

**Testimony of Ray A. Rothrock,
Managing General Partner, Venrock,
before the Blue Ribbon Commission on America's Nuclear
Future, Subcommittee on Reactor and Fuel Cycle Technology
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Thank you Chairman Domenici and Chairman Peterson and distinguished members of the subcommittee for the opportunity to provide testimony on the topic of how the federal government can better promote and support entrepreneurs and startups in the nuclear industry.

My name is Ray Rothrock, and I am presently a managing general partner of the venture capital firm Venrock. Venrock's activities in venture date back to 1938, when Laurance Rockefeller established a family investing office in entrepreneurial businesses. Today, Venrock is a diversified \$2 billion firm with three practices and limited partners and companies all over the world. In my 22 plus years as a venture capitalist, I have invested in 47 companies resulting in a lifetime investment internal rate of return (IRR) of 94%. I established Venrock's energy practice in 2004, and previously launched Venrock's Internet practice in 1992. Before joining Venrock, I participated in three venture capital-backed companies. The first two failed, but the last one – Sun Microsystems – was quite successful. These experiences introduced me to venture capital and its role in helping entrepreneurs innovate.

Prior to my startup and venture experiences, I was a licensed professional nuclear engineer on the team that performed transient and safety analysis and licensing for Yankee Rowe, a 180 megawatt electric (MWe) nuclear power plant commissioned in Rowe, Massachusetts in 1962. Now being decommissioned at its end of life, Yankee Rowe produced electricity until 1992 with an 85% capacity factor. The plant capital cost was on the order of \$50 million in 1960 dollars. I also spent a year at Exxon Nuclear in its fuel and uranium processing group before heading to the Silicon Valley to be an entrepreneur.

I presently serve on the board of the National Venture Capital Association and its Executive Committee, the MIT Visiting Committee of the Nuclear Science and Engineering Department, and I am chairman of the board of Tri Alpha Energy, a venture-backed, privately-financed nuclear energy company. I have a Bachelor of Science degree summa cum laude in nuclear engineering from Texas A&M University, a Master of Science degree in nuclear engineering from Massachusetts Institute of Technology, and a Master of Business Administration with distinction

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from the Harvard Business School. I am also a member of several professional scientific and engineering fraternities and associations, including the Tau Beta Pi, Sigma Xi, the Institute of Electrical and Electronic Engineers, the American Nuclear Society, and the Association of Computing Machinery.

Venture Capital in America

In the last 50 years venture capital has played a significant role in the development of major technology industries in the United States, including aviation, semiconductors, computer systems, networking, telecommunications, enterprise software, food additives, biotechnology, and the Internet. The venture industry has many contemporary success stories including Intel, Genentech, Apple, Amgen, Tesla, Millennium Pharmaceuticals, Gilead Pharmaceuticals, Google, Yahoo, Cisco, DoubleClick, Starbucks, Federal Express, and many older companies such as McDonnell Douglas, Eastern Airlines, Thermo Electron, and Minute Maid.

These companies all have two things in common: First, innovative entrepreneurs seeking to change the world started each of them. In previous generations, wealthy families backed these entrepreneurs. More recently, from the 1960s on, they have been backed by professional venture capital firms and more structured venture capital investment vehicles, which are the standard today.

The second thing these companies have in common is that they contributed in many ways to the nation's quality of life and economic well being, and have kept America the innovation leader of the world. As of 2009, U.S. companies originally backed by venture capital were responsible for 22% of the country's GDP and 12.1 million employees – 11% of all private-sector employment.

Venture capital's main function is sponsoring great entrepreneurs with world-changing ideas. The hope is that these companies result in enormous success for their customers, their investors, their employees and the entrepreneurs themselves. The core activity of a venture capital fund is efficient allocation of precious and finite capital against a huge opportunity set. Not every deal is suitable for venture: the percentage of proposed deals that actually receive investment is considerably less than 0.1%.

In addition to providing entrepreneurs with capital for business value and job creation, another benefit of venture capital is the allocation of human resources towards promising ideas. Venture-backed companies tend to attract a great deal of attention, receive a high level of scrutiny, and secure sufficient capital to succeed in very difficult environments. The strongest employees available in the market are attracted to these opportunities.

There is no doubt that venture capital has had an outsized impact on America's innovation and economic front. Many countries in the world have tried to copy

America's venture industry. It is an enviable feature of the United States with an enviable benefit to the public good.

