

BUILDING RESILIENCE IN AEROSPACE AND DEFENSE

Designing flexible supply chains and responsive
manufacturing for a more volatile world



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BECOMING MORE RESILIENT IN A MORE CHALLENGING WORLD

Aerospace and defense are industries under pressure

In the next 20 years, forecasts suggest a need for over 39,000 new passenger and freighter aircraft, with around 15,000 being replacements for older, less fuel-efficient models. As they rush to meet these demands, the drive for sustainability is changing the very nature of plane designs (and perhaps, aviation business models).

Defense had been reducing spend for years and discontinued many products, but must now restock and reinvent, as new threats arise and its support for Ukraine depletes supplies. Defense must become more dynamic, so that militaries are ready to meet more operational challenges – yet some military plane manufacturers currently quote 80-month lead times from order to fulfilment!

There are two immediate challenges for A&D companies to address: the first is scale up, the second is the reconfiguration towards sovereignty and resilience. Reducing dependences

on less friendly states is now a matter of growing importance - giving rise to 'onshoring' (bringing sourcing and manufacturing back to the country) and 'friendshoring' (bringing these back to allied countries).

The space domain is continuing its rapid growth also, with a growing number of space-based services and satellite launches - as the industry moves from individual satellite launches to satellite constellations. Like with other industries, space is scaling to a more efficient mass production model, which has implications for standardization and industrial organization. This will be important, as the demand for satellites continues to grow.

In this demanding, rapidly changing world, aerospace and defense companies must become more adaptive and resilient.

That will mean changes to their manufacturing and supply chains.

Manufacturing facilities built around churning out single product lines must become more adaptive, switching as changing demands filter through into new designs. Many will need to become much more efficient.

To deliver more flexible manufacturing, the massive global supply chains on which manufacturing relies must become more adaptive and more resilient. Supply chains are complicated, vulnerable to shocks, and hard to redirect. Yet, they face ever greater risks from material bottlenecks, geopolitics, war, inflation affecting supplier solvency, and disruptive events (from pandemics to boats getting stuck in the Suez Canal). The majority of products in aerospace and defense come from the external supply chain – this represents a big risk to ability to deliver products over the coming decade.

HOW TO RESPOND: RESILIENT SUPPLY CHAINS AND FLEXIBLE MANUFACTURING

To face the challenges of scaling and diversifying production, meet the need for a more distributed supply chains and industrial systems, and overcome geographical constraints (ie. achieving DAMASA: “design anywhere, manufacture anywhere, supply anywhere”) - two things must change.

The first is for supply chains to become more resilient, and the second is for manufacturing to become more flexible. We will look at each in turn.





BUILD RESILIENT SUPPLY CHAINS

Supply chain management is a complex business, and A&D supply chains are especially tricky due to the sheer complexity of the large products they produce. Airbus states that [it has approximately 8,000 direct and 18,000 indirect suppliers](#).

This is an increasingly fragile ecosystem, subject to global shocks. For example, a large amount of titanium, a rare material which is essential in aircraft manufacture, is sourced from Russia, and a significant amount of the world's neon, which is essential in semiconductor fabrication, comes from Ukraine. Both supplies seemed fairly assured just a few years ago. This growing demand for raw materials, both within A&D, and other industries, has created something of a power struggle. For example, the April 2023 acquisition

of Aubert & Duval by Airbus and Safran, in order to secure preferential access to essential raw materials.

And suppliers themselves aren't always able to withstand shocks – many went under during the pandemic when orders stopped, leaving some buyers surprised when things reopened that they could no longer buy what they needed. The current high inflation impacts borrowing, which may make suppliers less able to pay back loans or borrow to cope with short term cashflow issues.

The most efficient and capable industrial processes are useless without the necessary inputs. A&D therefore need to build the processes to make these supply chains resilient, to ensure they have the supplies they need, when they need them. To do so, they should consider the following.

Improve the resilience of your existing suppliers

The industry has a long tail of small but important suppliers, which are at risk in the face of shocks. Many have tight cashflow and could go under if they face major disruption. Sadly, you can't save them all, but you can understand the risks and react accordingly.

