AMVENTURES

ADDITIVE MANUFACTURING STARTUPS WHAT ARE THE KEY FACTORS FOR SUCCESS?

BY ALEXANDER SCHMOECKEL AND ARNO HELD

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IN BRIEF

Startups have been contributing to major technological innovation in the evolving additive manufacturing (AM) industry. By disrupting how companies are designed, these pioneers are driving AM toward industrial maturity. Using a proprietary database of AM startups, we determine what factors are key for startup success, drawing on the most recent high-tech literature.

Our findings reveal that a team's human capital, patent protection and its targeting of the B2B market significantly increase the likelihood of success. Furthermore, business model choice is important since it is a crucial source of competitive advantage. Our insights are relevant for AM practitioners and entrepreneurs alike.

This white paper is based on data provided through AM Ventures and on parts of the Master Thesis 'Success determinants of digital manufacturing startups: exploring the impact of founder's human capital, value capture and intellectual property' by Alexander Schmoeckel, written at the Chair of Entrepreneurial Finance, Technical University of Munich. It is meant as an insight into our findings. We hope that AM adoption in the market can be further accelerated.

WE PROVIDE INSIGHTS INTO

– why additive manufacturing startups have always been the driving force behind the AM industry
– the properties AM Ventures attribute to ultimate investment success
– to what extent human capital, business model choice and patent protection determine success

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MOTIVATION

A PREFACE BY ALEXANDER SCHMOECKEL

Why some startups succeed and others fail is one of the most important aspects of entrepreneurship. Identifying the factors that are key for the success of such companies enables entrepreneurs, their advisors and investors to draw their own conclusions and better assess their ventures accordingly. Not much research has been dedicated to the factors influencing the success of ventures in the field of AM.

Since its inception in 2015, AM Ventures has been interested in identifying these factors. This venture capital firm has scouted more than 2,500 startups in the business of developing hardware, software, materials and applications for industrial 3D printing.

We use this database and apply various regression models to test whether the properties that AM Ventures attribute to ultimate investment success are statistically significant. All data is based on the cutoff date 1 January 2021.

STARTUPS ARE THE DRIVING FORCE BEHIND THE AM INDUSTRY

More and more companies utilize AM for end-use products. The widespread use of AM shows that the technology is moving toward industrial maturity and the mass production scenarios can be expected in the long term. For about a year AM Ventures has also been seeing this big shift in its database: most of the identified startups are application-based **(see Figure 1)**. This increased AM adoption seen across multiple industries over the past decade is driven by innovation from companies that did not exist 10 years ago. New products and services introduced by Desktop Metal, Velo3D, Xometry, Markforged, Nano Dimension, Fast Radius, and Massivit 3D have transformed an entire industry. These players, today publicly listed companies, were startups and matured by employing proven methods of entrepreneurship and a mindset of venturing.
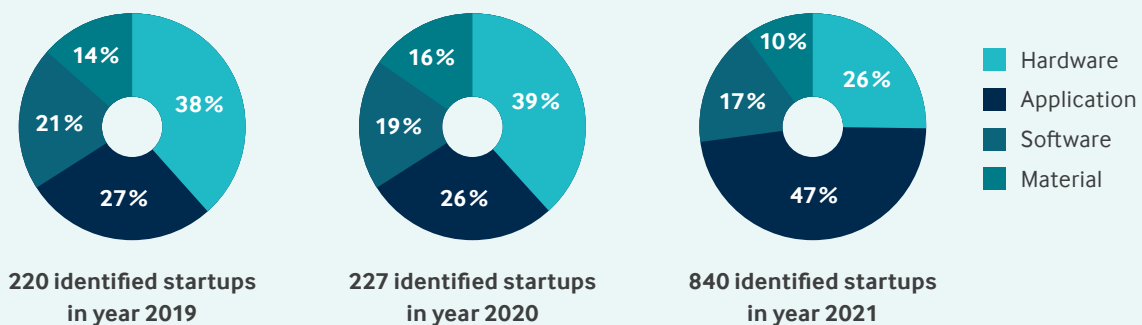
The first AM pioneers, such as 3D Systems, Stratasys or EOS, were also startups and designed their companies from the ground up. They realized that gradual change within legacy manufacturing structures does not allow for successful adoption of a new technology. Instead, a radical, completely new approach, a new way of thinking is needed, where everything — processes, the company culture and the entire organization — is centered around additive. That's what startups do — they disrupt how companies are designed.

