Eco Innovations: Small Spark, Big Impact

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Titan by Marc Dezemery (CC)

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Introduction

DEVIN STEWART: I am extremely pleased to have this panel. It's quite extraordinary. It's rare to have three people who have been a part of actually inventing things that are changing the world.

Just a humorous point, that their bios were so complex and sophisticated, we could barely understand them here. But it's a real honor to have all three of them coming from various parts of the country and for Niko Canner to graciously moderate.

Niko is from Booz & Company. He's a senior partner focusing on change and leadership.

Niko, I would like to just turn it right over to you, but before I do, I would like to thank you all for coming. Take it away, Niko.

Thanks.

Remarks

NIKO CANNER: Thank you so much. I am honored to be here.

All the work that I do is in some way about enterprises—whether at companies, nonprofits, or academic institutions—that all feel a need to create a new possibility. Organizations that do X that recognize the need to do Y, or organizations that do X realize that now they need to do X plus Y.

The three men on the panel with me today are each innovators who have lived versions of that story.

We sometimes think about ethics as the tough choices that we have between finite options. Today's panelists really underscore the possibility of ethics as the expansion of human possibilities.

Today's conversation should give us each the opportunity to think about what the world could be like if we built a better place for more people to do the kinds of innovation that these three in their own distinct ways represent. It also asks how can we make the kinds of things that they have learned through a combination of inspiration and accident more systematically teachable and learnable by the rest.

I see my role in this conversation as trying to ferret out a few of those insights and trying to provide a platform for us all to engage the three panelists around those kinds of questions.

Our first panelist is Peter Hartwell from the research side of HP, who works with a set of technologies cleverly

acronymed CeNSE that he will explain to us all.

PETER HARTWELL: Thank you, Niko. I am very, very happy to be here today. I'm going to introduce our technology and talk about a project we call CeNSE.

I am going to start off here with a little introduction. First off, I am from Hewlett-Packard, which is now the largest technology company in the world.

Hopefully, when you hear HP, you think of computers; maybe you at least think about printers and printing. But at the core of that is really our print cartridge, which has a very sophisticated chip in there. It's a silicon chip built in a technology that's called MEMS or microelectromechanical systems.

I am a MEMS engineer. I build stuff out of silicon in Silicon Valley. But not just integrated electronic circuits. We actually build moving parts. We like to think of the inkjet cartridge as the world's most sophisticated squirt gun. We can shoot 20-picoliter drop sizes and up to eight colors at 40,000 drops a second. It's an amazing technology.

Inside of HP, we look at what else we could do as the world's largest MEMS company.

In 2003 I was involved in a project that was trying to build a new storage device. We were trying to shrink a CD-rewritable technology and get it down onto a single silicon chip, so we were trying to put a moving disk inside on that chip, a read-write head technology. We were working toward, in 2003, a gigantic 2-gigabyte module.

The technology was pretty successful. But my job actually became what else could we do with that technology. What I looked at was the future of where things were going and realized you could turn this by running this little moving platform for the media backwards to create a sensor.

By sensor what I mean is inside your car right now you have what's called an automotive accelerometer. This is the sensor that is on your car to detect when you've had a collision, to deploy the airbag system.

Basically, the way that works is that there's a chip in the car and there's a little moving platform in there. Just like when the car stops quickly and you move towards the dashboard, on this chip there's this little platform suspended by springs. If the chip stops quickly, because it's connected to the car, that little platform inside moves, we can sense how it moved, and it moves just a little bit because if you bump the garbage cans in the driveway then it's no big deal.

If it moves a lot, then we know that you've actually caused a collision and that we need to deploy the airbag system.

What we were able to do at HP was create a new technology to actually move beyond the performance needed for [snapping fingers] measuring that into a much larger space.

Basically, right now what you're seeing in consumer electronics is these automotive-grade sensors that are moving into consumer electronics.

If you've played with the Nintendo gaming system or with these new smart phones where we actually can swing the controller as a tennis racket and you're not a tennis player, you say, "Hey, I can play tennis now."

If you are a tennis player, it takes about three swings before you're frustrated by the fact that it actually has no idea what top spin is; it doesn't even know the difference between forehand and backhand; and frankly, if you bang it on your leg, it will swing the racket. So if you want to go home and play with your kids today and say, "Let's play tennis," just sit there at the couch, say "I'm ready," bang it on your leg, and it will swing the racket. It is because it's an automotive-grade sensor.

Even in the consumer electronics, every one of these devices that HP ships has a three-axis accelerometer for measuring that drop, if the computer is on, to try to park the hard-drive head to save your data before it hits the ground.

But when you move to a thousand times more sensitivity, you open up an enormous new place for what you can do with data. But I work in a computer company, so they weren't interested. I had to figure out what else you could do with it.

If I take this sensor and I work at an IT company and I think about packaging it the way we take that chip on the end of our ink cartridges when we pack it, we then create something called a wireless sensor node. We take that chip and we package it with a CPU to process the signals coming in, some storage to store the data, a radio so we can broadcast what we've measured out to the world, and a battery to keep this running autonomously, and now

we're moving towards something like this.

This is kind of my ten-year vision, this little tie tack [points to tie tack pin he is wearing]. It's a little bit bigger right now, but you think of the progression of cell phones. We're working on that integration challenge. What happens now is you can take these nodes and you can build them into a network. You can take and collect that data over the network, start to do analysis on it, and create actionable information. The raw data you collect moves into this information.

This is a called a wireless sensor network. We think of this now as the central nervous system for the Earth. The idea is that what we're seeing with the Internet is this explosion of information technology, the ability now to access information wherever you are on the planet. But the nodes on the planet are actually largely blind, deaf, and numb. They don't feel what's going on in their surroundings.

Bringing sensors to the end of those nodes will actually put the next layer on the Internet. It's not just about measuring my heartbeat [which the tie tack is doing]. It's about measuring the heartbeat of the planet: What is the impact we're having with the planet? One of the biggest challenges with climate change is the fact that we don't have the information out there to see what is going on.

