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SPECIAL GUEST SPEAKER NATHAN MYHRVOLD

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The Regulatory Information Conference convened at the Bethesda North Marriott Hotel & Conference Center, 5701 Marinelli Road, at 11:00 a.m.

PRESENT:

NATHAN MYHRVOLD, Founder and Chief Executive Officer, Intellectual Ventures

RAYMOND FURSTENAU, Director, Office of Nuclear Regulatory Research

P-R-O-C-E-E-D-I-N-G-S

(11:04 a.m.)

MR. FURSTENAU: All right, everybody take their seats and we'll get started.

I'm really fortunate to be able to introduce our special guest speaker today, Nathan Myhrvold. He is going to talk about boosting innovation in nuclear energy, meeting the demand for clean energy to power the 21st century.

After Mr. Myhrvold talks, there will be questions and answers. It will be through microphones in the aisles. So he'll take some questions from the audience.

Nathan Myhrvold is an inventor, a technologist, an entrepreneur, a research scientist, and an award-winning cookbook author and food photographer. I was mentioning to him right before this that my life is pretty boring compared to just the first line of his biography.

He's the founding CEO of Intellectual Ventures, a prominent invention and investment firm. He's also co-founder and vice chairman of TerraPower.

He and Bill Gates together created and oversee the Global Good Fund which invents for humanitarian impact. He's a life-long inventor with more than 800 issued patents and he's an author of a high acclaimed, multi-volume book on the science of cooking and baking called Modernist Cuisine.

And of course, Nathan, that's easy to find stuff about you on the internet. And one of the things that I found kind of humorist, some of you may know Stephen Colbert. He's on one of the comedy channels and he interviews people and several years ago, I can't remember exactly when, but in 2011, 2012 time frame, he was interviewing you about your bi-volume book set on the Modernist Cuisine. And he introduced it as what he, in his mind, a cutting-edge food made with modern science. He defined that as Taco Bell meat filling.

(Laughter.)

But when I think after you showed him using science to make food, it's much more than that. I think you won him over with your pastrami. That took 72 hours to cook in warm water and your pistachio ice cream that was made without cream. So I thought that was pretty good.

So Dr. Myhrvold has a Ph.D. in theoretical physics from Princeton University. He does scientific research in planetary science, paleobiology and other fields and he also likes dinosaurs, I understand.

So with that, Dr. Myhrvold.

(Applause.)

DR. MYHRVOLD: Okay, so I'm going to talk about boosting innovation in nuclear energy. So the first point is the world needs huge amounts of energy and I'll try to persuade you of that. I think that means the world also needs huge amounts of nuclear energy.

I can argue --

(Applause.)

There you go. If I can't get applause in this audience from that --

(Laughter.)

And I would argue, in effect, it needs new advanced nuclear energy. And I'll try to make the case for that as well.

But to get advanced nuclear energy, you need to have innovators that are bold enough to bet on it.

Now I have a history at Microsoft and Intellectual Ventures. I've been involved with lots of companies. TerraPower is probably the most unusual one and a lot of my comments are going to be seen through the lens of somebody who has actually been trying to be an innovator in nuclear.

Now innovators actually aren't the only part of the equation. You know, if you come up with a new website, you can just put it out there. But an innovative nuclear plant doesn't get to turn on unless there's also the regulatory framework that can approve it.

And I'm going to argue to you folks that, in fact, innovation and how you look at things, proactive regulation is something that the world is going to need if we really fulfill the promised nuclear paths in the 21st century.

So first let's talk about how much energy we need. This is global consumption of primary energy. In this case, 1965 is a 100 and we're up around 350 now. If anything, this curve is likely to go up higher than it is.

Today, all primary energy is about 18 terawatts. Now in this figure, I'm including transportation and other things that might be done with fossil fuels, primarily today. But that's still the primary energy problem.

All right, folks, this is a picture we took for our bread book of a toaster. And here's why a toaster is important. The average American uses about 9.2 kilowatts. You're going to say is that kilowatts per unit time? No, kilowatts is power. And it's very much like we had in 9.2 toasters running at home, 7 by 24.

Now, obviously, we don't, but that is taking the entire usage of the American economy. And taking our pro rata share of it, it's like we had nine toasters. It's a convenient measure if you're a cookbook guy.

