

## **Proliferation Consequences of Laser Enrichment**

**October 26<sup>th</sup>, 2009**

**Andrew Riedy:** Welcome everyone. My name is Andrew Riedy and I'm a graduate student here at the George Washington University in the Security Policy program and I'm also an intern at the Center for Arms Control and Non-proliferation. I'd like to thank everyone for coming today for our discussion on the potential proliferation risks of laser uranium enrichment. I'd also like to thank the James Martin Center for Nonproliferation Studies and the affiliated Elliott School institutes, such as the Institute of Middle Eastern Studies and Security and Conflict Studies. I would just like to mention that here at the Elliott School the study of international affairs is not an abstract exercise. Our aim to make the world a safer place and the prevention of nuclear proliferation is an important element in that work. Here to take over is Miles Pomper. Here you are Miles.

**Miles Pomper:** Hi everyone, thank you for coming. I'm a senior research associate here at the James Martin Center for Nonproliferation Studies of the Monterey Institute of International Studies, so that is quite a mouthful. Anyway, welcome. I'd like also to thank our co-sponsors, the Center for Arms Control and Non-proliferation and George Washington University, the Elliott School.

As Andrew indicated, our subject here is a laser enrichment facility that is planned to be built in Wilmington, North Carolina. The consortium that is behind it is GE Hitachi and Cameco, which is a Canadian uranium mining company. Now we should know that this is one of several uranium enrichment plants that are being planned in the United States. There is a perception of growth in the nuclear industry, we've also got the phase-out of the Megatons to Megawatts program, which is a program to blend down Russian highly enriched uranium, which has been providing much of the uranium for US nuclear power plants for the last couple of decades. And some of the old gaseous diffusion plants in the US and overseas are also being phased out.

The difference between the plant at North Carolina and the other ones is that the other ones are using centrifuge technology, which as we know is not perfect from a proliferation point either. I mean we've seen the problems with centrifuge technology with Iran, North Korea, and elsewhere. But the difference with the laser enrichment technology that GLE acquired a few years from SILEX, an Australian company, is that this is even harder to detect. Just to tell you where the process stands with the GLE facility, GLE this summer began operating a test loop at its facility in Wilmington, North Carolina. It has also submitted the full license application to operate a commercial facility at the same site to the NRC a few months ago.

Two of the folks on this panel, James Acton and Charles Ferguson, myself, and some of the other people in this room have written to the NRC and Congressional committees raising concerns about the possibility of licensing this facility and the resulting proliferation consequences. Those letters to both the NRC and Congress should be in your packets.

So now I'd like to introduce the panel. We've got a really great group here and I don't want to take time away from them. I've already mentioned James Acton and Charles Ferguson, James is a Senior Associate at the Carnegie Endowment, Charles is the Phillip D. Reed Senior Fellow for Science and Technology at the Council of Foreign Relations, and as the third member of the panel we're honored to have Dr. John Ahearne, who is the former Chair of the Nuclear Regulatory Commission. The panelists will speak in reverse alphabetical order, if that is hard to follow that is basically the order they are sitting in from right to left. And we'll go for about 10-15 minutes each and there will be Q&A for about 45 minutes, which I'll moderate. I also wanted to mention that we invited representatives from the NRC and the GLE to participate, but they declined. So Charles if you want to take over.

**John Ahearne:** I just commented to Charles that it was the first time I've heard as being described as being on the left.

**Charles Ferguson:** But then I told Dr. Ahearne that a colleague who will remain nameless and is a fellow Democrat said that "You're not that liberal Charles, I'm more liberal than you." So we're all trying to liberalize each other now with the Obama administration, I guess.

[Laughter]

**Charles Ferguson:** So I'm very pleased to be here and thank you for the very nice introduction Miles. I think I have enough adrenaline to stay awake during this talk. But I will warn you that I just got back from Tokyo, I was there last week at a conference on extended deterrence and the Japan-U.S. partnership towards a nuclear-free world. Bill Perry was there and gave one of the keynote speeches, very excellent speech. It was a very exciting time to be in Japan.

And it is a very exciting time to look at this technology, which as I will show you, has been explored for many decades but is now showing maybe some commercial promise. First a caveat, there are those who know pretty much the full details of the SILEX system, but are not allowed to talk about because they signed non-disclosure agreements or they are under the cloak of the classification rules. And there are those, like myself, who know something about this, which maybe makes us a little bit dangerous, but we feel, as Miles was saying, an obligation to speak out about this issue now to raise the point that we need a more thorough investigation of this issue now before we proceed further and perhaps spark some kind of corporate proliferation, or even a called arms race, in this area. So what I'm going to do is walk you briefly through a tutorial on laser isotope separation or LIS technology. And then we'll talk a little bit about what is known publicly about the SILEX method being developed in Wilmington, North Carolina. We'll then briefly look at challenges at detecting and safeguarding these kinds of facilities and then finally and quickly assess the proliferation risk and I'll turn it over to my colleague James Acton.

So for those of you who aren't technically trained in the nuclear field, or interested in this subject, or need a quick refresher course, let me remind you why we need to enrich uranium. We

go out and dig up uranium out of the ground, we'll find two - excuse me, three - naturally occurring isotopes. Mainly uranium-238, it is fissionable but not considered fissile as it can't be made to easily fission by absorbing a neutron. And that is very abundant. 99.28% of the stuff in nature is uranium-238. Then there is uranium-235, the good stuff, the fissile stuff, but that is less than 1% of what is out there only .72% of the natural uranium is 235. And then finally there are some negligible amounts of uranium-234 but we don't have to worry about that. Well in order to use U-235 in either reactors, most reactors mind you, as there are some types of reactors like the Candu reactors in Canada or the special heavy-water reactors that can use natural uranium. Or graphite moderated reactors. But most commercial reactors and practically all research reactors need enriched uranium. You have to increase the concentration of that fissile isotope to make it useful for a reactor fuel or for bombs. So at the low enriched levels, typically 3-5% enrichment, that is what you need for commercial reactor fuel. And if you keep enriching it, up to what they call weapon-grade levels, 90% or more of 235, then you have weapon-grade bomb usable enriched uranium. Even 80% enrichment is bomb-usable. The average enrichment for the Hiroshima bomb was about 80% enriched uranium, so use that as point of reference. And the dividing line is 20% enrichment, between LEU and HEU.

So a brief tutorial of enrichment aside, now let's move on to the specific type of enrichment technology that is of interest to this panel, laser isotope separation. And there are a couple of different types, and I'll get to those in a moment. But first, in general, LIS is using lasers to selectively excite uranium-235 and try not to excite the more abundant isotope, uranium-238, to separate out the 235 isotopes from the 238 isotopes. Now, if this can prove commercially viable, you might be able to have an improved enrichment method that uses less energy, is more efficient, and therefore more desirable from the commercial standpoint than centrifuge or gaseous diffusion methods, so called first and second generation types of methods.

