

Beyond Aero image.



By James Careless

Preparing MROs for Electric and Hydrogen Aircraft

The move into electric and hydrogen-powered aircraft is going to present MROs with an unprecedented set of engineering and operational challenges.

To map out a survival strategy for MROs, Aviation Maintenance convened a virtual roundtable on what lies ahead. Our panelists are Roei Ganzarski, CEO of Alitheon, previously served as CEO of magniX, whose electric propulsion systems have powered multiple electric-aircraft programs and Universal Hydrogen's hydrogen-electric Dash 8 demonstrator. He was also executive chairman of Eviation, developer of the clean-sheet Alice all-electric commuter aircraft, and later served as an adviser to Universal Hydrogen. And Beyond Aero's Luiz Oliveira (chief engineer), Anaïs Cateni-Caudéran (head of marketing and communication), and Benjamin Le Drogo (head of sales): Beyond Aero is an aerospace company actively designing and developing a purpose-built hydrogen-electric business aircraft. Alitheon develops optical-AI technology for item-level authentication and supply-chain traceability.

Aviation Maintenance: What new maintenance, repair and overhaul (MRO) business opportunities do you see emerging first as hybrid, electric, and hydrogen aircraft enter service?

Roei Ganzarski: Start with the uncomfortable part: scheduled heavy engine overhaul revenue shrinks drastically. Electric

propulsion has a fraction of the moving parts of a turbine — no hot section, no fuel control, no oil system, and no borescope inspection cycles. Anyone whose financial model depends solely on traditional engine overhaul profit pools needs a different plan. The opportunity is that the money doesn't vanish; it moves.

First to arrive are shop qualifications and approvals. High-voltage DC, arc flash procedures, battery handling, and hydrogen safety do not sit in a standard A&P curriculum. Repair station ratings have to exist before the first revenue flight, making training and certification sellable products years ahead of the fleets.

Energy on the ramp is another major frontier. Charging is the new fueling business, and whoever owns ground energy at secondary airports owns access to the network. MROs and FBOs are the natural owners because they already hold the ramp, the permits, and the handling relationships.

Battery swapping and pack pooling will turn the battery pack into a rotatable rather than a fixed installation to minimize turnaround time. That means logbooks, cycle history, state-of-health testing, conditioning, storage, and leased pools — the closest structural analog to engine leasing and power-by-the-hour that exists in this architecture.

On-site hydrogen production via small-scale electrolysis inverts fuel logistics for remote networks in places like Alaska, northern Canada, or island routes. Alongside it, tank inspections, leak



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detection, high-pressure handling, and fuel cell stack health monitoring create new revenue streams.

Additionally, second-life battery packs retired from flight still retain significant stationary storage capacity to buffer airport chargers, giving MROs a second customer for pulled packs. Finally, short-sector regional flights will accumulate cycles fast, driving increased demand for line maintenance, airframe, gear, brakes, tires, and non-destructive testing.

Luiz Oliveira: We expect the first opportunities to appear around specialized support services rather than traditional heavy mechanical overhaul.

For hydrogen-electric aircraft, these include specialized training for technicians working around hydrogen and high-voltage systems, alongside specialized tooling, personal protective equipment, test equipment, and calibrated equipment packages.

There will be strong demand for fuel-cell health monitoring, inspection, repair, exchange, and overhaul services. Electric motors, inverters, power electronics, and high-voltage distribution systems will require clear inspection and component exchange policies.

MROs can also capture value in hydrogen storage system inspection, remote diagnostics, and rapid component-exchange programs rather than extensive on-aircraft repairs.

Furthermore, mobile technical response teams for propulsion-related Aircraft On Ground (AOG) events, software configuration management, and hydrogen ground-handling support for operators and airports present strong growth avenues.

Because AOG response, parts availability, and fast component exchange are major pain points in business aviation today, next-generation OEMs must design an integrated support model from the outset. Early on, OEM involvement will remain high for specialized propulsion systems, while local MROs perform conventional tasks like wheels, tires, brakes, and airframe inspections.

Aviation Maintenance: What specific new skills and knowledge will future Airframe and Powerplant (A&P) mechanics need to safely complete inspections on high-voltage systems, batteries, and fuel cells?

