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BRETT STERN

# Inventors at Work

## The Minds and Motivation Behind Modern Inventions

*Brett Stern*

Apress®

*Inventors at Work: The Minds and Motivation Behind Modern Inventions*

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*Mom, thanks for getting me all those LEGOS to play with and not making me clean up my room.*

*I was busy inventing.*

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# About the Author

**Brett Stern** is an industrial designer and inventor living in Portland, Oregon. He holds eight utility patents covering surgical instruments, medical implants, and robotic garment-manufacturing systems. He holds trademarks in 34 countries on a line of snack foods that he created. He has worked as an industrial design consultant for such clients as Pfizer, Revlon, and Saatchi & Saatchi, and as a costume materials technologist for Warner Bros.

Stern has been an instructor in industrial and product design at the Art Institute of Portland and Parsons School of Design. He has lectured on innovation and biomedical technology at Columbia University and Stanford University. He graduated from the University of Cincinnati with a degree in industrial design. Stern's work may be viewed at www.brettstern.com. Visit this book's website, www.inventorsatwork.com, and contact the author by email at invent@inventorsatwork.com.

# Acknowledgments

Seemed like everyone in Portland, Oregon, was writing a book except me. One day I got a call from Matt Wagner of the Fresh Books literary agency, asking me if I wanted to write this book. I got off my bike, put down my beer, and surrendered to the muse. Though I do know how to invent stuff, but really don't understand where all the commas are supposed to go, the publisher, Apress, teamed me up with several people who really obsess over proper punctuation and grammar to move this project forward:

Jeff Olson, Acquisitions Editor
Robert Hutchinson, Development Editor
Rita Fernando, Coordinating Editor
Kimberly Burton, Copy Editor

I greatly appreciate all of their efforts. They made it fun, and isn't that the whole point?,!,?,!,?

As I've asked my interview subjects about the benefits of having mentors in their lives, I would like to thank the mentors in my life: Michael Cousins, Richard Thompson, and Matthew Lesko.

And, finally, to all the people who said no to my crazy ideas. Thank you for the motivation to keep moving forward.

# Introduction

Inventions in steam engines, cotton mills, and iron works converged in the eighteenth century to propel the First Industrial Revolution. Inventions in internal combustion engines, electrification, and steelmaking in the nineteenth century ushered in the Second Industrial Revolution. Today, twentieth-century inventions in digital technology are being conjoined with twenty-first-century innovations in software, materials and advanced manufacturing processes, robotics, and web-based services to inaugurate the Third Industrial Revolution.

Today, at the dawn of the nexus of the future, ideas for inventions stand only a small chance of being realized and competing in the marketplace unless they're generated or picked up by corporations that can marshal teams of scientists and lawyers underwritten by enterprise-scale capital and infrastructure. Nonetheless, millions of individuals still cherish the dream of inventing and building a better mousetrap, bringing it to market, and being richly rewarded for those efforts. Americans love their pantheon of garage inventors. Thomas Edison, the Wright Brothers, Alexander Graham Bell, Bill Hewlett and Dave Packard, and Steve Wozniak and Steve Jobs are held up as culture heroes, celebrated for their entrepreneurial spirit no less than their inventive genius.

This book is a collection of interviews conducted with individuals who have distinguished themselves in the invention space. Some of the inventors interviewed here have their Aha! moments in government, institutional, or industrial labs; develop their inventions with multidisciplinary teams of experts; and leave the marketing of their inventions to other specialists in the organization. Other inventors in this book develop their inventions with small teams in academic labs and try to translate their research into product via licenses or start-up companies. Still other inventors carry on the classic lone-inventor-in-his-garage tradition and take on the task of bringing their products to market themselves. And a few mix and match their strategies, bringing skills honed in big labs home to their garages and licensing their personal inventions to big corporations.

This is not a recipe book. It doesn't aim to reduce invention to a foolproof sequence of steps: take an idea, go through the R&D process, develop prototypes, create intellectual property, build a brand, raise capital, and get product on store shelves. Rather, this book invites readers to touch their own creative impulses to the fires of real inventors speaking candidly about what possesses them every day of their lives: the passion to question the status quo and invent the future.

These privileged conversations have confirmed my belief that inventors are born to be inventors. Of the multitudes of clever people who get technical degrees in engineering and scientific fields, only a fraction contrive to add patents to their credentials. It is the rare individual who can combine curiosity, intellectual powers, mechanical knack, and focused awareness to see a novel solution to a problem, and then convert that insight into a physical invention that works. (For the sake of coherence, I decided to interview only the inventors of physical products, and not the inventors of software products alone.)

This collection of interviews shows how a startling variety of inventors selected for their widely divergent backgrounds, educations, fields, interests, personalities, ages, gender, ethnicities, business circumstances, and invention types—nonetheless share the ability and indeed the compulsion to create ideas and objects that are useful, exciting, and unprecedented. Many of the inventions described in this book by their creators have transformed our world; others simply made it a more fun place to live. But my intent in these interviews was not primarily to have the inventors talk about the details and significance of their inventions, which could scarcely be touched on in the course of a single conversation. My aim was instead to elicit self-revelations about the invention process and the creative personality.