I am going to talk a little bit about smart meters. It's like trying to figure out the energy usage in this building by putting one node at the end of the building, which is how much electricity is going in there. You had no idea that we had a beautiful luncheon upstairs, and I bet you the lights are still on upstairs.

We need to understand how that energy is being used. We can talk about tracking wildlife, we can talk about tracking assets that you're moving. Did that carton of eggs actually stay refrigerated through that whole part of the supply chain all the way to the grocery store?

Tsunami and earthquake warning systems, smart highways. If we looked at all the things we can measure to understand their impact on the planet, it would take a trillion sensor nodes to do that. So it's an enormous opportunity to really get a grasp on what's going on.

Inside HP we have all the technologies we need to pull this together. That's where we're working right now in building this integrated system. But at a research stage, where we're starting right now is going back to the smart meter.

What are you doing in your homes? We're trying to figure out where are you using power, from this simple measurement of vibration, coupled with the data from the smart meter. The house becomes smarter and can figure out how it can help you save energy.

If I take a step back, let's look at a building space. In this room, there's the thermostat on the wall over there. There's one temperature sensor for the entire room. I happen to know Nancy who is sitting in front is comfortable because she happens to be sitting next to the thermostat. The rest of you who are far away from that are at the mercy of how the air-handling system is balanced.

If we can put more temperature sensors in the room in a way that doesn't greatly impact it—the biggest challenge to that thermostat is it costs about $1,500 to put the wire there to hook it up. You move to a wireless place, and now we can actually measure that temperature in that place. Let's measure it in every cubicle.

We do this in data centers. If you can measure the inlet of every rack of computers, even though there's only three vents in the room, we can balance the room dynamically by adjusting the flow of those air handlers to control the temperature.

Our administrative assistant is always cold. If we set the room to 74 degrees so that she's comfortable, we all fall asleep. So we set it at 68 where we're comfortable and getting a lot of work done. She sits with a space heater under her desk all summer long, even though it's 80 degrees outside.

This is energy, this is low-hanging fruit, these are the things we can change with sensor networks.

But if, instead of just measuring temperature, I measure my sound and vibration like I was talking about, I could tell not who is in a cubicle but which cubicles are used. Let's ignore the ones that are empty. And at night this becomes a security system. I can see if the building is being accessed.

But let me go one step further. Let me push integration. As your smart phone is not just a phone now—it's a navigator device, picture recorder, video camera, Internet portal—let me add some other sensors in there through integration.

What I've learned now is that in this building the people over there by the windows like the view. In the afternoons they open up the shades. And because I have a light sensor on board through integration, what I learned is that the problem is not that the air conditioner is too small, the problem is it's bright by the windows and we have a heat load coming in, that when the green building was designed, the air conditioner was not big enough capacity. The answer is not a bigger air conditioner and trying to recycle the old unit. The answer is window fill or to adjust the window treatment.

What sensing is going to teach us is about how things are different. The next layer on the Internet, the next Google, is going to be a company that can take this sensor information from my trillion-node sensor network, overlay it with the information that's already there, whether it's from weather stations that are out there, or new weather stations coming in from these signals, and mix that with your Outlook calendar. This way if you are in the San Francisco Bay area you can know the traffic to get from where I work in Palo Alto to San Francisco Airport.

But if you mix all this information together, and you're not just trying to decide the quickest way to the freeway, what you actually really want to know is you forgot your son's birthday and there's an awesome comic book shop in Redwood City. You've got 15 extra minutes, and I'm going to take you to that comic book shop as part of your routing to the airport.

I'm going to adjust for traffic and I'm going to adjust for weather, but I'm also going to adjust for the fact that your Outlook calendar says, Oops, get birthday gift. That is where the next Google is going to come from: Who can integrate the sensor data and make sense of it?

We're all sitting on an airplane, we've all been hot or cold, or we're sitting in a movie theater and we've been hot or cold. We actually are all sitting on temperature sensors, wireless, with a network in our pocket. It's called a cell phone.

If my pocket is warm because I'm warm, if we were all broadcasting on the airplane that we're all hot on the airplane or all freezing in the movie theater, which we typically are, let's get the movie theater to adjust that sustainability. Or if the car in front of me on the freeway slams on the brakes, I would like to get that message back.

Whether it's comfort or safety—because comfort is really, in sustainability, how we're using energy—we can pull those signals back. But now we have to worry about what is actually going on. Do I actually want to know who is sitting on the airplane?

I really don't care whose cell phone is telling me that they're hot, or, in the movie theater, who actually skipped school today or skipped work or who is out with whom in a movie theater. I just need to know the privacy or whose phone is removed or even the car slamming on the freeway. You have to consider that if you're the one causing the accident, that's actually not as important as avoiding the accident to the folks behind you.

How do we adjust that privacy? How can we get this information from these people in a way that benefits us while being cognizant of the privacy concerns that we're starting to lose from this?

Privacy at the office: Back in my office space, I would love to to know which cubicles are occupied so I can adjust the energy usage so I am only using as much energy as I need. But at the same time I am also measuring who came in late today. How do you do that?

In fact in the network we're deploying in Palo Alto, I actually had to go talk to our privacy counsel. Privacy is an enormous part of HP's business model. We have millions of customers. Their information and the privacy of that is very important to them, and we take it very seriously. I actually have to put signs in place on my campus to say that now I'm monitoring these vibration signals.

The last thing I want to leave you with is this idea of what is the price of sustainability. As I fly overnight in an airplane—and I've done a lot of travel recently talking about this—here's a map of basically the streetlight usage in the United States at night from space. It took me a lot of digging. It's somewhere between 14 and 20 percent of the power, depending on how you account for it, in the United States is used for lighting. Do we need streetlights anymore?

If you go back and historically look this up, streetlights stopped crime. They really reduced crime in cities because it was harder to be lurking around in the dark. But we've reached the point now where the privacy and security concerns are such that if I turn all the streetlights off, I can only turn them on when somebody is walking down the street.

