
InFlight

Liebherr-Aerospace Magazine
2021 / 2022

LIEBHERR





Nicolas Bonleux, Francis Carla, Alex Vlieland, Martin Wandel, François Lehmann (from left to right)

Dear Reader,

As our world progressively emerges from the pandemic, our rail transportation and aerospace industries are showing signs of recovery. While the pace of the recovery will be quite diverse depending on our planet's many countries and regions, all the signs indicate that the fundamentals of both industries are quite solid over the long term, provided we are collectively able to address the challenges we are faced with: health protection, environmental sustainability, uncompromised quality, and cost-efficiency.

We are optimistic that our company is on the right track to bring its contribution to the coming growth.

With the remarkable engagement of our team worldwide, we have been able to protect the health and safety of our employees as much as possible, while also being able to continue supporting our customers and partners throughout the past months. In order to weather the turbulences, we had to revise our plans; we are now planning the gradual return to pre-pandemic mode. We pay particular attention to our global supply chain that we support so that it is in a position to sustain the upcoming growth.

In addition, this crisis offers the opportunity to make a significant contribution to a more viable world, more sustainable rail transport, and more sustainable aviation, in particular by accelerating the deployment of highly efficient, drastically lower CO₂ emissions models and technologies.

We have always been focused on long-term success and we will continue to be a major system supplier, contributing to the future of the transportation and the aerospace industries with our technologies, our operations, and our team worldwide. The company has shown much resilience in countering this exceptional crisis, while at the same time shaping a robust future.

We wish our customers all the very best, and would like to thank our employees and our business partners for this joint achievement.

We trust you will enjoy reading this magazine, which features numerous exciting examples of the many successes we have achieved over the last months. It also provides a unique overview of the potential of our technologies.

Best regards,



Nicolas Bonleux
Chief Commercial Officer



Francis Carla
Chief Technology Officer



François Lehmann
Chief Financial Officer



Alex Vlieland
Chief Services Officer



Martin Wandel
Chief Operating Officer

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Dear Reader,
 Since this magazine is reversible,
 please flip it over in order to read OnTrack,
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Also online:
 InFlight is also available at liebherr.com
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The World with Liebherr

Find out more news from Liebherr in this chapter in the other half of this reversible magazine.



