HISTORY IN THE MAKING

Driving the RF SOI Revolution
The Peregrine Semiconductor story is about many things. It is about a willingness to take risks, diligence, innovation, hard work and the nurturing of strong partnerships. It is the story of the founders’ ability to look forward and understand what would be important tomorrow - the ability to “read the tea leaves” if you will. It is the success story of a semiconductor company that accomplished what the industry thought was impossible, and now leads the market today as a communications company.

During the 1970s a battle was waged between analog and digital to determine the optimum method of electric signal distribution of information. Digital won in 1975 and took over everything through the 70s, 80s and 90s, driving a literal digital revolution. Computing power followed Moore’s Law – named after Intel co-founder Gordon E. Moore – which states that the number of transistors on integrated circuits doubles approximately every two years driving exponential improvement in performance. The digital revolution drove digital electronics into nearly every segment of the world economy. The semiconductor market on its own is relatively small, but the markets it drives are immense. Today, global semiconductor industry revenues exceed $300 billion annually, but it is the semiconductors’ capabilities that drive the global trillion dollar electronics industry. In the U.S. alone, the semiconductor industry, one of the country’s top exports, directly employs nearly 250,000 people, and the industry supports more than one million additional jobs.

In the late 70s, Peregrine’s founders began diligently solving the technical challenges and overcoming the barriers required to make advanced SOI (silicon on insulator) commercially feasible. Their research initially focused on a sapphire substrate, known by the industry
as SOS (silicon on sapphire). SOS, in spite of showing great promise, was demonstrating manufacturing problems that had led the other semiconductor companies to abandon further development of the sapphire substrate. While the rest of the industry deemed it impossible, the founders persisted, and after years of research and development, the “aha moment” came. In 1988, Peregrine founders Ron Reedy and Mark Burgener and colleague Graham Garcia published a research paper that would serve as the foundation for Peregrine’s UltraCMOS® technology, a patented advanced form of SOI.

Peregrine’s strength in sapphire substrates offered a clear advantage. Sapphire did not interfere with RF signals. With radios driving the advancement of wireless communications, Peregrine’s continuing development of the UltraCMOS technology was evolving to address the critical integration requirements for communications device development.

Today, Peregrine’s technology provides critical communication pathways for devices used around the globe and beyond, from the Mars Rover to the iPhone. Peregrine chips have traveled to every planet except Uranus. Handheld devices daily deliver conversations and critical data using a Peregrine chip. The critical communications channels used by our first responders and military rely on the performance of Peregrine’s chips in their devices and networks.

As the story continues to unfold, Peregrine announces the shipment of its two billionth chip and the release of UltraCMOS 10 technology, their newest integrated RF solution. With an eye always to the future, the 25 years of Peregrine innovation we describe here will surely be the springboard to the next 25.
The “Aha Moment”

In January 1988, Ron Reedy, Mark Burgener and Graham Garcia, researchers at the Naval Ocean Systems Center (NOSC), published their advanced SOI (silicon on insulator) research findings in the IEEE Electron Device Letters in a paper titled: “High Quality CMOS in Thin (100 nm) Silicon on Sapphire”. The findings in this paper unveiled the value and potential of sapphire as a substrate. This paper also served as the foundation for the continued research and development for Peregrine’s UltraCMOS technology. As the paper’s abstract notes, “These results indicate that DSPE-improved SOS films thinned to 100nm are suitable for application to high-performance down-scaled CMOS circuitry.”

1 gallon of gas: 91 cents
Movie Ticket: $3.50
US Postage Stamp: 24 cents
Dozen Eggs: 65 cents

CDs outsold vinyl records for the first time.
Motorola introduced the first flip phone.
The Berlin wall came down.

1988

1989
Peregrine Opens Its Doors

In 1990, Peregrine became a reality for founders Ron Reedy, Mark Burgener and Rory Moore. With Reedy and Burgener responsible for advancing the technology, Moore provided the startup capital and took on the role as the company’s first CFO responsible for finance, business development, marketing and human resources. He also led the funding efforts of the early investor rounds, which totaled more than $18M from friends and families of the founders.