The Beginnings of Nuclear Regulation

The nuclear industry's roots date back to the earliest days of the Cold War beginning with the formation of the Atomic Energy Commission (AEC) in 1947. This organization bifurcated into the Energy Research and Development Administration (ERDA) and Nuclear Regulatory Commission (NRC) in 1974, and in 1977 the ERDA and other organizations were subsumed into the Department of Energy (DOE) leaving NRC to stand-alone.

In the beginning, these government organizations contributed to the development of the nuclear industry and to its culture, methods, science, and results. Today, however, the NRC and DOE are primarily watch guards and caretakers of the America's nuclear infrastructure though there is a renewed emphasis towards nuclear energy in the DOE. To my knowledge, neither is an advocate of the industry per se, and education of the public on nuclear has only recently been initiated by the DOE. The culture, which might be described as "hunkered down," "closed," and "proprietary," stems from the nuclear industry's earliest military days. Literature on the AEC indicates that it had a broad mandate with substantial power when formed, and was mostly closed in its activities -- a posture with an impact that I believe reverberates today. It has changed over time, but very slowly.

One often-cited example pointing to military influence is the AEC-era decision not to pursue a thorium nuclear economy, since it was of no use to the military. Thorium is more plentiful than uranium, has better mechanical characteristics, and produces a less dangerous fission products profile. If it were the standard fuel in reactors today, it is possible that the proliferation problems we now face would be greatly diminished, since thorium is largely immune to use in nuclear weapons. Decisions like this one were made at a time when private industry was not so involved in the nuclear conversation with most everything driven with a military point of view. As a result, venture capital has played a very small role, if any, in the nuclear discussion in the United States for the last 50 years.

The Nuclear Regulatory Commission

The NRC today is viewed by venture capitalists as a "just say no" organization. And while it is always important for regulatory agencies to have the power and authority to say "no" when they need to -- to ensure public safety, for example -- a "no" orientation is fundamentally at odds with the inherent role of venture capital to enable -- not inhibit -- entrepreneurs and young companies to success. As such, no relationship, formal or informal currently exists between venture capitalists and the NRC. And neither side has actively reached out to the other. Only very recently are members of the NRC appearing at venture capital related conferences and events.

Despite the NRC's opaque image, there is strong nuclear-related deal flow among entrepreneurs seeking capital and counsel from venture capitalists. Nuclear innovation is happening, primarily because there is a clear understanding in both the venture and the entrepreneurial communities that nuclear energy is an essential part of our nation's energy future. It is the cleanest form of energy, has the highest energy density of all known sources, and addresses both the carbon challenge of climate change and the disturbing balance of payments for imported oil the United States faces (now \$400 billion). Further, 50 years of civilian nuclear-generated electricity -- plus the experience of the American nuclear navy -- have amply demonstrated all of these benefits and more. So, what's wrong with this picture? Why this gulf between the NRC and the venture community?

To begin, consider the NRC mission statement, which I have taken directly from the NRC web site:

"To regulate the nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment."

Nowhere in this mission statement is there a mention of the generation of electricity through nuclear power. When it is mentioned in other writings, the NRC cites electricity as an application of many over which it has jurisdiction, for example laboratories, test facilities, and waste management where certain nuclear materials are handled. In other words, regardless of the application, the NRC regulates materials and the implied safety, not the actual production of electricity by fission or fusion.

The Department of Energy

In his presentation of the 2011 DOE budget, Secretary Chu made the following point about the role of the DOE as it applies to nuclear energy: "Provide technical and financial support to restart the American nuclear power industry." And indeed he is doing this through activities such as loan guarantees, basic science research, and energy advocacy. But the DOE has many areas of focus, and nuclear innovation can only receive so much attention. Namely, \$900 million of a \$28.4 billion budget.

Recall that the current DOE is an amalgamation of agencies pulled together in 1977 during the second oil crisis, with a mission to eliminate dependence on foreign oil. That scope has evolved over time. Today the DOE manages and maintains the nation's nuclear arsenal; the nation's nuclear waste (most of which came from weapons development); has an environmental, energy and efficiency section; and a basic science office with oversight of America's national science laboratories. It provides no permits of application or use of nuclear materials to private industry, but it does control the flow of most federal funds to private-sector energy projects.

Regardless of their form, these direct grants, matching funds, and loan guarantees are essential in the capital-intensive energy projects often initiated by venture capital-backed companies. The venture industry has welcomed these programs because they lessen capital requirements from private sources. Numerous venture-backed companies, including Tesla in electric vehicles and Solyndra in solar modules, have relied on these programs as a vital bridge to the marketplace.

