GEM*STAR: Green Energy Multiplier – Safe Technology for Alternative Reactors

"Today's land-grant university, like those of the 19th century, must address economic and societal needs of this generation"
Virginia Tech President Sands

"We must harness the power of nuclear energy on behalf of our efforts to combat climate change, and to advance peace and opportunity for all people."
United States President Obama

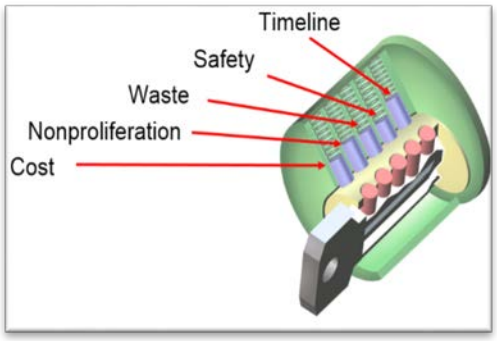

Fig. 1 – *All* the tumblers must be solved before you have an actual solution

The early promise of nuclear reactors to provide cheap, safe, and abundant 'green' energy that can be located near demand remains unrealized as reactors continue to be associated with weapons, waste, radiation release hazards, and relatively high expense.

The GEM*STAR design for nuclear energy breaks these links. It is not an incremental approach, but rather a strategy that addresses all the key stumbling blocks at once: safety, proliferation, waste, cost, and timeliness. This is what distinguishes it from all the other approaches being pursued today – making it transformative, but difficult to pursue through incremental 'consensus' funding avenues.

Importantly, GEM*STAR is a *sub-critical* system, making it intrinsically safer and simpler than a traditional critical reactor. In a 'critical' reactor, the number of fission neutrons in one generation is equal to those in the preceding generation. In a sub-critical reactor, the number of fission neutrons reduces from one generation to next, requiring the reactor to be continually driven by a separate neutron source. GEM*STAR uses a particle accelerator to generate these neutrons. The energy required is about two orders-of-magnitude less than the energy released in the subsequent fission chain so the accelerator consumes only a small fraction of the reactor output. If you turn off the accelerator, the fission chains simply stop. Furthermore, the combination of a molten salt fuel and particle accelerator allows GEM*STAR to burn *unenriched* uranium as well as the waste from existing reactors.

The GEM*STAR design is an integrated accelerator-target-reactor system using molten-salt fuels rather than the solid fuels in current reactors. (A molten-salt reactor was demonstrated at Oak Ridge National Laboratory, ORNL, in the 60's.) Molten salt fuels have several beneficial design attributes:

- low-pressure operation (the eutectic boiling points are about 1500 ºC)
- high temperature operation giving better efficiencies and broader applications
- no fuel cladding that can melt and result in uncontrolled radioactive release (e.g., Fukushima)
- excellent neutron efficiency

Additionally, today's accelerators have sufficient power and efficiency to drive the system, with megawatt working examples at Oak Ridge and Los Alamos. This offers a commercially-viable baseline energy system that can deeply burn multiple fuels, including (but not limited to) natural uranium, today's Light Water Reactor (LWR) spent fuel, and weapons-grade plutonium, all *without reprocessing* (which can be a step towards production of nuclear weapons).

GEM*STAR addresses all the key elements shown in Figure 1 as follows:

- **Cost Competitive with Coal:** Molten-salt reactors and accelerator technology have established cost estimates based on existing demonstrations. The projected complete cost makes production of electricity economically competitive with coal, and production of syngas for liquid transport fuel even more economically favorable.
- **Removes Key Nuclear Proliferation Concerns:**
  - no need for *enrichment* - the accelerator allows running on natural uranium
  - no need for *reprocessing* – unlike critical molten-salt systems (or LWR spent fuel usage)

- **Reduced Waste:** being a *subcritical* system offers important benefits:
    - *much* less long-lived wastes produced compared to LWRs since they are continuously burned
    - burning of existing waste – extract as much energy again from LWR spent fuel as had been originally produced, without additional long-lived waste
- **Removes Major Safety Concerns:** never a critical mass present in core; sub-criticality and molten-salt fuel offers major simplification in reactor safety systems and control
    - a critical reactor faces potential for super-criticality and requires a complex safety system
    - a solid fueled reactor requires the use of cladding that may melt under severe accidents
    - the boiling point of most molten salts is about 1500 ºC, allowing low-pressure systems, and higher operating temperatures (giving high efficiency, and high-quality process-heat)
- **Timeline within this Generation:** adequate technology is available today to demonstrate basic commercial viability. (Once demonstrated, ongoing research in terms of materials, accelerator efficiency, core design, uses of process heat, and implications for economics and security will motivate new funding opportunities where VT will be positioned to actually help *draft* the solicitations, and not simply respond.)
    - A time-critical doorway has opened to build a demonstration plant: to fulfill a 2011 treaty between Russia and the United States to dispose of 34 metric tons of weapons-grade plutonium (WGPu), the US began to build a MOX facility in South Carolina, but after expenditure of $5B, the effort has stalled and the Obama administration issued a call for alternatives. We believe GEM*STAR is particularly well suited to this task, and could net a significant profit using its uniquely high-temperature process heat, for example to generate diesel fuel.
    - The potential for regulatory delay is challenging, which is why the initial focus on DOE owned WGPu and property may be essential. However, by actually addressing the essential elements of the public's concerns about nuclear energy, coupled with the ever-increasing need for green-energy sources, public and political pressure may help create a faster regulatory process.

Virginia Tech has been working on GEM*STAR with ADNA Corporation since 2003, and Muons, Inc., since about 2010. GEM*STAR garnered the support of former President Steger, former Provost McNamee, Dean Chang, and many faculty, with VT internal exploratory funding coming from COS, OVPR, and the Provost's office ($225k total). ADNA holds some directly related intellectual property, and VT has filed a provisional patent application. The right collaborative framework was not in place then, but the WGPu issue has opened a new door, and we have now added support from the OVPR and COE. Our nuclear engineering program is critically involved and has confirmed the basic concepts. The right framework is now understood and last month we had very positive discussions with John Dooley about forming a joint venture called GEM*STAR that would involve the Virginia Tech Foundation and our industrial colleagues to pursue building a demonstration plant (estimated at $500M).

The recent White House announcement on the formation of GAIN (Gateway for Accelerated Innovation in Nuclear) and our engagement with ORNL offers an additional window of opportunity for the realization of GEM*STAR. On Nov 6, 2015, the White House reaffirmed nuclear as a clean energy, and announced the formation of the GAIN program to support small businesses engaged in innovative reactor designs. ORNL has long been in favor of molten-salt systems, and is very interested in participation with the GEM*STAR initiative.

GEM*STAR offers Virginia Tech an opportunity to help launch, and then benefit from the immediate and long-term multi-disciplinary research aspects of a new and transformative approach to nuclear energy and all its implications. We believe GEM*STAR could excite our donors looking for an identifiable program with broad impacts for energy, security, global warming, and the university. GEM*STAR is well aligned with a number of proposed Destination Areas, including *Energy, Water and Food* and *Security, Risk, and Resilience.* Launching a transformative approach to nuclear energy that addresses many societal problems with Virginia Tech as the lead university would add a very compelling aspect to multiple colleges and institutes, well beyond only technology, making VT the preferred destination for many new faculty and students.