

The Dawn of the Deep Tech Ecosystem

BCG



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tomorrow



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Hello Tomorrow is a global organisation dedicated to leveraging deep technologies to help solve world challenges. Through our Global Challenge for startups, which has had 18,000 applications from over 100 countries since 2014, we identify deep tech solutions by partnering with universities and research labs. We empower the pioneers who drive these solutions and connect them with industry leaders, investors, researchers, and regulators through conferences and networking events in 11 countries. In addition to facilitating a global deep tech ecosystem both physically and digitally, we offer consulting services to help companies integrate deep tech into their strategies, enable their organizations to adapt to faster and more open innovation, and train them to be more agile. For more information, please visit hello-tomorrow.org.

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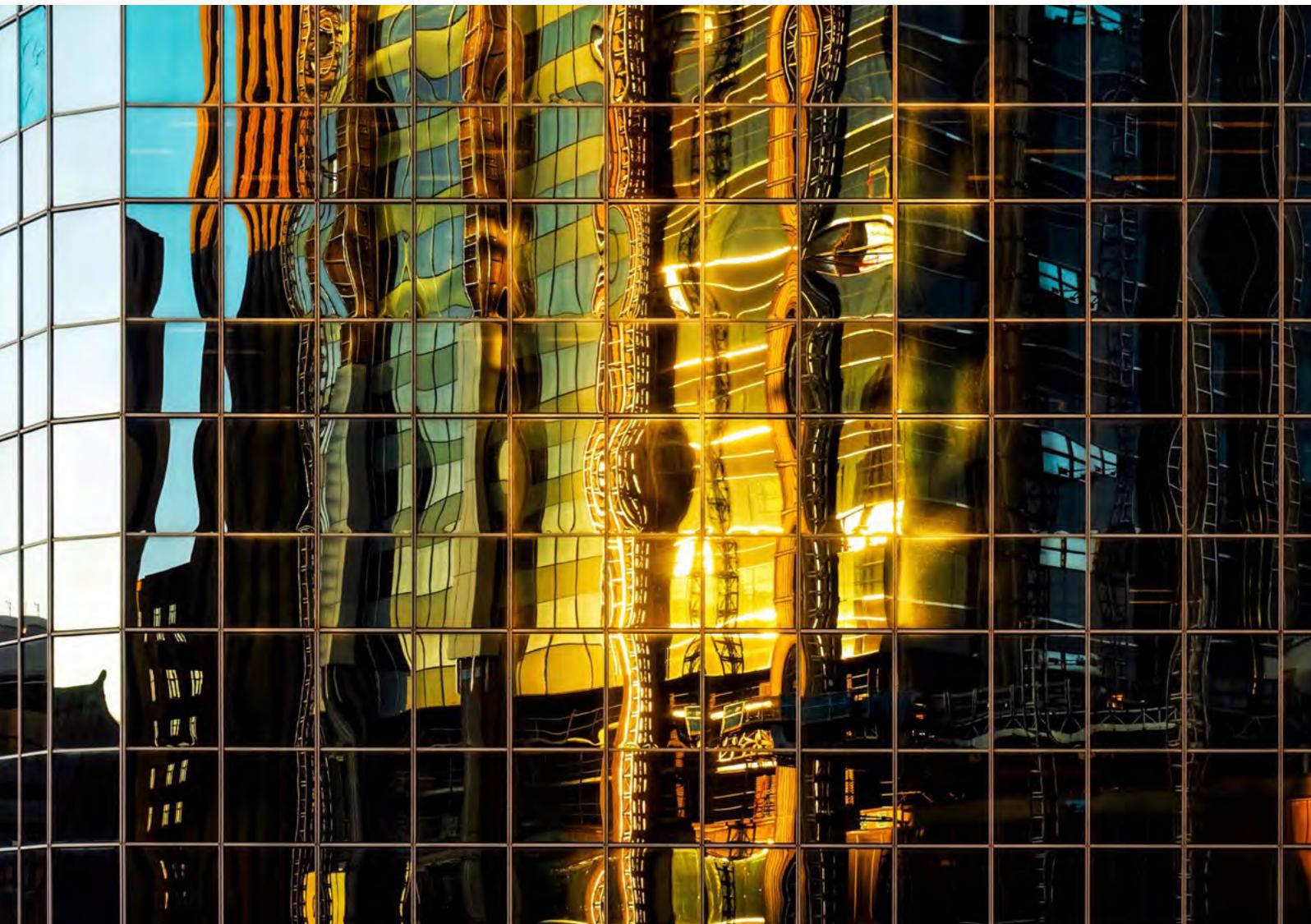
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Executive Summary



The pursuit of deep technologies around the world is both broad and deep. Investors are putting more money into companies conducting original technological research. The aggregate annual global private investment in seven deep tech categories studied for this report soared by more than 20% a year from 2015 through 2018 to reach almost \$18 billion. On a country-by-country basis, the big national players dominate, but they by no means own the playing field. While 53% of all deep tech companies in our study are based in the US, both the number of US firms and the US share of global deep tech have been declining in recent years.

Three attributes characterize deep tech in a business context. These technologies can have a big impact, take a long time to reach market-ready maturity, and require a substantial amount of capital. Deep technologies are novel and are significant advances over technologies currently in use. They require concerted R&D to develop practical business or consumer applications and bring them from the lab to the market. Many of these technologies address big societal and environmental challenges and will likely shape the way we solve some of the most pressing global problems. These technologies have the power to create their own markets or disrupt existing industries. The underlying IP is either hard to reproduce or well protected, so they often have a valuable competitive advantage or barrier to entry.

Deep tech is no longer the primary purview of deep pockets—or of the scientific community. The rise of powerful new platform technologies, falling barriers, and other factors make innovation today a much more fragmented and diverse endeavor than ever before—among big companies and startups alike. One result of this fragmentation and diversity of effort is that knowledge, skills, and information, while much more accessible, are also harder to harness because they reside in more, and more disparate, places—geographically, industrially, and functionally. This disparity is driving the need for new models of collaboration in basic R&D.

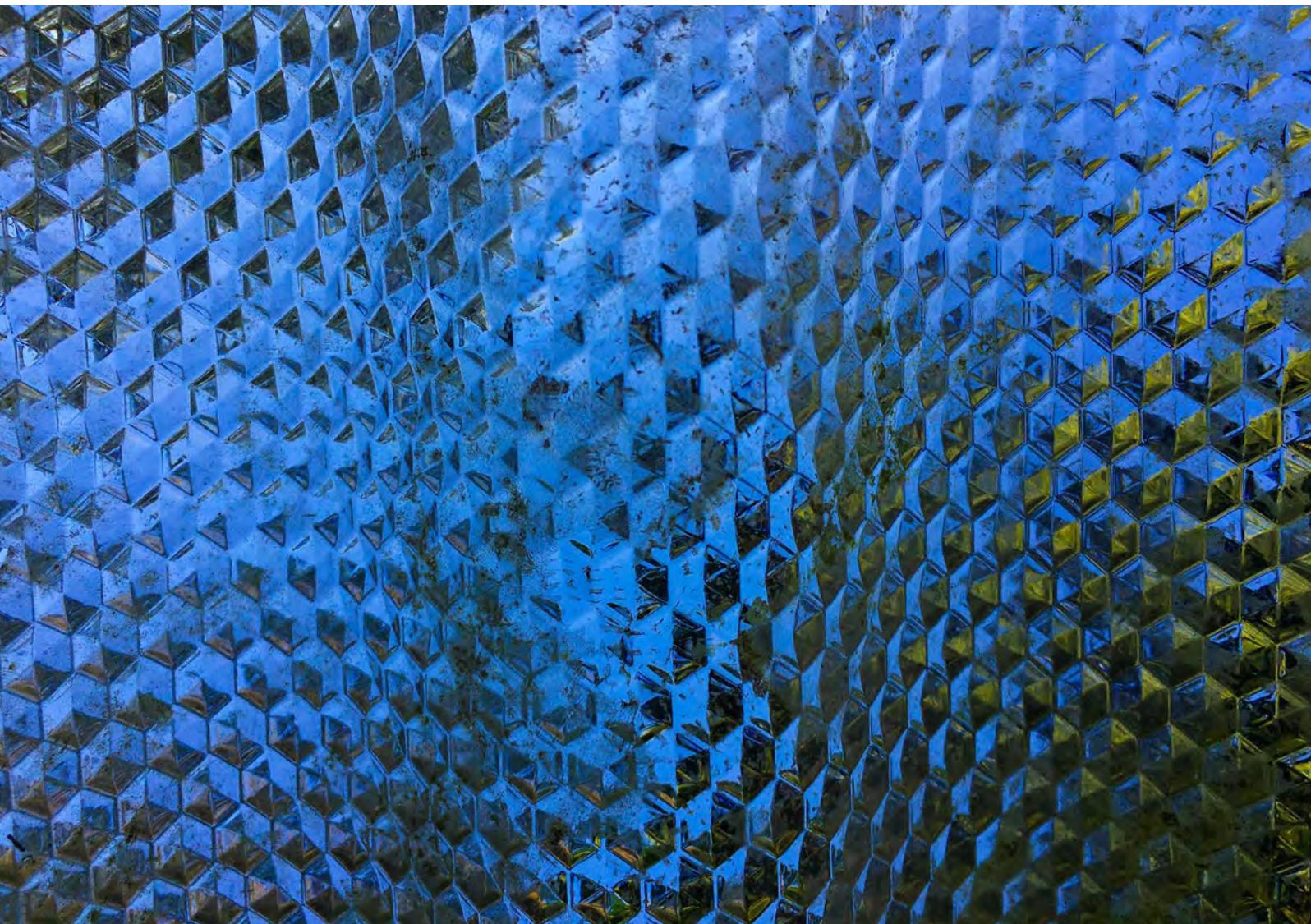
Deep tech today encompasses a broad ecosystem that includes multiple types of participants. Each is active in one or more smaller ecosystems that are organized around a particular field of research, technology, industry, or mission. These ecosystems have a set of characteristics that differentiate them from other business collaborations or partnerships. They involve more types of players from more diverse sources. They are highly dynamic—players come and go, and they create new kinds of relationships that are not always formal, defined by contracts, or well set. Deep tech collaborations rely less on a central orchestrator and more on multifaceted interactions among participants. While money is one important cur-

rency, it is far from the only means of exchange among participants. Knowledge, data, skills, expertise, contacts, and market access are also currencies that link ecosystem players.

Deep tech ecosystems can be hard for traditional companies to navigate. Newcomers frequently find themselves in unfamiliar territory, and carving out a role can be complex. Deep technologies often affect entire value or supply chains and therefore require a more thorough analysis of the stakeholders' interdependencies and value creation models in order to determine how to align goals, set strategies, and organize for interaction with others.

How each participant approaches the ecosystem affects its ability to achieve value as well as influence others and the whole. Companies, investors, startups, and others should be guided strategically by three questions about themselves and their goals. What do we bring to the ecosystem? What do we want from the ecosystem? How do we interact with others to achieve our goals?

Introduction



Is the shape of technology R&D changing? Is a new model emerging for developing and commercializing deep technologies—technologies that still require some advances to be market-ready but that are expected to have enormous impact? Are the central roles in the development of new scientific discoveries and their transfer to commercial applications that have traditionally been played by large entities and institutions—corporations, governments, universities, and others—being increasingly augmented, and in some instances replaced, by startups? Do the many stakeholders with a basic interest in technology R&D need to rethink how they play the game?

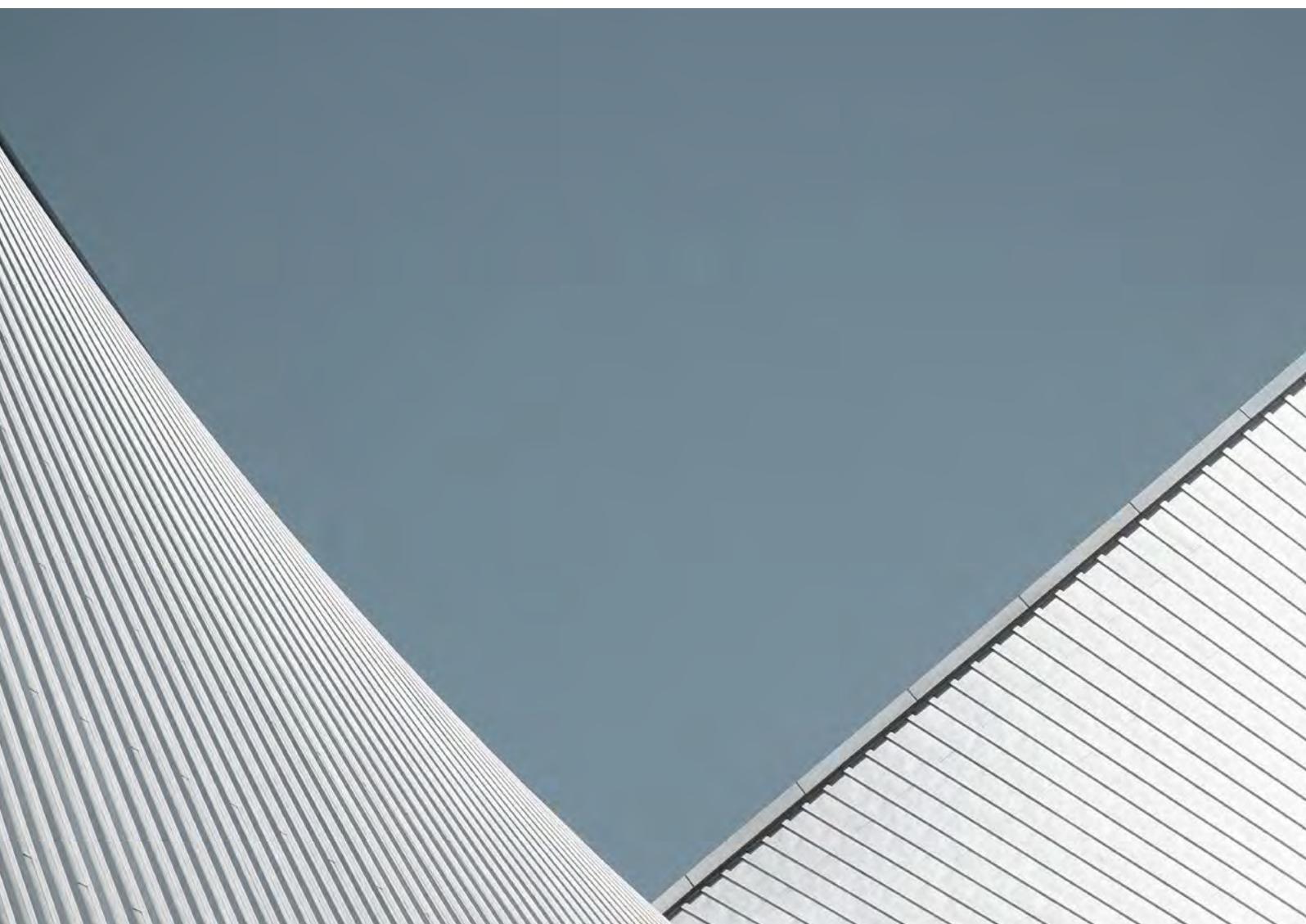
The overarching answer to all these questions is, yes. The amount of interest, activity, and funding in deep technologies—which range from biotechnologies to robotics to artificial intelligence (AI)—is undergoing an explosion that is as broad as it is deep. A number of major trends, involving the barriers to technology, the availability of capital, and the shifting priorities of major players, have brought us to a point of major change in how deep tech research is pursued and how new technologies are brought to market. Some suggest that we are at the beginning of a new cycle that could carry R&D for the next two to three generations or that we may be shifting from the end of one cycle, a “deployment” phase—which has been mostly about building applications that are based on existing information and communications technologies—to the beginning of an “installation” phase in which new technology infrastructures are constructed.

