Summary of Input from the Request for Information on

Creating a Robust Accelerator Science & Technology Ecosystem

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Introduction

To identify opportunities and barriers to accelerator science and technology in the U.S., the Office of Science, though its Office of Accelerator R&D and Production, posted a Request for Information (RFI) on January 29, 2021. The RFI asked 16 questions in five topical areas pertaining to the accelerator science and technology ecosystem: (1) the Status and Future of the Market, (2) Models for Technology Transfer, (3) Workforce Development, (4) Defining an Optimal Federal Role, and (5) Other. By the close of the RFI on March 15, 2021, the Federal Register posting had been viewed 1,332 times and 247 pages of original material had been submitted, along with a further 97 pages of articles and presentations. Responses were provided by 9 private companies, 6 national laboratories, 5 universities, 3 individuals, 2 scientific collaborations, and a federal agency. To enable frank input on topics that are business sensitive, respondents were notified that a high-level summary of the inputs would be made public, with identifying and confidential information removed. This document provides a high-level summary of the responses received and is provided with no guarantee as to the factual accuracy of statements made by the respondents.

Status and Future of the Market

Government investments that build up the domestic production capability of certain accelerator technologies may be leveraged by an existing or emerging commercial market, resulting in a production capability that will be at self-sustaining, and in some cases, even grow. While some niche technologies will not have non-Governmental applications and may require on-going Government investments, knowledge of which technologies are most relevant to the commercial market will help inform Federal investment priorities in the domestic accelerator technology production. (Note: commercial market sizes in the following paragraphs refer to worldwide, not just domestic, markets.)

Current market: The current commercial annual accelerator market is about $3B, compared to a market of about $0.5B for discovery science accelerator construction and operation for the Office of Science. The two biggest portions of the commercial market are medical systems and industrial systems, both on the order of $1B/yr. For medical systems, the largest market elements are accelerators to treat cancer and accelerators for medical isotope production. For industrial systems, the largest market elements are accelerators for food irradiation, accelerators for ion implantation for semiconductors, and accelerators for non-destructive testing. Security inspection systems comprise the next largest accelerator market.

Emerging and future market: The potential emerging market for accelerators represents up to an order of magnitude growth over the existing market, plus accelerator technologies may have even higher potential markets for non-accelerator applications. Some of the most promising accelerator market growth areas include compact medical systems for X-ray imaging (up to $10B/yr), new accelerators for novel medical isotope production (up to a few $B/yr), high-power accelerators for environmental remediation (up to about a $B/yr), and compact accelerators for cargo inspection (up to a couple $B/yr). Superconducting wires and magnets have a potential market of up to a couple $B/yr for MRI/NMR machines and over $100B/yr for wind power generation. If accelerator-driven sub-critical systems are adopted for large-scale energy production, the accelerator portion of that market would be even larger.

Challenges to maintaining a sustainable domestic production capability: There are significant obstacles for U.S. vendors both in entering the market and maintaining a sustainable business. Entry obstacles include robust competition from foreign state-sponsored vendors, lack of foreign customers (many foreign countries have policies against buying U.S. accelerator products), high cost of entering the market (e.g., the start-up costs for test labs, equipment, knowledge, etc.), competition for the limited supply of qualified workers, limited need of industrial products and services by national laboratories for technologies when they maintain a competing capability, and poor mechanisms for technology transfer from national laboratories. Another key challenge that discourages the development of new industry is that current technology is good enough for many applications (e.g., isotopes and MRI machines) which leads to low profit and manufacturing margin, and reduces risk tolerance and interest for innovative R&D. Moreover, novel medical technologies require long approvals to be marketed. A key challenge specific for technologies needed for large accelerators for discovery science is the highly fluctuating demand due to the sporadic nature of building large accelerator programs. Also, the long timescales of these project lead to long product validation times and inhibit investor ROI. Mid-scale industry is especially vulnerable to each of these challenges.

Models for Technology Transfer

Current models for technology transfer have not been optimized for developing and strengthening domestic accelerator technology vendors. A key issue in this space is that national laboratories tend to maintain their own ability to develop and produce certain technologies to ensure their required mission success, partly because the domestic commercial capability is so challenged. As a result, the domestic industry is often not treated as a partner in large U.S. accelerator upgrades and construction projects (although significant historical counterexamples do exist). As a result, current technology transfer and SBIR approaches favor special niche accelerator technologies which do not strategically leverage the large current and future commercial accelerator markets. The development of a balanced national laboratory/industrial ecosystem has “a chicken and the egg” element – the national laboratories need to maintain their own capabilities until a sufficient industrial base is built but the existence of the national laboratory capabilities suppresses the ability to develop that industrial base. These challenges may be solved with an appropriate public-private partnership (PPP) approach, which will likely be different for different sectors of accelerator technology.