What I found is that all of these very different inventions sprang from a set of common traits in their inventors: perseverance, drive, motivation, a touch of obsession, and—perhaps most importantly—a buoyant inability to see experimental failure as anything but a useful and stimulating part of the invention process. I was also struck by the fact that most of the inventors I interviewed expressed a similar set of preferences and work habits. They like to work on multiple projects simultaneously in multidisciplinary teams, freely sharing their ideas with others. They reach out to experts in other fields and ask lots of questions. They wake up in the middle of the night and sketch out their ideas on paper or visualize them vividly in their heads. They prototype ideas using materials that they are comfortable working with. They use physical exercise to relax their minds and jack up their concentration. They seek mental stimulation and different tempos of thought in areas outside their specialties. Most strikingly, they value slow time to ponder, dream, and free-associate. So ingrained are these traits and habits of mind that none of the inventors I interviewed could imagine ever ceasing to invent, even if they retired from their professions.

As for any project, I started this book with a clean piece of paper, on which I drew up a dream list of inventors and inventions that especially piqued my curiosity and admiration. And it was literally a dream list, since my underlying motive in undertaking the project was to investigate how dreamers have changed or influenced the everyday waking world of the rest of us.

The breadth of this book from conception to consumption illustrates how profoundly and rapidly our world has been transformed by these dreamers. I sat musing at my desk, then I Googled around on my Mac, and then I recruited my dream team on my iPhone. I conducted the interviews over Skype while recording the conversations using Call Recorder software, which I converted into MP3 files and then uploaded to Dropbox, from which a specialist transcribed them into Microsoft Word documents, probably with the aid of voice-recognition software. Then I uploaded the manuscript to my publisher's interactive platform, on which I collaborated with a team of brilliant editors and production people scattered all around the country, as cozily as though we were all sitting together around a table. You are reading this dialogue either in a paperback book that was printed almost instantly on demand, or on an e-book that you instantly downloaded from the cloud online from a vendor of your choice in whatever format you desired. Perhaps you are at this very moment being moved to tweet or blog about your insights learned from this book. Just imagine all of the inventions and inventors required to fulfill these tasks.

Even if you don't go to such rapturous lengths, I hope that you will join me in my homage to the inventors, engineers, and mad scientists who have reshaped our world. My goal in creating this book has been to inspire you to tap your creativity, to invent something really awesome, and to make the world a better place. Please, please follow your dreams and don't give up.

CHAPTER

1

# Gene Frantz

## Principal Fellow
## Texas Instruments

***Gene Frantz*** *always knew he wanted to be an engineer. He spent much of his youth taking things apart and subsequently earning his parents' clemency by convincing them it was all in the name of discovery. Now, as a Texas Instruments principal fellow and one of the industry's foremost experts in digital signal processing (DSP), Frantz continues to bend the rules to propel innovation.*

*Regarded as "the father of DSP" by many in the industry, Frantz has been intimately involved with the evolution of the technology—from theory, to product, and now to its phase as a true catalyst for new markets and products.*

*Having joined TI's consumer products division in 1974, Frantz helped lead the development of TI's educational products. He served as program manager for the Speak & Spell learning aid and headed the development team for all of TI's early speech products. Frantz is an Institute of Electrical and Electronics Engineers (IEEE) Fellow, and he holds more than 45 patents in the area of memories, speech, consumer products, and DSP.*

*Frantz received his BSEE from the University of Central Florida in 1971, his MSEE from Southern Methodist University in 1977, and his MBA from Texas Tech University in 1982.*

**Brett Stern:** So what does a principal fellow do all day?

**Gene Frantz:** Many years ago, a fella wrote a book on "intrapreneurs," which are those entrepreneurs that actually still have a job in a company. And you find out very quickly that intrapreneurs get fired a lot.

**Stern:** You're still there, so obviously you've done something either right or wrong.

**Frantz:** Let me define the term "firing" in these terms: I've been fired six or seven times at TI. And, don't write that down as derogatory yet. I tell people that when two words come up in conversation, I get fired. They are "schedule" and "profit." And the advantage that I have—as a friend of mine described it—is that TI is a start-up company with thirty thousand employees.

**Stern:** Well it's good that they can continue that frame of mind.

**Frantz:** But, if you think about having that much resource behind you, there comes a point when the innovation is over and it's time to make money. That's a different skill set. Now this was a different skill set than I had, and so it was easy to "fire" me and find a good business manager who could come in and take over, and run a business rather than a hobby shop.

**Stern:** So you're never really involved in the moneymaking side of it.

**Frantz:** No. That's correct. They learned to fire me far before [I got us into trouble]. I am a user of money and as I tell people, I am thankful every day of my life that almost one hundred percent of TI engineers are not innovators.

**Stern:** What are they then?

**Frantz:** Good, solid, thriving, development engineers who can make things happen and make them happen over and over and over and over again.

**Stern:** What is your definition of innovation?

**Frantz:** I have this little chart that I think came from public radio that says: "Knowledge is knowing the right answer or having the right answer. Intelligence is asking the right question." I take it two steps further. Creativity is asking the question for which there is no answer. And innovation is answering that question. There is another one actually below that: Business, which is making money off of the answer.

**Stern:** So what is your job?

**Frantz:** I have been called a serial innovator.

**Stern:** Your job is to find the answer?

**Frantz:** Yes. And sometimes ask a question. But generally, the question doesn't give you the start of a business. What gives you the start of the business is the answer to that question.

**Stern:** Well, in this process—because the process is very important—who asks the questions or who finds the questions?

**Frantz:** Sometimes I ask the questions. Sometimes the questions are asked by someone that didn't even know they were asking it.

