THE INTELLIGENT ENTERPRISE FOR THE AEROSPACE AND DEFENSE INDUSTRY

Mapping the way to a future data-centric manufacturing organization

THE BEST RUN **SAP**

WELCOME

Dear Aerospace and Defense Colleagues,

The aerospace and defense (A&D) industry has always been on the leading edge of advanced technology and, indeed, the public's imagination.

While such innovations as moon habitation, single-pilot airplanes, supersonic airplanes, electric propulsion, and autonomous aircraft transporting people are no longer the stuff of science fiction, A&D companies must embrace technical, cultural, and organizational change to maintain their place in the new experience economy.

The winners and losers of the future will be determined by the experiences they provide. With the right insights, delivered in real time, you can provide great customer experiences while simultaneously seeking out and eradicating poor experiences.

The world is facing social, economic, and environmental challenges that are reshaping the global economy. Cybersecurity and space security loom among society's biggest challenges. At the same time, customer expectations are rising, digital transformation presents organizational challenges, and competition is coming from unexpected quarters.

Disruption today comes from players who are able to identify the most critical gap between the customer expectations and the experience in reality to create a new experience.

The challenge is trying to do this by understanding various combinations of operational data and Big Data, or seeking sentiment for areas of known issues or opportunities for innovation such as Industry 4.0. Industry 4.0. is only one area where new digital technologies make it possible to gather and analyze data across machines and business systems to enable faster, more flexible, and more efficient processes.

The insight from data will transform the industry. In fact, we anticipate that data-related services will account for as much as half of the industry's revenue by 2025.

While there is no shortage of innovative products and services being dreamed up in response, their impact can be dulled by slow time to market and lagging iteration cycles. The key to eliminating these delays is data: Collecting, managing, and sharing data between manufacturers, suppliers, operators, and government agencies will improve efficiency and ensure that products and services are forward-looking.

Managing the data explosion and developing complex products with shorter innovation cycles will require new ways of working, an openness to collaboration, and the systems to enable it.

The companies that weave together formerly siloed processes, intelligent technologies, and real-world data from customers, connected devices, partners, and the environment will lead the way. And they will embrace a new generation of talent that embodies the curiosity that is in the industry's DNA.

This paper takes a deep dive into the trends shaping our industry and the path to innovation. In it, we propose a set of priorities that will drive transformation and the tools that will make it possible.

A&D sits at the forefront of innovation, shaping our world in ways that were once unimaginable. We are limited only by the extent of our willingness to embrace change and stretch our own creativity.

Sincerely yours,

Torsten Welte
Global Vice President
Aerospace and Defense
SAP SE

"The aerospace and defense industry is releasing the next generation of break-through innovations. Use of technologies such as artificial intelligence, machine learning, or robotic process automation will cross boundaries from products into value chain processes. We believe data will be the critical bridge between both worlds and will generate new business models."

Torsten Welte
Global Vice President
Aerospace and Defense
SAP SE

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OUR PLACE IN THE NEW WORLD

Global "megathemes" are impacting the aerospace and defense industry and providing new opportunities for growth.

▪ **Trusted products:** All players in the A&D industry live in a global economy with complex supply networks. People and enterprises need to trust the products they process and use. Counterfeiting, recalls, and lack of transparency are the biggest challenges A&D companies face today.

▪ **Global supply chains:** Contractual relationships, low manufacturing costs, new capabilities, and a lack of capacity require manufacturing companies to source their products from around the world. The need to reduce overall time and risk to deliver is driving OEMs to track products in the supply chain more closely or move production nearer to customers. Moving production closer to the OEM extends the amount of time available to incorporate customer changes.

▪ **Education and work:** Two trends are fundamentally changing the way we look at education and work. Automation, driven by robotics and machine learning, will fundamentally change the work environment of millions of people – from the unskilled worker to the highly specialized knowledge worker. A single education path or job is no longer enough to sustain a decades-long career; lifelong learning will become the norm. Future generations face a multistage career in jobs that might not exist today. Consequently, the required skill set of the workforce will evolve, necessitating manufacturers to undertake significant cultural change.

The A&D industry is being reshaped by major industry trends.

- **Optimization across the value chain:** Aerospace and defense enterprises face increased customer expectations for product innovations. Customers want more for less, along with performance-based services such as logistics. This revolutionizes how A&D companies manage complex programs and their global supply chains. In addition to providing a better product for less, companies – and their supply chains – are getting pressure from OEMs to reduce prices even further. The supplier base is shrinking, and many suppliers have to adjust to production rate increases with many of their customers. Robotics and automation are critical to make up for the lack of new engineers.

- **New business models and new players:** As industry boundaries are blurring, aerospace manufacturers are getting boxed in by suppliers moving up the value chain as well as by customers moving down the value chain. Vertical integration is again becoming increasingly important. New players are using new technologies and are not bound by legacy processes or cultures. Product improvements are based on engineering, experience, and operational data.

As vertical integration increases, suppliers that specialize will increase their footprint by using Big Data, the Internet of Things, and machine learning, enabling them to analyze data across machines and business systems.

Opportunities to enter the market and profoundly change the playing field arise for players with a strong technology background.

Companies capable of addressing global megathemes and industry challenges will be among the winners in the next 10 years. Successful business model innovation, process optimization, and workforce productivity are linked directly to delivering great customer and employee experiences. In fact, best-performing companies are pulling away from the rest and widening the performance gap by creating a landscape where they deliver great experiences and are the most profitable because they successfully adopt new technologies and deliver winning products and services more efficiently.

According to a study by Forrester Consulting, innovative companies focus on technologies to help them achieve digital innovation goals and digital transformation more than other manufacturing companies.[1]

Digital strategies are disruptive and changing the rules for aerospace and defense companies.

Diehl Aviation rapidly realized its vision of a complete digital twin that connects thousands of innovation workers while eliminating process inefficiencies with a leaner and smaller system landscape that includes the SAP® Engineering Control Center integration tool.

For Newport News Shipbuilding, driving change is a must. To keep up with increasing customer demand, the A&D manufacturer chose SAP HANA® as the platform to support its strategic transformation, which is optimizing business value across the organization.

European Space Agency and SAP teamed up to close the gap between traditional Earth observation and the digitalized business world.

Airbus America needed to digitalize and streamline its processes and refocus on the quality of the data to address customer needs. Now with the SAP Analytics Cloud solution, Airbus America can really focus on its end customers.

Thrush Aircraft transforms customer engagement with integrated, comprehensive SAP Customer Experience solutions.

Trenitalia, Italy's major train operator, is using the SAP Predictive Maintenance and Service solution to extract large amounts of data on a daily basis through onboard sensors on its trains, which is then transmitted over the ground network and analyzed by the information processing systems that run on SAP HANA.

INDUSTRY VISION 2025

In 2025, the world of aerospace will be data centric. Time to market for innovations will be reduced dramatically without compromising safety, as all innovation scenarios can be simulated along the complex value chain for optimized decision-making based on current and future environments.

Additionally, data and data-related services could deliver up to half of the overall revenue.

Upcoming innovations around moon habitation, satellites, single-pilot or supersonic airplanes, electric propulsion, autonomous aircraft transporting humans, and the intense focus of defense around cyber and space require more efficient processes for design, testing, certification, and manufacturing to support operations. Model-based simulation engineering is already adopted to improve design, but digitalization will expand across the entire lifecycle of products. Decisions will not only be based on operational data but expand to situational data as well as experience or emotional data. This experience data will influence not only product features but also how people work or interact with products. OEMs and suppliers will obtain the feedback to develop next-generation infrastructure and hardware in parallel.