Ganzarski: Today's A&P is trained for an airplane whose electrical system exists to run lights, radios, and fuel pumps at 28 volts DC. They are low energy, easy to de-energize, and treated as a support system. In an electric or hydrogen aircraft, the electrical system is the propulsion system. That single change reorders the entire skillset.

Mechanics must become comfortable with inverters, motor controllers, contactors, and liquid cooling loops, as thermal management becomes a flight-critical system. Diagnostics shift from physical inspection to data interpretation — reading logged parameters, cell balance, impedance trends, and thermal history. Firmware and configuration control become maintenance actions with direct airworthiness consequences, while bonding, shielding, and EMI control move from housekeeping to safety-critical mandates.

High voltage (800 to 1200 volts DC) leaves zero margin for error. Stored energy in a battery cannot simply be switched off, making standard lockout/tagout incomplete. Mechanics need arc flash awareness, PPE discipline, insulated tools, and insulation resistance testing on high-voltage harnesses.

Aviation also introduces challenges automotive training ignores: dielectric strength falls with altitude, making creepage, clearance, and partial discharge behavior critical, while thermal runaway in a confined fuselage requires entirely different containment strategies.

For hydrogen, instincts built around Jet A must be unlearned. Hydrogen is odorless, colorless, buoyant, and ignites across a wide concentration range with an almost invisible flame. Technicians need leak detection instrumentation, line purging and inerting procedures, an understanding of hydrogen embrittlement, and strict torque discipline.

For liquid hydrogen, add cryogenic handling, cold burn protection, boil-off behavior, and fuel cell stack health management. The talent for these systems exists today in automotive traction, industrial gas, rail, and space launch, but it doesn't hold an A&P certificate. The industry must deliberately create pathways for lateral entry rather than expecting traditional schools to start from scratch.

Anaïs Cateni-Cauderan: Technicians will increasingly combine traditional aircraft maintenance skills with electrical safety, energy-system knowledge, software diagnostics, and isolation procedures.



Additional system-specific authorization, training, protective equipment and dedicated tooling will need to be considered for maintainers of these future aircraft. Beyond Aero image.

For hydrogen-electric aircraft, relevant competencies must encompass high-voltage awareness, electrical shock hazard prevention, safe de-energization, and lockout/tagout procedures using insulated tools and proper PPE. Mechanics must understand systems that remain energized after aircraft shutdown, as well as fuel-cell fundamentals spanning electrical, thermal, air, water, and hydrogen interfaces.

On the hydrogen system side, technicians require skills in hydrogen detection, ventilation requirements, leak-response protocols, ignition-source control, and high-pressure depressurization precautions.

They will also need to handle power electronics, electric

motors, cabling, and cooling loops safely, while using digital diagnostic tools to interpret system-health data and manage post-maintenance software configurations.

A useful analogy comes from the automotive industry's handling of high-voltage vehicles: mechanics should not be permitted to intervene on high-voltage or hydrogen propulsion systems simply because they hold a general maintenance qualification. Additional system-specific authorization, training, protective equipment, and dedicated tooling must be strictly required.

Aviation Maintenance: How will traditional MRO facility infrastructure need to change to accommodate cryogenic

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hydrogen storage, fuel cell testing, and large-scale battery management?

Ganzarski: Hangars were designed around Jet A, a fuel that pools on the floor, stays where you put it, and needs a controllable ignition source. Neither hydrogen nor a lithium pack behaves that way, and the building envelope must change accordingly.

Because hydrogen is buoyant, it collects at the structure's highest point. Hangars require fixed gas detection at the roof line and ceiling pockets, ventilation engineered to sweep the top volume, and updated electrical classifications for fuel-present zones. Vent stacks must route to safe discharge points, purge capability must be plumbed directly into the shop, and separation distances must be reassessed.

Cryogenic liquid hydrogen demands vacuum-jacketed lines, boil-off management, cold burn protection, and oxygen deficiency monitoring. Most facilities will not retrofit this into an existing hangar, opting instead for separate outdoor or semi-enclosed areas with dedicated permitting.

