organisation on http://ec.europa.eu/research/participants/portal/desktop/en/organisations/lfv.html or to be covered by a financial viability check in an EU project for the last closed financial year. Where the result was "weak" or "insufficient", the coordinator confirms being aware of the measures that may be imposed in accordance with the H2020 Grants Manual (Chapter on Financial capacity check); or	○
- is exempt from the financial capacity check being a public body including international organisations, higher or secondary education establishment or a legal entity, whose viability is guaranteed by a Member State or associated country, as defined in the H2020 Grants Manual (Chapter on Financial capacity check); or	◉
- as sole participant in the proposal is exempt from the financial capacity check.	○

5) The coordinator hereby declares that each applicant has confirmed:

- they are fully eligible in accordance with the criteria set out in the specific call for proposals; and	☒
- they have the financial and operational capacity to carry out the proposed action.	☒
The coordinator is only responsible for the correctness of the information relating to his/her own organisation. Each applicant remains responsible for the correctness of the information related to him and declared above. Where the proposal to be retained for EU funding, the coordinator and each beneficiary applicant will be required to present a formal declaration in this respect.	

Note:

For **multi-beneficiary applications**, the coordinator vouches for its own organization and that all other participants confirmed their participation and compliance with conditions set out in the call. If the proposal is retained for funding, each participant will be required to submit a formal declaration of honor confirming this.

False statements or incorrect information may lead to administrative sanctions under the Financial Regulation 2018/1046.

Personal data will be collected, used and processed in accordance with Regulation 2018/1725 and the Funding & Tenders Portal privacy statement.

Please be however aware that, to protect EU financial interests, your data may be transferred to other EU institutions and bodies and be registered in the EDES database. Data in the EDES database is also subject to Regulation 2018/1725 and the EDES privacy statement.

2 - Participants & contacts

#	Participant Legal Name	Country	Action
1	FORSCHUNGSZENTRUM JULICH GMBH	DE	
2	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FR	
3	GRAND EQUIPEMENT NATIONAL DE CALCUL INTENSIF	FR	
4	BULL SAS	FR	
5	CONSIGLIO NAZIONALE DELLE RICERCHE	IT	
6	NATIONAL UNIVERSITY OF IRELAND GALWAY	IE	
7	UNIVERSITAET INNSBRUCK	AT	
8	EURICE EUROPEAN RESEARCH AND PROJECT OFFICE GMBH	DE	
9	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	
10	INSTITUT NATIONAL DE RECHERCHE ENINFORMATIQUE ET AUTOMATIQUE	FR	
11	Pasqal	FR	
12	CINECA CONSORZIO INTERUNIVERSITARIO	IT	
13	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	ES	
14	FLYSIGHT SRL	IT	
15	Parity Quantum Computing GmbH	AT	
16	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	DE	

2 - Administrative data of participating organisations

PIC	***Legal name***
999980470	*FORSCHUNGSZENTRUM JULICH GMBH*

Short name: FZJ

Address

Street WILHELM JOHNEN STRASSE

Town JULICH

Postcode 52428

Country Germany

Webpage www.fz-juelich.de

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....05/12/1967 - no

SME self-assessment ..... unknown

SME validation sme.....05/12/1967 - no

Department(s) carrying out the proposed work

Department 1

Department name: Juelich Supercomputing Centre (JSC) ☐ not applicable

☒ Same as proposing organisation's address

Street: WILHELM JOHNEN STRASSE

Town: JULICH

Postcode: 52428

Country: Germany

Department 2

Department name: Peter Grünberg Institute - Quantum Control (PGI-8) ☐ not applicable

☒ Same as proposing organisation's address

Street: WILHELM JOHNEN STRASSE

Town: JULICH

Postcode: 52428

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: ○ Male ◉ Female

First name: **Kristel** Last name: **Michielsen**

E-Mail: **k.michielsen@fz-juelich.de**

Position in org.: Scientist in Charge

Department: Juelich Supercomputing Centre (JSC) ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: WILHELM JOHNEN STRASSE

Town: JULICH Post code: 52428

Country: Germany

Website: www.fz-juelich.de

Phone: +49 2461 61 2524 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Project	OFFICE	projectoffice@eurice.eu	+xxx xxxxxxxxx
Volker	Marx	v.marx@fz-juelich.de	+49 2461 615831
Ina	Schmitz	schmitz@par-tec.com	+49 2461 611944
Thomas	Moschny	moschny@par-tec.com	+xxx xxxxxxxxx
Hugo	Falter	falter@par-tec.com	+xxx xxxxxxxxx

PIC	***Legal name***
999992401	*COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES*

Short name: CEA

Address

Street RUE LEBLANC 25

Town PARIS 15

Postcode 75015

Country France

Webpage www.cea.fr

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....17/05/2019 - no

SME self-assessment ..... unknown

SME validation sme.....01/10/2008 - no

Department(s) carrying out the proposed work

Department 1

Department name: DAM ☐ not applicable

☐ Same as proposing organisation's address

Street: CEA/DIF-DSSI BRUYERES -LE-CHATEL

Town: ARPAJON cedex

Postcode: 91297

Country: France

Department 2

Department name: DRF ☐ not applicable

☐ Same as proposing organisation's address

Street: IPhT - Orme des Merisiers

Town: GIF-SUR-YVETTE cedex

Postcode: 91191

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Jean-Philippe** Last name: **Nominé**

E-Mail: **jean-philippe.nomine@cea.fr**

Position in org.: HPC Strategic Collaborations Manager

Department: Département des Sciences de la Simulation et de l'Information ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: CEA/DIF BRUYERES -LE-CHATEL

Town: ARPAJON cedex Post code: 91297

Country: France

Website:

Phone: +33683841277 Phone 2: +33169264942 Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Guillaume	Colin de Verdière	guillaume.colin-de-verdiere@cea.fr	*+xxx xxxxxxxxx*
Christian	Cluzeau	christian.cluzeau@cea.fr	*+xxx xxxxxxxxx*
Jacques-Charles	LAFOUCRIERE	jacques-charles.lafoucriere@cea.fr	*+xxx xxxxxxxxx*

PIC	***Legal name***
999779680	*GRAND EQUIPEMENT NATIONAL DE CALCUL INTENSIF*

Short name: GENCI

Address

Street 6 BIS RUE AUGUSTE VITU

Town PARIS

Postcode 75015

Country France

Webpage

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....24/04/2007 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Stéphane** Last name: **Requena**

E-Mail: **stephane.requena@genci.fr**

Position in org.: CTO

Department: GRAND EQUIPEMENT NATIONAL DE CALCUL INTENSIF ☒ Same as organisation name

☒ Same as proposing organisation's address

Street: 6 BIS RUE AUGUSTE VITU

Town: PARIS Post code: 75015

Country: France

Website: http://www.genci.fr/en

Phone: +33 6 07 72 83 57 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Christelle	Piechurski	christelle.piechurski@genci.fr	+xxx xxxxxxxxx

PIC	***Legal name***
996058081	*BULL SAS*

Short name: ATOS

Address

Street RUE JEAN JAURES 68

Town LES CLAYES SOUS BOIS

Postcode 78340

Country France

Webpage www.bull.com

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....no

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Industry (private for profit).....yes

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....08/11/2017 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

Department 1

Department name: Strategy & Innovation / Quantum Computing R&D Dpt ☐ not applicable

☒ Same as proposing organisation's address

Street: RUE JEAN JAURES 68

Town: LES CLAYES SOUS BOIS

Postcode: 78340

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Cyril** Last name: **Allouche**

E-Mail: **cyril.allouche@atos.net**

Position in org.: Vice President, head of quantum computing R&D

Department: Quantum Computing R&D ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: RUE JEAN JAURES 68

Town: LES CLAYES SOUS BOIS Post code: 78340

Country: France

Website:

Phone: +33 6 33 58 98 70 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Claudine	Chouet	claudine.chouet@atos.net	*+33 130806269*
Sridharan	Medur	medur.sridharan@atos.net	*+33 130803024*
Sridharan	Medur	medur.sridharan@bull.net	*+xxx xxxxxxxxx*

PIC	***Legal name***
999979500	*CONSIGLIO NAZIONALE DELLE RICERCHE*

Short name: CNR

Address

Street PIAZZALE ALDO MORO 7

Town ROMA

Postcode 00185

Country Italy

Webpage www.cnr.it

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....18/05/2016 - no

SME self-assessment ..... unknown

SME validation sme.....05/12/2008 - no

Department(s) carrying out the proposed work

Department 1

Department name: Istituto Nazionale di Ottica (INO) ☐ not applicable

☐ Same as proposing organisation's address

Street: Largo Enrico Fermi, 6

Town: Firenze

Postcode: 50125

Country: Italy

Department 2

Department name: Istituto di Informatica e Telematica (IIT) ☐ not applicable

☐ Same as proposing organisation's address

Street: Via Moruzzi, 1

Town: Pisa

Postcode: 56124

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Augusto** Last name: **Smerzi**

E-Mail: **augusto.smerzi@ino.cnr.it**

Position in org.: Director of Researcher

Department: Istituto Nazionale di Ottica (INO) ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Largo Enrico Fermi, 6

Town: Firenze Post code: 50125

Country: Italy

Website: www.ino.it

Phone: +3905523081 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Marco	Conti	m.conti@iit.cnr.it	*+390503153062*
Andrea	Passarella	a.passarella@iit.cnr.it	*+390503153269*
Claudio	Cicconetti	c.cicconetti@iit.cnr.it	*+390503153057*
Giacomo	Cappellini	giacomo.cappellini@ino.cnr.it	*+390554572216*
Chiara	Mustarelli	chiara.mustarelli@cnr.it	*+390552308261*

PIC	***Legal name***
999978045	*NATIONAL UNIVERSITY OF IRELAND GALWAY*

Short name: NUIG-ICHEC

Address

Street UNIVERSITY ROAD

Town GALWAY

Postcode

Country Ireland

Webpage www.nuigalway.ie

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....no

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....19/05/2016 - no

SME self-assessment .....19/05/2016 - no

SME validation sme.....02/12/2008 - no

Department(s) carrying out the proposed work

Department 1

Department name: Irish Centre for High-End Computing (ICHEC) ☐ not applicable

☒ Same as proposing organisation's address

Street: UNIVERSITY ROAD

Town: GALWAY

Postcode: *Area code.*

Country: Ireland

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Venkatesh** Last name: **Kannan**

E-Mail: **venkatesh.kannan@ichec.ie**

Position in org.: Centre Technical Manager

Department: Irish Centre for High-End Computing (ICHEC) ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Trinity Technology & Enterprise Campus, Grand Canal Quay

Town: Dublin Post code: D02 HP83

Country: Ireland

Website: www.ichec.ie

Phone: +353 86 418 2825 Phone 2: +353 1 529 1028 Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Lee	O'Riordan	lee.oriordan@ichec.ie	*+353 1 5291049*
Nawar	Akhras	nawar.akhras@ichec.ie	*+353 1 5291035*

PIC	***Legal name***
999869114	*UNIVERSITAET INNSBRUCK*

Short name: UIBK

Address

Street INNRAIN 52

Town INNSBRUCK

Postcode 6020

Country Austria

Webpage http://www.uibk.ac.at

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....no

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....01/01/1900 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

Department 1

Department name: Center of Quantum Physics ☐ not applicable

☐ Same as proposing organisation's address

Street: Technikerstrasse 24

Town: Innsbruck

Postcode: 6020

Country: Austria

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Rick** Last name: **van Bijnen**

E-Mail: **rick.van-bijnen@uibk.ac.at**

Position in org.: Postdoctoral researcher

Department: Center of Quantum Physics ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Technikerstrasse 24

Town: Innsbruck Post code: 6020

Country: Austria

Website:

Phone: +43 512 507 4786 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Peter	Zoller	peter.zoller@uibk.ac.at	*+43 512 507 4780*
Katharina	Steimueller	katharina.steinmueller@uibk.ac.at	*+xxx xxxxxxxxx*
David	Lederbauer	david.lederbauer@uibk.ac.at	*+xxx xxxxxxxxx*

PIC	***Legal name***
999778419	*EURICE EUROPEAN RESEARCH AND PROJECT OFFICE GMBH*

Short name: EURICE

Address

Street HEINRICH-HERTZ-ALLEE 1

Town ST INGBERT

Postcode 66386

Country Germany

Webpage www.eurice.eu

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....no

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Industry (private for profit).....yes

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....31/12/2018 - yes

SME self-assessment .....31/12/2018 - yes

SME validation sme.....11/09/2008 - yes

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Mrs

Sex: ○ Male ◉ Female

First name: **Corinna** Last name: **Hahn**

E-Mail: **c.hahn@eurice.eu**

Position in org.: Senior Research & Innovation Manager

Department: EURICE EUROPEAN RESEARCH AND PROJECT OFFICE GMBH ☒ Same as organisation name

☒ Same as proposing organisation's address

Street: HEINRICH-HERTZ-ALLEE 1

Town: ST INGBERT Post code: 66386

Country: Germany

Website: www.eurice.eu

Phone: +49 6894 388 13-38 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

PIC	***Legal name***
999997930	*CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS*

Short name: CNRS

Address

Street RUE MICHEL ANGE 3

Town PARIS

Postcode 75794

Country France

Webpage www.cnrs.fr

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....18/11/2008 - no

SME self-assessment ..... unknown

SME validation sme.....18/11/2008 - no

Department(s) carrying out the proposed work

Department 1

Department name: UMR8243 Institut de Recherche en Informatique Fondamentale (IRIF) ☐ not applicable

☐ Same as proposing organisation's address

Street: UNIVERSITE PARIS DIDEROT Case 7014

Town: Paris Cedex 13

Postcode: 75205

Country: France

Department 2

Department name: UMR7503 LORIA ☐ not applicable

☐ Same as proposing organisation's address

Street: Campus scientifique - BP 239

Town: VANDOEUVRE LES NANCY

Postcode: 54506

Country: France

Department 3

Department name: CNRS UMR8623 Laboratoire de Recherche en Informatique (LRI) ☐ not applicable

☐ Same as proposing organisation's address

Street: rue Noetzlin

Town: ORSAY CEDEX

Postcode: 91405

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Frederic** Last name: **Magniez**

E-Mail: **magniez@irif.fr**

Position in org.: Director

Department: UMR8243 Institut de Recherche en Informatique Fondamentale (IRIF) ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: UNIVERSITE PARIS DIDEROT Case 7014

Town: Paris Cedex 13 Post code: 75205

Country: France

Website:

Phone: +33 1 57 27 94 0 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Marc	Lavaux	dr01.europe@cnrs.fr	+xxx xxxxxxxxx
Marie-Hélène	PAPILLON	dr04spv-europe@cnrs.fr	+xxx xxxxxxxxx
Jessica	NIETO	cjuste@dr6.cnrs.fr	+333 83 85 64 21
Anna	SARGSYAN-DELAVAL	spv@dr2.cnrs.fr	+xxx xxxxxxxxx

PIC	***Legal name***
999547074	*INSTITUT NATIONAL DE RECHERCHE ENINFORMATIQUE ET AUTOMATIQUE*

Short name: INRIA

Address

Street DOMAINE DE VOLUCEAU ROCQUENCOURT

Town LE CHESNAY CEDEX

Postcode 78153

Country France

Webpage www.inria.fr

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

Department 1

Department name: HIEPACS Research Group / Inria Bordeaux-Sud-Ouest ☐ not applicable

☐ Same as proposing organisation's address

Street: 200 avenue de la vieille tour

Town: Talence

Postcode: 33405

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Luc** Last name: **Giraud**

E-Mail: **emmanuel.agullo@inria.fr**

Position in org.: Research scientist

Department: HIEPACS Research Group / Inria Bordeaux-Sud-Ouest ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: 200 avenue de la vieille tour

Town: Talence Post code: 33405

Country: France

Website: https://team.inria.fr/hiepacs/team-members/emmanuel-agullo/

Phone: +33 (0)5 24 57 41 50 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Lucia	Marta	lucia.marta@inria.fr	*+33 (0)5 24 57 47 38*
Nicolas	Jahier	nicolas.jahier@inria.fr	*+33 (0)5 24 57 41 70*

PIC	***Legal name***
893652853	*Pasqal*

Short name: Pasqal

Address

Street 2 avenue Augustin Fresnel

Town Palaiseau

Postcode 91120

Country France

Webpage www.pasqal.io

Specific Legal Statuses

Legal person .....yes

Public body .....unknown

Non-profit .....unknown

International organisation .....unknown

International organisation of European interest .....unknown

Secondary or Higher education establishment .....unknown

Research organisation .....unknown

Industry (private for profit).....unknown

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Georges** Last name: **Reymond**

E-Mail: **georges@pasqal.io**

Position in org.: CEO

Department: Pasqal ☒ Same as organisation name

☒ Same as proposing organisation's address

Street: 2 avenue Augustin Fresnel

Town: Palaiseau Post code: 91120

Country: France

Website: https://pasqal.io/

Phone: +33 1 64 53 32 35 Phone 2: +33 6 59 98 67 29 Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Loïc	Henriet	loic@pasqal.io	+xxx xxxxxxxxx

PIC	***Legal name***
999843409	*CINECA CONSORZIO INTERUNIVERSITARIO*

Short name: CINECA

Address

Street VIA MAGNANELLI 6/3

Town CASALECCHIO DI RENO BO

Postcode 40033

Country Italy

Webpage www.cineca.it

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....13/07/1967 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

Department 1

Department name: High Performance Computing ☐ not applicable

☒ Same as proposing organisation's address

Street: VIA MAGNANELLI 6/3

Town: CASALECCHIO DI RENO BO

Postcode: 40033

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Mr. Sex: (•) Male ( ) Female

First name: **Sanzio** Last name: **Bassini**

E-Mail: **s.bassini@cineca.it**

Position in org.: Director of HPC Department

Department: High Performance Computing ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: VIA MAGNANELLI 6/3

Town: CASALECCHIO DI RENO BO Post code: 40033

Country: Italy

Website: www.cineca.it

Phone: +390516171514 Phone 2: +390516171411 Fax: +390516132198

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Daniele	Ottaviani	d.ottaviani@cineca.it	*+390516171699*
Paola	Alberigo	p.alberigo@cineca.it	*+390516171654*

PIC	***Legal name***
999655520	*BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION*

Short name: BSC

Address

Street Calle Jordi Girona 31

Town BARCELONA

Postcode 08034

Country Spain

Webpage www.bsc.es

Specific Legal Statuses

Legal person .....yes

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....01/03/2005 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

Department 1

Department name: Computer Applications in Science and Engineering (CASE) ☐ not applicable

☐ Same as proposing organisation's address

Street: Jordi Girona 29

Town: Barcelona

Postcode: 08034

Country: Spain

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Artur** Last name: **Garcia Saez**

E-Mail: **artur.garcia@bsc.es**

Position in org.: Established Researcher

Department: Computer Applications in Science and Engineering (CASE) ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Jordi Girona 29

Town: Barcelona Post code: 08034

Country: Spain

Website: https://www.bsc.es/

Phone: +34 934137163 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Marta	Rossello	marta.rossello@bsc.es	*+34934134081*

PIC	***Legal name***
893663911	*FLYSIGHT SRL*

Short name: FLS

Address

Street VIA AURELIO LAMPREDI

Town LIVORNO

Postcode 57121

Country Italy

Webpage https://www.flysight.it/

Specific Legal Statuses

Legal person .....yes

Public body .....unknown

Non-profit .....unknown

International organisation .....unknown

International organisation of European interest .....unknown

Secondary or Higher education establishment .....unknown

Research organisation .....unknown

Industry (private for profit).....unknown

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Andrea** Last name: **Masini**

E-Mail: **andrea.masini@flysight.it**

Position in org.: CTO

Department: FLYSIGHT SRL ☒ Same as organisation name

☒ Same as proposing organisation's address

Street: VIA AURELIO LAMPREDI

Town: LIVORNO Post code: 57121

Country: Italy

Website: www.flysight.it

Phone: +39 0586 505016 Phone 2: +39 393 9976370 Fax: +39 0586502770

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Emilio	Simeone	emilio.simeone@flysight.it	*+39 0586 505016*

PIC	***Legal name***
893423545	*Parity Quantum Computing GmbH*

Short name: Parity QC

Address

Street Technikerstraße 21a

Town Innsbruck

Postcode 6020

Country Austria

Webpage www.parityqc.com

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....no

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Industry (private for profit).....yes

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....14/01/2020 - yes

SME self-assessment .....14/01/2020 - yes

SME validation sme..... unknown

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Mrs

Sex: ○ Male ◉ Female

First name: **Magdalena** Last name: **Hauser**

E-Mail: **magdalena@parityqc.com**

Position in org.: CEO

Department: Parity Quantum Computing GmbH ☒ Same as organisation name

☒ Same as proposing organisation's address

Street: Technikerstraße 21a

Town: Innsbruck Post code: 6020

Country: Austria

Website: www.parityqc.com

Phone: +436504503800 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Wolfgang	Lechner	wolfgang@parityqc.com	*+43 6509838065*
Elisabeth	Thompson	e.thompson@parityqc.com	*+43 69911258239*

PIC	***Legal name***
999984059	*FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.*

Short name: Fraunhofer IAF

Address

Street HANSASTRASSE 27C

Town MUNCHEN

Postcode 80686

Country Germany

Webpage www.fraunhofer.de

Specific Legal Statuses

Legal person .....yes

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Industry (private for profit).....no

Enterprise Data

Based on the below details from the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status.....15/09/2008 - no

SME self-assessment ..... unknown

SME validation sme.....15/09/2008 - no

Department(s) carrying out the proposed work

Department 1

Department name: Fraunhofer IAF ☐ not applicable

☐ Same as proposing organisation's address

Street: Tullastr. 72

Town: Freiburg im Breisgau

Postcode: 79108

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Oliver** Last name: **Ambacher**

E-Mail: **oliver.ambacher@iaf.fraunhofer.de**

Position in org.: Director

Department: Fraunhofer IAF ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Tullastr. 72

Town: Freiburg im Breisgau Post code: 79108

Country: Germany

Website: www.iaf.fraunhofer.de

Phone: + 49 761 5150 410 Phone 2: + 49 761 5159 411 Fax: + 49 761 5159 300

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Joachim	Bank	joachim.bank@iaf.fraunhofer.de	*+49 761 5159-448*
Andrea	Zeumann	andrea.zeumann@zv.fraunhofer.de	*+49 89 1205-2723*

3 - Budget

No	Participant	Country	(A) Direct personnel costs/€	(B) Other direct costs/€	(C) Direct costs of sub-contracting/€	(D) Direct costs of providing financial support to third parties/€	(E) Costs of inkind contributions not used on the beneficiary's premises/€	(F) Indirect Costs / € (=0.25(A+B-E))	(G) Special unit costs covering direct & indirect costs / €	(H) Total estimated eligible costs / € (=A+B+C+D+F+G)	(I) Reimburse-ment rate (%)	(J) Max.EU Contribution / € (=H*I)	(K) Requested EU Contribution/ €
1	Forschungszentrum Julich Gmbh	DE	978067	3469000	0	0	0	1111766,75	0	5558833,75	50	2779416,88	2348166,85
2	Commissariat A L Energie Atomique Et	FR	287387	4000	0	0	0	72846,75	0	364233,75	50	182116,88	182116,88
3	Grand Equipement National De	FR	96525	3456000	0	0	0	888131,25	0	4440656,25	50	2220328,13	1789078,13
4	Bull Sas	FR	882367	12500	0	0	0	223716,75	0	1118583,75	50	559291,88	559291,88
5	Consiglio Nazionale Delle Ricerche	IT	215164	13700	0	0	0	57216,00	0	286080,00	50	143040,00	143040,00
6	National University Of Ireland Galway	IE	249780	22700	0	0	0	68120,00	0	340600,00	50	170300,00	170300,00
7	Universitaet Innsbruck	AT	126830	12100	0	0	0	34732,50	0	173662,50	50	86831,25	86831,25
8	Eurice European Research And	DE	279600	24226	7000	0	0	75956,50	0	386782,50	50	193391,25	193391,25
9	Centre National De La Recherche	FR	187892	0	0	0	0	46973,00	0	234865,00	50	117432,50	117432,50
10	Institut National De Recherche	FR	188600	2379	0	0	0	47744,75	0	238723,75	50	119361,88	119361,88

11	Pasqal	FR	174708	4800	0	0	0	44877,00	0	224385,00	50	112192,50	112192,50
12	Cineca Consorzio Interuniversitar	IT	22500	0	0	0	0	5625,00	0	28125,00	50	14062,50	14062,50
13	Barcelona Supercomputing Center -	ES	27500	6000	0	0	0	8375,00	0	41875,00	50	20937,50	20937,50
14	Flysight Srl	IT	58500	2400	0	0	0	15225,00	0	76125,00	50	38062,50	38062,50
15	Parity Quantum Computing	AT	123728	9800	0	0	0	33382,00	0	166910,00	50	83455,00	83455,00
16	Fraunhofer Gesellschaft Zur	DE	35647	0	0	0	0	8911,75	0	44558,75	50	22279,38	22279,38
	Total		3934795	7039605	7000	0	0	2743600,00	0	13725000,00		6862500,03	6000000,00

4 - Ethics

1. HUMAN EMBRYOS/FOETUSES		Page
Does your research involve Human Embryonic Stem Cells (hESCs)?	○ Yes ◉ No	
Does your research involve the use of human embryos?	○ Yes ◉ No	
Does your research involve the use of human foetal tissues / cells?	○ Yes ◉ No	
2. HUMANS		**Page**
Does your research involve human participants?	◉ Yes ○ No	121
Are they volunteers for social or human sciences research?	○ Yes ◉ No	
Are they persons unable to give informed consent?	○ Yes ◉ No	
Are they vulnerable individuals or groups?	○ Yes ◉ No	
Are they children/minors?	○ Yes ◉ No	
Are they patients?	○ Yes ◉ No	
Are they healthy volunteers for medical studies?	○ Yes ◉ No	
Does your research involve physical interventions on the study participants?	○ Yes ◉ No	
3. HUMAN CELLS / TISSUES		**Page**
Does your research involve human cells or tissues (other than from Human Embryos/ Foetuses, i.e. section 1)?	○ Yes ◉ No	
4. PERSONAL DATA		**Page**
Does your research involve personal data collection and/or processing?	◉ Yes ○ No	121
Does it involve the collection and/or processing of sensitive personal data (e.g: health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	○ Yes ◉ No	
Does it involve processing of genetic information?	○ Yes ◉ No	
Does it involve tracking or observation of participants?	○ Yes ◉ No	
Does your research involve further processing of previously collected personal data (secondary use)?	○ Yes ◉ No	
5. ANIMALS		**Page**

Does your research involve animals?	◯ Yes ◉ No	
6. THIRD COUNTRIES		Page
In case non-EU countries are involved, do the research related activities undertaken in these countries raise potential ethics issues?	◯ Yes ◉ No	
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	◯ Yes ◉ No	
Do you plan to import any material - including personal data - from non-EU countries into the EU?	◯ Yes ◉ No	
Do you plan to export any material - including personal data - from the EU to non-EU countries?	◯ Yes ◉ No	
In case your research involves low and/or lower middle income countries, are any benefits-sharing actions planned?	◯ Yes ◉ No	
Could the situation in the country put the individuals taking part in the research at risk?	◯ Yes ◉ No	
7. ENVIRONMENT & HEALTH and SAFETY		Page
Does your research involve the use of elements that may cause harm to the environment, to animals or plants?	◯ Yes ◉ No	
Does your research deal with endangered fauna and/or flora and/or protected areas?	◯ Yes ◉ No	
Does your research involve the use of elements that may cause harm to humans, including research staff?	◯ Yes ◉ No	
8. DUAL USE		Page
Does your research involve dual-use items in the sense of Regulation 428/2009, or other items for which an authorisation is required?	◯ Yes ◉ No	
9. EXCLUSIVE FOCUS ON CIVIL APPLICATIONS		Page
Could your research raise concerns regarding the exclusive focus on civil applications?	◯ Yes ◉ No	
10. MISUSE		Page
Does your research have the potential for misuse of research results?	◯ Yes ◉ No	
11. OTHER ETHICS ISSUES		Page
Are there any other ethics issues that should be taken into consideration? Please specify	◯ Yes ◉ No	

I confirm that I have taken into account all ethics issues described above and that, if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents. ☒

How to Complete your Ethics Self-Assessment

5 - Call-specific questions

Extended Open Research Data Pilot in Horizon 2020

If selected, applicants will by default participate in the Pilot on Open Research Data in Horizon 2020[1] , which aims to improve and maximise access to and re-use of research data generated by actions.

However, participation in the Pilot is flexible in the sense that it does not mean that all research data needs to be open. After the action has started, participants will formulate a Data Management Plan (DMP), which should address the relevant aspects of making data FAIR – findable, accessible, interoperable and re-usable, including what data the project will generate, whether and how it will be made accessible for verification and re-use, and how it will be curated and preserved. Through this DMP projects can define certain datasets to remain closed according to the principle "as open as possible, as closed as necessary". A Data Management Plan does not have to be submitted at the proposal stage.

Furthermore, applicants also have the possibility to opt out of this Pilot completely at any stage (before or after the grant signature). In this case, applicants must indicate a reason for this choice (see options below).

Please note that participation in this Pilot does not constitute part of the evaluation process. Proposals will not be penalised for opting out.

We wish to opt out of the Pilot on Open Research Data in Horizon 2020.	○ Yes	◉ No

Further guidance on open access and research data management is available on the Funding & Tenders portal: http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/open-access-dissemination_en.htm and in general annex L of the Work Programme.

[1] *According to article 43.2 of Regulation (EU) No 1290/2013 of the European Parliament and of the Council, of 11 December 2013, laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006.*

High Performance Computer and Quantum Simulator hybrid [HPCQS]

LIST OF PARTICIPANTS

Participant No		Participant organisation name	Country
1	FZJ (Coordinator)	Forschungszentrum Jülich GmbH	Germany
1b	ParTec (LTP*[1])	ParTec Cluster Competence Center GmbH	Germany
2	CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
3	GENCI	Grand équipement national de calcul intensif	France
4	ATOS	BULL SAS	France
5	CNR	Consiglio Nazionale delle Ricerche	Italy
6	NUIG-ICHEC	National University of Ireland Galway (Irish Centre for High-End Computing)	Ireland
7	UIBK	University of Innsbruck	Austria
8	EURICE	European Research and Project Office GmbH	Germany
9	CNRS	Centre national de la recherche scientifique	France
9a	Sorbonne (LTP*)	Sorbonne Université	France
9b	SUPELEC (LTP*)	SUPELEC	France
10	INRIA	Institut national de recherche en sciences et technologies du numérique	France
11	Pasqal	Quantum Processing Units out of atomic arrays Simulation, Computing	France
12	CINECA	Consorzio interuniversitario per il calcolo automatico	Italy
13	BSC	Barcelona Supercomputing Center	Spain
14	FLS	FlySight SRL	Italy
15	Parity QC	Parity Quantum Computing GmbH	Austria
16	Fraunhofer IAF	Fraunhofer Institute for Applied Solid State Physics	Germany

[1] Linked Third Party

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
API	Application Public Interface
APQU	Analog Quantum Processing Unit
CAP	Communication Activity Plan
CPU	Central Processing Unit
DEEP	Dynamical Exascale Entry Platform
DMP	Data Management Plan
EC	European Commission
EOSC	European Open Science Cloud
ETP4HPC	Interactive Computing E-Infrastructure
EUDAT	European Data Infrasctructure
GCS	Gauß Centre for Supercomputing
GPU	Graphics Processing Unit
HBP	Human Brain Project
HiPEAC	High Performance and Embedded Architecture and Compilation
HPC	High Performance Computing
HPCG	High Performance Conjugate Gradient
HPL	High Performance Linpack
HW	Hardware
IaaS	Infrastructure as a Surface
ICEI	Interactive Computing E-Infrastructure
I/O	Input/Output
IPR	Intellectual Property Rights
JUNIQ	Jülich UNified Infrastructure for Quantum computing
KER	Key Exploitable Results
KPI	Key Performance Indicator
LHZ	Lechner, Hauke and Zoller
ML	Machine Learning
MPI	Message Passing Interface
MSA	Modular Supercomputer Architecture
NISQ	Noisy, Intermediate Scale Quantum
NP	Non-deterministic Polynomial-time
PaaS	Platform as a Service
PPI4HPC	Public Procurement of Innovations for High Performance Computing
PRACE	Partnership for Advanced Computing in Europe
PATC	PRACE Advanced Training Course
PDE	Plan for the Dissemination and Exploitation
QAOA	Quantum Approximate Optimization
QC	Quantum Computer
QLM	Quantum Learning Machine
QLP	Quantum Learning Platform
QML	Quantum Machine Learning
QPI	Quantum Processing Ireland
QPU	Quantum Processing Unit
QS	Quantum Simulator
QT	Quantum Technology
QUBO	Quadratic Unconstrained Binary Optimization
RDM	Research Data Management
R&I	Research & Innovation
RIAG	Research and Innovation Advisory Group
R&D	Research & Development
RL	Reinforcement Learning
SaaS	Software as a Service
SAB	Strategic Advisory Board
SDL	Simulation and Data Laboratory
SME	Small and Medium Enterprises
SSH	Su-Shrieffer-Heeger
SW	Software
TRL	Technology Readiness Level
VQE	Variational Quantum Eigensolver
VQS	Variational Quantum Simulation

TABLE OF CONTENTS

1. Excellence

High Performance Computing (HPC) has become a decisive key technology in the digital world. All leading industrial nations are massively expanding their presence in the development and consider the use of this technology as strategic, as they regard self-determination and security of state-of-the-art data processing being central issues for the prosperity of their science, economy and society. **Supercomputers** as a silver bullet are mentioned in the very same breath as major challenges facing our society, such as climate change, pandemics and healthy living, sustainable management and energy or civil security. **Artificial intelligence**, especially deep learning, will further accelerate their triumphal advance, with **exascale** supercomputers as a next milestone.

All this notwithstanding, in very important areas of **industrial and scientific applications**, there are a host of highly relevant computing tasks that the classical supercomputers would be fighting tooth and nail to solve. These include complex **optimization problems** in engineering – a school example is the classic, NP-hard Traveling Salesman Problem –, the **simulation of genuine quantum systems** in chemistry, as well as **optimized machine learning (ML)**. This is the main reason why the expectations for the use of this new class of computer systems that exploits quantum effects such as quantum tunnelling, parallelization, and entanglement, are very high in both science and industry. Significant progress in the system and application-oriented development of such **quantum computers (QC)** opens up new approaches to this class of hard-to-compute problems.

Early entry into the practical application of the new quantum technologies (QT) is of greatest urgency. The prerequisite for this is the practical availability of QCs at the forefront of development, taking into account different technical approaches. The first practically usable systems based on European developments are so-called **quantum simulators (QS)**. A QS can be viewed as an analog version of a QC in the sense of a controllable quantum device. In fact, a QS does not require complete control of each individual component, and thus is simpler to build. Platforms for QSs include, among others, neutral atoms in arrays of optical tweezers, ultracold atoms in optical lattices, trapped ions, arrays of superconducting qubits or arrays of quantum dots and photons.
Today, most **applications in quantum computing** are realized algorithmically with a high degree of **hybridity**. This applies to many fields like materials design, drug discovery, logistics and transportation etc. In hybrid computations, classical algorithms are combined with quantum algorithms (e.g. quantum optimizers for ML or variational quantum algorithms). Furthermore, due to limitations of size and qubit connectivity, it often will be necessary to decompose the original large problem into subproblems and then to treat the subproblems in successive steps or iteratively. Furthermore, QCs/QSs can only process discrete binary variables. Therefore, large-scale optimization problems that contain both discrete variables and continuous variables are most effectively solved by hybrid strategies involving quantum and classical systems. Another argument for hybrid calculations arises from the side of HPC when considering the **energy consumption** of state-of-the-art supercomputers and the potential energy saving through the exploitation of QCs/QSs.
Consequently, the **seamless integration** of quantum hardware with classical computing resources based on CPUs and GPUs is an essential step towards handling realistic practical hybrid applications with QCs/QSs. The integration has to take place with lowest latency, because only then **quantum-classical**, i.e. hybrid computing models will run at a performance level from which they will be rewarding.

HPCQS will procure and acquire the **Pasqal QS Fresnel** model. At this time it is the only QS in Europe that will comprise more than **100 interacting quantum units**. It will be implemented as a **federated** system at the locations GENCI/CEA in France and the Jülich Supercomputing Centre (JSC) at FZJ in Germany. These sites act as Tier-0 systems in Europe serving the users through PRACE and are hosting candidates for the European exascale machines to come from 2023 onwards. The two pre-exascale EuroHPC sites BSC in Spain and CINECA in Italy, respectively, are already today closely federated with JSC and GENCI/CEA through the FENIX data infrastructure, which will be extended to include the HPCQS systems. This federation is the first step towards a pan-European quantum-HPC infrastructure integrating Tier-0 systems with various quantum HW technologies.

The HPCQS integration challenge is met through two major technological developments within HPCQS supported by a consequent co-design approach via use cases:
One important technical component is a production-ready programming environment and middleware for federated QS. The HPCQS environment is based on the **Quantum Learning Machine QLM®** by ATOS, which provides a programming environment on the one hand and a system for direct access to quantum computing backends like the Pasqal QS on the other hand. With the European QLM, users can develop the quantum part of their code. They can test, access and run the Pasqal QS through **cloud access**.
A second essential technical component serves to closely integrate the Pasqal QS into the high-end HPC systems. To this end, the interconnection between the classical HPC supercomputer and the QS has to be developed. HPCQS

will employ the concept of the **Modular Supercomputing Architecture (MSA)** for the integration to enable the lowest latency integration of the QS. The MSA has been developed in the series of Europe-funded DEEP projects and is based on ParTec's **ParaStation Modulo** middleware suite.
HPCQS concentrates on a few selected use cases to develop its infrastructure in the co-design process. They are seen as exemplary to enable the scientific and industrial communities to use the infrastructure:

Use Case 1 – Certification/Performance Analysis for Quantum Simulators – will develop a set of performance evaluation tools serving to benchmark and certify the behaviour of the QS.
Use Case 2 – Physics Simulations – will be composed of readily-implementable applications for simulating physics-based systems through the Ising model, Su-Shrieffer-Heeger (SSH) model, and simulation of many-body quenched dynamics, also targeting novel applications including simulation of strongly correlated materials.
Use Case 3 – Quantum Approximate Optimisation Algorithm (QAOA) – will demonstrate the application of QAOA to a number of problems including factorisation and unit-disk maximum independent set. The QAOA implementation on the Pasqal QS will be benchmarked against emulations on classical systems and QUBO solvers.
Use Case 4 – Variational Quantum Eigensolver (VQE) – will leverage the VQE algorithm to target applications in chemistry to solve the wave equation for the Helmholtz equation, calculating electronic structures to evaluate the performance of the Pasqal QS, and exploring a catalysis design relevant for nitrogen fixation.
Use Case 5 – Quantum Machine Learning (QML) – will target the development of hybrid classical-quantum algorithms for ML applications including reinforcement learning, quantum neural networks for pattern detection and classification.

The purpose of these use cases is to demonstrate both well understood and explorative applications of the integrated HPC and QS platforms for academic, research and industrial user groups. Use case 1 could define a benchmark to become a standard/reference for measuring QC capabilities such as HPL/HPCG in the HPC world. Details of the use cases are presented in section 1.3.4.
The following HW technologies, software (SW) platforms, and infrastructures either serve as a basis in HPCQS or will be developed for HPCQS:

Quantum simulator pilot (Pasqal)
The Institut d'Optique at the University of Paris-Saclay in France has exploited the potential of neutral atoms trapped in optical tweezers. 30 years of development in the field of laser-cooled atoms enable the optical control of qubits as well as contactless and scalable operations [Henriet20]. Today, Pasqal is the only European company that makes neutral atoms usable for QCs and QSs. It was founded in 2019 with the vision of building quantum processors and integrating them as accelerators in HPC. The technology grew from 49 qubits in 2018 to more than 100 today and presumably 1000 in 2023. Pasqal is currently building a bench-top QS, CHADOQ2, which is designed for 100 qubits.

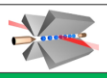
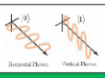
									
	Cold neutral atoms	**Superconducting qubits**	**Ion traps**	**Silicon photonics**	**Microwave photonics**	**Quantum dots in silicium**	**Nitrogen Vacancies centers in diamond**	**Topological qubits**	**Quantum annealing**
Qubit	**Trapped cold atoms**	Superconduction, Josephson effect	Trapped ions	Single photons	Single photons, superconduction	Electrons spins in semiconductors	Atomic nucleus spins	Quasiparticles (Anyon pair)	Superconduction, Josephson effect
Max Qubits demonstrated	**300 qubits**	53 qubits (IBM, Google)	53 qubits (NIST)	a few	1	49 qubits (Intel)	6 qubits (QDTI)	-	n.a.
State	**Atom energy levels**	Phase or energy or current direction	Energy level of the trapped ion	Polarization	Polarization	Electron spin direction	Energy level of the cavity	Anyon direction	Current direction
Gates	**Laser**	Microwaves and Josephson effect	Laser	Polarizing and dichroic filters	Microwaves	Microwaves	Laser	2D anyon inversion	No gates
Lead Scientists	**A. Broaweys M. Lukin**	J. Martinis D. Esteve	C. Monroe R. Blatt	J. O'Brien	M. Devoret A. Blais	M. Vinet A. Dzurak	M. Doherty	C. M. Marcus	E. Ladizinsky
Advantages	**Scalability (Toward 1000 Qubits) Performance & 3D Connectivity**	Short term	Entanglement	Room temperature Scalability	Performance (self correction)	Scalability	Performance (Theoritically)	Performance (Theoritically)	-
Drawbacks	-	Weak Scalability Error Correction	Weak scalability Performance	Performance not demonstrated	Long term Architecture to be demonstrated	Strong noise Early	Still Theoritical	The existence of these quasiparticles has barely been proven	Small number of applications Quantum Advantage not demonstrated

Table 1. Differences between the various quantum QC/QS technologies.

Neutral atoms have great potential for quantum simulation. Thanks to the interaction of qubits with light, which allows control over the finest physical parameters, it is a unique tool for studying the interaction of many body quantum systems. This field of research with this technology is wide open because the simulation complexity of these systems in principle exceeds that of all classical means. Table 1 shows that the technology of neutral atoms is the only candidate that will reach the 100 qubits range in the time frame set by HPCQS. It also has the capability to operate as a QC, i.e. implementing gates and NISQ algorithms. This considerably widens the range of applications and opens more perspectives for the future, well beyond quantum simulation.

The time for carrying out one simulation task takes O(100) ms on the QS. This number is primarily composed of I/O times to and from the registers, while the simulation process itself takes a few µs only, so there is plenty of room for improvement to meet the requirements of quantum-HPC hybrid simulations.

Atos Quantum Learning Machine - Atos QLM: Programming and access environment
The Atos QLM is a quantum programming environment providing not only a full quantum SW stack to write, compile and optimize hybrid quantum-classical programs, but also to execute these programs on HPC-based, realistic noisy emulators of quantum HW, as well as any actual quantum processing unit (QPU) (be it of the trapped-ion, superconducting, Rydberg atom type). It thus is the unique industrial European quantum programming environment.

ParaStation Modulo (ParTec): Software basis for modular supercomputing
ParaStation Modulo is the MSA-enabling supercomputing SW suite developed by ParTec. It is used in production environments, e.g., on the JURECA and JUWELS Cluster-Booster systems run by the JSC and will be driving the modular MeluXina system to be built in Luxembourg by the end of 2020.
Central to ParaStation Modulo is ParaStation MPI with the process management subsystem tailored to meet the demands of MSA computing scaling out to exascale. It consists of the standard-compatible MPI library, the modular, low-level communication library, and the runtime environment integrated with the Slurm workload manager. Besides the middleware, ParaStation Modulo comprises management components, the ParaStation ClusterTools for provisioning and administration, the ParaStation HealthChecker for automated error detection and integrity checking and the ParaStation TicketSuite for analysing and keeping track of issues. The ParaStation Modulo SW suite has been at the core of the MSA in context of the Cluster-Booster architecture in the DEEP project. It will be continuously extended towards exascale and be used for deep low-latency integration of the QS.

Jülich Supercomputing Centre - JSC (FZJ): HPC and QC resources
JSC operates supercomputers of the highest performance class for Germany and Europe. Currently, JSC hosts the JURECA Cluster and JURECA Booster, as well as the JUWELS Cluster. In the fall of 2020, the JUWELS Booster will become operational. Both the JURECA and JUWELS systems follow the innovative principle of the MSA developed in Jülich in the series of EC-funded DEEP projects. It will be further developed in the upcoming EuroHPC projects DEEP-SEA, IO-SEA and RED-SEA. The MSA realized in ParaStation Modulo is the basis for the low-latency integration of the QS in a HPC program. The JSC is a hosting member of the FENIX infrastructure.
JSC has set up the Jülich UNified Infrastructure for Quantum computing (JUNIQ) in the form of a uniform QC Platform as a Service (QC-PaaS). It offers user support and access to QC emulators and QC technologies at various stages of technological maturity. JUNIQ is the local platform to integrate QCs and quantum annealers in the form of quantum-classical hybrid computing systems into JSC's modular HPC environment, and operates an ATOS QLM system.

Très Grand Centre de Calcul - TGCC (CEA): HPC and QC resources
The TGCC is a CEA facility that hosts and runs the French Tier-0, GENCI owned, Joliot-Curie system, one of the most used systems by PRACE users. The TGCC hosts also the CCRT, a Tier-1 supercomputing system fully dedicated to CEA and more than 15 industrial partners. The TGCC offers the full infrastructure needed for those first-class systems, including, storage and visualization as well as a diversity of other services and, for that, has developed a unique expertise in creating, managing and running large computer centres using a vast variety of computing solutions. The TGCC is also hosting part of the FENIX infrastructure currently implemented by the HBP/ICEI project, with possible convergence with HPCQS regarding resources federation. CEA is also involved in the upcoming EuroHPC R&I projects DEEP-SEA, IO-SEA and RED-SEA.
The TGCC hosts an ATOS QLM, which is available to CEA and its industrial partners of the CCRT. The expertise gained with the ATOS QLM will be made available to the project. TGCC is ready to host new quantum platforms that will fit in this already established quantum facility. For the purpose of HPCQS CEA is also planning to deploy a dedicated QLM SW configuration on Joliot-Curie fat nodes made available in-kind by GENCI.

Barcelona Supercomputing Centre - BSC: HPC resources and QC resources
BSC is the Spanish national supercomputing facility and a hosting member of the PRACE distributed supercomputing infrastructure. BSC houses MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC is to research, develop and manage information technologies in order to facilitate scientific progress. BSC combines HPC service provision, and R&D into both computer and computational science (life, earth and engineering sciences). BSC participates in various bilateral joint research centres with companies such as IBM, Microsoft, Intel, NVIDIA and the Spanish oil company Repsol. BSC has been extremely active in the EC

Framework Programmes and is a founding member of HiPEAC, the ETP4HPC and other international forums. BSC is a hosting member of the FENIX infrastructure.
BSC coordinates the Quantum Computing pillar of the QuantumCAT project, co-funded by the European Union Regional Development Fund. To support this initiative, BSC has developed a set of classical simulation tools on HPC devices for large quantum systems. BSC has designed together with the High Energy Physics Lab (IFAE, Spain) a laboratory for a quantum annealer based on superconducting qubits. This device is in operation at IFAE.

CINECA: HPC and QC resources
CINECA is a non-profit consortium of 70 Italian Universities, the National Institute of Oceanography and Experimental Geophysics (OGS), the National Research Council (CNR), and the Ministry of Education, University and Research (MIUR). It also represents Italy in PRACE and is one of the four PRACE Tier-0 hosting centres. Besides the national scientific HPC facility, CINECA manages and exploits the supercomputing facility of the Italian Energy company (ENI), an integrated HPC facility with more than 80.000 cores. Right now, CINECA has the 9th most powerful supercomputer in the world, Marconi100, an upgrade of the "non conventional" partition of the Marconi Tier-0 system. It is an accelerated cluster based on Power9 chips and Volta NVIDIA GPUs, acquired by CINECA within the PPI4HPC European initiative. CINECA is a hosting member of the FENIX infrastructure.
At present, CINECA does not have quantum infrastructure. In any case, however, its systems are perfectly capable of hosting powerful emulators. In this first phase CINECA mainly concentrates on dissemination and scientific support. In the near future CINECA will host quantum machines to complete its HPC offerings.

Irish Centre for High-End Computing - NUIG-ICHEC: HPC and QC resources
NUIG-ICHEC is a Tier-1 HPC facility, hosted by the Irish Centre for High-End Computing (ICHEC). The current national HPC system, Kay, is offered to academic researchers through the national service infrastructure, in addition to access for industry partners, SMEs, for training events and national research projects. Kay offers support for heterogeneous workloads, with Xeon scalable CPUs, Nvidia Volta GPUs, and KNL nodes being made available to system users. NUIG-ICHEC is also involved in the upcoming EuroHPC R&I project IO-SEA.
NUIG-ICHEC will be providing access to a quantum learning platform (QLP) integrated with the HPC system (Kay) in Q4 2020, for the purposes of both research and training on quantum computing technologies and quantum-HPC hybrid applications. Under the Quantum Programming Ireland (QPI) initiative, ICHEC aims to develop a national training and education strategy for QTs, and will be coordinating its efforts to leverage results using the quantum learning platform, and dissemination of HPCQS research efforts.
Close cooperation and federation between the supercomputing centres/agencies BSC, CEA-TGCC, GENCI, CINECA, NUIG-ICHEC, JSC (FZJ) and partners from industry – these comprise large companies as well as SMEs and startups like ATOS, FlySight (FLS), ParityQC, ParTec, and Pasqal – as well as research institutes and major research organisations – CNRS, CNR, Fraunhofer, INRIA, UIBK, FZJ – has the potential to advance research into applications of quantum computing to real world problems and will put Europe at the forefront of applied quantum computing. HPCQS provides and validates a blueprint for a European ecosystem that includes

- a comprehensive quantum programming environment made in Europe for quantum computing and quantum-HPC hybrid applications;
- a first-of-its-kind low-latency integration of a QS into the new generation of modular HPC systems;
- safe cloud-based access for industrial and public organisations to a novel federated European HPC-QS infrastructure.

Vision:
Preparing European research and industry for the deployment and federated use of quantum computers and simulators to tackle most challenging computational challenges, by making European quantum simulator resources publicly available, deeply integrated with high-end HPC systems.

1.1 Objectives

In order to realize the vision described above, the HPCQS project will bring together leading quantum and computer experts from science and industry and thus create a worldwide unique incubator for charting and developing this unknown scientific and technological territory in order to prepare Europe for efficient practical quantum-HPC hybrid computations. The following objectives illustrate the targets to be achieved within each part of the HPCQS work plan:

- **The QSs shall become integral parts and constitutive elements of the multi-user environment of the HPC centres**. They will be integrated using the FENIX services for authentication and authorization and

they will contribute to advanced workflow, compute and data analytics services. Maintenance programs and stability monitoring under real life conditions will be established.

- **Close integration of the QSs with supercomputers through the MSA** will overcome latency limitations of (cloud) service-based approaches, and joint scheduling will ensure an efficient use of available resources. The QS will become a module of the modular supercomputers, closely coupled with other disaggregated modules such as the general purpose CPU and GPU acceleration systems or a tiered common high speed storage. This integration will be enabled by extending ParaStation Modulo with an execution environment for quantum-HPC hybrid simulations and workflows on modular supercomputers. A portal solution will provide convenient and flexible access to the QS pilot via a web browser enabling a production-level JupyterHub Portal for both the HPC (HPC-PaaS) and the Quantum Computing Platform as a Service (QC-PaaS). The latter has been pioneered through JUNIQ.
- **A highly abstracted Python-based analog programming framework** and a library of primitives for the QS will provide **a seamless integration of quantum and classical subroutines/functions for hybrid algorithms**, fully integrated into the ATOS QLM. A universal quantum intermediate language for analog operations shall be complemented by a graphical representation and manipulation language for easy optimization during compilation. Optimization, ML and lattice model libraries will help benchmarking and translate problems into the HPC-QS system. Analog quantum processing units (AQPUs) will expose the higher-level controls of the QS to the QLM environment. HW-aware libraries shall help to optimize the HW-agnostic programs for the specific QS-HW, supported by classical emulators and low level SW environments for the Pasqal HW.
- **Five categories of use cases will demonstrate the relevance of the HPC-QS approach** for scientific and industrial applications and serve as building blocks for **co-design**. **Training** material, user guides and courses will be provided for both scientific and industrial user needs and supporting the access and use of the HPCQS infrastructure.
- **The HPCQS will promote wide dissemination** among the large community of stakeholders in Europe supporting ecosystem development, operational support for use, publications and in particular innovation.

1.2 Relation to the work programme

The project HPCQS fits squarely to the challenges and scope of the Horizon 2020 call "Advanced Pilots towards the European Exascale Supercomputers" – Call ID: H2020-JTI-EuroHPC-2020-01) under the topic "Pilot on quantum simulator" – Call ID: EuroHPC-2020-01-b. With the goal of developing, deploying and coordinating at European level a European federated hybrid HPC-QS infrastructure that will provide non-commercial cloud access to public and private European users, including user support and training, HPCQS further relates to the work programme topic in the following specific aspects:

"Acquisition of one such quantum simulator [...] currently being developed by EU projects or by national projects in the EU Member States"

Within the project HPCQS, **FZJ** and **GENCI** will acquire a quantum device, consisting of two Pasqal Fresnel QSs with 100+ neutral atoms in arrays of optical tweezers, and maintenance services from the startup company **Pasqal**, a spin off from the Institut d'Optique at the University of Paris-Saclay in France. **Pasqal** was established in 2019 to leverage the QS technology developed at Institut d'Optique by the team of Antoine Browaeys and Thierry Lahaye in an academic setting for the purpose of building fully programmable QPUs for practical quantum advantage for customers. The Institut d'Optique (Antoine Browaeys) together with the Max Planck Institute of Quantum Optics (Immanuel Bloch) in Germany coordinates the European Quantum Flagship project PASQUANS (Programmable Atomic Large-Scale Quantum Simulation). Pasqal is the **only company in Europe at this time capable of delivering** a production-class QS with 100 qubits **in 2022**. Earlier in 2021 there is already an internal prototype called CHADOQ2 accessible for HPCQS use cases (see section 1.3.4).
FZJ and GENCI have decided to **procure and host Pasqal's Fresnel QSs as a** twin system. This twinning strategy allows to accelerate the project through parallel execution of tasks on the one hand, especially development and production runs can always take place at the same time through close coordination of the sites. On the other hand, HPCQS can achieve federation and standardization of integrated quantum-HPC systems in Europe right from the beginning. What is more, the validation of such highly tunable systems at an early stage can be carried out against each other both with regard to their intrinsic properties and their integration into different HPC environments.

"Development of the interconnection between the classical supercomputer and the quantum simulator"

HPCQS will deeply integrate the Pasqal QS into the Tier-0 HPC systems at the two sites foreseen. The QS front end system uses the same high-performance interconnect technology as the HPC system – this is the preferred connection – or it can be connected through a network bridge. Both network topologies will be joined by allowing for highest throughput and lowest possible latency. The concept of the MSA, developed in the series of Europe-funded **DEEP** projects, will enable the communication between the two subnets. The MSA technology is also able to bridge networks of different provenience as demonstrated by DEEP. The **ParaStation Modulo**® middleware suite, developed by **ParTec**, provides the means to spawn MPI-communicators over different network topologies. Thus, it will be possible to invoke **operations on the QPU** from within a code running on the **HPC cluster** by a straightforward function call. Organized parallel data transfer is realized through ParaStation Modulo, co-scheduling will be developed based on SLURM in combination with the ParaStation Modulo resource management.

