Additive Manufacturing Needs a Business Ecosystem

December 2020

By Wilderich Heising, Ulrich Pidun, Thomas Krüger, Daniel Küpper, and Maximilian Schüssler

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Additive Manufacturing Needs a Business Ecosystem

When it comes to realizing the growth potential of additive manufacturing (AM), industry players have been their own worst enemy. Although equipment providers, in particular, have enjoyed high margins by employing a razor-and-blades business model, intense competition within and across value chain segments has impeded end users' adoption of industrialized AM applications. As a result, despite high expectations, the industry remains a niche market.

The AM industry's natural business ecosystem has encouraged some companies to work together. But to unleash the potential of AM, industry players should go further and collaborate to advance the technology, identify new applications, and enable users to fully exploit its advantages. Research by the BCG Henderson Institute points to the concept of an actively managed business ecosystem as the best way to accomplish this goal.

Business ecosystems have important advantages over classic organizing structures, such as hierarchical supply chains or vertically integrated companies.

Well-managed business ecosystems have important advantages over classic organizing structures, such as hierarchical supply chains and vertically integrated companies, that are typically used to create a product or service. For example, managed ecosystems are made up of multiple partners that can contribute their specific capabilities toward "co-innovating" and developing new products and services. Such ecosystems can also scale quickly because their modular structure makes it easy to add partners. And they are very flexible and resilient because they enable a greater variety of offerings and adapt more easily to changing customer requirements and technologies.

The AM industry can use these advantages and apply the lessons learned by other successful managed ecosystems in order to foster collaboration among independent companies.

The Ecosystem Offers a Solution to Unmet Expectations

Since the 1990s, AM has been heralded as the answer to some of the most pressing issues in the manufacturing industry. Many have recognized AM's potential to promote a step change in productivity by reducing tooling costs, cutting the lead time for machine setup, and trimming raw-material waste. They also have seen the endless possibilities for customization and design flexibility.

In fact, several years ago, analysts projected that the AM market would exceed $20 billion by 2020. However, the reality has fallen short of expectations. At the end of 2019, AM was still a niche market, with a value of approximately $12 billion.

Intense rivalry has hindered efforts to increase the adoption of AM. Traditional companies have expanded their role along the value chain, and new ones have entered the market. Even end users have integrated backwards along the value chain—for example, in 2016, GE acquired Concept Laser and Arcam AB, two leading equipment providers for metal-based AM. As players are fighting for their share of the market, the AM industry is facing ongoing disruption.

Rather than seek advantage by undermining other industry participants, AM players should collaborate in an ecosystem—a dynamic group of largely independent economic players that create products or services that together constitute a coherent solution. This ecosystem should be characterized by a specific value proposition (the desired solution) and by a clearly defined, albeit changing, group of partners with different roles (such as producer, supplier, orchestrator, or complementor).

However, certain preconditions make an ecosystem work. It is best suited to a business environment that is both unpredictable and highly malleable. Specifically, offerings must be highly modular and require high levels of coordination to produce. Furthermore, because success requires joint problem solving, players need to have an incentive to participate.

In considering whether an industry meets the preconditions, the first issue to assess is which players and information, goods, and services are required for a coherent solution. In the case of AM, these players typically include:

- Suppliers of raw materials and formulations
- Providers of AM equipment
- Software companies that develop design and simulation software
- Service bureaus that print parts on demand

