FUSION

MAGAZINE #2 2026

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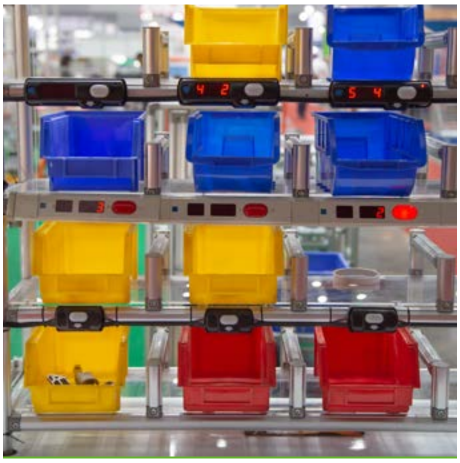

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THE PERFECT EXTENSION TO YOUR TEAM

DTC HUB is your digital partner for more innovative stock management and ordering.

From real-time inventory tracking to fast and accurate ordering, our platform ensures you have the materials you need, exactly when you need them.

What JEC World 2026 told us about where composites are heading

Every March, Paris hosts the moment the global composites industry takes stock of itself. JEC World 2026 drew more than 45,000 professionals from 94 countries, with over 1,400 exhibitors and 100 conference sessions across three days. It is the largest composites event on earth, and the themes that dominate it tend to define the year that follows.

Three themes dominated JEC World 2026: circularity, high-rate manufacturing, and digital coherence. Taken together, they tell a clear story about where the composites industry is heading – and what that means for the operations, supply chains and workshops that support it.

Circularity has moved from aspiration to practice

For several years, sustainability in composites has been a conversation about intention. At JEC 2026, it became a conversation about delivery. Recycling technologies of all types continued to gain momentum, with new partnerships, startups, and scale-up plans moving recyclable composite systems from laboratory demonstrations into credible industrial practice.

Thermoplastic composites continued to move into demanding structural roles across aerospace, automotive, maritime, energy and sport – materials that can be welded, reprocessed and recycled in ways that traditional thermoset systems cannot. The shift is not simply environmental. It is structural. As end-of-life regulations tighten and customer expectations around sustainability increase, the ability to demonstrate material recyclability is becoming a commercial requirement rather than a differentiating feature.

High-rate manufacturing is the defining challenge

With next-generation aerospace and defence programmes demanding faster production cycles, lighter materials and scalable processes, the emphasis at JEC 2026 was firmly on bridging the gap between innovation and industrial reality.

In the Netherlands, Airborne implemented its automated ply placement system in partnership with Airbus, creating a fully automated chain for producing dry-fibre

preforms for the A350 fuselage – with machine vision, automated cutting and dynamic recipe generation exemplifying the shift towards high-rate automation in aerospace manufacturing. The direction is clear. The processes that define composite manufacturing over the next decade will be faster, more automated and more data-driven than anything that preceded them.

Digital coherence is becoming the differentiator

Perhaps the most significant shift visible at JEC 2026 was not in materials or machinery, but in data. A continuous digital thread for the repair and manufacture of composite aerospace structures, integrating inspection, automated patch definition, scarfing strategies, manufacturing data, and return-to-service validation, was demonstrated, representing a system in which every stage of the process is connected, traceable, and verifiable.

For the industries DTC serves, this matters enormously. Process visibility, material traceability and data-driven quality control are no longer features of the most advanced OEM facilities. They are becoming the baseline expectation across aerospace, defence, marine and automotive manufacturing.

The composites sector is moving confidently towards a future defined by high-rate manufacturing, digital coherence and circularity – with materials becoming lighter, tougher and more sustainable, and manufacturing becoming leaner, smarter and more automated.

JEC 2026 confirmed the direction. The pace is accelerating.

HOW SUPERYACHT BUILDERS ARE REINVENTING THE HULL

In yards across Northern Europe and the Mediterranean, something fundamental is changing about how superyachts are built. Not the design. Not the propulsion systems. The hull itself.

> *"The race to zero is real. But it is not a sprint. It is a structural transformation of how hulls are designed, built, coated and eventually recovered"*

At **METSTRADE 2025**, an industrial alliance bringing together Arkema, Groupe Beneteau, Veolia, Composite Recycling, Owens Corning and Chomarat was named Sustainability Project of the Year for their work with Elium recyclable thermoplastic resin – a system that allows hulls and their fibres to be dismantled and reintroduced into the manufacturing process. It is a meaningful moment. Not because recyclable hulls are now standard, but because the conversation has shifted. The question is no longer whether sustainable hull construction is possible. It is how quickly the industry can get there – and how honest it is about the obstacles along the way.

What is actually being built

The materials arriving on the workshop floor are genuinely new. Bio-based epoxy systems such as Sicomin's SR GreenPoxy 550 are derived in part from plant sources, eliminating harmful substances while meeting or exceeding the properties of traditional resins. Compared to a traditional full-carbon composite hull, a hull built with bio-based epoxy and natural fibres can reduce the construction carbon footprint by up to 80 per cent, while offering comparable stiffness and structural integrity.

Natural fibres are also making inroads. Flax fibre composites are being used by builders, including Baltic Yachts, with the material growing from seed to crop in eight weeks, requiring no irrigation and no chemical inputs. Meanwhile, companies such as Baltic Yachts are building hulls from fifty per cent recycled material, and 3D printing technology is being applied to hull production – eliminating the need for moulds and reducing both production time and material waste.

These are not concept projects. They are production realities, moving at varying speeds through different segments of the market.

Where the difficulty lives

The honest picture is more complicated than the headlines suggest.

The structural performance of bio-based and natural fibre systems has improved considerably, but they are not yet equivalent to carbon or glass fibre across all applications. Resin control remains a particular challenge with natural fibres – without compression, the fibres can absorb excessive resin, which affects both weight and consistency. Vacuum infusion addresses this but introduces its own environmental considerations through single-use bagging materials.

End-of-life management presents a deeper problem. In the EU, there are approximately 80,000 abandoned boats, and projections indicate that the number of vessels reaching end-of-life will exceed 30,000 per year by 2030 – an average of over 23,000 tonnes of annual waste (Springer). Recyclable resin systems offer a genuine solution to this, but only if the infrastructure to process them at scale exists. Currently, it largely does not.

Cost remains the most persistent barrier. Bio-based and recyclable materials carry a price premium that narrows significantly at scale but remains real at the volumes associated with superyacht construction. For yards operating on long build timelines and highly customised specifications, the commercial case requires careful construction.

The coatings challenge

Below the waterline, a separate but equally significant transition is underway.

Traditional antifouling coatings have relied on toxic biocides that alter the chemical balance of water bodies, disrupting ecosystems and reducing biodiversity – and governments and environmental organisations are pushing for increasingly strict regulations. The IMO's Antifouling Convention has already banned organotin compounds, and the 2023 amendments extended controls to cybutryne, another antifouling biocide, with non-compliance risking vessel detention and disrupted itineraries.

The alternatives are developing quickly. At METS 2025, Seajet released a new series of silicone-based, biocide-free coatings, while coating suppliers are increasingly testing bio-based raw materials for use in underwater coating solutions. Foul-release systems that rely on physical properties rather than chemistry to prevent marine growth are gaining traction, particularly among owners whose vessels move frequently. For vessels that spend extended periods at anchor, the performance picture is less straightforward.

The superyacht industry is under increasing pressure to reduce its environmental footprint – not only from owners, but from regulatory bodies, marinas, charter clients and public opinion. That breadth of pressure is significant. It means sustainability in coatings is no longer driven solely by regulation. It is becoming a commercial expectation.

Why the pace matters

The superyacht sector is not the primary driver of global emissions. But it operates under a level of scrutiny disproportionate to its size, and the decisions made here tend to travel downstream into wider marine manufacturing.

With sixty per cent of ultra-high-net-worth superyacht owners now under fifty years old, sustainability is increasingly a purchasing priority rather than an afterthought – and that demographic shift is expected to accelerate investment in green technology across the sector.