**Stern:** Is that going into the marketplace, if you will?

**Frantz:** I spend about a third of my life at universities or small start-ups, listening.

**Stern:** What about listening or watching the actual end user, the consumer?

**Frantz:** That too. But I notice that with consumers—if you watch them correctly—you get the answer. But in many cases, the consumer doesn't know what they want until they've seen it.

**Stern:** Is it that they are afraid of new things or afraid of change?

**Frantz:** I think a bit of it has to do with that they don't know the capabilities of the technology.

**Stern:** So all the marketing out there—the market research and all those people spending their days asking for consumer feedback—what does that all mean?

**Frantz:** Well, you're right. That all works. I'm going to give you an example that I think is fun, which might get you down the path. The University of Southern California is doing research in the area of artificial vision. One of the research teams I glommed onto is creating a camera that fits in the eye, so it didn't have to put on a set of glasses. This camera is about the size of a grain of rice. Now in this case, I asked the question, "Where else can I put this camera?"

We did a lot of brainstorming on that and came to the conclusion that the camera, the size of a grain of rice, could actually create a $10 billion market opportunity. Use as an intraocular camera for artificial vision might be as much as $10 million.

The actual purpose it was designed for was only one-tenth of a percent of its value.

**Stern:** What were some of the variations you had for the tiny camera?

**Frantz:** I'm not going to tell you that.

**Stern:** Well, can you give me some background on how you got here before we really get into the interview? Your background, where you were born, your education, and your field of study?

**Frantz:** It's a fairly simple education—a bachelor's degree out of the University of Central Florida, and an MSEE out of Southern Methodist, and then an MBA out of Texas Tech. What I find about education is that, in more cases, education kills innovation than encourages it.

**Stern:** Obviously, you had some interest in inventing growing up. How did that first appear?

**Frantz:** Oh, I don't know. I had a third-grade teacher that sent a note to my mother that said, "Gene just stares out the window," and my mother sent back a

note that said, "He must be thinking great thoughts," and the teacher sent back a note that said, "Nope. He's just staring."

**Stern:** And what do you think you were thinking?

**Frantz:** Just staring.

**Stern:** So you didn't have inventions when you were a kid?

**Frantz:** No. I just don't remember. But, I think what made it all come together when I started work at Texas Instruments was being able to be in an organization at a time when we were trying to create new consumer products. I was in the calculator division and hooked up with a kid, Larry Brantingham, who was about my age that was really creative in the area of IC-integrated circuit development. I found myself to be very creative in the area of system development because I had the simple idea of asking the question, "Why does it have to be that?"

**Stern:** You're known as "the father of DSP technology"—digital signal processing. Can you explain that in technical terms? And then can you explain it in layperson's terms?

**Frantz:** First of all, I'm always careful not to take credit away from the people of theory who created the whole science of signal processing. I was more on the "let's go make it happen and prove it can be done" side. And it wasn't me alone. There were three other guys that worked with me. One of them was that same young kid. He and I worked for the consumer business at the time, and we were the two kids somebody would [come to and] say, "Here's a new idea. Why don't you see if you can do it." And we would figure out how to make it happen.

**Stern:** So you were the practical arm of the idea.

**Frantz:** The systems arm of the idea.

**Stern:** Could you explain the technology in technical terms?

**Frantz:** DSP, simply put, is based on the idea that all interesting signals in the world are analog. Once I say that, there'll be somebody in some business who says I'm wrong, but the heck with 'em. Sound is analog, vision is analog, feel is analog, taste is analog, and all of those are analog signals. The advancements in integrated circuit technology for decades has been on the digital side rather than the analog side, so if I wish to manipulate or use those analog signals to gain information and to do interesting things, then I need to do them in what is called digital signal processing. For example, your cell phone is fundamentally a digital signal processing solution. Your MP3 player is a digital signal processing solution. Digital TV is obviously a digital signal processing solution. Virtually everything we do now is driven by this concept of digital signal processing. Fundamentally, it is the mathematics that answers the question, "How do I mathematically model a system and then make it work?"

**Stern:** So your job back in '76 was to take this theory of how to do it and actually make a chip to do it.

**Frantz:** That was the other team's job—to make a chip. Mine was to make the whole system work. Understand that just because you made something speak—and that's what we were doing—doesn't mean it's a good idea. And if you go back and read the literature from the late seventies and early eighties, you'll find that we tried to make cars talk. That wasn't really exciting. As one person said [at the time], "Everybody knows a door is not a jar. Why does the car say, 'Your door is ajar?' "

And we made elevators talk. We made everything we could think of talk, and in most cases, people said, "I don't want it to talk. Would you please shut it up?" So there was this desire around the world of "I want to put speech on everything," and then a backlash of "but I don't want speech on everything." So it became [a question of], "Well, what things would best work with speech? Which ones would work without it?"

**Stern:** So where did the application get applied?

**Frantz:** What I began to do is to work with companies and try to help them understand what speech capability was, what the limitations were, and when they stepped over the bounds of usefulness.

**Stern:** The marketplace sort of defined where the technology would be applied.

**Frantz:** Yes, but the marketplace, as usual, doesn't understand when it works correctly and when it doesn't work. One of the products we came out with about a decade after the *Speak & Spell* was the Julie doll. She was a doll that had speech recognition on it.

**Stern:** And how did that go?

**Frantz:** Well, there were other things that made it die a short death. It happened to be that they brought it out in late 1987, which if you remember, there was the crash in the stock market, and start-ups didn't do very well through that crash. But I had been working with toy companies for years trying to add speech recognition to their products, and it really came down to this silly notion at that time that speech recognition did not work.