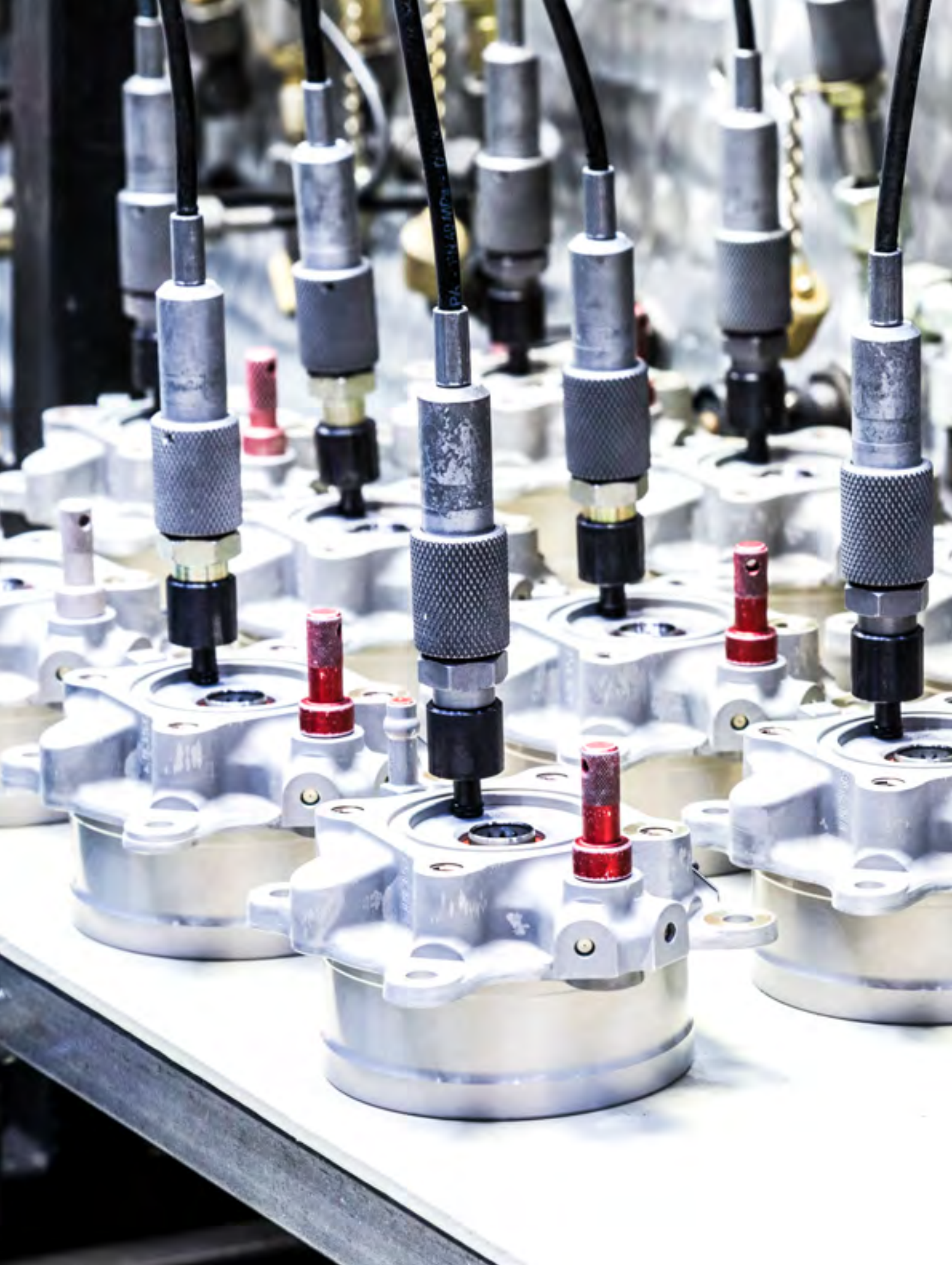


Impressions

The decisive cut

Liebherr-Aerospace uses cutting-edge laser technology to manufacture high-precision parts. The technology is so flexible that it enables a variety of manufacturing processes – such as marking, welding, cutting – for various materials, such as metals and ceramics. The power density is 300 times that of lightning, so high that materials evaporate quickly. The material processing laser is used to cut high-precision holes and contours needed to manufacture flight control components.







No pressure!

Several pressure-off brakes are connected to a low-pressure bank in order to detect any leaks. Each brake consists of 45 individual parts and is assembled manually at Liebherr-Aerospace in Lindenberg (Germany). The component is part of the power drive unit of the slat and flap systems on board a medium-range aircraft. It is a special brake: Unlike, for example, in a car or on a bicycle, no braking effect is achieved by actuating it. The brake is released only when there is no pressure.





Keeping the right balance

Compressor and turbine wheels are key parts of the turbomachinery used in aircraft air-conditioning systems. They provide the compression and expansion stages of the air cycle cooling process. Rotating at very high speeds, from 30,000 to 85,000 rpm depending on their application, they require very high-precision machining and balancing.

Industry Information

A robot changes manufacturing tools during the production process of landing gears. Up to 250 compartments are available in the machine's own tool magazine



The pandemic effect

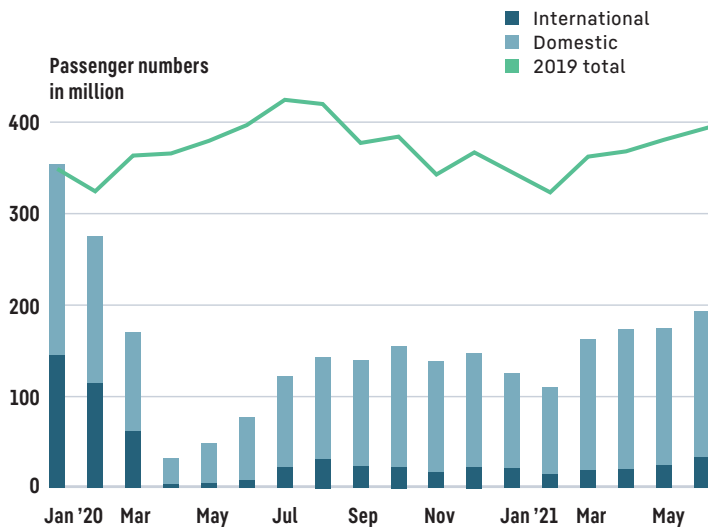
The COVID-19 pandemic brought about such an abrupt change in travel demand that it is still unknown whether or not the demand for air travel will ever return to pre-pandemic levels. Even if the industry does manage to make a full recovery, it will be a steep uphill battle. In fact, McKinsey & Company and others predict that air traffic will not return to 2019 levels before 2024.

Unlike any previous financial crisis, this health crisis has actually changed consumers' behaviors perhaps permanently. Business travel came to a screeching halt and virtual meetings have changed the demand for business travel.

Leisure travel, on the other hand, slowly started to pick up as lockdowns were lifted and more people got vaccinated. However, it is too early to estimate if or when passenger load will bounce back to pre-pandemic levels.

Aircraft manufacturers and their suppliers are also likely to be incentivized to further develop industrial policies that aim to propel the shift to alternative fuel sources, contributing to an acceleration in the development of low-carbon emissions/greener aircraft.

The key to survival as an industry will be to embrace these unavoidable changes and to seize the new opportunities that rise from the ashes, such as an increase in the development of greener technologies and innovative digital tools to ensure health and safety for travelers. The pandemic cannot be simply erased or forgotten, and it will be the companies that adapt to the new way of the world that see the most success.



Direct aviation jobs (at airlines, airports, manufacturers, and air-traffic-management) fell by 4.8 million (a 43% reduction compared with the pre-COVID situation).

Source: <https://airlines.iata.org/news/the-impact-of-covid-19-on-aviation> / 28 January 2021



The COVID-19 impact on international scheduled passenger traffic as seen by IATA

in 2020

(estimated actual results), compared to 2019 levels

50%

Overall reduction of seats offered by airlines

60%

Overall reduction of passengers

371 billion USD

Loss of gross passenger operating revenues of airlines

in 2021

(estimated actual results), compared to 2019 levels

35% to 38%

Overall reduction of seats offered by airlines

43% to 48%

Overall reduction of passengers

286-371 billion USD

Loss of gross passenger operating revenues of airlines



First digital suppliers' day

The global aviation market has been facing dire changes as a consequence of the COVID-19 pandemic. With worldwide lockdowns and travel bans in full force, Liebherr quickly became adept at conducting business remotely while socially distancing to ensure safety for all employees, customers, and partners. But, even in the midst of this universal crisis, Liebherr is still maintaining an unwavering commitment to develop and nurture trusting, long-term supplier relationships. That is why on March 17, 2021, the company hosted a digital Suppliers' Day, bringing together about 400 of its worldwide suppliers. The event was held in person in the past at both Toulouse (France) and Lindenberg (Germany) facilities.

