jobs, but only a subset of industry employers regularly use them.

So what might you do in industry? It's possible, but rare, that you may stay in the same field in which you did your doctoral research. Your field may have bountiful commercial applications, and you may find a company that sells specialized apparatus for them. But if you can't, don't despair. Chances are that the skills you learned when completing a PhD can still be put to good use.

In my case, I've found that the skills from experimental atomic, molecular, and optical physics are well suited to product development. An experimental physicist is a jack-of-all-trades, and understanding how all aspects of a system interact is critical when developing a product. Projects start with an analysis of the fundamental operating principles, but implementation depends on an intuition for the art of mechanical engineering, optics, and electronics. That insight is necessary when working with the engineers that will help bring the project to fruition. Experience in the machine shop and electronics lab has helped me to write more accurate specifications and better assess the elegance of a proposed solution.

If you choose to make the switch from academia to industry, consider what you value in a career. Are you looking for work–life balance? Is it important to see the impact of your work? Do you enjoy tackling every sort of problem, or do you see yourself as a specialist? Company size and culture has an impact on each of those. Last year's careers issue (PHYSICS TODAY, October 2021) explored a few of the options in private industry. Fittingly for physics, it covered businesses of the smallest and largest scales—from entrepreneurship (see the article by Christine Middleton, page 42) to the Ford Motor Company (see the article by Mike Tamor, page 32). But I'd like to add that there's still plenty of room in between. Small and midsize businesses may not have the name recognition of Alphabet or Apple, but they make up the bulk of the economy and can be rewarding places for physicists to work.

The informal term "small business" is not well defined. For the US Small Business Administration, the definition depends on the field.[3] Personally, I like the idea of "Dunbar's number," approximately 150, which is a proposed limit on the number of stable relationships one can maintain. A business with that many employees is still small enough to have much of the nimbleness of an entrepreneurial startup but is not so small that added responsibilities take a toll on work–life balance. Such a business can be large enough to have resources, but it is small enough that its employees are more than "shiny cogs" in the machine, and they can see the impact that their contributions make.

If you're interested in continuing to put your physics skills to use, consider the opportunities that industry has to offer. There's more out there than you may think.

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LETTERS

Fusion power's future

In the review of *The Star Builders: Nuclear Fusion and the Race to Power the Planet* (PHYSICS TODAY, October 2021, page 64), reference is made to the old joke that controlled fusion power is 30 years away and always will be. I would like to update that observation, and perhaps make it more rigorous, by noting the history of controlled fusion research dating from the 1950s. In my 60 years of association with plasma physics and both magnetic- and inertial-confinement fusion, I've heard countless briefings and promises: When the research programs were 10 years old, the reactor was 10 years away. After 20 years, it was 20 years away; 30 years on, it was 30 years away; and so on. Now a commercially viable reactor could be more than 50 years away. It appears to be a self-similar problem, where the only time scale is the elapsed time.

Such behavior is not restricted to controlled fusion. The same joke, including the 30-year time frame, used to be said of electric rocket propulsion, and there are now hundreds of spacecraft that use electric propulsion. Perhaps the problem is related to the so-called S curve for technology development. Until a technology rises above the early, exploratory stage, predictions about it becoming mature enough for practical use can be driven more by optimism and enthusiasm than by the available hard facts.

The recent surge in fusion startups[1] might be encouraging (to some), but it's reminiscent of the early days of aeronautics, when some folks began attempting heavier-than-air flight—and airplanes with heavy piston engines won out over the early aeronautical success of hot-air balloons. The accumulation of ideas and experience directed toward real systems may eventually make a difference for fusion power on its S curve. Electric rocket propulsion was helped by frequent, short-turnaround iterations, thereby providing a time scale for progress apart from the elapsed time. Unfortunately for fusion, the cost and size of useful technical demonstrations may preclude such iterations. Startup fusion concepts that substantially reduce cost and size offer optimism for faster progress.

Reference

1. D. L. Jassby, *Physics and Society*, October 2021, p. 5.

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More on being a physicist in industry

Mike Tamor's article, "Lessons from 35 years in industry" (Physics Today, October 2021, page 32), describes many of the challenges faced by a physicist trained in an academic institution and working in an industrial environment, including challenges involving management responsibilities. As someone who has worked in industry for many years—at places including General Dynamics and Mission Research—I would like to emphasize another factor that many academic scientists don't appreciate.

As Tamor points out, "Physicists are trained to revere new knowledge." In school, we are taught to push limits, explore the unknown, improve accuracy, explain the mysterious, and so on. That is the goal of fundamental research, which we are taught to respect above applied research. Fundamental research is relatively rare in industry—jobs for PhD physicists in industry across STEM (science, technology, engineering, and mathematics) and non-STEM fields are more likely to involve applied research, which can entail using a scientific approach to provide engineers with tools to solve practical problems.

The engineering world involves many trade-offs between considerations such as performance, cost, weight, and aesthetics, and they frequently compete with each other. The results can flow down to the research effort and influence required goals, such as performance and precision. Research scientists need to understand those goals, and they need to pursue the approaches that can reach the goals without expending undue effort that exceeds them. The leader of the research effort must have a clear understanding of the factors that are really important in the eventual application and how good is good enough—that is, when the design accomplishes its objective with an adequate margin and at a reasonable cost in resources.

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Correction

July 2022, page 49—The Cowan–Reines experiment used large tanks of water with dissolved cadmium sandwiched between tanks of liquid scintillator. PT

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