"Development of the necessary cloud access and middleware for programming and running applications on the quantum simulator"

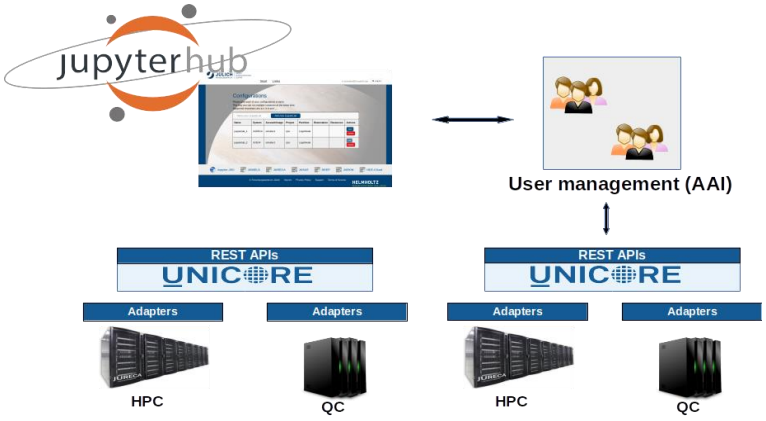


Figure 1: Portal-based access scheme to the federated HPCQS systems.

An essential element of HPCQS is the development of the **programming environment** and the **middleware for accessing the QS**. Here, HPCQS can recourse to the basics of the **ATOS QLM**, which will be extended to cover all requirements of the analog properties of the QS. **Portal-based access** in form of a QS-PaaS, will use the JupyterHub technology, and join with a HPC-PaaS as it is meanwhile available for large-scale HPC systems.

"The European quantum simulator should be hosted by a supercomputing centre located in the Union and co-located with a EuroHPC or Tier-0 supercomputer that should be existing at the moment when the project would start or soon after."

The QS of **Pasqal**, consisting of a twin QPU system with 100+ neutral atoms in arrays of optical tweezers, will be acquired by **GENC**I and hosted and operated by **CEA** in France and **JSC (FZJ)** in Germany, two Tier-0 HPC infrastructures in Europe serving the users through PRACE and being hosting candidates for the EuroHPC exascale machines to come from 2023 on. The **Pasqal** QPUs will be tightly integrated in the Tier-0 HPC systems Joliot Curie at **CEA-TGCC** and the JUWELS modular supercomputing complex at **JSC (FZJ)**.

"Help [European users] to familiarize with quantum technologies, to test their capabilities/performances and to develop their first quantum applications and algorithms"

HPCQS is set up in such a way that exemplary HPC-QS hybrid use cases are developed that cover a broad range of potential user requirements. The expected pilot users will receive training material, user guides and can attend training courses as well as enjoy personal support contacts. Collaboration with PRACE Training Centres (where FZJ/JSC, CEA/CNRS/INRIA, CINECA, BSC and NUIG-ICHEC play a major role) and newly created national HPC Competence Centres (CC) will allow to amplify training events and dissemination actions toward users communities from academia and industry.

"Develop an early ecosystem of quantum programming facilities and application libraries"

World-wide, HPCQS will be the first realization of an ecosystem for quantum programming, library development, HPC-QS provision and last, but not least, advanced user support, creating a continent-wide pan-European leadership facility. With the two federated Pasqal QPUs and the regular technological assessment of quantum computing HW and SW performed by the project, HPCQS will pave the way for a versatile and open pan-European hybrid quantum-HPC infrastructure (already several European quantum SMEs expressed the wish to be integrated as prototypes as well). HPCQS will be spanning over multiple Tier-0 and EuroHPC sites, offering federated access to various quantum HW-systems, endowed with a rich programming environment, including an agnostic programming model – the ATOS QLM – or applications and low-level libraries and fostering the convergence of European HPC and quantum expert communities.

1.3 Concept and methodology

(a) Concept

HPCQS promotes the **principle of self-determination and security of state-of-the-art data processing** as a central concern of European science, economy and society. The aim of HPCQS is to harness the significant progress that has recently been made in the development of QT for use in science and industry in Europe. While, in theory, quantum computing can solve computing problems that are inaccessible to classical computers, in practice, usable machines are still in their infancy. However, since the new technology offers completely new approaches to hard optimisation problems, efficient ML and simulations of complex quantum systems, it has great appeal and there is already clear consensus of the need of European science and industry to build competences in its practical application. HPCQS will meet this requirement by starting to build a pan-European user-infrastructure for quantum computing.

HPCQS will benefit from the **concept of the QS**. QSs are the first devices manufactured in Europe that can be used in practice and therefore are addressed in the present call. Although QSs are not at all intended to be already universal QCs – nota bene universal QCs with error correction seem still quite some years away – they are already promising for the simulation of small quantum systems relevant to some important fields. Still, they themselves are very new technology at its first prototypic stage. In Europe, the QS concept was most consistently put into practice by Pasqal, besides the developments of the company AQT in Austria. The **Pasqal QS** with 100+ qubits will be available and implemented in 2022.

HPCQS will realize a **model of a universal programming environment and access** to QCs/QSs across Europe. To this end, the **ATOS QLM** will be implemented. The QLM – here "learning" stands for learning how to carry out quantum computing – primarily simulates the laws of physics, which are at the very heart of quantum computing, in order to emulate real quantum systems. The QLM enables developers to focus on their applications and algorithms, while waiting for quantum machines to be available. However, in order to be able to mimic real systems, it already embeds all SW elements to drive a QC including programming environments, compilers and run-time elements linked to the devices' application public interfaces (API). Therefore, the QLM provides both a programming environment and a system for direct access to quantum computing backends like the Pasqal QS. SW developed on the Atos QLM runs simulated, as well as on QSs without changing a line of code.

HPCQS follows the **idea of quantum-hybrid simulations**. Today, most of the promising practical applications in quantum computing are realized algorithmically with a certain degree of hybridity by combining classical with quantum algorithms (e.g. quantum optimizers for ML or variable quantum algorithms) [Benedetti18, Hempel18, Ajagekar19, Pagano19]. Therefore, the seamless integration of quantum HW with classical accelerator resources (CPUs, GPUs, etc.) is an essential step towards handling realistic applications with QCs. We observe that QCs can only process discrete binary variables. Therefore, large-scale optimization problems involving both discrete decision variables and continuous variables are most effectively solved by hybrid solution strategies. Furthermore, the limitations in size and qubit connectivity make it necessary to decompose the original large problem into sub-problems and then to optimize the sub-problems iteratively with the QS.

Any practical use of QSs/QSs and especially quantum HPC hybrid computations based on lowest latency requires close integration with HPC infrastructures. The **concept of MSA**, developed by FZJ/JSC together with ParTec in the Europe-funded DEEP projects and manifested in ParaStation Modulo, has paved the way for this integration and promises to run practical HPC-QS hybrid computing at such a performance level that the use of QSs will become worthwhile. Such quantum-HPC hybrid simulations also are a paragon for **transdisciplinary activities**: quantum science meets computer science, both communities acting at the forefront of scientific and technological developments.

HPCQS puts **co-design** into practice advocating the central tenet of co-design, namely that users, as the best "experts" of their own experience and as representatives of public commitment, are placed at the centre of the design process of the technology they need. The project as a whole has the **role of facilitator**, providing opportunities for researchers and technicians from science, HPC centres and industry to interact and find ways to communicate, be creative, share knowledge and test new ideas.

To realize co-design, HPCQS relies on the **idea of use cases,** chosen from exemplary scientific and industrial fields such as molecular dynamics, biology, chemistry, pharmacology, or logistics. Note that here use case does not just denote a procedural element in SW engineering – although the agile SW development philosophy is used by HPCQS – rather a use case is a process to solve a specific complex problem through quantum-HPC hybrid computations, including a feedback loop to machine, operating system and middleware development, each use case seen as a template for solving similar practical problems.

Positioning of the project

HPCQS is a EuroHPC Research and Innovation Action project aiming at strengthening Europe's position in coupled high-performance and quantum simulations, providing access to and utilization of a first European federated infrastructure for quantum-HPC hybrid simulations. HPCQS will strengthen the competitiveness of Europe in one of the most advanced areas of high technology and will make it useful for applications of European science and industry. In order to achieve its goals, HPCQS will leverage successful existing European technologies and products as well as results from previous European and national projects running and activities (see section 1.3.3).

The approach of HPCQS is the following: Existing products and research results exist with a TRL between 6 and 8, i.e. they have reached the phase of technology demonstration up to system or subsystem development. Examples are the Pasqal QS, the ATOS QLM or the software suite ParaStation Modulo. Relevant components or features of these technologies have to be adapted to the needs of the project, partly further developed and merged. With regard to these specific requirements of HPCQS, the TRLs are between 3 and 5, i.e. they are in the technology development phase and must therefore be further developed for use in the HPCQS infrastructure. Other components are not yet available or exist as an idea only (TRLs 1 to 3) and thus need to be developed from scratch.

Table 2 summarises the HPCQS technology components that will be developed or brought together and be further developed jointly in the course of the project.

Item	TRL of basic Technology	Development of new features for HPCQS	TRL of items to develop	Related Task
Resource Management		Design and implement resource management (and job scheduling) for the analogue QS	3	3.1.1 3.1.2
Middleware – ParaStation Modulo	8	Integration of the QS into the HPC execution environment for tightly coupled, low-latency hybrid simulation codes	4 to 5	3.1.1 3.1.3
Runtime – ParaStation MPI	8 to 9	Develop support from the runtime environment to execute hybrid workload	4 to 5	3.1.4
Cloud-based access portal based on JUNIQ and JupyterHub	8 to 9	Extending JupyterHub Portal for joint HPC and cloud computing resources	4	3.2
QLM	7 to 8	Add the high-level programming, compiling and software environment for analog QPUs	3 to 5	4.1
Libraries for analog QPUs		Develop novel technical libraries for analog processors	3	4.2
APIs to Pasqal QS		Low level HW-SW APIs to attach the QS on a HPC-system	4	4.3
Code Optimizer		Libraries to transform HW-agnostic code to HW-optimized code	4	4.4
QS emulator	3 to 7	Development of diverse models of Pasqal QS	3	4.5
APIs to ParityOS	5	Development of plugins and connectors to	2	3.2

Item	TRL of basic Technology	Development of new features for HPCQS	TRL of items to develop	Related Task
		ParityOS		4.2

Table 2: Overview of technology readiness of HPCQS Components and Technologies.

With regard to the data centre integration of the QS systems, the state of the technology is located between lab and market. Substantial efforts must be made to bring such complex systems into the operational environment, see WP2.

Relation to national & international research, and synergies

Activity / project Partners	Input to / Link with HPCQS
EuroHPC JU FZJ, GENCI, BSC, CINECA, NUIG-ICHEC	All HPC agencies/centres are represented by their national Ministries inside the EuroHPC JU Governing Board. BSC and CINECA are EuroHPC hosting entities for pre-exascale systems in 2021, while FZJ and GENCI are considered to be candidate hosting entities for exascale systems in 2023. In the project HPCQS, FZJ and GENCI will integrate a QS in their HPC environment.
Quantum Flagship FZJ, CEA, CNRS, UIBK, CNR	Several partners are closely involved in the European Quantum Flagship, from its Strategic Advisory Board (SAB) to more operational activities.
Quantum Flagship project OpenSuperQ - An Open Superconducting QC FZJ, EURICE, ATOS	OpenSuperQ aims at designing, building and operating a quantum information processing system based on superconducting electronic circuits reaching the scale of 100 qubits. The OpenSuperQ device will be integrated through JUNIQ in the Jülich MSA and will be put in the cloud. An OpenSuperQ device specific part of a QC-PaaS will be developed. The usage of the OpenSuperQ prototype QC with its specific QC-PaaS by academic and industrial users will provide lessons learned for the usage of the Pasqal QS in HPCQS.
Quantum Flagship project PASQuanS - Programmable Atomic Large-Scale Quantum Simulation ATOS, FZJ, UIBK, Pasqal	PASQuanS aims at providing a broad spectrum of programmable analog QSs ranging from ultracold neutral atoms to trapped ions. Along with the continuous technical development of the platforms, it benchmarks them in terms of potential quantum advantage for a number of applications in the fields of quantum physics, ML, combinatorial optimization, etc. The lessons learned from this project will thus very positively benefit HPCQS.
Quantum Flagship project AQTION - Advanced Quantum computing with Trapped IONs ATOS, UIBK	AQTION aims at investigating the potential of digital trapped-ion QSs in terms of scalability, quality, integration, and applications. Within this project, a full-fledged demonstrator with remote access for the end user will be delivered. Despite the digital aspect of the project, the teachings and tools from this project will be easily leveraged to benefit HPCQS.
European Open Science Cloud (EOSC) FZJ, GENCI, NUIG-ICHEC, BSC, CINECA, CEA, CNRS	The EOSC partnership is an operational entity to serve EU researchers by enabling cross-fertilization across European Data Spaces. HPCQS as a European HPC/Quantum infrastructure will be made accessible to EOSC research communities enabling new users communities.
EUDAT FZJ	Deployment of data exchange and discovery services; transfer of large data collection from EUDAT storage facilities to external HPC facilities; replication of community data sets for long-term preservation; providing services as B2DROP and B2Share and data services to be used by HPCQS
European Technology Platform (ETP4HPC) ATOS (chair), CEA (vice chair), FZJ, NUIG-ICHEC, BSC, ParTec, CINECA, INRIA	An industry-led Association of 100 members, ETP4HPC is the voice for EU HPC technologies, fostering the development of a globally competitive EU HPC value chain (from technologies to applications via infrastructures). A private member of EuroHPC and represented in its Research and Innovation Advisory Group (RIAG), ETP4HPC has been strongly advocating the anticipation of the integration of quantum computing technologies with HPC, and could further liaise with HPCQS for future perspectives. ETP4HPC will welcome quantum startups involved in HPCQS, promote their activities and monitor the technological convergence of HPC and QC in the next edition of its Strategic Research Agenda.

Activity / project Partners	Input to / Link with HPCQS
HPC-Europa3 Transnational Access programme NUIG-ICHEC	HPC-Europa3 Transnational Access programme offers access to world-class HPC systems to academic and industrial researchers by supporting their visits and collaborative work with HPC centres. As one of the hosts in the HPC-Europa3 programme, NUIG-ICHEC will be able to host prospective HPCQS users for training, collaborative R&D and supporting their use of the HPCQS solutions.
PRACE FZJ, GENCI, CEA, INRIA, BSC, CINECA, NUIG-ICHEC	FZJ, BSC, CINECA and GENCI/CEA are representing four of the five current Hosting Members of PRACE, the European HPC research infrastructure. All together they offer a daily accumulated computing capacity of more than 150 PFlops to European users from academia and industry. NUIG-ICHEC, the Irish Tier-1 centre, is also a member of PRACE. All partners are also deeply involved in EU funded PRACE-xIP projects for developing training, user enabling, technology watch or SME support of PRACE. HPCQS will benefit from synergies with PRACE in using its user access mechanisms (preparatory access), dissemination channels (PRACEdays conferences) and collaborate with the PRACE Training Centres where GENCI (with CEA, CNRS, INRIA), FZJ, NUIG-ICHEC, BSC and CINECA are one of the major nodes.
GAIA-X ATOS, Fraunhofer	GAIA-X is a European project (with a strong Franco-German embryo) working towards an independent European cloud ecosystem; a European cloud federation, including HPC- and QC-access, will almost certainly be a part of such an ecosystem. Research findings and facilities from HPCQS could be used by GAIA-X through the FENIX federation to deliver European industries a secured and sovereign access to leading edge HPC+Quantum facilities and services to foster European competitiveness and access to technologies (Pasqal, ATOS, JUNIQ, …).
Gauß Centre for Supercomputing (GCS) FZJ	GCS is Germany's leading supercomputing institution. It is a non-profit organization, combining the three national supercomputing centres—HLRS, JSC, and LRZ into Germany's most powerful supercomputing organization. Its world-class HPC resources are openly available to national and European researchers from academia and industry through strict peer review.
FENIX/ICEI FZJ, CEA, BSC, CINECA	The FENIX e-infrastructure provides Europe-wide federated scalable cloud-based data repositories and scalable supercomputing systems (IaaS). It is being initialised through the ICEI project (Interactive Computing E-Infrastructure) as part of the European Human Brain Project (HBP). FENIX platforms (like EBRAINS) can serve as benchmarks for HPCQS.
Teratec Quantum Computing Initiative (TQCI) CEA, ATOS, INRIA	An initiative of TERATEC Association, TQCI brings together users, technology providers and research centres to rapidly gain competences and develop know-how in the field of quantum computing. Organisations such as TOTAL, EDF, CERFACS are active participants in TGCI, sharing their use cases exploration experience, leveraging in particular the ATOS QLM operated at CEA TGCC/CCRT Industrial Computing Centre. TQCI members could benefit from HPCQS training activities, as well as from early access to HPCQS platforms.
JUNIQ - Jülich UNified Infrastructure for Quantum computing FZJ	JUNIQ is a project funded by the German federal state and the state of North Rhine-Westphalia for the establishment of a quantum computing user infrastructure. JUNIQ will host and give access to a variety of quantum systems among them a D-Wave quantum annealer, the European OpenSuperQ-system and it is planned to host the Pasqal QS at FZJ for HPCQS.
Bitkom Working group: High Performance Computing & Quantum Computing FZJ	Bitkom is the association of the IT industry active in Germany, focuses on the usability of HPC and Quantum Computing by SMEs and is a liaison to SMEs and industry for HPCQS.
H2020 SLICES-DS CNR	SLICES-DS will deliver a pan-European integrated infrastructure for experimentally-driven networking. In perspective, SLICES could be exploited by HPCQS to experiment the interconnection of HPC-QS systems with large-scale networked resources.
Quantum Programming Ireland (QPI) Initiative NUIG-ICHEC	QPI is the Irish national initiative led by ICHEC for deploying a quantum computing platform, R&D and skill development in quantum computing and programming. Activities and projects in the QPI Initiative are in partnership with a number of industry partners funded by national and European projects. As a part of this, a QLP will be integrated with the Irish national supercomputer (Kay) in Q4 2020 for R&D and national-level training

Activity / project Partners	Input to / Link with HPCQS
	programmes for academic and industry participants. The QLP integrated with Kay and the HPCQS project will share techniques, tools and applications for integrating classical HPC and QS platforms.
PRACE-6IP QuantEx NUIG-ICHEC	In the QuantEx project, ICHEC is developing a platform consisting of modular quantum circuit simulation tools which use tensor network contraction methods, are capable of running efficiently on heterogeneous compute platforms and scaling to exploit pre-exascale and exascale compute resources. Modern development practices and SW design methodologies will be used along with hierarchical layers of abstraction to encapsulate complexity and enable these tools to be easily extended and integrated into users' circuit simulation codes. QuantEx can potentially offer routes to heterogeneous HPC computations of the HPCQS formulated lattice models at scale.
EuroHPC National Competence Centre NUIG-ICHEC, GENCI	The EuroHPC national HPC Competence Centres provide HPC services to industry (including to SMEs), academia and public administrations, delivering tailored /modular solutions for a wide variety of users, with an aim to ease and foster the transition towards wider uptake of HPC in Europe. As the national Competence Centre in Ireland, ICHEC coordinates all national initiatives, facilitating access of national stakeholders to European HPC competence and opportunities in different industrial sectors and domains. In France the national Competence Centre is coordinated by Teratec and CERFACS with the support of GENCI for specific actions toward startups and SMEs.
DEEP Project Series FZJ, ParTec, BSC	The series of DEEP projects first introduced the Cluster-Booster architecture as a novel approach for integrating heterogeneous resources in supercomputers. The concept was enhanced by novel I/O technologies and innovative mechanisms to improve resiliency in the DEEP-ER project. DEEP-EST finally extends the idea to a fully working MSA that will allow to even integrate compute resources beyond the von Neumann concept. One aim of DEEP-EST is to provide a software infrastructure that allows for an efficient utilisation of heterogeneous HPC resources by exascale workloads and at the same time is flexible enough to integrate novel computing concepts. The latter will enable the natural integration of the HPC-QS hardware into the existing HPC infrastructure as an additional module. By this means the execution of hybrid workloads that rely on both traditional HPC resources and the QS are facilitated.
X-SEA Project Series ATOS, CEA, FZJ, BSC, NUIG-ICHEC, ParTec	The X-SEA project series aims at defining the HW and SW components of future European exascale systems by following a modular design as proposed by the MSA. DEEP-SEA will deliver the programming environment while adapting all levels of the SW stack ranging from low-level drivers, via the middleware, through to programming abstractions with associated runtime systems and tools. IO-SEA will establish a novel data management and storage platform based on a hierarchical storage management. This comprises on-demand provisioning of storage services by introducing the novel concept of ephemeral data nodes. RED-SEA will pave the way to the next generation of European Exascale interconnect by specifying a new architecture using a HW-SW co-design. This will enable the seamless communication within and between the resources of MSA systems. By integrating the QS into the MSA as an additional module, HPC-QS will benefit from all these projects in terms of a comprehensive HPC infrastructure based on next generation, European technologies.
Plan National Quantique (PNQ) France GENCI, CEA, CNRS, INRIA ATOS. Pasqal	Following the publication in March 2020 of an initial report[2] three French Ministries (Research and Innovation, Defense and Finance) are finalising for Autumn 2020 an ambitious plan for developing Quantum in France. In this plan, it is expected that a quantum computing infrastructure, federated with the upcoming exascale machine, will be made available by GENCI (the national HPC agency) at TGCC (CEA). Such infrastructure will be available to researchers from academia and industry. HPCQS with a twin QS system deployed in Germany and France will answer to the recommendations of the initial report and bootstrap the national quantum computing infrastructure, aiming to integrate later new QC technologies like the ones provided by Alice et Bob, Muquans or CEA to name a few.

[2]https://forteza.fr/2020/01/09/quantique-le-virage-technologique-que-la-france-ne-ratera-pas-remise-de-mon-rapport-au-gouvernement-le-9-janvier-2020/

(b) Methodology

Procurement, acquisition, installation and operation of the quantum simulator pilot
The HW facilities deployed at GENCI-CEA and FZJ in HPCQS will serve as a key component of the French and German national quantum infrastructures. On the basis of an analysis of the requirements arising from both HPCQS and the national infrastructures and a market study, GENCI and FZJ concluded that Pasqal is the sole company able to meet the criteria of the call, in particular to deliver a 100 qubits QS in 2022 and to allow remote access to an internal demonstrator (CHADOQ2) even earlier. In such a case, direct procurement of the Pasqal QS by GENCI and FZJ is the appropriate procurement procedure.

Pasqal will be both supplier – the HW part, which is already on a quite a high TRL and will be further developed outside the project, in particular concerning its repetition frequency – and partner of HPCQS for some developments of low-level SW components, co-design of use cases and training.

After the pilots have been procured from Pasqal by GENCI and FZJ, the two hosting sites, they will install the systems with the support of Pasqal, integrate them in their respective datacentre and operate them over their lifetime (WP2). A key aspect will be to understand if essential HPC services (such as management, monitoring, system access, data access, etc.) can be shared. Another key point concerns the effective utilization of the QS by scientists and engineers. The access should become as transparent as possible for users and thus will require tight integration with the datacentre HPC batch scheduler to appropriately manage quantum resources available for users' jobs and understand sharing system capabilities in a multi-user environment for optimized resource usage. Exploiting real life QSs will also offer the possibility to get users' feedback to improve SW required, etc. In that respect, inter-work package sessions with WP3 and WP4 will become obligatory in order to exchange best practices. On the pure infrastructure point of view, while operating this type of new computing capabilities, it is a further challenge to understand how to maintain the entire system in operational conditions, what is the maintainability of individual modules and what are the adjustments required at datacentre level to operate the QS optimally. An open question is if time affects the stability of a quantum system as qubits are particles with natural properties rather than mathematical abstractions.

As the two hosting sites are deeply involved in the development of the FENIX European data infrastructure, this task will integrate existing and planned components of FENIX like authentication and authorization infrastructure services. These elements will form the underlying layer of the cloud-based access.

Integration of HPC system and quantum simulator pilot
The consortium will develop the necessary SW stack to integrate the high-level HPC system and the QS pilot in a seamless way (WP4). This will be achieved by first developing a programming environment for analog QSs, in order to allow programmers to easily generate complex quantum-HPC hybrid programs. This programming environment will come with a universal quantum intermediate language to communicate the generated instructions to the AQPU. It will fully leverage the existing programming framework and execution stack of the ATOS QLM.
The programming framework will be augmented by technical libraries that will enable users to translate high-level use cases (such as combinatorial optimization and ML, and the use cases presented below, see WP5) into analog quantum programs without having to deal with low-level instructions. It will also come with a variety of compilers to translate the HW-agnostic instructions generated by the technical libraries into HW-compliant instructions, with a specific focus on variational optimization, a class of algorithms that is promising for NISQ devices and is used in many of the use cases. These compilers will take into account the constraints of the underlying HW thanks to an appropriate API between the Pasqal simulator and the QLM stack.
The execution environment provided by ParaStation Modulo will enable the full and deep integration of the QLM/QS into the existing HPC infrastructure (WP3). Therefore, the QLM/QS will be integrated as an additional module into the MSA system, supporting the management of the associated resources among multiple jobs. This way, the QS can not only be utilised as part of quantum-HPC hybrid simulations and workflows but also accessed via a cloud-based user portal. This portal provides end-users a convenient and flexible access to the QLM/QS via the web browser. In doing so, it will take into account the specific use cases, requirements, and boundary conditions of the project.
Finally, in order to accelerate and pre-validate the integration of the HW, a realistic emulator of the Pasqal device will be provided equipped with the same API as the device itself. This will also allow an early investigation of the use cases.

Application use case strategy
A number of scientific and industry-relevant use cases will be developed in WP5 to co-design and for demonstration of the integrated QS-HPC system. Initially, they will be developed on the Pasqal emulator and

testbed platforms i.e. Pasqal's CHADOQ2 100 qubits internal pilot in 2021, and then developed on the Pasqal platforms that will be deployed and integrated with the HPC systems. The use cases that will be targeted for development are:

Use Case 1 – *Certification/Performance Analysis for Quantum Simulators* – will provide a versatile set of tools to certify the quantum features and accurately evaluate the performance of QSs.

1. CEA will develop witnesses to detect and quantify various forms of quantum correlations using low order moments of either individual or collective projective measurements. These witnesses will be applied to prove the quantum character of the QSs. CEA will also study *n* singlet states prepared between two simulators, with the fidelity of these *n* singlets, after applying the same Hamiltonian on the two simulators, being used to quantify the accuracy with which this Hamiltonian can be prepared. CNRS will extend their schemes [Schmied16, Sekatski18] for analog randomised benchmarking, to quantify the accuracy with which Hamiltonians can be prepared in QSs.
2. ParityQC will develop a benchmarking plugin that connects the ParityOS compiler to the SW developed in the consortium. The plugin is a hybrid classical-quantum tool that benchmarks the LHZ implementation of optimisation problems on the quantum device consortium.
3. FZJ will perform simple experimental benchmarking tests, as e.g. in [Michielsen17] on the QS and compare to the results of emulations.

Scientific/industry relevance: Use Case 1 will help in providing standards and reference tools to certify the quantum nature of simulators, to check periodically their proper functioning and to quantify accurately their performances.

Use Case 2 – *Physics simulations* – will leverage the technical libraries developed in WP4 to implement applications for simulation of physics-based systems. The applications have different levels of maturity, where the first and second one are widely studied and based on well-established methods for many-body physics systems, while the third, fourth and fifth are exploratory and are based on more recent bodies of work.

1. *Ising model in one and two-dimensions*: NUIG-ICHEC and UIBK will implement this model, which is widely used to study both fundamental physics and material properties. Recent experimental progress demonstrates exploration of this model for a variety of lattice geometries [Labuhn16].
2. *Su-Schrieffer-Heeger (SSH)*: NUIG-ICHEC and UIBK will implement this model which describes the behaviour of topological insulators. Recent experimental progress has demonstrated this model using Rydberg simulators [Léséleuc19].
3. *Many-body quenched dynamics*: NUIG-ICHEC and UIBK will pursue the implementation of models for many-body quenched dynamics simulations using a Rydberg atom simulator of up to 51 qubits [Bernien17]. Newly emergent phase transitions were observed with explanations offered by non-ergodic behaviour, attributed to quantum scarring [Turner18a, Turner18b].
4. *Strongly correlated materials*: ATOS will test and adapt existing proposals for examining strongly correlated materials, a promising avenue of study for quantum devices [Bauer16], via the Variational Quantum Simulation (VQS) Method [Kokail19]. The focus will be on the robustness to defects (noise) of the computed quantities, and its dependence on the algorithm's parameters (ansatz, classical optimizer, encoding, etc.).
5. *Benchmarking via entanglement*: CNR will benchmark the creation of entanglement in the many-body system using the quantum Fisher information [Pezze18] as a witness of multipartite entanglement. Quantum phases and quantum phase transitions – in both the Ising model and in topological models -- can be characterized by the scaling behavior of the quantum Fisher information with respect to the particle number [Pezze17, Gessner18].

Additionally, **CINECA** (in collaboration with INFN - Italian National Institute of Nuclear Physics - in the HPCQS user group) will investigate the feasibility and development of an application to simulate many-nucleon dynamics.

Scientific/industry relevance: Having a platform independent representation of these use cases will allow for the application of the above models to different problems. Enabling end-users (students, academics, industry) to demonstrate the above results in an on-demand and reproducible manner with a well-defined example workflow will be of significant advantage to European researchers for the further exploration of such systems.

Use Case 3 – *Quantum Approximate Optimisation Algorithm (QAOA)* – is one of the prime candidates for obtaining a quantum advantage in the solution of combinatorial optimization problems. A true large-scale quantum implementation of the algorithm is needed to definitively establish the existence of a quantum advantage.

1. UIBK will study the use of QAOA for solving instances of the Unit-Disk Maximum Independent Set problem, which is naturally very suited for the Rydberg platform [Pichler18].
2. Inspired by recent proposals [Anschuetz18], CEA will study the feasibility and implementability of factorisation.
3. FZJ will benchmark QAOA on the HPCQS hybrid system against large-scale emulators like the massively parallel QC emulator JUQCS [DeRaedt19], classical QUBO (quadratic unconstrained binary optimization) solvers and the D-Wave quantum annealer (accessible through JUNIQ) in order to assess the performance and scalability for real world applications. FZJ will consider Max-Cut and general QUBO problems with up to 43 qubits for a relatively small number of parameters (< 10) and with 40 qubits for a larger number of parameters (< 100). For solving Max-Cut problems it has been shown that quantum speedup will not be attainable until several hundreds to a few thousands of qubits are available [Guerreschi19]. For hard 2-SAT problems it has been shown that the performance of QAOA strongly depends on the problem instance and is surpassed by quantum annealing [Willsch19].
4. ParityQC will develop a plugin that connects to the ParityOS toolchain for QAOA. The LHZ based version of QAOA fits ideally to Rydberg based quantum chips [Glaetzle17]. The ParityQC QAOA plugin will be integrated into the SW stack developed in the HPCQS consortium.

Scientific/industry relevance: Combinatorial optimization problems are ubiquitous in both science and industry. Achieving a quantum advantage would have tremendous impact.

Use Case 4 – *Variational Quantum Eigensolver (VQE)* – will leverage the VQE algorithm to target the following applications that include chemistry, solutions to a wave equation and the phase-estimation quantum eigensolver.

1. Fraunhofer-IAF will develop and perform a quantum chemistry simulation benchmark to evaluate the performance of the QS by defining a series of electronic structure calculations. Multiple techniques like density matrix purification and active-space reduction via the frozen- core approximation and truncation of the virtual space are used to accommodate HW limitations such as a limited number of noisy qubits and a limited circuit depth, while staying within the hierarchy of quantum chemistry methods [McCaskey19]. CEA will extend this method for catalyst design relevant for nitrogen fixation by FeMoco, the active site of Mo-dependent nitrogenase. For computing the kinetics of the catalysed reaction, the energy of intermediates and transition structures needs to be estimated with very high precision, out of range of currently available supercomputers. For this, standard chemistry algorithms will be used to provide candidate intermediates and transition structures combined with a VQE based on [Reiher17], and will be tested on the Pasqal QS.
2. INRIA will consider the quantum algorithm resolution of the wave equation based on the VQE method aiming towards the resolution of the Helmholtz equation on a QC [Suau20].

Scientific/industry relevance: The wave equation and more generally the Helmholtz equation provide deep insight into complex systems such as wave propagation in aerospace industry (noise generation) and oil and gas industry (e.g., to serve as direct solver in large inverse problems to study the ground structure).
The production of ammonia – the basic element of nitrogen fertilisers which are widely used in agriculture – is estimated to consume up to 3% of the total natural gas production. Understanding biological nitrogen fixation may help reduce this energy cost or eventually to get rid of fertilisers themselves. Even if this perspective is quite speculative, chemical reactions that involve strongly correlated species are not limited to nitrogen fixation but include hydrogen and oxygen production or carbon dioxide fixation.

Use Case 5 – *Quantum Machine Learning* – Hybrid classical-quantum algorithms are likely to be required with future QSs/QCs to enhance certain aspects of classical ML algorithms running on classical machines whose computational power starts to become limited w.r.t. certain computational components in ML [Caruso16, Pozza20, Kerenidis19,20a-c, Mengoni19].

1. *Reinforcement learning*: CNR, CINECA and BSC will demonstrate new RL algorithms where the agent and/or the environment are quantum objects that are implemented on the QS platform for: (i) demonstrating possible speedups with respect to classical RL methods and more powerful optimisation methods based on RL, (ii) proposing and testing a new physically-oriented framework where future quantum physics experiments will be assisted by RL for both discovering new physics and for engineering new hybrid QTs, and (iii) using classical ML to assist the operation of a hybrid classical-quantum device to reach optimal operational configurations.
2. *Pattern detection*: CNRS, CNR and FLS will consider the problem of detection of known patterns, in big data, exploiting supervised learning approaches. The objective is to analyse the quantum neural network

techniques to provide the training environment for the precise pattern detection, to be used in several applications.

3. *Classification*: CINECA, CNR, FLS and BSC will consider the problem of classifying data points in the supervised learning scenario, thereby using similarity learning techniques, and possibly quantum neural network techniques to provide efficient and accurate quantum classifiers. CINECA and BSC will benchmark this demonstrator on real data sets to test the accuracy of the quantum algorithm and the impact of noise on the computation. They will also test such classification algorithms (running on Pasqal) on the huge amount of real data, for instance coming from LHC experiments. BSC will study techniques to control variational versions of a hybrid quantum classifier, where classical algorithms assist the supervised learning performed by the quantum algorithm. NUIG-ICHEC will demonstrate and evaluate the detection and classification algorithm implementations using remote sensing satellite image data. FLS will use an industry-oriented demonstration of the use cases including ML SW, development of image detector/classification approaches. Typical applications are the development of video processing and remote sensing solutions to provide geospatial situational awareness both for the on-ground segment and the on-board one.

Scientific/industry relevance: Machine Learning is already affecting our everyday life, e.g., among others, sophisticated domotic systems, autonomous cars, face and voice recognition, prediction of extreme events as financial crises or natural disasters, medical diagnostics, etc. Classification is a major application for ML in industry, for example in image recognition on autonomous vehicles, fraud detection, natural language processing etc.

Access provision and resource allocation

The HPCQS project aims to provide users with access to a federated hybrid HPC-QS infrastructure. The allocation of resources for this infrastructure should be driven by scientific excellence and should therefore be guided by the peer review principles that have been established on the European level by PRACE (where FZJ, BSC, CINECA, GENCI/CEA, and ICHEC are partners) the peer review process should be transparent, fair and proposals should be assessed by experts from the corresponding scientific fields as well as by technical experts for the HW devices.

Half of the resources will be provided via national processes (e.g. JUNIQ or GENCI' DARI) and grants. The other half are foreseen to be offered to users on the European level through inclusion of the HPCQS resources in the PRACE Tier-0 compute services (WP6). These services cover, on the one hand, project access to European high-end HPC computing and data management systems, and, on the other hand, preparatory access is offered to enable groups to prepare their computational approaches for the use of these systems. With the QS resources, a third type of access could be introduced, which would allow users from different scientific fields to explore this new technology. In the medium term the HPCQS resources could be used to augment and complement also the resources offered to Tier-0 projects and to be used in combination with HPC. In a later stage it can also be evaluated whether the HPCQS resources could augment and complement the FENIX infrastructure.

WP6 will link with PRACE to extend the existing allocation procedures (PRACE preparation and regular access) to include HPCQS resources. The type of resources offered on the QS and the way they are allocated and integrated into the HPC landscape will play an important role. WP3 and WP4 will develop solutions and provide information. Potential use cases developed in WP5 will also need to be considered. In addition, experts from different scientific fields with a background in quantum computing must be identified and recruited to support the corresponding peer review process. Finally, a resource allocation process will be implemented and the HPCQS resources will be integrated into the European HPC landscape.

User support and training

HPCQS will engage with the user communities to deliver training programmes on the HPCQS solutions and the platform via JUNIQ, and for developing hybrid classical-quantum applications. These training programmes will cover details about the integration of the HPCQS platform, the middleware and the cloud-based access portal to the HPCQS platform via JUNIQ, the high-level programming and SW environment and technical libraries that will be developed, and the use-case demonstrators for scientific and industry applications. The training programmes will be delivered throughout the project period via seminars (physical and/or online), hands-on tutorials, summer schools and hackathons. The training programmes will be targeted for scientific as well as industry audiences to address the fundamentals of programming on the HPCQS hybrid platform and the development of applications to demonstrate use cases.

HPCQS will also provide support to users within the consortium and external participants. This will include supporting their access and use of the JUNIQ platform. For engagement with external participants, a user group for

external participants from academia and industry will be established. The engagements with the user group will include identification of suitable applications and supporting the development/porting of their applications on the JUNIQ platform.

Another point in the field of training will be the cooperation with the PRACE training centres (where BSC, CINECA, GENCI/CEA, FZJ/JSC and ICHEC play an important role) to develop one of the first (or even the first) joint HPC/quantum training curriculum for the research and industrial communities with the support of all HPCQS partners.

Finally, there will also be cooperation at national level with the newly created EuroHPC Competence Centres (HPC-CC) to foster user engagement and enable industry, especially start-ups and SMEs, to discover, assess and even demonstrate a quantum advantage for their workload.

Sex and/or gender analysis

The project HPCQS consortium is committed to incorporating the principles of gender mainstreaming by using the Gender Impact Assessment (GIA) framework – the official gender mainstreaming tool in the European Union. The work in HPCQS will be fully gender neutral.

HPCQS will work in synergy with PRACE to promote the use (and access) of the QSs by women in scientific careers. An example where this type of synergies can bring a positive impact is the PRACE “Ada Lovelace Award” that is annually awarded to a female scientist making an outstanding contribution and impact on HPC in Europe and the world, and serves as a role model for women who are at the start of their scientific careers.

1.4 Ambition

Advance beyond the state-of-the-art and innovation potential

HPCQS is breaking new ground with the development of the integrated HPC-QS infrastructure. Certainly, for experimental purposes today one can get conditional access to systems of different origins, be it Alibaba, D-Wave, Google, IBM, Rigetti Computing, or IonQ, and first hybrid quantum-HPC calculations as a computer experiment can be performed there. Nevertheless, apart from JUNIQ, which is just taking a first step in this direction, there is no generally accessible infrastructure for practical applications that integrates QCs or QSs into an HPC environment.

HPCQS will create an IT-technology, in which Europe will be ahead of the rest of the world. Here Europe can be first in the field of computer science, which is considered to be “owned” by the USA or Japan and meanwhile China. In none of these countries are there approaches for such deep integration with low latency. Thus, HPCQS opens the opportunity that the innovative integration technology that is being developed will both generate intellectual property in Europe and lay the foundation for a HW-SW industry in this field. What is more, it is generally accepted that quantum computing bears highest systemic relevance for Europe, in an era where self-determination and security of state-of-the-art data processing have become central issues for European science, economy and society.

HPCQS fights the currently observable trend followed by the "hyperscalers" such as Amazon, Microsoft-Azure, Alibaba and IBM, who are on the "best path" towards a monopolistic business model in quantum computing, as known painfully from Google's data services, for example. They are obviously striving to bring their QCs into their data centres "behind the fence", in tight interaction with their own supercomputers. They do not intend to offer their quantum systems for sale, but only to make them available as services.

In marked contrast, HPCQS will create the technology to give European science and industry access to quantum computing in a fully transparent way. HPCQS will offer cloud-based access (QaaS) to state-of-the-art coupled Tier-0 systems with a twin of Pasqal's 100-qubit QSs operated according to the MSA. It will provide a HW-agnostic programming environment (ATOS QLM), optimized middleware (ParTec) and application libraries, and will support end users with co-design, training and expert services.

Moreover, the HPCQS infrastructure is designed to be open to new quantum HW architectures (several companies have already expressed their interest in early integration) and to new sites (such as EuroHPC), making HPCQS an unprecedentedly sovereign European offering in terms of HPC/quantum coupling, architectures supported, number of sites, diversity of users and uses, and integrated services offered.

As the industrial partners of HPCQS and a very significant number of expressions of interest and support from European companies and institutions have stated, this infrastructure will be a beacon for European start-ups and

SMEs in particular to make their technologies available and visible from the earliest stage – in the sense of technology assessment – to a production-class product, thus accelerating the development of their products and improving their competitiveness.

From a technical point of view, the high added value of this project results from the fact that it brings together just the right mix of component technologies such as Pasqal QS, ATOS QLM, ParTec ParaStation Modulo MSA software, available Tier-0 supercomputers, full-fledged data centre environments, interconnected systems, and expertise in algorithms, applications and implementations as well as training opportunities.

From the competence perspective, the HPCQS partners represent a truly complementary mix of HPC stakeholders, quantum HW and SW companies, research labs, start-ups and end-users, coherently aiming to build an innovative hybrid HPC and quantum European federated infrastructure that does not currently exist elsewhere in the world.

Patents and markets

The experts at HPCQS are up to date on the development of leading HPC software, cloud access and platform technologies, compilation and control software for quantum computers and the availability of quantum technologies in Europe and worldwide.

The Pasqal Fresnel QS leverages the potential of neutral atoms trapped in arrays of optical tweezers for QS, targeting more than 100 with CHADOQ2 in 2021 and probably 1000 in 2023. The neutral atoms have proven great potential for quantum simulation, and have gained the interest of science and industry research, in particular as they also have the capability to operate as a QC, i.e. implementing gates and NISQ algorithms. This considerably widens the range of applications and opens very good perspectives for the future, well beyond quantum simulation, to make an impact in the quantum computing market. Pasqal is currently protecting its IP. Three patents are pending, protecting both the path from 100 to 1000 qubits and the software compilation that is required for the QC mode.

The ATOS-QLM is currently the only comprehensive European software package for quantum computers. As a software development kit it is comparable to Qiskit from IBM, which is dealing with quantum computers at the level of pulses, circuits and algorithms, but ATOS-QLM goes beyond this as it is itself an HPC-based quantum computer emulator. ATOS-QLM has a similar position as to Google's Cirq, which tries to expose the details of the hardware instead of pulling them away, because in the field of analog quantum simulators, these details determine whether a circuit can be executed sensibly or not. However, ATOS-QLM is superior in that it starts from strict HW agnosticism and then brings in the HW details. HPCQS is the platform to show that ATOS-QLM will become the European quantum software. There is no doubt that ATOS-QLM has a good chance to participate in the quantum software market in a leading position.

ParityQC holds the patent family around the LHZ architecture EP15174362.2A and all its derived nationalized patents (including US20180218279A1, JP6656273B2, CN107980145A,...). The patents have been filed by the University of Innsbruck and the Austrian Academy of Sciences and have been fully transferred to ParityQC when founding the company. The vision of ParityQC is to keep these fundamental patents in Europe and build a world-wide infrastructure around it. HPCQS will be a considerable step in enabling this goal and help ParityQC to gain in market position.

ParTec's ParaStation Modulo is the unique cluster middleware on the worldwide market that can run the MSA. Thanks to the EU support for the DEEP projects, ParaStation Modulo has reached the right level of maturity to attract the interest of European petascale and exascale sites and will be used in two European infrastructure projects as the basic cluster OS and middleware, including its modularity features. ParTec, as European company, is the owner of the set of patents that became the basis of the MSA and its worldwide derivations. These are P83952PCTUS, P83952PCTRU, P83952PCTKR, P83952PCTJP, P83952PCTEP etc., as well as a few patents around the basic one. The patent protection of the MSA secures the long-term benefit for HPCQS by investing in this technology. Thus, there is a reasonable expectation that this software system will massively gain market share in the future.

As to cloud access, it is very important that HPCQS will gain a foothold in the market, where international competition is significant. While HPC in the cloud is a concept that emerged in the last years with cloud offerings for businesses and scientific communities through hyperscalers, most of the prominent international providers with 90 % of market share that so far offer IaaS, PaaS, and SaaS have already started to offer quantum services over the cloud. This includes Amazon Braket (https://aws.amazon.com/braket/) providing a development environment to explore and design quantum algorithms, test them on simulated QCs, and run them on different quantum HW

technologies; gate-based QCs from Rigetti Computing, quantum annealers from D-Wave Systems, and ion trap computers from IonQ; Azure Quantum (https://azure.microsoft.com/en-gb/services/quantum/), a full-stack, open cloud ecosystem providing a diverse set of quantum services, ranging from pre-built solutions to SW and quantum HW, supporting platforms from 1Qbit, Honeywell, IonQ and QCI as well as leverage Microsoft's Q# language; the IBM Quantum Experience (https://quantum-computing.ibm.com/), a cloud platform offering public access to gate-based QCs with up to 16 transmon qubits and to SW for simulating QCs with up to 32 qubits. Access to QC devices with 20 qubits, available through the IBM Q Network; the Alibaba Cloud Quantum Computing Service (http://quantumcomputer.ac.cn) providing access to a QC with 12 superconducting qubits; Quantum Inspire (https://www.quantum-inspire.com/), designed and built by QuTech in Delft, the Netherlands, providing access to various QC technologies as a QC simulator for simulating quantum algorithms with up to 37 qubits, and to a 2-qubit electron spin and a 5-qubit transmon QC; and Quantum in the Cloud of University of Bristol (http://www.bristol.ac.uk/physics/research/quantum/engagement/qcloud/) providing access to a QS and a four-qubit optical quantum system.

Here, it is again noted that a pure cloud approach to quantum HW is going to suffer from a latency problem that will become unacceptable for practical calculations in the not too far future. HPCQS will therefore promote the deep integration of HPC and quantum HW – being aware that the intrinsic latencies of current QSs are large (200 ms), but are going to be improved – and then offer cloud access to the quantum-HPC modular complex. Most importantly, this will happen under **European legislation**. HPCQS will follow the QC-PaaS pilot implementation of JUNIQ and approach the PRACE Research Infrastructure to support with preparatory and project access based on the federated data infrastructure FENIX, as well as the planned European industry-oriented federated cloud infrastructure Gaia-X. HPCQS is confident that its deeply integrated and HW-agnostic approach will prove superior to the singular offerings of hyperscalers and has the potential to gain market share in the future.

The Portal-based access and the QS-PaaS a user will actually work with at the highest level will be based on the open source Jupyter-Hub technology. It will be joined with a HPC-PaaS via an end-to-end safe UNICORE implementation. On this platform, safe development under European legislation is possible, contributing to the attractivity of HPCQS and bringing the European HPC-QS infrastructure closer to the market seen by SMEs and industry.

2. Impact

2.1 Expected impacts

Overall background and impact

HPCQS brings together two technology areas that are very important for the success of European science and its economic development: Supercomputing towards Exascale as the overall goal of EuroHPC and Quantum Computing, which is supported through the Union by one of its prestigious flagship projects. The QSs will be implemented at the Tier-0 systems hosted at GENCI/CEA and FZJ/JSC and will be federated with two EuroHPC Ppre-exascale sites at BSC and CINECA, as well as ICHEC. The synergy resulting from the interaction of the two areas through HPCQS' deeply integrated HPC-QS infrastructure promises immense mutual benefits, as for the first time an ecosystem for practical quantum-HPC hybrid simulations is emerging that will not only serve but also build a scalable community of European users from academia and industry in a cloud based access mode.

For this purpose, promising technological developments on the HW side of QT – the Pasqal QS – and on the software side of quantum technology – the ATOS-QLM and FZJ's JUNIQ – are combined with new paradigms in the field of supercomputing, like ParTec's modular supercomputing architecture, and will become accessible through advanced cloud technology promoted by PRACE through FENIX on the GÉANT backbone, with the effect of mutual reinforcement of both fields in the international competition of industry and companies.
Furthermore, through the activities of HPCQS, the community building of a pan-European community of HPC-QS experts begins, the impact of which will far reach into Europe's future and will contribute to European sovereignty.

Contribution to expected impacts mentioned in the work programme, under the relevant topic

Contribution to the realisation of the EuroHPC JU's overall and specific objectives
HPCQS considers itself a fervent supporter of the main mission of the EuroHPC Joint Undertaking, formulated in the Council Regulation 2018/1488, Article 3, subsection 1 (Art. 3, 1.). The project will add significantly to the technical development of the integrated supercomputing and data infrastructure of the EuroHPC JU and thus to the innovation and competitiveness of the European HPC ecosystem.

With regard to the EuroHPC JU's overall objectives, HPCQS shall support technology and application development to drive the best possible HPC and data infrastructure by integrating QS into HPC (Art. 3, 2.a). HPCQS follows the JUs ambitious research and innovation agenda as to endow petascale systems, pre-exascale systems and exascale systems with QC/QS capabilities, and in particular looking beyond exascale to new QC technologies (Art. 3, 2.d), including middleware, applications and services for quantum algorithms, the interconnection of HPC and QS systems and adds to know-how and skills (Art. 3, 2.e). HPCQS ensures through its SMEs and industrial partners the adoption and systematic exploitation of the research and innovation results achieved by science and industry (Art. 3, 2.f).

As far as the specific objectives of the EuroHPC Joint Undertaking are concerned, HPCQS contributes to the coordination of the HPC strategies of the Union and the Member States and helps to avoid fragmentation (Art. 3, 3.b). It complements, with the Pasqal QS, the ATOS- QLM and the ParTec MSA, the diversity of the integrated supercomputing and data infrastructure (Art. 3, 3.d) to achieve scientific excellence and to strengthen innovation and global competitiveness, and it addresses users from science, industry and SMEs to tackle data and particularly difficult to calculate problems using quantum HPC hybrid simulations (Art. 3, 3.e). HPCQS follows a strict co-design approach for the development of post-exascale HPC technologies, including the use of QPUs and the development of the appropriate middleware, and follows close integration with HPC leadership environments to promote their adoption (Art. 3, 3.f). It contributes to the strengthening of the Union's supply chain by involving leading European industrial companies (Art. 3, 3.g). In addition, HPCQS will provide pilot demonstrators in the form of two deeply integrated HPC QS systems that are federated and used in a coordinated manner (as twin systems) and federated via FENIX and GÉANT (Art. 3, 3.i) to a core group of five leading European HPC centres (Art. 3, 3.i), and will start to provide QS-based large-scale data applications and services in a wide range of scientific and industrial fields (Art. 3, 3.h). HPCQS networks national HPC centres and European HPC competence centres and intends to increase their participation in the creation of its user hub, thus increasing the innovation potential of industry and SMEs. (Art. 3, 3.j). HPCQS has received more than 30 letters of support, many of them from industry and SMEs. With its dissemination and training plans, HPCQS will build up competencies in quantum HPC hybrid computing (Art. 3, 3.k) and massively expand the scope of HPC use (Art. 3, 3.l).

Contribution to the development of a first ecosystem of hybrid HPC and quantum programming facilities and applications

HPCQS creates the core of the first pan-European quantum-HPC hybrid infrastructure providing Europe a visible position in quantum computing alongside the USA, China and Japan. Starting with the Pasqal QPU providing 100 qubits the HPCQS platform is prepared to integrate promising upcoming HW technologies created in the quantum flagship or through national projects, as for example based on superconducting or trapped ions, including additional hosting sites (WP2). HPCQS will achieve a deep integration of the QS into the HPC system at lowest latency, i.e. in the few µs-range, by using the idea of the MSA realized through ParTec's ParaStation Modulo (WP3). This is an investment in the future of quantum-HPC simulations, as current QS technology still has large intrinsic latency in the order of 100 ms, primarily due to I/O, but is on the way and has large room to improve. HPCQS promotes quantum programming models based on ATOS-QLM as a technology-agnostic solution. This technology can hide the underlying HW complexity (using specific HW optimizers) for programmers and aims at quantum code portability (WP4). HPCQS will co-design several quantum use cases paving the way to broader application engagement from academia and industry (WP5).

Contribution to the next generation of modular HPC systems

HPCQS helps to cope with the increasing complexity of computer systems as well as data and computer applications, such as interactive computing, urgent computing beyond-von-Neumann technologies (quantum neuromorph) or AI. Here, the MSA provides the technical and organisational structures by enabling the connection and joint operation of various specific and autonomous computers connected to each other with a very fast, lowest latency network (WP3/4). In this context, QS is, in a straightforward manner, seen as a new type of accelerator for problems that are difficult to calculate. Through MSA, QS is deeply integrated into modular system complexes, as previously demonstrated by the coordinated execution of disaggregated CPU and GPU systems. With this technology HPCQS will have a major impact on supercomputing architectures beyond 2023.

Providing Europe's scientists and engineers with first experimental facilities to familiarise themselves with quantum technologies and develop the use cases

HPCQS has a wide range of use cases (WP5) that serve two purposes: firstly, to help shape the integration technology for QS and HPC (as created in WP3 and WP4) preparing the experimental facility by developing the use cases and secondly, to bring the first users of HPCQS into contact with quantum HPC hybrid simulations and to support the users from the HPCQS user hub. As HPCQS has the ambition to prepare the gradual integration of

additional quantum technologies at more locations, it will provide a perfect testbed to prepare European scientists to best benefit from quantum advantages, thus dramatically increasing Europe's scientific and industrial competitiveness. For example, HPCQS expects a major impact on quantum chemical simulations not only for the fertilizer industry, but most possibly also for drug screening or design, as this has become so important in the COVID 19 crisis.

European quantum simulation technologies currently being developed by EU projects or by national projects in the Member States

By establishing the first pan-European quantum-HPC hybrid infrastructure with state-of-the-art QS capabilities, provided via cloud access to European researchers from academia and industry, HPCQS expects to have a long-term positive impact on the creation of start-ups developing novel quantum HW, sensor, metrology and isolation/cooling tools/devices or SW environments for programming QC and QS systems or developing end-user applications, which potentially will soon benefit from the quantum advantages. The dissemination and visibility (WP6) of all partner and user activities will motivate European researchers to use the facilities to demonstrate a potential quantum advantage for their applications at an early stage of development. Start-ups will see the infrastructure as a global lighthouse environment to showcase their own European quantum technologies, as is initially the case for Pasqal on the HW side and ATOS-QLM and JUNIQ on the SW side.

Substantial impacts not mentioned in the work programme

Environmental impact

Quantum-HPC hybrid simulations have the large potential to reduce the effective energy consumption for hard-to-compute applications. For QS, energy consumption will be a less dominant factor, while for exascale HPC systems it will be the biggest financial burden. The integration of the QS QPU into a modular supercomputer architecture should make it possible to replace parts of the computations on the classical HPC system with the help of the specialized co-processor to perform quantum-HPC hybrid computations, which should lead to a significant decrease power consumption per solution.

Educational and training impact

HPCQS will provide the perfect platform to extend the activities of the PRACE Advanced Training Course (PATC) (or similar activities in the future EuroHPC course) with quantum HPC hybrid training. HPCQS can motivate the training capacity to be expanded to be scalable with demand. It is expected to attract and apply in the order of hundreds of students during the course of the project and thereafter. Moreover, HPCQS expects a growing number of startups to become interested in training, starting from a few and reaching orders of 10 and more per year after the end of the project. HPCQS expects the EuroHPC competence centres to participate in these activities.

