Prepared Testimony
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Mr. Chairman, Senator Reid, and Members of the Committee, it is a pleasure to be here today to discuss General Electric Company's potential contribution to the Global Nuclear Energy Partnership (GNEP) program with the Power Reactor Innovative Small Module or "PRISM" reactor technology. In my previous role as GE's General Manager of Nuclear Technology, I had the opportunity to establish the foundation for utilizing this fast reactor technology. My testimony will provide a detailed summary of this technology and its potential role in meeting the objectives of the GNEP program.

This is a significant period for our country as we advance into a possible nuclear energy renaissance. GE supports the GNEP concept and is very interested in working with this Committee and the Department of Energy to realize the goals of GNEP. In so doing, we can make real and significant contributions to U.S. and international energy security needs. GE is especially interested in GNEP because it provides the policy framework for solving two of the more serious challenges impacting the nuclear industry today: waste and proliferation. The Advanced Recycling Center concept put forth in our response to the Department of Energy's request for Expressions of Interest for the Advanced Burner Reactor (ABR) and the Consolidated Fuel Treatment Center (CFTC) proposes our solution-based approach.

The Department of Energy has developed a broad implementation strategy for GNEP comprised of seven key elements. GE sees these elements grouped into two broad categories: technical and programmatic.

GNEP Technical Elements:

- Demonstrate proliferation-resistant recycling
- Develop advanced burner reactors
- Demonstrate small-scale reactors
- Minimize nuclear waste

GNEP Programmatic Elements:

- Expand the use of nuclear power
- Develop enhanced nuclear safeguards
- Establish reliable fuel services

While demonstration of proliferation-resistant fuel recycling is the crux of GNEP, we believe the first three technical elements can be best accomplished through a partnership between private industry and the government. The fourth follows with success in advancing the fuel cycle and ABR deployment. Accomplishment of the GNEP technical elements will “pull” the programmatic elements to success.

I have been asked to focus my remarks on the advanced reactor GE has developed – PRISM. That PRISM technology directly supports two key technical elements critical to GNEP success:

- Demonstrate an advanced burner reactor, and
- Demonstrate a small-scale reactor.

The PRISM can provide the energy to generate electricity while “burning” spent fuel from our nation’s 103 operating light water reactors (LWR) as well as future LWRs. Because of its relative small size and its inherently safe encapsulated design, PRISM can be factory built and transported to the site.

To assist the Committee in fully understanding this technology, my testimony will cover three areas:

- A historical overview of the origins of PRISM;
- The PRISM technology itself, developed with the support of funding provided by the Committee; and,
- A PRISM (or SuperPRISM) deployment roadmap for the Committee’s consideration.

Historical Overview

A preliminary safety information document referencing the PRISM design was released by the U.S. Nuclear Regulatory Commission (NRC) in February 1994. NUREG-1368 noted that “…the staff, with the [Advisory Committee on Reactor Safeguards] in agreement, concludes that no obvious impediments to licensing the PRISM ([Advanced Liquid Metal Reactor]) design have been identified.”

In the early 1980s, the Liquid Metal Fast Breeder Reactor program focused on deployment of the Clinch River Breeder Reactor (CRBR) in Tennessee. The program encountered difficulties because of cost escalations and schedule delays. The LMR program faced challenges because uranium was not becoming scarce and prohibitively expensive as earlier had been predicted.

While the CRBR project was being debated, a small group at GE's Advanced Reactors program pursued a technology other than large loop sodium reactors. At the time, the 1,000 MWt CRBR was envisioned as the stepping-stone to 3,000 MWt "commercial" plants - the scale thought necessary to be economically competitive with the large light water reactors. GE questioned the economics of large fast reactors, and conducted internal work based on alternative small modular reactor. This small reactor, with rated power in the range of 400 to 1,000 MWt could provide stair step plant power levels by adding reactor modules at a site to reach economic and power generation goals. This was the genesis of GE's Power Reactor Innovative Small Module – PRISM.

In August 1981, representatives from the Argonne National Laboratory's Special Project Office visited the Advanced Reactor team. We explained the idea that our relatively small PRISM reactor vessel could be transported to a refueling center about every 18 months. ANL explained their in-core refueling machine process for the Experimental Breeder Reactor II. It became apparent that rather than moving an entire reactor, technology was available to move just the fuel. From this synergistic meeting with the national laboratory, the concept of PRISM matured.