This requires a realistic crisis management strategy. Understanding where you have problems means doing the hard work of visiting suppliers. This may be part of a continuous auditing process, part of onboarding, or a specific intervention following a shock. For example, after the pandemic reopening, we found ourselves working with a client to audit their entire 200 company supply chain in just a couple of weeks, to assess readiness to scale.

Either way, it means sending experts to suppliers' sites to understand their situation, and gather info. These must be people who can spot problems or risks that would not show up in a call or data analysis, such as lower than reported stock, incorrect storage, lack of skills, crumbling machinery, or workers who have not been paid.

Having understood the problems and risks, you can identify a remediation or recovery plan. That may include upgrades, training, new processes, data collection and

reporting. It may mean agreeing shorter payment terms to ensure they can pay their own suppliers - increased resilience usually comes at a cost. You must also ensure your supplier implements it, using an appropriate mix of carrots (committed orders, investment) and sticks (threats to take business elsewhere).

Some risks lead to problems that are highly specific. A broken machine will delay orders. If the supplier is slow to act, the solution may literally be to send your auditor back to oversee the ordering of replacement parts and repair.

Other risks may be more structural. If suppliers are becoming reluctant to sell you aluminium – eg. because of a slowdown in global supply – you may need a change your approach, such as moving your commitment from six months to five years, or bidding higher to secure priority, or adding new suppliers, taking into account, of course, the long lead times and processes required to qualify new sources. That requires a careful analysis of your needs. If you make a commitment and the supplier goes bust, or you change to a non-aluminium design, you lose out. But if you do nothing, you may not have the materials to make your product.

Responses will be specific to the situation, but these can only be made if you have oversight of the problem.



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Strengthen key relationships

Another risk is that key suppliers don't want to work with you anymore. This may be because they have a higher bidder or longer-term commitment elsewhere. For aluminum and batteries, for example, aerospace competes with automotive, which has higher production volumes and can tempt suppliers with higher volume orders.

Furthermore, suppliers with a choice may be put off working with aerospace and defense because of the complexity of regulations, the reputational risk (for example, if a plane using their product goes wrong mid-flight) or because they see these industries as murky or, in defense's case, controversial.

Aerospace and defense should recognise and plan for this. There are no easy solutions. For immediate needs, they may consider long-term commitments to suppliers in the hope of jumping the queue. Though this comes with its own risks: if a better alternative comes along or demand for planes drops, they may be left with a large supply of material or components that they can't use.

Whilst most suppliers will put money first, long-term trusted relationships count for a lot, and decrease the risk of them abandoning you for a shiny new customer. Build trust by regularly engaging with suppliers through effective communication and collaboration - regularly share information, updates, and forecasts in order to join up your efforts and further engender trust. Support them, where possible, to become more efficient and secure. This may include sharing improved processes and systems, and providing training for your suppliers to make use of them. Building loyalty may encourage suppliers to prioritize you in challenging times.



Diversify your supply chain for resilience

In a world where problems constantly arise, you need supply chain flexibility. That may mean being global and local - building suppliers in new parts of the world, including a mix of reshoring and near shoring.

Expect new challenges. You may, for example, need to accept pricier, lower volume suppliers setup close to home, where there is a need to be more responsive to changes and bottlenecks, or where parts may be needed at short notice, with lower cost suppliers further away for longer term bulk orders. Meanwhile, you may need to pivot away from some countries you have previously relied upon. We have seen this recently with many companies that used to do business in Russia.



Build suppliers in new parts of the world, including a mix of reshoring and near shoring.

Get ready for new suppliers who do not know your industry and improve your onboarding

A&D will need to onboard new suppliers over the coming years, in areas from batteries and hydrogen to chips and software. They will also need to replace old ones - even with the best laid plans, suppliers fail. These new suppliers will have multiple customers and may not be set up to serve A&D. They will need some handholding.