In February of 1990, the company incorporated in Delaware, and in March, the name Peregrine Semiconductor became official. For the first half of the year, Peregrine conducted reviews with Intel, Motorola, HP, UC and others. In June, Peregrine obtained the fundamental UltraCMOS patent from HP and Caltech. In August of that year, the Cooperative Research and Development Agreement (CRADA) was submitted to the Naval Ocean Systems Center (NOSC). The company continued to focus on development of the business plan and refining the market analysis required to move the venture forward. They also continued development of a 6” wafer.

“I had a tenured government job, six weeks of paid vacation, a pension and a lab full of expensive equipment, but I also had this entrepreneurial spirit and a hunch that we could accomplish something great.”

Ron Reedy, co-founder of Peregrine

A space shuttle placed the Hubble Space Telescope in orbit.

The first in-car satellite navigation system was sold.
Commercializing the Technology

The CRADA submitted to NOSC was signed in 1991. This marked the launch point of Peregrine’s commercialization of the UltraCMOS technology. This spirit of cooperation represented NOSC’s willingness to allow businesses outside of the Federal Government to advance the development and application of unique technologies. This agreement enabled the development of integrated circuits using thin-film silicon on sapphire (TFSOS) sub-micron device technology. Research with TFSOS began in 1979 at the NOSC Microelectronics Lab. “We are now recognized as the world leader in TFSOS technology,” said Dr. Isaac Lagnado, senior staff scientist of the Marine Sciences and Technology Department at NOSC. “Peregrine will be seeking to develop specific applications of commercial value for this technology.

The world’s first commercial GSM call was made on July 1, 1991 over a Nokia-supplied network.
**Strategic Partnerships**

Co-founder Mark Burgener pulled together a top-notch team that worked on transferring the R&D technology to mainstream production. This included developing a technology that was simple to transfer and managing the relationships between Peregrine and the fabs. In 1991, Peregrine established a partnership with Union Carbide, the world’s leading supplier of silicon on sapphire wafers. Over the next few years, Union Carbide would work with Peregrine on developing a 6” wafer. In 1993, Peregrine selected IBM as its fab, and the UltraCMOS process was successfully installed at IBM’s Rochester, MN facility.

“Now that we had the technology, we needed to determine what exactly we would accomplish.”

Mark Burgener, co-founder of Peregrine

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**The Communication Revolution**

In 1993, at the annual Consumer Electronics Show (CES) – the showcase event for emerging technology – Ron Reedy challenged his team to observe and document the use of portable computers versus cell phones amongst the attendees at the show. When the results were tallied, the data demonstrated a sea change - cell phone use outpaced computer use by 30:1. The digital revolution was moving to the next phase of evolution – the communication revolution. Wireless communication was the future, and Peregrine was poised to be a leader.

On July 12, 1993 Peregrine filed its first UltraCMOS patent. Over the next 20 years, Peregrine would file more than 150 new patent applications.
**Peregrine Selects a New Fab**

In 1994, Peregrine selected Asahi Kasei Microsystems (AKM) as its new fab. The AKM Nobeoka wafer fabrication facility began its operation in 1993, and AKM Semiconductor Inc. was established in San Jose, Calif. in 1995. In January of 1996, Peregrine signed a six-year fab agreement with AKM.

Peregrine and Xilinx signed a licensing agreement allowing Peregrine to manufacture and sell its own three-volt, UltraCMOS versions of Xilinx’s XC3000 field programmable gate array family. This was the first demonstration of UltraCMOS technology for digital applications.

**First Chip Delivery**

In August 1995, Peregrine hand-delivered the first 100 chips of its first product, a 2.5 GHz fractional-N frequency synthesizer chip, to Tony Mauro and Bar-Giora Goldberg, CTO at Sciteq Electronics. Peregrine had begun a strategic relationship with Sciteq Electronics in early 1994, and the chip design had been finalized in November 1994.

"My entrepreneurial history and spirit spurred me to take on this challenge—bringing a brand new technology and new products to market. But it was quite the challenge. It’s amazing Peregrine succeeded."