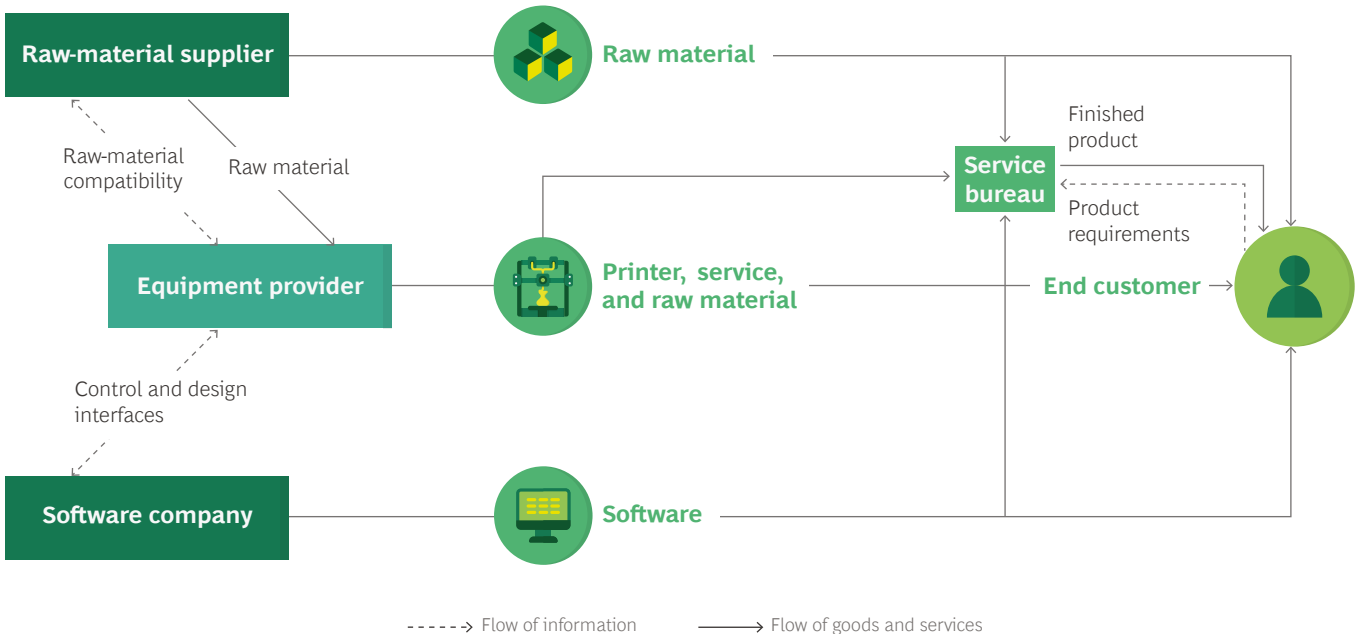
The AM industry can be mapped in a blueprint that connects these players along the flow of information and the flow of goods and services. (See Exhibit 1.)

An ecosystem is best suited to a business environment that is both unpredictable and highly malleable.

This blueprint, along with an analysis of the underlying activities, indicates that AM fulfills all relevant preconditions for successfully applying an ecosystem model:

- **A High Level of Modularity.** The solution is best created by flexibly combining components that are provided by various players, and the integration of components entails low transaction costs.
- **A Significant Need for Coordination.** The required partners for a specific solution are not easy to identify and match because the interfaces between components are not fully standardized.
- **A Problem That's Better Solved Jointly.** Achieving objectives that maximize end-user benefits, such as production flexibility and customization, can't be done singlehandedly.

Exhibit 1 - The Blueprint of the Additive Manufacturing Ecosystem



Source: BCG analysis.

The Challenges to Creating an Effective AM Ecosystem

Although AM meets all the preconditions for a successful ecosystem, industry players must overcome a variety of challenges to enable strong and coherent collaboration.

Innovating Collectively. In order for an ecosystem to function properly, multiple players must contribute innovations that when combined can achieve a common objective. If players do not co-innovate effectively, the ecosystem will fail—even if only one critical component is missing. Assessing the potential for co-innovation is therefore key to evaluating an ecosystem's probability of success, as well as to identifying the components that need most attention to prevent bottlenecks. The primary objective should not be to win the race to market but to develop a set of innovations that provides a coherent and compelling offering for end users.

To understand the importance of co-innovation, consider the race between Nokia and Sony Ericsson to bring to market the first 3G mobile phone that was capable of video streaming. Nokia won the race, selling its first 3G handset in 2002. But, as described in the book *The Wide Lens: A New Strategy for Innovation*, other players in the ecosystem had not yet developed the technologies and services that were needed to fully enable video streaming, including those for digital rights management. Until these innovations were in place, 3G video streaming was not viable, rendering the new handsets largely useless other than for making phone calls.

Similarly, a lack of co-innovation has prevented AM players from developing large-scale compelling use cases for major industrial players. To promote significantly higher adoption, AM players must work together to eliminate AM bottlenecks relating to production speed, raw-material properties, and engineering and design capabilities. Companies must also work to improve software solutions that integrate planning, production control, and logistics. Industry players must collaborate to address these innovation challenges—a single company cannot do it alone.

Balancing Market Growth and Monetization. Before companies agree to participate in an ecosystem, they must see opportunities for joint value creation and be assured that they can capture their fair share of the value created. That makes establishing a value proposition and monetization mechanism essential for building and sustaining the ecosystem. Unlike most traditional product or service businesses, however, ecosystems should focus on establishing their value proposition for customers before putting too much emphasis on monetization. In other words, these ecosystems should seek to grow the market before distributing the value created.

Those ecosystems that focus on monetization too soon typically lose out to competing ecosystems. Consider the competition in China between eBay and Alibaba, two e-commerce ecosystems. EBay charged customers a transaction fee, whereas Alibaba offered a commission-free marketplace to promote rapid growth. Once Alibaba had captured a large user base, the company sought to monetize it through advertising and complementary product sales, and it prevailed over eBay.