The race to zero is real. But it is not a sprint. It is a structural transformation of how hulls are designed, built, coated and eventually recovered – and it is happening across workshops, chemistry laboratories and regulatory bodies simultaneously.

For the yards, suppliers and finishing teams at the centre of it, the challenge is not deciding whether to engage. It is keeping pace with a transition that is moving faster than many anticipated, with solutions that are promising but not yet fully proven at scale.

The hull is changing. Everything built around it will need to change with it.

BRITAIN'S SECRET CLOUD: The £400 Million Google Deal Reshaping National Security

When the Ministry of Defence handed one of Silicon Valley's biggest names the keys to Britain's most sensitive military data, it raised a question nobody in Whitehall seemed keen to answer: what exactly did we just sign up for?

In September 2025, quietly timed to coincide with a US presidential state visit, the UK government announced one of the most significant and controversial defence technology deals in recent memory. Google Cloud was awarded a £400 million contract to deliver a sovereign cloud capability for the UK Ministry of Defence. The stated goal: to drag Britain's military infrastructure into the digital age and cement the UK-US intelligence relationship for decades to come.

On the surface, it sounds like a straightforward IT upgrade. But scratch beneath the press releases and you find a story that touches on national sovereignty, Silicon Valley's growing grip on global security, and the uncomfortable question of whether a private American corporation should ever hold the keys to a nation's secrets.

What is the "Secret Cloud"?

The agreement will see Google deploy sovereign datacentres in the UK based on its Google Distributed Cloud air-gapped platform, a system built to meet the highest data residency and security standards, designed to keep all MoD information under direct UK control.

"Air-gapped" is the critical phrase here. In technical terms, it means the system is completely severed from the public internet – a digital fortress with no outside connections. Google Distributed Cloud Air-Gapped was launched in July 2024 and has since been adopted by the German armed forces and the Singaporean Science and Technology Agency. Britain is now joining that exclusive club.

The platform will also integrate Google's AI, machine learning, and data analytics tools, enabling defence and national security specialists to draw faster insights and enhance operational readiness. In plain English: British military analysts will be able to process intelligence faster, spot patterns in vast datasets, and share information with allies at speeds previously impossible.

The big promise

The government's pitch is ambitious. The partnership means that the latest technology developed by Google Cloud, including AI, data analytics, and cybersecurity, will be used by defence intelligence and national security specialists to share secure information between partners and outcompete adversaries.

Defence Secretary John Healey was effusive. "Today's investment shows how defence is an engine for growth, supporting highly skilled UK jobs and a vibrant British tech start-up ecosystem," he said at the announcement. General Sir James Hockenhull, Commander of Cyber and Specialist Operations Command, called it "a critical component of our digital transformation strategy."

The deal has already led to millions of pounds in inward investment from Google Cloud, which will hire a dedicated specialist team in the UK to manage the technology. Jobs, growth, cutting-edge tech, it's a compelling package. But not everyone is convinced.

The questions nobody is answering

When the deal was announced, tech publication The Register immediately fired off a pointed question to the MoD: will US security services have access to and use the same Google sovereign cloud as the UK? The MoD did not answer. They were also asked to clarify what Defence Secretary Healey meant by "secret tech" – and what the Google contract means for existing cloud deals with AWS and Microsoft Azure. Silence, again.

This matters enormously. Amazon Web Services and Microsoft Azure already provide significant cloud services to defence customers, while Oracle Cloud is also in use. Britain's military data is now spread across multiple American tech giants – a fact that sits uneasily with the concept of "sovereignty."

The word itself deserves scrutiny. A truly sovereign system means a nation has full control – over its data, its people, its infrastructure, and critically, its ability to exit if something goes wrong. Announcements are intent. Delivery is proof. The MoD and Google still need to demonstrate a working operating model in practice – staffing cleared UK teams, running incidents under UK control, and producing repeatable evidence. Until those playbooks are proven on real workloads, this remains promising rather than bankable.

Big tech goes to war

The Google deal isn't happening in isolation. Across the Western world, defence ministries are increasingly turning to Silicon Valley to solve problems that traditional defence contractors simply can't. AI, cloud computing, and data analytics have become as strategically important as tanks and missiles – and the expertise lies firmly in the private sector.

Most defence organisations remain in the early stages of AI adoption, due in part to industry-related operational risks and regulatory requirements. But the pressure to modernise is immense. The UK government plans to construct a Digital Targeting Web by 2027, an ambitious network that will underpin battlefield decision-making in future conflicts. The Google cloud deal is one of the building blocks.

For Google itself, the strategic value extends well beyond the £400 million fee. A foothold in UK national security means credibility with other governments, influence over defence AI standards, and access to some of the world's most demanding engineering problems. It's a relationship that, once established, is very hard to unpick.

The bigger picture

Whether you find this deal reassuring or alarming largely depends on how much you trust the relationship between governments and big tech. Proponents will argue that Britain simply cannot build and maintain cutting-edge cloud infrastructure on its own, and that partnering with Google, under strict contractual controls, is the pragmatic choice.

Critics will counter that handing classified military data to any private company, however well-intentioned, however tightly contracted, is an irreversible shift in the balance of power. And that the questions the MoD refused to answer are precisely the ones that matter most.

One thing is certain: the age of the traditional defence contractor – the BAE Systems, the Raytheons, the Lockheed Martins – now has serious competition from a new kind of arms dealer. One that doesn't make weapons. It makes the infrastructure that makes weapons work.

Britain just paid £400 million to find out what that means.

> ***"Announcements are intent. Delivery is proof. The MoD and Google still need to demonstrate a working operating model in practice"***

FROM BARE METAL

Most people see the finish... Very few understand what it takes to get there

In a superyacht paintshop, the quality of the final coat is decided long before a spray gun is lifted. Environment checks, material staging and sequence confirmation all take place before the first painter suits up.

Temperature, humidity and airflow are verified first. In this environment, when those variables are wrong, everything that follows is compromised. There are no shortcuts that do not eventually show up on the hull.

This is not a dramatic environment. It is a controlled one. And the difference between those two things is where quality either holds or quietly falls apart.

Stage One: Surface Preparation

Before any coating touches the hull, the substrate has to be perfect. Not close. Not good enough. Perfect.

Surface preparation in a marine environment is unforgiving. Salt contamination, osmotic moisture and previous coating residue all create adhesion risk that no topcoat can compensate for. This stage often accounts for over sixty per cent of total labour time on a superyacht refinish, and it is where the wrong abrasive grade, the wrong technique or the wrong sequence costs the most.

The team begins with mechanical abrasion, working through grades systematically. Each transition is deliberate. The aim is not to remove material aggressively, but to create the correct surface profile for what follows. Dust extraction runs continuously. Contamination at this stage does not show up immediately. It appears in the topcoat, by which point rework has already doubled the cost.

One decision here defines the rest of the process. Is the surface genuinely ready, or does it just look ready? In a well run paintshop, those are never treated as the same question.

Stage Two: Primer Application

With the hull clean, profiled and dry, the painters move into the spray zone.

Primer selection is not a generic decision. The exposure profile of the vessel, whether coastal, offshore or tropical, determines the system required. Epoxy primers, tie coats and anti-corrosion systems all have defined application windows, pot lives and environmental tolerances.

Applying outside those tolerances does not always produce immediate failure. It shows up months later, offshore, where repair is neither simple nor cheap.

Spray equipment is calibrated before the first pass. Nozzle selection, pressure settings and material viscosity are all confirmed. HVLP application across a superyacht hull requires consistency over large surface areas, often in a continuous workflow. Overlaps, sags and dry spray are not acceptable at this level.

The painters work methodically. Film build must be correct, and cure windows must be respected before the next stage begins.

Stage Three: Filler and Fairing

Superyacht finishing standards operate at a different level to commercial marine work. A hull that would be considered acceptable on a working vessel is rejected here before it gets close to a topcoat.