The next generation of products will provide exponentially more data during the operation. As the digitalization of manufacturing and testing processes expands, the overall data volume will explode. Managing the magnitude of data volume through production and operations, collaboration, access, and analysis of data requires intelligent technologies such as AI and machine learning. Connected machines and business processes can help realize Industry 4.0 aspirations. Balancing the data explosion, complex products with more innovation cycles, a changing environment, and a less-experienced workforce require new technologies. AI and quantum computing will enable single-pilot airplanes and next-generation autopilot as well as all the processes within aerospace companies. The data war has already started, and A&D companies that can manage new partnerships, devise new business models, and use new technologies to their advantage will become the winners.
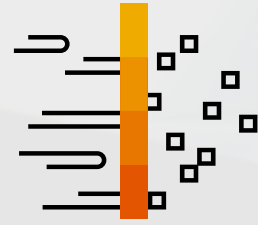
94%
Of digital leaders are investing in Big Data and analytics[2]

75 billion
IoT devices will be available by the year 2025[3]

84%
Of enterprises believe investing in AI will lead to greater competitive advantages[4]

US$3.7 trillion
Value creation potential of manufacturers and suppliers implementing Industry 4.0 in 2025[5]

FIVE PRIORITIES FOR SUCCESS

We have identified five strategic priorities necessary for aerospace and defense companies, helping them to innovate products and services that simplify life and deliver amazing experiences:

- Customer centricity

- Driving innovation

- Digital business networks

- Agile manufacturing

- New business models

CUSTOMER CENTRICITY

Creating great customer experiences by putting the customer's point of view at the center of every decision is the norm for success in the digital age.

It requires companies to capture feedback from both equipment and the people using it. It does not begin and end in the sales department but applies to what products are built and what services are offered. Operating in a real-time and intelligent self-service environment provides direct access to progress insights, predictions, and alerts on exceptions, enabling a new customer experience – one driven from production and aftermarket service data.

The Vision

In 2025 aerospace manufacturers will be hyper-focused on customers, driving a new customer experience that focuses on providing tailored benefits, improved performance, real-time insights, and, ultimately, reducing cost and risk. Starting with a detailed understanding of requirements and needs by collecting and analyzing customer feedback and experience data, and ending with the knowledge of how customers use their products, A&D companies will have a 360-degree understanding of their customers. By using Industry 4.0, machine learning,

and blockchain technology, as well as experience management, A&D product and regulatory processes will be automated and assisted. This means that innovation cycles will be shortened, compliance will be simplified, and A&D companies will not only focus on the customer but also drive the infrastructure needed to support the user, consumer, or passenger.

The Journey

Aerospace manufacturers will start by collaborating with customers in the design, development, and maintenance of their products. By extending the customer experience, A&D companies can bundle services and assets to fulfill performance-based contracts, reduce costs by using predictive analytics, and make strategic business decisions with real-time insight. The A&D company of 2025 will use the 360-degree perspective of the customer to optimize business decisions from contract bidding all the way through to aftermarket services.

Today

Transactional

Future

Customer for Life

The Brand Becomes the Experience.
With the adoption of technologies such as AI, analytics, and Big Data, by 2020, **10%** of companies will begin to integrate personalized brand promises into the customer experience.[6]

"We are committed to turning customer feedback into real insights for the company and real benefits for the customer."
Danny Cox, Director, Customer Support and Insights, JetBlue Airways[7]

Keeping the Promise: Creating a Great Customer Experience

Putting the end customer's point of view and feedback at the center of every decision is a key prerequisite for success in the digital age. It means capturing feedback from both the equipment and the people using it. And it does not stop with business development or product design but also applies to how products are built and what services are offered. Digital services must provide tailored benefits, improve product performance, and support outcome-oriented service models to reduce cost and risk.

Reimagine the New Art of Customer-Oriented Aftermarket Engagement

SAP solutions for a full digital representation of customer assets along their lifecycle deliver an embedded, collaborative, and real-time set of next-generation processes and systems for a customer-oriented, omnichannel, profitable, and predictive service business.

TRADITIONAL SCENARIO

| Untrustworthy and disparate asset and customer information | Limited capability to monitor asset condition and to predict asset health, remaining lifetime, and demand forecast; no capability to link operational data with customer experience data | Missing end-to-end transparency and multiple sources for parts catalogs | Multiple distributed data sources and communication channels for all parties involved, making business complex and not transparent | Longer resolution process for service requests based on outdated or incomplete information | No platform to connect all parties involved |

NEW-WORLD SCENARIO

| Leverage a digital twin for granular, real-time asset information in the context of service delivery, such as service parts and bulletins over the whole lifecycle as well as customer feedback and experience data about assets. | Monitor the condition of equipment health based on sensor data, with graphical visualization of warning and error zones; operational data is merged with experience data and draws insights that are used to design even better equipment and services. | Provide a superior customer experience across different channels through simplified service parts selection using a 3D viewer and a harmonized pricing and service offering from quote to cash. | Streamline service parts business through efficient spare-parts commerce platforms, digitally connecting all parties involved with full process transparency. | Simplify information flow based on access to service knowledge databases and machine learning capabilities to solve service requests automatically. | Connect multiple business partners for intercompany and intracompany information exchange and collaborative service processes. |

TOP VALUE DRIVERS

10%–20%
Increase in revenue from new products

10%–20%
Increase in customer satisfaction

15%
Increase in market agility and responsiveness

Source: SAP Performance Benchmarking

DRIVING INNOVATION

Shorter innovation cycles and rapidly changing customer needs are challenges the industry has to face due to its long product lifecycles.

The A&D industry is a highly innovative industry, one that has created many game-changing technologies. To incorporate the latest technology and customer needs in A&D products, development, testing, and certification processes have to become less time consuming and more agile while retaining the same level of quality and safety. Digital technologies support this journey by facilitating the management of highly sophisticated engineering and manufacturing tasks, more-efficient collaboration for better management of complex products, seamless communication and data sharing between departments and stakeholders, and virtualization of test and certification procedures.

The Vision

In 2025 innovation cycles will be much shorter. Opportunities for value-driven innovations will be able to be identified based on customer and stakeholder feedback from multiple channels. State-of-the-art technologies such as virtual reality and augmented reality will be incorporated into A&D products and processes to enable faster test and certification cycles, as well as 3D printing for rapid prototyping. Industry 4.0 innovations will facilitate manufacturing process efficiency and proactive awareness. Each physical product will be digitally represented by a network of digital twins, and all lifecycle data will be available

through a digital thread for all involved stakeholders, enabling them to predict future product behavior and find and execute the optimum solution for upcoming situations. Lifecycle data and customer feedback will be fed back to engineering for design improvements that will be implemented in frequent release cycles.

The Journey

A&D companies will start toward this goal by collecting not only product data but also experience data of customers and stakeholders. This data will be analyzed with Big Data methods to identify and focus on value-driven innovations that are required to meet market demand. To extend from there and to use all lifecycle data more efficiently, data silos within the lifecycle will be broken down step-by-step due to identified win-win situations within the ecosystem, for example, the improvement of a product and the production process by using production feedback in engineering. Digital technology will be incorporated, enabling efficient and secure collaboration between departments and companies, thereby setting the cornerstone for achieving the vision of the digital thread throughout the entire product lifecycle to drive innovation (see Figure 1).