Now here's the thing. The rest of the world, they also want nine toasters. Europe is around six toasters at the moment. China is around three. The world average is 2.4.

Now I like to make this point because a lot of folks in the United States tacitly assume that the world's energy problem is the same as our energy problem here. We have a mature, developed economy. We have energy-increased demand, but it's a relatively small amount. And so if you're that -- you can say well, gee, let's conserve a little and let's build some more wind plants and some more solar plants.

But in fact, like 2100, the whole world wants those nine toasters running for them. And you can just say well, maybe innovation in the use of energy will reduce that. It might.

There's something called Jevons paradox. Jevons was a British economist in the 19th century. And as people invented new ways of digging up coal and they also invented new steam engines that use less coal, he was concerned that, in fact, there would be a problem with this, that the coal mines would all go broke.

Well, sadly, that didn't occur and what he discovered was an interesting thing that the more you conserve and the more you develop efficiency, the more usage there is. Called Jevons paradox.

Now besides the fact that we want more toasters per capita, our per capita is going up and people have different projections as to whether the world peaks out at 9.6 billion people or 13 billion. But we're not done growing. So what it says is if you take our 18 terawatts today and then you bring up -- plus this new population, it's 119 terawatts.

So we actually have to build five times more power plants than we have today of some sort. And that's the context in which we view both nuclear and any kind of power is that the power industry needs to develop something that we can really deploy at a scale far larger than we have today.

Now if nuclear is to remain at parity in terms of its overall share of energy, we need to build five times more nuclear plants. There's also a lot of reasons that you might want to go above that, above parity.

And one of the reasons that this comes up is that energy really is the fulcrum that leverages human ingenuity. There are people in the United States who tacitly assume oh, well, Africa will stay poor. Well, that's a very cruel assumption to be making.

And as we think about our energy infrastructure, if we don't allow more toasters in those countries, more per capita energy consumption, if we don't allow that, we're consigning those people to a far lower standard of living, something we ourselves went through and rejected long ago.

So I was in India photographing tigers over the holidays. And these are two pictures I took in the Indian National Park. The smog is unbelievably bad, even in a national park full of tigers. And that's because a huge amount of the Indian infrastructure is still based on coal. And besides, their organized infrastructure, the informal infrastructure is based on burning wood and straw and cattle dung and there's open fires everywhere. Every small town has brick kilns that are fired by whatever they can find.

It's a beautiful place. Tigers are beautiful, but I never expected to have dense, Beijing-style smog in the middle of a national park, but it's true.

Now why more nuclear energy? Well, there's some powerful reasons. Here is a peer-reviewed paper of a few years ago that argued that the nuclear industry has so far saved two million lives. Now you say really? How could that be? Well, it turns out there are deaths associated with anything you do at a big scale. That includes deaths in mining. That includes a whole variety of things including results of pollution and so forth. And in fact, if you look at both deaths and serious illness, nuclear by any rational measure is the safest form of power.

Now we have a PR problem and not everyone understands that, but objectively, it actually improves public health. And besides basal electricity, nuclear has the ability to do -- process heat which is super important. India is built out of these bricks that they fire in homemade kilns that are very inefficient. Any of that or any number of a huge set of industrial things pretty easily can beat them with nuclear and generally it's cleaner and safer than existing approaches.

Okay, so why more advanced nuclear reactors? I come from the computer industry where innovation, novelty, the next great thing is taken as an article of faith. I have come to understand that may not be true in the nuclear industry in all aspects.

So I think we really need to invent things that can really clear several bars if we want to get out of the situations that we're in today where the public still doesn't trust nuclear power.

I think the first is we really need to make sure that the safety case is really nailed shut. Now let me be clear. I think nuclear reactors are incredibly safe. I actually told a reporter once, by accident, before my PR people kicked me, that nuclear reactors were too safe. I said if we took a little bit of that safety and we applied it to traffic deaths, where we kill 25,000 people a year in the United States, that would be a good thing. Well, I got kicked for that. Damn it, I guess I just said it again.

(Laughter.)

