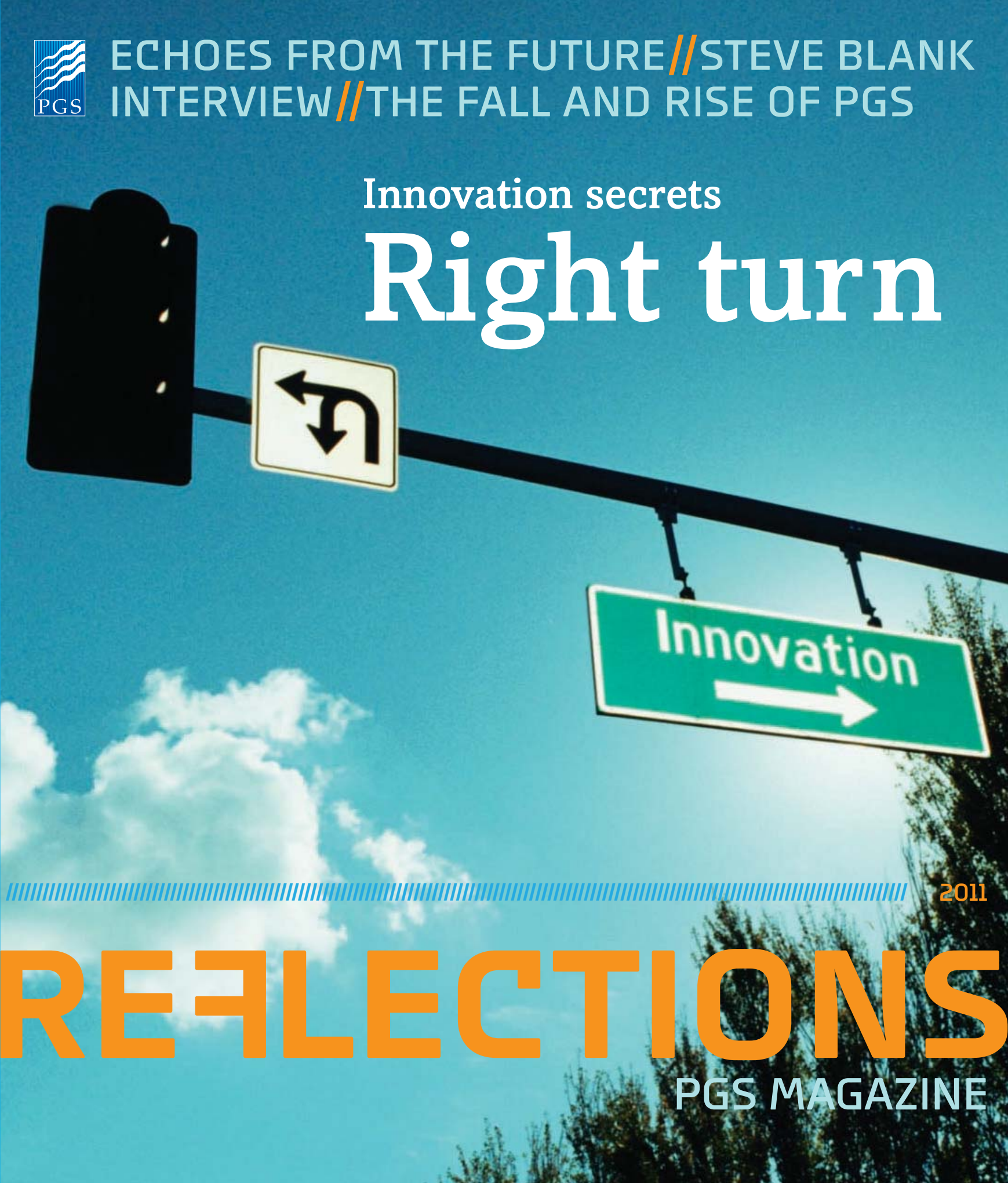
ECHOES FROM THE FUTURE//STEVE BLANK INTERVIEW//THE FALL AND RISE OF PGS

Innovation secrets

Right turn



2011

REFLECTIONS

PGS MAGAZINE

CONTENT
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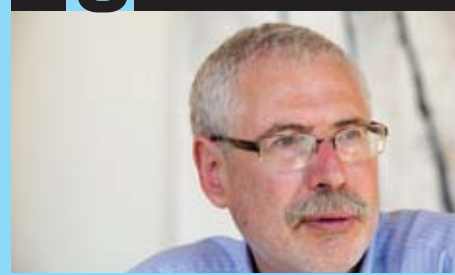
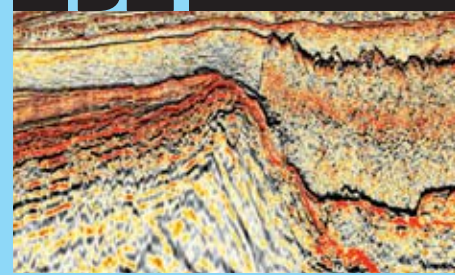
What lessons can we learn from the cradle of modern technology innovation?

Wonder boy Steve Blank has been involved in 8 start ups and learned from each of them.



Great minds don't always think alike. What's next on the development path for seismic technology?



The first 20 years of PGS history have been bumpy but far from dull. A story by three very different PGS CEOs …

Welcome to a new issue of Reflections. This time our focus is on innovation: how does it spawn, evolve and function and where will it take us next?

REFLECTIONS ON INNOVATION

This year has seen a lot of upheaval around the world. The basic laws of physics have been challenged at CERN in Switzerland, regimes have fallen in the Middle East, currencies are at risk. Must new ideas be spawned out of chaos? Is the process opportunistic and honed by failure, or can innovation be industrialized? We take a trip through Silicon Valley and talk with some of the hands that have rocked the cradle of modern technology.

Innovate or die, the adage says. PGS has tried both. Meet its three very different CEOs: Reidar Michaelsen, Svein Rennemo and Jon Erik Reinhardsen. We follow the thread of innovation through its 20 year history – from boom in the nineties, near-death at the millennium, to today's thriving hothouse of technology – and ask what kind of management style favors the development of new ideas?

Is seismic technology reaching the end of its development road? What disruptive step changes might we see in exploration methods going forward? Our research panel puts on its thinking caps to explore the future.

Modern HSEQ is about more than monitoring and measuring past mistakes. How can we get better at predicting and preventing accidents before they happen?

We hope that you enjoy the magazine and look forward to your comments and feedback, as usual.

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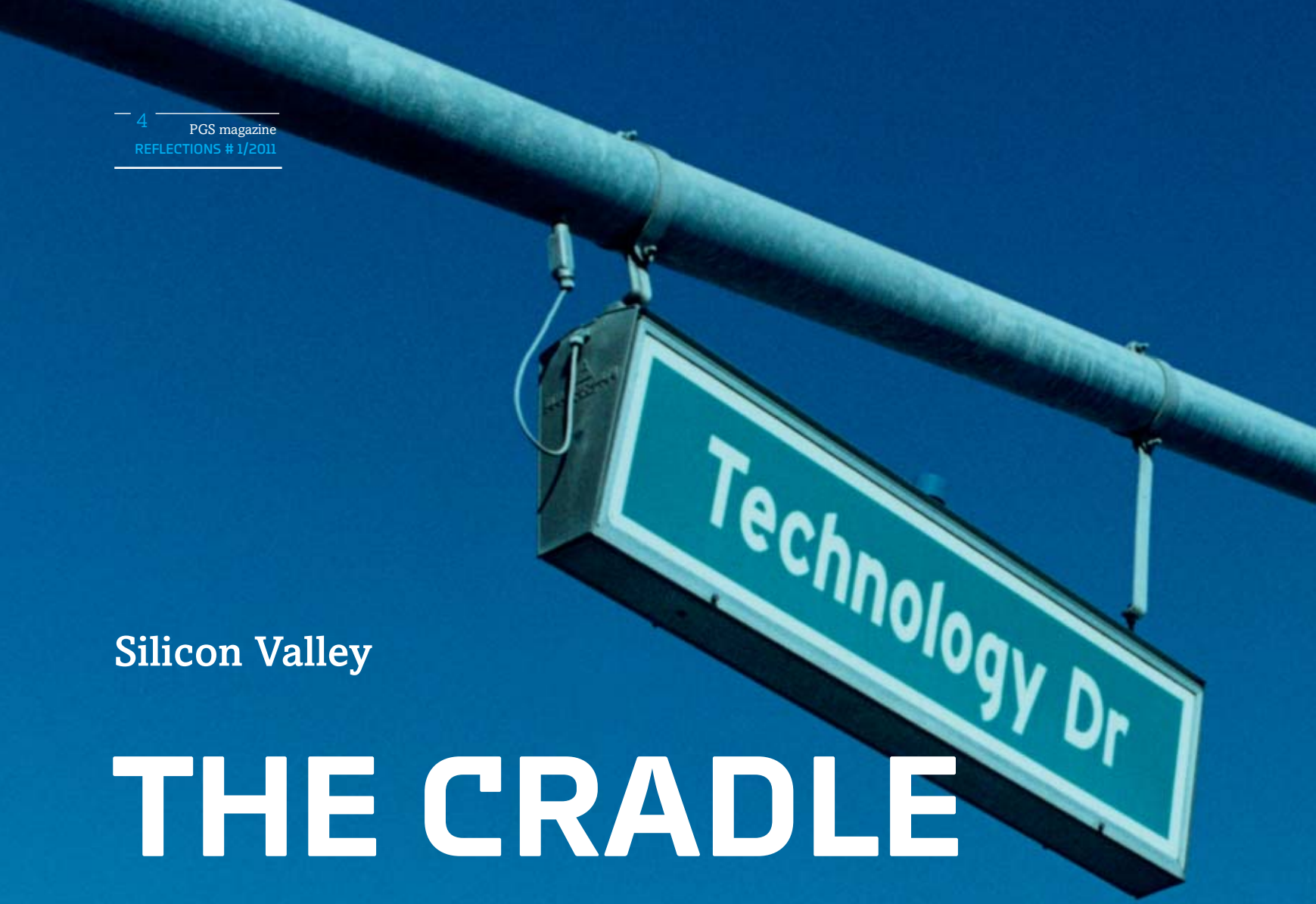

Silicon Valley

THE CRADLE OF IDEAS

AUTHOR: STEIN ARNE NISTAD **PHOTO:** BRUCE T. BROWN/GETTY IMAGES, STEIN ARNE NISTAD

Silicon Valley and San Francisco have long been hallowed ground for adventurers and fortune hunters. For the last sixty years, the area has been the world's richest seam of innovation and technology. What is the secret of its ongoing success?

Long before Apple was an icon, Silicon Valley was a land of fruit farms. This fertile valley stretches from the city of San Francisco along the bay to San Jose. Its crop of innovations and technology companies is overwhelming. It all started with Hewlett Packard in the middle of the 20th century. Today Apple, Facebook and Google have their HQ here. They head a list of technology companies that is already a mile long and still growing. Silicon Valley is a giant incubator for IT innovation. Despite many attempts, few have succeeded in replicating the cutting edge of the Bay area elsewhere. Is it the soil and the sunshine, or San Francisco's legacy of "foreigners, freewheelers, bohemians and adventurers?"

Treasure hunters

San Francisco is a magnet for freethinkers and alternative lifestyles. Two hundred and thirty years after the mission of St Francis was built at Golden Gate, the city is a melting pot of cultures and populations, not simply confined to its two universities. In 1849 the gold rush attracted adventurers from all over the continent. Despite devastation by fires and the great earthquake of 1904, the city has evolved and continued to grow in size and significance. Today the population is over 7 million. Its geographical surroundings are stunning. To the north are the lush, loamy

1 Clint Eastwood: actor, storyteller and former mayor of Carmel-by-the-Sea, south of Silicon Valley.

2 Golden Gate Bridge (1937) has been declared one of the modern Wonders of the World – and is in many ways a metaphor of the gateway to success and failure in Silicon Valley and the bay area.

3 Silicon Valley is probably still the most important place in the world when it comes to technology innovations.

In the San Francisco gold rush, fortunes were won in a week and squandered in a fortnight. Easy come, easy go still reigns.

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wineries of Napa Valley. While the southbound route down Highway 1, through the national park of Big Sur, is one of the most spectacular the United States can offer.

The marks of easy money

Adventures old and new have left their marks along the coastline. The family of newspaper magnate William Hearst made a fortune here from silver ore. On the site of that excavation, to the south of San Francisco, Mr. Hearst built the spectacular and extravagant Hearst Castle, equipped with its own man-made, deep water harbor, through which he shipped his collection of antiques and art from around the world to the castle. Today it is a national museum.

In Big Sur national park, Henry Miller lived and wrote. A few miles to the north, we find the quiet luxury of Carmel, where Clint Eastwood was mayor. The wealth created in the area and in Silicon Valley trickles down, irrigating the creative furrows of the arts. Carmel is just a stone’s throw from Monterey, where John Steinbeck penned Of Mice and Men and The Grapes of Wrath.