Figure 1: Alignment of the Digital World with the Physical World Covering the Entire Product Lifecycle
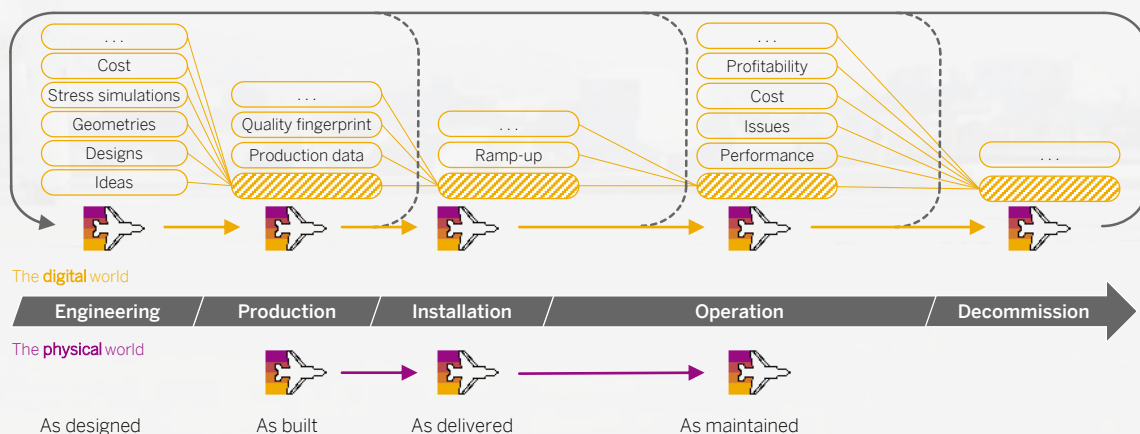
49% of large A&D firms consider their company to be on the forefront of adopting leading-edge technology.[8]

In the R&D and engineering field at A&D companies, **more than 50%** see 3D printing and Big Data analytics as the technologies that serve the primary value drivers to design innovative products that attract customers and fit the market.[9]

Making Products Smarter, More Reliable, and Cost-Efficient

Continuous innovation and changing customer needs are impacting aerospace and defense products and processes alike. With even more technology being embedded in products, OEMs aim to make products smarter, more reliable, and cost-efficient. As many companies recognize Industry 4.0 as a strategic priority, the IoT integration across the entire organization will unleash the potential, where the factory will become a flexible hybrid system of robots and humans, additive and subtractive manufacturing, and digital processes. Process automation benefits from intelligent network of systems, while 3D printing is being widely adopted across the industry for faster prototyping to shorten development cycles and to make spare parts available in the aftermarket more quickly and reliably.

Reimagine Efficient Delivery of Highly Customized Products

Solutions in the SAP digital product portfolio enable aerospace and defense companies to develop products with real-time insights across the product lifecycle. The solutions enable collaboration across departments and companies and the management of product development from initial ideas to manufacturing. With the integration of experience management technology, customer preferences are better understood and can be incorporated in the product design. This helps shorten the time to market of innovative and individualized products and lower the cost.

TRADITIONAL SCENARIO

Time-intensive process for customers to configure their products based on standard configuration options and adding additional options

Lack of a holistic view on project cost and status of a customer-specific order

Challenging to collaborate digitally with OEMs and partners on customer demand

Inability to calculate preliminary cost and profitability

Inability to collaborate with external manufacturing service providers for 3D printing of parts

Inability to offer and manage software and entitlements for product-embedded software and digital services

NEW-WORLD SCENARIO

Gain customer-oriented configure, price, and quote capabilities, allowing customers to build their own products.

Achieve intelligent product configuration based on historical data and customer experience insights on preferences.

Use integrated project and program management to allow tracking of actual cost, earned value, and project status in real time.

Take advantage of collaborative design of additional requirements on one IoT-integrated platform for customers, OEMs, and partners.

Use early product costing to enable engineering and sales to design for profitability and for better estimating of costs during early lifecycle phases.

Harness 3D printing for design optimization using an Industry 4.0–supported collaboration platform between OEMs and service providers, for seamless exchange on design documents, quality, and pricing.

Use embedded software management capabilities enhanced by constraints management of hardware and software components as part of the architecture of SAP S/4HANA®.

TOP VALUE DRIVERS

15%
Increase in market agility and responsiveness

10%
Reduction of total manufacturing cost

10%–20%
Increase in revenue from new products

10%–20%
Increase in customer satisfaction

Source: SAP Performance Benchmarking

DIGITAL BUSINESS NETWORKS

Increasing customer focus is driving A&D companies to expand business optimization to the entire network and find ways to fully digitalize and transform cross-company processes across the product lifecycle.

To manage the risk and complexity of globally distributed supply chains, A&D companies look for innovations that can add agility and flexibility and enable seamless collaboration and information exchange among partners. Embedding intelligence and combining operational and experience data into core processes with Industry 4.0 technologies such as autonomous robots, along with additive manufacturing or machine learning, will help to reimage supplier management or global resource orchestration across company boundaries and to respond faster and better to changing customer demands and market dynamics.

The Vision
In 2025 A&D companies will extend core processes through secure, scalable, transparent, and trusted business networks (see Figure 2). This will help the A&D industry break down complexity and trust barriers that exist today and allow seamless execution of diverse manufacturing and service programs as supply chains become more flexible. All stakeholders will collaboratively manage A&D products across their lifecycle in real time using digital twins, benefiting from the know-how of all partners.

The Journey
A&D companies will start by expanding real-time operational visibility from the enterprise to the network level to align with partner plans, increase awareness of supplier risks and alerts, and monitor networkwide performance. Critical alerts will be detected by the network automatically and shared on the network level along with predictive and prescriptive business context, helping to balance lead times and financial impact.

Experience data will be included into analysis like vendor sentiment to optimize forecasting. Supplier collaboration will be gradually extended and fully digitalized from standard procurement tracking to distributed production, shared quality assurance, and additive manufacturing services, all scalable to changing business and partner needs. Machine learning, simulations and prescriptive methods will be applied over time to optimize complex business problems on the network level, considering constraints and capabilities from all participants. Manufacturing and aftermarket will eventually be transformed using blockchain and digital twins to capture and control product data across the lifecycle and securely connect multiple business partners.

Figure 2: Transformation of A&D Supply Chain to Enable More Trust and Collaboration
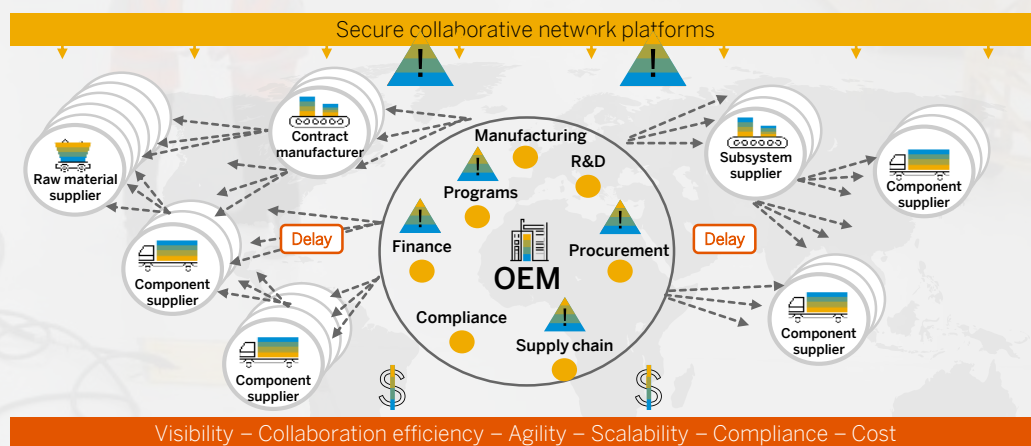
By 2020, **80%** of supply chain interactions will happen across cloud-based commerce networks, dramatically improving participants' resilience and reducing the impact of supply disruptions by up to 33%.[10]

96% of innovative discrete manufacturers say that the digital priority of digital supply networks is very important to them, compared to 70% of other manufacturers.[11]

Empowering All Business Partners to Operate Across One Supply Network

Following the Industry 4.0 strategy, the digital supply chain planning with embedded collaboration capabilities enables A&D companies to analyze and fine-tune planning and fulfillment holistically, empowering all business partners to operate on one consistent plan and easily exchange real-time information across the network. Companies gain much-needed agility to respond faster to real-life dynamics and disruptions, improving delivery performance and reducing supply chain cost. The combined integration of machines and engineering processes in Industry 4.0 will transform the production, where network performance analytics is highly automated, and decisions are based on data-driven intelligence and system-based solution proposals. Experience data enriches data analytics processes so companies can get insights on key performance drivers for supply chain processes and take action accordingly.

