

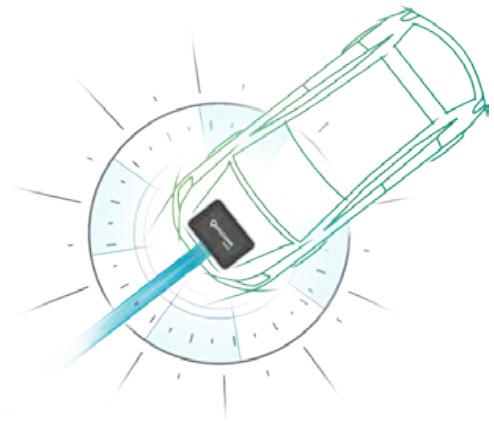
CHARGING AHEAD

By Grzegorz Ombach, Vice President, Engineering
Qualcomm, Munich, Germany



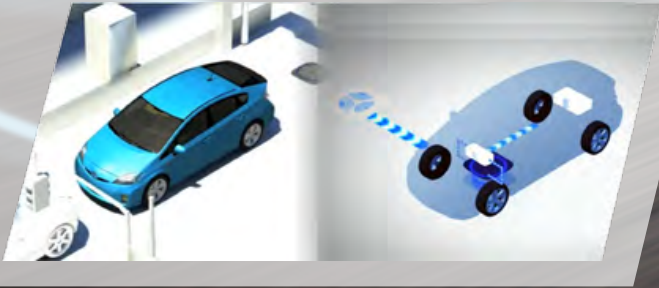
Already a leader in next-generation mobile and wireless technologies, Qualcomm Technologies, Inc., a subsidiary of Qualcomm Incorporated, is using a unique research and development approach to tackle a new frontier: wirelessly charging electric vehicles.

Qualcomm Incorporated, a global leader and innovator in wireless and mobile technologies, is committed to breakthrough innovation. In fact, Qualcomm spent \$5.5 billion on research and development in wireless and mobile technologies in 2014 alone — and \$34 billion over the company’s life. Qualcomm licenses its developed technologies across a broad range of organizations to help diverse suppliers deliver real value to their customers. Because Qualcomm is a “fabless” business with limited production capability to manufacture products, its sole focus is on driving extreme innovation via research and development.



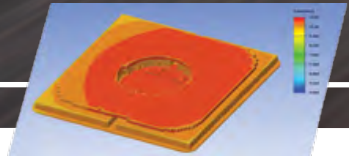
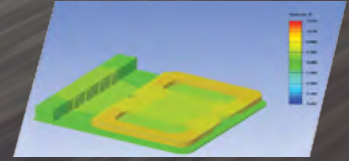
Founded as a startup 30 years ago, in many ways Qualcomm still has the culture of an agile, entrepreneurial company. New employees are hired based not only on their skill sets, but on their commitment to innovation, their passion for what they do, and their aptitude for collaboration and teamwork. These qualities are assessed during a 360-degree job interview process that includes meetings with managers and peers, and direct reports.

A flattened organizational structure makes it easy for employees to contribute ideas and have their voices heard. Risk-taking is encouraged, and mistakes are considered a necessary part of the creation process. One of the underlying philosophies at Qualcomm is: “Make a mistake by throwing the ball away — not by holding on to it too long.”



Qualcomm expects easy-to-use wireless electric vehicle charging to become the way all EVs are charged in the future.

Simulation of temperature distribution for the wireless electric vehicle charging pad helps Qualcomm to innovate in developing this technology.



Wireless Electric Vehicle Charging: The Next Frontier

Qualcomm has leveraged this risk-taking philosophy to develop universal and ubiquitous wireless charging solutions for mobile handsets and portable consumer electronics devices. Today, the company is turning its attention to developing broader applications for its wireless charging technology.

Wireless charging is about to take a huge leap in scale, as kilowatts can now be transferred efficiently over an air gap of hundreds of millimeters. The Qualcomm Halo business unit, part of Qualcomm Technologies, Inc., which is a subsidiary of Qualcomm Incorporated, focuses on research and development that will capitalize on these charging improvements – resulting in the market launch of Qualcomm’s innovative Qualcomm Halo™ wireless electric vehicle charging (WEVC) technology for passenger vehicles.

With about 70 percent of the world’s population expected to live in large cities by 2050, electric vehicles hold great promise for minimizing the footprint of service stations and decreasing emissions in urban areas. However, these vehicles will not be fully embraced by consumers until charging them becomes much easier and more convenient. The Qualcomm Halo business unit was founded in 2011 to address both technology and ease-of-use challenges, with the goal of making this vision a reality.

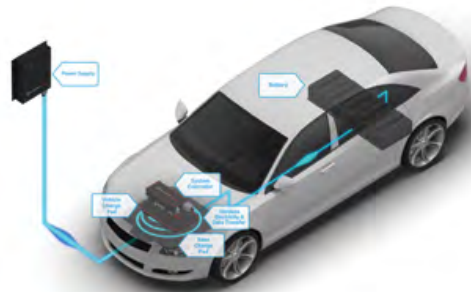


The first consumer product based on Qualcomm Halo’s wireless electric vehicle charging technology is currently expected in the next two to three years.