Now let's turn to the two types of laser isotope separation that have been investigated. First, AVLIS, which is Atomic Vapor Laser Isotope Separation, and then we'll look at MLIS or Molecular Laser Isotope Separation. With AVLIS, and here is kind of a cartoon sketch of what is mainly involved here, what we're trying to selectively excite this bandwidth here with a laser, U-235 bandwidth and leave the U-238 bandwidth alone, and basically ionize an electron, knock an electron off the uranium-235 atom and then that ionized uranium-235 will then be collected on a collection plate and then you can then, in principle, scoop off uranium-235 and you have enriched material. In practice, it is not so easy because some of the uranium-238 gets ionized in the process and that gets collected and you have to have laser repetition rates that are relatively fast, you have to have pulse widths that are relatively narrow, and you have to have the laser precisely tuned to that certain frequency band in order to excite the uranium-235 and not excite the uranium-238. So there are a lot of technical challenges to this method. And AVLIS has been proven, on a small scale for sure, certainly on milligram enrichment levels and even up to gram enrichment levels but I'm not sure whether it has really been proven up to the kilogram levels - at least commercially - and it involves two types of lasers as you can see here in the sketch

where you have these pump lasers that excite these lasers that can be tuned to the frequency that you need to excite the U-235. And now MLIS, unfortunately I don't have a sketch for molecular laser isotope separation but the underlying principle is basically the same. You are trying to excite the 235 substance and leave the 238 alone, but the details are different from AVLIS. One big difference is that instead of atomic uranium or metallic uranium, instead we're using uranium hexafluoride UF<sub>6</sub>, a type of molecule that is also used in gaseous centrifuge method and also the gaseous diffusion plants as well. So it is a common molecule that is used in other enrichment processes, so it is a known technique to make uranium hexafluoride. And the excitation wavelength is different; here you want a 16 micron infrared laser to selectively excite the uranium-235 hexafluoride gas and then another laser will disassociate a fluorine atom from that excited uranium-235 hexafluoride molecule and then you'll form uranium pentafluoride and then that precipitates out and you can collect that and then that is your enriched product. Now one of the complicating factors here is that you don't get the desired enrichment level with a single pass, so you basically have to have a cascade system in this method, sort of similar to the cascades that are being referred to when we read about the Iranian gaseous centrifuge plant. And there are different variations on the MLIS techniques; in fact SILEX itself is in fact a kind of molecular laser isotope separation method so keep that in mind when we get into SILEX in just a couple of minutes.

So very briefly, I thought it would be helpful to look at the history of laser isotope separation. There have been many countries that have explored this method, there have been twenty or so countries that we know of that have done research on this method but very few of them have gotten up to the stage where they have actually considered commercializing LIS and other AVLIS or MLIS forms. And here I list a dozen or so countries that have investigated this technique. The US, France, Japan and Brazil in particular have taken this method fairly far and the United States Enrichment Corporation itself was investigating AVLIS and also the SILEX technique but they have stopped and are now exploring the centrifuge method. Of note, during the past ten years, there have been a couple of programs that have attracted proliferation attention. We know from IAEA reports that Iran has done some laser isotope separation investigations. It is believed though that the Iranians didn't take this that far, maybe they've done milligram-level enrichment but I don't think they've done much more beyond that. And the South Korean scientists have also investigated laser isotope separation. They have been interested in this for decades but it was when South Korea underwent an additional protocol inspection that it was revealed that they had done these particular experiments. And then that was pretty much resolved. And so the question is are certain countries handled differently when it comes to these kinds of experimental investigations?

So let's turn to the topic of SILEX or separation of isotopes by laser excitation. A lot of this Miles already said, so I don't have to read this to you, but basically the work goes back almost twenty-some years into Australia and in the late '90s the United States got involved through the US Enrichment Corporation. USEC dropped out of investigating this and they relinquished a

license they had with SILEX in 2003. Then in 2006 SILEX interested GE's nuclear division in acquiring a license, there was a government-to-government agreement that was signed so there are classified rules and regulations on the handling of SILEX information and technologies. And then, as you may know, in 2007 GE formed an alliance with Hitachi so there is a GE Hitachi nuclear corporation and then in later 2007 they formed the Global Laser Enrichment Corporation that Miles mentioned;. In the following year Cameco, as Miles mentioned, joined GLE and Cameco has a 24% stake in the corporation. It is my understanding that GE Nuclear has a 51% controlling stake in GLE, so that means that an American-based, headquartered company actually has controlling rights on this particular technology development. And this year GLE is moving into test loop operations and that is why we're particularly looking at this issue today.

So how does this work? Like I said, I don't know the details, I haven't signed a non-disclosure agreements. But if I had signed a non-disclosure agreement I wouldn't be able to talk to you about any of this. And as someone who has a security clearance I know I have to follow those rules. But since I haven't signed that kind of agreement I can use some informed speculation and based on what I've read and some things I've talked to people about. Mainly I'm taking this from this reference here at the bottom of John Lyman's paper that I highly recommend – you can Google it – and that was written a few years back. It is one of the best papers out there on this technique. So, like a lot of MLIS, it uses UF<sub>6</sub> mixed in with a carrier gas. We don't know what the carrier gas is, that is proprietary. And this mixture is sent through a nozzle, it is a mixture that is cooled, in order to separate out the resident peaks of uranium-235 and uranium-238 UF<sub>6</sub> molecules to have better excitation from the lasers. And then a 16-micron laser is shined on that mixture to try to selectively excite that U-235 and there may be one or more laser frequencies used, according to Dr. Lyman. In order to get that precise wavelength, they use what is called a Raman conversion cell to convert a 10.8 micrometer laser pulses into this 16-micron pulses that you need. The actual separation efficiency, the laser repetition, and the pulse width of the laser are all classified information. Now, what is known is to have an efficient process, you would like high repetition rates, hundreds of Hertz or higher, and narrow pulse widths, less than 100 nanoseconds, are most desirable to get your enriched product. Enough enriched product to make it commercially useful.

So what are the reported advantages of SILEX? Well according to the corporation: low power consumption, capital costs, they say it is relatively simple and has practical separation modules and this modular separation technology will provide versatility in deployment. Well, like I said, they are in the testing phase so this has all yet to be proven and if it is, then they want to move ahead to a full-scale commercial facility in the next year so. And the NRC is involved in a 30-month review process at this time. The projected enrichment efficiency is anywhere from two to twenty as compared to a 1.3 factor for the centrifuge method.

So then a question to ask ourselves is: would a successful SILEX enrichment plant actually spark a so-called corporate arms race among other nuclear companies? And I can't name names of people I've talked to. I've talked to other nuclear companies but I know this is actually of

concern to some other companies. And the real point here I think is that if we go back to the Manhattan Project, the first atomic project, those scientists didn't know whether they could make the bomb or not. But once they made it, basically the main secret was out. Once smart people know something can be done, then if they devote enough resources and enough technical talent, they can figure it out and it can be replicated.