You know, there's a couple of design principles and not everyone may agree with these design principles, but getting high pressure out the system is a good thing. If you have a non-volatile coolant, you don't have high pressure. Sure, you have to make steam ultimately to run a turbine, but we think a non-volatile fuel -- excuse me, a coolant, is a great thing, designs that give operators a lot of time to analyze and act.

One of the problems with Fukushima is they didn't have very much time to act. The designs that can fundamentally shrink the safety perimeter of the plant, you know, the trouble is every nuclear plant is going to be in somebody's back yard, at least figuratively. And the better able we are to make the case that that's okay and the smaller the zone we need, the better off we're going to be. And new designs, I think, are the only way to address these things. You can't retrofit a different coolant.

So, here's a crash that was arranged by the Insurance Safety Institute. There's a 1959 Chevy and you have a 2009 Chevy that they have crashing into each other. Now, between these two cars you want to be in the 2009 car, not the 1959 car. In that interval, we got anti-lock brakes. We got all kinds of airbags in different positions. We got crash-resistant bumpers, crumple zones. And the result is that we dramatically reduced fatalities by more than a factor of two on a per-mile basis. And this was accomplished primarily by the folks who regulate. Sure, the car companies came with those innovations, but they came up because they were stimulated to do so by proactive regulation. And that regulation not only embraced innovation, it kind of required it. So I think that is an interesting example.

Now, I think cars -- I could have picked airplanes. I also could have picked drugs.

Now the current Gen III designs are a significant step forward, but I think there's also a lot of tremendous innovation in the fourth-generation space which is primarily where I have worked, whether it's in metal cooled, fast reactors, molten salt reactors, whether they're thermal or fast spectrum, even high-temperature gas reactors. Non-volatile coolants, you don't have this pressure issue and you have greater thermal inertia. But the key thing is more time to respond.

So here are the graphs of what happened

with those cars. The fatalities are down by a factor of two on a per-mile basis. But does that mean we have terrible cars? No, actually, it powers up by 46 percent. The mileage is up by 116 percent and emissions are down by 54 percent. So that is an example of a dynamic thing where, in fact, the combination of regulation and industry innovations really made a difference.

This is a graph of air travel. This is a cost graph. The airline industry has never been safer, Boeing issue notwithstanding. The capital costs and operating costs of the airline industry continue to go down. We've never had cheaper prices for flying.

Nuclear has got to be able to compete with renewables and even gas on price. There's a variety of arguments you can make that nuclear has advantages, certainly over renewables. It has the advantage that it's reliable. The sun goes down every day. It's a planned outage. But I think we really need to, as an industry, look to how we can be cost competitive because if you're not cost competitive, you're just not going to be able to grow up scale.

Now I think there are a lot of cost

benefits that the fourth generation can bring. Of course, we need to get these plants built in order to actually find out if that's true. But inherent safety gives you reduction of mass, it gives you less concrete, less steel, the site issue I already mentioned. We'll talk about fuel in a minute. All of these things are important to winning the public case for nuclear.

You need to design for the long term and for scale. So if all we're going to do is operate the existing fleet in the United States, plus or minus a couple of reactors, you don't need innovation. However, that isn't the world's problem. The world's problem is we need to build five times more power plants.

So in order to explain this, I like to say uranium is a fabulous source, but we all screwed up, because it had a use by date, okay? Best to use within the first 704 million years and it turns out all the uranium we have is way past its use by date. In fact, geologists have discovered that in West Africa there are some natural reactors. Uranium ore deposits that were moderated by ground water which would react just as they were.

Now the trouble is we weren't around to

use this stuff a billion years ago, so we have to enrich if we want to use U-235. Again, if all you're talking about is a tiny extension of the existing fleet, you probably could get by with U-235. If you want to build five times as many plants as we currently have, just to maintain parity, or ten times, if we want to increase the fraction of nuclear which is more what I think we should do, then I don't think U-235 is the only fuel that makes sense for the industry. So we need to be able to burn U-238 which means we need to have a fast reactor.

Now people realized this from the onset of the nuclear age. The trouble is as nuclear became less powerful publicly or less popular publicly, we stopped. It really made sense to us at TerraPower to say if we're going to build something that we think could really scale to meet the 21st century, we should work with the fast spectrum.

You know, nuclear plants need to serve a really wide variety of uses. There's very few products in the world that come in only one size or a tiny range of sizes and a tiny range of designs. We need, I think, more diversity here will allow us to address more of the world's power market.