Fairing is where the shape of the hull is refined. Imperfections are filled, contours checked with straight edges and raking light, and guide coats applied to reveal low spots that the eye would otherwise miss. It is slow, technical work, entirely dependent on the quality of the preparation beneath it.

Filler applied over a poorly prepared surface is not a solution. It is a delay.

The consumables used at this stage are not interchangeable. A filler system that cures too fast in warm conditions, or too slowly in cooler ones, disrupts the entire schedule. In a high throughput paintshop, one product decision can move a vessel's completion date.

TO FINAL COAT

Stage Four: Topcoat

At this stage, there is nothing left to correct. Only to reveal.

The topcoat exposes everything that came before it. Contamination, poor surface profile, incorrect film build or environmental variation all surface here.

Colour consistency across a superyacht hull is one of the most technically demanding finishes in any coating sector. Large surface areas, complex geometries and the level of client scrutiny leave no margin for error.

The final coat is applied in controlled passes. Wet film thickness is monitored throughout. The environment remains under constant observation. When the final panel is complete, the team assesses and begins quality checks.

There is no moment of celebration. In a paintshop operating at this level, meeting the standard is simply the expectation.

Why this matters

A day in a superyacht paintshop is not defined by dramatic moments. It is defined by the accumulation of small decisions made correctly, by people who understand that the process is the product.

The right consumable at the right stage. The right preparation before the right coating. The right environment maintained throughout.

When those things align, the finish holds. When they do not, the cost is never just financial. It is the vessel's reputation, the yard's reputation and the standard the industry is judged by.

In a live paintshop, there is no such thing as a minor detail. Only decisions that either hold the standard, or quietly compromise it.

Performance at Extreme Temperatures

Why Cryogenic Environments Are Forcing a Rethink in Materials and Processes

> *"adopting these materials is not always straightforward. They can introduce new handling requirements, different curing behaviours, and in some cases, higher costs"*

As industries push toward hydrogen, advanced aerospace systems, and next-generation energy infrastructure, a new set of operating conditions is becoming increasingly common. Extremely low temperatures, once limited to specialist scientific environments, are now a practical reality for a growing number of manufacturing and engineering teams. Cryogenic conditions, typically defined as below -150°C, are no longer an edge case. They are becoming part of everyday design considerations in sectors where performance, safety, and reliability cannot be compromised.

Hydrogen is a major driver behind this shift. In order to be stored and transported efficiently, hydrogen must be liquefied at around -253°C. Liquefied natural gas operates at approximately -162°C, presenting similar challenges. At the same time, aerospace and defence applications are routinely exposed to extreme thermal conditions, whether through high-altitude operation, space environments, or rapid temperature cycling during use. These factors are converging to create a demand for materials that can perform reliably far outside the temperature ranges they were originally designed for.

At these temperatures, materials behave very differently. Metals that perform predictably at ambient conditions can become brittle, losing their ability to absorb stress without fracturing. Polymers, which are often valued for their flexibility, can stiffen and lose elasticity. Adhesives and sealants can shrink as temperatures drop, leading to internal stress, cracking, or loss of adhesion. Even small differences in how materials expand and contract can create significant strain at bonded interfaces. Over time, this can result in microcracking, delamination, or full structural failure.

Composites introduce further complexity. While they are widely used for their strength-to-weight advantages, their performance in cryogenic conditions depends heavily on the behaviour of the resin systems that bind them. As temperatures fall, these resins can become more rigid and less tolerant to stress, increasing the risk of damage under load or during thermal cycling. In many cases, the challenge is not with a single material, but with how multiple materials interact under these conditions. What works in isolation at room temperature may not perform as expected when combined in a cryogenic environment.

For teams working on the shop floor, these changes are not theoretical. They have direct implications for how materials are selected, prepared, and applied. Surface preparation becomes more critical, as any inconsistency can be amplified once thermal stress is introduced. Adhesive selection is no longer based solely on strength or cure time, but on the ability to maintain performance across a wide temperature range. Seal integrity becomes harder to guarantee, particularly in systems that experience repeated cooling and warming cycles.

In hydrogen applications, there is an added layer of complexity. Hydrogen molecules are extremely small, which allows them to permeate materials more easily than other gases. This increases the risk of leakage and places greater emphasis on material compatibility and long-term stability. Microscopic flaws that would be insignificant in other environments can become critical failure points. As a result, the margin for error is significantly reduced, and the importance of process control, inspection, and validation becomes much greater.

This is forcing a shift in how materials are evaluated. Traditional criteria such as strength, weight, and ease of application are no longer sufficient on their own. Materials must now be assessed based on how they perform under extreme temperature conditions, including their resistance to thermal cycling, their compatibility with adjacent materials, and their long-term durability under repeated stress. In hydrogen systems, permeability is also becoming a key consideration. This has led to increased interest in specialised cryogenic adhesives, modified resin systems, and advanced composite formulations designed specifically for low-temperature performance.

However, adopting these materials is not always straightforward. They can introduce new handling requirements, different curing behaviours, and in some cases, higher costs. For many operations, this creates a balance between performance, practicality, and commercial viability. At the same time, standards and testing methods are still evolving, and long-term performance data is still being developed. This adds a layer of uncertainty for teams making decisions today that will impact performance years into the future.

What is clear is that cryogenic performance is moving from a niche requirement to a mainstream design consideration. As hydrogen infrastructure expands and aerospace systems continue to evolve, the expectation is shifting. Materials are no longer selected purely for how they perform under normal conditions, but for how they behave at the extremes. This changes not just individual material choices, but the way entire systems are designed and validated.

Ultimately, the challenge is not just about temperature. It is about how materials behave together when pushed beyond their traditional limits. Adhesives, sealants, coatings, and composites must all perform as part of a wider system, under conditions that

amplify even minor weaknesses. For operations teams, that means placing greater emphasis on compatibility, process control, and long-term reliability. Because at cryogenic temperatures, performance is not simply reduced. It is fundamentally redefined.

Anti-fouling is changing

and no one has a perfect replacement yet

Tighter environmental regulation is forcing the marine sector away from biocidal coatings – but the alternatives are still catching up. The result is an industry navigating real trade-offs with no clear answer in sight.

For decades, tributyltin was the gold standard. Effective, durable, and cheap, it kept hulls clean and fuel bills low. Then its environmental impact became impossible to ignore – and with the IMO ban in 2008, the industry adapted to copper-based biocides. Now those too are under pressure.

California has led restrictions on copper antifouling in recreational waters since 2020. The EU's Biocidal Products Regulation has tightened approval criteria significantly. And major shipowners, under pressure from sustainability frameworks, are voluntarily moving faster than the law requires.

The direction of travel is clear. What isn't clear is what comes next.

> *"The industry knows where it's going. It just doesn't know how to get there without losing something in the process."*

The leading alternatives – foul-release coatings, silicone-based systems, and ultrasonic anti-fouling – each offer genuine advantages. But they come with real limitations that biocidal coatings don't: higher upfront cost, speed sensitivity, and performance that varies significantly by vessel type, trade route, and docking frequency.

Foul-release coatings work on a simple principle: rather than killing organisms, they make the hull surface too slippery to hold on to. For vessels operating consistently above eight knots, the results can match or beat biocidal performance. Below that threshold, the system struggles – and slow-steaming, which has become standard practice for fuel economy, is precisely the operating profile where foul-release underperforms.

The consequence is that many yards are making decisions by elimination. Biocides are legally or reputationally difficult. Foul-release doesn't suit every vessel. Emerging technologies like biomimetic surfaces and enzymatic coatings are promising but not yet commercially proven at scale. The result is an extended period of in-between – where the best available option depends heavily on context, and applying the wrong system costs significantly more than just repainting.