So why is this comparatively hard to detect and can it be safeguarded? James is going to talk a bit more about this so I'll just touch upon this briefly. The land area for a LIS facility is relatively small compared to the amount of land taken up by a gaseous diffusion plant or even a centrifuge plant so it can be difficult to detect via satellites or other techniques. And it doesn't use as much energy as some of these other techniques, so that does make it relatively easier to conceal this type of system. And here I'll quote a presentation made, actually ten years ago, by a colleague of mine, Dr. David Daniels, who was then a graduate student at Harvard. He said that "the current international system is able to safeguard a declared LIS facility, but it is not able to timely detect the diversion of a significant amount of uranium to a LIS facility." So I should have underscored "declared". If we actually know where it is then we can put in place safeguard techniques. But the problem is trying to find an undeclared facility and also to make sure we can actually detect a timely diversion of significant amounts of uranium. A significant amount would be about twenty-five kilograms of highly enriched uranium, enough to make a first generation nuclear bomb. I'll also quote Stanley Erikson, another Los Alamos National Laboratory researcher, in a report he did in October 2001. He said an advance in technologies could "outflank export controls and nations with moderate size economies during the first decades of the 21<sup>st</sup> century." And in this paper he was specifically writing about enrichment technologies and the particular challenges in safeguarding them.

Well, for the proper balance in this presentation let me briefly look at why this may not pose a proliferation concern. There are a lot of technically challenging elements to the SILEX system, so it is not going to be easy for a country to master this technology. It would be hard to make a well-columnated stream of gas, the details of the carrier gas are still very closely held, the laser system is very advanced and very tricky to build to this and acquire that technology for the time being now but it may change in the future. And you most likely need a relatively large team of technical experts as well as a lot of financial resources.

And so I'll close by asking a provocative question: could this be the next AQ Khan black market in the making? I'll remind you that Dr. AQ Khan stole centrifuge designs from URENCO, the Dutch-German-British consortium that uses the centrifuge technique to enrich uranium. He did this in the early 1970s and he used the information to develop the uranium enrichment program for Pakistan, which is used to fuel Pakistan's nuclear weapons program. Many experts back then thought that Pakistan was too backward, technologically, to master enrichment. Dr. Khan proved them wrong so let's not be caught by surprise by laser enrichment on the near horizon. I'll close by saying I think we need a thorough analysis of proliferation risks of this technology, more detailed assessments by the Nuclear Regulatory Commission and by the Department of Energy,

and – I'm sure that my colleagues at DOE are probably already on top of this but I'll throw it out there anyway – we need to involve the IAEA in these thorough assessments. We need to ask ourselves: will the increasing use of advanced lasers in civilian non-nuclear applications leak over to nuclear proliferation? And can corporations agree not to pursue this technology? And I think that last question is a good segue to Dr. Acton's talk. Thank you for your attention.

**James Acton:** It is a great pleasure to be here today, first of all, and I think first of all I should acknowledge the International Institute of Strategic Studies in London, who commissioned this paper. Now unlike Charles who published in the *Bulletin*, which doesn't mind you photocopying the articles and handing them out, my journal *Survival* does. I have about 25 copies of the paper left, which is not enough for everybody, so they will be outside on the table and feel free to take one on your way out. If there is not any left, you can get a non-printable copy of this paper from my webpage at the Carnegie Endowment.

Charles ended with exactly the issue I'd like to address today. And that is if the United States commercializes laser enrichment, is it likely that other countries would try and follow? I want to argue that the answer to that question is yes. There is historical evidence that suggests that if one country tries to do something, other countries are likely to try and follow. This being Washington and me being in a think tank, I'm going to end by looking at some of the policy implications of this. My implication is not necessarily that the United States should choose not to license the facility, but it is that a much more thorough and serious, wide-ranging debate about laser enrichment and its potential proliferation consequences is required. And as far as I can see, and I suspect that Dr. Ahearne is going to talk about this much more, the kind of factors that I'm going to be talking about in my talk today, there doesn't seem to be a way of building them in to the assessment of whether the new facility should be licensed.

So what I want to point out is that states pursue nuclear technology for a whole range of reasons. Now some of the reasons why states pursue technology are economic and I mean that in the broadest sense of the word. Is this particular technology the cheapest way of producing power? Does it give other economic benefits like energy security or does it prevent global warming? But there is also a whole set of non-economic reasons that influence, to a greater or lesser extent, states' decisions to pursue technologies. And there are three non-economic reasons that I'd like to highlight today: hedging, getting hold of a technology to create the option to build nuclear weapons, prestige, the kudos among the international community that a technology gives you, and finally received wisdom. Received wisdom is the belief that because someone else is doing this technology, it must be very lucrative and a great opportunity so we have to do this as well. So one example of a situation that I think you have to invoke all three of these different factors to explain is the huge amount of interest in nuclear power in the Middle East at the moment. Between February 2006 and January 2007, thirteen Middle Eastern states – that is in eleven months – announced new or revived nuclear power programs. Now I think that nobody that has been to the region, and has done the interviewing and has spoken to people denies that some of these states are hedging against Iran. But hedging is not the complete explanation because there

are states that are pursuing nuclear power that really don't care about Iran particularly. So I think when you start looking at the competitiveness of this process of announcing of nuclear programs in the Middle East, and here I'm thinking about the friction between Saudi Arabia and the UAE as to who is going to be the first in that region – and I think it is going to be the UAE – but I think prestige clearly plays an element there and is necessary to explain the competitiveness. But I think a number of states in the region genuinely and honestly believe that nuclear power is a good economic option for them in that they can produce electricity cheaply and sell off the oil and gas that they would produce otherwise. But here is the crucial point: none of them could know that for sure when they made the political commitment to develop nuclear power. They made the political commitment before doing detailed cost studies to know whether it was the right option economically and taking global warming into account. Now, it may very well be the right option for them, but they didn't know that when they made the political commitment. And that is received wisdom. It is the fact that everyone else is talking about the nuclear renaissance and other countries are placing reactors all of a sudden, it must be the right thing to do and so we have to do it too. The evidence for that is the fact that the political commitment came before the detailed cost studies.

Let me talk a little bit more about prestige and received wisdom. I think hedging is unarguable. I don't think anyone disputes that hedging is part of states' technology choices. So let me talk a little bit more about prestige and received wisdom and give one example of each. I think a very good example where prestige plays a role amongst others is South Korea and the development of a technology there called advanced fuel conditioning or more colloquially known as pyro-processing. This is a reprocessing scheme in which fuel is separated electrolytically, i.e. by the passage of an electric current, rather than via chemistry, in normal processing. And based on a number of different sources of evidence, which I won't run through in huge depth now, I think there is no question that prestige plays a factor in influencing South Korea's decision to go down this route. Specifically, the United States holds prior consent rights to fuel in many parts of the world, including South Korea and Japan. What that means is that these states cannot separate the spent fuel, or enrich the fresh fuel, without the prior permission of the United States. Now the US has given prior consent rights to Japan. Japan is allowed to reprocess its fuel and it does that; it is opening a new massive facility that it is trying to get up and working at the moment. That permission has never been granted to Japan's great historical rival, South Korea. And I think that this discrimination – and it is discrimination between Japan and South Korea – influences very many of the scientists working on the ground, who are those that advise government, that pyro-processing advanced fuel conditioning is a good technology for South Korea to pursue. And I think that is a clear example where prestige plays an important role.