Social impact

It is obvious that the technology required to set up a QS system depends on a broad supply chain. This is where Europe can play to its strengths in its optical industries, which are world leaders, and it is expected that the success of Pasqal QS will trigger further activities in this area. What is more, variant technologies will play a role, and the strengths of Europe in cryo-technologies can be leveraged. Furthermore, HPCQS is confident that its activities will lead to significant employment growth in this high technology sector, both for postdoctoral researchers in academia and for researchers in industry, with hundreds of jobs being created over the next three years.

Market overview of HPC and QC market

The 2017 HPC market was valued globally at USD 34.62 billion. Grandview Research [GrandViewRes17] expects the market to expand at a CAGR of 7.2% from 2018 to 2025. All of the factors needed to drive further HPC are in place, the demand for high-end computing, the unprecedented amount of data being collected and in need of analysis, and trends in major industries within industry, defence, academia, energy, and utilities.

In addition to the HPC market, many companies and governments see a strong potential and strategic dimension in quantum computing. Currently, the overall market consists of roughly 200 QT companies worldwide including a number of big players, but also many start-ups offering highly specialised products and services in niche markets. Technology leaders from the U.S. (e.g. Google, IBM, Intel, Microsoft, etc.) and from China (e.g. Baidu, Alibaba, Tencent, etc.) are investing in the development and use of quantum computing technology. Market analysts (e.g. Tractica, Statista, BCG, Morgan Stanley and others) predict a strong growth within the QC market in the next 10 years – anywhere between 10 and 25 billion USD. A broad range of industries (e.g. Automotive, Aerospace, Health, Pharma, Financial Services, Engineering, Chemical, Media & Gaming, Geology, etc.) as well as large, medium and small enterprises can apply and benefit from quantum computing. The estimates indicate that QS technology with its present lead against QC has very good chances to participate in this market at an early stage.

Impact on market opportunities and growth of companies in relevant application areas

By making HPC and QS resources publicly available in a secure way, HPCQS aims to enable large companies and especially SMEs to increase their innovation capacity and speed by exploring the potential of the offered technologies for the companies' applications. Small and medium-sized enterprises (SMEs) as the backbone of Europe's economy represent 99% of all businesses in the EU. It is particularly important for high-tech SMEs in all sectors to adapt their products and services to ever higher performance requirements (fast maturity calculations, increasing data volumes) in order to secure further financing and remain competitive in the relevant markets. At the same time, however, they do not have the opportunity to purchase expensive in-house solutions or to access expensive external infrastructures and services. Contacts made by HPCQS with SMEs during the application phase in preparation for the establishment of the HPCQS User Panel have revealed a great interest in the HPCQS infrastructure and services of SMEs from a variety of sectors such as software development, aerospace and defence or health and life sciences. This shows the existing demand, but also that the expected impact is high.

Enhancing *innovation* capacity; creating new market opportunities, and strengthening competitiveness and growth of companies

Specifically, HPCQS will have a direct impact on the market opportunities and market growth of HPC and QT companies that are partners in HPCQS, i.e. ATOS, FlySight (FLS), PASQAL, ParTec and ParityQC (see part B2.2 for details on their usage expectations). In general, HPCQS is expected to enhance Europe's innovation capacity and create market opportunities in various segments. On the one hand, it will support the stakeholders in the relevant technology areas, i.e. the European quantum technologies and in particular in the quantum computer market as well as the European HPC players. On the other hand, HPCQS will help to create opportunities for potential end-users of technologies in a wide range of application areas, such as equipment manufacturers, tool developers and service providers, who will be able to develop tailor-made products at higher speed, i.e. speed up the time to market, which will give them a competitive advantage in the coming years.

Barriers/obstacles and framework conditions determining impact achievements

HPCQS is embedded in the HPC environment of five major supercomputer centres in Europe, namely BSC, CEA, CINECA, JSC and NUIG-ICHEC. These centres have extensive experience as user facilities in terms of authentication and authorisation for access to the facilities. The federation through FENIX is already running at two of these sites and will be completed during 2020. NUIG-ICHEC is a further candidate for federation through FENIX, and the entire infrastructure will be expanded further with new partners. On top, FENIX runs on the GÉANT backbone enabling a petascale data exchange across Europe. Together with the browser-based cloud access to the quantum-HPC hybrid system, users will be offered a highly convenient and effective, but technically very secure mode of use. HPCQS does not foresee any difficulties from the technical side, still the providers at GENCI/CEA and FZJ/JSC are prepared to act quickly in case of problems.

Regarding the effective use and exploitation of QCs/QSs, nine partners of HPCQS are active in the Quantum Flagship Governance and in research and outreach activities – FZJ, UIBK, Pascal, ATOS, Eurice, CEA, CNRS, CNR, NUIG-ICHEC. For example, users can receive high-level support from the JUNIQ Simulation and Data Laboratory for Quantum Computing at FZJ/JSC. Scientists from research centres and industry, CEA, NUIG-ICHEC, FZJ, CNR, CNRS, UIBK, INRIA, Fraunhofer IAF, BSC, CINECA, FLS, Pasqal, ATOS and ParityQC will form a powerful competence group that can be contacted by future users in case of obstacles and will itself exchange best practices and experiences.

As far as scientifically peer-reviewed access is concerned, HPCQS will ask PRACE for support. Here different access modes will be provided, so that from code development to large scale production, European users from EuroHPC member states will be granted access governed by the rules of the different access modes to be mandated by the EuroHPC governing board. All this taken together will keep barriers and obstacles for users low.

Yet one can and must anticipate potential obstacles and barriers for users and foresee corresponding risk mitigation measures:

- ***Technical limitation.*** Current execution parameters of Pasqal QS amount to about 200 ms to execute a simulation task, with an ensuing repetition rate of 5 Hz. Most of this time is spent on register preparation (100 ms), readout (10-50 ms), while the actual simulation takes only a few µs. It is obvious that these machine specific numbers must be reduced to the few ms-level during the project, otherwise quantum HPC-hybrid simulations would not be scalable given the huge speed of modern supercomputers. It is emphasized that this requirement applies to any type of quantum computer. Optimization of low-level APIs, the ATOS-QLM access technology and the ParTec MSA will help improve this situation.

- ***Industrial adoption.*** Currently, industry expectations for QC (and QS) are very high, but there are few algorithms with proven quantum acceleration. This places high demands on the success of the methodologies of HPCQS use cases such as optimization, machine learning and linear algebra. Here real quantum acceleration is still very speculative. Of course, this is the general risk of such potentially disruptive technology with promising theoretical anticipations - made with pen and paper - but this situation calls for exactly the strategy of HPCQS, namely to put QS into practice. The earlier the industry is aware of the real benefits to be expected, the better.
- ***Public acceptance.*** The current public attention to quantum computing could become a short-lived hype. The communication and dissemination plan of HPCQS is therefore aimed at reaching the public with reliable information so that quantum computing is not misunderstood in one direction or another. It is evident that continuity of future funding for the extension of the efforts to many European sites is mandatory.
- ***Entry barrier for using hybrid quantum-HPC simulations.*** At present, the quantum-classical hybrid simulation workflow is still in its infancy. HPCQS has the potential to advance its implementation and use. The development and sharing of use cases and prototype applications is a practice of collaborative innovation. Early and easy access to different implementations of the new workflows is crucial in the innovation process. HPCQS will therefore work with user communities to provide training programs aimed at educational, scientific and industrial audiences, covering the basics of programming on the HPCQS hybrid platform and the development of use case demonstration applications.

2.2 Measures to maximise impact

a) Dissemination and exploitation of results

HPCQS aims at developing, deploying and coordinating at European level a European federated infrastructure integrating a QS of circa 100+ interacting quantum units in an HPC system of the supercomputer centres FZJ/JSC and GENCI/CEA. The infrastructure will be accessible via the cloud to public and private European users, on a non-commercial basis. Based on a diverse set of use cases, developed in co-design with the HW integration, HPCQS will identify and address the key challenges of building an ecosystem in the field and user community.

Due to the significance of the dissemination and exploitation activities in achieving the ultimate goal of the project HPCQS manages and coordinates its diverse dissemination activities through a dedicated work package (WP6). There will be a close collaboration with WP5, which will deal with user engagement and training activities. In order to maximize the impact of its results, HPCQS will engage in a diverse set of dissemination and exploitation activities throughout and after the duration of the project.

Draft plan for the dissemination and exploitation of project results

Centralised and early planning of innovation management, i.e. communication, dissemination and exploitation activities ensures clear follow-up of actions and provides transparency to the consortium. Thus, innovation management in HPCQS will follow a multidimensional, customized and impact-oriented approach, aiming to achieve optimal visibility for the project through professional and targeted communication measures, and through structured dissemination and exploitation activities, to fully utilize the project´s innovation potential. To facilitate distinction of the terms communication, dissemination, and exploitation, Figure 2 shows the definitions described in the EC “Rules for Participation”, as well as the measures that will be taken to maximize the impact of HPCQS by each activity type.

Figure 2: EC Guidelines on Dissemination & Communication Activities.

Target audiences for communication and dissemination

A 'Plan for the Dissemination and Exploitation' (PDE) is established. The PDE contains measures describing the area where HPCQS makes an impact and lists the potential users of the results as well as the channels proposed for interaction. The PDE contains a list of Key Exploitable Results (KER) that are clearly defined, an exploitation strategy for each KER, and a lead partner responsible for the implementation. The PDE includes a stakeholder and user inventory (i.e. target groups and organizations for HPCQS dissemination measures) to be updated continuously during the project's lifetime. As primary groups, HPCQS will address stakeholders for different applications, i.e. the HPC research community as well as users from a wide variety of industry segments.

A systematic stakeholder analysis will be carried out within WP6, under the lead of project partner EURICE, and guided by the Communication Board. The **Communication Board** (EURICE, FZJ, further members to be included if need be) will safeguard guidance, content production and quality assurance for all communication measures. Such approach has proven extremely useful for an adequate, effective and efficient involvement of the wider stakeholder groups, both for targeting dissemination and communication actions, as well as exploitation strategy development. The stakeholder analysis will also help to bring new players to HPCQS to support the community and ecosystem building.

Dissemination of project results

The strategy for dissemination of results will involve diverse activities using multiple channels to deliver clear and consistent messages to a great variety of audiences, thereby maximizing the promotion of the project and its impact. The strategy aims in particular at knowledge transfer and training, scientific publications, contribution to standardisation and open source contributions.

Strategy for knowledge management and protection, incl. Open Access

Consortium agreement: The DESCA Consortium Agreement (updated according to the H2020 guidelines) is intended to be used as the basis for the HPCQS Consortium Agreement (pending final agreement by the legal departments of the consortium partners.) It will address aspects related to (amongst other things) the dissemination of key knowledge, IPRs, etc., thereby allowing partners, collectively and individually, to pursue market opportunities arising from the project's results. The appropriate structure of the consortium to support exploitation is addressed in section 3.3.

Open Access for knowledge management and protection: Open access to scientific information is expected to bring benefits in terms of:

- Acceleration of the research and discovery process, leading to increased returns on R&D investment;
- Avoidance of the duplication of research efforts, leading to savings in R&D expenditure;

- Enhanced opportunities for multi-disciplinary research, as well as inter-institutional and inter-sectorial collaborations;
- Broader and faster opportunities for the adoption and commercialization of research findings, generating increased returns on public investment in R&D and the potential for the emergence of new industries based on scientific information.

Journal Open Access publications

The coordinator will encourage the timely publication of results in leading peer-reviewed journals to maximize outreach to the scientific community. A publication strategy, detailing e.g. publication rules, selection of journals, review processes, guidelines on authorship and acknowledgements will support publication activities and avoid delays due to unclear responsibilities. Appropriate resources for Open Access are ensured in the budget to safeguard free access to project results to the widest possible readership. As for the Golden route, the publications will be made available Open Access directly at the publisher. A publication fee is required in this case (for most of the publishers); this will be covered by the Author Institutions. Additionally, for the main publications Zenodo or an equivalent tool will be used to upload original data files as well as Metadata showing the data analysis procedure. The partners have discussed possible publications and working titles for the publications that will result from the project's activities are shown in Table 3.

WP	Topic of expected publication	Lead partner acronym	Possible partner(s) in joint publication	Target journal(s) if appropriate
WP2	Blue-print of a European "Quantum Infrastructure as a Service" (QIaaS)	FZJ	All	ACM or book
WP2	First tight integration ever of a quantum processor in a supercomputing center	GENCI	CEA-TGCC, Pasqal	ACM
WP3	Enabling quantum-hybrid simulations and workflows on the MSAs	ParTec	Atos, FZJ, CNR	Science, ACM, Comp. Phys. Comm.
WP3	Cloud-based integration of QS in modular HPC infrastructures	FZJ	Atos, ParTec	IEEE, ACM
WP3	Optimised resource scheduling in hybrid HPC/QS	CNR	ATOS, ParTec, FZJ	Nature, Science, ACM TQC
WP4	Quantum Approximate Optimization Algorithm with k-body constrained optimization problems.	ParityQC	UIBK, ATOS, Pasqal	Nature, Science, PRX
WP4	Noise modelling and emulation of large-scale quantum systems	ATOS	NUIG-ICHEC, CNR, Pasqal	Physical Review A, PRX
WP4	Scientific publication on controllability in variational algorithms	UIBK	FZJ	Phys. Rev. A., PRX
WP5	Reconfigurable workflows for large-scale quantum simulations of physical systems	NUIG-ICHEC	UIBK, ATOS, CNR, CINECA, ParityQC, PASQAL	IOP Quantum Science and Technology, PRX Quantum
WP5	Simulation of many-body quenched dynamics using a QS	NUIG-ICHEC	UIBK, ATOS, INRIA, Pasqal	Nature, Science, PRX
WP5	Full benchmarking of a 100-qubit QS	CEA	CNRS, FZJ, Pasqal, ParityQC	Nature, Science, PRX
WP5	Adoption and use of HPCQS platform and technologies by scientific and industry users	NUIG-ICHEC	All partners	White paper
WP5	Scientific publication on QAOA with Rydberg tweezers	UIBK	Pasqal, FZJ, ParityQC	High level scientific journal

Table 3: Overview of planned publications from HPCQS project.

Website

The website will be the main communication tool developed in HPCQS and will be implemented and updated all along the project duration with two separate areas: private (addressed to project partners and also including a

specific section for Stakeholder Groups) and public (addressed to other target audiences). The website will publish on a regular basis the current status of the project and main results obtained, in a popularized format. The website will also offer an agenda for coming events where HPCQS partners will be present. In addition to the project website, this content will be published via various EC innovation union channels. Project partners and stakeholders, especially related projects and initiatives, will help Communication, dissemination and exploitation managers by providing the most complete list of websites where HPCQS content can be published.

Dissemination and communication material
Approximately 1,000 leaflets distributed at annual conferences, see table 4 below. In all those conferences there are typically >200 attendees. E-brochures will also be provided to the full list of attendees. Specific press releases will be delivered to the target General Press, issued to national and international media at the start, mid-term and end of the project to inform the public. A non-confidential presentation will be made available of the project and sent to the target groups previously identified. Press releases are typically done by EURICE with the whole consortium contribution on the various topics (project progress, outstanding results, attendance at the conferences and events, industry engagements etc.

Web Tutorials At least two online training sessions explaining central features and functionalities developed by HPCQS will be organised and promoted within the scientific and industrial community.
Audio-visual material: In order to increase and support public outreach, an animated video to explain key features of HPCQS and its impact will be produced. These activities will be coordinated by EURICE with the coordinator and other key partners. The material will be released on the project website and further promoted through e.g. social media platforms.

Social Media The Communication Board together with additional project members already active in social media will develop a sound social media strategy considering the most appropriate platforms, e.g. LinkedIn, Twitter, ResearchGate and best use according to the project's objectives.

Networking with the scientific community and standardisation bodies
All partners will participate in national and international conferences and fairs to present their project results through oral presentations, posters and personal discussions. Partners will plan participation in major conferences in the field in terms of appropriate format (individual talk, HPCQS session, booth), project representatives at events, and materials needed (leaflets, posters, demo, booth set-up).
In addition to the participation in scientific conferences and scientific events, networking with the scientific community will comprise liaising with other related projects, particularly EU-funded initiatives, as outlined above.

Data
Data that is generated during the project will be made available as open access data via the EUDAT services and FENIX. This could include raw data of benchmark tests, instances of optimization problems or calibration data.

A preliminary Communication Activity Plan (CAP) has been set up by the partners in Table 4.

Activity	Dissemination objective	Target audience	Month	KPI
Conferences				
ISC-BoF on cloud-based digital science and engineering	Raise awareness, find partners and collaborators	Industrial end users, European cloud-providers, EuroHPC centres	M12	50 participants, 4 follow up-activities
Super Computing (**SC**) and International Super Computing (**ISC**) conferences	Raise awareness, knowledge transfer	Scientific communities	M12 - M48	at least 3 presentations at relevant conferences
Presentations at **industry conferences** (e.g. pharmaceutical, automotive, aerospace, chemical, financial industry) or global (TERATEC)	Raise awareness, demonstrate business potential	Industry and public sector	M12 - M48	at least 3 presentations at relevant conferences
Presentations, BoFs and workshops at European Quantum Technologies Conference (**EQTC**)	Raise awareness, knowledge transfer, training, demonstrate business potential, attract potential customers, cross-	Academic, industry and public sector	M12 - M48	at least 3 presentations, and 3 BoFs or workshops

Activity	Dissemination objective	Target audience	Month	KPI
	fertilisation between academic and industry research			
Adiabatic Quantum Computing Conference **AQC**	Presentation of project results, attract potential customers and researchers	Industry and academia.	M12-M48	200 participants, at least 2 presentations and 2 posters.
Specific working groups				
Workshop within **Bitkom Working Group High Performance Computing & Quantum Computing**	Raise awareness, knowledge transfer	Industry, policy makers	M18	50 attendees from core stakeholder industry and policy maker group
Workshops for Expert Advisory Group of **Quantum Programming Ireland (QPI) Initiative** by NUIG-ICHEC	Raise awareness, knowledge transfer, training, demonstrate business potential, attract potential users	Academic, industry and public sector	M12 - M48	50 attendees from core stakeholder industry and policy maker group
HPCQS Webinar				
Webinar on "How to use Quantum Simulators, integrated in an HPC environment, for hybrid quantum-classical programming "	Raise awareness, interest potential customers, knowledge transfer	Industry, Public Sector, SMEs	M24	100 virtual participants
Institutional workshops and events				
FZJ - JUNIQ meetings, training events and visits	Education and knowledge dissemination about algorithms and prototype use cases, cross-fertilization between academic and industrial research	Academia & industry	Diverse TBD	At least 50 attendees
NUIG-ICHEC - Quantum Programming Ireland (QPI) Initiative meetings, training events and visits	Education and knowledge dissemination about algorithms and prototype use cases, cross-fertilization between academic and industrial research	Academia, industry, public sector	Diverse TBD	At least 50 attendees
Networking & Exchange with relevant infrastructures and projects				
EOSC Symposium or EuroHPC Summit Week & PRACEdays One of the largest, yearly EOSC events, including relevant Working Groups (Architecture, FAIR, Landscape, Rules of Participation, Sustainability)	Raise awareness, demonstrate business potential, knowledge transfer	Scientific Community, public e-infrastructures	M12	200-300 participants
Workshop at **European HPC projects** and initiatives (e.g. **ETP4HPC, EuroHPC-related coordination actions**, etc.)	Generate future research and innovation projects, knowledge transfer strengthen European high-end computing community	EC, Scientific community and Industry	M18-24	at least 2 workshops conducted
Engagement activities with H2020	Community building	Scientific	M12-M24	at least 2 joint

Activity	Dissemination objective	Target audience	Month	KPI
project SLICES-DS	European integrated testbed for Digital Sciences	Community, public e-infrastructures		sessions HPCQS / SLICES-DS co-located with project meetings

Table 4: Overview of planned dissemination activities – Initial CAP.

HPCQS exploitation

The work plan foresees a number of results that will be exploited by one or several partners in the consortium. Table 5 summarizes the expected Key Exploitable Results (KER), together with the partners foreseen to exploit the results, target groups and respective envisaged (preliminary) exploitation models for commercialisation as products and services. Further research and development, as well as capacity building and teaching aspects will also be taken into account and will be further elaborated in the PDE.

No	Description		USP/Comparison with potential competitors	Exploitation route	Target customers/segment
	Lead partner	Collaborators			
1	**Optimization Webinar**		Demonstration of solving optimization problems with the HPCQS Stack. Complete workflow compared to competitors	Training	Large to Mid-Scale companies with interest in QC
	ParityQC	All			
2	**Optimization Demonstrator**		SW package that demonstrates how to solve an optimization problem with the HPCQS stack	Service	Companies as well as interested individuals
	ParityQC	All			
3	**Programming a QS, leveraging ready-to-use libraries**		Ready to use libraries, targeting real use cases	Training and service	Large to Mid-Scale companies with interest in QC
	Pasqal	All			
4	**Full emulator of the QS**		Scalable and related to real HW	Training & further R&D	Large to Mid-Scale companies with interest in QC
	Pasqal	CNR, NUIG-ICHEC, ATOS			
5	**Simulator Benchmarking**		HW	Further R&D	
	Pasqal	CEA-DRF, CNRS, FZJ			
6	**A QS ready for a plug & play integration within a HPC**		> 100 qubits, plug & play	Product	HPC integrators and operators, providers of HPC in the cloud
	Pasqal				
7	**A full stack quantum programming platform for writing, optimizing, simulating and executing analog and digital quantum program on quantum accelerators in a HPC environment**		HW-agnostic programming, HW-specific compilation, and noisy simulation of large QCs	Product	Academic and industry customers, HPC centres, R&D partners
	ATOS	NUIG-ICHEC			
8	**Middleware for MSA systems comprising QS, enabling quantum-hybrid simulations and workflows**		Tight integration of the Quantum Computing/Simulation and HPC domains	Product	Academic and industry customers, HPC centres, R&D partners
	ParTec	FZJ, NUIG-ICHEC			

Table 5: Overview of exploitable results.

Business case and sustainability planning for HPCQS

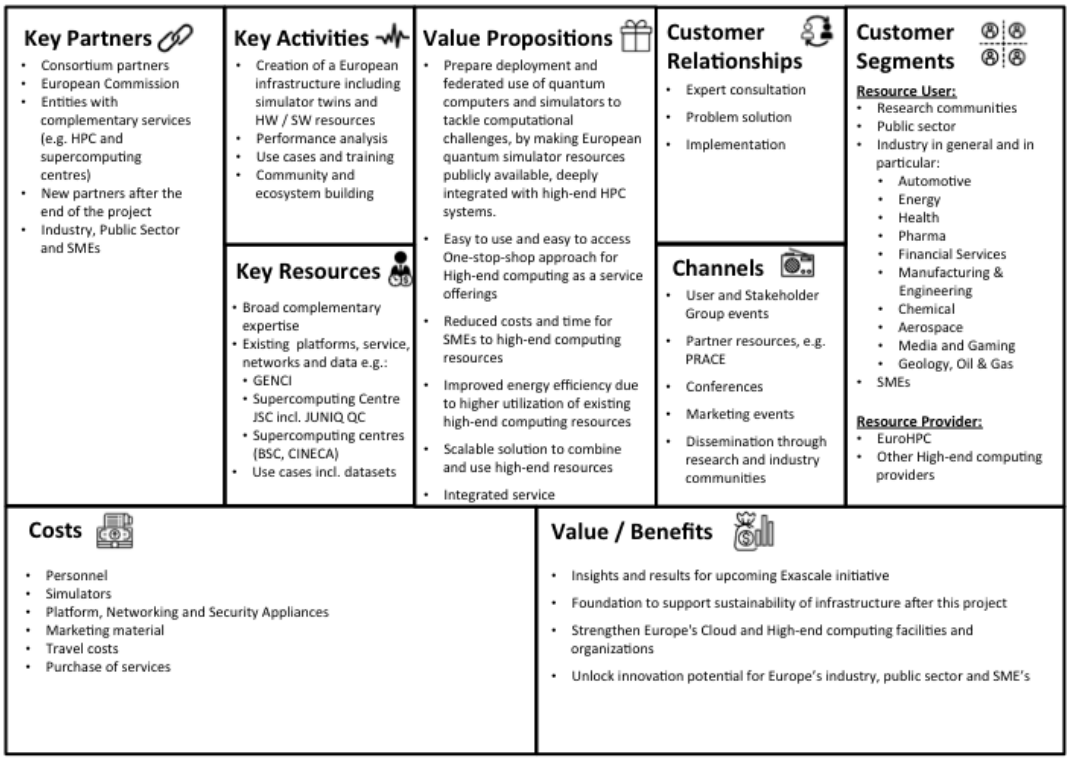


Figure 3: HPCQS Business Canvas

HPCQS market characteristics

HPCQS targets HPC research communities as well as large enterprises and small and medium-sized businesses leveraging high-end computing to solve practical problems. This includes companies who plan to use high-end computing for their own computing challenges as well as integrators of the offering. As an example: FZJ currently provides access to its supercomputers mainly to traditional HPC user communities in the public research and academic sector. The results of HPCQS will enhance the attractiveness for new user communities, both from the private and public sector, that are not accustomed to today's HPC provisioning and usage models.

HPCQS target customer groups

The HPCQS target group can be split into two main groups (see Figure 3): high-end computing resource providers and users. HPCQS helps resource providers to integrate and offer their resources to a broader range of customers via a high-performance, secure network and public cloud interface and most importantly to allow a high number and broad variety of customers to easily access high-computing resources in an easy, convenient and secure way. Almost all industries can benefit from high-end computing services. Currently, there is a strong growing demand from the automotive, aerospace, healthcare, chemical and manufacturing industry as well as from the scientific area. Customers use these resources either to solve their own computing and analytics challenges or they use it in order to offer a new or improved service for their clients.

Business case ParityQC (service provider)

ParityQC provides ParityOS, a quantum algorithm compiler and optimizer as a SaaS solution. The HPCQS project will allow ParityQC to reach new markets, develop a user-base and implement a scheme for user engagement. HPCQS will be of considerable importance for ParityQC to establish ParityOS as a viable tool within the European quantum computing community. Due to this long-term perspective ParityQC will provide all developed tools required for HPCQS as an in kind for the duration of the project.

Business case ParTec (service provider and HPC specialist)

ParTec Cluster Competence Center GmbH, one of the leading SMEs in the HPC domain in Europe, is the specialist for modular supercomputing and partner of choice in some of the largest supercomputing sites across Europe.

Together with FZJ, ParTec developed the concept of Modular Supercomputing since 2010 in the series of DEEP projects, and has since then brought it into production. ParTec will integrate the suitable features of the developed software components developed especially in WP3 into the ParaStation Resource Management as well as the ParaStation MPI components of the ParaStation Modulo software stack. This will allow HPC centres to offer modular systems enabling efficient execution of quantum-hybrid simulations and workflows.

Business case Pasqal (equipment manufacturer)

Pasqal was incorporated with the vision of leveraging the neutral atoms technology to build a QPU that would be hybridized with CPUs, like a GPU would do. Pasqal identified the QS as the most promising QPU in the near term. The HPCQS project is perfectly in line with Pasqal's vision and, as a consequence, will considerably speed up its developments. On the one hand, the concept of the "hybrid-QS" will be designed and implemented in its real environment, as a blueprint of a real product. Because of Pasqal's becoming a partner in HPCQS, Pasqal will be able to launch its QPU much more rapidly. On the other hand, HPCQS will also bring Pasqal a lot of visibility, thereby reaching a large fraction of the HPC end-users' community. This is key for a fast time to market and for developing use cases with potential customers. All these assets will finally help Pasqal to secure its funds raising.
Once the project is over, it is possible to foresee upgrades that will extend the lifetime of the pilots and enhance their performances and functionalities. Pasqal will indeed implement a full R&D plan during the timeline of HPCQS and the results could be transferred, under conditions to be determined, to the Fresnel devices. On one hand the number of qubits could be extended to a several hundred (200-300 range), with improved quantum control. On the other hand, the digital mode of the device could be activated, opening a new field of applications and increasing the traction of the facilities. Having two simulators integrated in HPC centres is definitely not the end of the quantum journey. Choosing the neutral atoms technology is of strategic interest to hit the ground running for the coming 10 years that will position Europe as the major player of the field.

Business case ATOS

ATOS, a HPC manufacturer and IT services provider, has been developing the Atos QLM since 2016 with the goal of helping its customers in Europe and elsewhere (academic laboratories, industrial groups, HPC centres) harness the power of quantum computing. The advances expected within HPCQS will allow for a further enhancement of the capabilities of the Atos QLM, most notably for programming, optimizing and executing quantum computations on analog QPUs. This will thus lower the adoption barrier between industrial use cases and the most advanced quantum HW. Furthermore, the new features developed e.g. in WP3 will help ATOS HPC customers to test and to adopt hybrid quantum-classical HPC infrastructures.

Sustainability via GENCI

In the upcoming French Quantum National Plan and upon request of three ministries (Research, Defence and Finance) GENCI, the French HPC agency (owned by French Ministry of Research, CEA, CNRS, Inria and all the French Universities) will setup and expand a national quantum computing infrastructure, operated by CEA/TGCC (in the south of Paris) closely integrated with its current Tier-0 and future Exascale system.

The infrastructure will progressively offer access to various QTs (neutral atoms, silicon spins based quantum systems, superconductors, self-correcting qubit allowing universal error-free quantum compute, etc.), SW (ATOS QLM, application libraries, etc.) and services (training, enabling, support) to French researchers from academia and industry for addressing scientific and societal grand challenges.

This infrastructure will be deployed / integrated together with similar initiatives in Germany and beyond in Europe. Around this infrastructure researchers teams from academia (CNRS, CEA, INRIA, Universities, labs in aerospace/aeronautics, energy, health, materials, security/communications…) and industry (energy, oil & gas, heath/medecine, finance/insurance, transport/automotive, chemistry, etc.) will co design the next generation of hybrid quantum-HPC applications.

Sustainability via JUNIQ

The JSC (FZJ) is currently setting up the QC user facility JUNIQ. JUNIQ already offers European users from science and industry support and access to the world's most powerful simulator code for QCs and QTs, JUQCS[2], running on the Jülich supercomputers, and to the QLM-30 (ATOS) as well as to the 5000-Qubit D-Wave quantum annealer, which will go into operation in FZJ in 2020. The prototype QC with superconducting qubits of the OpenSuperQ project in the European Quantum flagship will also be integrated in FZJ, and more will follow.

JUNIQ naturally makes HPCQS' dissemination and exploitation initiatives sustainable: FZJ has set up a Simulation and Data Laboratory (SDL) for JUNIQ, consisting of quantum and computer scientists and mathematicians. The

SDL will provide help to translate practical problems into algorithms that can be performed on QCs and quantum annealers and develop tools that can help mapping scientific and industrial applications into the quantum domain. This will be done in cooperation with the users and device providers. The SDL will pursue algorithm and end user SW development, organize meetings, training events and visits for the efficient and rapid exchange of knowledge, and help accelerate cross-fertilization between academic and industrial research.

Usage of and therefore also education and knowledge dissemination about the various quantum computing devices are key elements in JUNIQ. For this purpose, FZJ established EQUIPE, a user group to Enable Quantum Information Processing in Europe. The mission of this user group is to promote the exploitation of QC technologies for scientific and industry oriented research, such as optimization and ML. FZJ and partners intend to mutually exchange experience with this new computing technology, use computing time on a future diversity of HW, use joint potential, jointly organize conferences and workshops and create a basis for obtaining funding, etc. Currently, about 30 European research organizations and companies have expressed their interest.

Extension of the infrastructure and services

Following the initial results, it is expected that the infrastructure provided by HPCQS will be extended with new QC/QS technologies (such as those identified in the joint monitoring activities carried out by WP2) and additional hosting sites (such as those provided by the EuroHPC Joint Undertaking from 2021). The integration of quantum-based computing partitions into future EuroHPC exascale systems (and beyond) is foreseen.

Research data management

The research data management (RDM) strategy for HPCQS will address both the project data collected as part of its management and execution, as well as data used as part of the scientific deployments and use cases in the context of the project HPCQS. As such, the RDM strategy will focus on data sharing and re-use and in particular for the following aspects:

- What types of data will the project generate/collect?
- What standards will be used?
- How will data be exploited and/or shared/made accessible for verification and re-use?

HPCQS will use a set of modern guidelines based on the “Practical Guide to International Alignment of Research Data Management provided by Science Europe. The aim of the initiative was to develop a set of core requirements for data management plans (DMPs), as well as a list of criteria for the selection of trustworthy repositories where researchers can store their data for sharing. In light of the current development of the EOSC and an increasing tendency towards data sharing that HPCQS wants to actively promote, these requirements and criteria will help to harmonise the data management aspects of the HPCQS use cases. More broadly, they will contribute to the alignment and standardization of data management practices throughout Europe.

The HPCQS consortium participates in the pilot study on Open Research Data in H2020. A detailed first version of the DMP will be developed within the first 6 months of the project. The purpose of the DMP is to explain the provisions both for project data and the general approach for use case data, and produce an analysis of the main elements of the data management policy that will be used by the consortium. It will be consistent with the exploitation and IPR requirements as to be detailed in the Consortium Agreement.

The DMP covers the project data during the length of the project to cover the complete research data life cycle. It describes the types of research data that will be generated or collected during the HPCQS project, the standards that will be used, how the research data will be preserved and what parts of the datasets will be shared for verification or reuse. The DMP will consist of a living document to be updated throughout the project, whenever significant changes arise, such as new data to be included, changes in the consortium policies or consortium composition. The expected types of research data that will be collected and/or generated as part of HPCQS comprise the following data sets and categories (see Table 6):

Data Description	Work Package	Participants	Data Size	New or Existing
Quantum Simulator results	WP5	ATOS, BSC, CEA, CINECA, CNR, CNRS, FLS, Fraunhofer-IAF, FZJ, INRIA, NUIG-ICHEC, ParityQC, UIBK	~1-10 GB	New
Workflow scripts for use cases	WP5		<10 KB	New
Database of random generated use	WP5	ParityQC	~100 MB	New

cases for benchmarking				
Random generated synthetic data for machine learning	WP5	CNRS, CNR, FLS	<100 KB	New

Table 6: Overview of Data used in HPCQS.

For all research data the FAIR (Findable, Accessible, Interoperable and Reusable) principles in data management will be applied as broadly as possible.

When applicable, after analysis and publication (and/or patenting), the data will become publicly available as soon as possible. All data to which access can be granted will be deposited in appropriate public online data repositories. The HPCQS website will contain a private part (intranet) to exchange information such as reports, paper reprints, standardized protocols, and raw data, and will provide links to public data at all online repositories.

IP Management and exploitation framework

A Consortium Agreement (CA), based on the DESCA Horizon 2020 Model, will be elaborated and approved among partners. The ground-rules are the following:

- **Ownership of Results**: shall be the property of the contractor generating it. Where several contractors have jointly carried out work generating the knowledge a joint ownership of that knowledge shall be established by a Joint Ownership Agreement.
- **Confidentiality**: during the project execution, the partners shall treat any project information as confidential, which is designated as such by a disclosing partner. Partners shall apply the same obligations to employees and suppliers.
- **Dissemination**: any publication or communication proposed by one of the parties, regardless of the media, in connection with all or part of the project and of the knowledge is required to be submitted for the prior written consent of the Steering Committee of the project. Prior notice shall be given at least 45 calendar days before the publication, and any objection is to be formulated within 45 calendar days after receipt of the notice.
- **Use and dissemination**: as long as dissemination of results does not adversely affect its protection or use and subject to legitimate interests, the partners shall ensure further dissemination of their own results knowledge as provided under the Grant and the CA.
- **Background knowledge**: each partner is and remains the sole owner of its intellectual and industrial property rights over its background knowledge. A list of background knowledge over which they may grant access rights for the project is included in the CA.

Professional IP and innovation management measures will guarantee that exploitable results will be properly captured, protected and assessed, and pursued appropriately both on the individual partner level and collectively as the consortium. EURICE has been involved in the European IPR-Helpdesk project since 2005 and is currently coordinating the ‘IP Helpdesk’ project (2019 – 2021), which provides free-of-charge first line support services on IP issues to projects funded under the Research and Technological Development framework programmes. EURICE is specialised in managing impact and innovation and will provide fair, transparent and independent innovation-management decision-making support. The customized IP Management and Exploitation approach in HPCQS uses established tools to develop and implement successful IP & exploitation strategies. Activities are organized in two fields, (Figure 4), with ‘Capacity building and strategy validation phase 1’ and ‘Strategy and validation phase 2’, and aligned to the HPCQS work plan.

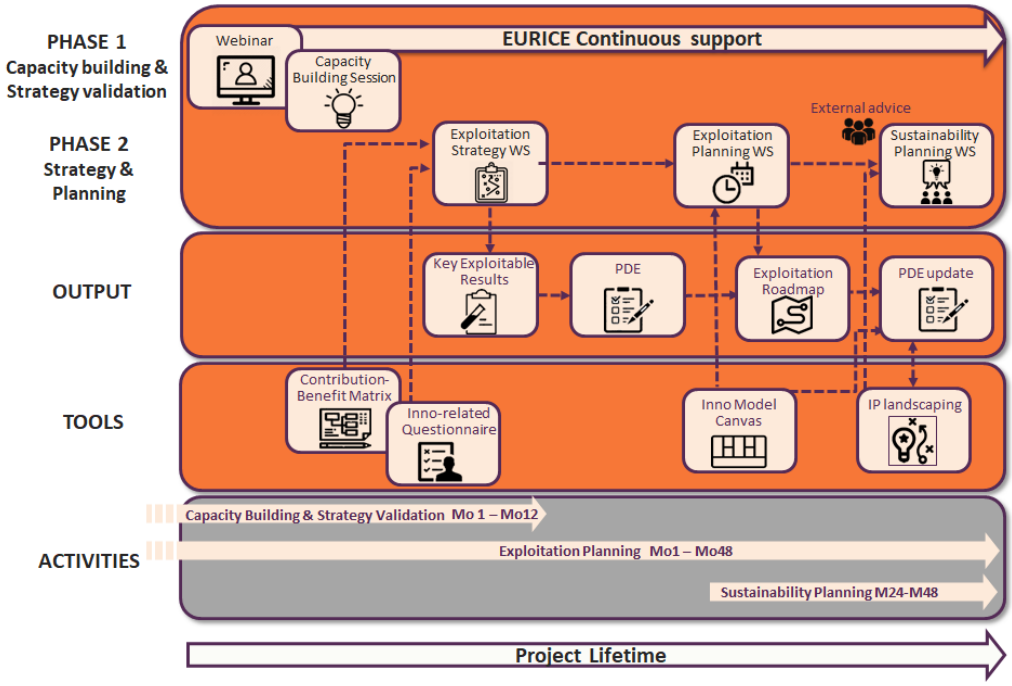


Figure 4: customized IP Management and Exploitation approach

Webinar. A Webinar recalling the rules for IPR in H2020 will be held to ensure a common basis of understanding regarding the general conditions of IP Management in H2020 among all HPCQS partners. This will be valuable in order to validate and refine initial exploitation plans made at the proposal stage.

Capacity building session. A capacity building session to further elaborate on this topic and to raise awareness of innovation in H2020 and to deepen the understanding of specific IPR topics relevant to the project, such as open innovation vs. proprietary IP.

Contribution-benefit matrix(es) (CBM) will help to visualize partner interactions, contributions and dependencies, and strengthen the development of responsibilities and commitments among partners.

Innovation-related questionnaires (IRQ) will be used to assess exploitation strategies at partner level.

Exploitation Strategy Workshop. The workshop will be used to consolidate findings gathered by the CBM and IRQ, to develop exploitation strategies at consortium level. If necessary, strategies for the expected uptake of results can be revised, and related risks and further needs to enable exploitation can be refined.

Key Exploitable Results (KER) candidates as anticipated during the proposal stage will be validated based on actual finding of the project, discussed and described. If necessary, exploitation strategies will be revised and adapted to new developments, taking into account the current state-of-the-art and newly gained results.

Exploitation Planning Workshop will be held to discuss concrete action plans for each KER. The aim of the workshop is to define an exploitation roadmap per KER. All discussed parameters will be documented in the Exploitation Roadmap and visualized using the Innovation Model Canvas.

Exploitation Roadmap. An Exploitation Roadmap will be established to structure exploitation planning per KER, including the definition of KER leads, detailed time planning for further steps to be taken, as well as issues to be clarified (e.g. IP status, value propositions, market segments, risks, competitors, legal and other issues etc.).

Innovation Model Canvas. The Innovation Model Canvas represents an adapted version of the Business Model Canvas. It will be used by the KER leads to share the advanced KER descriptions with the partners concerned and external experts (if need be) to visualize the status quo and to enable further input.

Sustainability Planning Workshop. The workshop will be used to structure concrete steps of market-oriented exploitation, supported by early-stage IP landscaping.

IP landscaping will enable early-stage Freedom-To-Operate Analysis, to identify "clear" space for further Research and Development/Innovation, i.e. supports decision-making about IP protection and exploitation pathways.

b) Communication activities

Target groups and KPIs for communication and outreach measures

The table below outlines the use of different communication and dissemination measures for different target groups, together with associated key performance indicators (KPIs). Guided by the Communication Board, target audiences, key messages and appropriate measures to address them will be defined in detail in the Communication Concept and the Communication Activity Plan (see initial plan below – Table 7) as part of Task 6.1.

Target audiences / Channels	Scientists	Public sector	Industrial end-users	General public	School + university staff, students	European Commission	Key performance Indicators (KPI)
Project website	X	X	X	X	X	X	1 project website
Audio-visual material	X	X	X	X	X	X	2 animated videos explaining key features of the project, or interview(s), clips, scribble(s)
marketing docs, posters, flyers, give-aways		X	X	X	X	X	2 flyer, 2 posters, 1-2 brochures
Press releases	X	X	X	X	X	X	> 8 press releases
Social media	X	X	X	X	X	X	1 social media account with > 200 followers, others as appropriate
Public events				X	X		3 events for general public
Scientific publications	X	X				X	10 manuscripts for OA publication
Scientific conferences	X						Participation in > 12 scientific conferences
HPCQS events	X					X	Organization of 6 HPCQS events
Networking, scientific	X	X					> 12 opportunities used for knowledge sharing and networking

Table 7: HPCQS communication KPIs.

3. Implementation

3.1 Work plan — Work packages, deliverables

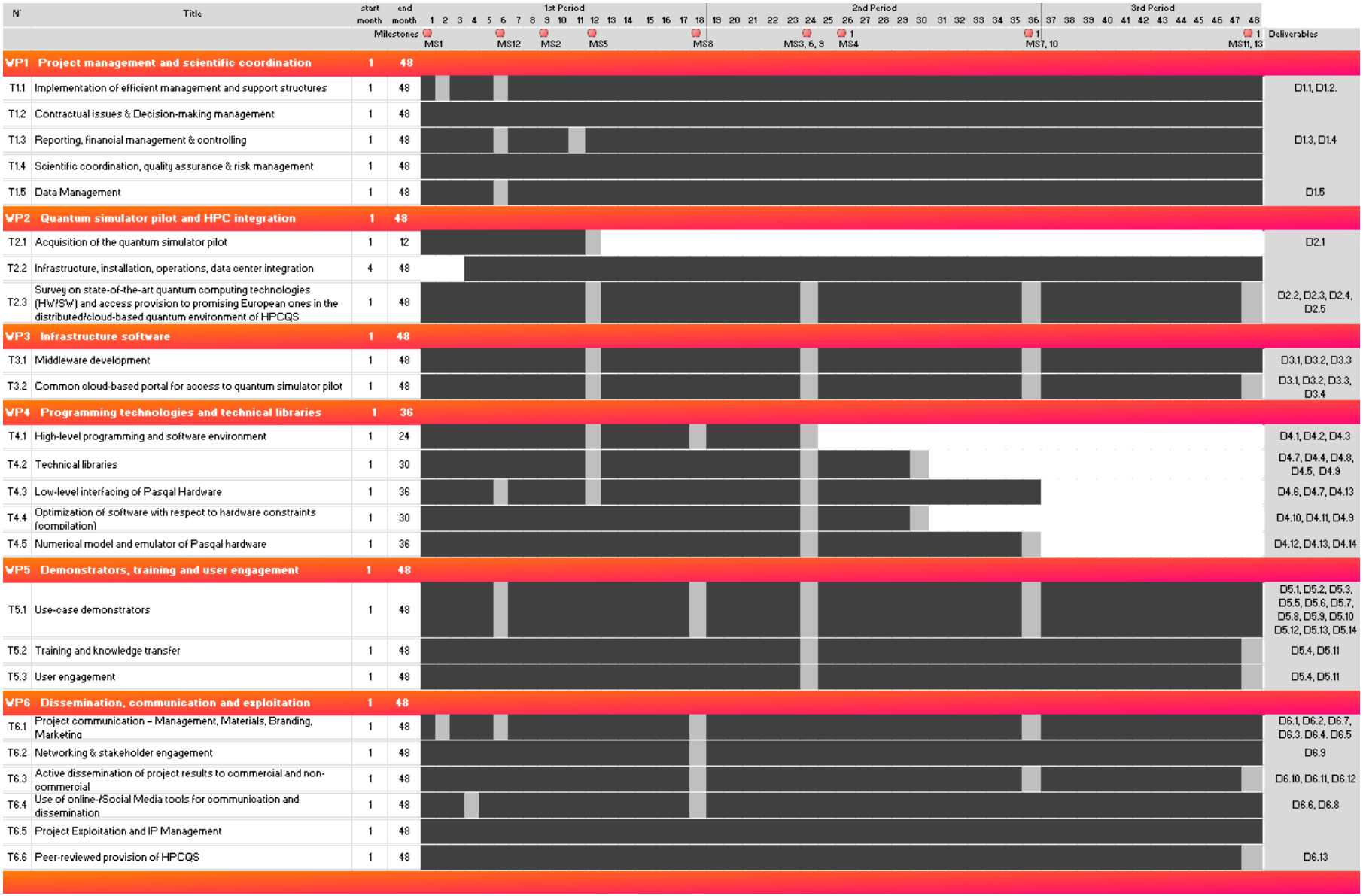
Brief presentation of the overall structure of the work plan

The work plan of HPCQS is highly networked by bringing together the experience of several leading groups and experienced researchers from the HPC and QT communities. To reach the consortium's highly complex goal of establishing a first European federated quantum-HPC infrastructure, integrating a QS of circa 100+ interacting quantum units in an HPC system of the supercomputer centres FZJ/JSC and GENCI/CEA, the participants share tasks and work together in an approach novel to this domain of research.

The five participating European HPC centres (FZJ/JSC, GENCI/CEA, NUIG-ICHEC, BSC, CINECA) collaborate closely with technological participants (Pasqal, ATOS, ParTec, FLS, ParityQC), and research participants (FZJ, CNRS, INRIA, CNR, UIBK, Fraunhofer IAF) to reach their joint goals. FZJ/JSC and GENCI/CEA, two Tier-0 systems in Europe serving their users through PRACE and hosting candidates for the European exascale machines, will acquire a QS from Pasqal and implement the Pasqal QS HW as a federated system at the two locations (WP2). As the two pre-exascale EuroHPC sites BSC and CINECA are already today closely federated with JSC/FZJ and GENCI/CEA through the FENIX data infrastructure, this collaboration is a first step towards a pan-European quantum-HPC infrastructure. The work of the technological partners serve two different purposes: it integrates, in collaboration with the two hosting sites, the Pasqal QS into the modular HPC systems (WP3), creates a hybrid HPC and quantum programming environment (WP4) and develops, together with research participants, use cases in a co-design process (WP5). The concerted activities of all participants culminate in the goal of establishing a first HPC-QS infrastructure and making it accessible to users of European industrial and public organisations (WP5, WP6). Existing collaborations between partners (AIDAS – FZJ/CEA, PRACE – BSC/FZJ/GENCI/CINECA/NUIG-ICHEC, DEEP-SEA – ATOS/BSC/CEA/FZJ/ParTec, FENIX – BSC/CEA/CINECA/FZJ, Groupe Mousquetaire – ATOS/CEA/FZJ/ParTec, GENCI – CEA/CNRS/INRIA, etc.) will allow for an immediate take-up of research at project start.

The work plan of the HPCQS project is structured in six work packages in order to address the objectives set in section 1.1. WP1 lays out the plan for the management and the scientific coordination of the project. WP2 focuses on the acquisition of the QS pilot of Pasqal, which will consist of two identical QSs with 100+ neutral atoms in arrays of optical tweezers for a federated integration and operation in the complementary Tier-0 environments of CEA-TGCC and FZJ. In addition, throughout the whole project lifetime, WP2 will carry out a survey on state-of-the-art quantum computing technologies (HW/SW) with a sufficiently high TRL with the aim to select promising European ones for early access provision in the distributed/cloud-based quantum environment of the HPCQS project. This pilot study prepares the HPCQS consortium for the future in hybrid classical/quantum computing. WP3 provides the full integration of the QLM/QS into the existing HPC infrastructure by relying on and extending ParaSTation Modulo. Additionally, a cloud-based portal will give users convenient and flexible access to the quantum resources. WP4 focuses on the programming environment and SW stack of the HPCQS platform. It enables end users to easily solve computational problems and optimize and execute the corresponding programs on the HPCQS simulator through a unified programming framework, technical libraries, compilers, interfaces and also a realistic emulator of the HW platform. It fully leverages the ATOS QLM to streamline the integration of these elements. WP5 concentrates on the development of use cases to demonstrate scientific and industry-relevant applications on the HPCQS platform. These use cases will serve to deliver training and education sessions to user groups across academia, research and industry audiences, and to support the users for leveraging and gaining access to the HPCQS technologies and results. WP6 takes care of the dissemination of the results and the development of communities and networks within the relevant stakeholder groups in order to shape a first ecosystem of hybrid HPC and quantum programming facilities and applications. The outreach to these communities includes a peer-reviewed provisioning process for access to the quantum-classical hybrid HW and SW infrastructure HPCQS that is integrated in the well-established peer-review process of PRACE for access to Tier-0 HPC systems in Europe.

Timing of the different work packages and their components (Gantt chart)



3.1.a List of work packages

Work Package No	Work package title	Lead Participant No	Lead Participant Short Name	Person-Months	Start Month	End Month
WP1	Project management and scientific coordination	1	FZJ	21	1	48
WP2	Quantum simulator pilot and HPC integration	3	GENCI	38	1	48
WP3	Infrastructure software	1b	ParTec	115,6	1	48
WP4	Programming technologies and technical libraries	4	ATOS	195	1	48
WP5	Demonstrators, training and user engagement	6	NUIG-ICHEC	214	1	48
WP6	Dissemination, communication and exploitation	8	EURICE	35,8	1	48
Total person-months				**619,4**		

3.1.b Work package description

Work package number	**WP1**							**Lead beneficiary**		**FZJ**							
Work package title	**Project management and scientific coordination**																
Participant number	**1**	1b	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Participant short name	**FZJ**	ParTec	CEA	GENCI	ATOS	CNR	NUIG-ICHEC	UIBK	EURICE	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	**6**	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0
Start month	1							**End month**		48							

Objectives (O)

The objectives of WP1 are to provide a clear organizational framework and all necessary support mechanisms to enable a smooth project workflow in HPCQS and to ensure that all contractual commitments will be met in time.
O1.1: Provide optimal guidance and support to all partners through a quick set-up of effective management & communication structures
O1.2: Transparency for consortium partners and the EC through proper project documentation
O1.3: Maximize effectiveness of project activities: ensure the timely and qualitative achievement of project results through scientific and administrative coordination
O1.4: Ensure efficiency: use resources wisely, avoid duplication of efforts, reduce waste of time and energy

Description of work

Task 1.1: Implementation of efficient management and support structures
Set-up of the project's organisational and internal communication structure in order to safeguard a smooth project start and enable an immediate uptake of activities. Each partner will be informed on H2020 rules and regulations as well as on specific project internal workflows. This will be complemented by an electronic storage of the project framework on the password-protected, web-based project management platform (D1.1), specifically developed for EU projects, which will be set up and readily available at the project start. This will provide all partner staff members with an up-to-date overview of the project status at all times and facilitate comprehensive project management. The management platform will provide all partner staff members with an up-to-date overview of the project status at all times and facilitate comprehensive project documentation. The platform will also be used for data storage and file-sharing between consortium members and will support the reporting of efforts, costs and requested reimbursements, the compilation of periodic reports as well as the preparation and documentation of deliverables. Major management procedures and workflows will be defined in a Management Guide to give clear

guidance to the partners (D1.2). The development and implementation of consortium-wide agreed internal standards and processes for capturing and assessing of partner project outputs will lay the foundations for successful dissemination and exploitation activities as described in WP6. This task also includes the organisation of consortium meetings (GA, SC, WP) as described in section 3.2.
Partners involved: ***EURICE****, All partners*
Duration: month 1 – month 48

Task 1.2: Contractual issues & Decision-making management
The project management team will be responsible for the preparation, collection and maintenance of contractual documents (Grant Agreement - GA and Consortium Agreement - CA) and will ensure that project partners are aware of the project's legal framework at all times. In this context, direct communication lines will be established with the legal departments of all project partners. The CA, based on a recognized model agreement such as the DESCA model agreement, and adapted to the project specifics, will be negotiated in parallel to GA negotiations with the EC to ensure that an agreed and signed version is ready at the project start. Should the need arise, contract amendments will be prepared and requested immediately to minimize delays in project implementation. Clear rules laid out in the CA will facilitate management workflows when quick decisions are needed. Furthermore, the management team is responsible for the organisation and follow-up of periodic project meetings to assess and discuss project progress. This will allow for informed decision making, thorough risk review and, if needed, prompt conflict resolution.
Partners involved: ***FZJ****, EURICE, All partners*
Duration: month 1 – month 48

Task 1.3: Reporting, financial management & controlling
Following an 18-months reporting schedule, three periodic reports (P1: M1-18, P2: M19-36, P3: M37-48) and one final report (M48) will be submitted to the EC. Moreover, the consortium will implement internal progress reports in M11 to monitor the project´s progress steadily to ensure a quick uptake of activities (D1.4).
In addition, individual financial records (updated budgets and cash flow overviews) will be compiled and regularly provided to each partner individually. The management team will coordinate the collection and monitoring of periodic cost claims, appropriate justification of declared costs in project reports, follow-up of EC payments including the timely distribution to the partners and collection of necessary audit certificates at the end of the project. Deviations from the planned use of resources will be discussed with the affected partners and brought to the attention of the responsible WP leader and/or the coordinator. A webinar on H2020 financial management will familiarize all individuals involved in the financial reporting process (scientists and administrators) with the relevant H2020 rules and regulations and related project internal procedures (D1.3).
Partners involved: ***FZJ****, EURICE, All partners*
Duration: month 1 – month 48

Task 1.4: Scientific coordination, quality assurance & risk management
High quality outputs are the basis for an effective project implementation as well as for a successful exploitation strategy in the project. To ensure that all project outputs fulfil the best possible quality standards, deliverables will be prepared by the responsible partner, quality controlled by the WP leader, reviewed by the Management Team for formal and scientific completeness and correctness and finally submitted to the EC by the coordinator. The management team will monitor the work package status by measuring against deliverable and milestone planning, and the quality assessment of project outcomes. The progress of each WP will be presented by the responsible WP leaders during the regular project meetings and also ad hoc by personal communication if the need arises, and assessed by the General Assembly. Elaborated drafts of deliverables will be uploaded on the management platform immediately upon completion by the responsible partner and quality controlled by the WP leader and the coordinator before submission to the Participant Portal of the EC. A close work plan follow-up integrating information from all partners will lead to a timely identification of bottlenecks, risks, or delays, and the initiation of appropriate contingency planning on project level, resulting in timely adjustments of the work plan whenever necessary and their translation into contract amendments without delay. Periodic teleconferences will be organized to facilitate the follow-up of the activities.