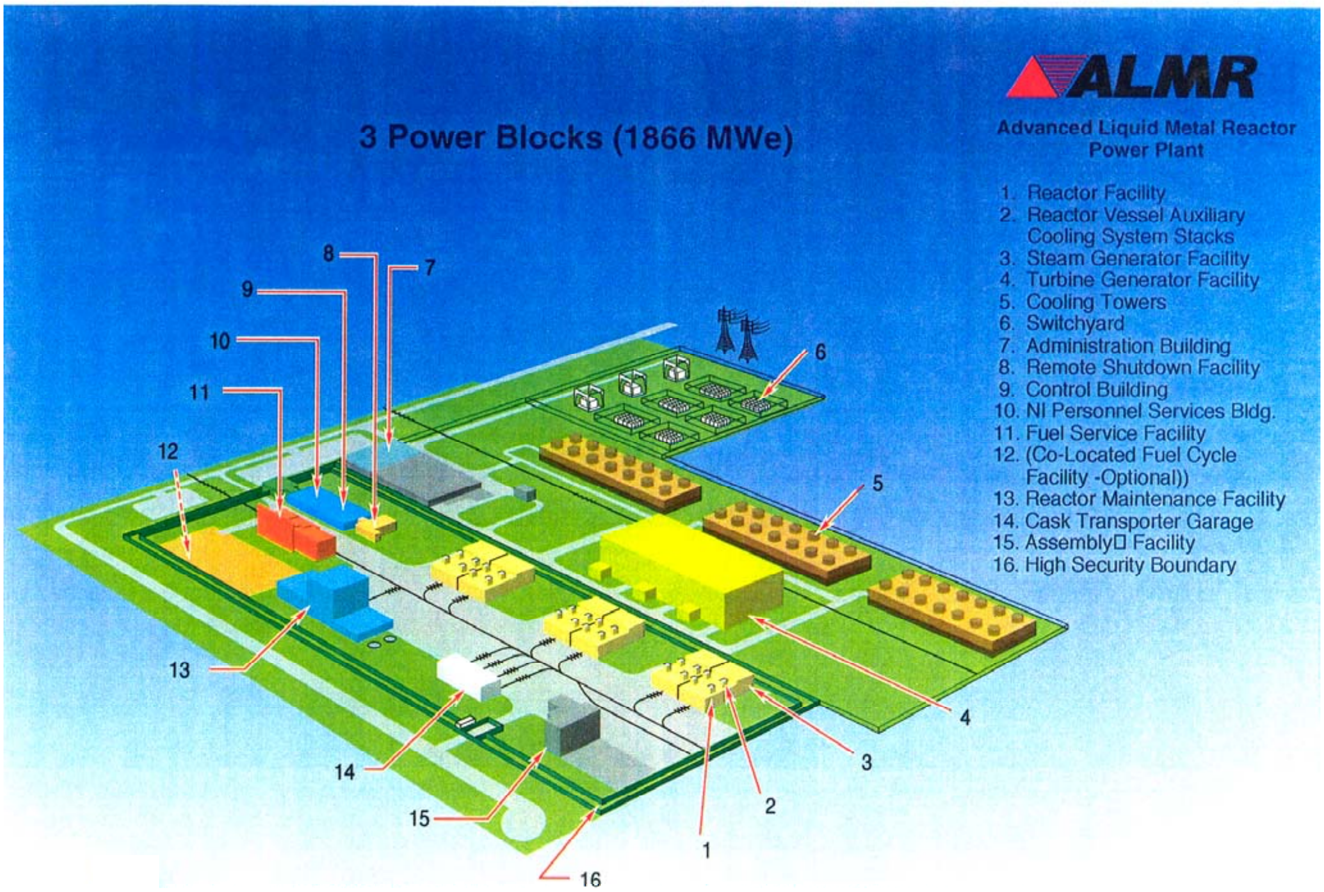
When Congress terminated the CRBR project in 1983, DOE began the Advanced Liquid Metal Reactor program. The goal of the ALMR program was to increase the efficiency of uranium usage by breeding plutonium and create the condition wherein transuranic isotopes would never leave the site. The ALMR was designed to allow any transuranic isotope to be consumed as fuel, and is the forerunner to the GNEP framework we have today.

GE competed for leadership of the ALMR program against another fast reactor technology. GE won the competition and joined the ALMR program with its two key elements: reactor design and fuel cycle development. GE led seven industry partners to refine the conceptual design of the PRISM reactor. The national laboratories, led principally by ANL, tackled the fuel cycle development and waste characterization with 80% of the ALMR funding.