THE CORE TENSION:

Regulation

Pushing away from proven biocidal systems faster than alternatives mature

Performance

Each alternative has a vessel profile where it works – and several where it doesn't

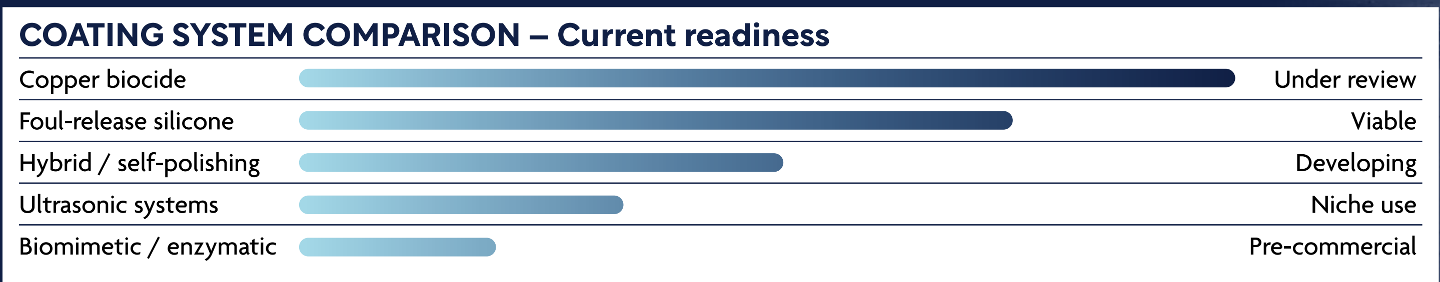
Maintenance

Increased docking frequency and inspection cycles add cost back in

Decision risk

Wrong system choice means full strip and recoat – not just touch-up

What yards are doing right now: most are running biocidal systems to the end of their service life while piloting alternatives on lower-risk vessels. Few are making fleet-wide commitments. The absence of a clear market winner is itself shaping strategy.



THE HYDROGEN
What it means for the

The aircraft of the future is being built right now. Not in the hangars where finished jets roll out to waiting airlines, but in research facilities, certification offices and engineering labs where the fundamental questions about hydrogen-powered flight are still being answered.

Some of those answers are proving harder to find than the industry anticipated.

Earlier this year, Airbus confirmed the technical feasibility of its ZEROe 100-seat hydrogen fuel cell concept, an aircraft capable of carrying 100 passengers on routes up to 1,000 nautical miles, powered by four 2.4-megawatt electric motors driven by hydrogen fuel cells. It is a genuine milestone, representing years of engineering work and a clear statement of direction.

The company is now building a 1.2-megawatt powertrain demonstrator at its German facility, with testing set to expand through 2027.

At the same time, Airbus has confirmed that the ZEROe programme is to be delayed. Reports suggest the timeline could slip by between five and ten years from the original 2035 target, and the programme budget has been reduced. The reason is straightforward. The technology is not developing as quickly as hoped, and building a hydrogen ecosystem, including infrastructure, production, distribution and regulatory frameworks, requires global coordination that no single organisation can accelerate alone.

This is not a story of failure. It is a story of complexity meeting industrial reality. And for the manufacturing and MRO environments that will eventually be asked to build, service and support these aircraft, that distinction matters.

A different kind of aircraft entirely

Hydrogen is not a drop-in fuel. It cannot simply replace kerosene in an existing design or operate on existing infrastructure. The aircraft itself must be fundamentally redesigned around the fuel, and with it, the processes required to build, inspect and maintain it.

Liquid hydrogen must be stored at minus 253 degrees Celsius, requiring cryogenic tanks that are larger, heavier and structurally more complex than conventional fuel systems. Airbus is actively exploring lighter hydrogen storage tanks and advanced carbon fibre materials compatible with cryogenic temperatures, which do not yet exist in production at the required scale.

This is where the shop floor implications become real. The composites, adhesives, sealants and surface treatments that perform reliably at ambient temperatures behave differently under cryogenic conditions. Materials that are stable today may not perform under the conditions hydrogen demands.

Every material in contact with or adjacent to the fuel system must be requalified. The consumables that work today may not be appropriate for the aircraft of the next decade, and the processes for working with new material systems will need to be developed, validated and trained before a single production aircraft is built.

AIRCRAFT shop floor

> *“organisations that begin developing them now will hold a clear advantage when the market arrives”*

Where progress is continuing

Away from the headline programme delays, technical progress continues.

ZeroAvia is targeting a 300-mile range in ten to twenty-seat hydrogen-electric aircraft by the end of 2026, and up to 700-mile range in forty to eighty-seat aircraft by 2028. In November 2025, ZeroAvia was awarded Design Organisation Approval by the UK Civil Aviation Authority, a critical certification milestone on the path to commercial hydrogen-electric engines.

KLM and ZeroAvia are targeting a liquid hydrogen-powered flight demonstration in 2026, with ZeroAvia planning to begin selling its ZA2000 powertrain, designed for 80-passenger aircraft, in 2027. These are programme commitments with regulatory engagement already underway.

The zero-emission aircraft market, valued at USD 28 billion in 2025, is forecast to reach USD 32 billion in 2026 and USD 56 billion by 2030. This level of investment reflects long-term industrial commitment rather than short-term momentum.

The technology is advancing. The timeline is longer than originally stated. Both remain true.

The certification reality

For manufacturing operations, the certification timeline is one of the most important factors to understand. Current regulatory frameworks were not written with hydrogen aircraft in mind. EASA and the FAA are developing the safety standards that hydrogen systems must meet, a process that is thorough by design and cannot be rushed.

The UK Civil Aviation Authority has taken a more proactive position, expanding its Hydrogen Challenge programme as part of a wider effort to position the UK at the forefront of hydrogen-powered aviation.

For UK-based aerospace manufacturers and MRO operations, this signals an environment where early engagement with hydrogen-compatible processes and materials will be supported rather than delayed.

Organisations that develop familiarity with hydrogen-compatible materials, bonding systems and surface treatments now will be better positioned than those who wait for the technology to arrive fully formed.

Why now is still the moment to pay attention

The delays are real. The complexity is significant. The transition will take longer than originally expected.

But manufacturing does not wait for final products. It prepares for them.

The composite structures, thermal management systems, surface treatments and sealing technologies being developed today will define what is possible when hydrogen aircraft move from demonstrator to production. The supply chains, skills and process knowledge required cannot be built overnight.

The organisations that begin developing them now will hold a clear advantage when the market arrives.

Hydrogen offers three times the energy per kilogram of conventional jet fuel. If applied at commercial scale, this would fundamentally change the weight, structural logic and material requirements of aircraft design, and reshape the supply chains that support it.

The question for the aerospace manufacturing community is not whether hydrogen is coming. The direction is clear.

The question is whether the skills, materials and processes required to support it are already being developed.

The aircraft of the future is being built right now. The shop floor that supports it needs to be ready, even if the timeline for its arrival has quietly extended.

What offshore wind is teaching composite manufacturers

The largest composite structures ever built are generating lessons the whole industry needs to hear

Offshore wind turbine blades are now among the largest composite structures ever manufactured. The most powerful offshore turbines currently operating have blades spanning 100 metres, structures that must perform reliably for two decades in some of the harshest environments on Earth. Salt exposure, extreme fatigue loading, constant moisture and remote inaccessibility combine to create a testing ground for composite manufacturing that no laboratory could replicate.

The lessons being learned here are not staying within the wind industry. They are travelling into marine, aerospace, automotive and defence manufacturing, and the organisations paying attention are gaining a significant advantage.

Scale exposes what small structures hide

When composite structures reach the scale of an offshore wind blade, every process variable that might be tolerated in smaller production becomes a structural risk. Vacuum infusion across thick sections requires precise flow strategies to prevent dry spots – defects that, in smaller components, might be manageable, but at the blade scale can compromise structural integrity across metres of laminate.

Cure management becomes equally critical. Thermal and cure gradients across thick laminates must be carefully controlled, with low exotherm epoxy systems and optimised thermal cycles used to ensure consistent material properties throughout the section. The margin for variation is narrow. At this scale, inconsistency does not produce a localised defect. It produces a structural liability.