Worth the journey

The entrepreneurs don’t come for the view. This is a city carved out of ideas. How was that pioneering culture created? How do you turn that force into a cluster of successful businesses? Maybe history holds the answer. In the San Francisco gold rush,

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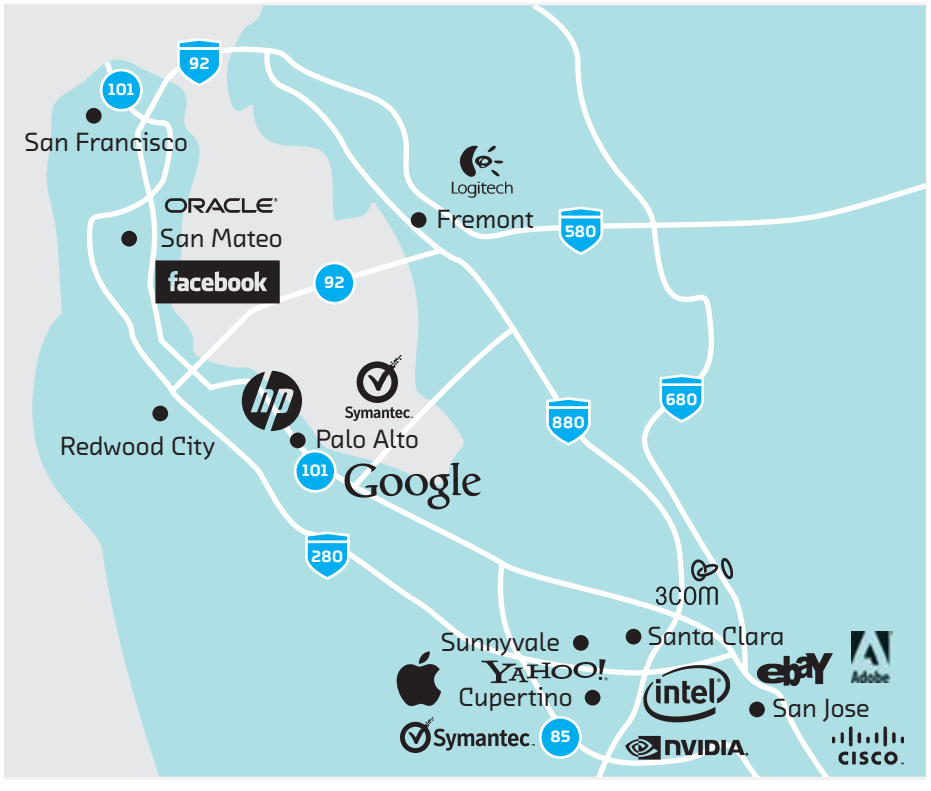
fortunes were won in a week and squandered in a fortnight. It has been shaped by treasure hunters ever since. Does that "easy come, easy go philosophy" still reign? Is the whole area a giant game of chance?

People who might know

In search of answers, we left the metropolis and headed along the coast to the valley, on Highway 1. Our mission was to breathe the air and feel the pulse of some of the people who have shaped their own part of the legend. One of them, Steve Blank, is one of the most influential people in Silicon Valley. He has started eight companies. According to his own reckoning: two disasters, four homeruns and two mega successes. We met him at his ranch with a 180 degree Pacific view.

Over at Carmel, John Nesheim believes he has documented the successful innovation process. His lectures and books offer a roadmap to success. Stephen Hoover at PARC explains how established elephants can quickstep to a new tune. Join our journey to the cradle of ideas. Enjoy the ride!

SILICON VALLEY



Portrait interview

By Stein Arne Nistad

STEVE BLANK

START WITH A BLANK PAGE

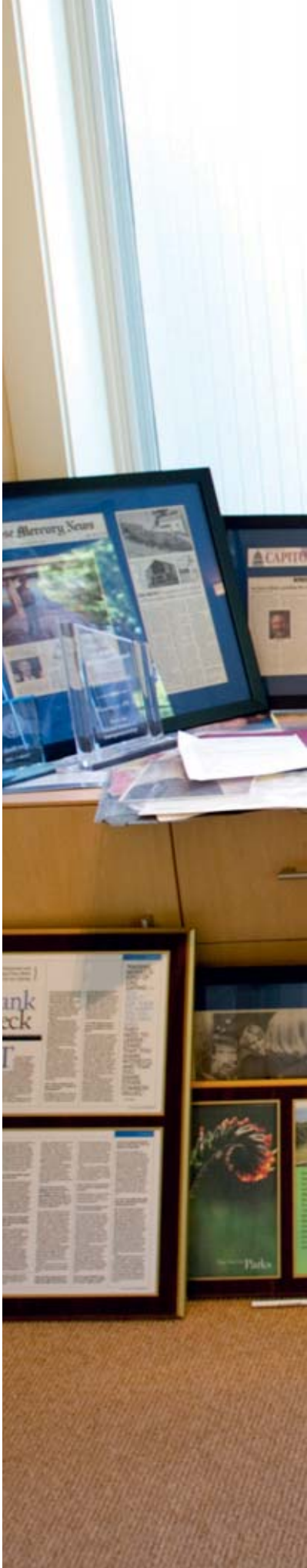
AUTHOR: STEIN ARNE NISTAD **PHOTO:** DARCY PADILLA, STEIN ARNE NISTAD

Steve Blank is considered one of the most influential people in Silicon Valley. After eight startups and more than 20 years as a successful entrepreneur he is regarded as an innovation guru. He separates truth from myth and explains why innovation is such a tough game.

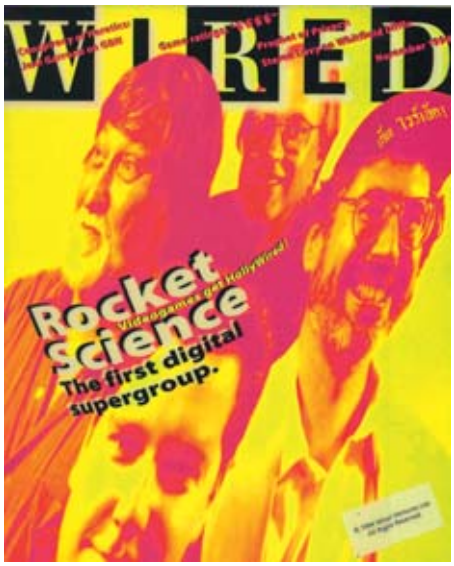
The ranch is an hour's drive heading south from San Francisco along the coast. We pass the lyrically named Half Moon Bay. The view is spectacular, with a clear blue sky, glittering sea and sandy beaches that beckon surfers. The city is far behind us. A sign warns: Watch out for snakes! We take a left off Highway 1 and follow a dirt road up the hill to Steve Blank's house and a stunning 180 degree Pacific view. Maybe innovation success is about gaining perspective and overview? Blank meets us at the door, smiling and welcoming but insistent that we take off our shoes before we enter. That's the rule for everybody!

A Cold War warrior!

It is easy to get comfortable in Blank's magnificent living room. He talks enthusiastically about his recent trip to Finland and Russia. It's all about roots. Blank's parents are refugees from Russia. "It's so



Steve surrounded by memorabilia from a lifetime at the heart of where it happens.



Blank's biggest crater captured the cover of WIRED magazine, November 1994. Rocket Science lost $35 million in in less than three years, giving Steve Blank (right) valuable "experience". His next start up, "E.piphany" attained $8-billion in market capitalization a few years later.

weird," he explains: "People born after 1970 see Moscow as a normal city. I was born in 1953 and I am a true child of the Cold War. I find it quite absurd to walk the streets of Moscow. Hello, I have been at war with them!" He talks about his career as a fighter plane engineer in Thailand during the Vietnam War. But things have changed. Blank continues, "Today Moscow is overseas travel, where I do 23 lectures during two weeks!" He is employed by Stanford University, giving lectures on innovation and innovation processes worldwide. His credentials are strong. Blank has founded eight companies and retired before he was fifty. He took what he describes as a value-based choice; he chose to see his children grow up.

What is risk?

It was the military that brought him to the Valley. After four years in the US Air Force, he was engaged by a Silicon Valley-based, military intelligence company. The CEO was William J. Perry, who eventually became United States Secretary of Defense. "I didn't know much about software or innovation when I came. One of the most important lessons I learned was the link between war and market strategy. Success is about understanding the order of battle: observe, orient, decide and act! Innovation is, among other things, about risk taking."

Blank had his own perspective on the meaning of risk: "In war you can die. From my point of view, it's quite hard to die from taking risk in California. You will not freeze to death, and it is possible to obtain food in a way. So how bad can it actually be?"

Silicon Valley – the culture

"The cultures in Silicon Valley are special," Blank continues. "There are several reasons for that. First of all, during the 1940s and 1950s, Stanford's Dean of Engineering, Frederick Terman, often called the Father of Silicon Valley, encouraged faculty and graduates to start their own companies. It was equally acceptable to create a company based on research ideas, compared to doing an academic career. He stimulated students to run startups based on their ideas, created at the university. Experimental ideas that might work were taken directly from the lab and tested as real world concepts. As a consequence, a very high failure rate was accepted. In research environments failure is often the normal outcome of an experiment."

Crazy ideas and crazy money

"The fact that nine out of ten ideas did not work, was expected", Blank continues. "However, that didn't matter as long as the tenth worked and gave astronomical return on investment. This had an impact on the innovation culture: A failure in Silicon Valley was and still isn't considered a failure. It's rather considered as learning and gaining experience. Hence, a failure or experience is a necessary stepping stone towards making a success on the next attempt. That risk-willingness was in turn adopted by investors. Venture capitalists could offer crazy money. The expectation was to lose money on nine out of ten investments. This is hardly accepted anywhere else in the world. The consequence is that Silicon Valley has developed a technical, financial and academic innovation culture."

Nobody's home!

"Another important factor in Silicon Valley is that almost none of the people who work in the Valley actually belong here," according to Blank. "Silicon Valley is a magnet that attracts people from all over the United States and the world. Mom is not looking over your shoulder, anxious about her child's future in the process of getting experienced. No one cares about the fact that job changes occur frequently, once

We managed to create a perfect hallucination of what the market needed. It was like starting the production of an oil field without bothering to drill a test well “

every two years or more often. This creates a kind of freedom, as well as dynamics and flexibility in terms of ideas, manpower and culture that may be unique to Silicon Valley.”

What is innovation?
Then we discuss the essence of innovation. Steve Blank is clear: “The problem is that innovation is not one but many things. It’s like the Eskimos who have many terms for different types of snow. There are also a number of different types of innovation.” Blank has defined a taxonomy based on six different groups of innovators and entrepreneurs:

1) **Lifestyle entrepreneurs:** They make a business of their passion, working for no one but themselves, living the lives they love, while making enough money to enjoy their passion. Examples of this along the California coast where Blank lives include owners of small surfing and diving lesson shops.

2) **Small business entrepreneurs:** Their ambition is to make a business large enough to feed a family. The ideas are simple and small and they are often financed by family, friends and banks.

3) **Scalable startups:** These are focused on new ideas and big visions challenging major market players or creating new high-growth markets. Typical examples are Google, Facebook etc.

4) **Buyable startups:** Technology development has reduced startup costs drastically – they can even be founded on a founder`s credit card. This type of startup is founded with the intention of being sold to a larger company for $5 to $10 million.

5) **Large company innovations:** Innovation within existing companies aimed at improving or creating new products or solutions.

6) **Social startups:** These entrepreneurs work to make the world a better place, not create wealth for the founders. They are sometimes non-profits.

“So when you ask me what innovation is, it’s not one but many different things. But success, in all the six types, needs a functioning eco-system of policies, strategies and incentives that vary from type to type. Silicon Valley is mostly about scalable and buyable startups,” says Blank.

The idea is an hallucination
But aren’t innovations founded on a fundamental idea or a vision? Blank answers: “In fact this is more an hallucination than an idea. It turns out in practice that any basic idea and vision must be reshaped and transformed before it materializes into something that works. Innovation is in reality about testing out a basic idea in the marketplace. It has to be adapted to the real needs and the real problem to be solved. A common mistake is to imagine how a hypothetical problem can be solved. It’s very simple. You create what is needed, not what you think is needed!”

Success and failure
One of Blank’s largest failures was caused by not listening to what the market and the customer really wanted. He talks about Ardent computers: “It was a concept that

FACTS ABOUT STEVE BLANK

In 2009, The San Jose Mercury News listed him as one of the 10 influencers in Silicon Valley.

Track record
Steve arrived in Silicon Valley in 1978 as boom times began. He retired in 1999 after 21 years and 8 high-technology startups:

He co-founded his last company, E.piphany, in his living room in1996. Other startups include two semiconductor companies, Zilog and MIPS Computers; a workstation company Convergent Technologies; a consulting stint for graphics hardware/software spinout Pixar; a supercomputer firm, Ardent; a computer peripheral supplies, SuperMac; a military intelligence systems supplier, ESL and a video game company, Rocket Science Games.

Total Silicon Valley Score:
Two large craters (Rocket Science and Ardent), one dot.com bubble home run (E.piphany) and several at base hits.

