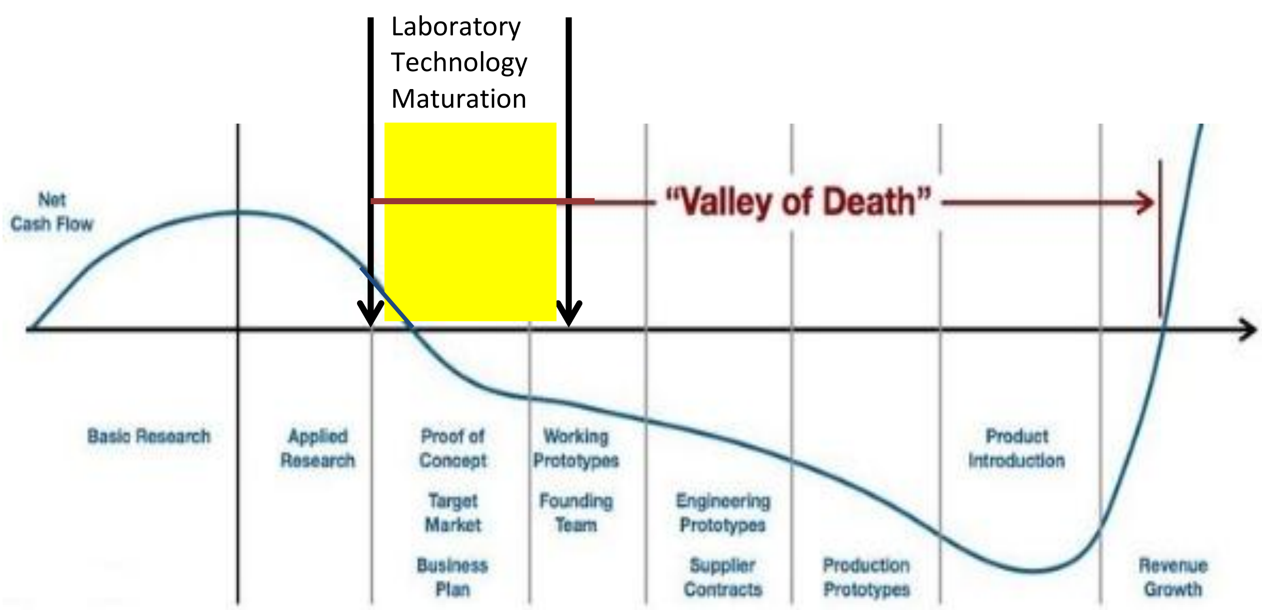
DRAFT

TECHNOLOGY MATURATION WHITE PAPER

Although its priority seems to ebb and flow over time, improving the contributions of DOE laboratories and facilities to U.S. economic competitiveness has been a consistent theme for many years and has recently been receiving renewed attention. Many of the past and current reviews of the Laboratories, such as the ones conducted by the Secretary of Energy's Advisory Board, have made this a key component of their studies. However, in spite of this emphasis, no comprehensive DOE program to advance laboratory developed technology to the point where it can be adopted and utilized by U.S. industry presently exists. Funding provided for such a program is often called technology maturation funding. This white paper will lay out a ground work for technology maturation funding, describe selected examples in the Federal Government where it is already being done, and propose some alternatives for providing additional technology maturation resources to the DO laboratories.

I. What is Technology Maturation Funding and Why Is It Needed?

In simple terms, technology maturation is simply the technical de-risking of a technology in a specific application. Further information on technical risk and how it is commonly measured will be presented in the second section of this paper. Suffice to say for now that in many DOE programs, a significant gap exists between the point where a DOE program funds a technology and the point where the private sector is interested in investing significant resources in advance it. The gap between research and commercialization is often referred to as the "valley of death" and is generally illustrated in the figure below. There is no intent that a Government-funded technology maturation program should fill the entire Valley of Death. The vast majority of the needed investment should be made by private industry. However, much of DOE's research projects do not even reach the "Valley of Death" illustrated in the figure, since this requires moving beyond research to a "proof of concept." The yellow shaded box below illustrates the area in which a laboratory technology maturation program could be helpful in technically de-risking technology to increase adoption by the private sector.



In recent years, much emphasis has been placed on streamlining processes and procedures so that the DOE laboratories are easier for industry to contract and collaborate with. While these efforts are important, they do not deal with the fundamental issue that many Laboratory developed technologies and capabilities are simply too immature for industry to fully embrace. The technical risk that the technology will not offer sufficient performance in specific applications limits industry's willingness to invest – proof-of-principle demonstrations are needed and industry will generally not fund them. For many technologies, potential industrial applications of Government technology are never explored because there is no funding to do so.