Fuel cell and high-voltage test cells require heavy electrical service, water treatment for stack loops, thermal load rejection, and regenerative load banks so energy drawn during testing isn't dumped purely as waste heat.

Battery storage requires climate-controlled, fire-rated rooms with physical separation between units, suppression tailored for lithium fires, containment for suppression water, quarantine bays for

damaged packs, and state-of-charge management infrastructure.

The overriding constraint is electrical utility service. Charging, testing, storage conditioning, and on-site electrolysis all draw heavily from the same feed. Transformer lead times and grid upgrade schedules often exceed aircraft certification timelines, making utility capacity the primary bottleneck to plan around.

Benjamin Le Drogo: For Beyond Aero, it is important to clarify that our aircraft architecture is based on gaseous hydrogen (GH₂) rather than cryogenic liquid hydrogen (LH₂).

Because we do not use liquid hydrogen, Beyond Aero does not require cryogenic insulation, boil-off gas management, cold-burn protection, or thermal-equilibrium controls. Our GH₂ infrastructure requirements focus instead on high-pressure storage, piping isolation, depressurization, leak detection, ventilation, and safe venting.

For traditional MRO facilities, the required level of adaptation depends on the task. Line maintenance activities where the fuel system remains closed could continue within existing MRO hangars using proportionate adaptations.

These include high-level ceiling hydrogen detectors, enhanced ventilation with air recirculation controls, interlocks between gas alarms and ventilation systems, grounding and bonding provisions, hot-work controls, and defined entry and towing procedures.

More detailed maintenance tasks involving fuel system openings require dedicated areas with system isolation, defueling, line inerting, external vent connections, and



"For traditional MRO facilities, the required level of adaptation depends on the task. Line maintenance activities where the fuel system remains closed could continue within existing MRO hangars using proportionate adaptations," says Beyond Aero's Benjamin Le Drogo. Beyond Aero image.

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Additionally, because our primary energy source is hydrogen rather than battery packs, MROs servicing our aircraft avoid the large-scale battery handling, charging, quarantine, and thermal-runaway infrastructure required by battery-electric fleets. The goal is adapting existing MRO facilities proportionately without recreating the entire maintenance environment.

Aviation Maintenance: What new diagnostic tools and software will technicians need to use, and how will this differ from traditional mechanical troubleshooting?

Ganzarski: The mental shift is bigger than the toolbox shift. Traditional troubleshooting is sensory and physical — looking for metal in a filter, feeling for play, smelling fuel, or borescoping a turbine section. The aircraft reveals its condition physically, and the mechanic's judgment is the primary instrument.

An electric or hydrogen powertrain does not present that way. A battery pack has no wear you can see, a fuel cell stack degrades invisibly, and a motor controller fails through software, thermal history, or electrical connectors. The system reports its health through data, shifting the technician's job from physical observation to data interpretation.

The primary tools become battery management system interfaces, cell-level state-of-health and impedance analyzers, motor controller diagnostic software, thermal imaging cameras,

insulation testers, and gas detection instruments. Much of the diagnosis occurs on a tablet or laptop connected to the aircraft.

Maintenance triggers also shift from calendar intervals to trend analysis. A cell balance drifting over fifty cycles matters far more than any single static reading within limits. This is true condition-based maintenance, requiring shops to track fleet histories over time.

Firmware versions, calibration files, and software updates become airworthiness-critical items. Loading an incorrect configuration carries consequences as severe as installing a wrong part.

Furthermore, rotatables like battery packs and fuel cell stacks require data logs that travel with the physical unit across removal, storage, testing, and secondary applications. Technicians must maintain the discipline to verify diagnostic instruments, ensuring drift or software miscalibrations don't report false system health.

Oliveira: Maintenance will become overwhelmingly data-driven because electric, electronic, and software systems control a larger share of the powertrain.

Technicians will use tools that integrate traditional maintenance documentation with high-voltage insulation testing, fuel-cell performance diagnostics, hydrogen pressure checks, power electronics health monitoring, thermal tracking, and event-history logs. Remote troubleshooting connections with OEM engineering teams and digital maintenance planning platforms will become standard.