Reimagine Integrated Demand and Supply Planning.
With SAP solutions at their digital core and using solutions for strategic planning, supplier management, and collaboration, aerospace and defense companies can make the tactical and operational decisions to set the demand plan, capacity, and inventory targets and digitally integrate critical suppliers in this process.

TRADITIONAL SCENARIO

| Alignment between sales plan and capacity plan excluding inventory targets

Limited financial alignment with business plan | Inability to combine all forecast demands from sales, marketing, production, and after-sales, and to include experience data such as vendor sentiment | Limited capabilities to share forecasting plans with suppliers, and no digital visibility into availability of supply | Propagation of supply requirements through company's network, with limited consideration of business priorities and no connection to fulfillment planning | Late and inconsistent visibility of shipments and deliveries from suppliers, making it difficult to react to delays | Use of e-mails, phone calls, and spreadsheets to resolve issues when there is a supply disruption or a demand change to determine how to respond |

NEW-WORLD SCENARIO

| Create the optimal business plan to drive revenue growth and increase market share.

Align holistically to the business plan, including financials and inventory target setting, supported by internal collaboration. | Allow a consolidated demand plan across all streams, including spare-parts forecasts, customer options and preferences, and a long-term production plan. | Get a holistic overview with Industry 4.0 to analyze data across the network to fuel more collaborative planning and fulfillment, helping to manage bottlenecks and risks early. | Base finite planning on optimization or business priority rules, enabling more robust plans by considering internal and external capacities – both rough cut and detailed. | Share purchase order updates electronically with suppliers and receive confirmations in real time to increase transparency on critical exceptions for production planning. | Gain full visibility into demand and supply across the extended network to be able to simulate changes to plans, with root-cause analysis to understand and resolve issues. |

TOP VALUE DRIVERS

5%–7%
Reduction of total landed costs

8%–10%
Reduction of revenue loss due to stock-outs

10%–12%
Reduction of days in inventory

10%
Reduction of manufacturing cycle time

Source: SAP Performance Benchmarking

AGILE MANUFACTURING

A&D companies are faced with strategic challenges, including record production backlogs, global competition, an ongoing demand for lower unit cost, and next-generation workforce shortages.

Companies must become more agile, shorten time to market, and eliminate manufacturing inefficiencies. Historically, A&D manufacturing operated in a siloed fashion with inputs from product lifecycle management and ERP. Moving forward, A&D manufacturing must be absorbed into a common digital thread, responding in real time to driving forces in change management, workforce engagement, plant connectivity, and the extended supply chain. Any future vision must eliminate the data silo of the manufacturing execution system.
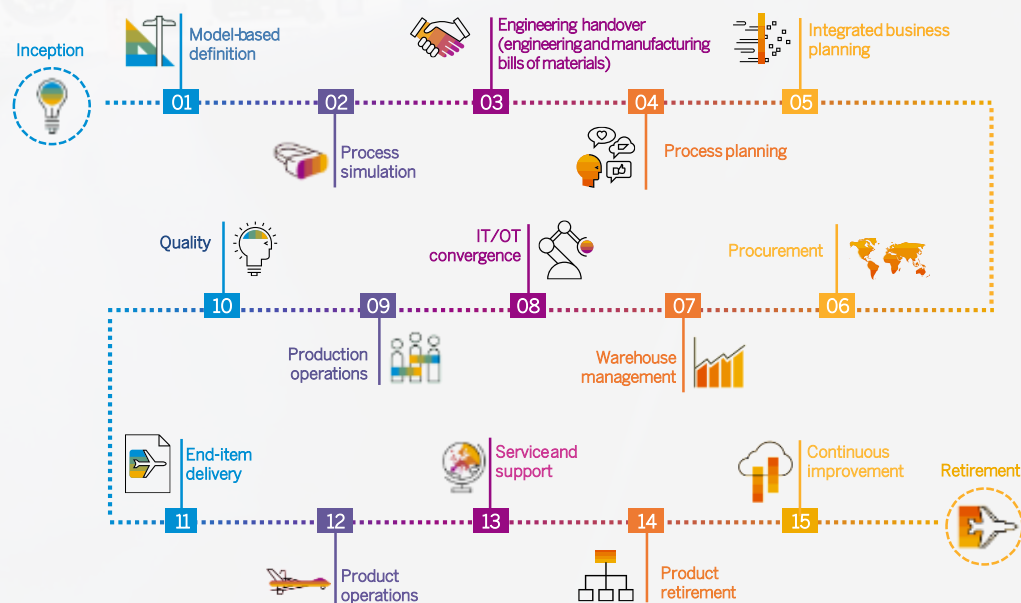
The Vision

In 2025 smart, connected factories with advanced automation and integrated shop-floor processes will deliver granular data for optimizing products and processes while improving compliance and employee satisfaction. Production and supply chain processes will have the flexibility to accelerate reactions to changes in demand, supply, and resources – driving optimization in virtual capacity and operational efficiency.

The Journey

A&D companies will start with an intelligent enterprise approach, where the manufacturing process is embodied with the digital thread to optimize simultaneous engineering and manufacturing. With the Industry 4.0 strategy, the software architecture behind the production equipment will see a shift from transactional production execution to data-driven business process execution and optimization while connecting all sensors, devices, and machines. Model-based definitions will be extended, enabling machine-to-machine communication and collaboration for information technology/operational technology (IT/OT) convergence strategies. Model-based simulation will be used for work instruction delivery and digital twin considerations. Transformation is recognized when production operations are a seamless extension of the extended supply chain, and the entire organization operates as an agile manufacturing center of excellence across all elements of the digital thread (see Figure 3). This will lead to new ways of interacting with customers and suppliers by focusing processes, tools, and training to enable rapid response to customer needs and market changes – while maintaining high quality and controlling the overall costs. Attention will be given to employee experience, motivation, and satisfaction to attract and retain next-generation workers.

