

## SOFTQPRO

Coordinateur du projet

Nom : **Perdrix**

Prénom : **Simon**

Aucun droit de réponse n'a été enregistré par le coordinateur de projet.

## Qualité et originalité des recherches proposées

<b>CLARTÉ DES OBJECTIFS ET DES HYPOTHÈSES DE RECHERCHE</b>	The overarching goal of the project is to develop an end-to-end solution for the development and execution of quantum algorithms, comprising a pipeline from high-level language (Quipper), through an intermediate graphical language, through to implementations, either on real hardware or an HPC simulator. The objectives and hypotheses are clearly set out and well-explained.
<b>CARACTÈRE INNOVANT ET PROGRÈS PAR RAPPORT À L'ÉTAT DE L'ART</b>	The project is very innovative, in that there are currently very few large-scale systems for taking quantum algorithms from programming language through to compiled code; the main competitor at this point is Microsoft's proprietary environment LIQuID. Given the rapid development of quantum hardware, the development of such systems is an urgent problem. The applicants also plan to use their expertise in formal and graphical methods to enable verification and optimization of quantum programs, which could go beyond the capabilities of current software.
<b>FAISABILITÉ NOTAMMENT AU REGARD DES MÉTHODES ET DE LA GESTION DES RISQUES SCIENTIFIQUES</b>	The project seems very feasible. It includes aspects relating to implementations and also theoretical parts, which by their nature are higher-risk. However, the risk-management plan is detailed and appropriate, and there seems to be no doubt that the project will produce the desired deliverables. The methods proposed are also detailed and appropriate.

## Organisation du projet et moyens mis en œuvre

<b>COMPÉTENCE, EXPERTISE ET IMPLICATION DU COORDINATEUR SCIENTIFIQUE</b>	The scientific coordinator is a leading international expert in some of the main topics covered by the proposal (eg. the ZX-calculus), and the co-PI brings complementary, and essential, expertise in quantum programming languages. They are thus ideal candidates to manage such a project. They will act as leaders of the consortium as well as contributing their own scientific expertise.
<b>QUALITÉ ET COMPLÉMENTARITÉ DU CONSORTIUM, QUALITÉ DE LA COLLABORATION POUR LES PRC, PRCE, OU QUALITÉ, COMPLÉMENTARITÉ ET POTENTIEL DE L'ÉQUIPE POUR LES JJC</b>	The consortium includes partners who are experts in each of the key areas of the proposal: language design, formal methods, code optimizations, and implementation. In particular, it includes the industrial partner Atos-Bull, which will provide access to its HPC hardware and, more generally, expertise in implementation, benchmarking, etc. This is an important aspect of the project and should greatly increase its impact.
<b>ADÉQUATION DES MOYENS AUX OBJECTIFS</b>	The resources requested are modest and proportionate, and will be used to support postdocs, students, and staff at Atos-Bull, as well as for travel and consumables.

## Impact et retombées du projet

<b>IMPACT POTENTIEL DANS LES DOMAINES SCIENTIFIQUE, ÉCONOMIQUE, SOCIAL OU CULTUREL</b>	The development of large-scale quantum computers is predicted to have an immense impact on almost every aspect of society. This project would contribute to this upcoming quantum revolution. The release of an open and fully-featured software package for end-to-end quantum programming and compilation could be an important event in the field, and could greatly accelerate the uptake of quantum computing within industry.
<b>CAPACITÉ DU PROJET À RÉPONDRE AUX ENJEUX DE L'AXE DU DÉFI (OU DU DÉFI POUR LE DEFAS) PAR SON CARACTÈRE SCIENTIFIQUE, ÉCONOMIQUE, SOCIAL OU CULTUREL.</b>	The project combines the areas of quantum technologies and high-performance computing, which have been identified as European priorities. It would address important challenges within these areas.

## STRATÉGIE DE DIFFUSION OU DE VALORISATION DES RÉSULTATS

The strategies laid out for scientific dissemination are standard, and a detailed plan is given for the setup of project websites, etc. However, one aspect of the exploitation plan is not clear, and this is my one criticism of this proposal. It appears that WP4 will produce both open and proprietary source code, but the division between these is not clearly defined. In my opinion, the most important deliverable for this project would be an open, freely accessible, full solution for developing quantum programs, right through to compilation for hardware platforms. From the list of deliverables, it appears that some of this pipeline may be proprietary. It was not completely clear to me whether the proprietary parts are just targeted optimizations for specific HPC hardware platforms, or are essential in order to use the overall toolchain. In any case, I do not believe it would be appropriate for this funding to be used to directly support Atos-Bull to develop proprietary code which would then be sold commercially. This point should therefore be clarified by the applicants.

## Qualité et originalité des recherches proposées

### CLARTÉ DES OBJECTIFS ET DES HYPOTHÈSES DE RECHERCHE

There are four key objectives (G1-G4) which are clearly expressed.

Quantum computation is emerging as an important field that is likely to have a profound impact on society. To build quantum systems it is essential that we have good programming language support, good formal methods, good optimization methods, and good simulation methods. That is the objective of this project.

While it will always take highly-skilled physicists and algorithm designers to come up with new quantum techniques, the science and technology in this project is all about integrating these kinds of techniques into larger software projects, suggesting variations on these techniques, investigating via simulation how variations in layout and implementation affect performance. So this project is playing a crucial role.

### CARACTÈRE INNOVANT ET PROGRÈS PAR RAPPORT À L'ÉTAT DE L'ART

The innovation here is strong. For me, the main highlight of the innovation comes from bringing together the two leaders, Perdrix and Valiron, who have established strong reputations in the field of quantum computation and quantum programming, but whose work is in different directions. It is exciting to see their research agendas and their different perspectives brought together. It is also interesting to see Why3 brought into the picture.