As previously indicated, DOE should not supplant the role of industry in addressing the "valley of death". The vast bulk of Government research and development funding should remain focused on answering basic scientific questions and maintaining national security. However, a program to transition selected technologies to commercial application could provide a useful complement to these missions. It is important that such projects be industry driven, with substantive input from industry on the project goals and, in most cases, in-kind or co-funding from an industry partner.

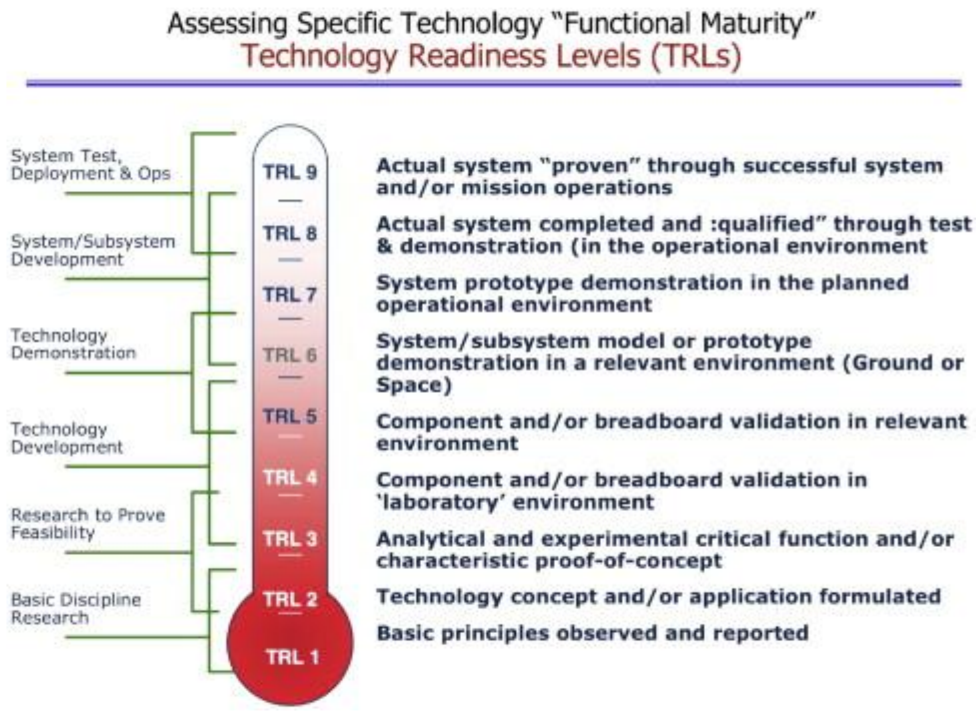
In addition to the technical de-risking of technology, funding for technology maturation would provide more motivation for the scientists at the DOE laboratories to develop and foster relationships with private sector companies. The primary motivation for staff working at DOE laboratories is maintaining and growing funding to support their research. A technology maturation program requiring significant industry input and contributions would incentivize laboratory scientists to seek engagement with industry partners.

A number of examples exist where on a selected basis, the Federal Government (including DOE) manages successful technology maturation programs, even though such programs may not be labeled as such. The problem is that these programs are typically not broad based, so that resources are available to mature technologies of highest potential interest to industry. In addition, the current programs typically are not linked with technologies arising from the DOE Office of Science and the NNSA funded research, which constitutes the bulk of the funding at the DOE laboratories. The next section of this paper will describe some of these programs.

II. Examples of Successful Technology Maturation Programs

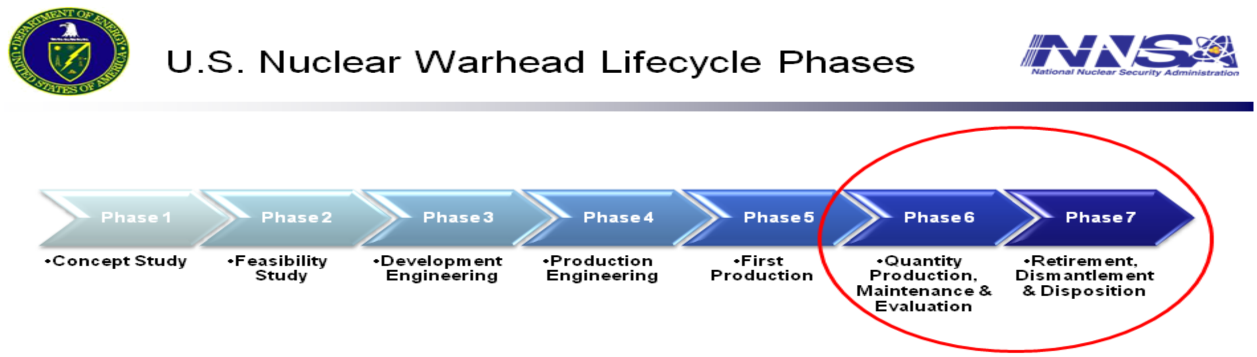
As noted previously, technology maturation is about "de-risking" a technology so that investors will see it as more attractive than might otherwise be the case. In certain government programs, where new products or services are needed but not otherwise available, and where there is not a strong enough commercial market to attract private capital, the Government frequently funds the entire development. This has been the case in Department of Defense (DOD) for the development and production of new weapons systems, in NASA's developments for the Space Program, in DOE/NNSA for the development of Nuclear Weapons, and in certain DOE Energy programs. Although in many cases, the Government will eventually purchase the fully developed technology from the private sector, the perceived risk in these opportunities as viewed by the private investment community is too high and the resulting return on investment too low, to justify their full participation and funding. Thus, the government must accept the risk and fund the technology development process to a much more mature state-of-development, often to the point of high-volume production.