"Going digital was a great success with a high level of attendance and engagement as our partners were eager to gain industry insights during this challenging time,"

says François Lehmann, Managing Director and Chief Financial Officer at Liebherr-Aerospace & Transportation SAS. "It was an effective platform to share short-term and long-term strategic ideas that will help our aviation ecosystem come back strong with enhanced performance and high-quality products."

He furthermore emphasized the level of cooperation, resilience, and flexibility of all suppliers, and explained that together with its partners, Liebherr will be able to make a significant contribution to sustainable aviation. The company will accelerate the deployment of highly efficient aircraft models with modern technologies and lower CO₂ emissions. In order to reach these goals, an efficient supply chain characterized by competitiveness, outstanding performances, high agility, as well as innovation capabilities, is key.



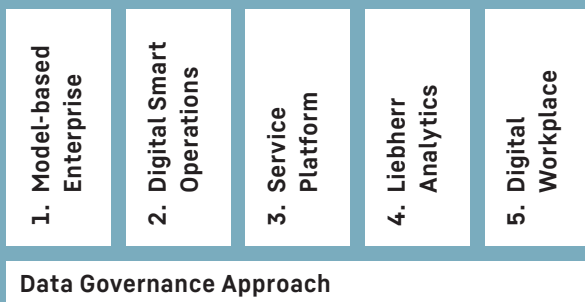
... quiet and action! Preparation of the virtual Suppliers' Day

Creating value from data

Fueling innovation has always been – and will continue to be – a top priority at Liebherr. The Aerospace and Transportation Division has launched a Digital Transformation initiative to continue to utilize technology to support the growth of the division. At the very core of the company’s initiatives lie two questions: “How will this innovation help us deliver on the promise to provide high-quality products and services to our customers? What will bring the greatest value for customers?”

Over the years, Liebherr has invested in disruptive technology to further enhance its competencies in a few key strategic areas. Its Digital Transformation is articulated around:

Digital Transformation



They are the foundation to transforming the way the company works today in order to increase efficiency and to create additional value for customers.

The first project, and maybe the most ambitious one, is the **Model-based Enterprise**. This project aims to implement Digital Continuity and the Model-based Approach for all product lines of the division. The project will create a new way of working from product development to manufacturing and customer support. Several initiatives have already been launched, such as the “3D Master Product” project that uses 3D models to direct machining and inspect parts.

For **Digital Smart Operations**, various innovations were launched both on the Liebherr-Aerospace OE and on the MRO side. One recent example is the Remote Assistance Technology that virtually assists the teams. This technology has been tested in the facilities in Singapore and Shanghai (China). In addition, Liebherr is evaluating the implementation of a Manufacturing Execution System (MES) to digitalize and interconnect several functionalities on the shop floor.

A new interface platform for customers was launched in May 2021 within the project **Service Platform** and the first services are available through a Web interface. With this platform, each customer is able to check the status of repair orders, request technical support, or download the Components Maintenance Manuals (CMM) from the account. More services are in development including online purchases.

In order to support the development of the **Liebherr Analytics** solution, a data platform hosted by Liebherr-IT Services has been set up to store airlines’ data of Liebherr-Aerospace’s products. The data is processed with algorithms developed by Liebherr’s Data Lab in coordination with the Liebherr-Aerospace engineering departments to monitor and anticipate failures of systems and components. It allows the company to proactively provide better services to the customers. This data platform, called “Artic,” has been operational since early 2021.

Finally, in collaboration with Liebherr-IT Services, the **Digital Workplace** program aims to develop several more efficient tools facilitating collaboration and knowledge sharing.

The five pillars will be supported by a strong transverse **Data Governance Approach**, conciliating the promises of the latest data valuation innovation with the key challenges of data protection in regards to ethics, commitments, and regulations.

Liebherr strives to strike the perfect balance between strong, personal human interactions and a seamless digital customer journey experience to increase efficiency and quality of services provided. The objective is to augment positive customer and employee experiences with digitalization and not to replace human interaction. The pairing of cutting-edge technology and efficient processes, with a customer-centric, highly trained staff, will continue to satisfy customers.

Deepening cooperation between Liebherr plants

“Collaboration divides the tasks and multiplies the results” is something that Liebherr really gives credence to. At first glance, the Aerospace and Gear Technology divisions do not seem to have too much in common, but, when taking a closer look, the precision of Liebherr’s gear technology was the perfect match for the strenuous requirements of the aviation industry.



Getting ready for transport: The new gear-grinding machine LGG 280 “hovers” to its destination

A culture of cooperation is the linchpin of growth and success. Being a global, diversified organization is a major advantage: the Liebherr Group can leverage knowledge and resources from one industry (and location) to another. With that in mind, Liebherr-Aerospace in Friedrichshafen (Germany) and Liebherr-Verzahntechnik in Kempten (Germany) joined forces and pooled their expertise as leading manufacturers of gearboxes and machine tools. Together they adapted the new gear-grinding machine LGG 280 to be able to grind very small and high-quality components that meet the high-precision requirements of the aviation industry.

