

European Software

Industrial Software Primer: a fast-growing \$50bn+ market

Primer

Industrial software: key drivers / key players

In this Primer on Industrial software, we review the structure of the global Product Lifecycle Management (PLM) market and the main dynamics and trends underlying the industry. We review the key structural trends, in particular cloud migration, Industry 4.0 and dynamics across verticals, and we conduct a deep dive on the main market segments including Collaborative Product Data Management, Computer Aided Design (CAD), Electronic Design Automation and Architecture Engineering Construction. We review key players' strategy and positioning in PLM including Dassault Systemes, Siemens, PTC, Aveva, Hexagon, Autodesk and Aspen Technology.

PLM: a high moat / high growth software category

PLM represents an all-encompassing toolset for managing data relating to the design, production, support, and ultimate disposal of goods. This includes applications aiding in the design stage like 2D and 3D CAD, but also simulation & analysis, and digital manufacturing software to model production outcomes and manage manufacturing processes. PLM companies like PTC, Siemens, and Dassault provide technology to scale those processes on an enterprise level, from design and production quality all the way to sales and delivery. According to CIMdata, The overall PLM market is estimated at \$57bn in 2021 and expected to grow to \$87bn by 2026, a 9% CAGR, and is seeing very resilient share with limited inroads from cloud-native competition (contrary to Enterprise SaaS). Dassault, Siemens and PTC have among the most comprehensive PLM platforms with a wide range of capabilities.

Cloud transition set to accelerate

Many enterprise software segments (e.g. Salesforce in CRM, Workday in ERP, MS Office 365) have successfully shifted to cloud-native solutions, proving this model provides greater customer life-time-value. However, PLM has historically been a cloud laggard, often due to highly customised PLM deployments, security concerns, and lack of competitive cloud-equivalent offerings. Nonetheless, we would expect cloud traction to accelerate as companies are increasingly focused on developing cloud-native solutions and have set ambitious targets on cloud adoption. We are also seeing a matching customer appetite, particularly post C-19 (COVID-19), where a number of industrial segments are looking to accelerate their digital transformation and seeking better collaboration with the supply chain. We see this happening in three phases: 1) shift in model from license to subscription; 2) cloud first deployments & RD prioritisation from on-premise incumbents; and 3) growth of cloud-native platforms.

15 September 2021

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Glossary of Terms at end of this report - see table of contents below.

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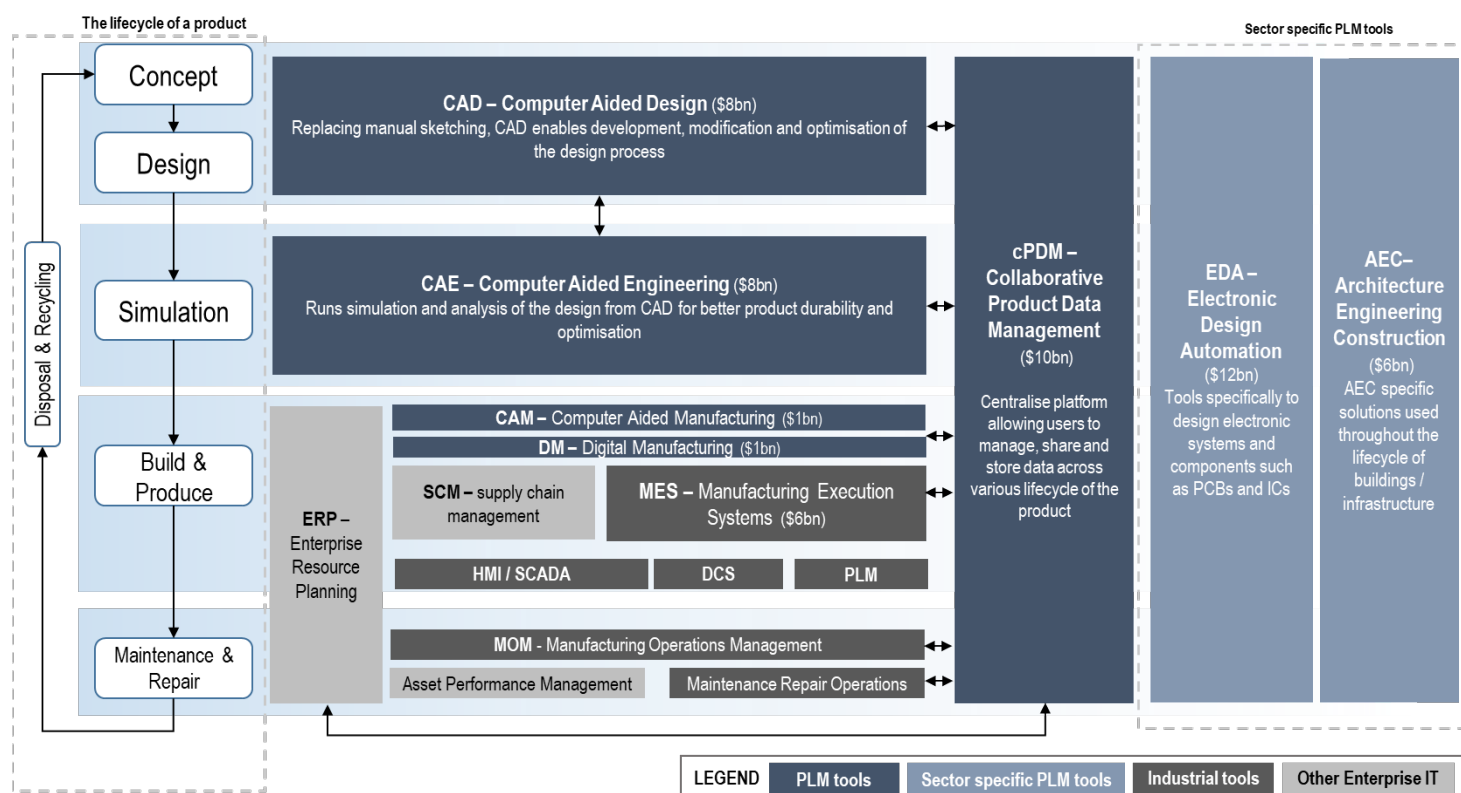
Industrial Software Market Overview

In this primer on Industrial software, we review the structure of the global PLM market and the main dynamics and trends underlying the industry. In particular, we review:

- The key structural trends shaping the industry, in particular cloud migration, Industry 4.0 and dynamics across verticals (1. Accelerating shift to subscription and cloud)
- The PLM market structure, history, main segments, with an overview of the capabilities of the key players: Siemens, Dassault Systemes, PTC and Autodesk (PLM Software Overview)
- The main market segments including Collaborative Product Data management, Computer Aided Design, Electronic Design Automation and Architecture Engineering Construction (Collaborative Product Definition Management (cPDM))
- Key players in PLM including Dassault Systemes, Siemens, PTC, Aveva, Hexagon, Autodesk and Aspen Technology (Key players in PLM)

Exhibit 1: PLM represents an all-encompassing vision for managing data relating to design, production, support, and ultimate disposal of goods.

Software overview to manage the entire lifecycle of a product



Source: BoFA Global Research

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Evolving PLM Trends

1. Accelerating shift to subscription and cloud

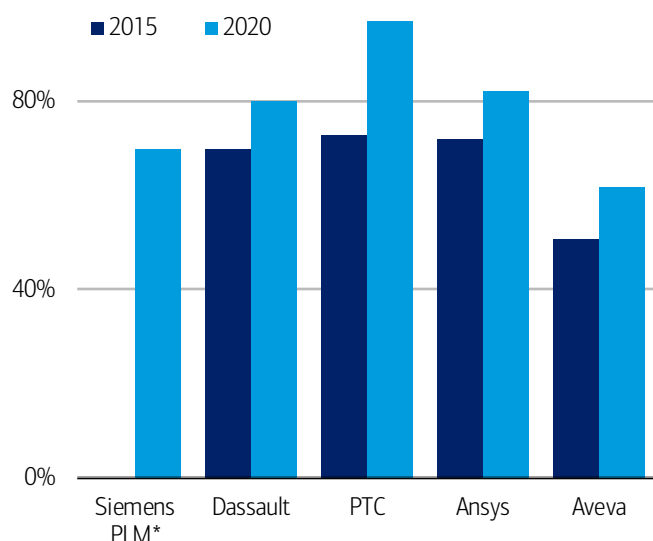
Many enterprise software segments (e.g. Salesforce in CRM, Workday in ERP, MS Office 365) have successfully shifted to cloud-native solutions, which have proven to provide greater customer life-time-value. However, PLM has historically been a cloud laggard, often due to: 1) high organisational resistance to change; 2) highly customised PLM deployments; and 3) the lack of competitive cloud-equivalent offerings. However, in our view, the PLM industry is at the tipping point of change as companies are increasingly focused on developing cloud-native solutions and have set ambitious targets on cloud adoption (Exhibit 3). We are also seeing a matching customer appetite (Exhibit 7), particularly post C-19, where a number of industrial segments are looking to accelerate their digital transformation and seeking for better collaboration with the supply chain. We see this happening in broadly three phases:

Phase 1: high % of recurring revenue but with little subscription mix

Like many other enterprise software segments, the business model for PLM software has already been shifting from a lumpy one-off perpetual license to a mix of subscription-based licensing, license leasing and pay-as-you-go models.

Exhibit 2: Companies have moved away from selling perpetual licenses to a mix of recurring revenue streams...

Percentage of recurring revenue in 2015 and 2020



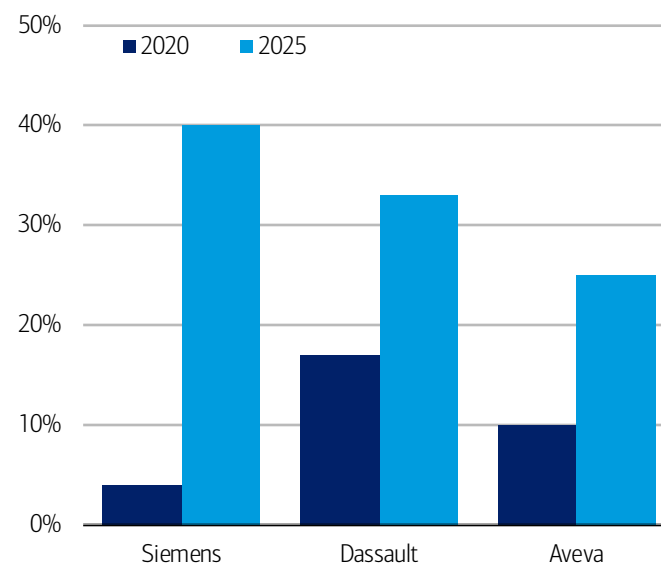
Source: BofA Global Research estimates, company report

*No data available for Siemens PLM in 2015

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Exhibit 3: ... yet the mix of cloud revenue is still low (<20%), but companies are clearly expecting cloud adoption to accelerate to >25% by 2025

Percentage of cloud revenue out of total revenue



Source: BofA Global Research estimates, Company

*Aveva target is for 2026 instead of 2025

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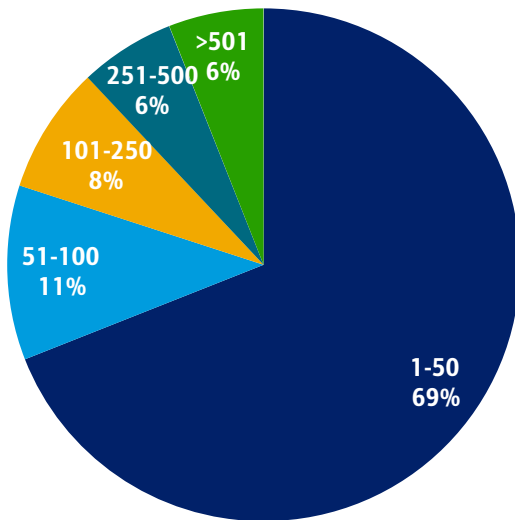
These pricing models are gaining traction (>70% recurring in many PLM players as shown in Exhibit 2) as they provide stable recurring revenue to companies whilst typically requiring less upfront commitment and offering more flexibility to customers.

Phase 2: more subscription and cloud-like deployments

Currently, the bulk of recurring revenue for most PLM players is heavily skewed towards maintenance (on perpetual licenses) and term-based license leasing and, as such, few companies disclose subscription metrics. PTC is an exception where it has successfully transitioned to subscription over the past few years, from 6% in FY15 to 70% of revenues in FY20.

Exhibit 4: Cloud deployments are still relatively small...

No of seats on users using/planning to use cloud based CAD



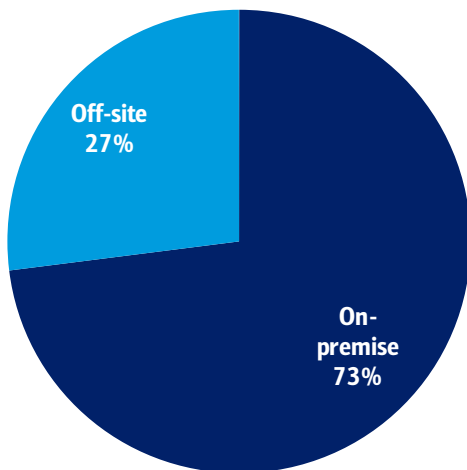
Source: CIMdata Cloud-SaaS PLM Research (2021)

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We are currently in a phase where new point solutions (e.g. CAD) are increasingly cloud-based as end-users expect new deployments in the cloud (Exhibit 7). Right now, these cloud point solutions typically still have a low number of seats (Exhibit 4) as users often shift to cloud by trialling on a small group of users. On a platform level, early cloud deployments tend to involve PLM players reinstalling on-premise software to a single-tenant cloud deployment, and serving back to customers through a managed services model.

Exhibit 6: Shift to cloud is broadly in line with survey results back in 2017 where 30% respondents expected to be in cloud by 2021...

Deployment type of the current primary PLM-enabling solution



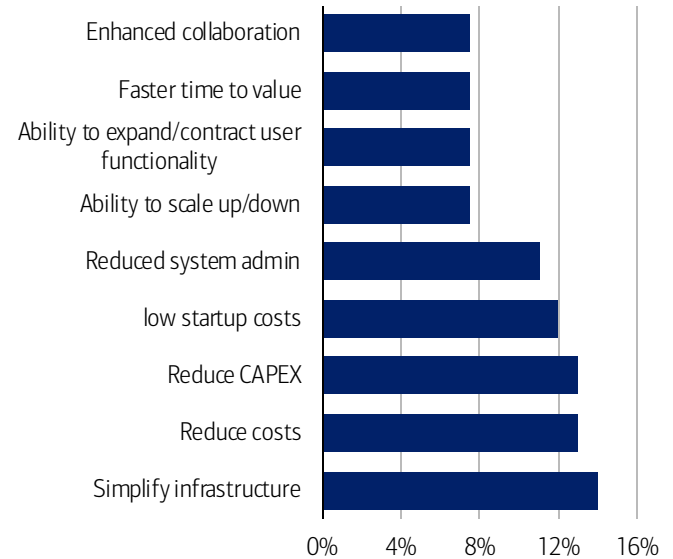
Source: CIMdata Cloud-SaaS PLM Research (2021)

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In our view, not all sectors are as welcoming to the cloud, and sectors with large and highly customised PLM implementations (e.g. Autos and A&D) are more resistant to such a move, based on concerns about security, accessibility, bandwidth and the ability to customise to support particular requirements.

Exhibit 5: ...but are already realizing some cloud potential

Benefits achieved from investment in cloud CAD

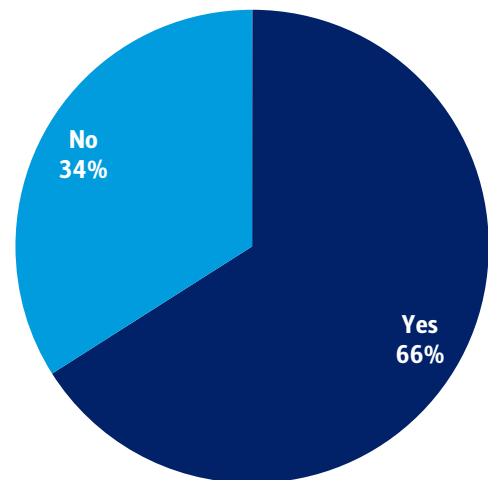


Source: CIMdata Cloud-SaaS PLM Research (2021)

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Exhibit 7: ...but we now see demand for cloud-based solutions speeding up, in part accelerated by C-19

Q: "Is your company considering a move to using cloud-based PLM solutions?"



Source: CIMdata Cloud-SaaS PLM Research (2021)

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Phase 3: uplifting to cloud native platforms and 2x the revenue?

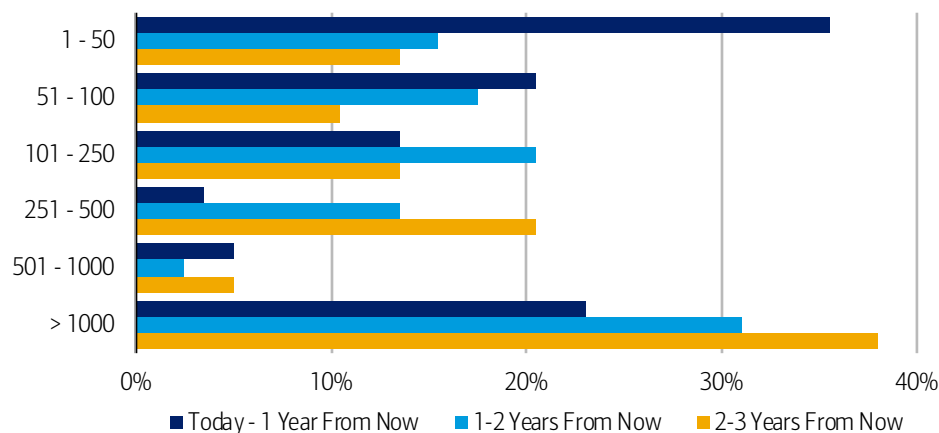
While moving point solutions to the cloud is in the right direction, it also misses many of the benefits a true cloud platform can provide. As the PLM cloud solutions start to mature, we believe the market is prime for disruption by true multi-tenant cloud platforms. C-19 has also somewhat validated the PLM cloud market as both PLM players and users increasingly seek to embrace cloud capabilities.

“If you have \$1 of ARR on-premise, and you, as we say, lift and shift that into the cloud, it becomes \$2 of ARR.”

James E. Heppelmann, PTC CEO, May 2021

Exhibit 8: Users are expecting cloud deployments to massively scale in the next 3 years

Plans for scaling up implementation among CIMdata survey respondents (No. of users over time)



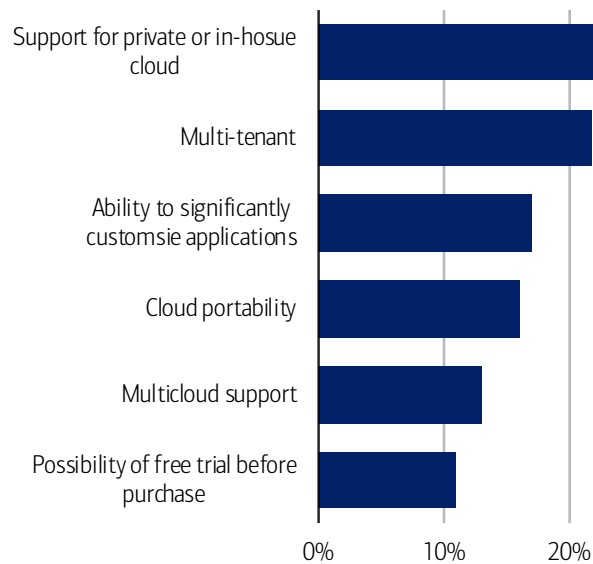
Source: 2021 CIMdata Cloud-SaaS PLM Research

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We see this as a win-win for both the PLM players and the end-users. For end-users, SaaS deployments often result in lower total cost of ownership for customers compared to on-premise solutions, and reduce the burden on customer in-house IT to manage the technology stack. For PLM players, SaaS will result in higher total contract value (TCV) vs on-premise license, with PTC estimating a 2x uplift in revenue potential. Aveva also noted an expected 50%-60% uplift in Annual Contract Value for SaaS vs on-premise subscription in its recent CMD.

Exhibit 9: Cloud needs; clients want support, customization and multi-tenant offers

Important Offering Characteristics

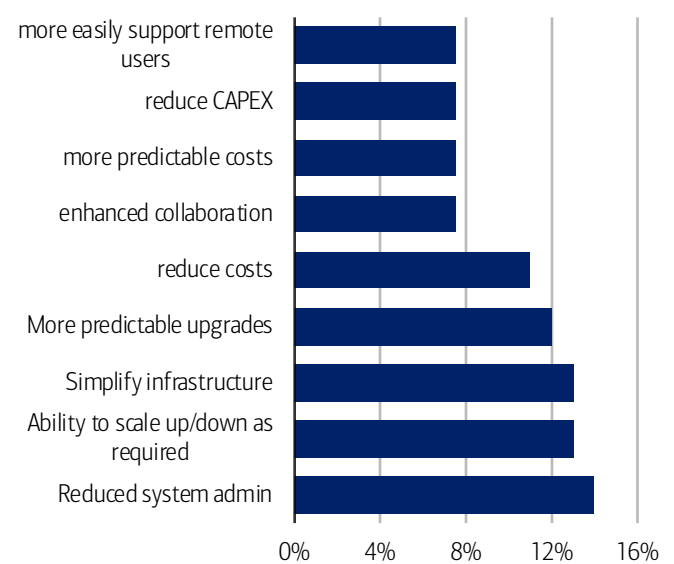


Source: CIMdata Cloud-SaaS PLM Research (2021)

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Exhibit 10: Scalability and simplification the main drivers of Cloud migration

Potential Benefits of Cloud-Based Solutions



Source: CIMdata Cloud-SaaS PLM Research (2021)

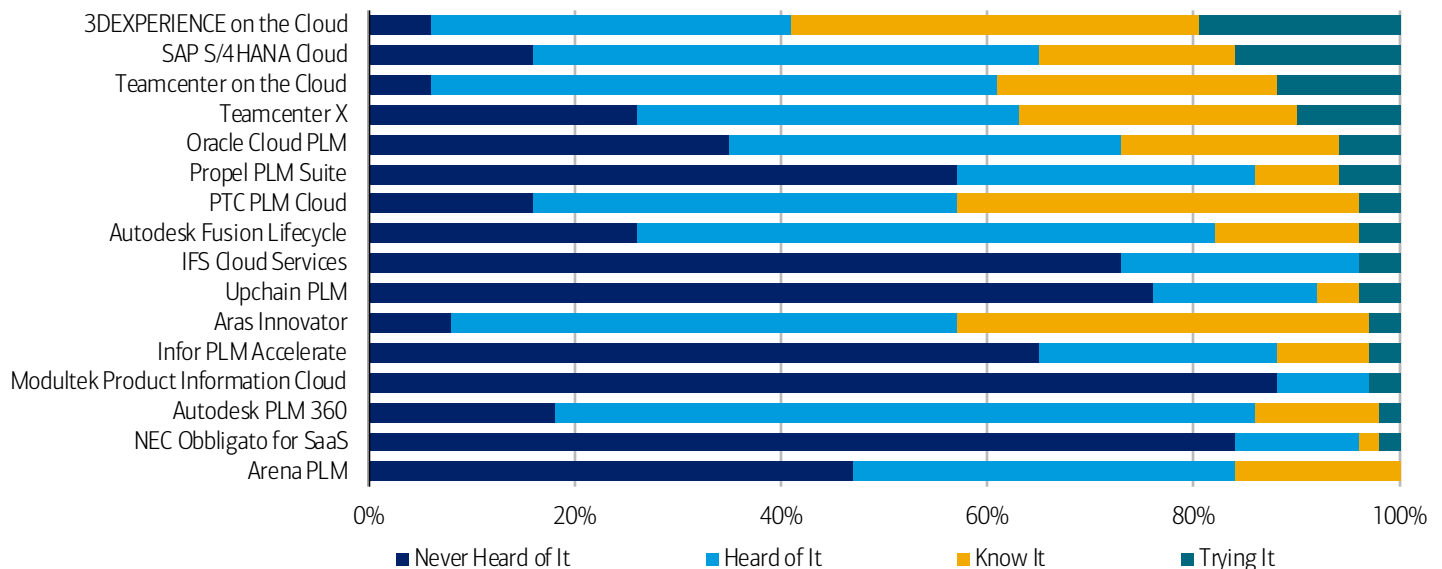
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Who is leading on cloud?

PLM players are now focused on the cloud with some (e.g. Dassault, Siemens, Aveva) setting ambitious medium-term targets on cloud revenue. PTC and Autodesk do not have explicit cloud targets but are also heavily investing in cloud transition. Both have arguably transitioned further to the cloud with their lower-end offerings (e.g. OnShape/Arena for PTC, 360 Cloud services for Autodesk) where users are less resistant to migrate. On the high-end offerings, Dassault 3DX and Siemens' TeamCenter lead the PLM space (Exhibit 11) on cloud adoption.