Clearly, a new deep tech ecosystem is taking shape, with big ramifications for all players, most notably companies, investors, and startups. This ecosystem reflects a new model, one that is far more fluid and dynamic than the ways in which research and technological development have been conducted in the past.

This report builds on research conducted by BCG and Hello Tomorrow, that also led to two publications in 2017 on the business prospects of emerging technologies. (See [“What Deep-Tech Startups Want from Corporate Partners”](#) and [“A Framework for Deep-Tech Collaboration,”](#) articles by BCG and Hello Tomorrow, April 2017.) The report is based on in-depth interviews, market research, examinations of funding, patent and publication data, and a survey of more than 2,000 startups from the Hello Tomorrow Global Challenge, a competition that assesses deep tech startups on four criteria: technological innovation, business model, team skills, and expected impact. The report examines seven fields of deep tech endeavor and the roles of multiple types of deep tech ecosystem participants. Deep tech companies were identified on the basis of relevant patent filings and scientific literature publications since 2000 either by the company or by its key team members.

We take a tour of the evolving deep tech ecosystem and offer some observations on how the different types of participants can maximize the value of their efforts. If indeed we are on the cusp of a new era in technology R&D, we set the stage for what is to come and in particular how corporations, investors, and startups need to think about their future roles.

Deep Tech Takes Off



The pursuit of deep technologies around the world in recent years has been expanding fast. We researched funding and other activity in seven categories that together constitute a comprehensive sample of advanced technologies in early development and more mature market application. (See the sidebar “Where Is Technology Going?”) The aggregate global private investment in these deep tech categories soared by more than 20% a year from 2015 through 2018 to reach almost \$18 billion. (See Exhibit 1.)

Follow the Money

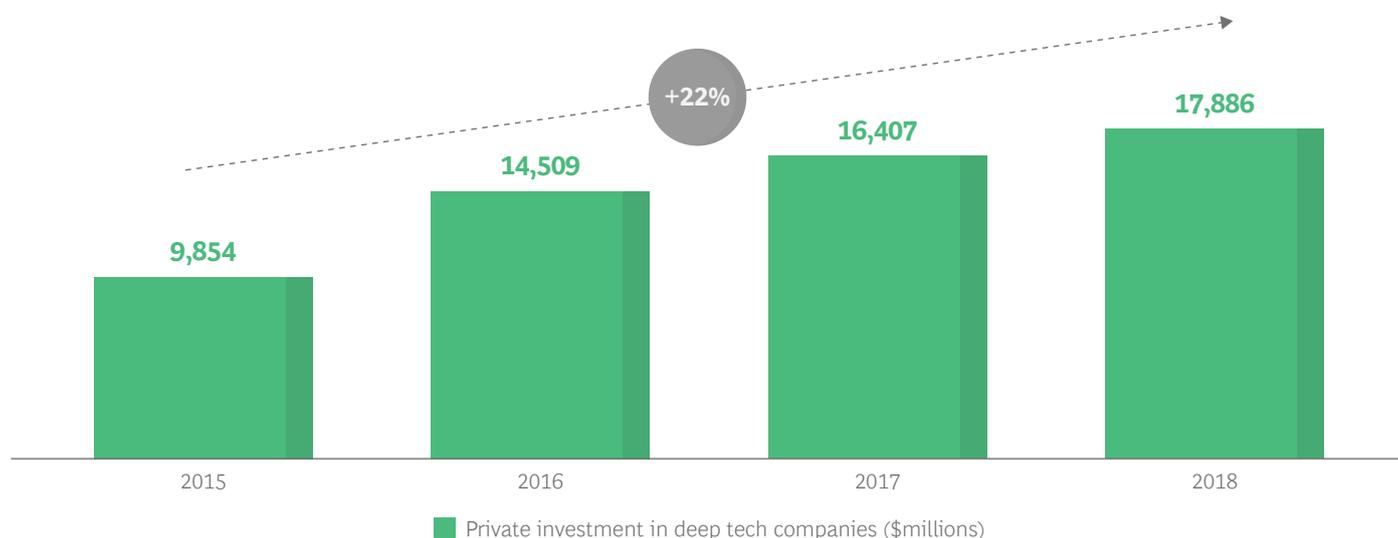
Investors are putting a greater amount of money into companies conducting original scientific research than those that are focused more on market applications. This may be partly because companies working in the early stages need more time and money to bring their products to market (and some don’t even have products yet), but it is also a sign of the willingness of companies and venture capital firms to make substantial, long-term bets on new and untested technologies. As one Japanese venture capitalist puts it, “We are interested in the outcome (shaping entire industries), not only the income.”

Across all the categories we studied, we found almost 8,700 deep tech companies (those leveraging technological breakthroughs that require intense R&D) in close to 70 markets. (See Exhibit 2.) Deep tech companies consistently receive

more funding than other kinds of tech firms (which are more likely to use off-the-shelf technologies to develop their solutions). (See Exhibit 3.) The same picture holds for startups (companies founded since 2013). Moreover, deep tech companies have more funding events than their non-deep-tech cousins, indicating that investors take a continuing interest in the progress of the deep tech firms that they help finance. (See Exhibit 4.) These results are driven in part by corporate venture capital (CVC), which has been on the rise in recent years—though it tailed off a bit in 2018—and has been expanding its participation in deep tech. (See Exhibit 5.)

On a country-by-country basis, the big national players dominate, which is to be expected, but by no means do they own the playing field. The US and China landed about 81% of global private investments in deep tech companies from 2015 through 2018, with approximately \$32.8 billion and \$14.6 billion invested in each country, respectively. In most categories, the US leads as an investment center, but several other countries vie for second, third, and fourth place. (See Exhibit 6.) Greater China is by far the biggest driver of deep tech investment growth, with funding increasing at an annual rate of more than 80% from 2015 through 2018. Investments in US companies grew by 10% over the period. (See Exhibit 7.) While 53% of all recently formed deep tech companies in our study are based in the US, both the number of US firms and the US share of global deep tech have been declining in recent years. (See Exhibit 8.)

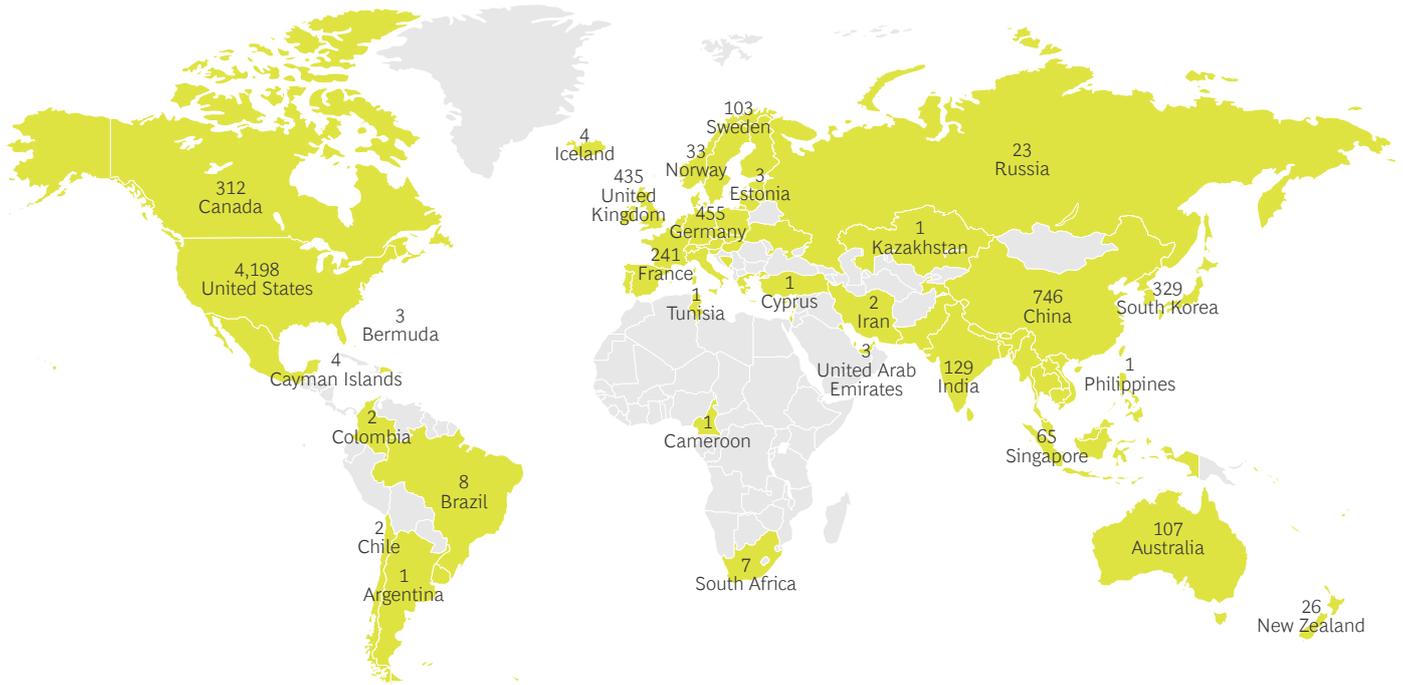
Exhibit 1 - Global Private Investment in Deep Tech Has Soared



Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Note: Includes investment in seven deep tech categories: advanced materials, artificial intelligence, biotechnology, blockchain, drones and robotics, photonics and electronics, and quantum computing. Private-investment sums are based on transactions with disclosed amounts. Some 41% of private investments in deep tech companies remain undisclosed.

Exhibit 2 - Deep Tech Is a Global Phenomenon: 8,682 Companies in 69 Markets



US (4,198)	France (241)	Italy (70)	Austria (35)
Greater China ¹ (746)	Israel (195)	Spain (66)	Norway (33)
Germany (455)	Switzerland (147)	Singapore (65)	New Zealand (26)
UK (435)	India (129)	Denmark (59)	Russia (23)
Japan (363)	Australia (107)	Belgium (41)	Poland (20)
South Korea (329)	Sweden (103)	Finland (41)	Portugal (10)
Canada (312)	Netherlands (78)	Ireland (39)	

Sources: Tableau; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Note: Analysis is based on 8,682 deep tech companies related to 16 technologies across seven categories: advanced materials, artificial intelligence, biotechnology, blockchain, drones and robotics, photonics and electronics, and quantum computing. Exhibit is missing geographic information for 199 companies.

¹Greater China includes the People's Republic of China, Hong Kong, Macau, and Taiwan.

Defining Deep Tech

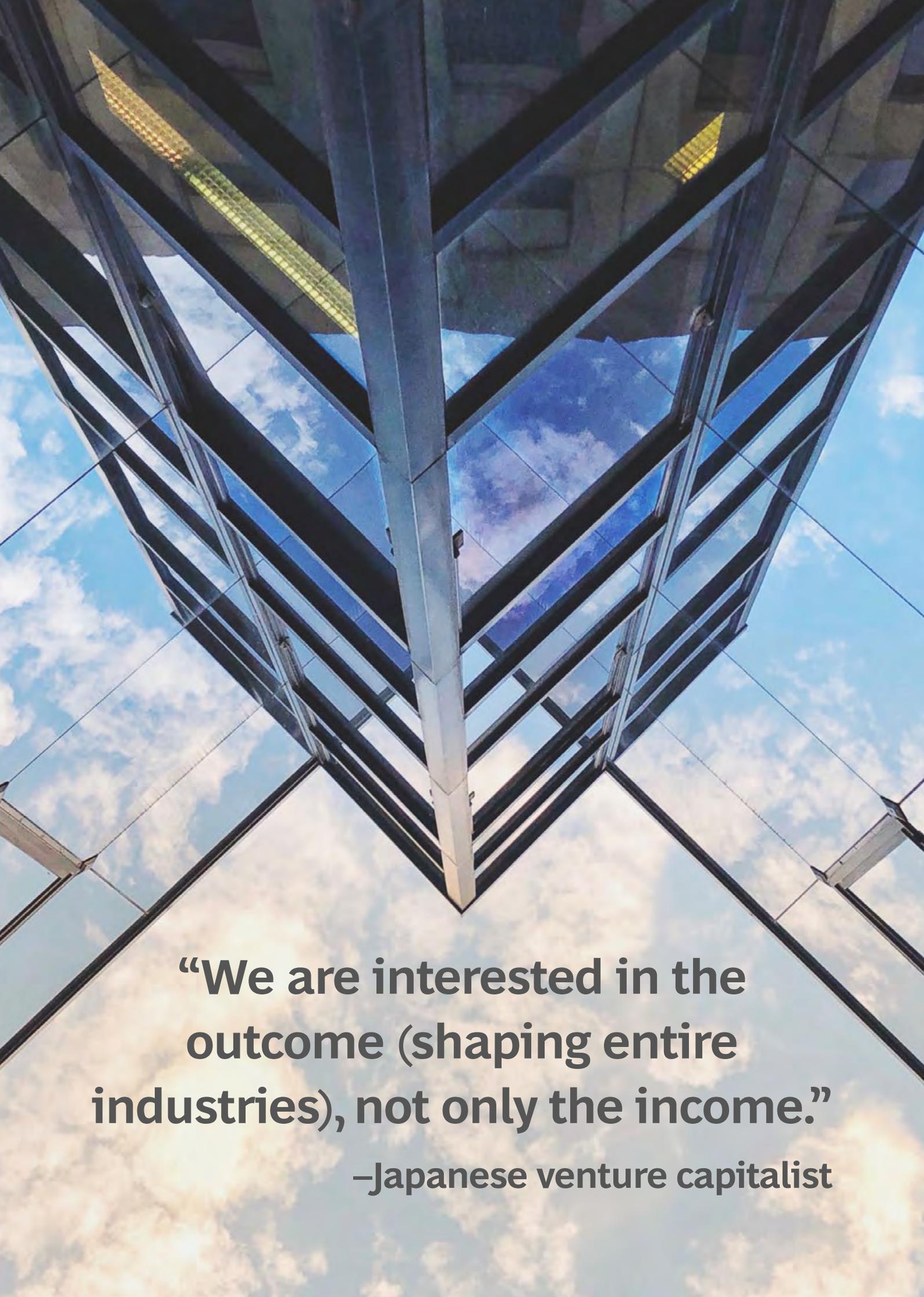
What constitutes a deep technology? What sets deep tech companies apart from their other tech peers?

Deep technologies are novel and offer significant advances over technologies currently in use. They require substantial R&D to develop practical business or consumer applications and bring them from the lab to the market. Many of these technologies address big societal and environmental challenges and will likely shape the way we solve some of the most pressing global problems. These technologies have the power to create their own markets or disrupt existing industries. The underlying IP is either hard to

reproduce or well protected, so they often have a valuable competitive advantage or barrier to entry.

Following the past decade of digital innovation, deep technologies—which will be at the center of the next wave of industrial and information revolution—are the “next big thing” that both corporations and venture investors are seeking.

Three attributes in particular characterize deep tech in a business context. These technologies can have a big impact, take a long time to reach market-ready maturity, and require a significant amount of capital.