Mark Burgener, co-founder of Peregrine

**Peregrine Expands Executive Team**

In 1996, the executive team at Peregrine was enriched with the addition of Jim Cable as VP of Technology and Operations. Jim, Peregrine’s current CEO, joined the team from Hughes Microelectronics Center where he managed the technology and fab operations for the company.
THE WORD IS SPREADING

In the June 29, 1997 issue of BusinessWeek Magazine, Peregrine was featured in a story about the future of very small communications devices. The communication revolution was alive and well, and Peregrine remained poised to make a significant contribution. The discussion around the “micro communicator” was growing.

And that was just the beginning. Vertical industry publications were talking about the technology innovation; business publications were talking about the applications. Headlines included:

June 2, 1997: EE Times “Sapphire-substrate process applied to SOI”
July 6, 1997: The Sunday Times Business “Sapphire chips cut the size of phones”

And local media outlets were beginning to recognize the results. As the U-T San Diego explained in an August 1997 article on “San Diego’s Cool 25 for 1997”:

Peregrine likes to call itself the “Microcommunicator Company”...already Peregrine has been able to reduce the 7-to-10 chips found in a mobile phone to a single chip that uses a tenth of the power to operate.

TINIER PHONES STUDDED WITH CHIPS OF SAPPHIRE WRISTWATCH COMMUNICATORS could finally become a reality, thanks to new technology from startup Peregrine Semiconductor Corp. The San Diego-based company has perfected a process to build ultrathin silicon chips on a base of pure sapphire.

Unlike semiconductor bases, which allow some electricity to pass through (hence the name--they semi-conduct), the sapphire layer is nonconductive. That means that radio frequency and logic circuits that previously had to be built in separate chips because they interfered with each other can now be crammed side-by-side on a single chip. Peregrine has licensed the technology to a Japanese chipmaker, and the company predicts that by next year, such chips could lead to cheaper satellites and mobile phones. By 2001, the technology should enable the making of tiny portable communicators, such as Dick Tracy-style wristwatch phones. Watch out, Pruneface! EDITED BY CATHERINE ARNST Andy Reinhardt

The world met Dolly the sheep, the first mammal to be cloned from cells of an adult animal.

Google founded.
**1999**

**Going Where No Man Has Gone Before**

To expand European operations, Peregrine opened Peregrine Semiconductor Europe in 1999.

The PE9601 became the first Peregrine product in space. It was launched by NT Space (then NEC). This would be the first of many Peregrine products that would find their way into space – reaching every planet except Uranus.

![Image of solar system with planets](image1.png)

*The first full internet service on mobile phones was introduced in Japan by NTT DoCoMo.*

**2000**

**New Products, New Fab, First Million Piece Order**

In 2000, Peregrine launched the PE4120, the world’s most linear MOFSET quad mixer. In the same year, Peregrine acquired a wafer fabrication facility in Sydney, Australia with the goal of significantly increasing production capability for their highly integrated radio frequency synthesizer and transceiver chips for wireless customers. The company also shipped its first million piece order to MiniCircuits. This was the first order shipped from the newly acquired Australian fab facility.

![Image of PE4120](image2.png)

*The dot-com bubble burst.*

**2001**

**Fully Integrated Switches, New Business Unit, Making the Investment**

In 2001, Peregrine shipped its first RF SOI fully integrated switches – the PE4210/20/30 for cable TV, military and other markets out of the newly acquired Australian fab facility. The company also announced that year that it had completed construction of its clean room upgrade to enable the fabrication of .25 micron integrated circuits in its Australian fab.

The U.S. Defense Microelectronics Activity selected Peregrine Semiconductor to supply advanced process technology for radiation hardened integrated circuits. The contract was valued at $4.8 million.

![Image of PE4210/20/30](image3.png)
**New Products, New Partners**

After years of success in the military and aerospace markets, Peregrine formally formed the Space and Defense Business Unit to address the increasing interest and business opportunities being presented in that market segment. The unit was led by Ron Reedy.

That same year, the company introduced the industry’s highest performance PLL synthesizers with embedded EEPROM field-programmable memory – the PE3341 and PE3342. The company also entered into a strategic UltraCMOS partnership agreement with Oki Electric.