Nevertheless, the DOE's lack of focus on nuclear-generated electricity is reflected in its 2011 budget proposal. Key elements of the DOE budget are \$12.1B for nuclear security (weapons), \$6.0B for environmental management (nuclear waste), \$4.2B for energy projects (nuclear and fossil, efficiency), \$5.1B for science (basic research), \$0.3 for ARPA-E, and \$1.9B for other uses. This is a very large agenda, but it is focused largely on maintenance, and, in my view, causes an unfortunate division in the leadership's time at the DOE with regard to its mission. This is not a criticism of the DOE so much but a statement of the reality of the DOE's enormous breadth of activities.

Simply put, neither the NRC nor the DOE are chartered, organized, or managed as a partner of the venture industry and entrepreneurs towards nuclear-based electricity production. Finally, on its face, with two agencies in a regulatory role over the nuclear industry is a clear signal that there is a lack of focus.

Success Stories of Federal Agencies and Venture Capital

Venture capital has historically focused on technology that results in products sold to consumers or to companies. Many of these products are controlled and protected by federal regulations, and many of the responsible regulatory agencies have constructive, beneficial relationships with the venture capital industry. While the Defense Advanced Research Projects Agency (DARPA) and Federal Aviation Administration (FAA) are good examples, perhaps the best model is the Food and Drug Administration (FDA).

This the FDA's stated mission, taken directly from its website:

“The FDA is responsible for protecting the public health by assuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation.

The FDA is also responsible for advancing the public health by helping to speed innovations that make medicines and foods more effective, safer, and more affordable; and helping the public get the accurate, science-based information they need to use medicines and foods to improve their health.”

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The FDA is the most notable federal agency success story as it pertains to venture because it is organized to assist health science companies, small and large, to bring new products to market. It manages the safety of and monitoring of pharmaceutical products, and the education of the public regarding pharmaceuticals and food-related products. It has a well-understood structure for interfacing with companies – entrepreneurs and venture capitalists alike – because it provides an orderly, predictable and finite process for bringing new products to market.

The FDA's charter is unique among agencies to which venture capital interfaces. And it has resulted in a broadly held view that the FDA is a "Yes" agency – an agency that is approachable, fair, and workable. The FDA's charter specifies that it must ensure public safety (like the NRC), but it specifically states that it promotes, educates, and considers economic risk/rewards in the course of its operations (unlike the NRC). In addition, it is chartered with bringing worthy products to market in a timely manner. An organization similar to the FDA with a similar process focused on nuclear power could be an excellent partner to venture and venture-based companies to say nothing of the nuclear electric industry in general.

As an illustration of the FDA's "yes" approach to industry and its understandable process, please note the following chart. "Yes" does not mean that every submission succeeds. It means that the FDA is receptive, helpful, and predictable. The data for this table was assembled in less than an hour from Venrock's healthcare team when asked about the FDA's process for evaluating novel drugs. The Venrock experience behind this data is about 100 healthcare deals of which 50 were in biotechnology, one of the most difficult categories of healthcare products to develop. The important point here is that the orderliness, clarity and certainty of this process enables investors and entrepreneurs to plan for success or cut their losses when it is not working.

Stage	Elapsed Time (years)	Capital Required (million)	Purpose and Objective	Market Value (million)	Historical Success (probability)
Pre-clinical	1 to 5	\$10 to \$50	Pre-human validation	\$10 to \$20	10%
Phase I	1-2	\$5 to \$20	Safety	\$10 to \$50	65%
Phase II	2-3	\$20 to \$50	Efficacy and dose	\$50 to \$100	50%
Phase III	3	\$40 to \$100	Registration Trial	\$200 to \$400	65%
New Drug Application	1	\$20 to \$50	Manufacturing FDA Approval	\$500 to \$1000	90%

Not every new drug idea makes it through the process, of course. On average over the last decade about 10 novel drugs a year do so, each representing about \$200 to \$500 million of investment over a 7 year process. Often, it takes multiple "shots on goal" by a company to clear the Phase I hurdle, lengthening the process by an additional 5 years or more. When a company starts down this pay, this is expected based on experience.

An additional benefit of such a well-understood process for the submitting company is that at each phase, the project receives a third-party validation of scientific or health value creation. This means that projects that do not make it to final approval do not necessarily expend \$200 million and 7 years. They can fall from the process at numerous steps. These staged validation and valuation milestones are significant in allowing entrepreneurs and small startup companies to participate in the market. Of course, the successful drug that makes it all the way through usually addresses a huge market and can be worth billions of dollars in the end – hence the interest in entrepreneurs and venture capitalist wanting to embark on such long and difficult entrepreneurial treks.