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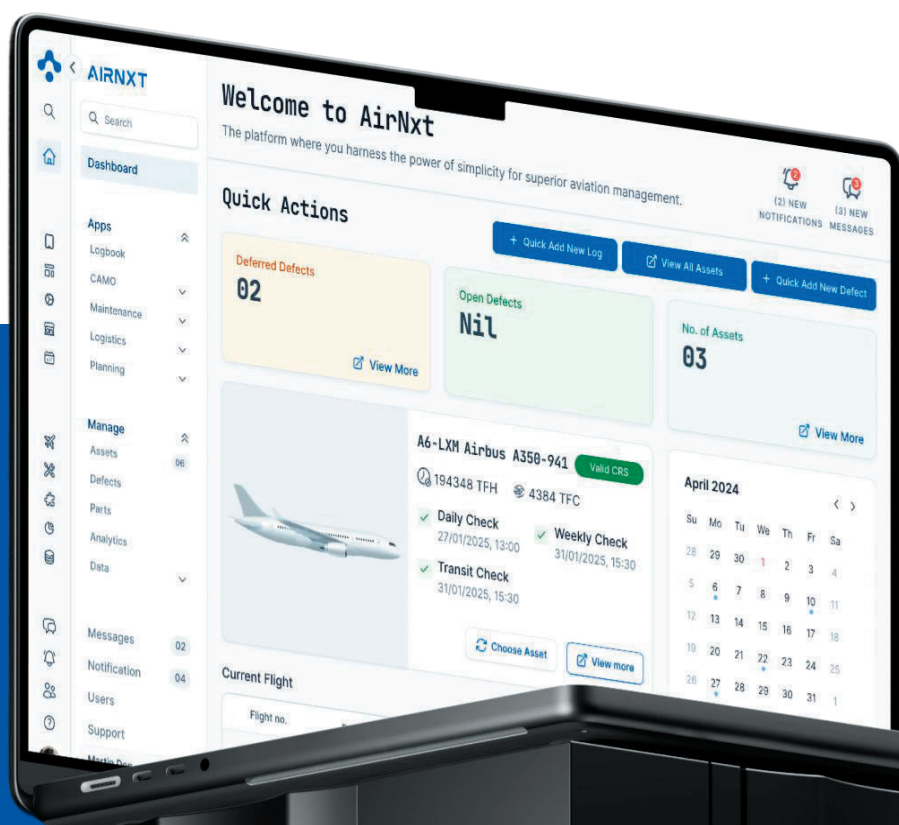
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However, more data does not automatically yield better maintenance. Excessive sensing or poorly calibrated alerting can trigger false fault codes, escalating the costly "no fault found" component removals that already burden the industry.

We place high value on predictive diagnostics and prognostic tools that help technicians isolate root causes rather than simply generating more alerts.

We also strongly advocate retaining familiar aviation maintenance conventions. Maintenance manuals should preserve established ATA-style structures and terminology, updated with digital hyperlinks between procedures, parts catalogs, and troubleshooting flows. New propulsion architectures should be easy to navigate without forcing technicians to relearn basic documentation logic.

Aviation Maintenance: How is the current industry shortage of aviation maintenance technicians impacting your strategy for training teams on these advanced, next-generation technologies?

Ganzarski: I don't agree with the premise of a labor shortage. There is no shortage of people; there is a shortage of people willing to work in aviation maintenance under the terms the industry currently offers.

The skills needed for next-generation aircraft sit in automotive traction systems, industrial electrical work, rail, industrial gas, and space launch. Those workers exist, but they choose other sectors that offer day shifts, air-conditioned working environments, competitive pay, and employer-funded training, compared to aviation's night shifts, cold hangars, and self-funded certifications.

If you fix the terms, the pipeline fills. Our strategy is to recruit people who already possess the difficult technical skills — high-voltage discipline or gas handling — and teach them the aviation regulatory and documentation layer, which is procedural and teachable. This lateral entry path is far faster than building high-voltage expertise from scratch in traditional A&P programs.

Furthermore, we are establishing job structures before fleets enter service, free from legacy shift patterns or inherited contracts. If electric and hydrogen aviation sets better workplace terms from the start, it will pull talent from both outside industries and legacy maintenance.