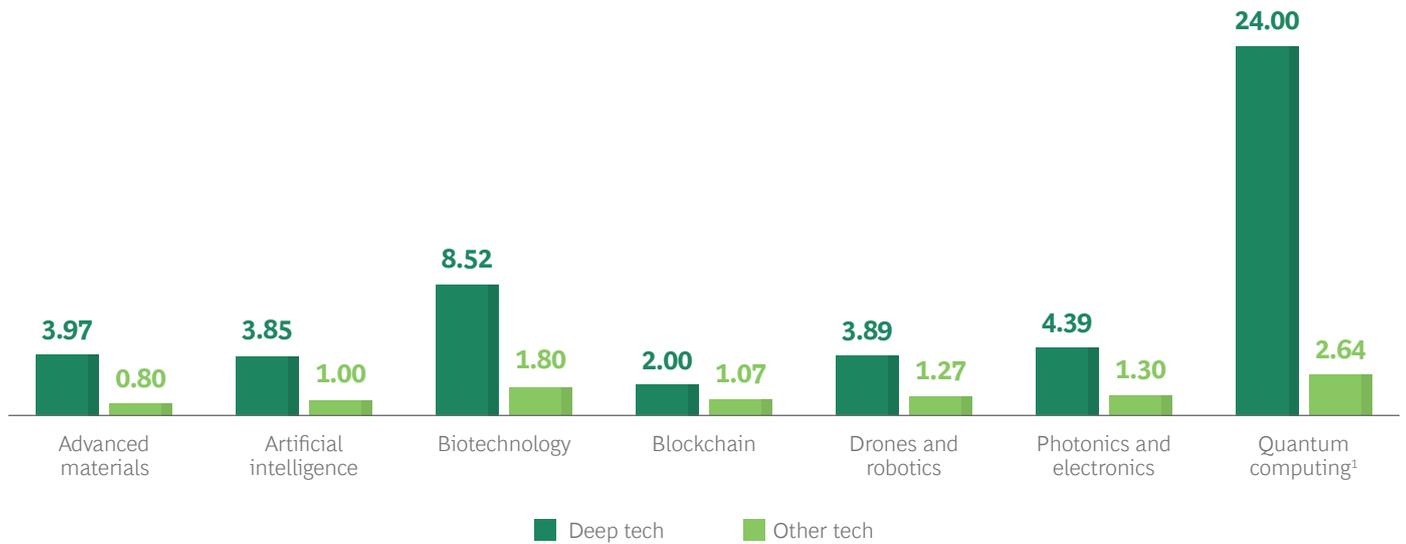


**“We are interested in the
outcome (shaping entire
industries), not only the income.”**

–Japanese venture capitalist

Exhibit 3 - Deep Tech Companies Attract More Private Investment Funding Than Others

Median private investment funding, 2015–2018 (\$millions)

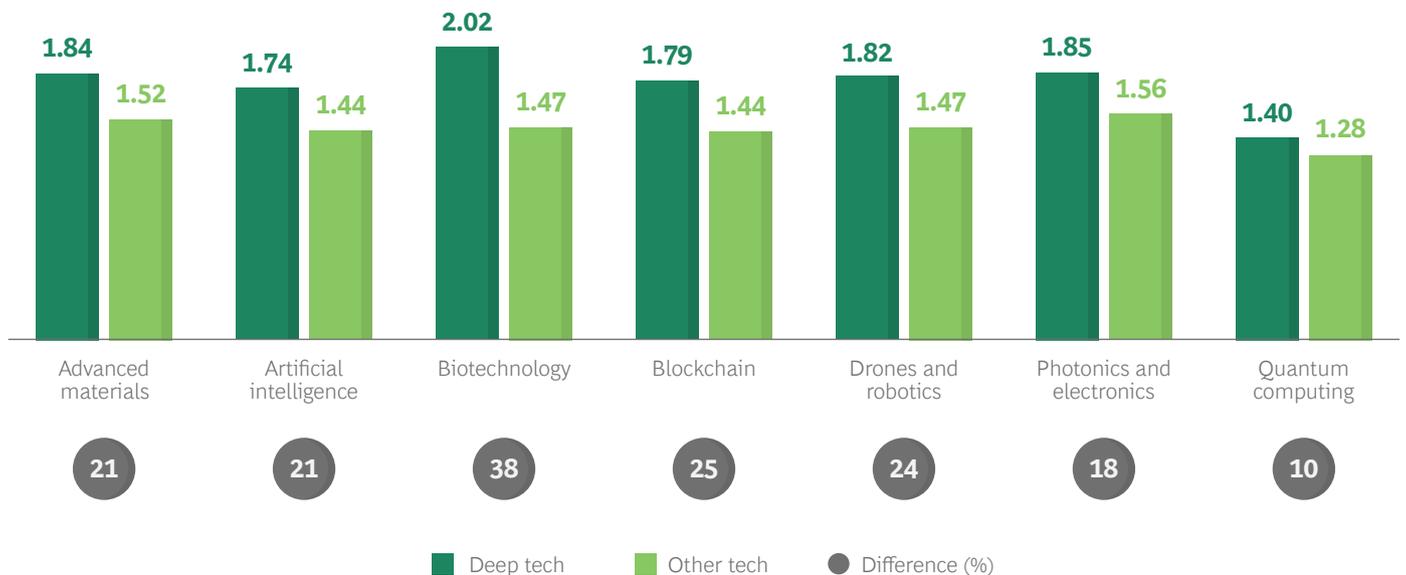


Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

¹Quantum computing has only eight deep tech companies, with two raising a combined \$64 million in 2016 and 2017.

Exhibit 4 - Deep Tech Companies Hold More Private-Funding Events Than Others

Private-funding events per company, 2015–2018



Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Deep technologies can have a big impact, take a long time to reach market-ready maturity, and require a significant amount of capital.

Impact. Innovations based on deep tech change lives, economies, and societies. Silicon-based chips enabled calculations at a speed and scale previously unimaginable. The combination of Moore’s law, mobile technologies, and innovations in screen displays put that computing capability in everyone’s pocket. Discoveries in biotechnology lead to new medical treatments and add to life expectancy. Advances in physics move other sciences forward and lead to other new discoveries. These innovations are often, but not always, radical and disruptive. They can generate enormous economic value, but their ultimate impact extends far beyond the financial realm to everyday life.

Hello Tomorrow’s annual Global Challenge draws some 4,500 applicants from 120 countries. Our analysis of the 1,646 startups that qualified in 2018 shows that these companies expect to have an impact on a wide variety of the United Nations’ sustainable development goals (SDGs). The goal receiving the most deep tech attention is good health and well-being (51%), followed by those related to industry, innovation, and infrastructure (50%), and mitigating human impact on the environment (sustainable cities and communities—28%, responsible consumption and production—25%, climate action—22%, affordable and

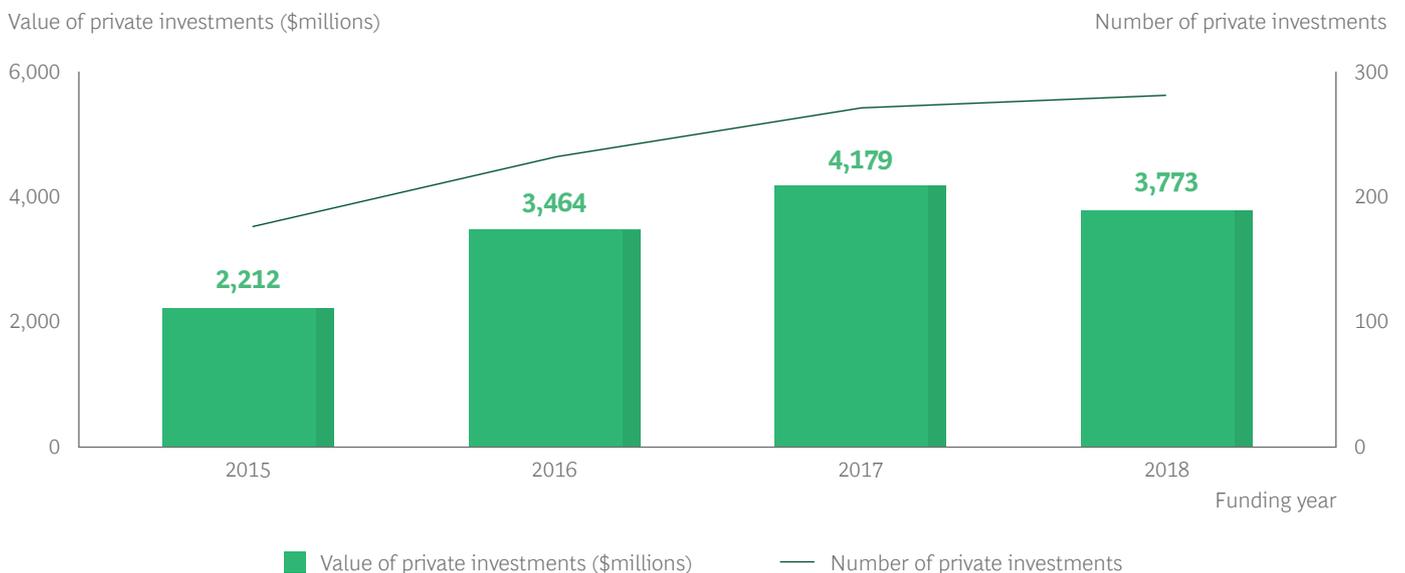
clean energy—18%, and clean water and sanitation—10%). Social SDGs, such as peace, justice, and strong institutions, and gender equality, tend to receive less attention since their long-term solutions are more likely to be political than technological. (See Exhibit 9.)

Time and Scale. Deep tech takes time to move from basic science to a technology that can be applied to actual use cases. For example, it took researchers decades (and recent advances in computing power) to develop the underlying technology of AI, and quantum computers have been under development for years. Now, companies are rapidly deploying AI technology and developing new and innovative use cases, while quantum computers capable of practical applications in such fields as pharmaceuticals and chemistry are expected to become a reality within the next five years.

Indeed, the incorporation of a startup is not the beginning of the story but rather a milestone in the development of a technology—the point when the science has been proven and the work starts to target a particular market. Two-thirds of the startups applying to the Hello Tomorrow Global Challenge incorporated at the experimental proof of concept or minimum viable product stage.

The amount of time to reach the market varies substantially by technology and application. An analysis of the startups in

Exhibit 5 - Corporate Investment in Deep Tech Is on the Rise



Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Note: Includes investment in seven deep tech categories: advanced materials, artificial intelligence, biotechnology, blockchain, drones and robotics, photonics and electronics, and quantum computing.



20% a year

Growth in global private investment in
deep tech from 2015 through 2018

Deep Tech Funding Growth

The amount of interest, activity, and funding in deep technologies is undergoing an explosion that is as broad as it is deep.

Deep tech companies consistently receive more funding than other kinds of tech firms.

the Hello Tomorrow Challenge shows that it takes an average of 4 years in biotech (1.8 years from incorporation to the first prototype, then another 2.2 years to reach the market), while it's only 2.4 years for a startup in blockchain (1.4 years to first prototype and 1 year to market) (See Exhibit 10.) But it is almost always longer than the amount of time it would take to develop an innovation based on a widely available technology (think of a new mobile application).

The wild card is technology itself; each advance seems to speed the next. For example, it is hard to forecast the full impact of AI or quantum computing, which constitute step changes in capability, on the development of subsequent technologies.

Investment. The funding needs of deep tech companies vary significantly with the technology. (See Exhibit 11.) For example, data from Hello Tomorrow's Challenge participants shows that developing the first prototype in biotech costs an average of almost \$1.3 million, but in blockchain, it costs only about \$200,000. Several factors complicate deep tech investment.

One is market risk. Many companies are seeking funding in the early research phase, long before they can put a product or even prototype in the hands of potential customers, meaning that investors have few if any KPIs with which they can evaluate traction and market potential.

Another factor is technology risk; many investors don't have the specific expertise in-house that they need to accurately assess the potential of emerging technologies. Mitigation strategies include analyzing the value of patents, coinvesting with corporations that have the expertise to evaluate the technology, using incubators, or developing a network of experts to assist in IP evaluations (although this takes significant time and specialization). Some investors simply stay away from unfamiliar technologies, but this reduces their scope and forces specialization.

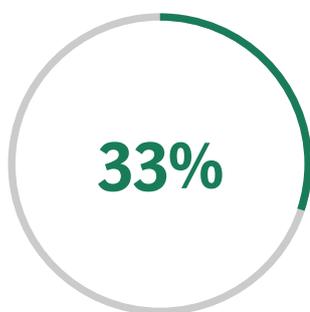
The long time to market required for deep tech is a challenge for many venture funds that need to return the money to limited partners after a set period (often less

than ten years). It doesn't help that there are few if any successful exits in emerging fields. As a consequence, many investors seek domains that have proven early-exit routes (such as biotech, where big pharma frequently buys the startup before clinical tests), or they invest later in the product development process.

As a consequence, deep tech startups rarely follow the established funding progression of other types of young tech enterprises that seek money from friends and family, then angel or seed investors, then successive rounds of venture capital investment at increasing valuations (which validate the decisions of previous investors), leading ultimately to a trade sale or an IPO.

Deep tech investors require vision, confidence, and patience. Silicon Valley garage to giga-riches stories make headlines—along with the eye-popping returns earned by their backers—but in deep tech, these investments often come late in the cycle, when the early, hard, and frequently time-consuming basic-research groundwork has been laid and the focus is on developing business and market applications. In deep tech, public funding plays an important role in the early phase; friends and family money is rarely significant relative to the substantial capital requirement of early R&D. More than one-third of the top 500 startups in Hello Tomorrow's 2018 Challenge received public non-equity funding. Almost 20% participated in accelerators or incubators, 7% received money from friends and family, and 2% accessed crowdfunding sources.

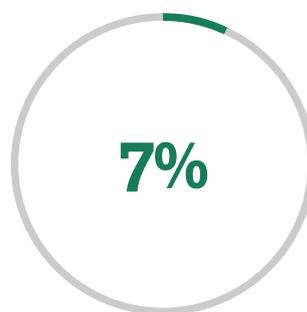
Research by BCG and Hello Tomorrow shows that deep tech entrepreneurs today need to be able to tap into a variety of private and public funding sources. (See Exhibit 12 and "A Deep Dive into Deep Tech Investing," BCG infographic, forthcoming.) Private-public financing schemes are becoming increasingly important to funding deep tech ventures along their entire life cycle, and CVC funds, incubators, and accelerators also have become important partners since they provide not only financing but other critical forms of support.