The new generation machine is suitable for processing all gears up to 280 mm diameter. In addition, workpieces can be machined to 650 mm in length. The machine combines short grinding times with consistently high-quality and high-volume operations.

Cooperation requires the razor-sharp concentration of Liebherr teams in various locations and capacities. It is the result of a long process. For example, the grinding wheels of the machine – called CBN wheels – are an important component of the assembly, and they are manufactured within the Liebherr Group in yet another location – the Ettlingen plant, about 260 kilometers north of Friedrichshafen.



The LGG 280 machine at its new home in the production hall of Liebherr-Aerospace in Friedrichshafen

The LGG 280 machine is now manufacturing planetary gears, also known as epicyclical gears, which are a perfect fit for a variety of aerospace applications with their high tooth and surface qualities.

Another extraordinary example of cooperation was the high-capacity machine jointly developed by teams at Liebherr-Verzahntechnik and Liebherr-Aerospace Toulouse SAS (France). The new five-axis machining center with a Rotary Loading System (RLS) has been installed in Liebherr-Aerospace's facility in Campsas (France). It features a six-wheel tool magazine, which contains 363 cutting tools. It is equipped with a 52 kW/430 Nm milling spindle that can rotate at 12,000 rpm. In addition, an IoT connector package enables real-time monitoring of the equipment and remote maintenance. The RLS can lift up to 1.5 tons, stores up to 15 workpieces in its cell and guarantees autonomy as well as production flexibility with different control modes.

The Liebherr organization as a whole greatly benefits from this exchange of internal know-how. The incorporation of the new machines into the aerospace production line is a good example of synergies achieved as a result of the company's diversified capabilities and efficiencies gained in internal knowledge transfer. Optimal conditions were successfully created to fulfill the unique requirements of aviation customers.



The new high-capacity five-axis machining center with a Rotary Loading System at Liebherr-Aerospace in Campsas



Research & Development

Liebherr is carrying out research under the Clean Sky umbrella. This ESTER landing gear test rig is part of it



Latest news from Clean Sky

Amid the many new challenges brought by the coronavirus pandemic, the European Union finished 2020 with a strong positive review and outlook of its ambitious program for making air travel cleaner, safer, and more efficient: the Clean Sky Joint Undertaking. As part of the EU's Horizon 2020 program, and in alignment with the European Green Deal, Clean Sky aims to obtain reductions of 20-30 percent in CO₂/NO_x and noise emissions compared to current state-of-the-art aircraft by 2024. Liebherr-Aerospace, as a leading supplier of systems for the aviation industry for more than six decades, is carrying out research under the Clean Sky umbrella on several fronts:

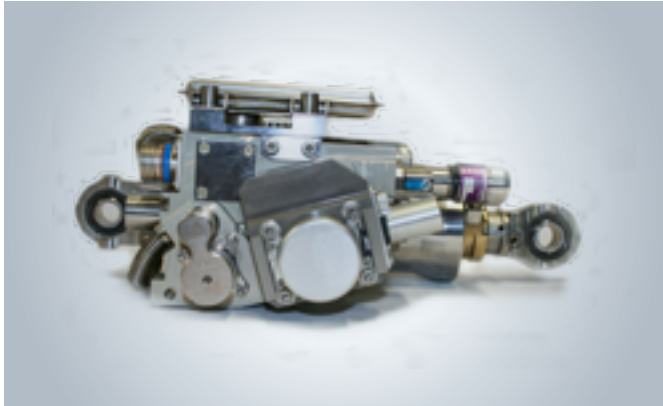
Electrical Environmental Control System (eECS)

The next-generation Electrical Environmental Control System (eECS) for large aircraft is designed to provide reliable air supply, and to ensure optimized thermal control and cabin pressurization for the crew and passengers on board an aircraft. The concept developed by the Liebherr-Aerospace team in Toulouse (France) uses air from outside the aircraft (ambient air), in order to process it for both pressurization and air-conditioning – lowering fuel consumption and emissions, and obtaining higher economic efficiency.

Smart Integrated Wing Demonstrator

The Smart Integrated Wing Demonstrator is located at Liebherr-Aerospace's German site in Lindenberg (Germany), and it is utilized to test a number of innovative technologies that contribute to cleaner skies. The universal control system runs at the heart of the demonstrator. It is able to integrate all flight control functions via a decentralized digital network. Not only can the network attach any new equipment very flexibly, it can also guarantee the safety and redundancy levels required in critical aerospace systems.





Flight control actuator with REU on top

The demonstrator includes Remote Electronic Units (REU) and flight controls containing current and future actuation technologies with electrohydraulic servo (EHSA), electro-mechanical (EMA), and electrohydrostatic (EHA) actuators, all equipped with REUs. They can be used separately and/or together to demonstrate operations of various control surfaces through the network. The network concept is estimated to save around 200 kg of mass on a large aircraft; translating directly into urgently required emissions reduction on every flight.

Further developments are underway related to power distribution and supply technologies. Future high voltage direct current supply provides power to the electrical actuation functions in a decentralized manner. The new Liebherr hydraulic power pack is about to be integrated in 2021. It is able to provide hydraulic power locally and efficiently to a number of hydraulic actuation equipment while requiring only electrical power from the aircraft. The Smart Integrated Wing platform provides a great opportunity to further develop a broad range of technologies for future aircraft while showing Liebherr's customers what their next systems may look like.