Let me give another example which is received wisdom. Prior to the early to mid 1970s, the two most developed Western nuclear power programs were the United Kingdom and the United States. And early on during the development of nuclear power, I'm talking about the 50s and early 60s here –maybe even later than that – there was a huge belief that uranium was limited,

that uranium stocks were going to be depleted very quickly. And so again, these states – both the UK and the US – started to pursue reprocessing in order to extract the plutonium and use it in the closed fuel cycle. And this created received wisdom; this created the belief that reprocessing, closing the fuel cycle, was the way to go. I think this is the only way to explain the fact that, prior to the mid-1970s, every single Western nuclear power program apart from Canada intended to reprocess. That was the stated spent fuel management policy of every Western power program apart from Canada: to close the fuel cycle. There is no evidence that these states did detailed cost studies to know whether it was the right thing to do. They were, I believe, very simply copying the United States and the United Kingdom. I think it is very noticeable that when the United States announced its moratorium on the public funding of reprocessing in 1976, the specific Japanese criticism at time was that ‘our belief in the necessity of plutonium recycle is based on American teaching.’ Very clearly saying that you told us that this is the right thing to do and now you’re going back and doing something different. But in fact received wisdom didn’t just affect Japan and countries outside the UK and US, it also influenced the British and American programs for decades to come. Those governments did not seriously reassess whether or not reprocessing was the right thing to do for about twenty-five years. In 1976, the NRC and the United States wrote, and I quote, ‘It has been assumed that the uranium and plutonium in spent fuel would be recovered and recycled, therefore detailed analysis of the technologies of spent fuel disposal are not be found in the open literature.’ Two years later, in the United Kingdom, at the time of the planning inquiry into the new processing facility at Thorpe, the judge who approved the facility and was very much a supporter of going down this route, wrote, ‘Although BNFL (British Nuclear Fuels Limited) made alleged financial advantages part of their case, no detailed financial analysis was produced by them.’ And that turns out because they didn’t do it. So I think this is a very clear example that because of initial beliefs that were based on the information at the time, which I think were perfectly well-founded, that uranium was very short, this initial belief that you had to recycle and that you had to reprocess really permeated nuclear power programs for the better of twenty to twenty-five years and it was received wisdom, it wasn’t being retested all the time and they weren’t doing new economic analysis, it was just this pervasive wisdom about what had to be done.

So what I want to argue then is that these three factors - hedging, prestige, and received wisdom in – influence states’ decisions to develop new nuclear technologies. And just on a slightly digressional note to point here: there is a very long-running debate about whether the United States’ decision in 1976 to desist from reprocessing lead to other countries doing so. What I want to point is that the dynamics of starting a technology are very different from giving up a technology. They are very, very different processes at work. So for me the debate over whether other countries stopped reprocessing because of the Carter administration, actually it was the Ford administration, is a very, very different debate from that of whether the United States going down the route of laser enrichment will encourage other countries to do so as well. The dynamics are quite different there.

So what are the implications of my argument for laser enrichment? Well, I think they are two-fold: first, if you buy that prestige and received wisdom are factors in leading states to choose to develop new technologies, I think it is true that this dynamic will make it more likely that other states will try to follow the United States in developing laser enrichment. If they are successful, this by itself won't cause them to proliferate, but it will give them a latent capability that will be useful for proliferation. Secondly, if the United States goes down this route, it also makes it much harder for the US to argue against other states going down this same route. As Charles pointed out, twenty states have tried to develop laser enrichment. As least some of these, and particularly we think of Iran here, were clearly not doing it for civilian peaceful purposes. But if the US is doing a technology, pursuing a route, it makes it very hard for it to argue against other countries doing so. So those dynamics there lead me to think that if the United States goes down this route of commercializing laser enrichment, other countries are likely to try and follow.

This is not the be all and end all in the debate about whether we should commercialize laser enrichment. Industry, I think, would make at least two arguments against what I've said. Firstly, industry would argue that there are potential economic advantages to them from laser enrichment, which is an important argument. And secondly, industry would also argue that these proliferation consequences that I've been talking about can be managed by effective technology control. If you can successfully classify this technology and prevent its leakage, then you can prevent the spread of this technology. Personally, I believe both of these arguments are somewhat overstated. But that is not the point. The point is that they need to be debated, publicly and openly, within a democratic system. It seems to me that the decision over whether to commercialize this new technology has very significant implications, both positive and negative, and my criticism of the process at the moment is that it doesn't seem to me that there is any way that these broader proliferation consequences that I'm talking about are brought into the NRC licensing process. I mean, I might be wrong there I don't want to claim to be an expert on NRC licensing but as far as I understand it licensing is restricted at the moment to just the question of whether the technology is tightly controlled, whether or not GLEH can classify it to prevent leakage, not on whether it leads other countries to want to follow this route. So I feel very strongly that the way to move forward from here is to have a serious, genuine, open and honest debate, publicly, about the pros and cons of this technology.

There is one final observation I want to make and that is the other aspect of this debate: what if it does spread? Can safeguards, IAEA safeguards, make a significant difference? If other countries develop this technology but place it under IAEA safeguards, will this enable this technology to diffuse and spread safely? What I want to point out about IAEA safeguards is that the weakest point of agency safeguards is not verification but rather enforcement. I don't want to claim that the IAEA verification system is perfect as it is not, although I actually think it is pretty good. I think the real limiting factor is the ability of the international community to do something when they detect that a state has broken the rules. And this is particularly worrying in the case of enrichment technology like the SILEX process. My understanding - and I could be wrong about

this because as Charles says a lot of details about this technology are classified so it is very hard to know that you are making accurate statements - but my understanding is that this particular kind of enrichment technology can be reconfigured in relatively short time to produce HEU. If that is true, then the warning time that the international community gets regarding misbehavior is pretty short. And that worries me. That is exactly the kind of situation in which safeguards are least effective since the warning time is short so the ability of the international community to do anything is severely limited. So from what I know at the moment, it doesn't seem to me that safeguards, however effective, mitigate the consequences of the spread of laser enrichment significantly. But again, on that point, without knowing the classified details of the process - I'm not expecting to be told the classified details of the process - I rather get the feeling that there is more that GLEH could discuss with us publicly.

So that is the message that I would like to leave you on. It seems to me that there are strong arguments both for and against licensing these facilities, but the ones that I worry about most are the broader proliferation consequences, the 'follow-the-leader' consequences are those that get swept under the carpet. I hope that from here we can progress and have a serious debate, looking at both sides of this new technology.

**John Ahearne:** Obviously the previous two speakers have thought a lot about this and what I'm going to do is a very short comment on the technology, briefly on why it is a concern, and then talk about the NRC's process.