Exhibit 11: Level of knowledge among CIMdata survey respondents for cloud-based PLM-enabling solutions

Dassault 3DX the most widely adopted cloud PLM among the survey respondents, followed by SAP's S/4 HANA and Siemens's TeamCenter



Source: 2021 CIMdata Cloud-SaaS PLM Research

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Dassault – 3DX platform to drive significant cloud revs by 2025

Cloud business made up 20% of revenues in 2020. The stated objective is to increase this to >1/3rd in 2025. Dassault (DSY) has enjoyed triple-digit growth for 3DX on the cloud in the past 3 years and expects this to continue for the next 3. Early cloud adopters are often start-ups in AEC and retail, but the technology is being increasingly embraced by large accounts wanting to compete with the early adopters. DSY flags that a number of new customers start directly with cloud solutions, in life science, construction, consumer goods or EVs.

Siemens – targeting 40% cloud revenues by 2025 (currently 4%)

At its recent Capital Markets Day, Siemens revealed that c. 70% of revenue is recurring (subscription, SaaS and maintenance), with growth underpinned by transition to cloud-based SaaS, which Siemens targets to account for 40% of ARR by 2025 (currently 4%). Siemens expects up to 200bps margin impact with the move to SaaS but the profit margin to be back to FY21 levels by FY25.

PTC – expanding cloud-native platform with Arena and OnShape

PTC is a cloud pioneer, offering Windchill (cPDM platform) as a managed service for nearly 20 years. There is clearly more focus on SaaS/cloud following the Arena acquisition. With OnShape, and now Arena, PTC has the product suite to benefit from the trend of SaaS/cloud adoption. There was a notable shift in tone at PTC's investor day (December 2020) with a clear emphasis on SaaS offerings.

Aveva – >80% recurring and 25% cloud revs by 2026

Between FY2018 and FY2021, recurring revenue increased from 52% to 68% of the total. During that same period, subscription (on premise rental and Cloud SaaS) revenue increased from 22% to 44% of the total. By 2026, AVEVA expects recurring revenue to increase to >80% of total revenue, with SaaS at c.25% of total revenue.

Industrial Internet solutions are providing a compelling reason for AVEVA's customers to invest in a software platform. SES's historical focus on hardware and services is being replaced by a focus on software. The OSIsoft deal should help create an asset capable of delivering faster growth (OSIsoft's 10% growth is above AVV's original medium-term ambitions) and build diversity in both geography and end-market concentration (away from O&G).

Ansys – high computing resources for simulation limits shift to Cloud

Apart from a SaaS-based model increasing the scope of future revenue and cash flow generation, it also allows for penetration into new market segments (small/medium-sized businesses). However, given current technology limitations and computing requirements for pervasive simulation, Ansys' transition to a SaaS/cloud model could lag peers.

The company currently has 80% of its revenue coming from a recurring subscription model (combination of lease and maintenance support). The remaining 20% is tied to perpetual license and related services. The strategic view of the management team is to support customers via a software model that aligns with their needs. Ansys has capability to support customers on a cloud platform through channel partners (Microsoft Azure), although it does not currently offer a pure-SaaS product given the high level of compute needed to model pervasive simulation. As the company adds core products to the cloud and technology advancements make for solving problems on the cloud easier (i.e., less compute), cloud-based offerings will become more feasible.

SaaS TAM scenario: looking at industrial software TAM expansion through SaaS

At our US analysts' IIoT Summit in Sept 2020, several speakers, including industrial software management teams and industry consultants, noted expectations for SaaS and cloud-based mix to reach ~50% within 5-10 years across the industry. In the scenario outlined below, we show what a shift to 50% SaaS mix by 2030 implies for broader

industrial software TAM (\$bn). Consensus is that roughly 10% of software in the market is SaaS-based. Historically, the industrial software market has increased at ~6% CAGR. A shift to SaaS at 50% mix by 2030 would imply SaaS software growing at ~30% CAGR and has the potential to accelerate TAM growth to ~10% (400bp above the historical CAGR).

Exhibit 12: SaaS TAM Scenario (10 years to achieve 50% SaaS mix)

Currently SaaS-based models comprise around 10% of software sold

	2020	2030
Industrial software TAM (\$bn)	60	156
Industrial software TAM annual growth (%)		10%
% Legacy	90%	50%
Legacy software revenue (\$bn)	54	78
Legacy implied annual growth (%)		4%
% SaaS	10%	50%
SaaS software revenue (\$bn)	6	78
SaaS implied annual growth (%)		29%

Source: BofA Global Research estimates

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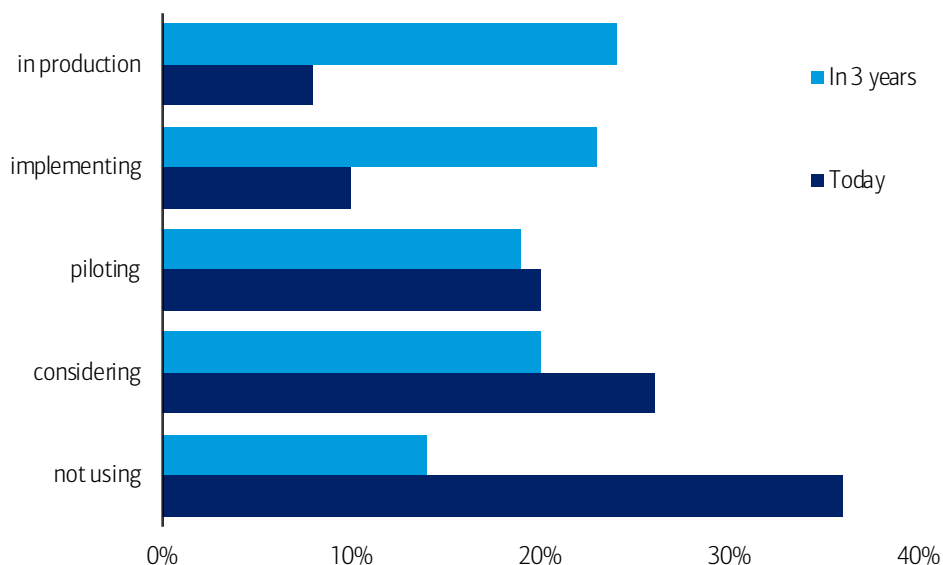
2. Digital Transformation post C-19

We continue to see accelerated digital transformation post C-19 across various enterprise software segments. In some respects, the PLM sector has been preparing for such a shift in the last decade, building out the capabilities, technologies, software and infrastructure to support such transformation; and it has often been the employees that are more resistant to change rather than issues with the technology. However, CIMdata recently noted in its 2021 PLM survey that C-19 has caused companies from a number of industrial segments to accelerate their digital transformation. Two key drivers are:

- **Digital thread** – as C-19 disrupted a big part of how the workforce works, there has been a big acceleration toward a smart connected future, often powered by IoT and Industrial IoT. As products become more complex, it becomes increasingly difficult to design products within silos, and there is growing demand for more simulation and modelling not just during the development phase, but across the whole lifecycle of the product. A digital twin helps address the issue being an evolving entity that accompanies its real-world physical companion throughout its lifecycle – evolving as the physical version changes. The majority of end-users are expecting more widespread adoption in the next few years (Exhibit 13).
- **Collaboration across value chains:** While OEMs (particularly in Autos) have been the biggest spenders on PLM solutions as they need to integrate all the components together, suppliers have also been increasingly sharing the responsibility for more integrated product development. As a result, we are starting to see higher growth in suppliers vs OEMs as the former progressively modernise their IT stack to compete.

Exhibit 13: Digital Twin Adoption progressing and becoming more widespread

State of Digital Twin Adoption



Source: CIMdata survey

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Where PLM fits in the broader industrial information / operational tech

Growth in automation software revenue over the past 5 years has been strong despite the broader industrial automation environment being relatively muted. The strategy for operational tech (OT) firms has been to build out their information tech (IT) presence through M&A. Simply put, automation firms are finding that acquiring software assets is the quickest/easiest way to broaden capabilities outside of hardware automation.

Exhibit 14: Estimated revenues derived from industrial software for main automation suppliers

Estimated revenues derived from industrial software for main automation suppliers

2019, USDm Software revenue	OPERATIONAL TECH					%	INFORMATION TECH						%	TOTAL	Software % auto'n
	DCS	PLC	SCADA	HMI	CNC		PLM	MES	PAM	EAM	SCM	ERP			
SAP						0%	945	81		49	3,260	6,310	100%	10,645	79%
Oracle						0%	599	93		34	1,449	3,155	100%	5,330	79%
Siemens	446	250	238	307	271	29%	3,437	257	15				71%	5,220	38%
Dassault						0%	3,634				21		100%	3,655	88%
Autodesk						0%	2,056						100%	2,056	80%
Schneider/Aveva	372	82	317	270		57%	254	513	18	14			43%	1,839	37%
Infor						0%				119	242	1,434	100%	1,795	71%
Sage						0%						1,721	100%	1,721	80%
Workday						0%						1,721	100%	1,721	80%
ABB	473	72	423			61%		324	29	104		172	39%	1,597	27%
Ansys						0%	1,218						100%	1,218	80%
Honeywell	446	5	213			56%		102	10	11	400		44%	1,186	25%
PTC						0%	1,005				87		100%	1,092	80%
Hexagon						0%	884						100%	1,061	80%
Emerson	501	29	300			79%	96	53	67				21%	1,046	29%
Rockwell	195	188	127	188		75%		213	22				25%	933	20%
Microsoft						0%				6		860	100%	866	78%
Kronos						0%						860	100%	860	80%
IBM						0%				110	180	287	100%	577	51%
Aspentech						0%	169	169			145		100%	483	94%
Fanuc					470	100%							0%	470	22%
GE				142		47%			160				53%	302	10%
Mitsubishi					190	100%							0%	190	9%
Yokogawa	84					57%		62					43%	146	8%
Alstom	28					100%							0%	28	9%
Valmet	28					100%							0%	28	8%
Others	193	193	1,353	186	720	11%	405	2,570	152	315	6,292	12,161	90%	24,333	0%
TOTAL	2,058	819	2,762	1,091	1,651	12%	14,880	4,439	473	713	12,075	28,682	87%	70,371	0%

Source: ARC, Frost & Sullivan, CIMdata

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For example, automation firms like Schneider, Rockwell and Siemens have continued to build out IT software offerings for the plant floor. Siemens has done so through M&A and internal investments, while Schneider has done so through its merger with AVEVA's software business. PLM makes for one of the largest pieces of the Information Technology market.

The move towards the development of fully fledged software businesses by Industrial Automation vendors began when Siemens acquired UGS and its virtual design and manufacturing software in 2007. ABB (2010) and Schneider (2011) followed, buying asset management software capabilities. Since then most major global competitors have added to their respective software & hardware capabilities, with many seeking to participate in the PLM market. We see COVID-19 as an accelerator in the adoption of PLM and Industrial IoT technologies as companies seek to position themselves for recovery, increase operational flexibility and shift supply chains.

3. Expansion into new and existing industry verticals

While Autos and A&D sectors have been key users in PLM tools, we continue to see growth both in other sectors as well as more traditional ones. Key growth areas include:

- **Healthcare:** growth of Simulation & Analysis (S&A) in healthcare, particularly in pharma and medical device manufacturing, is supported by the accelerating trend of Pharma 4.0 post-COVID as pharma manufacturers look to digitize product lifecycle and manufacturing processes. Several key automation providers like ROK and EMR have highlighted the strong growth outlook for Life Sciences, while the segment is a major growth priority for DSY post the acquisition of Medidata.



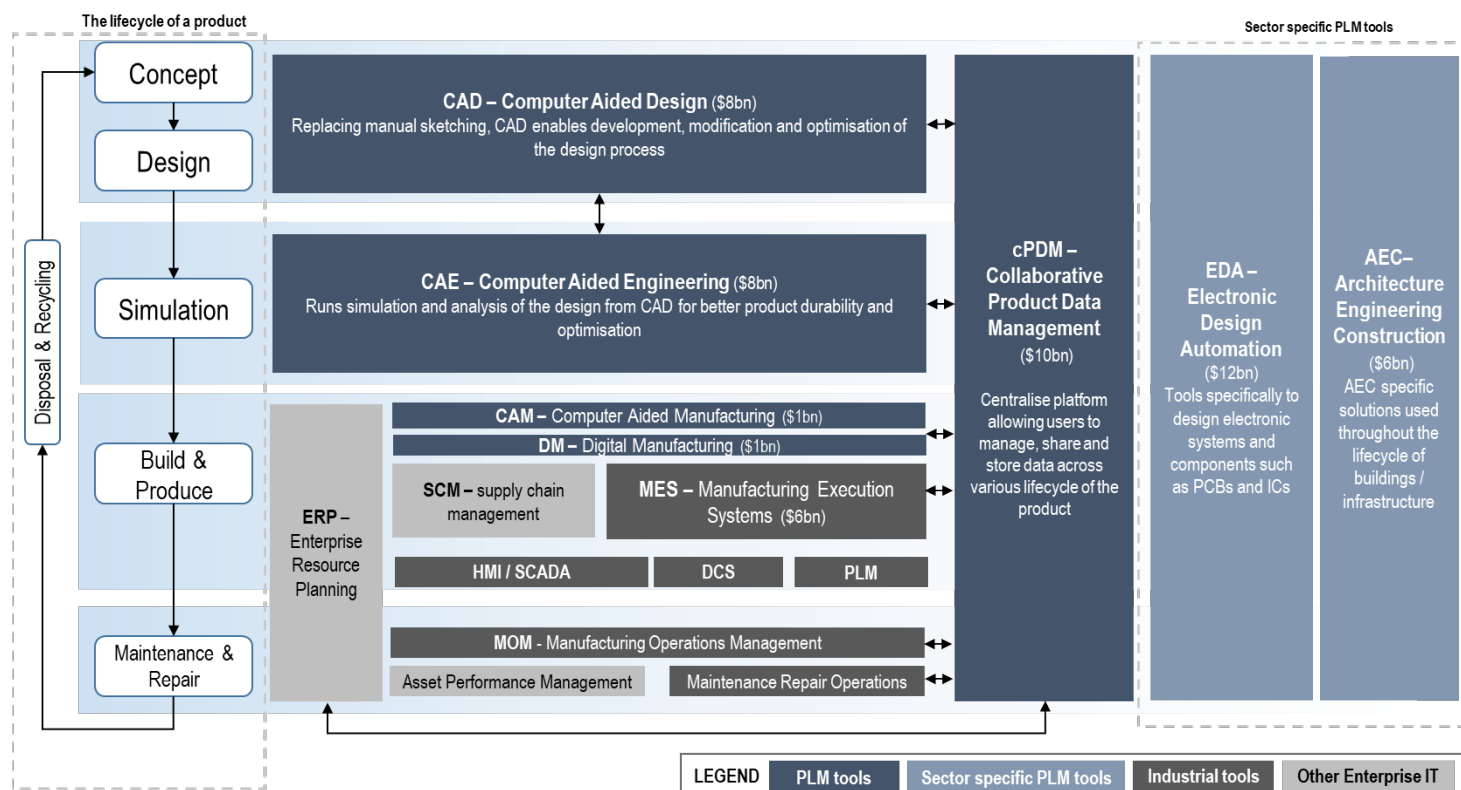
- **AEC:** the sector overall still relies more on pen and paper, and so is in much need to digitise to address considerable inefficiency in terms of time, capital and energy. The implications of COVID-induced changes to the use of buildings as well as the political and consumer focus on resource efficiency are likely to induce an acceleration in the adoption of software and next generation technology to help address the considerable inefficiencies in the sector.
- **Industrial manufacturing:** adoption of simulation is becoming a more viable use case for discrete manufacturing and other industrial applications, aided by increasing c-suite support of digital implementation and increased processing power that allows for real-time simulation on the factory floor. Ansys' partnerships with ROK and PTC are key here for better integration between OT hardware and other key IT technology (PLM, CAD, IoT, etc.), in our view.
- **Aerospace:** historically, the aerospace & defence industry has been a key user of S&A software. We expect accelerated growth, supported by rising military budgets and increasing use of flight simulation software (digital twin).
- **Automotive:** as electrification and roll-out of electric vehicles gain momentum, this makes the clear case for growth in simulation software that is needed to model real-time outcomes and monitor vehicle performance.

PLM Software Overview

The overall PLM market is estimated at \$57bn in 2021 and expected to grow to \$87bn by 2026 (9% CAGR). It represents an all-encompassing toolset for managing data relating to design, production, support, and ultimate disposal of goods. Dassault, Siemens and PTC have the most comprehensive PLM platforms with the widest range of capabilities.

Exhibit 15: PLM represents an all-encompassing vision for managing data relating to design, production, support, and ultimate disposal of goods

Software overview to manage the entire lifecycle of a product



Source: BofA Global Research

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What is Product Lifecycle Management?

PLM represents an all-encompassing vision for managing all data relating to the design, production, support, and ultimate disposal of goods. This would include applications aiding in the design stage like 2D and 3D computer-aided design (CAD), but would also include simulation & analysis and digital manufacturing software to model production outcomes and manage manufacturing processes. Product data management (PDM) is an application within the PLM universe that aggregates engineering data (primarily related to CAD) to manage revisions and changes in product design. PLM companies like PTC, Siemens and Dassault provide technology to scale said processes on an enterprise level, from design and production quality all the way to sales and delivery.

PLM software tends to be very sticky and customers rarely switch onto competing software platforms given unwanted inefficiencies of integrating a new system. Once engineers are trained on a specific platform, it becomes difficult to change them from a

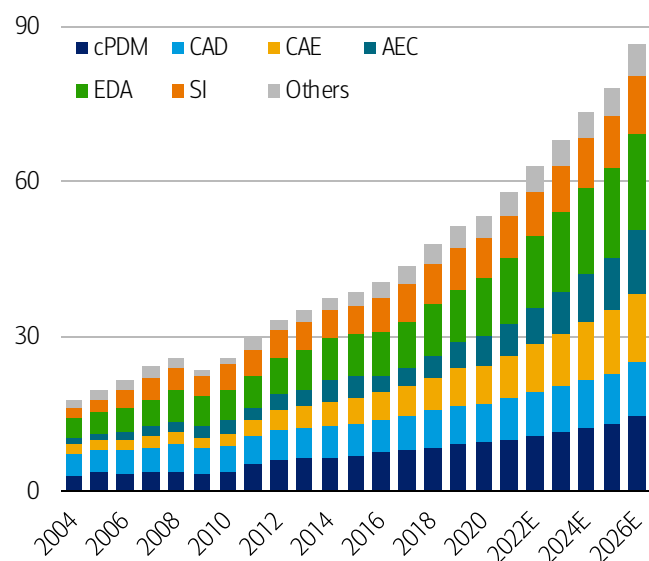
training and cultural standpoint. Therefore, it is challenging for firms to gain market share in the space, and early winners have dominated the market.

A \$57bn market with a 9% CAGR in the next 5 years

Sizing the PLM market is difficult as many industry players define the scope and capabilities differently. CIMdata, the leading consulting and research authority focused on PLM, defines the “comprehensive” PLM industry as including all relevant players along the value chain – 3rd party resellers/service providers and companies focused in niche industries and applications. It also includes highly sector-specific tools like electronic design-automation (EDA), architecture, engineering, and construction (AEC), and application lifecycle management (ALM). Under this definition, CIMdata estimates a broader served PLM market of around \$57bn.

Exhibit 16: PLM expected to grow 9% CAGR in the next 5 years

PLM market share by solutions over a 22 year period

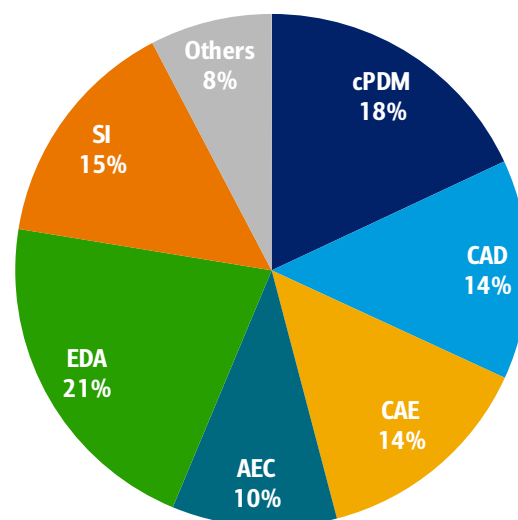


Source: CIMdata

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Exhibit 17: 2020 PLM market share by solution offerings

EDA (21%), cDPM (18%), CAD (14%) & CAE (14%) the largest PLM segments



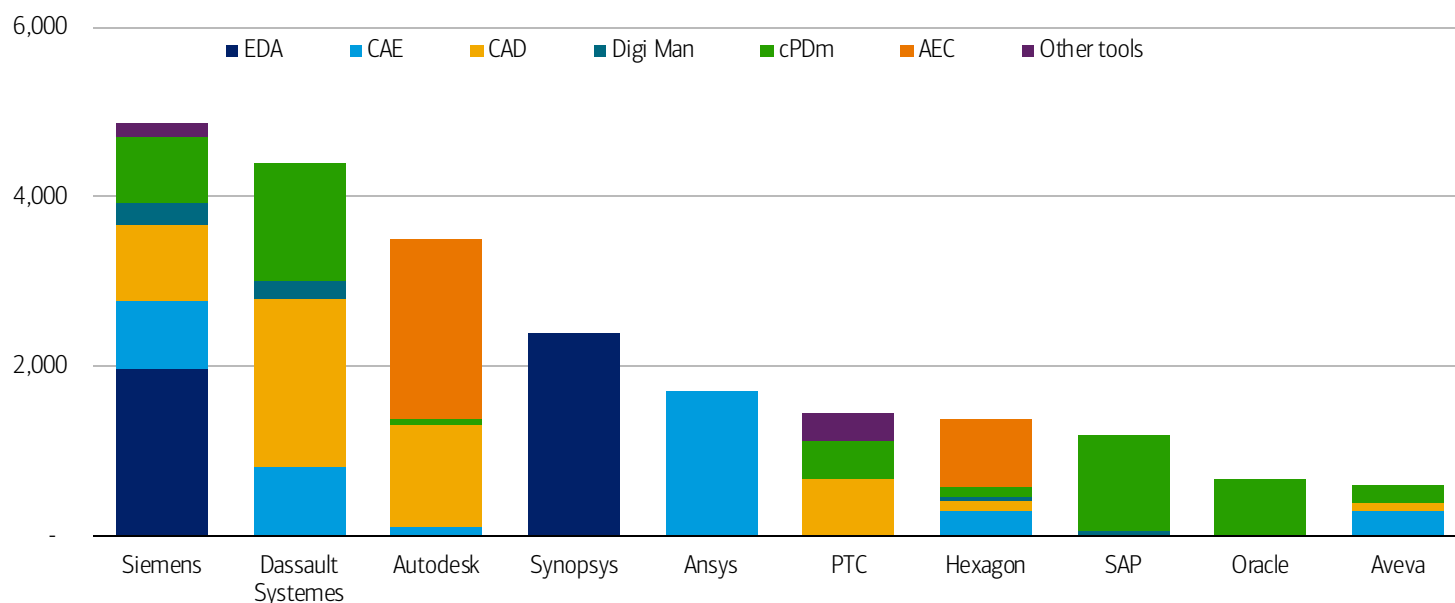
Source: CIMdata

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Given the breadth of the PLM market and the ranging capabilities between providers, we try to paint a better picture of key companies' capabilities to provide some understanding of relative growth rates both historically and in prospect.