For composite manufacturers working at smaller scales, these are not abstract concerns. They are the same variables – contamination, cure control, vacuum integrity, laminate consistency – that define quality in every composite process. Offshore wind simply makes the consequences of getting them wrong impossible to ignore.

The recyclability challenge is forcing material innovation

The vast majority of wind turbine blades currently end their operational life in landfill – a problem that is growing as the first generation of large offshore installations reaches the end of their life. The pressure to solve this is driving material development that will reshape composite manufacturing well beyond the wind sector.

Thermoplastic composites are being developed and tested as a direct alternative to conventional thermoset systems, offering comparable structural properties alongside the critical advantage of recyclability. Thermoplastic resin systems such as Arkema's Elium can serve as a direct replacement for epoxy in existing infusion processes, requiring no new tooling or manufacturing equipment, while enabling blades to be recycled rather than buried.

This development matters far beyond wind energy. Thermoplastic composites that can be welded, recycled, and reprocessed open new possibilities in marine, automotive, and aerospace applications, where end-of-life sustainability is becoming a regulatory and commercial requirement.

What this means for the wider industry

The offshore wind sector is investing at a scale that few other industries can match in composite manufacturing research. Structural health monitoring, damage detection systems and novel inspection methodologies are being developed specifically for composite blade environments – and the techniques emerging from that work are directly applicable to composite structures in defence, marine and aerospace.

Process discipline developed under offshore wind conditions, where inaccessibility makes in-service repair enormously costly, is producing a generation of manufacturing standards focused on getting it right the first time, every time. That mindset, and the process controls that support it, is exactly what high-performance manufacturing in every sector is moving towards.

The blades rotating offshore are not just generating electricity. They are generating knowledge. The composite manufacturers who engage with that knowledge now will find it directly applicable to the work on their own shop floors.

DIGITAL TWINS ARE COMING TO THE WORKSHOP FLOOR

The concept of a digital twin has traditionally been associated with large aerospace OEMs, complex production lines and high-end simulation environments. But that is beginning to change. What was once reserved for design and engineering teams is starting to move closer to the workshop floor, into environments where processes are physical, fast-moving and often difficult to track in real time.

At its simplest, a digital twin is a virtual representation of a physical process. It mirrors what is happening in the real world, using data to provide visibility, insight and, increasingly, predictive capability. In manufacturing, this has been used to model production lines, test changes before implementation and optimise performance at scale.

What is different now is where that capability is starting to appear.

As data capture becomes easier and more accessible, digital twins are no longer limited to large, fixed production systems. They are beginning to reflect smaller, more variable operations, including maintenance, refit and workshop environments. These are the types of environments where processes are less linear, where work is often bespoke, and where visibility has traditionally relied on experience rather than structured data.

In practical terms, this shift is not about creating a perfect virtual replica of an entire facility. It is about building a clearer picture of how work actually flows.

In a paint environment, for example, a digital twin could map the movement of a component from preparation through to topcoat, capturing time, material usage and environmental conditions at each stage. It allows teams to see where delays occur, where variability is introduced, and where processes deviate from the intended sequence.

The value is not just in observation. It is in understanding cause and effect.

If rework increases, is it linked to a specific stage, a specific material, or a change in environmental conditions? If throughput drops, is it due to process inefficiency, stock availability or workflow disruption? These are questions that are often answered retrospectively, if at all. A digital twin brings them into view as they happen.

For workshop environments, this creates a different way of thinking about control. Rather than relying solely on standard operating procedures and individual experience, decisions can be supported by data that reflects real activity, not assumptions.

It also changes how improvements are made. Instead of trial and error on live work, adjustments can be modelled, tested and understood before they are implemented.

This reduces risk, particularly in environments where quality standards are high and the cost of rework is high.

Importantly, adopting digital twin principles does not require a full system overhaul. In many cases, it begins with better visibility of key variables. Material usage, stock levels, environmental conditions and process timing all contribute to a more complete picture of operations.

As these data points become connected, the foundation of a digital twin begins to take shape.

This is where workshop environments start to close the gap with larger manufacturing operations. Not by replicating their scale, but by adopting the same mindset. Understanding processes as systems, rather than isolated tasks.

For industries where precision, consistency and traceability matter, this shift has clear implications.

It supports more predictable outcomes. It reduces reliance on reactive decision-making. It highlights inefficiencies that would otherwise remain hidden.

Digital twins will not replace the skill and judgement of experienced operators. But they will change the context in which those decisions are made.

As the technology becomes more accessible, the question is no longer whether digital twins belong in workshop environments. It is how quickly those environments begin to benefit from the visibility they provide.

In operations where performance is shaped by detail, seeing the process clearly is often the first step towards improving it.

Why Finish Quality is Lost Before the Final Coat

The problem is not application. It is everything leading up to it

For most yacht builders and paint teams, the final coat is where quality is judged. It is the most visible stage of the process, the point at which a surface is either accepted or rejected, and the moment where weeks of work are either confirmed or undone.

But in marine finishing, the final coat rarely determines the outcome. It reveals it.

By the time a surface reaches application, most variables influencing finish quality have already been set. Contamination has either been introduced or controlled. Surface preparation has either been consistent or variable. The environment has either been stable or gradually drifting out of tolerance.

The challenge is not that these factors are unknown. It is assumed that they are under control when, in practice, they are where most variability is introduced.

The pressure has never been higher

Expectations in marine finishing are not static. As build standards rise and client scrutiny increases, the tolerance for variability is narrowing. A finish that would have been accepted a decade ago is increasingly likely to require correction today. At the same time, yards are operating under tighter schedules, with less margin for rework and greater pressure to maintain throughput without compromising quality. The gap between what clients expect and what inconsistent processes deliver is widening – and the cost of that gap is no longer easily absorbed.

Where the problem actually begins

Every surface entering a paint process carries a history.

Handling, storage, transport and exposure to the surrounding environment all leave an impact. In marine environments, that impact is amplified. Salt, moisture and airborne particulates are constant variables, even before a component enters a controlled paintshop.

A surface can appear clean while still carrying enough contamination to interfere with adhesion or finish consistency. Oils from handling, microscopic salt deposits and residue from previous processes are not always visible, but they remain present.

This creates the first gap between perception and reality. The surface looks ready. The process moves forward. The risk has not been removed.

Preparation is understood, but not always controlled

Surface preparation is widely recognised as critical. It is also one of the most inconsistent stages in the entire process.

Abrasive grades, sanding patterns and surface profiling are typically defined. What varies is how consistently those standards are applied across large structures, multiple teams and extended timeframes.

In yacht construction, surfaces are rarely uniform in scale or accessibility. Vertical sections, complex geometries and confined areas all require adjustments in approach. Over time, these adjustments introduce variation.

That variation does not immediately show. It is carried forward into the next stage, where it becomes harder to isolate and correct.

Cleaning does not always remove risk

Cleaning and wipe-down stages are often treated as the final safeguard before application. In practice, they can introduce their own set of variables.

Cloths may carry contamination between areas. Solvents may be applied inconsistently. Residue can be redistributed rather than removed. In some cases, cleaning materials themselves become a source of contamination.

The step is completed. The surface appears clean. The process continues.

What is rarely verified is whether contamination has actually been removed, or simply spread more evenly across the surface.

This is where many processes create a false sense of control. The action is visible. The outcome is assumed.

The environment is not static

Paint environments are designed to control airflow, temperature and particulate levels. That control, however, is not fixed.

Movement between preparation areas and spray zones introduces variation. Temporary protection degrades over time. Overspray build-up changes internal booth conditions gradually, not suddenly.

These changes are subtle. They do not trigger immediate concern. Over time, however, they influence how materials behave, how coatings cure and how finishes appear.

Because the shift is gradual, it is often accepted as normal. The process continues to operate, but under conditions that are no longer consistent with the original specification.

Application works within the limits set before it

By the time the coating is applied, the opportunity to correct earlier issues has passed.