Risk assessment will be scheduled for every project meeting in order to identify, quantify, track and mitigate risks within the project. The consortium will seek to identify potential and newly emerging risks and develop strategies on how to mitigate their effects. The result of the discussions will subsequently be added to the minute meetings. The management of risks and failures and back-up strategies is described in further detail in section 3.2 "Risks and mitigation measures".

Partners involved: ***FZJ****, EURICE, All partners*
Duration: month 1 – month 48

Task 1.5: Data Management
This task includes the elaboration of the DMP-data management plan (D1.5) and facilitation of the data access process by partners. See section 2.2 for more details about the structure and content of the DMP.
Partners involved: ***FZJ****, All partners*
Duration: month 1 – month 48

Roles of the Partners: **FZJ** is the WP leader and will supervise WP1 aiming to guarantee efficient coordination of the project and appropriate overall project strategy, implement common consortium activities and manage communication and administrative, financial and contractual commitments to the EC.

While the coordinator is the intermediary for all communications and interactions with the EC (e.g. submission of reports and deliverables, processing of EC payment to the partners, communication of risks and events that will affect the implementation of the project), Eurice's emphasis will be on assisting the coordinator in the aforementioned tasks and on facilitating a smooth management of the project at consortium level.

Deliverables

D1.1 Project management platform (M2); **D1.2** Project management platform (M6); **D1.3** Webinar on Horizon 2020 financial management (M6); **D1.4** Internal Progress Report (covering M1–M9) (M11); **D1.5** Data Management Plan (M6)

Work package number	**WP2**							**Lead beneficiary**		**GENCI**							
Work package title	**Quantum simulator pilot and HPC integration**																
Participant number	1	1b	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	16
Participant short name	FZJ	ParTec	CEA	**GENCI**	ATOS	CNR	NUIG-ICHEC	UIBK	EURICE	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	7	0	6	**8**	0	1	0	0	0	0	0	16	0	0	0	0	0
Start month	1							**End month**		48							

Objectives (O)

The objectives of WP2 are
O2.1: Acquire a federated 100+ qubit simulator at GENCI/CEA and at FZJ
O2.2: Perform a regular technological assessment of quantum computing HW and SW
O2.3: Integrate the Pasqal QS in the Tier-0 HPC environments of CEA-TGCC and FZJ and operate the hybrid classical/quantum infrastructure

Description of work

Task 2.1: Acquisition of the quantum simulator pilot
2.1.1 Preparatory work to procurement: sizing and characterization of the quantum simulator pilot
The two hosting entities **CEA** and **FZJ** will collaborate in sizing and determining the main physical characteristics of the Pasql QS to be procured and in exploring how to integrate it with an operational HPC production Tier-0 system (Joliot Curie at CEA and JUWELS at FZJ). The outcome will form the basis for the tender package to be developed by FZJ and GENCI to procure two pilot systems of 100+ qubits each.
Partners involved: ***CEA*** *and* ***FZJ***
Duration: month 1 - month 3

2.1.2 Procurement of the quantum simulators
Based on the outcome of the preparatory work to procurement, **GENCI** and **FZJ** will collaborate in defining an appropriate negotiated procedure to either launch a common tender or two independent tenders (one run by **GENCI** – one run by **FZJ**) for the acquisition of a quantum device of Pasqal consisting of a twin QS system with

100+ neutral atoms in arrays of optical tweezers with the capability to integrate the 100+ qubits QSs in complementary Tier-0 environments (Joliot Curie at CEA and JUWELS at FZJ). A procurement report for the QS pilot will be written (D2.1).
Partners involved: ***GENCI, CEA*** *and* ***FZJ***
Duration: month 4 - month 12

Task 2.2: Infrastructure, installation, operations, data centre integration
Based on the outcome of Task 2.1 and in collaboration with WP3 this task will work on the infrastructure requirements to host a QS tightly coupled with a HPC Tier-0 infrastructure (mutualization of peripheral services around HPC computing resources: login nodes/network/Storage up to batch scheduler). Such activity will lead to the production of a best practices guide on how to integrate efficiently a quantum computing system in an HPC infrastructure.
Once the two twin pilots acquired by GENCI and FZJ, operational teams of **JSC** and **CEA** in collaboration with **Pasqal** and **ParTec** will ensure their proper installation in respective data centres, perform regular SW/HW maintenances, ensure first level of system/application user support and guarantee stability, maturity and usability of the solution. In that goal, operational yearly reports will be produced by the two sites.
Finally, in relation with WP4 and WP5, Task 2.2 will integrate the needed SW environment for allowing the development of the ad-hoc SW stack and the codesing end end user applications.
Pasqal will carry out risk management and quality insurance activities, securing the delivery of the two pilots.
Partners involved: ***CEA****, GENCI****,*** *FZJ, ParTec, Pasqal*
Duration: month 4 - month 48

Task 2.3: Survey on state-of-the-art quantum computing technologies (HW/SW) and access provision to promising European ones in the distributed/cloud-based quantum environment of HPCQS
2.3.1 Survey on state-of-the-art quantum computing technologies (HW/SW)
Throughout the project lifetime, **GENCI, FZJ** and **CEA** will conduct a permanent survey of state-of-the-art quantum computing HW and SW, with a specific focus on those developed in Europe. Yearly reports and white papers will be produced about the assessment of emergent and promising quantum computing technologies, including HW and SW roadmaps (D2.2/D2.3/D2.4/D2.5). They will be used to drive potential access provision to promising quantum computing technologies as prototypes in the HPCQS hybrid classical-quantum infrastructure.
Partners involved: ***GENCI****,* ***FZJ,*** *CEA, CNR*
Duration: month 1 - month 48

2.3.2 Access provision to small-scale prototype quantum computing technologies, provided in-kind by suppliers, in the distributed/cloud-based quantum environment
Quantum computing technologies with an appropriate TRL that have been identified in the survey as being of interest for assessment, will be made accessible for European researchers and engineers in preparation of further future integration of HPC and quantum computing technologies. While the QS pilot with 100+ qubits will be hosted onsite and integrated with HPC supercomputers, these prototypes will only be remotely accessible from suppliers' premises. In all cases, these small-scale prototypes will be provided in-kind by startups/SMEs and will be accessible for European researchers and engineers through the cloud-based environment/portal of HPCQS. Alongside with the 100+ qubits QS simulator from Pasqal, such activity will foster the visibility of promising quantum European technologies and pave the way for their inclusion in future production-class HPC-QC environments.
Partners involved: ***GENCI****, CEA, FZJ, CNR*
Duration: month 1 - month 48

Deliverables

D2.1 Quantum pilot procurement (M12); **D2.2** Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies (M12); **D2.3** Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies (M24); **D2.4** Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies (M36); **D2.5** Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies (M48); **D2.6** Yearly operational report (M24); **D2.7** Yearly operational report (M36); **D2.8** Yearly operational report (M48); **D2.9** Best practices guide for the integration of a QS with a Tier 0 HPC infrastructure (M48)

Work package number	WP3						Lead beneficiary		ParTec								
Work package title	**Infrastructure software**																
Participant number	1	**1b**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Participant short name	FZJ	**ParTec**	CEA	GENCI	ATOS	CNR	NUIG-ICHEC	UIBK	EURICE	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	26,6	**36**	2	0	35	13	0	0	0	0	0	0	0	0	0	3	0
Start month	1							**End month**		48							

Objectives (O)

The objectives of WP3 are:
O3.1: Design and definition of a resource management interface to the QLM/QS
O3.2: Fully integrate the QLM/QS into the Modular Supercomputing Architecture
O3.3: Provide access to the QLM/QS via a cloud-based portal to the users
O3.4: Enable the co-existence of both the full integration and the cloud-based access via a common resource management

Description of work

Task 3.1: Middleware development

A tight integration of the QS into the infrastructure of supercomputing centres—in contrast to a service-based approach—is crucial for enabling application scenarios going beyond pure digital or analog quantum processing. Especially, coupled simulation codes using a feedback loop, connecting parts running on traditional, von Neumann-based architectures, and those being simulated on a QS, require means for low-latency data exchange on system level. Furthermore, an efficient utilization of the available resources can only be guaranteed if the QS is considered by both the central scheduler and the resource manager of the traditional HPC infrastructure.

The MSA provides solutions to the above-identified demands for embedding of a QS in a traditional HPC system. The approach aims at orchestrating heterogeneity by integrating HW components exposing common characteristics at the system level. These HW components are considered as individual modules of a single system connected by a federated high-speed network. In accordance with the MSA, the QS will be an additional module of the supercomputer, tightly coupled to existing modules such as the general-purpose CPU and accelerator modules. This introduces novel usage models in contrast to its operation as an isolated resource with independent resource management and scheduling. On the one hand, tightly coupled simulation codes will be able to benefit from efficient data exchange via the federated high-speed network. On the other hand, workflows become possible exhibiting one or more stages running on the QS while pre- and post-processing tasks are being executed on other modules of the MSA system.

In contrast to traditional computing modules (e.g., an accelerator module based on GPGPUS), the QS is a scarce resource that cannot be used concurrently by multiple users. However, its efficient utilisation is only possible by enabling a pseudo-shared usage model—at least from the resource management's point of view. For example, a time slice-based assignment of usage time on the QS would enable the utilisation of the QS by multiple jobs concurrently. Time-slices could even be assigned dynamically, e.g., allowing two or more tightly-coupled simulation codes to run alternatingly on the QS and the remaining modules of the MSA system. Such a shared usage model is likewise a necessary precondition enabling the tight integration of the QS into the MSA while simultaneously supporting a service-based utilisation (e.g., via a web portal, cf. WP3, Task 3.2).

3.1.1 Preliminary design of a resource management interface between HPC system and QLM/QS

The aim of this subtask is to define the most appropriate level of resource management (and job scheduling) for the analogue QS.

In this subtask, **ATOS, ParTec** and **CNR** will investigate the two main scenarios for resource management:

1. Direct management of the quantum resources (i.e., the AQPUs), with possibly a queuing system at the level of the AQPU. In particular, the relevance of asynchronous calls to AQPUs will be examined, taking into account the characteristics of Pasqal's HW (repetition rate, latency).

2. Management of the higher-level quantum programming framework (developed in WP4 Task 4.1): control over full variational optimisation tasks in the framework of Variational Quantum Simulation (VQS) over compilation jobs.

Both alternatives need to be properly investigated. The right level of resource management is indeed a subtle issue that has to take into account the following features of Noisy, Intermediate Scale Quantum (NISQ) computing:

- NISQ computations typically consist of hybrid quantum-classical computations necessitating constant back-and-forth between the classical and quantum processors;
- Repetition rates on Rydberg platforms are typically quite low (a couple of Hertz)
- (Classical) compilation tasks may also require substantial resources

Depending on the output of this analysis (D3.1), an interface (API) to the QLM services at either the AQPU level, or programming framework level will be defined and published. This will specify the possible inputs, outputs, and parameters to QLM services accessible from the outside world. It will allow for a seamless integration of QLM tools with the resource management system.
Partners involved: ***ATOS****, ParTec, CNR*
Duration: month 1 - month 12

3.1.2 Implementation of the API to QLM/QS

The implementation of the API as defined in the previous subtask will follow a two-step approach. Initially, the minimal requirements for the integration of the QLM/QS into the resource management of the HPC infrastructure will be fulfilled. This initial prototype will support the allocation of the associated resources by a single job at a time while avoiding their overexploitation (D3.2), e.g., by providing a simple queueing facility.

The abstraction and scheduling of the QLM/QS will be the focus of the second step enabling its utilisation by multiple jobs concurrently. In this context, the characteristics of the QLM/QS for the definition of an abstraction as tasks/jobs that can be queued for execution will be analysed. Additionally, a mathematical model will be proposed taking into account the constraints from both the upper layers (e.g., priorities, deadlines) and the physical platform (e.g., execution/failure rates, start-up/tear-down times). This model will support the design of an on-line scheduler fed by realistic data coming from WP2 (QLM/QS characteristics), WP4 (elementary programming elements), and WP5 (use case requirements and typical scenarios). A reference implementation of the scheduler will enable the flexible and efficient utilisation of the QLM/QS resources. (D3.3)
Partners involved: ***ATOS****, CNR*
Duration: month 6 - month 24

3.1.3 Full integration into the HPC infrastructure

The integration of the QS into the execution environment of the existing HPC infrastructure is crucial for the execution of tightly coupled, hybrid simulation codes. As the QS is a scarce resource, it has to be integrated on the module level into the MSA. Therefore, this subtask will leverage the interface provided by 3.1.2 to make the QS available via the resource management provided by ParaStation Modulo (D3.2, D3.3). This will not only enable the utilisation of the QS as part of the modular HPC infrastructure but also the execution of (hybrid) workflows via the cloud-based user portal (Task 3.2). The specific characteristics of the two pilot computer centres will be taken into account to make ParaStation Modulo more suitable for the integration of various production environments. ParityQC will develop a plugin for the cloud-based user portal that connects the ParityOS toolchain to the software stack developed by the HPCQS consortium.
Partners involved: ***ParTec****, CEA, ParityQC*
Duration: month 12 - month 48

3.1.4 Modular supercomputing runtime for hybrid workloads

Besides the management of quantum resources via ParaStation Modulo, users will require support from the runtime environment to execute hybrid workloads. Therefore, ParaStation MPI will be extended to support the high-level programming environment that will be developed as part of WP4. The MPI for Python (mpi4py) package provides means for writing MPI applications using the Python language which is common in quantum computing. The goal of this subtask is to ensure interoperability between both the mpi4py package and the Python-based programming environment (4.1.1) with ParaStation MPI. Where necessary, ParaStation MPI will be extended to improve the stability, usability, and performance of hybrid workloads leveraging both traditional HPC resources and the QS (D3.2, D3.3).
As for 3.1.3, an adaptation to ATOS OpenMPI will be discussed with CEA based on the experience gained on ParaSTation MPI.

Partners involved: ***ParTec****, CEA*
Duration: month 18 - month 48

Task 3.2: Common cloud-based portal for access to quantum simulator pilot
This task provides a portal solution that allows end-users convenient and flexible access to the QS pilot via the web browser. The task is led by **FZJ** and will be based on FZJ's extensive experience with a production-level JupyterHub Portal for both HPC and cloud computing resources and on FZJ's experience with the current setup of the Quantum Computing Platform as a Service (QC-PaaS) JUNIQ. JUNIQ will provide user access to various quantum emulators, a D-Wave quantum annealer, the quantum computing device with superconducting qubits of the Quantum Flagship project OpenSuperQ, and others to follow (not part of this project). The task includes

- Definition and documentation of the Portal architecture
- User management (authentication, authorization, managing projects and group and quotas) including interfacing to the existing user management infrastructure at the HPC centres (JSC, CEA, BSC, CINECA, ICHEC)
- Installation and operation of JupyterHub and the required infrastructure

3.2.1 Architecture and design of a JupyterHub-based Portal
Starting from the architecture of the existing JupyterHub solution that is in production at FZJ, we will design the HPCQS Portal, taking into account the specific use cases, requirements and boundary conditions of the project. (D3.1)
Partners involved: ***FZJ***
Duration: month 1 - month 12

3.2.2 User management (AAI)
Providing solutions for user authentication, managing user access to resources, interfacing to existing solutions (such as FENIX/FURMS) as well as accounting and usage reporting. (D3.2, D3.3)
Partners involved: ***FZJ***
Duration: month 12 - month 36

3.2.3 Installation and operation of the Portal and its required infrastructure
Apart from the JupyterHub service itself, the Portal requires UNICORE for interfacing JupyterHub to the HPC/QC resource managers as well as SW on the resource front-ends (login nodes) that provide the supported Jupyter kernels.
This subtask deals with the installation and operation of the JupyterHub service, the required UNICORE adapters to the HPC and QC resources and their associated resource management SW (SLURM), as well as installing and maintaining the SW modules providing the Jupyter kernels and any required libraries (D3.4).
Partners involved: ***FZJ, CEA***
Duration: *month 24 - month 48*

Deliverables

D3.1 Report on the architecture specification (M12); **D3.2** Report on the prototype software implementation (M24); **D3.3** Report on the complete software implementation (M36); **D3.4** Final support and operation report (M48)

Work package number	WP4						Lead beneficiary		ATOS								
Work package title	**Programming technologies and application libraries**																
Participant number	1	1b	2	3	**4**	5	6	7	8	9	10	11	12	13	14	15	16
Participant short name	FZJ	ParTec	CEA	GENCI	**ATOS**	CNR	NUIG-ICHEC	UIBK	EURICE	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	14	0	2	0	**70**	1,5	22	12	0	18	36	3	0	3	0	13,5	0
Start month	1							**End month**		48							

Objectives (O)

The objectives of WP4 are:
O4.1: Develop a high-level analog programming framework and SW environment
O4.2: Develop technical libraries to translate application use cases into analog programs
O4.3: Develop compilers to adapt HW-agnostic analog programs to Pasqal constraints
O4.4: Develop a realistic and scalable emulator of Pasqal
O4.5: Develop the low-level interface with Pasqal HW

Description of work

Task 4.1: High-level programming and software environment
The programming of analog QCs or QSs is largely an uncharted territory, contrary to that of gate-based (digital) QCs. In fact, while the digital paradigm has attracted a great deal of attention due to its similarities to classical logic circuits, the formalism for programming analog machines is yet to be laid out.
The high-level programming language and SW environment must at the same time be (i) flexible, HW-agnostic in order to describe generic analog computer programs ("schedules") executed on the machine with a high level of abstraction, (ii) enable the seamless integration of quantum and classical subroutines, since hybrid algorithms (like variational algorithms) are likely the only ones to provide quantum advantage on early analog machines; all this while allowing for (iii) a proper handling of the HW constraints by the lower levels of the stack.
The goal of this task is to design and deliver such an analog programming framework. This framework will be the first of this kind, given the absence of any established paradigm for analog programming.

4.1.1 High-level programming framework
ATOS will provide a HW-agnostic, high-level, Python-based, programming environment that shall enable the programmer to describe the various operations that can be performed on an analog QC (D4.1). Specifically, **ATOS** will provide a library of primitives to allow the programmer to specify the temporal evolution of their Hamiltonian and the operatorial content of the analog program. This abstract description may, or may not, directly correspond to the operations available on the target HW (Pasqal); the adaptation to specific constraints (like a limited operation set or topology) will be addressed in Task 4.4. Alongside with this description of "Resource Hamiltonian" (as formalized in [Kokail19]), **ATOS** will provide a library to facilitate the description of the observables (the "Target Hamiltonian") that will need to be evaluated at the end of the execution.
This programming framework will be fully integrated within the ATOS QLM. Most notably, it will leverage the existing capacities of the QLM for describing quantum "Observables".
Partners involved: ***ATOS***
Duration: month 1 – month 12

4.1.2 Quantum intermediate language: Schedules and Observables
ATOS will provide a universal quantum intermediate language, akin to QASM-type languages in the digital paradigm (D4.1). This assembly-level language is meant to describe as economically as possible the instructions that the previously established programming framework has allowed to generate. It will describe analog quantum "Schedules", namely the analog counterparts of quantum Circuits, quantum "Observables" (which specify what is to be measured at the end of the analog schedule).
This Schedule and Observable will be fully serializable, and ready for being compiled to comply with the HW constraints of the target AQPU (see 4.3.1) using ad-hoc, HW-specific compilers (see Task 4.4).
Partners involved: ***ATOS***

Duration: month 1 – month 12

4.1.3 Graphical language for analog programming

CNRS and **INRIA** will provide a graphical way of representing and manipulating the schedules described in 4.1.2. It will allow for an easier optimization of these very schedules during the compilation steps (Task 4.3).

The ZX-calculus will be used to graphically describe schedules, hamiltonians and observables. ZX-calculus is a powerful framework which has already been successfully used for gate-based optimisations. Quantum dynamics, including Hamiltonians, can also be described in such categorical frameworks [Gogioso17], moreover recent developments on the ZX-calculus involve Pauli gadgets, which occur naturally in the description of Hamiltonians [Cowtan19].

This graphical language library (D4.2) will be interfaced to the quantum intermediate language defined in 4.1.2.

*Partners involved: **CNRS**, INRIA*

Duration: month 1 – month 18

4.1.4 Type systems and static analysis for analog programs

CNRS and **INRIA** will develop a tool that statically analyses an analog quantum program (Schedule and Observable) taking into account the HW constraints (topology, available operations, etc) (D4.3). Indeed, the size and topological constraints of the HW will have an impact on the way algorithms are concretely implemented. In order to reflect these restrictions, **CNRS** and **INRIA** plan to develop a set of techniques based on formal methods: type systems, program static analysis (abstract interpretation, implicit computational complexity).

*Partners involved: **CNRS**, INRIA*

Duration: month 12 – month 24

Task 4.2: Technical libraries

4.2.1 Combinatorial optimization

ATOS will contribute a combinatorial-optimization library for analog processors (D4.4). It will make it possible to specify the problem at hand (graph), generate the quantum schedule and target cost function (Observable), and perform custom optimizations using classical optimizers. This will be done for a variety of NP-hard combinatorial optimization problems (e.g., graph colouring, MaxCut, Maximum Independent Set). Emphasis will be put on the unit-disk maximum independent set problem (UDMIS), for which ATOS recently conducted a thorough study of the effects of realistic noise on analog Rydberg platforms [Serret20].

This library will be integrated as a binary with the lower parts of the stack (compilers [Task 4.4], AQPU). Access will be granted to the other partners until the project's end. No source code will be shared.

*Partners involved: **ATOS***

Duration: month 1 – month 24

4.2.2 Machine Learning

CNRS will contribute to a basic technical library for ML applications in the setting of analog computing (D4.7). Following the line of **CNRS'** work [Coyle20], **CNRS** plans to adapt, to convert or to rebuild a set of libraries for designing quantum ML algorithms. **CNRS** will investigate the potential of quantum generative modelling to explore the potential of quantum approaches for reducing the amount of data needed to learn. In particular, **CNRS** will explore the adaptation to the analog computing along the same lines of research they have done for benchmarking [Derbyshire20]. The point of the commonality and interest from the analog setting is that **CNRS** can program the underlying Hamiltonian rather than the circuit gates being developed after discretization of the nature Hamiltonian. So, in principle **CNRS'** approach to generative modelling that focuses on sampling models similar to VQE or QAOA can be easily adapted to the analog setting.

CNR will develop and adapt ML algorithms for quantum state estimation and discrimination, with special emphasis on applications in multiparameter-estimation, such as the estimation of a spatially-varying magnetic field in a multi-qubit system. In particular, **CNR** will develop ML protocols for Bayesian and frequentists approaches [Nolan20].

BSC will develop a QML library for supervised learning using quantum states. Basic functionality of the library will include the encoding of classical information into quantum states and the use of quantum circuits as classificators. **BSC** will also design hybrid techniques based on classical RL for fine tuning of operational parameters of a quantum device.

This part of the work will also represent a link with UC5 Quantum Machine Learning in WP5. This library (D4.4) will be integrated with the programming framework put in place in 4.1.1 (see 4.2.4).

*Partners involved: **BSC**, CNRS, CNR*

Duration: month 1 – month 24

4.2.3 Lattice-model libraries

NUIG-ICHEC, UIBK, ParityQC will develop libraries for arbitrary lattice model generation, wherein the interfaces can be mapped to the target system(s) of choice (D4.8, D4.9). **NUIG-ICHEC, UIBK, ParityQC** propose to develop lattice models for 1D, 2D, and 3D systems, with parameterizable geometries and interactions. Support for well-known lattice models (1D: chains; 2D: square, triangular, Kagome, etc.) will be made available, with the goal of providing a platform-agnostic framework for representing higher-level problems. All subsequent operations necessary to realize such models will be translated to the underlying QS. This allows to decouple the problem specification from the underlying details of the HW. In addition, the respective lattice model can be mapped to a classical simulation methodology, allowing for a direct scalability analysis and resulting comparison of the lattice model results on both classical and quantum HW platforms. **ParityQC** will develop tools to integrate the LHZ lattice model to the library. The LHZ model consists of 4-body plaquette interactions and local fields.
This library will be integrated with the programming framework put in place in 4.1.1 (see 4.2.4). It will also tie in directly with the use-case efforts on many-body physics simulations and strongly correlated materials in WP5, Task 1.3, which can depend on 4.2.3.
*Partners involved: **NUIG-ICHEC**, UIBK, ParityQC*
Duration: month 1 – month 24

4.2.4 Integration of technical libraries

ATOS, CNRS, NUIG-ICHEC, UIBK, ParityQC, BSC will integrate the libraries developed in 4.2.1, 4.2.2, 4.2.3 to the programming framework and quantum intermediate language defined in 4.1.1 and 4.1.2 (D4.5).
All three libraries will produce, as a final output, Schedules and Observables (4.1.2) that can be input to the lower part of the SW stack (compilation and execution).
*Partners involved: **ATOS**, CNRS, NUIG-ICHEC, UIBK, ParityQC, BSC*
Duration: month 24 – month 30

Task 4.3: Low-level interfacing of Pasqal HW

This task will focus on the integration of the Pasqal HW into an HPC system. It will make sure that the HPC machines are able to talk to the Quantum Device in a manner that is compatible with the normal operation of an HPC system. This task will define the HW and SW interfaces that are needed.

4.3.1 Interfacing with Quantum Learning Machine

ATOS will provide an interface (API) to connect analog AQPUs, including the Pasqal HW, to its QLM environment. It will thus extend the QLM's simulation capabilities to a real HW implementation, allowing users to test their program on various simulated HW along with a real one. The specification of this API will be made available to all the partners of the project (D4.6), with free usage rights for the duration of the project.
*Partners involved: **ATOS***
Duration: month 1 – month 6

4.3.2 Implementation of the interface

Pasqal will provide an implementation of the interface defined in 4.3.1 (D4.7). This interface will expose the high-level controls of Pasqal HW to the QLM environment. In the analog regime, such controls include the spatial configuration of the atoms and the tuneable physical parameters of the Hamiltonians.
A first task will consist in fine-tuning the interface developed in 4.3.1, if the case arises that specific HW performance and constraints aspects need to be specifically adjusted. The second task will consist in implementing the interface itself, based on the specifications of the API.
*Partners involved: **Pasqal***
Duration: month 6 – month 12

4.3.3 HPC integration

CEA and **FZJ** will focus on integrating the Pasqal HW in an HPC system. The objective is to define the architecture of the final solution (for example a connection through PCI-Express or via remote procedure calls on TCP/IP) depending on the way the centres run their supercomputers (D4.13).
*Partners involved: **CEA**, **FZJ***
Duration: month 3 – month 36

Task 4.4: Optimization of software with respect to hardware constraints (compilation)
The quantum programs described by the quantum intermediate language (4.1.2) and generated by the technical libraries (Task 4.2) do not necessarily take into account HW constraints. The goal of this task is to provide libraries to transform these HW-agnostic programs to HW-optimized programs.

4.4.1 Code optimization under constraints through ZX calculus
Shrinking as much as possible the memory footprint of a computation is crucial, in particular when a hundred atoms are available. **CNRS** and **INRIA** will transform the user code, taking into account the HW constraints, by using the intermediate language (4.1.2) and its ZX-calculus-based graphical language (4.1.3). The ZX-calculus [Jeandel20] is equipped with a complete equational theory which allows graphical transformations [Vilmart 2019], that will be used for optimising the code, and taking into account the HW constraints to make the analog computation implementable. Thus, a code optimization framework will be developed for analog quantum computing under HW constraints based on the ZX-calculus representation (D4.9).
*Partners involved: **CNRS**, INRIA*
Duration: month 12 – month 30

4.4.2 LHZ compiler for k-body Hamiltonians with constraints
ParityQC will contribute a plugin that connects the SW developed by the HPCQS consortium with the ParityOS compiler (D4.10). The ParityOS compiler takes as an input a higher-order k-body Hamiltonian with additional side conditions. Such a Hamiltonian is typically generated by the technical library developed in 4.2.1 as the target Hamiltonian of some combinatorial optimization problems (e.g scheduling). ParityOS is offered as a SaaS by **ParityQC** and a generalization of the LHZ architecture [Lechner15] The generalization allows one to encode i) arbitrary k-body interactions and also ii) side conditions on a square lattice with Rydberg atoms. The library developed by ParityQC within the HPCQS project will allow the consortium to integrate the tools seamlessly to the Pasqal SW stack. The result is a schedule and qubit layout for the Pasqal chip for coherent adiabatic quantum optimization, counter-diabatic annealing or quantum annealing.
*Partners involved: **ParityQC***
Duration: month 1 – month 24

4.4.3 Variational Quantum Simulation & Optimization toolbox
Several of the proposed use cases (UC2, UC3, UC4, UC5) in WP5 rely on the variational principle: the QS prepares a parameterized quantum state, while a classical computer iteratively optimizes the parameters towards a desired final state, taking decisions based on measurement outcomes.
In this context, **FZJ** and **UIBK** will investigate *controllability* and *simulatability*, i.e. whether a given set of quantum operations is theoretically capable of transforming an initial state into the desired final state or implementing a given unitary [Zimboras15]). A toolbox will be developed that can check controllability and simulatability and that suggests sets of quantum operations suitable for a particular implementation target (D4.11).
Furthermore, **UIBK** and **FZJ** will investigate and develop optimization algorithms [Kokail19, Omran19], specialized to variational quantum problems, where information on the cost function is only available through noisy projective measurements.
The tools developed in this subtask will be fully integrated to the higher parts of the stack (quantum intermediate language developed in 4.1.2) and the lower ones (i.e, the output programs will be suitable for execution on the AQPU whose interface will have been developed in 4.3.1), and will be available as building blocks for the tasks in WP5 (UC2, UC3, UC4, UC5).
*Partners involved: **UIBK**, FZJ*
Duration: month 1 – month 24

Task 4.5: Numerical model and emulator of Pasqal hardware

4.5.1 Characterization of noise models on Pasqal hardware
NUIG-ICHEC, Pasqal and CNR will contribute to the development of a model of the Pasqal HW, which will take into account different noise sources (described as noisy quantum maps [Caruso14]), ranging from the effect of stray electric and magnetic fields to detection noise, which may have a detrimental impact on the machine performances. We will start with a 2-level quantum system model for the prototype Pasqal Rydberg simulator, including terms for the effects of dephasing and spontaneous emission, as well as State Preparation and Measurement (SPAM) errors. Given the observation of more complex effects, additional levels can be included in the Hamiltonian to emulate the system behaviour.
Following the effective modelling provided by this emulator, **Pasqal**, **CNR** and **NUIG-ICHEC** will deliver the

resulting Hamiltonian and required operators for 4.5.2 to develop the model at scale. The deliverable (i.e the corresponding Hamiltonians and operators) will be fully interfaced with the noisy emulator of 4.5.2 (D4.12).
Partners involved: ***NUIG-ICHEC****, PASQAL, CNR*
Duration: month 1 – month 24

4.5.2 Pasqal noisy emulator
ATOS will contribute a HPC module for the noisy emulation of the Pasqal HW (D4.13). It will take as input a Hamiltonian description of the HW, as well as a noise model in the form of, e.g., Lindblad operators [Daley14]. To get started (i.e before 4.5.1 yields its first results), **ATOS** will propose a first set of these parameters, and **Pasqal** shall be able to provide a more accurate one. In a similar way, outcomes are expected from 4.5.1.
Depending on the regime of simulation, this emulator may make use of tensor network representations. Integration into the computing centres (CEA, FZJ) will be taken care of in a separate subtask (4.5.3).

ATOS will deliver this module as a binary executable (no source code).
Partners involved: ***ATOS****, Pasqal*
Duration: month 3 – month 24

4.5.3 Emulator integration
For the purpose of HPCQS, **CEA** is planning to deploy a dedicated QLM SW configuration, provided in-kind by **ATOS**, on Joliot-Curie fat nodes made available in-kind by **GENCI**. This subtask will thus consist in dedicating some nodes of the Joliot-Curie supercomputer to the HPCQS project, installing the SW from **ATOS** and integrating the HPCQS users' submissions to a dedicated queue in the standard production framework **(D4.14)**. **FZJ** will integrate the access to the Pasqal noisy emulator (4.5.3) in the QC-PaaS of JUNIQ to run the ATOS SW on JUWELS **(D4.14)**.
Partners involved: ***CEA****,* ***FZJ***
Duration: month 3 – month 36

Deliverables

D4.1 Analog programming framework and quantum intermediate language (M12); **D4.2** Graphical language interface (M18); **D4.3** Static analysis toolbox (M24); **D4.4** Technical libraries (Combinatorial optimization, Machine learning, Lattice toolbox) (M24); **D4.5** Integration of technical libraries into Quantum Intermediate Language defined in D4.2 (M30); **D4.6** Publication of AQPU Interface (M6); **D4.7** Implementation of the AQPU Interface (M12); **D4.8** Architectures descriptions of the integration of Pasqal HW at JSC and TGCC (M24); **D4.9** Code optimization framework for analog quantum computing under HW constraints (M30); **D4.10** LHZ Compiler plugin (M24); **D4.11** VQS and optimization toolbox (M24); **D4.12** Report on emulator model, with comparison of large-scale emulator results using provided models, and validation with actual device (M24); **D4.13** HPC Emulator of Pasqal HW (M24); **D4.14** Integration of emulator into GENCI/CEA and FZJ HPC systems (M36)

Work package number	**WP5**						**Lead beneficiary**			**NUIG-ICHEC**							
Work package title	**Demonstrators, training and user engagement**																
Participant number	1	1b	2	3	4	5	**6**	7	8	9	10	11	12	13	14	15	16
Participant short name	FZJ	ParTec	CEA	GENCI	ATOS	CNR	**NUIG-ICHEC**	UIBK	EURICE	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	38	0	42	2	9	17,5	**22**	9,5	0	17	10	15	4,5	2	13	7,5	5
Start month	1							**End month**		48							

Objectives (O)

The objectives of WP5 for user engagement and training on the HPCQS platform and solutions via JUNIQ are:
O5.1: To build applications to demonstrate scientific and industry-relevant use-cases.
O5.2: To develop training material and user guides.
O5.3: To engage with and conduct training events for academic and industry users.
O5.4: To support the use of JUNIQ for application development by consortium and external users.

Description of work

Task 5.1: Use-case demonstrators

This task will focus on developing applications that serve as use case demonstrators, as outlined in section 1.3.4, for scientific and industry users by leveraging the models and libraries developed in WP4. These use cases will serve in building the training material and guides for activities in Tasks 5.2 and 5.3, and dissemination in WP6.

Initially, the use cases that are listed below will be developed on the Pasqal emulator and testbed platforms, and then developed on the Pasqal platforms that will be deployed and integrated with the HPC systems. At the start of this task, the technical requirements for development of the use cases (including development and continuous integration environments) will be defined (D5.1).

Here, Use Case (UC) 1 is devoted to the certification and benchmarking of the QS. They are followed by four additional use case demonstrators with different degrees of maturity. Particularly, UCs 2.1, 2.2, 2.3 and 3.1 are known to be readily implementable on neutral atom quantum processors, while other UCs are more exploratory and will be based on an initial phase of feasibility study and definition of their implementation scope. An interim report summarising detailed definitions of the use cases and their feasibility analyses will be delivered (D5.3).

UC1. **Certification/Performance Analysis for Quantum Simulators** will provide a set of tools to certify the quantum features and accurately evaluate the performance of QSs. They will include the following:

1. **CEA** and **CNRS** will develop witness-based, device independent and analog randomised benchmarking and performance analysis schemes (D5.2, D5.5).
2. **ParityQC** will implement a benchmarking plugin to connect the use-case applications to the ParityOS compiler (D5.5).
3. **FZJ** will perform simple experimental benchmarking tests on the QS and compare the results to emulations (D5.7).

UC2. **Physics Simulations** will leverage the technical libraries developed in WP4 (such as the lattice-model library) to implement applications for simulation of physics-based systems.

1. **NUIG-ICHEC** and **UIBK** will implement the Ising model in one- and two-dimensions (D5.8).
2. **NUIG-ICHEC** and **UIBK** will implement the Su-Schrieffer-Heeger (SSH) model (D5.12).
3. **NUIG-ICHEC** and **UIBK** will pursue implementation of recently demonstrated many-body quenched dynamics simulations (D5.12).
4. **ATOS** will develop numerical simulation of strongly correlated materials via the Variational Quantum Simulation Method (D5.8).
5. **CNR** will benchmark the creation of entanglement in many-body systems using the Quantum Fisher Information (D5.8).

Additionally, **CINECA** will investigate the feasibility and development of an application to simulate many-nucleon dynamics through funded as well as in-kind efforts.

UC3. **Quantum Approximate Optimisation Algorithm (QAOA)** will demonstrate the following applications:

1. **UIBK** will develop solutions for instances of Unit-Disk Maximum Independent Set problem (D5.6).
2. **CEA** will study and demonstrate the application of QAOA for factorisation (D5.9).
3. **FZJ** will benchmark QAOA on the Pasqal simulator against large-scale emulators on classical systems, classical QUBO solvers and the D-Wave quantum annealer (D5.13).
4. **ParityQC** will develop a plugin that connects QAOA applications to the ParityOS toolchain (D5.6).

UC4. **Variational Quantum Eigensolver (VQE)** will leverage the VQE algorithm to target the following applications in chemistry, solving wave equation and phase-estimation quantum Eigensolver:

1. **Fraunhofer-IAF** will define a series of electronic structure calculations to evaluate the performance of the Pasqal QS. **CEA** will work on designing catalysts relevant for nitrogen fixation (D5.14).
2. **INRIA** will develop the quantum algorithm resolution of the wave equation for the Helmholtz equation (D5.14).

UC5. **Quantum Machine Learning** will target the development of hybrid classical-quantum algorithms for the following ML applications:

1. **CNR**, **CINECA** and **BSC** will demonstrate reinforcement learning algorithms (D5.10).
2. **CNRS**, **CNR** and **FLS** will develop a pattern detection application using quantum neural network techniques (D5.10).
3. **CINECA, CNR, FLS** and **BSC** will work on classifying data points in a supervised learning scenario using quantum neural networks and testing them on real data (e.g. LHC experiments) (D5.10).

NUIG-ICHEC will demonstrate and evaluate the detection and classification algorithm implementations using remote sensing satellite image data. **FLS** will use an industry-oriented demonstration of the use-cases including machine learning software, development of image detector/classification approaches.

Typical applications are the development of video processing and remote sensing solutions to provide geospatial situational awareness both for the on-ground segment and the on-board one.

The development of all use cases will involve **Pasqal** to provide expert contributions on their quantum simulation platform and technology.

*Partners involved: **NUIG-ICHEC**, BSC, ATOS, CEA, CINECA, CNR, CNRS, FLS, Fraunhofer-IAF, FZJ, INRIA, ParityQC, Pasqal, UIBK*

Duration: month 1 – month 48

Task 5.2: Training and knowledge transfer

This task will engage with the user communities to deliver training programmes for knowledge transfer about the HPCQS platform via JUNIQ and developing hybrid classical-quantum applications on it.

To achieve this, the following project results will be leveraged to prepare tutorials and material for the training programmes:

- Schematic integration of the HPCQS platform with JUNIQ from WP2.
- Middleware and cloud-based access portal to the HPCQS platform via JUNIQ from WP3.
- High-level programming and SW environment with technical libraries from WP4.
- Use-case demonstrators for scientific and industry applications from Task 5.1.

The following types of training programmes will be delivered throughout the project period as summarised in section 1.3.4:

- Seminars (physical and/or online)
- Hands-on tutorials
- Summer schools
- Hackathons

The training programmes will be targeted for scientific as well as industry audiences to address the fundamentals of programming on the HPCQS hybrid platform and the development of applications to demonstrate use cases. Structured feedback will be collected from the trainees and reported.

Where feasible, training programmes will also be organised through engagement with PRACE Training Centres, European Centres of Excellence and EuroHPC National Competence Centres by leveraging the dissemination activities in WP6. These events will be co-located with related HPC and/or QT events such as International Supercomputing Conference (ISC), Supercomputing Conference (SC), European Quantum Technologies Conference (EQTC) and others listed in section 2.2.2.

Mid-term (D5.4) and final (D5.11) reports on training activities will be delivered.

NUIG-ICHEC will lead this task and the integration of results from all WPs into a coherent training material.

FZJ will provide material for courses and tutorials that are necessary for using the JUNIQ Portal and will also expand its JUNIQ and HPC courses to include the use of the HPCQS platform at the MSA level. HPCQS training programmes will be integrated in the JUNIQ training programme.

BSC, **CEA**, **CINECA**, **CNR**, **CNRS**, **Fraunhofer-IAF**, **FZJ**, **GENCI** and **NUIG-ICHEC** will leverage their QTs education programmes and national/European quantum training events to develop and deliver training sessions on the HPCQS project technologies and results.

ParityQC will provide training for usage of the plugins and SW developed in WP4 and WP5.

Pasqal will contribute to the training using their existing learning resources and their platform expertise.

*Partners involved: **NUIG-ICHEC**, CEA, CNR, CNRS, Fraunhofer-IAF, FZJ, GENCI, ParityQC, Pasqal*

Duration: month 1 – month 48

Task 5.3: User engagement

This task will provide support to users within the consortium and external participants. This will include developing user guides for the platform and supporting the access and use of the JUNIQ platform.

For engagement with external participants, a group for external users and stakeholders from academia and industry will be established from the project commencement. The engagements with this group will include identification of suitable applications and supporting the development/porting of their applications on the JUNIQ platform.

Structured feedback will be collected from the consortium and external users and reported. The feedback mechanism and its implementation will be defined at the start of the project. The external user and stakeholder group will also be engaged through the training programmes in Task 5.2.

Mid-term (D5.4) and final (D5.11) reports on user engagement activities will be delivered.

FZJ will lead this task and extend the user guides for the JUNIQ platform with details about HPCQS. In addition, FZJ will support the user groups of the JUNIQ system according to the integrated support structure applied at FZJ. All participants in this task will contribute to user guide extensions and support the engagements with the user groups (internal consortium participants and external users).

BSC, CEA, CINECA, CNR, CNRS, Fraunhofer-IAF, GENCI and **NUIG-ICHEC** will also leverage their national and European HPC and quantum user engagement and support programmes to target relevant scientific and industry users to leverage the HPCQS project technologies and results.
ParityQC will provide training for usage of the plugins and software developed in WP4 and WP5.
Pasqal will contribute to the training using their existing learning resources and their platform expertise.
*Partners involved: **FZJ**, CEA, CNR, Fraunhofer-IAF, GENCI, NUIG-ICHEC, ParityQC, Pasqal*
Duration: month 1 – month 48

Deliverables

D5.1 Technical requirements for use cases development (M6); **D5.2** Certification/Performance Analysis (witness-based performance analysis, analog randomised benchmarking) (M18); **D5.3** Interim report on use cases definitions (M18); **D5.4** Mid-term report on user engagement and training (M24); **D5.5** Certification/Performance Analysis (device-independent benchmarking, benchmarking plugin for ParityOS) (M24); **D5.6** QAOA use cases (unit-disk maximum independent set, plugin for ParityOS) (M24); **D5.7** Experimental benchmark tests for certification/performance analysis (M36); **D5.8** Physics simulations use cases (Ising model in 1D and 2D, strongly correlated materials, entanglement benchmarking) (M36); **D5.9** QAOA use case for factorisation (M36); **D5.10** Quantum Machine Learning use case (classification, reinforcement learning, pattern detection) (M48); **D5.11** Final report on user engagement and training (M48); **D5.12** Physics simulations use cases (Su-Schrieffer-Heeger, many-body quenched dynamics) (M48); **D5.13** QAOA benchmarking (M48); **D5.14** VQE use cases (electronic structure calculations, catalyst for nitrogen fixation, solution for wave equation) (M48)

Work package number	**WP6**						**Lead beneficiary**		**EURICE**								
Work package title	**Dissemination, communication and exploitation**																
Participant number	1	1b	2	3	4	5	6	7	**8**	9	10	11	12	13	14	15	16
Participant short name	FZJ	ParTec	CEA	GENCI	ATOS	CNR	NUIG-ICHEC	UIBK	**EURICE**	CNRS	INRIA	Pasqal	CINECA	BSC	FLS	ParityQC	Fraunhofer IAF
Person-months per participant	4	0	1	1	3	2	2	0	**20**	0	0	2	0,5	0	0	0,3	0
Start month	1							**End month**		48							

Objectives (O)

Main Objective: Consistent dissemination, outreach and communication, as well as a wide outreach to the large stakeholder community to support the building of an ecosystem, and operational support for exploitation.
Specific objectives:
O6.1: Steer communication, create visibility and encourage project outreach
O6.2: Disseminate results to the large stakeholder group. A detailed publication strategy will lead to a considerable number of high-quality publications. Specific workshops for different stakeholders will be organised
O6.3: Foster innovation capacity, with key exploitable results identified and exploitation strategies developed
O6.4: Peer-review provision of the HPCQS infrastructure.

Description of work

Task 6.1: Project communication – Management, Materials, Branding, Marketing
The project and its results will be promoted by professional communication measures providing targeted information via different channels (internet, social media, conferences, exhibitions) to multiple audiences, incl. the media and general public, in a strategic and effective manner. This will guarantee a high visibility of HPCQS from the very start of the project. Work in this work package is closely aligned with WP5 activities.

Strategic Planning, Management and Monitoring of Project Communication
Communication Board (CB): A CB, comprising **EURICE**, **FZJ** and **potentially further partners to be involved** will be established at the kick-off meeting. The CB will be in charge of guiding external project communication, collecting and producing content and quality assurance for all communication measures.
Communication Concept: As a basis for all communication measures, **EURICE** and **FZJ**, will elaborate a basic communication concept defining key messages and appropriate communication means to address major target

groups/audiences (e.g. specific stakeholder/user groups, broad public, see Part 2.2). The concept will annually be updated to incorporate internal project results and external developments (D6.1).
Communication Activity Plan (CAP): A CAP systematically outlining envisaged communication activities will be set up and regularly updated. The CAP will also serve as an internal communication monitoring tool, see also the preliminary Communication Activity Plan in section 2.2 (D6.2/D6.3/D6.4/D6.5)**.**

Project Branding & Marketing including Communication Material
Communication Toolkit: A Communication Toolkit (D6.7) based on the established Corporate Identity (CI) of HPCQS will be developed including core communication material such as adapted templates (e.g. posters, presentations, reports, internal documents), and will be further expanded during the course of the project by leaflets, equipment for a booth, roll-ups and give-aways. The partners will carry out a marketing campaign at the start of the project to address potential users.
*Partners involved: **EURICE**, FZJ*
Duration: month 1 – month 48

Task 6.2: Networking & stakeholder engagement
A systematic stakeholder analysis will be carried out within WP6 in close cooperation with WP5, under the lead of project partner **EURICE**, and guided by the CB. A user board will be established at the start of the project. Particular attention will be paid to liaising with related initiatives and platforms in the relevant communities (HPC, Quantum, relevant industries), see also sections 1.3 and B2.2 to foster the building of an ecosystem as well as to create synergies and leveraging effects (D6.9).
*Partners involved: **EURICE,** FZJ, CINECA, CNR, GENCI, NUIG-ICHEC*
Duration: month 1 – month 48

Task 6.3: Active dissemination of project results to commercial and non-commercial stakeholders
Pro-active publication planning will be initiated during the kick-off meeting and continued throughout the project's lifetime. Planned and implemented dissemination and exploitation activities and scientific publications will be summarized in the periodically updated PDE (D6.10/6.11/6.12).
Scientific (Open Access, OA) Publications: The coordinator will encourage, assist and monitor the timely publication of results in peer-reviewed journals (see table of planned publications in section 2.2) and at international conferences while ensuring that no conflicts with IPR issues arise. The project budget includes required resources to publish OA**.**
Scientific Events: The partners will carefully plan the presentation of results and participation in scientific workshops and conferences. (see preliminary Communication Activity Plan in section 2.2)
Media Relations: The CB will identify research results of special interest and trigger press releases to be published on the project website and relevant international science information platforms (e.g. CORDIS, Eurekalert). Press releases will be distributed to all partners' press departments to stimulate decentralized communications and a broad addressing of media outlets/journalists on a regional and national level.
*Partners involved: **FZJ**, CNR, NUIG-ICHEC*
Duration: month 1 – month 48

Task 6.4: Use of online-/Social Media tools for communication and dissemination of envisioned project results
Project Website: EURICE will set up and maintain the public project website (D6.6), including the development of a content structure, web design and web hosting. The website will serve as a central showcase for the project's activities and achievements. All partners will regularly provide new content to keep the website up-to-date.
Audio-visual Material: Audio-visual material such as a corporate video and animated videos to explain key features of the project or short interview/event clips will be produced (D6.8). The material will be released on the HPCQS website and promoted via social media platforms, on events and through individual communication measures of each partner.
Social Media: EURICE together with additional project members active in social media will develop a sound social media strategy considering the most appropriate platforms, e.g. LinkedIn, Twitter, ResearchGate and best use according to the project's objectives.
*Partners involved: **EURICE**, all partners*
Duration: month 1 – month 48

Task 6.5: Project Exploitation and IP Management
A step-wise approach of IP Management is implemented to identify key project results with high potential for further exploitation. Exploitation activities comprise strategic planning as well as operational support. The scope

and timing of activities is shaped to match the progress of work and level of maturity of results, starting from a broader scope and increasing the specificity continuously, as described in the following.

Phase 1: Capacity building and Strategy Validation: In the 1st project year a common basis on the general conditions of IP Management and on validating and refining initial exploitation plans is developed. A webinar laying out the rules for IP rights and management will be offered by **EURICE** at the kick-off meeting. Together with a capacity building session, this will deepen the understanding of specific IPR topics relevant to HPCQS technologies and stimulate reflection on the initial exploitation plans. An individual partner contribution-benefit matrix (CBM) will be compiled to obtain a consolidated overview to visualize and strengthen the development of responsibilities and commitments among partners, led by **EURICE**. To clearly define exploitation plans at partner level, innovation-related questionnaires (IRQ) will be collected towards the end of year 1.

Phase 2: Strategy execution and evaluation of new IPR, patent filings and market evaluation: Starting at the end of the 1st year and at the beginning of the 2nd project year, exploitation strategies are further developed at consortium level, and the findings from the CBM and IRQ consolidated. An Exploitation Strategy Workshop will be organized at the M12 project meeting to validate Key Exploitable Results (KER), and IPR evaluations will be done at partner level. Towards the end of the 2nd project year, specifically during the M18 and M24 meetings, an Exploitation Planning Workshop is held to support partners in their IPR filings and to discuss concrete plans for their identified KERs. Specifically, for the SMEs, an exploitation roadmap is discussed to clarify IP status, value propositions, market segments, risks, competitors, legal and other further steps to be taken. For each KER, a KER lead will be identified to document key parameters of the KERs, e.g. using the Innovation Model Canvas, an adapted version of the Business Model Canvas. Work is led by **EURICE. I**n the 3rd and 4th project years exploitation roadmaps will be further developed, and the KER leads will share updated results at the project meetings. If need be, external experts are invited to advise on specific aspects, such as regulatory, data and IP protection issues. Towards the end of the project, activities will focus on the planning of concrete steps towards the market-oriented exploitation of KERs, particularly relevant to the industrial partners. A Sustainability Planning Workshop will be held at the M36 project meeting, and a competitive early-stage IP landscaping will identify 'clear' or 'white' space for further R&D. Results will support decision-making about IP protection and potential exploitation pathways, thereby avoiding dead ends and blocking risks, also using early stage Freedom-To-Operate-Analysis. Workshop materials will lay the basis for the elaboration of the exploitation part of the PDE.
*Partners involved: **EURICE**, FZJ, All Partners*
Duration: month 1 – month 48

Task 6.6: Peer-reviewed provision of HPCQS
A peer-reviewed provisioning process for access to the quantum-classical hybrid SW and HW infrastructure HPCQS will be set up and operated. Half of the infrastructure resources will be provided via national processes (e.g. JUNIQ or GENCI/DARI) and grants and half will be offered to users on the European level. For the latter, in the first project year, the feasibility of the inclusion of the HPCQS resources in the PRACE Tier-0 compute services will be evaluated. PRACE has a well-established peer review process involving numerous scientists from various fields across Europe, which will contribute to project visibility and encouraging project outreach. In the second project year, experts from different scientific fields with a background in quantum computing will be identified and attracted to support the corresponding peer review process. Finally, a resource allocation process will be implemented and the HPCQS resources will be integrated into the European HPC landscape. The whole peer-reviewed provisioning process will be documented (D6.13).
*Partners involved: **FZJ**, GENCI*
Duration: month 1 – month 48

Deliverables

D6.1 Communication Concept including appropriate communication measures (M2); **D6.2** Communication Activity Plan (M2); **D6.3** Communication Activity Plan (M18); **D6.4** Communication Activity Plan (M36); **D6.5** Communication Activity Plan (M48); **D6.6.** Public project website and social media accounts established on LinkedIn (M4); **D6.7** Corporate design and communication toolkit (M6); **D6.8** Audio Visual Material provided (M18); D**6.9** Liaison activities with external stakeholders –report (M18); **D6.10** Plan and record of Dissemination & Exploitation of project results (M18); **D6.11** Plan and record of Dissemination & Exploitation of project results (M36); **D6.12** Plan and record of Dissemination & Exploitation of project results (M48); **D6.13** Report about the peer-reviewed provisioning process (M48)

3.1.c List of Deliverables

Del. no.	Deliverable name	WP no.	Lead participant	Type	Dissemination level	Delivery date (in months)
D1.1	Project management platform	1	EURICE	DEC	CO	2
D6.1	Communication Concept including appropriate communication measures	6	EURICE	R	CO	2
D6.2	Communication Activity Plan	6	EURICE	R	CO	2
D6.6	Public project website and social media accounts established on LinkedIn	6	EURICE	DEC	PU	4
D1.2	Management Guide - workflows and information for the project implementation	1	EURICE	R	CO	6
D1.3	Webinar on Horizon 2020 financial management	1	EURICE	OTHER	CO	6
D1.5	Data Management Plan	1	FZJ	R	CO	6
D4.6	Publication of AQPU Interface	4	ATOS	OTHER	CO	6
D5.1	Technical requirements for use cases development	5	NUIG-ICHEC	R	CO	6
D6.7	Corporate design and communication toolkit	6	EURICE	R	CO	6
D1.4	Internal Progress Report (covering Mo 1–9)	1	EURICE	R	CO	11
D2.1	Quantum pilot procurement	2	GENCI	R	CO	12
D4.1	Analog programming framework and quantum intermediate language	4	ATOS	OTHER	CO	12
D2.2	Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies	2	GENCI	R	PU	12
D3.1	Report on the architecture specification	3	FZJ	R	PU	12
D4.7	Implementation of the AQPU Interface (M12)	4	Pasqal	OTHER	CO	12
D4.2	Graphical language interface	4	CNRS	OTHER	OU	18
D5.2	Certification/performance analysis (witness-based performance analysis, analog randomised benchmarking)	5	CEA	OTHER	PU	18
D5.3	Interim report on use cases definition	5	NUIG-ICHEC	R	PU	18
D6.3	Communication Activity Plan	6	EURICE	R	CO	18
D6.8	Audio Visual Material provided	6	EURICE	DEC	PU	18
D6.9	Liaison activities with external stakeholders –report	6	EURICE	R	CO	18
D6.10	Plan and record of Dissemination & Exploitation of project results	6	EURICE	R	CO	18
D2.3	Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies	2	GENCI	R	PU	24
D2.6	Yearly operational report	2	CEA	R	PU	24
D3.2	Report on the prototype software implementation	3	ParTec	R	PU	24
D4.3	Static analysis toolbox	4	xxx	xxx	xxx	24
D4.4	Static analysis toolbox and Technical libraries (Combinatorial optimization, Machine learning, Lattice toolbox)	4	ATOS	OTHER	PU	24
D4.8	Architectures descriptions of the integration of Pasqal HW at JSC and TGCC	4	FZJ	R	PU	24
D4.10	LHZ Compiler plugin	4	ParityQC	OTHER	CO	24
D4.11	VQS and optimization toolbox	4	UIBK	OTHER	CO	24
D4.12	Report on emulator model, with comparison of large-scale emulator results using provided models, and validation with actual device	4	NUIG-ICHEC	R	PU	24
D4.13	HPC Emulator of Pasqal Hardware	4	ATOS	OTHER	CO	24
D5.4	Mid-term report on user engagement and training	5	FZJ	R	PU	24
D5.5	Certification/performance analysis (device-independent benchmarking, benchmarking plugin for ParityOS)	5	CEA	OTHER	PU	24
D5.6	QAOA use cases (unit-disk maximum independent set, plugin for ParityOS)	5	UIBK	OTHER	PU	24
D4.5	Integration of technical libraries into Quantum Intermediate Language defined in D4.2	4	ATOS	OTHER	PU	30
D4.9	Code optimization framework for analog quantum	4	CNRS	OTHER	PU	30

Del. no.	Deliverable name	WP no.	Lead participant	Type	Dissemination level	Delivery date (in months)
	computing under HW constraints					
D2.4	Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies	2	GENCI	R	PU	36
D2.7	Yearly operational report	2	FZJ	R	PU	36
D3.3	Report on the complete software implementation	3	ParTec	R	PU	36
D4.14	Integration of emulator into GENCI/CEA and FZJ HPC systems	4	CEA	OTHER	CO	36
D5.7	Experimental benchmark tests for certification/performance analysis	5	FZJ	OTHER	PU	36
D5.8	Physics simulations use cases (Ising model in 1D and 2D, strongly correlated materials, entanglement benchmarking)	5	NUIG-ICHEC	OTHER	PU	36
D5.9	QAOA use case for factorisation	5	CEA	OTHER	PU	36
D6.4	Communication Activity Plan	6	EURICE	R	CO	36
D6.11	Plan and record of Dissemination & Exploitation of project results	6	EURICE	R	CO	36
D2.5	Quantum computing technologies roadmap (HW/SW) and assessment of emergent and promising quantum computing technologies	2	GENCI	R	PU	48
D2.8	Yearly operational report	2	CEA	R	PU	48
D2.9	Best practices guide for the integration of a quantum simulator with a Tier 0 HPC infrastructure	2	FZJ	R	PU	48
D3.4	Final support and operation report	3	FZJ	R	PU	48
D5.10	Quantum Machine Learning use case (classification, reinforcement learning, pattern detection)	5	CNR	OTHER	PU	48
D5.11	Final report on user engagement and training	5	FZJ	R	PU	48
D5.12	Physics simulations use cases (Su-Schrieffer-Heeger, many-body quenched dynamics)	5	NUIG-ICHEC	OTHER	PU	48
D5.13	QAOA benchmarking	5	FZJ	OTHER	PU	48
D5.14	VQE use cases (electronic structure calculations, catalyst for nitrogen fixation, solution for wave equation)	5	CEA	OTHER	PU	48
D6.5	Communication Activity Plan	6	EURICE	R	CO	48
D6.12	Plan and record of Dissemination & Exploitation of project results	6	EURICE	R	CO	48
D6.13	Report about the peer-reviewed provisioning process	6	FZJ	R	CO	48

Graphical presentation of components showing how they inter-relate (Pert chart or similar)

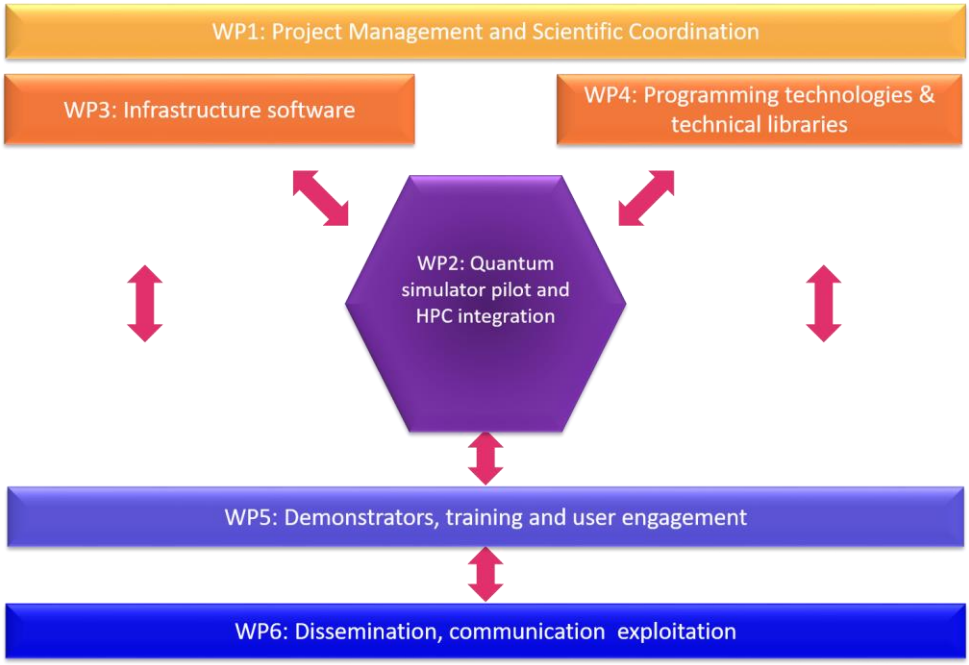


Figure 5: HPCQS work package structure.