Left picture: Controller plate for More Electric Aircraft (MEA) test application

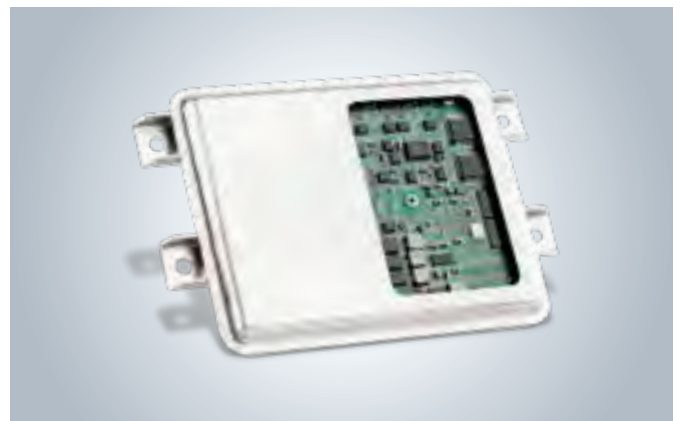
ESTER

Liebherr is a major player in landing gear structure and actuation systems. The company has been working diligently for the past few years on concepts that allow the operation of landing gears independently of a central hydraulic system, which will no longer be present in future More Electric Aircraft (MEA) architectures. The nose landing gear is a particular challenge given the number of functions that have to be performed simultaneously, such as landing gear and door actuation, unlocking, steering, and shimmy protection.

The Electrohydraulic Steering, Extension, and Retraction system – in short ESTER – was conceived to cope with these challenges, providing local hydraulic power to ensure the proper operation of the equipment. ESTER is based on the electrohydrostatic actuation technology, which Liebherr has already mastered in flight control systems.

Additional challenges associated with the landing gear application include the controllability, thermal management, maintainability, and the integration of the equipment into the landing gear itself. These challenges were identified and addressed resulting in a successful Technical Readiness Level 6 demonstration achievement. Performance, maintainability, and environmental tests were performed, and a proof of concept demonstrator is available for testing on test rigs and possibly also on aircraft. ESTER was conceived to work with other technologies being developed in parallel by Liebherr, such as the remote control electronics architecture. Furthermore, it is now ready for HVDC electrical power supply.

The projects are supported by funding from EU's H2020 Clean Sky 2 program under Grant Agreement 945535.



View inside a Remote Electronic Unit (REU)



International Focus

Liebherr-Aerospace Brasil enhances its competitiveness

Liebherr-Aerospace Brasil achieved a new milestone in the development of the company: when supplying parts to third-party customers, the company now manages its supply chain and hence increases continuously its control over the share of its performance and of its competitiveness that is linked with its suppliers.



Surface treatment of a component

Initially founded as a pure machining subcontractor, Liebherr-Aerospace Brasil gradually expanded in the past the scope of its capabilities by adding assembly of sub-components, painting, and surface treatment. This enabled it to substantially enlarge its capacity to serve its customers' needs.

The company has completed one significant additional step for parts supplied to third-party customers by building up the ability to select and manage suppliers, both domestic and international.

Liebherr-Aerospace Brasil is now fully positioned as a full-scope supplier of complex machined subassemblies to serve customers in and outside Brazil.

Liebherr-Aerospace Brasil facility in Guaratinguetá



German embassy delegates visit Liebherr-Singapore

Liebherr-Singapore Pte. Ltd. welcomed Christoph Thelen, Armaments Attaché, and Michael Kaemmerer, Defence Attaché, from the Embassy of Germany to Singapore. Their visit was hosted by Liebherr's executives Steffen Kroner, Managing Director, and Ekkehard Pracht, General Manager Aerospace.

Both guests had an opportunity to learn about the history of the facility and current operations. They were then taken on a tour to experience at first hand the broad scope of Liebherr-Aerospace's service capabilities. The delegates were very impressed with Liebherr's ongoing commitment to its customers in Singapore. This can be seen in the expansion of capabilities to include repairs of high-performance hydraulics, to the full overhaul and recoring of heat exchangers.

Since 1995, Liebherr-Singapore is home of Liebherr-Aerospace's dedicated service center in the Asia-Pacific region, providing product support and services for the products manufactured at the European Original Equipment Manufacturers Liebherr-Aerospace Lindenberg in Germany and Liebherr-Aerospace Toulouse in France.

Liebherr-Singapore is a Part 145-certified service center (for example CAAS, CAAC, EASA, and FAA). Its capabilities include testing, repairing, and overhauling components including air-conditioning, cabin pressure controls, bleed air systems, system controllers, flight control actuators, hydraulic equipment, as well as landing gear accessories.



Ekkehard Pracht (Liebherr-Aerospace), Christoph Thelen (German Embassy), and Michael Kaemmerer (German Embassy) at Liebherr-Singapore (from left to right)

Global efficiency with a local touch

There are many benefits in having regional offices – for one, it fosters strong long-term relationships with partners and customers. Local offices help the company to break down barriers of communication, language, time zones, and, most importantly, to nurture deeper relationships with customers while at the same time leveraging the synergies from the network of the Liebherr Group as a whole.