What I have done is I've removed the ability for you to take a private walk in the middle of the night to get alone with your thoughts, and the way we probably all do it, to actually go have an innovation, because you never know

when you get stuck and you look for that inspiration for something to strike.

We take this very seriously in our research. How does the privacy of being able to measure everything make an adjustment through sustainability and security, but how does that also feed back into the impact of that? So privacy is a huge part of our research.

Hopefully, that was an introduction to the future of sensing but also the associated consequences that can come through technology if you don't think ahead.

NIKO CANNER: Now that Peter has been the first person in a long time to show us a new meaning of having a light bulb come on when you come up with an idea, we will move on to our next panelist.

Rick Cook is cofounder of the architecture firm Cook+Fox and one of the innovators in the area of ecologically friendly building.

RICHARD COOK: That was great, Peter. Thank you.

What my discussion might be more about is not so much the how but maybe the why.

I am an architect, I am trained as an architect, and like many, I went through the whole period of being pretty self-involved and hoping everybody would think that architecture was really cool.

We had an opportunity to work on our first green building in East Hampton called the Ross Institute Center for Well-Being. We were talking a lot about how you can educate the next generation about global citizenship. So, of course, the food is all organic, you recycle everything, the building is heated and cooled by geothermal, and has rapidly renewable resources.

But in fact it didn't change my life. It didn't change the way I was thinking about being an architect.

That really happened when I went to Cambodia and we became an adoptive family. So in two ways: One, that I saw what it meant to be a citizen of the first world and what was happening very quickly in the developing world. The other is that the heart of the green movement is "Do you view your life as something for you to do and make money and move on and gain satisfaction, or do you view your life as a steward of resources for future generations?" That really fundamentally changed my view on the world.

This first image [shows slide of traditional Cambodian house on stilts in a field] is that we're in a tour bus before we met our sons, twin boys, and they were actually in this little western style building in the back which is an orphanage. I took this picture out of the little tour bus that I was in with future adoptive parents. It brings up the idea of the developing world having the ability to provide an example: air cooled, rainwater collection, direct connection with the environment and agriculture, where the food comes from.

At that exact same moment, I took a picture out of the other side of the bus [shows slide of road with buses and cars, people waiting]. This was at the exact same moment. This was a traffic jam going into Phnom Penh. This was about eight years ago now. It brought up another reality: choking congestion, rapid urbanization.

This same year China was urbanizing at the rate of 15 million people a year, so two New York Cities moving from the countryside to the city every single year, and they want the exact same things that we have, not that this all works perfectly. But how could we possibly, ethically, say that you have to slow down, you can't have the things that we have; you can't have the healthcare that we've become accustomed to?

Fast forwarding to the big picture, René Dubos in 1972 working for the UN coins a term: "Think globally, act locally." I grew up with this as a kid in the early 1970s. It was maybe the most overused term of the green movement.

But we had an opportunity to act locally while thinking globally. Cook + Fox are the architects for the Bank of America Tower at 1 Bryant Park. It's now the second-tallest building in New York and the greenest skyscraper in America.

People ask, "What's so green about a giant skyscraper in the middle of Manhattan?" A skyscraper in the middle of Manhattan is essentially green not because of how buildings use energy, but how people use energy and how people get to work. An urban environment tied to the mass transit system produces an inherently much lower CO2 footprint than how people get to work conventionally across the United States.

New York City has 1.2 billion rider trips a year. I have a hybrid vehicle. It is definitely not the answer. A subway car gets 540 passenger miles per gallon. We actually did a calculation that showed that a building like this, a LEED

[Leadership in Energy and Environmental Design] Platinum under the U.S. Green Building Rating System, uses about one-twentieth of the energy in how people get to work than if it was a campus in Greenwich, Connecticut.

This is a view of the building as it exists right now, with the new subway connection on Sixth Avenue, a below-ground connection which will link the Sixth Avenue with the Times Square stop [shows slide]. So it's about how do we operate in the urban environment and how is that carbon footprint different, not just what's the whiz-bang technology in any one building.

Also, my partner said to me, "I'm really getting tired of talking about how buildings use energy; I'm interested in how we make energy." In the United States, we use an extremely inefficient energy grid. Being a designer, I like to go to artists. I think that sometimes artists see things ahead of us all.

This is an installation by Richard Box called "Field." That's 1,301 fluorescent tubes, no wires, they're lit completely by the stray voltage of the overhead power lines. Not being a scientist, I have no idea what that means, but it can't be good [laughter].

What is it about how we make power? What happens is we take an energy source, typically, on average, in the United States, and we put an energy source into a plant. We waste about two-thirds up the smokestack in waste heat.

There is no host for that waste heat. We lose about another 7 percent in the energy transmission to the source. That's the overhead lines that we talked about. So by the time we plug in, like we are here, we're about 27 percent efficient use of power.

The answer on this particular building was on-site power generation. It's a natural gas-fired turbine that captures as much of the waste heat as technologically feasible right now. So the building itself is producing about two-thirds of its annual energy usage at almost three times the efficiency of the grid. So it's just where is the power being generated and how.

Also, one of the things that happens in America is that about 90 percent of the smog is produced by about half of the power plants. We get these beautiful sunsets in August, and that's because we turn on something called the peaker power plants. We pay private energy companies to sit on very dirty power plants and not turn them on. But we need that peak capacity—think 3 o'clock in the afternoon on August 14.

So what we can do is store energy. This is an example of the ice storage tanks going into the building [shows slide]. There are 44 of these 10-foot-diameter stainless steel tanks, and every night they freeze solid, giant ice cubes. It doesn't save any energy; it changes when we use it. It's kind of a thermal lag technology.

Then water. Most of the world views water as a precious resource. We are blessed with an incredible resource that people planned over 100 years ago, but we get about four feet of rain in New York City, and we tend to squander it; in fact we overload our sewage treatment system and we pump raw sewage directly out into our rivers almost every time in rains in New York City.