Exhibit 18: None of the companies cover the entire breadth of PLM tools but Siemens and Dassault have the most diversified platforms (4 or more PLM sub-sectors) with revenues >USD\$ 4,000mln

Estimated breakdown of PLM companies revenue by capabilities (2020, USD\$ mln)



Source: CIMdata, company reports

Note: S&A = Simulation & Analysis, AEC = Architecture, Engineering, & Construction, Other Tools include ALM or SLM

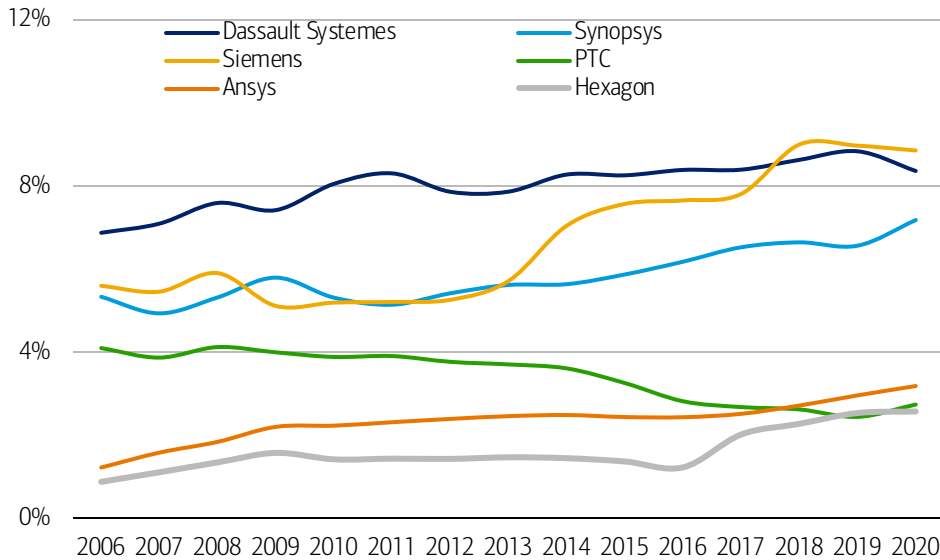
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The PLM space has been a highly acquisitive sector throughout the last 2 decades, where large players continue to buy new capabilities in addition to in-house R&D. We summarise the strategies of key players below:

- **Dassault Systemes'** M&A can be loosely grouped into three phases, which has proceeded more or less sequentially. Phase 1 was going from CAD to PLM; so addressing different parts of the product design process. Phase 2 was adding multi-physics to the existing toolset, thereby allowing it to add value in mechatronic products. Phase 3, where the focus appears today, is adding new industry domain expertise. The overarching concept is described by management as the 'product, nature and life' strategy.
- **Siemens PLM** has followed a similar path to Dassault, including building a PLM suite and then filling in scientific niches. However, more recently it has focused on electronics modelling (notably the Mentor Graphics acquisition) and less on health.
- **PTC** did follow the route taken by both Dassault and Siemens PLM for phase 1 and 2, but it has proven to be less successful. It has gone back into scope expansion (phase 1) more recently with a much more successful pivot into IOT solutions. It has not done many phase 3 acquisitions, outside of the industrials verticals.
- **ANSYS** stands a little apart from the others, since it hasn't really attempted to build a PLM suite ('phase 1'), and instead remains focused on simulation. It has though been the pioneer of 'phase 2' type acquisitions – adding multi-physics competence to its simulation product.

Exhibit 19: Relative positioning of companies remains largely unchanged over the last 15 years with Siemens and Dassault Systemes each with >8% market share, followed by Synopsys (7%) and the other players (<4% market share)

PLM market share over time by vendor



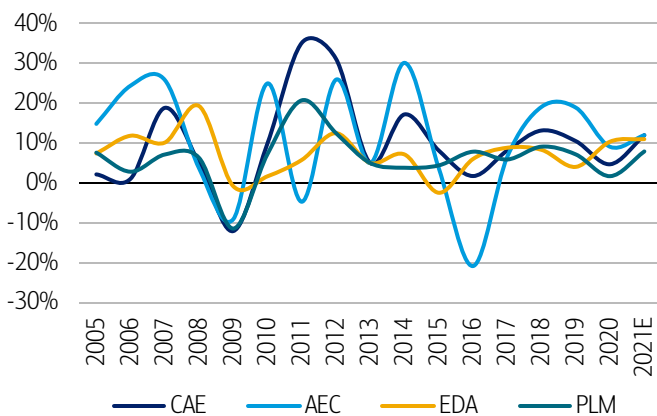
Source: Company data, CIMdata

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Despite the M&A over the last 2 decades, the relative positioning of the companies remains largely unchanged. Dassault and Siemens continue to be platform leaders while PTC has lost share. Siemens has gained market share in the overall PLM space in recent years due to its acquisitions of leading vendors in high-growth sub-segments: Mentor Graphics in EDA and CD Adapco in CAE. However, we think the market share gains/losses in other sub-segments for Siemens are less noticeable. Similarly, Synopsys and Ansys gained share due to their continue dominance and higher growth in their sub-segments. Hexagon has entered the discrete PLM market with the acquisition of MSc Software (previously Hexagon was only process-industry focused through Intergraph/PP&M).

Exhibit 20: Key sub-sectors of PLM that have outgrown the broader market over time should continue to do so again in recovery, growing at 10% or more vs. 8% for the PLM sector in 2021

YoY growth of PLM sub-segments

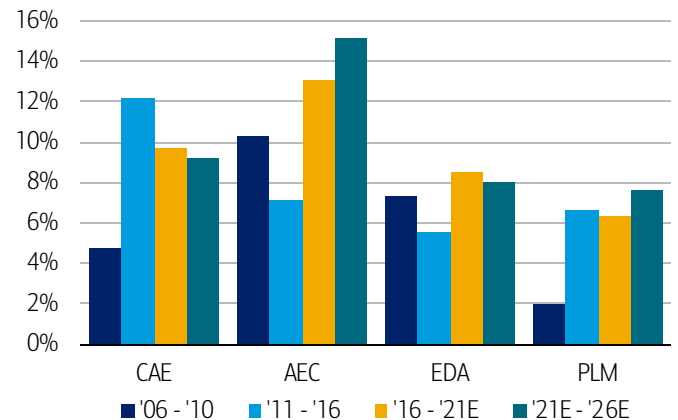


Source: CIMdata

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Exhibit 21: CAE, AEC and EDA sub-segments should all grow at >8% over the 2021-2026 period, faster than the broader PLM market (7.6% expected growth)

CAGR growth of PLM sub-segments



Source: CIMdata

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The growth rates for the AEC and EDA markets are expected to be as strong as, or stronger than the mainstream PLM market for the next 5 years, which is particularly

helpful for Siemens and Autodesk. Of the PLM providers we cover, only Siemens has exposure to the EDA market (through its acquisition of Mentor Graphics in 2017), while Hexagon has significant relative exposure to the AEC market, which is actually expected to increase at a 10% CAGR to 2024E.

Exhibit 22: Dassault has leading CAD and cPDM software whereas Siemens lead on EDA and cPDM capabilities

Comparative strength and positioning of various PLM tools – red is weakest while green is strongest

	Dassault	PTC	Siemens	Autodesk
cPDM	ENOVIA/3DX	Windchill	TeamCenter	Vault/Fusion 360
CAD - High	CATIA	CREO	Siemens NX	AutoCAD / Inventor
CAD - Low	Solidworks		Solid Edge	AutoCAD LT
EDA / ECAD	CST Studio Suite / idEM	-	Mentor Graphics	EAGLE / 123D Circuits
CAE	SIMULIA	CREO	Simcenter	Fusion 360
CAM	CATIA	CREO		Fusion 360
AEC	Design for Fabrication / DraftSight	-	Partnership with Bentley	Multiple software
DM	DELMIA	Thingworx	Tecnomatix	Fusion 360
CFD	FloEFD	FloEFD	FloEFD	

Source: BofA Global Research

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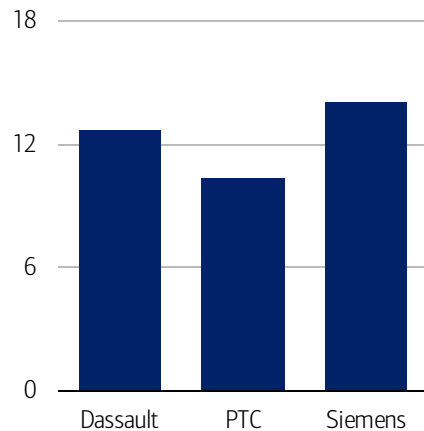
Long upgrade cycles due to customisations and cost

While PLM-related technologies have been evolving at a fast pace in the last couple of decades, the upgrade cycles for PLM solutions are notoriously long and complex, as customers often run into a number of challenges when implementing PLM:

- **Resistance to change:** We see this as the biggest challenge for PLM upgrades or migrations. Often times, engineers build their expertise around an ecosystem from a very early stage – often likely at university – and so are collectively very resistant to change. This sentiment often grows as their careers progress, meaning key decision makers are often as reluctant to change as the junior peers.
- **Resource availability:** Maintaining a modern and well-architected PLM implementation requires the right company strategy and resources at the right time, and companies often struggle to get the best out of new tech initiatives.
- **Sustainability:** PLM historically requires heavy customisation where a lot of coding was done on top of the off-the-shelf product. However, this coding is often not upgrade compatible and so becomes legacy over time.

Exhibit 23: PLM historically has a very long upgrade cycle of more than 10 years

Average years elapsed since last upgrade

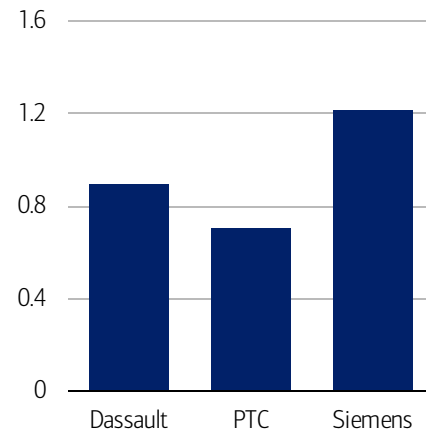


Source: CIMdata

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Exhibit 24: ...in part due to upfront cost which range from US\$700k to over US\$1mln...

Average cost of the last PLM upgrade (\$m)

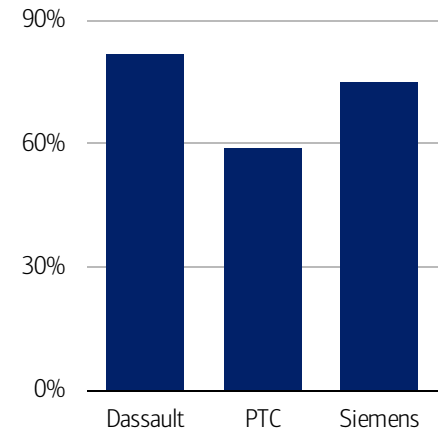


Source: CIMdata

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Exhibit 25: ...and in part due to customisations, as identified by 59% to 82% respondents in those companies

% of respondents saying yes to "Are customisations inhibiting growth?"



Source: CIMdata

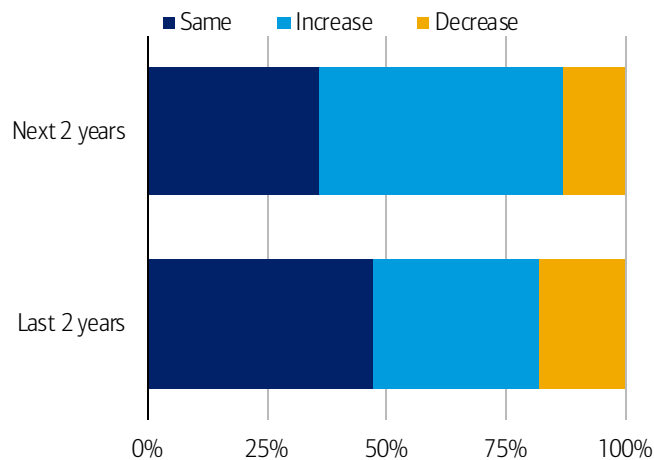
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PLM customers are therefore often stuck in decade-old PLM implementations that increasingly need to be upgraded and modernised, and so we see a growing trend for PLM platforms that are more scalable, upgradable, configurable and adaptable long term at a reasonable cost.

Cloud is often seen as a key enabler and Aras is likely the best case in point. Aras, an open-source SaaS-based PLM vendor, has been considered a mind-share leader in this space. While understandably Aras PLM implementations are likely substantially less complex than those of the likes of Dassault and Siemens customers, in the same survey as above, Aras customers upgrade roughly every 2 years and upfront cost is a fraction of that of peers, in part due to its subscription model and in part due to little customisation to begin with.

Exhibit 26: Customers increasingly see value in PLM investment

PLM budget trend from survey respondents

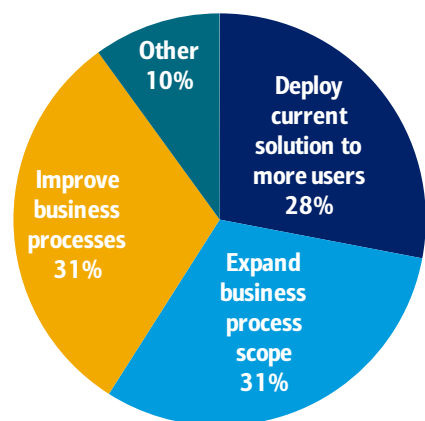


Source: CIMdata

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Exhibit 27: Multiple growth drivers for PLM investment

Split of PLM investment from survey respondents



Source: CIMdata

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A Brief History of PLM

CAD/CAM was first introduced in the 1950s and has closely paralleled the development of computers through the decades, as designers increasingly leverage computers for their calculations. First-gen CAD software was typically 2D drafting applications, and it was not until the late 1960s when CAD gained significant commercial interest. 3D CAD started to demonstrate its commercial benefits in the 1970s and, owing to the high computing costs, aerospace and automotive sectors became the first commercial users of CAD software.

PDM was established in the 1980s, as continued development of CAD/CAM applications generated more data, and PDM helps manage it through the design process. The concept was expanded in the 1990s to encompass the full product definition lifecycle, from designing, to manufacturing to servicing. The data is also no longer confined internally, but is shared across the chain, from suppliers to resellers and customers alike. This expanded concept is known as Collaborative Product Definition Management (**cPDM**).

In the early 2000s, the concept of Product Lifecycle Management (**PLM**) was introduced. PLM expands on beyond cPDM and manages the entire lifecycle, from initially understanding customer requirements to the decommissioning and recycling of obsolete products. PLM encapsulates a broad range of functions, including CAD, CAE, CAM, cPDM and Digital Manufacturing (DM), etc.

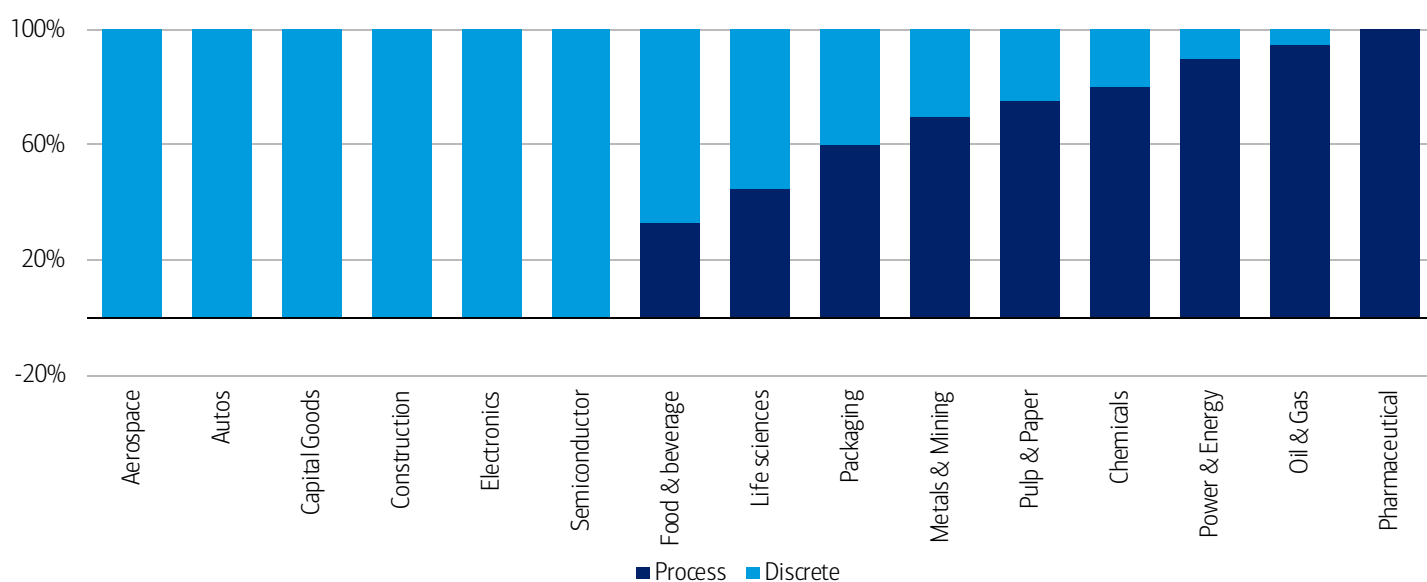
In recent years, the PLM space has carried on evolving, and product offerings have not only increased in both breadth and depth, but they are also integrating and supplementing each other better. This enables concepts like digital thread and digital twins in DM, which in turn further improves multiple stages of the lifecycle.

Sector verticals in PLM

While Autos and Aerospace are early adopters and big users of PLM, other sectors have increasingly adopted PLM tools in the last couple of years, particularly in electronics, AEC and life sciences.

Exhibit 28: Discrete industries have been the biggest users of PLM software

Discrete vs Process industries / Hybrid in between



Source: BofA Global Research

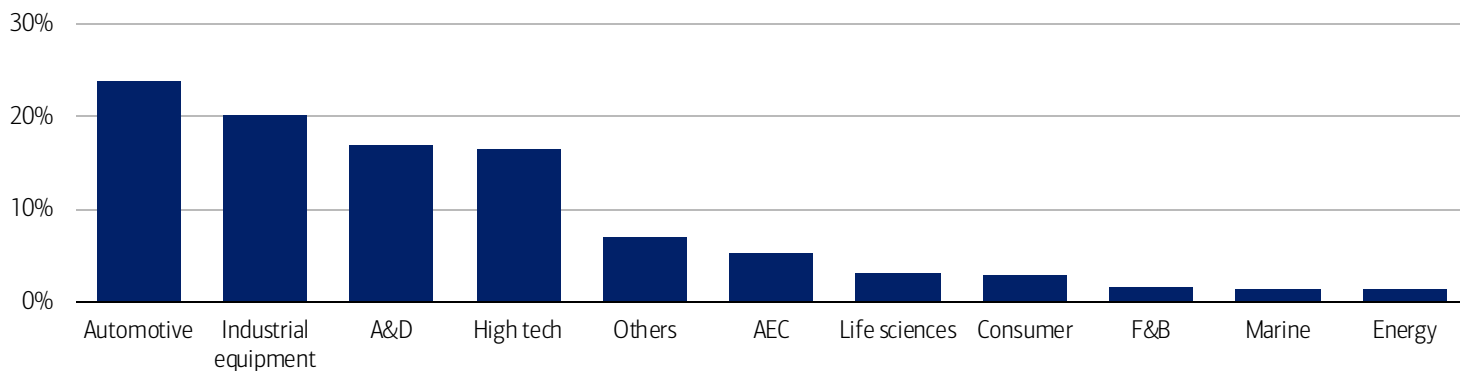
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From a customer standpoint, the PLM market generally serves discrete manufacturers and, to a smaller extent, hybrid manufacturers (i.e. Pharma and Life Sciences). Automotive (24%), Industrial equipment (20%), and Aerospace & Defence (17%), and High Tech (17%) manufacturers make up the majority of the market.

Exhibit 29: PLM market, share by industry vertical

PLM market dominated by automotive (24%), industrial equipment (20%), Aerospace and Defence (17%), and High Tech (17%)



Source: BofA Global Research, Quadrant Market Research

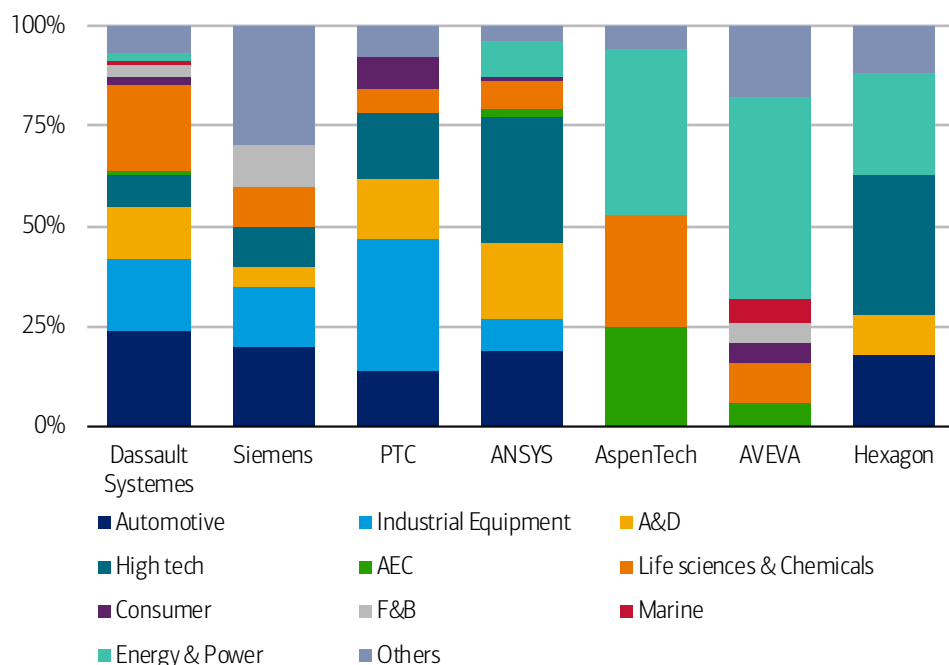
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While automotive and aerospace supply chains are clearly under considerable pressure right now, growth from semiconductor and electronics markets is likely to increase with the return to growth in spending in those end-markets (discussed later in the report). With capital spending under significant pressure in the aftermath of the COVID-19 economic impact, the demand for simulation & analysis is likely to increase, particularly as capabilities in that area extend beyond just the product design to production planning, certification and operational analysis in the context of through-life digital twins.

In addition, the Architecture, Engineering & Construction (AEC) market is starting to adopt software solutions in a far more holistic way, and the growth there is also expected to be strong in the medium term, despite our concerns around project sanctioning.

Exhibit 30: Company revenue split by vertical sectors

A wide range of end market exposure



Source: BofA Global Research estimates, Company data

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Automotive

Automakers have historically been the leading sector for PLM implementations, as automakers aim to differentiate their products by competing on quality, comfort and safety. CAD helps scale down production costs by reducing the number of expensive car prototypes, while CAE simulation helps reduce product recalls that are a seemingly inevitable part of the industry.

The electrification and roll-out of electric vehicles make a clear case for growth in simulation software that is needed to model real-time outcomes and monitor vehicle performance. There is also more demand for higher interoperability among PLM tools to connect vehicle design, engineering changes and prototyping together with manufacturing and sales. Dassault has recently commented that most EV players are adopting cloud-based solutions, leading to higher traction in its cloud solutions.

Exhibit 31: Pairing Dassault CATIA with Siemens TeamCenter has been a common theme across automakers and we see few changes in the past 5 years

PLM solutions used by automakers

Automaker	cPDM	CAD	EDA	CAE	CAM
BMW	PTC Windchill	Dassault CATIA	Siemens Mentor Graphics	Dassault SIMULIA	Dassault DELMIA
	Aras	PTC Creo		Siemens Simcenter	Siemens Tecnomatix
Daimler	Siemens PLM	Siemens NX	Siemens Mentor Graphics	Dassault SIMULIA	Dassault DELMIA
				Siemens Simcenter	Siemens Tecnomatix
FIAT	Siemens Teamcenter	Siemens NX	Siemens Mentor Graphics	Siemens Simcenter	Siemens Tecnomatix
				Dassault SIMULIA	
Ford	Siemens Teamcenter	Dassault CATIA	Siemens Mentor Graphics	Dassault SIMULIA	Siemens Tecnomatix
		Siemens NX			
GM	Siemens PLM	Siemens NX	Siemens Mentor Graphics	Siemens Simcenter	Siemens Tecnomatix
	Aras				
Honda	Dassault ENOVIA	Dassault CATIA	Siemens Mentor Graphics	Siemens Simcenter	Dassault DELMIA
	Siemens Teamcenter			Dassault SIMULIA	Siemens Tecnomatix
	Aras			Fusion 360	
Hyundai	PTC Windchill	Dassault CATIA	N.A.	Siemens Simcenter	Dassault DELMIA
		PTC Creo		Dassault SIMULIA	Siemens Tecnomatix
		Siemens Solid Edge			
Jaguar Land Rover	Dassault PLM	Dassault CATIA	Siemens Mentor Graphics	Dassault SIMULIA	Dassault DELMIA
	Siemens Teamcenter			Simcenter	
Nissan	Siemens Teamcenter	Siemens NX	N.A.	Siemens NX	Dassault DELMIA
	Autodesk Vault	Autodesk AutoCAD			Siemens Tecnomatix
PSA	Dassault ENOVIA	Dassault CATIA	Siemens Mentor Graphics	Siemens Simcenter	Dassault DELMIA
Renault	Dassault 3DX	Dassault CATIA	Siemens Mentor Graphics	Siemens Simcenter	Siemens Tecnomatix
Suzuki	Siemens Teamcenter	Siemens NX	N.A.	Siemens Simcenter	Siemens Tecnomatix
Tesla	Dassault V6	Dassault CATIA	Siemens Mentor Graphics	N.A.	Dassault DELMIA
		Autodesk ALIAS			
		Siemens NX			
		PV SOL			
Toyota	PTC Windchill	Dassault CATIA	Siemens Mentor Graphics	Siemens Simcenter	Dassault DELMIA
	Siemens Teamcenter	PTC Creo			Siemens Tecnomatix
Volkswagen	Siemens Teamcenter	Dassault CATIA	Siemens Mentor Graphics	Fusion 360	Siemens Tecnomatix
		PTC Creo			
Volvo	Siemens PLM	Dassault CATIA	Siemens Mentor Graphics	Siemens Simcenter	Siemens Tecnomatix
	PTC Windchill	Creo			

Source: BofA Global Research

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While autos has been one of the leading industries to implement PLM solutions, changes in the PLM backbone vendor happens infrequently. We have been tracking what automakers use (Exhibit 31) based on information available on the internet for the past 5 years and we note minimal changes. Pairing Dassault CATIA with Siemens Teamcenter continues to be a popular combination across automakers, though increasingly we see more automakers also testing out Aras implementations, but often likely with very few seats to date, with GM being a notable exception where it committed to 50,000 Aras seats in 2016.