Current technology transfer mechanisms: Current methods are CRADAs, Strategic Partnership Programs (SPPs), SBIRs, STTRs and joint government-funded contracts. CRADAs can be funded by both sides or solely by the industrial partner and have significantly varying impacts.

The SBIR/STTR program is largely considered effective for technologies needed for small projects that require technology development that is narrow in scope with little required production capability and SBIR shops that maintain a close partnership with university groups seem to be the most effective. The program doesn’t scale well to broad technology industrialization. Another perceived limitation is that the SBIR funding increments are too small to bring a technology to market, leading to needing multiple

SBIR contracts to achieve a true commercialization goal. Overall, DOE technology transfer mechanisms are considered too slow to respond quickly to emerging needs.

Other existing Government programs include Small Business Voucher Pilot (SBV) and the Technology Commercialization Fund (TCF); unfortunately, the TCF time length for approvals has suppressed the possible industrialization of some technologies. ARPA-E has demonstrated additional schemes to industrialize fusion technologies with their ALPHA, BETHE, and GAMOW programs. EERE, NIH, and DOD also have developed successful partnerships through their own programs. Current DOE technology transfer programs are having a difficult time competing with activities like the European Commission AMICI program which strengthens the competitiveness of European companies more directly than allowed by U.S. law.

Technology transfer requirements for successful PPPs: A long-term commitment between national laboratories and industry for technology transfer is an essential tool in building up the industrial capability through PPPs. Long-term funding maintains the workforce and keeps the supply chain healthy. The PPP approach needs to allow the Government to support vendors with R&D, industrialization of accelerator manufacturing, and maintaining industrial production capabilities in a manner that competes effectively with analogous mechanisms foreign governments use with foreign competitors. Foremost to ensure the success of the industrial partners in a PPP, industry must be a principal stakeholder in the technology transfer process from the start which means the national laboratories need to be incentivized to contract R&D with industrial partners and share technologies. The environment for the national laboratories must be sufficiently supportive to remove their current reluctance in reducing their own R&D footprint where appropriate for technology industrialization, and which includes making sure the national laboratories benefit from new information developed by their industrial partners. Initial risk must be owned by the Government through the national laboratories in order to minimize the obstacles for industrial entry into the marketplace with new technologies (as opposed to having industry own the risk with fixed price contracts). The TRL valley of death must be crossed during the process, with targeted Federal funding leading to the joint development of functional prototypes and possibly up to a “first production unit”. Tools developed at national laboratories needed for production should be considered for transfer to the industrial partners and long-term collaborative R&D should be maintained to ensure market success, which might include a reverse open contract allowing industry to have reach-back in the national laboratories to solve technical problems. Finally, since some technologies take decades to mature, multi-year roadmaps for coordinating industry and laboratory strengths and multi-year supply chain supplier roadmaps need to be developed and followed, which may include stockpiling certain supply chain raw materials and specialized parts.

Possible future mechanisms for technology transfer optimized for PPPs: “Super SBIRs” with significantly more funding and less focus on R&D, and ideally including a rapid-response capability, may satisfy the needs of some PPPs. Another possible approach that is more supportive of multiple domestic vendors could take the form of an “innovation institute”, which houses key manufacturing equipment and serves as a repository of information and knowledge on certain technologies. Such an institute can also enable broad industrial engagement with Federal programs and will help national laboratories and industry understand each other’s business models. Workshops such as the LTSW (which has shown informal yet successful national laboratory/industry partnerships for SBIRs and STTRs) can serve as a model for these kinds of institutes, though it is unlikely an informal approach would be able to scale up to the desired PPP size for some accelerator technologies. Additional mechanisms can include having the national laboratories support technology incubators that lower the cost of entry into the market and that would facilitate a broader reach-back capability. Especially for smaller domestic companies, required contributions-in-kind to a PPP may be an overwhelming obstacle, so a mechanism that is initially fully Federally funded but with a future royalty payout may be a more realistic solution.

Workforce Development

The United States Particle Accelerator School (USPAS) is overwhelmingly appreciated for the value it brings to the accelerator community, and USPAS students are likely to remain in the field. Hybrid/online courses would increase participation by the broader community, including industry, thus new training modalities are needed. USPAS offerings are driven by needs of the labs, but greater input from industry and universities not affiliated with Labs is needed. Specialized courses tailored to industrial users could include topics in energy efficiency, engineering materials for accelerators, mechanical engineering challenges, cryogenics, metal working, measurement techniques, superconductors, and the like. Educational material suitable for early-career scientists and engineers should be made available online. Universities need robust, sustainably funded programs and state-of-the-art facilities to facilitate forefront research by faculty and students. Such facilities are also highly effective in attracting talented new students. Programs between universities and Labs, including universities that serve underrepresented communities, should be expanded. Physics education typically lacks hardware experience and exposure to the kinds of broader applications of accelerators that are needed by labs and industry. More training in topics related to conventional accelerators, not just advanced topics, is needed.