Companies will need to identify those with the technical capabilities to deliver, then work closely to explain the specific rules and constraints of aerospace and defense – the design, the tests it must undergo, and the data needed to get regulator approval. A&D companies will need to take time to provide the suppliers with all the information and advice they need to do a good job – including specifications, measurement approaches, tolerances, data standards and so on.

A good model is the Advanced Product Quality Planning (APQP) framework, a set of processes widely used in automotive for designing and communicating specifications to all stakeholders. Capgemini is sufficiently impressed by this approach that we have developed a set of methodologies built on it to support aerospace customers with onboarding and managing suppliers.

This must all be kept as simple as possible. A&D are complex and highly regulated. This is often reflected in the procurement experience - which can be slow and arduous for suppliers. Obviously, this is not what you want when trying to attract (and onboard) new partners who are used to working with far less 'red tape'. Thought should be given to your suppliers' 'user experience' whilst, of course, ensuring your technical and safety criteria are met.

A&D could benefit from standardizing the processes it uses for onboarding and integrating suppliers at an industry level. The wind turbine industry has APQP4Wind - which was first published in 2017, and "aims to revolutionize the global wind industry supply chain, by promoting quality assurance and collaboration between the wind customer and supplier".

Have good systems to manage everyday problems

Supply chains are complicated and even reliable suppliers get things wrong. A key part of supplier resilience is having quick and efficient processes for resolving day-to-day problems, which can create bottlenecks and quickly add up to a large costs of business. Issues like rejecting defective goods.

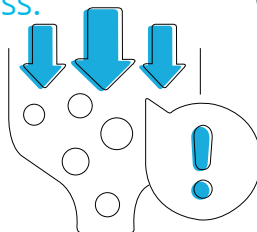
Intricate processes (like high rate flow lines and just in time manufacturing) require a highly reactive organization, with clear procedures for whenever a failure occurs. This may entail a dedicated team that can respond immediately to quickly solve the problem, or escalate it if not - shortening the time from problem to solution.

Often companies handle this at a local level, but a central team with a dedicated company-wide platform is usually more efficient. When there is an issue at any level, it is flagged in the system, and resolved by dedicated experts. This may include processing the issue, reordering, resolving payments, and closing it. This also allows centralized data to be gathered, so recurring issues can be detected, and solutions shared globally.

The key to getting this right is having people with technical knowledge, change management skills, and the soft skills to get suppliers to listen and act. This requires a combination of approaches - a central team managing the global relationship, and networks of local experts with ease of access to supplier premises. This, for example, is especially important for defense suppliers, in which site access is often not granted to foreign nationals.



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Understand the nature of your supply chain

In an ideal environment, a resilient supply chain would provide visibility of stock levels and events, backed by AI that provides real-time optimization, the ideal solution to complex scheduling problems, and actionable information - for example, lead times, potential bottlenecks and demand forecasting. Indeed [Capgemini has insight on how to build such a system](#).

But such a system is only as good as the data going in. Individual supplier resilience data, gathered directly from supplier forms and from audits, is a vital source, as discussed above. This can be augmented by real-time data for improved inventory management, eg. RFID tracking tied to components, or IoT sensors.

That can then be fed into Business Intelligence (BI) tools, risk models and expert analysis to build up full situational awareness across the supply chain – a moderate risk at one supplier may be manageable, but if that risk is replicated across all suppliers of that product, that may be a red flag that needs addressing.

Being able to map or visualize all points of the supply chain in some degree of detail is essential, and will increase transparency. Ultimately, this digitization will help you work towards a high-fidelity, real time digital twin of the supply chain. A digital twin is a virtual model designed to accurately reflect a physical object or process. The twin itself is not the goal - but its capabilities are - such a twin (or a connected series of twins) could help to provide a situational awareness picture in which all important information about your supply chain can be visualized, and planned for.

Better understanding means better outcomes; allowing you to better identify and closely monitor risky areas, and ultimately be in a position to respond to supply chain shocks.

As we cover in more detail in [How greater intelligence could supercharge supply chains](#), achieving organisational supply chain transformation will be multifaceted. It will entail changes in technology, governance, capabilities, extended ecosystems, collaboration, and economic models for organisations. It will also require data-sharing and collaborative platforms to break siloes and provide end-to-end visibility and traceability.