3.2 Management structure, milestones and procedures

Organisational structure and decision-making

The HPCQS project management will provide a clear organisational framework and all necessary support mechanisms, to enable a smooth project workflow and to ensure that all contractual commitments are met on time. Project management activities will comprise a wide array of activities that will all go hand in hand, including scientific and administrative management, contractual management, financial management, management of ethical issues, data management, management of communication, and innovation management.

The organisational structure jointly agreed on by the consortium is designed to be simple, democratic, consensus-oriented and efficient, and has been adapted to the size and composition of the consortium and the tasks and duties of all partners involved (Figure 6).

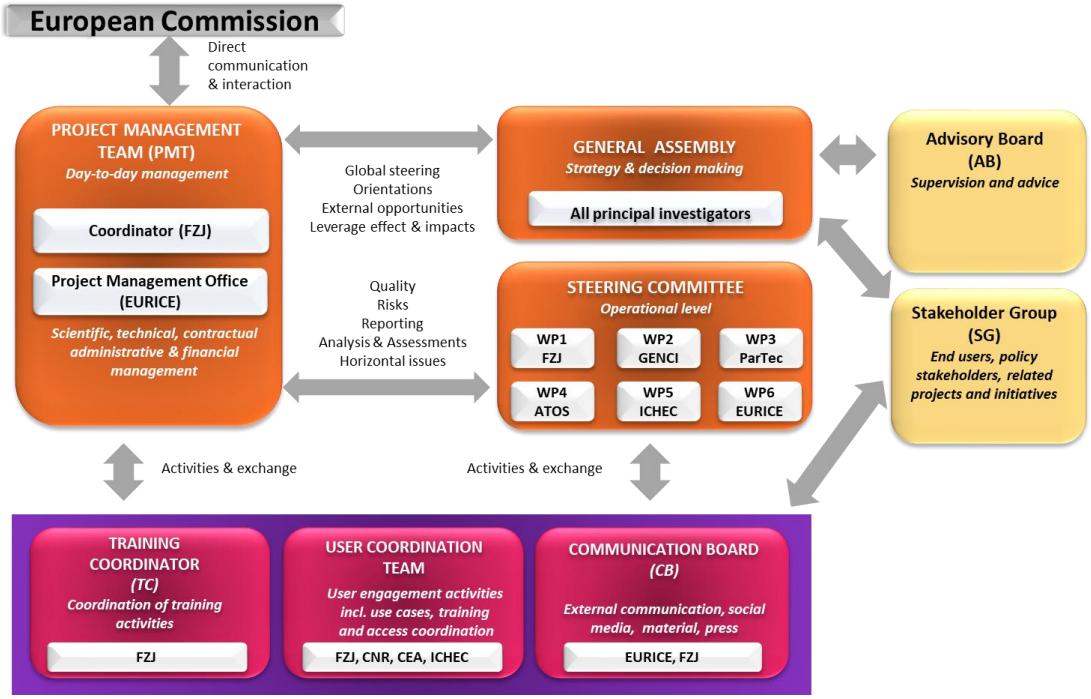


Figure 6: HPCQS organisational structure.

Management Bodies

The Coordinator (COO) is represented by Kristel Michielsen, who has longstanding experience in the implementation and management of regional, national and international multidisciplinary grants, including EU grants. Apart from being coordinator of the HPCQS project, her participation in further relevant EU projects (e.g. OpenSuperQ) and the involvement of FZJ at the level of the European Technology Platform ETP4HPC and relevant infrastructures (PRACE, EuroHPC), will guarantee the integration and interconnectedness of HPCQS thanks to strong links with relevant stakeholders.

The COO will be in charge of the overall management of the HPCQS project and will act as the intermediary for all communications and interactions with the European Commission. In more detail, the tasks of the COO include the coordination of any scientific, technical, dissemination as well as exploitation related activity at consortium level. In close collaboration with the Work Package Leaders, she will follow-up on the work plan and the status of deliverables and milestones, carry out risk assessment and contingency planning, and monitor the overall implementation of the project.

The Project Management Office (PMO) EURICE has extensive experience in EU project management and as innovation management partner in international collaborative projects. EURICE has been involved in EU-Framework Programmes since FP4 and has been supporting researchers in over 250 EU funded projects to date.
The PMO will support the COO in all administrative, contractual, financial and organisational management tasks, and will serve as a 'helpdesk' for all partners, giving guidance in any administrative, financial and EC regulatory questions in day-to-day work. Requests will be consolidated and channelled by EURICE before forwarding them to the COO to reduce his/her administrative workload to a minimum. EURICE will coordinate and monitor project communication as well as reporting. In summary, the PMO will be at the consortium's service during the entire lifetime of the project supporting the COO and all partners in every aspect of project implementation.

Together, the COO and the PMO will form the Project Management Team (PMT) and will be in charge of all management tasks in HPCQS. The PMT will assume the role of an interface between the consortium and the European Commission and as such be responsible for the delivery of reports as well as uptake and implementation of EC suggestions and requests. The PMT meets (via teleconference) at least every month.

The Steering Committee (SC) consists of the coordinator and the Work Package Leaders. It monitors the project and meets virtually at least every month. The SC represents the interface between the General Assembly (GA, see below) and the PMT. Thus, the SC allows for focused and comprehensive monitoring of the status in the different activities measured against deliverable and milestone planning, control of deliverable timeliness and quality in order to ensure timely and accurate work plan follow-up, early identification of possible technical and organisational problems and for troubleshooting.

The General Assembly (GA) will be composed of one representative per partner (Principal Investigator, PI). The GA will be chaired by the COO. The GA will act as the ultimate democratic, consensus-driven decision making body in HPCQS. Decisions will comprise any technical or scientific changes to be made to the objectives and the overall work plan, project management related matters including re-allocation of tasks or resources or actions with regard to a defaulting party, resolving administrative or organisational issues, modifications to the consortium agreement and conflict management in general. Decisions will be made regularly at project meetings or when the need arises. Each partner will have one vote but may define an authorized deputy in order to guarantee that the GA is quorate at any time. In case of parity the COO will have the casting vote. Detailed rights and obligations of the GA will be laid down in the consortium agreement, which will be concluded jointly by all partners before the start of the project.

User Coordination Team
The User Coordination Team, composed of representatives from FZJ, CNR, CEA, GENCI and NUIG-ICHEC, will function as a central coordination team for all user engagement activities including preparation of use case demonstrators, training and access coordination. Main tasks are assigned to WP5 and WP6 which include the following:

- preparing training material, tutorials and guides for training and user engagement activities,
- planning and conducting training programmes throughout the project period, and
- leveraging related national, European and international activities and projects to provide training, user access and support.

Training coordinator – FZJ
This role is encompassed within WP5. The training coordinator will initiate and manage the training programme with the help of the User Coordination Team, EURICE and local organisers, who will undertake organisation of venues, recruitment to workshops, registration, accommodation and report submission relating to the training activities.
Related activities will be regularly reviewed during the WP5 work plan meetings where input from other partners can be gathered. NUIG-ICHEC will support FZJ by leading the preparation of the use case demonstrators and related material/resources for the training activities.

External user and stakeholder group
The External user and stakeholder group consisting of members from academia and industry will be set up at the start of the project. Its activities will be managed by the User Coordination Team with the support of the PMT and all partners. New participants will be integrated through the planned stakeholder analysis. The participants are involved in the training and use case activities to be carried out under WP5. The GA will validate each of the participants and specific involvement and will deal with conflicts of interests between partners and stakeholders.

An initial stakeholder analysis has been carried out already during the proposal stage to prepare for use case and training activities as well as to receive a first feedback on user needs and requirements with regard to the planned infrastructure. Contacted stakeholders included:

- Relevant research institutions in the field of quantum technologies, but also application areas
- Supercomputing centres
- Companies in the field of quantum technologies, but also application areas, including HW manufacturers, SW developers as well as service providers with a focus on SMEs
- Large companies in major application areas, such as automotive, pharma, energy and electricity, telecommunications
- Associations representing players in relevant fields

48 stakeholders have expressed their interest in becoming members of the planned user board and have provided Letters of Support (see Annex including an overview table as well as a selection of Letters of Support).

Advisory Board
Upon commencement of the project an Advisory Board (AB) will be formed, consisting of appropriate representatives from relevant research areas. At the start of the project, some of those interested in participating in the User Board (reference to letters of support) will be solicited to participate in the Advisory Board. The role of the AB will be to receive an appraisal of project developments and to advise the project on issues relating to priority research directions. As its name points out, its role is purely advisory and is to be seen on a more strategic level. The AB will meet up to once a year before yearly GA meetings and will be given briefing material before each meeting.

The members of the AB shall sign non-disclosure agreements (NDA) before obtaining access to any confidential project-related information. The specific provisions of the NDA to be signed will be agreed on with all beneficiaries during the first months of the project. Upon decision of the GA, the board will be open to include further members to establish links with further relevant projects and infrastructures.
The participation in individual meetings of board members will be discussed and adapted to the status of the project and current needs. Where possible and appropriate, tele meetings (video and telephone conferences) will be used.

Monitoring project progress and reporting

Internal communication structure
The internal communication activities keep all partners fully informed about the project status and other relevant issues and increase the synergy and cooperation culture within the consortium. The PMT will be responsible for distributing all appropriate information (i.e. reports, minutes of meetings, etc.) to the consortium. HPCQS will use a project management platform set up and maintained by EURICE, where all documents and exchange can be made, with complete traceability and data safety. The document repository gathering all the documentation related to the specific project, is encrypted and accessible only to the members of the consortium dealing with it.

A core element to enable success will be the biweekly jour fixe conference calls that are open to the GA plus ad-hoc invitees if necessary and thematically structured by the coordinator with the help of the Steering Committee. Depending on the issue at hand these can be discussions about milestones and deliverables, risks, technical aspects as well as any matter related to the global operation and mission of HPCQS. In addition, each WP leader manages his/her group of partners with the help of regular teleconferences.

Procedures
Within the SC all activities will be coordinated in close cooperation between the COO and the WPL: Each WPL will monitor the status of deliverables, milestones and financials of his/her WP and will inform all SC members on the status quo during project meetings and ad hoc by personal communication if the need arises. To assist the WPL in their tasks, EURICE will collect administrative and financial information from each partner and compile an overview on WP level at regular intervals.

Following the 18-months default reporting period in Horizon2020, three periodic technical reports and one final report will be submitted to the EC (months 18, 36, 48). Compilation of these reports will be managed by the PMT. Besides these contractual obligations, the consortium will implement an internal progress report after the first half of reporting period 1 to ensure a quick uptake of activities, the proper use of resources and adherence to guidelines immediately from the project start. Specific reporting needs as required by the Joint Undertaking and national funding agencies will be taken into account by the PMT and implemented using appropriate tools and templates. Internal and official/contractual reporting will be implemented based on the following procedure:

A) Team Leader report (TLR): Each partner will prepare TLRs for each WP they are involved in, to inform the relevant WPL of progress towards the achievement of particular deliverables in compliance with the work plan.
B) Work Package Leader report (WPLR): Based on the input of each partner given in the individual TLR, each WPL will then prepare a WPLR, summarizing the activities of all partners within the respective WP.

Both TLR and WPLR will comprise a description of tasks carried out and technical progress, as well as deviations from the work plan. **EURICE** will collect administrative and financial information from each partner. The overall project progress will be monitored by the PMT based on these WPL reports.

Project meetings. Meetings will be planned taking into account potential restrictions due to COVID-19 and economical aspects. Major meetings will be held once a year alternating between FZJ and GENCI sites and will be divided into a scientific progress section, a scientific workshop section, and an administrative management section. Additional virtual meetings will be held as necessary. Further meetings will be held typically connected to a conference as described in the dissemination part. These meetings will gather the representatives of the partners, members of the user board and further relevant stakeholders as appropriate.

Decision making, redirection of strategies, contingency planning as well as explanation of appropriateness

Decisions will be made by the different project bodies as described above including voting rights, etc. Detailed rules for decision making and risk management will be laid down in the HPCQS consortium agreement, to be jointly agreed on by all partners before the start of the project. The document will be the basis for the legal, administrative, financial and organisational management of HPCQS and will include regulations on:

- **Technical provision**s (technical resources made available, maximum efforts, modification procedures)
- **Rules for dissemination and use** (particularly confidentiality, ownership of results, legal protection of results, pre-existing knowledge of partners (background))
- **Organisational provisions** (committees, cooperation supervision, revision of the agreement)
- **Financial provisions** (financing plan, modification procedures, mutual payments, etc.)
- **Legal provisions** (legal cooperation status, terms of the agreement, penalties for non-compliance with obligations, applicable law)

The **organisational structure of HPCQS** has been designed to provide for **maximum efficiency in project management issues**. WPs are headed by experienced Work Package leaders who will function as primary responsible persons for the smooth implementation of their WP, or, if necessary, for quick and efficient troubleshooting. The WPLs will be closely supported by an experienced **Project Management Team** (PMT), which has implemented effective management structures and procedures in comparable initiatives before. It must remain **the responsibility of each individual project partner to report any risk situations** that may conflict with the project objectives or their successful completion immediately to the WPL concerned as well as to the PMT. A number of potential risks to which particular attention will be paid right from the start of the project have been identified already and are described in detail in section 3.2.b. Upon reporting of an occurring risk, the COO will consult with the concerned WPL or the entire SC according to the gravity of the problem. Possible mitigation measures, including changes in the scheduling of deliverables and/or allocated budget will be discussed immediately and decided on in a timely manner.

The work plan follow-up and decision-making process designed for HPCQS has taken these factors into account, and **the PMT as well as all selected WPLs are well experienced in dealing with the managerial tasks** to which they were assigned. In case of a need for remedial action, the PMT will set the schedule for finding solutions and the COO will chair all discussions. In the case of critical deviations from the work plan the EC will be informed and consulted immediately. Every issue will be managed in accordance with the provisions of the Grant Agreement and the Consortium Agreement. General Assembly meetings will be called, whenever necessary.

3.2.a List of milestones

Milestone no.	Milestone name	Related WP(s)	Due date (in month)	Lead participant	Means of verification
MS1	Kick-Off Meeting; Appointment of all board members and implementation of management structure	WP1	M1	FZJ	Report of meeting with all partners (meeting minutes) àstart of project
MS2	Procurement of the Pasqal Fresnel twin QPU system	WP2	M9	GENCI and FZJ	Report of quantum pilot procurement (D2.1)
MS3	Installation of the two QPUs at GENCI/CEA and FZJ/JSC	WP2	M24	GENCI and FZJ	QS HW equipment acceptance form
MS4	QPUs made available to the users	WP2	M26	GENCI and FZJ	QSs available through the JUNIQ portal
MS5	Architecture defined	WP3	M12	FZJ	Specification report
MS6	SW prototype implemented	WP3	M24	ParTec	Prototype implementation report
MS7	SW implemented and deployed	WP3	M36	ParTec	Deployment report
MS8	Use cases definitions and feasibility analyses completed	WP5	M18	NUIG-ICHEC	Interim report with use cases definitions (D5.3)
MS9	Interim training and user engagement plans with first set of use case demonstrators prepared	WP5	M24	FZJ and NUIG-ICHEC	Mid-term report on user engagement and training (D5.4); use case deliverables (D5.5, D5.6)
MS10	Second set of use case demonstrators prepared	WP5	M36	NUIG-ICHEC	Use case deliverables (D5.7-5.9)
MS11	Training and user engagement with use case demonstrators completed	WP5	M48	FZJ and NUIG-ICHEC	Final report on user engagement and training (D5.11); use case deliverables (D5.10,

Milestone no.	Milestone name	Related WP(s)	Due date (in month)	Lead participant	Means of verification
					D5.12-5.14)
MS12	Basic communication concept & activity plan	WP6	M6	EURICE	Concept paper
MS13	Implementation of an allocation process for the HPCQS resources and complementation of the HPC reviewer pool	WP6	M48	FZJ and GENCI	Resource allocation report

Innovation management

Innovation management is considered an important task by the HPCQS consortium. WP6 and WP1 in close cooperation with WP5 will deal with innovation-related activities to guarantee that the innovation potential of the project results is identified, and respective measures can be taken.
The project will constantly look for internal and external opportunities in order to promote innovation. The Use cases, the direct involvement of users in the project (such as BSC, CINECA, FLS) as well as the involvement of users via the User board and Training programme - together with the planned dissemination, communication and exploitation strategy – will help to identify needs and requirements of end-users and collect feedback. Such feedback will be taken into account to design the planned infrastructure and linked services. Innovative results include the identification of suitable applications by the user group and supporting the development/porting of their applications on the JUNIQ platform. An innovation in the field of training will be the planned cooperation with the PRACE training centres to develop one of the first (or even the first) common HPC/Quantum training curriculum for the research and industrial communities with the support of all HPCQS partners.

While the focus of the project is on building the HPCQS infrastructure around the simulators and corresponding services with the ultimate aim of sustaining the sites, involved companies along the value chain (services providers, equipment manufacturers, end users) expect considerable innovation potential for their products and services as described in Part B2.2. exploitation. Other results will be exploited for further research, teaching and training/capacity building.

The project work plan foresees that individual exploitation strategies will be collected and depicted right at the beginning of the project (building on what has already been collected and discussed on the proposal phase) and merged to a coherent exploitation strategy on consortium level.

The exploitation section of the Plan for the Dissemination and Exploitation of results (PDE) will include a table detailing each identifiable project result with the owner(s) of such result, sectors of potential application and an overall plan for the protection and exploitation of the result(s), to be updated regularly as the project progresses. As an unbiased party, EURICE will monitor all innovation-related progress and moderate innovation-related activities to help reach mutually agreed settlements at consortium level. EURICE will serve as a contact person for all consortium members for any innovation and IP related questions that may arise during the course of the project. EURICE was a partner in the “European IPR helpdesk” (2015-2018) and is now coordinating the “IP Helpdesk” project (2019-2021), which provides free-of-charge first line support services on IP issues to projects funded under the Research and Technological Development framework programmes.

Critical risks and mitigation measures

All consortium members have long-standing experience in scientific research as well as participation in or coordination of projects at international levels. Thus, the consortium is capable of identifying and dealing with potential risks due to the fact that partners are experienced in planning and implementing appropriate contingency measures. Already established tight links and well-functioning communication lines through earlier and ongoing cooperation in other projects is a strong asset that will help reduce complications and ensure short reaction time should quick action be needed.

Furthermore, efficient management structures will be implemented in HPCQS, allowing for close monitoring of WP status, early identification of possible scientific, technological, experimental, organisational and administrative problems, troubleshooting and conflict resolution.

Taken together, the consortium is convinced that risks that may arise during the project are kept to a minimum.

3.2.b Critical risks for implementation

Description of risk (indicate level of likelihood: Low/Medium/High)	WP(s) involved	Proposed risk-mitigation measures
WP leaders not coordinating activities properly or timely (**Medium**). Individual partners not performing the assigned tasks on time (**Medium**).	WP1, all WPs	A robust project management structure will be implemented to enable pro-active management. A clear work plan has been elaborated specifying 'who does what', and responsibilities for individual tasks have been allocated to experienced partners. Internal progress reports will allow close monitoring and enable corrective actions. Project meetings will be carried out at a regular basis to discuss and solve problems by consensus. A Consortium Agreement defining responsibilities and obligations of all partners will be jointly concluded, binding the actions and commitment of the partners. An experienced management team and professional project management office will implement risk reflection strategies at a problem-oriented level. Hence, it is expected that conflicts become apparent very quickly in day-to-day communication and thus severe discordances will be excluded. By doing so, conflict resolution will not affect the consortium nor has any implications on the work plan.
Delay in the procurement or the provision of the Pasqal Fresnel QPUs (**Medium**)	WP2, all WPs	1) Pasqal will carry out risk management and quality insurance activities (setting-up and updating a risk register tracking any risks that could affect the project; monitoring the risks, assess their probability and consequences, implementing mitigation strategies; producing a quality assurance plan detailing project management procedures, deliverable production and review mechanisms) 2) Pasqal provides support to build an emulator as part of Tasks 4.5.1 and 4.5.2 and will provide in 2021 access to the project partners to an internal (already existing 100-qubit) system 3) Two devices are to be delivered. This is already, to some extent, a mitigation task. The two QSs will work in parallel to catch up the delays.
Delays in technical library development & integration (**Medium**)	WP4, WP5	Appropriately abstracting technical implementation and defining all expected interfaces and communication layers will allow dependent tasks in WP5 to proceed, and overlap while WP4 tasks are completed.
Certain exploratory use cases are too complex to implement as planned (**Medium**)	WP5	Task 5.1 will involve an initial phase to define the detailed scope and feasibility of the use case implementation. This will identify any issues related to the scale and scope of their realisation on the HPCQS infrastructure within the project period. If required, the scope of a use case will be scaled back to implement a demonstrable, yet relevant, use case.
Training activities are inhibited by restricted/limited travel and gathering due to public emergencies, such as COVID-19 (**Low**)	WP5	All partners involved in Task 5.2 for training and knowledge transfer are experienced in designing and delivering web-based training programmes (live and/or recorded). In case of restrictions to conduct face-to-face training activities, virtual web-based training programmes will be organised and delivered.
Partners not engaged in project dissemination and/or exploitation (**Medium**). Conflicts over IP management (**Low**).	WP6, all WPs	Open access planning for scientific publications will be implemented jointly by all partners. A publication strategy will be elaborated to clarify writing responsibilities, rules and obligations. The periodically updated PDE will include a current overview of the project's (open access) publication status. The Consortium Agreement will provide the legal framework for IP-management, with a specific section dealing with innovation-related clauses (ownership, access rights, decision making procedures, etc. Innovation management will follow a structured approach and consolidates all individual partner´s interests. Key Exploitable Results will be identified and exploitation opportunities will be planned jointly.

3.3 Consortium as a whole

Consortium description

The HPCQS consortium, with partners from academia and industry from six European countries, brings together all necessary levels of expertise needed for the project. The five participating European HPC centres FZJ/JSC, GENCI/CEA, NUIG-ICHEC, BSC, and CINECA collaborate closely with the technological participants Pasqal,

ATOS, ParTec, FLS, ParityQC, and the research participants FZJ, CEA, CNRS, INRIA, CNR, UIBK, Fraunhofer IAF to reach their joint goals. The project management office EURICE provides HPCQS with its expertise in innovation-related activities and project coordination.

Apart from NUIG-ICHEC, which is a Tier-1 site, all other HPC centrs are Tier-1 sites of which BSC and CINECA are pre-exascale EuroHPC sites and FZJ/JSC and GENCI are hosting candidates for the EuroHPC exascale machines to come from 2023 on. The four Tier-0 HPC centres are also hosting members of the FENIX infrastructure. Both Tier-1 sites FZJ/JSC and CEA/GENCI will host, integrate and operate the Pasqal QS. The technological participants, ranging from startup to multinational companies will participate in HPCQS with their expertise in quantum and HPC HW, infrastructures and end-user SW and services. The research participants come from leading European research centres of which many are involved in the research and governance activities of the European Quantum Flagship. Apart from ParTec and EURICE, all consortium partners are involved in the development of the use cases.

The company ParTec participates in HPCQS as linked third party to FZJ. In 2010, FZJ made a decision to partner with ParTec to co-develop in all aspects of system SW, especially for the MSA. Since then, when both institutions work together in R&D projects (e.g., in the EU-funded projects DEEP, DEEP-ER, and DEEP-EST), ParTec consequently holds a position as linked third party to FZJ. Due to the history and positive experience of this partnership, ParTec keeps its position as FZJ's linked third party also for the HPCQS project. To make its involvement totally transparent to the reviewers, EuroHPC JU and the consortium, ParTec's contributions to HPCQS, its role and responsibilities are displayed explicitly in the proposal body (sections 1-3).

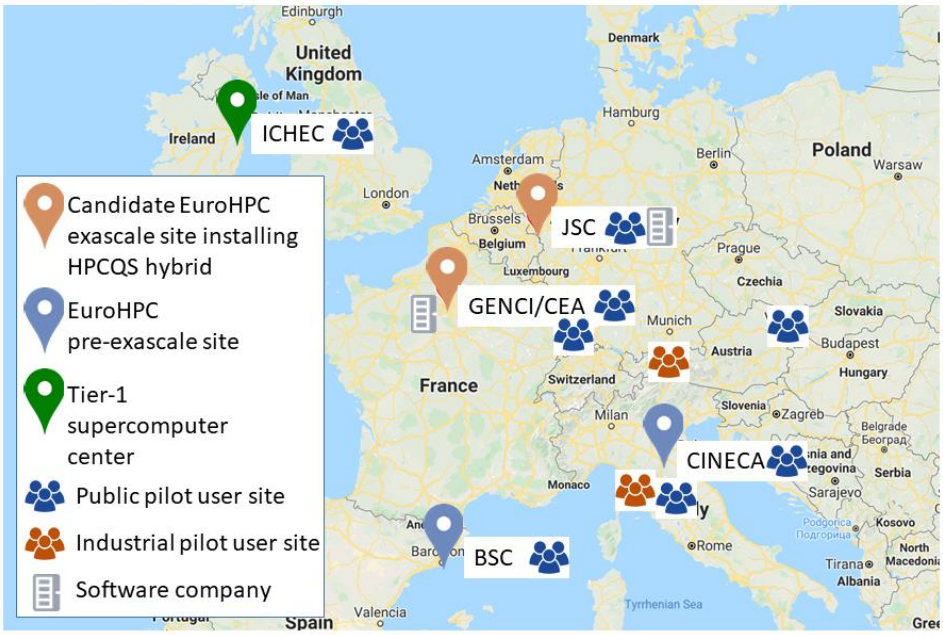


Figure 7: HPCQS consortium.

Industrial/ Commercial involvement

With **Pasqal**, **ATOS**, **ParTec**, **FLS** and **ParityQC** industry players from Europe are directly involved in the project. The companies cover the value chain from equipment manufacturers and service providers enabling the establishment of the infrastructure to end-users being interested in using the infrastructure and giving valuable feedback during project implementation, see detailed descriptions of their contributions in Part 1 and exploitation plans in Section Part B2.2. Beyond their own developments, the commercial partners will profit from a close collaboration with all the other partners, which may constitute the foundation of future joint commercial relationships.

FZJ's linked third party ParTec with its ParaStation Modulo software suite will be one of the main beneficiaries of future system solutions, as it will provide commercial support for their software solution for the integration of quantum resources into the Modular Supercomputing Architecture.

Other countries and international organisations

All participants requesting funding are in Member States or Associated countries.

3.4 Resources to be committed

The HPCQS project is a very ambitious, large-scale initiative. During the proposal preparation, the partners have thoroughly analysed the required resources (personnel, infrastructure, equipment, other direct costs) and arrived to the conclusion that the effort and overall budget volume exceed the available funding available in this call. In light of this situation and with the ultimate success of HPCQS in mind, some partners commit to contribute own resources in the form of personnel effort and SW to the project. For example, FZJ's linked third party ParTec bears additional 12 PMs in WP3 (despite their role as WP3 leader), and 16 PMs in WP2 by own resources. Furthermore, the partners will make use of synergies and leverage EU and national funding by using results from previous projects, as described in section 1.3.

The HPCQS budget is distributed among the different cost categories. About 36% of the total EuroHPC JU funding is dedicated to personnel, with the remaining 64% distributed between the other direct cost categories 'ODC': travel (1%), other goods and services (0,4)%, subcontracts (0,06%) and equipment (63%).

In the benefit of acquiring the largest possible prototype, the consortium renounces the 25% indirect costs associated with HW under the cost category 'ODC'. This ensures that the total funding reserved for HW procurement (Equipment: 6,9 M€) will indeed be fully dedicated to the purchase of the system. Therefore, in Table 8 the overhead for the hardware has been excluded from the calculation of the indirect costs as well as the total direct costs and the Requested EU contribution. In Part A of the proposal, since the indirect costs cannot be adjusted, only the Requested EU Contribution has been modified to subtract the respective indirect costs.

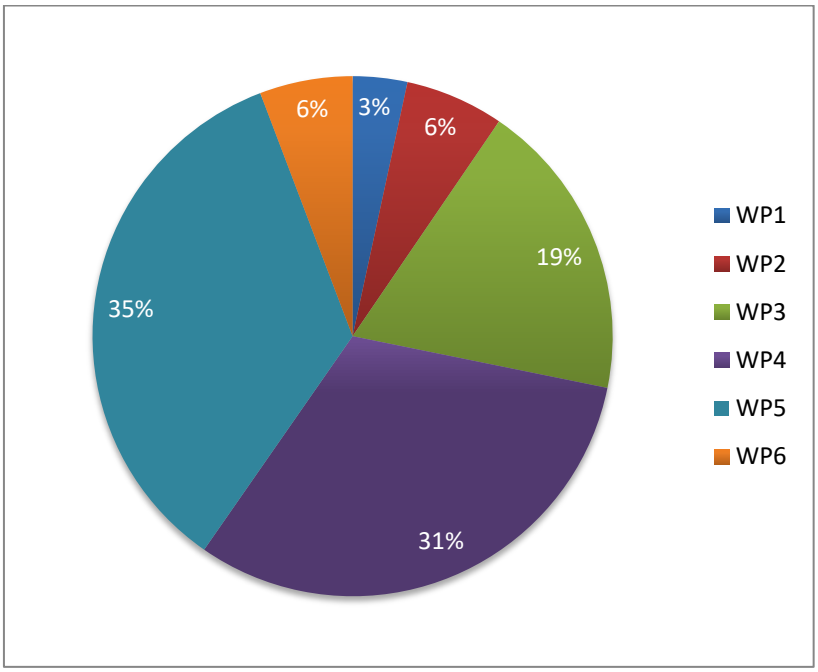


Figure 8: Distribution of Resources (PM)

BUDGET OVERVIEW											
	Beneficiary		Direct Personnel costs	Other direct costs			Subcon-tracting	Total direct costs	Indirect costs	Total costs	Requested EU contribution (50%)
				Travel	Other goods and services	Equipment					
1	FZJ	DE	666,919.27	4,000	5,000.00	3,450,000	0	4,125,919.27	168,979.75	4,294,898.76	2,147,449.38
1a	ParTec	DE	311,148.00	10,000	0	0	0	321,148.00	80,287.00	401,435.00	200,717.50
2	CEA	FR	287.387.00	4,000	0	0	0	291,387.00	72,846.75	364,233.75	182,116.88
3	GENCI	FR	96,525.00	3,000	3,000	3,450,000	0	3,552,525.00	25,631.25	3,578.156.25	1,789,078.13
4	ATOS	FR	882,367.00	7,500	5,000	0	0	894,867.00	223,716.75	1,118,583.75	559,291.88
5	CNR	IT	215,164.00	11,800	1,900	0	0	228,864.00	57,216.00	286,080.00	143,040.00
6	NUIG-ICHEC	IR	249,780.00	19,700	3,000	0	0	272,480.00	68,120.00	340,600.00	170,300.00
7	UIBK	AU	126,830.00	7,100	5,000	0	0	138,930.00	34,732.50	173,662.50	86,831.25
8	EURICE	DE	279,600.00	9,600	14,625.73	0	7,000	310,825.73	75,956.43	386,782.16	193,391.08
9	CNRS	FR	120,992.00	0	0	0	0	120,992.00	30,248.00	151,240.00	75,620.00
9a	Sorbonne	FR	52,800.00	0	0	0	0	52,800,00	13,200.00	66,000.00	33,000.00
9b	Supelec	FR	14,100.00	0	0	0	0	14,100.00	3,525.00	17,625.00	8,812.50
10	INRIA	FR	188,600.00	2,379	0	0	0	190,979.00	47,744.75	238,723.75	119,361.88
11	PASQAL	FR	174,708.00	4,800	0	0	0	179,508.00	44,877.90	224,385.00	112,192.50
12	CINECA	IT	22,500.00	0	0	0	0	22,500.00	5,625.00	28,125.00	14,062.50
13	BSC	ES	27,500.00	3,000	3,000	0	0	33,500.00	8,375.00	41,875.00	20,937.50
14	FLS	IT	58,500.00	2,400	0	0	0	60,700.00	15,225.00	76,125.00	38,062.50
15	PARITY QC	AU	123,728.00	4,800	0	5,000	0	133,528.00	33,382.00	166,910.00	83,455.00
16	Fraunhofer IAF	DE	35,647.00	0	0	0	0	35,647.00	8,911.75	44,558.75	22,279.38
TOTAL			**3,934,795.27**	**94,079.00**	**40,525.73**	**6,905,000**	**7,000**	**10,981,400.00**	**1,018,600.00**	**12,000,000.00**	**6,000,000.00**

Table 8: Budget overview

3.4.a Summary of staff effort

	WP1	WP2	WP3	WP4	WP5	WP6	Total Person/Months
1/FZJ	6	7	26,6	14	38	4	**95,6**
1b/ParTec	0	0	36	0	0	0	**36**
2/CEA	0	6	2	2	42	1	**53**
3/GENCI	0	8	0	0	2	1	**11**
4/ATOS	0	0	35	70	9	3	**117**
5/CNR	0	1	13	1,5	17,5	2	**35**
6/NUIG-ICHEC	0	0	0	22	22	2	**46**
7/UIBK	0	0	0	12	9,5	0	**21,5**
8/EURICE	15	0	0	0	0	20	**35**
9/CNRS	0	0	0	18	17	0	**35**
9a/Sorbonne	0	0	0	0	12	0	**12**
9b/SUPELEC	0	0	0	2	1	0	**3**
10/INRIA	0	0	0	36	10	0	**46**
11/PASQAL	0	16	0	3	15	2	**36**
12/CINECA	0	0	0	0	4,5	0,5	**5**
13/BSC	0	0	0	3	2	0	**5**
14/FLS	0	0	0	0	13	0	**13**
15/ParityQC	0	0	3	13,5	7,5	0,3	**24,3**
16/Fraunhofer IAF	0	0	0	0	5	0	**5**
Total Person/Months	**21**	**38**	**115,6**	**195**	**214**	**35,8**	**619,4**

3.4.b 'Other direct cost' items (travel, equipment, other goods and services, large research infrastructure)

P1- FZJ	Cost (€)	Justification
Travel	€ 4,000	Travel costs to ensure participation in bilateral meetings, consortium meetings and relevant conferences
Equipment	€ 3,450,000	Pasqal quantum simulator with 100+ qubits
Other goods and services	€ 5,000	Budget for open access publication costs Certificate on the Financial Statements (CFS)
Total	€ 3,459,000	

P3- GENCI	Cost (€)	Justification
Travel	€ 3,000	Travel costs to ensure participation in annual project meetings
Equipment	€ 3,450,000	Pasqal quantum simulator with 100+ qubits
Other goods and services	€ 3,000	Certificate on the Financial Statements (CFS)
Total	€ 3,456,000	

P13 - BSC	Cost (€)	Justification
Travel	€ 3,000	Travel costs to ensure participation in annual project meetings
Equipment	€0	n/a
Other goods and services	€ 3000	Budget for open access publication costs
Total	€ 6000	

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4. Members of the consortium

4.1. Participants (applicants)

P1 – FZJ: Forschungszentrum Jülich GmbH

Description of the legal entity

Forschungszentrum Jülich (FZJ) is a member of the Helmholtz Association of German Research Centres and is one of the largest interdisciplinary research centres in Europe. FZJ is organized in various research institutions, each one addressing a specifically defined scientific goal or societal challenge. The research of FZJ focusses on three major areas: information, energy, and bio-economy. In the research field information its long-standing interests include among others: supercomputing, data management, information security, and quantum computing.

Legal status

FZJ is a public research institution of non-profit character registered as Forschungszentrum Jülich GmbH at the Handelsregister B des Amtsgerichts Düren, with number HRB 3498. The German Republic and the State of Nordrhein-Westfalen are the owners of FZJ, to 90% and 10%, respectively. FZJ exclusively and directly pursues the non-profit purposes stipulated in Article 2 of the Articles of Association, in particular the advancement of science and research in the meaning of the section on tax-privileged purposes of the German Fiscal Code (§§ 5168 AO) as amended on 16.03.1976 (BGBl. I p.613).

FZJ follows long-time research and education goals of the German state as member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V. (HGF). In this context, FZJ is bound to goal-oriented national funding schemes. FZJ's goal is to promote research and investigation exclusively for non-military applications, through research activities, initiatives and events, often within national and international collaborations with Universities and other research institutions. FZJ is required to publish the results of its research activities and to make them available to the public.

Role and main tasks in the project

FZJ is coordinating the HPCQS consortium scientifically and serves, jointly together with Eurice, as first point of contact for management and partners. FZJ will be involved in all work packages.

In WP1, FZJ will monitor project progress against milestones, coordinate and mediate between partners and proactively plan risk mitigation and corrective action.

In WP2, FZJ will, together with GENCI, be responsible for the procurement of the quantum simulator and its installation, integration and operation in the FZJ HPC infrastructure. FZJ will, together with other partners, also be involved in the regular technological assessment of quantum computing hardware and software.

In WP3, FZJ will lead the task to provide a portal solution that allows end-users convenient and flexible access to the quantum simulator via the web browser.

In WP4, FZJ will, together with UIBK, develop a variational quantum simulation & optimization toolbox.

In WP5, FZJ will perform simple experimental benchmarking tests on the quantum simulator and benchmark QAOA on the HPCQS hybrid against large-scale emulators and the D-Wave quantum annealer in order to assess the performance and scalability for real world applications. In addition, FZJ will contribute to training, knowledge transfer and user engagement via JUNIQ.

In WP6, FZJ will be involved in all the dissemination and community engagement activities and set up a peer-reviewed provisioning process for access to the quantum-classical hybrid software and hardware infrastructure.

Profile of staff members involved

Prof. Dr. Kristel Michielsen (female):

Education and career: 1985-89 studies of physics at the University of Antwerp, Belgium; 1990-93 doctoral studies at the University of Groningen, the Netherlands (supervisor Prof. Dr. Hans De Raedt), graduated as Doctor of Science; 1993-2005 Postdoc and research scientist, University of Groningen, the Netherlands; 2006-present Founder and CEO of EMBD, a Belgian company providing scientific services and software products for industrial and academic customers; 2009-present Group leader of the research group "Quantum Information Processing", Jülich Supercomputing Centre, Professor at RWTH Aachen University.

Awards: Wim Nieuwpoort Award for "Massively Parallel Quantum Dynamics Simulator", awarded to Prof. Dr. H.A. De Raedt and co-applicants Dr. F. Jin and Prof. Dr. K. Michielsen (2011); Google Faculty Research Award

2018 “Containerization of the universal quantum computer simulator JUQCS for usage in the Cloud”
Service: Organization of the International Workshop on Quantum Annealing and its Applications in Science and Industry (QuAASI’16), FZJ (2016); organization of the special conference session on Quantum Annealing & Its Applications for Simulation in Science & Industry at ISC 2017, the international supercomputing conference held in Frankfurt am Main (2017); organization of the special conference session on Quantum Computer Applications at ISC 2018, the international supercomputing conference held in Frankfurt am Main (2018); organization of the special conference session on Applications for Quantum Computing at ISC 2019, the international supercomputing conference held in Frankfurt am Main (2019); Workshops co-chair for the IEEE Quantum Week 2020.

Prof. Dr. Dr. Thomas Lippert (male)
Education and career: 1980-1987 studies of physics at the University of Würzburg; received his first doctorate in 1993 from the University of Wuppertal on lattice gauge theories and his second doctorate in 1998 from the University of Groningen in the field of supercomputing; 2001: habilitation on simulations of quantum chromodynamics at the University of Wuppertal; since 2004 Professor of Computational Theoretical Physics at the University of Wuppertal and Director of the Jülich Supercomputing Centre (JSC) at Forschungszentrum Jülich; August 2020: new full Professorship at the Goethe University, Frankfurt as chair in Modular Supercomputing and Quantum Computing. He is senior fellow of the Frankfurt Institute for Advanced Studies (FIAS). He has authored several hundred papers and holds patents in the field of modular supercomputing.
Service: Thomas Lippert has played a leading role in the founding and the establishment of numerous large research infrastructures and is active in them, including the JSC, the John von Neumann Institute for Computing of the Helmholtz Association, PRACE (Partnership for Advanced Computing in Europe, or the Human Brain Project, EBRAINS and FENIX. He served as the Chair of the Council of PRACE from 2018 to 2020, and he serves as the vice chair of the Research advisory board of the EuroHPC Joint Undertaking. He is member of the board of the Gauß Centre for Supercomputing (GCS), as program chair of the HELMHOLTZ programs Supercomputing and Big Data and Engineering Digital Futures, and as Executive Director of the Board of Directors of the John-von-Neunmann Institute for Computing (NIC). He has repeatedly led Evaluation Committees for the RIKEN and Swiss National Supercomputing centers. He has initiated the DEEP series of EU funded development projects for the modular supercomputing architecture followed by the three new x.SEA projects in the 2019 call of EuroHPC.

Prof. Dr. Tommaso Calarco (male)
Education and career: 1988-1994 studies of physics at the University of Padua, Italy; 1994-1998 PhD in Physics, University of Ferrara; 1998-2007 post-doctoral studies in various institutions (University of Trento, NIST, ECT*, Harvard University, IQOQI Innsbruck, CNR-BEC); 2008-2018 Full Professor (W3, with tenure since 2009) of Quantum Information Processing, University of Ulm (Germany); 2011-2018 Director, Institute of Quantum Information Processing, University of Ulm (Germany); 2014-2018 Director, Centre for Integrated Quantum Science and Technology, Universities of Ulm/Stuttgart/Max-Planck Institute for Solid-State Research (Germany) and Director, Institute of Complex Quantum Systems, University of Ulm (Germany); since 2018 Professor of Quantum Information, Institute of Theoretical Physics, University of Cologne (Germany) and Director, Peter Grünberg Institute PGI-8: Quantum Control, Forschungszentrum Jülich (Germany).
Awards: Marie-Curie Fellowship of the European Commission (2000; 2004); Fulbright Fellowship of the US Department of State (2002); “E. Wallnöfer” Prize of the Tyrolean Industry Association (2002)
Service: Tommaso Calarco has served as coordinator in both Research Project (STREPs, IPs) and Coordination and Support Actions funded by the European Commission in the field of Quantum Information Science and Technologies. He played a leading role in the establishment in 2018 of the European Quantum Flagship initiative, being one of the authors of the Quantum Manifesto (2016) and a member of the Quantum Flagship’s High-Level Steering Committee (2017). He is currently the Chairman of one of the Flagship’s Governing Bodies: The Quantum Community Network. In addition, he has served as Chairman of the Gordon Research Conference on Quantum Control of Light and Matter (2017), and since 2018 he is the Editor-in-Chief of the European Physics Journal D.

Dr. Thomas Eickermann (male)
Education and career: 1983-1989 studies of physics at the University of Düsseldorf, Germany; 1989-1994 doctoral studies at the University of Düsseldorf, graduated as Dr. re. nat.; since 1994 employed at JSC. Activities

cover system administration, grid computing, and networking. Since 2002, head of the communication systems of JSC and since 2012 deputy head of JSC.
Service: Thomas Eickermann has been a member of the Board of Directors of PRACE aisbl and is coordinator of the PRACE-6IP project.

Dr. Dorian Krause (male)
Education and career: 2003-2008 studies of mathematics at the University of Cologne and University of Boon, Germany; 2009-2013 doctoral studies at University of Lugano, Switzerland, graduated as Doctor of Philosophy in Informatics; since 2014 employed at JSC as HPC systems engineer. Since 2014, head of the division "High performance computing systems".

Prof. Dr. Norbert Eicker (male)
Education and career: 1990-1996 studies of physics at the University of Wuppertal; 1996-2001 doctoral studies at University of Wuppertal, graduated as Dr. rer. nat on lattice gauge theories; 2001-2004 software developer at ParTec, the company behind ParaStation; since 2004 employed at JSC leading the group working on Cluster Computing; since 2014 Professor for parallel hard- and software systems at University of Wuppertal.
Service: Lead architect of the JUROPA and JURECA supercomputers at JSC; technical lead of the DEEP projects and the DEEP-SEA project.

Dr. Wolfgang Frings (male)
Education and career: 2004 diploma Computer Science from the University of Hagen; 2016 PhD in Computer Science from RWTH Aachen University; since 1990 employed at JSC and currently leading the application support team and the cross-sectional team application optimization, where he works together with developers and users on porting and optimizing applications, specially focusing on parallel I/O.
Service: Author of several software tools such as SIONlib (a library to support task-local parallel I/O on large-scale systems), LLview (a batch-system monitoring SW), and LinkTest (a highly scalable MPI point-to-point network) and worked also on the initial version of the benchmarking environment JUBE.

Dr. Florian Janetzko (male)
Education and career: 1994-2000 studies of chemistry at the University of Hannover; 2000-2003 doctoral studies at the University of Hannover in theoretical chemistry, graduated as Doctor of Science 2003; 2003-2004 postdoc and research associate, University of Hannover; 2004-2006 postdoc and research associate, CINVESTAV, Mexico-City, Mexico; 2006-2007 postdoc and research associate, University of Calgary, Canada; 2007-2008 postdoc and research associate, University of Bonn, Germany; 2008-present research associate, Jülich Supercomputing Centre; 2015-present Head of the Coordination office for the Allocation of Computing Time at JSC.
Service: Florian Janetzko has been involved in JSC's HPC support and teaching activities; furthermore, he acted as local coordinator for the DECI calls in the European projects DEISA and PRACE between 2008 and 2012; he is co-organizer of the local and national resource allocation processes with JSC's involvement and organizes JSC's appearances at the ISC and SC conferences.

Dr. Bernd Schuller (male)
Education and career: 1992 - 1998 studies of Physics at the Technical University (RWTH) Aachen (Germany); 1999 - 2002 doctoral studies at the RWTH Aachen, graduated as Dr. rer. nat; since 2002 working at JSC; involved in many research projects as a scientist and software architect, most recently the Human Brain Project (HBP); activities and research interests include distributed and federated computing, workflow systems, data management and security.
Service: Bernd Schuller is one of the lead developers of the UNICORE federated computing middleware (https://www.unicore.eu).

Relevant publications and/or products, services

1. M. Willsch, D. Willsch, F. Jin, H. De Raedt, and K. Michielsen, *Benchmarking the quantum approximate optimization algorithm*, Quant. Inf. Proc. 19, 197 (2020)
2. D. Willsch, M. Willsch, H. De Raedt, and K. Michielsen, *Support vector machines on the D-Wave quantum annealer*, Comput. Phys. Comm. 248, 107006 (2020)

3. H. De Raedt, F. Jin, D. Willsch, M. Nocon, N. Yoshioka, N. Ito, S. Yuan, K. Michielsen, *Massively parallel quantum computer simulator, eleven years later*, Comp. Phys. Comm. 237, 47 – 61 (2019)
4. F. Arute, [...], K. Michielsen, [...], M. Martinis, *Quantum supremacy using a programmable superconducting processor*, Nature 574, 505 – 510 (2019)
5. A. Omran, H. Levine, A. Keesling, G. Semeghini, T.T. Wang, S. Ebadi, H. Bernien, A.S. Zibrov, H. Pichler, S. Choi, C. Jian, M. Rossignolo, P. Rembold, S. Montangero, T. Calarco, M. Endres, M. Greiner, V. Vuletić, M.D. Lukin, *Generation and manipulation of Schrödinger cat states in Rydberg atom arrays*, Science 365, 570 - 574 (2019)
6. F. Janetzko, JARDS Ein Softwarewerkzeug zur Handhabung von Ressourcenvergabeprozessen, ZKI-AK Supercomputing Herbsttagung 2019, Berlin, Germany, 26 Sep 2019 - 27 Sep 2019. http://hdl.handle.net/2128/23753
7. M.S. Memon, M. Riedel, F. Janetzko, et al., Advancements of the UltraScan scientific gateway for open standards-based cyberinfrastructures, *Concurrency and computation* 26, 2280 - 2291 (2014). 10.1002/cpe.3251
8. N. Attig, J. Docter, W. Frings, et al., Blue Gene/P: JUGENE, Contemporary High Performance Computing: From Petascale toward Exascale Computational Science Series 153-188 (2013).
9. W. Frings, A. Schnurpfeil, S. Meier, F. Janetzko, L. Arnold, A Flexible, Application- and Platform-Independent Environment for Benchmarking, Parallel Computing: From Multicores and GPU's to Petascale, / ed.: B. Chapman, F. Desprez, G.R. Joubert, A. Lichnewsky, F. Peters and T. Priol, Amsterdam, IOS Press, 2010. Advances in Parallel Computing Volume 19. - 978-1-60750-529-7. - S. 423 – 430.

Relevant previous projects or activities

1. EU-H2020 (H2020-EU.1.2.3. - FET Flagships-820363), OpenSuperQ 'Project of FET Flagship on Quantum Technologies', Grant number 820363, 2018-2021 (https://opensuperq.eu/)
2. EU-H2020 (H2020-EU.1.2.3. - FET Flagships-817482), PASQuanS 'Project of FET Flagship on Quantum Technologies', Grant number 817482, 2018-2021 (https://pasquans.eu/)
3. 2ICEI: H2020-EU.1.4. - EXCELLENT SCIENCE - Research Infrastructures - Grant agreement ID: 800858, 2018-2023, data and compute infrastructure FENIX (https://fenix-ri.eu/)
4. Data infrastructure: EUDAT services hosted in Jülich: B2DROP, B2SHARE
5. Compute and Data Infrastructure: PRACE Implementation Project 6: https://prace-ri.eu/about/ip-projects/#PRACE6IP, Grant number 823767, 2019-2021
6. EOSC-Hub, Grant number 777536, 2018-2020 (https://www.eosc-hub.eu/)

Significant infrastructure and/ or any major items of technical equipment

Jülich Supercomputing Centre (JSC): German supercomputer facility, which provides high-end HPC and the by today largest German data capacities for scientists at FZJ, in the Helmholtz Association, at universities and at research laboratories in Germany and all over Europe (via PRACE) as well as for industrial partners. The facility is contributing to the development of modular supercomputing and future data center technology, aiming at exascale for supercomputing and data management systems in collaboration with world-class manufacturers and users, and strives to become a European exascale facility. The facility is carrying out and will enhance its research and development for advanced computing architectures such as quantum computers, quantum simulators, quantum annealers, digital annealers and neuromorphic computing. It will focus on integrating quantum (see JUNIQ) and neuromorphic systems into its modular supercomputing and data analytics environment.

Jülich Supercomputing Centre (JSC) – HPC resources

JSC operates a world-leading HPC infrastructure and make it available to external users in Germany, Europe and worldwide. JSC is one of the few sites in Europe where competences in the field of system architecture, technology evaluation and co-development of supercomputing technology comes together with development of system software. What is more, at JSC there is a deep involvement in research and development on key components for advanced computer technologies such as quantum computing and neuromorphic computing.