After he retired:
- Blank wrote a book about building early stage companies called “The Four Steps to the Epiphany.”
- He teaches entrepreneurship at UC Berkeley, Stanford University and the Columbia University/Berkeley Joint Executive MBA program.
- Blank’s ground-breaking entrepreneurship class at Stanford, The Lean LaunchPad, was adopted by the National Science Foundation’s new Innovation Corps in July. The program is taking the most promising research projects in American university laboratories and teaching the scientists the basics of entrepreneurship.
- In 2007 the Governor of California appointed Blank to serve on the California Coastal Commission.
- In 2010 he was appointed to the Expert Advisory Panel for the California Ocean Protection Council.

I had lost 35 million dollars but the investors did not want the money back – but instead offered me ten million dollars that I could use. I had simply become more experienced“

would compete with the super computer CRAY. One problem was that when we founded the company, the management came directly from a huge success. We were all convinced of our own superiority and the excellence of our own ideas. We managed to create a perfect hallucination of what the market needed and we built a computer based on the hallucination. It was like starting the production of an oil field without bothering to drill a test well. We were convinced that WE knew where the oil was!”

The oil expert

“The market is always the key,” Blank continues. “An idea can in itself theoretically be excellent – but it’s never better than the market it creates.” Therefore Blank has always focused on the market potential. He talks about how different industries have different power centers. New York is the financial center, Silicon Valley the IT power center and Houston is about oil. The target group for the Ardent supercomputer initiative included the oil sector. They believed the computer would be perfect for running complex reservoir simulations. To get market information, Ardent needed an oil expert to communicate properly with potential customers. The problem was that in Silicon Valley it was close to impossible to hire a person with any oil industry and reservoir simulation knowledge. They were all down in Texas. To present and get business, Ardent needed a marketing manager with the necessary knowledge. To solve the problem, Blank traveled to Houston. He went to the library and read all the literature on reservoir simulation he could find. Then he made a presentation at a conference for high level managers of Mobil, Chevron and other big oil companies. The presentations went very well, despite the fact that Blank’s knowledge covered more or less exactly what was presented. After the presentation, one of the mangers walked over to Blank

Entrepreneurs may not come to Silicon Valley for the view, but it doesn’t hurt that it’s beautiful.

and said, 'Usually IT companies send salespeople down here who do not have a clue about oil. This is the first time I met someone who actually knows this field!' "Then he offered me a job!" says Blank. "The truth is that I balanced on a knife's edge and was a hair's breadth from being revealed. My point is still important: Without having sufficient knowledge to understand the market and the industry, any idea is almost doomed to fail. It must be adapted to the needs of the market and not some in-house hallucination. Our arrogance and lack of market knowledge was the main reason that Ardent cratered. The idea was good, but the machines shaped to be result-oriented were fatal."

The distortion of success

"My second crater was a gaming company," Blank continues. "We got everything in place: Money, people and ideas. Even SEGA, one of the big game innovators at the time, was in. We created a distortion field so large, that everyone would buy our ideas. And they did. We had skilled technologists, but knew little about gaming. It was a bit like the world's best camera manufacturer suddenly hoping to become a fabulous movie maker. We were not good at it. Had someone asked me, 'Steve Blank, are you a skilled game maker?' The answer would have been obvious. It was not a particularly good starting point – and it gets worse. The entertainment sector is special. In Hollywood, they produce hundreds of movies each year, while only a few are profitable. Very few are major hits. The same goes for computer games. It is a hit-based market and it's close to impossible to know in advance what is really going to be a hit. The result was a real fiasco, and we lost a ton of money. After I had worked my last day, I reflected on who was responsible for the debacle. No matter how I looked at the case, the fault was mine. I had to take the heavy round to the investors and explain the situation. After that I called my mother and told her that I had lost 35 million dollars. She turned silent, and then asked me if they required me to pay it back. The funny thing, I told her, is that the investors did not want the money back – but instead offered me ten million dollars that I could use. This is the difference between Silicon Valley and elsewhere. I had simply become more experienced," says Blank.

Sustainable innovation

"Innovation within an existing business can be difficult," continues Blank. There is a significant difference in the overall goals for a startup and a company in execution mode. An innovative entrepreneur company needed people with the ability to think outside the box. That is the premise of creating innovations. When the business is established and is in execute mode, the situation is completely different. First, the organizational structures are in place, and there are job descriptions that people fit into. It is appropriate because the company's focus is on creating results and delivering. But it also implies that an employee is put into a position where the requirements and limits are defined independently of who is actually occupying the box. In other words, it is easy to measure whether an employee delivers what is expected. The frames and goals are so well defined, that there is little room for innovation, because it is a diversion from executing business. It also increases the risk. Of course there is a need for innovations in such businesses. But it is often to create more efficiency, better solutions and development of existing products. This type of innovation is called sustainable innovation and is necessary for the business to meet the requirements in the existing market."

Interrupted innovation

"Focusing only on sustainable innovation tends to fail in the long term," claims Blank.

> **In execute mode business there are job descriptions that people fit into. The requirements and limits are defined independently of who is actually occupying the box…**

"Take Nokia as an example. They produced all sorts of stuff from tires to computers, before they focused on mobile phones as their main product. And it worked great. They were mobile phones leaders and they probably still are. The problem occurred when iPhone and other smartphones showed up. A smartphone is still a phone, but the core functionality is completely different and is more like a portable computer. Nokia may be a world leader in making mobile phones, but it is in trouble when the market demands smartphones."

Three phases of management

"Many companies are struggling with the transition from the innovative startup phase,

The Valley is a magnet that attracts the best people from all over the U.S and the rest of the world, says Blank.

Successful large innovative global businesses have one thing in common: The founder and the visionary leader is still the CEO and remains an innovative force “

through the establishment of operation phase to execute mode," says Blank. "The organizational requirements and the necessary skills for employees and management are different in these phases. Yet it turns out that some businesses have managed to maintain innovation power in execute mode. Large innovative global businesses like Facebook, Google, Apple, Oracle and Microsoft all have one thing in common in their most successful periods. The founder and the visionary leader is still the CEO and remains an innovative force. Steve Jobs created Apple. When he disappeared, the company was close to bankruptcy in 1995. With Apple's acquisition of NeXT, Jobs returned, and the rest is history. This company managed to focus on execution and innovation at the same time. It requires a visionary leader and sustainable incentives to create innovation – despite economical short-time goals."

A blueprint of Silicon Valley?

Is it possible to recreate Silicon Valley elsewhere? "Earlier we believed that the idea that was the key," says Blank. "If you had a good idea and the right people, it was bound to be a success. Now we understand the stages and the process needed to transform an idea to a global success. A successful startup tends to follow fairly fixed sequence of phases and patterns. This process can in itself be recreated quite easily. But Silicon Valley is about far more. We can list the things that have to be in place. You need a university, venture capital, business experience, entrepreneurs with the ability to distinguish between an idea and how to create a company. Furthermore you need a risk culture. You need predictable and stable financial eco-systems, and the list of factors continues. Each of these factors may in itself be recreated, but the challenge is to create a complete culture and eco-system infrastructure that works. All over the world, they try hard to recreate an innovation environment like Silicon Valley. It is possible to measure the success by calculating innovative power per capita. Silicon Valley is the place to be.

I give lectures and teach around the world. After I'm finished summarizing what is needed, I am always asked this question: What does it take to get to Silicon Valley? The Valley is a magnet that attracts the best people from all over the U.S and the rest of the world. This is the way it is," concludes Blank.

Point Blank

We follow Blank through his fantastic house, with the breathtaking Pacific view and the quiet trappings of success. We slip on our shoes, say goodbye and head back to San Francisco. Following a blueprint to success seems simple enough but the odds are still just 1 in 10.

Success and failure

IN THE VALLEY OF THE KINGS

AUTHOR: STEIN ARNE NISTAD **PHOTO:** DARCY PADILLA, IAN PHILIP MILLER/GETTY IMAGES

Silicon Valley may be our modern version of Egypt's Valley of the Kings. If we sift through the ashes of all the unsuccessful startups, would we find the seeds of the successes? Do the failures strengthen the ideas gene pool? As Bob Dylan wrote, "There's no success like failure – and failure's no success at all."

Heading south on Highway 1, we come to Carmel. The heady scent of money pervades the atmosphere. Like an alluvial flow from the innovation successes further north, this is where it has come to rest. The whole town glows with a blush of wealth. Here we meet John Nesheim, innovation advisor to clients like Facebook and gaming giant Zynga. He describes innovation as a well-defined process rather than as talent or a brilliant idea.

Innovation report

Nesheim came to Silicon Valley in the 1970's to work for National Semiconductor. Back then, local companies met regularly to share ideas and experience. As his CEO was unable to join these meetings, Nesheim frequently took his place. He met a lot of pioneer entrepreneurs and deduced that the successful companies almost invariably followed the same process. "There was no shortage of good ideas, but the idea itself was almost never the root of success," says Nesheim. "Engineers are good at solutions and creating new technology but they have zero competence when it comes to creating a business." Nesheim became fascinated by the characteristics and processes of successful companies. In 1981 he published

> Research is the transformation of money into knowledge, while innovation is the transformation of knowledge into money "

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It is rare that the initial idea is realized. It may be an offspring or development of it. However, it is the force in the process itself that creates successes, not necessarily the original idea “

Innovation guru John Nesheim is an advisor to clients like Facebook and gaming giant Zynga.

a report on the phenomenon. Though the report was much appreciated, at U.S. $ 3,000 a copy, it did not sell fast. So Nesheim made a book out of it. Self-published on Amazon, it became a bestseller. A major publishing house took it on and Nesheim was established as an international innovation guru. Today, he lectures and advises in innovation around the world. He says innovation is no alchemy, it is a predictable process.

Targeted innovation
It is important to understand that the idea itself is not necessarily the driving force. Of course there must be one, but it turns out that it is rare that the initial idea is realized. It may be an offspring or development of it. However, it is the force in the process itself that creates successes, not necessarily the original idea.” maintains Nesheim. The former research and development director of 3M, Geoff Nicholson, echoed this rather nicely when he said: “Research is the transformation of money into knowledge, while innovation is the transformation of knowledge into money.”

Risk optimization vs. risk minimization
“The problem with innovation in existing businesses,“ Nesheim claims, “is that it inevitably creates conflicts and challenges on several levels. Innovation is fundamentally about taking risk and doing risk optimization. Investors know this, and reduce risk by spreading it over several companies. They lose money on some projects – but earn piles on successful startups. In other words, it is a kind of game where you are bound to lose money to earn money.”

Focus on the bottom line is fatal
According to Neshim, the opposite is the case in an operational company. ”Their goal is simply to reduce risk, to make the operational business as profitable as possible. There is no place to spend large resources and funding for innovation activities that might be profitable. The reason is simple – these investments go straight on the bottom line. The paradox is that most companies are dependent on a certain degree of innovation. They need to develop new products, services and business models. In bad times investors and boards demand reduced operational cost. Expenses that do not provide short time returns are cut first; typically the innovation projects. When good times return, the innovation process has to start all over again from scratch! This observation is not limited to Silicon Valley.”

Geoff Nicholson is reported to agree. The Post-it note nearly came to a sticky end, he recalls, as the 3M marketing department did not believe there was a market for replacing the back of the envelope. “All great new ideas are killed three times by management processes,” he says.

Perspectives and constraints
Reflecting over a lifetime of analysis, Nesheim observes: “Executive management too often suffers from a fairly static mindset and attitudes. Innovation is constrained by a framework of rules and regulations. In practice it is difficult and almost impossible to develop truly ground-breaking ideas and innovations in such an environment. However, that is precisely what is needed and asked for. Many companies, like Google, struggle to continue an innovation culture as the company transforms from innovation to execution mode,” says Nesheim. Albert Einstein once said, “Problems cannot be solved by the same level of thinking that created them.”It’s a limitation that can prove fatal.

Remote innovation
There are methods to avoid the suffocation of corporate myopia, says Nesheim. He gives an example, “Lockheed Martin needed to implement an important innovative process, without limits and constraints. The manager for the project demanded that the process should take place at a different physical location and forbade contact between the operational people and the innovation team before the project was completed. The purpose was to prevent old ideas, rules and regulations from pollut-

ing the fragile innovations project." There is obviously a divide here between the creative process and its implementation.

Across the peninsula at the Palo Alto Research Center (PARC), Xerox has taken a rather bolder approach to creating "arm's length". Stephen Hoover the CEO of PARC recounts: "We are a very unique place. PARC started as a captive research center but then about ten years ago Xerox realized that open innovation was the future. We have innovative ideas that are relevant to the outside word. Xerox is our largest client but today it's just about half our business. We have a very different model than a traditional captive research center. This really is an innovation eco-system."

Risky innovation

"An innovator is typically a risk-taker," observes Nesheim, "with a special ability to combine different influences and knowledge to generate new ideas. It's about an ability to create networks of concepts, by combining input from different sources. Innovators are often extrovert and good at building relationships and creating professional and social networks. Moreover, an innovator has the ability to create and believe in the big concepts with no boundaries. He does not follow the rules, hoping for acceptance rather than permission. Women are often better innovators than men. They are right brainers and superior to men in building new combinations of things. They also don't have the dominant alpha male nature. They are simply better at building relationships." Despite this interesting thought there are not many women on the list of the Silicon Valley greats.