Agency Economics and Industry Charge Back

The U.S. taxpayer pays for the FDA process described above. The company pays a nominal filing fee. This is based on the concept that the public is the ultimate benefactor of FDA activities, so the public should broadly pay for this protection. This is not the case at the NRC. The NRC charges back its expenses to companies seeking NRC permits on a time and materials basis regardless of the purpose of permit.

It is my view that power plants have a general public benefit similar to those of a successful pharmaceutical, and therefore expenses should not be paid for by the applicant though filing fees are appropriate. One size does not fit all in this case, but it does at the NRC today regarding cost charge back. Optimistically, for a successful application for a small modular reactor design certificate, the charge back costs are estimated to be on the order of \$50 million to the NRC, and the process takes about three years to complete. Of course, such a design is probably worth well more than the \$95 million in total cost (\$50 million to the NRC, plus an estimated at \$15 million per year of company costs over three years), but that is an unknown going in since it takes \$95 million to find out. (Some estimates top \$300 million for other design applications.)

With no interim steps or checkpoints – such as those built in to the FDA drug approval process – this is a huge commitment by a small, venture-backed company, and thus, practically a showstopper in venture.

Organizational Culture and Leadership DNA

The venture industry has spawned thousands of successful companies. I have personally led and been involved in the growth of over 50 organizations, some to considerable size. The drivers of failure and success across startups are surprisingly similar. The ability to learn from mistakes in other companies and bring those lessons to new companies is a key value-add of venture capital. I call this pattern recognition.

One pattern that venture capitalists recognize early is whether a company has a culture suited for success. Startup companies are difficult enough and without good culture it is even more likely to fail. Often, company culture is referred to as startup DNA – that is to say the company's tempo, attitude, mission and focus are inherent parts of its makeup. It is self-evident when it exists. The best technology companies all have a strong culture, set by the founder(s) and maintained in the people selected to work there. This culture can last a long time even when a company has tens of thousands of employees. All the successful companies cited in the introduction of this testimony have this characteristic: individuals like Bill Gates, Steve Jobs, Gordon Moore, Elon Musk, and many more are textbook examples of leaders who created a strong and successful culture that lasts. How does this apply to the NRC or DOE?

Retooling the culture of existing federal agencies is not a proposal I would support. While the leaders of these agencies change from time to time and from administration to administration, the organizational cultures are likely perpetuated by the staffs that remain for the long run with culture set and inherited a long time ago. Strong leadership is recruited to run these organizations, but the leadership is not around long enough to change the culture to any significant degree.

Therefore, to retool the NRC or parts of the DOE to accommodate a new relationship model that encourages engaging the private sector for entrepreneurs and venture capital would be very difficult, if not impossible. It also is not one that could be executed in a short time. The DOE and NRC are agencies that are too mature to change their culture and manner of business in the time frame required to renew America's nuclear future.

Recommendation One: United States Nuclear Power Agency

Therefore, my primary recommendation is to establish a new federal agency to drive nuclear innovation – similar to what occurred in 1977 when the federal government reorganized existing agencies into the DOE to respond to a new challenge – the oil crisis. The new agency should be single-minded in its mission and focus on nuclear-generated electricity, from fuel development through waste management. The new agency should be set up with processes that mimic the best practices from existing agencies that reflect good industry relationships and processes, such as the FDA. It should be established with a culture of “yes” while

also being the custodian of the public's safety, scientific rigor, and public education. It must consider risk and reward and include economic evaluations of benefits from its activities and the clients it serves – the public. I would call it:

United States Nuclear Power Agency.

Like all great and successful organizations, the United States Nuclear Power Agency needs a strong leader – one with credibility, presence, and vision. Setting the right mission and getting the right culture at the start are crucial because we know it will last for decades and is essential for rapid success. Furthermore, the new agency will require complete support of the President and of Congress. Finally, it's not an accident that I suggest that its name connote its mission and purpose, much like the FDA.

From the literature, it is clear that the DOE, NRC, and AEC received such backing in the past. This support is essential in setting a new standard for the public conversation that the agency would be charged with – an essential element in success of America's nuclear future. Demonstrated confidence from America's leaders in other roles and walks of life is also essential for success. The call to action for a new agency, and for nuclear power in America, is an urgent one, on the order of the action that created the Manhattan Project.

Recommendation Two: Economic Policy

I further recommend two other policy actions. The first is a total carbon tax on energy and the second, an agency review process without charge back.