What can any one building do about that? We can collect the rainwater that falls on the site and use it for what we call cooling tower makeup. One of the things we don't talk about much is the way that we cool buildings is we make them sweat, we evaporate enormous quantities of water, and we can be capturing rainwater to do that.

I don't have enough time to talk about it tonight, but much of what we were going after was thinking "Do you feel connected to your environment in the building?" If you don't feel different in the building, we haven't accomplished any of our goals.

Some of the things that are going on inside are sensors for CO2 and VOCs [volatile organic compounds] so that we can bring just the right amount of fresh air. In fact, the anecdote goes that they were starting to pick up flashes of VOCs in the building, and they realized that people were getting out their Purell and cleaning their hands and the sensors were actually picking it up.

This is Bryant Park down there, the most used per-person-per-square-foot park in America [shows slide].

This is the building in context now, now the second-tallest building, that's looking out to Bryant [shows slide].

The other story that was going on at the same time is that I met a whole series of really interesting people. When you go out and profess to be thinking about how to build buildings in the future and how to live and stewardship, you get to meet some really interesting people.

This is a photograph by artist-photographer Kenro Izu, who went to Cambodia to film the Angkor Wat temples and

was astonished by the state of healthcare in Cambodia [shows slide of Cambodian face]. He came back and said that when he takes one of his pictures, he is capturing some love from that place, and he couldn't sell it and make a profit, when Cambodia was in such need.

He came back and sold a series of photographs and he raised $300,000. Two of his friends said, "Kenro, if you're going to put $300,000 towards this hospital, we'll each put $300,000." They started a new hospital for children in Cambodia with $900,000. He wanted the story to get out that he knew nothing about healthcare, he knew nothing about not-for-profits; it only took one person who cared to try to make a difference.

Then he approached us and asked us if we would help him get the story out, and we designed a little building in Siem Reap [the town near Angkor Wat], next to the hospital, to get the word out.

The Khmer at one time were one of the most advanced cultures on Earth. There are some scholars who say the temple complex at Angkor Wat, if you take into account the hydraulics, is by far the largest temple complex on Earth, and so much was lost with the horror of the Pol Pot years. I think something like only 17 doctors survived the Pol Pot years. They started over from ground zero.

That led, in a kind of crazy way, to a biofuels project that we're interested in. We were trying to take Kenro's idea of loving fellow man with the healthcare that was being provided for children. There's a high-oil-content nut called Jatropha Curcas. In Cambodia it's called the *Lhong Kwong*. So we started this biofuels project to press this nut oil and use it in lieu of diesel fuel. So much of the developing world is power by diesel-powered gen-sets [engine-generators], which then make the people sick, who then go to the hospital. It seemed like a terrible cycle, and we were hoping to break that.

The way these things go, we planted a plantation, we got half the refinery in; through the tyranny of distance, language and corruption, everything completely imploded.

In fact what happened was with the birth of a consumer nation, which was kind of horrifying to watch, there was also a birth of waste products, which never existed in Cambodia.

Everybody used waste cooking oils over and over again. But the restaurants were producing waste cooking oil so quickly based on the standard of care for the tourist industry that there was a new waste oil product that was easier to process than Jatropha, and so we now have a biofuels project up and being refined using waste vegetable oils. It's providing all of the power for the visitor center, fueling all of their vehicles in both the Angkor Hospital for Children and the Sihanouk Hospital of HOPE, which is the best adult-care hospital in Phnom Penh.

This is our office here in New York [shows slide]. Our office was the first LEED Platinum space in New York City. This is a view—*National Geographic* was doing a special on green roofs, and this is a picture that they took [shows slide]. The editor of *National Geographic* had this to say about our roof and green roofs in general: "Here's where being responsible and attuned to the environment pairs up with spiritual satisfaction."

That really brings up the point about why do we do the things that we do. There's no question that we can radically cut the cost of energy in buildings through sensing and how we produce it.

But what are we seeking ultimately? It's a higher quality of life.

One of the heroes of the green building movement is E.O. Wilson, who happens to be a biologist from Harvard. He's the world best expert on ants, of all things. He said, "I think what we're going to need for the future is a new standard for success, which is not the quantity of stuff but the quality of life." I think that involves also a spiritual satisfaction: Where do you feel good in the world?

Thank you.

NIKO CANNER: This question of the satisfaction in every moment is a good transition to our third panelist, Shakeel Avadhany, the founder of Levant. He has the most inspiring story that I have heard in recent years of how an innovation can come to you in even the most ordinary moment of life.

SHAKEEL AVADHANY: Thanks, Niko.

I will start my presentation with a question I would like to just pose to the audience. You're at the gas station and you put 20 gallons of fuel in your car. I am curious to know, how many gallons do you think, of the 20 gallons, actually moves the car forward?

It happens to be three gallons. Out of the 20 gallons that you put in your car—and I am now referring to a standard internal combustion-engine vehicle—three gallons out of the 20 moves the vehicle forward.

It's kind of disgusting, and the question arises: Where does the rest go?

If you look across all the sources of waste in your car, you lose a bunch in your internal combustion engine, in your drive line, in braking, in rolling resistance and so forth.

A question for the merchant marines back there in the audience, how many do you think you lose in your Humvee?

I won't even go there. Thank you for your service [laughter]. No, I mean it.

We've got a big problem on our hands, and incremental solutions today are going to address this problem of fuel economy.

Levant Power is a startup company founded out of MIT in January 2008. I am a recent graduate of MIT.

We were a bunch of students, during school, driving over a bumpy road during our summer vacation. It occurred to us while we were driving on this bumpy road, "Hey, wouldn't it be cool if we were generating power from these bumps in the road?" My buddies looked at me and said, "Hey, Shak, that's a good idea."

I am thinking, well, it has probably been done before, and how significant is it going to really be?