Nuclear power and nuclear weapons require technical knowledge to design, build, and maintain, they require funding and commitments, plants and weapons take time to build and are costly. But the common aspect for both is the nuclear material. For weapons, that gives you the plutonium and uranium. For plants, it could be thorium but it is usually uranium. Uranium is widely distributed around the world. As was commented, there was a period in which people thought that there wasn't much around. That is now not the case. It is now widely found. And many of those countries that were mentioned in the Middle East that have begun to have interests in nuclear power programs are also pointing out that they have uranium. So this leads to concern about what they are going to do with that uranium. And as has been pointed out, enrichment technologies can be used both to enrich the uranium for a power reactor but it can go on to enrich the uranium for a nuclear weapon. Now last year a joint committee of the U.S. Academy of Sciences and the Russian Academy of Sciences published a report on international organization of the different fuel cycles. Just two items that will be mentioned there: 'Uranium enrichment and spent fuel reprocessing are the key technologies that enable countries to produce direct-use materials for nuclear weapons. The more countries to which either technology, enrichment or reprocessing, spreads, the greater the proliferation risks. Any approach for enhancing the nonproliferation features of the international fuel cycles must be staged in response to nonproliferation needs of the time period.' Today this suggests a focus on convincing countries that they do not need to establish their own enrichment facilities. And this is has probed efforts by several countries, in international organizations, to address the enrichment issue. Concern

obviously is that if the country decides to have a nuclear power program and they arguably have uranium there, that uranium has to be enriched. And concern that has spread throughout much of the international community is how to convince countries that they can build a nuclear power plant and get fuel if they don't have their own enrichment facility. As was mentioned, gaseous diffusion was the original use in the United States for decades; it used gaseous diffusion for enriching. Gaseous diffusion plants are large and they require an enormous amount of energy. Because of their size and the electricity use, they are pretty easy to see. Pretty easy to find and it is not something you can easily hide. The centrifuge plants are smaller, use less electricity, and they can be hidden as we have now seen in Iran where the inspectors yesterday went into a facility that was buried in a mountain. It is obvious that you can make a centrifuge facility that is very difficult to find. As was mentioned, laser technology may be even harder to find due to less electricity use and smaller size. It was also mentioned that laser technology has the potential of being able to produce enriched uranium at a lower cost. Now the fuel costs are a very small part of a nuclear reactor program. And the gaseous diffusion was expensive, centrifuge is less expensive and is one of the reasons why there are several centrifuge plants being planned to be built in the United States. How much less expensive the fuel for a laser facility will be is hard to say because, as was pointed, the laser facilities are not yet commercially operating. I know of no operating commercial laser facilities and I know of no actually functioning laser facilities although there might be some clandestine ones. Many years ago there was a Atlas facility built at Lawrence Livermore National Laboratory by a commercial firm. It never functioned well; it never went commercial. It has since been dismantled. The suspensions of what the GE Hitachi plant proposes to use is the Australian-developed SILEX methodology.

Now the sensitivity of the SILEX technology can be seen in the formal agreement between Australia and the US which address the protection of the classified information related to SILEX. The SILEX technology is classified up to secret, restricted data and a Q clearance and need-to-know is required. A Q clearance in SRD is the class clearances necessary for nuclear weapons knowledge. So it indicates SILEX is viewed as a very sensitive topic. The NRC has determined that 'because of the sensitive nature of the technology, the current plan is to limit the number of NRC staff to a core team of five to six individuals, who will be trained on a need-to-know basis on specific SILEX technology.'

Now how is the NRC going to approach this? In 1990, Congress passed the Solar, Wind, Waste, and Geothermal Power Production Incentives Act. Doesn't sound like it is covering enrichment, but it is. Because the legislation amended the Atomic Energy Act to require licensing of uranium enrichment facilities under the Nuclear Regulatory Commission and the act also stated that the construction and operation of uranium enrichment facilities is considered a major federal action significantly affecting the quality of the human environment. Environment impact statements need to be prepared and under the legislation the judiciary hearing on the licensing of the construction of the operation is required and the hearing must be completed before the license can be issued.

Now the previous speakers mentioned that the test loop is being constructed. It is a two-phase project: phase one is the development of the test loop at the existing fuel manufacturing facility in Wilmington, North Carolina. The test loop by GE would use no more than two hundred kilograms of uranium hexafluoride and small quantities of enriched material which would then be re-blended and recycled back into the test loop. GE staff predicts that the acts of severance associated with the test loop would be bounded by the current facility safety basis. And they confirmed that the test would be about half scale. Phase two of the project would be a full-scale commercial facility. GE staff estimated that approximately 250 individual security clearances may be required for the operating staff of a multi-unit facility and they also noted that they may need additional clearances for maintenance and support. Phase two would be considered a uranium enrichment facility requiring an EIS and mandatory hearings. In July 2007, GE submitted a license amendment request. In May 2008, NRC approved the amendment. In January 2009, GE submitted the environmental report and on June 26<sup>th</sup>, 2009, GE submitted a license application for the full-scale commercial facility and the NRC has accepted the application. The NRC has now begun preparing its own environmental assessment which would be documented in the environmental impact statement.

As James mentioned, there may be some question as to how the NRC can approach nonproliferation issues. I asked a senior NRC official what regulations would allow them to address nonproliferation. The response I got was that there definitely is a statutory hook for the NRC to consider nonproliferation licensing. A laser enrichment facility would be considered a production facility. In evaluating a license application for a commercial production facility, an applicant must provide such technical information and data concerning activities under such license as the Commission may determine necessary to promote the common defense and security and protect the health and safety of the public. That phrase 'the common defense and security and protect the health and safety of the public' is the key phrase out of the Atomic Energy Act, which is the overriding legislation guiding the NRC's approach. The common defense and security prong provides the NRC with the authority to consider nonproliferation issues. Even if there were no regulation on a point, the NRC would not be restricted from making inquiry about anything that it feels is necessary to meet these statutory requirements

Now the NRC has addressed the proliferation aspects of enrichment facilities and this was recently, relatively recently, evident in addressing an application from the Louisiana Energy Enrichment Services Company to build an enrichment facility, a centrifuge facility, in New Mexico. The Atomic Safety and Licensing Board rejected the interveners request to have nonproliferation considered. They appealed it to the Commission and in November 2005 the Commission reached a verdict on that. The interveners argued that the Licensing Board erred in declining to admit for hearing their proposed contentions alleging the need to analyze potential impacts of the proposed LES facility, the Louisiana Enrichment Services, on national nuclear nonproliferation objectives. Note that is essentially the issue James would like them to address. [Unintelligible] requires a reasonably close causal relationship between the alleged

environmental effect and the alleged cause. They concluded that nuclear nonproliferation concerns span a host of factors far removed from the licensing action [unintelligible], this was the licensing action to allow construction of the enrichment facility. 'Any potential effects of the LES facility on nonproliferation policies and programs are far afield from our decision whether to license the facility given that achieving nonproliferation goals depends on independent future actions by numerous third parties, including the President, Congress, and officials of other nations. The process simply does not extend to all conceived consequences of agency actions no matter how far down the causal chain from a nuclear licensing decision or no matter how unpredictable. The nation's nonproliferation objectives are international in nature and do not have a proximate cause in connection to the proposed uranium enrichment facility sufficient to require further inquiry.'