Many startups have entered the market since AM first emerged in 1986 and have challenged manufacturing incumbents by presenting new concepts, methods and approaches to AM. Many technological breakthroughs in industrial 3D printing were achieved by startups, rather than large printing and engineering firms. These young innovative companies have always been the driving force behind the industry.

The AM landscape keeps growing. The big question for investors and startups entering the AM market is what factors contribute most to the success of AM startups. However, it is essential to start with how we define success for this white paper and how it should be measured in this context.

Figure 1: Application-based startups are on the rise

Hardware
Application
Software
Material

220 identified startups in year 2019: Hardware 38%, Application 27%, Software 21%, Material 14%

227 identified startups in year 2020: Hardware 39%, Application 26%, Software 19%, Material 16%

840 identified startups in year 2021: Hardware 26%, Application 47%, Software 17%, Material 10%

Source: AM Ventures

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VARIOUS APPROACHES ON HOW TO MEASURE SUCCESS

The literature uses various parameters and approaches for defining startup success **(see Figure 2)**. It is therefore difficult to find a meaningful definition straight away.

The term success can be interpreted from different perspectives. While an entrepreneur might define it according to whether the new venture achieves personal fulfilment, an investor considers success more from a financial perspective, for example, whether the portfolio firm generates the desired rate of return.

The most appealing approach to measuring success is by profitability. However, such data is largely unavailable to privately held companies. Differences between various investments in product and market developments enormously affect reported profitability. In addition, performance measures such as return on sales or net profit are more relevant for companies in their later stage. Early-stage startups are different, as they may initially have little or no revenue to report, and growth rates do not fully represent the real value of an early-stage firm.

AUTHORS	DEFINITIONS
March-Chorda (2004)	Success is defined by the number of jobs the company has generated.
Gelderen/Thurik/Bosma (2005)	It is given by its share in the market and the size of the customers.
Wong/Cheung/Venuvinod (2005) Hormiga/Batista-Canino/Sánchez-Medina (2011)	It is the growth of sales and profitability, which has to be similar or higher than the industry average.
Spiegel et al. (2016)	It is the good financial performance of the company.
Sulayman et al. (2014)	Success is in creating something that truly contributes to improving the lives of others.

Figure 2: List of success definitions used by various researchers

FOR OUR ANALYSIS WE MEASURE SUCCESS IN TWO WAYS

WE FOLLOW PRIOR STUDIES AND MANIFEST STARTUP SUCCESS IN TWO DIFFERENT WAYS:

1. First, we take the venture capital (VC) view. A successful AM startup is a new venture firm that has raised a high amount of VC financing. In this context, we measure success by the round of financing the AM startup was able to close. We categorize the startup from 'failure' to 'survival' to 'successful'. While we describe 'failure' as a firm that is out of business, 'survival' means that an AM startup has managed to acquire funding from a business angel or seed investor. We tag a startup as being 'successful' once it has been able to receive at least a Series A VC funding round or has even managed to go public or be acquired by another company.

2. Second, we describe the success of a startup in terms of firm size. We measure it by the proxy of its (log of the) number of employees. For high-tech startups, an increase in employees represents a direct indicator of growth, as it serves as a proxy for the growing managerial complexity.

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SUCCESS FACTORS IN THE MOST RECENT LITERATURE

AM Ventures is convinced that successful startups have certain properties **(see Figure 3)**. The AM Ventures team looks out for these critical elements when a potential investment company is evaluated. For this white paper, we focus on the founding team's human capital, business model choice and patent protection since they are important success factors in most recent literature on high-tech startups. First, we provide insights on this research and explain why the factors are important for ventures in the field of AM.

TEAM, TEAM, TEAM

When 885 institutional venture capitalists were asked in a recent study which factor they attribute to their investment success, the team was mentioned the most. One method we choose for capturing the team factor is by assessing the human capital[1] the founders possess. There are various ways to measure a team's human capital (e.g. educational background). In this white paper, we consider whether the entrepreneur already has experience in venturing prior to founding an AM startup.

