MUNICH QUANTUM SOFTWARE FORUM

9-10th of OCTOBER 2023

Technical University of Munich

European Research Council
Established by the European Commission

Munich Quantum Valley

9 - 10th of October 2023
Munich, Germany

www.cda.cit.tum.de/research/quantum/mqsf/

Preface

Welcome to the Munich Quantum Software Forum!

Robert Wille
Technical University of Munich

It is our honor and pleasure to welcome you to the Munich Quantum Software Forum! As you know, quantum computing is becoming a reality and, with recent accomplishments, software for this promising technology is becoming key for successful utilization. Numerous players frequently introduce new software solutions for quantum computing and, with this event, we want to bring the "who's who" behind these developments together. We are happy that you followed this call!

We hope the program will provide you with plenty opportunity to get insights into the various quantum computing software and allow you to network with the corresponding stakeholders. To this end, we are very thankful to Laura Schulz (LRZ), Leon Stok (IBM), Lukas Burgholzer (TU Munich), Mathias Soeken (Microsoft), Ivana Kurečić (Xanadu), Fred Chong (UChicago), Ross Duncan (Quantinuum), Nir Minerbi (Classiq), Eric Kessler (Amazon), Austin Fowler (Google), and Constin Iancu (LBNL) for their presentations as well as to everyone who showcases his/her software during the event!

While these presentations are of course the main focus of the event, we also would like to invite you to do more than "just" attending talks. Feel free to use our "lounge area" during breakout sessions to check out the posters, to connect to other participants, to have some hands-on sittings, or to just philosophize about quantum computing software in general. We hope you will enjoy your stay in Munich and at our university!

Finally, please allow us to thank the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No. 101001318), the Bavarian State Ministry for Science and Arts through the Distinguished Professorship Program, the Munich Quantum Valley, as well as the Technical University of Munich for their support in organizing this event!

Program

Day 1: Monday, October 9, 2023

Time	Event	Speaker
8:00 – 8:45	**Welcome Coffee & Snacks**	
8:45 – 9:00	**Opening Session**	Robert Wille (TU Munich)
9:00 – 10:00	**Brez'n, Bits and Qubits: How Bavaria Leads the Way for Quantum-Accelerated Supercomputing**	Laura Schulz (LRZ)
10:00 – 11:00	**Challenges from Heterogeneous Quantum Systems**	Leon Stok (IBM)
11:00 – 12:00	**Poster Pitches**	
12:00 – 13:30	**Lunch Break & Posters**	
13:30 – 14:30	**The Munich Quantum Toolkit (MQT): Utilizing Design Automation Methods for Quantum Computing**	Lukas Burgholzer (TU Munich)
14:30 – 15:30	**Azure Quantum Resource Estimator**	Mathias Soeken (Microsoft)
15:30 – 16:00	**Coffee Break + Breakout Sessions**	
16:00 – 17:00	**The future of differentiable quantum programming with PennyLane**	Ivana Kurečić (Xanadu)
17:00 – 18:00	**Physics-Aware, Full-Stack Software Optimizations**	Fred Chong (UChicago)
18:00 – 18:15	**Closing Day 1**	
19:30	**Dinner**	

Day 2: Tuesday, October 10, 2023

Time	Event	Speaker
8:30 – 9:00	**Welcome Coffee & Snacks**	
9:00 – 10:00	**TKET 2 - Next Generation Quantum Compiler**	Ross Duncan (Quantinuum)
10:00 – 11:00	**Classiq – Quantum Algorithm Design Automation**	Nir Minerbi (Classiq)
11:00 – 12:00	**Amazon Braket – Enabling quantum computing research and software development**	Eric Kessler (Amazon)
12:00 – 13:30	**Lunch Break & Posters**	
13:30 – 14:30	**Computing with fewer qubits: pitfalls and tools to keep you safe**	Austin Fowler (Google)
14:30 – 15:30	**Exploring the Quantum Design Space with Circuit Synthesis**	Costin Iancu (LBNL)
After 15:30	**Closing** **Get Together with Coffee & Snacks**	

Talks & Speakers

Brez'n, Bits and Qubits: How Bavaria Leads the Way for Quantum-Accelerated Supercomputing

Laura Schulz
Leibniz Supercomputing Centre (LRZ)

Abstract
Quantum computing is a breakthrough science and technology solo star, but its true power lies in partnering with supercomputing. To deliver that, upcoming quantum-enabled HPC systems must leverage many best practices hard-won from decades of development in supercomputing, including workflows, standards, and programming tools. In this presentation, I'll highlight Bavaria's multi-dimensional efforts to provide, merge and optimize various quantum accelerators into HPC systems and workflows. This includes insights into the development of the Munich Quantum Software Stack – the unifying software stack of the Munich Quantum Valley for its developed quantum modalities of superconducting materials, ions, and atoms – and its mission to fold them into current and upcoming supercomputing systems.