In the short term, while many OEMs and tier suppliers are mostly still restricted on projects that deliver a very short ROI (often 6-8 months), we also see noted some ongoing digital transformation in place, with supplies progressively making upgrades to their entire enterprise technology stack (e.g. not just in PLM, but also to cloud ERP, MES, TMS, etc.).

Aerospace & Defence

Dassault and Siemens dominate this sector, with a number of major companies using both as vendors. Similar to the Autos sector, Aras is a challenger in the cPDM space where it signed a 30,000 seat deal with Airbus back in 2015.

Exhibit 32: Dassault and Siemens dominate the A&D space

PLM solutions used by A&D players

	CAD	PDM	EDA	CAE
Airbus	Dassault CATIA	Aras Dassault 3DX	CST Studio Suite	Simcenter
Boeing	Dassault CATIA Siemens NX	Aras Dassault 3DX	Mentor Graphics	Dassault SIMULIA
Embraer	Dassault CATIA			
Dassault Aviation	Dassault CATIA			
Israel Aerospace Industries	Siemens PLM			
Lockheed Martin	Siemens PLM			
Sukhoi	Dassault CATIA, Siemens NX and Teamcenter			

Source: BofA Global Research

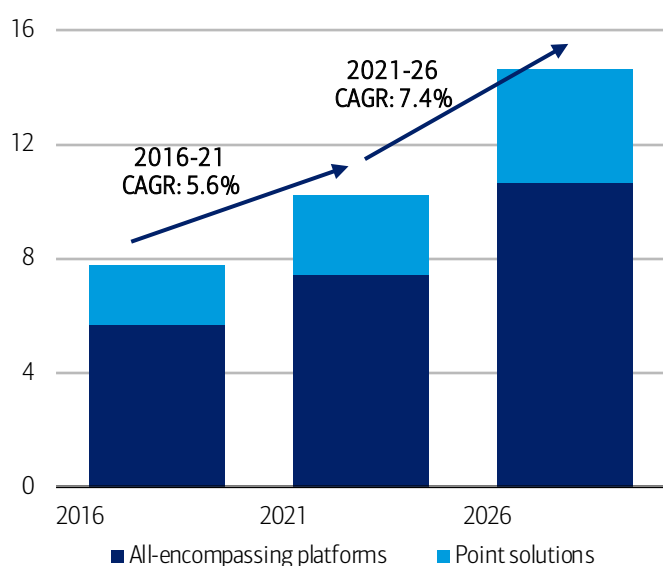
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Collaborative Product Definition Management (cPDM)

The overall cPDM market is estimated at \$10bn in 2021 growing to \$15bn by 2026 (7% CAGR). It serves as the backbone and platform for all PLM tools, as it manages all the data cross the lifecycle of a product. Key players include Dassault (ENOVIA/3DX), Siemens (TeamCenter), PTC (WindChill), Aras and SAP.

Exhibit 33: cPDM is expected to grow 7% CAGR FY21-26E
cPDM software market size (\$bn)



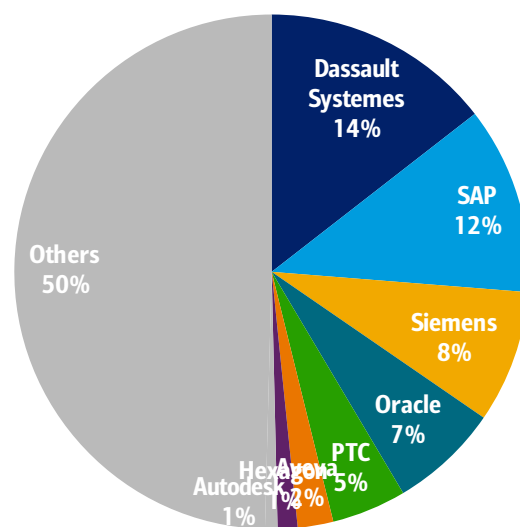
Source: CIMdata

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Collaborative Product Definition Management (cPDM) software is used to manage and integrate product data into a centralised system for better tracking and enhanced collaboration among teams as well as increasingly along the entire value chain. cPDM software modules are used throughout the PLM process given all steps (concept, design, execution, commissioning and disposal) require close collaboration between the numerous actors involved. Those solutions also help in effective product data management, collaborative product visualisation, collaborative product commerce, effective integration of cPDM with enterprise applications, and supplier relationship management.

cPDM has evolved to include dozens of features, but we have highlighted below a few of the key ones that have helped address some of the biggest issues facing the industry:

Exhibit 34: Dassault leads the market with ENOVIA and 3DX
cPDM software market share (2020)



Source: BoFA Global Research estimates

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Exhibit 35: cPDM form the backbone of PLM software with a host of essential features

A select list of cPDM common capabilities

Core capabilities	document management	Bill of Materials	component management	configuration management
Other additional capabilities	Links to ERP/MES Quality mgt Business Intelligence	Authoring systems Source code mgt Collaboration	Compliance mgt Sourcing Reporting & Analytics	MRO Mgt Visualisation Workflow Mgt

Source: BofA Global Research

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cPDM has also evolved over the last two decades to serve a wider purpose and to encapsulate more data:

Exhibit 36: Comparison between legacy PDM and modern cPDM

Modern cPDM is increasingly becoming an essential part of PLM solutions

	Legacy PDM	Modern cPDM
Data managed	MCAD file document, some BoMs	Almost everything
Data sharing	e-mail, FTP, shared drives	Secure environment
Supply Chain	Not involved	Full supply chain support
Discipline	Mostly mechanical	Multi-discipline (mechanical, electrical, software engineering, etc.)
Bill of Materials	Typically from ERP software	Support both mBoM and eBoM
Interoperability	Limited	High
Integration with others	Limited	High

Source: BofA Global Research

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Replacing or upgrading existing cPDM solutions in production often requires significant resources and knowledge. Cloud migration can eliminate direct hardware costs and related operational IT overheads, but cPDM implementations are often complex and require expertise typically not available in-house.

Competitive landscape in cPDM

Top cPDM software include solutions from leading PLM vendors – Teamcenter (Siemens), ENOVIA (Dassault), Windchill (PTC) – as well as SAP PLM and Aras Innovator from Aras, a small company but a mindshare leader in this space.

Dassault 3DX – a collaboration platform

We expect Dassault's long-term investment into a design and collaboration platform ('3DEXperience') could result in market share gains and further scope expansion with key customers. Platform deal wins with leaders across industries (Boeing, Toyota, EDF, BHP Billiton, ExxonMobil and others) suggest the platform has resonated well with customers across the spectrum. Further, the acquisition of Medidata (clinical trial software company) has transformed Dassault's healthcare exposure – a sector well placed to reap significant benefits from digitisation, in our view.

We note management's bullish comments on competitive wins versus competition – albeit with the caveat that relative growth rates are not reflecting such a drastic win ration in competitive bids.

In Q2'21 earnings call, Dassault COO & CFO Pascal noted 3DX having displaced most of the Siemens TeamCenter competition in A&D, and while where Autos there is still a significant Siemens presence, he noted that newer Autos players (e.g. Tesla, Rivian, etc.) have all standardised on the 3DX platform.

Exhibit 37: Dassault Systemes 3DX Platform

Integrating 3D modelling, collaborative, information intelligence and simulation apps on a single platform



Source: Company

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Siemens SAP Partnership to create a tighter ecosystem

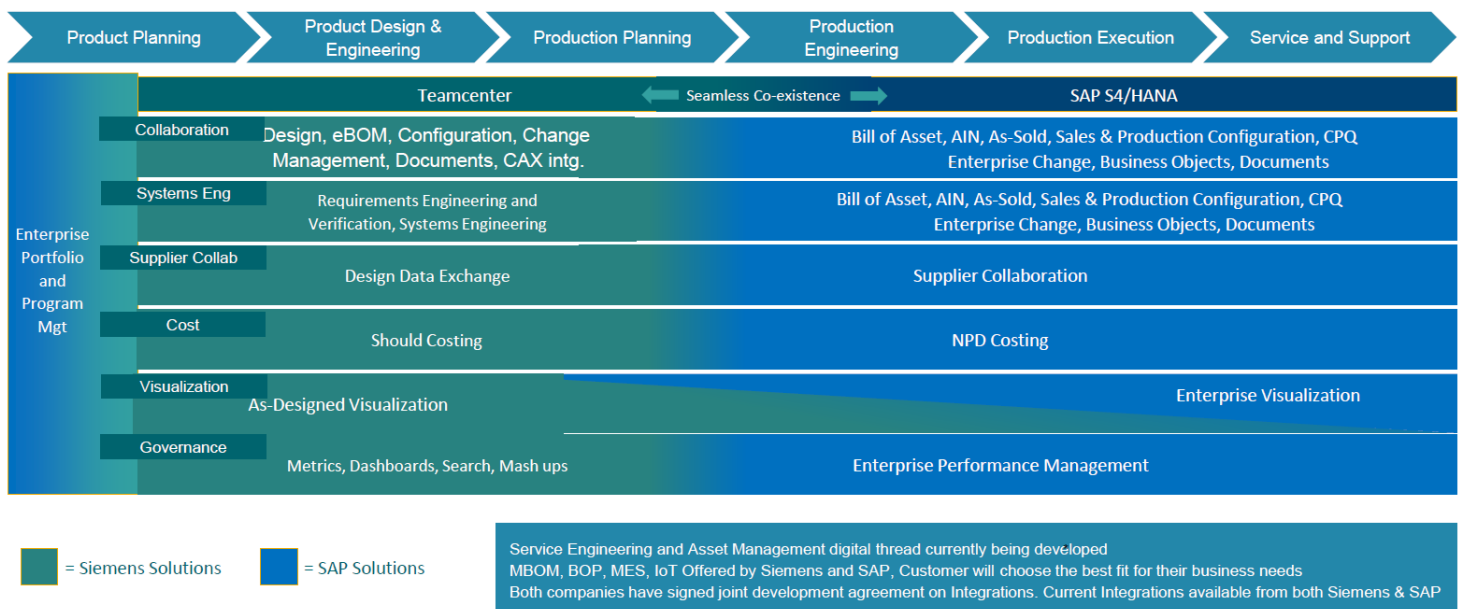
In July 2020, Siemens and SAP announced a new strategic partnership to integrate their PLM and ERP offerings working towards an integrated digital thread. Initially focusing on discrete manufacturing industries, both companies have also committed to cross-sell solutions to their respective user-base. In July 2021, both companies provided a comprehensive roadmap to integrate SAP S/4 HANA (ERP solution) and Siemens's TeamCenter (PLM solution) in three phases through to 2022.

Exhibit 38: Siemens SAP Partnership Areas of Synergy

Siemens SAP PLM partnership

Siemens/SAP Creating End-to-End Digital Threads

Partnership Areas of Synergy



Source: Company

BofA GLOBAL RESEARCH

These new joint solutions close the loop between IT and OT systems, which is a key driver to realising digital thread. While previously joint SAP and Siemens customers have had to build the digital thread themselves, SAP-Siemens will likely be doing most of the heavy lifting, and the end-solution for customers is presumably better, more robust and with a lower total cost of ownership.

It is worth noting that SAP has also remain committed to work on its SAP PLM product through to 2040, which has a strong customer base outside discrete manufacturing.

PTC's \$715m acquisition of SaaS cPDM/PLM provider Arena

PTC completed the acquisition of Arena, SaaS cPDM/PLM provider, in early 2021. Arena unifies a number of cPDM capabilities in the cloud, allowing The Arena Solutions product realisation platform unifies PLM, quality management, and requirements management and allows participants along the value chain to work together in a secure cloud environment. In our view, the announced acquisition underscores the need to accelerate the transition to SaaS/cloud post COVID-19. Together with OnShape, Arena Solutions enables PTC to provide a more comprehensive CAD + PLM SaaS solution.

The next step would be to leverage the Atlas platform to transition core CAD (Creo) and PLM (Windchill) software into a multi-tenant SaaS/cloud ecosystem. PTC has not indicated a strict timeline around this eventual shift to SaaS. However, the Arena acquisition and management's messaging suggest this shift could happen more quickly than initially expected (our IIoT Summit indicated potentially by FY25).

Aras – major investment from GI Partners to build out platform

Aras has been gaining a lot of attention in recent years for its solution Aras Innovator, a free open-source cPDM solution. Since 2017, it has been on the “PLM Mind Share Leaders” list compiled by CIMdata, which comprises major players Dassault, Siemens PLM, Autodesk, SAP, PTC, IBM and Oracle. Revenue from any of the other players continues to dwarf that of Aras, but Aras is often highly regarded due to its open source business model as well as technological and thought leadership. Notable big wins for Aras include automaker GM (50,000 seats), Airbus (30,000 seats) and global automotive supplier Schaeffler Group (20,000 seats).

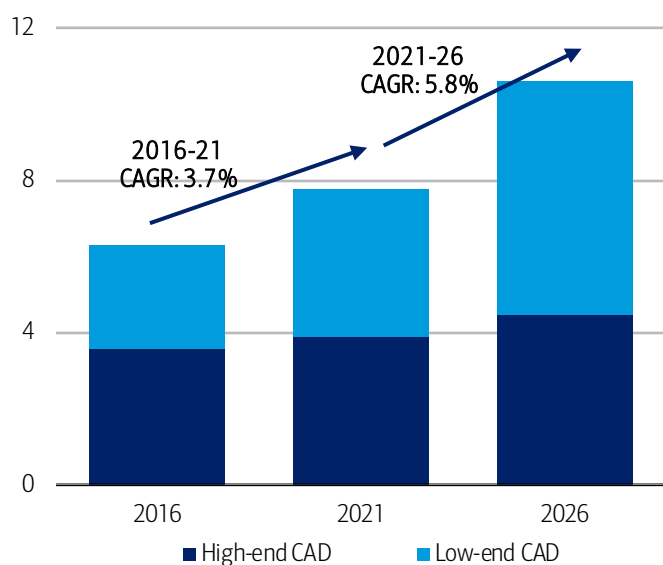
In April 2021, PE firm GI Partners made a major investment (est. at \$860m by CIMdata) in Aras, allowing it to further build out the Aras Innovator platform and to compete head-to-head against other mindshare leaders.

Computer-aided Design (CAD)

The overall CAD market is estimated at \$8bn in 2021 growing to \$11bn by 2026 (6% CAGR). CAD modelling software that allows users to create and design 3D renderings of products or plant assets and use those digital models to train workers, define and solve problems, and improve design productivity for faster time to market. Key players include Dassault, Siemens, Autodesk and PTC.

CAD modelling software allows users to create and design 3D renderings of products or plant assets and use those digital models to train workers, define and solve problems, and improve design productivity for faster time to market. CAD has historically been most commonly used in the Autos and A&D industries, but has since expanded to many other discrete manufacturing and process industries.

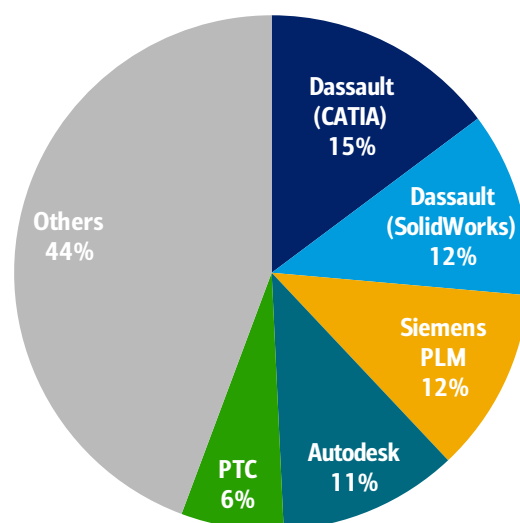
Exhibit 39: CAD expected to grow 6% 21-26 CAGR driven by lower-end
CAD software market size (\$bn)



Source: CIMdata

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Exhibit 40: Dassault is the runaway CAD leader with CATIA and SW
2020 market share of the CAD software market



Source: BofA Global Research estimates

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Dassault the leader in CAD market with CATIA and SW

Dassault's CATIA and SolidWorks dominate the CAD market, with CATIA positioned in the high end, vs SolidWorks in the low-end (mainstream). **Siemens's NX and SolidEdge** are the closest competitors to CATIA and SW. **PTC's CERO** competes. PTC has also partnered with ANSYS, a leader in engineering simulation. The combined offering provides customers with PTC's 3D CAD modelling and ANSYS's Discovery Live platform, bringing real-time simulation into the modelling environment. This enables engineers to see real-time results of design changes in their virtual models.

Exhibit 41: Dassault has leading software in both the high-end and low-end CAD market

List of notable CAD software by different vendors

	High-end	Low-end
Dassault	CATIA	SolidWorks
Siemens	NX	Solid Edge
PTC	CREO	OnShape
Autodesk	AutoCAD / Inventor	AutoCAD LT
Sector specific	AEC: Nemetschek, Bentley Plant Design: AVEVA, Hexagon Shipbuilding: AVEVA, AutoDesk EDA: Cadence, Synopsys	

Source: BofA Global Research

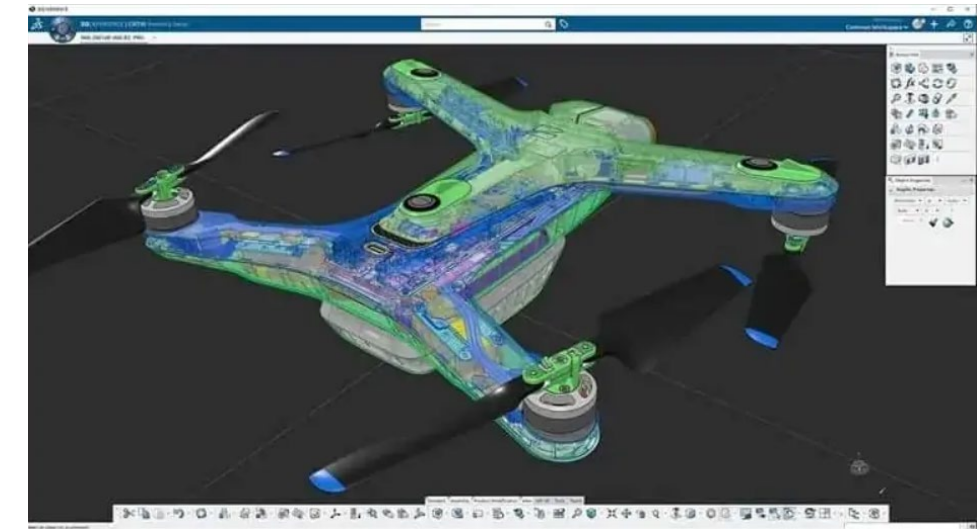
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There are mainly two types of modelling in CAD:

- **Parametric modelling** uses parameters to define a model. The parameters may include dimensions, density of the material, and data related to the material surface. The dimension control capabilities and feature definition properties make parametric modelling a preferred choice for many designers.
- **Direct modelling** enables designers to get direct access to the geometry of the product. This allows complete manipulation and editing with least concerns about features and dimensions.

Exhibit 42: CATIA is the leading CAD software

Screenshot of Dassault's CATIA software



Source: Company

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Most CAD software use both direct and parametric modelling types. Direct modelling is often preferred during the initial stage of conceptualising, while parametric modelling is useful in detailed designing. CAD players are developing new solutions that use direct modelling without losing the benefits of parametric modelling. Siemens's synchronous technology is often considered market leading in this regard as it focuses on enhancing the interaction with parametric models directly with a high level of efficiency.



Exhibit 43: Dassault and Siemens offer the broadest set of CAD capabilities with mature low-end and high-end CAD solutions

Summary of CAD software capabilities

Vendor	Product	Price	Known for
Dassault	CATIA	*****	Most advanced capabilities, often used in Autos and A&D
	SolidWorks	***	Broad range of industrial users
Siemens PLM	NX	****	Strong cPDM integration with TeamCenter
	Solid Edge	***	Similar to SolidWorks but with less Autos bias and more AEC
PTC	CREO	***	Strong integration with Windchill and ANSYS
	OnShape	**	Browser-based and requires no installation
Autodesk	Inventor	***	Focuses on digital prototyping and simulation
	AutoCAD	**	Broad range of users, focuses on 2D drafting
	Fusion360	*	Common among enthusiasts and start-ups

Source: BofA Global Research

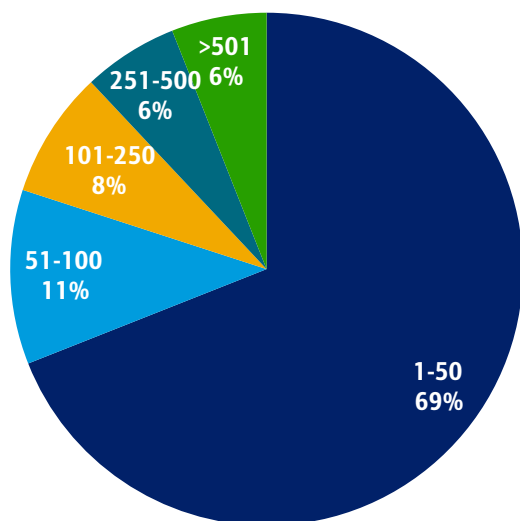
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Leading PLM tools shift to the cloud

CAD has been one of the sub-segments of PLM that has kick-started the shift to cloud. However, we note that cloud-based CAD now are often either not fully native, or lag behind in capabilities compared to best-in-class solutions like CATIA and NX. Cloud deployments are also relatively small (Exhibit 44).

Exhibit 44: A few sizeable Cloud implementations ahead

No of seats on users using/planning to use cloud based CAD

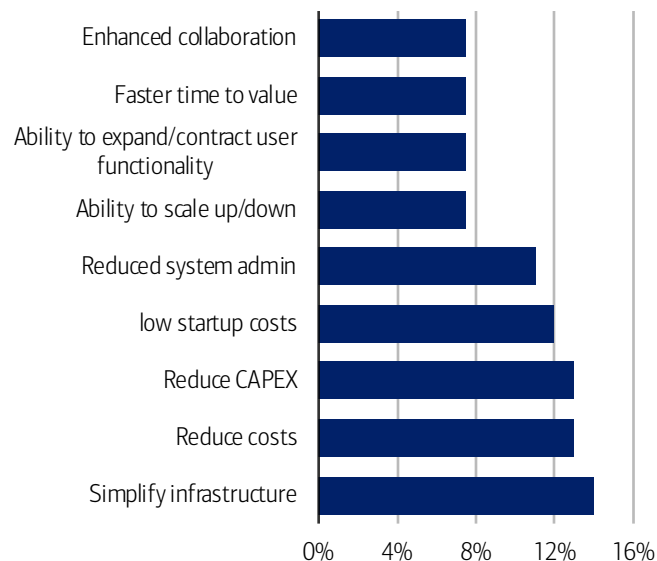


Source: 2021 CIMdata survey

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Exhibit 45: Benefits achieved from investment in cloud MCAD

Infrastructure simplification and cost savings the main drivers for Cloud migration



Source: 2021 CIMdata survey

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OnShape progress: tracking well ahead of expectations

COVID-19 has accelerated demand for OnShape, given its cloud and browser-native interface has allowed for users to collaborate remotely in work-from-home environments (versus on-premise Creo). In 2020, PTC displaced 700+ competitive logos and grew its OnShape ACV by 82% in 4QF20. This was largely driven by growth in educational users (now at ~1 million, 330% y/y growth in FY20). The FY21E growth outlook is strong, supported by a robust pipeline of deals. We think OnShape is nearing an inflection point and should start to contribute meaningfully to Growth ARR as PTC further penetrates key industrial verticals. By FY23, we estimate OnShape could be 10% of Growth ARR. We note OnShape (and its SaaS functionality) is the foundation of the Atlas platform and provides the building blocks for PTC to begin its core SaaS transition.

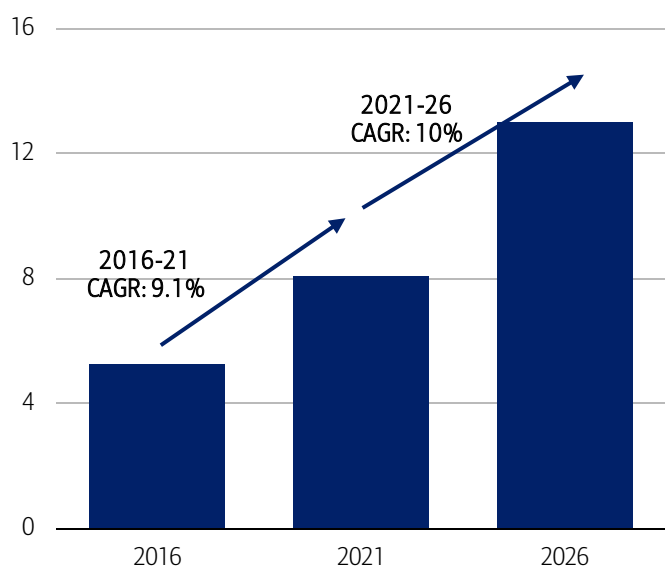
Computer-aided Engineering (CAE)

The overall CAE market is estimated at \$8bn in 2021 growing to \$13bn by 2026 (10% CAGR). CAE is also often referred to as simulation & analysis tools (S&A), CAE is more niche and less fragmented compared to the broader PLM market. Key players include specialists like ANSYS, MathWorks, Altair and MSC Software, as well as larger PLM players like Dassault and Siemens.