The ALMR program was funded from 1984 to 1994. Two products emerged from the expenditure of approximately $100 million in government funds: the advanced conceptual PRISM reactor design and the highly proliferation resistant pyroprocess for spent fuel recycle. At the point at which the ALMR program was terminated, the

PRISM design was less than five years from construction contracting. Figure 1 shows the typical power plant site design developed as a part of the ALMR program.

Figure 1: Typical Advanced Liquid Metal Reactor
Power Plant Site Layout



A major outcome from this early work on PRISM, focused on safety and economics, was the possibility of deploying a small reactor competitive with large light water reactors. The PRISM designers evaluated light water reactor systems such as defense in depth, active intervention system, and active emergency backups, and developed a passive, inherently safe design that did not depend upon control rods to SCRAM (immediate shut down of the reactor), back up emergency systems, etc.

The passive safety philosophy developed with PRISM has been transferred to advanced light water reactor designs. DOE designates these reactor designs as GENERATION III+. At GE, we call ours the ESBWR. For example GE's ESBWR relies on gravity for both core and containment cooling, therefore providing passive safety.

Following the discontinuation of DOE's ALMR program, GE continued to develop a more advanced modular fast reactor design called SuperPRISM, or S-PRISM. The thermal rating of each reactor module was increased to 1,000MWt from the PRISM's original 840 MWt. The SuperPRISM design sought to further improve upon the commercial potential of PRISM with:

- increased power output;
- compact reactor building on single seismically isolated base pad;
- multi-cell containment system; and
- improved steam cycle efficiency.

These improvements enabled an estimated capital cost of $1,335/kWe, with a busbar cost of 29.0 mills/KWh for the two-power-block plant with a net plant output of 1520 MWe (capital cost and busbar cost in 1998 dollars).

This history demonstrates that the national laboratories and private industry learned a great deal from the Clinch River Breeder Reactor project and the follow-on Advanced Liquid Metal Reactor project. GE was privileged to lead a very talented industrial team.

PRISM is an important technology that America has already largely developed. I will now describe the details of the technology.

PRISM Technology

PRISM is an advanced fast neutron spectrum reactor plant design with passive reactor shutdown, passive shutdown heat removal, and passive reactor cavity cooling. PRISM supports a sustainable and flexible fuel cycle to consume transuranic elements within the fuel as it generates electricity. The essence of the reactor technology is a reactor core housed within a 316 stainless steel reactor vessel. Liquid sodium is circulated within the reactor vessel and through the reactor core by four electromagnetic pumps suspended from the reactor closure head. Two intermediate heat exchangers (IHX) inside the reactor vessel remove heat for electrical generation.

The PRISM technology is deployed as a power block with two reactors side by side supporting a single steam turbine generator set. The plant is divided into two areas: the nuclear island (reactors through steam generators) and balance of plant (steam turbine to generate electricity). The nuclear island is two reactors in separate containments, plus steam generators, and shared services, in a single, seismically isolated, partially buried building as depicted in the cutaway view of a PRISM nuclear island shown in Figure 2. Each reactor heats an intermediate coolant loop, sending heat to a steam generator. Steam from the steam generators is combined and sent to the balance of plant, where a single turbine generator produces electricity. Figure 3 shows the overall PRISM power train that converts transuranics into electricity.

I will now provide some additional details of the components that make up the power block.