Tiny reactors are one example. Now the

challenge is too, and I don't want to say tiny reactors are the future. There's a physics issue with them which is surface to volume ratio. You'll lose neutrons out the side, but the biggest problem for most nuclear operators today is siting. If the not in my backyard situation and it turns out people complained as much about 100 megawatts as a gigawatt. They're not calibrating their complaints in the power outage output. So that is a challenge for tiny reactors. That said, there's lots of -- I think there are lots of opportunities for them.

Floating reactors are another idea. And I don't think the United States is taking the lead here, except for our nuclear navy, of course, which is this, but these people, rather than powering a ship for another purpose, they said we'll put a power plant on a ship. Our coolant is right below us and if we're far enough off shore, the worst happens, we just sink. Now what about encouraging faster innovation? Well, there's a bunch of issues here. We have to have an environment that encourages persistence. You're unlikely to get -- when was the last time you heard oh, there was a new nuclear design and it went viral?

(Laughter.)

That isn't how it works here. You have to be incredibly persistent. Of course, some of that persistence is entirely warranted, but if you make it too hard for people that are persistent, you'll winnow down the numbers.

And this quote of Thomas Edison's is one of the things I tell myself whenever TerraPower has hit a bump in the road and he's right. I haven't realized it because we haven't gotten all the way there yet, but some day. We also haven't given up.

You know, you need young talent. When we first started TerraPower, we basically had two kinds of people, people who had built a plant, who we were all hiring out of retirement, and people who were idealistic and out of school and there was no one in the middle.

And here's a degrees in nuclear engineering graph that sort of illustrates that. So the good news is we're on an upswing. The bad news is if we don't start building new plants that isn't going to keep going. And I have to say if you don't build new plants, you don't have a nuclear industry.

This is like the difference between a community and retirement community. In the retirement community, no one is reproducing and if you didn't let new people in, it's just a matter of time.

(Laughter.)

We need to have a nuclear industry that's able to build. Now in some parts of the world, you can build plants today. In the U.S., there are people trying, but it's not particularly easy.

Now, we also have a storied history and we have to make sure that some of the great lessons of history are not forgotten. You know, we used to do incredibly innovative things in this country: FFTF at Hanford, molten salt reactors at Oak Ridge, EBR II at INL. Without those particular projects, we wouldn't have been able to make the progress that we have made at TerraPower. And it's really important that we connect with that past. So the young people do need to know about what happened in the past.

At the same time, it's not like you can put a whole lot more things on that list at the moment because we stopped doing the most innovative projects. Now, there's also another kind of fueling issue. Every nuclear company has one fuel it completely needs. And that's vast amounts of cash.

(Laughter.)

You burn money long before you burn uranium. And if you don't have an environment where you can attract investment, you're not going to get anywhere.

And so you need to have funders that are undaunted by uncertainty, but we also have to make the uncertainty a little less. And here's a good example. So the FDA has an extremely rigorous regulatory process. If I was a pharmaceutical executive, I would complain it's too expensive. It takes too long, all of these things. But guess what? For all of its faults, (a) it protects the public, and (b), the pharmaceutical industry still brings drugs to it. It's not so bad that the people stopped putting their drugs into trials. And that's largely because there's a fundamental faith in the pharmaceutical industry that if we have a drug that really makes sick people better, it will get approved. We have to prove our case. We have to dot our i's, cross our t's. We have to make sure there's no unexpected side effects, but they have a fundamental faith.

It's become much harder to have that fundamental faith in the nuclear business. And I don't mean recently. I mean this is the last, the history of the last 30 years. You know, there's a question of how long will it take to get to regulation, but investors are also burned by the fact they say what if we don't ever make our way through?

And there's plenty of examples of plants that were completely built and never turned on. And to the degree that that is viewed as an understandable and predictable thing, just like if a new drug doesn't work or it kills people, everyone understands yeah, okay, we have to take that off the market. If it's unpredictable, investors won't be pumping up the billions of dollars that are necessary.

Testing in silico, using advanced computing is one of the things I believe in strongly in all areas. It was a material reason that airplanes are more efficient. It's a material reason that cars are safer because they were able to do a whole lot more tests in a computer simulation, validated, of course. But I think the nuclear industry has to embrace that and I think ultimately that means regulators need to understand how they're going to treat things that are proven in silico.