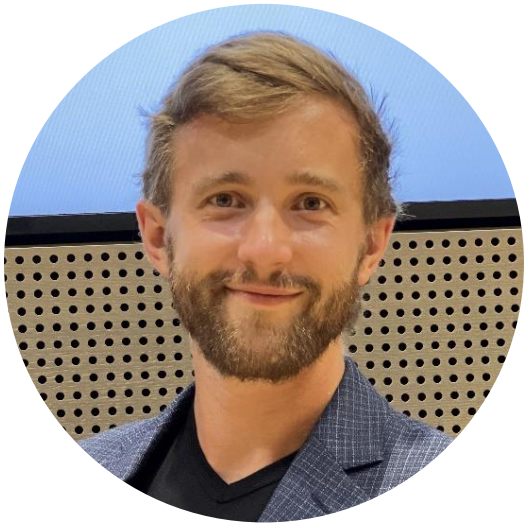
Biography
Laura Schulz is head of Quantum Computing and Technologies at the Leibniz Supercomputing Centre (LRZ) in Garching, Germany. She drives multiple efforts toward integrating emerging quantum accelerators into several layers of the high-performance computing (HPC) ecosystem. Laura is the PI for Germany's Euro-Q-Exa project to seat a EuroHPC Joint Undertaking quantum system in Bavaria and is co-founder of the monthly Bavarian Quantum Computing eXchange (BQCX). Recently, Laura was named an HPCWire 2023 Person to Watch.

Challenges from Heterogeneous Quantum Systems

Leon Stok
IBM

Abstract
Quantum computing is now available on real hardware via the cloud through IBM Quantum. This radically new kind of computing holds open the possibility of solving some problems that are now and perhaps always will be intractable for “classical” computers. Quantum Systems are rapidly becoming complex heterogenous systems. On one side a practical implementation must reckon with imperfections and noise. Error mitigation and dynamic circuits and other state-of-the-art techniques are necessary to bridge the gap between the logical and physical worlds. At the same time, multiple parallel chips will communicate using quantum communication links or classical communication links. Combining these together will allow us to build systems with several thousands of qubits and provides a clear path to 100,000 qubits and beyond. Quantum software will need to be able to understand the heterogeneity of these Quantum Systems and overcome the challenges associated with this.

Biography
Leon Stok is Vice President of IBM's Electronic Design Automation group. His team delivers world-class design and verification flows and tools being used to design the world’s largest supercomputers, IBM Z and Power systems and IBM Quantum Systems. Prior to this he held positions as director of EDA and executive assistant to IBM's Senior Vice President of Technology and Intellectual Property and executive assistant to IBM's Senior Vice President of the Technology group.

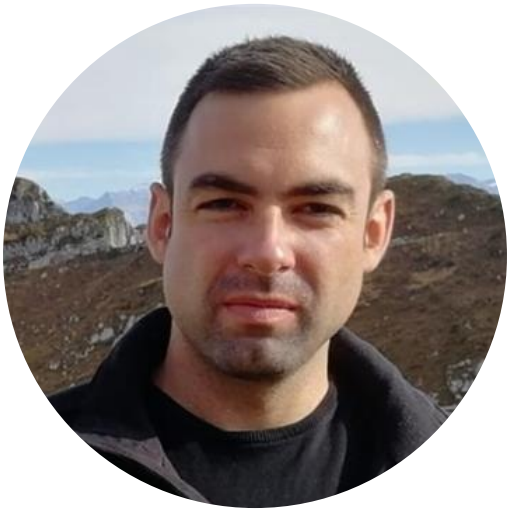


The Munich Quantum Toolkit (MQT): Utilizing Design Automation Methods for Quantum Computing

Lukas Burgholzer
Technical University of Munich (TUM)

Abstract
For decades, we have relied on design automation methods to realize conventional systems – from the most basic embedded systems to the most advanced processors, smartphones, and AI solutions. However, must we start from scratch when designing solutions for quantum computing? The Munich Quantum Toolkit (MQT) aims to avoid that! From supporting end-users in realizing quantum applications to streamlining complex tasks like classical simulation, compilation, and verification of quantum circuits, MQT paves the way to utilize these decades of expertise in design automation for quantum computing.