**Stern:** Did the companies know how the technology worked in those situations? Did the companies come to you looking for something? Or were you going to the companies, saying, "I have a great solution."?

**Frantz:** A little bit of both. I went after companies, saying, "We have this new technology—now what can you do with it?" And companies came to me saying things like, "We have a brilliant idea, and all we need is your speech recognition capability to make it work."

**Stern:** So back in the day, what was the prior art? Or what else was going on in the industry with this technology?

**Frantz:** Well, that particular one was mostly used in military systems to do specific things, of which you spent more time training the user than training the product. There were just too many problems. A lot of it was how you match the problem to the technology.

**Stern:** Your career has been in a corporate setting. Can you talk about that as far as being an inventor person, and then being part of a team that went out and developed the technology or commercialized it?

**Frantz:** In a corporate setting in a place like Texas Instruments, we fundamentally make our money selling integrated circuits and selling a lot of them. So we're looking at where we can sell products—areas that could use our devices that we haven't thought about up to this point. I could give many, many examples of working on a new business start [many would be certain] was not an interesting area. Yet as we pursued it and made it possible, it became very, very much a large part of the company.

**Stern:** So whose responsibility is it to get rid of the old stuff and sort of embrace the new stuff?

**Frantz:** We don't really get rid of stuff in that sense. The market actually decides to quit buying our old stuff and it goes away. We still have things that sell. TTL [transistor-transistor logic] was introduced in the early seventies. We still sell it today. Many of the early DSPs we created, we still sell today. So old stuff stays around as long as our customers can innovatively figure out how to use them.

**Stern:** Does Texas Instruments work such that you have a technology and then your group just tries to find new uses for it?

**Frantz:** Yes. When you find a new market area that is interesting, your first attempt is to build a business based on products that already exist. And then as you get some success out of that, you begin to look at how you could add something to a device that's already in design for another market. Usually it's at the third or fourth generation when you begin to say, "Well, now, let me do an actual integrated circuit specifically for this market."

**Stern:** Generally, is there a timeline to go from first to fourth generation?

**Frantz:** I usually assume each generation is somewhere between three and five years.

**Stern:** Okay, so it's almost a generational lifetime then.

**Frantz:** Yes, it's quite a long time. And if you think of most corporate situations, at least in integrated circuit technology where three years is a fairly long time, you say, "Well, that's an extremely long time to wait for a market to take off."

And that's why it is best to start that first one with effectively no investment specific to that new market opportunity.

**Stern:** But, you have all that manufacturing capacity behind you, so that's a pretty big investment.

**Frantz:** Yes, that's correct. That's back to the start-up with thirty thousand employees.

**Stern:** Going back to that thirty thousand employees, you talked earlier about this team effort. I think that there is this urban myth of the inventor. A lone guy in a garage, if you will. Can you talk about team effort and how you divide responsibilities?

**Frantz:** And it's back to something you caught me on earlier, and that is that creative moment of "Aha! I think we can go do this." By the time it gets to the end user, you may have had hundreds of people doing innovation to get it there.

**Stern:** The "aha" moment is a fraction of a second.

**Frantz:** Yeah, yeah, yeah. The creative movement is really an "aha" moment. And it's a lot of hard work thereon.

**Stern:** So basically the "aha" moment, which is the fun time, is a fraction of a second, and then you really have to just sit down and work after that.

**Frantz:** There are a lot of issues that have to be solved. I tell engineers and particularly engineering students that they have spent their four years at a university learning how to solve problems. Do they ever worry that we're running out of problems? And then I inform them that that's my job I create problems.

**Stern:** So, you are a problem creator. Well, in the team, whether you're managing the team or being part of the team, how does it get divided as far as the skill sets or the tasks for each to find the problem? You put three engineers in a room and you say, "Solve this problem." How does it get figured out?

**Frantz:** First off, you don't put three engineers in a room randomly. If you look at that team of four that started the *Speak & Spell*, we each had complementary skills and we were also at a point where we had nothing to do. And by the way, the creative "aha" moment was by my boss, not the other three of us.

**Stern:** If there are four people in a room, all bright individuals, and you get several directions to go down, several paths if you will, how do you decide which is the correct direction?

**Frantz:** When I worked through my MBA, one of the lessons that I learned from my business class was there are two reasons a start-up goes out of business. One is they have only one idea and the other is they have too many ideas.

**Stern:** So what's the right number?

**Frantz:** The right number is many ideas, but you focus on one until it's completed and then you go to the next.

**Stern:** In talking about the idea, can you explain or define your ideation process then?

**Frantz:** When I talk about innovation, I talk about how there are two ways of innovating. One is to create technology, and then figure out where to use it. And the other one is to figure out an itch that hasn't been scratched yet, and figure out what technology you have to pull through to make that happen.

And I go for the latter, so I am busily looking for that new idea, that new thing that nobody knows they need yet, but once it's available will say, "Well of course I have to have that."

**Stern:** You focus on finding the problem.

**Frantz:** Yes.

**Stern:** As compared to finding the solution?

**Frantz:** That's right, because the solution, in my view, is fairly straightforward to define and determine whether you have an opportunity to make it viable. I'll chase a rabbit here for just a second. I tell researchers that if they want to figure out new research topics to pursue, to go back and read the papers from twenty or thirty years ago to find out all those areas where people said, "This is really, really neat, but the technology is not available to do it." It's probably available to do it today.

