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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