Figure 3: The A&D End-to-End Digital Thread

- Inception
- 01 Model-based definition
- 02 Process simulation
- 03 Engineering handover (engineering and manufacturing bills of materials)
- 04 Process planning
- 05 Integrated business planning
- 06 Procurement
- 07 Warehouse management
- 08 IT/OT convergence
- 09 Production operations
- 10 Quality
- 11 End-item delivery
- 12 Product operations
- 13 Service and support
- 14 Product retirement
- 15 Continuous improvement
- Retirement

95% of innovative discrete manufacturers say that the digital priority of connected products is very important to them, compared to 67% of other manufacturers.[12]

"We want to achieve radical change. This kind of transformation cannot be done without strategic partners. So we are working with SAP to accelerate our digital transformation."
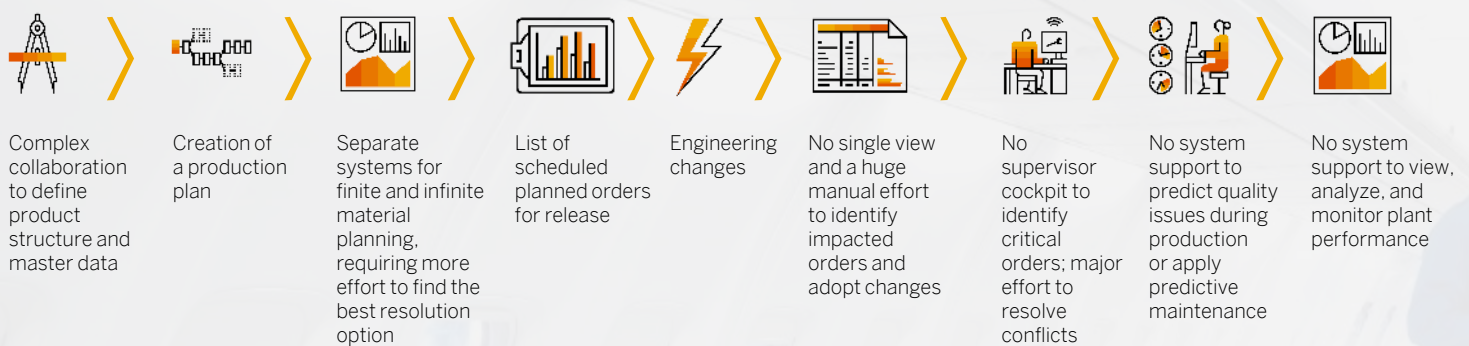Bharat Amin, Vice President and CIO, Newport News Shipbuilding[13]

Optimizing Products and Processes and Improving Compliance

Smart, connected factories with advanced automation and integration of shop-floor processes deliver granular data for optimizing products and processes and improving compliance and customer satisfaction. Production and supply chain processes gain flexibility and accelerate reactions to changes in demand, supply, and resources, driving optimization in virtual capacity and operational efficiency.
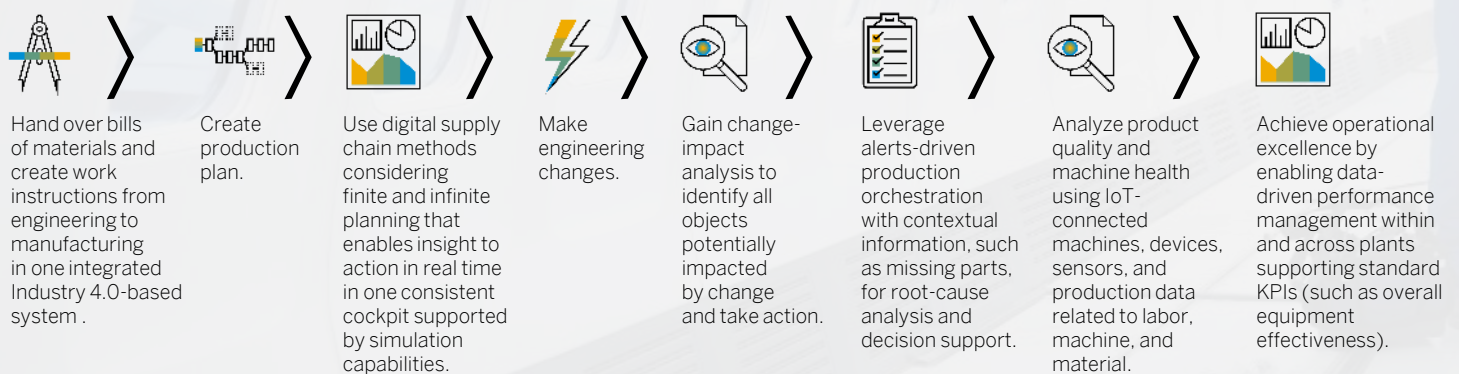
Reimagine Engineering-Driven Production

The digital core and digital manufacturing solutions from SAP enable aerospace and defense companies to bridge the gap between engineering and manufacturing by providing a single source of truth for manufacturing master data. They can react faster to engineering changes and manage and control manufacturing and shop-floor operations to realize Industry 4.0.

TRADITIONAL SCENARIO

| Complex collaboration to define product structure and master data | Creation of a production plan | Separate systems for finite and infinite material planning, requiring more effort to find the best resolution option | List of scheduled planned orders for release | Engineering changes | No single view and a huge manual effort to identify impacted orders and adopt changes | No supervisor cockpit to identify critical orders; major effort to resolve conflicts | No system support to predict quality issues during production or apply predictive maintenance | No system support to view, analyze, and monitor plant performance |

NEW-WORLD SCENARIO

| Hand over bills of materials and create work instructions from engineering to manufacturing in one integrated Industry 4.0-based system . | Create production plan. | Use digital supply chain methods considering finite and infinite planning that enables insight to action in real time in one consistent cockpit supported by simulation capabilities. | Make engineering changes. | Gain change-impact analysis to identify all objects potentially impacted by change and take action. | Leverage alerts-driven production orchestration with contextual information, such as missing parts, for root-cause analysis and decision support. | Analyze product quality and machine health using IoT-connected machines, devices, sensors, and production data related to labor, machine, and material. | Achieve operational excellence by enabling data-driven performance management within and across plants supporting standard KPIs (such as overall equipment effectiveness). |

TOP VALUE DRIVERS

15%
Increase in market agility and responsiveness

10%
Reduction of change management costs

10%–20%
Increase in on-time delivery

Up to **10%**
Reduction of total manufacturing costs

Source: SAP Performance Benchmarking

NEW BUSINESS MODELS

Harnessing massive amounts of IoT data across the product lifecycle, managing Big Data economically, hosting digital services, and analyzing customer experience data. Each of these activities allows OEMs to diversify their portfolio.

They offer opportunities for OEMs to create new revenue streams and business models with "information as a product," using data collected and consolidated from different systems and exchanged on digital commerce platforms. Examples include increasing revenue from aftermarket engineering, providing health monitoring services for assets, or selling digital services directly to consumers.

The Vision

In 2025 A&D revenue streams will come from services that are based on and built around smart products, the value they deliver to customers, and the data they create (see Figure 4). A&D businesses will use data as a product, especially for new after-sales services and highly customized products and operations.

Their revenue will come from four sources:
- Data as a service – Integrate, orchestrate, process, and sell all kinds of data
- Mobility as a service – Shift from selling an aircraft to a mobility service; for example, per landing or per seat
- Digital products as a service – Sell digital products directly to consumers by leveraging massive amounts of data

- Outcome-based services – Retrieve outcome data from connected customer assets to help ensure the highest level of asset availability, and make this data available for billing and contract performance

The Journey

A&D companies will start toward this goal by running more profitable performance-based contracts – using IoT data and intelligent technologies, for example, to extend contract analytics to enable more effective analysis of granular performance data and costs drivers. As they continue to collect increasing amounts of data from their own business operations and from the use of their assets by fleet customers, they will be able to offer new digital services through an IoT platform. That further enables monetization of the data by deriving insights of value for customers and partners. The data collection and analysis process is then extended to experience data. This leads to the final step on the transformation journey of A&D companies: they have a better understanding of consumer needs, which allows them to expand their business by providing new mobility-as-a-service infrastructures.