Now, as was mentioned, the infamous AQ Khan, while working as a contractor at an enrichment facility in Europe, stole the necessary designs which led to Pakistan's nuclear weapons program and the spread of enrichment facilities to other, potentially proliferative countries. The interveners here alleged that the proposed facility would enhance nuclear proliferation risks because individuals who were contractors working for URENCO took plans for centrifuge construction to Iraq in the late 1980s and another individual working for URENCO in the late 1970s stole centrifuge technology information that was later obtained by Pakistan and later shared with Libya, North Korea and Iran. 'But the interveners have not shown how these long ago alleged historical events pertain to the proposed facility. Allegations of management improprieties or poor integrity must be more than just historical interest, they must relate directly to the proposed licensing action. The Licensing Board correctly found that the interveners did not demonstrate a direct and obvious relationship between the alleged management character issues and the licensing action issue. Therefore the Commission discerns no reason to revisit the Board's rulings on the interveners' nonproliferation contentions.'

Now obviously, many of the issues that Charles and James raised, were raised by the interveners in the case of the centrifuge enrichment facility and the Commission declined to consider. However, I will note that from this November 2005 decision, there is only one of the five Commissioners who rendered that decision still on the Commission, so it is quite possible that the new Commission might take a different look at this and that is something that my colleagues are hoping will happen.

**Miles Pomper:** Thank you everyone. That was a wonderful panel. We'll now take some questions. We've got a mic for questions and answers so please wait for it to come to you. So we'll start with you. Please direct your question to an individual on the panel and please keep it as a question.

**Debra Decker:** I'm Debra Decker, I'm with the Belfer Center at Harvard University. I'm not a physicist but I have more of a financial background and I saw that Cameco paid for its 24% share in the laser enrichment venture enough to value that venture at half a billion. And so if it is not that the horse is out of the barn, I'm thinking that this is something that will be developed. My question is how it can be developed in such a way so that it limits the potential for problems in the future. One of the things that I looked at before is the in the Megatons to Megawatts program there was discussion of tagging of the materials as things were...as the highly enriched uranium was brought down to lower enrichments or just the whole tagging process. Is there some way that if you can't stop this process, which seems to be the implication of what you want, is there some way that some additional tagging can be brought in as a requirement of doing this process? So therefore there can be some...you know, if the process is shared with other countries there is some possibility of determining where it came from.

**John Ahearne:** When we finally figured out where the centrifuge information came from in regards to Pakistan, but that was based on a large amount of intelligence information. I think the same technology, once it is successfully shown to work, there will actually be many other companies who will be interested because if there really are a large number of nuclear plants being built in the world, then the enrichment business is going to be a very profitable business. If this is a mechanism that enables you to produce the enriched uranium at much lower costs than the other methods, there will be many other companies trying to get into the business. And they will probably be able to buy certain property rights from the owners.

**James Acton:** I agree with that absolutely. Very briefly, I want to make clear that I'm not in principle against this facility being licensed. My argument is not that we should stop it. My argument is that the full implications need to be taken into account because I don't see any way [unintelligible]. What I'm talking about is the very fact that a state that has done this technology is an encouragement to others to do that. Clearly you can prevent...you can have better classification barriers to stop some leakage but the basic impetus to other states and companies to follow I don't think you can separate. And that is why I think that the full proliferation analysis, a full proliferation analysis of this facility, needs to take place. John explained the exact reasons why the NRC denied looking at those reasons last time. And that is what I'm arguing for: that analysis. I'm not arguing for the outcome of that analysis but rather I'm saying that analysis ought to take place.

**Charles Ferguson:** Two points and this as more of a economical person, let me reference the market forces. Market forces can be very powerful. Point one is that market forces are distorted in the energy field, through subsidies and other actions. Surprise, surprise, right? A dear colleague of mine likes say that we need to figure out what are the externalities, the external costs, as much as possible, identify that and factor that into the internal price of this

technology, whether it is nuclear energy or any energy technology. One huge market distortion as we know is the effects of climate change. We may cap and trade or some type of price placed on greenhouse gas emissions and that can be very favorable to nuclear power. But another market distortion is the fact that this is a very special and risky enterprise; it isn't just another way to boil water. So when it comes to the safeguards challenge that we've been talking about...we need to get a proper accounting, as best we can, as to what is the cost of safeguarding or maybe at best just monitoring, hopefully at or near real-time, what is going on at these enrichment plants. And, as much as possible, make sure that the people, companies, and countries doing this are paying the proper cost so that the IAEA and whoever else is responsible for inspecting these facilities has adequate resources of funding for what they need to do this. And we've seen the IAEA eroded...Dr. ElBaradei, the outgoing Director-General, has said on many occasions that is becoming a hollowed-out agency, becoming less than world-class because countries aren't contributing what they need to contribute to make sure that these activities are properly monitored and safeguarded. And I think what we are talking about today is an outstanding example of that. So what I'd like to see at a minimum is at least making sure that companies involved in this are contributing their fair share to make sure that these things are adequately monitored and safeguarded. And the final brief point is that we've been talking about commercialization and we need to distinguish between commercialization and a facility that could be much smaller and could pose a proliferation concern. And that could be much harder to detect and would be immune to market forces. And that gets into what James has been arguing in his paper about received wisdom and prestige. Why do countries do what they do? It is not necessarily because of market forces, it is because they want to hedge and they want those kinds of abilities. So we need to keep that mind in too when we are making these kinds of assessments.

**Tom Cochran:** Tom Cochran. Just a couple of comments. Some of these issues were addressed in the '70s by a committee of the Secretary of Energy's advisory board and I believe they looked at not only the whole AVLIS process but John I think the commercial firm was [unintelligible], which was independent of Livermore.

**John Ahearne:** It was. The facility was at Livermore.

**Tom Cochran:** Secondly, nobody has mentioned the plutonium isotope separation in regards to proliferation aspects. And finally it seems to me that the issue at hand really is whether the proliferation aspects of laser isotope separation are significantly different and larger than centrifuge technology. And none of you really made that case and if they are not, the solution then is not in eliminating or changing AVLIS or MLIS but is in reforming the oversight of all of these technologies.

**James Acton:** I think, for me that was a very eloquent explanation for why the public debate that I argued for needs to happen. I have simply no idea whether SILEX can be applied to the separation of plutonium isotopes, none whatsoever. And I think we need to know whether it does or not. Similarly, I think there are reasons that Charles explains very well in his *Bulletin* article for warning that the proliferation consequences of laser enrichment are greater than those of centrifuge enrichment: size of the plant, electricity consumption, ability to evade export controls. But again, you need an analysis of the level of detail that is not available in the public domain to really establish those factors. So I agree with you in that understanding how laser enrichment compares to centrifuge enrichment for its proliferation consequences is very important. I find it very hard to do that based on the information that is currently in the public domain.

**John Ahearne:** I would hate if the focus on laser enrichment concerns led to a decrease in the focus on attention of centrifuge enrichment concerns because I think that, to use a phrase from the past, is ‘an immediate and present danger.’