Founding a startup in the field of AM is complex and challenging. Entrepreneurs are subject to large capital requirements in order to develop prototypes. In that regard, a serial entrepreneur may know from prior founding experience how to connect with VC investors to overcome the capital need. Furthermore, a serial entrepreneur may have a better network of contacts from experience at a previous startup, which helps in successfully launching a high-tech venture by partnering with suppliers. Studies show that serial founders are expected to have better managerial and technical skills and thereby be better equipped to recognize and exploit new business opportunities. Startups just entering the field of AM need to understand their business opportunities.

As for the representation of a team's human capital, we utilize the serial founding experience of the founding team. If one founder has prior founding experience, we assign the independent variable *Serial Entrepreneur* a value of '1', otherwise '0'.

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1   Human capital is generally described as capabilities, skills and knowledge that have been obtained from an individual's education and experience, see UNGER ET AL. (2011).

CRITICAL FACTORS AM VENTURES LOOKS OUT FOR

FOUNDING TEAM'S HUMAN CAPITAL
- Synergetic well-educated with leadership qualities and industry experience
- Knowledgeable in venture capital with a rough roadmap for funding and scaling in mind
- Clear alignment with the growth-oriented vision of the company
- Strong social and professional network

COMPANY ATTRIBUTES
- Clear growth-oriented vision for the company
- Good geographic location regarding labour pool, industrial and academic infrastructure
- A not too fragmented Cap table without any strong strategic players
- Multiple clear exit routes
- Thorough well-aligned planning from strategic goals to monthly targets

BUSINESS PRACTICES
- Addressing a huge problem in a multi-billion existing market with a new innovative solution protected by IP creating tangible benefits for their customers
- Scalable B2B business model with recurring revenues which shows growth potential beyond Additive Manufacturing alone
- Clear roadmap from a focussed market entry to multiple verticals
- Inspiring sales team with deep customer knowledge supported by creative marketing & communication efforts
- Excellent not only in R&D and Strategy but also in execution and creating traction
- Having set sound environmental, social and governance standards creating long-term upsides

HR PRACTICES
- deep-rooted company culture based on a shared vision and values
- Training and employee development is in place or planned
- Pay-for-performance plans (in general)
- Financial Incentives and stock options for key employees
- Exemplary recruitment and selection

Figure 3: Critical elements AM Ventures looks out for

Source: AM Ventures

RECAPTURE THE VALUE YOU CREATE FOR YOUR CUSTOMER

Another valuable resource for business success which has gained increasing attention in the literature are the value capture mechanisms within the business model[2] design of the company. In principle, a firm's value capture consists of instruments and tools that a firm uses to recapture the value it creates. Value capture reinvents how a company gets paid by realizing untapped revenue streams and therefore creates novel, innovative pricing systems.

Customers within the AM industry face various challenges when adopting AM. Buying equipment often requires high capital expenditure (CAPEX) investments. AM knowledge across the whole value chain needs to be built up. To fully utilize the benefits of AM, a fundamental rethinking of engineers on how to design parts for AM is required. In addition, AM continues to develop at a rapid pace, resulting in changing innovation regarding software, hardware, process and material developments. If a manufacturer of a rapidly evolving asset sells its ownership rights via a one-time payment, the equipment will appear to be outdated

quickly from a customer point of view. However, against this background new service offerings have emerged in recent years to diversify such risks. Customers can select from a pool of value capture mechanisms ranging from full in-house production using purchased equipment for printing and post-processing, to fully integrated pay-per-part opportunities that require less CAPEX. AM's shift from CAPEX to operational expenditure significantly lowers time to market and investment needs.

For the factor business model choice, we choose the independent variable *Business Model Innovation*. The variable takes the value of '1' if the AM startup uses mainly a novel innovative revenue model. This is either a recurring predefined revenue (e.g. subscription), a recurring usage-based payment (e.g. pay-per-use), a mixed approach or any other approach (e.g. transaction fee). Otherwise, we assign the value '0' for *Business Model Innovation* if the revenue model is solely based on a one-time payment approach indicating that the ownership of the product is sold.

