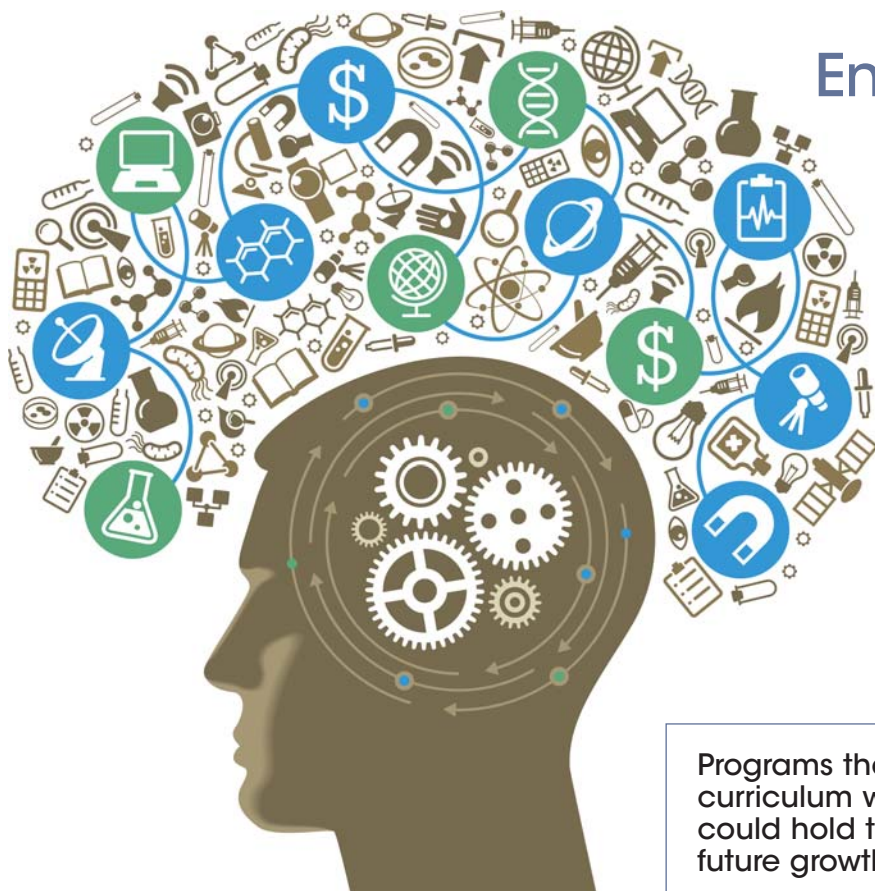


# Things your adviser never told you:

## Entrepreneurship's role in physics education

Douglas N. Arion



Programs that augment the core physics curriculum with real-world business skills could hold the key to the discipline's future growth.

Somehow or other, we got hooked on physics—hooked enough to study it and to be readers of *PHYSICS TODAY*. Many of us became physicists and now practice the discipline either directly or indirectly in our chosen careers. Some of those careers involve the traditional academic positions of faculty or research staff, others are in industry or government, and still others are in fields less directly tied to physics, but in which physics education and training are extremely valuable nonetheless. All those career outcomes have something in common: None of us received formal academic preparation for them. Doing physics and working as a physicist are not one and the same.

We who are physics professors often recruit students by telling them that the discipline is great prepa-

ration for virtually any career—and we genuinely believe that to be true. The traditional physics education, however, is designed for creating faculty, even though most students will never find a permanent academic position.

Consider that in 2011 approximately 6000 bachelor's degrees and 1600 PhDs were conferred in physics, yet only 400–500 faculty positions are filled annually, and most of those are part-time or short-term positions. The funnel effect is apparent: In 2010 just 37% of bachelor's degree recipients went on to graduate school in physics or astronomy and 32% of recipients reported that their ultimate goal was to end up on the faculty at a college or university; in all likelihood, only about 10% will actually become professors.<sup>1</sup>

Where do the rest go? Figure 1 shows the employment-sector breakdown of professionals reporting a physics background. Most work in the private sector, with many applying their physics ed-

**Douglas Arion** is a professor of physics and astronomy and of entrepreneurship at Carthage College in Kenosha, Wisconsin.

ucation indirectly. Even for the ones that do go on to teach, there is much to know that the academy didn't provide.