**Stern:** So what you're saying is there's generally a twenty-year time lag between solution and implementation?

**Frantz:** There could be, and that's part of "Aha! I have this new idea." Is the technology available today? Will it be available in three years? Could it be available in three years if we pushed hard?" In other words, if you say naturally it will be ten years before we get there, can I pull it in [closer to today] by being creative?

**Stern:** After you see this problem or the possibility of a problem, do you write it down? How do you really define what that problem is?

**Frantz:** I write it down. A lot of times, I'll do a presentation because I need pictures to show this. I tell people the appropriate way to do a presentation is with a big font, short words, and lots of pictures—just because that helps get the base information down and allows for a lot of creativity to be filled in.

**Stern:** Are the pictures of situations or actual objects?

**Frantz:** Could be objects, could be drawings, could be whatever. It still works out that in many cases it is on the back of a napkin.

**Stern:** So you have this graphic representation of the idea. What are the next steps to ideate or brainstorm? Do you sketch? Do you prototype? What is the process that you personally go through or some examples that your team members go through to get to that solution?

**Frantz:** I do a lot of brainstorming with people.

**Stern:** So just sitting around a room and talking.

**Frantz:** Yeah. Or going to the whiteboard and screaming and yelling at each other. Or talking to an audience and getting them to give feedback. A lot of what I'm doing—after having this brilliant idea and keeping it to myself and figuring out how to make money, in many cases, since it is the end equipment that I am innovating and TI as a corporation does not sell end equipment but the components that go into it—I spend a lot of time throwing ideas, half-baked ideas, out to our customers and letting them finish the idea.

**Stern:** There is so much negativity toward new thoughts, new thinking, and new ideas, how do you personally have that confidence to say something that is off-the-wall and half-baked? What gives you the ability to do that?

**Frantz:** I've done it my entire career, so everyone's kind of used to these crazy ideas.

**Stern:** What do you think prevents people from having that ability?

**Frantz:** I have lots of people who will say to me, "You can do that because of the position you hold."

**Stern:** Which is true.

**Frantz:** And I say the reason I have this position is because I've been doing this my entire career. I tell people that innovation is the sport of young people. And there are a couple reasons I say that. One is that it is a twenty-four-hour, seven-days-a-week activity to innovate and create a new product. There is a second reason, and that is people with reputations are more interested in protecting their reputations than taking risk. And young people have no reputation to lose.

**Stern:** So you feel just by the nature of youthful indiscretion that you have that ability to throw ideas out there and say, "What if . . . ?"

**Frantz:** Yes. And as I say, it is a sport of young people, but you need to have gray-hair types around to keep them pointed.

**Stern:** How do you control the failures?

**Frantz:** I don't think you ever control failures. You just realize they are a failure and go on to the next one.

**Stern:** How do you recognize failures?

**Frantz:** There are two types of failures. First, there are technical failures, where the technology actually didn't work. Second, the technology was successful but there was no market for it, no customer. And so if I go back to that Julie doll, for example, it was a marketing failure. But it was a brilliant piece of technology and I say brilliant because there were several people that caught the idea and the sense of what had to happen, and did wonderful design to make it work. And I was the instigator and not the guy with all those brilliant ideas.

**Stern:** Where do you see how the technology—transforming analog to digital information—has been most influential in society?

**Frantz:** I'd say that it's hard to specify one area.

**Stern:** Well, how about several areas then?

**Frantz:** The cloud. That's all a result of this thing called digital signal processing. Now you'll hear somebody else say, "No, it was actually the computer," but those pipes getting your information to the cloud are all DSP-based. All the gathering of the information and putting it into a form of data and then taking the data and making different information out of it—that's signal processing.

If you look at the way we handle our music, the record has gone by the wayside, the CD is almost gone, and now everything we do is either on a computer or on a memory stick. If you look at our automobiles, many of the safety issues lately have been the whole concept of how do I create braking systems that work better than the human can actually consider. That's a signal processing task. If you look at airbags, that's a signal processing task. If you look at cars now that can parallel park themselves, that's a signal processing task. If you look at adaptive driving or adaptive cruise control, that's a signal processing task. You just keep going down the line and you find out there aren't many aspects of our lives that have not been affected by this silly thing that thirty years ago we thought was impossible—and that's signal processing.

**Stern:** In the next thirty years, where do you think the technology will be?

**Frantz:** It's easy to put on an evolutionary hat and say it will be smaller, easier to use, implantable, and more invasive in our lives. I think there's a whole set of "aha" moments that we haven't thought of that will occur, which we cannot predict. We can only look back and say, "Well yeah, obviously."

**Stern:** You just said that technology would be invasive in our lives. That, in a sense, has somewhat of a negative connotation.

**Frantz:** Of course.

**Stern:** How do you balance the positive and the negative?

**Frantz:** That's a hard thing to do. And the reason I say it's a hard thing to do is because as an engineer and as an innovator, my job is to create the capability,

not necessarily to decide on the morality of its use. And that always irritates me when I talk to engineering students. I tell them that they are at the beginning of some of the greatest opportunities to make an impact on society—so please make sure it's a positive impact.

**Stern:** And how do you control that moral judgment?

**Frantz:** I'll just basically say that's not an engineering activity. That's a community activity. But let me go back to an example. One of the things we added to a lot of our consumer products many, many years ago was text-to-speech. Many of the text-to-speech systems at that time would not allow you to spell a dirty word and have it pronounced. We chose that if you were going to spell a dirty word or an obscene word, [the product] would pronounce it correctly. And we did that because we felt it was our job to be true to the science and not be the moral compass of the user.