Liebherr-Aerospace's activities in Canada date back to 1993 when Liebherr-Aerospace Toulouse SAS (France) was selected as a supplier for Bombardier Aerospace's Global Express aircraft. An office to represent the Aerospace and Transportation Systems division was created within Liebherr-Canada Ltd. in 1997. The facility is located in Laval, Quebec, and currently houses a 1,400 m² (15,000 sq ft) assembly area and a 550 m² (6,000 sq ft) warehouse in addition to office space.

The office in Canada currently has 19 local employees performing a broad range of tasks: They provide technical support and logistics coordination between factories in Europe and customers' teams in various countries, such as Mexico, Brazil, the US, and Canada. Other functions performed include:

- **warehousing**
- **product quality inspections**
- **final assembly**
- **certification of products in accordance with EASA Part 21G**
- **commissioning support**
- **technical assistance at the customers' final assembly lines (FAL support)**
- **aftersales logistics support**
- **Aircraft on Ground (AOG) support services**
- **technical publications**



The office serves as a hub to optimize the flow of parts from North American suppliers to customers all over the Americas. Products are received, inspected, and stored prior to redistribution on behalf of the OEMs Liebherr-Aerospace Toulouse SAS and Liebherr-Aerospace Lindenberg GmbH. Optimized logistics create benefits such as reduction in inventory levels, transport costs, and transit times. In addition, there is a positive environmental effect as well, since parts travel shorter distances to reach customers' destinations.

Guillaume Perrin, Logistics and Customer Service Manager, explains: "My team of three warehouse workers shipped 53,000 parts to Liebherr's customers in the Americas in 2020. We also have two logistics agents ensuring that parts returned from the customers' sites for rework or repair at various suppliers all around the globe are handled swiftly and returned within agreed-upon time frames." For more than 20 years, Liebherr has provided logistics and customer support in proximity to its key customers in the Montreal area, including Bombardier and Airbus.



The team in Laval is periodically audited and recognized by French authorities to perform various logistics and support tasks on behalf of Liebherr-Aerospace Toulouse. An AS9100D-certified quality management system and an ISO 14001-certified environmental management system were put in place to ensure consistent results and enhanced performance.

As part of a global network of liaison offices, the Laval team plays an important role in Liebherr's success, addressing customer requests quickly, and working closely with the headquarters and the factories to identify new opportunities locally.



Programs & Contracts

With an intercontinental range of 5,500 nm (10,000 km), the Falcon 6X will fly from London to Hong Kong or Los Angeles to Moscow nonstop



First flight of the Falcon 6X

On March 10, 2021, the all-new business jet Falcon 6X, manufactured by Dassault Aviation, took off for its maiden flight and landed safely after a flight lasting two and a half hours at Bordeaux-Mérignac (France).

“Developing a new program comes with a long list of challenges; therefore, choosing the right partners is critical to our success,” said Vadim Feldzer, Head of Falcon Global Communications at Dassault Aviation. “Liebherr brought ingenuity to the program with unmatched dedication and commitment to our success. Our flight team was extremely impressed with the 6X’s precise performance and handling. We are energized to continue pushing forward with our test program and to have the aircraft enter service in 2022.”

Liebherr delivered the integrated air management system as well as the cabin air humidification system for this long-range aircraft. All were developed by Liebherr-Aerospace Toulouse SAS, Liebherr’s center of excellence for air management systems.

The relationship between Liebherr and Dassault is seven decades strong with Liebherr developing, manufacturing, and servicing major systems and components for various Dassault aircraft, including all members of the Falcon family, such as 7X, 8X, 900, 2000/2000EX and the 50EX.

It is all “thumbs up” after the successful first flight of the Falcon 6X!



Unveiling Dassault Aviation's new Falcon 10X business jet

On May 6, 2021, the Falcon 10X was launched by Dassault Aviation, and Liebherr will supply major systems and components for the all-new business jet. These include the integrated air management system supplied to Dassault Aviation and landing gear components supplied to Héroux-Devtek.



© Dassault Aviation

The Falcon 10X, the latest business jet from Dassault Aviation

Liebherr-Aerospace Toulouse SAS (France), Liebherr's center of excellence for air management systems, is responsible for the Falcon 10X's integrated air management system. This major work package covers the bleed, air-conditioning, cabin pressure control, air preparation, overheat detection, and wing anti-ice protection systems.

Building on the architecture of the Dassault Falcon 6X air management system also supplied by Liebherr, this new package provides a combination of robust and proven equipment along with new Liebherr component technology developments. One example is the introduction of smart valves developed by Liebherr, which offer increased digital control, opening the door to system-control optimization and increased product health management.

Furthermore, the Liebherr-Aerospace team in Lindenberg (Germany) was commissioned by the Canadian company Héroux-Devtek to supply landing gear actuation and steering components for the Falcon 10X. Based on its experience, Liebherr was able to offer the business jet the latest technology based on the newest environmental requirements within a very short time.



© Dassault Aviation

Comfort on board the Falcon 10X – example of an interior layout

First delivery of stand-alone electronics systems

The Liebherr team has reached a major milestone with the delivery of the first engineering prototypes of the Nose Wheel Steering Remote Electronic Unit for the Boeing 787 Dreamliner and Main Gear Steering Control Unit for the Boeing Model 777 family of aircraft.

Liebherr started the program for the Boeing 787 Nose Wheel Steering Remote Electronic Unit and for the Boeing 777 Main Gear Steering Control Unit in the second half of 2018, followed by the in-time design and the implementation phase. The company provided the first engineering prototype units for testing at Boeing in February 2020, after intense testing at the Liebherr facilities.