Biography
Lukas Burgholzer, a postdoc at the Technical University of Munich's Chair for Design Automation, drives innovation at the intersection of design automation and quantum computing. As one of the driving forces behind the Munich Quantum Toolkit, he crafts software that brings the future within our grasp today. In a field where physicists and computer scientists speak different languages, he bridges the gap and weaves threads of understanding into comprehensive solutions. His work underscores the power of design automation in shaping tomorrow's technology and in how we design, develop, and interact with the computers of the future.



Azure Quantum Resource Estimator

Mathias Soeken
Microsoft

Abstract

Join me in unlocking the power of practical quantum advantage with Azure Quantum Resource Estimator! Discover the true cost of running quantum algorithms on future fault-tolerant quantum computers and take control of your algorithm inputs and hardware assumptions. With the ability to optimize resource estimates and analyze your favorite applications, such as in chemistry and material science, the possibilities for groundbreaking discoveries and innovations are limitless. We showcase practical applications and guide you through the process of estimating physical resources. Get started today and unlock the potential of practical quantum computing!

Biography

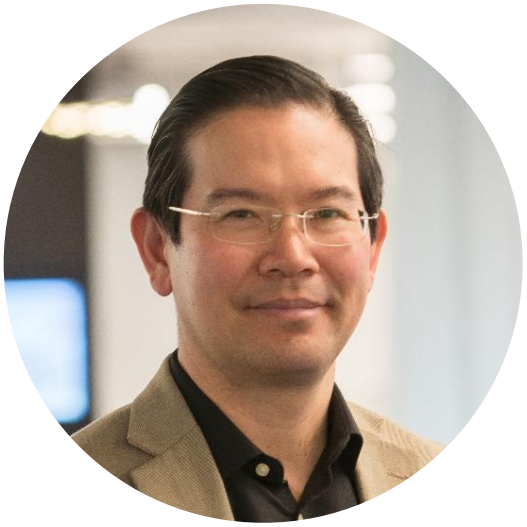
Mathias Soeken works at the Azure Quantum team at Microsoft. From 2015 to 2020, he has been with École Polytechnique Fédérale Lausanne (EPFL), Switzerland as postdoctoral scientist. He holds a Ph.D. degree (Dr.-Ing.) in Computer Science from University of Bremen, Germany (2013). His research interests are logic synthesis, quantum computing, reversible logic, and formal verification.

The future of differentiable quantum programming with PennyLane

Ivana Kurečić
Xanadu

Abstract
Xanadu is a Canadian quantum computing company with the mission to build quantum computers that are useful and available to people everywhere. As one of the companies at the forefront of quantum hardware and software, Xanadu also leads the development of PennyLane, a Python-based open-source quantum software library built around the concept of differentiable programming. Attendees will learn about differentiable quantum programming and its role in application development for quantum computing, quantum chemistry, and quantum machine learning. By the end of the session, they will also have an understanding of Xanadu's photonic architecture and learn about some of our key areas of research and development.

Biography
Ivana Kurečić is a quantum computing educator at Xanadu, where they work to support the growing quantum computing community, be it in research or education. As a Munich-based Xanadu team member, Ivana has an ear out for the European community and helps develop a quantum future accessible to all. Personal website: https://happyturtlethings.net/



Physics-Aware, Full-Stack Software Optimizations

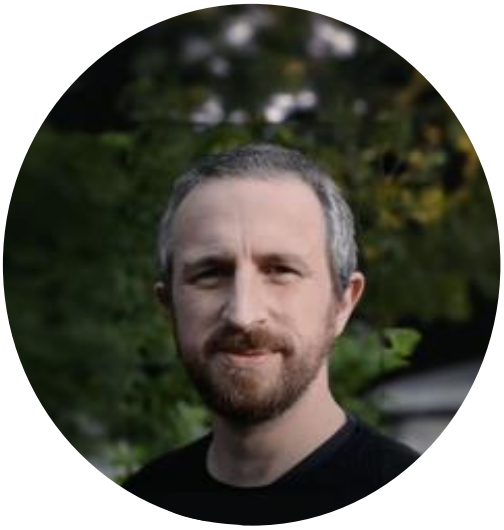
Fred Chong
University of Chicago, Infleqtion