> **Ecosystems should seek to grow the market before distributing the value created.**

Many providers of AM equipment, especially for plastic-based applications, have similarly focused too much on *capturing* value by increasing margins, rather than on *creating* value by increasing the size of the market. Equipment providers typically employ a razor-and-blades model in which they require end users to purchase raw materials from them, instead of allowing end users to select a raw-material supplier. Although this model fosters equipment providers' profitability, it has impeded the growth of the AM market. The absence of competitive pricing for materials has increased the cost of production for end users. It also has limited the possible use cases for AM because equipment providers offer a more limited portfolio of materials than would be available in an open ecosystem.

Achieving Demand-Side Economies of Scale. Like most traditional business models, many ecosystems promote supply-side economies of scale through declining fixed or variable costs. But unlike traditional models, ecosystems also have the potential to generate demand-side economies of scale (also known as network effects)—as more users participate in the ecosystem, it becomes more attractive to additional users as well.

Airbnb is an example of an ecosystem with substantial demand-side economies of scale (in addition to supply-side economies of scale from spreading the high fixed-cost of technology and marketing across many landlords). As the number of landlords offering rooms increases, more potential tenants are attracted to the platform, which in turn attracts more room offerings, resulting in a positive feedback loop. The flywheel effect enables the ecosystem to capture most, if not all, of the market share.

The AM industry today has supply-side economies of scale, but players have not exploited the potential for demand-side economies of scale. For example, the industry could foster the faster expansion of software applications or the development of standards. This would help engineers understand how to design for AM manufacturing (a lack of knowledge is a major limiting factor for adoption today) and increase the breadth and attractiveness of potential applications for customers.


The AM industry can apply the lessons learned by other successful ecosystems to foster collaboration among companies.

How to Design an AM Ecosystem

Designing an ecosystem is a complex undertaking—one that's more like conceiving of a residential district than planning a single house. By learning from successes and failures of ecosystems in other industries and making the right design choices, AM players will be able to address the challenges outlined above.

Select an Orchestrator to Take the Lead

To address the co-innovation challenges, as well as other coordination issues, an ecosystem needs a central entity that assumes a leadership role. This role can best be described as the orchestrator. The orchestrator builds the ecosystem, encourages others to join, defines standards and rules, and acts as the arbiter in cases of conflict. As the residual-claim holder of the ecosystem, the orchestrator must also make sure that all relevant players earn a decent profit. In return for its efforts, the orchestrator keeps the residual profit, which can be substantial if the ecosystem is successful.

> **The orchestrator builds the ecosystem, encourages others to join, defines standards and rules, and acts as the arbiter in cases of conflict.**

Sometimes a company recognizes that an orchestrator is needed. For example, according to the book *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*, Intel realized in the 1990s that its increasingly powerful microprocessors would have only limited benefits for users unless other component players in the PC system redesigned their products to be compatible with the chips. To orchestrate the ecosystem of component makers, the company created the Intel Architecture Lab. The lab sought to promote architectural improvements for PCs, stimulate and facilitate innovation on complementary products, and coordinate outside firms' innovations to drive the development of new system capabilities.

In many ecosystems, however, it is not clear which entity should be the orchestrator. The choice for the role can be narrowed by assessing the players according to these criteria:

- Is a company an essential member of the ecosystem, and does it control key resources?
- Does a player hold a central position and share strong interdependencies with other ecosystem participants?
- Is a company perceived as fair (or neutral) by other participants?
- Is a player likely to gain a large benefit, and can it shoulder large upfront investments?

Considering these criteria, equipment providers could be viewed as the natural candidates to fill the orchestrator role in the AM ecosystem. In addition to controlling essential resources (printers), equipment providers are centrally positioned with strong interdependencies to all other players, and they are likely to be perceived as fair or neutral. They also stand to gain large benefits from broad adoption. However, other players, such as raw-material suppliers, could also aim for the orchestrator role, provided that their estimated benefits are large enough to justify the investment and that they are able to position themselves as a fair or neutral player.

Recognizing the significant benefits of being an orchestrator, some industry participants have initiated intensive efforts to enhance coordination among all players. For example, the printer manufacturer EOS is seeking to improve the sharing of application know-how. It has also launched a consulting branch, called Additive Minds, to integrate multiple solutions into a single offering. Additionally, EOS has joined forces with Daimler and Premium Aerotec to develop custom-made and ready-to-use production lines for aluminum parts. The overall goal of these efforts is to promote greater adoption of AM in serial production through increased automation, the standardization of interfaces, and the use of software that connects automation with overarching software platforms, such as EOSConnect or Siemens NX.