At present JSC hosts several high-end HPC production systems:

- JUWELS: This system is constructed as a Modular Supercomputer, an architectural paradigm developed at JSC in cooperation with ParTec over the past years. The system has two components: Cluster and Booster.

The Cluster has 2271 standard and 240 large memory Intel Xeon (Platinum) compute nodes. In addition, the system has 56 accelerated Intel Xeon (Gold) compute nodes, each having four NVIDIA V100 GPUs. The Booster is currently being installed. It will have 936 nodes each equipped with two AMD EPYC (Rome) CPUs and four NVIDIA A100 GPUs. The interconnect is InfiniBand EDR. The system uses ParTec's ParaStation cluster middleware.

- JURECA: This system has two components: Cluster and Booster. The Cluster, has 1872 Intel Xeon (Haswell) compute nodes, from which 75 are equipped with 2 NVIDIA K80 GPUs. The interconnect is InfiniBand EDR. The Booster has 1640 Intel Xeon Phi (Knights Landing) nodes. The system uses ParTec's ParaStation cluster middleware.

Jülich UNified Infrastructure for Quantum Computing (JUNIQ) of JSC: User facility providing access to quantum emulators and to quantum technologies at different technological levels of maturity – quantum computers, simulators and annealers – for European science and industry within a single, user-friendly platform (quantum computing platform as a service, QC-PaaS). The focus is on support, training and cooperation with users. JUNIQ develops software tools, modelling concepts and algorithms as well as prototype applications. In order to make practical use of quantum technologies in scientific computing, they must be integrated into HPC infrastructures. The necessary modular architecture of hardware and software has been developed at the JSC and is step by step being implemented.

P1b – ParTec: ParTec Cluster Competence Center GmbH

Description of the legal entity

The partner FZJ involves a Third Party in the HPCQS project. Forschungszentrum Jülich (FZJ) made a decision in 2010 to partner with ParTec to co-develop in all aspects of system software, especially for the Modular System Architecture (MSA). Since then, when both institutions work together in R&D projects (e.g., in the EU-funded projects DEEP, DEEP-ER, and DEEP-EST), ParTec consequently holds a position as linked third party to FZJ. Due to the history and positive experience of this partnership, ParTec keeps its position as FZJ's linked third party also for the HPCQS project. To make its involvement totally transparent to the reviewers, EuroHPC JU and the consortium, ParTec's contributions to HPCQS, its role and responsibilities are displayed explicitly in the proposal body (Sections 1-3).

The Forschungszentrum Jülich GmbH (FZJ) has a long-duration relationship with the ParTec Cluster Competence Center GmbH (ParTec), certified by the signature of four long-term agreements:

1 The "ParaStation Consortium", with the goal of developing the open-source cluster operating and management system "ParaStation". A corresponding contract was signed in 2005 and is still active. No end-of-contract date has been defined.
2 JURECA: A Collaboration contract has been signed in November 2016 and will be active until November 2021.
3 JUWELS: A Collaboration contract has been signed in April 2020 (expected duration until end of 2026).
4 The "Exa-Cluster Laboratory" (ECL), where FZJ, ParTec and Intel GmbH operate together a joint laboratory with common ownership and the common goal of developing Exascale hardware-software technology. The cooperation agreement has been signed in May 2010 and has been active until May 2020.

As stated above, the formal relationship between FZJ and ParTec is based on both, MoUs and Cooperation Agreements, with duration beyond the HPCQS project, predating and outlasting the EC-GA. ParTec is already FZJ's Third Party in the European-funded series of DEEP projects.

ParTec Cluster Competence Centre GmbH, one of the leading SMEs in the HPC domain in Europe and the specialist for modular supercomputing, develops and supports a comprehensive suite of HPC systems' management tools and a runtime environment specifically tuned for the largest distributed-memory supercomputers in existence today and beyond. ParTec's unrivaled expertise in developing HPC software includes the self-developed ParaStation MPI and tools like TicketSuite and HealthChecker. In conjunction with professional services, consultancy and support, ParTec was elected as the partner of choice in some of the leading HPC sites across Europe. For more than 20 years, ParTec has been a strong general-purpose HPC specialist in the German and EMEA HPC market.
ParTec's ParaStation Modulo is extensively used in production environments, e.g. on the JURECA Cluster and Booster system with a 6.56 PFlop/s peak performance and ranked no. 52 in the June 2019 TOP500 list, both operated by the Jülich Supercomputing Centre (JSC).
The existing JUWELS Cluster system with a 9.89 PFlop/s peak performance, run by the Jülich Supercomputing Centre (JSC) and ranked no. 30 in the June 2019 TOP500 list will be extended by a Booster in mid 2020. The expected peak performance for both systems is around 70 PFlop/s. Besides the mentioned large systems, ParTec also supports some experimental systems. ParTec is the chosen partner for the co-design and the support of the JUROPA family, HDF-ML and ICCP-ICEI systems, likewise operated by the Jülich Supercomputing Centre.
ParTec participates in nationally funded research projects like FAST and Envelope as well as in EU-funded Exascale projects like DEEP, DEEP-ER and DEEP-EST. There, ParTec contributes to the runtime and middleware of the DEEP-EST prototype, and recently focuses on improvements and extensions to the scheduling and resource management for the Modular Supercomputing Architecture (MSA) as well as the programming models and libraries used. In addition, ParTec supports the coordinator internally at the project management level.
Together with Intel GmbH and ForschungszentrumJülich, ParTec forms the ExaCluster Laboratory (ECL), developing promising new HPC architectures and prototypes to enter the Exascale era.

Role and main tasks in the project

Using its comprehensive experience in HPC in general and in the Modular Supercomputing Architecture (MSA) in particular, ParTec will contribute to the integration of the Quantum Simulator (QS) pilot into an HPC

environment following the MSA concept. In this project, ParTec will lead WP3, addressing the required infrastructure software for providing the essential HPC services and interfaces for resource, user and access management. ParTec will drive the work on extending ParaStation Modulo for the interaction with the QS through the Quantum Learning Machine (QLM). The interfaces for the managment of the QS resources will be jointly developed, enabling quantum-hybrid simulations and workflows in modular supercomputing architectures.

Profile of staff members involved

Hugo Falter (male) is Co-founder and Chief Executive Officer of the ParTec Cluster Competence Center GmbH, a spin-off from the Computer Science Department of the University of Karlsruhe in 1999. Mr. Falter studied law in Regensburg and Munich. Together with a Munich law firm he specialised in bringing innovative technology companies to market. In the Munich law firm Frohwitter, Hugo Falter is responsible for the firm's subsidiary ParTec Cluster Competence Center GmbH.

Thomas Moschny (male) is working at ParTec since 2008, from 2013 as the Chief Technology Officer (CTO). He has got a Diploma in Theoretical Particle Physics from the University of Wuppertal. From 2000 to 2008 he was member of the group of Prof. Tichy at the CS Department of University of Karlsruhe (now Karlsruhe Institute of Technology, KIT), working on high performance communication software and parallel programming environments. In addition to the CTO responsibilities his main focus now is on programming models and workload management topics of the Modular Supercomputing Architecture (MSA). He is the leader of the System software and management work package in the DEEP-EST project.

Dr. Carsten Clauss (male) is with ParTec since 2013. From 2004 to 2013 he was as research associate of the Chair for Operating Systems at the RWTH Aachen University. He has got a diploma and a doctorate degree in Electrical Engineering with focus on Computer Engineering as well as master's degrees in Computer Science and Business Administration. From 2018 to 2020, he held a part-time professorship for Informatics at the IUBH International University of Applied Sciences. In the DEEP-ER project, he was leader of the resiliency benchmarking task. In DEEP-EST, he leads the ParaStation MPI task and is deputy to the leader of the System Software and Management work package.

Dr. Simon Pickartz (male) is working at ParTec since 2019. He holds a doctoral degree in electrical engineering which he received from RWTH Aachen University in 2018. From 2014 until 2018 he worked as a research associate in the HPC group at the Institute for Automation of Complex Power Systems. During this time he investigated the prospects and challenges of virtualization techniques applied to the field of high performance computing. At ParTec he is working as a software developer and research engineer. His main focus is the development of the ParaStation MPI communication stack. He published three journal papers, contributed to two book chapters and authored over 15 workshop and conference papers.

Ina Schmitz (female) is working as project manager at ParTec since 2010. She has got a Diploma in Natural Science from TU Bergakademie Freiberg. Today, her activities include the internal and external organization of large projects. At ParTec she is part of the ExaCluster Laboratory and member of the Project Management Team (PMT) in the already finished DEEP- and DEEP-ER projects and in the follow-up project DEEP-EST, which will end in March 2021.

Relevant publications and/or products, services

1. Peña, V. Beltran, C. Clauss, T. Moschny: Supporting Automatic Recovery in Offloaded Distributed Programming Models Through MPI-3 Techniques, In Proceedings of the International Conference on Supercomputing (ICS), June 2017
2. C. Clauss, T. Moschny, N. Eicker: Dynamic Process Management with Allocation-internal Co-Scheduling towards Interactive Supercomputing, In 1st HiPEAC Workshop on Co-Scheduling of HPC Applications (COSH), European Network on High Performance and Embedded Architecture and Compilation (HiPEAC), January 2016
3. N. Eicker, T. Lippert, T. Moschny, E. Suarez: The DEEP Project - An alternative approach to heterogeneous cluster-computing in the many-core era, In Concurrency and computation: Practice and Experience, Vol. 28

(8) 2016, pp. 2394-2411, DOI: 10.1002/cpe.3562
4. S. Pickartz, C. Clauss, S. Lankes, S. Krempel, T. Moschny, A. Monti: Non-Intrusive Migration of MPI Processes in OS-bypass Networks, In Proceedings of the 1st Workshop on Emerging Parallel and Distributed Runtime Systems and Middleware (IPRDM), IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW), May 2016
5. Th. Moschny, J. Labarta, J. Gimenez, M. Knobloch: The DEEP Programming model and analysis tools First joint DEEP/CRESTA/Mont-Blanc Workshop, Barcelona, June 10-11, 2013

Relevant previous projects or activities

1. DEEP projects: ParTec participated in the DEEP projects as Jülich's Third Party.
   - Dynamical Exascale Entry Platform, FP7-ICT-287530 (DEEP): The main contributions of ParTec focused on the operating system and middle- ware of the DEEP system. The ParaStation Global MPI connects Cluster and Booster parts transparently, partly hiding the heterogeneity of the DEEP system. This is a key feature when distributing parallel applications on Cluster and Booster for maximal efficiency. ParTec also provided installation and administration support for the system. Finally, ParTec was member of the Project Management Team (PMT) and supported Jülich in the internal communication with the partners, the quality control process of the deliverables, and the preparation of reviews.
   - DEEP - Extended Reach, FP7-ICT-610476 (DEEP-ER): In continuation of the efforts within DEEP, ParTec focused on the operating system and middleware of the system, with a special emphasis on resiliency. The ParaStation Global MPI has been extended to support and coordinate both, system-level resiliency features on task level as provided by the OmpSs runtime, as well as checkpoint and restart on application level. This allows parallel applications together with their off-loaded, highly-scalable code parts to become fully fault-tolerant. ParTec also provided installation and administration support for the system. Finally, ParTec was member of the Project Management Team (PMT) and supported Jülich in the internal communication with the partners, the quality control process of the deliverables, and the preparation of reviews.
   - DEEP - Extreme Scale Technologies, H2020-FETHPC-754304 (DEEP-EST): Building on its middleware ParaStation Modulo, namely the MPI and process management, ParTec's focus is on designing and implementing improvements to the scheduling and resource management for the Modular Supercomputing Architecture (MSA), as well as the improvements and extensions to the programming models and libraries employed in DEEP-EST. In addition, ParTec supports FZJ internally in the DEEP-EST project with the communication between the partners, the quality control process of the deliverables, and the preparation of reviews.
2. *SEA projects: ParTec participated in the DEEP projects as Jülich's Third Party.
   - DEEP - Software for Exascale Architectures, H2020-JTI-EuroHPC-955606 (DEEP-SEA):
     Leveraging its profound experience in HPC in general and in the MSA architecture in particular, the SME ParTec will continue to work on improving the efficiency and the usability of heterogeneous systems on all levels, deemed essential on the way to Exascale. ParTec will lead WP3, addressing system software and architectural topics for MSA-based systems. In this WP, ParTec will lead the work on the low-level communication stack and containerisation. ParTec will provide central elements of the DEEP-SEA runtime system by extending the ParaStation Management. On the module level, ParTec will contribute significantly to several tasks in WP5, addressing malleability and tuning, as well as interoperability and composability aspects of ParaStation MPI with other programming paradigms. As member of the Project Management Team (PMT) ParTec will furthermore support FZJ in WP7 on the management and coordination topics, especially regarding intra-project communication and quality control.
   - IO - Software for Exascale Projects, H2020-JTI-EuroHPC- 955811 (IO-SEA):
     ParTec will continue to improve and extend the ParaStation Modulo software suite especially with respect to the resource management in the context of HSM and ephemeral data services. In particular, ParTec will extend its resource manager ParaStation Management by support for the on-demand allocation of resources within modular and heterogeneous supercomputers. ParTec will further enhance its proprietary solution for health checking, the ParaStation HealthChecker, to account for the existence of ephemeral data nodes exceeding the lifespan of single jobs as part of a workflow.

- RED - SEA Network Solution for Exascale Architectures, H2020-JTI-EuroHPC- 955776 (RED-SEA): ParTec will continue to improve and extend ParaStation MPI, its own runtime for parallel processing in distributed memory supercomputers by support for the European Interconnect BXI. These developments will comprise support for efficient point-to-point communication in large-scale supercomputers. Besides traditional MPI workload relying on message passing, these enhancements will likewise target one-sided communication semantics for the simultaneous support of different programming paradigms in HPC. The integration of BXI support within ParaStation MPI will enable the construction of BXI-based modules within supercomputers following the MSA approach.

Significant infrastructure and/ or any major items of technical equipment

ParTec is supporting, in close collaboration with the local staff, a number of larger HPC systems at JSC employing the MSA, for example the JURECA Cluster-Booster system, the JUWELS Cluster Module and its Booster Module (once deployed), the PPI4HPC Cluster Module, as well as a number of smaller, research-oriented systems like the DEEP prototype, providing access to recent hardware technologies and tools.

P2 – CEA: Commissariat à l'Energie Atomique et aux Energies Alternatives

Description of the legal entity

The French Alternative Energies and Atomic Energy Commission (CEA) is a French Research and Technological Organisation (RTO).

Missions: CEA is a key player in research, development and innovation in four main areas: low carbon energies (nuclear and renewable energies), technological research for industry, fundamental research in the physical sciences and life sciences, defence and security.

HPC infrastructure: CEA owns and operates two world class supercomputing facilities (TERA and TGCC), and deploys related HPC services, for the benefit of national and European research, industry (CCRT) and defence.
TGCC hosts and operates the PRACE French Tier-0 system JOLIOT-CURIE funded and made available by GENCI. As part of TGCC, CCRT is another dedicated infrastructure for industrial uses of HPC and related partnerships.

HPC R&D: CEA is active in HPC R&D&I all along the value chain (micro-nano-electronics components, system architecture and related co-design, system integration, HPC facilities and infrastructures design and optimisation, energy efficiency, HPC software stacks and middleware, solvers and applications in numerical simulation, big data and AI).

Quantum information and technologies:
CEA scientists and engineers offer a holistic view of quantum technologies that can benefit to many classes of users:

- Since many years, CEA has been doing fundamental and technological research on quantum information, quantum physics and materials - including superconducting quantum bits, nuclear spin qubits, and CMOS qubits.
- In 2018 CEA installed an ATOS QLM emulator at TGGC/CCRT, as a pilot for industrial and scientific use cases in quantum computing.

Role and main tasks in the project

CEA will:

- Host and operate one of the Pasqal systems, together with a QLM ad hoc configuration (and ensure WP2.2 task lead)
- Contribute, in WP2, to specifications of the system and its environment and to its infrastructure integration
- Contribute to state-of-the-art and technology watch in WP2
- In WP3 and WP4, contribute to HPC/quantum computing coupling definition, and to the definition of the relationship with resource management, so as to prepare the Pilot deployment as symmetrically as possible w.r.t the one in FZJ
- Deploy the user environment, portal and access layers, and contribute to user support and various dissemination activities
- In WP5, develop/contribute to use cases in the areas of:
    - Certification/Performance Analysis for Quantum Simulators – incl. device-independent approaches
    - Quantum Approximate Optimisation Algorithms (factorisation aspects)
    - Variational Quantum Eigensolver (VQE) - for catalyst design relevant in nitrogen fixation

Profile of staff members involved

Dr. Guillaume Colin de Verdière, CEA/DIF (male): HPC "International Expert" at CEA. Dr. Guillaume Colin de Verdière is a CEA staff member since 1984 and got his PhD in 2019. He has been working in various fields of HPC ever since. His expertise ranges from large scientific code development to high performance scientific visualization. Since 2008, Guillaume is involved in novel architectures explorations, either through internal studies or in various European projects (Prace IP, H4H, EXDCI, Exanode, MontBlanc2020, EPI…). He is investigating their potential to form the core of an Exascale computer.

Xavier Delaruelle, CEA/DIF (male): After graduating in 2005, Xavier Delaruelle worked in the Grid'5000 French national initiative at INRIA. Xavier then joined CEA HPC division at CEA/DIF in Bruyères-le-Châtel in

2007. Xavier has been active in PRACE PP and IP projects WP6 since 12 years, in "system administration and services" related tasks. He is now Chief Operations Officer of CEA "Très Grand Centre de Calcul" (TGCC).

Dr. Jean-Philippe Nominé, CEA/DIF (male): HPC "International Expert" at CEA, Dr. Nominé joined CEA HPC division in 1992, where he held different managing positions in HPC software development. Dr. Nominé has been involved in PRACE since its preparation in 2007 and has coordinated CEA efforts in all PRACE PP/IP projects. He was a Member of PRACE AISBL Board of Directors in 2010-2011. He was then ETP4HPC Office manager between 2012 and 2019 and is now a member of ETP4HPC Steering Board, and of EuroHPC Research and Innovation Advisory Group (RIAG). At CEA he manages HPC strategic collaborations (EU and international). J.P. Nominé graduated from Ecole Polytechnique (engineer degree) and holds a PhD from Université Pierre-et-Marie-Curie (Paris).

Gilles Wiber, CEA/DIF (male): Gilles is Department Leader in CEA HPC division (supercomputing systems administration, mass storage, systems operations, networks, and related R&D in hardware and software). His areas of expertise and technical centres of interest are related to HPC systems and computing centres architectures, and their exploitation. Gilles played an active role in PPI4HPC – recent Public Procurement for Innovative Solutions in HPC European project. He got an engineer degree in computer science from ENSIMAG in Grenoble.

Dr. Nicolas Sangouard, CEA/DRF (male): After a PhD on coherent control, University of Burgundy, and a postdoc in quantum optics with M. Fleischhauer in Kaiserslautern in 2005 and also with Nicolas Gisin in Geneva in 2006, Dr. Sangouard obtained a Maître de Conferences position at the University Paris VII in 2007. Then back to Geneva in 2009, he headed the theoretical activities related to quantum optics in Nicolas Gisin's group, while on leave from his permanent position in Paris. He received a professorship from the Swiss National Foundation in 2014, running an independent research group at the Department of Physics, in the University of Basel, before joining Institut de Physique Théorique at CEA-Saclay to build up a group in Theoretical Quantum Information.
Dr Sangouard is particularly interested in quantum technologies, and works in close collaboration with leading experimental groups. In the context of the optimization of quantum algorithms and implementation of quantum computers, and of the certification of their proper functioning, Bell tests are of particular interest: certification can be device-independent. In this area Dr. Sangouard made significant contributions: first robust device-independent certification of quantum channels, the first device-independent certification of quantum instruments and the first demonstration of Bell correlation on many-body systems – a significant step towards the device independent certification of quantum simulators.
Dr. Sangouard's thesis was awarded by the Carnot Prize. He received a professorship by the Swiss National Science Foundation, and is also the co-recipient of the Paul Ehrenfest Best Paper Award for Quantum Foundations 2017. Google Scholar: h-index: 38, >6500 citations. More than 70 peer-reviewed papers (including Nature (2), Science (1), Nature Physics/Nature Photonics/Nature Communication (4), PRL (20) and RMP (2)).

Relevant publications and/or products, services

1. F. Berberich, J. Liebmann, J. Nominé, O. Pineda, P. Segers and V. Teodor, "European HPC Landscape," 2019 15th International Conference on eScience (eScience), San Diego, CA, USA, 2019, pp. 471-478, doi: 10.1109/eScience.2019.00062.
2. R. Schmied, J.-D. Bancal, B. Allard, M. Fadel, V. Scarani, P. Treutlein, and N. Sangouard, *Bell correlations in a Bose-Einstein condensate*, Science **352**, 441 (2016)
3. P. Sekatski, J.-D. Bancal, S. Wagner and N. Sangouard, *Certifying the building blocks of quantum computers from Bell's theorem*, Phys. Rev. Lett. **121**, 180505 (2018)
4. S. Wagner, J.-D. Bancal, N. Sangouard, and P. Sekatski, *Device-independent characterization of quantum instruments*, Quantum **4**, 243 (2020)Advances in Parallel Computing Volume 19. - 978-1-60750-529-7. - S. 423 – 430.

Relevant previous projects or activities

1. HPC infrastructure: CEA/TGCC participates in Horizon 2020 EINFRA PRACE 6IP project (and participated in all previous PRACE IP projects); this supports the implementation of pan-European HPC infrastructures

since 2010; Horizon 2020 PPI4HPC EINFRA project (a Public Procurement of Innovative Solutions in the area of HPC) led to the extension of TGCC's Joliot-Curie in 2019

2. HPC infrastructure: CEA/TGCC participates in Human Brain Project ICEIn which implements FENIX, a federated infrastructure of compute/data interactive HPC resources
3. Quantum Computing: CEA/TGCC is part of TERATEC's TQCI initiative (Teratec Quantum Computing Initiative), bringing together users, technology providers and research centres to increase competences and develop know-how in the field of quantum computing (mathematical formulation, algorithms and numerical methods, showcases with usage and experimentation, training, information and community management)
4. Quantum information: Dr. Sangouard is Principal Investigator of Quantum Internet Alliance (QIA), EU project FET Flagship on Quantum Technologies, 2018-2021, Principal Investigator of *Certifying the quantum nature of complex systems from Bell's theorem*, project funded by the Swiss National Science Foundation, 2018-2020, and was PI of *Certifying the building blocks of quantum computers from Bell's theorem*, project funded by the Swiss National Science Foundation, 2018-2019
5. Quantum information: Dr.Sangouard is Associate Member of the National Center of Competence in Research (NCCR) project Quantum Sciences and Technologies (QSIT), 2014-2020

Significant infrastructure and/ or any major items of technical equipment

- In its supercomputing complex Research Component at TGCC, *CEA host and operates GENCI's* **Joliot-Curie supercomputer and various related equipment**, which will constitute the HPC environment to install a Quantum Simulator and connect it to HPC equipment
- In its supercomputing complex Industry Component at **TGCC (CCRT)**, CEA installed and operates an **ATOS Quantum Learning Machine** - QLM (as a pioneering Quantum computing facility in particular for industrial partners to emulate quantum algorithms and applications, independently of any specific physical quantum device, anticipating the deployment of future quantum computing solutions)

GENCI	**P3 – GENCI: Grand Equipement National de Calcul Intensif**

Description of the legal entity

Created in 2007 by the public authorities, GENCI's mission is to democratize the use of numerical simulation through high-performance computing (HPC) associated with the use of artificial intelligence (AI), to support French scientific and industrial competitiveness.
GENCI is a "civil company" (société civile) under the French law, and 49% owned by the State, represented by the Ministère en charge de l'Enseignement supérieur et de la recherche et de l'innovation, 20% by CEA, 20% by CNRS, 10% by the Universities, which are represented by the Conférence des présidents d'Université, and 1% by Inria. GENCI has an annual budget of €39 million.
GENCI's role is to implement the national strategy for equipping in HPC and storage resources/services the three national computing centres (TGCC for CEA, IDRIS for CNRS and CINES for French Universities) and making the systems available for French researchers; to support the creation of an integrated European high performance computing ecosystem; to work to promote numerical simulation and high performance computing within the academic and industrial communities.
Early 2020 the 3 national supercomputers of GENCI, hosted and operated in TGCC, IDRIS and CINES are representing a cumulated peak performance of more than 40 petaflop/s, based on complementary architectures, for addressing the daily needs of > 3000 users.
As said GENCI is one of the founding members and one of the 5 Hosting Members of PRACE, the European HPC research infrastructure.
GENCI is also involved in European projects like successive PRACE implementation projects, EPI (European processor initiative), PPI4HPC (which aims to jointly with 3 others partners acquire innovative and energy efficient HPC solutions), EXDCI2 and international initiatives like BDEC.
At the national level GENCI is coordinating a network of 17 regional centers, ensuring a seamless and integrated national HPC pyramid of facilities and services and also involved into SiMSEO a project helping startups and SMEs to adopt and use HPC and AI for increasing their competitiveness.

Role and main tasks in the project

GENCI will lead WP2 and will be involved inside tasks 5.1, 5.2 and 6.2

Profile of staff members involved

Christelle Piechurski (female) is chief HPC project officer at GENCI since May 2019. Part of her responsibilities is to support French national centers procurement for the acquisition of innovating and performant computing and storage capabilities for researchers. In addition, she is leading the technology watch activity group @GENCI keeping eyes on promising solutions to ensure their early adoption by users, assessing new technologies at the applications level. She is also co-leading in PRACE 6IP the HPC Commissioning and Prototyping Work Package (WP5). She has a postgraduate degree in Physics and belongs to the HPC world for more than 20 years. She started her career in the oil and Gas industry at CGG where she stayed for 11 years before moving to former SGI (HPE), joining former Bull/Atos in 2011 as HPC principal architect /presales. Among her activities, she also covered the business development on data management activities (HPSS) and quantum computing solutions.

Stéphane Requena (male): Director Technology and Innovation at GENCI (France) and former member of the PRACE Board of Directors. He has been during 10 years in charge of the HPC facilities at Institut Français du Pétrole and involved into optimisation and parallelisation of oil & gas (geology, seismic, reservoir modelling) and automotive applications. Previously he worked in CS a French service company in parallelising applications in the field of energy for EDF and CEA. He has been involved in several European projects including EESI (European Exascale Software Initiative) and EXDCI (European eXtreme Data and Computing Initiative) in relation to the scientific and industrial applications roadmaps. At GENCI he is also in charge of the development of innovative services and the technical part of GENCI' procurements for HPC and storage facilities.

Philippe LAVOCAT (male) is graduated as Engineer-Physicist (specialties High Energy Physics and Data & Signal Processing) in 1983 accompanied by a diploma of Equivalence of Master in Physics in 1982. He joined CEA research teams in HEP in 1983 (superconducting magnets, accelerators/detector (CERN & Fermilab (USA) till 1994: Positions of expert, several Projects Manager. He joined in 1995 the CEA Astrophysics Service as

National Project Manager (INTEGRAL ESA-NASA space mission (Gamma ray) and created in 1997 the CEA space Instrumentation Group. He supervised till 2002 and participated in developments of instrumentation for ESA, NASA, Chinese & Japanese Space Agencies. In 2003, he joined till 2006, CNRS-IN2P3 headquarters as Technical Director and Scientific Director for space and accelerators. In 2007, he joined back CEA-Division of Fundamental Research headquarters as Deputy Director (Space & Accelerators, Industrial Policy, large scale Research Infrastructures); member of Councils of ILL, ESRF, FAIR, XFEL, SOLEIL and follow-up of ITER activity. In 2009 (till 2012), he became Special Advisor in the cabinet of the High Commissioner for Atomic Energy. In 2012, he joined French Ministry for Higher Education, Research & Innovation as Special Advisor of the General Director for Space, Large Scale Research Infrastructures & International Policy. He became in 2014 Head of the Service of the national Strategy of Research.
In 2016, he became Chairman and CEO of GENCI, French national agency in charge of implementing French national policy for HPC and AI activities. He is member of different councils: French Delegate in PRACE Council, Council of CERFACS (European Center for research and advanced training in scientific computation), CINES Council (National Center for Its of Higher Education); national Ministry Steering Committee for HPC, Data & Network; since end 2018, Technical Advisor of French Delegate in EuroHPC-Governing Board

Relevant publications and/or products, services

1. ETP4HPC Strategic Research Agenda – Fourth Edition, 2019 – GENCI contributors - https://www.etp4hpc.eu/sra.html
2. BDEC Pathways to Convergence Report - GENCI contributors - https://www.exascale.org/bdec/sites/www.exascale.org.bdec/files/whitepapers/bdec_pathways.pdf
3. EXDCI Inputs to the PRACE Scientific Case - GENCI contributors - https://exdci.eu/sites/default/files/public/files/d3.2.pdf/files/d3.2.pdf

Relevant previous projects or activities

1. GENCI participates in the Horizon 2020 EPI (European Processor Initiative) which aims to design and implement a European general purpose processor architecture based on ARM technologies coupled with accelerators like Risc-V (Titan accelerator), GPUs or later quantum blades for specific workloads, in order to possibly integrate such component into one of the 2 planned European Exascale systems to be procured by the EuroHPC JU.
2. GENCI participates in Horizon 2020 EINFRA PRACE 6IP project (and participated in all previous PRACE IP projects); this supports the implementation of pan-European HPC infrastructures since 2010;
3. Horizon 2020 PPI4HPC EINFRA project, GENCI as lead procurer for a global procedure (a Public Procurement of Innovative Solutions in the area of HPC) with France, Italy, Spain and Germany which led to the extension of GENCI's Joliot-Curie in 2019

Significant infrastructure and/ or any major items of technical equipment

- Early 2020 the 3 national supercomputers of GENCI, hosted and operated in TGCC, IDRIS and CINES are representing a cumulated peak performance of more than 40 petaflop/s, based on complementary architectures, for addressing the daily needs of > 3000 users.
- Among them Joliot-Curie, hosted and operated at TGCC/CEA, is also the French Tier-0 system (alongside with 6 others systems provided by Germany, Italy, Spain and Switzerland) of PRACE.
  Joliot-Curie, a 22 petaflop/s peak performance modular and balanced system, is the most powerful supercomputer of GENCI at date, its composed by several compute partitions spanning from standard x86, manycores as well as a converged HPC+AI partition composed by 128 nVIDIA GPUs. Such compute partitions are sharing a 2 level Lustre parallel filesystem of more that 10 PB @ 500 GB/s.
- **In the field of the current proposal it's proposed to interconnect Joliot Curie, the French Tier0 system with the quantum simulator and beyond to the newly created European quantum infrastructure.**

	P4 – ATOS: BULL SAS

Description of the legal entity

Atos is a global leader in digital transformation with 110,000 employees in 73 countries and annual revenue of over 12 billion. European number one in Cloud, Cybersecurity and High-Performance Computing, the Group provides end-to-end Orchestrated Hybrid Cloud, Big Data, Business Applications and Digital Workplace solutions through its Digital Transformation Factory, as well as transactional services through Worldline, the European leader in the payment industry. With its cutting-edge technologies and industry knowledge, Atos supports the digital transformation of its clients across all business sectors. The Group is the Worldwide Information Technology Partner for the Olympic & Paralympic Games and operates under the brands Atos, Atos Syntel, Unify and Worldline. Atos is listed on the CAC40 Paris stock index. With its deep technology expertise and industry knowledge, the Group works with clients across different business sectors: Defense, Financial Services, Health, Manufacturing, Media, Utilities, Public sector, Retail, Telecommunications, and Transportation.

Atos Big Data Security (BDS), contributing to this project, is the business line for Atos' technology products and software (former BULL SAS). With a rich heritage of over 80 years of technological innovation, 2,000 patents and a 700 strong R&D team supported by the Atos Scientific Community, Atos BDS offers products and value-added software to assist clients in their digital transformation, specifically in the areas of Big Data and cyber security.

Atos BDS is in charge of HPC and quantum computing, among other technological areas. Atos BDS has been developing the Atos Quantum Learning Machine and its free community edition, myQLM. This platform is among the most complete and fastest quantum programming environment in the world. It is used by circa 20 public and private large research facilities in 10+ countries.

Atos BDS is #1 HPC manufacturer in Europe, #4 worldwide, and among the world leaders in the nascent field of quantum software.

Role and main tasks in the project

ATOS is involved in the design and the implementation of the interface between HPC System and QLM/QS as contributor to the WP3 "Infrastructure Software".

ATOS will drive the development of the programming environment as leader of WP4 "Programming technology and Technical Libraries".

ATOS will develop numerical simulation of strongly correlated materials via the Variational Quantum Simulation Method as part of WP5 - UC 2 Physics Simulations.

ATOS supports dissemination, communication & exploitation of innovation activities (WP6) and project management and scientific coordination activities (WP1).

Profile of staff members involved

Dr. Cyril Allouche (male) (Lead) is Bull Vice-President in charge of quantum computing research & development. He is a member of the Atos Fellows group, the 5 highest skilled experts of the Atos Group, in charge of advising Atos' CTO. Cyril received his Engineer degree from Ecole Polytechnique in 1998 and his PhD in Computer Science from University Paris-Sud in 2002. Starting December 2015, he has been in charge of building then managing Atos' research activities in quantum computing. Dr. ALLOUCHE was an industry member of the High-Level Steering Committee for Quantum Technologies of the European Commission and, is member of several national scientific & industrial councils for quantum engineering. Dr. ALLOUCHE is an inventor of 11 patents, 2 of them in quantum computing.

Dr. Thomas Ayral (male) obtained his Engineer degree from Ecole Polytechnique in 2012 and his PhD in Theoretical Physics from Ecole Polytechnique & CEA Saclay in 2015. During his Phd and subsequent postdoctoral appointment at Rutgers University (New Jersey, USA), he developed new algorithmic and computational approaches to the fermionic many-body problem and strongly-correlated materials. Since September 2017 he has been a research engineer in the Bull Quantum R&D department, working on numerical models of quantum noise and on theoretical aspects of quantum simulation.

Dr. Patrice Calegari (male) has more than 25 years of experience in HPC. He is the Technical Domain Leader of GUIs for the "HPC & AI software R&D" at Atos. He is also the Product Owner of the Atos' HPC web portal:

Extreme Computing Studio (XCS) and of the new Atos web GUI & Security framework (named BIRD). He joined Bull, now an Atos company, in 2005 as an HPC Application Expert to help start the HPC business at Bull. He was a key contributor to the development of Bull's HPC-as-a-Service Cloud offer. Patrice holds a Magistère in Computer Science from ENS Lyon in France and obtained a Ph.D. from the Swiss Federal Institute of Technology (EPFL) on the parallelization of population-based evolutionary algorithms for combinatorial optimization problems.

Relevant publications and/or products, services

Products and services: the "Atos Quantum" Programme and the Quantum Learning Machine: https://atos.net/en/insights-and-innovation/atos-quantum

Relevant publications

1. Allouche C, Baboulin M, Goubault de Brugière T, Valiron B - Reuse method for quantum circuit synthesis, 2017
2. Kerenidis I, Landman J, Luongo A, Prakash A - q-means: A quantum algorithm for unsupervised machine learning, 2018
3. Kerenidis I, Luongo A - Quantum classification of the MNIST dataset via Slow Feature Analysis, 2018
4. Goubault de Brugière T, Valiron B, Allouche C, Baboulin M - Synthesizing Quantum Circuits via Numerical Optimization, 2019 - ICCS
5. Goubault de Brugière T, Valiron B, Allouche C, Baboulin M - Quantum circuits synthesis using Householder transformations, accepted, Computer physics communications
6. Ayral T, Le Régent FM, Saleem Z, Alexeev Y, Suchara M - Quantum Divide and Compute: Hardware Demonstrations and Noisy Simulations, ISVLSI 2020
7. Serret F, Marchand B, Ayral T - Solving optimization problems with Rydberg analog quantum computers: Realistic requirements for quantum advantage using noisy simulation and classical benchmarks, 2020
8. Martiel S, Remaud M - Practical implementation of a quantum backtracking algorithm, accepted, SOFSEM 2020
9. Patrice Calegari, Marc Levrier, and Paweł Balczyński. "Web Portals for High-performance Computing: A Survey". ACM Transactions on the Web (TWEB), vol. 13, no. 1, Article 5 (February 2019), 36 pages. https://doi.org/10.1145/3197385

Relevant previous projects or activities

1. AQTion (Quantum Flagship, computing pilar): trapped-ion based quantum computer - work package leader on software stack for ions and responsible of noise models - http://aqtion.euhttp
2. PASQuanS (Quantum Flagship, simulation pilar): programmable atomic simulation platforms – work package leader on industrial applications, coordinator of industrial associate members – http://pasquans.eu
3. QuantAlgo (QuantEra): quantum algorithms
4. SoftQPro (ANR, France): quantum algorithms and quantum software
5. Quantex (PIA, France): quantum software and high-performance computing for quantum simulation
6. a founding member of ETP4HPC, Atos BDS is also involved in many European and national projects in HPC, including leader of the MontBlanc project (green supercomputer), and of the EPI project

Significant infrastructure and/ or any major items of technical equipment

P5 – CNR: Consiglio Nazionale delle Ricerche

Description of the legal entity

The CNR (**National Research Council** - https://www.cnr.it/en) is the largest public research institution in Italy, counting more than 8000 employees. It carries out multidisciplinary research activities, from medicine to ICT and fundamental and applied physics. CNR was founded the 18 November 1923, its mission being: to promote research within its Institutes; to stimulate innovation and competitiveness of the national industrial system to provide technologies and solutions to emerging public and private needs; and to advise Government and other public institutions.

CNR will participate in the project through the National Institute of Optics (INO) with headquarter located in Florence (Italy) and the Institute of Informatics and Telematics (IIT) with headquarter located in Pisa (Italy).

The activities of CNR-INO (https://www.ino.it/) include pure and applied research programs, technological transfer, optical metrology and certification. The main research areas are Quantum Optics, Nonlinear Optics, Spectroscopy, Coherent Sources, Optical systems, Optical Metrology, Visual Science and more recently Degenerate Quantum Gases. CNR-INO has worldwide-leading experimental and theoretical research activity on quantum degenerate atomic gases, Rydberg atoms, and ultracold stable molecules. These are prominent platforms enabling quantum simulation of complex phenomena of condensed-matter, high-energy, and gravitation physics, allowing to design and engineer brand-new materials and devices. Recently, quantum simulation has been extended to new quantum cascade laser frequency combs.

CNR-IIT (https://www.iit.cnr.it/en) carries out activities of research, assessment, technology transfer and training in the field of Information and Communication Technologies and of Computational Sciences. The research areas where CNR-IIT is active include computer systems, pervasive systems, parallel/distributed systems, sensor networks, cyber-physical systems, quantum computing and communications, cybersecurity and privacy, distributed, parallel and network algorithms, artificial intelligence, intelligent systems, machine learning, scientific computing, design, modelling, performance evaluation, through analysis and simulation, of computing and communication systems.

Role and main tasks in the project

CNR will contribute to the definition of the infrastructure software, with a focus on the design and implementation of the interface to QS, with optimised management and online scheduling of resources.

CNR will contribute to the development of several Use Case Demonstrators for end-users, focusing in particular on benchmarking the creation of entanglement in many-body systems, and on the development of hybrid classical-quantum phase estimation and machine-learning algorithms.

Profile of staff members involved

CNR-INO

Dr. Augusto Smerzi is Director of Research at the National Research Council (INO-CNR) and coordinator of the theory group of the QSTAR institute in Florence. He has recently been awarded two “One Hundred Talent” projects and the “111 Master” project of the Shanxi province of China for Distinguished Visiting Professors. He is “Mercator Fellow” of the Deutsche Forschungsgemeinschaft (DFG) and has been visiting professor at the University of Hannover.

Augusto has published 161 papers and have more than 13000 citations with an H-index = 51 (source Google Scholar). Augusto is coauthoring a book on “Quantum Interferometry” for the Springer-Verlag, series: “Springer Tracts in Modern Physics” (to be submitted), a Review Modern Physics on the same subject, and has published 4 Book Chapters. Augusto delivered more than 100 talks in international conferences and seminars and co-organized 6 conferences. He teaches the course “Quantum Paradoxes” at the University of Florence and supervised 21 Laurea and PhD thesis. Augusto is currently coordinating, as international PI, the project QOMBS of the European quantum flagship in Quantum Technologies and has been the international coordinator as PI of the QIBEC (284584) project within the european FP7. He regularly serves as panel member of the European ERC, the French IUF and, as external referee, of the US NSF and other national agencies. He is reviewer for Science, Nature, Nature Physics, Nature Communication, Physical Review Letters and other journals. The main research interests are on the emerging of macroscopic quantum coherence phenomena in ultracold gases and in quantum interferometry, where the goal is to exploit multiparticle entanglement to enhance the sensitivity of a phase estimation problem.

Dr. Giacomo Cappellini (male) is a permanent researcher at CNR-INO. Dr. Cappellini obtained his PhD degree in 2016 at the University of Florence with a thesis on quantum simulation with ultracold two-electron atoms. After the PhD training, he worked as postdoc at University of Florence until 2018, and in 2019 he worked as researcher at INRiM in Turin before moving to CNR-INO in December 2019. In his career, Dr. Cappellini has developed a strong expertise in experimental research in the fields of quantum simulation and optical atomic clocks, atomic physics and high-resolution spectroscopy. Dr. Cappellini is co-author of papers on high-impact factor journals (Science, Nature Physics, Phys. Rev. Letters, Phys. Rev. X), with more than 1300 Google Scholar citations (H-index 10, Google Scholar) . His most cited works regard the first observations of chiral edge states in a systems with synthetic gauge fields simulated exploiting internal degrees of freedom of neutral atoms coupled with laser light, the first characterization of one-dimensional systems with spin multiplicity higher than two and an extensive study of strongly interacting systems with electronic state and nuclear spin degrees of freedom.

Dr. Luca Pezzé (male) PhD at University of Trento (2007), Post-doc at the BEC group (Trento, 2007) and at the Institut d'Optique (Palaiseau, 2008-2011); CNR researcher since 2011 and associate researcher at LENS since 2015. His area of expertise covers the physics of quantum correlations in complex many-body systems and quantum technologies. He contributed to notion of useful entanglement in quantum metrology [PRL 102, 100401 (2009), Rev. Mod. Phys. 90, 035005 (2018)]. He is author of about 70 publications (3200 citations in the last 5 years, h-index 34).

Prof. Filippo Caruso (male) is Associate Professor in the Physics Department of Florence University and associated member at CNR-INO. He got his PhD in 2008 in Scuola Normale Superiore in Pisa, then was a postdoctoral research in Imperial College London (UK) and later in Ulm University in 2008-2011 (Germany). He has been awarded with two consecutive prestigious individual EU Marie-Curie fellowships (for 2 and 4 years) and then was PI of a very competitive three-year Future in Research project (FIRB) by the Italian Ministry of Education, University and Research (MIUR). Currently he is coordinating a 5-year H2020 EU FET-OPEN project PATHOS on quantum sensing. Despite his young age he has already published more than 60 articles (30 as first author, 20 as last, 1 as single) with more than 3000 citations (h-index 26, i-10 index 41, from Google Scholar), including 1 Rev. Mod. Phys., 3 Nature Commun., 1 Nature Mat., 3 Phys. Rev. Lett., 16 Phys. Rev., 10 New J. Phys., 1 AdP. Beyond his outreach activities as invited by the Italian Presidents of both the Council of Ministers and of the Chamber of Deputies and his participation to more than 80 international conferences (>40 invited talks), he has been Chair Organizer of the Italian Quantum Information Science conference (IQIS2017) in Florence (Sept. 2017). Among several prizes, he received the Physics 2015 Award of the oldest scientific academy of the world (Accademia dei Lincei, Roma) by the President of the Italian Republic. His main expertise is in quantum information science, with major contributions to open quantum systems, decoherence and entanglement, space/time noise correlations, transport over complex networks, optimal control, quantum biology, stochastic measurements, complex biological systems and quantum machine learning.

Dr. Chiara Mustarelli (female) Master in Management of Structural funds. She is financial project officer of QuantERA for CNR and involved in the QFlag FET FLAGSHIP CSA (820350). CNR Project manager of the Competence Centre ARTES4.0. More than 10 years' experience in PM support: follow up the financial implementation of the grants, analysis of financial reports and the associated eligibility of costs; maintain, manage and document all project reports and statements; assist and support project team members in completing projects. Has been in charge of the European and International CNR-INO Project Office from 2008 to 2015, appointed LEAR of the Coirich consortium. She played active part in writing and revising the management and dissemination reports of the "Qibec Project (284584).

CNR-IIT

Dr. Marco Conti (male) is the Director of IIT-CNR. He was the coordinator of FET-open project "Mobile Metropolitan Ad hoc Network (MobileMAN)" (2002-2005), and he has been the CNR Principal Investigator (PI) in several projects funded by the European Commission: FP6 FET HAGGLE (2006-2009), FP6 NEST MEMORY (2007-2010), FP7 EU-MESH (2008-2010), FP7 FET SOCIALNETS (2008-2011), FP7 FIRE project SCAMPI (2010-2013), FP7 FIRE EINS (2011-15) and CNR Co-PI for the FP7 FET project RECOGNITION

(2010-2013). Currently, is the CNR PI for the H2020 SCC REPLICATE project. He has been member of the steering committee that has defined the Italian roadmap for the FET Flagship on Quantum Technologies (http://www.qtflagship.cnr.it/committees/) and he is member of the steering committee that is setting up a national PhD program on Artificial Intelligence. He has published in journals and conference proceedings more than 400 research papers (29000+ citations, ref. Google Scholar) related to design, modelling, and performance evaluation of computer and communications systems. His H-index is 68 (Google Scholar). He is included in the "2017 Highly Cited Researchers" list compiled by Clarivate / Web of Science as, in 2017, he was ranked among the most cited researchers worldwide (top 1%) for the "computer science" area. Since January 2019 he has been a member of the START 4.0 Board of Directors ("Security and optimization of strategic infrastructures 4.0") and of the ARTES 4.0 Scientific Technical Committee ("Advanced Robotics and enabling digital TEchnologies & Systems 4.0"). START 4.0 and ARTES 4.0 are competence centers on Industry 4.0 funded by the Italian Ministry for Economic Development. Currently, he is the chair of Registro .it, the Italian Registry for Internet domain names.

Dr. Andrea Passarella (male) is a CNR Research Director and Head of UI-IIT. Prior to join IIT he was with the Computer Laboratory of the University of Cambridge, UK. He has published 160+ papers on decentralised AI, opportunistic, ad hoc and sensor networks, Online and Mobile social networks, receiving the best paper award at IFIP Networking 2011 and IEEE WoWMoM 2013. He was Co-Editor of several special sections/issues in international journals on various topics in the area of Future Networks. He is currently the scientific (co-)PI for IIT-CNR in the H2020 SoBigData++, HumanE-AI-Net, MARVEL, SLICES-DS, REPLICATE projects, and has been (co-)PI for IIT-CNR in several FP7 and H2020 past projects, including H2020 AUTOWARE and SoBigData, FP7 MOTO, EIT Digital MOSES and Efficient IoT projects, FP7 SOCIALNETS, SCAMPI and RECOGNITION. He is the coordinator of CNR activities in the ARTES 4.0 competence centre on Industry 4.0, funded by the Italian Ministry for Economic Development. He is the chair of the IFIP WG 6.3 "Performance of Communication Systems". His H-index is 42 (Google Scholar).

Dr. Claudio Cicconetti (male) is a Researcher at the IIT of CNR. He holds a PhD in Information Engineering from the University of Pisa (2007), where he also received his Laurea degree in Computer Science Engineering. He has been working in Intecs S.p.a. (Italy) from 2009 to 2013 as an R&D Manager and a Business Unit leader within the Telecommunications division, where he also acted as the official contact for ETSI and Net!Works. From 2014 to 2018 he has been a software engineer at MBI S.r.l. (Italy) working on the design, development, validation, and operation of Software Defined Radio satellite communication platforms. He has been the project manager of projects CROWD (FP7) and SAT4NET (ESA/ESTEC), the team leader for Intecs in SANDRA (FP7), and the chief promoter of FP7 projects BETaaS and ICSI. In the past he has been involved in MOTO (FP7), EuQoS (FP6), WINNER+ (Celtic), and other national R&D projects (QuaSAR, NADIR, IPERMOB). He has served as a member of the organisation committee of several international conferences (WoWMoM, IoT-SoS, ISCC, WiOpt, European Wireless, SIMUTools, Valuetools, QoSim, NSTools). He co-authored 60+ papers published in international journals, peer-reviewed conference proceedings and book chapters, and two international patents. His H-index is 25 (Google Scholar)

Relevant publications and/or products, services

1. L. Pezzè, A. Smerzi, M. Oberthaler, R. Schmied and P. Treutlein, “Quantum metrology with non classical states of atomic ensembles”, Reviews of Modern Physics 90, 035005 (2018)
2. M. Bellini, F.S. Cataliotti, M. Conti, I.P. Degiovanni, P. Villoresi. “Quantum Technologies” in White Book: The Future of Cybersecurity in Italy: Strategic project areas”, https://www.consorzio-cini.it/index.php/it/labcs-home/labcs-news/1273-white-book-2018-en
3. M. Mancini, G. Pagano, G. Cappellini, L. F. Livi, M. Rider, J. Catani, C. Sias, P. Zoller, M. Inguscio, M. Dalmonte, and L. Fallani, Observation of chiral edge states with neutral fermions in synthetic Hall ribbons, Science 349, 1510 (2015).
4. F. Caruso, A. Crespi, A.G. Ciriolo, F. Sciarrino, and R. Osellame,"Fast Escape from Quantum Mazes in Integrated Photonics", Nature Commun. 7, 11682 (2016);
5. F. Caruso, V. Giovannetti, C. Lupo, and S. Mancini, "Quantum channels and memory effects", Rev. Mod.

Phys. 86, 1203 (2014)

Relevant previous projects or activities

1. QuantERA – ERANET Cofund H2020 GA 731473 - is a network of 32 organizations from 26 countries, coordinated by the National Science Centre, Poland. The main goal of QuantERA is to fund excellent international research projects in the field of quantum technologies through joint calls for proposals. CNR has an active role as member of the Management Team. Overall project cost: 32Meuros.
2. The European call for the QuantERA II project closed at beginning of July 2020. CNR is still a partner of the consortium. Overall project cost: 36MEuros
3. QFlag FET FLAGSHIP CSA (GA 820350) will provide the key support towards objectives and the governance structure of the EU FET Flagship on Quantum Technologies (QT). By establishing an open, transparent and inclusive community driven initiative, the QT Flagship will be able to unfold its full potential, namely to develop and implement a truly European strategy and position Europe as outstanding region of QT excellence in the world. Overall project cost: 2698996,25 Euros.
4. QIBEC FP7-ICT (GA 284584) Quantum Interferometry with Bose-Einstein Condensates. Coordinated by CNR-INO. The project aims at the realization of a new class of interferometers based on entangled states of atomic Bose-Einstein condensates. Overall project budget: 2662833,00 Euros.
5. QUANCOM "Development of quantum systems and technologies for information security in communication networks" Project coordinated by CNR in the framework of the National Research Program of the Italian Ministry of Education, University and Research; overall project cost: 9.225.000,00 Euro.
6. H2020 SLICES-DS "Scientific Large-scale Infrastructure for Computing/Communication Experimental Studies – Design Study". Project aiming at defining the Design Study for a pan-European Research Infrastructure European-wide test-platform for experimentally-driven research on Next Generation Internet, providing advanced compute, storage and network components, interconnected by dedicated high-speed links.

Significant infrastructure and/ or any major items of technical equipment

CNR-INO and CNR-IIT are currently developing with the financial support (3M Euro for 2020) of the Italian Ministry of Research and with CNR co-founding a hybrid multidisciplinary research infrastructure which integrates high-performance computing systems with a quantum coprocessor to be used as an accelerator for effectively solve problems which are intractable when using, independently, legacy or quantum computing systems. Specifically, the quantum accelerator will be a quantum simulator based on programmable and scalable arrays of single atoms in micro optical traps.

CNR-IIT owns HPC computing facilities, including five high-end multi-core workstations with NVIDIA GPUs. Furthermore, CNR-IIT, together with other CNR Institutes, is currently developing with the financial support (3M Euro for 2020) of the Italian Ministry of Research and with CNR co-founding a HPC center for AI with 3000 Tflops peack performance. These facilities can be used within the project for development and unit testing of the solutions in WP3. CNR-IIT owns HPC computing facilities, including five high-end multi-core workstations with NVIDIA GPUs. Furthermore, CNR-IIT, together with other CNR Institutes, is currently developing with the financial support (3M Euro for 2020) of the Italian Ministry of Research and with CNR co-founding a HPC center for AI with 3000 Tflops peack performance. These facilities can be used within the project for development and unit testing of the solutions in WP3.

P6 – NUIG-ICHEC: National University of Ireland Galway, Irish Centre for High-End Computing

Description of the legal entity

The **Irish Centre for High-End Computing** (ICHEC) is the national HPC centre in Ireland. (www.ichec.ie) It was established in 2005 under the aegis of the **National University of Ireland Galway** (NUIG). With its 40 staff, ICHEC is pursuing an active policy of engagement and collaboration in the research community to support the development of internationally competitive computational methods and solutions across a wide range of application domains. ICHEC both facilitates and actively participates in many research activities in Ireland and Europe through engagement with research, enterprise and public sector organisations. ICHEC hosts the national supercomputer Kay (www.ichec.ie/about/infrastructure/kay) and offers high-performance computational expertise through the national service, research projects and commercial engagements.

In 2018, ICHEC identified the opportunities in developing algorithms and software for current and future quantum computing platforms, and launched the Quantum Programming Ireland (Q_π) Initiative (www.ichec.ie/qpi) in 2018 with three primary lines of action:

1. Development of practical applications on currently available quantum computing platforms (hardware and software simulators).
2. R&D in software development to enable programming quantum computing platforms.
3. Education/training to the academic and enterprise communities.

The Q_π Initiative engages with Irish and international partners through enterprise, Government and EU funded programmes to develop practically relevant quantum algorithms and applications. Following are key milestones as of the Q_π Initiative as of July 2020:

1. Collaborative R&D projects with industry partners (such as Intel, Accenture, Nuritas) to develop quantum computing applications in the areas of natural language processing (AI), analysing environmental pollutants and biotechnology.
2. Deployment of a Quantum Learning Platform (QLP) in Q3 2020 for national R&D and training activities in quantum programming through funding awarded by the Irish Government.
3. Developing a national industry-oriented training programme in quantum programming from 2021.
4. Working with the EU Quantum Flagship to organise the European Quantum Technologies Conference (EQTC 2021) in Dublin which will serve to highlight Ireland's activities and capabilities in this domain.
5. Working with the Tyndall National Institute to establish the Irish Quantum Initiative (IQI) which will be a national Centre of Excellence in the science, engineering and application of quantum computing technologies.

As of May 2020, the activities in the Q_π Initiative have received a total funding of ~€2M over 2 years from the Irish Government, EU and enterprise partners.
ICHEC has also been involved in a number of H2020, scientific and industrial projects targeting energy-efficiency, exascale, and large-scale application profiling and optimisation. Some have led to very noteworthy improvements, namely the PRACE (Partnership for Advanced Computing in Europe) programme. The Novel Technologies and Performance Engineering Programmes at ICHEC conducts research and services by working closely with scientific and industrial stakeholders to leverage existing and upcoming platform technologies for applications from various domains that require extreme-scale (and potentially exascale) capabilities. In particular, a number of projects in the Performance Engineering Programme address the development of techniques and tools for optimising I/O operations in HPC applications that operate on large datasets. Since its establishment in 1845, NUI Galway has developed a distinguished record in scholarship, research and education. The university is one of Ireland's foremost educational institutions.