Abstract

Quantum software can be a force multiplier that can significantly shorten the timeline for utility-scale results from quantum hardware. In particular, several key research directions will help realize practical quantum advantage. Physics-aware, cross-layer optimizations will continue to yield important efficiencies to allow applications to make the most of quantum resources. Additionally, applications will be hybrid computations involving high-performance classical resources as well as quantum hardware serving as special-purpose accelerators. Finally, defining abstractions that control compiler complexity yet selectively expose key physical machine properties will also be a key area in the future.

Biography

Fred Chong is the Seymour Goodman Professor in the Department of Computer Science at the University of Chicago and the Chief Scientist for Quantum Software at Infleqtion. He is also Lead Principal Investigator for the EPiQC Project (Enabling Practical-scale Quantum Computing), an NSF Expedition in Computing. Chong is a member of the National Quantum Advisory Committee (NQIAC) which provides advice to the President on the National Quantum Initiative Program. In 2020, he co-founded Super.tech, a quantum software company, which was acquired by Infleqtion (formerly ColdQuanta) in 2022. Chong received his Ph.D. from MIT in 1996 and was a faculty member and Chancellor's fellow at UC Davis from 1997-2005. He was also a Professor of Computer Science, Director of Computer Engineering, and Director of the Greenscale Center for Energy-Efficient Computing at UCSB from 2005-2015. He is a fellow of the IEEE and a recipient of the NSF CAREER award, the Intel Outstanding Researcher Award, and 13 best paper awards.

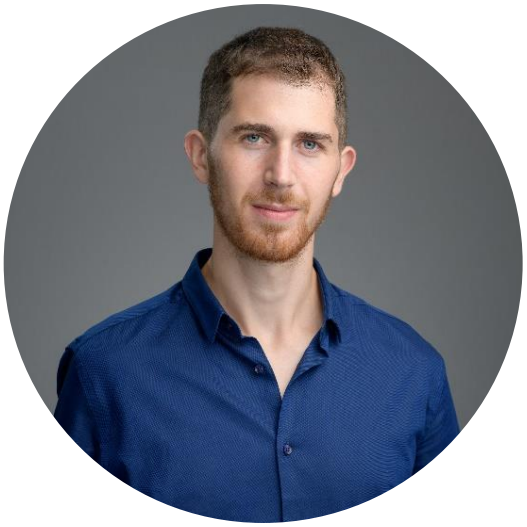


TKET 2 - Next Generation Quantum Compiler

Ross Duncan
Quantinuum, University of Strathclyde, University College London

Abstract
Since its introduction in 2018, TKET has been among the best performing compilers for quantum circuits. However, the world has moved on, and TKET is being re-engineered from the ground up to address the challenges of moving beyond the NISQ era. In this talk, I'll give a high-level perspective of the challenges that post-NISQ compilers face and how TKET 2 addresses those challenges.

Biography
Ross Duncan obtained his doctorate from Oxford in 2006 on "Types for Quantum Computing". During his postdoctoral years in Oxford then Brussels, he invented the ZX-calculus with Bob Coecke. After five years as lecturer of Computer Science at the University of Strathclyde, he joined Cambridge Quantum Computing in 2018 where he mostly focused on the TKET compiler, which he still does now, at Quantinuum, when he can.

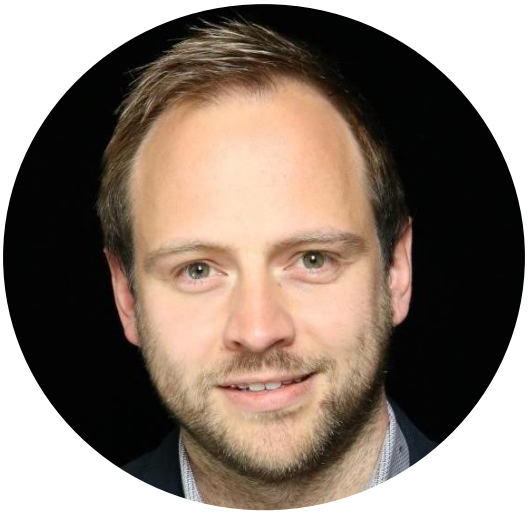


Classiq - Quantum Algorithm Design Automation

Nir Minerbi
Classiq

Abstract
Classiq is a leader in quantum computing software. By bringing design automation to the quantum software stack, Classiq provides the compiler, operating system, and IDE for quantum computing. The session will include both theoretical background, as well as industrial case studies.