A carbon tax would accelerate America's sustainable energy adoption in general, and nuclear in particular. A carbon tax would establish an economic ceiling under which a startup company could target its economics. This would enhance the speed of startup development by removing a key variable from the table. This would benefit every carbon-free energy development activity, and would draw a bright line regarding the economic standards by which nuclear designs and power plants would be measured (to say nothing of solar, wind, and other sources of electricity). It's economics that drive venture capitalists and venture-backed companies – not government-based incentives.

Fossil fuels are capable of very low costs (capital and operating expenses) when considering only the production of fuel and of electricity. Unfortunately the human costs are not considered (that is, an average of 30 deaths per year in coal mining in the U.S.), and certainly not the long-term costs of pumping carbon in the atmosphere. Coal, a vast natural resource in the United States, is a fantastic fuel since it is local, cheap, and very well understood. Unfortunately it is dirty, costly to the air we breathe, and not fully safe to produce as measured by human life. Natural gas is also a fantastic fuel but has issues similar to coal in terms of impact on air quality.

Oil, on the other hand, is not local and not cheap. The costs of oil must include the costs of national and economic security in a true evaluation. The price of oil – controlled by others – varies widely, and we have observed exactly what happens to public behavior when it reaches very high levels north of \$100 per barrel like in the summer of 2008, to say nothing of the two oil price shocks in the 1970s. But, even with oil being heavily subsidized through various activities of the U.S., its total cost is not well understood.

The market price of electricity from the use of coal, oil, gas does not consider these additional costs. A carbon tax applied at the source of the fuel production is simple, understandable, and impactful in any policy success.

To illustrate a hidden cost of oil, please consider this simple calculation. The total cost of the Iraq and Afghanistan wars in the last 8 years is approximately \$1.1 trillion [National Priorities Project, 2010]. The total oil imported in the same period of time from OPEC nations is approximately 18 billion barrels [U.S. EIA 2010]. The ratio of these two numbers indicates an implied direct cost or tax of \$61 per barrel in addition to the produced cost, which today is about \$73 per barrel. This cost is paid on April 15th each year, not at the gas pump – so we see no real change in behavior regarding the use of oil (gasoline), just a heavier tax burden which has a drag effect on the broader economy. This simple analysis does not even attempt to put a price on the lives lost in this effort.

Regarding my second recommendation on charge backs to applicants, presumably a nuclear powered electric future would have broad societal benefit. Thus, is a case to be made for United States Nuclear Power Agency activities to be paid for by the U.S. taxpayer, and not the company submitting applications for design or use (other than normal fees as is the case in other federal regulatory agencies). If a new agency is not created, I recommend the Commission investigate this as a policy element in the current regulations.

Conclusion and Summary

In summary, the venture industry is reluctant to engage the federal nuclear regulatory establishment for a variety of reasons. A few startups have for sure. The entrepreneurial and venture segments of the United States are active in pursuing nuclear deals and companies, and they recognize the importance of a nuclear future in the United States. Required for a successful discussion and rapid engagement is a federal process that is orderly, predictable and finite. It is not required that every project make it through the federal review process. It is required, however, that every project get a fair shake and that companies and investors know exactly where they stand, what is required for success, and how much it is likely to cost when they start.

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The existing NRC and DOE federal agencies are simply not set up to support this kind of dialogue with the private venture sector. Experience in the real world indicates that redirecting or altering the missions of these organizations is not practical and likely not to be successful. Therefore, a single-minded, mission-driven United States Nuclear Power Agency should be created with the best practices of agencies that have a successful relationship with the private venture sector, in particular the FDA.

Essential also is an economic element of policy that would accelerate development of new nuclear technologies in the form of a total carbon tax at the source of the carbon. Such a standard would provide an economic target, enabling entrepreneurs and investors to evaluate projects. With existing sources of electricity from coal or gas, whose prices fluctuate and are not the same all over the country, the pursuit of new nuclear technology has a significant unknown against which it must compete and thus a result may be reduced interest or speed of innovation. In addition, charge back fees billed back to applicants for regulatory practices are inherent friction to startup companies since the financial commitments in advance of any knowledge of success or risk/reward are enormous on a relative basis.

Nuclear power is critical for the nation and the world's energy future. America once led the world with the development and deployment of safe nuclear-based electricity production, and can lead again. Creating a new agency dedicated to this mission would unmistakably demonstrate to the world America's commitment to lowering our nation's carbon footprint, developing secure and local sources of power for our citizens, and reduce the national debt caused by the purchase of foreign oil.

I wish to thank the Blue Ribbon Commission Subcommittee on Reactor and Fuel Cycle Technology for hearing my testimony on this most important subject.

If there is any further service I can perform for the Commission, please do not hesitate to call on me.