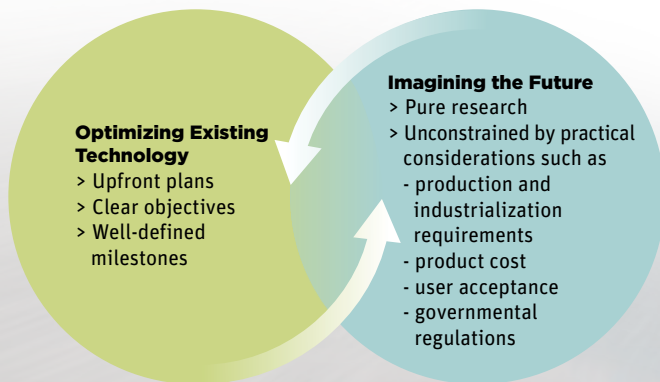
In collaboration with Auckland UniServices – the commercialization office of the University of Auckland, New Zealand – the Qualcomm Halo business unit has developed a complete wireless-charging system, including both power-transfer and ancillary technologies for safety and positioning. A final product based on this technology is currently expected to be launched in the next two to three years. With the basic research and development completed for this first-generation system, the Qualcomm Halo business unit has now formed three engineering teams with very different goals.

One team, headquartered in Munich, Germany, focuses primarily on making the incremental improvements and technology customizations that will lead to broad adoption of the first-generation Qualcomm Halo WEVC technology. The second team, based in Zurich, Switzerland, is more visionary – imagining the state of passive vehicle charging in about five years. And the final team, headquartered in Auckland, is a true think tank that focuses on the wireless charging innovations that might revolutionize the global auto industry a decade from now.

The company is turning its attention to *developing* broader applications for its *wireless charging* technology.



Why has the Qualcomm Halo business unit implemented this three-pronged approach to product development? Qualcomm's long history in consumer product innovation has taught the company that incremental product improvement and clean-sheet, visionary innovation require different skill sets and work processes. For example, while engineering simulation is a common tool for all teams, it is used very differently by engineers in Munich than by those in Zurich and Auckland.



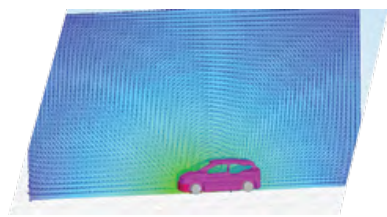
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Munich: Optimizing an Existing Technology

Qualcomm Halo's research and development team in Munich is very similar to the engineering organization in most companies. These engineers, representing more than 20 different nationalities, are experts in practical problem-solving. They apply engineering simulation to solve a range of real-world problems that will pave the way for the launch of the WEVC systems based on Qualcomm Halo WEVC technology. The national diversity of this team is critical, as the trio of Qualcomm Halo business units wants to ensure engineering support and cooperation with the technical teams of Qualcomm Incorporated's licensees.

The Munich team is guided by upfront plans, clear objectives and well-defined milestones. Because they are solving practical problems that relate to automotive design, engineering and production, many of these engineers have years of prior experience in the automotive industry. They understand manufacturing constraints and cost controls. They interact directly with existing and potential licensees of the Qualcomm Halo WEVC technology to understand and address their real-world concerns.

Qualcomm's sole focus is on driving *extreme innovation* via research and development.



The Qualcomm Halo team in Munich simulated the magnetic field distribution around a vehicle during stationary charging.

Before WEVC systems can be released for use in residential garages and public parking lots, a number of specific questions must be answered with an extremely high degree of confidence. For example, what are the safety aspects of the electromagnetic field generated by the charging pad while in use? What if a metal object — such as a coin — is dropped onto the base pad's surface? Could such an event generate sufficient thermal buildup to start a fire or to burn someone who retrieves the object?

The Munich team leverages engineering simulation at a very granular level to understand and solve these kinds of very specific problems. Obviously, any wireless technology must be proven safe for humans and animals before it can be launched into the world — and simulation, together with laboratory testing, supports the risk-free study of relevant compliance issues.

Other issues the Munich team is studying include creating interoperable solutions for diverse vehicles. WEVC technology must be adapted so that it is compatible with many vehicle types — for example, both sports cars and SUVs. In addition, the cost of the complete solution for charging must be minimized. For these and other challenges, engineering simulation is providing an easy, rapid way to get answers, troubleshoot any remaining issues, and speed the launch of the Qualcomm Halo WEVC system.

Because there are so many complex issues to consider, and much of the development work is at the system level, it would be impossible for the Munich team to develop the Qualcomm Halo technology rapidly without the use of engineering simulation.