Role and main tasks in the project

NUIG-ICHEC leads WP5 (Demonstrators, training and user engagement). In particular, NUIG-ICHEC will contribute to the development of applications in the "Physics Simulations" use case and demonstrate applications in the "Quantum Machine Learning" use case in Task 5.1. NUIG-ICHEC will also develop technical libraries in WP4 (Programming technologies and technical libraries) related to the "Physics Simulations" use cases in WP5. Furthermore, NUIG-ICHEC will lead and contribute Task 5.2 on training, and contribute to Task 5.3 on user engagement, WP6 (Dissemination, communication and innovation exploitation), and WP1 (Project management

and scientific coordination).

Profile of staff members involved

Dr. Venkatesh Kannan (male) Venkatesh will be the principal investigator at NUIG-ICHEC. He is the Centre Technical Manager at ICHEC and works with all ICHEC staff including a team of 40 computational scientists on a number of academic, public and private sector projects across offices in Dublin and Galway. Venkatesh is also manager of the Novel Technologies Programme which runs the Quantum Programming Initiative. He was/is principal investigator in a number of Irish and European projects on quantum computing and HPC, including the Quantum Natural Language Processing (QNLP) in collaboration with Intel, Quantum Computing Simulation of PFAS Molecules (QPFAS) in collaboration with Accenture and H2020 READEX. He is actively involved in ICHEC's contributions to the Quantum Flagship, Irish National Quantum Initiative, Irish National AI Strategy, PRACE, ETP4HPC, and academic/industrial consultation, training and teaching activities. Venkatesh also leads the Intel Parallel Computing Center (IPCC) at ICHEC, which also investigates scaling the Intel Quantum Simulator on Exascale HPC systems (ExaIQS). He is actively involved as co-ordinator and/or principle investigator in proposals for EU projects.

Dr. Lee O'Riordan (male) Lee is Quantum Computing Programme Manager at ICHEC and will lead the technical contributions in WP3, WP4 and WP5. He lead development of a quantum computing application for use in natural language processing problems in the QNLP project, and also leads the QPFAS and ExaIQS projects, and contributes to the PRACE-6IP QuantEx project. He has worked on developing software solutions under the Exascale Computing Project (ECP) for applications in structural biology (ExaFEL) targeting NERSC's Cori supercomputer. During his PhD he has worked on investigating the dynamical behaviour of Bose-Einstein condensates, and is the lead author of the GPU-enabled linear and non-linear Schrodinger equation solver suite "GPUE". He has experience developing for GPU, multi-core, and multi-node systems. Prior to this, Lee was a software developer at IBM, Dublin Software Labs.

Dr. Niall Moran (male) Niall is a senior computational scientist at ICHEC and leads the Artificial Intelligence Activities. Niall works on multiple projects covering the areas of Quantum Computation, AI and traditional HPC. He is the PI and project leader of the PRACE-6IP WP8 QuantEx project which develops scalable quantum circuit simulation tools for exa-scale platforms. He also spent a number of years in academia - completing his PhD in mathematical physics at Maynooth university and going on to work as a postdoc at École normale supérieure, Paris and Maynooth University. During this time he worked on quantum computation and simulation of systems relevant to topological quantum computation.

Dr. John Brennan John Brennan joined ICHEC in March, 2020 as a Computational Scientist. He is working on the PRACE WP8 QuantEx project which looks at developing scalable quantum circuit simulation tools for exa-scale platforms. His previous research involved the use and development of numerical methods to study topological quantum phases and their applications in topological quantum computation. John worked as a lecturer at Maynooth University until January 2020. He lectured undergraduate courses in vector calculus, complex analysis, fluid mechanics and computational physics.

Mr. Myles Doyle (male) Myles is a Research Computational Scientist at ICHEC. He is experienced in the application of existing quantum algorithms in quantum computing, specifically for the use case of natural language processing in the QNLP project, and also contributes to the QPFAS and ExaIQS projects. He completed his M.Sc. in High Performance Computing (HPC) after finishing his B.A. Mod. in Mathematics, both at Trinity College Dublin. Previous work involved developing and delivering course material for an Introduction to Deep Learning course, and research into dynamic tuning of HPC applications for energy optimisation.

Dr. Goar Sanchez (male) Goar is the lead quantum computational chemist at ICHEC in the QPFAS project and also manages the national HPC service and users support activity. He is an experienced researcher with track record domain expertise in Computational and Theoretical Chemistry (PhD Computational Chemistry, Universidad Autónoma de Madrid, Spain). Goar leads the centre's engagements with academy and researchers in third-level HEIs. He has dilated experience in molecular structure, reactions modelling and electronic properties

research (91 international peer- review papers, ~1900 citations, h=23). He has also collaborative research with groups at TCD, UCD and TU Dublin and also in Spain.

Relevant publications and/or products, services

1. Lee O'Riordan, Myles Doyle, Venkatesh Kannan, "D1.1 Overview of DisCo Algorithms & Methods for Testing & Evaluation", Report from Quantum Natural Language Processing project, April 2019.
2. Lee O'Riordan, Myles Doyle, Venkatesh Kannan, "D1.2 Implementation, Testing and Evaluation of DisCo Algorithms: Closest Vector Algorithm", Report from Quantum Natural Language Processing project, August 2019.
3. L. J. O'Riordan, "Non-equilibrium vortex dynamics in rapidly rotating Bose-Einstein condensates", Okinawa Institute of Science and Technology Graduate University, 2017.
4. L. J. O'Riordan, A. C. White, and T. Busch, "Moiré superlattice structures in kicked Bose- Einstein condensates", Physical Review A, 2016.
5. M. Fremling, C. Repellin, J.M. Stéphan, N. Moran, J. K. Slingerland, M. Haque, "Dynamics and level statistics of interacting fermions in the Lowest Landau Level", New J. Phys., 2018.
6. E. Rico, R. Hübener, S. Montangero, N. Moran, B. Pirvu, J. Vala, H.J. Briegel. "Valence bond states: link models", Ann. Phys., 2009.
7. N. Moran, G. Kells, J. Vala, "Diagonalisation of quantum observables on regular lattices and general graphs", Comp. Phys. Comm., 2011.
8. G. Sánchez-Sanz, I. Alkorta, J. Elguero, and C. Trujillo, "Sequestration of CO2 by Phosphatrane Molecules", ChemPhysChem., 2019, in press.
9. C. Trujillo, I. Rozas, I. Alkorta, J. Elguero, and G. Sánchez-Sanz, "Modulating Intramolecular Chalcogen Bonds in Aromatic (thio)(seleno)phene-Based derivatives", Phys. Chem. Chem. Phys., 2019, in press.
10. G. Sánchez-Sanz, C. Trujillo, I. Alkorta, and J Elguero, "Understanding regium bonds and their competition with hydrogen bonds in Au2:HX complexes", ChemPhysChem., (Cover Article) 2019.
11. G. Sánchez-Sanz, D. Crowe, A. Nicholson, A. Fleming, E. Carey, and F. Kelleher, "Conformational studies of Gram-negative bacterial quorum sensing acyl homoserine lactone (AHL) molecules: the importance of the n* interaction", Biophys. Chem., 2018.

Relevant previous projects or activities

1. Quantum Natural Language Processing (QNLP)", Intel Corporation and Enterprise Ireland and Intel, www.ichec.ie/qpi/qnlp , 2018-2020 (Budget: €151,543).
2. "Quantum Computation Simulation of PFAS Molecules (QPFAS)", Accenture and Enterprise Ireland, www.ichec.ie/qpi/qpfas , 2019-2021 (Budget: €302,610).
3. "Exascaling Intel Quantum Simulator (ExaIQS)", Intel Parallel Computing Centre, www.ichec.ie/qpi/exaiqs , 2019-2021 (Budget: €102, 063).
4. ICHEC's Quantum Programming Ireland initiative, www.ichec.ie/qpi, 2018-present.

Significant infrastructure and/ or any major items of technical equipment

Irish national supercomputer, Kay:

- 336 node cluster
- 13,440 CPU cores
- 63 TB distributed memory
- Dual-socket 20-core Intel® Xeon Gold (Skylake) 6148 at 2.4 GHz with 192 GB memory
- 400 GB local SSD scratch
- 100 GB Intel® OmniPath network
- 1 PB Lustre filesystem storage on DDN SFK14A system
- Additional partitions
  - o Dual NVIDIA Tesla V100
  - o Intel Xeon Phi (Knights Landing architecture)
  - o High-memory 1.5 TB RAM with 1TB local SSD scratch

P7 – UIBK: University of Innsbruck

Description of the legal entity

The Center of Quantum Physics at the University of Innsbruck hosts researchers focusing on theoretical and experimental challenges in quantum computing and quantum simulation. The physics research in Innsbruck has an excellent international reputation and has many intense collaborations with leading research centers worldwide and forms an international environment for scientists from all over the world. With ground-breaking theoretical proposals in quantum science, in particular for ions and Rydberg atom quantum simulations, Innsbruck hosts leading experts in the field.

Role and main tasks in the project

The main tasks for UIBK within the proposal are the investigation (WP4) and implementation (WP4, WP5) of variational hybrid-quantum classical protocols suited for the analog quantum simulator device. UIBK can leverage here the experience gathered in the recent implementation of operating a trapped-ion experiment in the quantum cloud, resulting in one of the most successful and to-date largest scale realisations of variational quantum-classical experiments [C. Kokail, C. Maier, R. van Bijnen, et al., Nature, (2019)].

Profile of staff members involved

Dr. Rick van Bijnen (male), is a senior postdoc at the Institute for Quantum Optics and Quantum Information, hosted at the University of Innsbruck, and working in the high-profile group of Prof. Peter Zoller. He obtained his PhD in 2013 from the Eindhoven University of Technology with the highest possible distinction, and subsequently worked as a postdoc at the Max Planck Institute for Complex Physics in Dresden, Germany from 2013-2016, finally moving to Innsbruck in 2016. He performs theoretical research and made numerous contributions to the field of dipolar quantum gases, Rydberg atoms, and novel quantum algorithms for quantum simulators, resulting in several high-profile publications.

Prof. Peter Zoller (male), made ground-breaking contributions to the quantum optics and quantum simulation, in particular by interdisciplinary connections between atomic, molecular, and optical (AMO) systems and applications in quantum information processing and the realization of fundamental models from condensed matter physics. Experience: (1994 -present) Prof. of Physics with tenure at University of Innsbruck, (2003-present), Director of IQOQI, Austrian Academy of Sciences (Austria); Prof. of Physics with tenure at JILA/Boulder (1991-1994), and JILA Fellow (1994 - present) Guest Professorships: Loeb Lecturer (2004), Lorentz-Professor, Leiden (2005), Moore Distinguished Scholar Fellow, Caltech/Harvard (2008, 2010) Jacques Solvay Prof. (2015), Arnold-Sommerfeld Lecturer, LMU Munich (2010), External Member Max-Planck Society, Max-Planck Institute for Quantum Optics, Garching (2014-present). Selected Prizes / Awards / Fellowships: Wittgenstein-Award (Austrian Science Foundation) (1998), Max Planck Medal (German Physical Society) (2005), Dirac Medal (ICTP Trieste) (2006), Benjamin Franklin Medal (2010), Honorary doctorate from the Free University of Amsterdam (2012), Wolf Prize in Physics (2013), Herbert-Walther-Preis der Optical Society of America und der Deutschen Physikalischen Gesellschaft (2016), Norman F. Ramsey Prize (2018).

Relevant publications and/or products, services

1. C. Kokail*, C. Maier*, R. van Bijnen*, T. Brydges, M.K. Joshi, P. Jurcevic, C.A. Muschik, P. Silvi, R. Blatt, C.F. Roos, P. Zoller, Self-verifying variational quantum simulation of lattice models, Nature, 569, 355 (2019)
2. A. Glaetzle*, R. van Bijnen*, P. Zoller, W. Lechner, A coherent quantum annealer with Rydberg atoms, Nature Communications 8, 15813 (2017)
3. R. M. W. van Bijnen, T. Pohl, Quantum magnetism and topological ordering via Rydberg dressing near Förster resonances, Physical Review Letters 114, 243002 (2015)
4. M. D. Lukin, M. Fleischhauer, R. Cote, L. M. Duan, D. Jaksch, J. I. Cirac, and P. Zoller, Dipole Blockade and Quantum Information Processing in Mesoscopic Atomic Ensembles, Physical Review Letters 87, 037901 (2001)
5. J. I. Cirac, P. Zoller, Quantum computations with cold trapped ions, Physical Review Letters 74, 4091 (1995)

Relevant previous projects or activities

1. EU-H2020 Quantum Flagship Project PASQUANS, Programmable Analog Quantum Simulators, Grant Agreement No. 817482.
2. ERC Synergy Grant UQUAM: Collaborative project with the goal to explore ultracold quantum matter.
3. FET Proactive (RIA) Project RYSQ: Collaborative project with the goal to advance Rydberg atom based

quantum simulators.

4. FET Proactive (ICT) Project SIQS: Cross platform collaborative project aiming at the exploitation of strong quantum correlations for future applications.

Significant infrastructure and/ or any major items of technical equipment

UIBK provides an outstanding scientific environment with pioneers in the field of quantum optics and quantum information. This ideal environment for the proposed research is driven by the strong interplay between theory and experimental groups hosted at the same institution. UIBK provides laboratories with state of the art infrastructure for carrying out trapped-ion experiments investigating quantum many-body physics, and access to the LEO3 and LEO4 high-performance computer clusters.

P8 – EURICE: European Research and Project Office GmbH

Description of the legal entity

Founded in 2000, **European Research and Project Office GmbH** (EURICE) provides comprehensive support services for the planning, initiation, and implementation of international collaborative research and innovation projects. EURICE ranks among Europe's largest project management offices, with a dedicated team of >40 staff members with different professional and scientific background and expertise, such as law, medicine, biology, chemistry, communications, social and computer sciences. **Within Horizon 2020, EURICE has been successfully involved in the coordination of 50 collaborative projects.** Our portfolio ranks from collaborative projects in the field of experimental research (TRL 2-4) up to demonstration and technology validation projects in an operational environment (TRL 5-8). According to the actual CORDIS datasets, EURICE belongs to the **Top 3 of SMEs in Europe** regarding the number of signed Horizon 2020 agreements.

Consortium partners benefit from our extensive expertise gathered from over 100 project co-ordinations in EU Funding Programmes and take advantage of our sophisticated Project Management Office infrastructure. We offer backbone services for a successful project management approach by providing fair, transparent and neutral decision support information. EURICE is specialised in managing impact and innovation in all areas of research and innovation projects. We offer expert knowledge to brief EC staff, evaluators and proposers on how to maximise the impact and exploitation of research outcomes. In order to pave the way for successful project exploitation, we support consortia in identifying, capturing, protecting and nurturing the Intellectual Property (IP) generated in research collaborations. Thus, EURICE accompanies researchers and innovative companies through the entire life cycle of a project – from the first idea to successful project completion – and beyond.

We developed specific training modules (on-site, webinars, audio-visual) for successful innovation and project management in collaborative Horizon 2020 research and innovation projects. We welcomed over 4,500 users (Researchers, SMEs, EC project monitoring staff, Reviewers) in our extensive training programme in 2019 alone.

Furthermore, EURICE provides expert knowledge to several 'Innovation Support Actions' aiming at maximising values of Horizon 2020 and focusing on the exploitation of Horizon 2020 results:

- **European IP Helpdesk** which provides hands-on assistance in the field of **IP & innovation management** for researchers and SMEs involved in Horizon 2020;
- **Inno-Coaching** which offers **high-level innovation audits** for European SMEs;
- **IP4Business**, which offers training for EU SMEs in the field of **IP diagnostics and commercialisation** of innovative ideas (bilateral co-operation with the European Patent Office);
- **Common Exploitation Booster,** which supports Horizon 2020 consortia **to develop exploitation strategies** and analyse related risks and opportunities;
- **Innovation Radar**, which focuses on the **identification of high potential innovations** and the key innovators in Horizon 2020 projects.

Role and main tasks in the project

Project Management:

EURICE will support the coordinator in all aspects of project management, including administrative, legal and financial matters, to ensure a smooth project implementation. As key partner of WP1 EURICE will assist the coordinator in project monitoring, progress management, and decision making. EURICE will facilitate the project workflow in general, stimulate interaction between the different project management bodies. EURICE will set up, host and maintain the Project Management Platform.

Communication & Dissemination:

Together with all partners, EURICE will ensure strategic and systematic management of communication and dissemination measures to help maximise project impact, and facilitate the sustainable use and uptake of results. In cooperation with all partners, EURICE will thus safeguard consistent external communication of the project itself and its outcomes towards relevant target groups via a broad range of appropriate communication and dissemination channels/tools. In addition, EURICE will support all partners in networking activities and in questions concerning stakeholder and media relations throughout the project.

Innovation-related activities:

Together with the coordinator and industrial partners – EURICE will ensure the synthesis of the results from work packages 2-5 and support innovation-related activities such as dissemination and exploitation of results, to

maximise project impact. EURICE will provide advice concerning Horizon 2020-specific rules and regulations regarding Intellectual Property Rights (IPR)-issues to all partners throughout the project. Tailored to the different phases and specific needs of HPCQS, EURICE offers structured innovation support through well-defined measures, such as Exploitation Strategy Workshops, innovation questionnaires, lean Canvas-Method of Exploitation Planning and/or IP portfolio management tools.

Profile of staff members involved

Jörg Scherer (male), Managing Director, has been working as a licensed innovation manager and business advisor in both the academic and industrial sector for over 20 years. He has an outstanding track record of participation/ coordination in over sixty European research and innovation projects, spanning from FP4-Horizon 2020. He acts as senior innovation management expert for different EC units, Executive Agencies and EU business associations. In 2018, he provided over 50 lectures and training sessions in the field of IP management and exploitation strategies in Horizon 2020.

Corinna Hahn (female), Senior Research & Innovation Manager. She has been working in international collaborative projects for over 20 years during which she acquired profound expertise in formal, contractual, managerial and organisational aspects of EU projects as well as in dissemination and exploitation of project outcomes. She has a strong interest in interdisciplinary research initiatives with a particular expertise in engineering projects. Additionally, Corinna provides training sessions and workshops on knowledge transfer and innovation management.

Noreen Rach (female), Project Manager, hands-on expertise in the administrative management of EU-funded research projects, including day-to-day management and coordination of project activities, contractual and financial management, decision making management, communication & reporting.

Ulrike Waltsgott (female), Diploma, Communication Manager, professional skills and expertise in communication management including development of integrated communication strategies, social media management, stakeholder & media relations, creation of (digital/print) editorial content/ marketing materials as well as audio-visual material.

Relevant publications and/or products, services

1. Strategic and operational Project Management and Project Administration services
2. Communication & dissemination activities, including Open Access strategies
3. Training Modules: “Maximising impact of Horizon 2020 projects” & “IP and Innovation Management in Horizon 2020”
4. IP Management Guides for EC services: “Your Guide to IP in Horizon 2020 (2019)” and “Your Guide to IP Commercialisation (2019)”; 12,000 printed copies + audio-visual material (https://www.iprhelpdesk.eu/animated-clip-IP-in-Horizon-2020)
5. Publications, such as “Making the Most of Your H2020-Project - boosting the impact of your project through effective communication, dissemination and exploitation” (2018), IPR helpdesk brochure available through the EC´s Funding & Tenders Portal

Relevant previous projects or activities

1. EU-H2020 project (FETFLAG-03-2018): OpenSuperQ - An Open Superconducting Quantum Computer, Grant Agreement No. 820363, 2018-2021.
2. EU-H2020 project (DT-2019-1): PLATOON - Digital PLAtform and analytic TOOls for eNergy, Grant Agreement No. 872592, 2020-2022.
3. FP7 project (ICT-2011-9): CHIC - Computational Horizons In Cancer, Grant Agreement No. 600841, 2013-2017
4. EU-H2020 project (H2020-INNOSUP-2014-2): European IPR Helpdesk, Grant Agreement No. 641474, 2011-2018.
5. EC-H2020 (EASME/H2020/2018/008): European IP Helpdesk, 2019-2021

Significant infrastructure and/ or any major items of technical equipment

EURICE EUROPEAN RESEARCH AND PROJECT OFFICE GMBH	**P8 – EURICE: European Research and Project Office GmbH**
Eurice - based in St. Ingbert and Berlin - offers full professional Project Management Office (PMO) services for research networks and collaborative research and innovation projects on national and particularly international level. The highly qualified team provides **a comprehensive set of expertise, tools and experiences** in grants management (including legal and financial affairs), project management (strategic & operational), communication, exploitation management and training activities (online/ on-site)	

P9 – CNRS: Centre national de la recherche scientifique

Description of the legal entity

The Centre National de la Recherche Scientifique is a public organization and the largest fundamental research organization in Europe. CNRS carries out research in all fields of knowledge, through its ten disciplinary institutes and more than 1100 research and service units involving about 11 000 researchers.

Four laboratories will contribute to the project through the umbrella of CNRS: IRIF, LIP6, LORIA and LRI.

IRIF (lead by Frédéric Magniez) is a CNRS research unit, jointly with Université de Paris. The research conducted at IRIF is based on the study and understanding of the foundations of all computer science, in order to provide innovative solutions to the current and future challenges of digital sciences. IRIF hosts about 200 people.

The LIP6, Sorbonne University and French National Center for Scientific Research (UMR 7606 Sorbonne University - CNRS), is a computer science research institute dedicated to the modeling and the resolution of fundamental problems driven by applications, as well as to the implementation and the validation through academic and industrial partnerships. LIP6 host about 550 people.

LRI is the Laboratory for Computer Science at Université Paris-Sud, joint with CNRS, the National Center for Scientific Research. It has over 240 members. The research themes addressed by LRI cover a wide spectrum of computer science focused on software ranging from fundamental to applied research.

LORIA is a research unit, common to CNRS, the University of Lorraine and INRIA. Loria's missions mainly deal with fundamental and applied research in computer sciences. Bolstered by the 400 people working in the lab, its scientific work is conducted in 28 teams including 15 common teams with INRIA. LORIA is today one of the biggest research labs in Lorraine.

IRIF and LIP6 are fondators of The Paris Centre for Quantum Computing (PCQC). PCQC brings together a multi-disciplinary team of computer scientists, mathematicians, theoretical and experimental physicists, with the objective of performing high impact research and of becoming a pole of excellence for research in quantum information both in Europe and internationally. The general objective of PCQC is to develop quantum technologies for applications in computation and communication. The Centre has a strong expertise in quantum algorithms (general framework for quantum walks, first real-world application of quantum machine learning in recommendation systems, optimization techniques), and verification of quantum computation (pioneers of verifiable blind delegation). PCQC members have an extensive experience in coordinating and collaborating in national and EU-funded projects, including ERC projects, ERANET CHIST-ERA, QUANT-ERA, FET-Open STREP projects, H2020 Marie-Curie ITN, as well as national projects, including numerous ANR, Ile de France Region, and Ville de Paris projects.

Role and main tasks in the project

LRI and LORIA will contribute mostly in Workpackage 4, for Task 4.1. They will develop the front-end of the software framework dedicated to analog quantum computing and simulation. The objective is to provide an environment for programming the quantum simulator. CNRS will also develop formal methods for code transformation and optimization, taking into account the constraints of the hardware, like the available transformations, the topology of the quantum memory, the noise, etc. In Task 4.4, they will develop tools to optimize the quantum code.

LIP6 and IRIF will contribute to Workpackages 4 and 5. In Workpackage 4, for Task 4.2, they will contribute to a basic technical library for machine learning applications in the setting of analog computing. Following the line of their previous work, they plan to adapt, to convert or to rebuild a set of libraries for designing quantum ML algorithms. They will investigate the potential of quantum generative modeling to explore the potential of quantum approaches for reducing the amount of data needed to learn. They will use their long experience with quantum algorithms in order to understand what type of quantum solutions one can offer, and in particular, what resources are required.

Last, for Task 5.2, all participants will use their longstanding experience in training and advertising quantum computation in order to support any training and knowledge transfer activities (seminars, summer schools and hackatons).

Profile of staff members involved

Elham Kashefi, CNRS/LIP6 & PCQC (female):

Current position: Senior CNRS Researcher, Professor of Computer Science University of Edinburgh, NQIT quantum hub associate director

Education:

- June 03 – Sep 07, University of Oxford Christ Church College Junior Research Fellow
- Jan 05 – Jan 06 Institute for Quantum Computing, University of Waterloo Post-doctoral Fellow
- 1999 – 2003 Imperial College, London, UK Research Assistant and PhD student in Computer Science Supervisor: Prof. Vlatko Vedral
- « Complexity Analysis and Semantics for Quantum Computing »
- 1996 – 1998 Sharif University of Technology, Iran MSc in Applied Mathematics, Supervisor: Prof. Ebad Mahmoodian « Combinatorial Game Theory »
- 1991 – 1996 Sharif University of Technology, Iran BSc in Applied Mathematics and Computer Science

Expertise: Quantum Verification, Models of Quantum Computing, Quantum Cloud Computing, Quantum Cryptography

Leadership and organizational responsibilities:

- Supervising a large group of researchers jointly between UK and France: 10 PDRs (5 completed), 12 PhDs (5 completed), 11 masters (8 completed) and 9 undergraduates (6 completed).
- Served on 15 Program Committees
- Co-Founder of VeriQloud, a quantum startup in France, 2017
- Advisory board of EPSRC research programme grant on "Engineering Photonic Quantum Technologies" 2016 – 2021
- Advisory board of EPSRC research programme grant on "Designing out of equilibrium many-body quantum systems" 2017 – 2022
- Managing board member and Associate director in charge of Quantum Applications development of the Networked Quantum Information Technology Hub 2014 - 2020
- Managing board member and Senior Science Team Member in charge of Quantum Software development of the Quantum Computing and Simulation Hub 2020 - 2025
- Executive Team Member of the EU Flagship Quantum Internet Alliance Project since 2019

Honors and awards:

- US Air Force Office of Scientific Research Fellowship, 2016 – 2020
- UK EPSRC Established Career Fellowship 2015 - 2021
- UK EPSRC Advanced Research Fellowship 2008 - 2013
- Elected member of the Royal Society of Edinburgh Young Academy of Scotland, 2011 - 2016
- Oxford Christ Church College Junior Research Fellowship, 2003 – 2007
- Distinction for Master Thesis, Sharif University of Technology, Iran, 1998

Iordanis Kerenidis, CNRS/IRIF & PCQC (male):

Current position: Senior CNRS Researcher, Director of PCQC

Education:

- 2004 – 2006: Massachusetts Institute of Technology, Postdoctoral Associate in the Dept. of Mathematics, Supervisor: Peter Shor
- 2000 – 2004: PhD, University of California, Berkeley, 'Quantum Encodings and Applications to Locally Decodable Codes and Communication Complexity', Adviser: Umesh Vazirani
- 1995 – 2000: National Technical University of Athens GRAD. in Electrical and Computer Engineering

Expertise: Quantum algorithms and complexity, quantum machine learning, quantum games, quantum communications, quantum cryptography

Leadership and organizational responsibilities:

- 2014 – now: Director of Paris Centre for Quantum Computing
- 2010 – now: CNRS Senior Researcher DR
- 2009 – now: CQT, Singapore, Visiting Professor
- 2006 – 2010: CNRS Junior Researcher

Honors and awards:

- ERC Starting Grant, 2013-2018.
- Prime d'Excellence Scientifique CNRS, 2011-2014
- ANR JCJC (French Young Researchers Grant), 2009-2013.
- Marie Curie International Reintegration Grant, 2006-2008.
- UC Berkeley Regents Fellowship, 2000-2003
- Award for highest GPA among all graduating students at NTU, Athens 2000.

Other: Patent under way on relativistic cryptography

Frédéric Magniez, CNRS/IRIF & PCQC (male):

Current position: Senior CNRS Researcher, Director of IRIF

Education

- 2008: Habilitation in CS
- 2000: PhD in CS at Universté Paris-Sud
- 1996-97: Military service at CEA
- 1992-95: Graduate studies at ENS Cachan in Maths and CS

Expertise:

- Quantum computing: algorithms, self-testing, cryptography
- Sublinear algorithms: property testing, streaming algorithms

Leadership and organizational responsibilities:

- 2017-now: Director of Institut de Recherche en Informatique Fondamentale (IRIF)
- 2015-17: Deputy director of Fondation Sciences Mathématiques de Paris
- 2013-17: Head of research group "Algorithms and Complexity" at IRIF
- 2009-10: CNRS Senior research scientist at LRI, Université Paris Sud
- 2000-09: CNRS Research scientist at LRI, Université Paris Sud
- Advising: 8 PhD students
- Research schools: 6
- PC committees: 15

Honors and awards:

- Professor at College de France, 2020-21
- ICDT 2012 Best Newcomer Paper Award
- Prime d'Excellence Scientifique CNRS, since 2010
- Lecturer at Collège Belgique for courses in quantum computing, 2009
- PhD award by Association Française d'Informatique Théorique, 2000

Other: Principal Investigator of the following grants:

- Quantum Algorithms for Massive Data (ANR Générique 2019-22)
- Algorithmic Techniques for Restricted Data Access Models (ANR Blanc, 2013-17)
- Quantum and Randomized Algorithms and Complexity (ANR Defis, 2009-12)
- Collaborative student training in Quantum Information Processing (Europe-Canada Transatlantic Exchange programme, 2008-11)

Simon Perdrix, CNRS/LORIA (male):

Current position: CNRS Researcher, LORIA

Education:

- 2019: Habilitation in CS at Université de Lorraine
- 2006: PhD in CS at Grenoble INP
- 2003-3005: Student at ENS Cachan
- 2003: Engineering degree in CS at ENSIMAG.

Expertise: Quantum computing: Models of quantum computing, Formal methods, Categorical quantum

mechanics.

Leadership and organizational responsibilities:

- 2014-now: Head of the GT-IQ@Gdr-IM (CNRS network on quantum computing)
- 2015-now: Board of GdR IQFA
- 2016-2021: Scientific secretary of Section 6 (Computer Science) at CoNRS
- Advising: 8 PhD students

Honors and awards:

- Future Leader 2018, initiative of Lorraine Université d'Excellence.
- PEDR CNRS (2018-2021)
- Prime d'Excellence Scientifique CNRS (2012-2015)
- Best Ph.D. thesis award from Grenoble INP.

Other: Principal Investigator of the following grants:

- ANR PRCE SoftQPro (2017-2022)
- CNRS-PEPS GraphIQ (2010-2011)

Benoît Valiron, CNRS/LRI (male):

Current position: Assistant professor at the engineering school CentraleSupelec.

Education:

- 2004-2008: PhD in Mathematics, University of Ottawa, Canada
- 2002-2004: MSc in Mathematics, University of Ottawa, Canada

Expertise:

- Design of quantum programming languages
- Formal methods, analysis of quantum programs

Leadership and organizational responsibilities:

- Advising: 4 PhD students ongoing, 1 finished.
- PC committees: 9
- Conference Organising committees: 2

Honors and awards:

- 2018 - 2020. Project QuCa funded by ECOS-Sud Argentine.
- 2017 - 2020. Quantex research grant, with national funding from BPI/GDN, from Ministère de l'Economie et des Finances. Partnership with LORIA (Nancy) and Atos/Bull.
- 2017 - 2021. ANR SoftQPro - National grant for a project partnered with LORIA (Nancy), CEA-NanoInnov and Atos/Bull.
- 2007 - 2008. Graduate Scholarship, Provincial Government of Ontario.
- 2007 - 2008. Excellence Scholarship, University of Ottawa.

Relevant publications and/or products, services

1. Iordanis Kerenidis, Jonas Landman, Alessandro Luongo, Anupam Prakash: q-means: A quantum algorithm for unsupervised machine learning. NeurIPS 2019: 4136-4146
2. Yassine Hamoudi, Frédéric Magniez: Quantum Chebyshev's Inequality and Applications. ICALP 2019: 69:1-69:16
3. E. Jeandel, S. Perdrix, R. Vilmart. A complete axiomatisation of the ZX-calculus for Clifford+T quantum mechanics. ACM/IEEE LICS 2018: 559-568
4. A. Scherer, B. Valiron, S.-C. Mau, Scott Alexander, E. van den Berg and T. E. Chapuran. Concrete resource analysis of the quantum linear-system algorithm used to compute the electromagnetic scattering cross section of a 2D target. Quantum Information Processing 16:60, 2017
5. The Born Supremacy: Quantum Advantage and Training of an Ising Born Machine, Brian Coyle, Daniel Mills, Vincent Danos, Elham Kashefi, NPJ Quantum Information

Relevant previous projects or activities

	P9 – CNRS: Centre national de la recherche scientifique

1. QUANT-ERA project ‘Quantum Algorithms’, 2M EUR, 2018-2021
2. FP7 FET-Proactive Project ‘Quantum Algorithmics’ 2013-2016
3. 2020 FET-Quantum Flagship, NEASQC "NExt ApplicationS of Quantum Computing" 2020-2023
4. French BPI France PIA project ‘Quantex’ 2017-2020
5. French ANR project ‘Quantum algorithms for massive data’, 2019-2022

Significant infrastructure and/ or any major items of technical equipment

P10 – INRIA: Institut National de Recherche en Informatique et Automatique

Description of the legal entity

Established in 1967, Inria is the only French public research body fully dedicated to computational sciences. It is a national operator in research in digital sciences and is a primary contact point for the French Government on digital matters. Under its founding decree as a public science and technology institution, jointly supervised by the French ministries for research and industry, Inria's missions are to produce outstanding research in the computing and mathematical fields of digital sciences and to ensure the impact of this research on the economy and society in particular. Inria covers the entire spectrum of research at the heart of these activity fields and works on digitally-related issues raised by other sciences and by actors in the economy and society at large. Beyond its structures, Inria's identity and strength are forged by its ability to develop a culture of scientific innovation, to stimulate creativity in digital research. Throughout its 8 research centres and its 178 project teams, Inria has a workforce of 2 600 scientists with an annual budget of 230 million euros, 27% of which coming from its own resources. Inria's mission is to pursue excellent research in computer science and applied mathematics in order to play a major role in resolving scientific, societal and industrial challenges. Therefore, Inria actively collaborates with public and private bodies including strategic partnerships with large firms, SME's technology platforms and industrial clusters. Technology transfer is further enhanced by helping to launch new companies (since 1984, about 140 companies have stemmed from Inria) and by forming partnerships with innovative SMEs.
Inria has been very active in the previous European framework programmes (in FP7: 231 projects). The institute is strongly involved in programmes aimed at fostering scientific excellence, such as the European Research Council: 32 Grants in FP7 and 17 Grants in Horizon 2020. Inria makes a firm commitment to Horizon 2020, with which the institute's strategic plan is aligned. The objective is to combine scientific excellence with a more focused consideration of major European and global societal challenges to which Inria can bring a key contribution. Inria is currently involved in more than 75 H2020 funded projects). Inria is also playing a lead role in the construction of the Knowledge and Innovation Community (KIC) EIT Digital as host of the French node. EIT Digital's ambition is to create for Europe a structure dedicated to technology transfer and innovation in the digital field. Besides EIT Digital, Inria is also a core partner of the KIC EIT Health.

Role and main tasks in the project

The team COSMIQ, located at the Inria centre in Paris is working on quantum programming languages and ZX calculus with the aim of developing new quantum algorithms with optimized resources that can be implemented on near-term quantum processors. Several Inria research teams are in the process of creating a dedicated Inria Project Lab on Engineering for Quantum Information Processors, which will include the collaboration with industrial players (notably, ATOS) and which is of high relevance for this project, in particular to WP 4, Programming technologies and application libraries with contribution from Inria's research teams:
CAMBIUM, DEDUCTEAM, MOCQUA, PACAP. Inria will also contribute to a Use Case in WP 5 on a solver for Helmholtz that is of primary interest for some of its teams including HIEPACS as well as some close industrial partners such as Airbus or Total.

Profile of staff members involved

Caroline Collange (female) is a Research Scientist at Inria Rennes since 2012. Her research interests include compiler optimizations for quantum computers and Graphics-Processing Units, architecture of throughput processors and GPUs, and computer arithmetic. Some of her key contributions to these areas are micro-architecture mechanisms for dynamic inter-thread vectorization in high-performance processors and a general framework for solving qubit allocation in connectivity-constrained quantum computers. She was previously post-doc researcher at UFMG, Brazil and Assistant Professor at ENS Lyon, France. She has a PhD from Université de Perpignan, France and a MSc from École normale supérieure de Lyon, France.

Luc Giraud (male) (PhD in 1991 and and Habilitation à Diriger des Recherches in 2000, Institut Polyechnique de Toulouse) is a senior research scientist at Inria Bordeaux –Sud-Ouest. Previously he was research scientist at CERFACS (1991-2005), full professor in applied math at ENSEEIHT (2005-2009) and joined Inria in 2009 where is currently leading the HiePACS project-team that aims at contributing to the design and implementations of simulations code for emerging computing platforms. He participated as a partner or coordinator to many European projects back to FP5, international academic collaborative research actions such as the IESP and EESI initiatives to name a few. He is currently involved in various academic and industrial collaborative projects related to large scale simulations (e.g., H2020 EoCoE-2, PRACE 6IP). He is regularly involved in the program

committee for major HPC conferences and acts currently as associate editor for two SIAM journals (namely SISC and SIMAX).

Christophe Vuillot (male) did a PhD on quantum error correction and fault-tolerant quantum computing under the supervision of Barbara Terhal (split between RWTH Aachen Germany and TU Delft Netherlands). He defended his thesis January 15th 2020. Since November 2019 he is working as a postdoc in the inria team COSMIQ in Paris funded by the European project QCDA (funded through Quantera) and is currently being recruited by Inria as junior researcher. His research focuses on fault-tolerant quantum computation and quantum error correction using either discrete quantum systems such as qubits or continuous quantumsystems such as quantum oscillators.

Renaud Vilmart (male) graduated with a engineering diploma (from Ecole des Mines, with a specialisation in computer science), together with a master's degree in formal methods. After defending his Ph.D. in 2019 (done at Loria, Université de Lorraine, with Emmanuel Jeandel and Simon Perdrix), he has been working at LRI, Université Paris-Saclay, as a PostDoc on funds from the project Quantex. He is currently being recruited by Inria. His work focusses on graphical languages for quantum computing, and he has worked within the projects SoftQPro and Quantex.

Relevant publications and/or products, services

1. Alzaix B., Giraud L., Michielsen B., Poirier J.R., (2020), A plane wave scattering dedicated integral equation, IEEE Transactions on Antennas and Propagation, Institute of Electrical and Electronics Engineers, 68(2):1088-1097
2. Siraichi M. Y., dos Santos V. F., Collange C., and Pereira F. M. Q. (2019). Qubit allocation as a combination of subgraph isomorphism and token swapping. Proceedings of the ACM on Programming Languages, Volume 3, Issue OOPSLA, Article 120
3. Jeandel E., Perdrix S., Renaud Vilmart R (2020). Completeness of the ZX-Calculus. Logical Methods in Computer Science, Logical Methods in Computer Science Association, 16 (2):11:1 -- 11:72.
4. Vilmart R. (2019): A Near-Minimal Axiomatisation of ZX-Calculus for Pure Qubit Quantum Mechanics. In: 34th Annual ACM/IEEE Symposium on Logic in Computer Science (LICS), 1–10,(Kleene Award.)
5. Campbell E. T., Terhal B. M., Vuillot C. (2017), Roads towards fault-tolerant universal quantum computation, Journal Article Nature, 549 (7671):172–179.

Relevant previous projects or activities

1. Horizon 2020 EINFRA PRACE 6IP project; this supports the implementation of pan-European HPC;
2. Horizon 2020-INFRAEDI-2018-1, EoCoE-II: Energy Oriented Center of Excellence: toward exascale for energy;
3. Horizon H2020 - EuroLab-4-HPC: Foundations of a European Research Center of Excellence in High Performance Computing Systems.Systems.

Significant infrastructure and/ or any major items of technical equipment

PASQAL	**P11 – Pasqal: Quantum Processing Units out of atomic arrays Simulation, Computing**

Description of the legal entity

Pasqal is a Quantum Computing company, located in France and born out of works performed at Institut d'Optique / CNRS. The team builds on a decade of expertise and numerous achievements in the engineering of lasers, atom manipulation with lasers and detection systems, to manufacture Quantum Information Processors that tackle complex issues, from fundamental science to grand challenges. Pasqal is backed by Quantonation, an early stage venture capital fund focusing on Deep Physics and Quantum Technologies.
Pasqal was incorporated in March 2019 and is a simplified joint-stock company.

Role and main tasks in the project

Pasqal, as provider, will deliver 2 quantum simulators with 100 qubits capability, one at GENCI/TGCC and one at FZJ.
Pasqal will also be involved as a partner in WP4, preparing the low-level interfacing of the HW with the upper level of the software stack, adjusting the algorithms according to the HW; and in WP5, working on the use cases with users and providing training plus support.

Profile of staff members involved

Lucas Béguin (male) is a quantum engineer in charge of hardware at Pasqal since June 2019. He received a PhD degree from the Institut d'Optique of Palaiseau in 2013, where he studied dipolar interactions between Rydberg atoms. Between 2014 and 2017, he joined the Basel research group of Philipp Treutlein in Switzerland as a postdoctoral fellow to work on efficient semiconductor-atom interface in quantum networks. In 2017, he joined the Kastler Brossel laboratory at the Ecole Normale Supérieure in Paris on a research project using alkaline-earth atoms for quantum metrology. Since 2019 within the quantum hardware team of engineers at Pasqal, he has been participating to the design and the fabrication of an industrial Quantum Processing Unit powered by arrays of neutral atoms.

Georges-Olivier REYMOND (male) is the CEO and co-founder of Pasqal. He did a phD in quantum physics, pioneering the control of single atoms with light in 2000-2002. He worked for 16 years in various companies, from start-up to big corporate, developing high tech products embedding cutting edge optics, such as airborne sights for defence applications, or metrological tools measuring at the manometer scale for semiconductor players. He holds 9 patents.
He created Pasqal in 2019 with the vision of harnessing the neutral atom technology to bring quantum advantage for end-users in the short term.

Loïc Henriet (male) Head of software at PASQAL (France). He has been in charge of the software development at Pasqal since July 2019, building the middleware layer and emulator, working on applications and use cases. Previously, he worked as a researcher in quantum physics and quantum technologies at Ecole Polytechnique for his PhD (France, 2016) and later at the Institute for photonic sciences (ICFO) in Barcelona, where he participated to the European ERC project FOQAL led by Prof. D. Chang, which was highlighted as one of most promising projects funded by the ERC in 2020.

Henrique SILVERIO (male) Quantum software developer at PASQAL (France). He has been in charge of the development of Pasqal middleware software since January 2020. He holds a degree in Physics Engineering from the Instituto Superior Técnico, with master studies focused on the Quantum Computation field. He participated to the Qiskit Camp Europe 2019.

Relevant publications and/or products, services

1. Accurate Mapping of Multilevel Rydberg Atoms on Interacting Spin-1/2 Particles for the Quantum Simulation of Ising Models, https://journals.aps.org/prl
2. Observing the Space- and Time-Dependent Growth of Correlations in Dynamically Tuned Synthetic Ising Models with Antiferromagnetic Interactions, https://journals.aps.org/prx
3. Robustness to spontaneous emission of a variational quantum algorithm, https://journals.aps.org/pra/
4. Quantum Computing with Neutral Atoms, https://arxiv.org/abs/2006.12326

PASQAL	**P11 – Pasqal: Quantum Processing Units out of atomic arrays Simulation, Computing**

Relevant previous projects or activities

1. Award of Innovation challenge (to be published)
2. "Innov'up Leader PIA", program funded by "Région Ile de France" to advance quantum chemistry aided by Quantum Computing
3. Finalist of the HelloTomorrow challenge
4. Several grants of the French Public Bank of Innovation

Significant infrastructure and/ or any major items of technical equipment

Pasqal is currently building its first quantum simulator. It is a benchtop version of the two pilots delivered during this project. It will be available for the partners as a very early stage device, preparing the training and the development of applications. An emulator, working on classical infrastructures, will also support this stage.

P12 – CINECA: Consorzio interuniversitario per il calcolo automatico

Description of the legal entity

CINECA, established in 1969, is a non-profit consortium of 70 Italian Universities, the National Institute of Oceanography and Experimental Geophysics (OGS), the National Research Council (CNR), and the Ministry of Education, University and Research (MIUR). CINECA is the largest Italian supercomputing centre with an HPC environment equipped with cutting-edge technology and highly qualified personnel, which cooperates with researchers in the use of the HPC infrastructure, in both the academic and industrial fields. CINECA's mission is to enable researchers to use HPC systems in a profitable way, exploiting the newest technology advances in HPC. CINECA represents Italy in PRACE and is one of the four PRACE Tier-0 Hosting Centers. Sanzio Bassini, director of HPC Department in CINECA, served as chair of the PRACE Council from 2014 to 2016.
Besides the national scientific HPC facility CINECA manages and exploits the supercomputing facility of the Italian Energy company (ENI), an integrated HPC facility with more than 80.000 cores. Some of the most important Italian industries (e.g. ENI, Dompè, Unipol, Lamborghini, etc.) use CINECA's HPC facilities. The HPC Department in CINECA has a long experience in cooperating with the researchers in parallelising, enabling and scaling up their applications in different computational disciplines, covering condensed matter physics, astrophysics, geophysics, chemistry, earth sciences, engineering, CFD, mathematics and bioinformatics, but also "non-traditional" ones, such as biomedicine, archaeology and data-analytics. CINECA has a wide experience in providing education and training in the different fields of parallel computing and computational sciences and is one of the six PRACE Advanced Training Centers (PATCs).

Role and main tasks in the project

CINECA will be envolved in task 5.1,5.2,5.3 and 6.2

Profile of staff members involved

Sanzio Bassini (male). Director of Supercomputing Application and Innovation Department of Cineca, Italian Inter University Consortium. He has been Independent reviewer of many international digital infrastructure projects, recently Member of the Expert committee of the Canadian Major Science initiative Fund 2017 - 2022. He served as Vice Chairman for the Research Area of European Technology Platform for HPC - ETP4HPC AISBL in the years 2012 – 2014 and as Chairman of the Partnership for Advanced Computing - PRACE Council in the period 2014 – 2106. Currently he is Member of the EuroHPC Infrastructure Advisory Board and Leader of EuroHPC Italian Pre-Exascale Infrastructure Leonardo project.

Daniele Ottaviani (male). Ph.D. in Mathematics, MBA in Scientific Calculus. He obtained his Ph.D. at the University of L'Aquila and his MBA at he University of Rome "Sapienza". Currently, he is working at CINECA as HPC/Quantum Software Development. He was the first member of the CINECA Quantum Computing Team.
Riccardo Mengoni (male). He obtained his master degree in theoretical physics at University of Camerino, Italy, with a thesis on quantum computing. Then he moved to the computer science department of University of Verona for his PhD, where he worked on quantum machine learning. In summer 2018 he was selected for the USRA Quantum Academy that gave him the opportunity to be a NASA intern working on quantum annealing applications. Since 2019, he is a member of the Cineca Quantum Computing Team, working on quantum solution to industry-relevant problems.

Fabio Affinito (male). Ph.D. in Physics. He is currently working as lead of the High-level Support team in the CINECA Italian supercomputing center. He works on electronic structure and atomistic and molecular simulations codes, and in particular he participates to the development of the Quantum ESPRESSO DFT suite. He participates to many EU-funded projects (including PRACE and MaX) and he represents CINECA in the CECAM Council.

Relevant publications and/or products, services

1. Daniele Ottaviani, Alfonso Amendola, *Low Rank Non-Negative Matrix Factorization with D-Wave 2000Q*, arXiv:1808.08721
2. Riccardo Mengoni, Daniele Ottaviani, Paolino Iorio, *Breaking RSA Security With A Low Noise D-Wave 2000Q Quantum Annealer: Computational Times, Limitations And Prospects*, arXiv:2005.02268

3. L Bottarelli, M Bicego, M Denitto, A Di Pierro, A Farinelli, R Mengoni, *Biclustering with a quantum annealer*, Soft Computing 22 (18), 6247-6260
4. R Mengoni, A Di Pierro, L Memarzadeh, S Mancini, *Persistent homology analysis of multiqubit entanglement*, arXiv preprint arXiv:1907.06914
5. R Mengoni, A Di Pierro, *Kernel methods in Quantum Machine Learning*, Quantum Machine Intelligence, 1-7

Relevant previous projects or activities

1. FENIX/ICEI: The FENIX e-infrastructure provides Europe-wide federated scalable cloud-based data repositories and scalable supercomputing systems (IaaS). It is being initialised through the ICEI project (Interactive Computing E-Infrastructure) as part of the European Human Brain Project (HBP). FENIX platforms (like EBRAINS) can serve as benchmarks for HPCQS
2. European Technology Platform (ETP4HPC): An industry-led Association of 100 members, ETP4HPC is the voice for EU HPC technologies, producing recurring roadmaps and R&D recommendations, and fostering the development of a globally competitive EU HPC value chain (from technologies to applications via infrastructures). A private member of EuroHPC and represented in its Research and Innovation Advisory Group (RIAG), ETP4HPC has been strongly advocating the anticipation of the integration of Quantum Computing technologies with HPC, and could further liaise with HPCQS for future perspectives. NB: ATOS chairs ETP4HPC, CEA holds the Research Vice Chair position, FZJ CINECA, BSC, and ParTec are also founding members of ETP4HPC.
3. European Open Science Cloud (EOSC): The EOSC partnership is an operational entity to serve EU researchers by enabling cross-fertilization across European Data Spaces1. promoting convergence across HPCaaS and QC infrastructures, enabling cutting-edge R&D across classical AI approaches and QML, aligned with FAIR principles and in adequacy with the current European legislation

Significant infrastructure and/ or any major items of technical equipment

Marconi100
This system is an upgrade of the "not conventional" partition of the Marconi Tier-0 system. It is an accelerated cluster based on Power9 chips and Volta NVIDIA GPUs, acquired by Cineca within the PPI4HPC European initiative.
System Architecture
Architecture: IBM Power 9 AC922
Internal Network: Mellanox Infiniband EDR DragonFly+
Storage: 8 PB (raw) GPFS of local storage
Login nodes: 8 Login IBM Power9 LC922 (similar to the compute nodes)
Model: IBM Power AC922 (Whiterspoon)
Racks: 55 total (49 compute)
Nodes: 980
Processors: 2x16 cores IBM POWER9 AC922 at 2.6(3.1) GHz
Accelerators: 4 x NVIDIA Volta V100 GPUs/node, Nvlink 2.0, 16GB
Cores: 32 cores/node, Hyperthreading x4
RAM: 256 GB/node (242 usable)
Peak Performance: about 32 Pflop/s, 32 TFlops per node
Internal Network: Mellanox IB EDR DragonFly++
Disk Space: 8PB raw GPFS storage
Peak performance details
The peak performance of M100 (980 compute nodes + 8 login nodes) is about 32PFlops. The performance of the single node is 32 TFlops due to 0.8 for the CPU part and 7.8x4 for the four GPUs on the node.
The theoretical peak performance is 988*(0,8+4*7,8) = 31,6 PFlop/s

[1] https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

In the below table you can find the single node theoretical peak performance of the AC992 CN node with two Power9 processors and four NVIdia V100 GPUs.

Node Performance		
Theoretical Peak Performance	CPU (nominal/peak freq.)	691/791 GFlops
	GPU	31.2 TFlops
	Total	**32 TFlops**
Memory Bandwidth (nominal/peak freq.)		220/300 GB/s

Galileo

The GALILEO supercomputer has been introduced first in January 2015 and in its first configuration, it has been available to the Italian public and industrial researchers until January 2018. It has been the national Tier-1 system for scientific research. Starting from January 2018 GALILEO has been reconfigured with Intel Xeon E5-2697 v4 (Broadwell) nodes, inherited from MARCONI system. The cluster with this reconfiguration has opened for production in March of the same year. Starting from August 2019 a new reconfiguration phase led to a new, upgraded environment, equipped with Intel Omni-Path internal network and increasing the number of compute nodes available to 1022 Intel Xeon E5-2697 v4 (Broadwell).

System Architecture

Compute Nodes: There are currently 1022 36-core compute nodes. Each one contains 2 18-cores Intel Xeon E5-2697 v4 (Broadwell) at 2.30 GHz. All the compute nodes have 128 GB of memory. Of these compute nodes, 60 are equipped with nVidia K80 GPU and two with nVidia V100.

Login and Service nodes: There are 8 Login & Viz nodes available (5 are academic nodes and 3 are for industrial users). There are 8 service nodes for I/O and cluster management.

All the nodes are interconnected through an Infiniband network, with OPA v10.6, capable of a maximum bandwidth of 100Gbit/s between each pair of nodes.

Model: Lenovo NeXtScale
Architecture: Linux Infiniband Cluster
Nodes: 1022
Processors: 2 x 18-cores Intel Xeon E5-2697 v4 (Broadwell) at 2.30 GHz
Cores: 36 cores/node
RAM: 128 GB/node, 3.5 GB/core
Internal Network: Intel OmniPath, 100 Gb/s
Peak performance single node: 1.3 TFlop/s
Peak Performance: 1.5 PFlop/s
Accelerators: 60 nodes equipped with 1 nVidia K80 GPU
2 nodes equipped with 1 nVidia V100 GPU

P13 – BSC: Barcelona Supercomputing Center

Description of the legal entity

The **Barcelona Supercomputing Center** (BSC) was established in 2005 and is the Spanish national supercomputing facility and a hosting member of the PRACE distributed supercomputing infrastructure. The Center houses MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC is to research, develop and manage information technologies in order to facilitate scientific progress. BSC combines HPC service provision, and R&D into both computer and computational science (life, earth and engineering sciences) under one roof and currently has over 350 staff from 41 countries. BSC has collaborated with industry since its creation, and participates in various bilateral joint research centers with companies such as IBM, Microsoft, Intel, NVIDIA and Spanish oil company Repsol. The center has been extremely active in the EC Framework Programmes and has participated in seventy-nine projects funded by it. BSC is a founding member of HiPEAC, the ETP4HPC and other international forums. In 2011 BSC-CNS was one of the 8 institutions granted with Severo Ochoa award for excellence, an award given by the Spanish Ministry for Research to Spanish research centres that rank internationally among the most competitive in their fields.

BSC is an active and well recognized participant of different initiatives for the integration and consolidation of High Performance Computing and data management in Europe and Spain. The BSC manages all the information generated by the HPC simulations executed in their computational resources. In order to fulfill the datarequirements of scientists, BSC has more than 20 PB of available disk space and a tape library with up to 6PB. At the international level, BSC is currently working in more than 42 European projects. At infrastructure level, the main e-infrastructures projects where BSC is working are EUDAT2020, PRACE (where BSC is one of the tier-0 partners) and HBP, in all of these projects BSC is acting at the same time as a Data center and HPC center.

The quantum computation group at BSC, QUANTIC, was established in June 2016 to lead the development of quantum computers in Spain and in the Mediterranean area. The group is led by Artur Garcia Saez and has worked on many areas in quantum information, particularly quantum simulation and quantum algorithms, including quantum annealing and adiabatic quantum computation. Since the creation of the QUANTIC group at BSC, a local network of collaborations was established with other research centers in the area of Barcelona, including UB (3d party of BSC), ICN2 (partner in CoQuA), IMB-CNM and ICFO.

Role and main tasks in the project

The main tasks carried by BSC are related to WP4 and WP5, with contributions to the implementation of Quantum Machine Learning algorithms, and the elaboration of Use cases related to optimization using Machine Learning techniques.

Profile of staff members involved

Dr. Artur Garcia Saez (male), obtained a Ph.D in Physics from the Institute of Photonic Sciences in 2010, working on quantum and classical correlations in quantum systems. Since then, has worked as a Potsdoctoral Researcher at Universitat of Barcelona and the Yang Institute of theoretical Physics, Stony Brook University. Since 2013 he is a researcher of The Barcelona Supercomputing Center, with projects in Quantum Computation, Machine Learning and High Performance Computing applications for science and Industry.