Computer aided Engineering (CAE) is the use of computer software to aid in engineering analysis. It helps analyse performance and robustness of components through validation, simulation and optimisation, which in turn provide key data to help support decision-making in the design choices. Hence, CAE is particularly relevant during the designing phase of a product's lifecycle, especially via the use of Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), multibody dynamics and simulation and optimisation.

Exhibit 46: CAE is expected to grow 10% CAGR FY21-26E

CAE software market size (\$bn)

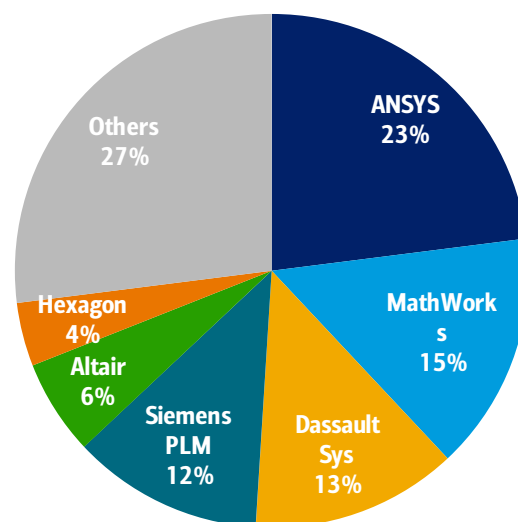


Source: CIMdata

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Exhibit 47: CAE specialists have >50% market share in the space

2020 market share of the CAE software market; ANSYS has largest share at 23%



Source: BofA Global Research estimates, CIMdata, Company reports

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Over the past 5 years, the CAE market grew at an estimated 9% CAGR versus the broader Product Lifecycle Management (PLM) market growing at a 7% CAGR. In 2020 amidst pandemic-related headwinds, CAE was one of only two verticals of PLM that grew, highlighting the importance of simulation as a way for companies to reduce inefficiencies early on in product development. We see the trend of digitalization, which has arguably accelerated post-COVID, as a meaningful tailwind to market growth going forward. Recent advancements in technology (digital twin and pervasive simulation) provide new use cases for simulation, particularly within industrial manufacturing environments. We also note the trend of the industry moving to SaaS-based models as a potentially very meaningful tailwind to market growth.

ANSYS is the leader in the CAE market

ANSYS is the industry-recognized thought leader in the global simulation & analysis (S&A) market, with an estimated 23% market share for 2020E. Exhibit 47 outlines other key players in the space, including MathWorks (private company with ~15% share), Dassault Systemes (13% share), Siemens PLM (12% share), Altair (6% share), and Hexagon (acquired MSC Software, 4% share). ANSS' "difficult-to-copy," physics-based approach, industry recognition, and ability to focus on research and development in simulation & analysis have made the name a clear frontrunner.

Medium and long-term outlook for the CAE market is strong, driven by secular growth in digitalization, re-shoring, and the increasing need for manufacturers to improve operational efficiencies and automate production. Over the past five years, the S&A market grew at a ~8% CAGR (versus broader PLM at ~6% CAGR). CIMdata estimates the S&A market is one of only two segments that grew in 2020. We forecast the S&A market grew 1% in 2020 versus the broader PLM market at roughly flat. We attribute this relative resilience to accelerated digital efforts brought on by COVID-19. Ansys management has highlighted that it anticipates its revenue CAGR will accelerate materially post-COVID due to this trend. For the broader S&A market, we forecast 12% growth in 2021 accelerating to 14% growth in 2022.

Growth drivers for CAE market

Key growth areas by sector

- **Industrial manufacturing:** adoption of simulation is becoming a more viable use case for discrete manufacturing and other industrial applications, aided by increasing c-suite support of digital implementation and increased processing power that allows for real-time simulation on the factory floor. Ansys' partnerships with ROK and PTC are examples for better integration between OT hardware and other key IT technology (PLM, CAD, IoT, etc.).
- **Automotive:** as electrification and roll-out of electric vehicles gain momentum, this makes the clear case for growth in simulation software that is needed to model real-time outcomes and monitor vehicle performance. While the automotive industry has already been a big user of CAE software, this has been more closely tied to modelling in the design phase and not pervasive, real-time simulation needed for autonomous vehicles.
- **Aerospace:** historically, the aerospace & defense industry has been a key user of CAE software. We expect accelerated growth going forward supported by strong military budgets and increasing use of flight simulation software (digital twin).
- **Healthcare:** growth of S&A in healthcare, particularly in pharma and medical device manufacturing, is supported by the accelerating trend of Pharma 4.0 post-COVID as Pharma manufacturers look to digitize product lifecycle and manufacturing processes. Several key automation providers like ROK and EMR have highlighted strong growth outlook for Life Sciences.

Shift to cloud, but slower than rest of PLM tools

As discussed in earlier sections, SaaS-based model increasing the scope of future revenue and cash flow generation, it also allows for penetration into new market segments (small/medium sized businesses), where previously the costs to setup might have been prohibitively high. However, given current technology limitations and computing requirements needed for pervasive simulation, we do think that CAE transition to the cloud could lag vs other PLM tools.



How does simulation work?

Despite advances in computing power, it is still infeasible to analyse a product from atom to atom. **Pre-processing phase** first takes the model output from CAD software and breaks it down into very small pieces (a finite element mesh). It then defines material properties, load conditions, and boundary conditions. All the pieces are inter-related through matrix equations.

The **analysis phase** then applies mathematical formulas to solve these equations using solvers. Mechanical solvers are most common, but there are also other kinds of solvers, e.g. acoustic solvers, electromagnetic solvers and thermic solvers, for calculating each respective domain. This process is the most compute intensive phase and can take hours or days to run. Dynamic non-linear analysis will be more accurate but will also be more resource intensive compared to static linear analysis. Refer to section below for further explanation.

The **post-processing phase** then reports the results, in graphical format for better visual understanding, and in text format (log files) for error debugging. Such feedbacks can then go back to the CAD designs for further improvement and the FEA process repeated.

Types of CAE

CAE analysis can broadly be defined in the following four types:

- **Finite Element Analysis (FEA)** sources CAD software's model output and breaks it down into very small pieces (a finite element mesh). It then defines material properties, load conditions, and boundary conditions. All the pieces are inter-related through matrix equations. The analysis phase then applies mathematical formulas to solve these equations using solvers.
- **Computational Fluid Dynamics (CFD)** is also applied during the designing stage of the product's life: it analyses the flow, turbulence, pressure distribution and interaction of liquids and gases with various structures, as is used mostly in to analyse thermal, acoustic and air turbulence.
- **Multibody dynamics (MDB)** has two types – inverse dynamics and forward dynamics. Inverse dynamics analyses the forces to move the system in a specific way while forward dynamics analyses the movement of individual components by external forces.
- **Simulation & Optimisation** involves techniques to automate and enhance the use of CAE tools.

Static vs dynamic, linear vs non-linear analysis

Static analysis assumes applied load does not vary with time and ignores effects like inertia, vibrations and damping. Dynamic analysis takes these factors into account, which is essential for tests like crash tests and drop tests.

Linear elastic material (e.g. steel) and an elastomeric material (e.g. rubber): Linear analysis can be applied to steel when stress applied moderately. As long as it is below the yield strength, steel will return to original shape when the stress is removed, making linear-analysis suitable. However, when excess stress is applied, it will deform permanently and exhibits material non-linearity. Other materials, such as rubber, are inherently non-linear. Non-linear analysis is required in these two scenarios.

Geometry non-linearity happens when the shape of the object has deformed materially, leading to a change in the stiffness of the object. For linear analysis, calculations are based only on initial geometry, meaning non-linear analysis is required instead.

MSC is considered a benchmark for simple linear solutions whereas ANSYS is good at both and is a leader in non-linear solutions.

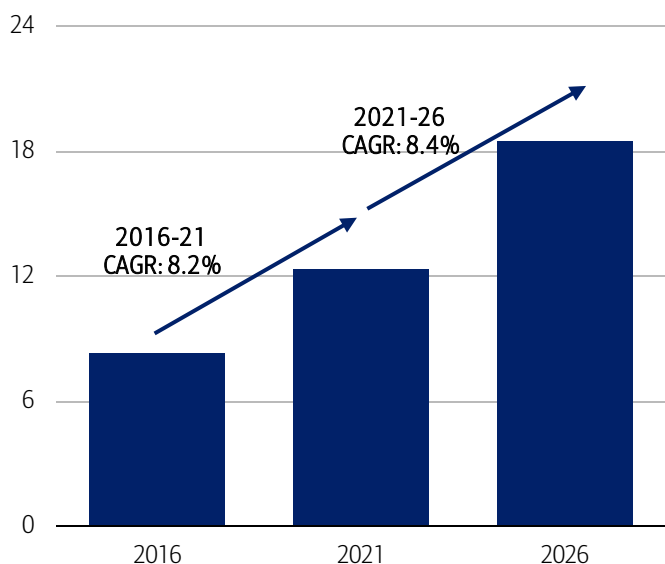
Electronic Design Automation (EDA)

EDA software is a \$12bn market growing at 6%, focusing on designing electronic components like circuit boards and integrated circuits that is present in anything electrical. Key players include Cadence Design Systems, Synopsys and Siemens (through acquisition of Mentor Graphics).

Electronic Design Automation (EDA) software are tools for designing electronic systems such as integrated circuits and printed circuit boards (PCB). As electronics are embedded into more and more products and as PCB and chip designs become increasingly complex, EDA software tools has also become more important and valuable over time. The EDA market is roughly \$12bn currently, having grown 8% CAGR FY16-21 and we continue to expect similar growth trajectory in the next 5 years, driven by higher chip demand from the major end-users of semiconductors. Notable examples include electrification and autonomous driving in Autos, more IoT connected devices in industrials and more complex hi-tech devices over time.

Exhibit 48: EDA has been growing 8% CAGR for the last 5 years

Market size of EDA software market

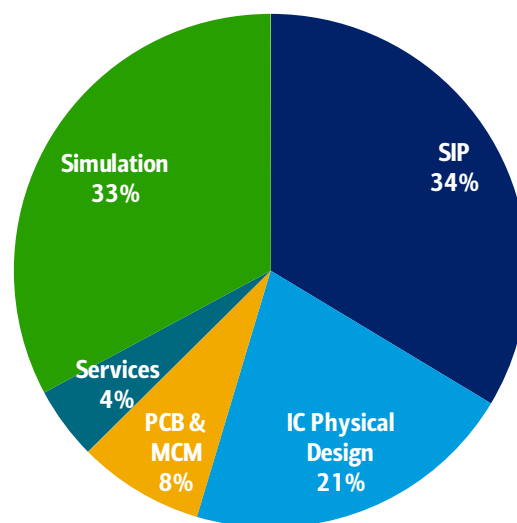


Source: CIMdata

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Exhibit 49: SIP (34%) & simulation analysis (33%) accounts for the bulk of EDA

Split of EDA software market



Source: BofA Global Research estimates

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Synopsys is the overall #1 in EDA, followed by #2 Cadence and #3 Siemens (Mentor Graphics). Siemens is the #1 in IC Physical Design and Verification whereas Cadence is #2 in most EDA sub-segments.

EDA is split into four key segments:



SIP

Semiconductor Intellectual Property (SIP) is the largest segment of the global EDA market. This include three sub segments Processor IP, Physical IP and Digital IP. The rising demand for semiconductors in industries, such as automotive, industrials, and healthcare continue to underpin growth within this segment.

Simulation & Analysis

Simulation & analysis (S&A) is the second largest segment in the global EDA market. This segment includes electronic security level (ESL), register-transfer level (RTL) simulation, hardware-assisted verification, analysis tool, synthesis, analog and mixed-signal simulator, formal verification, design entry, and logic and formal verification segments. Semiconductor players are increasingly outsourcing their CAE capabilities to EDA players as it is costlier to develop it in-house.

IC Physical Design and Verification

The IC physical design and verification segment is the third largest segment of the global EDA market and has historically been growing low-mid single digits. Physical design converts circuit designs into geometric representations of integrated circuits. Main steps include partitioning, floor planning, placement, clock tree synthesis, signal routing and timing closure. Verification then confirms if design layout is correct.

PCB & MCM

A printed circuit board (PCB) is a thin board made of fiberglass that connects the electrical and mechanical components in an electronic device using conduction tracks (e.g. copper). PCBs are used in a very wide range of electrical products. A Multi-chip Module (MCM) integrates IC chips and semiconductors into a single unit.

Architecture, Engineering & Construction

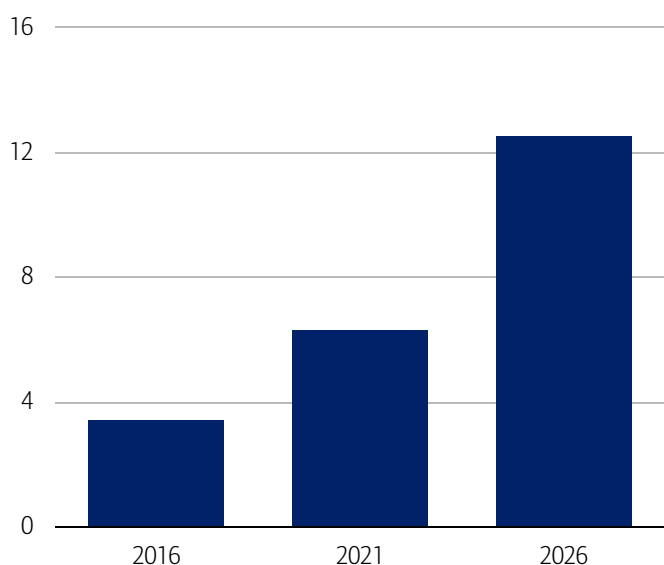
The overall AEC market is estimated at \$6bn in 2021 growing to \$13bn by 2026 (15% CAGR), reflecting the need for the sector to digitise to address considerable inefficiency in terms of time, capital and energy. Key players include Autodesk, Bentley, AVEVA, Nemetschek and Trimble.

We estimate the demand for software and automation systems in the construction and building sector is will grow double digit levels for the medium term, reflecting the need for the sector to digitise to address considerable inefficiency in terms of time, capital and energy. The implications of COVID-induced changes to the use of buildings as well as the political & consumer focus on resource efficiency are likely to induce an acceleration in the adoption of software & next generation technology to help address the considerable inefficiencies in the sector.

See more details in our Cap Good teams recent Primer on AEC here: [Capital Goods - Global: Digital Buildings: Enhancing construction, 15 June 2021](#)

Exhibit 50: CAE is expected to grow 15% CAGR FY21-26E

AEC software market size (\$bn)

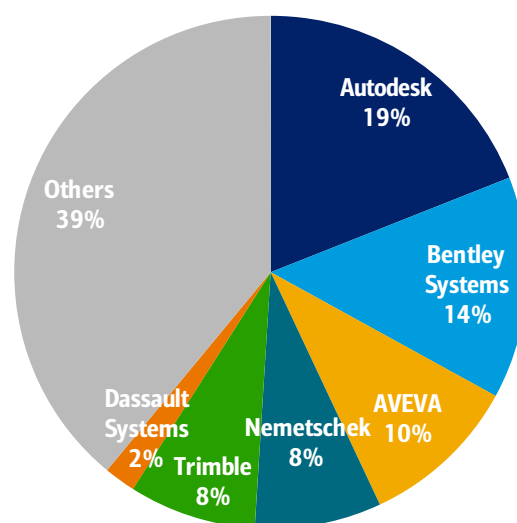


Source: CIMdata

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Exhibit 51: 2020 market share of the CAE software market

CAE dominated by Autodesk (19%) and Bentley Systems (14%)



Source: BofA Global Research estimates

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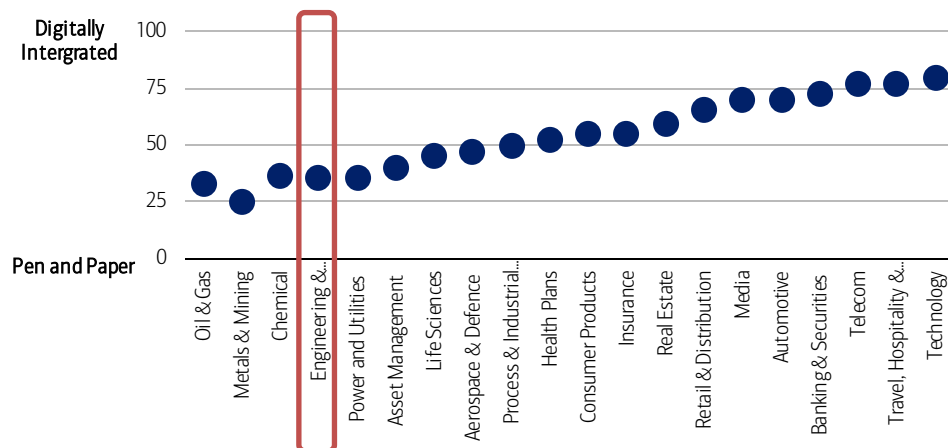
Setting the scene: vitally important but digitally immature

According to the UN Environment Programme (UNEP), the building sector is worth c10% of global GDP and employs 111m people (source: UNEP, Energy Efficiency for Buildings). Residential and commercial buildings consume c60% of the world's electricity, with buildings in general accounting for 40% of global energy and 25% of global water, emitting c1/3rd of Greenhouse Gas emissions (the largest sector contribution). Existing building stock is often old and operates at well below the energy efficiency current technology is capable of delivering. Underlying all of this, the sector falls well behind in terms of digital maturity in the context of global industrials sector development.

Addressing the resource inefficiencies of the construction and building sector is a strategic imperative for all market participants and one we think will only accelerate as the industry emerges from COVID-induced lockdown.

Exhibit 52: Digital maturity by industry (2019)

Engineering & Construction as an industry remains dominated by "pen & paper"



Source: BofA Global Research estimates, Hexagon

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We set out a summary of the key market participants who sell the software and systems, demand for which we believe will benefit the most from efforts to digitise the construction and buildings sector. These companies vary from the pure software suppliers to the broader, multi-industrial incumbents in the Building Automation Systems market. The list is not exhaustive, but covers the main listed companies.

Exhibit 53: Summary of largest market participants in Design, Build, Operate software & systems market (not exhaustive)

Revenue reflects software & systems related revenue for design, construction & operation of buildings and does not include product revenue. For SIE, SU, HON & JCI we show BAS and BEMS revenue only, 2020

	Americas	Europe	Asia	Design	Build	Operate	Residential	Commercial	Industrial	Infrastructure
Autodesk*	41%	40%	19%							
Hexagon	29%	38%	29%							
Bentley	45%	30%	18%							
Nemetschek*	30%	62%	8%							
AVEVA	34%	39%	27%							
RIB*	27%	57%	16%							
Trimble*	60%	30%	10%							
Procore*	88%	10%	2%							
Glodon		10%	90%							
Dassault Systemes	39%	37%	23%							
Siemens	33%	51%	16%							
Schneider	38%	33%	29%							
Honeywell	50%	37%	13%							
Johnson Controls*	60%	30%	10%							

Capabilities Strong Solid Some Limited

Source: BofA Global Research estimates, company report, Frost & Sullivan. *Note indicates not covered by BofA.

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Combining software tools with practical application

Historically the architect's design (and involvement with the building process) stopped when the drawings (paper or virtual) were passed on to the main EPC, but with ever higher levels of BIM (Level 3 now exists incorporating what is called 6D and 7D capabilities, more of which below) the adoption of the original model as a single source of truth is becoming more universal, even mandated in some markets (e.g. the UK) and digital twins are becoming more pervasive. Many of the legacy suppliers of CAD tools to the architecture profession are the same vendors developing dynamic software tools for the construction industry. For this reason we have combined Design and Build topics into one to examine market growth and competitive landscape.

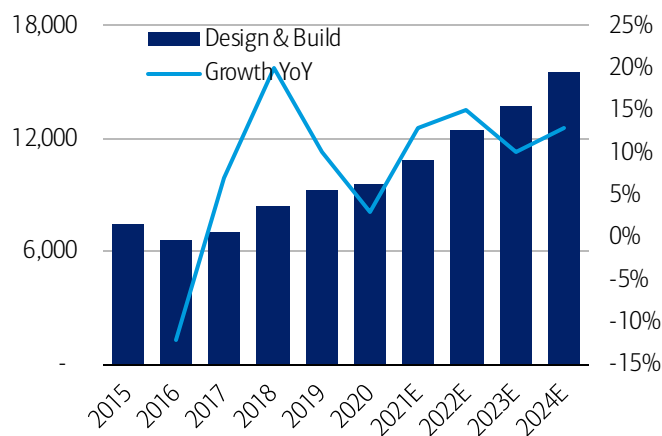
Design and construction typically account c20% of the costs of a building with the design side of things considered a mature market in software terms. Architects have

been using software tools for years, but the concept of Building Information Modelling has only really been around since the turn of the millennium and the adoption of BIM by the construction industry for better project management appears not much more than a decade old.

There are differing definitions of what comprises BIM software or AEC software; AEC is the overall descriptor of the segment, though we believe BIM ultimately can be more comprehensive through the sector given it will extend from design into operation. AEC software tools seem to us to encompass those CAD tools required in the design of a building whereas BIM now extends beyond those elements of the process to include operational scope as well, or at least software that extends beyond the scope of design to include construction and operation.

Exhibit 54: Design & Build software market development

We expect double digit growth after a strong recovery from 2020's low growth rate

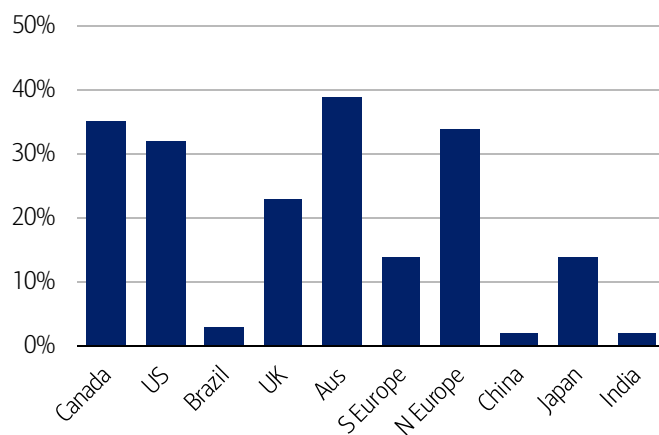


Source: CIMdata

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Exhibit 55: Regional penetration of BIM software (2020)

Despite strong growth in the BIM software market, penetration rates remains relatively low even in developed construction markets, and are particularly low in China, Brazil and India



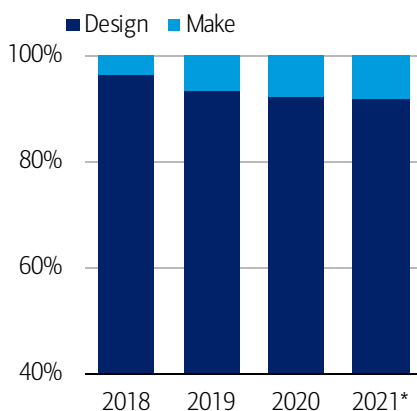
Source: Autodesk

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Some companies, such as Autodesk and Nemetschek, provide a break out of their respective Design and Build revenue but many others do not. We show the evolution of Autodesk and Nemetschek Design and Build software businesses to highlight the differences in terms of proportion of revenue and growth.

Exhibit 56: Autodesk revenue mix

Make represents c10% of total now

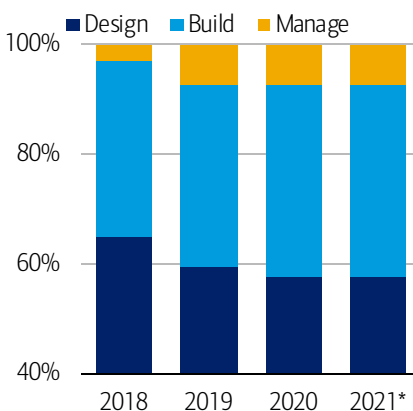


Source: Company report
Note: 2021 is LTM

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Exhibit 57: Nemetschek revenue mix

Manage represents c10%, Build c35%

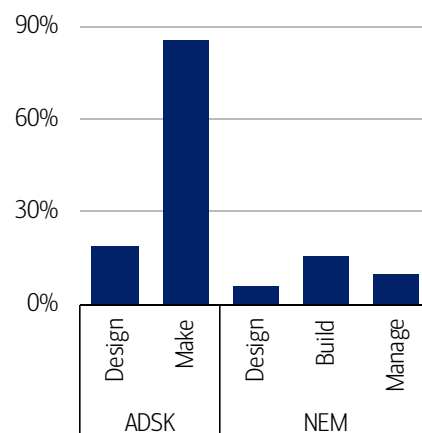


Source: Company report
Note: 2021 is LTM

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Exhibit 58: Average growth since Q1'10

Make/Build has seen the fastest growth



Source: Company report

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So what is BIM?