This marked the first time for Liebherr to supply stand-alone electronics, and the company is very happy and proud to share this historic milestone with its customer Boeing. Stand-alone electronics is electronic hardware with a software operation system, as well as application software to integrate into dedicated aircraft systems.

Boeing engineers successfully carried out development tests and continue to perform testing to confirm the correct operation of the components. The Boeing and Liebherr teams are working closely together on the final reviews and preparation for qualification testing.

The high level of functionality and maturity of the Liebherr products is already evident from the engineering tests completed, which will support a successful qualification phase in advance of Liebherr's serial release and Boeing's subsequent entry into service on the 777 family and the 787. The teams are very satisfied with the progress to date, underscored by a successful Critical Design Review between Boeing and Liebherr; a great basis for further Liebherr stand-alone electronics system projects.



© Boeing

Boeing 787 Dreamliner

Landing gear actuators for Boeing's 777 and 777X aircraft



© Boeing

The Boeing 777X is the latest series of the long-range Boeing 777 family

Since the contract for the power-control actuator of the 777 and 777X's main-gear steering components was signed in 2018, Liebherr and Boeing have been working diligently to design, manufacture, and test the new actuator. The first delivery of two units to Boeing's lab last year marked a major milestone for this built-to-print project. A dedicated team of manufacturing and qualification engineers has been working meticulously to ensure that this new actuator exceeds all requirements.

Liebherr-Aerospace will manufacture these parts specifically for Boeing's 777 and 777X programs. Liebherr's competence center for flight controls, gears, gearboxes, and

landing gears, Liebherr-Aerospace Lindenberg GmbH, was selected to manufacture and test the actuator because the company understands that cost-effectiveness, quality, and efficiency are the linchpins of successful long-term partnerships.

The power-control actuators are part of the main gear steering system. They support taxi maneuvers of the aircraft and reduce tire wear. Together, with the main gear steering control unit and the nose gear steering position transducer, Liebherr supplies the complete main gear steering system.

Air preparation subsystem for A321 Extra Long Range (XLR) fuel tank inerting system

Liebherr-Aerospace was selected by Parker Aerospace based in Irvine, California (USA) to design, develop, produce, and service the air supply subsystem for the fuel tank inerting system (FTIS) for the Airbus A321 XLR program.

The FTIS decreases the probability of fuel combustion in the fuel tanks on board an aircraft. The air supply subsystem's purpose is to supply air at the required pressure and temperature to enable the optimized operation of the inert gas generation membrane. The subsystem consists of compact, lightweight, and highly reliable components. It will be designed and produced at Liebherr-Aerospace Toulouse SAS, Toulouse (France), Liebherr's center of excellence for air management systems.

Liebherr has vast experience in air supply subsystems for the FTIS of the Airbus A320 family and the A330 family, as well as a wide array of other aircraft programs such as Embraer's E-Jet E2 and COMAC's C919.

This know-how and experience in pneumatics is evidenced by the fact that Liebherr components are present in most of the commercial aircraft programs that entered service over the last two decades: pneumatic valves, heat exchangers, compressors and turbines, and associated controls that are employed in engine pneumatics, engine bleed air systems, air-conditioning systems, or fuel tank inerting systems.

The Airbus A321 XLR will fly with Liebherr technology on board



Outstanding performance in COMAC's ARJ21 program

Liebherr-Aerospace's long-time customer COMAC recognized the company's outstanding performance for the air management system on board the ARJ21 aircraft at COMAC's Supplier Conference held in October 2020 in Shanghai (China). Liebherr was honored to receive the "Year On-time Delivery Excellence Award." The award is a testament to the company's commitment to on-time deliveries and to its rapid response to the customer's needs.

Additionally, Liebherr received the prestigious "2020 Supplier of the Year – Performance Excellence Gold Award" at COMAC's Global Supplier Conference in April 2021, held in Nanchang. The award was in recognition of excellence in the air management system for the ARJ21 aircraft program as well. COMAC also highlighted Liebherr's first-class performance amidst the COVID-19 pandemic and the continuous improvement of quality in its work.

Beside the integrated air management system, Liebherr-Aerospace is also responsible for the development, manufacture, and support of the landing gear system for the ARJ21.

Liebherr has been in the Chinese market since 1978, with Liebherr (China) Co., Ltd. as a regional headquarters based in Shanghai. The company has developed a local footprint for its aerospace activities with a liaison office and MRO facility in Shanghai and a joint venture with AVIC LAMC in Changsha – Liebherr LAMC Aviation (Changsha) Co., Ltd. – supplying landing gears for the ARJ21 and C919.



Representatives of AVIC Special Aircraft Research Institute and HIWING, as well as Yu Zemin, General Manager of SAMC and Julien Moll, General Manager – Aerospace Division, Liebherr (China) Co., Ltd. (from left to right)



Julien Moll, General Manager – Aerospace Division, Liebherr (China) Co., Ltd., Yuerang Zhao, Vice Chairman, President and Deputy Secretary of the Party Committee of COMAC and a representative of AVIC SAC Commercial Aircraft Co., Ltd. (from left to right)

Among the best suppliers of Embraer



Embraer's Supplier Awards lined up for the ceremony: Liebherr was honored to receive awards in two categories

The pandemic has changed the way business is conducted, but it certainly has not changed the commitment of Liebherr-Aerospace to excellence. "We are very grateful that once again we were recognized by our valued customer Embraer as Best Supplier in not one, but two categories," says Nicolas Bonleux, Managing Director and Chief Commercial Officer at Liebherr-Aerospace & Transportation SAS.