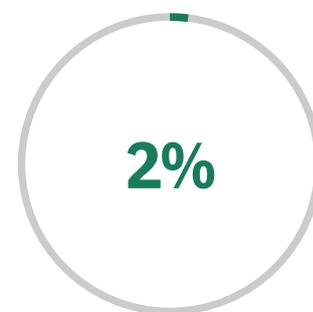
More than 33% of the top 500 startups in Hello Tomorrow's 2018 Challenge received public nonequity funding



Almost 20% participated in accelerators or incubators



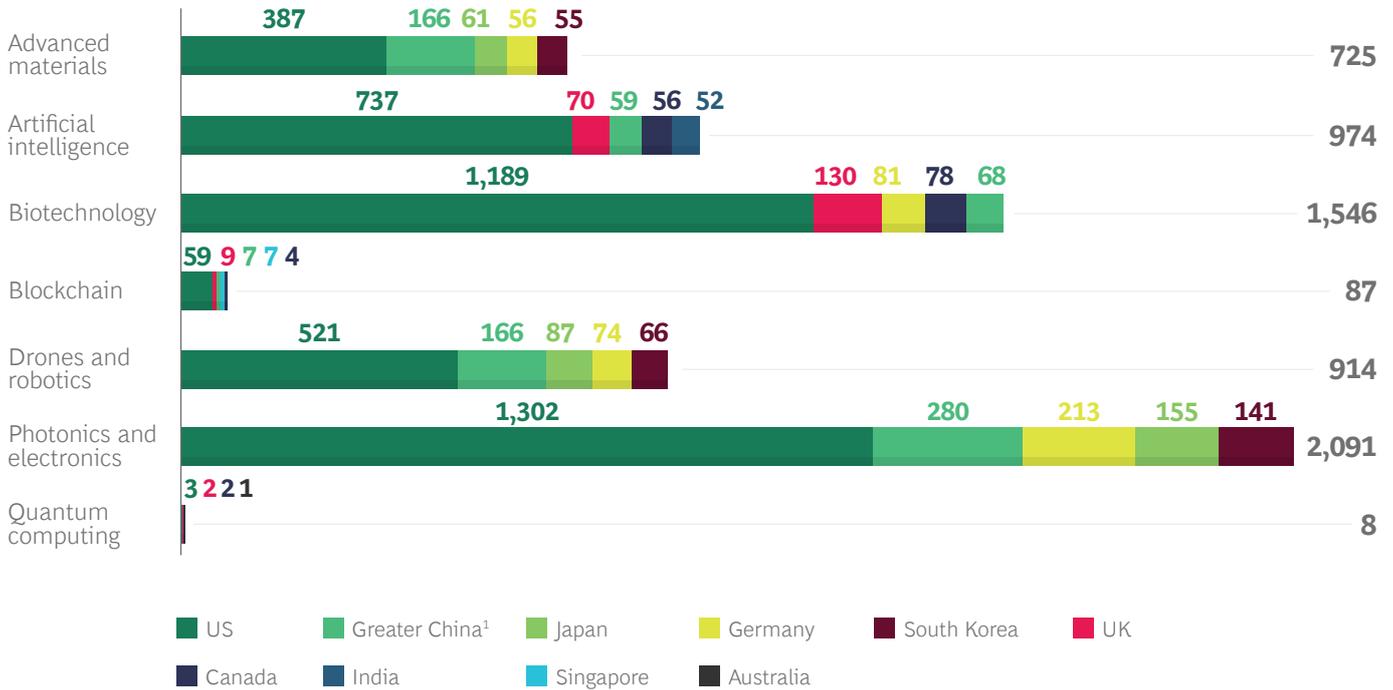
Only 7% received money from friends and family



Just 2% accessed crowdfunding sources

Exhibit 6 - The US Leads as a Deep Tech Hub, but Considerable Activity Is Occurring Elsewhere

Categories Top five deep tech markets for each deep tech category, 2015–2018

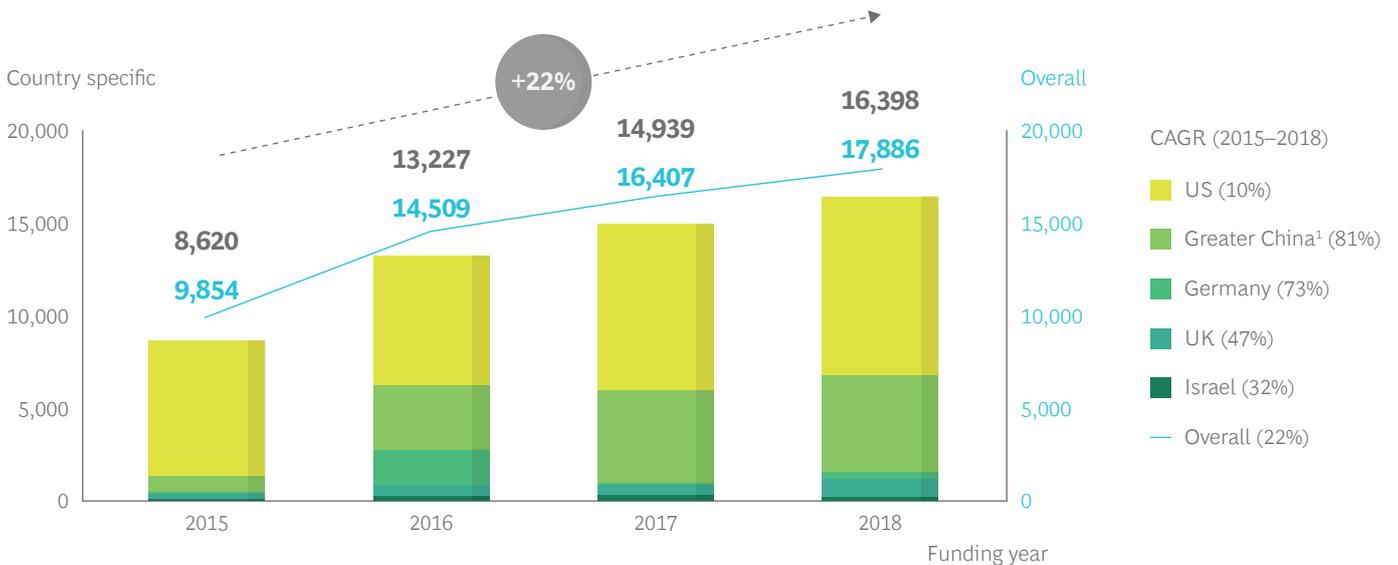


Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

¹Greater China includes mainland China, Hong Kong, Macau, and Taiwan.

Exhibit 7 - Private Investments in Chinese, German, and UK Deep Tech Companies Are Rising Fast

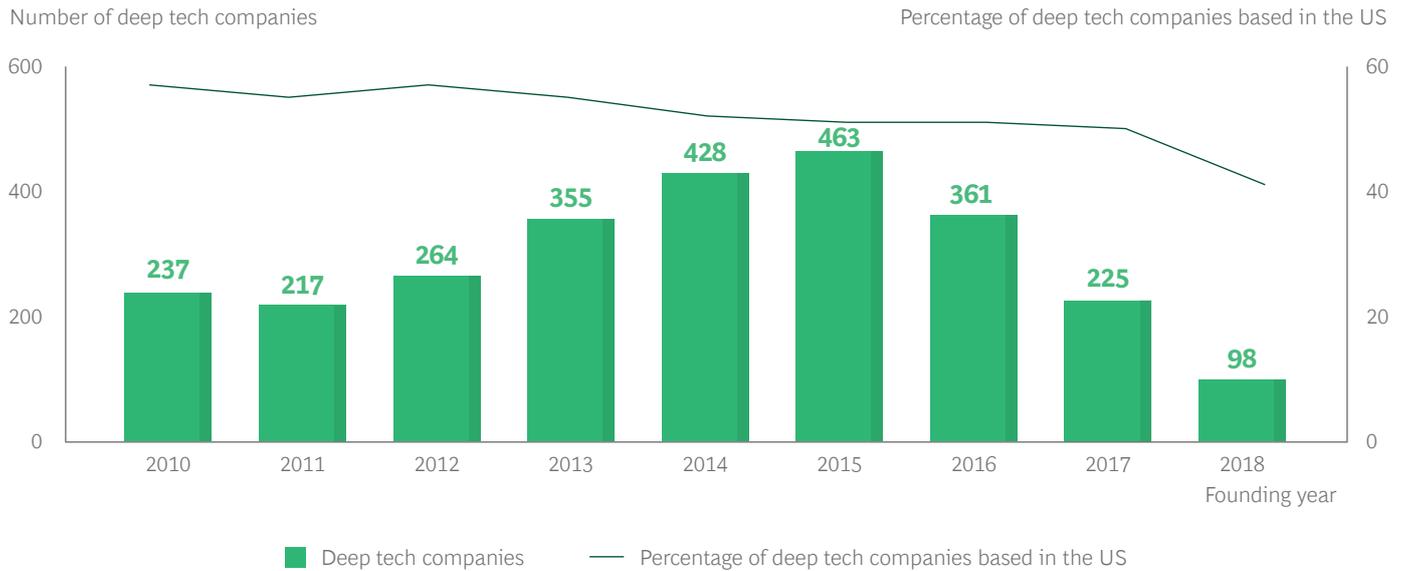
Sum of private investments in deep tech companies (\$millions)



Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

¹Greater China includes mainland China, Hong Kong, Macau, and Taiwan.

Exhibit 8 - About 53% of All Recently Formed Deep Tech Companies Are Based in the US



Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Note: Includes investment in seven deep tech categories: advanced materials, artificial intelligence, biotechnology, blockchain, drones and robotics, photonics and electronics, and quantum computing. The number of deep tech companies formed in 2017 and 2018 is likely incomplete because of the 18-month publication delay in patent filings, making it difficult to fully identify whether companies are active in deep tech.

Exhibit 9 - Share of Deep Tech Startups Targeting Each United Nations Sustainable Development Goal

Sustainable Development Goal	Number	Share (%)
Good health and well-being	837	51
Industry, innovation, and infrastructure	827	50
Sustainable cities and communities	469	28
Responsible consumption and production	413	25
Climate action	369	22
Decent work and economic growth	340	21
Affordable and clean energy	289	18
Reduced inequalities	231	14
Clean water and sanitation	165	10
Life on land	160	10
Quality education	160	10
Zero hunger	156	9
No poverty	137	8
Gender equality	100	6
Peace, justice, and strong institutions	95	6
Life below water	79	5
Total number of qualified startups	1,646¹	100

Sources: Hello Tomorrow Challenge; BCG and Hello Tomorrow analysis.

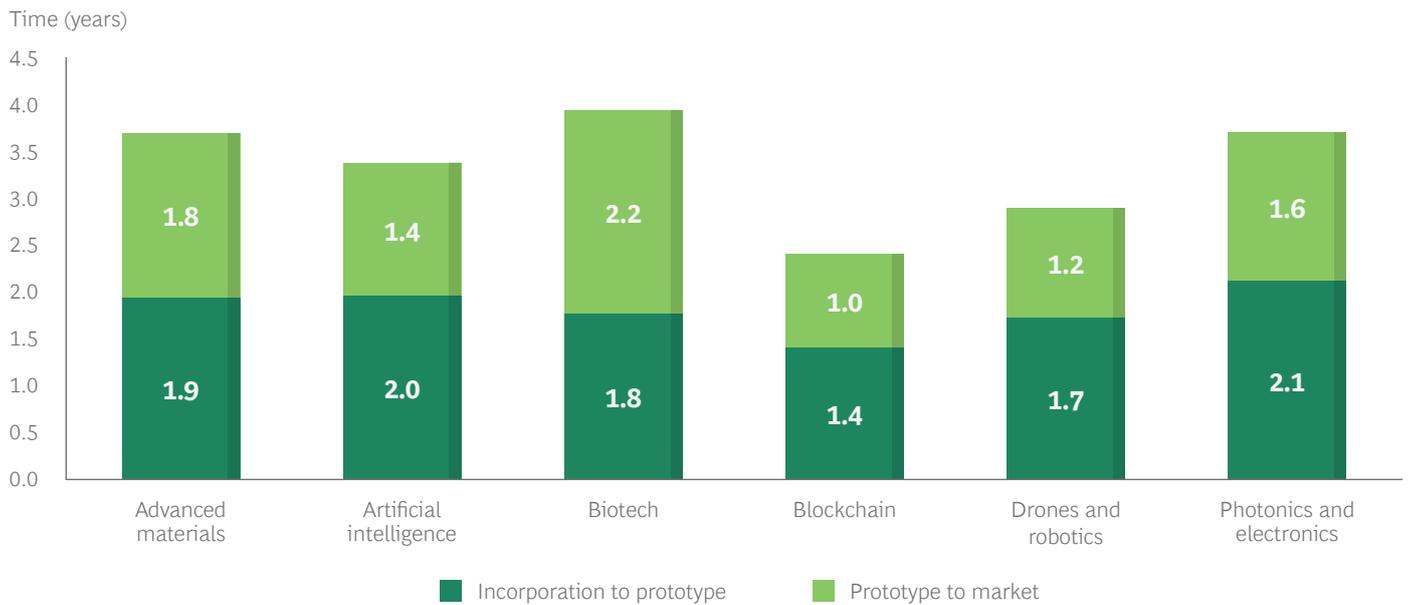
Note: Based on data from 1,646 deep tech startups that qualified for the second round of the Hello Tomorrow Challenge in 2018 (from 4,500 applications).

¹Many startups address more than one UN sustainable development goal.



Deep tech startups rarely follow the established funding progression of other types of young tech enterprises.

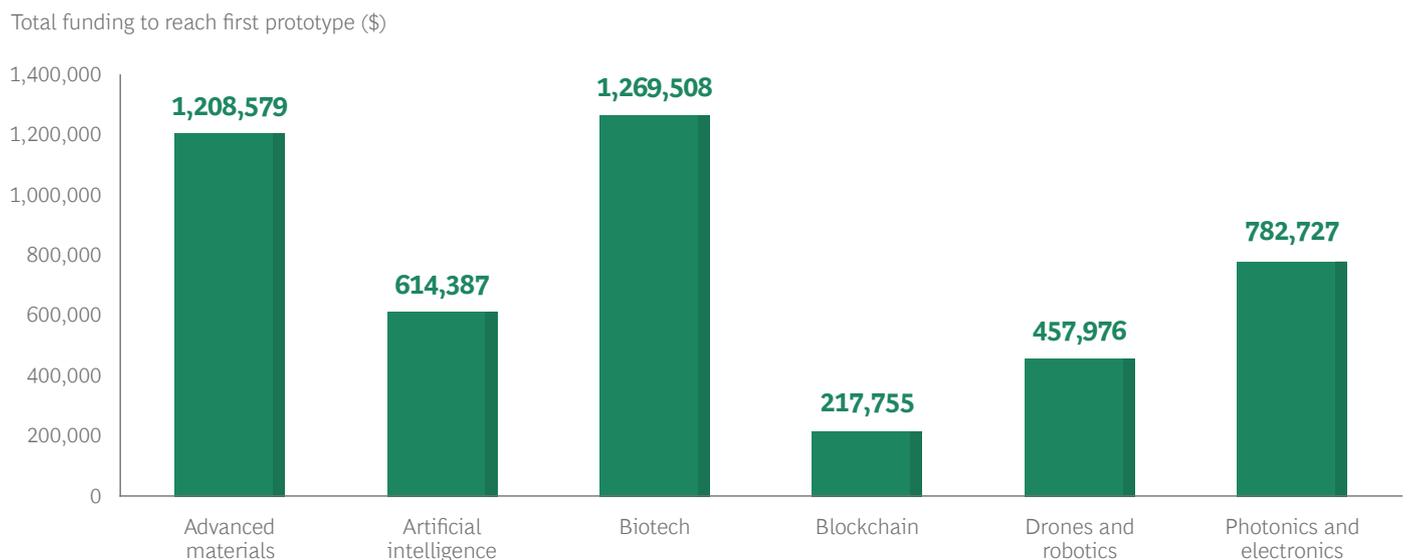
Exhibit 10 - The Average Time Required from Incorporation to Market Varies by Technology



Sources: Hello Tomorrow Challenge; BCG and Hello Tomorrow analysis.

Note: Based on data from 1,500 startups (the 500 best startups from the Hello Tomorrow Challenge in 2016, 2017, and 2018 assessed on technological innovation, business model, team skills and complementarity, and expected social and environmental impact).

Exhibit 11 - The Average Total Funding (Equity and Nonequity) Required to Build the First Prototype Varies by Technology

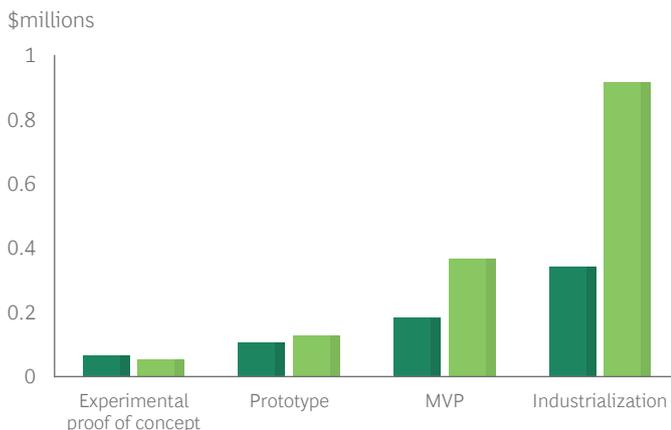


Sources: Hello Tomorrow Challenge; BCG and Hello Tomorrow analysis.