**Charles Ferguson:** I concur.

**Allen Krass:** I’m Allen Krass. I worked...thirty-two years ago I published a paper in *Science* magazine called ‘Laser Enrichment of Uranium: The Proliferation Connection’ or something like that. It was all classified then as well, AVLIS and MLIS. I did it independently; I spent six months at Princeton and basically just did it from looking at the physics of it. I got as far as I could from basic physical principles and I just wanted to make a couple of comments. First of all, the comment on what James said that he has some information that suggests that it is fairly easy to make HEU from lasers...my understanding was quite different from that. That in fact you ran into significant problems technically in trying to do more than go to a few percent enrichment. Now that may be different now, I don’t know. I can’t talk about the SILEX technology. But the other thing I learned in doing this research, back thirty-two years ago...by the way, this was at least as frightening an issue back then...people were talking about being able to enrich uranium in their garage or in their basement at that time. That is why I did that study and write that article, to try to discern whether there was any real validity to these kinds of fears. And I ended up, and I used it in the article as well, telling the story of Edward Teller and Robert Oppenheimer when the news that the Soviets had exploded the atomic bomb was broadcast. And Teller called up Robert Oppenheimer and asked, in a real state of anxiety, ‘What are we going to do, what are we going to do?’ And Robert Oppenheimer said ‘Keep your shirt on.’ And I felt that, from the studies that I did on laser enrichment convinced me that we ought to keep our shirts on and not be spreading fear in this way. And in the ensuing thirty-two years I think have really borne out that at least for MLIS and AVLIS, which were the technologies of the day, none of this turned out to be a serious proliferation threat. And who knows, maybe this is magical bullet, maybe this is

really the one. But I have to say that I'm really skeptical and that what I have learned technically about using lasers to enrich uranium really leaves me skeptical. Why these companies have invested hundreds of millions of dollars in this, I hope I'm around long enough to find out and see how it works. But I am skeptical.

**Charles Ferguson:** I'm glad that Dr. Krass is here. He is one of the leading experts in this field and it is a pleasure to hear his comments. I agree with him in his first comment in the difficulty about making HEU. In the paper I quoted by John Lyman at Los Alamos, in there he did a more or less independent study. He had some insider information on SILEX and other laser enrichment techniques but he had not signed a full non-disclosure agreement so he could do some analysis. Based on the state of the art back when he looked at this in the late 1990s, it appeared to him that it didn't have a significant highly enriched uranium potential. And he said that looking at the laser repetition rates, the pulse widths, some of the the other characteristics of the laser system, and he also pointed out how you work the carrier gas and how well you can columnate it, there are a lot of tricky technical things that you have to get just right. And he said that certainly on a milligram scale and maybe on a gram scale you can get low enriched quantities out but...it may have changed within the past few years, we don't know. If you read the press statements from the GLE they are very exciting, they are right on the verge of a major breakthrough. But then as John mentioned USEC and Livermore parted ways in 1999 and now USEC is going in the centrifuge business and that is risky too because they're trying to build these ten-meter tall centrifuges and why are they investing hundreds of millions of dollars? It could be a huge payoff but it is a very risky financial business and these companies are apparently willing to risk it for the big payoff but if it doesn't go through then they have other things that they can fall back on.

**John Ahearne:** I will point out that the nuclear industry is not famous for deep insight into financial business.

[Laughter]

**James Acton:** I can tell you exactly where I got my information that HEU production is possible with laser enrichment and that is from the IAEA report – and I can't remember the number of the report – but in the facility in Iran where they say in the opinion, and I forget the exact quote but 'in the opinion of IAEA experts, had the full package of equipment been delivered, it would have been capable producing significant amounts of HEU.' I think that is almost a word-for-word quote. Now, that is not to say that the IAEA experts have it right, I don't know, but again it does come back to the point that if in fact laser enrichment really isn't very good for producing HEU then I think a lot of the concerns I have don't exist so much. But it does come back to the point about the lack of knowledge about the SILEX process and that is what worries me in this regard.

**John Ahearne:** It will also be difficult in the NRC licensing since so much of this information is classified that will restrict the access of interveners and it will certainly the access of any public information.

**Sharon Squassoni:** Sharon Squassoni, Carnegie Endowment. Follow-up question for James. Was that IAEA assessment about Iranian potential capabilities based on Russian AVLIS? And do we know...could you compare Russian AVLIS with SILEX technology in terms of tricks of the trade that someone might have to know to make it work?

**James Acton:** Well, I think the answer to your first question is yes and the answer to your second question is no.

**Jack Edlow:** My name is Jack Edlow. I transport a lot of material but I know a lot about the nuclear business. It seems to me that the question here is not whether really whether lasers can be used for enrichment because clearly they can be used for enrichment. The question is can you control the technology of lasers, not of the enrichment capability of lasers. For instance, the lasers used in SILEX did not originate in the United States and did not originate in Australia where SILEX was developed. It originated elsewhere. So I think what you need to look at is how to control laser technology because it is the lasers that are the issue and not the fact that they actually enrich uranium. Would the panel please address that?

**Charles Ferguson:** Jack, it is a good point. But as Allan and I were saying in a previous question, it is more than just the lasers too. There are other technologies that you have to master in this process, such as handling the gas, knowing what the carrier gas is, and also not just the lasers itself but there are other technical things that you have to master in terms of handling the laser.

**Allan Krass:** You have to...if you are going to make HEU, you're not going to make it in one pass. Which means that this stuff is going to have to be sent through again and again and again and in fact it is not like centrifuges which is basically the same gas with a different isotopic content. Here you are going to have a chemical reaction which is going to separate the enriched material from the depleted, which means you're going to have to do chemistry again and then send it through again. So it becomes much more complicated.

**James Acton:** Again, I kind of approach this from the perspective which is very unusual in this town, which is someone who genuinely doesn't know whether this technology should be licensed. I'm here to say let's have the argument. Let's have the debate. So in regards to the issue about the extent to control lasers, I think it is worth emphasizing the difficulty of getting non-nuclear weapon states to agree to talk export controls when you have a dual-use

technology like lasers and as far as I understand it, and is exactly the point you make that these lasers weren't designed by the US or Australia specifically for the SILEX process but rather were designed for other purposes and used for this purpose. Getting states to agree on really serious and strict export controls is very, very difficult. I don't want to say that it is impossible but it seems to me that you need to work out the export control implications first before you go ahead and license the technology. If you go ahead and license the technology and then try to use export controls as a sticking plaster afterwards, you don't know if you're going to succeed. So ...I think this would be a very creative and constructive thing for GLE to do. Would be to start on trying to get agreement amongst other relevant organizations about some kind of industry agreement on the use of these dual-use lasers. But again, I think that is the kind of thing you need to know before you license the facility It needs to be taken into account and I'm not saying it needs to be more than that.

**Rebecca Cooper:** Rebecca Cooper with the Exchange Monitor Publications. This question is you and also for John. The NRC is very protective of its role not as a policy making body but as a regulator and it seems that the debate you're calling for here may be something they would be unwilling, as they were in 2005, to take on as part of GLE's license application. So could you go into more specifics about how you can see that going forward? Do you see that going forward at NRC or do you see it going forward in some other forum?

**John Ahearne:** The NRC is really a regulatory body. And it operates under the constraints of the legislation that set it up and then of course any regulations that it ends up putting in. As you said, it is not really a policy body. And consequently since so many of these areas here in the nonproliferation area can be interpreted as policy issues, it is going to be a challenge to the Commission when it provides direction to the Licensing Board to what extent do they consider the international policy implications. And it is possible...I think it is possible to make the argument that the common defense and security framework does require you to be concerned about whether you have enough safeguards put in place. But my guess would be that it might lead the Commission to require tighter safeguards as opposed to not allowing the license.