Application technique, equipment setup and material selection still play a role, but they operate within the constraints created by preparation, cleaning and environment. Contamination, inconsistent profiling and environmental variation all surface at this stage.

The result is often rework.

Not because the application failed, but because the process leading into it was not fully controlled.

Where the real cost sits

In many operations, rework is treated as part of the process. An expected outcome rather than a signal.

But rework is not just additional labour. It is compounded cost.

Time is lost not only in correction, but in disruption. Materials are used twice. Schedules shift. Downstream processes are delayed. In large marine projects, even a small area of rework can ripple across an entire programme.

More importantly, rework rarely addresses the root cause. The surface is corrected, but the process that introduced the issue often remains unchanged.

The same conditions persist. The same variability remains.

Where control is actually gained

Improving finish quality is not about changing a single stage. It is about reducing variability across the entire process.

Consistent preparation methods.
Verified cleaning processes.
Stable environmental conditions.
Consumables that behave predictably every time they are used.

These are not new ideas. What separates high-performing operations is how consistently they are applied.

Control is not created at the point of application. It is built into every stage that leads to it.

What this means for the shop floor

For yacht builders and paint teams, the implication is straightforward.

The focus shifts upstream. From the final coat to the stages that define it. From visible finish quality to underlying process consistency.

Because in marine environments, where expectations are high and surfaces are unforgiving, the difference between a flawless finish and a costly rework is rarely a single mistake.

It is the accumulation of small variations that were never fully controlled.

The finish does not create quality – it exposes it

And by the time it does, the opportunity to change it has already passed

WP10

LAYERSHIELD™

A 5-layer spray booth wall protection film designed to maintain clean, controlled paint environments and reduce contamination over time.

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- EASY & FAST APPLICATION
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BAXT

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Increase spray booth productivity time by reducing cleaning and maintenance.

INCREASE QUALITY:
Improve your throughput and reduce re-work by maintaining a clean working environment.

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Protect your spray booth and keep this valuable asset in top working order.

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Boost employee morale and productivity by providing a bright and clean work area.

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WHEN LEAN BECOMES BRITTLE

The systems designed to speed up automotive manufacturing are now making it more fragile. Understanding why is the first step to adapting.

For years, automotive manufacturing has been built on a single principle: efficiency above all else. Lean systems, just-in-time delivery and tightly controlled supply chains have allowed manufacturers to reduce waste, minimise inventory and operate at remarkable speed. In stable conditions, the model works.

But those conditions are no longer stable. And the same systems that deliver efficiency under normal circumstances can create acute vulnerability when those circumstances shift.

The illusion of control

Just-in-time supply was designed to eliminate excess. Materials arrive when needed, not before. Inventory is reduced, storage costs fall, and cash is not tied up in stock. The assumption underpinning all of this is consistency – suppliers deliver on time, transport flows as expected, and demand is predictable.

That assumption has been tested repeatedly in recent years. When the global semiconductor shortage took hold from 2021 onwards, manufacturers found that a component costing a few pounds could halt the production of a vehicle worth tens of thousands. Ford, Volkswagen and Toyota all cut output significantly – not because of broad systemic failure, but because just-in-time left almost no buffer when a single supply stream ran dry.

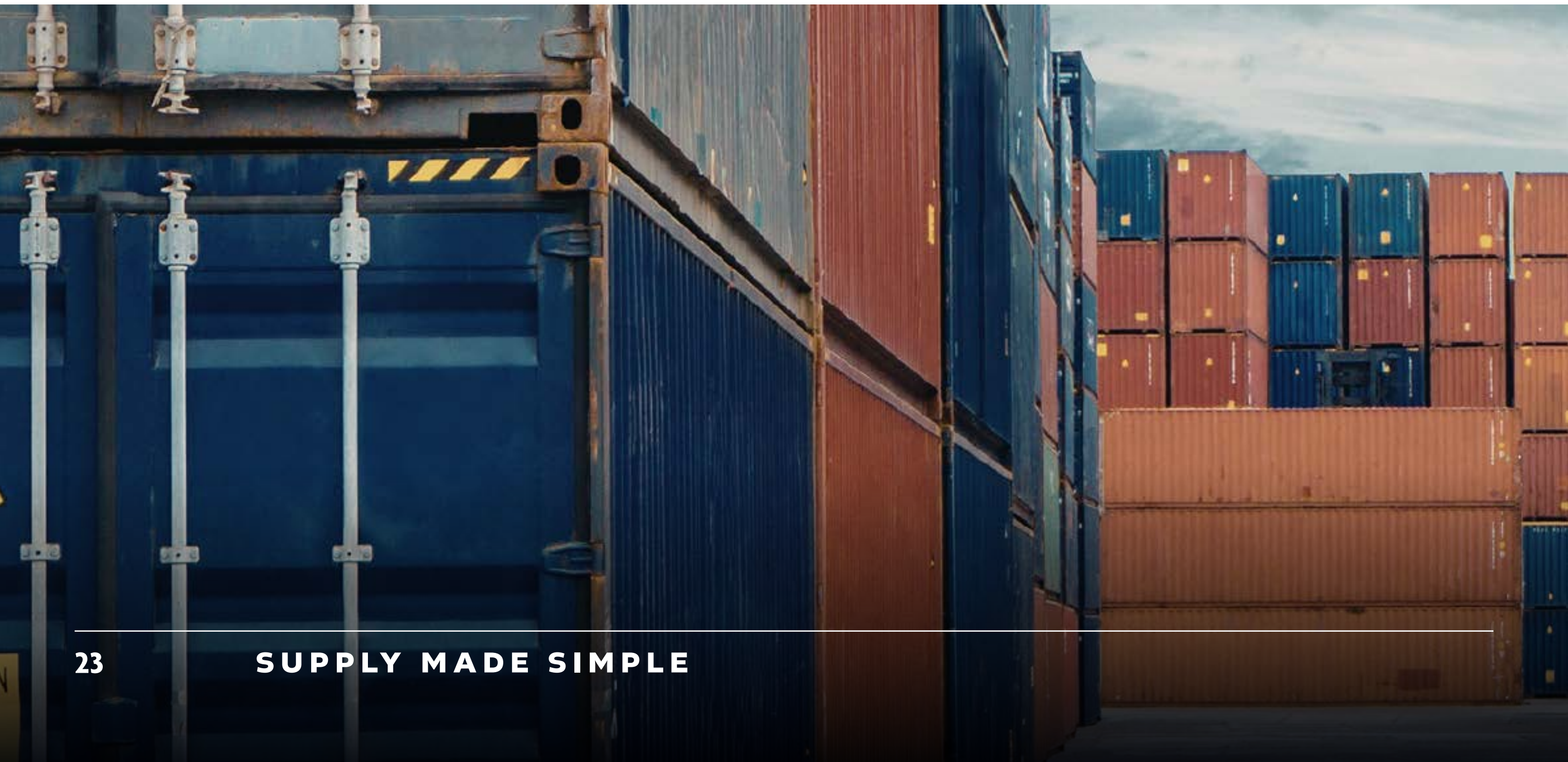
> *"Just-in-time does not remove risk. It concentrates it"*

When everything is aligned, the system is efficient. When it is not, there is very little margin for recovery.

A single ship, a global standstill

The semiconductor shortage was a slow-build crisis. The blockage of the Suez Canal in March 2021 was the opposite – a single event, lasting six days, that disrupted an estimated 12% of global trade. For automotive manufacturers reliant on components routed through that corridor, it exposed just how little redundancy existed in their supply chains.

Neither event was unforeseeable in type, only in timing. And therein lies the problem. Supply chains are now global and interconnected to a degree that makes them highly efficient under normal conditions and highly susceptible under abnormal ones. A disruption in one location can affect production thousands of miles away, often in ways that are difficult to trace until the impact is already being felt on the line.



More variants, more exposure

Modern vehicles are more complex than ever. Multiple powertrain options, increasing electronic content, more variants across the same platform, and greater integration between systems. Each adds value. Each also adds complexity.