In fact, on the *Speak & Spell* program, I remember an instance where we had a parent call in concern that her little Johnny was typing dirty words into the *Speak & Spell*. Why didn't we stop that from happening? And my response was, "Well, first of all, did he spell them correctly? Because that is the purpose of the product." And secondly—and here's why they wouldn't let me talk to the parent—"I'd like to have a discussion with you on parental guidance." It was not our job to be the moral compass for that child. It was the parents' job.

You know, any time you create a new technology, you know that it is going to be misused as well as used properly. If you decide not to offer technology because it might be misused, you lose the opportunity for the good it can provide. I was on a panel many years ago at a major conference, and this very topic came up. I made a comment that it was frustrating to me that in many cases the early adopters of a new technology were either pornographers or con artists. Well, the rest of it was an interesting debate between an editor of a magazine and me about whether that was appropriate or not. But it really comes down to this it does not stop me from considering that next innovation.

**Stern:** Where do you seek and where do you find inspiration or solutions?

**Frantz:** I told you I was a serial innovator. Most of it is listening to people, and then taking a different view of what they said or what they were thinking, and describing our product.

**Stern:** Going back to when you were in the third grade staring out the window—I'm talking about the inspiration. Where do you come up with a possible solution for things?

**Frantz:** Oh, my engineering background tells me what's possible. I have the background to have a pretty good feel of what I can do, or what we can do and what we cannot do. Then it's just a matter of that "aha" moment—"Well then, why don't we do this?"

But let me just talk you through a story. When I give a talk on cloud computing, I show a slide of a cloud with clutter around it and I always say it's clutter because it's disorganized and it should be disorganized. One of the things I show around that cloud is a cup. Then I talk about what I think would be a great product: I go into Starbucks wanting a cup of coffee so I can sit down at a table and read my e-mails and surf the web. And I want to spend four, five, six hours there. Well, the trouble is that my coffee is going to last me about thirty minutes. Then I'm going to have to get up and get another cup of coffee and watch my table to make sure nobody steals my computer or any of my stuff.

Starbucks should have this new offer of the infinite cup. I go in and I order the infinite cup. I take it to my table. I sit there. And when the cup is almost empty, it tells the cloud in the Starbucks shop that my cup is empty and for them to come over and refill it with the appropriate coffee—and by the way, charge my credit card a little bit of money. So there's a service that doesn't exist anywhere in the world.

Would that be an interesting service? Yes. Could Starbucks make extra money on it? Yes. In fact, if they sold me a special cup and I came in every Friday to spend three or four hours, it could be set up so as I walked in the front door, my cup would say to the cash register through their cloud, "Gene just showed up. Say hi to him, tell him to go sit over at that table, and you'll bring him his coffee shortly."

**Stern:** And they'll know if you want cream and sugar.

**Frantz:** And they might even know that I want my first cup black and hot, I want a cappuccino for the second cup, I want iced coffee for the third cup, and just bring me a glass of water for the fourth cup. So I have a preset menu that they all know about. Now you say, "Well, would that be valuable to Starbucks?" Yes. They could make more money and their customers would be happier.

But then I say, let me spread that out [into other areas]. What if I went to a restaurant and all of the glasses on my table were tied to their cloud? So when my glass of water was nearly empty, they'd come over and fill it without me having to wave them down. Would that be valuable? Yes. I would be a happier customer. I would give bigger tips. So to me there's a cloud, there's an opportunity and, by golly, here's something I could do with it.

**Stern:** Does that leave out the opportunity for any spontaneity?

**Frantz:** Spontaneity in what sense?

**Stern:** Well, everything is predicted beforehand.

**Frantz:** Oh, you can always add spontaneity to anything, even if it's predictable. I could go in and say I don't want that. I want to change it this time. It's all about customer service, but that's an example of a product that just kind of hit me that might be interesting given every store in the world now has a cloud and I might

be able to tie to that cloud. Now, that's a simple "aha" moment. Unfortunately, the technology to make that happen is not such an "aha" moment.

**Stern:** What has to come about for that technology to catch up?

**Frantz:** Oh, how do I have a cup of coffee that can actually talk to the cloud? What's my sensor? What's my power source?

**Stern:** So is that a third party or—

**Frantz:** Or, it's a customer of mine. I tell stories like this to audiences waiting for somebody in the audience to have the "aha" moment of "Oh yeah. I could go do that and I could make a fortune at it. And I'll use TI components to make that happen." Or they jump to that next conclusion of "Well, wait a minute. Gene just talked about an inanimate object that, tied to the cloud, could be useful. What other inanimate objects in my life could I tie to the cloud and make useful?" And so I tell people an interesting brainstorming session is pick any inanimate object in your room and brainstorm what you could do with it if it were tied to the cloud.

**Stern:** It seems that you're at a point in your career where you get to mentor. To speak to people and give them direction. Do you have mentors in your life and where do you find them?

**Frantz:** I probably don't have mentors anymore. You get to a point where the mentors you would like to have had have either died, or quit, or gone away. So no, I think at some point you run out of mentors that are useful to you. And I'm not certain I would say what I'm doing to these younger engineers is mentoring them as much as I am enticing them to think about something new.

**Stern:** Would you say that you have professional heroes or had professional heroes?

**Frantz:** Yes, I've had some. Inside of TI, I think you kind of have to point to Jack Kilby as a hero.

**Stern:** And why's that?

**Frantz:** He invented the integrated circuit.

**Stern:** And do you have any inventions or inventors outside of TI? Inventions in your daily life that you really like?