Building Information Modelling is the term given to the set of software tools developed to automate building design, construction and ultimately operational processes. At their culmination, a BIM will be a fully functioning digital twin of the building, but at present, perhaps 20 years into development (the term being first really coined by Autodesk), BIM is about 2D and 3D CAD drawings and models, defined as Level 1 BIM. These 2D and 3D models are combined in a common data environment which allows limited levels of collaboration between the architects and the main contractors.

Level 2 BIM introduces the concept of full collaboration and includes additional dimensions in the common data environment; 4D representing time management and 5D representing budget calculating capabilities. Most construction firms operate somewhere between Level 1 and Level 2 BIM, with more and more countries mandating the use of Level 1 and Level 2 BIM in construction projects. The UK is among the most advanced of these regulatory environments, and had planned on implementing Level 3 BIM requirements in 2020 until COVID and lockdowns got in the way to postpone implementation. Level 3 BIM includes Asset Lifecycle Management (6D) and cloud capabilities (7D) to enable full, real time collaboration in construction and operation.

Exhibit 59: Evolution of the BIM model

With the introduction of smart devices, ubiquitous connectivity and faster processing speeds, dynamic digital twins of buildings are achievable

1990	2010	2020	2025+
2D/2D CAD	BIM	BIM + Digital Twin	Smart Building Platform
2D drawing 3D CAD model Siloed process Paper based Built environment Closed information sources	3D static model Lack of stakeholder engagement Design & build phase 3rd party integration	3D dynamic model Broader stakeholder integration Real time building lifecycle mgmt Simulation of project Virtual building asset Integration of sustainability	Real time optimisation of design, build & operate Real time project management Dynamic digital twin Full integration of design & reality

Source: BofA Global Research

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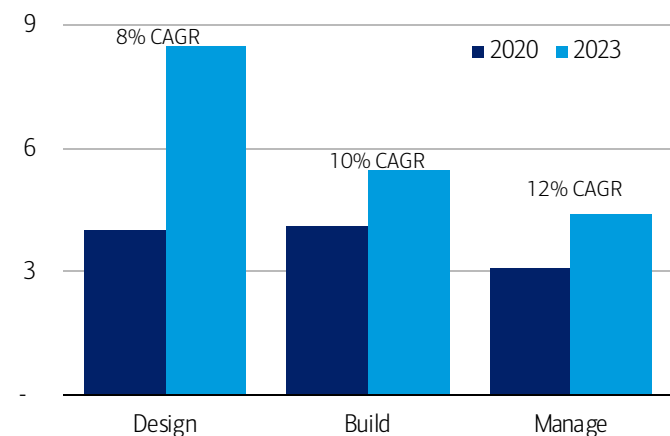
As each Dimension is added to the BIM model it contains more data and becomes more intelligent. As the Level rises (often referred to as maturity), the model becomes more integrated and dynamic.

Defining addressable markets

Market participants such as Autodesk, Trimble and Nemetschek define their addressable markets on the basis of their respective business portfolios.

Exhibit 60: Nemetschek Addressable Mkt assessment, 2020/23 (€bn)

Software related to building management has the highest growth rate

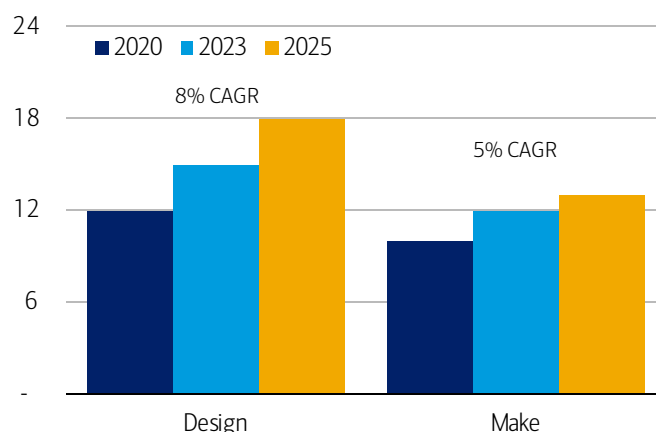


Source: Company report

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Exhibit 61: Autodesk Addressable Mkt assessment (US\$bn), 2020/23/25

Autodesk still believes design tools have the fastest growth



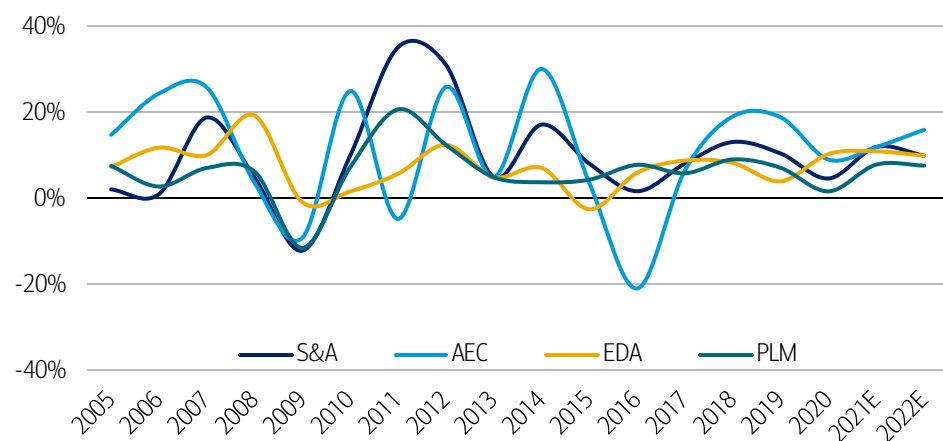
Source: Company report

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What seems a fair conclusion to us is that market growth is solidly double digit for the foreseeable future and is well above the average growth we see in other areas of industrial software. The main reason for this seemingly is the level of penetration in the construction and building industry relative to the broader industrial complex.

Exhibit 62: Comparing AEC software growth to broader PLM markets and other segments of fast growing industrial software, 2005-2022E

Though more volatile, AEC appears to have delivered stronger growth in software demand than even EDA



Source: CIMdata

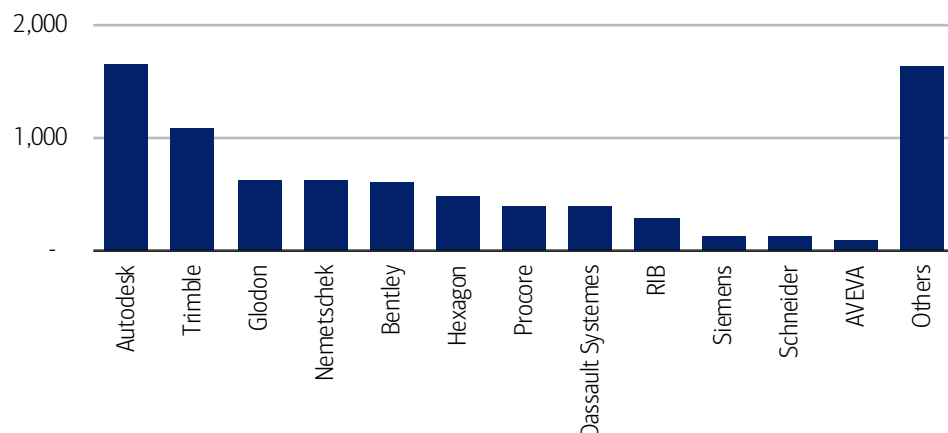
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Market participants range from pure software providers such as Autodesk and Nemetschek to what we have called hybrid providers such as Hexagon or Trimble who combine both software and hardware to offer integrated solutions to the EPCs undertaking the construction projects. Many of the software providers focus on specific end market verticals (e.g. Bentley dominates the US Department of Transport work, while Aveva and Hexagon have historically focused on heavy process plant or oil & gas infrastructure).



Exhibit 63: 2020 revenue derived from AEC Design & Build software (US\$m)

We estimate Autodesk is the largest vendor, but the market remains relatively fragmented



Source: Company report, Frost & Sullivan

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We have seen some overlap from the Operational side of the building to Design & Build processes with Schneider's acquisition of RIB Software and Nemetschek's portfolio development with the acquisition of Spacewell.

Vendor landscape

We have provided a brief profile for major vendors below with an emphasis on their respective AEC solutions.

Autodesk (Not Covered)

Autodesk (ADSK) is the largest of the vendors of AEC software and a pioneer in the context of BIM software. Revenue is split roughly 40:40:20 between Americas, Europe & Asia. Historically ADSK has been present mostly in Design, with c90% of revenue still derived from that segment. Recent diversification and M&A has been focused on manufacturing and even EDA sectors, while the Make strategy, i.e. software for production/construction is also growing fast (now early 10% of revenue). Has also launched the Autodesk Construction Cloud for cloud-based workflow management tools. Products include Revit, FormIt, Civil 3D, AutoCAD, InfraWorks, Navisworks Manage and Autodesk Docs.

Aveva

Smart City is one of Aveva's focus area, both on Asset Performance Management and Monitoring & control. In addition, Aveva has established position in Smart Infrastructure and Transportation. Aveva focuses on water and wastewater utilities, power utilities, facility and campus managers, transportation operators, and data centres. Aveva offers a number of solutions enabling the creation of a 360-degree view of critical infrastructure and its performance, combining data from engineering data systems; operational control systems; maintenance data; and predictive or performance data. The resulting digital twin, enabling a unified operation centre, can digitally transform the value of existing infrastructure while supporting future expansion. Aveva has won a number of contracts including with Barcelona (Remote monitoring of infrastructure, optimized water supply), Bremen (building Management System) or Carson City (Nevada).

Dassault Systemes

Infrastructure & Cities accounts for a low 10% of group revenues for Dassault Systemes, but is one of the main growth opportunities identified by DSY. It has a 6% share in a \$9bn identified TAM, and plans to grow this segment at 12-14% CAGR by 2025 in a 7% growth market. DSY sees itself as a disruptor in this field, in a largely non digitised market. DSY sees Cloud mobility for construction and platform for supply and logistics as key drivers. To flag some existing clients; Aden is building manufactured turnkey

hospitals, delivered with China construction. Bouygues construction applies the same platform for project management and virtual twin onsite. DSY has partnered with a number of architects on the following fields: Large scale 3D printing, Integration of design and technology, digitally designed and manufactured architecture.

Hexagon

Hexagon has been a pioneer of digital twins for many years, marrying the ability to measure and capture the physical world with the software capabilities to analyse and manipulate the digital model, defining what Hexagon calls the Smart Digital Reality. Hexagon's Autonomous Connected Ecosystem strategy serves five different verticals including the construction industry. Historically Hexagon's portfolio has consisted of multiple point solutions, including design software (Bricsys), project management software (EcoSys) and the scanning & surveying capabilities within GeoSystems (Leica etc.) but Smart Build is the solution that brings all these point solutions together to offer an integrated, dynamic digital twin-based solution to the Design & Build segment of the construction work flow.

Honeywell

Honeywell is a scaled player in the building technology space with offerings in hardware, services, and software. Key hardware offerings include commercial fire systems, security systems, and building management controllers & devices. Hardware is sold mainly through distribution, which has created an installed base of over 10mn buildings. Honeywell also acts as a system integrator (Honeywell Building Solutions) for complex projects. This has created a \$1+bn stream of contractual and project-based aftermarket services.

The majority of software revenues are tied to Building Management Systems (BMS). Honeywell's Forge platform competes against IBM's Tririga, Fortive's Accruent, Entouch Controls, and SpaceIQ. The company is also adding software content into core hardware offerings. Examples include Connected Life Safety Services (cloud platform for fire systems), MAXPRO Cloud (hosted security controls & video storage), and the 2020 acquisition of Sine Group (visitor management software). Honeywell is also using partnerships to expand its software reach. Last year, the company teamed with SAP to create Honeywell Forge Real Estate Operations. The offering leverages combines Honeywell's operational data with SAP's financial data. According to management, the product is seeing high double-digit growth, aided by SAP's installed base and sales force.

Nemetschek (Not Covered)

Nemetschek was founded in 1963 and generated €550m in 2020. Nemetschek concentrates exclusively on the AEC industry and covers the entire workflow in the construction and infrastructure market from design to operation. Nemetschek is one of the few vendors in the market with capabilities across all three segments of software (organised along the three segments of Design, Build and Manage). The group has established software tools such as Graphisoft, Vectorworks and SCIA that support the architecture segment with CAD, BIM and Open BIM tools, while also offering real estate management software (CREM) and the COBUNDU IoT platform acquired with Spacewell in 2018. Spacewell puts Nemetschek among the leaders in the IWMS software space.

Schneider

Schneider is the market leader in energy management solutions covering low voltage products to BMS across the whole residential and non-residential market. With the recent acquisition of RIB Software Schneider has moved from the Operate segment into Build, acquiring web-based software tools that enable workflow management in the construction process. With the majority-ownership of Aveva Schneider also has some capabilities in AEC design (albeit with a focus primarily on the process industries and infrastructure). The most recent investment in Planon augments Schneider's position in the IWMS market, complementing its capabilities in BAS/BEMS. Schneider has multiple platform offerings including Workplace Adviser, Building Adviser, Power Adviser, Resource Adviser all underpinned by EcoStruxure, Schneider's open-architecture IoT platform.

Siemens

Siemens is the leading European provider of BAS/BEMS, with strong positions also in North America, Asia-Pac and the Middle East. Through its Smart Infrastructure segment and legacy Building Technologies business Siemens has market leading positions in both BAS and BEMS through solutions such as Navigator, Navigator Hub (cloud-based data analytics platform) and Desigo CC. With recent acquisitions such as Enlighted and Comfy Siemens is also developing capabilities within building analyst tools and occupant/user data analytics, all underpinned by the MindSphere IoT operating system. One area Siemens appears to have limited exposure to is Design, in contrast to its market leading position in PLM software in the industrial world. Siemens also offers the Siveillance Suite, an integrated security and monitoring system to enable holistic control of physical security and access control.

Other Industrial Software

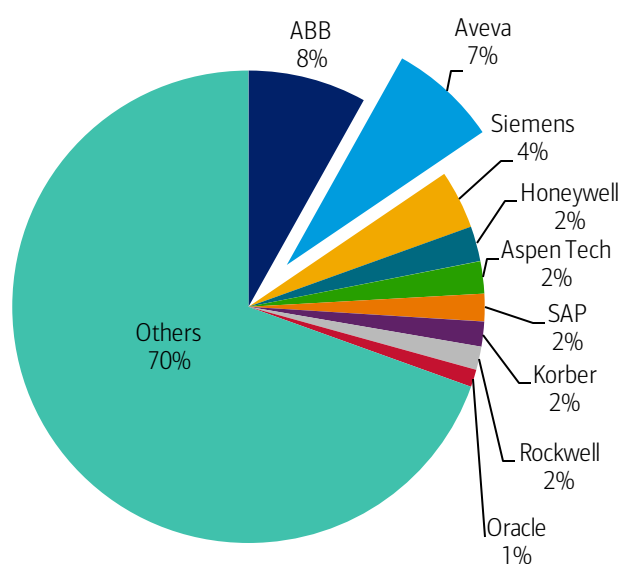
MES: a fragmented market

Estimated market size: US\$4bn

Estimated market growth in 2021 - 26 CAGR: mid-high single digits

We estimate the manufacturing execution systems (MES) segment to have a market size of c.US\$4bn, excluding value-added resellers, system integrators and partners. About 60% of the market is in the discrete industries. AVEVA is a market leader (**Error! Reference source not found.**) in the process industries MES market, and has established positions in food & beverages, chemicals, pharmaceutical, oil and gas (downstream), mining and water. This covers almost the entire spectrum of the MES market in process industries (Exhibit 64).

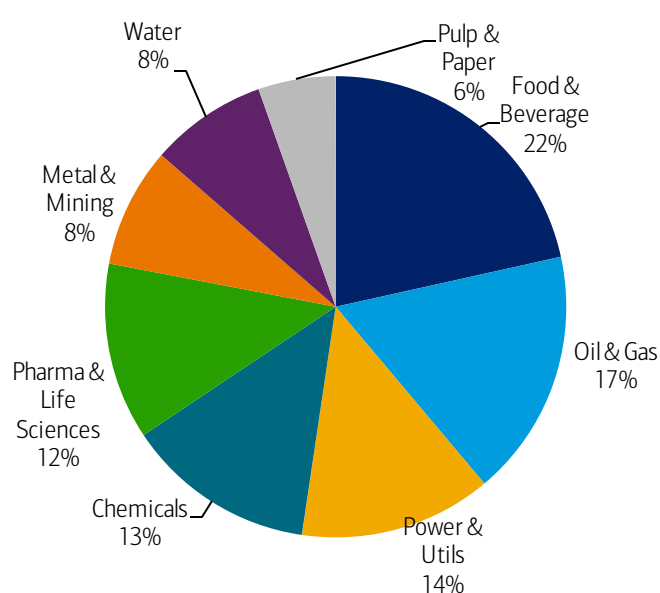
Exhibit 64: MES in Process Industries is fragmented
MES main player



Source: Frost & Sullivan

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Exhibit 64: MES Market split by process industries
MES Industries



Source: Frost & Sullivan

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SCADA/HMI: AVEVA and Rockwell the leaders

Estimated market size: US\$1bn

Estimated market growth in 2021 - 26 CAGR: mid-single digits

We estimate the supervisory control and data acquisition/human machine interface (SCADA/HMI) segment to have a market size of c.US\$1bn (excluding hardware, the bigger portion of the HMI market, which most IT players do not provide). We estimate growth of mid-single digits in the coming few years, driven partly by the progressive increase in SCADA functionality. Some vendors have started providing some built-in MES functions in SCADA, and are continuously improving its integration with other enterprise solutions, particularly in ERP and MES, making the functioning of SCADA more efficient.

AVEVA and Rockwell are leaders in this space, though we believe both have been conceding market share slowly in recent years. AVEVA's flagship product, AVEVA MES (formerly Wonderware), has historically been the best solution, both visually and functionally. Inductive Automation, a relatively new entrant, has quickly been gaining market share with its product Ignition.

Key players in PLM

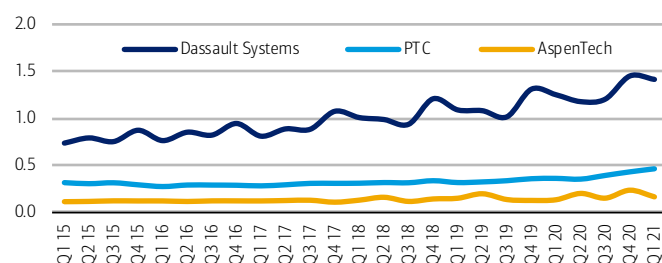
Dassault Systemes

Dassault Systèmes is one of the global market leaders in PLM, specifically in the field of industrial software. It initially paved the way in the offering of high-end 3D CAD (Computer Aided Design). While 3D CAD remains one of Dassault Systemes' main competitive advantages, notably through the offering of its 3DEXPERIENCE software suite, the company has consistently taken part in M&A to both consolidate and diversify its offering in order to tap into new pockets of growth.

Market share: #2 with 8.4% share in 2020

Exhibit 65: Sales (US\$bn)

Dassault Systemes c.10% software org. revenue was above their c.7-9% range



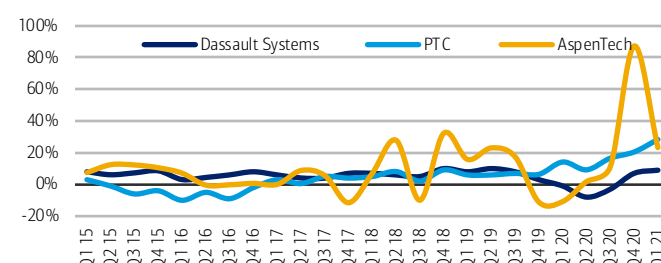
Source: Company data

Note: PTC: Sep ending; AspenTech – June ending

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Exhibit 66: Organic y-o-y sales growth (%)

Aspen and PTC have outgrown Dassault Systemes



Source: Company data

Note: PTC: Sep ending; AspenTech – June ending

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Segment specialties – where do they lead?

Leader in CAD – CATIA and SolidWorks

Dassault Systemes pioneered the offering of 3D CAD with its CATIA software – developed while the company was still part of Dassault Aviation. CAD became increasingly relevant in the Aerospace, Automotive and Industrial sectors, all of which required digital solutions to develop prototypes of complex products (i.e. planes and cars) digitally before the production stage. Because Dassault Systemes was one of the first players in this market, it initially secured a solid market share, which was maintained notably via M&A, with the acquisition of several competitors such as mid-market 3D CAD peer SolidWorks.

Throughout the years, Dassault Systemes has continuously improved CATIA and SolidWorks solutions: nowadays, those CAD systems also include several multidisciplinary features spanning from electrical and printed circuit board design, product data management, manufacturing and technical communication to cognitive augmented design (fusing simulation and modelling). For this reason, these programmes have great success with early adopters, for example in the field of education: SolidWorks is used in c.80% of the world's top engineering schools. To this day, Dassault Systemes remains the undisputed leader in 3D CAD software, with a market share of 27%.

Leader in PLM integrated systems – 3DEXPERIENCE

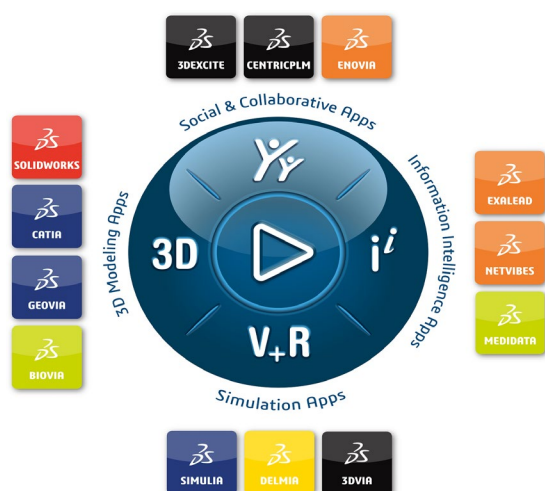
Mostly through acquisitions, Dassault Systemes has increased its capabilities into the PLM sector, building a platform that would integrate several other PLM modules in addition to the CAD applications. While doing so, Dassault Systemes made sure that each new module would be specifically relevant to its existing customer base, which was overwhelmingly from the Aerospace, Automotive and Industrial sectors. It notably

developed a strong Computer Aided Manufacturing (CAM) platform, DELMIA, allowing to turn CAD designs into physical products. In addition, Dassault Systemes also developed SIMULIA, built notably on the acquisition of companies such as Abaqus, CST and Next Limit Dynamics, and which allows to simulate behaviour in the fields of electromagnetics, fluids, structures and vibroacoustics.

3DEXPERIENCE, or 3DX, is the company's new generation of products which pulls together all of those modules, notably the PDM tools (ENOVIA) with CATIA, SolidWorks, SIMULIA and DELMIA. The rationale of the 3DX platform is that although none of these modules are quite as good a market leader as its CAD software offering, it is the organised and coherent integration of all those modules into the 3DEXPERIENCE platform which would provide Dassault Systemes with a strong edge over its PLM competitors. However, the adoption of the 3DX product suite was not linear and Dassault Systemes faced some backlash over some features, which required significant adjustments from customers' IT departments. Perhaps as a result of this, the 3DX product cycle has taken a long time to get going. However, there has recently been clear signs of adoption – first in aerospace with both Boeing and Airbus, and then in automotive with the likes of Scania, Porsche and recently Toyota committing to the new generation 3DX system.

Exhibit 67: Dassault Systemes 3DX Platform

Integrating 3D modelling, collaborative, information intelligence and simulation apps on a single platform



Source: Company website

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In our view, this platform could be beneficial for Dassault Systemes for two reasons.

1. This integrated platform would increase the already high switching costs required to change PLM system: in the PLM sector, customers tend to move through the product offering of their vendors. Still, a PLM customer could choose to switch a module in their PLM suite (i.e. use the CAD software of provider A along with the simulation software of provider B). However, the 3DX system is highly path-dependent: the different modules are integrated into the platform and therefore with one another. Hence a product designed on the 3DX platform with the CAD module CATIA would also benefit from the insights of the DELMIA, SIMULIA and other pieces of software built in the platform. In fact, even if a user does in fact prefer to use a different simulation software (i.e. Ansys simulation software), they would do so in addition to using the 3DX platform, rather than instead of it.
2. Historically, Dassault Systemes' PLM software suite has been tailored to the major players in the Aerospace and Automobile industry, where it remains the clear leader to this day. However the 3DX platform is equally as well suited to smaller companies

that are less specialised than the aforementioned leaders. Those companies may not require the depth of analysis or specialisation features and accuracy that airplane manufacturers do, but instead may be looking for an easy-to-use, highly integrated system with numerous PLM modules allowing for easy collaboration between all business lines. Dassault Systemes' launch of the 3DEXPERIENCE WORKS family in 2019 c seems to be the latest attempt to implement this strategy. Indeed 3DX WORKS bundles together the company's more mainstream offerings (CAD application Solidworks, CAE (Computer Aided Engineering) application SIMULIA, cPDM (Collaborative Product Definition Management) application ENOVIA, DM (Digital Manufacturing) application DELMIA) and is explicitly marketed at small and midsized companies.