From a manufacturing perspective, this means more components, more suppliers, and more potential points of failure. The relationship between cause and effect becomes harder to track as systems become more interconnected – a small disruption in one area can have a disproportionate impact elsewhere, and identifying the source takes time that production schedules rarely allow.

Resilience as the new efficiency

In response, manufacturers are beginning to rethink what "efficient" actually means. Efficiency is no longer measured purely in speed or cost. It is increasingly measured by the ability to keep operating under disruption.

Holding more stock at critical points. Qualifying secondary suppliers. Increasing visibility across the supply chain. These approaches were traditionally considered incompatible with lean manufacturing. They are becoming more common – not as a rejection of lean principles, but as an evolution of them.

> ***“ A process that can maintain performance under varying conditions, even at slightly higher cost, may deliver better overall outcomes than one optimised purely for speed. ”***

The gap between disruption and response

One of the biggest operational challenges is visibility. Many disruptions are not apparent until they reach the point of impact. A delayed shipment or a supplier issue may only become visible when production is already affected – by which point the response is reactive rather than managed.

For operations teams, this is already a daily reality. Schedules are less predictable. Material availability can change with little notice. Processes that rely on perfect conditions become harder to sustain, and the focus shifts from optimisation to recovery.

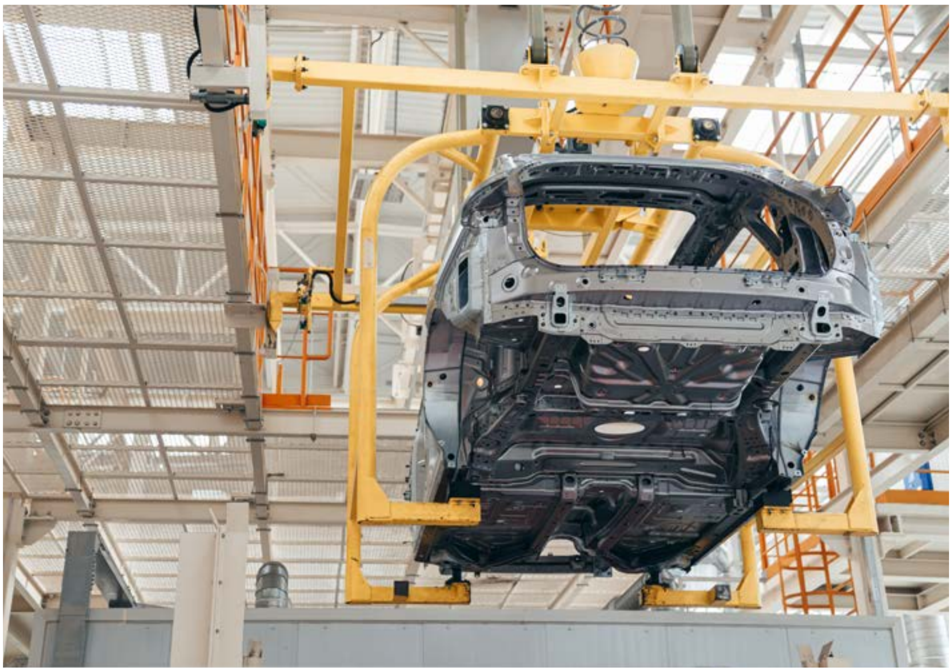
Improving visibility across the facility and the wider supply chain is not about eliminating disruption. It is about responding to it earlier, before it compounds.

Variability is now the baseline

It would be tempting to view the disruptions of recent years as exceptional – a pandemic, a blocked canal, a chip shortage. But the underlying drivers are structural. Supply chains are global and complex. Vehicle content continues to increase. Regulatory and market pressures are evolving rapidly. None of these trends are reversing.

The implication is that variability is no longer the exception. It is becoming part of normal operations. For automotive manufacturing, the question is no longer just how fast a system can run. It is how well it continues to run when conditions change.

The industry has spent decades optimising for speed. The next phase will be defined by how well it balances that speed with stability.



THE CLOCK IS ALWAYS RUNNING

Why unplanned downtime is the cost marine operations consistently underestimate

In marine operations, time out of service is never free. It is simply a cost that is absorbed elsewhere or not accounted for at all.

Major refits can run into the millions, and extended yard periods are already one of the biggest barriers to planning. Those costs are well understood. What is less consistently measured is the impact of unplanned delay.

The days were added because materials were unavailable. The schedule slipped because the right consumable was not on site. The rework that doubled the labour on a stage that should have been completed once.

These costs do not arrive dramatically. They accumulate quietly, and they are rarely traced back to their source.

Where the time actually goes

Minimising downtime and maintaining quality are fundamental to any marine operation. In practice, however, material availability is still often managed reactively rather than planned with precision.

A preparation stage runs out of the correct abrasive grade. A primer system is not available in the required specification. A consumable that should take minutes to source takes days.

Individually, these delays appear minor. Collectively, they extend a yard period in ways that are difficult to recover from without compressing other stages. That compression introduces risk, whether in quality, compliance or both.

With refit cycles typically running every five to seven years, and significant investment tied to each one, the margin for avoidable delay is effectively zero.

The compounding effect

Unplanned downtime does not just cost time. It compounds.

Unexpected issues regularly require contingency budgets above planned maintenance spend. When delays push a vessel beyond its return-to-service date, the impact extends beyond the yard.

Charter income is disrupted. Owner commitments are affected. In a market where vessels are updated regularly to remain competitive, a delayed return is not just inconvenient. It is commercially damaging.

The cause is rarely a single failure. It is the accumulation of small gaps across the process. Reactive ordering. Inconsistent material supply. Consumable management based on assumption rather than visibility.

What high-performing yards do differently

Operations that consistently deliver on schedule are not necessarily working any faster. They are working with fewer unknowns.

Materials are staged before they are needed. Stock levels are monitored continuously, not checked when something runs out. Consumables are specified for the process, not substituted at the point of use.

Supply relationships are built around reliability and responsiveness, not just unit cost.

In an environment where a single day of downtime can outweigh the cost difference between suppliers, the economics are clear.

The cost is already there

The clock in a marine yard is always running.

The question is not whether downtime has a cost. It is whether that cost is understood and controlled or simply absorbed.

Because in most cases, it is already there.
It is just not being measured.

What VMI actually looks like in practice

Moving from reactive ordering to controlled supply – and what changes on the shop floor.

What VMI is designed to fix

Most consumable supply issues are not caused by a lack of product. They are caused by a lack of visibility and structure.

Stock is stored centrally, but not always where it is needed. Levels are checked manually, often inconsistently. Ordering is reactive – triggered when something runs low or runs out. Different teams use materials at different rates, but that usage is rarely tracked accurately.

The result is familiar: stockouts in critical moments, over-ordering of low-use items, time lost locating materials, and a constant reliance on individuals to keep things running. VMI is designed to remove that variability.

How it works in practice

In a working VMI setup, stock is not just delivered – it is structured. Consumables are placed at the point of use: within a paintshop, composite bay, or production line. Each location is defined, and each product has a set minimum and maximum level based on actual usage data, not estimation.

Stock is checked on a scheduled cycle – either through physical visits or supported by simple digital tools. When levels reach a defined trigger point, replenishment is initiated automatically. No manual purchase order. No waiting until stock runs out.

Over time, usage data builds. Levels are adjusted from what is actually consumed rather than what was estimated at setup. The system becomes self-correcting.

1	Stock placed at point of use
2	Usage tracked vs. set levels
3	Trigger point reached
4	Auto replenishment
5	Levels tuned from real data

What changes on the shop floor

Materials are where they are needed, when they are needed. Time spent searching for stock drops. Interruptions caused by missing items stop happening.

Teams are no longer responsible for manually monitoring stock levels – reducing human error and freeing up time for higher-value work. Stock levels become more accurate: excess inventory is reduced without increasing the risk of running out.