**Frantz:** I can't really think of any. And I don't mean to sound tongue-in-cheek on that because my strength you might say is that I don't really think a lot. Some people read and learn, but I just kind of listen, and then things come to mind. You can almost say I'm a loner and that's fine.

**Stern:** Outside the digital world, do you have any products that you like having on your desk or in your home that give you comfort in any way?

**Frantz:** Not really. How's that? Although if you talk to my wife, she'd tell you I do really crazy things. I have a home theater. The house we bought about ten years ago, my goal was to make sure I had a room for a home theater, and so I have a home theater. I probably use it once every six months, but I'm happy to have it there.

**Stern:** Are there any technologies that you find not useful that are out there?

**Frantz:** Of course. I just can't think what they are.

**Stern:** When you are at a dinner party and you're sitting next to a new person, what do you say that you do?

**Frantz:** I tell them I'm an engineer at TI and I try to figure out what's going to be capable within five to ten years. And then change the subject to something else.

**Stern:** Do you have any advice for would-be inventors about the required skill sets you think they need to have?

**Frantz:** I tell people that it's okay to be crazy, it's okay to have stupid ideas, and it's okay to talk about them because sometimes a stupid idea is the nub of what will become a growing idea. You just don't know when that is. When I talk about the cloud, I always say had the pet rock been popular today, it would be tied to the cloud. I don't know why, but it would be tied to the cloud. And the reason I use that example, if you remember when the pet rock came out, what you kinda had to say was, "Really? Somebody would actually spend money to put a rock on his desk and give it a name?"

**Stern:** But it was an idea someone had, and he told a good story around it.

**Frantz:** It was a really stupid idea. They made a lot of money and I don't want to pick on the pet rock particularly, but I could probably go down a list of forty or fifty products that were really, really dumb ideas that people made a fortune on.

**Stern:** What does that say about the marketplace?

**Frantz:** That we're tolerant of a lot of interesting ideas.

**Stern:** That's true. With all these interesting ideas out there, could you talk a little bit about the intellectual property side? What's your method? You have forty, fifty patents out there. What is your responsibility when you're thinking of new ideas? And do you have any comments about the USPTO?

**Frantz:** I'll leave the US Patent Office alone. I just don't have any negative thing to say about them. They're doing their job the best they know how to do and this is a difficult, difficult area—to try to figure out how to capture intellectual property. What I tend to do—for example on this idea of a cup tied to the cloud—before I went out to make those presentations to the industry to give examples of what you might do with the cloud, I turned in a patent disclosure to TI for us to get that protected. So generally, it's like anything else: you turn in the patent disclosure. My job is to disclose I had an idea, not to determine its value.

Sometimes TI looks at it and says, "That's a dumb idea and we're not going to patent it." That's fine. About half of those patents in my portfolio have to do with a really dumb idea we had in the mid eighties trying to sell DSPs into the TV world.

About four or five years later, I had a patent lawyer call me and say, "You know that patent you had four or five years ago?" I thought we were going to have to restruggle through it again because it was a real pain getting it patented, and he said "No. That's the earliest description I can find of a synchronous DRAM."

**Stern:** So it had value.

**Frantz:** Long before there was a synchronous DRAM, we invented it.

**Stern:** Right. But did you know you invented it back then?

**Frantz:** Oh heavens. Heck no. It just wasn't called a synchronous DRAM at the time. We knew that we invented it, but it wasn't needed in the industry for another four or five years, and then once it was needed, everybody glommed onto it—and by golly, it did exactly what we had done.

**Stern:** Just as an overview, do you have any particular final advice for inventors out there?

**Frantz:** No. Invent. It's a fun thing. And advice to the non-inventors: find out what you're good at and do it. Not everybody can invent, not everybody can create, and what makes money is not necessarily the creation or the invention but the day-to-day work—making today's production just like yesterday's production and selling it into the market.

**Stern:** What do you do for fun or distraction?

**Frantz:** Oh, actually I do a real strange thing. I collect baseball cards.

**Stern:** Any particular year or field?

**Frantz:** Old ones.

**Stern:** What's your favorite card?

**Frantz:** I'm a Yankee fan, so it's my Mantle rookie.

**Stern:** What card don't you have that you're looking for?

**Frantz:** It just sold in an auction last week. It's called the Honus Wagner T206 card.

**Stern:** How much did it go for?

**Frantz:** $1.2 million.

**Stern:** And you weren't bidding on it?

**Frantz:** I'm still married.

**Stern:** Do you plan to retire at any point?

**Frantz:** There'll come a time where as a corporate innovator I will outlive my usefulness and I will go be a mentor to small corporations starting up, and I will help them grow into big companies.

**Stern:** You're going to continue the effort, but on a different scale.

**Frantz:** Yes.

**Stern:** Any final words of wisdom you want to offer the marketplace?

**Frantz:** Not really. I think the crazies out there that are the inventors of the world know who they are, but just won't admit it, and that's pretty typical. I just encourage them to continue to be crazy. I used to call them the lunatic fringe, but that got me in trouble.