PATENTS CAN SPRINGBOARD STARTUPS INTO A STRONG COMMERCIAL POSITION

VC investors often ask startups why a large company with more resources would not be in a better position to bring the entrepreneur's innovation to market more effectively. In response, founders often refer to a patent they have secured.

The AM industry is very research intensive. Patent protection is seen as creating an innovation incentive for research and development (R&D). In addition, it promotes the diffusion of ideas and facilitates entry of new venture firms with limited assets for recovering their R&D efforts and costs. Patents can springboard startups in the AM market into a strong commercial position relative to their competition by providing exclusive rights to commercialize new materials, processes, or applications. We see the power of patents

in the AM ecosystem additionally in the context of mergers and acquisitions (M&A). When General Electric (GE) acquired Arcam and Concept Laser, GE not only obtained two different AM technologies but also the patents relating to these methods. Post-acquisition, GE has at least 346 AM-related patents. Finally, patent protection functions as intellectual property rights and reduces information asymmetries, thereby signaling company quality to a VC firm.

To indicate the factor patent protection, we utilize the independent variable *Patent*, assigning the value of '1' if the AM startup owns at least one granted patent. The dummy variable takes the value of '0' if no information about a company's patent protection was found.

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2 We use the definition introduced by TEECE (2010) and define business model as the design of "value, creation, delivery, and capture mechanism" of a firm.

METHODOLOGY

We follow prior research and first define success in VC terms. We regress the dependent variable *Success* on the three independent variables described above (*Serial Entrepreneur, Business Model Innovation, Patent*) and several other control variables by applying an ordinal logistic regression (OLOGIT).

Second, we relate success to firm size that is often measured by the proxy (log of the) number of employees. We thereby regress the variable *Logemployees* on the same set of independent and control variables used in the aforementioned OLOGIT. In this context, we utilize a multiple linear regression analysis (MLR).

Several factors that might influence the success of AM startups in addition to the three independent variables need to be controlled for.
- We account for firm's age with the variable *Age*.
- The dummy variable Business-to-Business (*B2B*) is assigned the value of '1' if the AM startup generates its revenue with a company rather than an individual consumer.
- We further control for the technological landscape in which the AM startup primarily operates. In this regard, we introduce four dummy variables, each assigned the value of '1' if the AM startup mainly operates in the areas of *Hardware, Software, Material* or *Application*. It is important to account for all four categories, as all four differ in their structure. For example, a hardware-related business represents the gateway to customers and requires more CAPEX than a software-related business.
- Lastly, we control for the region from which the AM startup originates by introducing the following dummy variables: *British Isles, DACH, East Europe & Israel, France & Benelux, Middle East & Africa, Nordics, North America, South Europe*. It is necessary to control for the location, as certain regions are fertile breeding grounds for start-ups.

Figure 4 illustrates both regression models according to the success definition used, the dependent variables and control variables.

	DEPENDENT VARIABLE	INDEPENDENT VARIABLE (FACTORS)	CONTROL VARIABLE	REGRESSION MODEL
I. Success in terms of VC financing	*Success* – failure – survival – successful	– *Serial Entrepreneur* – *Business Model Innovation* – *Patent*	– *Age* – *B2B* – *Hardware* – *Software* – *Material* – *Application* – Dummy variables for region (e. g. *DACH*)	Ordinal logistic regression (OLOGIT)
II. Success in terms of firm size	*Logemployees* (log of the number of employees)			Multiple linear regression (MLR)