**Heading to Mars**

Equipped with a Peregrine PLL, the Mars Express Orbiter from the European Space Agency began its journey 400 million miles into space in 2003.

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The United States Department of Homeland Security officially began operation.

The Spirit Rover launched, beginning NASA’s Mars Exploration Rover mission.

Euro notes and coins were first circulated.
Entry Into Handsets

In 2004, Peregrine entered the handset market and in August, introduced the world's first high power, high linearity, fully integrated RF SOI UltraCMOS flip-chip SP4T handset switch for dual-band GSM handsets – the PE4261. Through advanced packaging technology, the fully integrated RF UltraCMOS handset switch reduced the printed circuit board (PCB) area by a factor of nine when compared to conventional wire bonding.

The company also announced an RF switch for broadband applications that exceeded the strict FCC 15.115 regulations.

In 2004, Peregrine introduced the world’s first single chip digital step attenuator (DSA), the PE430x (1-6) family. These DSAs were the most linear, most accurate RF CMOS DSAs available and were the best chips of its kind for nearly a decade.

The Rosetta Space Probe from ESA launched in March 2004 carrying Peregrine radio control chips. The probe will rendezvous with the 67P/Comet Churyumov-Gerasimenko. The trip to the comet will take 10 years to accomplish and then it will spend two years actively investigating.

In 2004, Peregrine continued to expand its extensive IP portfolio with the issuance of the first patent in the RF switch family.

HARP™ Another Breakthrough for Handsets

In October 2005, Peregrine introduced the patented HARP™ design technology enabling dramatic improvement in harmonic performance, linearity and overall RF performance. This breakthrough would continue to offer significantly differentiated performance for Peregrine products in the years to come.

In 2005, the Peregrine PE4305 and PE4306 were in mass production.

YouTube, the popular Internet site on which videos may be shared and viewed by others, launched in the United States.

Microsoft released the Xbox 360 gaming console.
**Heading to Pluto**

In 2006, Peregrine was selected by the European Space Agency to develop the first PLL device that would be integrated in European space applications. In April, ESA launched the Venus Express with Peregrine parts.

NASA’s New Horizons space vehicle equipped with Peregrine parts was launched for Pluto with an anticipated arrival date of July 2015. The journey will take New Horizons past Mars, Jupiter and Saturn.

**Rewarded for Innovation**

In August 2007, Peregrine Semiconductor was recognized by Frost & Sullivan for their commitment to innovation and global excellence with receipt of the 2007 Global Wireless Radio Frequency Emerging Technology of the Year Award.

**Mobile Antenna Tuning**

Peregrine announced the UltraCMOS DTC technology for mobile antenna tuning in 2008. Peregrine’s digital tunable capacitor (DTC) technology provided a solution to one of the biggest challenges in RF design — antenna impedance matching. Peregrine’s UltraCMOS DTC technology became the ideal solution for both cellular and mobile TV applications. In February, Peregrine filed the patent for digitally tuning a capacitor in an integrated circuit device.

With two critical Peregrine chips inside, Motorola announced multi-band two-way radios for first responders.

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**2006**

Google acquired YouTube for $1.65 billion in stock.

**2007**

Apple released the first generation iPhone.

**2008**

The first Android-powered phone was sold.
**The Return of Hayabusa**

In May 2003, the unmanned spacecraft Hayabusa (literal translation from Japanese is “Peregrine Falcon”) carrying Peregrine chips for the radio control was launched to asteroid Itokawa by the Japanese Space Agency. In June 2010, the craft returned carrying space dust from the asteroid for scientific investigation.

Peregrine partnered with Soitec to develop the new bonded SOS substrate that was qualified for use in manufacturing Peregrine’s next generation STeP5 UltraCMOS RF IC semiconductors.

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**Big Number, Big Milestones**

2011 was a milestone year for Peregrine. The company won several awards and announced multiple industry-leading products, but the biggest announcement in 2011 was when Peregrine shipped its one billionth chip.

For test and measurement applications, Peregrine announced an SPDT device that operated from 9kHz to 6.0 GHz. The RF switch was used by Rohde & Schwarz in the R&S SMA 100A signal generator.