To discuss this process in more detail, it is informative to utilize the concept of Technology Readiness Levels or TRLs. The TRLs describe the maturity of a technology from its initial research phase through full product production readiness. In this context, low TRL or "immature" signifies higher risk of failure with respect to product production success, and higher TRL represents more "mature" and lower risk with respect to that success. The TRL definitions used by the DOD are shown below.



The DOD's history of new weapons development is well understood and documented. When the DOD wants a new weapon system, such as a Stealth Fighter, it calls for proposals from a set of DOD contractors who have the expertise to take the project from R&D through production. The winning development team gets a series of contracts to fund the technology through all nine TRLs. NASA has historically followed the same process to develop the assets it needs to execute the Space program.

For mission related research in the DOE Office of Science, the product of that research is knowledge and not necessarily commercial value. However, in many cases that research may have commercial value if it is further developed and matured. In the DOE NNSA programs, where the research is intended to solve national security problems, again it may have some commercial value if properly matured. In both of these cases, the TRL for the research/technology as discussed above and relevant to requirements of commercial markets, frequently stops at about Level 2 or 3. However, in cases where the results of a research effort are to be put into the nuclear weapons stockpile, the NNSA frequently funds the work from TRL 1 all the way to TRL 9. When the NNSA Labs were actually developing weapons over 20 years ago, the development chain for weapons R&D analogous to the TRL scale above, was defined as Phase One to Phase Seven as shown below. All seven Phases were funded by the DOE NNSA.



In some DOE energy programs, such as EERE, where the goal is to introduce renewable energy technologies into the market, the risk to private investors may often be perceived as too high. Thus, these programs frequently provide resources to help "de-risk" the development and deployment of new energy technologies into the market. In the early phases of technology development and de-risking, the ARPA-E program plays an important role. In this case the de-risking is all about technology, i.e. will the technology perform the way it must, in order to develop a successful product or service. In the latter phases of new energy system development and deployment, DOE sometimes moves beyond the technical de-risking that is the subject of this white paper and addresses market acceptance on a larger scale. For example, the DOE Loan Programs Office has a $40B fund that will fund up to 80% of a project to demonstrate its market readiness, acceptance and value. Examples of the DOE Loan Program Office investments are Tesla Motors and Ivanpah, the world's largest concentrating solar power plant. Once demonstrated, the hope is that private capital will fund future expansion.

DOE recently formed the Office of Technology Transitions to serve as a DOE-wide functional unit that coordinates the commercial development of DOE's research outputs and has responsibility for the statutorily-created Energy Technology Commercialization Fund (TCF). This nearly $20 million fund will leverage the R&D funding in the applied energy programs to pursue high-impact commercialization activities.

The above examples indicate that providing funds to mature technology towards commercial readiness is not an unknown concept within either DOE or the Federal Government. However, as noted in the previous section, such resources are not available to the DOE laboratories and facilities on a broad basis that enables them to pursue commercial opportunities outside of specific mission areas. Even the TCF would appear to be limited to technologies and capabilities arising from DOE's applied energy programs.

A significant fraction of the technology developed by the laboratories has commercial value in markets for which the technology was not originally intended, often described as "spin-off" technology. The immature state of these technologies relative to their readiness for commercial markets represents a significant roadblock to their commercialization. As stated above, these spin-off technologies are often at TRL 2-3 as they come from the laboratories and commercial developers often want technology to be at TRL 5 or above (preferably 7 or 8) before they are interested in investing or adopting the technology. This "Valley of Death" where the government does not want to pay for further development and the commercial sector sees the technology as too immature for investment purposes limits the contributions of the DOE laboratories to enhancing U.S. economic growth. The final section of this paper describes some potential alternatives for the DOE and its laboratories to bridge this gap.