Consider your own position. How do you spend your typical workday? How much time is spent doing physics—that is, designing and conducting experiments or doing calculations and analyses? How much is spent teaching? Studying the literature?

Now compare that with the time spent writing proposals and grant applications, developing budgets, making purchases, hiring and managing staff, creating memoranda of understanding or teaming agreements, negotiating contracts, preparing press releases, handling intellectual-property disclosures, developing products or processes, and so forth. The picture is clear: Whether the position is industrial, municipal, in an allied or unrelated field, or even academic, nonphysics activities are ubiquitous in any physics career.

A big gap exists between the preparation physicists receive as students and the skills they need to enter the real world. To be fair, that gap is present in every academic discipline, and in some cases it is even more pronounced than in physics, but the gap's potential impact on physics education and on the success of physics as a discipline makes closing it critically important.

### The physics education revival

Beginning in the 1990s, the physics education community began a major revitalization effort. The numbers of majors had been dropping and many departments were either closing or being reduced to offering service courses. Starting with the Physics at the Crossroads conference<sup>2</sup> organized by the American Association of Physics Teachers in 1996, workshops and studies were held to develop and implement new practices to prepare and retain faculty, adapt and update curricula, and broaden interest in physics. Perhaps no study or report had broader impact than the 2003 *Strategic Programs for Innovations in Undergraduate Physics: Project Report*.<sup>3</sup>

As a result of those and other activities, several programs were able to save themselves from near-certain oblivion, and even healthy programs improved their curricula and delivery methods. Physics, as a whole, is ahead of other technical disciplines in conducting serious research into pedagogy and teaching methods, tools and texts, and labs and experiential learning. (See the article by Carl Wieman and Katherine Perkins, *PHYSICS TODAY*, November 2005, page 36.) So far, so good.

The revitalization process, however, did not emphasize the issue of preparing students for careers—that is, except for the general acknowledgment of the so-called “hidden physicist” problem: Due to the broad range of careers in which physicists work, it can be difficult for entering college students to identify a path to success through physics.<sup>4</sup> That is in stark contrast to, say, engineer-

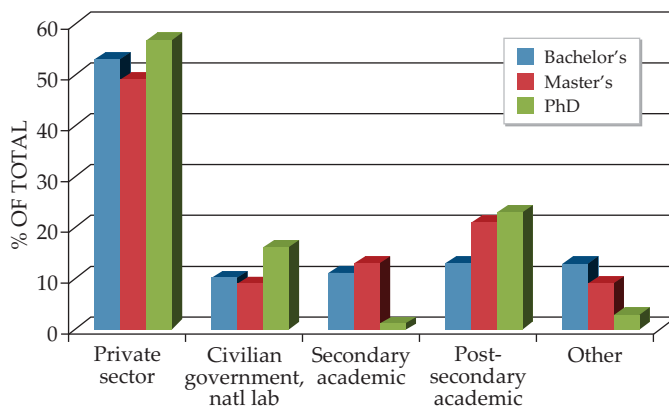
ing and chemistry, disciplines whose names often appear directly in their associated job titles.

### The rise of entrepreneurship education

Around the same time physics education was undergoing revitalization, a separate movement got under way. Its aim was to leverage the creativity of students to create new products, services, and business ventures. Several successful inventors, entrepreneurs, and businessmen were instrumental in the creation of academic programs designed to instill in students the “entrepreneurial mindset.” Notable among the movement's founders were Jerome Lemelson and Donald Hedberg. With more than 600 patents, Lemelson was one of the world's most prolific inventors; Hedberg, a chemist by training, founded and ultimately sold Lab Safety Supply.

Hedberg's basic premise was that the technical students of today will be the world and business leaders of tomorrow but are woefully unprepared to actually take on those roles. He himself had done some teaching and started several ill-fated companies before eventually stumbling on the venture that became Lab Safety Supply. In the early 1990s, he provided funding to his alma mater, Carthage College in Kenosha, Wisconsin, for a science-focused undergraduate entrepreneurship program and an accompanying endowed professorship. (I have the privilege of being the inaugural holder of that professorship.)