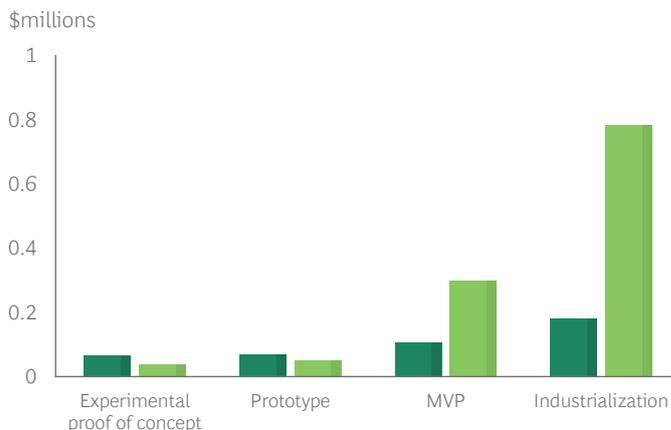
Note: Based on data from 1,500 startups (the 500 best startups from the Hello Tomorrow Challenge in 2016, 2017, and 2018 assessed on technological innovation, business model, team skills and complementarity, and expected social and environmental impact). Does not take into account the funding before incorporation (e.g., through research grants).

Exhibit 12 - Deep Tech Startups' Equity and Nonequity Funding at Progressive Stages of Development

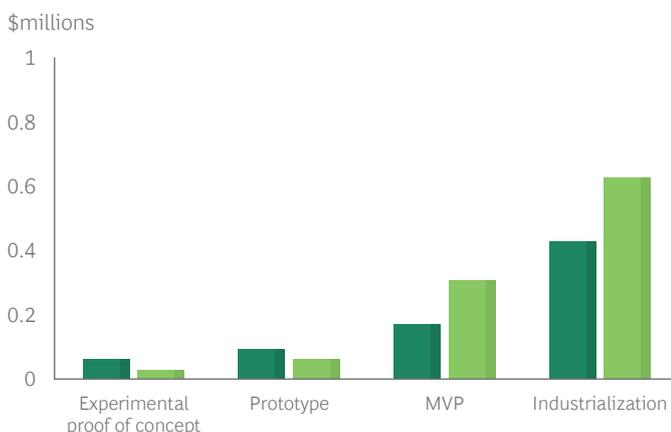
Biotechnology: median 2017 and 2018



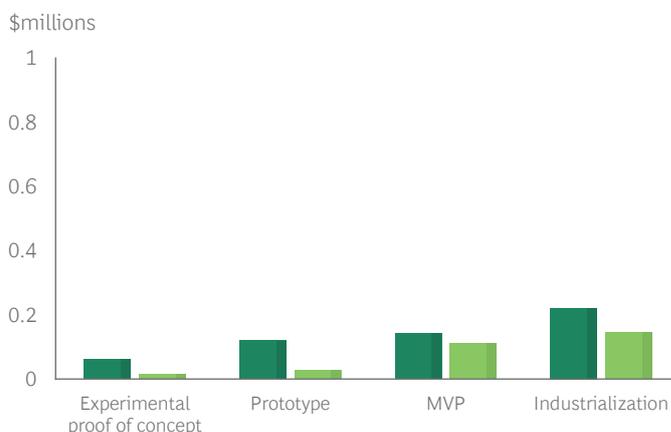
Robotics and drones: median 2017 and 2018



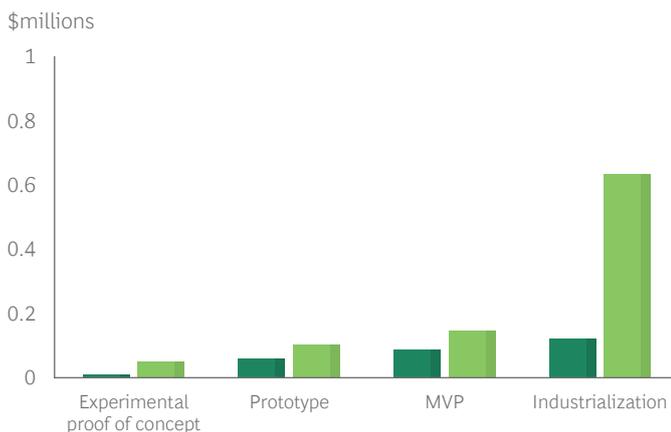
Photonics and electronics: median 2017 and 2018



Advanced materials: median 2017 and 2018



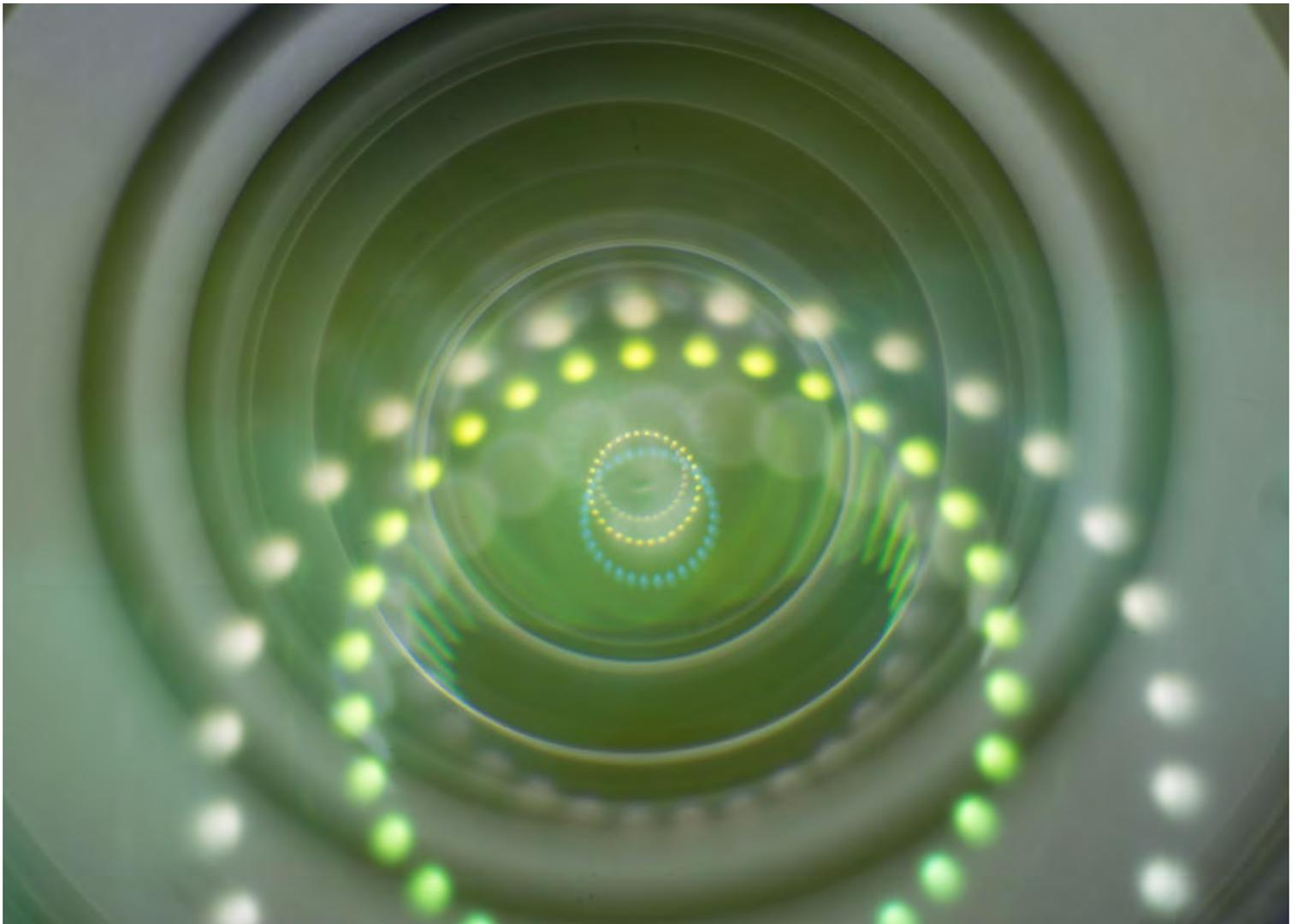
Artificial intelligence: median 2017 and 2018



■ Nonequity funding
■ Equity funding

Sources: Hello Tomorrow Challenge; BCG and Hello Tomorrow analysis.

Note: Based on data from 1,000 startups (the 500 best startups from the Hello Tomorrow Challenge in 2017 and 2018 assessed on technological innovation, business model, team skills and complementarity, and expected social and environmental impact). MVP = minimum viable product.



Where Is Technology Going?

BCG and Hello Tomorrow researched seven areas of deep technology R&D that in our judgment are the most promising and active fields. They also span the spectrum from very early research to market applications in full development and therefore provide a representative picture of the deep tech landscape. The exhibit on page 20 shows the percentage of top deep tech startups in Hello Tomorrow's Global Challenge from 2016, 2017, and 2018 (based on technological innovation, business model, team skills and complementarity, and expected social and environmental impact) that are active in selected sectors.

Advanced Materials

Advanced materials, whether biobased or synthetic, include all new materials and modifications to existing materials that yield a superior performance (graphene is an example). New materials can also be made from two or more

existing materials that differ significantly from one another but, when combined, produce a material with its own characteristics, also known as a composite material (such as fiberglass). Advanced materials have applications in many industries (including new battery technologies, CO₂ capture and storage, and smart textiles).

Artificial Intelligence

Artificial intelligence refers to algorithms and computer systems that can perform tasks that used to be the exclusive purview of humans. The widespread use of AI today is based substantially on advances in the field of machine learning—the ability of a computer to learn without being explicitly programmed, meaning that automation is no longer limited to what humans can understand. The improved design of machine-learning algorithms, combined with increasing computer power, has led to the successful

implementation of AI in autonomous mobility, voice assistants, medical-imagery analysis, and industrial big data analytics, among other areas.

Biotechnology

Biotechnology aims to create valuable products by exploiting existing biological processes or by developing new ones. Of particular interest are the genetic manipulation of microorganisms for the production of antibiotics and vaccines or valuable intermediates for industrial purposes that can't be synthesized chemically. Recently, the discovery of CRISPR-Cas9 has led scientists to dream of genetic cures for diseases such as cancer. In addition to uses in the industrial and pharmaceutical sectors, the agricultural industry uses biotechnology to create new, more resistant plant varieties, which can secure a food supply for a projected 10 billion people, and biomaterials open new perspectives across all industries from construction to fashion.

Blockchain

A blockchain is a distributed ledger that stores a history of transactions (such as for a particular unit of currency or potentially an individual's medical history) in a secure and transparent way. The data is stored in "blocks" and is successively appended to the "chain" (hence the term "blockchain"). All users of the blockchain can track the history, add blocks to the chain according to their permissions, and follow transactions from end to end. Blockchain potentially ends the need for intermediaries that act as a central, trusted authority for other participants, which could speed up transactions and reduce costs. Blockchain also obviates the need to build trust, which is essential for many kinds of transactions but is time-consuming and expensive. After blockchain's debut in the financial sector, players in other industries are looking for use cases where transparent and secure transactions between distributed accounts can save time and reduce cost.

Drones and Robotics

Robotics is the discipline of design, construction, and use of machines to perform tasks in an automated fashion. Robots are widely used in automobile manufacturing, for example, as well as in industries where work is performed in an environment that is hazardous for human beings. More-recent robotics are geared toward self-sufficiency. Artificially intelligent robots are equipped with the equivalent of human senses, such as vision and touch, which permit mobility and decision making in an unstructured environment and cohabitation with humans at home or in the factory, leading to the concept of "cobots."

Drones are a subcategory of robots. Usually, they are more mobile than classic robots (some can fly) and are used to transport goods, inspect assets, or map unknown territory in a semiautonomous fashion.

Photonics and Electronics

The field of photonics aims to generate and harness the properties of photons, the quantum unit of light. Photons are used to transmit information through optic fibers or laser beams at the speed of light, which allows digital information to be sent around the world in milliseconds. Light is also used to generate electricity through photovoltaic technology (solar cells), cut through materials (lasers), survey surroundings and measure distance (LIDAR), and characterize materials and molecules on the basis of their spectral properties (spectroscopy).

In a similar fashion, the field of electronics harnesses the properties of electrons. The directed movement of electrons is used to produce energy in the form of electricity. Our modern world is based on electronic parts such as computers. In combination with photons, the properties of electrons allow for digital information processing.

Quantum Computing

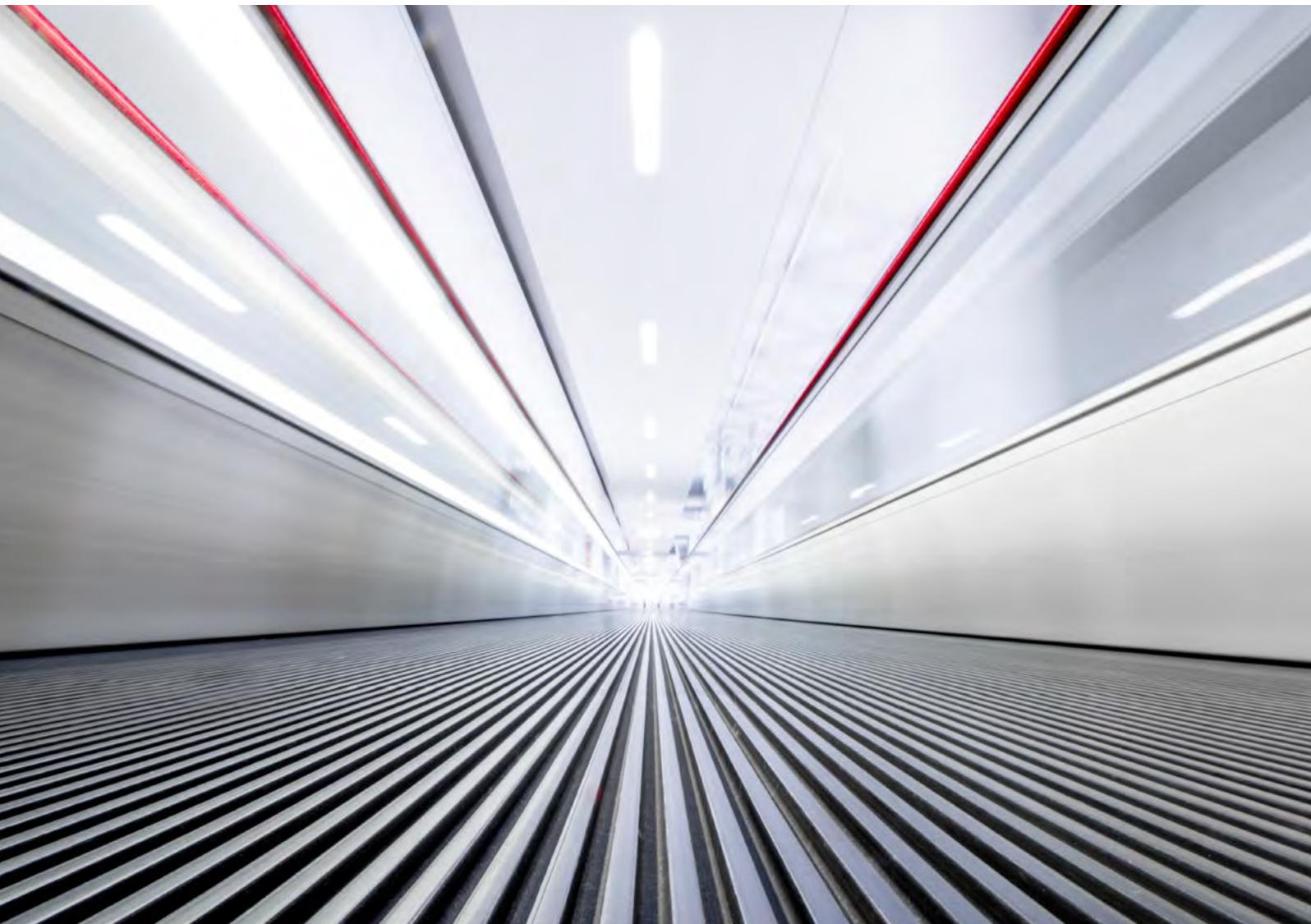
Quantum computers, building on the pioneering ideas of physicists Richard Feynman and David Deutsch in the 1980s, leverage the unique properties of matter at nanoscale. They differ from classical computers in two fundamental ways. First, quantum computing is not built on bits that are either zero or one but on qubits that can be overlays of zeros and ones (meaning part zero and part one at the same time). Second, qubits do not exist in isolation but instead become entangled and act as a group. These two properties enable qubits to achieve an exponentially higher information density than classical computers. (See *The Next Decade in Quantum Computing—and How to Play*, BCG report, November 2018; and *The Coming Leap in Quantum Computing*, BCG Focus, May 2018.)