Figure 4: New Business Models That Increase Manufacturers' Share of Asset Lifecycle Spend
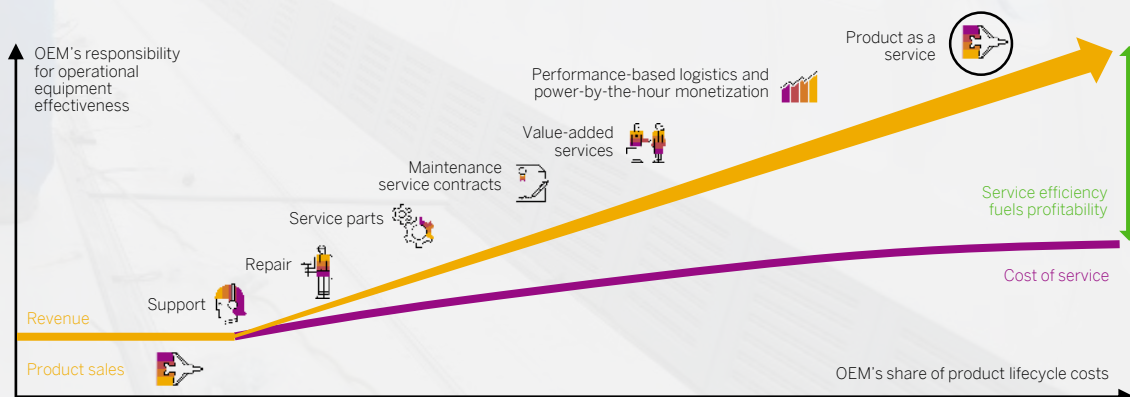
Digital leaders are **46%** more likely than all other companies to be investing in the Internet of Things.[14]

Sensors that are combined with IoT solutions from SAP and SAP HANA allow Trenitalia to provide its customers with a more efficient and reliable service and save up to **10%** in maintenance costs.[15]

Generating New Revenue Streams By Delivering Business Outcomes

New business models are disrupting traditional business models, creating new markets, and generating new revenue streams by delivering outcomes. They use data as a product, for example, for new after-sales services.

Reimagine Profitable, Performance-Based Contracting

Performance-based logistics or power-by-the-hour concepts focus on delivering performance outcomes as defined by performance metrics. To effectively and profitably manage these performance-based contracts, OEMs and service providers require new capabilities impacting product lifecycle management, data management and services across sources and systems, collaboration with the entire ecosystem, real-time contract management, and data-driven analytics. The implementation of Industry 4.0, where all sensors, devices, machines, and other equipment are connected in one single network, will provide an unprecedented amount of insight about the used parts that eventually is going to reveal new business opportunities, such as predictive maintenance, which further improves the experience around the product.

TRADITIONAL SCENARIO

- No real-time holistic view of asset performance
- Limited opportunities to optimize mainte-nance cost, risk, and performance and act more proactively
- Risk of failure with the customer

Maintenance contracts with service-level agreements

Time-based inspection planning › Inspection › Maintenance › Invoicing

Unplanned maintenance › Maintenance › Invoicing

NEW-WORLD SCENARIO

- Dynamic maintenance management across all resources
- Contract analytics to analyze granular performance and costs and more effectively manage performance contracts
- Monitoring, scoring, and prediction of asset health based on machine learning algorithms
- Optimizing return on assets across lifecycles by monitoring, reviewing, and improving maintenance activities

Performance-based contracts › Maintenance strategies based on anomaly detection, predictive forecasting, and optimization of maintenance strategies › Connecting multiple data sources for one unified view of financial and asset performance with what-if simulations and root-cause analysis

TOP VALUE DRIVERS

3%–10%

Improvement of service profit margin

Increase of return on assets and optimized asset performance

Increase of asset performance and reduction in maintenance cycle times

Source: SAP Performance Benchmarking

KEY
TECHNOLOGIES

The current pace of technological advancements has the most profound impact on enabling how A&D manufacturers transform themselves to respond to their customers' needs and to market trends.

Intelligent technologies promise to bring great benefits such as productivity and efficiency gains, enabling innovative new business models and new revenue streams. The following intelligent technologies are instrumental in helping A&D companies respond to market trends.

Artificial Intelligence and Machine Learning
Machine learning enables algorithms to "learn" from existing data and achieve the best-possible outcomes without being explicitly programmed. Once the algorithm is trained, it can then predict future outcomes based on new data. Businesses can use these capabilities to predict inventory shortages, for example, to help reduce supply chain risks or identify risk areas for projects with limits on cost and time. Voice interfaces, as part of conversational AI, will be the go-to technology for the next generation of applications, allowing for greater simplicity, mobility, and efficiency while increasing worker productivity and reducing the need for training. With artificial intelligence and machine learning, aerospace companies will operate as an integrated system in a fashion similar to a fly-by-wire airplane on autopilot – efficiently, safely, and constantly adapting to the situation.

The Internet of Things and Industry 4.0
Collecting data in scale along the value chain by connecting to objects or machines to optimize or automate decision preparation is the job of the Internet of Things (IoT). New open standards bring IoT sensors into a person's decision process, making the idea of "instrumentation everywhere" a reality. IoT

dovetails with Big Data and machine learning to make effective use of the huge volume of IoT data. Although aerospace manufacturers have been using IoT for some time, now the entire value chain can be connected – from development to production to supply chain to operation, enabling faster, more flexible, and more efficient processes to produce higher-quality individualized goods at reduced cost. Data-driven insights allow simulation of any decision along the value chain. This transformation will improve resource productivity and efficiency, drive agility, responsiveness, and speed to market, and enable customization to meet customer needs. Additionally, remote condition monitoring of assets provides real-time data from machines to predict maintenance needs and identify potential quality problems in manufacturing processes before they occur. Assets can be jointly managed as digital twins by manufacturers, customers, and partners, thereby improving asset data and modeling.

Advanced Analytics
Advanced analytics is the combination of different data sources, being able to simulate situations, use different tools to visualize, and create actions out of insights. The integration of capabilities – including situational awareness – into applications enables business users to analyze data on the fly and drives better decision-making from the shop floor to the top floor. Empowered users can get real-time visibility into their operations, customer feedback, and changing environment; simulate the impact of business decisions; mitigate risk; and achieve better outcomes.

Blockchain

is necessary to establish the trusted sharing of data between different partners. Through a digital ledger, the information is distributed to all participants with clear tracking for any updates. This digitalization allows visibility and data transparency to reduce overall processing time, for example, within the supply chain.

Virtual and Augmented Reality

Virtual reality (VR), the use of digital technology to create immersive simulations, was once the stuff of science fiction. So was augmented reality (AR), which lets users interact with digital content that's overlaid on the real world. Commercial aviation maintenance, repair, and overhaul (MRO) exploits AR to speed training, thereby addressing the skills shortage. Fully immersive AR headsets let skilled engineers provide expert remote support without leaving their facility.

Robotic Process Automation

Robotic process automation (RPA) is transforming the way tasks are handled across many industries. RPA automates processes that are manual and spans multiple business transactions or systems. This allows automation and increases data quality. RPA allows software robots to mimic actions that human workers in aircraft maintenance and engineering and MRO would normally perform. However, robots are able to perform faster and without the potential for human error. As such, RPA has a huge potential in supporting, for example, airline airworthiness management and maintenance departments by freeing up their staff to focus on the things that really matter rather than performing boring and repetitive tasks.