Biography
Nir Minerbi is the co-founder and CEO of Classiq, the leader in quantum software. Nir has a history of leading cutting-edge technology teams and projects to extraordinary outcomes. He has a Master's degree in Physics and is a graduate of the prestigious 'Talpiot' program, described by Forbes magazine as "a Rhodes scholarship, a presidential fellowship, and a Harvard M.B.A. rolled into one.



Amazon Braket – Enabling quantum computing research and software development

Eric Kessler
Amazon

Abstract
Amazon Braket, the quantum computing service by AWS, provides on-demand access to a variety of quantum computing technologies to researchers and developers around the world. In this talk, we introduce Amazon Braket and explain the philosophy behind its software stack. Besides that, we dive into a new, experimental quantum programming interface called AutoQASM, designed to tackle the challenges posed by the next frontier in quantum computing: fast, classical control flow. AutoQASM is Python-native, clean, and expressive for general control flow as well as for low-level and device-dependent quantum instructions. It generates OpenQASM 3.0 programs and integrates with the Amazon Braket software development kit, allowing program composition, execution, and analysis to be done in the same environment.

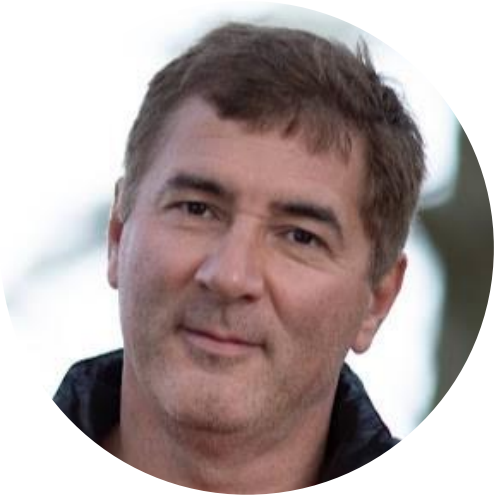
Biography
Eric Kessler is a Sr. Manager for Applied Science at Amazon Braket, working to bring quantum computing technology to the AWS cloud. Over the past decade, Eric has been working in various industry roles across quantum computing and machine learning, enabling enterprises in their adoption of emerging technologies. Eric has a PhD from the Max-Planck-Institute for Quantum Optics and has worked several years as an academic researcher in quantum information theory and computing.

Computing with fewer qubits: pitfalls and tools to keep you safe

Austin Fowler
Google

Abstract
Making reliable qubits is hard, so it is important to use them efficiently to perform as much reliable quantum computation as possible. For many architectures, this means using topological quantum error correction (TQEC), and we'll review this fascinating field. Optimizing TQEC is challenging as there are a number of pitfalls that can degrade performance yet are hard to notice without advanced simulation tools. We'll discuss both the pitfalls and the tools to identify them and techniques to avoid them, and present a number of open problems suitable for people new to quantum computing but experienced in programming.

Biography
I am a Google Senior Research Scientist specializing in Quantum Error Correction (QEC). I like practical things: realistic quantum computer architectures, QEC codes that fit on these architectures, detailed analyses of such codes that enable one to calculate the overhead of fault-tolerant computation, and software to help us find and cope with errors in real time and interactively guide the quantum algorithm. My main focus these days is supporting and coding real time QEC software.