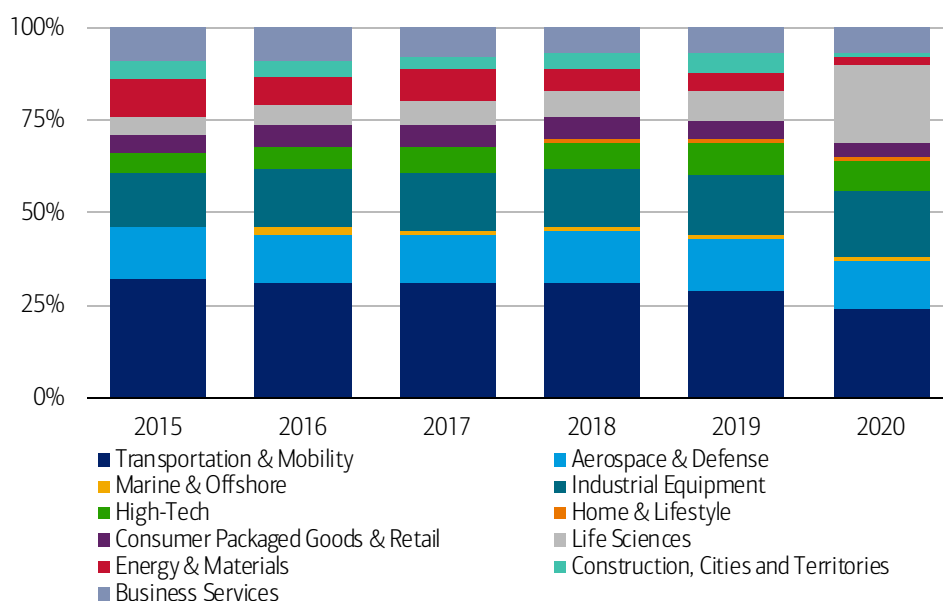
End market exposure

Dassault Systemes operates in 11 key end-markets, grouped in three categories: Manufacturing Industries, Life Sciences & Healthcare and Infrastructure & Cities. Historically, Dassault Systemes specialised in serving four "core" industries: Transportation & Mobility, Aerospace & Defence, Industrial equipment and Business Services. Together, those sectors have accounted for c.65%-70% of revenues in the past five years. Today, still, those four markets make up over 60% of revenues.

However, in an effort to tap into new pockets of growth, Dassault Systemes has consistently invested into new sectors where its product suite can be leveraged. Most recently, the company has focused on the medical sector, a market which remains less digitalised than the Aerospace and Automotive sectors and where PLM has the potential to offer innovative solutions. The 2019 acquisition of Medidata, a data platform used to digitise the process of running drug trials, has allowed to significantly diversify the revenue base, with the revenues from the Life & Science industry representing 21% of total revenues in 2020 (vs. 8% the previous year).

Exhibit 68: Legacy industries continue to make up the largest part of revenues, though new sectors like Life & Sciences are increasingly relevant

Dassault Systemes' revenue split by industry



Source: BofA Global Research Estimates, company data

Capabilities build-out / notable acquisitions

Dassault's M&A can be grouped into three phases: Building PLM: DSY built capabilities to go from CAD (Computer Aided Design) to PLM (Product Lifecycle Management); so addressing different parts of the product design process. Then DSY went on adding multi-physics to the existing toolset, thereby allowing it to add value in mechatronic

products. Later, DSY focused on expanding to new industries. The overarching concept is described by management as the ‘product, nature and life’ strategy recently adopted by Dassault Systemes.

This last phase can therefore be conceptualised as a strategy of diversification into new verticals, specifically the Life & Sciences market for Dassault Systemes. It estimates the total addressable market in this sector to be currently worth \$8bn, with a potential to reach up to \$20bn. It is also the market that is the least penetrated and by the fewest PLM vendors, especially in comparison with the Manufacturing and Infrastructure sectors, where the top five providers already share over 75% of the market. Companies in the Manufacturing and Infrastructure sectors have also been using PLM solutions for decades whereas the Life Sciences and Healthcare sector is expanding the use of those solutions: it is therefore also the market which is expected to grow at the highest rate.

Exhibit 69: Strong growth and market share consolidation expected across all three sectors

Dassault Systemes’ strategic sectors growth outlook

	Manufacturing Industries	Life Sciences & Healthcare	Infrastructure & Cities
Total Addressable Market (US\$, bn)	24	8	9
Potential Addressable Market (US\$, bn)	50	20	30
Current DSY Market Share	29%	11%	6%
Expected Market Growth 2020-25	5%	9%	7%
Expected DSY Growth 2020-25	6-8%	13-15%	12-14%

Source: BofA Global Research Estimates, company data

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Siemens

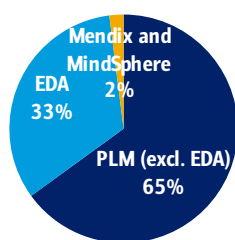
Siemens, through its Digital Industries portfolio, is the #1 provider of industrial software, factory automation and motion control. Its competitive positioning in PLM is strengthened by being able to offer customers holistic solutions that integrate its market leading software with hardware and automation capabilities (notably through its cloud-based IoT platform MindSphere) but also through its numerous partnerships, with SAP for example.

PLM Market share: #1 with 8.8% market share in 2020

Siemens differentiates between traditional PLM software business, which provided revenues of c.€2.7bn in 2020, and EDA (Electronic Design Automation) software business, revenues from which came in at c.€1.4bn, conferring it the #3 largest market share in EDA after only Cadence and Synopsys.

Exhibit 70: Software business revenues of €4.1bn in 2020

Software business split between PLM and EDA



Source: BofA Global Research Estimates, company data

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Segment Specialty – where do they lead?**Electronic Design Automation (Mentor Graphics) integrated in the cPDM system (Teamcenter)**

With the acquisition of Mentor Graphics in 2017 and subsequent integration to its PLM software suite, Siemens has been attempting to develop a “system of systems” that would integrate the different engineering disciplines involved in the lifecycle of a product. With Mentor Graphics, Siemens specifically integrated the electronics to its PLM suite: the company provides a complete semiconductor design flow that includes simulation, emulations, place and route, verification, design for manufacturing and testing. As today’s products – from smartphones and household appliances to automobiles, aircraft and machinery – continue to increase the use of sophisticated embedded electronics, Siemens has uniquely positioned itself to provide a seamless and comprehensive software solutions to the companies that develop these products.

This depth of expertise in EDA (Electronic Design Automation) is especially relevant when considering that no other PLM provider has an offering that could compete with Mentor Graphics’

This expertise is also coupled with a powerful cPDM (Collaborative Product Definition Management) platform, Teamcenter, which seems to be popular with several industry leaders. Automakers tend to use Dassault Systemes’ 3D CAD module CATIA within the Teamcenter platform, as this also allows them to leverage Mentor Graphics’ EDA expertise: to this day, 29/30 top automakers use some modules of the Siemens PLM software.

Symbiotic relationship of Software and Hardware

In addition to being a global leader in EDA and PLM software, Siemens is also a leading provider of industrial hardware. Although hardware technically falls outside the scope of this study, it is relevant here given the implications it bears on the popularity of Siemens’ software: indeed, it is the combination of software capabilities, factory floor hardware product portfolio and IoT platform (MindSphere) across a range of industry verticals which puts Siemens at the forefront of developing industrial automation.

Hardware is also required to provide the input/output for/from the “smarts” in the software. The relationship between software and hardware is symbiotic, the only question is where the analytics happens and even there the answer is not clear cut; the shift to off-premise analytics is balanced by the need to undertake an element of analysis and decision making at “the edge”. To be able to deal with digital exhaust (too much data!) is to undertake basic analysis at the edge, i.e. enable, or smarten, the hardware and ultimately embed even more functionality therein. More convoluted and detailed analysis gets routed up to the cloud. This brings emphasis back to “Smart hardware”, which basically means embedded software, and we are back to where the incumbent automation vendors started; Siemens continues to have the broadest

installed base of control hardware in discrete industries. Something which Dassault Systemes and PTC do not.

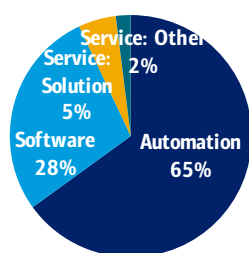
End market exposure

Siemens Digital Industries is comprised of three segments: Automation, Software and Services, with Software accounting for c.28% of total revenues. The company has a strong foothold in Europe, which represents more than half of its revenues. Nonetheless, it is also geographically diversified, with China and the US accounting for 20% and 17% of revenues respectively, with the rest of Asia accounting for the remaining 12% of revenues.

Siemens Digital offers its services to a broad range of industries. Automotive and Machine Tools are two sectors which are highly reliant on PLM products, and which are also likely to require the entire suite of Siemens Digital's products i.e. not only software but also automation and service solutions. It is unsurprising, then, that those two industries account for more than 1/3rd of Siemens Digital revenues. However, Siemens Digital is also a diversified company, with well-balanced revenue streams from a wide range of industries i.e. Pharma & Chemicals, Food & Beverages, Electronics, Aerospace & Defence.

Exhibit 71: Software represents c.1/3rd of revenues

Siemens Digital business mix

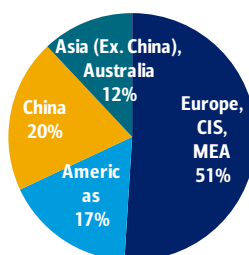


Source: BofA Global Research, company data

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Exhibit 72: Diversified geographical exposure with strong reliance on EMEA (51%)

Siemens Digital geographical mix

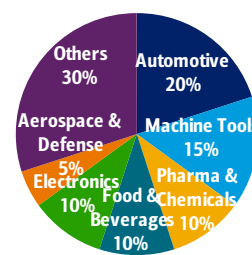


Source: BofA Global Research, company data

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Exhibit 73: Diversified industry exposure with Automotive (20%) and Machine Tools ahead (15%)

Siemens Digital industry mix



Source: BofA Global Research, company data

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Capabilities build-out / notable acquisitions and partnerships:

As previously explained, Siemens is aiming to provide digital solutions that leverage not only its business models in IT, but also in operational technology (OT) as well as products. This stems from a strategy spanning decades: since 2007, Siemens has spent more than US\$10bn on M&A to acquire software companies in order to develop a comprehensive portfolio which would cover the entirety of the digital thread from IT to OT. Multiple acquisitions have built the portfolio including UGS originally (which provided the base of Siemens' PLM offering) and Mentor Graphics in 2017, which allowed Siemens to establish leadership in EDA.

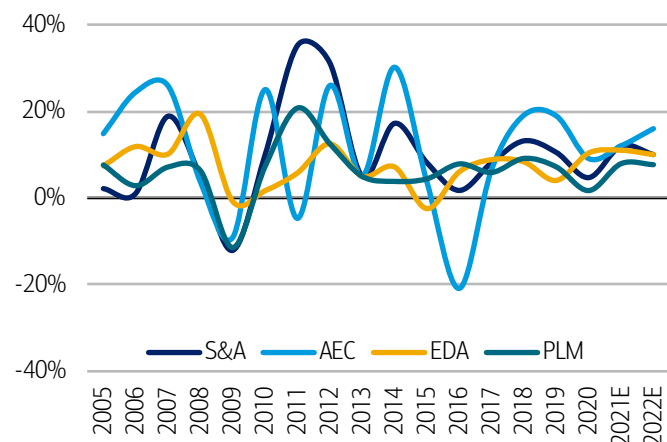
In addition to acquisition, Siemens has also developed partnerships and joint ventures with segment leaders. For example, it announced a partnership with SAP in order to cross sell PLM and ERP (Enterprise Resource Planning) solutions, allowing it to further advance its expertise in digital transformation from the production floor to upstream fields in IT. Perhaps more importantly, this signals a strategic shift from SAP to pull back from the PLM market by committing to push Siemens' PLM solutions to SAP's ERP customers. Siemens also developed PlantSight, jointly with Bentley Systems, Inc. (Bentley). The platform uses real-time analytics and AI to generate new insights and enable real-time collaboration between engineering, operations and maintenance functions. Those partnerships allow Siemens to cover the entire Digital Thread from Information Tech to Operational Tech, whilst also remaining the specialist on hardware and controls on the factory floor as well.

Growth Outlook

While clearly automotive and aerospace supply chains are under considerable pressure right now, growth from semiconductor and electronics markets is likely to increase with the return to growth in spending in those end markets. With capital spending under significant pressure in the aftermath of COVID-19 economic impact, the demand for Simulation & Analysis is likely to increase, particularly as capabilities in that area extend beyond just the product design to production planning, certification and operational analysis in the context of through-life digital twins.

Exhibit 74: Key sub-sectors of PLM that have outgrown the broader market over time should continue to do so again in recovery, growing at 10% or more vs. 8% for the PLM sector in 2021

YoY growth of PLM sub-segments

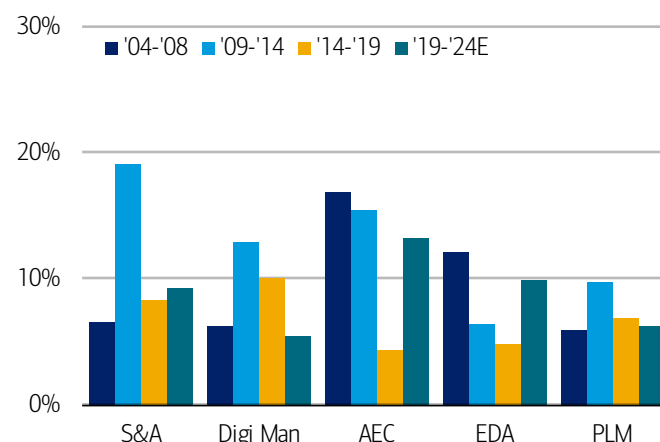


Source: CIMdata

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Exhibit 75: S&A, AEC and EDA sub-segments should all grow at >8% over the 2019-2024 period, faster than the broader PLM market (6% expected growth) – Digital Manufacturing expected to lag at 5%

CAGR growth of PLM sub-segments



Source: BofA Global Research estimates, CIMdata

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The growth rates for the AEC and EDA markets are expected to be as strong as or stronger than the mainstream PLM market for the next five years, which we expect will be to the benefit of Siemens. In fact, the company expects its Industrial Software division to grow c.8% yearly until 2025, driven by (i) the adoption of new technologies and business models, (ii) increased investments in sustainable digital innovation and (iii) the rise of value creating partnerships and ecosystems.

At its recent Capital Markets Day, Siemens revealed that Annual Recurring Revenue of €2.6bn accounted for c70% of DI's software revenue and that ARR is expected to grow >10% CAGR to 2025, underpinned by transition to cloud-based SaaS which Siemens targets growing from c4% of ARR to >40% of ARR by 2025.

PTC

Market share: key overall PLM player with 2.7% market share in 2020

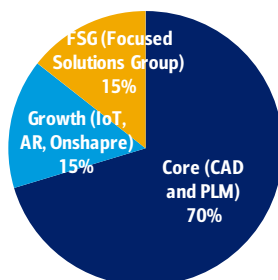
Segment specialties – where do they lead?

Core Products: Creo (CAD), Mathcad and Windchill (cPDM)

After losing some market share in the CAD market to Dassault and Siemens who successfully navigated M&A transactions to remain leaders in this field in the past 20 years, PTC recently rebranded its flagship CAD offering into Creo. PTC outgrew the broader CAD/PLM market in 2020 due in part to the resilience of its subscription-based model. This notably includes Unite technology, which enables the integration of CAD files between Creo and its largest competitors (including Dassault's offering of SolidWorks and CATIA). PTC thereby allows OEMs to use Dassault's market-leading CAD offering in conjunction with Creo, and within PTC's own cPDM system Windchill. PTC also boasts the Mathcad software, which helps analysing and disseminating crucial calculations associated with the product development.

End market exposure

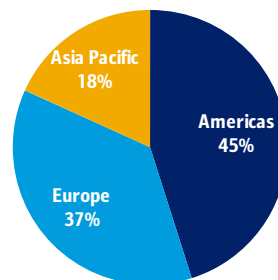
Exhibit 76: Predominance of CAD and PLM products, with increased focus on Growth and Solutions business
PTC business mix



Source: BofA Global Research Estimates, company data

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Exhibit 77: Well diversified business with foothold on all continents
PTC geographical mix



Source: BofA Global Research Estimates, company data

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Capabilities build-out / notable acquisitions and partnerships & Growth Outlook

In order to gain an edge over its competitors, PTC has entered into a partnership with Ansys, the simulation specialist, to power Creo Simulation Live, which notably offers fluid flow analysis, structural analysis, as well as thermal and modal analysis. Although not all PLM users necessarily require advanced simulation analysis, those who do will often turn to Creo Simulation Live, which is largely viewed as the best-in-class.

PTC has also made a substantial number of material acquisitions since 2013 in an effort to establish itself as the leader in IIoT (Industrial Internet of Things) for discrete manufacturers globally. By integrating those acquisitions together i.e. by building Vuforia's augmented reality capabilities onto the ThingWorx platform and with its existing applications, PTC is attempting to secure strong market share gains in IIoT ahead of its competitors. Although it is too soon to provide a verdict on the outcome of this strategy, it is in our view less likely to be successful for PTC than it is for Siemens, who already has strong competences in OT and hardware on which to harness these IT capabilities.

Exhibit 78: Flurry of acquisitions to establish leadership in the "Industrial Internet of Things"

Major PTC acquisitions since 2014

Company	Year	Price (US\$mIn)	Description & Rationale
Axeda	2014	170	Axeda provides a cloud-based platform for applications that provide secure connections between devices and people. It's an out-of-the-box industrial IoT solution that complements ThingWorx, which is geared more toward companies that want to run their own cloud or build customized applications. PTC draws on the connectivity of these platforms to help companies remotely manage, service, and collect data from thousands of devices.
ThingWorx	2014	112	ThingWorx's platform makes it easier for businesses to develop applications of the "connected world." It has tools that make it easier to design and build apps and process and make sense of all the data that is generated. ThingWorx will help PTC provide Internet of things solutions to its 27,000 customers, so they can respond to the changing market and take advantage of new business opportunities.
ColdLight	2015	105	ColdLight makes machine learning technology that detects patterns in data collected from sensors embedded in medical devices, manufacturing equipment and consumer products. To be coupled with ThingWorx's platform.
Vuforia	2015	65	The Vuforia platform is one of the industry's most advanced and widely adopted augmented reality (AR) technology platform. The combination of Vuforia and PTC leverages two transformational technology trends – Internet of Things (IoT) and augmented reality (AR) – that will allow PTC to deliver a new class of products that merge the digital and physical worlds.
Kepware	2015	100	Kepware is a software development company that provides communications connectivity to industrial automation environments. The acquisition will enhance PTC's portfolio of Internet of Things (IoT) technology, and accelerate the company's entry into the factory setting and Industrial IoT (IIoT).

Source: BofA Global Research, company website

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In November 2019, PTC announced the acquisition of multitenant cloud based CAD software provider, Onshape. This acquisition is expected to accelerate the ability to attract new customers with SaaS-based products offering. This positions PTC alongside Autodesk (Fusion 360) as one of the only two global SaaS CAD vendors. The acquisition of Arena in December 2020 also strengthened PTC's platform and created an opportunity to grow faster in the lower end of the market, an area that has been historically dominated by the likes of Autodesk and Aras (and where Dassault Systemes has also been trying to gain market share via its 3DX WORKS offering).

Segment leaders

Aveva

AVEVA provides design and information management tools to customers in three main sectors: Oil and Gas, Power and Marine. Engineering software represents around one-third of total revenues, while Operational software represents the other two-thirds. Engineering solutions include (i) engineering and design software, (ii) process simulation software (with a focus on pipelines, refining and Chemicals), (iii) project execution software and (iv) asset information management. Operational solutions consist of (i) operations control (enabling users to visualise from both factory and enterprise level), (ii) asset performance management (to increase efficiency via big data, cloud, AI and digital twin technology), (iii) value chain optimisation and, (iv) information management.

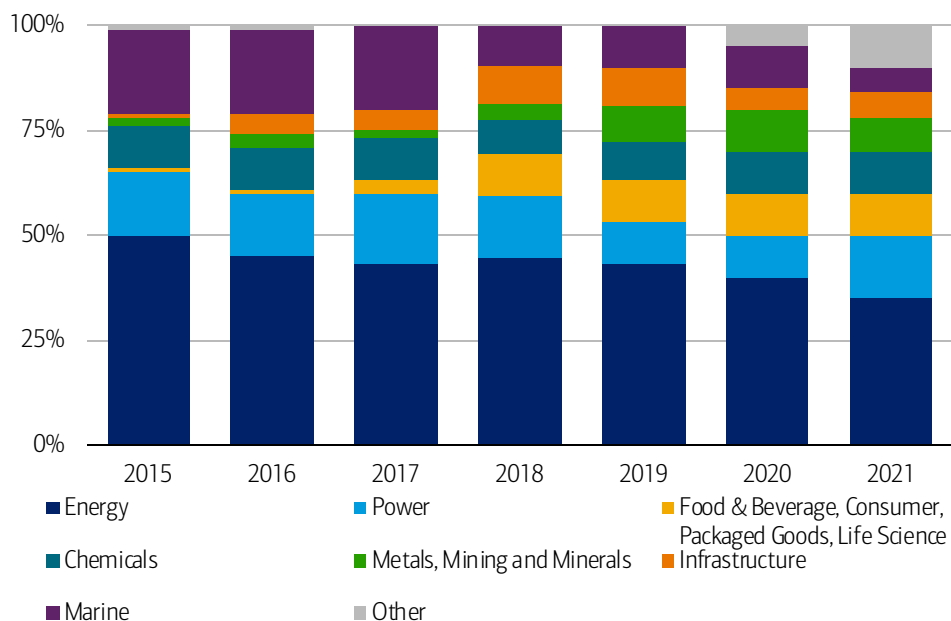
AVEVA's largest end market is Energy (c.35% of revenue), which includes not only the upstream, mid-stream and downstream Oil & Gas sectors but also the increasingly emerging renewable energy sector. This contribution has been decreasing since 2015, notably due to the volatility of in oil prices which has challenged the Energy sector. Other large markets have proven more resilient and this has resulted in a rebalancing of revenue contribution from the rest of the different sectors in recent years, with further diversification with the acquisition of OSIsoft.

In March 2021, AVEVA completed the acquisition of global industrial data software competitor OSIsoft for US\$5bn. In our view, the OSIsoft deal should help create an asset capable of delivering faster growth: indeed, OSIsoft's 10% growth is above AVV's original medium term ambitions.

In addition, this deal will also allow for further end-market diversification, with an expansion in hybrid end-markets (such as the Life Sciences, Food and Beverages and Consumer Packaged Goods) and infrastructure end-markets (including data centres, cities and renewable energy); this will provide new potential avenues for growth and enable additional resilience in cyclical and market downturns. This acquisition will also allow for geographical diversification, accelerating growth in both EMEA and APAC regions. Other opportunities for revenue synergies include cross-selling AVEVA products into OSIsoft's customer base (specifically those in the Power and Metals & Mining sectors) whilst also expanding the product portfolio to include emerging trends (i.e. Industrial IoT).

Exhibit 79: Increased industry diversification since 2015, with Energy sector losing prevalence

Aveva industry mix



Source: BofA Global Research Estimates, company data

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Autodesk

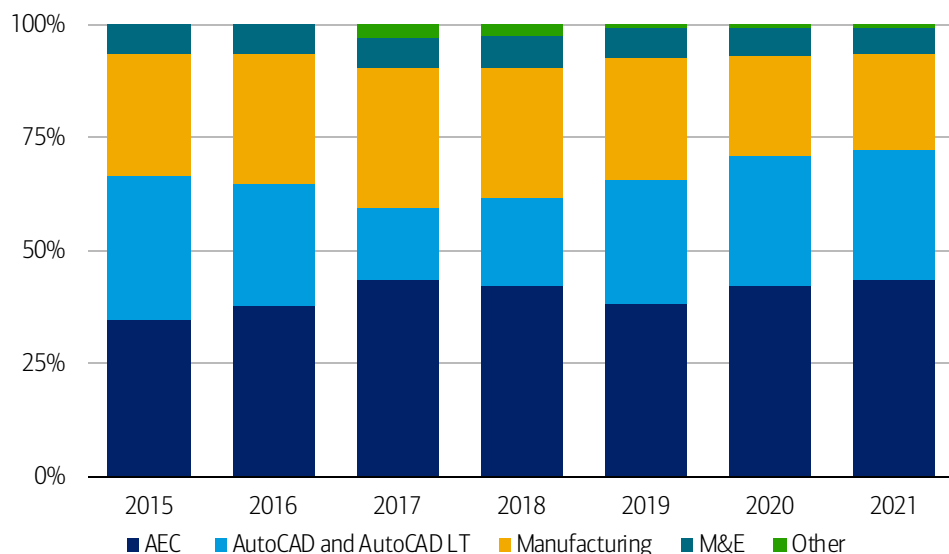
Autodesk offers a broad portfolio for software and mechanical simulations specifically used for Building Information Modelling (BIM). BIM refers to the digital representation of a construction project and is used by architects, engineers and other construction professionals: it specifically applies the concept of PLM to the Architecture, Engineering and Construction (AEC) sector.