III. Potential Approaches and to Bridging the Gap through Technology Maturation

Through internal laboratory funding

As mentioned in the 2013 report by the Institute for Defense Analyses entitled "Department of Energy Technology Maturation Programs", several DOE laboratories currently use part of their royalty revenues to fund a technology maturation program. Through the years, these programs have been successful in garnering industry interest and have resulted in licensing and commercial partnership opportunities for the laboratories and their staff. However, one of the major drawbacks of a royalty funded technology maturation program is their limited nature. These limitations include the number of projects that can be funded as well as the amount that can be allocated per project. In addition, some of the DOE laboratories do not have sufficient royalty revenues to fund even a limited program. The availability of funds is largely dependent upon the level of past success of the laboratory in licensing technology.

It would be beneficial to explore other sources of funds that can support a laboratory initiated technology maturation program. For example, the possibility of allowing the DOE contractors to use overhead funds for funding their respective technology maturation programs needs to be further explored. Projects would focus on technical "de-risking" demonstrations of a technology in applications relevant to a commercial need. The details of "what" needs to be demonstrated would be provided by the commercial partner and the "how" of the demonstration would be done by the laboratories. Laboratory efforts would focus on demonstration, not research and development which presumably had already been done. In-kind and/or co-funding by an industry partner would be required. Individual projects would be relatively small (e.g. less than $250K). The laboratories would select the projects to be funded through a process approved by DOE and DOE would have the right and responsibility to periodically assess the projects for impact and to suggest changes to the selection process.

The Stevenson-Wydler Act of 1980 requires that *"each Federal agency which operates or directs one or more Federal laboratories make available not less than 0.5 percent of the agency's research and development budget to support the technology transfer function at the agency and at its laboratories." A* reasonable interpretation of this language indicates that technology maturation could be included within the 0.5 percent of funding required by the Act. However, if the current language is insufficient, a legislative clarification to the language could be sought. In addition, the 0.5 percent is a minimum required level. The amount could be increased to allow for a viable technology maturation program.

Through DOE technology maturation funding with industry co-funding and participation

In the 1990s, DOE established successful laboratory technology maturation/partnership programs in both the Office of Science and the NNSA that are no longer operational. Reestablishing similar programs could significantly enhance the value of DOE's laboratories and facilities to the U.S. economy.

Below are the two potential funding sources for the envisioned DOE- funded technology maturation program:

- Similar to the SBIR and STTR programs, a nominal percentage (likely less than one percent) of DOE program research and development funds (minus those that already fund the TCF) could be assessed and pooled to support a cross-cutting technology maturation program. These funds could be used to support laboratory and facility efforts and all projects would be cost-shared with industry, with the bulk of industry contributions likely to be in-kind.

- Require each of the DOE programs to allocate a small portion of their funds to support technology transfer and transition projects appropriate to their respective program's specific mission. The allocation can be modeled along the lines of the TCF but extended more broadly to programs beyond the applied energy programs. In this approach, some of the funds allotted by the various programs could be used for working directly with industry in the same manner as described above. However, in other cases, funding could be used to transition a technology from a DOE basic science program to an applied energy program, or to transition an NNSA developed technology for use within the DOE defense complex.

These programs could be operated in a manner similar to the current SBIR/STTR program, except that the funds would flow to the DOE laboratories following a competitive peer review of proposals for collaborative projects submitted by the laboratories and their Industry partners. In addition, the funds could be used to assist laboratory researchers who have participated in a commercialization training program such as NSF iCorps or the new EERE initiated Lab Corps to mature a technology found to have substantial commercial interest.

The key features of the proposed DOE funded technology maturation program should include:

- Cost share (in-kind and/or funds-in) by industry partners in all funded projects;
- Clearly defined evaluation criteria;
- Competitive review of proposals by a review committee that includes technical and industry experts;
- A well-defined set of metrics to monitor the effectiveness and continued improvement of the program.

Summary/Recommendations

This report has identified that a need clearly exists for a broad-based technology maturation program to bridge the gap between where most DOE programs leave a technology and industry is willing to make major contributions to its further development and commercialization. Although establishing a new program within DOE to support technology maturation would have potential advantages in terms of available funding levels and direct DOE oversight, this is not believed to be likely within the current funding environment and interests of the major DOE programs. A much more practical route is to allow the DOE Contractors, within defined limits and DOE oversight, to utilize a small amount of their overhead funds to support technology maturation. It is acknowledged that this has been previously proposed to DOE and was not approved, although no formal rationale for this disapproval has ever been provided. We believe that it is time for DOE to reconsider this issue, if it is truly serious about improving the contribution of its laboratories to the U.S. economy.