I sat down, did the calculations, looked at the patent record and saw a green light. We actually sat down to do the calculations from a passenger sedan all the way up to an M1152 Humvee. We saw a notable fuel economy gain that could be delivered that could make impact to the industry.

So we sat down, we designed a bunch of different systems, we picked the one that we felt was going to be most economic to commercialize, and we presented it to a bunch of our professors on campus. The response was very positive.

The concept is something fairly simple. You're driving in your car. The next time you see a pothole, think of me [laughter]. You hit the pothole, a spurt of power comes out of your suspension.

Now, I just want to clarify this technology. Regenerative braking: When you step on the brakes, your car slows down, you're generating power as the car slows down, and what regenerating braking is, it's harvesting waste energy.

Similarly, the idea that we've come up with is the analogy for braking to the suspension system.

In a vehicle suspension, you've got four springs at each corner of the vehicle, and you have something called shock absorbers.

How many people here are familiar with shocks? If you were to have, let's just say, no shocks on your car and you're driving with just the springs at each corner, you would pretty much lose control of your vehicle. If you just took a sudden turn, you would probably flip, or some unfortunate event would follow.

What the shock does is it is a safety device. It provides handling, and it does it in a very simple fashion. Its purpose is to pull energy out of the spring so that the spring no longer vibrates. As soon as you take that sharp turn, that spring no longer has energy there to make you lose you control of the vehicle. The damper, the shock absorber, its purpose is to sap energy out of the spring as heat, so it just dissipates heat.

On a number of defense platforms, the shock absorbers—like I said, they dissipate heat, and they can get so hot that in Afghanistan that they can glow red. On a class eight truck, on a transit bus, after a ride, you touch a shock, you're going to feel it. That amount of energy is what we're pursuing in sapping—not as heat but as electricity—and we're going to use that electricity for something useful that the car can use in fuel economy gains or onboard electrical power.

The genesis of the idea was just a capricious remark which had merit in it; we looked into it further, designed it, and presented it to professors. They said, "Guys, if I were you, I'd run with it." That's what we ended up doing.

In January 2008 the company was incorporated and patents were filed. Family money came in to support us, and market interest quickly came. We started getting folks knocking at our door. Little did they know we were a bunch of guys in dorm rooms. I was taking calls on my cell phone from executives at large automotive companies.

We got our start first on the Humvee. We had an H1 Hummer shipped to us, straight to our dorm on a flatbed

truck [laughter]. It was the first platform. It makes sense. Let's start with a Humvee, let's prove this, and then let's start looking at the other opportunities we can pursue, and we demonstrated the concept.

From January of 2008 to January of 2009, it took us twelve months and $50,000 to get the Humvee fully retrofitted with the GenShock technology, and it worked. It generated a notable amount of power that raised eyebrows of people that mattered in the industry.

We had a press blitz. It started with the MIT press. They came and did an article on us. We had photographers come out and do a photo shoot of our truck, and we had our mascot, the Humvee.

We were just young American innovators having fun with a product that made a difference; it solved the problem that had inspired my team. Then market validation came.As soon as the press got out there, we had folks knocking at our door.

Today the company is funded now. We're based out of Boston. We've pulled in significant revenue and we're starting to complete our pilot programs on a various number of platforms that the product makes sense—for class 8 truck fleets, transit fleets, and actually a bus in Manhattan right now is testing our shocks.

We also have some unique work that we're doing out in the ocean. We're scaling our technology for ocean wave harvesting for some unique applications.

The product is a market push. There's a problem out there, and then we identified the problem and then had a technology to address that problem. It has been a very exciting time for us so far.

I am happy to answer questions as we get into the question-and-answer session. Thanks.

Questions and Answers

NIKO CANNER: We have in a very pure form at the two ends of our panel two different kinds of modes of innovation. Peter is sort of the classic solutions-in-search-of-problems form of innovation. I know what the solution is, it's MEMS, now what was the problem that you were asking me about?

Then we have, in as pure a form as you could want it, at the other end of the panel, Shakeel in the problems in search of solutions. What if every pothole was like striking oil? And is there a way to do that?

I would be curious to hear the two of you, starting from these two ends of the spectrum, if you imagined a world in which it was easier for the solutions and the problems to find each other, what might that look like?

What kinds of innovations in connecting the two would be interesting to each of the two of you?

PETER HARTWELL: For my solution, to address a trillion sensors, which is really where we see the opportunity; the barrier is the cost. The value is in the information which allows you to make a difference. The challenge is getting the cost of the technology to the point where it financially makes sense. We see that in an awful lot of green technologies, where there is this break-even point.

Even the cost of generating electricity right now, which runs at three to six cents a kilowatt hour, is not a painful enough point for us to make a transition to alternative generation technologies.

For us it is a challenge of getting the volume of shipping to where it pushes that commoditization point where you saw the automotive sensor cross over into entertainment.

Getting this to cross over from the point where, if you think of the original cell phone and what that cost and who had them. First responders, doctors on call that needed to get messages, and it's grown to the point where my niece is texting me from class. It's not the need she has, but the technology is so ubiquitous now and inexpensive that we can keep in touch.

For me the challenge is finding those applications where the economics makes sense, until we all have the epiphany of where it spiritually makes sense and that that can be a driver. That's what we wrestle with, that balance between does it economically impact my pocketbook or can I actually afford to do the right thing?

NIKO CANNER: Shakeel, if you think about a world in which there are 10,000 Peters, people sitting in big companies who have solutions to a problem of importance, and you think about the thousands of people like you who have an inspiration that could make it out into the world if they have the right connections and the right technology, how would you want what the Peters of the world do to be more accessible to people like you?

SHAKEEL AVADHANY: The question is technology pull versus market push. I have an enormous amount of respect for both approaches, and there is a huge laundry list of successes from both approaches.

I am running a business that is backed by private investors. Typically, when you're a bootstrapped startup company, you need to have something that addresses a problem where people are desperate for a solution. Otherwise it's going to be tough, because you're going to be burning through money to still look for customers.