Build sustainability into your supply chain

Organizations are committing to greater sustainability of products and services as a central strategic imperative. However, such ambitions cannot be achieved without a strong focus on supply-chain sustainability - large aerospace companies rely on suppliers for up to 80% of the finished product.

In A&D, sustainability is a hugely important trend in its own right, but also contributes to resilience in a few ways. For example, climate-related disruptions (and their associated challenges, like conflict over resources or potential changes in migration patterns) may threaten regional security, and, by extension, parts of the supply chain.

There are also potential reputational risks in the context of a world that is working towards net zero emissions by 2050. This is particularly true in an industry like aerospace, which is seen as a polluter. Buyers (and society as a whole, including governments) are becoming more conscious of sustainability - and it will be increasingly important to demonstrate that steps are being taken across the business (including the supply chain) to reduce carbon emissions. Future legislation (eg. carbon taxation) may even punish companies with heavy tariffs that don't make these changes fast enough.

So, what can be done now?

The first thing to decarbonise A&D is to focus on supply chain - since lower carbon fuels like sustainable aviation fuel (SAF) and hydrogen are still some years away. To be truly green, aviation therefore needs to audit its supply chains emissions (known as upstream Scope 3 emissions), select sustainable suppliers, and support/incentivise suppliers to go greener.

Manufacturers must explain to their suppliers and procurement teams that sustainability is critical. The basis of this is proper emissions accounting. That is hard because there are lots of suppliers and they are a mixed group, from major global companies, to specialist SMEs with no knowledge of how to track emissions. Some may be three or four steps down the supply chain. And there is no industry agreed approach to emissions accounting, so even when suppliers are tracking emissions, there is no guarantee their approach will work for you.

The big picture need is for the industry to come together and agree what platform and standards they will use. An industry-led project in automotive, Catena-X, provides a good model for sharing data across a supply chain. Aerospace needs its own such initiatives.

Unlike tier 1 companies, smaller tier 3 or tier 4 suppliers may not yet have in-house resources to monitor and optimise their GHG emissions. So, shorter term, there is a need to do something that can help your ecosystem. Setting clear and reasonable rules for what suppliers should report, how they should report it, and providing a cloud-based platform for them to report into is a good start. Setting consistent policies for data collection and formats in your own organisation is also a wise move if it has not already been done. Removing suppliers is not preferable, for many reasons.

If suppliers are unable to meet your requirements, a variety of solutions could help, from software that can translate supplier data formats into your system's format, to deploying sensors at supplier sites, to workshops and training. If real-world data is not available, the International Aerospace Environmental Group (IAEG) has an easy-to-use Excel-based Scope 3 emissions calculator, which enables initial assessments.



CREATE FLEXIBLE SMART MANUFACTURING OPERATIONS

For decades, A&D manufacturing processes have been geared towards the production of single or small groups of products from centralized facilities, using fixed assembly lines and largely manual and labor-intensive processes. Their specialization has made it hard for such facilities to quickly adapt their product offering, or quickly scale in response to demand. One example of the limitations of this approach was noticed in 2020, when the Trump administration

invoked the Defense Production Act. Many A&D OEMs were now required to produce things (like ventilators) to aid in the American public health response to COVID-19, but not all of these OEMs were able to make the transition smoothly.

Smart manufacturing exploits new technologies – like AI, robotics, additive manufacturing, and the Industrial Internet of Things (IIoT) - to produce a greater diversity of products, more

quickly and more efficiently. In a world where demands change rapidly and multi-year lead times are not good enough, A&D will need to embrace these technologies to become more flexible and adaptive.

To do so, they should consider the following.

The share of organizations with a long-term roadmap for digital twins increased from

57%
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73%
now



Become a platform organization

We can think of the above as a move from a 'project organisation' to 'platform organisation'. Rather than setting up a facility to deliver a product line, we are setting up a platform that can be easily adapted, through changes to software and hardware, to deliver a wide range of products - bridging the physical and the virtual world, mutualizing resources, whilst driving design and operational efficiencies.