Figure 2: Cutaway view of a PRISM nuclear island

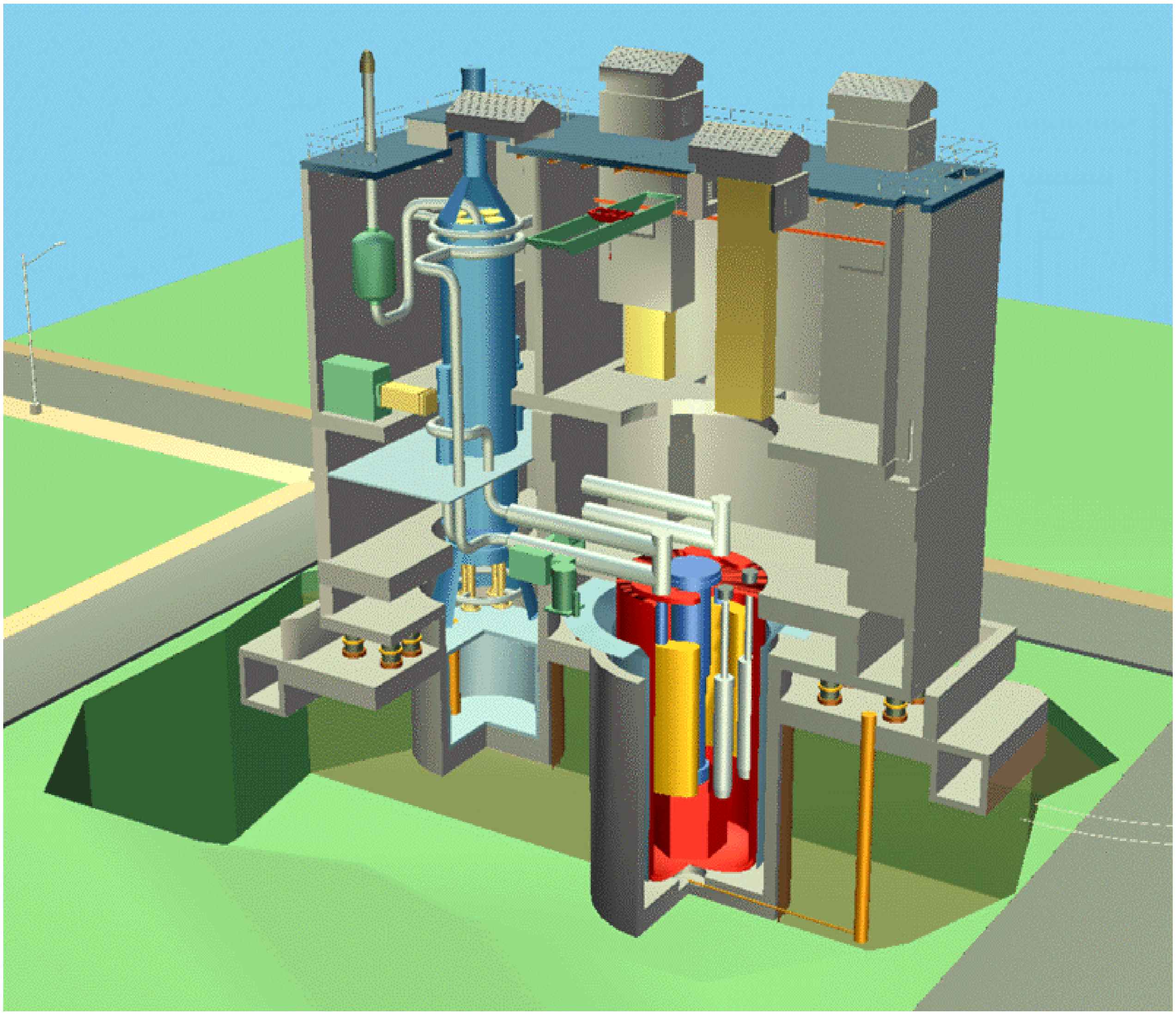
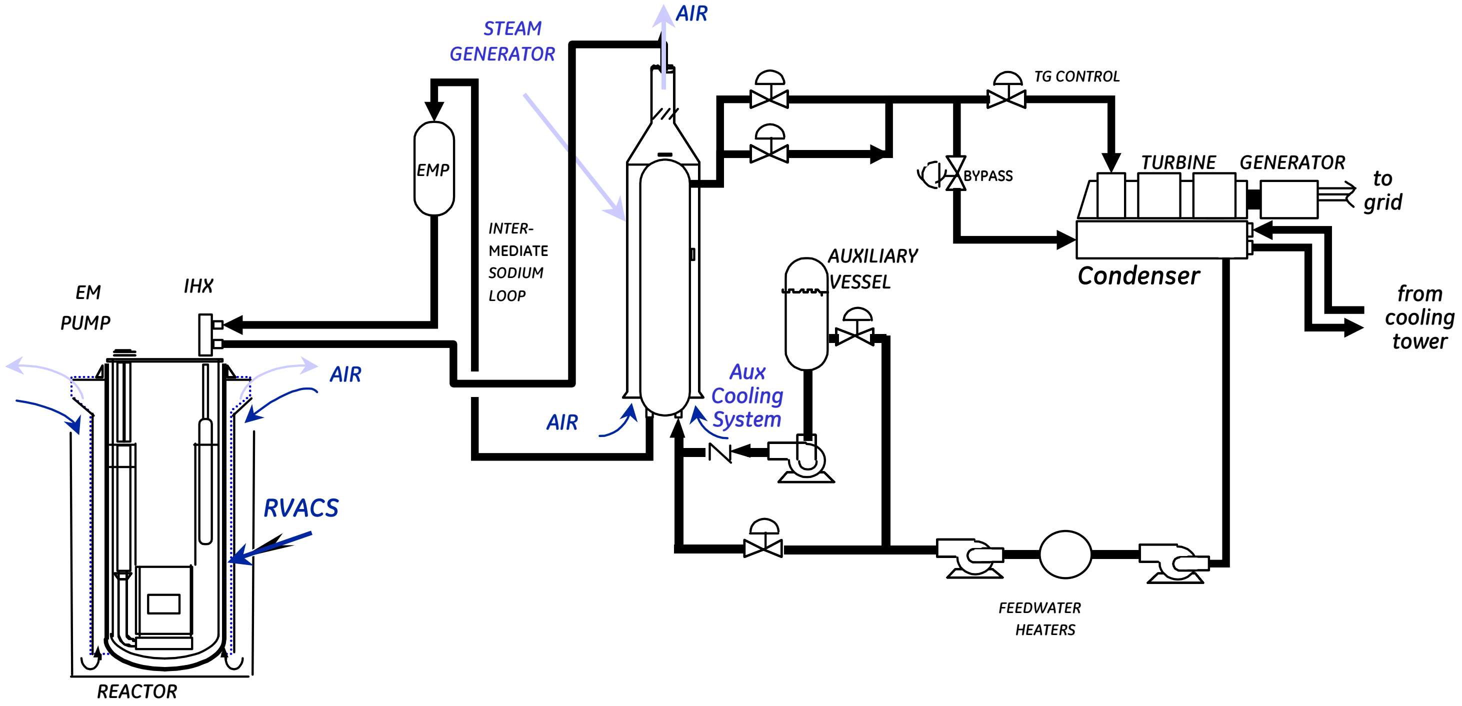