But the history of large R&D houses and academic institutions—for example, the laser, the light-emitting diode—Jerry Woodall is one of my mentors—those were technologies that have made an enormous impact today that really did not initially have, from what I understand, an immediate problem to solve, nor did they have desperate customers for a solution.

To answer your question, the patent records are there. The U.S. Patent and Trademark Office has done a phenomenal job in being able to catalog inventions of big R&D houses that have, unfortunately, been shelved and are not seeing the light of day. It's an opportunity for private-sector guys like me to identify a lost jewel that has been shelved—it has a couple of inches of dust on it—to pull it off the shelf, brush it off, and actually have it see the light of day.

PETER HARTWELL: Are we actually desperate to get from three gallons out of 20 being used to four? Is it too hard to put a bigger gas tank on the Hummer?

The pull of your application to get more energy on that mobile platform—why not put a solar panel on it? Where is the pull for that technology?

SHAKEEL AVADHANY: The pull for us is if you look at the automotive industry it is very risk-averse.

Guess how many miles a gallon the The Model T gets? I believe it was 25.

Cars today are much higher performing than the Model T, but it's just an indication where 25 miles a gallon back in 1902 could get you from point A to point B. Twenty-five miles a gallon today—we've got work to do now.

What is remarkable is when you turn on the ignition in your car, that thing works. There are thousands of parts in that four-stroke engine, those valves pulsing. It's remarkable that the automotive industry has really got it down, and they are very reluctant to change parts of the product that have been proven.

As I mentioned, if you look at where the energy is going, 60 percent is lost in the internal combustion engine and 10 percent lost in the drive line. Technology pull. The suspension system is relatively insignificant compared to the internal combustion engine and the drive-line losses.

Just to quantify what we mean, we are anywhere between 1 to 6 percent fuel economy gain, depending on the application, low end on the passenger vehicles, high end on defense.

The reason we've chosen this and the reason we've seen the market appetite is because we are a turnkey solution that is not changing out the engine. Do you want to design a new engine? Go at it. Good luck. There are people out there that are doing it, and by 2020 or 2025, we may have a radical new engine design that's the standard across all vehicles.

But when you're running a small bootstrapped company like I am in the automotive industry, fuel economy is the lowest hanging fruit to provide value.

NIKO CANNER: Rick, I would be curious to hear your perspective on this, because in some ways you sit in the middle of the two panelists.

A building is a collection of an awful lot of problems that could potentially be solved in more sustainable ways, and I would imagine that you see some problems associated with buildings where there's a lot of innovation and some problems where there's relatively little.

Is there something to be learned about the contrast between the two?

RICHARD COOK: We do sort of sit in the middle, so we don't get funded. Money is what makes things flow. There is no money for R&D in the building-design world in the United States, so we weave a whole series of technologies together, such as super high-tech sensors so you can change the way you deliver air conditioning to the kind of right-size and right-time.

Elevators—most of you have probably been into a building where now you plug in what floor you're going to and it

tells you which elevator to go to. It's just more efficient. These are technologies that are available.

We have the technology right now to so that as you approach the building from two or five miles away, it knows you're coming and your office turns on the air conditioning. This is an invention that exists right now.

It's a question of do people want to pay for that in their office so it is just the right temperature when you get there?

When you walk through the turnstile, it says, "Elevator D4," and you go and wait for that one because that's the most efficient way to get you to the 72nd floor. It knows how to do these things.

So these technologies all exist. Is there a marketplace for them? That's the real issue. That's where I get back to the why: Why do we do these things?

Back to the military, we have a separate company called Terrapin Bright Green. Our partner there, Bill Browning, comes from a career military family. If the fuel depot is across an unprotected highway, you lose human life traveling back and forth. If you think about lives saved, if you had air-conditioned tents out in the desert and if you can reduce the rate at which you're sending fuel convoys to get fuel and bring it back to the air-conditioned tents, you will literally save lives.

So that's a pretty big why.

For the military, replacing people is expensive. Getting vehicles blown up is expensive. Then there's the moral and ethical issue of if you have a technology that would reduce the need to send people across an unprotected highway, why aren't you doing it?

There's a big demand side there. Photovoltaics on tents, super-insulating tents, things like that are what is happening.

It's the demand side that we really need. That's why I keep on going back to the why do you need to do these things? Why would you want to do it?

The sensor that somebody hit their brakes up there means you can save lives, maybe save some energy because you could brake in a more sane pattern, or sensors that say don't take that highway because you're going to sit stuck in traffic. But the why is higher quality of life and protection of life.

QUESTION: ...but you don't want to create a world where it's full of potholes.

SHAKEEL AVADHANY: Certainly.

QUESTIONER: So what other way can you trigger this burst of energy? You don't want a world full of potholes.

SHAKEEL AVADHANY: We certainly don't want a world full of potholes, but we have to deal with them anyway. That's kind of where we're taking an opportunity that roads degrade, and they degrade quite quickly.

We're there to address an opportunity of waste where we're going to have to deal with it, whether or not President Obama or Congress is really going to pass this $50 billion sweep across our transportation infrastructure. It's an opportunity of waste, and we don't like waste in this new environment.

QUESTION: I wanted to ask Peter if your sensor thing is working on the concept of knowing when a car is about to hit something else and stopping an accident from happening, which would allow then the car to be built much lighter because you don't have to worry about the safety element.

PETER HARTWELL: The sensing technology that I have right now is sensing motion or changes in motion. It feeds into the larger vehicle dynamics system about getting better information about how the car is performing or being used. We are seeing this technology coming forward.

Part of the challenge in fuel economy is adding the technology to do this. Like you were saying, the crumple zones add to the weight and decrease the fuel economy. That's the real challenge.

The other part of this challenge, and Richard alluded to it a little bit, is retrofitting the infrastructure. If you actually get to a highway system where the vehicles are smart and they're intercommunicating and interacting with the highway, and when somebody swerves it's notified and it's passed along and we all begin to react to it, the 1965 Mustang is no longer compatible. Then we will have gotten to a point where you can only drive that old car on city streets now or something like the dedicated parks for the antique cars.