Such a platform can also connect up to other systems, such as engineering and supply chains, allowing engineers to run models of new designs on simulations of your real manufacturing environment and, once approved, quickly translate new designs into manufacturing setups and instructions, without having to move through silos.

Getting this right will need work creating consistent data and models that work across the organisations – between design and manufacturing and between plants – which will require data standardization, ontology definition and so on.

The value of maintaining a 'digital thread' of this platform data and 'digital twins' of its various components and products is well understood across OEMs, suppliers, operators and space companies. In fact, our latest Capgemini Research Institute report, [Mirroring reality: Digital twins in aerospace and defense](#), reveals the share of organizations with a long-term roadmap for digital twins increased from 57% eighteen months ago to 73% now.

Create a roadmap and define success

Such transformative endeavors are difficult and are unlikely to succeed without an informed plan of action. This doesn't necessarily mean starting afresh with a new greenfield site. Think of it instead as an incremental process of 'smartening' your existing capabilities, allowing you to do more with your existing infrastructure.

Clearly outline the objectives you want to achieve with smart manufacturing. Analyze the existing challenges and pain points in manufacturing and the supply chain that you wish to address. What are the risks (eg. cyber, political, skills shortage, legislative changes and sustainability) and how will you mitigate them? What will constitute a positive ROI? Audit your infrastructure - will you need to modify existing systems, or do you require new ones?

To become more responsive, new setups and facilities are inevitable. But misjudgments in their design can cause even more delays. This is why it's important to simulate new approaches first.

For example, dynamic flow simulation can be used to model how a factory setup will work, visualizing how parts will move through a production line, and allowing you to optimize setups. We worked with a company to model a new production facility, and model factory resources, machinery, and people flows to get a changeover cycle time between takt windows from 30 minutes down to the target of 15, by changing the rules and equipment used.

Iterate all of this in fast but manageable steps with stage gates to learn and adapt. If we've learned anything from the technology sector, it's to make 'small bets', and quickly learn from them. To this end, you could try 'dipping your feet' in a smart manufacturing proof of concept. For example, can you test a 'dark shift', where your factory runs overnight using automation, entirely without people present? Or can you trial a limited introduction on a line?

This way, inevitable mistakes can be made (and corresponding lessons learned) on a small scale - before being applied to the business as a whole.

Automate everything

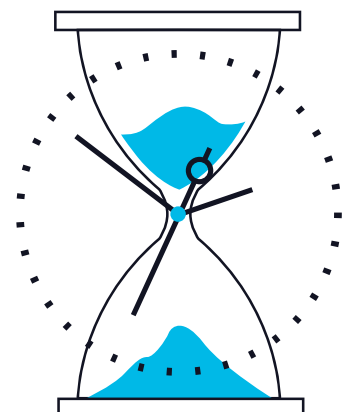
This may sound like a recommendation from ten years ago, but many shop floors still have lots of legacy manual technology. To increase production outputs and become more flexible, they must first automate as much as possible.

Evaluate the solution space. Which legacy manual systems will be easiest to automate, through replacement or the addition of connectivity?

Take the example of logistics. In a relatively simple intervention, Automated Guided Vehicles (AGVs) or more sophisticated Autonomous Mobile Robots (AMRs) could be used to automate the movement of goods and materials between lines or cells.



For example, can you test a 'dark shift', where your factory runs overnight using automation, entirely without people present?





Make production lines more flexible

In this context, 'flexibility' can be thought of as the ability to move from one product to another very quickly. A&D production lines are typically built around producing a single product. Yet, as demands change, factories can benefit from more flexible setups – for example, a sudden rush of orders for small planes and a drop off for large ones may leave some factories overburdened and others twiddling their thumbs.

Being able to efficiently produce a diversity of products requires manufacturing flexibility. This can be aided by late diversification. This describes a production method in which products are customized to match the customer configuration

at the latest point in the industrial process - which can simplify production, decreasing the number of specialized parts, and the need for sub-assemblies.