Figure 3: PRISM Power Train



Reactor Core

GE's extensive fuel cycle evaluations indicate a preference for metal fuel. This fuel type best consumes transuranics, recycles spent nuclear fuel and destroys weapons grade material. The reactor core, however, can use either a metal fuel or an oxide-based fuel without changes to the reactor structure or refueling system.

As noted in the history described above, PRISM core power can range from ~800 to 1,000 MWt. Metal fuel bundles allow a higher heavy metal fraction in the fuel resulting in a lower fissile enrichment and better internal transmutation compared to oxide fuel. Thus, the metal fuel core could satisfy nuclear goals with fewer fuel assemblies and a more compact core. The fission gas plenum is located above the fuel column. Upper axial shielding is provided by the long fission gas plenum region and the sodium pool above the core. Lower axial shielding is provided by long pin end plugs. Reflector assemblies contain pin bundles of solid HT9 rods.

Intermediate Heat Transport System (IHTS)

The IHTS is located within the reactor vessel. The internal electromagnetic pumps (EMP) – pumps with no moving parts that move conductive fluids by way of a magnetic field – circulate the molten sodium through the reactor core and then to the IHTS. Another sodium loop, a closed loop system, transports the reactor generated heat to the steam generator (SG) system by circulating non-radioactive sodium between the Intermediate Heat Exchangers (IHX) and the SG. The hot leg sodium is transported in pipes from the two IHXs to a single SG. Two high temperature EMPs in the cold legs return the sodium to the IHX units at ~350°C. The high temperature secondary EMPs are similar to the ones used inside the reactor core.

Steam Generator (SG) System

The steam generator (SG) system is comprised of the startup recirculation tank/pump, leak detection subsystem, steam generator isolation valves, sodium dump tank, and the steam generator. The SG provides a high integrity pressure boundary to assure separation between the sodium and water/steam. The SG is a vertically oriented, helical coil, sodium-to-water counter flow shell-and-tube heat exchanger. This basic design was developed over 15 years in the ALMR program. Further, a 76 MWt prototype SG was fabricated and tested at the DOE Energy Technology Engineering Center for four years. Based on this development work, testing, and GE trade studies, this design was selected as the reference design for S-PRISM. This SG design also provides passive protection from the effects of a significant sodium/water reaction.

Functionally the steam generator operates as follows. Water enters the steam generator through four non-radial inlet nozzles at the bottom. Water is heated as it flows upward through the inlet tubes, helical coil tube bundle, and the outlet tubes connecting the tube bundle to four outlet nozzles sending steam to the turbine. The helical coil design features a longer tube length resulting in fewer tubes. Hot sodium enters the steam generator through a single inlet nozzle at the top. The sodium is distributed uniformly and flows downward around the helical coil bundle at low velocity, which provides a large design margin against flow-induced vibrations.