Figure 4: Methodology

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RESULTS

Success in terms of Dependent variable Model	VC FINANCING *Success* OLOGIT		FIRM SIZE *Logemployees* MLR	
	ß	SE	ß	SE
Control variables				
Age	-0.016	[0.062]	0.151***	[0.040]
B2B	0.939***	[0.273]*	0.579**	[0.203]
Hardware	-0.271	[0.450]	0.509	[0.330]
Application	0.327	[0.491]	0.556	[0.358]
Software	0.162	[0.536]	0.342	[0.395]
British Isles	-0.209	[0.603]	0.205	[0.437]
DACH	-0.030	[0.564]	-0.085	[0.364]
East Europe & Israel	-0.452	[0.610]	-0.111	[0.411]
France & Benelux	-0.349	[0.612]	-0.016	[0.434]
Middle East & Africa	-0.610	[1.181]	0.507	[1.152]
Nordics	0.257	[0.764]	-0.759	[0.591]
North America	0.341	[0.552]	0.335	[0.360]
South Europe	-0.010	[0.660]	0.048	[0.441]
Independent variables				
Serial Entrepreneur	0.719***	[0.243]	0.293*	[0.165]
Business Model Innovation	0.013	[0.303]	0.136	[0.232]
Patent	1.469***	[0.287]	0.384**	[0.178]
Number of observations	312		196	
McFadden's R-squared	0.120			
R-squared			0.2277	

Standard errors are reported in brackets; Column 2 and 3 present the results of the OLOGIT regression.

Column 4 and 5 report the results of the MLR regression; * p < 0.10, ** p < 0.05, *** p < 0.01

Figure 5: Output of the regression models

Source: AM Ventures

POSITIVE IMPACT OF TARGETING B2B MARKET

Our analysis shows that targeting the B2B market increases the likelihood of startup success **(see Figure 5)**. This effect is consistent across both regression models. We attribute this to three reasons. First, AM technology has a longer tradition in B2B markets. Second, B2B is generally a more focused customer market with long-term oriented relationships. Third, less marketing and communication efforts are required to convince customers to purchase the product.

POSITIVE INFLUENCE OF HUMAN CAPITAL

With both regression models, we find that prior founding experience of a team has a positive influence on success in terms of VC financing and firm size **(see Figure 5)**. This finding is in line with other empirical studies that argue that, consistent with concepts of entrepreneurial learning, serial entrepreneurs run successively better-performing businesses. Furthermore, they are more likely to indicate strong entrepreneurial quality when it comes to venture funding. However, we believe that this finding is not set in stone and should be understood in a broader context in a way that a team's human capital matters in early stages. Based on our experience, we are convinced that first-time founders are successful as well.

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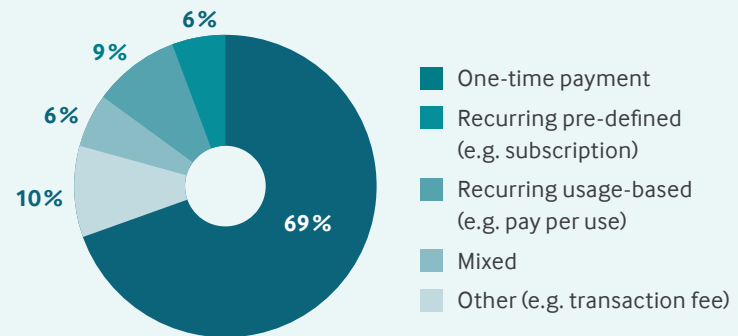# NO STATISTICAL SUPPORT FOR BUSINESS MODEL CHOICE, BUT!

We are surprised to find no significant relationship between business model choice and success **(see Figure 5)**, since prior research confirms that value capture mechanisms with novel features is positively associated with the success of new venture firms.

However, our finding must be understood in a broader context and can be explained as follows. Entrepreneurial firms encounter significant challenges in finding a viable business model. Technology-based venture firms in additive manufacturing experience high degrees of uncertainty and ambiguity. Consequently, in less mature, highly capital-intensive and high-velocity industries, the adoption of a business model is crucial for success. Thus, business model choice cannot be seen through static lenses, but rather as having dynamic mechanisms. Within this white paper, our independent variable *Business Model Innovation* does not account for pivoting. It is a snapshot of the current type of revenue model. For us, it is not an exclusion criterion, if the early-stage startup has not yet a mature business model. We always look to see, if a novel innovative business model can be developed and applied over time. That's what we have seen over the years: not a single company that we have worked with has become successful with its original business model. Over time, they always pivot into something else - together with their investors as sparring partners. And it's always the team members who turn the company around.