Providing standardized interfaces for all ecosystem players provides another opportunity for a company to step up to the orchestrator's role. For example, Siemens has started the Additive Manufacturing Network to connect players via an online platform that offers streamlined collaboration, quoting, procurement, and order monitoring processes.

If none of the equipment providers are willing or able to take on the orchestrator role, raw-material suppliers have an opportunity. BASF, for example, has moved to obtain a strong foothold in the AM market by bundling its offerings within its Forward AM subsidiary. The company's full-service solution addresses many of end users' unmet needs, including optimizing part designs, simulating part and process properties, testing part behavior under load, finishing printed objects, and determining the most suitable 3D-printing process. The company continually adds capabilities by integrating service bureaus worldwide into its network.

By improving the coordination between the players, or in some cases taking responsibility to address some bottlenecks, an orchestrator can accelerate AM adoption and resolve many of the existing co-innovation challenges more rapidly than many players currently expect is possible.

Employ a More Open Governance Model

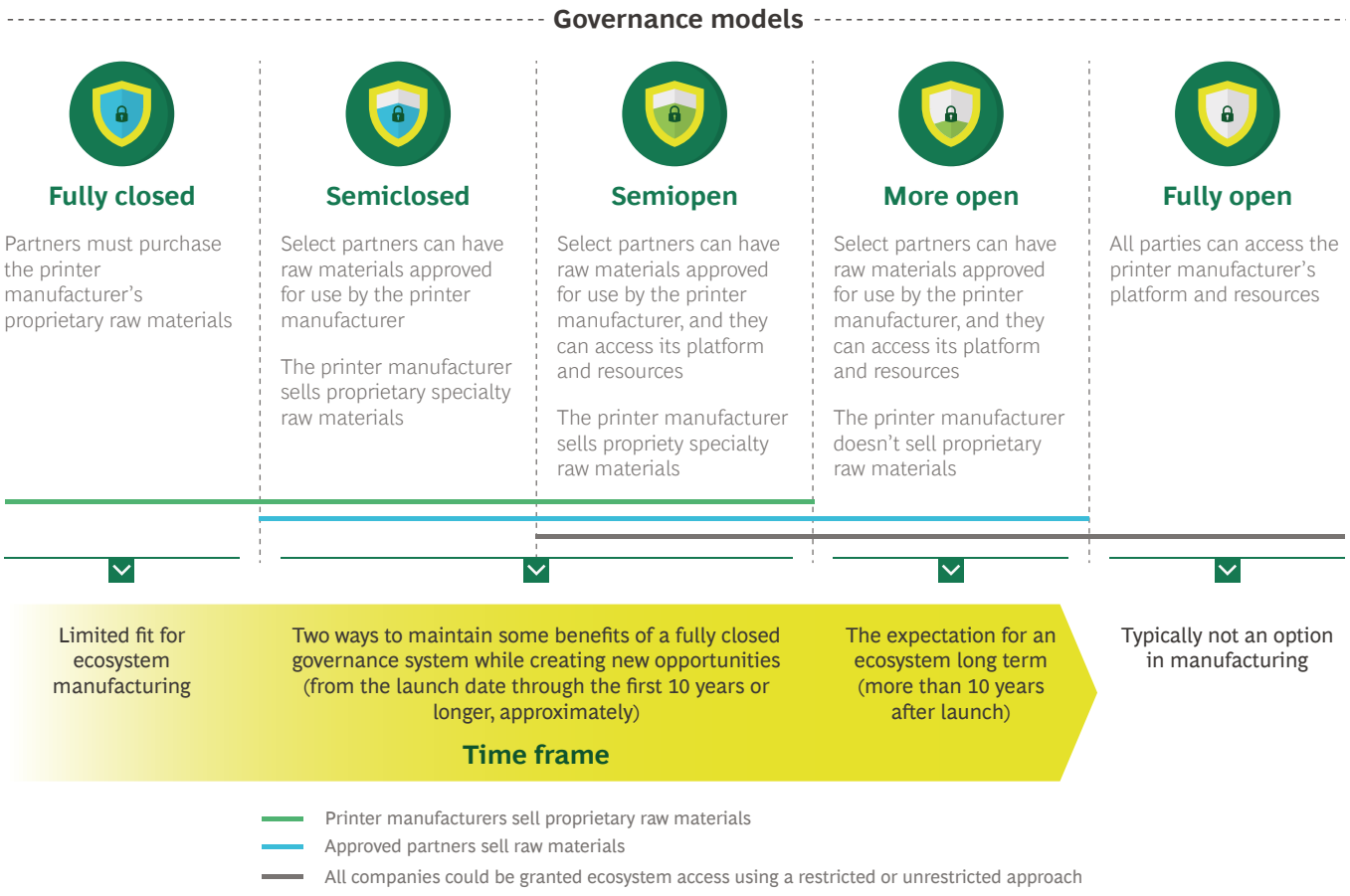
The governance model defines the rules and boundaries within which participants operate in an ecosystem. Implementing the right governance model at each stage of the ecosystem's development is critical to striking the appropriate balance between market growth and monetization.