The system detects any water-to-sodium leaks in the SG and can identify the approximate size of the leak. The steam side isolation valves and the sodium blowdown tank rapidly separate water/steam and sodium – stopping the reaction. Gas backfilling prevents backflow of sodium. If this system fails, an innovative design feature using the gas space inside the SG and rupture disks provide increased steam venting capability to prevent steam from being forced backward into the sodium flow.

This helical coil steam generator design provides high reliability, availability, and safety.

Reactor Vessel Auxiliary Cooling System (RVACS)

The Reactor Vessel Auxiliary Cooling System (RVACS) provides ultimate passive cooling for the reactor if all other methods are unavailable. It is always "on" since it utilizes natural circulation of sodium and air, constantly removing a small amount of heat (<0.5 MWt) from the reactor modules. Radiant heat transfer is employed to transfer heat from the reactor vessel, through the containment vessel, and then to the naturally circulating air.

When RVACS is required for decay heat removal, natural circulation of primary sodium carries heat from the core to the reactor vessel. As the temperature of the reactor sodium and reactor vessel automatically rise, the radiant heat transfer across the argon gap to the containment vessel increases to accommodate the heat load. With the increase in containment vessel temperature, the heat transfer from the containment vessel to the atmospheric air surrounding the containment vessel increases.

The inherent safety features are the circulation patterns, which follow the basic laws of physics. They are constant, and the natural airflow can be easily confirmed, which gives us transparent safety.

Containment

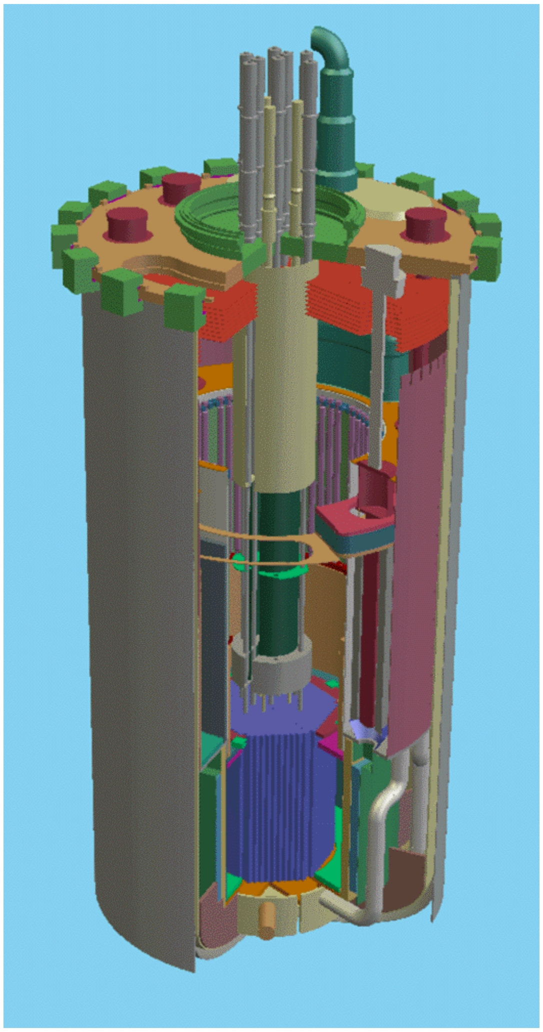
The containment system envisioned for PRISM would use three successive barriers – fuel cladding, primary coolant boundary (reactor vessel cutaway view shown in Figure 4), and a containment boundary that surrounds the reactor vessel – to provide defense-in-depth from postulated releases from the reactor vessel. The containment boundary is a steel lined concrete upper structure that encloses the reactor module as shown in Figure 2. Controlled venting from the containment region above one of the reactors in the power block into a service cell (between each reactor of the power block) would relieve the containment boundary system pressure. If necessary the service cell can vent into the reactor containment boundary of the other unit(s) in the power block. This multi-cell approach reduces containment system expense while improving safety.

What is unique about the PRISM reactor is that the reactor vessel is positioned below grade in a concrete silo – a fourth containment boundary (Figure 2). In the beyond credible event of containment breach, the sodium complies with the natural law of gravity and is contained in the silo. Its relatively simple construction process also reduces cost.