Lemelson felt that creativity peaks at a young age and that college students should be learning to apply their creativity to invent new products for human betterment. He helped to found a program in entrepreneurial ventures at Hampshire College in Amherst, Massachusetts. He also provided funding and motivation to start the National Collegiate Inventors and Innovators Alliance, initially based at



**Figure 1. Employment-sector breakdown** of physics degree recipients, by degree type. Only about 10% of physics bachelor's degree holders obtain permanent faculty positions at postsecondary institutions. More than half work in the private sector. (Source: AIP Statistical Research Center.)

Hampshire, to promote student entrepreneurship on campuses across the country. In the mid 1990s, he established a center for technology entrepreneurship at the Smithsonian Institution's National Museum of American History and funded a prize for innovation awarded through MIT.

Over time more benefactors and organizations entered the fray, including Robert Kern, founder of Generac Power Systems and benefactor of the Kern Family Foundation; NSF, which operates the Innovation Corps program; the Kauffman and Coleman foundations; the Collegiate Entrepreneurs' Organization; and the US Association for Small Business and Entrepreneurship.

Entrepreneurship education has always had a bit of an identity crisis. The very word entrepreneurship conjures visions of tinkerers creating gizmos and gadgets and risking all in the pursuit of personal and financial glory. Yet the skills that entrepreneurship programs aim to impart are the same ones we all wish we had been given in school: the abilities to identify business opportunities, plan and manage projects and finances, handle legal and intellectual property issues, manage people and teams, write and communicate clearly, navigate the product life cycle, manage supply chains, and so forth. So, notwithstanding the name, entrepreneurship programs are the perfect bridge between the core physics curriculum we know and love and the practical skills we need in the real world.

### ScienceWorks: A case study

Hedberg's primary goal was to turn science students into traditional entrepreneurs. But through my experience as a staff member and then senior manager at

Science Applications International Corp and as a physics educator, I've learned that not only will most students not become faculty, most won't start businesses either. Rather, most students will obtain positions in companies, and then, perhaps, a select few will eventually start their own ventures.<sup>5</sup> (For perspectives from some of those physicists who became entrepreneurs, see the article by Orville Butler and Joseph Anderson, *PHYSICS TODAY*, December 2012, page 39.) All are going to need practical business skills.

When my colleagues and I set out to design the curriculum for the Hedberg-funded entrepreneurship program at Carthage in 1994, entrepreneurship education was new and, in technical disciplines, nonexistent. We encountered a truly double-edged sword: no standard to follow but no restrictions either. From scratch, we created a program of courses and experiential learning activities that covered the knowledge, skills, and attitudes that students needed in the business world. We dubbed the program ScienceWorks and offered it as a minor, to be completed alongside a traditional major program, usually in a science discipline. As a PhD physicist and former corporate executive who had both launched and mentored new and developing businesses, I could bring realism and credibility to the program.

Funding was hard to obtain, both because the discipline was in its infancy and because Carthage is a small liberal arts college. But over the years the program has grown and been quite successful at preparing students for their future lives. Every three years we send an assessment survey to program alumni and their employers or graduate-school advisers. Almost universally, students report that the ScienceWorks program was the most valuable

## Box 1. Technology entrepreneurship at Case Western Reserve

Formed in 1999, the Physics Entrepreneurship Program (PEP) at Case Western Reserve University is a professional science master's in physics with an entrepreneurship focus. Core courses introduce students to business, finance, intellectual property, technology transfer, and the process of innovation. Electives include graduate-level physics and business courses. Students are required to write a master's thesis involving a real project in technology commercialization. Throughout the program, students hone their critical thinking and creative problem-solving skills and are shown how those skills can be applied both inside and outside physics.

All PEP students are expected to either start their own company or find an internship that involves bringing new technologies to market. In both cases, students perform a variety of tasks to help the business get off the ground, including assessing the commercial viability of a technology, finding early customers, and chasing funding. Intimately involved in the process are a mentor who is an experienced CEO, entrepreneur, or sales leader; a mentor who is an experienced researcher in academia or industry; and a PEP adviser who understands the pitfalls of straddling

academia and innovation and is well connected to the local startup community.

Toward the end of the two-year program, a PEP student who does an internship with a startup will typically join the company as a permanent hire. Some students take alternate routes: About 1 in 10 will stay at Case Western Reserve and earn a PhD in imaging physics while working on projects with a mid- to large-size company; 10% will start their own company; and 10% will pursue an MBA.