Autodesk is the market leader of these solutions, and has systematically generated around c.35-40% of its revenues from the AEC sector; we estimate that it holds a nearly 30% market share in this market. Its exposure to the early stage of software adoption in the AEC markets makes the company more resilient than other PLM providers. In addition, as previously mentioned, we do expect the AEC sector to continue to grow significantly in the coming years, which should benefit Autodesk.



Exhibit 80: Strong specialisation in AEC ensures sustainable growth

Autodesk product mix



Source: BofA Global Research Estimates, company data

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The company also offers products in three other segments: (i) Platform solutions and emerging business (CAD solutions i.e. AutoCAD and AutoCAD LT software), (ii) Manufacturing (Autodesk Products Design Suites, Autodesk Inventor, Autodesk Moldflow) and (iii) Media and Entertainment (Autodesk 3ds Max, Autodesk Maya, Autodesk Flame, Smoke and Lustre).

Like several other PLM players, Autodesk has also relied on an extensive M&A strategy, which has been two-fold. First, bolt-on acquisitions have consolidated Autodesk's offering and market share in the sectors where it already operates i.e. in PLM and BIM software as well as games and media software. However, Autodesk has also been using M&A to position itself as a leader in emerging, high growth segments in PLM, such as the development of digital twins and the Industrial IoT.

Exhibit 81: M&A activity has allowed Autodesk to both consolidate its market share in existing businesses and expand into new sectors

Major Autodesk Acquisitions since 2012

Company	Year	Price (US\$m)	Description & Rationale
Qontext	2012	Undisclosed	Qontext is an enterprise social collaboration software, from India-based Pramati Technologies. The acquisition of the Qontext technology and development team will accelerate Autodesk's ongoing move to the cloud and expansion of social capabilities in the Autodesk cloud-based service.
Graitec	2013	Undisclosed	Graitec is a global provider of CAD and engineering software for structural engineering, civil engineering and building construction. The acquisition will enhance Autodesk's current offerings for structural engineering and expand its portfolio of technology for Building Information Modeling (BIM) for structural fabrication and detailing.
Shotgun Software	2014	Undisclosed	Shotgun Software is a developer of scalable, cloud-based production tracking, review, and asset management software for the film, television and games industries. Shotgun's tools for production management are used by some of the world's leading production studios, and are tightly integrated with many of the most widely used tools in the industry including Autodesk 3ds Max and Autodesk Maya software.
Bitsquid	2014	Undisclosed	Bitsquid is the creator of the Bitsquid game engine. The acquisition brings to Autodesk expertise in 3D game development and proven technology that will enable Autodesk to supercharge its portfolio of tools for game makers through the development of a new 3D game engine.
Netfabb	2015	Undisclosed	Netfabb is a developer of software solutions for industrial additive design and manufacturing. Autodesk will also make a strategic investment in FIT Technology Group, the parent company of Netfabb and provider of additive manufacturing software and services, to increase adoption of technology for industrial additive manufacturing.
Seecontrol	2015	Undisclosed	SeeControl is the developer of an enterprise Internet of Things (IoT) cloud service platform. The SeeControl service helps manufacturers and systems integrators connect, analyze, control, and manage remote products, things, and assets and create new service revenue opportunities. Autodesk intends to continue to sell and support the SeeControl platform and to incorporate the technology into design solutions for the manufacturing and building industries. Autodesk also plans to develop a new IoT solution based on the SeeControl technology that will allow companies to gain real world insights of how their products perform, enabling customers to explore innovative new service models.
Solid Angle	2016	Undisclosed	Solid Angle is the developer of Arnold, an advanced, ray-tracing image renderer for high-quality 3D animation and visual effects creation used in film, television and advertising worldwide. As part of Autodesk, Solid Angle's development team will continue to drive the evolution of Arnold working in close collaboration with its user community.

Exhibit 81: M&A activity has allowed Autodesk to both consolidate its market share in existing businesses and expand into new sectors

Major Autodesk Acquisitions since 2012

Company	Year	Price (US\$mIn)	Description & Rationale
Assemble Systems	2018	Undisclosed	Assemble Systems provides a SaaS solution that enables construction professionals to condition, query and connect BIM data to key workflows across bid management, estimating, scheduling, site management and finance. Over time, Assemble Systems' solution will be integrated with Autodesk's new BIM 360 project management platform.
PlanGrid	2018	875	PlanGrid is a leading provider of construction productivity software. Autodesk plans to integrate workflows between PlanGrid's software and both Autodesk Revit and Autodesk BIM 360 for a seamless exchange of information between all project members.
BuildingConnected	2019	275	BuildingConnected is the largest and most active digital network in the construction industry: it centralizes the bid management process and simplifies communication to make finding, qualifying and selecting the right subcontractors or responding to the right project opportunities fast and easy. Autodesk plans to integrate workflows between BuildingConnected, Autodesk BIM 360, Revit and AutoCAD, as well as PlanGrid and Assemble Systems, to provide a comprehensive construction offering that addresses the critical processes and workflows across the project lifecycle from start-to-finish.
Pype	2020	Undisclosed	Pype is a provider of cloud-based solutions for automating construction project management workflows. The acquisition will empower general contractors, subcontractors and owners to gain even more value from Autodesk Construction Cloud by automating critical construction workflows such as submittals and closeouts to increase productivity and mitigate project risk.
Spacemaker	2020	240	Spacemaker is a Provider of AI and Generative Design-enabled Urban Design Platform. The acquisition of Spacemaker provides Autodesk with a powerful platform to drive modern, user-centric automation and accelerate outcome-based design capabilities for architects, and urban designers and planners.
Innovyze	2021	1,000	Innovyze is a leading provider of Smart Water Infrastructure Modeling, Simulation, and Predictive Technologies. The acquisition positions Autodesk as a leading global provider of end-to-end digital solutions from design to operations of water infrastructure, accelerates Autodesk's digital twin strategy, and creates a clearer path to a more sustainable and digitized water industry.
Upchain	2021	Undisclosed	Upchain is a provider of instant-on, cloud-based product lifecycle management (PLM) and product data management (PDM) solutions. The acquisition positions Autodesk to deliver more value for engineers, manufacturers, suppliers and other product stakeholders by increasing collaboration across the decentralized product value chain, regardless of CAD system.

Source: BofA Global Research, company website

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Ansys

Ansys is the #1 expert in simulation software, according to CIMdata. It pursues a strategy of "Pervasive Engineering Simulation", which seeks not only to deepen the use of simulation in core customers but also to inject simulation throughout the product lifecycle and to embed it into the ecosystem of the integrated PLM providers (i.e. Dassault Systemes, Siemens DI, PTC, etc.). Ansys has strategic partnerships with Microsoft, Synopsys, PTC, Rockwell Automation, Autodesk, and SAP.

In addition to the aforementioned partnership with PTC's Creo software, Ansys also maintains marketing and software development relationships with leading EDA companies, including Cadence Design Systems, Synopsys, Siemens and Zuken. These relationships support the transfer of data between electronics design and layout software and Ansys' electronics simulation portfolio. The company notably has an integration and distribution agreement with Synopsys to cooperatively integrate Ansys RedHawk technology into an in-design add-on to a Synopsys design tool, providing customers with direct, in-design access to this technology.

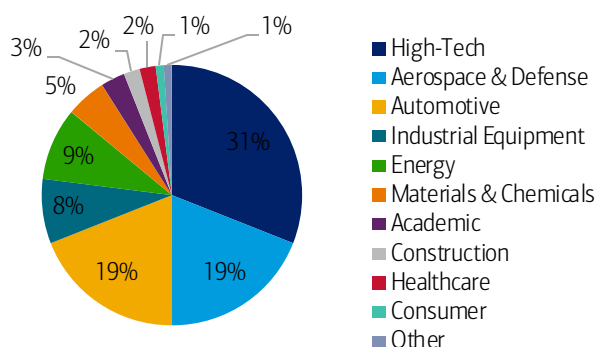
Importantly, Ansys also has a strategic relationship with Microsoft that spans several business units and markets. The primary focus of the relationship centers on Ansys Cloud, a cloud-based simulation service hosted on Microsoft's Azure Cloud infrastructure, which provides on-demand access to HPC directly from within Microsoft's flagship platform. Other marker-specific collaborations with Microsoft include Ansys' digital twin connection with Microsoft Azure IoT solutions and Ansys' autonomy software for autonomous vehicles running on Azure.

Ansys' strategy to deepen its expertise in simulation and to largely rely on the integration of its software into the platforms of integrated PLM players has provided it with excellent market share in all sectors and a diversified revenue stream. In addition, those partnerships have also allowed to diversify the geographic split of revenue, half of which remains US-driven.



Exhibit 82: Ansys strong specialisation in simulation software ensures wide variety of clients from all industries

Ansys industry mix

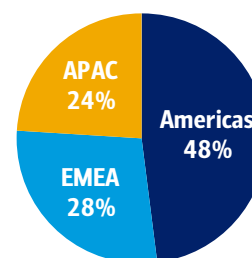


Source: BofA Global Research Estimates, company data

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Exhibit 83: Ansys is predominantly reliant on US markets (48%)

Ansys geographical mix



Source: BofA Global Research Estimates, company data

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In terms of growth outlook, the engineering software simulation market is strong and growing. This growth is notably driven by customers' need for rapid, quality innovation in a cost-efficient manner, enabling faster time to market of new products and lower warranty costs. While the transition away from physical prototyping toward simulation is prevalent through all industries, its demand is heightened by investments in high-growth solutions, including 5G, electrification, autonomy and the IIoT (Industrial Internet of Thing).

Exhibit 84: Expected growth in Total Addressable Market (TAM) to boost growth across products

Autodesk Strategic Sectors Growth Outlook

	2026 TAM (US\$ bn)	8-year CAGR to 2026
Foundation	9.3 - 9.7	8%
Emerging high-Growth Solutions	3.8 - 5.4	18%
New Adjacencies	2.7 - 5.5	34%

Source: Company data

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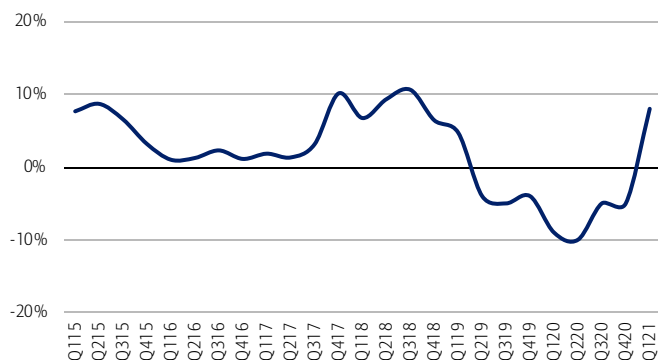
Hexagon

Hexagon is a leading supplier of measurement technology. It operates in two main segments: Industrial Enterprise Solutions (IES) and Geospatial Enterprise Solutions (GES). Hexagon's PLM capabilities reside primarily in the IES division, in both Process Power & Marine (PPM) and Manufacturing Intelligence (MI) businesses. Historically, PPM (based on the Intergraph business bought in 2010) focused primarily on design software for process plant, offshore plant and shipbuilding but in recent years (with the acquisition of EcoSys and BricSys) PPM's end market exposure has moved away from the dominance of process sectors to include more "traditional" infrastructure and construction end markets. The AEC market is currently driving much of the growth in the division as Hexagon launches its SmartBuild strategy focused on providing software/hardware solutions to enable the digitisation of the construction industry with the provision of digital twins from design to build to operation.

In MI, which represents the legacy of Hexagon's factory automation exposure through the original Brown & Sharp acquisition (provides Coordinate Measurement Machines, CMM), the acquisition of MSC Software in 2017 brought Computer Aided Manufacturing & Computer Aided Engineering (CAM/CAE) capabilities to enhance Hexagon's PLM solutions. Hexagon's position at the heart of a continuous positive feedback loop (i.e. being able to measure and compare what has actually been made with what was meant to be made) is a unique capability in the context of the PLM vendors.

Exhibit 85: Industrial Enterprise Solutions Organic Sales Growth

Having bounced off the trough of -10% in Q2'20, organic growth has slowed, at 8% in Q1'21, hampered by delayed recovery in automotive and continued challenges in O&G

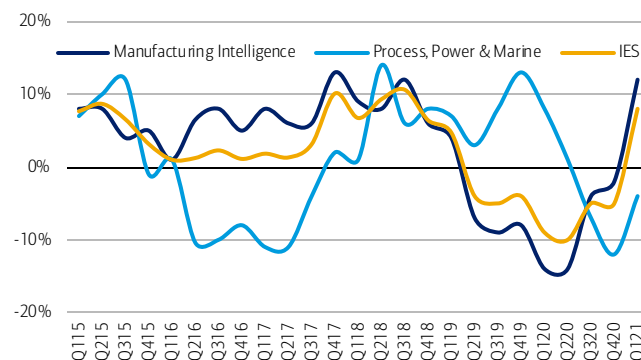


Source: Company data

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Exhibit 86: IES breakdown Organic Sales Growth

MI has started to recover to 12% in Q1'21, helped by China, but PPM has lost all momentum at -4% in Q1'21 and is being considerably hindered by the weak demand in O&G markets

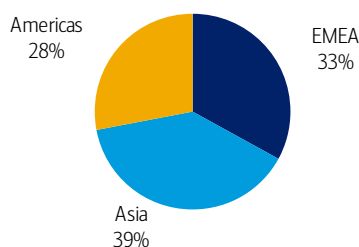


Source: Company data

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Exhibit 87: IES: Q121 Sales by Geography

IES remains balanced regionally, but Asia is the largest market with 39% of total sales

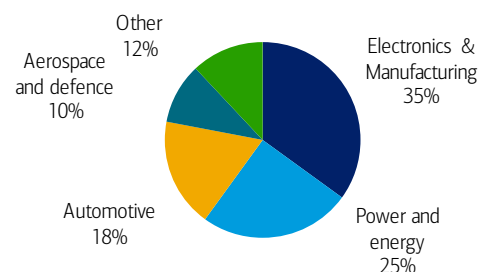


Source: BofA Global Research estimates, company data

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Exhibit 88: IES: Q121 Sales by End Market

Electronics & Auto combine for over 50% of sales

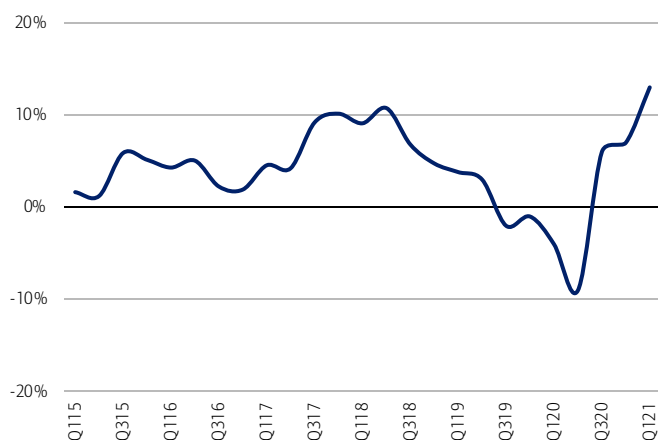


Source: BofA Global Research estimates, company data

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Exhibit 89: GES Organic Sales Growth

Organic growth has recovered strongly, helped by China

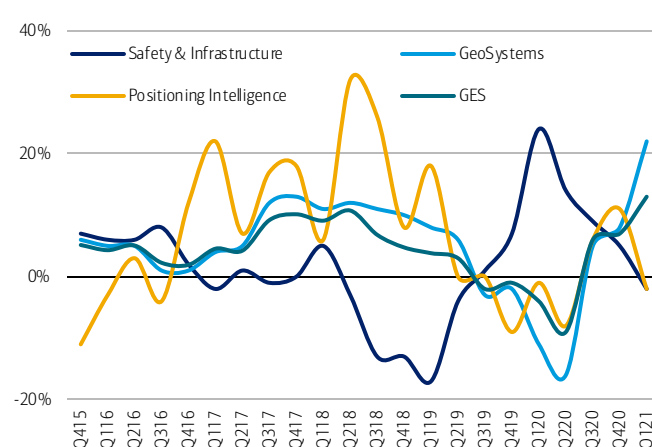


Source: BofA Global Research estimates, company data

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Exhibit 90: GES breakdown Organic Sales Growth

All three divisions are reporting solid organic growth recovery



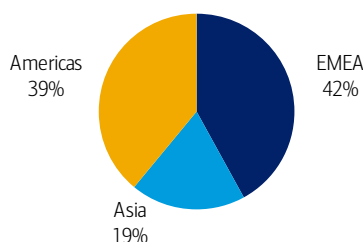
Source: BofA Global Research estimates, company data

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Exhibit 91: GES: Q121 Sales by Geography

EMEA and Asia are similar in size, but China is the largest market

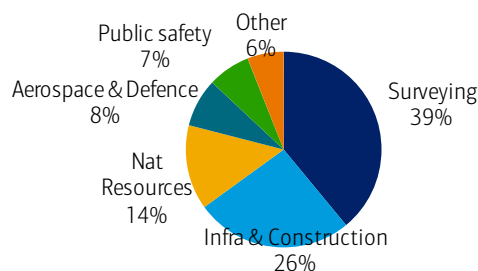


Source: BofA Global Research estimates, company data

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Exhibit 92: Geospatial: Q121 Sales by End Market

Surveying, infrastructure & construction dominate the sales mix



Source: BofA Global Research estimates, company data

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In terms of growth outlook, we believe Hexagon is a high-quality company, offering solid growth opportunities via its metrology and overall exposure to the theme of the industrial internet. With its measurement and analytical capabilities, Hexagon sits at the fulcrum of the concept of digital twins, enabling the connection between the physical and digital worlds across a number of end market verticals. In addition, with the launch of Xalt (Hexagon's software backbone) and the Autonomous Connected Ecosystem (ACE) strategy Hexagon is shifting from a portfolio of capabilities being marketed individually as point solutions to a more holistic and integrated approach, which we believe is likely to underpin above market growth for the medium term.

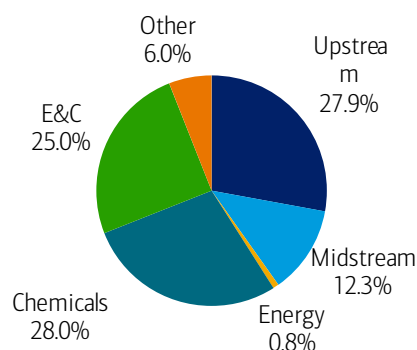
Hexagon continues to actively pursue M&A, most recently with its acquisition of Infor EAM from Koch Industries. EAM software underpins operational performance of installed equipment across a wide range of end markets from buildings to process plants to factories and this acquisition sees Hexagon "complete" a portfolio of capabilities along the digital thread from design to build to operate. The market is growing c6-7% pa to US\$3.8bn by 2023E according to Hexagon (citing Gartner), but the advent of the Internet of Things is driving an evolution of EAM from a reactive to proactive & predictive capability; Asset Performance Management. Shifting from on premise solutions to cloud-based (SaaS) drives increased adoption potential for customers and more consistent revenue and cash generation for vendors. The SaaS EAM market is expected to grow 20% pa to 2023E (Hexagon, citing Gartner).

Aspen Technology

AspenTech is a US-based global leader in process optimization software. The company has a suite of software platforms and applications: Engineering (primarily CAD and simulation & analysis), Manufacturing Execution System (MES), Supply Chain Management (SCM), and Asset Performance Management (APM). AZPN serves a broad set of process industries, including oil & gas, chemicals, and engineering & construction, and to a smaller extent power, pharmaceuticals, metals & mining, and pulp & paper. The company has a high degree of revenue concentration, with its top 250 customers accounting for 80% of revenue.

Exhibit 93: Heavy reliance of Energy, Chemicals and sectors

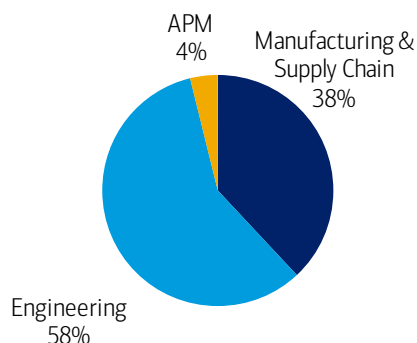
Aspen industry mix



Source: BofA Global Research estimates, company reports
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Exhibit 94: Engineering and Manufacturing & SC make up majority of revenues

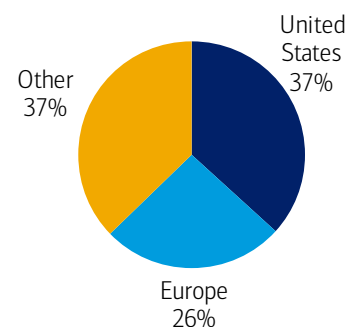
Aspen software suite



Source: BofA Global Research, company presentation
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Exhibit 95: Well-balanced geographical exposure

Aspen geographical mix



Source: BofA Global Research estimates, company filings
Note: "Other" primarily includes APAC, Canada, LatAm, and the Middle East

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Aspen's products are organised into three suites: (i) Engineering (design of new plants, re-vamp of existing plants, simulation and optimisation of existing processes), (ii) Manufacturing and Supply Chain (optimisation of processing activities, inventory levels, asset efficiency) and (iii) Asset Performance Management (APM) (analysis and prediction of system reliability through machine learning and analytics technology).

Unique business model drives recurring revenue

AZPN's deep domain expertise and established presence in process verticals means that customers rarely switch onto competing software platforms given unwanted inefficiencies of integrating a new system. This is best evidenced by AZPN's customer base —the company has a dominant presence among the largest E&C Oil & Gas (20 out of 20), Petroleum (19 out of 20), and Chemical (20 out of 20) companies.

AZPN's subscription-model also lends itself to customer longevity and a more resilient revenue profile. Customers sign 5-6 year contracts to use AZPN's aspenONE software suites. Because of the critical nature of its software and expertise, AZPN is able to raise prices on contract payments by 2-3% annually. Price escalation and "New Spend" (from amendments to contracts and new contracts) offset customer attrition, which runs anywhere between 3-6%.

As of FY20, about 94% of AZPN's revenue was recurring in nature.

Key process end markets challenged

Our BofA bottom-up capex tracker shows that oil & gas and chemicals firms are expected to reduce capex budgets by 25% y/y and 8% y/y on average in 2020. In 2021, our analysis suggest some projects could be delayed further. The COVID-19 downturn and recent oil price volatility have caused customers to cut internal investment and nonessential costs. While current conditions are driving higher efficiency in the industry leading to better adoption of the digital tools, at the same time, this also limits the spending upside. With oil prices expected to remain below \$50/bbl through 2021, production rates and customer investment will likely remain under pressure.

While vertical expertise has proven a winning strategy for numerous players in the industrial software industry (notably in the AEC sector), it is unclear whether this will be the case for Aspen. With a significant exposure to the oil and gas industry (c.41% of revenues stemming from this sector, including Upstream, Midstream), the exposure to oil prices volatility is likely to weigh on growth in the future.

APM adoption key

Asset Performance Management (APM) is a predictive analytics software tool that helps operators detect anomalies in process equipment. AZPN has built out its APM suite through recent acquisitions. As of FY20, it represented 4% of annual spend. The APM software is supported by customers realizing that maximising equipment reliability is one of the key use cases for digitalisation, in our view. AZPN is currently meaningfully outgrowing the market (+256% y/y in FY19 and +64% y/y in FY20).

Glossary: Key acronyms

AEC – Architecture, Engineering & Construction

BOM – bills of materials (also see EBOM and MBOM)

CAD – Computer-aided design

CAE – Computer-aided engineering

CDE – Connected Data Environment

CNC – Computer Numerical Control

cPDM – collaborative product definition management

DCS – Distributed Control System

EAM – Enterprise Asset Management

EBOM – engineering bills of materials (see BOM)

ERP – Enterprise Resource Planning

FEA – Finite Element Analysis (It is the practical implementation of FEM (see below).)

FEM – Finite Element Method

HMI – Human Machine Interface

MBOM – manufacturing bills of materials

MBSE - Model based systems engineering

MBx – Model Based-“x” (Collective abbreviation of some MBx terminologies, including MBD, MBE, MBSE.)

MEP – Mechanical, electrical and plumbing engineering (This is a term commonly used in AEC, and are the three important components for building interiors.)

MES – Manufacturing Execution System

MRO

PAM – Plant Asset Management

PDM – Product data management

PLC – Programmable Logic Controller

PLM – Product lifecycle management

RFLP – Requirement, Functional, Logical and Physical

SCADA – Supervisory Control and Data Acquisition

SCM – Supply Chain Management

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