The PRISM reactor design benefits from testing of prototype steam generators and electromagnetic pump at DOE's Energy Technology and Engineering Center. The reactor vessel design and material selection benefit from the standards and testing conducted during the Clinch River Breeder Reactor Program. A Probabilistic Risk Assessment (PRA) was completed as part of the design evaluation to ensure its reliability and public safety. The PRA meets the NRC safety goals for core damage frequency, includes potential design improvements, and developed baseline fault models for future use by the NRC.

This body of component testing, advanced design, and safety philosophy mitigates technical risk if PRISM is deployed for GNEP's ABR.

Figure 4: Cutaway view of a PRISM reactor vessel



PRISM Technology for the Future

We stand today at a major energy policy juncture. As Deputy Secretary of Energy Clay Sell stated before the Committee in March, "[GNEP] is a comprehensive strategy that would lay the foundation for expanded use of nuclear energy in the U.S. and the world by demonstrating and deploying new technologies that recycle nuclear fuel, significantly reduce waste, and address proliferation concerns."

GNEP's underlying principal is that LWR spent nuclear fuel is an asset to be managed using fast reactor technology. PRISM technology is synergistic in this respect because it consumes transuranics produced by our current fleet of LWRs. During that consumption, electricity is produced. GE believes PRISM is the fast reactor technology to best manage this spent nuclear fuel asset.

GNEP is about deployment of a nuclear reactor with a different coolant. This coolant, sodium, allows different reactor performance characteristics, beneficial for the intended mission. At this point, the key issues in deployment of this new technology are related to design, codes, and standards. If the government chooses to deploy a PRISM reactor to achieve the goals of GNEP, the work that remains is really about nuts and bolts project engineering and management – the technology is ready to be deployed. GE is ready to leverage our commercial expertise in reactor plant design and construction to support deployment of a PRISM reactor as part of GNEP.

GE has experience in taking government research results from the Nuclear Reactor Testing Station, Idaho - the BORAX reactors – and developing and commercializing the Boiling Water Reactor from initial reactor tests. This technology commercialization was accomplished with public-private partnerships. Today's PRISM technology deployment requires the same working partnership. With expanding demand for domestically produced non-carbon emitting energy, and the fuel supply - spent nuclear fuel - tied to government ownership, only a public-private partnership can make GNEP happen.

In 1965 GE started the SEFOR (Southwest Experimental Fast Oxide Reactor) project in Arkansas to develop first-hand design, construction, and operational experience for a commercial-scale liquid metal reactor. A remarkable aspect of SEFOR was that the total eight-year program was described in detail in the initial contract and, except for minor variations, was carried out exactly as planned. Contrast the successful SEFOR project to the Clinch River Breeder Reactor project.

The success of SEFOR provides an important lesson. At GE we are proud of our past contributions to fast reactor development in this country. PRISM technology has been extensively researched using both federal and private industry funding. A wealth of documentation and expertise is available from the national laboratories and industry. GE has the infrastructure and the processes to build the PRISM with a "Made in America" stamp. PRISM can be deployed now on a commercial scale – generating revenue by putting electricity on the grid – using GE's state-of-the-art management tools. We have proven this in our deployment of ABWR abroad, and GE hopes to continue this tradition with the deployment of both ABWR and ESBWR in the U.S. in the near term.

Records and Documentation

"Prototype Plan" (GEFR-0933) December 1993 – one of many documents delivered to the government in the early 1990s – presented what looks very similar to the current GNEP "plan." It proposed a system with three subsystems – reactor power plant, fuel recycle facilities, and the LWR actinide recycle facilities. The estimated cost for the reactor subsystem and safety testing was estimated then at $1.6 billion. This estimate accounted for the difference between the standard plant and the prototype, which must support running the safety tests and fuel testing until NRC certification is granted.

The NRC licensing approach defined in "Licensing Approach" (GEFR-00842, UC-87Ta) presents a process and schedule for achieving standard design certification. The "Certification Test Plan" (GEFR-0808[DR], UC-87Ta) identifies all testing needed for the design certification. "1993 Capital and Bus Bar Cost Estimates" (GEFR-0915, UC-87Ta) provides a bottom-up capital cost and bus bar estimate. As part of these earlier efforts, GE delivered documents on exactly how to fabricate the reactor vessel, test fuel, build steam generators, etc. As I stated before, NUREG-1368, Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid Metal Reactor, Final Report, February 1994, stated that, "…the staff, with the ACRS in agreement, concludes that no obvious impediments to licensing the PRISM (ALMR) design have been identified."