In addition, when customers scale their AM business, they shift from being an explorer to being a producer. Therefore, convenient capital models are needed providing the predictability, transparency and flexibility. However, only a limited number of startups has implemented new AM service offerings to address this need. **Figure 6** illustrates this finding and shows that the one-time payment approach dominates as a value capture mechanism (69%).

Figure 6: Various value capture mechanisms used by AM startups (N=540)

- One-time payment
- Recurring pre-defined (e.g. subscription)
- Recurring usage-based (e.g. pay per use)
- Mixed
- Other (e.g. transaction fee)

Source: AM Ventures

We believe that an analysis with a different independent variable – one that focuses on recurring revenues – would point to a positive and significant relationship between business model choice and the likelihood of success. Recurring revenues are attractive for a startup (cash flow stability), its customers (access new technology even if liquidity constraints exist) and its investors (positive signal for predictable revenues). We are looking forward to future research that is already on its way.

POSITIVE INFLUENCE OF PATENT PROTECTION

Our finding confirms our expectation that patent protection positively impacts the likelihood of success **(see Figure 5)**. The finding is in line with prior studies showing that in complex product industries, such as biotechnology, semiconductors or information technology, patents are positively associated to both the probability of raising funding and the amount of VC the start-up receives. Patents are a powerful protection mechanism to protect the startup's market position.
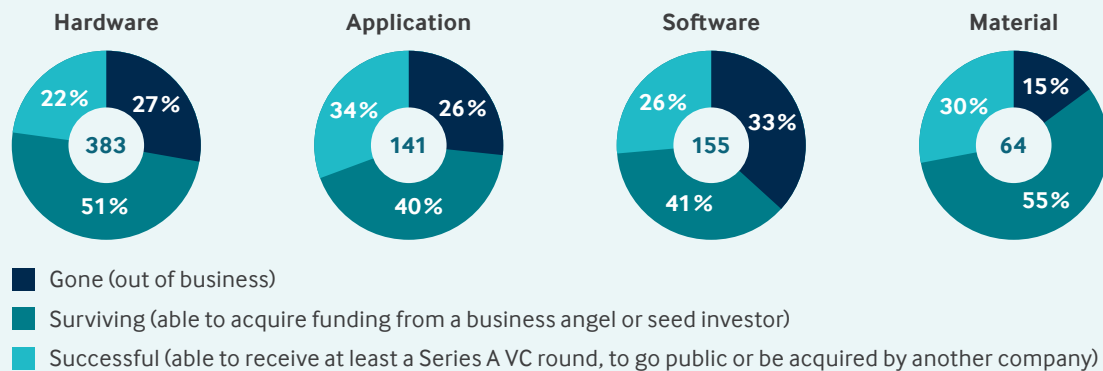
OTHER FINDINGS

Our findings reveal no statistical relationship between the region in which the startup originates and its likelihood of success. We believe that this can be explained as follows. The biggest regional AM powerhouses around Boston, Munich and Tel Aviv do not appear individually as they are aggregated into larger regions.

We believe that a closer look at these hotspots would result in a statistical relationship, because these breeding grounds for AM companies have five things in common: world class technical universities; availability of large corporations with high tech capabilities serving as partners and customers; experienced and well connected VC firms providing the necessary smart capital for today's fastest-growing entre-

preneurial AM companies; and lastly, outstanding technical and commercial infrastructure with worldwide access.

As illustrated in **Figure 7** below, application-based startups have the highest success rate in the descriptive statistics. However, we find no statistical support in our white paper for this result. Based on our analysis, the technological landscape is not decisive for success in terms of VC financing and firm size. Nevertheless, our investment credo is that we evaluate every startup to a certain extent through the application lenses, since applications are the justification why AM exists. We are excited about future studies that could reevaluate with a broader database if the picture also holds true statistically.

Figure 7: Survival and success rate per technical field

Hardware — 383: 22%, 27%, 51%
Application — 141: 34%, 26%, 40%
Software — 155: 26%, 33%, 41%
Material — 64: 30%, 15%, 55%

■ Gone (out of business)
■ Surviving (able to acquire funding from a business angel or seed investor)
■ Successful (able to receive at least a Series A VC round, to go public or be acquired by another company)

Source: AM Ventures

ACKNOWLEDGEMENT

SECURING LONG-TERM SUCCESS

It's great to see statistical stars in our database. Reflecting on the companies we have backed so far, I want to highlight that, in the early stages of a startup, it's all about the team. In addition, as the literature review reveals that business model choice matters, we look out for a sound business model with a strong lock-in effect and good streams of recurring revenues. An important contributor to secure long-term success.