Governance can be broken down into three basic issues:

- **Access.** Which players will be allowed to participate in the ecosystem? Which requirements do they have to fulfill in order to gain access to the platform and its resources?
- **Participation.** To what extent are ecosystem partners invited to shape the ecosystem? What is the scope, detail, and strictness of the rules governing this? Who decides how the value created is distributed among partners?
- **Commitment.** What levels of ecosystem-specific investments and "cospecialization" among partners are required? Is exclusivity demanded, or are partners allowed to join other competing ecosystems?

The choices relating to these governance issues depend on where the participants, under the leadership of the orchestrator, want the ecosystem to be on the continuum between fully closed and fully open. For example, a closed ecosystem, with restricted access, gives the orchestrator greater control over the development of the ecosystem and the behavior of participants, which ultimately helps to ensure the quality of the offering. (See Exhibit 2.) It also facilitates monetization, such as by making it easier to charge participants for access. In contrast, an open ecosystem, with looser restrictions on access and behavior, fosters faster growth and increases the speed of innovation.

Exhibit 2 - Choosing the Right Level of Access Is Critical



Source: BCG analysis.

The right balance between a closed and open design may change as the life cycle progresses. For example, Google initially designed an open ecosystem for its Android mobile operating system in order to promote growth that would allow Android to catch up with Apple's iOS. To incentivize developers to join, Google shared jointly created value with them by taking a commission on app sales that was lower than the one Apple charged. After Android achieved a leading market position, Google increased its control of the ecosystem—such as by exercising approval rights over changes to the operating system and increasing its commission on app sales.

For AM, a relatively closed ecosystem seems to be better suited to the industry's needs, at least initially. In the early stages of ecosystem formation, AM players need to make deliberate choices on design, control participation, and manage downside risks effectively. Indeed, 3D Systems, EOS, and Stratasys have followed a relatively closed model for their AM ecosystems. However, this approach has led to higher prices for the end user and limited experimentation with new materials, ultimately resulting in a slower adoption of AM solutions.

In our view, the AM industry will soon be ready to take the next step in its development. Players should focus on fueling growth and innovation, tapping the creativity of a broader set of players, and growing the pie.

Some entrants to the AM industry, such as HP, have used a more open or semiopen platform model and not compromised on quality. For example, in HP's ecosystem, material suppliers qualify their materials via a process that is transparent to end users as well as to other material suppliers. This enables the ecosystem to build a broader material database and gives end users the opportunity to source materials at the lowest available price and with the best-suited properties for the application. The ecosystem also has an innovation platform that software companies and other innovators can use to advance the development of software across a variety of applications.

An open ecosystem model needs to be supported by industry standards. For example, a consortium of large equipment providers and software developers have established an improved 3D-printing file format called 3MF. The format makes the design-to-print process easier and more intuitive. AM adoption can also be fueled by using open application programming interfaces (APIs) and expanding the use of data.

Experiment with Innovative Monetization Strategies

In defining an ecosystem's monetization strategy, participants must balance competing objectives: maximizing the size of the total pie, ensuring fair value distribution, and anticipating scale effects that kick in when the ecosystem matures. The appropriate balance depends on the answers to three questions:

- What should the ecosystem charge for?
- Whom should the ecosystem charge?
- How much should it charge?

In general, an ecosystem should design a monetization strategy that encourages and incentivizes participation, thus fostering network effects. Moreover, the ecosystem should use monetization to overcome AM bottlenecks by subsidizing R&D investments, for example. The ecosystem should also encourage innovation by offering better terms for new products, including by providing support for development. For example, in its role as orchestrator, a printer manufacturer could cofund the development of advanced materials, thereby encouraging innovation by raw-material suppliers.

> **In addition to capturing margin, participants can set their prices to promote further growth and scaling of the ecosystem.**

In an AM ecosystem, as in other solution ecosystems, participants capture value by selling a product or service. In addition to capturing margin, participants can set their prices to promote further growth and scaling of the ecosystem. If possible, participants should also establish control points—products, services, or technical features that are essential to the overall solution—so that they can be monetized as the ecosystem matures.