Data Platform to Manage Experience

In the digital economy, the cycle time to sense, analyze, and respond is a big competitive differentiator. We will see a data explosion as more data is captured and created along the value chain. Transfer of data to data lakes creates a time delay and potential for manipulated data. Complete visibility of data and sources of data is necessary to support real-time operations. Leaders are connecting operational data from companies' business systems (what is happening) with the experience data coming from customers, products, and employees (why it is happening) to get 360-degree views and actionable insights, and to deliver better experiences.

Predictive analytics
70%

Of A&D companies see real-time aircraft health-status monitoring and predictive intervention analysis being essential in the future[16]

Blockchain
~30%

Of manufacturers will use blockchain networks in production[17]

3D printing
25%

Compound annual growth rate is expected in the aerospace 3D printing market by 2023[18]

Augmented reality
75%

Of manufacturers will provide their service teams with access to searchable video content through mobility and wearables by 2021[19]
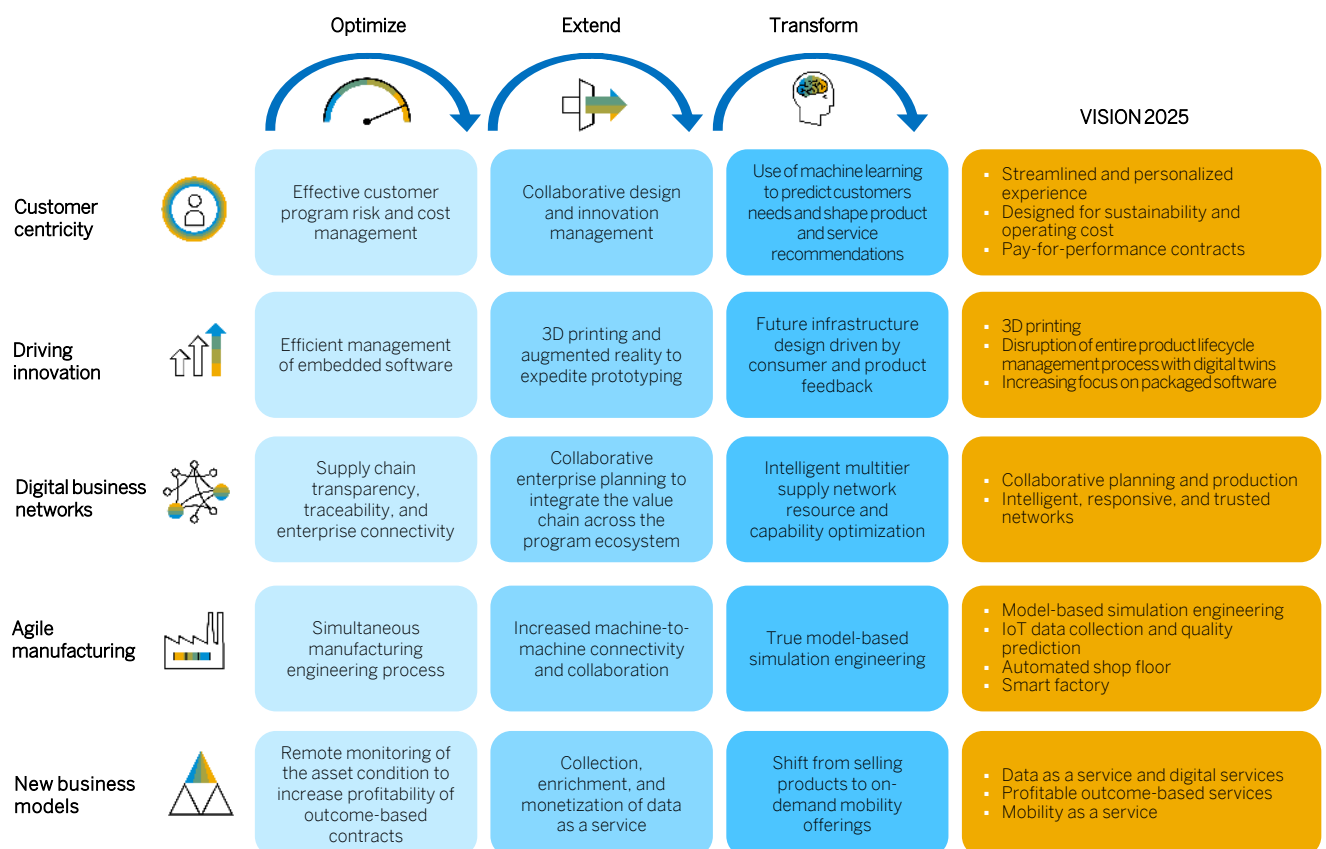
Industry 4.0
68%

Of discrete manufacturers consider Industry 4.0 as a top priority[20]

GETTING THERE:
A PHASED APPROACH

Companies will become intelligent enterprises on three distinct tracks as they evolve their strategic priorities to match their company's vision. They will:

- **Optimize** what they already do by implementing a stable and scalable digital core to make processes more transparent and integrated

- **Extend** their current processes by connecting them to the real world using IoT technologies

- **Transform** their business using a constant stream of data enabling new service-driven business models (see Figure 5)

Figure 5: **Strategic Priorities Across the Maturity Framework**

	Optimize	Extend	Transform	VISION 2025
Customer centricity	Effective customer program risk and cost management	Collaborative design and innovation management	Use of machine learning to predict customers needs and shape product and service recommendations	• Streamlined and personalized experience • Designed for sustainability and operating cost • Pay-for-performance contracts
Driving innovation	Efficient management of embedded software	3D printing and augmented reality to expedite prototyping	Future infrastructure design driven by consumer and product feedback	• 3D printing • Disruption of entire product lifecycle management process with digital twins • Increasing focus on packaged software
Digital business networks	Supply chain transparency, traceability, and enterprise connectivity	Collaborative enterprise planning to integrate the value chain across the program ecosystem	Intelligent multitier supply network resource and capability optimization	• Collaborative planning and production • Intelligent, responsive, and trusted networks
Agile manufacturing	Simultaneous manufacturing engineering process	Increased machine-to-machine connectivity and collaboration	True model-based simulation engineering	• Model-based simulation engineering • IoT data collection and quality prediction • Automated shop floor • Smart factory
New business models	Remote monitoring of the asset condition to increase profitability of outcome-based contracts	Collection, enrichment, and monetization of data as a service	Shift from selling products to on-demand mobility offerings	• Data as a service and digital services • Profitable outcome-based services • Mobility as a service

EARLY DIGITAL ADOPTERS
LEAD THE WAY

How do you achieve these strategic priorities?

Start with reimagining your business together with your customers. Then build a path for even more optimization and intelligent automation to simplify your business and free up resources to invest in even more digital transformation programs and find new business models and revenue streams.

According to a July 2018 study by Forrester Consulting that was commissioned by SAP, innovative companies focus on digital priorities to help them achieve digital transformation more than other manufacturing companies. (See Figure 6.)

Figure 6: Innovators Focus More on Digital Priorities than Others[21]

		Innovators	Others
Smart factories		97%	63%
New business models and networks		97%	76%
Digital supply networks		96%	70%
Connected products		95%	67%
Customer experience		92%	70%

SAP'S FRAMEWORK FOR THE
INTELLIGENT ENTERPRISE

Most organizations understand what is happening in their business but may not always know why.

They know what's happening because they have systems that capture operational data (O-data) – about their customer transactions, supply chain, manufacturing, spending, and the activities of their workforce. They can see that data through reports and dashboards. They can see trends and predict what will happen next.

But to influence what happens next, companies need data about the interactions that people have with their products and their business. Experience data (X-data) captures beliefs, emotions, opinions, and perceptions – the "why" something is happening. And when companies know why something is happening, they can make an informed decision about the best way to respond.