A means to provide cross-experiences between academia, labs, and industry would be valuable for scientists and engineers. Sabbaticals between industry and labs to encourage cooperation on selected key topics from focused workshops would help train researchers and students to understand industrial needs. SBIR/STTR funding is unsuitable for industrial MS/PhD engineer training, but multi-year R&D contracts would enable industry to hire scientists and engineers who can focus on research while integrating into the business environment. Sabbatical exchanges between US and foreign labs would be valuable for both.

Mentoring of staff members is extremely important and is critical for early-career workers and those at points of transition. Better career planning and implementation for early- and mid-career people would help with retention. Knowledge must be transferred before aging workers retire; mentor/mentee relationships are a common way to implement that kind of knowledge transfer. Managers must be able to lead, but they must also be able to work with people; technical expertise is necessary but not sufficient. Leadership must constantly maintain an awareness of emerging skillset needs. An innovation institute could serve as a repository for critical manufacturing knowledge and could even house key manufacturing equipment/technology, to enable rapid developments and leverage university and Lab research.

Optimal Federal Models

Accelerator R&D should be driven by national labs and universities as they are shepherds of accelerator technology. Labs and academia should leverage industry expertise in materials, processes, and specific technologies, identify related and mutually beneficial industrial applications, and help sustain the critical technology capabilities relevant for accelerators. Implementation and scope of technology transfer R&D should be based on a clear understanding of the market and be led by persons with knowledge of both technology and business. Development of commercially viable technology to serve domain-specific industries requires the identification of independent market opportunities, each with its own technological scope and timeline. Technology transfer efforts in these domains should be led by industrial entities with laboratory or academic partners providing feedback and guidance. In this effort, government sponsors can act as intermediaries, directing resources that enable efficient collaboration between parties without compromising the primary aims of each entity. It is challenging for national laboratories and universities to drive engineering innovation with the intent to migrate a technology to industry. The boundary conditions for what is important in the more academic settings can be very different from what it takes to successfully bring something to market.

Continued, long-term partnerships between laboratories and key vendors are essential to maintain a high level of knowledge and expertise at the vendors. Previous SBIR experience between universities, industry and DOE, with academia responsible for fundamental R&D, industry responsible for fabrication and quality, and labs responsible for testing & qualification has been successful. This approach cultivated a partnership between industry and the DOE but, without a mechanism to sustain the industry, the technology transfer is lost. A sustaining mechanism to preserve technical know-how might be in the creation of topic-specific institutes for specific technologies. These institutes could be based at DOE labs, providing a nucleus to support research and students together with facilities and infrastructure for industrial use in fabrication and testing.

Successful endeavors require trust between industry and lab scientists and engineers and that requires sustained efforts over a long time. The semiconductor industry's SEMATECH model is worth studying and emulating. While strong partnerships are possible via collaboration through the SBIR/STTR program, it would be much more effective to facilitate long-term partnerships that do not have to satisfy the stringent conditions of the SBIR/STTR program. Many companies in these fields are small spin-offs from larger companies, led by one or two individuals, and they lack the resources to support 50:50 matching or in-kind contributions.

The optimal handoff point for technology transfer (when federal involvement is significantly reduced) is well-handled by the SBIR and I-Corps programs. Some respondents felt that Federal support would always be needed; others felt it would be needed until successful demonstration of a prototype, until private capital entered the market, or until sales became sustainable, particularly in markets outside of the original niche.

Short term measures of success include number of patents, current TRL/MRL achieved for each technology, invention disclosures, number of licenses, number of SBIRs, and royalty returns. Over the longer term, commercialization of the technology, sales, and visible use of commercial products by the relevant community are more solid measures of success.

Facilitating factors include (a) making the government's right to royalty-free licensing optional and (b) prohibiting labs from expanding their R&D portfolios in jointly pursued technology areas to avoid conflicts of interest. Negative factors include financial incentives for technology transfer which have backfired on occasion, driving unproven technologies out the door before they are ready.

Other Comments

DOE should foster Industrial Partnerships across multiple labs, sponsor workshops at lower TRL, and provide software support.

Technology transfer is complex: possibly stifling innovation and consuming resources, negatively impacted by international competition, and limiting broader engagement with talent and applications.

It is desirable to explicitly promote markets on the boundaries of the traditional accelerator technology including other areas within DOE (e.g., NNSA, fusion, EERE, etc.) but also with industry. This can spark unexpected innovation at "boundaries" and broaden the systems experience base that contributes to the cost-effective deployment of advanced accelerators. Too narrow a focus on specific science outcomes or technology choices—often rooted in lab experience—inhibits technology transfer.