For example, although Apple has historically been a product-focused company, it has built an ecosystem with a variety of monetization models that support a variety of revenue streams, including revenue from app commissions and subscription services. The models are generally designed to support further usage or growth of the ecosystem, while ensuring that Apple retains control of monetization opportunities.

To create additional value and encourage adoption, the AM ecosystem could experiment with more innovative approaches that other manufacturing-heavy industries have employed. These include:

- **Pay per Use.** The pay-per-use model has been a hot topic in the manufacturing industry in recent years, and adoption is increasing. For example, a laser manufacturer charges customers for the number of items produced using its equipment, instead of selling customers the production equipment. And an elevator company charges customers on the basis of their usage of its products. Such models lock in customers and generate steady cash flows. They also provide a way for companies to bring innovative machinery to the market, because customers only pay if the equipment delivers the impact promised by the innovation.

- **Data Sharing.** Equipment providers could offer customers reduced prices for machinery if they share the data that they generate by using the equipment. The provider could then sell the data to other parties interested in aggregated insights on the goods produced or processes used. By sharing data across companies, manufacturers can unlock additional value and accelerate innovation.

EOS pursues a mixed monetization approach. The majority of its revenue is from traditional printer sales and leasing as well as raw-material sales. In addition, the company offers full-service packages, which include personnel to operate the printers at the customer's site. EOS offers these packages mainly to customers that are new to AM. On the basis of the experience gained on these projects, the company created software solutions and platforms that let customers and partners apply pay-per-use models (for example, paying per laser- or machine-hour or per printed part).

One cautionary note: although new monetization models can provide additional revenue for some ecosystem partners and increase the adoption of AM by industrial companies, the models can have a negative impact on other ecosystem players (as does the razor-and-blades model). Thus, before implementing new monetization models, players should consider the potential negative consequences for their partners in the ecosystem.

Ultimately, each player should ask this key question: "How can my company make the best use of the ecosystem to earn money?" The answer to this question should focus on a joint approach that increases the size of the pie, not on maximizing one's own share of the pie at the expense of partners.

Solve the Chicken-or-Egg Problem During Launch

Solving the chicken-or-egg problem of creating a critical mass of both partners and customers during the launch is among the most difficult challenges ecosystems face as they seek to promote both supply- and demand-side economies of scale.

> **A successful launch requires not only a large enough number of participants but also the right participants in the right proportions.**

The traditional approach to product development calls for building a full version of a product and then testing it in a small pilot market, improving it, and rolling it out across the broader market. In contrast, as described in *The Wide Lens: A New Strategy for Innovation*, most successful ecosystems start by launching a minimum viable ecosystem (MVE) with limited scope that seeks to achieve full scale by quickly establishing a dense network of partners and customers. Over time, the ecosystem then can expand its scope and value proposition in a series of staged expansions.

For example, like other companies that make smart-home solutions, Amazon employed an MVE approach when it launched Alexa and focused on voice recognition, although it also included some early smart-light applications. The Alexa ecosystem then sequentially added more and more use cases, and Amazon now features more than 100,000 applications that can be downloaded in its store.

A successful launch requires not only a large enough number of participants but also the right participants in the right proportions. The challenge is that the breadth of suppliers affects the number of customers attracted to the ecosystem, and vice versa. Thus, the selection of early members and the sequence of attracting members can have a big impact on the ecosystem's success.

By adopting a business ecosystem approach, companies may achieve the long-awaited step change in the AM industry's development.

Achieving critical mass—on both the supply and demand sides—has been a slow process in the AM industry. For example, Stratasys, one of the largest equipment providers, took more than 20 years to reach sales exceeding $660 million. To foster the growth of the ecosystem, AM players can choose among a broad set of proven options. For example:

- **Start with a well-functioning customer application and then add others.** This approach is often used to introduce complex business-to-business solutions that use the Internet of Things. For example, Formlabs, a printer startup, initially focused on the consumer segment with simple products, but it soon expanded its offerings to professional users. It now emphasizes significantly more advanced products (such as industrial printers and materials and resins) for medical applications. GE uses key applications to showcase its AM offerings while adding applications that use more advanced technology. The most prominent example is its fuel nozzle tip for the jet engine. The company's superior design allows it to produce more efficient turbines.

- **Develop or acquire products to complement the core offering.** In the smart-home market, Amazon and Google have invested heavily in physical products that complement their voice technology. AM players have employed this approach—most notably, photopolymer printer manufacturers have developed their own photo resin materials. For example, Carbon, Inc., developed proprietary raw materials to boost its technology, and Markforged developed fiber-reinforced filaments for its thermoplastic extrusion printers.