If you're flying home from here, you'll be flying in an airplane where the pilots are trained in a simulator which is awesome because in the unlikely event of a water landing -- no -- the unlikely event of a problem, they will have practiced things that would be completely irresponsible to ever actually do. But in a simulator, you can, and you can practice them again and again and get good at them.

This is one of our simulations at TerraPower. We use simulations a tremendous amount. We also, however, have an active laboratory program because you do need to calibrate that your simulations are working well.

On the other hand, the Navier-Stokes equation that governs fluid flow is extremely well understood. Within the Reynold's number and thermal environment that we're in, you can simulate that as well as you like.

This is one of our test rigs at TerraPower. We got the building before we decided to do this and then we had this problem do you raise the roof or dig a hole because the rods were too tall, so we dug a hole.

So it's the combination of actually doing practical things in a hands-on basis and simulating that I think is a powerful tool. And it makes the overall innovation thing occur faster and cheaper.

Here's a system simulator. So I think since you are nuclear regulators here, I really think that proactive regulation, which is something you find in many of these other areas, is something you need to at least consider.

Now I may also be betraying my naivete, you know your business way better than I do, but we're not going to get the best result if all we do is preside over a shrinking fleet and then the clean up afterwards. In order to really expand the industry, we need new ideas, new technologies, new approaches. So that's sort of this point again. All of these other cases, it's actually worked very well.

You know, I think part of this is there's a huge advantage, any engineer will tell you, of going back to a blank sheet. And that's something that's extremely hard if your whole mindset is we must be incremental. And incremental innovations are nice, but they don't get you big changes. They get you little changes.

And this is the point I made before. We need to have an environment where we're back to building plants. At the moment, the country getting the most experience building nuclear plants is China. Other parts of the world are also building plants in much smaller numbers and much lower diversity in the design plan are building, but if we're not in a situation where we can think up new things and build them, I don't think we're going to get innovation and I don't think we're going to get the improvements we need to change the public's perception.

Uncertainties. I mentioned this before. It's one thing to convince people to give you a billion dollars to develop a new plant, but if you say oh, and by the way, besides all the technical risks, there's a reasonable chance that political risk or something out of left field that has nothing to do with the quality could stop you.

Now I also realize that this is not in any single person's power or any single agency's power. There's all kinds of moving parts here, but overall, the system needs to be one where people are willing to invest. That includes the government by the way. I don't think any first of a kind plant has ever been built anywhere on earth without substantial government funding because there's a strategic element to saying your country and the industry in your country has the expertise to build this. We have to get to the situation where that's a politically viable proposition.

So we need five times more power plants. And if we don't, I think -- if we don't build a lot of them that's nuclear, that national park in India is going to look even worse, much less the whole global environmental.

So with that, I thank you, and I'm happy to take questions and it looks like I went fast enough. We have a fair amount of time.

(Applause.)

Yes? I think there are microphones in the aisles, I should have said that. So I think that's the easiest. Yes, go ahead.

MR. OSTROFF: Hi. Jim Ostroff with Platts Nuclear Publications.

Let me just ask with respect to TerraPower, you previously had talked about doing a great deal of work on the system in China. That's now not possible given this administration's restrictions. What is happening? Are you pursuing this elsewhere? Is it the end of the project?

DR. MYHRVOLD: We actually did -- I mean all of our work has been in Bellevue and in national labs around the United States and some labs around the world that we support. But we did have a deal in China to create a joint venture to build the plant.

So the work has actually been in the U.S. up until now, but nuclear is a strategic and regulated industry including its export and while we had worked under a license that was not only developed, but strongly encouraged by the Department of Energy, they decided to end that. And I think it's fair to say that wasn't due to any problem that occurred with TerraPower, our joint venture there, at least its offices, but it's not like they had actually done very much yet. Instead, I think we were a pawn in a much larger geopolitical situation involving our trade war with China and security concerns and all sorts of things.

And look, we're an American company. If our government says we can't export, we can't export. So, of course, we're looking for other places to build our plant because we have a lot of the design done and we think it's got some real benefits.