The Percentage of Startups from the Hello Tomorrow Challenge Active in Each Deep Tech Category and Selected Sectors

	Advanced materials (%)	Artificial intelligence (%)	Biotechnology (%)	Blockchain (%)	Drones and robotics (%)	Photonics and electronics (%)
Aerospace and airline services	4.9	3.4	0.0	0.0	4.2	6.2
Agriculture	3.2	3.1	2.8	0.4	3.5	4.9
Automotive and transportation	6.2	6.8	0.2	0.2	4.8	10.8
Business products and services	8.6	9.8	5.4	0.8	5.0	15.7
Consumer products and services	6.3	5.3	3.2	0.2	2.5	10.8
Energy and utilities	8.6	4.9	0.6	0.5	5.6	12.8
Food and beverages	3.3	1.8	3.5	0.5	1.1	3.1
Health care	13.0	9.8	16.0	0.7	3.7	17.4
Manufacturing and construction	13.3	4.1	2.4	0.1	4.8	9.4
Metals and mining	3.2	0.6	1.2	0.1	0.5	2.1
Mobile and telecommunications	4.0	3.2	0.1	0.1	1.9	6.3
Retail	4.0	3.2	0.1	0.1	1.9	6.3
Software	2.2	10.3	0.9	0.9	3.7	8.6
Waste and water	1.9	0.7	1.2	0.1	0.5	2.8

Source: Based on data from 1,500 startups (the 500 best startups from the Hello Tomorrow Challenge in 2016, 2017, and 2018 assessed on technological innovation, business model, team skills and complementarity, and expected social and environmental impact).

What's Driving Deep Tech?



In 2017, a young entrepreneur named Alexander Belcredi, armed with degrees in history, economics, and business as well as some consulting experience, launched a biotech startup focused on phages—antibiotics developed from natural viruses. Phages were discovered a century ago but mostly ignored until recently, when pioneers such as Alex started using newly available technologies—genomic sequencing and AI—to build an entirely new biotech industry segment. Alex and his partners have raised millions of dollars and put together a team of experts to pursue their research. His company, PhagoMed, and others in the emerging field have made enough progress that manufacturers, regulators, and others are starting to create a mini-ecosystem around phage development.

So far, this is a typical deep tech startup story—but it has a twist. Alex has no scientific background or training (although his partners do). “I was able to do this because of the easy access to publications and past research, cheap and effective genomics sequencing, and simple access to experts around the world,” he says. “We needed genomic sequencing to be easily available, cheap and fast in order to innovate in this space.”

Deep tech is no longer the primary purview of deep pockets—or of the scientific community. To be sure, big companies, universities, and governments are still major players, but deep tech R&D in the seven fields we examined is now just as likely to be driven by a team of visionaries with a radical idea for innovation or entrepreneurs like Alex and his partners, who believe they can develop solutions to big problems more quickly than incumbents. A European survey of more than 2,000 startups (including both deep tech and non-deep-tech ventures) in 2017 showed that more than 60% of the companies’ founders did not have a technical background.¹ Among Hello Tomorrow 2018 Challenge participants, the share of spinoffs from universities was 30%, down from 49% in 2016.

There have always been aggressive and visionary scientists and entrepreneurs (remember Pasteur and Edison). What’s changed is the ability of these individuals to access technological capabilities, financing, and other critical resources to bring their dreams into the real-life lab and perhaps to market. There is a growing deep tech ecosystem today (see the next chapter) that facilitates research into almost any kind of technology, from things we can’t see to concepts that relatively few can explain. This ecosystem is rooted in a handful of trends.

The Rise of New Platform Technologies

Innovation in the past few decades has been driven mainly by a small number of powerful platform technologies: silicon chips and desktop computers in the 1960s and 1970s, the internet in the 1980s and 1990s, and mobile technologies in the 2000s. They are referred to as platforms because they lead to a wide range of applications across many industries (as opposed to other technologies whose applications are more specific, such as photovoltaics, which is used mostly to produce electricity from sunlight).

After decades of incubation in basic research, some powerful new platform technologies are emerging, leading to concrete applications across industries and paving the way for innovation over the next several decades. It’s happening simultaneously in software (machine learning), hardware (quantum computing), and biology (genetic sequencing and CRISPR-Cas9, which are reenergizing biotech). This convergence multiplies their potential and creates the kind of momentum that drives new industrial revolutions. For example, the combination of CRISPR, genetic sequencing, robotics, and AI is fueling a revolution in synthetic biology. Biotech startups are already using machine-learning algorithms to compute millions of possibilities for cancer-curing agents and will one day use quantum computing to model protein folding and its applications.

Falling Barriers

As new platform technologies rise, barriers fall. Technology begets technology; inventors build on the inventions of their predecessors. Today’s innovators have a wealth of technological capability at their fingertips. PCs are inexpensive and powerful, and even more powerful computing hardware is on offer from cloud-based services offered by the likes of Amazon, Microsoft, and IBM. Easy access to hardware obviates big upfront capital expenditures for tech. Likewise, software is both open-source and widely available as a service. Computer-aided design and manufacturing as well as 3D printing have revolutionized prototyping. In biotechnology, sequencing and synthesizing DNA have become standard services. At the same time, many governments are reducing or removing the administrative and bureaucratic hurdles for entrepreneurs, making it easier than ever to start a business. The internet and open-minded innovators make technical and scientific research easy to access, as Alex attests. It’s a powerful combination.

1. Atomico, *The State of European Tech 2017*, <https://2017.stateofeuropeantech.com>.

More Fragmentation and Diverse Approaches for Business

Innovation today is a much more fragmented and varied endeavor than ever before. As a consequence of falling barriers, more young companies in more places are pursuing more new avenues of invention, and many of these involve advances in new technologies. Our research into seven deep technologies found an enormous breadth of activity. In AI, for example, we counted more than 1,300 companies in 48 countries and 401 cities. (See Exhibit 13.)

At the same time, big corporations are diversifying their innovation programs, using CVC and other venturing tools to gain access to new technologies. (See *How the Best Corporate Venturers Keep Getting Better*, BCG Focus, August 2018.) Research for this report shows that the number of private venture investments with CVC participation grew from 161 in 2015 to 203 in 2018, and the total value of private venture investments with CVC participation increased from approximately \$3.2 billion in 2015 to \$5.7 billion in 2018. As Sophie Park, chief of strategy at Bayer G4A, puts it, “To realize our mission of changing the experience of health, we at G4A make it a priority to partner with early stage deep tech startups.”

In addition to their use of CVC, more and more large companies are deploying a variety of innovation investment and development vehicles, matching the tool to the circumstances (such as time to market) and their objectives (such as assessing new or disruptive technologies, improving existing technologies, or gaining control of a new technology). The vehicles in wide use today include incubators and accelerators, innovation labs, traditional R&D functions, partnerships, and M&A.

One result of this fragmentation and diversity of effort is that knowledge, skills, and information, while much more accessible, are also harder to harness because they reside in more, and more disparate, places—geographically, industrially, and functionally. This disparity is driving the need for new models of collaboration in basic R&D.

Growth in Available Capital

There has been no shortage of venture capital in recent years, and the capacity for startups to achieve new scientific and commercial levels of success has encouraged investors to infuse hundreds of billions of dollars into small companies. According to Crunchbase, global venture deal value approached \$100 billion in the third quarter of 2018, up more than 40% over 2017. Deal volume also rose 40% during this period, coming close to 10,000 rounds.

Our own research shows plenty of funding activity for deep tech companies. As we noted in the previous chapter, both deep tech startups and more mature companies have attracted a greater amount of funding than other types of tech companies in the past five years. Deep tech companies have also completed more funding rounds.

Some of the ready availability of capital must be credited to macroeconomic conditions, however—most significantly, the unprecedented period of low (or no) interest rates following the 2008 financial crisis, which appears to be coming to an end. In addition, many believe that the already-high, and still rising, valuations of many tech unicorns cannot be sustained. There is a growing view that the valuations ascribed to some of these companies in recent funding rounds have outstripped the companies’ ability to support them in terms of actual revenues and earnings.

Exhibit 13 - Deep Tech Activity Is Widespread

Category	Companies	Countries	Cities
Advanced materials	987	38	545
Artificial intelligence	1,302	48	401
Biotechnology	2,028	42	757
Blockchain	121	20	65
Drones and robotics	1,326	40	697
Photonics and electronics	2,910	51	1,305
Quantum computing	8	4	8

Sources: Capital IQ; Quid; BCG Center for Innovation Analytics; BCG and Hello Tomorrow analysis.

Note: Includes investment in seven deep tech categories: advanced materials, artificial intelligence, biotechnology, blockchain, drones and robotics, photonics and electronics, and quantum computing. Private-investment sums are based on transactions with disclosed amounts. Some 41% of private investments in deep tech companies remain undisclosed.

Venture funding, like other types of capital, runs in cycles, and we should not be surprised to see a pullback in the coming years.

A Shifting Role for Governments

Governments around the world have undergone shifting roles in new technology R&D support, with the two biggest players, the US and China, moving in opposite directions.

In the US, according to the American Association for the Advancement of Science, federal spending on R&D as a percentage of GDP dropped from more than 1.2% in 1976 to about 0.7% in 2018. Industry and others have picked up the slack. According to UNESCO, total spending on R&D in the US equaled 2.7% of GDP, followed by China at 2.1% and the EU at 2.0%. The US government also used to play an important part as an early customer for new technological innovations (think GPS satellites, for example), a role that is much less prevalent today.

In contrast to the US, China is on an R&D tear. According to data compiled by the *Economist*, China's spending on R&D on a purchasing-power-parity basis has risen about 400% over the past two decades to exceed \$400 billion a year and approach that of Europe and the US. "China needs to enter the ranks of innovative countries and become a big technological innovation power by 2050," China's minister of science and technology, Wan Gang, told *Reuters* in February 2018. "Basic research and frontier exploration is the big lesson that must be done now."

One major field in which the US and China are competing head-to-head for a leadership role is AI. Most experts give the nod to China, for the moment at least, thanks in part to the highly focused and concerted nature of its government's support of R&D².

In Europe, the EU has had a program in place since 2014, Horizon 2020, that encourages member nations to invest 3% of GDP in R&D (1% from government and 2% from the private sector) and makes nearly €80 billion in EU funding available to strengthen the EU's position in science, support industrial innovation, and address major social concerns³. The European Commission has promised a successor program as part of the EU budget following 2020.

2. See, for example, Kai-Fu Lee, "What China Can Teach the US About Artificial Intelligence," *New York Times*, September 22, 2018; Steve Andriole, "Artificial Intelligence, China and the U.S.—How the U.S. Is Losing the Technology War," *Forbes*, November 9, 2018; and Nicholas Thompson and Ian Bremmer, "The AI Cold War That Threatens Us All," *Wired*, October 23, 2018.

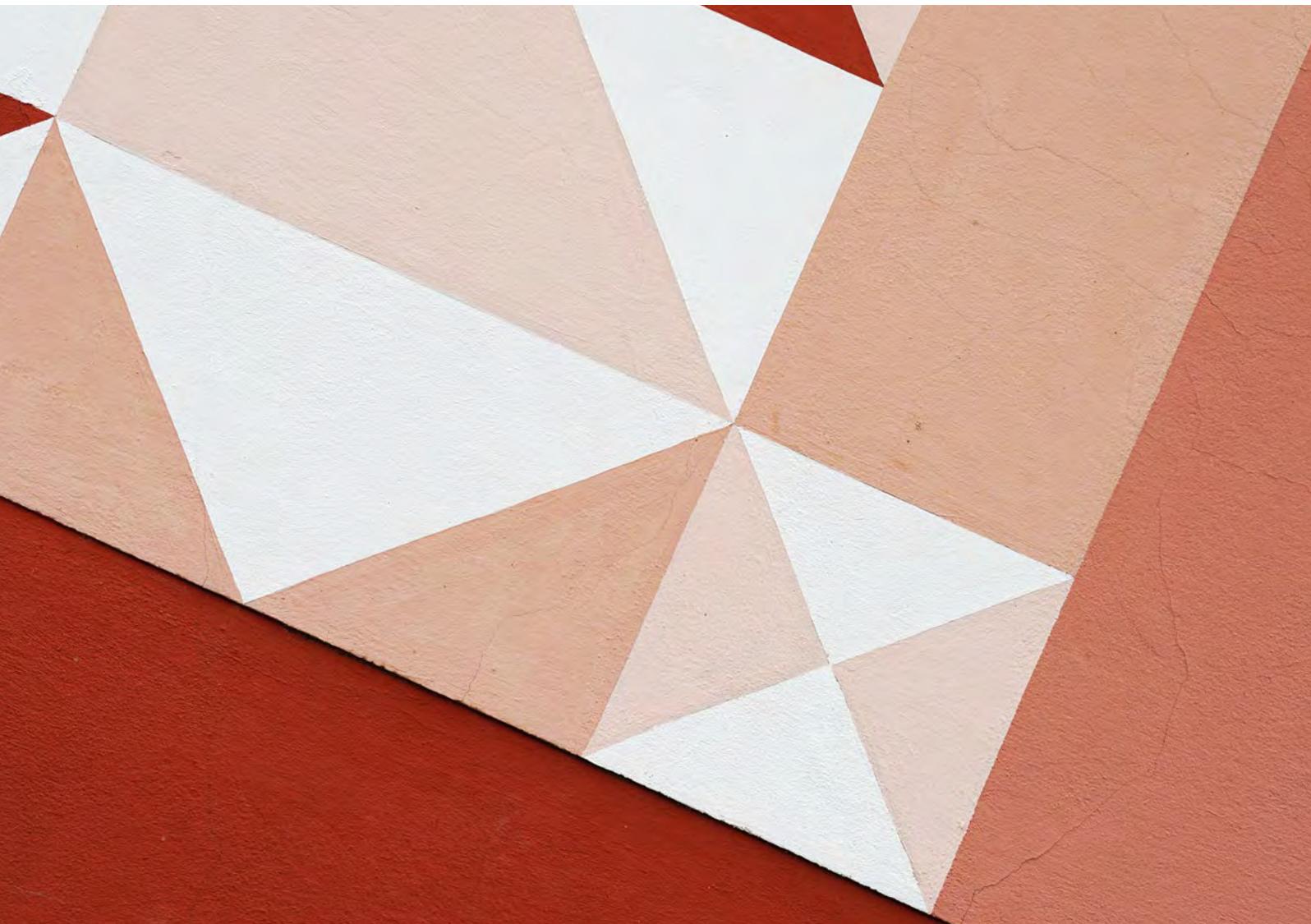
3. For more information on EU efforts in this area, see https://europa.eu/european-union/topics/research-innovation_en.