- **Provide free or subsidized tools or services.** For example, Google's tools for search engine optimization create value for advertisers by allowing them to more effectively and efficiently use Google search (the company's core service). BASF gives its conventional-manufacturing customers free software to simulate properties of injection molded parts. The software runs optimally only when used with BASF's engineering plastics. A similar approach could be followed for printed parts. As an early example, Stratasys supports designers and engineers in its GrabCAD community by giving them free access to a computer-aided design library.

- **Demonstrate commitment to the ecosystem and partners by making large upfront investments.** For example, Xbox used this approach when entering the video game console market. By making credible commitments to the project, it convinced developers to create games exclusively for Xbox. HP employed a similar approach when entering the 3D-printing market. The company boldly positioned its technology as a replacement for injection molding and said it would use an open platform for raw materials. Industry participants considered both claims to be disruptive, which created strong traction for HP and helped to establish its brand in AM.

Taking Actions Jointly and Individually

To realize the growth potential of an AM ecosystem, the partners need to take actions collectively and individually.

All partners need to adopt an ecosystem perspective in order to understand interdependencies that lead to co-innovation challenges and to develop joint solutions. In developing solutions, it is critical to consider the tradeoffs between gaining advantages from increased adoption and potentially taking market share from partners in the ecosystem. To drive adoption of the solutions, ecosystem partners should create industry-wide standards. They should also experiment with new monetization models and innovative launch strategies.

Raw-material suppliers have an opportunity to increase the scope of their role in the ecosystem. This includes offering a wide variety of materials through multiple channels, taking a leadership role in the formulation and certification of new materials, supporting the development of a material database, and offering printing services. To be successful, suppliers need to clearly prioritize their focus application areas, better understand end-user needs (for example, through collaborations with service bureaus), and increasingly expand their offering (for example, by providing free support software).

Equipment providers that are considering launching an ecosystem should follow a three-step approach to taking on the orchestrator role, promoting standards, and fostering connections among ecosystem partners. First, the equipment providers should establish a semiopen raw-material platform that gives material suppliers access to the ecosystem, and they should use the platform to increase the range of applications and reduce material prices, thereby promoting adoption. If the existing AM equipment providers fail to open their systems, new entrants (such as HP) will have an opportunity to conquer the market with their more open approaches.

> **In developing solutions, it is critical to consider the tradeoffs between gaining advantages from increased adoption and potentially taking market share from partners in the ecosystem.**

Second, equipment providers should define industry standards and norms on the basis of the ecosystem's technology. Standards and norms facilitate part design and the approval and certification process and promote adoption among engineers in users' industries.

And third, equipment providers should use standardized and open APIs and other interfaces to facilitate the integration and use of the ecosystem's equipment in end-to-end production processes.

Software companies should encourage other ecosystem participants to employ a more open approach and to pursue standardization with respect to design as well as process-stability solutions. APIs will be essential to enable connections in the ecosystem and with end customers. Software companies should also seek to drive adoption by integrating their software into manufacturing execution systems. In addition, these participants have an opportunity to support less-experienced end customers by establishing their software platform as the single point of entry to the ecosystem. Finally, software companies are well positioned to evaluate and harness the potential of data sharing among players.

Service bureaus should support customers in navigating the AM ecosystem and exploit resulting business opportunities (for example, by offering value-added services and training for AM engineers). Through these efforts, service bureaus can avoid being commoditized as an outsourced labor force. To succeed in the emerging AM ecosystems, service bureaus should take advantage of their proximity to customers to understand unmet needs; offer value-added services—including virtual services (such as software and design platforms) and physical services (such as educating users, screening parts to identify future applications for customers, and optimizing designs); and team up with material and equipment players to optimize materials and printers.

Although AM offers great potential, it has yet to deliver on the promise of industrialized applications. By adopting a managed business ecosystem approach that is based on the success factors of other industry ecosystems, companies may finally be able to achieve the long-awaited step change in the AM industry's development.

About the Authors

Wilderich Heising is a partner and associate director in the Frankfurt office of Boston Consulting Group and a core member of the firm's Operations Center. He is a coleader of BCG's global work in advanced network optimization and of the firm's work in additive manufacturing in Europe. You may contact him by email at heising.wilderich@bcg.com.

Ulrich Pidun is a partner and director in the firm's Frankfurt office. He is a core member of the Corporate Finance & Strategy practice, an expert in corporate strategy, and a fellow at the BCG Henderson Institute. You may contact him by email at pidun.ulrich@bcg.com.

Thomas Krüger is a project leader in BCG's Frankfurt office. He is a core member of the firm's Operations Center, focusing on the digitization of operations and on additive manufacturing. You may contact him by email at krueger.t@bcg.com.