Exploring the Quantum Design Space with Circuit Synthesis

Costin Iancu
Lawrence Berkeley National Laboratory (LBNL)

Abstract
Most existing compilers transform quantum circuits using a combination of local peephole optimization and pattern rewriting rules on concrete circuit representations. In contrast, at small scale (three to 12 qubits), unitary based quantum circuit synthesis methods combine search over circuit structures with global instantiation of parameterized circuit representations and they are able to produce “resource” optimal circuits. In this talk I will describe the Berkeley Quantum Synthesis Toolkit (BQSKit) and its scalable topology aware synthesis engine able to to generate resource efficient circuits for programs with thousands of qubits. I will also describe several practical uses: 1) gate set transpilation for program portability; 2) error mitigation using program approximations; 3) algorithm design exploration for Hamiltonian simulation; 4) discovering multi-qubit ansatz generators for classes of algorithms; and 5) hardware design exploration across native gate sets and chip topologies. Hopefully this talk incentivizes the audience to incorporate synthesis into
their quantum program development workflows.

Biography
I am a senior scientist at Lawrence Berkeley National Laboratory, where I've spent a long time working on programming language design and implementation for High Performance Computing. I've always favored finding the simplest solution for a problem and I like writing software that sees use in the community at large. Circa 2019, I started the BQSKit project to develop efficient quantum circuit synthesis, which resulted in a very competitive (and almost production ready) infrastructure, able to compete against commercial quantum compilers. BQSKit has been extensively used both in academia and industry and we have already seen +150K downloads of its software packages. The methods within have received multiple best paper awards. I was very lucky to work with very gifted collaborators: in particular I really appreciate the enthusiasm and dedication of our BQSKit collaborators and users.

Posters

Aqarios Luna: Bridging the Gap from Business to Quantum
Michael Lachner (Aqarios)

Bloqade: Premier Software Development Kit for Neutral Atom Quantum Computing
John Long, Phillip Weinberg (QuEra Computing)

Control Software Stack for Shuttling-Based Trapped-Ion Quantum Computing
Christian Melzer (neQxt)

Demonstrating qBraid's automated quantum software management platform as well as the qBraid SDK, a write-once-target-all quantum device
python package, to greatly reduce friction in quantum software development
Ricky Young (qBraid)

Getting Quantum Ready: A Framework for Exploiting Quantum Computing in Small and Medium-sized Enterprises
Stefan Hillmich (Software Competence Center Hagenberg GmbH)

KQCircuits: An Open-Source Tool for Superconducting Quantum Processor Design
Pavel Smirnov (IQM)

Intel® Quantum SDK: a full-stack approach to quantum computing
Gian Giacomo Guerreschi (Intel)

ParityOS, a universal framework to map optimization problems onto qubits
Stefan Rombouts (ParityQC)

Perceval: A Software Plateform for Discrete Variable Photonic Quantum Computing.
Nicolas Heurtel (Quandela)

Qaptiva – The quantum computing solution by Eviden
Marius Schöndorf (Eviden)

QuCUN - A unified platform for easy access to quantum computing
Sebastian Zielinski, Tobias Rohe (TUM)

QURI - exploration of chemical calculations on quantum computers for classroom use.
Laurynas Vanagas (QunaSys)

Qutritium: A quantum software for qutrit processing techniques
Bao Gia Bach (University of Delaware)

Real-time hybrid quantum classical computations for trapped ions
Tobias Schmale, Daniel Borcherding (Quantum Valley Lower Saxony - Uni Hannover)

Superstaq: Deep Optimization of Quantum Programs
Victory Omole (Infleqtion)

Tequila: An Abstraction, Automation, and Application Framework for Quantum Information Processing
Jakob Kottmann (University of Augsburg)

Thanks!

Organizational Team

Kevin Mato

Aaron Sander

Robert Wille

The Munich Quantum Software Forum would not be possible without the help of the great team at the Chair for Design Automation at the Technical University of Munich! Besides their main job (developing quantum computing software, doing research, teaching, having fun, etc.) they dedicate a lot of effort in setting up the event and making you all feel comfortable!

In particular, special thanks to Kevin Mato and Aaron Sander for their tremendous help in the organization of the event!

Besides that, many thanks to Lucas Berent, Lukas Burgholzer, Jan Drewniok, Philipp Ebner, Maria Emmerich, Stefan Engels, Benjamin Hien, Simon Hofmann, Jagatheesan Kunasaikaran, Tom Peham, Nils Quetschlich, Lorenzo Servadei, Ludwig Schmid, Kathrin Schmöller, Daniel Schönberger, Michel Takken, and Marcel Walter for all the support in the background!

You are the best team someone could wish for! Really great that we pulled this off! :o)