Intuitive innovation

"Another paradox, is that innovation is intuition ," Nesheim continues. Basically it is about establishing a need, sometimes before the market has discovered it has a problem. "The problem in established businesses is that managers are square heads. They make decisions based on economic numbers and figures. The substance in a project is quantified and calculated in terms of investments and returns. Ground-breaking innovations don't work that way."

At Palo Alto, the creative think tank at PARC thrives on the broader set of challenges made possible by being independent. PARC supplies ideas to a range of companies and governments – from toner to green technology, water purification to internet architecture. Ideas in one field spawn others elsewhere connected by threads such as particle separation and processing technology. Thinking out of the box is good but the odds of success are increased if you already have some competence in the area, either with the technology, or the market.

"Sometimes you have the idea and then go looking for uses. Usually it is a combination of: What are the problems? What are our intellectual assets and knowledge? Then there is a protracted period of experiment," explains PARC's Stephen Hoover.

The riddle of the Sphinx

"Innovation is coupled with risk," says Hoover. "You want to take risk because it is coupled with reward. But if you take risk you fail sometimes. So the bad part that you really need to create the culture around is not that failure is bad, but late, expensive failure is bad."

Timing is also an issue, he says: "You have to give people enough time to explore ideas before they can prove that they have a good one. Because it takes time."

At the end of the day Hoover concludes: "Every dollar, and exactly what you're going to spend it on, can't be predetermined. You've got to hire smart people and give them freedom to explore ideas that come to them, in the end there is a selection process. They can't make the cut every time."

If Silicon Valley is our Valley of the Kings, and success is the Sphinx, then the key to the riddle is a brutal assessment of need and market value that outranks the beauty of the idea.

It's not that failure is bad, but late, expensive failure is bad "

Stephen Hoover CEO of PARC, an innovation eco-system at Palo Alto. PHOTO: AMY SULLIVAN

OLD VIEWS OF THE FUTURE

Sometimes a stroke of genius needs time to evolve into a good idea. For the helicopter, that took 400 years. However, lately the cycle has been somewhat shorter.

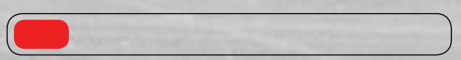
IDEA: FLYING CARS

Innovation: Flying cars

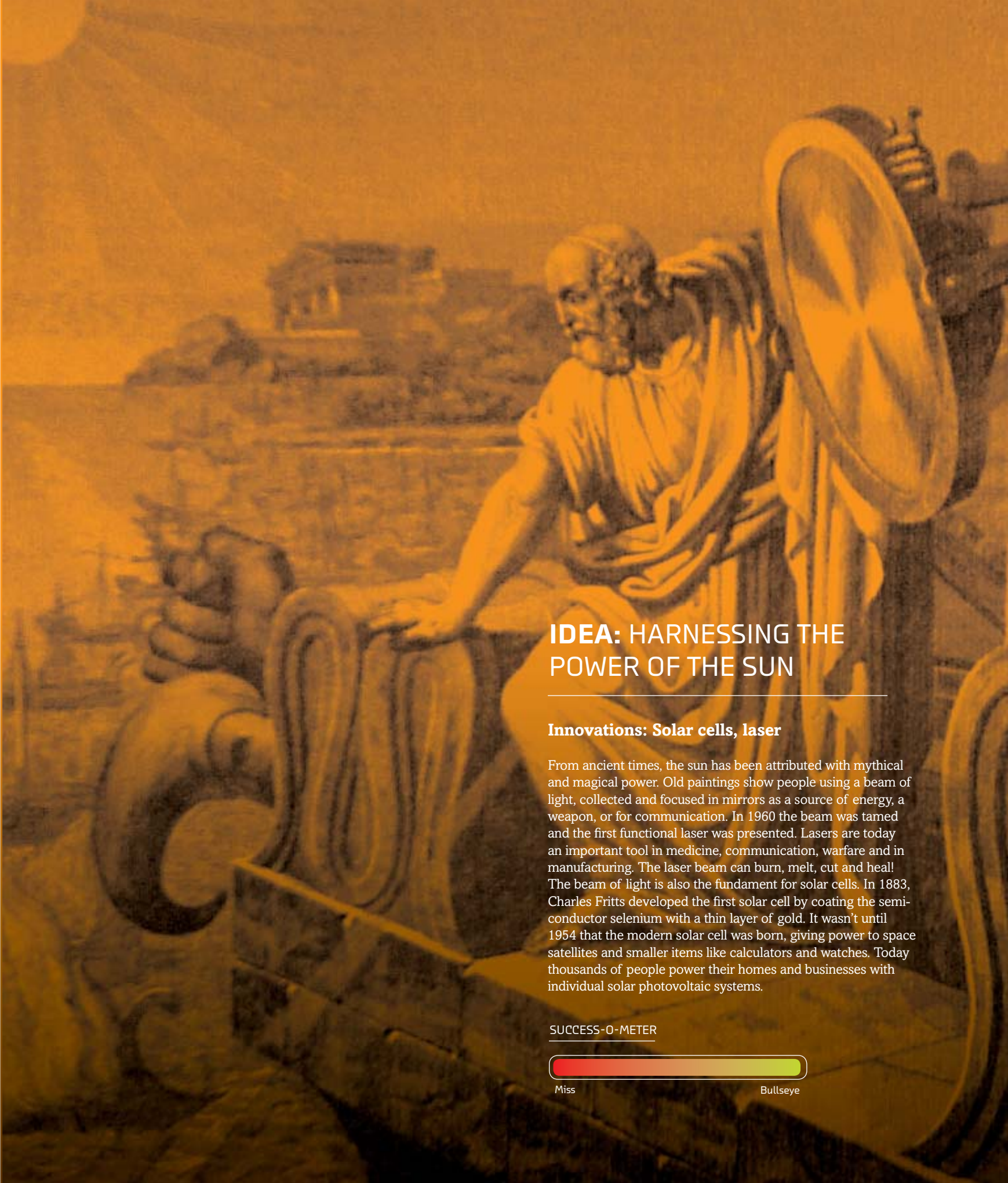
Back in 1917, the pioneering aviator Glenn Curtiss built an autoplane, but it didn't do much more than hop. Other famous attempts are Henry Smolinski's AVE Mizar. Built between 1971-73 this coupled the rear end of a Cessna 337 with a Ford Pinto. Tragically, the hybrid came apart in midair, killing Smolinski and his pilot. Flying cars have been hugely popular in science fiction and fantasy. The fantastic Chitty Chitty Bang Bang, from the 1968 movie of the same name, is still an icon. In the 1982 movie Blade Runner, transportation in a futuristic LA is based on flying cars. How realistic is this vision? In the 1950s, a feasibility study by Ford Motor Company deemed the flying car to be technically feasible with significant realistic markets. The critical problem, they determined, was that air traffic control was inadequate for the volume of traffic proposed. Today, flying cars are once again topical. Terrafugia, a roadable light sports aircraft, can fold its wings in 30 seconds and operate as a traditional road vehicle and as a general aviation plane. The Transition® "Personal Air Vehicle" will be released to customers in late 2011.

PHOTO: GETTYIMAGES

SUCCESS-O-METER



Miss Bullseye



IDEA: HARNESSING THE POWER OF THE SUN

Innovations: Solar cells, laser

From ancient times, the sun has been attributed with mythical and magical power. Old paintings show people using a beam of light, collected and focused in mirrors as a source of energy, a weapon, or for communication. In 1960 the beam was tamed and the first functional laser was presented. Lasers are today an important tool in medicine, communication, warfare and in manufacturing. The laser beam can burn, melt, cut and heal! The beam of light is also the fundament for solar cells. In 1883, Charles Fritts developed the first solar cell by coating the semi-conductor selenium with a thin layer of gold. It wasn't until 1954 that the modern solar cell was born, giving power to space satellites and smaller items like calculators and watches. Today thousands of people power their homes and businesses with individual solar photovoltaic systems.

SUCCESS-O-METER

Miss Bullseye

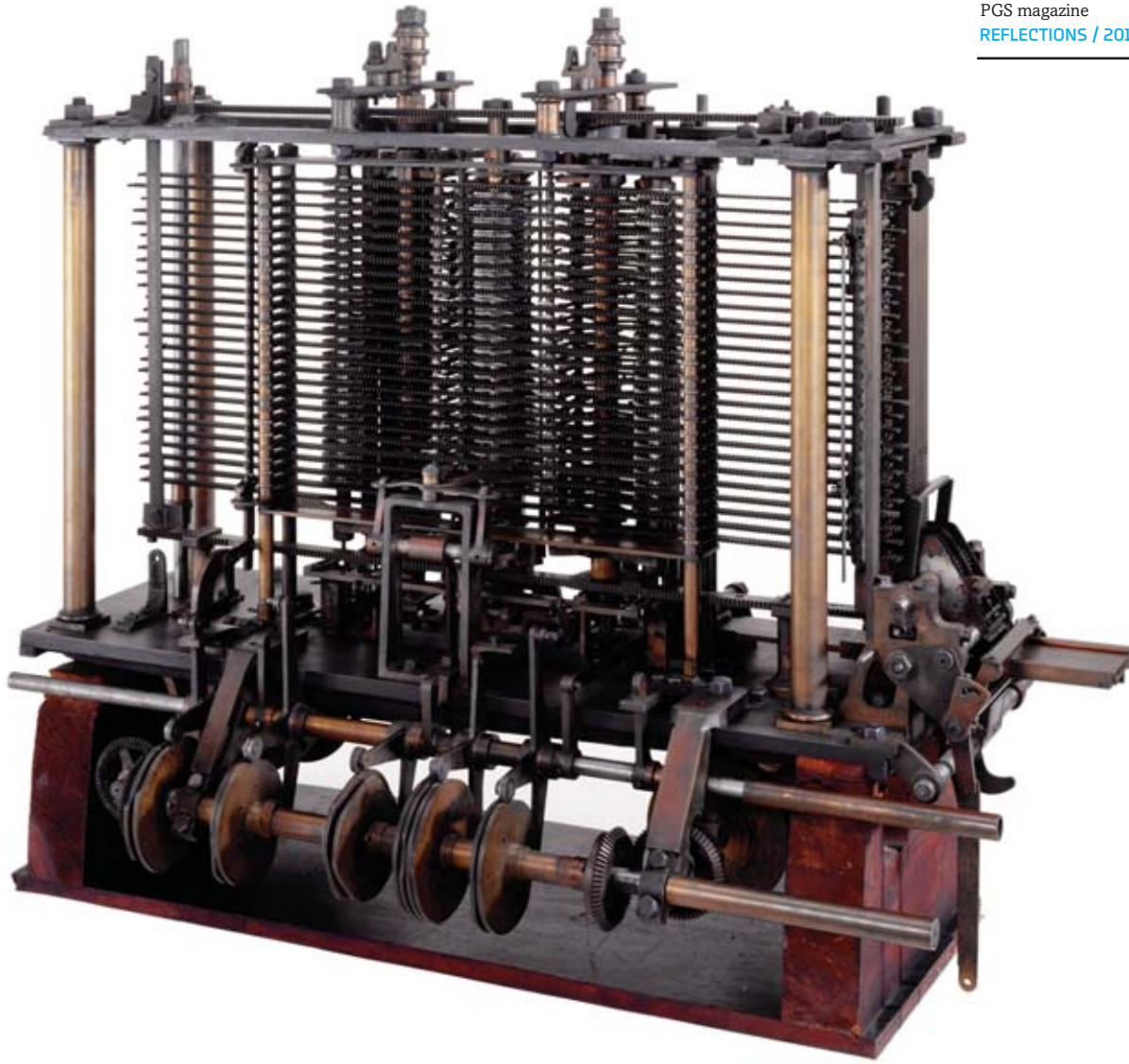
IDEA: ROBOTS – A MECHANICAL COPY OF A HUMAN BEING

Innovations: Industrial robots, lawn mower

Many ancient mythologies feature artificial people, such as the mechanical servants built by the Greek god Hephaestus. However, the word robot was first introduced to the public in 1920, by the Czech writer Karel Capek in his play R.U.R. (Rossum's Universal Robots). Since that point interest in robots has grown inexorably, with the mechanical beings appearing in countless science fiction movies and books. Arguably the most famous of these is Isaac Asimov's groundbreaking 1950 anthology, "I Robot." This defined the three laws of robotics and discussed the more philosophical aspects of robots' relationships with their human overlords. Back in the real world, George Devol applied for the first robotics patents in 1954. This heralded the first stage in the age of industrial robots. Devol's Unimate was a digitally operated, programmable, multipurpose robotic arm. It first flexed its artificial muscles in the automotive industry for General Motors. Since 1970 robots have been used in industrial production worldwide, and today there are more than a million in use. However, the idea of a society populated by artificial beings is still consigned to science fiction. That said, the last decade has seen the advent of robotic vacuum cleaners and lawnmowers designed for home use. Most seem helpful enough, but there may yet be a twist in this sci-fi tale – in 2007 a Danish man was killed by a robotic lawnmower.