Daniel Küpper is a managing director and partner in the firm's Cologne office. He is a coleader of our manufacturing and supply chain team, and he leads BCG's Innovation Center for Operations. You may contact him by email at kuepper.daniel@bcg.com.

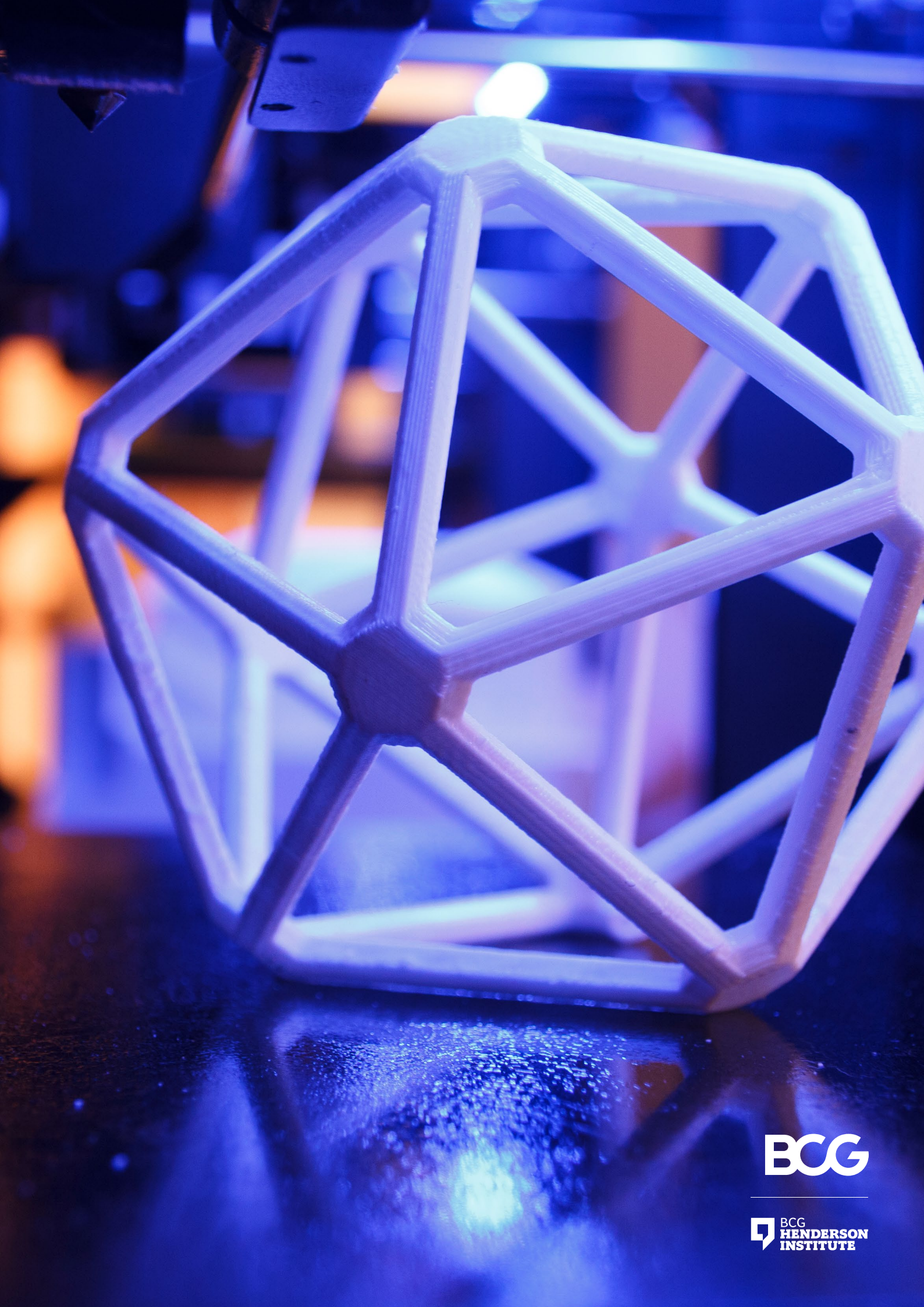
Maximilian Schüssler is a former project leader with BCG and a former ambassador with the BCG Henderson Institute.

Acknowledgments

The authors thank their BCG colleagues Dominik Deradjat and Niklas Knust, as well as Gerret Lukas and Tobias Stittgen at RWTH Aachen University, for their contributions to this report. They also thank Katherine Andrews, Kim Friedman, Abby Garland, David Klein, Shannon Nardi, Trudy Neuhaus, and Andras Szabadi for editorial, design, and marketing support.

For Further Contact

If you would like to discuss this report, please contact one of the authors.



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