Relevant publications and/or products, services

1. Data re-uploading for a universal quantum classifier, A. Pérez-Salinas, A. Cervera-Lierta, E. Gil-Fuster, J. I. Latorre,Quantum 4, 226 (2020).
2. Quantum circuits for maximally entangled gates, A. Cervera-Lierta, J. I. Latorre,D. Goyeneche, Physical Review A 100, 022342 (2019).
3. Multipartite entanglement in spin chains and the Hyperdeterminant, Alba Cervera-Lierta, Albert Gasull, José I. Latorre, German Sierra, Journal of Physics A: Mathematical and Theoretical51, 505301 (2018).
4. Experimental test of Mermin inequalities on a five-qubit quantum computer, Alsina, D.; Latorre,J. I. , Phys. Rev. A 94, 012314 (2016).
5. Topological Transitions from Multipartite Entanglement with Tensor Networks: A Procedure for Sharper and Faster Characterization,Roman Orus, Tzu-Chieh Wei, Oliver Buerschaper, Artur Garcia-Saez, Phys. Rev. Lett. 113, 257202 (2014).

Relevant previous projects or activities

1. "Realistic Quantum Computation", Spanish national funding agency Ministry of Economy, Industry and Competitiveness, ref. FIS2017-89860-P, 124 k€. Period: 2018-2021.
2. "Quantum entanglement in many-body systems", Spanish national funding agency Ministry of Economy and Competitiveness, ref. FIS2015-69167-C2-2-P, 75 k€. Period: 2016-2018. Lead PI: J. I. Latorre.

Significant infrastructure and/ or any major items of technical equipment

BSC operates the most powerful supercomputer in Spain, MareNostrum 4, that has a performance capacity of 13,7 Petaflop/s and is located in the Torre Girona chapel, home to its predecessors, the MareNostrum 1, 2, and 3. The new machine has two distinct parts. The general-purpose element, provided by Lenovo, 48 racks with more than 3,400 nodes with next generation Intel Xeon processors and a central memory of 390 Terabytes. Its peak power is over 11 Petaflop/s, i.e. it is able to perform more than 11,000 trillion operations per second, ten times more than the MareNostrum 3, which was installed between 2012 and 2013. Despite this increase in capacity, it consumes only 30% more power, reaching 1.3 MW/year.

The second element of MareNostrum 4 is formed of clusters of three different technologies. These are technologies currently being developed in the USA and Japan to accelerate the arrival of the new generation of pre-exascale supercomputers. One of these clusters consists of IBM POWER9 processors and NVIDIA GPUs. Its computing power is over 1.5 Petaflop/s. The second cluster is made up of Intel Knights Landing (KNL) and Intel Knights Hill (KNH) processors provided by Fujitsu and Lenovo respectively. They are the same processors that will be inside the Theta and Aurora supercomputers purchased by the U.S. Department of Energy for the Argonne National Laboratory. Its computing power is in excess of 0.5 Petaflop/s. Finally, a third cluster is formed of the same 64 bit ARMv8 processors that Fujitsu provided in a prototype machine, using state-of-the-art technologies from the Japanese Post-K supercomputer.

P14 – FLS: FLYSIGHT SRL

Description of the legal entity

FlySight Srl is the Defence Security and Space Company of Flyby Srl, an Italian hi-tech group specialized in the development of DSSs (Decision Support Systems) exploiting edge technologies in the fields of Signal Processing and Big Data Analytics.

The solutions proposed are based on AI (Artificial Intelligence) approaches exploiting the latest cognitive signal processing and adaptive data fusion algorithms. Typical applications are for space, avionics, naval and underwater sectors providing geospatial situational awareness both for the on-ground segment and for the on-board one.

The company vision is based on the new frontiers opened by many kind of devices, especially imaging systems, in providing data to be analysed, fused and elaborated according to physical modelling, artificial intelligence and machine learning methods. The aggregated knowledge becomes cognition when the system can solve and think on this basis, finally providing a prediction for supporting decision making. FlySight is focusing on these cognitive processes from data to decisions, offering high-value solutions in Defence & Security, where data analytics methodologies running on a basis of heterogeneous information are mainly required.

FlySight's cutting-edge competences are complex systems modelling and the development of dedicated algorithms for data processing, especially those coming from optical sensors. Such capabilities stem from the multi-disciplinary background of FlySight's R&D personnel, who is active both in assimilating the latest achievements from science and in collaborating with high-level public/private research centres, thus achieving the goal of designing and implementing innovative solutions tailored to any specific Defence & Security application.

FlySight's key competences are in the following fields: Optical Physics, Signal Processing and Computer Vision, Geomatics, Big Data Analytics, Simulation, Embedded Systems.

The FlySight's flagship product is OpenSIGHT, a Geospatial Solution for Processing, Exploitation and Dissemination. This product is a modular cost-effective system resulting from over 10 years of experience in the development of on-board and on-ground solutions. OpenSIGHT exploits real information in a synthetic environment for Geospatial Situational Awareness and provides a new approach in the definition of Decision Support Systems as a tool for the real-time mission analysis, enabling real-time collaboration in a COP (Common Operating Picture) of the scenario.

All the processes in the Company are managed according to UNI EN ISO9001:2015 quality standards. For the more demanding Military and Space projects Flyby applies the rules and the quality requirements set down respectively by the MIL-STD-498 and by the ECSS standards.

Role and main tasks in the project

The role of FlySight in the project is to support the research with our industrial skills in term of design and development in different use case. The main contribution is in the Machine Learning field for image processing (Detection, Classification and Identification of object).

FlySight will be involved inside tasks 5.1

Profile of staff members involved

Dr. Andrea Masini (male) received his Laurea degree (M.S.) in Telecommunications Engineering and his Ph.D. degree in Remote Sensing from the University of Pisa (Italy) in 2004 and 2008, respectively. He worked at the University of Pisa as associate researcher in the field of data and video fusion, and he has been external consultant of Leonardo S.p.a. in the field of electro-optical sensors signal processing. He is now working as Chief Technical Officer (CTO) at Flysight S.r.l. (Livorno, Italy). His current research interests concern with image processing, environmental monitoring from remotely sensed images, pattern recognition and information fusion. He has been Project Manager of international and national funded projects. He is author or co-author of more than 30 scientific papers in journals and conference proceedings.

Dr. Andrea Bracci (male) received his Bachelor Degree in Mechanical Engineering in 2002, his Master's Degree in Automation Engineering in 2004 and its PhD degree in Automation, Robotics and Bioengineering in 2008 at the University of Pisa. He was a post-doc fellow at the Department of Mechanical, Nuclear and

Production Engineering of the University of Pisa from 2008 to 2011, where he was a researcher and software developer for high performance aeronautical applications. He is now working with FlySight S.r.l, in the research and development section for signal and image processing. His current research concerns software development for scientific computation and real-time applications. He is author or co-author of more than 10 papers in international peer-reviewed journals and international and national conferences.

Dr. Benedetto Michelozzi (male) received his Laurea degree (M.S.) in Physics from the University of Pisa (Italy) in 1989. He worked as researcher in Large and SME companies increasing his knowledge from the radio frequency and electromagnetic compatibility to the optical characterization and data analysis. He has been a co-founder of Polab S.r.l. (an Italian SME specialized in electromagnetic compatibility measurements). Currently he is the key person in the Flysight R&D Team. His current research interests concern with the development of AI methodologies for remote sensing HW/SW applications, acquisition/processing of Visible/IR/Multispectral/Hyperspectral images, data fusion and enhancement.

Relevant publications and/or products, services

1. A. Masini, M. Carpin, "A modern approach for improved situational awareness using data fusion trough OpenSIGHT", Data fusions for behavioural analysis and predictive analytics trough image data, EDA 19 February 2020, Brussels, Belgium.
2. A. Betti, B. Michelozzi, A. Bracci, A. Masini, "Real-Time Target Detection in Maritime Scenarios based on YOLOv3 Model", 9th International symposium on optronic in defence & security, 28-30 January 2020, Paris.
3. A. Masini et al., "Quantum-enhanced Sensors with Spins and Photons", Quantum Technologies in Optronics Workshop, EDA EO Sensors technologies CapTech,12 March 2019, Toulouse, France
4. A. Masini, A. Betti, "A Convolutional Neural Network Model for Automatic Target Recognition in Maritime Scenarios", Artificial Intelligence for Optronics systems Workshop, EDA EO Sensors technologies CapTech, 22 October 2018, Brussels, Belgium.

Relevant previous projects or activities

FlySight is a start-up founded in early 2020, relevant projects and experiences have been inherited from the mother company Flyby Srl and are the ones linked to FlySight flagship product OpenSIGHT.

Significant infrastructure and/ or any major items of technical equipment

OpenSIGHT ATR (Automatic Target Recognition): It is the FlySight Software Development Kit to exploit innovative Deep learning approach for detection, classification, and identification of targets from images or video.

P15 – ParityQC: Parity Quantum Computing GmbH

Description of the legal entity

ParityQC was founded in January 2020 in Innsbruck, Austria and is a spin-off from the University of Innsbruck and the Austrian Academy of Sciences. ParityQC's mission is to enable quantum computers to solve real-world combinatorial optimization problems with the use of the patented LHZ architecture and the accompanying software suite called ParityOS™.
ParityQC is a "limited liability company" (GmbH) under the Austrian law. The shareholders are distributed as follows: Wolfgang Lechner (47,5%), Hermann Hauser Investment GmbH (23,75%), University of Innsbruck (11,875%), Austrian Academy of Sciences (11,875%), Magdalena Hauser (5%).
ParityQC is a quantum architecture company which develops blueprints for quantum computers to solve optimization problems. The architecture delivers the instruction set and layout for quantum chips and offers fundamental advantages on the hardware and algorithmic side. The architecture is based on the LHZ architecture and is compatible with all current hardware platforms including both gate-based and annealing methods. The software suite ParityOS™ optimizes the quantum algorithms as well as the hardware parameters and allows amongst other advantages a compact mapping of optimization problems on the hardware grid.
Building upon Wolfgang Lechner's efforts since 2015, ParityQC is now entitled to realize the potential of the research achievements and patents. The company fosters a close relationship to and exchange with the research group at the University of Innsbruck.

Role and main tasks in the project

ParityQC will be involved in WP3, WP4 and WP5 and inside tasks 3.2, 4.2.3, 4.2.4, 4.4.2, 5.1-UC1, 5.1-UC2, 5.2 and 5.3. The main task will be to develop a connection from the proposed middleware to the software suite and provide access to the suite to explore potential use cases.

Profile of staff members involved

Benjamin Niehoff (male) is lead quantum software engineer at ParityQC. Part of his responsibilities is to exploit and automatize the advantages of the LHZ architecture to the software suite. He has a postgraduate degree in Physics and received the renowned Marie Sklodowska-Curie Fellowship in 2017. Before his postdoctoral research at KU Leuven, he worked at the University of Cambridge studying theoretical and mathematical physics topics. Between his BSc and PhD at Purdue University and University of Southern California, he worked at Intel and IBM in the Server and Flash Memory Layout groups.

Wolfgang Lechner (male) is Professor at the University of Innsbruck with a scientific focus on Quantum Computing and co-founder and CEO of ParityQC. His group at the Institute for Theoretical Physics is dedicated to developing quantum
optimization algorithms and proposals for implementations. Wolfgang is best known for the so-called LHZ architecture, a reformulation of optimization problems as a lattice gauge model. He received his PhD in 2009 at the University of Vienna, worked as a PostDoc at the University Amsterdam and Innsbruck and received his Habilitation in 2019 from the University of Innsbruck. He authored 40 peer-reviewed publications, 35 international invited talks, and 150 international talks. He received the Loschmidt Prize (2011), the Wallnöfter-Prize (2015), the Thirring Prize (2017), the START Prize (2017), the Houska-Prize (2019) and the Google Research Faculty Award (2020).

Elisabeth Thompson (female) is responsible for grants and reports at ParityQC. She has more than 18 years of experience in this field and currently holds the Vice Chair for European research projects (FP7, Horizon 2020) at the European Commission in Brussels. Within ParityQC she supervises all grant activity including grant applications and reporting.

Magdalena Hauser (female) is, together with Wolfgang Lechner, co-founder and CEO of ParityQC since January 2020. After studying Management and Economics she co-founded the I.E.C.T. – Hermann Hauser in 2016. They focused on providing access to international know-how and smart money. Since February 2018 she took the position of the CEO and became proxy for the Hermann Hauser's investment vehicle. Her main activities contained amongst others running the investment process, developing new programs to foster entrepreneurship within the research and science society and building up a startup friendly ecosystem with national and international partners. Alongside she worked as mentor and coach for different programs and is co-founder of the non-profit association AI Austria - Austrian Society for Artificial Intelligence. 2018 she was

selected among the Forbes 30under30 for her activities in the investment field.

Relevant publications and/or products, services

1. Lechner, Wolfgang, Hauke, Philipp, Zoller, Peter, (2015). A quantum annealing architecture with all-to-all connectivity from local interactions. Science Advances, Vol 1 (Nr.9), e1500838
2. Glaetzle, A.W., van Bijnen, R. M. W., Zoller, P., Lechner, W. (2017). A coherent quantum annealer with Rydberg atoms. Nature, Vol. 8, 15813
3. Hauke, P., Katzgraber, H.G., Lechner, W., Nishimori, H., Oliver, W. D. (2020). Perspectives of quantum annealing: methods and. Implementations. Reports on Progress in Physics, Vol. 83 (Nr. 5), 054401
4. Hartmann, Andreas, Lechner, Wolfgang (2019). Rapid counter-diabatic sweeps in lattice gauge adiabatic quantum computing. New J. Phys., Vol. 21, 043025
5. Lechner, Wolfgang (2018). Quantum Approximate Optimization with Parallelizable Gates. arXiv.org (https://arxiv.org/abs/1802.01157)

Relevant previous projects or activities

1. *EU-H2020:* Wolfgang Lechner is co-PI in the Quantum Flagship project "PASQuanS" https://pasquans.eu/oesterreichische-akademie-der-wissenschaften/ which aims to develop an programmable large scale atom based quantum simulator as part of the European Union´s Horizon 2020 research and innovation program under grant agreement No. 817482.
2. FWF: Wolfgang Lechner is PI of the FWF START project “ParityQC” which aims to develop a Toolbox for quantum computing using parity constraints. Project No. Y1067-N27
3. FWF: Wolfgang Lechner is PI in the SFB BeyondC Project No. F7108-N38 of the FWF which aims at developing quantum devices that show quantum advantage.

Significant infrastructure and/ or any major items of technical equipment

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P16 – Fraunhofer IAF: Fraunhofer-Gesellschaft für Angewandte Forschung

Description of the legal entity

Incorporated association: The Fraunhofer organization model is a non-profit business model, dedicated to advance scientific and economic development. Around 70 percent of Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. (https://www.fraunhofer.de/en.html)
The Fraunhofer Institute for Applied Solid State Physics IAF is one of the research institutes of the Fraunhofer-Gesellschaft in Germany. IAF is a leading research institution in the field of micro- and nanostructured compound semiconductors. It features an innovative production line for nano- and quantum based circuits, modules and systems. Existing activities in the field of quantum sensing or quantum computing include the development of low-noise cryogenic amplifiers for readout electronics (cooperation with IBM in the EU project SEQUENCE) and quantum sensor technology with NV centers in diamond as qubits (Fraunhofer Light House Project "QMag"). Within the framework of a cooperation agreement between Fraunhofer-Gesellschaft and IBM, IAF is responsible for the coordination of the Competence Center Quantum Computing Baden-Württemberg. This includes access to a quantum computer operated by IBM (initially via cloud in the USA, from 2021 on in Germany), which will be used in HPCQS. The Fraunhofer IAF Institute was founded in 1957 and now has a total staff of about 300 scientists, engineers and technicians with an annual budget of about 40 million Euros.

Role and main tasks in the project

IAF will contribute to WP5 (UC2) and will be involved in tasks 5.2 and 5.3. in order to develop a quantum chemistry simulation benchmark to evaluate the performance of quantum computing systems.

Profile of staff members involved

Prof. Dr. Oliver Ambacher (male), director of Fraunhofer IAF, obtained his PhD in physics at the Technical University in Munich in 1993. Between 1990 and 2000, he was a researcher in the field of gallium nitride (GaN) at TU Munich (Walter Schottky Institute) and at Cornell University (USA). Following his position as professor for nanotechnology at the TU Ilmenau, Ambacher held a professorship for compound semiconductors at Albert-Ludwigs-Universität Freiburg from 2007-2016. In 2017 he changed his position within in the University of Freiburg to the Chair of Power Electronics. Since 2007, Oliver Ambacher has been the Director of Fraunhofer-Institute for Applied Solid State Physics (IAF), where he is involved in the development of quantum sensors and electronic components for quantum computers. Within the FhG-activities, he is involved in the evaluation and development of a national Quantum Technology Roadmap initiated by the German government and also acts as representative of the Fraunhofer Strategic Research Field Quantum Technologies.

PD Dr. Thomas Wellens (male) has been working for Fraunhofer IAF since September 2019 to support the expansion of its activities in the field of quantum computing. He has many years of research experience as a theoretical physicist at university level, especially in the areas of quantum state preparation, quantum information (quantification of entanglement) and the development of diagrammatic methods for the description of disordered many-body quantum systems.

Relevant publications and/or products, services

1. Walschaers M. et al., 2016, Quantum Transport on Disordered and Noisy Networks, Annual Review of Condensed Matter Physics 7, 1
2. Tamborenea P.I. et al., 2017, Spin-relaxation time in impurity band of wurtzite semiconductors, Phys. Rev. B, 96, 125205
3. Thome F. et al., 2019, W-Band LNA MMICs Based on a Noise-Optimized 50-nm Gate-Length Metamorphic HEMT Technology, Proceedings of the 2019 IEEE MTT-S International Microwave Symposium (IMS) doi: 10.1109/MWSYM.2019.8700792
4. 4. Dyck A. et al., 2019, A Transmitter System-in-Package at 300 GHz With an Off-Chip Antenna and GaAs-Based MMICs, IEEE Transactions on Terahertz Science and Technology 9 (3), 335, doi: 10.1109/TTHZ.2019.2910511

Relevant previous projects or activities

1. EU-H2020 (H2020-ICT-2015 - 688784) INSIGHT "Integration of III-V Nanowire Semiconductors for next Generation High Performance CMOS SOC Technologies", Grant number 688784, 2015-2019.

2. EU-H2020 (H2020-EUJ-2018 - 814523) ThoR “TeraHertz end-to-end wireless systems supportingultra high data Rate applications”, Grant number 814523, 2018-2021.
3. EU-H2020 (H2020-INFRAIA-2016-1 - 730562) RadioNet “Advanced Radio Astronomy in Europe”, Grant number 730562, 2017-2020.
4. EU-H2020 (2020-ICT-2019-2 - 871764) SEQUENCE “Cryogenic 3D Nanoelectronics”, Grant number 871764, 2020-2022.
5. Fraunhofer Light House Project »Quantum Sensing« (Quantum Magnetometry, 2018 - 2023)»Quantum Sensing« (Quantum Magnetometry, 2018 - 2023)

Significant infrastructure and/ or any major items of technical equipment

Centre of Competence Quantum Computing Baden-Württemberg:
Within the framework of the partnership with Fraunhofer-Gesellschaft, IBM Germany provides a state-of-the-art quantum computer (IBM Q System One, Quantumvolume 30) which will be used in HPCQS.

Important Infrastructure: Clean room, well established millimeter wave GaAs-based mHEMT technologies, MMIC design and layout capabilities, measurement equipment and labs for on-wafer and module/package measurements beyond 750 GHz, 10 K cryo on-wafer measurements up to 50 GHz, wafer dicing and packaging capabilities, high precision millimeter wave module.

4.2. Third parties involved in the project (including use of third party resources)

Participant		Third parties involved
1	**FZJ (Coordinator)**	**Please see details below**
2	CEA	No third parties involved
3	GENCI	No third parties involved
4	ATOS	No third parties involved
5	CNR	No third parties involved
6	NUIG-ICHEC	No third parties involved
7	UIBK	No third parties involved
8	**EURICE**	**Please see details below**
9	**CNRS**	**Please see details below**
10	INRIA	No third parties involved
11	Pasqal	No third parties involved
12	CINECA	No third parties involved
13	BSC	No third parties involved
14	FLS	No third parties involved
15	Parity QC	No third parties involved
16	Fraunhofer IAF	No third parties involved

P1 - FZJ	
Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)?	No
Does the participant envisage that part of its work is performed by linked third parties?	Yes
Using its comprehensive experience in HPC in general and in the Modular Supercomputing Architecture (MSA) in particular, ParTec will contribute to the integration of the Quantum Simulator (QS) pilot into an HPC environment following the MSA concept. In this project, ParTec will lead WP3, addressing the required infrastructure software for providing the essential HPC services and interfaces for resource, user and access management. ParTec will drive the work on extending ParaStation Modulo for the interaction with the QS through the Quantum Learning Machine (QLM). The interfaces for the managment of the QS resources will be jointly developed, enabling quantum-hybrid simulations and workflows in modular supercomputing architectures. To make its involvement totally transparent to the reviewers, EuroHPC JU and the consortium, ParTec's contributions to HPCQS, its role and responsibilities are displayed explicitly in the proposal body (Sections 1-3). • Financial information: Personnel costs (311,148€) / Person Month (WP3: 36PM) / Travel costs (10,000€)	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)?	No
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	No

P8 - EURICE	
Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)?	Yes
WP6, Task 6.4 (4,000€) - the production of audio-visual materials will be subcontracted. Audio-visual materials may comprise a short project clip and/ or interview statements to be disseminated through well-established online video platforms in order to help raise awareness and inform about purpose, content and outputs of the project. The subcontract will ensure the best value-for-money considering the quality of the service proposed.	
Does the participant envisage that part of its work is performed by linked third parties?	No
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)?	No
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	No

P9 - CNRS	
Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)?	No
Does the participant envisage that part of its work is performed by linked third parties?	Yes

IRIF,LIP6,LRI and LORIA are are a joint research units (JRU) managed by CNRS (PIC 999997930).

- IRIF is a research laboratory created by the signature of a contract between CNRS and Université de Paris (PIC 897691060).
- **LIP6**, is a research laboratory created by the signature of a contract between CNRS and **Sorbonne Université** (PIC 909875521).
- **LRI**, is a research laboratory created by the signature of a contract between CNRS and Université Paris-Saclay (PIC 897067059) **and SUPELEC**
- LORIA, is a research laboratory created by the signature of a contract between CNRS and Université de Lorraine (PIC 954831626).

CNRS is the beneficiary of the project but may charge costs incurred by the third parties Université de Paris, Sorbonne Université, Université Paris-Saclay and Université de Lorraine, carrying out the project under the article 14 of the Grant Agreement. In this project, Sorbonne Université and SUPELEC will perform part of the work and will be therefore involved as Linked Third Parties of CNRs in the project.

Linked Third Party 1 : Sorbonne Université (PIC 909875521)

- WP5, Task 5.1: Strong involvement in Task 5.1 of WP5 for UC 1.1 for providing a set of tools to certify the quantum features and accurately evaluate the performance of quantum simulators.
- Financial information: Personnel costs (52,800€) / Person Month (WP5: 12PM)

Linked Third Party 2 : SUPELEC

- WP4, Task 4.1: Supelec will participate in Task 4.1 in the design of a graphical language for representing analog programming and the development of related formal analysis tool.
  Supelec will exploit its long standing expertise in programming language for quantum computing in order to provide tools for optimazing quantum codes.
- WP5, Task 5.2, 5.3: Supelec will contribute to user engagement (Task 5.3) and training activities (seminars, summer schools, hackaton, Task 5.2) based on the expertise they developed in the past.
- Financial information: Personnel costs (14,100€) / Person Month (WP4: 2PM; WP5: 1PM)

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)?	No
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	No

5. Ethics and Security

5.1 Ethics

Personal data

Within the framework of the HPCQS project, the consortium partners will carry out activities involving third parties under WP5 "Demonstrators, training and user engagement" and WP6 "Dissemination, Communication and Exploitation". Methods to be used will include among others questionnaires, interviews, and workshops.
The consortium partners are familiar with the ethical challenges associated with research involving humans and with the processes needed to meet such requirements when conducting workshops, meetings, training activities and research tasks involving external users.

Data protection is both a central issue for research ethics in Europe and a fundamental human right. Therefore, in addition to the GDPR, HPCQS partners also take into account national legislation and related EU measures. Recommendations of The European Data Protection Board (EDPB) and of other national or European data protection authorities, such as the Federal Commissioner for Data Protection and Freedom of Information, are taken into consideration. Particular attention is paid to data sharing involving special categories of data (formerly known as 'sensitive data'), profiling, automated decision-making, data-mining techniques, big-data analytics and artificial intelligence, as such processing operations may pose higher risks to the rights and freedoms of data subjects. Where it is necessary to retain a link between the research subjects and their personal data, the partners will, wherever possible, pseudonymise the data in order to protect the data subject's privacy and minimise the risk to their fundamental rights in the event of unauthorised access. Appropriate technical and organisational measures will be identified and implemented.

Informed consent

Informed consent will be included in questionnaires dealing with personal data.
In relation to WPs 5 and 6 HPCQS partners might have to collect and process personal data. Personal data is all information relating to an identified or identifiable individual (Art. 4 no. 2 General Data Protection Regulation (GDPR)). Processing personal data is generally prohibited, unless it is expressly allowed by law, or the data subject has consented to the processing.

The following steps are taken by the HPCQS partners to determine the legal basis and the appropriate informed consent process in the frame of its training, communication and dissemination activities as part of the HPCQS project. In a first step, the legal basis Art. 6 (b) GDPR – Art. 6 (f) GDPR have to be checked, as consent to data processing is not required if a legal basis permits or even requires the processing without the consent of the data subject. If none of those legal bases is applicable, the informed consent of the data subject is needed to process the personal data lawfully. All HPCQS partners are aware that a process to ensure the appropriate handling of informed consents should be implemented.

Vulnerable groups and children/minors will not be involved in the activities described above.

None of the tasks described above involves the collection of special categories of personal data (religious beliefs, political opinions, health, sexual orientation, race, membership in organisations).

5.2 Security

Please indicate if your project will involve:

- activities or results raising security issues: NO
- 'EU-classified information' as background or results: NO

Annex – Letters of Support

An initial stakeholder analysis has been carried out already during the proposal stage to prepare for use case and training activities as well as to receive a first feedback on user needs and requirements with regard to the planned infrastructure. Contacted stakeholders included:

- Relevant research institutions in the field of quantum technologies, but also application areas
- Supercomputing centres
- Companies in the field of quantum technologies, but also application areas, including HW manufacturers, SW developers as well as service providers with a focus on SMEs
- Large companies in major application areas, such as automotive, pharma, energy and electricity, telecommunications
- Associations representing players in relevant fields

48 stakeholders have expressed their interest in becoming members of the planned user board and have provided Letters of Support, see overview table below as well as a selection of Letters of Support (names are marked in bold in the table) attached.

Institution name	Type of organisation	Area	Country
Aalto University – Centre for Quantum Engineering	Higher Education	Control of charges, photons, phonons, and plasmons at the ultimate quantum level	Finland
AIRBUS SE	**Large company**	**Aeronautics**	**France**
AMETIC	Assocation	Association of Electronics, Information and Communications Technologies, Telecommu-nications and Digital Content Companies	Spain
BAYER AG	**Large company**	**Pharma, Chemical**	**Germany**
CESQ - Centre Européen des Sciences Quantiques	Research Institute	Cutting-edge research at the interface of quantum physics, chemistry, materials science and computing	France
CNES - Centre National d'Etudes Spatiales	Research Institute	Space	France
Covestro AG	**Large company**	**Polymer solutions, specialty chemicals for heat insulation foams and transparent polycarbonate plastics**	**Germany**
Cerfacs	Research centre	High-performance computing modelling and numerical simulation	France
CESGA - Fundacion Publica Gallega Centro Tecnologico de Supercomputacion de Galicia	Research centre	Supercomputing centre	Spain
EDF Group	Large company	Electricity: generation, transmission, distribution, energy supply and trading, energy services	France
Data Reply	Large company	Data Reply is the Reply Group company devoted to deliver advanced solution on Big Data, AI, Machine Learning, Accelerated Computing and Quantum Computing.	Italy/France/ Germany
Delft circuits	SME	Manufacturers of the flexible microwave cryogenic cabling	The Netherlands
DLR - German Aerospace Center	Research Centre	Robotics, Aerospace, aeronautics	Germany
Dual Software GmbH	SME	Software developer, consulting, simulation	Germany
HQS GmbH Quantum Simulation	SME	Software company, applications for quantum computers and potentially for quantum simulators	Germany
Infineon Technologies	Large company	Semiconductor solutions, microcontrollers, LED drivers, sensors and Automotive & Power Management ICs	Germany
ITMATI	**Research Institute**	**Technological Institute for Industrial Mathematics**	**Spain**
Jos Quantum GmbH	SME	High performance software and algorithms to enable the next technological revolution for capital markets, finance and insurance	Germany
LightOn, SAS	SME	Highly innovative computing hardware for AI and HPC purposes. Research in the area of photonics hardware accelerators.	France

Institution name	Type of organisation	Area	Country
Max Planck Computing and Data Facility (MPCDF)	MPG Service provider	HPC and data services to all Max Planck Institutes	Germany
MBDA missile systems	Large company	Weapon systems and effectors	France
MERCK KGaA	**Large company**	**Pharma, chemicals**	**Germany**
MULTIVERSE COMPUTING S.L.	SME	Quantitative finance, quantum computing	Spain
NAG - The Numerical Algorithms Group (NAG) Ltd	Large company	Numerical algorithms for novel architectures including Quantum Computing	UK
ONERA - Office national d'études et de recherches aérospatiales	Research Centre	Aerospace	France
PCQC - Paris Centre for Quantum Computing	Research Centre	Quantum Computing	France
Planetek Italia srl	**SME**	**Space**	**Italy / Greece**
Rahko LTD	SME	New algorithms and methods to accelerate computational material discovery	UK
QCware	SME	Quantum algorithms and software	France
Qu&Co	**SME**	**Novel quantum-algorithms and quantum-software for ab-initio chemistry simulations, quantum-machine-learning and quantum-enhanced fluid-dynamics simulations**	**The Netherlands**
Quandela	SME	optical quantum technologies, specifically focusing on the manipulation of quantum states of light using photonic chips and photonic processors for the development of Quantum computers	France
Quantware	**SME**	**Scalable quantum processors**	**The Netherlands**
Quside Technologies S.L. spin-off from ICFO-The Institute of Photonic Sciences in Barcelona	**SME**	**Quantum technologies to advance computing capabilities towards higher performance and lower energy consumption**	**Spain**
Safran	Int. high-tech technology group	Aircraft, propulsion, defence	France
Sirteq	Large-scale project	Large scale project which gathers all the academic research on Quantum Technlogies in the Paris Region (more than 750 permanent and non permanent researchers)	France
SURFsara	Research	Supercomputing centre	The Netherlands
SVA GmbH	SME	IT integration	Germany
Syndesis LTD. SPIN OFF company of the National Centre of Scientific Research Demokritos	SME	AI/algorithms health domain	Greece
Association TERATEC	Association	Stimulate research and collaborative projects in the area of HPC/Simulation/Big Data/AI, as an Association of 100 members gathering advanced industrial users, HPC manufacturers, numerous hardware and software technology suppliers, ISVs, service providers as well as research organisations.	France
Thales Alenia Space	**Large company**	**Space**	**France/Italy**
Total	**Large company**	**Energy producer and provider, is the world's 4th-ranked international oil and gas company and a major player in low-carbon energies**	**France**
T-Systems	**Large company**	**Telecommunication, IT**	**Germany**
United Technologies Research Centre Ireland, Ltd. (affiliate of Raytheon Technologies)	**Research Institute**	**Power distribution, advanced propulsion, energy storage, autonomy and human-machine interaction and innovative aircraft systems**	**Ireland**
University Bretagne IRISA,	Higher	Major research centre dedicated to	France

Institution name	Type of organisation	Area	Country
OBELIX group	education	computer science, signal/image processing, and robotics in France	
University of Oxford, Quantum Computing & Simulation Hub	**Higher Education**	**Quantum Computing & Simulation**	**UK**
VW - Volkswagen AG	Large company	Automotive	Germany
Waterford Institute of Technology, TSSG	Research Institute	Quantum Technologies	Ireland
Zapata Computing Inc. and Zapata Computing Spain S.I.	**SME**	**Algorithms for quantum optimization, quantum machine learning and quantum chemistry**	**Spain**

AIRBUS

DEFENCE AND SPACE

Airbus Defence and Space, Anchorage Road, Portsmouth, PO3 5PU, UK

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Our ref: EL-2018-02-19_1

27 July 2020

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Subject: Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

At Airbus we understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Airbus, as a user of HPC, is highly interested in the project. As part of our own agenda, we are researching on how Quantum Computing could be used as an additional tool in the field of HPC.
Hence, as Airbus we welcome a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board and Advisory Board to follow the progress, attending meetings (preferably by tele- and video-conferencing) as relevant with respect to our use cases and needs.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis.

With our best regards

Paolo Bianco
R&T Co-operation Manager

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

we write this letter in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.
We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.
As part of our own agenda, we are conducting research in the area of Health Care and Crop Science and consider quantum technologies to be a chance to improve lots of features along our value chain. Bayer is highly interested in the project, because we believe that Quantum Computing will be a game changer once it's full potential has been expanded within the next ten years and will help us in fulfilling our mission and vision, "Health for all, hunger for none".
Bayer welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Yours sincerely,

Bayer AG

Dr. Ulf Hengstmann
Digital Lead Medical Affairs & Pharmacovigilance

////////////////

July 22, 2020

Dr. Ulf Hengstmann
Digital Lead Medical Affairs&
Pharmacovigilance
////////////////
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Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

23. Juli 2020
Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

I write this letter in my position of Expert Advanced Computational Concepts and Quantum Computing at Covestro Deutschland AG in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, local, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Covestro Digital R&D is highly interested in the project. Covestro has identified quantum computing as one of the most promising technologies to overcome current limitations in materials research. Practical challenges in simulating quantum systems on classical computers have been widely recognized in the quantum physics and quantum chemistry communities over the past century. Although many approximation methods have been introduced, the complexity of quantum mechanics remains hard to appease. The advent of quantum simulation and computation brings new pathways to navigate this challenging and complex landscape.

At Covestro, we are actively developing use cases for quantum computing in the chemistry and materials science sector. Therefore, having access to European quantum hardware is of great importance to protect our computationally hard and data-sensitive processes.

We welcome a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavor. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Best Regards

Christian Gogolin
Expert Advanced Computational Concepts and Quantum Computing

Covestro Deutschland AG
BU Polyurethanes
Building B 108 RD10
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Germany

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Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of Technological Institute for Industrial Mathematics (ITMATI) in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

ITMATI is highly interested in the project, because we have been researching in quantum technologies. As part of our own agenda, we were conducting a research in this area with an industrial company and consider quantum technologies to be a chance to develop better algorithms for solving optimization problems using the power of Quantum computing in both perspectives, theoretical and experimental. It is also suitable for new training methods in deep learning.

ITMATI welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress of the HPCQS project.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Yours sincerely,

Santiago de Compostela, 23rd July 2020.

36038289A
PEREGRINA QUINTELA
(R: S1500111H)

Signed.: Mrs. Peregrina Quintela Estévez

Director of ITMATI

Instituto Tecnológico
de Matemática Industrial

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Merck · Frankfurter Str. 250 · 64293 Darmstadt · Germany

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Date 22 Jul 2020
Contact Dr. Thomas Ehmer
Phone +49 (0)151 14542639
Mail Thomas.ehmer@merckgroup.com

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

At Merck, we are well aware of the disruptive potential that quantum computing, and quantum technologies in general, can have in our three core areas of business: Healthcare, Life Sciences, and Performance Materials. To prepare us for the quantum age, we have formed a Quantum Task Force encompassing a variety of researchers from across the entire corporation. This Task Force has engaged with a multitude of initiatives and players in the quantum computing space, ranging from quantum chip manufacturers, over peripheral hardware manufacturers, to quantum software engineers.

We quickly learned that while the promise of quantum computing is indeed a paradigm shift, lot of hope is currently hype due to the lack of available algorithms, a lack of principle understanding how to reformulate existing business problems for quantum computers, as well as limits in existing hardware (NISQ). A key question and current challenge for our business in the process of engaging with quantum service providers is to validate the widely varying claims of different parties. We see the lack of standardization across the software and hardware industry as a key gap that impedes a fast validation scheme. Moreover, there is a lack of processes that allow us to benchmark proposed quantum solutions against the existing classical computational approaches that are currently in use in our computational research and development steps.

In so far Merck is highly interested in the project, because we are convinced that only by collaboration the best solutions can be found. As part of our own agenda, we are conducting research in the area of healthcare, life science and also as an industrial company are manufacturers of performance materials and consider quantum technologies to be a chance to complement our research and development in many areas.

Merck welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board – and also the Advisory Board to follow the progress for application development for gate and annealing and also for upcoming performance material needs, the development of a first ecosystem of hybrid HPC and quantum programming facilities and applications and the next generation of modular HPC systems.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Dr. Philipp Harbach
Head of In Silico Research
Digital Organization

Dr. Daniel Franke
Investment Associate
M Ventures

Dr. Thomas Ehmer
Healthcare R&D Informatics Innovation
Group Information Service

ONERA
THE FRENCH AEROSPACE LAB

DSG/L-n° 013/20

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Palaiseau,
July, 24th 2020

Object : **Letter of Support for HORIZON2020 proposal HPCQS**

Dear Prof. Michielsen,

I write you as General Scientific Director of ONERA in support of your innovative research project HPCQS (High Performance Computer and Quantum Simulator), which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of HPCQS is to setup a pan European integrated HPC and Quantum Simulator (100 qubits) resources publicly available and accessible for everyone in a secure, high performance, productive and energy efficient way addressing the needs of European research and industry.

ONERA, the French aerospace research center, meets future aerospace challenges and contributes to the competitiveness of the aerospace industry. High performance numerical simulation plays a major role in the ONERA mission of preparing the future of aerospace. Therefore ONERA is highly interested in the HPCQS project which will strongly contribute to the future of HPC.

More precisely, the main actors in quantum computing are present in this project, actors who have already proven themselves, ONERA has already been able to test the QLM environment at CCRT into TGCC supercomputing center, JSC already has extensive experience in the deployment of infrastructure with JUNIQ, which offers access to several technologies. The hybrid simulation and NISQ approach should make it possible to solve problems with around a hundred qubits more quickly than on a conventional supercomputer, and this with very low power consumption. The project is coherent by offering through a portal access to quantum computer simulator, taking into account algorithms, protocols, tools, and test cases. User support and training are taken into account, which is important in the development of any new technologies. The Cloud

approach is suitable for the dissemination of this technology to many players, which guarantees the success in dissemination of the project.

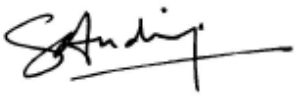
As part of our own agenda, we are starting research actions, which will initially be more oriented in the field of optimization and deep learning for aerospace applications and consider quantum technologies to be a chance which will subsequently serve to increase the competitiveness of the industry. ONERA is a hinge between industry and academic research and as such can provide use cases for this project.

ONERA welcomes a close collaboration with HPCQS partners and would be happy to serve as a member of the planned User Board to follow the progress and guide the development of future services. Alain Refloch, special advisor for HPC at ONERA, would be the right person to perform this.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

We appreciate the opportunity to support this proposal and wish you a successful outcome from the proposal selection process.

Sincerely,



Stéphane ANDRIEUX
General Scientific Director

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Office National d'Etudes et de Recherches Aérospatiales

planetek
italia

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Bari, 21/07/2020
Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,
We write this letter on behalf of Planetek Italia srl in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Planetek Italia is an Italian SME with a sister company present in Greece (Planetek Hellas) acting in the Space field with some of our production workflows needing very intensive processing capabilities.

In fact, in the last years we have evolved our workflow to make them running on different supercomputer centers like the one in the University of Bari (RECAS) or in the OSLO University. Moreover we are involved in the Qu3D Quantera project for quantum sensing and, again, our goal is to improve the sustainability of the high demanding processing steps.

So, we are highly interested in the project, because, as part of our own agenda, we are conducting research in the area of Quantum Computing to improve and make sustainable our processing workflows.

Planetek Italia, by means of its employee Eng. Cristoforo Abbattista Head of the SpaceStream Strategic Business Unit, welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Cristoforo Abbattista

Qu & Co

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of our company Qu&Co in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Qu & Co develops novel quantum-algorithms and quantum-software for ab-initio chemistry simulations, quantum-machine-learning and quantum-enhanced fluid-dynamics simulations. We would like to use the proposed HPC/QS resources in our own quantum-algorithm research.

Qu&Co therefore welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board or Advisory Board to follow the progress.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Benno Broer
CEO, Qu&Co
Benno.broer@quandco.com
tel: +31655336315

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QuantWare b.v.

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Kantoorgracht 72c
2611PE Delft, NL
Tel: 06 29286632
Web: Quantware.eu

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of QuantWare in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

QuantWare is highly interested in the project, because we will soon offer quantum hardware solutions to the European market. As part of our own industrial agenda, we are currently manufacturing scalable quantum processors for QEC and NISQ applications employing innovative interconnects that allow for 50+ qubit in our first generation QPU by the end of 2020. Our aim is then to quickly proceed to 100+ qubits, a territory where a reliable and fast quantum simulator will have a tremendous role to guide and validate experimental results.

Quantware welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Committee or Advisory Board to follow the progress, and to be an early adopter of the simulator in order to validate the performances of our products.
Moreover, I hereby manifest our interest to have a closer connection also with regards to opportunities to provide physical quantum processors in the content of the HPCQS project.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Dr. Alessandro Bruno
QuantWare CEO

26/07/2020

QUSIDE

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of Quside Technologies S.L. in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

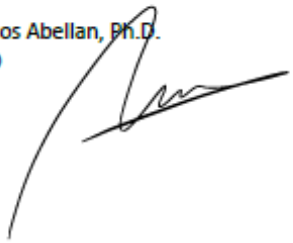
Quside is highly interested in the project, as employing quantum technologies to advancing computing capabilities towards higher performance and lower energy consumption are core objectives of our company. As part of our own agenda, we are conducting research in the area of advanced computation in heterogeneous computing architectures. In addition, we will be making hardware accelerators for randomized computation available for early adopters soon.

Quside welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Carlos Abellan, Ph.D.
CEO



ThalesAlenia Space
a Thales / Leonardo company

Thales Alenia Space España, S.A.
C/ Einstein, 7 (PTM)
28760 Tres Cantos - Madrid
España
Tél.: + 34 (9)1 807 70 00
Fax: + 34 (9)1 807 79 79

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of Thales Alenia Space in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

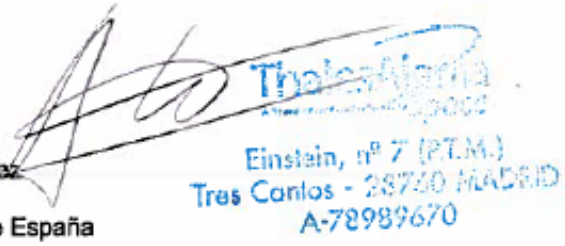
We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.
Thales Alenia Space is highly interested in the project because our corporation is exploring all the applications and impacts that the quantum technologies can have in the space domain. As part of our own agenda, we are conducting research in the area of quantum communications, quantum cryptography and quantum computing applied to space systems both in Telecommunication and Earth Observation systems.

Thales Alenia Space, as an industrial company are manufacturers of space based solutions including satellites and its components and consider quantum technologies as the ones proposed in HPCQS to be a chance to improve the resolution of optimization problems, which is the daily bread of industry. We have identified that it could help us in designing antenna reflectors, validating performance of navigation systems, help optimizing radio resource allocation in telecom systems, support AI in image recognition applications, etc...

Thales Alenia Space welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board to follow the progress of the HPCQS project.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,



Angel Alvaro Sanchez
R&D Manager
Thales Alenia Space España

Marie-Noëlle SEMERIA
Directrice Recherche et Développement
TOTAL
Tour Coupole / Nano-INNOV
2, place Jean Millier
92078 Paris La Défense Cedex – France

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

We write this letter on behalf of Total SA in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Total SA is highly interested in the project, because it aims at deeply integrating quantum technologies with HPC and giving access to the whole research community, from academics to large industrial groups, while being able to integrate latest quantum technologies in a agile way. As part of our own agenda of a multi-energy company committed to carbon neutrality, we are conducting research in the area of materials science and energy efficiency for a low carbon world and we consider quantum technologies to be a chance to improve products performances and optimize energy consumption of our facilities and customers to lower the carbon footprint of our activities and of our clients.

Total SA welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned user Board to follow the progress, give feedback, share its vision, bring use cases...

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Marie-Noëlle SEMERIA

T · · Systems ·

T-SYSTEMS INFORMATION SERVICES GMBH
Pascalstraße 11, 10587 Berlin

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich

REFERENZEN
ANSPRECHPARTNER Dr.Alfred Geiger
TELEFONNUMMER +49815390992423
DATUM 22. Juli 2020
BETRIFFT Letter of Support

Dear Prof. Michielsen,

T-Systems is operating a public cloud environment (OTC - Open Telekom Cloud) fully compliant with European regulations and completely located in the EU. High End Computing is a focus topic of this service and therefore HPC-flavours are integrated as well as the seamless access to high-end supercomputing. Next goal is the integration of Quantum Computing and related software-environments including simulation. The use-cases will come from corporate research of Deutsche Telekom in telecommunications as well as from B2B customers of T-Systems.
T-Systems understands, that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

In this sense we support the proposed project and we are interested in the results of this excellent endeavour. We are prepared to get a member of the user- or advisory-board and understand that our contribution in detail will be agreed at the project start on a non-binding basis.

Best Regards

i.A. Dr.-Ing.habil Alfred Geiger, Scientific Computing

T-SYSTEMS INFORMATION SERVICES GMBH
Geschäftsanschrift: Pascalstr. 11, 10587 Berlin
Telefon: +49 30 8353 86971, E-Mail: info.t-systems-ifz@t-systems.com
Konto: Deutsche Bank AG, IBAN DE04660700840340836800, BIC DEUTDESS660
Geschäftsführer: Holger Lesch, Dr. Claudia Schopf, Stefan Schreiner, Robert Woithe
Handelsregister: Amtsgericht Berlin Charlottenburg HRB 209918 B, Sitz der Gesellschaft Berlin
USt-IdNr. DE193456493

United Technologies Research Centre Ireland, Ltd.
2nd Floor, Penrose Business Centre,
Penrose Wharf,
Cork, Ireland.
+353 (0)21 450 8440

Raytheon Technologies

23 July 2020 P.E00.0541

Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Attention: Prof. Kristel Michielsen
Phone:+49 2461 61-2524
Email: k.michielsen@fz-juelich.de

Subject: **Letter of Support for "High-Performance Computing and Quantum Simulation" (HPCQS) Proposal**

United Technologies Research Centre Ireland, Ltd. (UTRC-I) confirms our support for your ambitious proposal HPCQS to be submitted under the EuroHPC-2020-01-b H2020 call.

United Technologies Research Centre Ireland, Ltd. (UTRC-I) is an affiliate of Raytheon Technologies. It was established in Cork in 2010 to operate as Raytheon Technologies European research hub, with a mission to develop advanced technologies – "what's next" – for all the businesses of Raytheon Technologies, particularly those based in Europe, and to work with other industry, national labs and academic institutions to broaden the scope and impact of new technology developments along the value chain.

In Ireland, the Research Center has approximately 75 employees who investigate the "what ifs" of power distribution, advanced propulsion, energy storage, autonomy and human-machine interaction and innovative aircraft systems. This application focus, coupled with the extensive experience of the Research Centre in system engineering, controls, modelling, formal methods, and embedded system development, its close-knit interaction with the diversity of Raytheon Technologies' European businesses, ideally place the Research Center to support the HPCQS project.

The proposed research program advances UTRC-I's research agenda in the area of next-generation computing technologies, by making European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry. We believe further development of this technology, together with widespread dissemination across future generations of leading engineers, will help meet the design challenges of next-generation aerospace systems.

We at UTRC-I are excited by the opportunity to work with the HPCQS consortium, and look forward to furthering our relationship in this critical technology area through the HPCQS User Board.

Sincerely,

UNITED TECHNOLOGIES RESEARCH CENTRE IRELAND, LIMITED

Menouer Boubekeur, PhD
Associate Director, Strategic Business Development

DIRECTORS: G.R. STEPHENSON (USA) S. TAHILIANI (USA) I. COHEN (USA)
REGISTERED IN IRELAND NO. 472601 REGISTERED OFFICE 4TH FLOOR PENROSE BUSINESS CENTRE, PENROSE WHARF, CORK

Quantum Computing & Simulation Hub

LEAD PARTNER

UNIVERSITY OF OXFORD

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,
We write this letter on behalf of the UK Quantum Technology Hub in Quantum Computing and Simulation in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

The UK Quantum Technology Hub in Computing and Simulation is a strategic collaboration of 17 universities and 28 industrial partners focused on pushing quantum computing technologies from the lab to the marketplace. The Hub will foster the emerging quantum industry through technology development, engagement with users, and by training the next generation of quantum engineers.

Quantum simulation is a key theme of the Hub, with work in Cold Atoms, Photonics, and Software relevant to this area. Professor Elham Kashefi, a member of the scientific leadership of the Hub is a Co-Investigator in the proposal so will provide a strong connection to the proposed work. Professor Andrew Daley, who is workpackage leader for Cold Atoms in the Hub will help to bridge between our compatible activities to ensure there is knowledge exchange where beneficial to both projects. We would be also be happy to nominate a member of the Hub to be on an advisory or user board as relevant.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

Yours sincerely,
Dominic O'Br
Professor Dominic O'Brien
Director UK Quantum Technology Hub in Computing and Simulation

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

Quantum Computing & Simulation Hub
An EPSRC Technology Hub, part of the UK National Quantum Technologies Programme

Director: *Prof Dominic O'Brien;* **Co-Director:** *Prof David Lucas;* **Co-Director:** *Evert Geurtsen*
University of Oxford Department of Physics, Clarendon Laboratory, Parks Rd., Oxford OX1 3PU. Tel: +44 (0) 1865 282449
www.qcshub.org info@qcshub.org

Zapata Computing, Inc.
100 Federal Street, 20th Floor

Zapata Computing Spain S.I.
Calle Entença 325-335, Piso 1
8029 Barcelona, Spain

Reply to: Witold Kowalczyk
witold@zapatacomputing.com
+48 668 402 035

Prof. Kristel Michielsen
Forschungszentrum Jülich GmbH
Institute for Advanced Simulation (IAS)
Jülich Supercomputing Centre (JSC)
Wilhelm-Johnen-Straße
52425 Jülich
Germany

Letter of Support for HORIZON2020 proposal HPCQS

Dear Prof. Michielsen,

we write this letter on behalf of Zapata Computing Inc. and Zapata Computing Spain S.I. in support of your ambitious research project HPCQS, which will be submitted to the Horizon 2020 call EuroHPC-2020-01-b.

We understand that the vision of the HPCQS project is to make European integrated HPC/QS resources publicly available and accessible for everyone in a secure, high performance, high-speed, energy efficient way addressing the needs of European research and industry.

Zapata Computing is highly interested in the project, because we believe that the use of quantum simulation tools is an essential element of developing new quantum algorithms and applications. As part of our own agenda, we are conducting research in the area of algorithms for quantum optimization, quantum machine learning and quantum chemistry and consider quantum simulation to be a significant resource in our quest to improve our solutions.

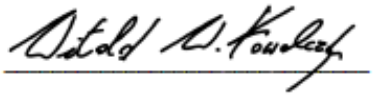
Zapata Computing Inc.

Zapata Computing welcomes a close collaboration with the ambitious project and would be happy to serve as a member of the planned User Board and Advisory Board to follow the progress of the project and assist in its development.

In this sense we wholeheartedly support the proposed project and we are interested in the results of this excellent endeavour. We understand that our contribution in detail will be agreed at the project start on a non-binding basis. In the case of a participation in project meetings, travel costs will be taken over by the project budget.

Sincerely,

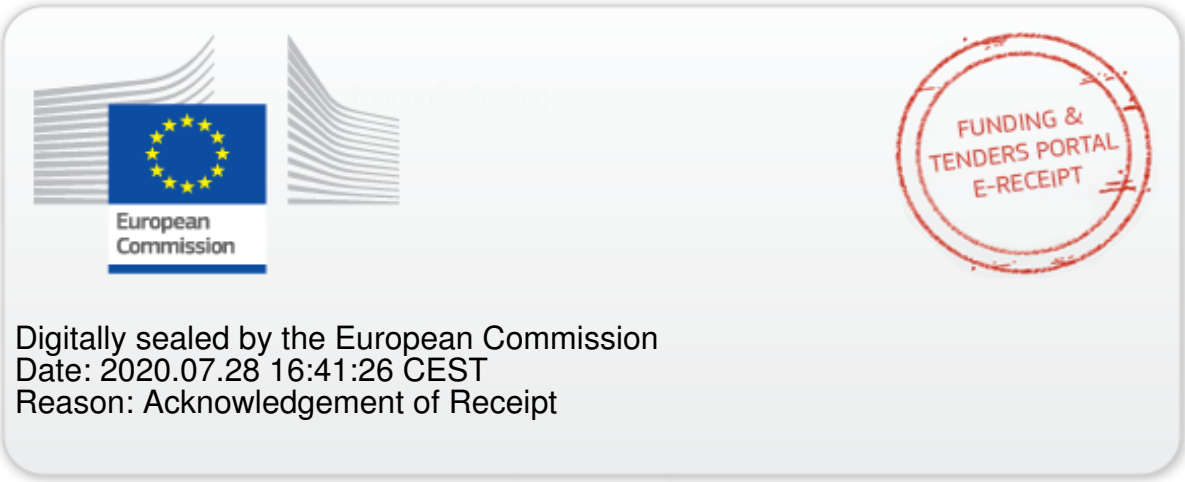
Zapata Computing, Inc.



Witold Kowalczyk
Director of European Business Development

27th of July 2020

Proposal Number	Proposal Acronym	Business Name	Participant Identification Code (PIC)	Requested National Contribution / €
SEP-210692928	HPCQS	FORSCHUNGSZENTRUM JULICH GMBH	999980470	2,348,166.88
SEP-210692928	HPCQS	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	999992401	182,116.88
SEP-210692928	HPCQS	GRAND EQUIPEMENT NATIONAL DE CALCUL INTENSIF	999779680	1,789,078.13
SEP-210692928	HPCQS	BULL SAS	996058081	559,291.88
SEP-210692928	HPCQS	CONSIGLIO NAZIONALE DELLE RICERCHE	999979500	143,040.00
SEP-210692928	HPCQS	NATIONAL UNIVERSITY OF IRELAND GALWAY	999978045	170,300.00
SEP-210692928	HPCQS	UNIVERSITAET INNSBRUCK	999869114	86,831.25
SEP-210692928	HPCQS	EURICE EUROPEAN RESEARCH AND PROJECT OFFICE GMBH	999778419	193,391.25
SEP-210692928	HPCQS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	999997930	117,432.50
SEP-210692928	HPCQS	INSTITUT NATIONAL DE RECHERCHE ENINFORMATIQUE ET AUTOMATIQUE	999547074	119,361.88
SEP-210692928	HPCQS	Pasqal	893652853	112,192.50
SEP-210692928	HPCQS	CINECA CONSORZIO INTERUNIVERSITARIO	999843409	14,062.50
SEP-210692928	HPCQS	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	999655520	20,937.50
SEP-210692928	HPCQS	FLYSIGHT SRL	893663911	38,062.50
SEP-210692928	HPCQS	Parity Quantum Computing GmbH	893423545	83,455.00
SEP-210692928	HPCQS	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	999984059	22,279.38
				6,000,000.01



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