Zurich and Auckland: Imagining the Future

The Qualcomm Halo development teams in Zurich and Auckland are envisioning what WEVC technology might look like in five or 10 years. These teams work in a “pure research” environment; they include many Ph.D.s who have spent their careers at universities or in research labs. These engineers are less constrained by practical considerations such as production and industrialization needs, product cost, user acceptance and governmental regulations. They have minimal direct interaction with Qualcomm Halo licensees, who might see their visionary ideas as impractical or cost-prohibitive in today's world.

The Swiss team is looking for various ancillary technologies, such as safety and guidance systems, which might help drivers make optimal use of wireless charging stations. The Auckland engineers are studying how WEVC technology might be embedded in roadways, so that vehicles are charged continuously as they move around urban areas. In doing so, the team investigates a variety of modes for embedding the charging stations — should they be buried? Placed on the road surface? Or flush mounted? Simulation helps these researchers examine the implications of each type of installation against a variety of



parameters: human exposure to a magnetic field, charging performance, cost and other considerations. In addition, the Auckland team is imagining the advent of futuristic automotive developments such as autonomous vehicles — and studying how dynamic wireless charging might play a role.

Both the Zurich and Auckland teams rely on engineering simulation because Qualcomm firmly believes that simulation must be injected into all stages of product development — from conceptual design to detailed engineering. However, the Zurich and Auckland teams work at a very high level, taking a systems perspective. Then, as a product idea moves through development, the engineers drill down toward more practical questions. The issues transform from “Can we embed chargers in the roadway?” to “Can we embed chargers in the roadway in, for example, London?” Simulation has proven effective in helping these teams to answer big-picture questions as well as study very specific details.



As the ideas developed in Zurich and Auckland become more feasible — and actual technologies are considered for transfer to licensees for production — these projects will be handed off to the engineering organization in Munich. There, the finest details of final product performance, production and real-world applications will be hammered out, allowing

Qualcomm Halo to take advantage of the strengths of its multi-pronged engineering approach.

Encouraging Collaboration and Teamwork

The three research and development teams at the Qualcomm Halo business unit report to a single manager who monitors their progress, encourages collaboration as needed, and manages project handoffs. Originally, all Qualcomm Halo engineers met once annually to share their progress toward making WEVC a reality. But today, the global engineering team benefits from more frequent, informal discussions.

Qualcomm Halo engineers from around the world meet on a weekly basis via an online forum called the “coffee break.” Via phone or video conferencing technology, these engineers share simulation results, engineering drawings or PowerPoint® slides with their peers. Qualcomm Halo coffee breaks are aimed at solving practical problems, establishing best practices, and supporting continual improvement. For example, one engineer’s recent suggestion about upgrading a set of office applications on all the desktops led to a 30 percent reduction in simulation processing times for the entire global team.

About Grzegorz Ombach



Dr. Grzegorz Ombach is vice president, Engineering, at Qualcomm, with responsibility for research and development

of Qualcomm’s wireless electric vehicle charging technology. Ombach joined Qualcomm in April 2012 from Brose Fahrzeugteile, where he managed the design of automotive electric drive systems as director of Advanced Development Drives. He holds an M.Sc. in Electrical Engineering from the Technical University of Lodz, Poland, and a Ph.D. in electrical engineering from the Silesian University of Technology, Poland. Ombach has authored more than 70 papers and holds more than 25 patents (awarded and pending) on various automotive electrical systems.

Qualcomm firmly believes that *simulation* must be injected into all stages of *product development* – from conceptual design to detailed engineering.




Qualcomm works with automakers and their suppliers to offer WEVC systems that are optimized for each vehicle and that meet their critical design criteria.

These informal meetings reinforce Qualcomm's entrepreneurial culture by demonstrating that every employee's input is valuable. No matter what their role or location, all Qualcomm Halo engineers are invited to join these weekly roundtables and have their voices heard.

Bringing the Future Closer Every Day

At Qualcomm, making WEVC a reality is an exciting mission in which employees are proud to participate. Qualcomm has worked hard to create an elite engineering organization that is committed to keeping WEVC technology development on track by leveraging best-in-class technology tools and best practices in simulation. Qualcomm's corporate goal is to bring the future closer every day, and the Qualcomm Halo business unit is most certainly aligned with that objective.

While it's an expensive proposition to have three distinct research and development teams, in Qualcomm's view this approach is essential to maintaining technology and market leadership over the long term. Nearly every company looks at a two- or three-year horizon, focusing on near-term market launches. But Qualcomm believes that true leadership will be achieved only by those who take a longer view and begin acting on that vision today.

Looking over a 10-year horizon requires patience. Many ideas will be considered and rejected – a process that goes much faster with simulation but is still a time-consuming endeavor. However, in the end, the rewards are well worth the investment. 

Qualcomm at a Glance

- ➔ **2014 revenues: U.S. \$26.49 billion**
- ➔ **Number of employees: 31,300**
- ➔ **Headquarters: San Diego, California, U.S.A.**

QUALCOMM HALO™