Deep Problems Call for Deep Technologies

The scientists and entrepreneurs working in deep tech are not put off by big problems—or the time and effort it takes to solve them. Indeed, for many, these problems are part of the attraction. Those active in deep tech also do not lack for choice—major challenges abound. In addition, more and more consumers and employees expect companies to be socially and environmentally responsible. (Some 30,000 students from the top scientific and business schools in France signed a manifesto in 2018 calling for recruiting companies to take on greater environmental responsibility.) Mitigating climate change, feeding 8 billion people, and keeping an aging population healthy are big problems—and big markets that attract a lot of attention from investors and corporations.

In this context, deep technologies are receiving more attention since they are seen as potentially contributing to solutions. The startups in the 2018 Hello Tomorrow Challenge are tackling the UN's SDGs, especially those related to health and environmental issues. Because they could profoundly change the way we produce food, industrial goods, and energy, deep technologies have the potential to drive entire industries toward sustainability, and deep tech entrepreneurs are turning this potential into concrete solutions. (See "Engineered Symbiosis, the Earth and Us," Hello Tomorrow article, November 2018.)

It Takes an Ecosystem



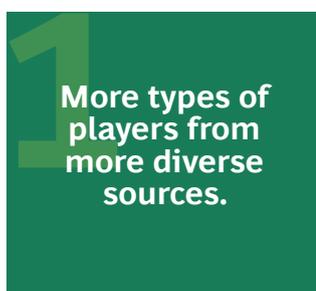
From R&D to industrialization and commercialization, deep tech today encompasses a broad ecosystem that includes multiple types of participants. Smaller ecosystems are organized around particular fields of research, technology, industry, or mission. These ecosystems have a set of characteristics that differentiate them from other business collaborations or partnerships.

Business ecosystems are not new, of course. Many industries have well-established ecosystems that have been functioning in much the same way for years, including automakers and their suppliers and dealers; airlines, aircraft makers, and engine manufacturers; and media companies and content producers. As digital technologies have become more pervasive, many more traditional companies have adopted an ecosystem model as a way to gain access to the technologies, skills, and capabilities they need to digitize their processes and offerings. (See “Getting Physical: The Rise of Hybrid Ecosystems,” BCG article, September 2017; and “The Emerging Art of Ecosystem Management,” BCG article, January 2019.)

At their core, these ecosystems are expansions of traditional ways of organizing and doing business; they are more inclusive, but they tend to have established hierarchies and structures. One company is typically the leader or orchestrator (the auto OEM, the aircraft maker, the media company), and the other participants have well-defined roles. A central characteristic is that collaboration trumps competition, and collaboration is the opposite of a zero-sum game; if the ecosystem wins, the individual participants win as well.

Deep tech ecosystems are nascent and operate in emerging—and therefore not yet stabilized—technologies and industries. As a consequence, they are a different breed. BCG and Hello Tomorrow have identified four traits that characterize these collaborations. They involve more types of players from more diverse sources. Deep tech ecosystems are highly dynamic—players come and go, and they create new kinds of relationships that are not always formal, defined by contracts, or well set. Deep tech collaborations rely less on a central orchestrator and more on multifaceted interactions among participants.

Four Traits of Deep Tech Ecosystems



While money is one important currency, it is far from the only means of exchange among participants. Knowledge, data, skills, expertise, contacts, and market access are also currencies that link ecosystem players.

Deep tech ecosystems can be hard for traditional companies to navigate. Newcomers often find themselves in unfamiliar territory, and carving out a role can be complex. But they need to find their way. Deep technologies can affect entire value or supply chains and therefore require a more thorough analysis of the stakeholders’ interdependencies and value creation models in order to determine how to align goals, set strategies, and organize for interaction with others.

Let’s look at the characteristics of deep tech ecosystems in more depth.

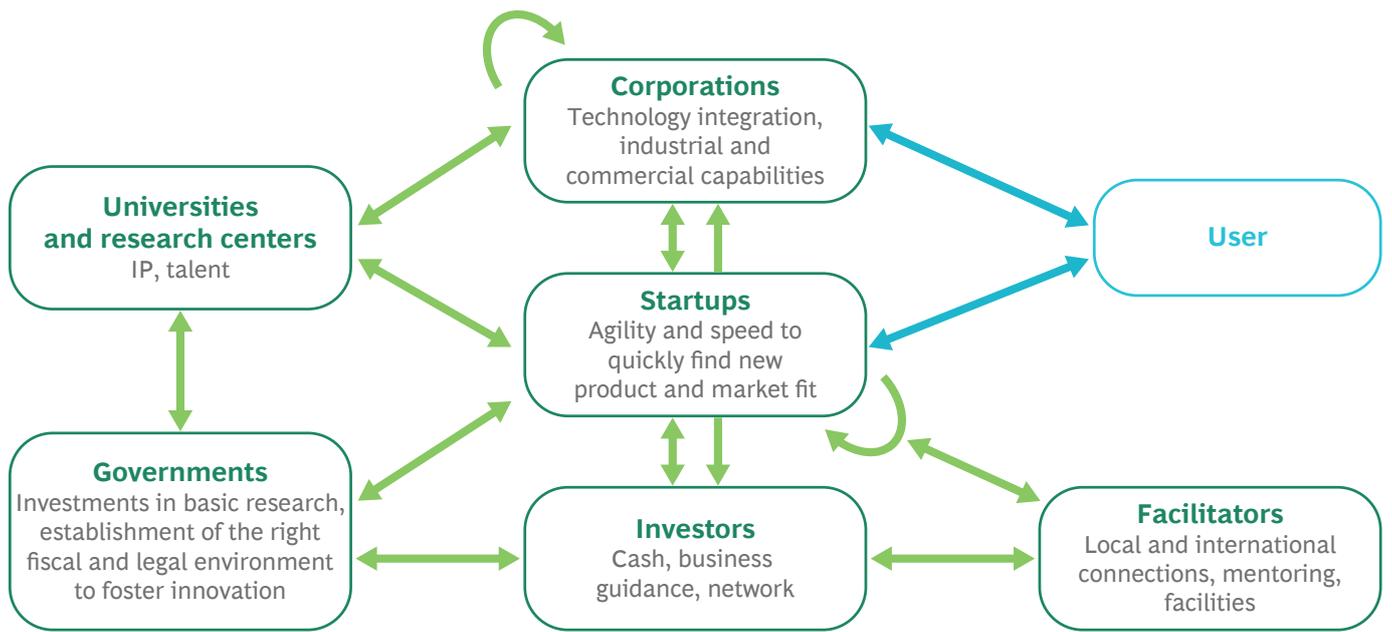
A Multientity Association

The deep tech ecosystem includes a diverse set of entities from the public and private sectors, each with its own needs and priorities. (See Exhibit 14.)

Startups. In many ways, startups sit at the center of deep tech ecosystems because they play an important role in speeding the research, development, and commercialization of a new technology or product and sometimes in leading radical innovation that is too risky for incumbents.

A variety of other actors assist startups in their efforts, with some playing multiple roles. For example, investors provide funding but often also offer expertise in corporate development and go-to-market strategies. Likewise, corporate partners supply funding and a host of other necessities, not least of which is access to markets and potential customers. (The wide potential variety of corporate interactions is one reason that Hello Tomorrow’s research has found companies are the preferred partner for many startups.) Universities can also be important research partners, and facilitators (such as startup accelerators) frequently play a key role in helping startups develop other necessary relationships.

Exhibit 14 - Each Type of Participant in the Deep Tech Ecosystem Makes Different Kinds of Contributions



Sources: Hello Tomorrow; BCG and Hello Tomorrow analysis.

Startups have an assortment of needs. Our 2017 survey found that the most common top priority is funding: 80% ranked it among their top three requirements. But it is far from their only need. Startups look to the ecosystem for help with market access (61%), technical expertise (39%), and business expertise and knowledge (26%). These needs evolve as startups and their products move closer to market, and the attractiveness of various types of funding partners shifts as well.

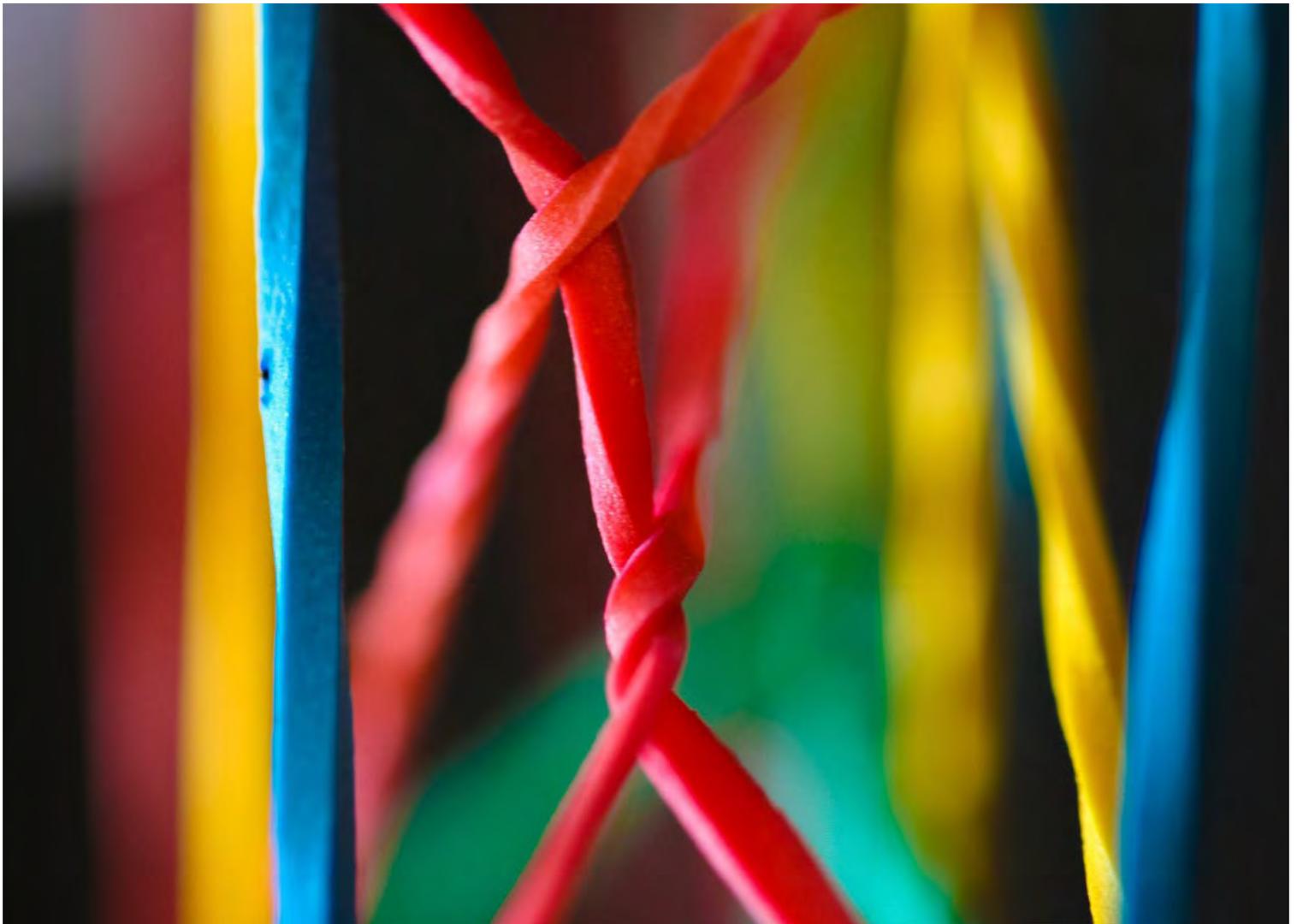
Corporations. Large companies have long incorporated external innovations through a variety of mechanisms, including acquisitions, partnerships, joint ventures, and licensing. But the technical basis of so many innovations has increased both the need to access new technologies and capabilities from outside the company and the variety of models for doing so. Regardless of the source of the innovation, the biggest challenge many companies must still overcome is the not-invented-here mentality that they encounter when they attempt to bring a new idea, capability, or model into their organizations. (See [“Bringing Outside Innovation Inside,”](#) BCG article, January 2017.)

Many companies regard startups, especially digital startups, with skepticism and sometimes fear. They are not wrong—plenty of startups are out to disrupt existing industries with new approaches and models and aim to take

share and growth from incumbents. In deep tech, the situation is different. Most startups can’t bring a new solution from scratch to market on their own; they need access to data, labs and testing infrastructure, or production lines. For their part, companies want access to the technology or product the startup is developing. More often than not, startups and big corporations have complementary goals.

Corporations are frequently the preferred partners for startups looking to establish market position through, for example, access to market and customer data, an existing customer base, or a distribution network. Big companies’ technological and industrial capabilities enable them to play an important role in due diligence, especially the technical due diligence that is key to deep tech, and the acceleration of the startup’s growth. (See the sidebar [“The Rise of the Corporate-Investor Hybrid.”](#))

In B2B markets, corporate partners are indispensable for demonstrating proof of concept in real conditions. For example, Canard Drones and Groupe ADP worked together to enable the startup to test its solution for aeronautical navigation aids in a real airport operated by Groupe ADP. Large companies can be especially helpful with challenges that digital tools cannot solve, such as building a pilot production line (and then a factory) or gaining access to suppliers. Air Liquide cooperates with deep tech startups to



The Rise of the Corporate-Investor Hybrid

Corporate venture capital, which can take several forms, is playing an increasingly active role in the deep tech ecosystem. As noted in the previous chapter, CVC investments are on the rise. We are seeing more corporations invest alongside traditional venture capitalists as CVC investors or as limited partners in venture capital funds.

In addition to financing, corporations have several advantages as investors compared with traditional VCs, including greater financial flexibility as they typically do not need to return money to limited partners after a set period of time. They can leverage technical and industrial expertise to

perform due diligence and support the startup. Traditional investors often see corporate involvement as mitigating the technology risk of their participation.

While most CVCs have strategic interests that are broadly aligned with the financial interests of other investors, they can differ on priorities and exit strategies. Investors and startups need to assess such factors as exclusivity, veto rights, and rights of first refusal when coinvesting with corporations.

facilitate their access to market by leveraging the group's industrial experience and global customer base. It is a win-win relationship; Air Liquide can access new technologies, and startups can accelerate the industrialization of their solutions. WeHealth by Servier helps startups with its expertise and knowledge of patients and health providers as well as other capabilities.

If they join the right ecosystem and make the right moves, forward-looking companies have the chance to disrupt themselves and their industries while leveraging their incumbent physical and IP assets to establish lasting advantage. But entrepreneurs are also wary; they know that cultures can clash, corporate partnerships are difficult to make work, and things do not always work out. Instead of marrying the agility of the startup and the power of the large company, collaborations can easily crumble under the fragility of the startup and the inertia of the large company.