PHOTO: GETTYIMAGES

SUCCESS-O-METER



IDEA: THE COMPUTER

Innovations: The digital world as we know it

From as early as 2500 BC mankind has had a recurring dream of computing machines and programmable devices. The word "computer" was first used in 1613, referring to a person who carried out calculations, or computations. Driven by the high error rates of "human computers", Charles Babbage, in 1822, theorized and designed the first precursor to the modern data processing device. Babbage's analytical engine was the first general computational device with the ability to solve different types of equations. The machine`s memory consisted of gears. Its processing unit used cams, clutches, cranks and gears. The first electronic digital number crunchers appeared in the mid-20th century (1940–1945) occupying a large room and using lots of power. Modern computers, based on integrated circuits, are millions to billions of times more capable than the early machines, and occupy a fraction of the space. Today, a world without computers is unthinkable, and would not function. Computers are everywhere, and it is hard to find any electric device not containing one, including lasers, robots and cars. PHOTO: GETTYIMAGES

SUCCESS-O-METER

20 YEARS OF INNOVATION

AUTHOR: PAMELA RISAN PHOTO: PGS

Over two decades, new ideas have flourished at PGS: commercial, operational and technical. Not all of our bright ideas have been equally successful, but our batting average is positive and the spirit continues undaunted. Some you win, some you lose, some you wait for.

1 Strong and silent type?

In 1993 PGS was getting ready to launch its latest 3D seismic ship, the Nordic Explorer, towing up to 5 seismic streamers – almost twice as many as its competitors. Acquisition Manager Einar Nilsen was at Langsten yard on the west of Norway, when he saw a pale gray vision of the future, drawings of the mysterious Marjata, a Norwegian navy spy-ship. This delta-shaped maritime Mata Hari was designed to lie quietly and listen for Russian submarines in the Arctic. Extremely stable and broad in the beam, she was built to withstand top-ice but all that space had other potential in Einar's mind. He met the designer Roar Ramde and explained a bit about multi-streamer seismic operations. Then he got on the phone to the PGS office at Lysaker to tell them that the holy grail of seismic had been found. Within a few weeks PGS agreed, on a handshake, to build the first two seismic Ramforms, tying the design indelibly to the PGS brand.

SAY NO MORE

2 Lying low

Ocean Bottom Seismic (OBS) is one of the best technologies not to make it big in seismic. Pressure and velocity sensors collocated in the same cable are placed on the seafloor, well out of the weather window, offering clearer 3D images in shallow water and obstructed areas, and more effective multiple attenuation. PGS attempted repeatedly to get the idea to work in the mid 1990s, with towed and dragged arrays, using two sensors 2C and four sensors 4C (FourCe) before dropping out of the field in 2005. Unfortunately the market was too small to make it a profitable business. Though OBS fans insist that its time will come, this technology has so far failed to thrive. Processing remains a challenge, especially those pesky converted waves and operational efficiency is low compared to modern towed streamer operations. Technologists still like the science, but economists are not keen on the ROI.

ROCK BOTTOM

1991

- Petroleum Geo-Services is formed in Norway from A/S Geoteam
- Subsidiary, Precision Seismic Inc., is established in Houston
- Enter partnership with TGS for marketing 3D data
- First North Sea 3D survey with GeoExplorer
- PGS merges with Nopec
- PGS introduces 3D MultiClient
- First delivery of full volume pre-stack data

1992

- First 3D operation in Gulf of Mexico
- Registration on Oslo Stock Exchange

1993

- Nordic Explorer and Ocean Explorer join the fleet
- Tensor Geophysical joins PGS with high volume 3D processing
- PGS offers full onboard processing
- PGS Board approves construction of the first Ramform
- Nordic Explorer is first ever to tow 5 streamers

4 Funny shaped boats

In 1996 the then PGS Chief Operating Officer declared his vision of PGS as "the company with the funny shaped boats". The Ramform seismic design was a fantastic success. Unfortunately, attempts to bend the shape to fit everything from a floating production vessel, to a well intervention ship and drilling platform proved increasingly difficult to pull off. "We expect the new Ramform production ship to revolutionize the industry with the same effect as the high-tech Ramform seismic vessel," predicted the COO. While the delta-shaped seismic vessel has become an icon for PGS, the production and drilling boats may have been a case of blurred vision.

MISSED THE BOAT

3 Stand up and be counted

Using the vertical cable method, strings of seismic receivers were suspended vertically in the water column, held at the surface by submerged floats and fixed to the seabed by anchors. In theory, the 3-dimensional receiver grid allowed endless flexibility in acquisition geometry, both azimuth and offset. It seemed ideal for smaller complex surveys, especially in obstructed areas. However, the model was difficult to emulate in real life, as currents twisted the perfect lines into less desirable formations. The market never materialized. Just one customer was interested in sponsoring this technology.

VERTICAL FELL FLAT

5 Dead in the water

August 2002, Norsk Hydro transferred its share of Production License 038 in the North Sea to PGS. PL 038, otherwise known as the Varg field, was considered to be on its last legs with increasingly watery extractions and declining reserves. PGS had a particular interest in keeping production going, as owner of the floating production facility on site, FPSO Petrojarl Varg. PGS believed that better seismic data and a new production plan could significantly extend the life of the field. It was a hunch that paid off. We bought the field for 1 Norwegian krone. Recoverable reserves on Varg more than doubled following the drilling of two new wells, based on the industry's first commercial MAZ survey and inspired work from the PGS reservoir team. Pertra, the business created from this venture, was sold for NOK 1.5 billion.

FLOATED THE BOAT

1994

- Atlantic Explorer and American Explorer join the fleet
- ERC reservoir consultants joins PGS
- Largest ever 3D survey using 3-vessel acquisition
- PGS acquires Mapware, renamed PGS Data Management
- Seres joins the Group
- Start-up of PGS OBS Inc
- PGS-designed Seafire lifejacket becomes North Sea standard

1995

- Ramform Explorer enters the fleet
- PGS develops industry's first shared data bank
- OBS active in Gulf of Mexico and Australia
- PGS begins North Sea vertical cable project
- Orient Explorer joins the fleet

1996

- Ramform Challenger enters the fleet
- PGS is registered on NASDAQ
- First deepwater OBS
- Ramform Explorer tows 10 streamers
- PGS Offshore Technology is established to adapt Ramform to production, drilling, well intervention and cable laying
- Vertical cables deployed in GOM
- Introduction of GeoBank

1997

- Conoco awards contract for the Banff FPSO
- PGS listed on New York Stock Exchange NYSE
- Acquisition of GolarNor FPSO business from Awilco
- First deepwater FPSO operations at Foinaven
- Ramform Explorer tows 12 streamers
- Partnership with Petrobras to remaster its seismic data

1998

- Atlantic Power joins PGS with over 1350 employees
- Ramform Valiant and Ramform Viking join the fleet
- Ramform Explorer tows 1350m wide spread

1999

- Ramform Banff produces first oil on the Banff field
- PGS acquires FPSO, Petrojarl Varg
- Ramform Victory and Ramform Vanguard enter the fleet
- 11 marine and land crews shut down

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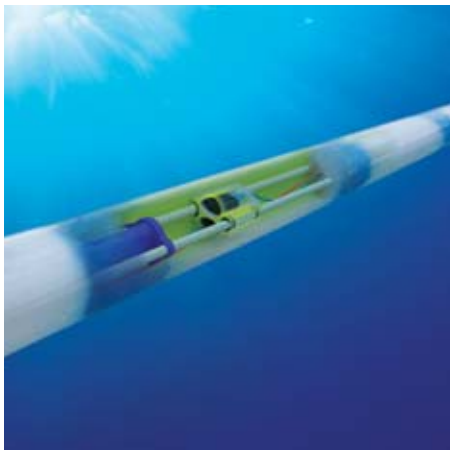
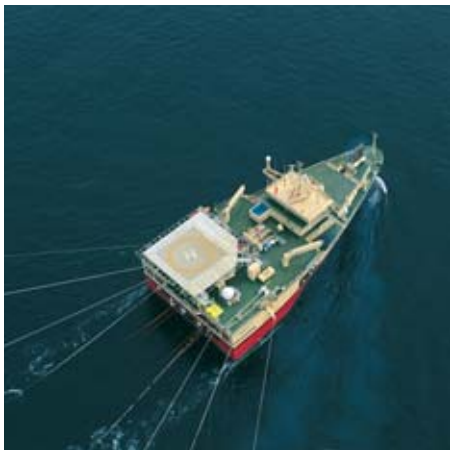




6 Ghostbusters – part 1

In 2001 PGS financial woes meant non-essential activity ground to a halt. The development of GeoStreamer was in its early days and its results were far from stellar at this stage. Nevertheless, PGS management calculated that the potential upside of making this work was worth the risk and voted to protect the program. Six years later the new ghost busting technology took the industry by storm and launched the broadband seismic revolution, opening up a host of new development opportunities.

THAT'S THE SPIRIT!

7 Need for speed

In 2010 PGS launched the hyperBeam, a unique combination of beam migration and immersive visualization. The beam machine slashed months off the time from survey to production by reducing cycle times for velocity modeling from months to minutes. Rapid depth imaging and model building brought the interpreters, geologists and engineers closer to the processing team.

DECISION RIGHT ON BEAM

8 Ghostbusters – part 2

In 2011 PGS expanded on its de-ghosted GeoStreamer receiver technology with a time and depth-distributed source, designed to avoid all ghost effects on the emitted source signal spectrum. Complementary signals emitted by sub-sources in the array allow the source ghost effects to be removed, permitting the recovery of much richer low and high frequency signal information.

HAUNTING HIGH AND LOW

20 YEARS OF INNOVATION

2000
- PGS divests Spinnaker for $150.5 million
- Petrobank is sold for $170 million
- Senior management reorganization

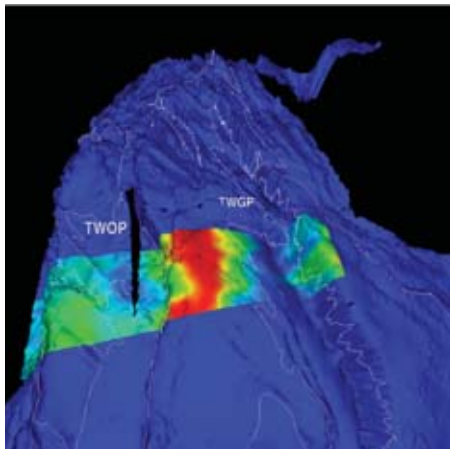
2001
- Data Management is sold for $165.7 million
- Production and geophysical operations management reorganized
- Merger negotiations with Veritas DGC commence

2002
- Merger discussions terminated with Veritas DGC
- New Board of Directors appointed
- New CEO and CFO appointed
- Financial restructuring commences
- PGS becomes operator of the Varg field

2003
- 3 FPSO contracts extended
- PGS exits Chapter 11
- Development of passive acoustic monitoring (PAM) for cetaceans
- First all-optical seafloor cable tested
- Varg reserves doubled

2004
- Rejection of takeover bid from CGG
- NYSE re-listing

2005
- Sale of oil company Pertra for NOK 1.5 billion
- Improved margins and sales growth
- Majority of debt repaid or refinanced



9 Who says resistance is futile

In the noughty years after the turn of the millennium there was a buzz in the air around electromatics. EM was touted as the panacea for dry holes. A single sweep of data would determine the content of the reservoir before drilling. PGS leapt into the fray, pouncing on a UK startup with a budding alternative technology called multi transient electromagnetic. It was a learning experience and education can be expensive. Though MTEM did not fulfill its early promise, and EM claims are slightly more humble these days, the drive to find an efficient electromagnetic solution is still very much alive and crackling. PGS aims to play to its strengths with a combination of data quality and unbeatable operational efficiency using a new towed streamer and source.

FORGET NODE, TRY TOWED

10 Under the ice

Developed in the early 1990s, the remotely operated marine vibrator has been described as the next big thing in seismic for over two decades. Twenty years on, it is still flushed with promise but still on the test bench. As exploration advances towards the poles, its developers are hoping that inertia will thaw. The marine vibrator could yet tip the balance in arctic and ice-bound exploration. It also promises a range of other exciting potential benefits, from low frequency signals to multiple, flexible source arrays.

CHILLING AND THRILLING

11 Buried treasure

Permanent seismic monitoring has enormous potential, but our industry has been slow to adopt it on a grand scale. One problem is reliability of electronics over the producing life of a field. The PGS developed OptoSeis draws on the longevity of fiber optics to measure dynamic reservoir properties. First application will be on the Jubarte field of Brazil.