I'm not being coy about saying more. This took us quite by surprise I think it's fair to say. So we're working on it. And if anyone here would love to have a traveling wave reactor in your background, be sure to see Chris Levesque, the CEO. He's right here. Okay?

Next question.

MR. LYMAN: Hi. I'm Ed Lyman from the Union of Concerned Scientists. One question is and you touched on this a little bit, but you consider the nature of innovation in the software industry. It's quite a bit different from what it would take to innovate nuclear technology because of the -- again, you touched on it, but the persistence you need over a very long period of time, trial and error can take longer. You need simply the experiments you have to do to validate models can take a long period of time.

Could you comment on there may be some of these substantial differences that may make the model, the Silicon Valley model not really applicable to nuclear technology?

DR. MYHRVOLD: Well, I agree with you. As I have told the software people at TerraPower, a system crash means something different to me than you. But that's why I didn't use the software industry as a point of comparison. I used drugs which are highly regulated and take decades to develop a new brand new drug and get it all the way through regulatory approval. Or cars or airplanes which also have very long cycles. And look, even after using those analogies, you're right, nuclear is different.

I totally agree that nuclear is

different. So you know, if I put up a Moore's law chart and I said oh, I want nuclear plants ought to double their efficiency every 18 months, it would be absurd. Nevertheless, there's a difference between saying yes, it's hard to no, we shouldn't try to do something different. What I was exhorting people to do is to say yes, we need innovation. And of course, that innovation has to first of all, deal with the realities of nuclear and it's got to be safe.

But I don't think the concern, if we had people who run drug trials up here, they want their drugs to be safe, too, and again, it's an analogy. And I think we can do better.

When the last -- a great irony, when the last nuclear plant in the United States, they announced the cancellation of it, it was announced by Al Gore, who in the same announcement said they would be replaced with clean coal plants. The inconvenient truth here hadn't quite happened yet.

It seemed in that year, like there was no downside to having coal. Now we realize that actually there is a downside. Unfortunately, that decision to stop building plants also meant we stopped doing all those other facilities, FFTF, for example. And that is the thing that I think was most unfortunate is that if we're not -- besides not building new power plants, the R&D was slashed by the government. I think R&D, and understanding is a really good thing.

MR. LYMAN: One other quick question, if I may. So you talked about how regulators should be proactive. So the NRC actually does not have any rule or policy that says that new reactors have to be safer than existing reactors. There's a policy statement which says they're favored, that new applicants should strive for greater safety, but there's no actual requirement. So I was wondering if you could comment on whether you thought a requirement in that area might be the kind of spur that advanced nuclear would need. Thank you.

DR. MYHRVOLD: Well, in that particular case, look, I am not an expert on the details of the actual regulations. I think as a practical matter, everyone doing a new design does think about safety to a huge extent. Should they mandate safety things? I don't know. That's a little bit beyond the -- what I was thinking of here.

The first part of encouraging innovation is to allow it. Particularly when I was at Microsoft, but also now, people from big companies say how can we be more innovative? And I would say the first thing is don't shoot the innovators. That sounds silly, but in fact, the innovations always are a little messy and they always color a little bit outside the lines.

So whether you require new plants to be safer, or you strongly encourage -- that issue isn't as important as saying new plants will be new and when you have a new plant, you need to analyze both its new failure modes, but also its new benefits and take all of that into account.

Another question?

MR. FINNERTY: Hello.

DR. MYHRVOLD: Sorry. These lights are really bright, so I can't see you.

MR. FINNERTY: It's Mike Finnerty from Office of Nuclear Regulation in the U.K.

So in today's current climate, one of the issues we see is that new nuclear power stations the design is continually, continually evolving almost to the point where the stations are unaffordable. And most of these design changes, they're not driven by regulators, but instead it's just designers who are seeking to do things better. But as a result, you're getting designs which essentially you've just first of a kind costs continually.

And so we are seeing, particularly, for example in the U.K., we are seeing almost that the power stations they're getting close to being unaffordable. And I guess this is one of the canopy issues. It's almost like a dichotomy with innovation.

So how do you -- I mean, I think that the examples that you've talked about, how do you ensure that we don't fall into the same trap again with advance reactors and future designs so that actually we can get a design, fix a design, and then just replicate it so we don't have continually first of a kind costs which is continually escalating the cost of new nuclear?