CHAPTER

2

# Eric Fossum

## Image Sensor Physicist, Professor
## Dartmouth

***Dr. Eric R. Fossum*** *is a solid-state image sensor device physicist and engineer. He is the primary inventor of the modern CMOS active pixel image sensor used in nearly all camera phones and web cameras, many DSLRs, high-speed motion capture cameras, automotive cameras, dental X-ray cameras, and swallowable pill cameras.*

*Born and raised in Connecticut, he received his BS in physics and engineering from Trinity College in Hartford and his PhD in engineering from Yale. In 1990, Dr. Fossum joined the NASA Jet Propulsion Laboratory (JPL) at the California Institute of Technology. He managed JPL's image sensor and infrared focal-plane technology research and advanced development. At JPL he invented the CMOS active pixel sensor (APS) camera-on-a-chip technology and led its development and the subsequent transfer of the technology to US industry. In 1995 he co-founded Photobit Corporation to commercialize the technology.*

*In late 2001, with over 100 employees and revenue exceeding $20 million per year, Photobit was acquired by Micron Technology, Inc. In 2010, he joined the faculty of the Thayer School of Engineering at Dartmouth as a research professor teaching and performing research in advanced imaging devices.*

*Dr. Fossum has more than 140 US patents and is a Fellow member of the IEEE. In 1996, he was inducted into the Space Technology Hall of Fame. In 2010, he was named "Inventor of the Year" by the New York Intellectual Property Law Association (NYIPLA). In 2011, he was inducted into the National Inventors Hall of Fame.*

**Brett Stern:** Can you tell me about your background—where were you born, education, and your field of study?

**Eric Fossum:** I was born in Connecticut and went to a public high school there. I went to Trinity College in Hartford and studied both physics and engineering. From there I went to Yale and worked on my PhD. My field is solid-state devices.

**Stern:** When you were growing up, would you consider yourself an inventive kid? Were you playing around making things or fixing things?

**Fossum:** Strangely, not as much as I would have liked. I actually attended a special program on Saturdays at the Talcott Mountain Science Center in Connecticut. There were students always coming up with these neat ideas of things to study and I was very frustrated because I felt like I really couldn't think of anything original at all.

**Stern:** What eventually got you out of that frustration?

**Fossum:** It's hard to say. I think it's because at that time I was busy trying to find a problem. I couldn't think of a good problem to solve and when I started finding problems to solve in the course of doing my graduate work, it was very easy to come up with creative solutions. So it was really that old adage, "necessity is the mother of invention." Once there was a clear problem to solve, then it became quite easy.

**Stern:** I was reading in some of your background information that your great-great-great-grandfather, Benjamin Franklin Johnson, was a steam engineer, and various members of your family have backgrounds as machinists or engineers. Would you say any of that was an influence to you?

**Fossum:** Well, I didn't know most of those relatives because they were so far back. My father was a mechanical engineer and a creative guy, and so I suppose he must have had a big influence on me. As a teenager it didn't quite seem to be such a big influence at the time. It was more like trying to figure out how not to be like him.

**Stern:** So it's part of your DNA, but not necessarily in the front.

**Fossum:** Right. And my brother is also a mechanical engineer, so I guess there must be something to it.

**Stern:** Could you provide some background—first in technical terms, and then in layperson terms—about the technology and the field of study you are known for?

**Fossum:** My main area is microelectronics and microelectronic devices. My efforts are in the area of image sensors and the chips that convert light into electronic signals. They are used in cameras and camcorders, and that kind of thing.

**Stern:** At what point did you go into this direction?

**Fossum:** I was always interested in what is called artificial intelligence, in kind of a computer science sense, as I was growing up. I had a lot of exposure to computers early on, but then as I became more interested in physics and solid-state devices, I wasn't sure how those two interests connected. But I spent a summer at the Hughes Aircraft Company working on infrared sensors for various applications, and that really sparked my interest in smart imaging. How can we make a smart eyeball? That was really what fueled my interest in image sensors.

**Stern:** What was the state of the art prior to when you started the investigation?

**Fossum:** The state of the art image sensor at that time in the 1980s was the "charge coupled device" or CCD. Most were coming out of Japan for use in camcorders for consumer use, and it used to be that a camcorder would run for about an hour with a battery the size of a brick. A large part of that power consumption had to do with all the electronics required to make a CCD operate.

The CCD was a fairly power-hungry device and not so miniature. Of course, it was quite miniature compared to a vacuum tube, which was the previous television camera technology before the CCD. Definitely not something that would fit in your shirt pocket like a cell phone does today. I was at Columbia University after Yale, as a professor for six years. We were working on very high-speed image sensors for very fast cameras and signal processing. We were also working on smart image sensors, the sensor chip that had some smarts built into it, but it was still all CCD-based, which was the prevalent technology at the time.

**Stern:** Was this work for pure research or was there some industry collaboration going on?

**Fossum:** I would say it was more applied research but not much industry collaboration at that time.

**Stern:** Was there necessarily a problem you were solving or was this just sort of a "gee whiz, can we do this?" situation?

**Fossum:** I would say it was more in the "gee whiz, can we do this?" category as I look back at it. We were trying to solve the general problem of how you can put some of the smarts or some of the computing requirements for vision into the imaging chip itself, but there was no consumer application at that time.

I was generally thinking that it would be good for robotics, but in 1990 I left Columbia to go to the Jet Propulsion Lab, which was part of Caltech. When I came to JPL, I was asked to help solve a problem they were having with CCD cameras that were flying on interplanetary spacecraft. These cameras were relatively large and they consumed a lot of power, and they also were very susceptible to radiation effects in space. I was asked to try to help them improve that situation for the future. And that was the necessity that was the mother of this invention.