The confluence of GE processes and project management with this wealth of ALMR documentation (requiring relatively little updating) provides significant input for a systematic path forward for GNEP.

Reactor Fuel Qualification

We recognize the need to perform rigorous qualification of the new fuel forms available for PRISM. We recommend establishing a "Fuel Team" to provide integration between GE and DOE's national laboratories to develop technologies to separate and fabricate fast reactor transmutation fuel. This team approach will insure qualifying transuranic fuel that meets the project schedule, and is both cost effective and reliable. In order make a cost effective and reliable driver fuel, GE believes it should be based on the U-Zr or the U-Pu-Zr fuel used at EBR-II, because of the considerable operational experience.

The prototype PRISM reactor would incorporate more instrumentation than would be employed in subsequent commercial units in order to measure fuel temperature and flux in support of the fuel qualification program. Both DOE's national laboratories and GE could conduct the fuel examinations.

The PRISM reactor is the best vehicle for fuel qualification since it has more in-core positions for fuel testing and operates that fuel at prototypical conditions.

Resources Required for Public-Private Partnership:

Two areas deserve consideration by this Committee to assure success of GNEP:

- A multi-year funding commitment for reactor construction to mitigate cost risk, consistent with other DOE energy programs.
- Access by the GNEP prime contractor to information developed by the national laboratories applicable to PRISM. Some examples are:
    1. Heat transfer correlations for Reactor Vessel Auxiliary Heat Removal System water simulations tests for confirming the in-reactor sodium flow paths to expedite validation simulations using new CFD codes.
    2. Electromagnetic pump electrical insulation material testing data to finalize pump design.
    3. Post-test evaluations of the seismic isolation bearings to support the detailed design process for the seismic isolation system.
    4. Support to recover the EM pump at the Energy Technology Engineering Center.

- The total R&D cost for the PRISM development was estimated to be $300 million in 1998. Some examples of this R&D identified in NUREG-1368 are:
    1. Seismic isolation: The PRISM design uses seismic isolation bearings. The response of buildings with these installed bearings is needed to support ABR seismic code validation. International cooperation with France and Japan, which also have used this seismic isolation design, can provide additional empirical data.
    2. Fuel System: TRU metal-fuel development, supported by in-reactor and ex-reactor experiments.
    3. Thermal Hydraulics: New analytical tools will be developed for core thermal hydraulics.
    4. Heat Exchanger: Evaluation of the Intermediate Heat Exchanger System gimbaled joints.

Summary

Our nation has already made much of the necessary investment in facilities, analysis, study, research and experimentation on the design and deployment of fast reactors (now called the Advanced Burner Reactor). The national laboratories have amassed extensive documentation and proof of the PRISM concept, its safety, and its viability. We should take advantage of that wealth of knowledge and expertise, and move ahead with this available technology to deploy a commercial scale advanced burner reactor, the PRISM. Importantly, in contrast to current reactors that require outsourcing of components because of their size, the key elements of PRISM small module reactor technology – including the reactor vessel, the steam generator and the steam turbine – are capable of being fabricated domestically. As the last U.S. publicly owned reactor vendor, GE is ready, if tasked by our government, to move forward.

In his testimony before the Committee this spring, Deputy Secretary Sell succinctly defined our nation's status on nuclear energy and the potential for PRISM technology:

> . . . nuclear energy by itself is not a silver bullet for energy supply, in the world or for the U.S. and we need all technologies to address the anticipated growth in demand for energy. Regardless of the steps the U.S. takes, nuclear energy is expected to continue to expand around the globe.
>
> We can continue down the same path that we have been on for the last thirty years or we can lead a transformation to a new, safer, and more secure approach to nuclear energy, an approach that brings the benefits of nuclear energy to the world while reducing vulnerabilities from proliferation and nuclear waste. We are in a much stronger position to shape the nuclear future if we are part of it and hence, GNEP. GNEP is a program that that looks at the energy challenges of today and tomorrow and envisions a safer and more secure future, encouraging cooperation between nations to permit peaceful expansion of nuclear technology while helping to address the challenges of energy supply, proliferation, and global climate change.

PRISM is a technology that can close the nuclear fuel cycle using the energy contained in our nation's spent nuclear fuel. PRISM can generate stable base load electricity to help meet our growing electricity needs and enhance our energy security. As we do so, we reduce the need for additional geologic storage capacity. GNEP provides a unique opportunity to regain the historical U.S. leadership position in nuclear science and technology.

Thank you. This concludes my formal statement. I would be pleased to answer any questions you may have at this time.