Furthermore, another key success factor is a powerful and well-connected network of advisors and investors such as AM Ventures that can help open doors to top-customers and strategic partners. We look forward to continuing to share the knowledge that we gain from our body of work.

Lastly, I would like to thank my dear colleague Alexander 'Bezi' Schmoeckel for his great contribution. Not only in condensing AM Ventures' knowledge in this white paper but also generally in his inspiring inputs into our daily work. Alex constantly motivates the entire team through his enthusiasm, positive energy and endless passion for our cause and is an impressive demonstration of the fact mentioned above: every success is based on great people doing great things. Thank you, Bezi!

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ADDITIVE MANUFACTURING STARTUPS
WHAT ARE THE KEY FACTORS FOR SUCCESS?

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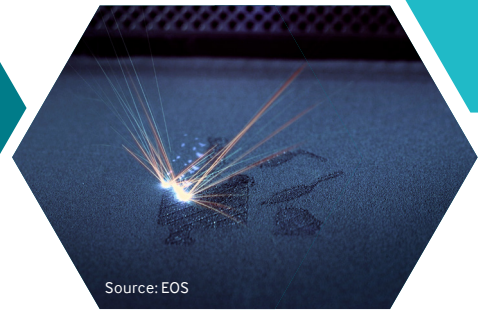
ALEXANDER SCHMOECKEL
ANALYST

Alexander Schmoeckel joined AM Ventures in 2018. He started as a student and supported AM Ventures' global scouting activities, conducted market and technology analysis for evaluating potential investment cases. He completed his master thesis in collaboration with AM Ventures and the Chair of Entrepreneurial Finance at the Technical University of Munich. In 2022, he became a full-time employee as an analyst. Besides being responsible for technology scouting in North America, he takes care of AM Venture's social media activities. In addition, he supports the integration of ESG aspects in the organization's processes.

Alexander holds a Bachelor and a Master degree in Management and Technology from the Technical University of Munich with a specialization in finance and accounting and mechanical engineering. During his studies, he spent one semester abroad in Paris. He was also a scholarship holder of Prof. Dr. Gunther Friedl's TUM Finance and Accounting Selectes Talents (TUMfast) program, an exclusive network for students highly talented in the fields of controlling, finance and accounting.

ARNO HELD
MANAGING PARTNER

Arno Held is Managing Partner of AM Ventures and specializes on the firm's ecosystem, as well as its global footprint and organizational growth. He started AM Ventures together with Johann Oberhofer in 2014. In total, Arno has more than 23 years of experience in industrial laser and manufacturing technologies and spent more than half of this time in the world of industrial 3D printing.

Since founding AM Ventures, Arno has been instrumental in building the AM Ventures team that has scouted more than 2,500 3D printing startups all over the world, conducted more than 35 rounds, built a €100m VC fund and today holds a portfolio of 17+ shareholdings in six countries on three continents.

Arno holds an engineering degree in industrial engineering and management from the University of Applied Sciences in Karlsruhe (Germany), as well as an international executive MBA from the University of St. Gallen (Switzerland). Arno completed his studies in Shanghai, China and Cape Town, South Africa.

IF YOU HAVE ANY REMARKS OR COMMENTS, PLEASE GET IN TOUCH

ABOUT AM VENTURES

The leading venture capital firm in industrial 3D printing (additive manufacturing, AM) AM Ventures has backed 20+ successful companies in seven countries on three continents. The team possesses in-depth technology know-how and is well connected with the most experienced experts in the field.

As an investment partner, the company provides a globally leading ecosystem of sustainable investments in AM and introduces entrepreneurs to a large pool of industry veterans offering decades of experience in engineering, manufacturing, and executive management. In 2021, AM Ventures was set up as a venture capital fund.

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