HIGH FIBER OPTION

2006

- Demerger of FPSO activities as Petrojarl ASA
- PGS is re-dedicated to geophysical services
- First Crystal WAZ survey in Gulf of Mexico
- PGS orders 2 new Ramforms

2007

- Launch of GeoStreamer®
- PGS sells Ramform Victory to the Japanese government
- Cooperation agreement with Japanese Ministry of Economy and Energy
- Acquisition of Arrow Seismic
- Acquisition of MTEM
- Acquisition of Applied Geophysical Services (AGS)
- Acquisition of Roxicon Geogrids

2008

- New CEO appointed
- Ramform Sovereign enters the fleet
- GeoStreamer® achieves commercial success

2009

- Delivery of Ramform Sterling
- Launch of PGS hyperBeam®
- Sale of GeoAtlantic
- Cancellation of Arrow Seismic vessel newbuilds
- PGS Onshore is sold to Geokinetics

2010

- Accelerated GeoStreamer rollout
- PGS Apollo joins the fleet
- Ramform Explorer upgraded
- Petrobras awards OptoSeis contract for Jubarte
- Fleet expansion and renewal program begins

2011

- Launch of GeoStreamer GS
- Announcement of towed EM solution
- Upgrade of Ramform Viking and Ramform Challenger
- Extension of METI agreement
- Order of 2 new supersize Ramforms from Japan

THE RISE, FALL & RISE OF PGS

PGS has gone from new kid on the block, to cock of the walk, fallen briefly into Chapter 11 and re-scaled the heights to technology leader in its field. We take a look back over 20 years and analyse what role innovation has had to play during its ups and downs. And what better way to do this than to discuss the topic with its three very different chief executive officers (CEOs)?

AUTHOR: RICHIE MACTAGGART AND PAMELA RISAN **PHOTO:** NANCY BUNDT

The story of PGS began in 1991, when Reidar Michaelsen gathered the finances and key management to start a Norwegian 3D seismic company. He grafted the embryo onto an established corporate root, a small survey company Geoteam, changed the name to Petroleum Geo-Services (PGS) and became its first CEO and Chairman of the board. Tall, tanned, confident and still commercially active at 67, Michaelsen sits behind a broad mahogany desk with a panoramic view of the Oslo fjord. He spreads his hands in an expansive gesture and explains: "We set out with a clear vision for the company – we had the intention of building a top geophysical company." The vision was founded on a single, bold and innovative idea – to slash the operational cost of 3D seismic, turn up the volume of acquisition and take over the market.

Technologies alone do not bring success. Michaelsen says: "Any successful endeavour involves having the right people doing the right things. You have to have people who can collect ideas, pick the correct ones rapidly, and put them into action to generate value. The key here is people."

"We had a fantastic team – right from the management through to operations. A lot of

You have to have people who can collect ideas, pick the correct ones rapidly, and put them into action “

There were many successes and a few failures – these things happen when you are trying to grow a company

REIDAR MICHAELSEN

guys that ran the vessels were farmers and fishermen, used to doing lots of things at one time and fixing problems. That meant they could find solutions to stop problems occurring, which meant costs came down."

Michaelsen's role was to get the funding to grow the business. He was highly successful. The company was a stock exchange darling in Oslo and New York through the 1990s. The spirit of innovation was rife at all levels, from the highly efficient back deck layout, to the design of the crazy shaped ships, to multiple parallel processing and data management solutions. The main focus was singularly commercial. "MultiClient was not a new idea, it was common for 2D but we decided to do the same for 3D. This was a very good business as we had a low cost base per square kilometre," points out Michaelsen. PGS flourished and the share price soared.

The geophysical business is very cyclical and PGS rode the up-cycle at the front of the pack. In order to manage risk, it was decided to expand down the value chain from exploration into production. Rather than start from scratch, PGS bought the established FPSO business Golar Nor from Wilhelm Wilhelmsen, with vessels Petrojarl and Foinaven, and developed its own FPSO design based on the Ramform.

Some parts of this strategy worked, some did not. For example, PGS bought the Norsk Hydro-owned Varg field for one Norwegian crown, plus liability for NOK 50 million abandonment costs. They applied high density 3D seismic data, state of the art imaging and G&G expertise to the challenge. Pertra, the company that was created from this purchase was eventually sold for NOK 1.5 billion.

Though the 3D MultiClient business was a huge success, with phenomenal growth worldwide, it became a cancerous burden in certain areas. As the cycle turned and the seismic market went into free fall, PGS bled its balance sheet to keep its fleet busy. In the Gulf of Mexico in particular, projects were taken on with little or no pre-funding. The library grew but sales faltered. "The auditors began to take a more negative view of the value of the data library," explains Michaelsen. He oversaw an eventual write off of the Gulf of Mexico library for a value much lower than the original investment. However, Michaelsen is pragmatic about this. "There were many successes and a few failures –these things happen when you are trying to grow a company."

"You need to believe in yourself and your team and take some risks, to be able to drive the business. Sometimes you are not fully in control of circumstances, but if you can go to sleep knowing you have done the best you can, you can do no more."

The initial seed capital from Norsk Vekst was NOK 170 million and at registration the company was valued at around NOK 350 million. After five years, PGS market capitalization had grown to more than NOK 20 billion. As revenues grew and profits piled up, there was a discussion as to what to do next. Merger with a major oil service company seemed a natural path to take. "You need people and capital as the means to grow and it is easier to do that in partnership with someone else," says Michaelsen.

"Our vision was to be one of the three biggest oil service companies in the world. Ultimately, the timing was wrong and we were not able to find the partner that we wanted and this strategy had to be parked,"

The business model of a broadly based services company was flawed and unsustainable

SVEIN RENNEMO

he explains. PGS became caught in the undertow of the falling oil price and a tumbling seismic market.

The period of growth had come to an abrupt end. It was time for a new approach.

Near death experience

When Svein Rennemo took over at PGS, the agenda was one of survival. The oil price was under USD20 a barrel. With little money to be made in exploration, major oil companies concerned themselves instead with an endless series of mergers and acquisitions. The seismic industry was in the doldrums. The future of PGS hung on a knife's edge, with the abyss of bankruptcy in sight.

The new CEO was appointed by investor and then major shareholder, Jens Ulltveit Moe, as a steady hand to focus on operation while he unknotted the financial tangle. There was a full shakeout of both the board of directors and the executive management. The new team pruned the company back to its seismic roots.

Rennemo listens attentively to our précis of the state of the company in 2002. He nods quietly, and then interjects in a firm and measured tone. "This was not an obvious route, but a very deliberate strategic choice. The business model of a broadly based services company was flawed and unsustainable. Divesting Pertra and the IPO of Petrojarl were key steps to make PGS what it is today," he explains.

In the fallout from Chapter 11, the operational staff were left to do what they did best: manage an efficient fleet of ships. Rennemo recalls: "My entire focus was on meeting cash flow obligations. The debt was rescheduled and cut very substantially, allowing us to steer a path through the Chapter 11 process. Despite the fact that at the time PGS was in dire financial straits, we showed a remarkable capability to beat the competition. There was strength in the company due to our people and our operational capabilities and we were able to sustain this at a critical time."

For the first two years, Rennemo spent his time communicating extensively with creditors and with customers. The whole account management team was engaged to explain how and why the company would survive. Customers wanted PGS to succeed, recognizing competition was healthy for the market. As PGS exited, with record speed, from Chapter 11, the market cycle swung around once more and prices and margins headed skyward.

Though Rennemo was not a technologist, he was impressed by the knowledge and innovative drive of the management group he had inherited. "Throughout the 2000s," Rennemo says, "PGS was developing a lot of innovative ideas and producing innovative products." This included the GeoStreamer which continued to be funded despite the cuts. "The board of directors was excited by the ideas presented by key technical people, who were given the opportunity to communicate their ideas and innovations in the boardroom and among the executives. This environment, in which innovation is able to flourish, can never be underestimated," he underlines.

"From 2006 onwards we had the money to expand and the financial market was pushing us to do so," Rennemo recalls. "We invested in the new Ramforms as soon as we could and then we made a few decisions which were perhaps not optimal but

PGS CEO

Svein Rennemo

Rennemo was PGS CEO from 2002 until 2008. In April 2008 he took on the role of chairman of the board of Statoil. From 1994 to 2001, he worked for Danish olefins and polyolefin producer Borealis, first as CFO and then as CEO. Previously, Rennemo held various management positions in Statoil from 1982 to 1994, eventually as head of the petrochemical division. From 1972 to 1982, he was an analyst and monetary policy and economics adviser at the Norwegian Central Bank, the OECD Secretariat in Paris and the Norwegian Ministry of Finance. He is an economist, from the University of Oslo.

Jon Erik Reinhardsen

Reinhardsen has been President and CEO of PGS since April 2008. Previously, he served as President, Global Primary Products Growth in Alcoa. He joined Alcoa from Aker Solutions, an international contractor in the oil, gas, chemicals and polymers industry, where he was group executive vice president, based in Houston. Earlier Mr. Reinhardsen led the Aker Maritime ASA product business in Norway, where he was involved in merger and acquisition activities, new business development, marketing and sales, and investor relations. He also led Aker's seismic venture Aker Geo that was later sold to CGG. Mr. Reinhardsen serves as a Board director of various oil service and shipping companies. Reinhardsen has an MSc Applied Mathematics and Geophysics from the University of Bergen, Norway and is a graduate of the International Executive Program of the Institute for Management Development (IMD) in Lausanne, Switzerland

Reidar Michaelsen

Reidar Michaelsen was the founder of PGS and its president from 1991 to 1993. He served as chairman of the board and chief executive officer of PGS from 1993 to 2002. From 1989 to 1991 Michaelsen served as Managing Director of Norsk Vekst AS. He headed the Selmer Sande Group from 1986 to 1989 and was with Geco Geophysical Company, Inc., Houston from 1982 to 1986, reaching the position of managing director. Today, he is operating executive of Tri-Artisan Partners LLC, a merchant bank specializing in private equity investments. Michaelsen holds an M.B.A. from University of Wisconsin and a degree in business economics from the Norwegian School of Management.

Left to right: Svein Rennemo, Jon Erik Reinhardsen, Reidar Michaelsen.

Now we try to think like an industrial company. Instead of trying to hit the peaks, we aim to invest constantly throughout the cycle

“ JON ERIK REINHARDSEN

seemed right at the time. Like the acquisition of Arrow. Electro-magnetic was also very interesting but in retrospect we paid too much for too little. But it seems that PGS is now developing this into a towed streamer technology.”

In his youth, Rennemo was a communist. He matured into a state economist and evolved into a captain of industry. Do any of those early principles remain? He smiles and considers the question: “I believe very much in a collaborative approach and I think I learned then how to mobilize a group, rather than dominate it. You need to feel that you are heard and feel that you have a value to the group.”

Ride the cycle, avoid the wave

Jon Erik Reinhardsen took up the reins of CEO at PGS, as the market peaked in spring 2008, with a good platform for growth. “We had come into the up cycle of the industry somewhat starved of financial muscle and unable to expand. However, we were beginning to harvest our innovative technologies and our operational performance was good, so I was sure that we were well positioned for success.”

Within six months of Reinhardsen’s arrival, Lehman brothers collapsed and the market began its giddy descent once again. He has not regretted the move: “Margins are still higher at PGS than among peers. I initiated analysis into cash costs of vessels – how much vessels brought in through operational hours. This showed strongly that not only were the skilled and experienced crews essential, but that there is a hardware element that drives performance. That is a result of technology development since the start of the company. The number of streamers we can tow is the overriding factor. Our S-class vessels took this to a new level when compared against our peers and our 5th generation Ramform will go further still.”

PGS now has in place very robust procedures to manage the business. Reinhardsen explains: “Now we try to think like an industrial company and to manage the technology development process accordingly. Instead of trying to hit the peaks, we aim to invest constantly throughout the cycle, to establish a foundation for steady growth. That means having new vessels come out regularly, every couple of years, rather than when there is excess capacity in the market. You need to maintain a strong balance sheet to do this. We have done all these things and it means we can spend time developing the next technologies. $60 million a year in investments is proof of this.”

Reinhardsen sees his role as bringing the lessons of industrial management from his time with Alcoa to PGS, but without losing the ´Googlish´ culture that is constantly seeking innovative technologies and ways of working. “Creativity has always been a part of PGS and I do not want to destroy this as we become more industrial.”

“We have established a group called Disruptive Technologies. Some of our great innovations have come from these people,” says Reinhardsen. Innovation is encouraged in all parts of the organization he says. This means funding and room to test out ideas from other industries.

Innovation needs to be managed, Reinhardsen believes, with funding and operational processes – checks and gates. A technology council helps drive development and select the best projects to back for the future.

Innovation, it seems, is a ticklish beast. A combination of attitude, ideas, insight and timing, it is more than the sum of its parts. At stake are margins and survival. Successful innovations like the Ramform and the GeoStreamer have helped PGS both to ride the bulls and tame the bears. In the cyclic fall and rise of the oil business, managing this process with predictability can provide consistently better margins to cushion the fall when the market drops, as history has shown that it can.

GeoStreamer GS (R) offers a major improvement in the imaging of complex geology, as this data from the Møre Margin amply illustrates.

ECHOES FROM THE FUTURE

Visions of the future may be enlightened, amusing, or wacky. With the risks clearly stated, we asked four of our sharpest free-thinkers to put their heads on the block and shine a light down the path to the future. Is seismic technology reaching the end of its development road?

AUTHOR: PAMELA RISAN PHOTO: TOM LOVELOCK

Q: Have all the major inventions already been made – is all that is left incremental change?