DR. MYHRVOLD: One of the things that is -- this is a general problem in life. Okay? It turns out design is hard and it's harder than we normally think. A custom-made thing is more expensive than something you make lots of. A standard design, you can always make cheaper eventually than innovating in a tiny way each time. Totally true.

And that's why for some things the world will fixate for a period of time on a standard. We all have cell phones here I trust and those cell phones have to do a standard that's accepted by cell towers or it isn't going to work. 4G is where we are now. 5G is coming. If we all had a different kind of 5G that wouldn't work. Or if they changed the standard every week and our cell phones stopped working, that wouldn't work either. The computer industry is that way.

I was at Microsoft before we got Windows going and people will sometimes say to me now well, gee, hasn't Windows been around for a really long time? Well, there's a huge cost in changing.

But I would also say the small changes are just that. They're small changes. And if you're in an environment where no one makes big blank sheet of paper change things completely deals, you will get lots of tiny, incremental changes and those incremental changes can just drive the cost up for no reason.

The difference between layering additional kinds of additional security circuits like the EPR versus saying no, we're going to go to a liquid metal fuel that doesn't boil. Those are radically different approaches. One is incremental and it's not even incremental. I don't mean to diss all incremental. But really radical changes are how you make the biggest leaps.

With the plants that we have in service today in most parts of the world are direct extension of the nuclear navy program in the United States in the late '40s and '50s. And the design choices made there aren't necessarily the best design choices for all time.

At the same time, tweaking things for the sake of it doesn't help and failing to get the advantages of standardized manufacturing, you know, is another issue. But one of the things about design is, it's very hard to have a single rule, a royal road to success.

The AP1000 design is much simpler in many ways than EPR. This is just my amateur view. But it requires a couple of parts that seem to be almost impossible for the world to make. So that was -- in retrospect maybe not having those motors upside down would have been a good idea.

So you can make a mistake by innovating too much without enough benefit, I agree. But zero innovation isn't the answer either unless you're totally satisfied with what we have which I don't think we are given we have to build five times more this century.

Yes.

MR. NAFT: Hi. I feel like you're in the line-up and I'm one of the policemen looking at you. Sorry about that.

My name is Barry Naft. I'm the president of Environment International, but I think more to the point here I'm one of those guys that was on the original design team for the Westinghouse 1000-megawatt reactor.

DR. MYHRVOLD: Okay.

MR. NAFT: Still around and can talk about it. Look, when I look at that progression of 1000 megawatt design, so it's all advanced like you just discussed methods, we had demonstration reactors like Shippingport. We had 500 megawatt reactors like San Onofre, a lot of good operating data and a lot of experimental data that's never been made public. So what did we get out of that? We put 30 percent margin on that, what we thought was a regulatory-acceptable design. And the industry went through about two decades of 50 percent plus or minus availability before it started to become close to its 80 percent design target. It's up in the low 90s now, so we paid the price over almost 50 years to get a mature design.

I'm all in on your energy projections and I think nuclear has a place in all of the above strategies, but I can't see it competing with combined cycle gas turbines that are twice as thermodynamically efficient just passing 60 percent more.

Are we really ready to start into all that again?

DR. MYHRVOLD: Well, we are.

(Laughter and applause.)

And look, N years out, you may be able to tell this story about how this silly guy stood up and said that in front of all you folks and was proved wrong.

We think there's fundamental reasons that it's worth trying and simply saying this is the be all and end all, we have reached its pinnacle, for us doesn't work for a variety of reasons, all of which are mentioned in my talk, you know. We can't build five times as many plants and fuel them efficiently with U-235.

By the way, we'd have to build a whole lot of enrichment plants. Enrichment plants are something that you have a variety of issues because you don't have to stop at 5 percent. In fact, it's counter intuitive that 5 percent is actually about half the way that you need to go to weapons-grade material.

So there are a set of reasons why we think you can have new ideas that would be useful. And we think that it's worth pursuing all of that.