In particular, the Quipper system, on which Valiron played a leading role, is widely seen as a tremendous success. It probably the most advanced quantum programming system in the world. It is exciting to see this being taken to the next level.

The proposal is a little light on technical details for the specialist reader. For examples of this, I focus on Task 1. What is an example of something that is missing in Quipper that could be improved by building QuaML? The proposal mentions "policies in the type system", I suppose this means things like "qubits cannot be duplicated" and "this circuit only uses two ancillas", but it is not spelt out. Similarly, I suppose a new QuaML compiler will be built, but building a modern compiler is a massive task -- will something be used as a starting point? There is a proposal to use Why3, but I wonder what challenges are envisaged in using Why3 -- to my knowledge it has not yet been used for even a prototype quantum language. Having said this, I am entirely confident in the leaders of the project on the technical side, based on their strong track records.

### FAISABILITÉ NOTAMMENT AU REGARD DES MÉTHODES ET DE LA GESTION DES RISQUES SCIENTIFIQUES

The risks are managed well. I have no doubt that much high quality research will come out of this project. For example, the outcomes of the risky tasks are exciting, especially the ones about implicit complexity which may lead to new ideas in quantum complexity theory (WP2, T3-4) but the other parts of the project do not depend on them.

## Organisation du projet et moyens mis en œuvre

### COMPÉTENCE, EXPERTISE ET IMPLICATION DU COORDINATEUR SCIENTIFIQUE

The coordinator, Simon Perdrix, is a recognized expert in quantum programming and abstract reasoning about quantum systems. He has many papers on different areas of quantum systems, dating back over 10 years, with many different coauthors. He has served on programme committees of quantum computation conferences.

He has proven management abilities, having been involved as PI in several projects previously.

**QUALITÉ ET COMPLÉMENTARITÉ  
DU CONSORTIUM, QUALITÉ DE LA  
COLLABORATION POUR LES PRC,  
PRCE, OU QUALITÉ,  
COMPLÉMENTARITÉ ET POTENTIEL  
DE L'ÉQUIPE POUR LES JCJC**

Each member of the consortium brings a different set of skills, which is exciting.

The LORIA and LRI sites have a strong track record in quantum programming and the theory of quantum systems, and it is exciting to see them working together. I am confident that some strong publications will come out of this collaboration.

I am concerned about the CEA and Bull sites.

With the CEA site, I am concerned that there appears to be no-one with quantum computation expertise listed among the participants. Quantum computation is a very subtle phenomenon. I would say it takes at least a year to get up to speed with the subject enough to be able to make some new academic contributions. So the collaboration with the other sites will have to be very intense if it is to work. I apologise if I am missing something. A mitigating factor is that some collaboration (albeit on reversible computing) has already begun.

With the Bull collaboration, I am concerned about how the relationship will work in several ways. I am concerned about who will own the intellectual property which comes from this work, which will overlap with ongoing Bull projects; I expected to see some discussion of this. I am also concerned about publishing: I would expect publications to be the main output of this project, and yet the Bull collaborators do not seem to have any track record on publishing on quantum computation, and their mini CV's are omitted from the appendix. Thirdly if the outcome of the Bull collaboration is supposed to be specific software, rather than an open-ended expectation of publications, I would have expected a more thorough specification of what software is required. This concern is somewhat mitigated by the fact that it will be of immense benefit to this project to have access to Bull's HPC simulation expertise.

**ADÉQUATION DES MOYENS AUX  
OBJECTIFS**

The resources seem appropriate across the LORIA, LRI, and CEA sites. The allocation of postdocs and travel money is appropriate and well planned.

I am concerned about the Bull resources (which form a fairly large part). First, I am not sure why Bull need the ANR to buy hardware for them, when it will only be used for a short time and they presumably have some spare that can be borrowed. The high cost (50k EUR) is not broken down. Second, if ANR are to employ people at Bull for 56 months, even if they only actually pay for a quarter of that time, I would expect a clearer specification of the expected outcome. (I should add that I have not been involved in a PRCE project before, and it is possible that there is something that I have misunderstood about the process.)

## Impact et retombées du projet

**IMPACT POTENTIEL DANS LES  
DOMAINES SCIENTIFIQUE,  
ÉCONOMIQUE, SOCIAL OU  
CULTUREL**

The main impact of this work will be in the scientific domain.

It is widely believed that quantum computation will have a massive impact on wider society over the next 10-20 years, and the kind of support for quantum systems that comes out of this project will play a key role in this.

**CAPACITÉ DU PROJET À  
RÉPONDRE AUX ENJEUX DE L'AXE  
DU DÉFI (OU DU DÉFI POUR LE  
DEFAS) PAR SON CARACTÈRE  
SCIENTIFIQUE, ÉCONOMIQUE,  
SOCIAL OU CULTUREL.**

The project ties in well with Challenge 7 Theme 1, particularly Theoretical computer science: ... formal methods ... semantics ... quantum computing. The project will address central challenges in this theme.

**STRATÉGIE DE DIFFUSION OU DE  
VALORISATION DES RÉSULTATS**

The main strategy for dissemination is in publishing in top venues. This is entirely appropriate: the main societal impact of this work will go well beyond the timescale of this project. It is of crucial importance that the outcomes of this project are recorded in the literature for subsequent projects to build on.

The other dissemination technique is in releasing open source software. This is also entirely appropriate as it allows other researchers to experiment with the software and means that the software development can continue even after the project ends. It mirrors the dissemination of quipper, and so Valiron is entirely familiar with the process and well positioned to understand the challenges involved.