Over the years PEP has grown into a family of master's degrees. Similar programs are now offered in biology and chemistry. Combined, nearly 100 alumni have completed the entrepreneurship programs since 2001, and 50 of them graduated from PEP. Among the PEP alumni are CEOs, program managers, analysts, project managers, sales associates, chief scientists and engineers, chief technologists, astronaut trainers, and executive directors with companies ranging from startups to Fortune 100 corporations.

**Edward M. Caner**

*Director, Physics Entrepreneurship Program  
Case Western Reserve University  
Cleveland, Ohio*



coursework of their college experience; employers and advisers praise the graduates for their abilities and report those students as receiving higher salaries and more rapid advancement than other contemporaneous hires. Graduate programs also snap up ScienceWorks alumni: Having completed an additional course of study and a senior business-plan project, ScienceWorks students are seen as uniquely and broadly prepared for the challenges of graduate school. And, yes, a few graduates have started their own—so far successful—ventures.

### Technology entrepreneurship

Dozens of entrepreneurship education programs are now in operation at institutions around the country. Some, such as those of Babson College in Massachusetts and the University of Wisconsin–Whitewater, are housed in business schools and do not specifically address technology ventures. Other schools address entrepreneurship and professional development through summer-school programs or continuing education. Dartmouth College, for instance, offers the Tuck Business Bridge Program, aimed at recent college graduates. Still other schools incorporate entrepreneurship education through special campus residential and programming structures. An example is the University of Maryland, College Park, which offers the project-based Entrepreneurship and Innovation Program, targeted at freshmen and sophomores.

Of the programs that do focus on technology entrepreneurship, few are geared toward students in the natural sciences, much less in physics. Rather, most are conducted in engineering, where the direct pathway into industry and the long history of academic-industrial partnerships and cooperative education

make the programs a relatively easy sell. A common approach is to establish a joint program between the engineering and business schools. That works fine if the institution is large, has separate dedicated schools, and has deans that get along (which is not always the case). In other situations, an engineering-based program may invite faculty from business departments to team-teach courses or consult on projects. Some engineering programs leverage the industrial experience of their faculty or recruit businesspeople from local companies to act as mentors.

Engineering programs typically include a senior design course, an ideal vehicle for incorporating entrepreneurial content. The courses are project based and often take advantage of industrial partnerships to provide experiential learning opportunities. Notwithstanding the challenges that schools face to achieve and maintain accreditation, engineering schools have been very successful—more so than the natural sciences and liberal arts—at bringing entrepreneurship into the curriculum.

Among the few schools that are working to bring entrepreneurship skills specifically to physics students, two stand out: Case Western Reserve University and the University of Colorado (UC) Denver. (See the boxes on page 44 and below.) Case Western Reserve was the first school to bridge business and physics in a single graduate degree program—the professional science master's (PSM). A quick internet search reveals that other PSM programs addressing physics can now be found at Appalachian State University (Boone, North Carolina), New York University, Oregon State University (Corvallis), Rice University (Houston, Texas), Towson University (Maryland), Southern Connecticut State University

### Box 2. Technology entrepreneurship at UC Denver

The effort to connect physics and entrepreneurship at the University of Colorado (UC) Denver is defined by three key projects:

- ▶ With funding from the National Collegiate Inventors and Innovators Alliance and in collaboration with physician Arlen Meyers of the UC Denver School of Medicine, the physics department at UC Denver provides an opportunity for majors specializing in biophysics and medical physics to help develop prototypes of medical devices and biomedical instrumentation. The goal is to apply recent scientific developments, such as new optical technologies and modeling frameworks, to real needs in biomedicine. For example, students are developing laboratory methods for cancer detection based on light propagation in tissues. The project uses ideas from Hamiltonian optics, chaos theory, direct electromagnetic wave simulation, and stochastic models.

- ▶ The entrepreneurship program collaborates with a school district in Aurora, Colorado, to involve 9th–12th graders in innovation projects oriented toward biomedical problems. The program has given rise to a dedicated facility called the Innovation Hyperlab, which gives students access to materials, mechanical

components, actuators, electronics, optics, and other technical resources. (Imagine shrinking the range of technical resources of a major national lab—say, the Jet Propulsion Laboratory—so that it fits into a single building.) The lab provides a rich working environment for making prototypes for innovation projects. An example, by a team of five high school students under the guidance of an experienced teacher and a university undergraduate, is a “smart” bed, in which various sensors passively monitor a person's condition while sleeping.