EF: Well there are plenty of challenges left to resolve but most improvements will be, and have always been, incremental. That is in the nature of science. There will be step changes from time to time but there is a lot more to be discovered between each disruption and that takes time.

SBD: I am a believer in step change. You can't predict what it will be but you have to plan that there will be something that upsets the balance. Not shifts in the fundamental laws of physics perhaps, but new ways of measuring things, or changes in information technology that will allow us to treat our data in a very different way.

GC: Perhaps in seismic exploration there are only incremental changes, but there may conceivably be something beyond seismic. That would be a real revolution.

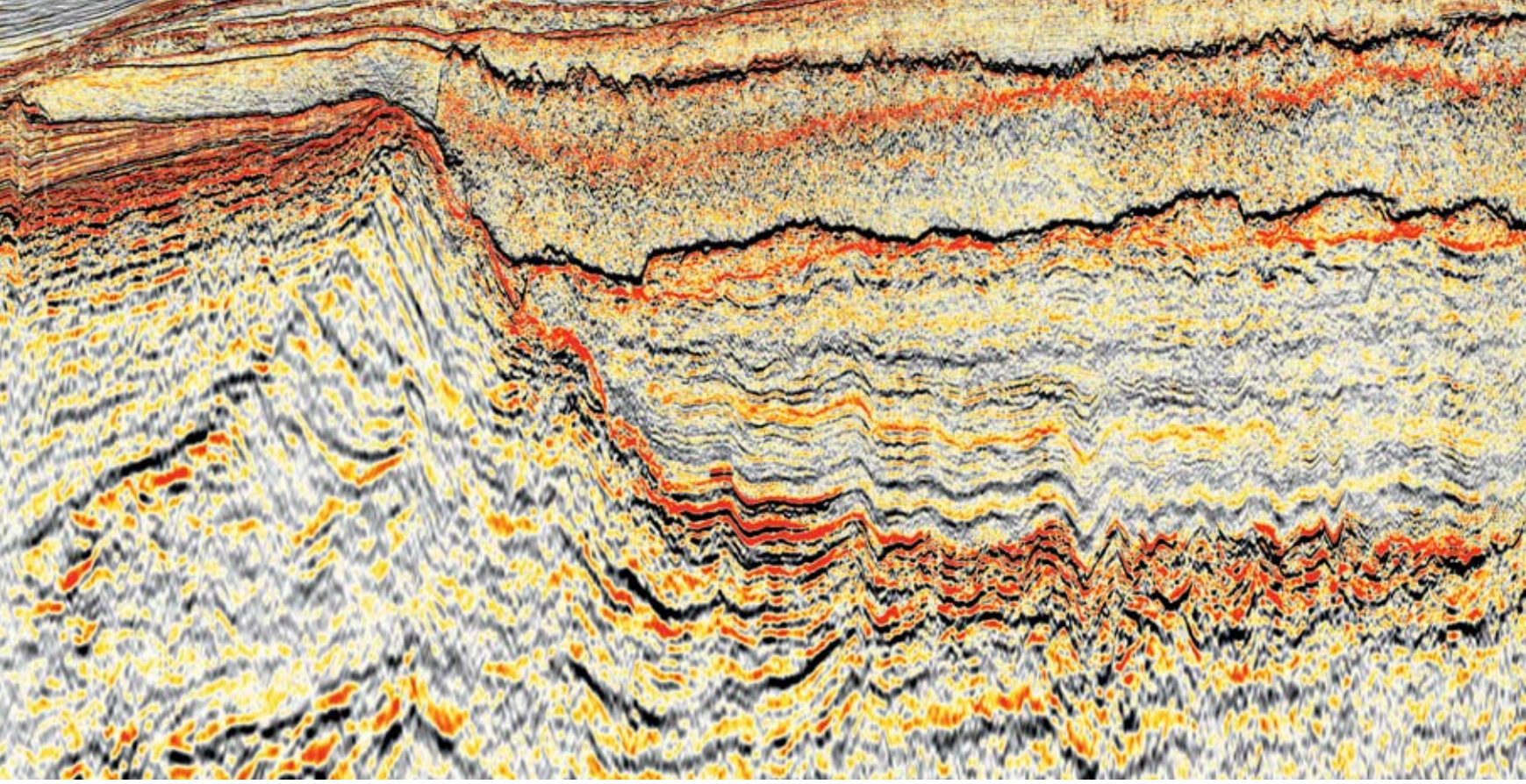
RT: There will be both. Technology becomes better and cheaper. Going forward, sensors will be cheap, high performance and available to anyone. We will be able to apply them differently and in vast numbers. On land we are already talking about millions of sensors. Then, the drive to compete will produce totally new ways to acquire seismic.

Q: What do believe are the time scales for the next major technology change?

RT: The pace of change is just so fast that technology is old almost by the time you bring it into production. We need much quicker cycles and new ways to compete. What we compete with today will not be valid in 5–10 years.

EF: Actually, I'm not so sure about that. When I joined the industry 27 years ago, 3D had already been introduced. Over under streamers to increase the bandwidth were already in their infancy, though it took quite a long time to mature it to a commercial stage. We tend to underestimate the time from idea to an industrial product.

GC: There have been a few fundamental changes but there is a significant time gap between concept and commercial reality. Cost is a key factor. In the early 1980s people were talking about going from 2D to 3D but it took another ten years to actually enable it. PGS played a major role in that



by introducing the high capacity vessels. It was simply too expensive before.

SBD: For data processing, emerging technologies seem to mature over a set time period; I postulate a 30 year cycle. Beam migration was invented in the 60s and became a break though in the 1990s. Reverse-time migration (RTM) was invented in the 1970s and was made a reality in the 2000s when computer power caught up. Full waveform invention was introduced in the1980s and entered the commercial stage around 2010. Theory is enabled by computers. What I see as the biggest challenge ahead is how we handle the volume of information of data we collect. Storage and data transfer are not keeping up with the CPU capacity growth.

GC: I would argue that progress has been accelerating, and it is driven by inventions in acquisition. Recently we have had 4D and wide azimuth (WAZ), both profoundly changing marine seismic. Now we have the broadband revolution. So in less than 10 years we have had three significant steps.

RT: The rate of innovation is not linear, it's logarithmic. Once a thread is established, more and more improvements keep on coming until you get to a point where you can't get any further with that technology. Then you need a paradigm shift.

Q: But how far are we from that tipping point for change, and in what direction is it heading?

EF: Perhaps it's time to revisit permanent installations, ten years on? In Brazil they are looking for very subtle sealing-on-sealing faults. Perhaps a very repeatable solution is actually the only way.

GC: Petrobras is going about things the right way, I think. The problem with 4D acquisition is that the area where you expect most changes is probably right below the production unit. With a permanent installation just below the production ship, you can undershoot and have very accurate information just where you need it most. I think it is the right balance in investment in data quality. I am very impressed by their approach.

RT: Actually, I think the next big change will be sources. They are overdue for reinvention. In the future these will be 100% repeatable. You will know exactly what your receivers are recording and that will probably significantly increase what you see.

SBD: Isn't that still incremental? Let's take a bigger leap. What if you don't have to repeat? What if you can sample a reservoir sufficiently well, that you can predict the changes that will take place, like weather forecasting? What we really want to know is how to optimally produce reserves, not just an observation on how well we have done until today. Oil companies routinely do history matching of reservoirs, I believe what they really want is reservoir prediction.

Q: What would you need to do that? Seismic wouldn't be enough, what would you combine it with?

EF: To make that kind of forecast you measure derivatives, you have snapshots, you sample various volumes. Then you extrapolate. I'm sure there will be other information added into this well performance prediction, including non-seismic measurements.

SBD: We would be trying to predict an advanced set of reservoir properties including permeability, things that we know are very difficult to predict with seismic.

EF: That is my point. Isn't that what permanent installations and on-demand seismic was meant to deliver?

TITLE

GUILLAUME CAMBOIS **Executive Vice President Data Processing and Technology**

Guillaume joined PGS in 2007 as senior advisor spearheading the GeoStreamer technology deployment. From March 2009 he acted as Marine President Asia-Pacific. Prior to joining PGS, Guillaume spent 20 years with CGG where he held various management positions including Executive Vice President Data Processing and Chief Technology Officer. He is an active member of the Society of Exploration Geophysicists where he served as Vice President in 2007-2008.Guillaume holds a Ph.D. in Geophysics from the University of Texas at Austin.

EIVIND FROMYR **Chief Geophysicist**

Eivind Fromyr is widely recognized within the industry as an educator and technologist. He has more than 25 years oilfield service experience and over that time has been a standard bearer for new technologies such as multi- and wide azimuth acquisition and multi-component seabed solutions. Before joining PGS in 1995 he was co-founder of Read Well Services. Eivind holds a BSc in Economics and MSc in both Cybernetics and Physics.

RUNE TENGHAM **Vice President Innovation & Development**

Rune Tengham joined PGS in 1993 in charge of software development for marine technology. Today he is Vice President for Innovation & Development and heads our Disruptive Technology unit. Tengham is an innovation veteran with 35 patents to his name and is widely known as the father of GeoStreamer. He holds an MSc in Engineering Physics from Chalmers Technical University, Gothenburg and is an executive graduate of Harvard Business School.

SVERRE BRANDSBERG-DAHL **Program Manager Imaging and Processing**

Sverre is a specialist in depth and sub-salt imaging, as well as velocity model building. Before joining PGS in 2007, to head our imaging and processing development program, he worked as a research geophysicist within the BP Advanced Imaging Team with focus on sub-salt imaging. Brandsberg-Dahl holds an MSc in Geophysics from the Norwegian Technical & Science University NTNU, Trondheim and a PhD from the Colorado School of Mines.

SBD: Permanent monitoring enables rapid access and exhaustive data collections, but we still don't know which bit we want. In the medical world, doctors tend to approach a similar problem in a different way. They do a big ultrasound scan, then spend time probing just a few places to get the detail they require. The oil industry still takes more of a blanket approach and then aims to fix it in processing. Maybe we need to move towards more focused data acquisition, that better helps answer the few hard questions our clients tend to have about their reservoirs?

RT: I think we can be sure that we will combine a lot more information than we do today. New smart methods will emerge to record micro seismic less than 1Hz, and EM to monitoring and identify fluids.

GC: I agree. The next big revolution will be going sub Hertz, with active or passive sources. That will be interesting.

RT: That will be a shift that will require some new processing solutions, to handle that very low frequency data.

GC: We've seen how low frequencies, down to 3 Hz with GeoStreamer, improve both exploration and production data in reservoir characterization. Imagine going sub Hertz.

SBD: I like the idea of an acoustic contrast fluid, or a nano-device that crawls through the pore space, increasing the acoustic contrast and in turn enabling us to better detect hydrocarbons in place. In the medical field, they inject such devices to attach to certain cells. When they are exposed to laser light, the nano-devices are activated to emit acoustic signals, enabling them to track the cells.

GC: Actually gas is the best imaging agent we have for the earth. By fracking and passively listening to the micro-tremors, you can follow the fluids as they propagate through the formation. You can actually have a seismic measure of permeability.

SBD: Or a stress axis – where it cracks.

Q: Is technology creating new plays, or are the oil & gas companies pushing us to expand and improve the technology?

EF: Like us, our clients are pushing for very low frequencies, broader bandwidth and flexible geometry. They also want new solutions for the difficult areas around installations, and extreme locations like the Arctic.

RT: Perhaps, at last, the time will be ripe for the marine vibrator? It's a pity the development has taken so very long. When the industry starts to use marine vibrators, many options and advantages will appear. Using several arrays simultaneously, we can increase efficiency. Eventually it will come.

GC: Perhaps, but geophone technology is almost 100 years old. There have been some improvements but they are essentially the same. Why? Because it works so well that it is hard to beat it. It's the same for the marine air gun source. For all its faults, it is a pretty good source: reliable and hard to beat.

RT: Good enough for today perhaps, but when you look at very difficult areas, and also environmentally sensitive ones, we have to start using AUVs. If you have ice, then you can't tow streamers. You need either sensors on the sea floor, or to send something under the ice. I think the seismic industry will go on forever because we will get better and better technology.

SBD: I still maintain that discoveries are about forecasting and diagnosing. We are still doing that in a very primitive way.

GC: Isn't that the way mankind exploits any kind of natural resources? You go for the easy stuff first. Technology makes the impossible just a bit less difficult. That's what we see in seismic too. Look at Brazil! Nobody was looking for oil under salt, but now that we can we image beautifully and drill under salt, a new play emerges.

SBD: Will ships become like military platforms with a bunch of autonomous sensor drones?

RT: I think one vessel will remain the most efficient means of acquisition for most areas.

What if you can sample a reservoir sufficiently well, that you can predict the changes that will take place, like weather forecasting? “

Q: What do you think will be the most influential drivers over the next 10–20 years?

RT: Most of the drivers for new algorithms and data processing come from acquisition. Suddenly you are presented with other possibilities to measure things. Computers are not a limit at all.

SBD: But data management is! We need a paradigm shift in how we generate and deal with information. Today it can take longer to list the files on the hard disk than it does to run a big migration. If we continue as now, we will get stuck in these bottlenecks. New ways of extracting the important information from our data is top of our agenda. Compressive sensing is a field that can hold some great promise for our industry.