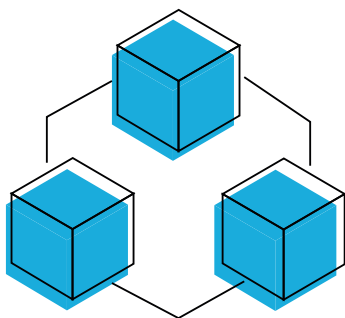
Smarter setups can help. For example, the use of AI tools that can anticipate, using analytics, to avoid blockages of production lines. Flexible production techniques such as robotics and 3D printing can be adjusted on the fly with software. A digital twin of a production setup can then be mapped from one factory to the next, to change what is being made.

Doing this means investing in production systems capable of being adaptive, connecting them up, 'softwarizing' them (ie. creating digital versions on the network that can be controlled through digital interfaces) and designing a network that connects

them all intuitively, so that whole new setup can be easily programmed.

Be sure to consider system integration when investing in new systems for your lines - are there open standards that will ensure 'out of the box' compatibility as you introduce new capabilities - or will further work be required? Assess whether you have in house skills to do this, and, if not, identify new employees or partners (like a system integrator) who can deliver it.

By designing products that can be initially produced as modules, then assembled in the final stages, you increase the work that can be done outside of final assembly lines



Redesign modular products for flexible manufacturing

Where possible, design your products to be produced from a diverse range of parts, materials, and locations.

Modularity and interoperability aren't just buzzwords, they're ways to build in flexibility. By designing products that can be initially produced as modules, then assembled in the final stages, you increase the work that can be done outside of final assembly lines, building in much more flexibility to your process. A number of major aerospace companies have already embraced this approach, redesigning their industrial processes around the major component assembly (MCA) concept - in which major components, like the fuselage and wings, come from suppliers mostly preassembled - making the manufacturer's job easier and faster when completing the final product.

Thought should also be given to the 'design to manufacture' approach - a concept that breaks the siloes between engineering and manufacturing, merging process and product design.

The benefit of this approach is that the design process doesn't just optimize the platform, but also the production of the platform - ensuring that manufacturing a new system is as efficient and requires as little retooling as possible. Put another way, avoiding the scenario in which a company designs a sophisticated product that is too sophisticated to produce effectively.

Prepare to share

Sharing data with other business is not a default behaviour for A&D actors. There are very real concerns about customer privacy and IP. However, if done correctly, companies can share and collaborate to help build a more resilient A&D manufacturing and supply chain environment.

Where possible, embrace cloud-based digital engineering platforms for better communication of needs, specifications and relevant data (eg. forecasts or demand information) to suppliers. There are some existing examples that may be worth looking at - for example, the UK MOD's [Engineering Delivery Partner](#) - a route for procuring engineering services for various MOD departments and agencies.

Use the data model you're building to create a situational awareness picture of your supply chains. Develop mitigation strategies to address these risks and establish contingency plans - for example, what will you do when (... not if) the next pandemic hits, demand rapidly declines, and suppliers fold? Or if conflict engulfs an area you rely upon for vital services or materials? Consider also the growing importance of cybersecurity, as supply chains grow increasingly digitized.

Again, we reiterate the importance of a crisis management strategy - not just for your supply chain, but also in your manufacturing.

SEIZE THE MOMENT

Making the best of uncertain times

The last few years have clearly been quite difficult and, at the time of writing, we aren't 'out of the woods' yet.

Demand for A&D products is high, and rising and there is, quite obviously, no way to really mitigate risk as a whole. The pandemic took most of us by surprise, but, challenges and further 'black swan' events will come again. We just don't know when.

If we've learned anything from the supply chains in the last few years, it's that risk assessment and a 'plan b' are essential. Clearly, some risks are easier

to identify (and mitigate) than others, but, everything else being equal, flexibility is resilience, and resilience is a competitive advantage.

A&D companies must be prepared to adapt - meeting as many eventualities as possible; changing how they procure and how they produce in order to make the best of a difficult situation and quickly changing needs. This will not be easy, and requires an updated approach - both to supply chains and manufacturing. Those who do this best will prosper. Those who don't may face even greater difficulties in future.



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