- ▶ With funding from NSF and UC Denver, the physics department has developed a modular curriculum of laboratory-based short courses to give students on-demand instruction in the use of the Innovation Hyperlab's various technical resources. That mode of learning is typical of how innovators and graduate student researchers pick up knowledge just when they need it. A challenge remains to find ways to fit such a modular curriculum into conventional school and university course frameworks.

**Randall Tagg**

*Associate Professor of Physics  
University of Colorado Denver*

(New Haven), the University of Houston–Clear Lake, and the University of Northern Iowa (Cedar Falls).

Through PSMs, the physics community can provide business and career skills to students who weren't able to obtain them during their undergraduate experience. But only a small subset of students will benefit from those programs; they are only offered at the master's level, and the topics they cover lie outside the realm of the traditional graduate education track.

The UC Denver program targets a totally different audience—undergraduates—and leverages partnerships with industry and regional secondary schools. The link with secondary schools serves as a valuable recruiting tool for the physics department; it creates an opportunity for physics faculty to expose the next generation of physics majors to the wide variety of industrial and academic opportunities that the discipline offers. Parents who fear that a degree in physics won't lead to job opportunities after graduation are often averse to their children studying it. Many prefer that their children major, or at least minor, in business. Entrepreneurship programs like the Carthage and UC Denver programs can help convince students and parents

ketplace<sup>6</sup>—calls for a core set of skills and knowledge. In the ScienceWorks program at Carthage, students develop those core skills through dedicated coursework, then integrate their newly acquired knowledge and skills by completing a business plan project.

Some of the material covered in the ScienceWorks courses is summarized in figure 3. Physics teachers who peruse the list will likely see topics that they can easily incorporate into existing courses, and perhaps some that they already do. Other topics can be taught by guest lecturers from other departments or by visitors from the community. Some can be addressed through student projects. For example, having students contact a business to develop potential industrial applications of a material they are studying in a physics course can be an effective way to incorporate ideation and creativity into an existing curriculum. And certainly, suggesting courses from other departments that address entrepreneurial topics can be excellent advice.

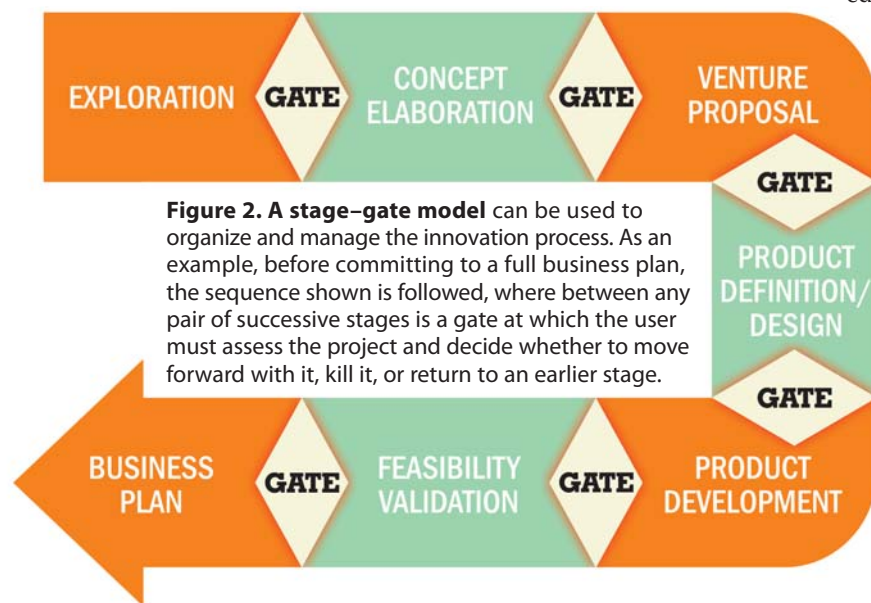
Although physics faculty can address some entrepreneurship topics, it is both perfectly acceptable and highly recommended by the entrepreneurship education community to bring in outside experts from industry. The real-time information they can bring to students and the community connections they bring to the classroom are invaluable.