NASA launched a one-way mission to Jupiter. With an anticipated arrival date of July 4, 2016, the Juno mission, equipped with a Peregrine PLL, will orbit Jupiter 33 times and then intentionally self-destruct into the planet.

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Apple released the iPad.

Super Bowl XLIV – New Orleans Saints defeated the Indianapolis Colts 31-17 to win their first super bowl.
IEEE Recognizes Peregrine Founders

Peregrine founders, Mark Burgener and Ron Reedy, received the Daniel E. Noble Medal for Emerging Technology from the IEEE in 2011. The following is taken directly from the IEEE publication announcing the award and chronicles the challenges faced, and overcome, to bring silicon on sapphire technology to market as a viable commercial product:

The persistence and contributions of Mark L. Burgener and Ronald E. Reedy overcame barriers to make silicon on sapphire (SOS) technology commercially feasible for wireless communications. Drs. Burgener and Reedy stood by SOS technology that, despite great promise, had initially been abandoned by semiconductor market leaders. First discovered during the 1960s, SOS technology presented manufacturing problems that prevented companies from pursuing commercialization. The efforts of Drs. Burgener and Reedy during the 1980s and 1990s overcame these obstacles, making SOS commercially viable for producing integrated circuits with improved speed, lower power consumption, and more isolation compared to bulk silicon circuits. Even after demonstrating viable SOS circuits, the pair had to erase the stigma associated with the earlier problems. They co-founded Peregrine Semiconductor in 1990 to spur their commercialization efforts. They developed the UltraCMOS process, which solved critical manufacturing issues and made SOS cost-effective. After an initial shipment of 100 chips in 1995, today Peregrine has sold over 500 million UltraCMOS integrated circuits. Both IEEE Members, Dr. Burgener is vice president of advanced research and Dr. Reedy is the chief operating officer at Peregrine Semiconductor Corporation, San Diego, Calif.

That same year, Argonne National Laboratory was awarded the R&D 100 Award for an Integrated RF MEMS Switch/CMOS Device. Peregrine was credited and cited as a co-developer/contributor to this award-winning technology.
**Peregrine Goes Public**

On August 8, 2012, Peregrine stock began trading on the NASDAQ under the ticker symbol “PSMI.” The IPO raised $77 million dollars as the company sold 5.35 million shares at $14 each. Peregrine CEO Jim Cable rang the opening bell of the NASDAQ on Nov. 27, 2012.

**Continuing to Lead the Soi Revolution**

In 2013, Peregrine signed a collaborative sourcing and licensing agreement with Murata Manufacturing Company, the leading supplier of RF front-end modules for the global mobile wireless marketplace.

Today, Peregrine, the founder of commercialized RF SOI, continues to revolutionize the industry with high-performance, integrated RF solutions. The company offers industry-leading products for market leaders in aerospace/defense, automotive, broadband, energy management, industrial, mobile devices, test and measurement equipment and wireless infrastructure.
Celebrating 25 Years of Continued Innovation

As Peregrine celebrates their 25-year anniversary, they share with the world two landmark announcements:

2 Billion Chips

A few short years after shipping the first billion units, Peregrine has reached the two billion chip mark. The two billionth chip was shipped in an order to Murata Manufacturing Company.

Accelerating RF Front-End Design with UltraCMOS 10 Technology Platform

Peregrine announces UltraCMOS 10 technology, once again setting the worldwide performance standard for RF CMOS. UltraCMOS 10 technology platform delivers both flexibility and unparalleled performance for addressing the ever-increasing challenges of RF front-end design. Peregrine’s latest update delivers the performance of the UltraCMOS technology with the economies of SOI and delivers a 50-percent performance improvement over comparable RF SOI processes.

Peregrine is enhancing a long-term relationship and leveraging a new one for the UltraCMOS 10 technology introduction – Soitec’s revolutionary semiconductor materials coupled with tier-one fab GLOBALFOUNDARIES’ custom fabrication flow.

Peregrine’s versatile, new 130 nm UltraCMOS 10 technology can deliver the support needed for the latest generation of LTE-Advanced smartphones and, for the first time, will allow the company to deliver cost-competitive products for 3G smartphones.