**James Acton:** To be honest I'm not all that familiar with the debate, but the NRC played a much different role in the late 1970s, when it really did take a much broader view of its mandate. So I think there are various options. I think number one would be for the NRC to reinterpret its own mandate, which it has done in the past. Number two would be for Congress to broaden the NRC's mandate. Or number three would be actually to have the debate in Congress rather than in the NRC. I don't view as any of those as being bad options or good options. I think those are the options of where the debate could take place.

**Miles Pomper:** Just to make clear, we have James and Charles on this panel who have written to both the NRC and committees on Congress to consider the issue, so there are two different fora. That is Charles.

Sharon, do you have another question?

**Sharon Squassoni:** In some respects, I would say that the argument is already lost. Because the compromise that we are now going to see in the Nuclear Suppliers Group over the black boxing of enrichment leaves a little loophole, I believe, that Canada insisted on. And that has to do with...I forget the wording exactly. Does anyone remember the wording? It is something about if future enrichment technology should come along that they would be able to exercise...

**Miles Pomper:** Well if they develop it themselves. It is not their ability to export.

**Sharon Squassoni;** Well I think the U.S. government left the door open there quite purposefully. So it may be that this needs to be a broader...that decision is not yet formalized but you may have to take this debate to the international level.

**Charles Ferguson:** That is a good point, Sharon. And yeah, as the old saying goes 'the horse is out of the barn.' We're already seeing this black-boxing going on here in the United States. John referred to the LES facility in New Mexico and we have AREVA interested in building a facility in Eagle Rock, Idaho. So these are examples of foreign-owned entities building enrichment plants in the United States and the U.S. itself is not going to have access to those particular centrifuge technologies. They are going to be hidden and shrouded. And one reason why they are building in the United States is that the U.S. is a nuclear-weapon state. So we have to remind ourselves that proliferation, like in real estate, has three main rules: location, location, location. And I don't want to sound discriminatory and play 'good countries and bad countries' but there are certain areas with higher proliferation concerns than others. And we feel more comfortable with a laser enrichment plant, if it works and is well protected and well safeguarded, in the United States or other nuclear weapon states versus Iran or some other countries of the world.

**John Ahearne:** Well, to be careful I don't think you mean all nuclear-weapon states.

[Laughter]

**Miles Pomper:** I think it is also important to clarify Sharon that NSG rules are on countries exporting the reprocessing and enrichment technologies. It is not on others mirroring what the United States or other countries are doing. It isn't the same issue entirely. And I would be

more skeptical about the ability of the NSG to reach an agreement than you seem to be since they have been trying to do this for a year and haven't reached an agreement.

**Sharon Squassoni:** No, the issue is additional countries that do not now enrich getting access to that technology in the future.

**John Ahearne:** Well, as you know the major push in the last five years...several governments including the U.S. and the IAEA have been trying to restrict the spread of the enrichment facilities and it is not clear what is going to work. The real test will be when some of the countries that are going to build a nuclear power plant...whether they would be willing to accept the fuel assurance programs that have been announced. That much is not obvious.

**Miles Pomper:** We have time for one more question. Anyone else?

**Leonor Tomero:** Well I guess that this kind of falls in with Sharon's question. And it does go back to what you already said in terms of the importance of what the U.S. is doing and the importance of U.S. leadership. I guess in the context of the Nuclear Suppliers Group where we might weaken the transfer of sensitive nuclear technology to make it more criteria-based instead of just encouraging wholesale [unintelligible] from transferring. So I guess my question is: do you think we can really restrict the transfer based on the kind of technology and have we seen that before? I'm thinking, for example, about the different kinds of reactors versus light-water reactors where there are no restrictions on current nuclear power plant technology based on the proliferation risks. Or maybe there are and I don't know about them. And so how will this affect the likelihood that we can do this... [unintelligible].

**Charles Ferguson:** Well, actually I want to say that James Acton in his *Survival* paper makes a pretty compelling argument about light-water reactors. And not that we have restrictions or directly forcing countries to buy those types of reactors but James' paper has a historical development of those technologies, those reactors that are more proliferation resistant than the heavy-water reactors and other kinds. And depending on how the technology is developed it is very stringent in looking at the adoption of the light-water reactors. So it is kind of key to then allowing the flourishing of that technology. So in some sense maybe it is not so much of imposing a set of rules but it is more about getting the market forces and incentives right. And maybe I'm influenced but the latest thing I've read, but there is a very intriguing book out called "Nudge" written by Thaler and Sunstein, two economists who developed the method they call libertarian-paternalism. And, you know, they said that if you pick each of those separately then people will have a bad reaction. You know...libertarianism and paternalism...bad. But put them together and it sounds pretty good because what it is says is that if you are libertarian so you give people a lot of choices but then you are paternalistic enough to structure your system, your system architecture, so they navigate to

choices that are best for them, whether it is making the right investments, or finances, or for their health insurance, or in this case the proliferation of nuclear technologies. And then you are not restricting or denying access but instead you are designing a system where you have choices but countries and companies are going to gravitate to the types of technologies that are less risky

**John Ahearne:** You know, the one point I would add is that economics has driven most choices. And once the U.S. locked into light-water reactors then light-water reactors spread because it turned out that people knew how to build them and operate them. And they ended up being looked at as being much less expensive than some of the other, perhaps technologically superior technologies. And I think that as long as the centrifuge technologies keep producing enriched uranium at a reasonable cost, it is going to be very hard for a new technology to really break into that market.

**James Acton:** I agree with that very strongly. I think that we agree that we have a bad record when controlling technology. I think when we have been willing to trade in the least proliferation sensitive technology available, we have had a very good record of influencing countries and companies in a positive way. As Charles was kind enough to reference my argument, which is that light-water reactors are the least proliferative reactor available because the best thing we can do from a proliferation standpoint is to trade with them. Because I would rather that other countries have that than the alternatives on the market. It is a slightly different but related argument which is that I don't believe the technological trajectory of nuclear energy is inevitable. I mean, I think that there is historical evidence and it is exactly this issue about that if you look back at the early 60s or even 50s – I forget the exact date – the choice between heavy-water reactors, gas-cooled reactors, and light-water reactors is not at all clear. It is not at all clear which route the nuclear industry is going to go down at that point. And it goes the light-water reactor route because that is what the U.S. invests for its submarine reactors and that then, because that was where all the investment was going, became the cheapest option and so countries went down that route. I think for that reason, I don't have time to elaborate the argument in full here, but it is a mistake to believe that laser enrichment is inevitable if the United States doesn't do it. Other states will certainly do it. The nuclear industry has the ability to decide its destiny. And the issue you have to do is make that decision rather than leave it to inertia.

**Miles Pomper:** Thank you everyone for the panel. Let's give them all a hand.

[Applause]

*This transcript was prepared by Richard Sabatini of the James Martin Center for Nonproliferation Studies, Washington, DC office.*