Other ecosystem participants have their own concerns about corporate participation. If corporate involvement includes an ownership stake, investors in particular see a potential roadblock to their own profitable exit through a trade sale or an IPO. Because of the interconnected nature of the deep tech ecosystem and the win-win nature of success, large companies need to consider carefully the needs and priorities of other participants as they consider how to play.

Investors. Venture investing has become increasingly competitive as the number of venture capital firms rose 8% a year from 2007 through 2017 and the amount of venture capital raised increased 12% a year from 2010 through 2016. The expansion of available capital has caused investors to compete on other attributes, such as business expertise, the ability to make high-level connections, and hands-on support in legal or HR. Competition has also led to an increasingly specialized approach, with some investors focusing on a few technologies or sectors and adjusting their time horizons for generating a return. Wise entrepreneurs often refuse the highest financial offer in favor of gaining access to critical nonfinancial resources.

Universities and Research Centers. Besides being institutions of learning and research, universities are accelerating the development of innovation and innovation capabilities as well as technology transfer. Many are actively involved in helping faculty, students, and alumni foster, test, and develop novel ideas by providing technical facilities, entrepreneurship programs, accelerators, and even venture funds. But this should not jeopardize their role in the basic research that fuels long-term innovation.

Universities also serve as active ecosystem builders by bringing together (physically and virtually) networks of individuals with relevant technical backgrounds from industry and other fields of endeavor. (See the sidebar “Ecosystem Engagement at the MIT Media Lab.”) We estimate that some 1,500 universities and research labs worldwide are involved in deep tech R&D. The number of entrepreneurship courses grew by a factor of 20, from 250 in 1985 to 5,000 in 2008; they currently serve some 400,000 students a year. Research by the OECD shows the number of doctoral candidates increased by big double-digit percentages from 1998 through 2014 in the 15 largest doctorate markets; 40% of these postgrads are STEM students.

A growing number of universities are building strong relationships with industrial partners, seeking to accelerate both learning and IP transfer through collaborative partnerships and consortia. Examples include WeHealth by Servier with the University of California, San Francisco's Center for Digital Health Innovation or MIT AgeLab, which has multiple partners from other sectors and explores new avenues for meeting future needs in medicine and connected home care.

Governments. As noted in the previous chapter, governments support deep tech R&D but with varying degrees of intensity and cash. In recent years, China's government has been by far the most aggressive, one reason that the country has emerged as a major force in technology R&D. The US government, which in the past was a big supporter of technology R&D, has let the center of activity shift to the private sector. A 2015 report by MIT highlighted a number of specific areas in which the US government plays a reduced role in basic research, including health, energy, supercomputing, and space.⁴ European governments are active but less muscular.

On a global basis, direct government grants for deep tech R&D have shown an inconsistent pattern in recent years. The number of grants rose from 2,200 in 2013 to 3,200 each in 2015 and 2016 but dropped back to 1,500 in 2018. Dollar volume increased from \$4.5 billion in 2013 to \$6.1 billion in 2015 but fell to \$4.7 billion in 2018.

Facilitators. Facilitators include incubators and accelerators, facilitating laboratories (fab labs), and groups that organize competitions, events, and communities. They focus on connections, mentorship, and facilities provision and are a differentiating factor for deep tech ecosystems. Facilitators are predominantly local, and their presence makes an important contribution to the dynamism of a local ecosystem. But they are expanding their footprint, and the ability to provide international connections and

4. To learn more about the drop in US investment, see *The Future Postponed: Why Declining Investment in Basic Research Threatens a U.S. Innovation Deficit*, MIT, April 2015. <https://dc.mit.edu/sites/default/files/Future%20Postponed.pdf>



Ecosystem Engagement at the MIT Media Lab

Founded in 1985, the MIT Media Lab is a research institution that eschews traditional academic disciplines in favor of a thematic approach that encourages “antidisciplinary” research often focused on developing new and unique technologies. Today, more than 800 faculty, research staff, visiting researchers, and others work in over 25 groups on more than 750 projects, many of which involve deep technologies, including robotics, advanced computing, and advanced imaging. According to the Lab’s website, “Researchers are committed to delving into the questions not yet asked, whose answers could radically improve the way people live, learn, express themselves, work and play.”

The Lab engages with its member consortium—it has more than 80 sponsors, many of which are companies that provide funding, connections, and other forms of support. The Lab operates on an undirected research model; sponsors fund general research rather than specific projects—an approach consistent with ecosystem advancement. Members gain access to the Lab’s IP without paying licensing fees or royalties.

market opportunities is an important advantage for them. In 2018, there were 1,200 fab labs and more than 1,500 deep tech incubators and accelerators worldwide. The rising level of facilitator activity is also evident in the soaring number of meetings and conferences. The number of all such events in Europe jumped from 8,000 in 2012 to 63,000 in 2017.

Dynamic Structures and Relationships

Deep tech ecosystems are more dynamic and fluid than other types of ecosystems. As an emerging technology or industry grows and matures, so do the relationships between the ecosystem’s stakeholders. From the research phase to commercialization, roles and expectations evolve. Compared with early-stage startups, for example, mature startups in the commercialization phase need expertise and lab and testing facilities less, and talent, visibility, and access to the market more. (See Exhibit 15.)

The attractiveness of various types of partners shifts as well because startups turn to different stakeholders over time in order to obtain access to needed resources. For example, the percentage of qualified startups in the 2018 Hello Tomorrow Challenge that are looking to corporate partners for help with product development drops from 38% to 24% between the experimental and the commercialization stages, while the percentage seeking assistance with product distribution rises from 24% to 47%.

Corporations and investors seek financial returns, but in the early phases of technology development, they might have other more important priorities, such as access to knowledge in a particular technology or the desire to have a stake in the game in case things start to take off. When the prospects for commercialization become more concrete, the focus shifts to financial goals. As a consequence of these evolving needs and priorities, the nature of collaboration also changes, and companies deploy different tools and models for their ecosystem participation.

Exhibit 15 - Deep Tech Startups’ Most-Needed Resources Evolve as the Company Matures



Sources: Hello Tomorrow Challenge; Hello Tomorrow and BCG analysis.

Note: Based on data from 1,646 deep tech startups that qualified for the second round of the Hello Tomorrow Challenge in 2018 (from 4,500 applications). TRL = technology readiness level on a NASA-originated scale of 1 to 9.

A Horizontal and Decentralized Structure

Even when an ecosystem has a strong orchestrator (generally the participant that brought the other parties together), rarely is any entity in complete control. The orchestrator's role is more that of magnet than managing partner. Each partner can influence the direction of the whole. Larger and more financially powerful participants, though not central to the ecosystem's purpose, can play an influential role, such as setting the direction that the research and market development take. Alliances among participants can also shift the balance of power over key strategic questions.

Ecosystem management can be as much an exercise in diplomacy and negotiation as business strategy and direction. Ecosystem development is driven by alignment around a common vision, body of knowledge, and concrete goals. But for ecosystems to be sustainable, the stakeholders need to share goodwill and competencies, and they require mechanisms to manage expectations and control commitment. For some, questions of responsibility and potential liability could provide sticky points of contention. How is responsibility determined for the safety of autonomous vehicles, for example?

Nonfinancial Linkages

Traditional financial measures, such as revenues and profits, are not always the best means for assessing value realized. Deep tech ecosystems often involve relationships that are built around nontraditional, indirect, or nonfinancial linkages (involving data or services, for example) that push corporations, startups, investors, and others to develop new models for collaboration and remuneration. Ecosystems trade in a variety of currencies at the same time.

The Rules of Win-Win in Deep Tech Ecosystems



How each participant approaches the ecosystem affects its ability to achieve value as well as influence others and the whole. Our next publication in the deep tech series will examine this question in more detail, but companies, investors, startups, and others should be guided strategically by three questions about themselves and their goals.

What Do We Bring to the Ecosystem?

Since ecosystems operate on a win-win model, each participant needs to think about not only its own goals but the goals of the whole and how it can help the ecosystem advance a particular technology or market. The answer may be money, data, expertise, market access, or some other attribute. All participants need to contribute their currency, and make the ecosystem stronger, before they can realize their individual gains. Ecosystems by definition collaborate. Corporations and investors in particular need to play an active role in developing the ecosystem, regardless of immediate individual gain, to establish their own positions and encourage others to work with them. This is especially true when the primary focus is developing a new technology platform. Competition may return to the mix as the focus shifts to developing business applications for the new technology.

One key to the success of an ecosystem is for each participant to demonstrate the ability to build collaborative relationships that extend beyond those that already exist in current industrial value chains. One challenge is to align around a shared vision with short- and long-term goals and a shared body of knowledge. For example, in the space industry, the historical leaders have been the integrators of complex products, such as launchers and satellites, while startups are now developing new commercial applications. But all need an aligned vision in order for the launchers to be adapted to a new space market.

Another challenge is to “find what you are not looking for”—that is, to develop new solutions through the convergence of expertise from unconnected fields or industries. (For example, Tara Expeditions put scientists who analyze the human microbiome in an environment where they can apply their expertise to the ocean’s microbiome.) The key is not to rely on serendipity only but to intentionally bring unconnected expertise from distant industries to bear by expanding and sharing a common body of knowledge.

Sometimes ecosystems take root simply because organizations are in contact (through procurement and sales teams, for example), but these contacts are not initiated by the people or functions that can pursue codevelopment of ideas, especially those involving basic research. They can evolve into more collaborative associations.

The win-win nature of deep tech ecosystems requires that all participants invest time and effort in developing a 360-degree and almost exhaustive view of the main stakeholders’ goals, needs, and priorities, including a full understanding of what, specifically, constitutes a win for them. More often than not, these wins relate to the multiple currencies of the ecosystem, such as data, knowledge, and expertise, rather than money. No two ecosystems are the same, so participants need to adopt a user-centric and bottom-up approach to understanding what drives other players.

Because there are few models to adopt or roadmaps to follow, all participants must think not only about the development of the technology but about how to jump-start nascent or nonexistent markets. They face challenges of industrialization and scaling up production. Corporate participants have lots of experience in both areas. Some groundbreaking products are based on advanced materials and newly developed resources, so startups need sharply honed business and industrial skills, or the help of others, to work through challenges such as procurement, manufacturing, and achieving scale. Investors and universities have access to other entrepreneurs who may have encountered similar issues.

For corporations in particular, getting value from deep tech ventures depends in part on engaging the relevant people and parts of their own businesses. The company needs to identify the capabilities that potentially provide value to the ecosystem—for example, data and access to customers, networks, mentors, and technical experts—and allow others to navigate as freely as possible among them. Creating a network of engaged experts and champions across the business to act as project managers for deep tech collaborations can help. Immersion programs enable talent from the company to work with startups for predetermined periods. In addition to providing startups with access to expertise, such programs help companies enrich the development of their up-and-coming executive talent and emphasize entrepreneurial values in their own corporate culture.

What Do We Want from the Ecosystem?

All participants should also be clear on why they are engaging with the deep tech ecosystem and what they hope to achieve. One answer for many, of course, is ROI, but the goals—and their associated timeframes—should be detailed with as much specificity as possible. Participants need to assess the value realized from all dimensions, not only financial ones. Since the monetization of technology in its early stages can be difficult to predict, participants also need to build use cases and define the value of participating in them before developing business models.



All participants need to contribute their currency, and make the ecosystem stronger, before they can realize their individual gains.

Goals need to be laid out clearly in engagements with others so all participants interact with as much transparency as possible. This may constitute a change in behavior for many companies and investors that are not used to sharing their internal thinking publicly (or even on a wide basis internally). But our experience has shown that a major impediment to deep tech success is a failure to clearly define a relationship right from the beginning; participants need to agree upfront on vision, business, knowledge, and HR objectives and must be able to update this definition as the relationship evolves.

Like financial metrics, traditional KPIs, which are based on past results, often are not the best indicators of success.

In a complex environment, where not only change but the nature of change are often unanticipated, deep tech organizations and therefore ecosystems frequently adapt their management styles on the basis of feedback from employees and stakeholders. This typically leads away from strict and vertical hierarchies toward more horizontal and informal ways of operating.

Companies also need to make sure that leadership and the organization are aligned behind deep tech ventures. Both BCG and Hello Tomorrow have found that a failure to define a clear status and role for startups within the larger company, the absence of high-level sponsorship for the startup, and a lack of buy-in from the core business are all factors that can hinder investments in new ventures, especially those that are complex, slow to develop, and require nurturing over time.

How Do We Interact with Others to Achieve Our Goals?

Two characteristics of ecosystems require a rethinking of textbook management techniques, especially for more traditional participants.

First, ecosystems are collaborative—they grow and strengthen through the continual interaction of all stakeholders—and the need for collaboration can trump more traditional competitive considerations. An automotive and an aerospace company might work with a startup on the development of next-generation batteries but so might two automakers, the startup, and a government agency because they all want the technology to come to market. Investors and companies typically have different goals and timeframes, but they each bring strengths that the entire ecosystem can benefit from, so they need to

find ways to overcome such issues as conflicting exit strategies.

Networks play an important role in collaboration because they foster the exchange of different ecosystem currencies. By interacting with universities, for example, companies and investors can learn about the latest ideas and even help determine how they are developed. Universities can learn about funders' priorities and ways that developers of emerging technologies can go about building a nascent market. Any participant can take a technology that is not finding a market in one area and transfer it to another where it can solve different problems. Facilitators play a key role in connecting participants through a variety of vehicles, such as conferences and competitions.

Second, ecosystems are loose associations with uncertain futures and paths of progress. Any given startup—or emergent technology—may or may not succeed. There is enough uncertainty that traditional top-down strategy often loses out to other influences in the ecosystem. Different management approaches can definitely provoke, foster, and increase the odds of the desired result, but they cannot engineer it.

In such an environment, companies and investors should not think in terms of a single “bet” or “bets.” They need to engage with and nurture the entire ecosystem and look for the winning startup or technology to emerge from it. This could mean, for instance, getting involved in associations or challenges (such as the one organized by Hello Tomorrow) and supporting facilitators or even playing a facilitator role to strengthen the ecosystem and increase the chances that the right technology matures. Investors can play an important role in cross-pollinating different parts of the ecosystem, transferring technology from one area of application to another. Both investors and corporations can also influence the part of the ecosystem that they want to nurture through the use of different incentives.

Corporate partners may have the most difficult time adjusting to the ecosystem model. They need to think carefully about how they organize and staff their innovation and R&D programs and vehicles (such as CVC funds and incubators) to interact with others. Many will need to overcome slow and bureaucratic processes and governance procedures in order to engage more nimbly with fast-moving startups. They need to make ecosystem management an important piece of the overall innovation strategy by putting the right people, tools, and methodologies in place. This may require breaking down organizational silos and connecting areas of different expertise.

Finally, all participants can learn from failures. It is in the very nature of deep tech that many ventures will not succeed. But they will almost always impart lessons that can inform the next initiative or collaboration.

We are in the early days of the new deep tech ecosystem paradigm. Players, roles, and rules will all evolve as new discoveries are made and technologies demonstrate their potential. Perhaps the first rule for all would-be stakeholders is to set their goals and get into the game. Only then can they really learn and tap into the power and potential of the win-win ecosystem.

A circular opening in a wooden structure, looking out onto a bright sky. The wooden structure is made of many small, rectangular pieces arranged in a circular pattern, creating a grid-like texture. The sky is a pale, overcast blue. The text is centered within the circular opening.

Companies and investors should not think in terms of a single “bet” or “bets.” They need to engage with and nurture the entire ecosystem and look for the winning startup or technology to emerge from it.

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