RT: Perhaps we need different ways to make decisions, computer systems that mimic the human brain?

SBD: That is what you see in military technology. We need machines that behave like a human. I think we can assume that exploration managers will always be human.

Q: What two big changes do you forecast long term – 20 years hence?

RT: That we will do seismic without much human interaction.

SBD: 2030 we will have randomized sensors, deployed everywhere. Maybe you only have a clear acoustic vision in a few places. Mass blanket acquisition is over – we will have targeted probes, like the doctors.

GC: We will be measuring displacements via satellite. We will still have a source vessel but measurements will be made from the sky, using lasers to pick up small displacements at the surface of the sea.

EF: Autonomous acquisition systems may play a much bigger role – self positioning advanced nodes. Blended acquisition with different types of sources low and high frequency.

RT: By 2030 each vessel will need at least 1 million sensors.

GC: We will use a lot more low frequency and passive monitoring.

EF: We are still just playing with a few of the 21 elastic parameters of the earth. By 2030 we will measure more, perhaps up to 10 of them.

SBD: Then you will have moved the seismic industry into the realm of probabilistic theory – what is the least number of parameters necessary to predict our data?

As the discussion spirals into some rather esoteric mathematical puzzles that lie ahead, it is obvious that neither the challenges nor the appetite for innovation are diminishing. Turning the big ideas into efficient operational solutions will continue to be the focus of our efforts. Thanks to Guillaume, Eivind, Sverre and Rune for sharing their thoughts with our readers.

NEW STEPS ALONG THE PATH TO SAFETY

Health and safety are core concerns in our industry. Yet working at sea, with heavy equipment, at the mercy of the elements, is inherently dangerous. Staying home is not an alternative. The answer is to find new ways of predicting and preventing accidents before they happen.

AUTHOR: PAMELA RISAN ILLUSTRATION: THINKSTOCK

Traditional HSE thinking was all about responding to accidents and investigating the root cause, then changing the hardware, processes and procedures in order to prevent repetition. It had two real limitations: first, progress is limited if you only look behind at where you've been. Secondly, it all comes down to people – you can't regulate everything. Practitioners of HSE are eager to get better by preventing accidents in the first place.

Joanna Oustad is Senior Vice President HSEQ at PGS. Before joining PGS six years ago, she worked as an HSE and risk management consultant with large oil and gas clients. She points to a fundamental change over recent years in how HSE is managed in the exploration industry that – despite the sometimes spectacular failures – puts it ahead of other sectors in managing complex operational risk. "One of the crucial differences is when you start taking the potential consequences of an accident into account. If a man falls overboard and is rescued without injury, you need to consider the potential of his drowning (even if he didn't)," she says.

Oustad describes a triangle where the base consists of the broad number of unsafe actions or conditions. For every X number of unsafe actions, there will be a minor injury (the next step up the triangle). For a given X number of minor injuries, there will be an injury requiring medical assistance, another step up. Then, there are lost time incidents, and finally fatalities at the top of the pyramid.

"By putting our focus on the base of this pyramid, we reduce the number of unsafe actions and conditions, creating a knock-on effect that reduces the frequency of even less desirable outcomes higher in the pyramid," says Oustad.

The theory sounds solid. So why does it fail? The answers are complex, according to Oustad. Some of this reflects the manifold risks of our business and some the infinite complexity of human nature. Effective HSE thrives in an open culture, where employees report unsafe actions or conditions without fear of reprisal. It requires convincing everyone involved – from the mechanic that tripped on deck, to the peers that saw him stumble, to the president of the company – that the accidents that didn't happen also need attention. Any incident that could have led to a fatality (HIPO or High-Potential Incident), or lost-time injury, is reported all the way up to PGS' top corporate management.

"The oil and gas industry and the seismic contractors have made vast improvements in how they manage HSE. There is an evolution at work," explains Oustad, "from avoiding being caught, to following procedures, to self preservation, to taking responsibility to protect the team. The industry has worked hard to push this development."

Changing attitudes is the key

Oustad sketches a graph showing number of injuries against HSE focus. First came better equipment, to reduce some fundamental risks, then came procedures, finally came a change in culture. The initial rapid gains in reduced injuries have largely flattened out over time. At the far right of the HSE intensity graph, where many companies are now, is behavior.

We need to combat the tendency towards an ever complex rule book, before complexity tips into confusion

"Tools and procedures have a tremendous impact, but it's changed behavior and attitudes that finally make the difference, and we cannot be complacent." says Oustad. She explains that the major offshore bodies (OGP and IAGC) member companies openly share their operating experience. There are radically increased models for collaboration within the industry. This openness is helping to drive changes in behavior.

"Each company presents high potential incidents (those that could have led to a fatality), as well as any serious near-misses. Also, oil companies share information about the HSE performance they are facing," says Oustad. That openness also has to extend to the workplace, changing cultural attitudes to intervention and reporting on failure and oversight.

The odds of human error

Most accidents are caused by human error. What can we do about that? Several things may help, suggests Oustad. First, operators need to guard against the gradual acceptance of behaviors that almost meet requirements, so-called tacit non-conformance.

Then people have to do more than just follow the rules. They need to take a proactive approach to HSE, in order to recognize and act on hazard warnings before they become dangers. Individuals have to evolve a feeling of personal responsibility for their own safety, their colleagues and the world around them. To make that happen, responsible operators need to work relentlessly to build an HSE culture throughout the organization. That may combat the tendency towards an ever complex rule book, before we reach a point where complexity tips into confusion.

"We need to engage heads, hearts and hands, if we want people to take initiative to stop an incident unfolding even when there is currently no rule that governs it. There is only so much you can regulate."

GLOSSARY

4D – A series of seismic surveys carried out to map dynamic changes in reservoir properties, typically movement of fluid or gas fronts.

Passive sources – Sources of background acoustic energy which are not triggered or controlled by the seismic crew, but which nonetheless can be used for seismic surveying in some way.

AUV – Autonomous underwater vehicle.

Beam migration – A very fast Kirchhoff-like PSDM technique. It is very well suited to application in areas with highly complex geology.

Broadband seismic – Seismic signals which contains a range of frequencies significantly higher than normal, both at high and low frequencies.

Acoustic contrast fluid – A fluid with a particularly high acoustic impedance so its fluid front would show up clearly on seismic data.

Elastic parameters – Refers to the mechanical properties of rocks. Elasticity is the natural property of a material to return to its former shape or size following deformation, such as the propagation of an acoustic wave.

Flexible geometry – Refers to a highly flexible layout of sources and sensors with respect to each other.

Fracking – A method by which rock formations are fractured in a well bore, most often by introduction of a highly pressurised liquid.

FWI – A method of inverting for one important rock property – acoustic velocity. In FWI the solution of the wave equation is more advanced than other inversion approaches, solving for acoustic propagation both from the earth model and from the seismic data. This uses what is known as forward modeling (creating a synthetic seismic dataset based upon a certain geological model) and also the inverse of that, reducing a seismic dataset itself to a geological model. The output of FWI is highly dependent on the accuracy of the input data. Hence, it requires broad bandwidth and rich azimuth distributions. Considerable compute resources are employed. FWI promises more accurate and higher resolution velocity inversion than other methods.

Geophone – A type of sensor which records particle motion rather than pressure variations. It is conventionally used in land seismic and in ocean floor recording systems where the sensors are in contact with the earth. They are used together with hydrophones in the GeoStreamer system.

GeoStreamer – A unique seismic streamer system which uses particle motion sensors as well as conventional pressure sensors (hydrophones) to yield a vastly superior seismic image.

Ghost – Disturbances to seismic signals caused by the reflected sound waves bouncing off the sea/air interface and overlaying the desired signals with a similar signal arriving around 10 milliseconds or so later. Causes a loss of low and high frequency content in the seismic image. Solved by the GeoStreamer technology.

Marine air gun – Most commonly used acoustic source for marine seismic surveying, working by releasing air under high pressure.

Marine vibrator – A source which generates acoustic energy by vibrating mechanical devices.

MAZ – A survey design where a seismic vessel records several times over the same survey area, but in a different direction (azimuth) each time. A combination of narrow-azimuth surveys.

Micro-seismic – The recording of very small seismic events, normally within a reservoir, caused by fracturing of the reservoir for instance.

Multiples – Multiply-reflected seismic energy. Any event in seismic data that has incurred more than one reflection in its travel path. These arrive later than the primary signal from the reflector in question, and are often highly problematic, as they can mask desired signals from deeper targets arriving at the same time.

Nano-device – A very small device where at least some components have a size of less than 100 nanometers. One nanometer is a billionth of a meter.

On-demand seismic – Refers to the ability to acquire seismic data at virtually any time since the receivers are permanently deployed.

Permanent installations – Seismic receivers permanently deployed around producing fields to enable on demand seismic.

Pore space – Voids between the particles making up a rock formation. The pore space may be filled with hydrocarbons or other liquid.

Reservoir properties – The parameters that describe the physical properties of a reservoir formation and its content.

RTM – Reverse Time Migration, a sophisticated two way implementation of the wave migration. It is a more costly, but more accurate method of imaging structure in complex areas.

Sub-Hertz – Hertz (Hz) is a measure of frequency, where one Hertz is equal to one cycle per second. Sub-Hertz is less than that, i.e. very low frequency.

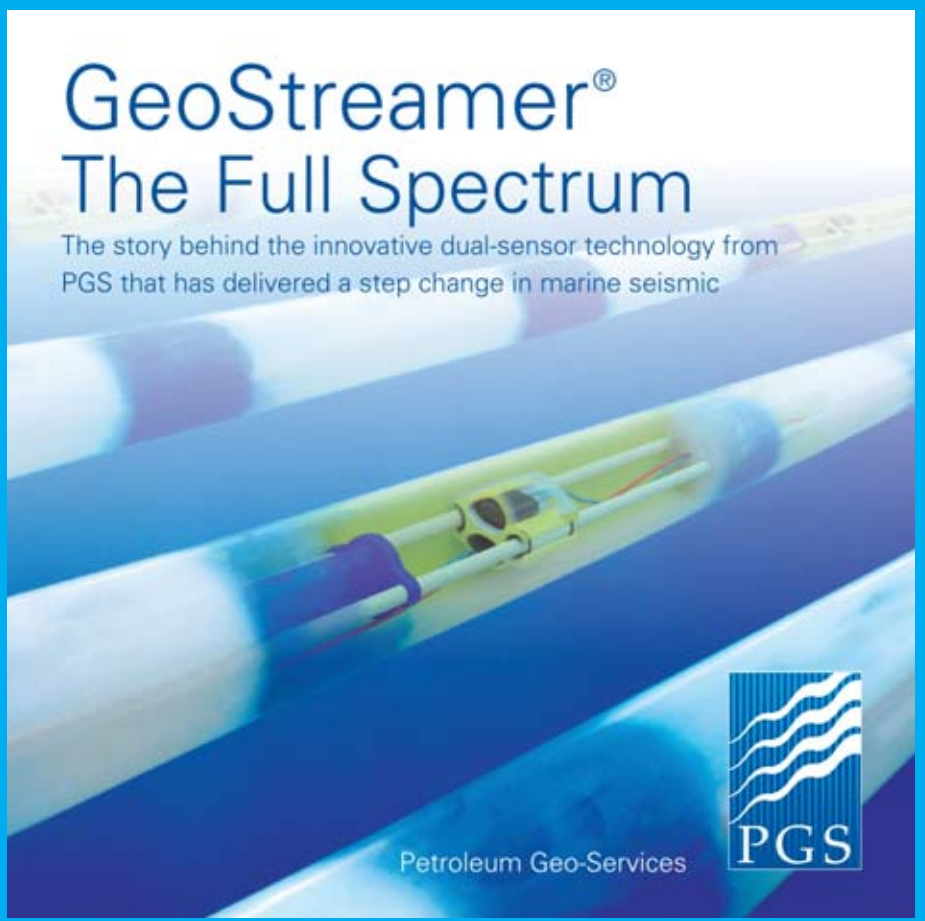
Ultrasound – Acoustic energy which is beyond the range of human hearing. The audible range for humans is between 20 Hz and 20K Hz approximately.

Wide-azimuth (WAZ) – Term describing a survey design where separate source vessels are used to record seismic reflections from areas out to the side of the recording spread.

Petroleum Geo-Services is a focused geophysical company providing a broad range of seismic and reservoir services, including acquisition, processing, interpretation, and field evaluation. The company also possesses the world's most extensive Multi-Client data library. PGS operates on a worldwide basis with headquarters at Lysaker, Norway. For more information on Petroleum Geo-Services visit www.pgs.com

REFLECTIONS / 2011
PGS MAGAZINE

This issue:



GeoStreamer® is the first towed dual-sensor seismic acquisition system. Its arrival in 2007 started a broadband revolution within the seismic industry. In film and animations this DVD describes the challenges of removing the receiver ghost and the benefits gained by its elimination. We review the development path and exactly how the de-ghosting is achieved. Five presentations of varying length, plus an electronic brochure, answer most questions associated with this exciting technology.

REFLECTIONS

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