Now it turns out combined cycle is more efficient, but if you have a reactor that operates at higher temperature you get some of that efficiency back. And by the way, combined cycle isn't actually what's used. So everyone quotes gas as being 60 something percent. Well, if you look it up that was one plant that for two weeks ran to win an award. The ultra-efficient plants are more expensive. It turns out gas is cheap at least right now. So no one actually uses those more efficient plants. The percentage of the natural gas in the United States that gets above 60 percent is zero.

PARTICIPANT: Thank you. A thought just came to mind. The plants that we have now are all based on light water. Some in Canada, the ones in Canada are based on heavy water, but they're essentially the same idea.

Now you're talking about the traveling

wave reactor, liquid sodium, there are high temperature gas cooled reactors. There's all kinds of things in the offing. Chances are in the world in the distant future, they're not all going to be working. Something will dominate.

And I'm wondering about how do folks like you and your what I would think of as economic competitors actually have an incentive to work together in order to figure out which one of those is going to dominate. How does that work?

DR. MYHRVOLD: Well, the best innovations generally don't come by having one team of people. In the case of the original nuclear plants it was one team of people, but they have Hyman Rickover whipping them into shape on a daily basis and if we could dig up Hyman and get a few more of him, we could solve a whole lot of the world's problems.

That unusual degree of focus is kind of legendary.

PARTICIPANT: That focus is what I think is the problem. The issue that I'm asking about is how do you decide between liquid sodium, lead cooled, high temperature gas, thorium fuel, other kinds of uranium fuel.

So Rickover had a single focus and drove a whole mess of people in a single direction. What I'm talking about is how do you handle this wide variety.

DR. MYHRVOLD: Well, the independent companies will each have their own ideas. And the management of those companies and the technical people in those companies will come up with what they think is the best approach. You know, in TerraPower, we're actually doing two things. We have a molten salt effort and we have a traveling wave effort. Each one has its own sets of challenges.

The traveling wave reactor uses a liquid sodium coolant and that's frankly, more mature than molten salt. It's more mature because the guys at Oak Ridge eventually stopped. If they kept going, I think we would have a lot of innovation there. But each of the reactors has different characteristics. And for now we're supporting both of those.

Other people will see the same sets of design possibilities and they'll come up with their own ideas just like they do with cars and airplanes and other things.

You're right that eventually industries tend to pick a couple of models. It's usually not just one. Cars on the road are mostly gasoline, but trucks are mostly diesel and there's a lot of diesel cars, too. And now there's some electric cars and some hybrids. So we go through periods where there's a tremendous diversity and where there's also a down selection.

At the moment, I don't think it's my place to tell other companies what they ought to be doing. They'll make their design choices and they may beat mine.

Yes?

MR. KUGELMASS: Hi, Bret Kugelmass from the Energy Impact Center.

DR. MYHRVOLD: One more question.

MR. KUGELMASS: So you mentioned needing government support for this, but you're one of the few people on the planet who has friends that could afford to lose tens of billions even and not feel the difference. So I'm wondering why has there been so much trouble getting private monies into the sector, especially if the opportunity is to capture five times current energy on planet Earth? And why not, you personally, just keep dumping more and more and more money if it's so important to the environment and climate?

DR. MYHRVOLD: Well, implicit in your question is the suggestion that we are not dumping more money in. In fact, we are.

Another issue with your question, however, is it turns out that people who could afford to lose $10 billion, they still don't like to.

(Laughter and applause.)

But the other -- finally, there are -- there's very long-range research that it's impossible to fund in a company. And nuclear is, as it should be, a highly-regulated industry. So it's not like oh, if we have private funding, we can just do whatever we want in our backyard. No, of course not.

So governments that both -- you know, here's a good example. We need to test a variety of materials at high neutron bombardment. Well, we need to do that before we build our reactor, not after. We need to do it before. So we need a reactor to bombard them in. And unfortunately we shut down FFTF, so we don't have a great source in the United States to do that. And that's the kind of investment that I think the government has to make.

And ultimately, if you want to have a vibrant nuclear industry in your country, historically, what's always happened is the government has footed some of the bill for that because of the strategic issues involved. But I think with that, I will get off the stage.

(Applause.)

MR. FURSTENAU: That concludes the morning sessions. We're breaking until 1:30 for lunch and then the technical sessions start.

Let's give another hand to Nathan Myhrvold.

(Applause.)

(Whereupon, the above-entitled matter went off the record at 12:03 p.m.)