We should also market this sector as deep-tech rather than traditional aircraft maintenance to attract modern technical talent.

Cateni-Caudéran: The industry landscape makes simplicity and scalability critical. Our objective cannot be requiring an entirely new skillset for every routine maintenance action. We must preserve the existing technician skill base while introducing clearly defined qualifications for high-voltage, fuel-cell, and hydrogen systems.

Experienced mechanics already understand aircraft structures, flight controls, avionics, human factors, and airworthiness processes. We build on that foundation through a layered qualification model.

Under this model, conventional airframe maintenance remains accessible to existing rated technicians. Specific training modules grant authorization for high-voltage and hydrogen tasks, while deeper propulsion work is handled by specialized OEM teams or qualified network centers.

Digital diagnostics and remote engineering support allow local technicians to troubleshoot effectively without requiring specialists physically present at every station.

Training strategies must also align with workforce retention. A service center loses capability rapidly if experienced technicians leave, making workplace retention and training economics central to long-term readiness.

Aviation Maintenance: What are the biggest safety risks associated with servicing electric motors and hydrogen systems, and how should MROs prepare for them on the hangar floor?

Le Drogo: For electric propulsion, primary hazards include high-voltage shock, stored electrical energy, unexpected system energization, arc flashes, and thermal hazards in power electronics or energy storage units. For hydrogen systems, hazards center on gas leaks, flammable mixture formation, high-pressure releases, and servicing un-isolated lines.

Human factors pose an equally significant risk. New technology can induce incorrect assumptions about whether a system is isolated or safe. Conventional aviation offers many examples where technicians altered cockpit or avionics setups for maintenance without correctly restoring configurations prior to flight.

On next-generation aircraft, configuration control is paramount. Hangar floor preparation requires clearly defined safe-isolation sequences and physical verification that systems are fully de-energized, depressurized, and inert before any intervention begins.

MROs must establish hydrogen detection, adequate ventilation, control over ignition sources, and strict access restrictions for high-voltage zones.

Technicians require insulated tools, dedicated PPE, clear visual

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status indicators on the aircraft, and double-check verifications for safety-critical interventions to ensure the aircraft's state is completely unambiguous to everyone nearby.

Aviation Maintenance: Finally, what is the single most important step a traditional MRO provider should take today to make sure they are ready when these new aircraft officially enter the market?

Oliveira: The vital step for MROs today is building competency frameworks in early partnership with aircraft OEMs, rather than making heavy investments in hydrogen equipment prematurely.

MROs should focus first on identifying which existing skills remain applicable, mapping new competency needs, defining tasks that require special authorizations, and outlining future tooling requirements.

Beyond Aero is taking action by working with engineering institutions like ISAE-SUPAERO in Toulouse to anticipate the skills hydrogen-electric aviation will demand and translate them into tangible training pathways.

Market adoption will depend heavily on whether operators

believe aircraft can be supported quickly when an issue arises.

For an MRO, true readiness means building technical competence while preparing the broader operational ecosystem: trained personnel, approved procedures, parts access, digital diagnostic links, and rapid escalation pathways to the OEM. The strongest model brings the traditional MRO ecosystem into the development process early, building on decades of established maintenance experience.

Ganzarski: The single most critical, unaddressed challenge is battery cell provenance.

In traditional turbine engines, major components like discs are large, high-value, individually serialized parts produced by a small set of tightly regulated suppliers. A battery pack, by contrast, contains thousands of low-value cells drawn from commodity supply chains that aviation does not control, where gray-market and counterfeit channels thrive.

Substandard turbine parts typically degrade gradually, allowing inspection cycles to catch them. A defective battery cell undergoes thermal runaway, propagating violently to adjacent cells and causing an uncontained event in flight. No borescope or

visual inspection can detect a compromised cell in advance.

The industry cannot rely on paper certificates, serial numbers, or barcodes for traceability. As recent engine parts documentation scandals proved, paper proxies can be forged or transferred to uncertified items.