Reactive ordering vs. VMI

Before	With VMI
Stock checked when someone notices it is low	Levels monitored on a defined cycle
Orders raised manually when stock runs out	Replenishment triggered automatically
Materials stored centrally	Stock placed at point of use
Usage estimated, often inaccurately	Levels set from actual consumption data
Stockouts disrupt production	Shortages prevented before they occur

Where it delivers most value

Paintshop	Composite bay	Assembly	Maintenance
High consumable variety, continuous use, sensitive to interruption	Multiple materials per stage, expiry-sensitive stock	Line-stop risk if fasteners or compounds run short	Unpredictable demand spikes, critical availability requirements

What it is not – and why it matters

VMI is not simply a supplier holding more stock. Without structure it becomes over-supply rather than controlled supply. The value comes from how stock is positioned, monitored, and replenished – not just from who owns it.

It also does not remove the need for oversight. It replaces manual, ad-hoc processes with defined ones – but still relies on accurate setup and ongoing management to stay calibrated.

As operations become more complex and supply chains less predictable, the ability to control internal stock becomes more important. VMI shifts the focus from reacting to shortages to preventing them – creating visibility where there was uncertainty, and consistency where there was variation.

AUTOCLAVES:
Where composite performance is set

In high-performance manufacturing, there are few processes as critical or as unforgiving as the autoclave. For those working with advanced composites, it is not just a piece of equipment. It is the stage where material behaviour is fixed, and where the difference between acceptable and exceptional becomes clear.

The fundamentals are well understood. Controlled heat, controlled pressure, defined cycles. What matters is how consistently those conditions are delivered, and how well everything leading into that cycle has been managed. At this stage, no further adjustment is needed. Only confirmation.

Control Defines Outcome

Autoclave curing is governed by tightly controlled cycles, but the challenge is not defining them. It is maintaining them without variation. Temperature ramps, dwell times and pressure levels must align exactly with the material system in use. Small deviations are enough to shift the outcome.

These changes are not always visible. A component can leave the autoclave looking correct while carrying internal inconsistencies that only surface under load or over time. This is where experienced teams separate themselves – not in knowing the process, but in controlling it repeatably. Every cycle must deliver the same result. Without exception.

Preparation Before the Cure

The autoclave does not compensate for what happens before it. Layup quality, handling discipline and environmental control all feed directly into the outcome. Fibre alignment, resin consistency and contamination control are not variables that can be corrected later.

Vacuum bagging is often where this is either secured or compromised. Bag integrity, breather placement and vacuum performance determine how effectively the laminate consolidates under pressure. A poorly prepared layup does not improve inside the autoclave. It is simply cured in its existing state.

At this level, preparation is not a stage. It is the foundation on which everything else rests.

The Role of Consumables

Consumables rarely receive the same attention as materials or equipment, yet they are central to process stability. Release films, peel plies, breather fabrics and bagging materials influence pressure distribution, gas evacuation and surface finish. Their behaviour under heat and pressure is not incidental – it forms part of the overall system.

Treating them as interchangeable introduces variability into a process that depends on control. Changes in permeability, thickness or thermal response can shift the outcome without any change to the cure cycle itself. In high-performance environments, consistency in consumables is not a preference. It is a requirement.

Throughput vs Precision

Autoclaves are often the constraint within composite production. Cycle times are fixed, capacity is limited, and demand rarely aligns neatly with availability. The pressure to increase throughput is constant, but the risk lies in how that pressure is applied.

Shortening cycles or increasing load density without full understanding introduces variability. Heat distribution becomes less uniform, and pressure is not applied consistently across all parts. Leading operations are not accelerating the cure. They are reducing inefficiency around it.

Dynamic scheduling systems are increasingly being deployed to make better use of available capacity – continuously monitoring material readiness and coordinating batch curing so that components are autoclave-ready before a cycle begins rather than after it. The gains do not come from compressing the cure. They come from eliminating the idle time and coordination gaps that surround it.

The principle is straightforward. The autoclave should never be waiting. Everything else in the process should be organised around ensuring it is not.

The Sustainability Pressure

Autoclave curing is effective. It is also energy-intensive. That reality is becoming harder to ignore as sustainability expectations increase – not only from regulators, but from customers who are placing greater scrutiny on how components are produced, not just what they produce.

The response across the industry is not to move away from autoclaves, but to operate them with greater discipline. Optimised loading, improved thermal insulation, and heat recovery between cycles are becoming part of standard practice rather than optional improvements.

The expectation is shifting. It is no longer enough to achieve the result. Operations are increasingly required to demonstrate how efficiently that result was delivered.

Where the Industry Is Moving

Autoclaves remain the benchmark for high-performance composite curing, but they are no longer the only conversation. Out-of-autoclave processes are being adopted where the application allows, particularly where cost, cycle time and sustainability offer clear advantages without compromising structural requirements.

At the same time, digitalisation is changing how autoclave environments are managed. Greater visibility of cycle data, material traceability and process performance is reducing reliance on assumptions and informal knowledge. The process is becoming more measurable. And therefore, more controllable.

For operations where compliance and quality assurance are non-negotiable, that shift matters. Being able to demonstrate what happened in every cycle, not just that the cycle completed, is becoming as important as the result itself.

Why It Matters

For those working with composites, the autoclave is not where quality is created. It is where it is confirmed. Every decision made before the cycle begins is carried through it – from material selection and preparation to handling and consumables.

When those elements are aligned, performance is consistent. When they are not, the result is fixed in place. In high-performance environments, there is little room for correction after cure.

The autoclave does not create quality. It reveals it.

Why robots still can't replace the human painter

The investment in painting automation has been enormous. The global market for paint robots has grown rapidly, and the technology has advanced considerably. Robotic painting systems now achieve significantly higher transfer efficiency than manual spray application, with no fatigue-related variation in quality. On paper, the case for full automation is compelling.

And yet, in marine yards, aerospace MRO facilities and specialist automotive paintshops across the industry, skilled human painters remain not just present but essential. The reasons why reveal something important about the nature of finishing work, and about where the real complexity in a paintshop actually sits.

Where robots excel and where they do not

Robotic painting systems are exceptionally well-suited to high-volume, uniform environments. In modern automotive factories, robots handle complex painting and finishing processes, delivering consistent film builds, precise coating thickness, and minimal overspray across standardised body panels produced at high volume. The geometry is predictable. The process is repeatable. The robot performs the same path, at the same speed, with the same settings, thousands of times without variation.

But marine and aerospace finishing does not work that way.

For highly complex or low-volume work, skilled manual painters still hold clear advantages. While collaborative robots are improving performance in mixed environments, they have not eliminated the gap.

A superyacht hull is not a car door. An aircraft control surface is not a simple component. The geometries are complex, the specifications are exacting, the volumes are low, and the consequences of a substandard finish are significant. Programming a robot to navigate those variables requires time, expertise and investment that often outweighs the efficiency gain, particularly when the next job has an entirely different specification.

The judgement that cannot be programmed

Beyond geometry, there is something more fundamental that automation has not yet replicated. The judgement of an experienced painter.

A skilled painter assesses a surface before applying a single drop of material. They identify contamination that sensors may miss. They adjust their technique in real time in response to subtle changes in environmental conditions. A shift in temperature. A change in airflow. A variation in the substrate.

These decisions are made instantly. A robotic system would require reprogramming to respond in the same way.

Good painters are becoming harder to find, and that shortage is driving increased interest in automation. But this does not reduce the value of human capability. It increases it.

The painter who can consistently deliver a flawless finish across complex, varied and high specification work remains one of the most valuable people in any finishing operation, and one of the hardest to replace.

The future is collaboration, not replacement

The most effective finishing operations are not choosing between robots and human painters. They are using both with intent.

Robots improve efficiency, consistency and safety in repeatable tasks. Human painters handle the work that demands judgement, adaptability and experience.

In a paintshop where both are used well, the robot handles the repeatable and the human handles the exceptional. The result is a level of quality that neither could achieve alone.

That balance, rather than full replacement, is where the industry is heading.

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