How do you get back to what do you do with the obsolete?

It's definitely enough gains that it has gone almost as far as it can on the passive side of vehicle safety and as part of this program. In fact some of our interactions with the U.S. Department of Transportation are on the active side going forward, really getting the cars to anticipate what's going on.

NIKO CANNER: Our host promised us an event in which we would hear some innovators talk about the creative process of sustainable innovation and what a more sustainable society might look like.

I would like to make sure that we are true to our advertising, which requires a few questions that relate to creative process and/or what if we could be better at this kind of innovation, what might that mean for society?

So a few that fit that, beginning with you.

QUESTION: I am in town developing an international standard for energy management as a system. It taps into the quality management as a system, ISO 9000, and the 14000, which is the environmental management system. So all these things are being done.

My question, though, is you're ethical and I think I am. How do we guarantee ethics in the future? How is it that HP is not going to sell out your idea to the nasty people?

PETER HARTWELL: We mentioned the super-villain thing, and it's something I take very seriously.

As a steward of the technology, the best I can do is to try to develop it in a way that, from the start, has safeguards for the privacy and the security of that data. What we haven't talked about here is what happens when you start throwing incorrect data into these automated systems, and the systems are reacting now to someone creating a false accident on one highway, so he is the only one with a clear shot to the airport.

That's another whole side of the research. We haven't talked about the security of that information as well.

We just take it, at this stage of the research, as fundamentally part of what we deal with. In HP we have a culture of privacy and security, and it's woven into the core of the protocols, and the standards that you were alluding to, of how this information is coming. If you are going to act automatically upon it, you must guarantee the integrity. Otherwise, chaos is going to ensue.

NIKO CANNER: Let's ask our other panelists about safeguarding the ethical consequences of the innovations we have.

RICHARD COOK: It's why we talk about the why and not just if we can, but should we. These are really important questions.

Why do we apply technologies? What's our intent? Is it to make more money? Is it to make life a better place? Is it to improve healthcare?

The why is extremely important. It's one of those things, even in something as simple as coming up with technologies to apply to a building. If each one of you were out doing your house, you would say, "Oh, I'll put the photovoltaics on if they pay for themselves and I can get a tax break." It's a pretty simple financial analysis. It usually doesn't involve the "should I reduce my impact?" Or, "It would be neat if I could, as long as it actually pays for itself."

If the financial analysis is the ultimate determinant on why you do something or don't do something, for me that's a pretty scary place, because it's devoid of the underlying issue of ethics: Is it moral to do this way?

Not to get too preachy about it, but I have to face my sons, who are now nine, and they say, "Dad, you knew about my place of birth and what was happening there right now. Did you do anything about it?" Or, "Was it okay that Americans are 4.5 percent of the world's population but currently we consume about 25 percent of the world's resources and we produce about 25 percent of the world's CO2?"

Is that morally okay that we continue to do that? Do we feel that we have a mandate to change that formula that is beyond financial?

We have to have discussions about why we conduct ethical behavior for global citizenship.

NIKO CANNER: Continuing this discussion about ethics, across the room.

QUESTION: Just to follow up on that, we already know there's a digital divide in the world and the implications of that. We have it in this country and globally. I would be interested in hearing from the speakers a little bit more about how we can really increase the ability of people in developing countries to access some of the technologies you are talking about.

For example, with the sensors, how wonderful it would be if women who collect fuel wood across Africa and Asia, if there were some way to help them to know where to go, rather than wasting their time as they have to do now.

But it seems to me an enormous challenge to build that interface, and I just wonder if any of your companies are working on that.

PETER HARTWELL: I always get in trouble for saying this, but these things have got to be free. At a trillion of them, depending on whatever cost you put on there, it sinks the world.

They should be deployed on every polar bear. The opportunity to go in the rainforest and monitor the vibrations of the logging, instead of six months later we get a satellite image and realize where they had been and what they've destroyed. What I look for are places where the information that comes out of this has multiple end-consumers, because the value is in the information we create.

If in Africa I can deploy a sensor network to help someone gather the resources that is also at the same time providing climate information that is helping scientists—basically, we are creating another new resource that you can find consumers for.

It's about finding that place where there's enough financial support to pull the technology or to push it into place that it is going to have other benefits in the environment. Those are the applications that I'm looking for: Joint uses for the system or that there are multiple people. That makes sense from a reuse standpoint as well.

A lot of people also ask me, if I put a trillion sensors out there, aren't I just filling the world with eco waste? If I don't know where they are or where the information came from, it's not useful to me.

QUESTION: As you talk in various ways about going to scale, about going from one automobile model or one building or one set of sensors to a trillion or to every automobile, what kind of creative process is needed for thinking about that? How do you change a conversation about a single technology to a conversation about taking on the more global or more dramatically diverse and larger problems?

SHAKEEL AVADHANY: That's a really relevant question for me at this very moment. I eat, sleep, and breathe that question today, because we are still proving out the maturity of our product.

Our partners and our customers are, "Where's my product? Let's see it." Durability, reliability, proving the value proposition over all sorts of environmental conditions is still in play. We need to be thinking about volume.

For a company our size currently and for the market that we're playing in, to speak just on what I know right now is that auto manufacturers really cannot afford another giant recall, so it's important that when they source components they've got a trusted supplier behind it.

What we're doing now is we are very much engaged with a number of big tier suppliers of shocks, struts, springs and so forth that are very excited about the innovative product that we have that has a potential to disrupt their industry and look to partner with them to look at mass manufacturing. That is what's happening now with us.

RICHARD COOK: One of the thoughts in your question is marketplace transformation. The construction industry is kind of a "dumb" industry in the same way as automotive. People like to do things exactly the way they did them before and debug them.

We know that in the world gypsum production and cement production are huge CO_2 producers. We know that we can make very strong concrete using cement with blast furnace slag, which is a waste product, 45 percent blast furnace slag.