Because battery packs will be rotables swapped, leased, pooled, and transitioned into second-life storage, every handoff creates risk. MROs need physical, object-level authentication technologies that permanently bind the physical item to its digital record, ensuring verification does not depend on trusting paper documentation. **AVI**

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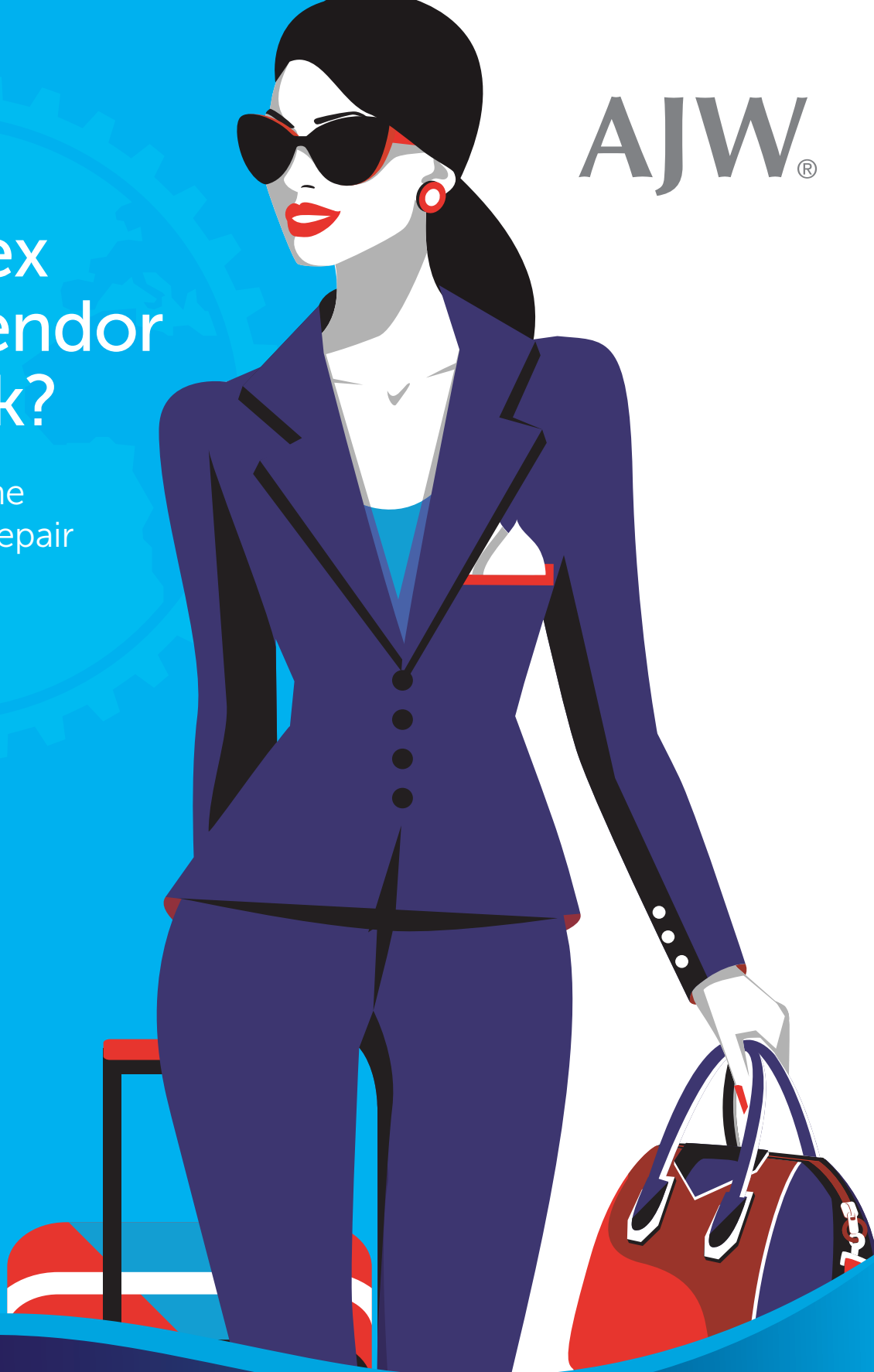


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