To win in this experience economy, intelligent enterprises connect experiences with operations. They use both experience and operational data to guide their business decisions. Intelligent enterprises collect insights from customers, employees, products, and brands at every touch point. They use powerful technologies to automate and integrate their data, processes, and applications, enabling them to sense risks, trends, and opportunities. And they act on this intelligence across every part of their business. (See Figure 7.)

Only SAP has the strategy, expertise, and solutions to deliver on this vision, enabling intelligent enterprises to turn insight into action.

Figure 7: SAP® Intelligent Enterprise Framework

HOW TO PLAN YOUR PATH TO THE
INTELLIGENTENTERPRISE

In the digital economy, intelligent technologies and integrated business processes are now driving digital transformation.

To do this effectively requires an end-to-end plan for becoming an intelligent enterprise. This includes creating an intelligent enterprise road map and implementation plan with proven best practices and deployment options that optimize for continuous innovation with a focus on intelligent outcomes.

The End-to-End Journey to Becoming an Intelligent Enterprise

Plan
well to manage expectations

Simplify and innovate
- Reimagined business models, business processes, and work
- SAP Intelligent Enterprise Framework methodology as a guide for digital transformation
- Value-based innovation road maps

Build and launch
with proven best practices

Standardize and innovate
- Model-company approach to accelerate adoption with model-industry solutions
- Design thinking and rapid, tangible prototypes
- Coengineered industry innovations delivered with agility

Run
all deployment models

Run with one global support
- One global, consistent experience
- End-to-end support – on premise, in the cloud, or with a hybrid approach

Optimize
for continuous innovation

Optimize to realize value
Continuously captured and realized benefits of digital transformation

To move forward with speed and agility, it helps to focus on live digital data and combine solution know-how and industry-specific process expertise with data analytics so that the right digital reference architecture is defined and delivered. In that context, a model-company approach is aimed at simplifying and increasing the speed of the digital transformation journey. Model companies represent the ideal form of standardization for a specific line of business or industry. They are built on preconfigured SAP solutions based on best practices supported by SAP, along with the business content that encompasses our experience and expertise relevant for the industry. They provide a comprehensive baseline and come with the accelerators to jump-start digital transformation projects.

COMPREHENSIVE SAP ECOSYSTEM: ORCHESTRATING THE PARTNER ECOSYSTEM TO DELIVER VALUE FASTER

Our comprehensive ecosystem for aerospace and defense industry offers:

- The Intelligent Enterprise as the overarching strategy to meet future requirements, providing:

  - SAP S/4HANA co-development programs for customers and partners

  - Industry co-innovation programs for industry-specific use cases

  - Delivery of enterprise-to-enterprise industry clouds

  - Thought leadership, evangelism, and enablement by industry through events, councils, and regular customer exchange

- Integration into a wide range of business services (OEMs, suppliers, key vendors, and more)

- Open architecture, with a choice of hardware and software specifically designed to meet requirements

- Complementary and innovative third-party solutions to provide leading-edge and state-of-the-art technology

SAP is the founding member of the Open Industry 4.0 Alliance, which aims to overcome proprietary isolated solutions with a common reference architecture to accelerate the implementation of Industry 4.0 solutions and services.

Our partner ecosystem includes, among others:

accenture · BLACKLINE · Capgemini · celonis · CREATECH · dassian

delaware · Deloitte. · DIGITAL PROSPECTORS · DocuSign · DXC.technology · EY

HCL · IBM · Infosys · itelligence NTT DATA Business Solutions · KRONOS · LeverX

mx mendix · Microsoft Azure · NS2 · NTT DATA Trusted Global Innovator · OPEN INDUSTRY 4.0 ALLIANCE · OPENTEXT

OrgaTech · pwc · REDWOOD · Scheer · software AG GOVERNMENT SOLUTIONS · Syniti BackOffice ASSOCIATES

TATA · TWENTY5 BETTER BUSINESS INSIGHTS · warp IT · wipro · workforce SOFTWARE

SAP IS COMMITTED
TO INNOVATION

10-Year Innovation Vision

SAP delivers fully intelligent business solutions and networks that span across company boundaries and promote purpose-driven businesses. These solutions will be the most empathic symbiosis between machine intelligence and human ingenuity.

- Self-running enterprise systems
- Self-organizing business ecosystems
- New markets and business models

Comprehensive Industry Coverage

SAP enables comprehensive coverage of the complete A&D value chain across the enterprise. With its clear industry road map, SAP is the partner of choice for the A&D industry.

- More than 1,400 A&D companies in over 50 countries innovate with SAP solutions
- 9 of the world's top 10 most admired A&D companies (Forbes 2000 ranking) are members of the SAP Advisory Council for A&D
- All lines of business are supported on a single platform

Proven Services Offering

By bringing together world-class innovators, industry and emerging technology expertise, proven use cases, and design thinking methods, we help A&D companies develop innovations that deliver impact at scale.

- Proven methodologies to drive innovation, from reimagining customer experiences to enhancing operations
- Innovation that is fueled through a managed innovation ecosystem from SAP
- Ability to build your own innovation capability and culture

SAP supports A&D companies in becoming intelligent enterprises – providing integrated business applications that use intelligent technologies and can be extended on SAP Cloud Platform to deliver breakthrough business value.

Learn more

- SAP.com for A&D
- SAP Services and Support

RESOURCES

Outlined below is external research that was used as supporting material for this paper.

1. "Emerging Opportunities to Deploy Industry Processes in the Cloud," Forrester Consulting on behalf of SAP, July 2018.

2. "SAP Digital Transformation Executive Study: 4 Ways Leaders Set Themselves Apart," SAP Center for Business Insight and Oxford Economics, 2017.

3. "A Vision of the Future of the Tech Industry," Electronics Weekly.com, January 24, 2018.

4. "Business Organizations' Reasons for Adopting Artificial Intelligence (AI) Worldwide, as of 2017," Statista, September 2017.

5. "Capturing Value at Scale in Discrete Manufacturing with Industry 4.0," McKinsey & Company, September 2019.

6. "IDC FutureScape: Worldwide Customer Experience 2019 Predictions," IDC, Doc. #US43484818, December 2018.

7. JetBlue Airways Customer Story, Qualtrics Web site.

8., 9. "Technology in Aerospace and Defense," Aviation Week Network, Sponsored by SAP, 2017

10. "IDC FutureScape: Worldwide Manufacturing 2018 Predictions," IDC, Doc. #US42126117, October 2017.

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13. "Newport News Shipbuilding," SAP customer reference video.

14. "4 Ways Leaders Set Themselves Apart," SAP Center for Business Insight and Oxford Economics, 2017.

15. "SAP and Trenitalia: All Aboard the IoT Express," SAP TV, October 2016.

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17. "IDC FutureScape: Worldwide IT Industry 2018 Predictions," IDC, Doc. #US43171317, October 2017.

18. "3D Printing in Aerospace and Defense Market - Growth, Trends, and Forecast (2020 - 2025)," Research and Markets, 2020.

19. "IDC FutureScape: Worldwide Manufacturing Product and Service Innovation 2019 Predictions," IDC, Doc. #US43135918, October 2018.

20. "Capturing Value at Scale in Discrete Manufacturing with Industry 4.0," McKinsey & Company, September 2019.

21. "Emerging Opportunities to Deploy Industry Processes in the Cloud," Forrester Consulting on behalf of SAP, July 2018.

Note: All sources cited as "SAP" or "SAP Performance Benchmarking" are based on our research with customers through our benchmarking program and other direct interactions with customers.

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