For every one ton of cement that we produce, we produce about one ton of CO_2 into the atmosphere. It's a nice little formula. It's easy even for an architect to remember.

For every one ton of cement that you substitute something else for that doesn't have the same carbon footprint, you save a ton of CO_2 out in the atmosphere.

The construction industry in New York—picture that one for a second. It is very much just like you're probably

picturing [laughter]. There's nothing movie-making about that. Very resistant to change.

The New York State Government, under the Battery Park City Authority, mandated the use of fly ash or blast furnace-slag concrete in Battery Park City. They mandated it.

The first few developers who came to build there and the first few contractors said, "We can't do it, we don't know this, the concrete won't set up in time," and they said, "Well, then you won't build your building here." It took somebody to say that you must do it.

After we got the first few buildings pouring blast furnace-slag concrete, it allowed us to do the same in buildings like the Bank of America Tower, where nobody legislated that we had to—we just wanted to. We used 45 percent blast furnace slag there. It still cost a little bit more, but it had been a proven technology in a place where it was mandated.

Then while we were doing that project, another project we did had 50 percent blast furnace slag at no additional cost because the industry understood that this was fine. They changed their admixture a little bit. It set up even harder and even faster. It has become kind of a norm in the concrete industry right now. It doesn't cost any more money to get blast furnace slag and radically reduce the amount of carbon produced.

Just one building was 25,560 tons of carbon-reduced by changing one technology that would not have happened if it had not been for government stepping in at one point in the initial part.

I am not a big fan of government being involved in the private sector, but it did take that to start it, so we need to have incentives and leadership from the government side.

PETER HARTWELL: From an innovation standpoint, it is really easy to draw parallels to the consumer electronics base.

I am basically trying to create a cell phone, throw away the interface and the display, and replace that with sensing technology. We look at some of the successes and the failures of that moving forward, but you also have to look at the various markets that have drawn that technology out to the point where it gets ubiquitous.

Shakeel talked about the LED or the laser. You look at the technologies that it took to get a laser to the point—nobody ever thought, when light first lased, that it was going to be in your car so you could listen to music, and in fact now that is obsolete. So it has run its course.

The challenge is to find these technologies and application spaces that are going to open that door to the paradigm shift. If there is one law in the right place that makes it big enough that the industry finally has to adapt, then suddenly it is the right thing to do and it moves forward.

As an innovator, those are the challenges. What can actually be used to move the technology to the next step where finally you break through that barrier, you're across this chasm, and then the volume just explodes.

NIKO CANNER: And our final question?

QUESTION: My question is for Mr. Cook. You keep saying how important it is for us to think about why we do things, and I completely agree.

My question is, how do you get others to think the same way? How do you create a society of individuals who are all thinking why, who are all thinking how do I adjust my life to live by these higher motivations?

RICHARD COOK: I'm a flaming extrovert, so I have an underlying belief in communication, telling the story. I am not a scholar. I learn by one person telling me a story and I talk about that story to somebody else.

So I think it's each one of us. We each have our responsibility. Kenro Izu was an artist, and he is out telling all his artist friends, "Hey, I started a hospital. Go do something. Don't complain about your government. Go do something." Each one of us can do something, and the more of us that are out there telling the story, then each one of us can make a difference in our own way.

Shakeel has this idea about a bumpy road and makes it a reality. You have this idea about sensing technology and thinking about how it could potentially save lives. Each one of us can go out and share with everybody around us what our belief system is.

I personally believe very strongly in faith and communities of faith. I just lost both of my parents, and I am out there talking about why in America is every death a shock when it's the only thing certain about life? So just

talking about how do we deal with end-of-life care and things like that, also.

Being an extrovert, an answer to your question is that each one of us has an obligation to share our belief system, that we have obligations to others and not just extraction of resources.

NIKO CANNER: Building on what Rick said and in closing, as I think about what is in common across these three innovators and what can we take away from their stories that is of equal applicability to us regardless of what we do, I think actually about the example of a Japanese artist named On Kawara. You can see a series of his paintings called "Today" in the Dia Museum up in Beacon, New York.

In some ways, this is about the least promising artistic concept that you could imagine. These paintings called "Today," each of them consists of a monochromatic canvas, usually black, occasionally blue or red, with a date painted in a standard font that Kawara uses in the middle of the canvas. One could not really imagine anything visually less interesting.

At one corner of this gallery in the Beacon Museum is a chart. The chart has the 365 days of the year on the horizontal axis and the years from 1900 forward on the vertical axis. Kawara is about 67 years old. You can see highlighted across the chart starting in 1933 the span of his life.

Beginning around his 33rd birthday, there start appearing dots, each dot for a day in which he executed one of these paintings called "Today." There is never a period of more than three weeks in which there isn't a dot. Often every day for a period of time, he will paint one of these paintings.

Over the course of his life to date, he has painted paintings in this series that hang in 94 different countries. This concept, as unpromising as it is, has come to have incredible meaning. His paintings have hung next to masterpieces of all kinds in museums.

Kawara has never in his life given an interview, which gives people like me complete license to interpret his work however we see fit. I would interpret it in this context as saying that any endeavor, even as seemingly meaningless as painting a date on a canvas, will be meaningful and will contribute to the world if it follows two very simple principles.

The first is intense absorption in the moment itself, which to me is embodied in the very simple act that Shakeel described to us of you're riding in a car, you hit a bump; what could that bump mean to the world? The second principle os sustaining an endeavor over the very long term.

So this is not the easiest moment, as Rick said earlier over lunch, to be using other people's borrowed money to generate green building projects, and yet, if people don't continue that endeavor at these difficult moments, the world does not move forward.

If we ask, all of us, the why that Rick asks about if we are an instrument for something—for each other, for the generations to come—what could that be an instrument for?

So I hope we take away from this panel not only the incredible ingenuity of these three people but the simplicity of some of the principles of their thought.

Thank you.