One challenge that schools face is finding instructors with appropriate expertise and credentials; some ideal teachers—say, businesspeople or professionals in law or finance—may lack the academic pedigree for a traditional faculty appointment. One solution, instituted at the University of Texas at Austin, is to create so-called professorships of practice, to allow for non-traditional hires. Such arrangements also confer advantages to the corporate partners: Their participation in on-campus educational ventures can help to both improve the preparation of future hires and improve their own economic viability.

At the institutional, departmental, and program levels, there are a variety of methods for introducing business skills to students. Although many schools may not be able to adopt the engineering model or implement dedicated programs like those at UC Denver and Carthage, they may be able to organize entrepreneurship-oriented speaker series, industrial internships, business plan competitions, or campus clubs—local chapters of the Collegiate Entrepreneurs' Organization or Enactus (formerly known as Students in Free Enterprise), for instance. Different institutions recruit different kinds of students, work with different resources, and face different challenges. There is no one-size-fits-all approach to incorporating entrepreneurship education into a physics curriculum.

## Getting started

Professional organizations devoted to entrepreneurship education are an excellent source of partnerships, information, and, in some cases, funding to



**Figure 2. A stage-gate model** can be used to organize and manage the innovation process. As an example, before committing to a full business plan, the sequence shown is followed, where between any pair of successive stages is a gate at which the user must assess the project and decide whether to move forward with it, kill it, or return to an earlier stage.

alike that studying physics can be a practical career choice, especially when coupled with real-world business skills. Indeed, entrepreneurship education can be a marketing tool to build enrollments and better prepare students for their futures.

## What can you do?

Entrepreneurial skills and attitudes can be brought into the academic environment via a myriad of methods. The fundamental concepts can be tailored to the needs, resources, and goals of particular programs, departments, and students. Figure 2 illustrates one tool, the so-called stage-gate model, which can be used to help organize the process of converting a technological innovation into a market-ready product. Successful completion of the various stages—from identifying a product need to refining the concept to launching the product into the mar-

**Figure 3. Top 100 Business Topics**

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**Figure 3. Topics covered in** ScienceWorks, an entrepreneurship program at Carthage College in Kenosha, Wisconsin, span the set of skills, knowledge, and attitudes found in commercial and industrial environments. This collection of topics has been honed over the years through the feedback of the program's advisers and graduates.

create and expand new programs. At the top of a pyramid of organizations dedicated to technology entrepreneurship is the National Collegiate Inventors and Innovators Alliance. The organization provides funding both for new programs and for student-generated technology ventures; its annual meeting, held every March, is the best venue for learning about entrepreneurship education techniques and becoming part of the growing technology entrepreneurship community.

Although neither emphasizes technology entrepreneurship per se, both the US Association for Small Business and Entrepreneurship and the Collegiate Entrepreneurs' Organization offer educators opportunities to engage with others who are trying to bring entrepreneurial and professional skills to students across campuses. The Consortium for Entrepreneurship Education publishes standards that can be used to guide program development. Another helpful resource is the American Society for Engineering Education, which disseminates many entrepreneurship education tools applicable to physics.

The American Physical Society is currently assembling resources to help the physics community incorporate entrepreneurial content into its curricula and programs. In June 2014 the society will host a workshop at its headquarters in College Park, Maryland, to introduce physics faculty to entrepreneurship-focused tools, resources, and content that can be used in existing programs to better prepare graduates for professional paths. As with the physics education revitalization movement, we may be witnessing the start of a new phase of physics education that will enhance the lives of students and the physics community at large. The technology entrepreneurship community is a big family, happy to reach across institutional boundaries to help toward those goals.

## An eye toward growth

There is eminently good reason for physics departments to become involved in entrepreneurship education. From the purely pedagogical point of view, the full preparation of students for their futures requires more than solving Schrödinger's equation, crunching data, and avoiding ground loops. From a purely mercenary point of view, entrepreneurship education makes the study of physics more attractive to students and especially to their tuition-paying parents, and it can help build enrollments; it adds zest and excitement to departments. Links between physicists and regional industries and businesses are mutually beneficial and can be fodder for new technologies and products. With the breadth of resources and information available in the technology-entrepreneurship community, any physics program—whether at a liberal arts college, a private research university, or a large state institution—can find the tools it needs to get started.

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