Due to the pandemic, the Suppliers Conference took place virtually on December 18, 2020. Liebherr-Aerospace Toulouse (France) received awards for "Best Supplier Development Programs" and "Best Supplier

Mechanical Systems," which are a testament of the company's unwavering commitment for technological and operational excellence. They materialize the relentless effort that both Embraer's and Liebherr's teams have been investing into the very high quality of their relationship.

Liebherr-Aerospace Toulouse SAS (France), Liebherr's center of competence for air management systems, develops, manufactures, supplies, and provides customer services for various systems and components to several programs of Embraer, including the E-Jet E2 family, the ALX Super Tucano, the Praetor 600, and the C-390 Millennium program.

The world's largest aero engine

By the end of 2021, Rolls-Royce will have completed the first UltraFan® demonstrator, which will be the world's largest aero engine. One of the key components of this new engine is the power gearbox, which is developed in a partnership between Liebherr-Aerospace and Rolls-Royce.

The demonstrator will have a diameter of 140 inches. The UltraFan offers an impressive improvement of 25 percent in fuel efficiency for the next generation of narrow body and wide body aircraft, when compared with the first generation of the Trent engine. The power gearbox is being developed and manufactured by the 50:50 joint venture Aerospace Transmission Technologies GmbH (ATT) that was established by Rolls-Royce and Liebherr-Aerospace Lindenberg GmbH in 2015, and is based in Friedrichshafen (Germany).

Through this joint venture, Rolls-Royce leads the design definition and design integration of the power gearbox as well as the testing activities. Liebherr brings in its expertise in the production of gears and the know-how in machining centers for gears, which the company has been developing and manufacturing for decades. ATT's objective is to produce the best aerospace power train gearboxes in the world by continuous innovation and taking gear manufacturing to new levels.

The power gearbox will enable the UltraFan to deliver efficient power over a range of take-off thrusts for high-bypass ratio engines of the future. For the highest thrust engines, each single gearbox will be capable of handling the equivalent horsepower produced by more than 500 family cars.

UltraFan® is part of Rolls-Royce's Intelligent Engine vision. For example, each fan blade has a digital twin, which stores real-life test data, allowing engineers to predict in-service performance. When on test at Rolls-Royce's new GBP 90 Million Testbed 80 facility, data can be taken from more than 10,000 parameters, detecting the tiniest of vibrations at a rate of up to 200,000 samples per second.

Source: Rolls-Royce Press Release – March 29, 2021



© Rolls-Royce plc

UltraFan® power gearbox



© Rolls-Royce plc

Carbon fiber composite and titanium fan set with a diameter of more than 3.50 meters (140 inches)

The UltraFan is based on technology that offers advantages not only in fuel burn efficiency, but also in carbon emissions, noise, and weight. The performance improvement brought by this engine will set a new benchmark – especially in a new post-COVID era of aviation where sustainability will be at the center of recovery. The first test run of the engine will be conducted on 100 percent sustainable aviation fuel.

Significant investment has been made to develop the UltraFan demonstrator and associated technologies, not only by Rolls-Royce but also by a variety of funding agencies, including the Aerospace Technology Institute and Innovate UK (United Kingdom), LuFo (Germany), and Clean Sky Joint Undertaking (European Union).



© Rolls-Royce plc

Working on the UltraFan® demonstrator



Customer Service

Working at a test bench in Singapore
while being connected with colleagues
in Europe via VR glasses



Innovation in maintenance, repair, and operations

The best path for a more efficient, reliable, and safe aviation industry takes us straight to digitalization. For manufacturers like Liebherr-Aerospace, optimizing maintenance, repair, and overhaul (MRO) through innovative digital solutions can help not only to bring down costs but also to reduce the environmental impact of the activity.

Engaging in a framework that uses the power of digital tools to enable exploration, adaptation, and, in some cases, the development of technologies to streamline operations and improve efficiencies across functions is key. Especially in MRO, where Liebherr has to manage, for example, more than 40,000 component repairs and 100 landing gear overhauls a year through its worldwide service network.

Building local test capabilities with smart glasses

As part of the strategy to expand its MRO capabilities, Liebherr has started using remote assistance technologies within the scope of the “Smart MRO” initiative. Smart glasses, for example, enable teams at different locations to share information in real time. They allow employees to work on the objects with both hands while their colleagues follow the procedure via a camera positioned next to the eye of the colleague performing the work steps. And instructors are able to direct colleagues using the smart glasses.

Smart glasses were used when a team of Liebherr engineers in Shanghai (China), built a new test rig for air management system components of the COMAC aircraft programs ARJ21 and C919. Their colleagues located in Toulouse (France) supported them. At around the same time, the team in Singapore worked on a new high-performance hydraulic test cell to enable local test capabilities for Airbus A350 flap and landing gear actuators. Also here, colleagues from Lindenberg (Germany), Liebherr’s center of competence for flight controls, landing gear systems, gears, and gearboxes, and electronics were able to offer guidance via these remote assistance technologies.

Encouraged by the consistent positive feedback received from the teams involved, the company intends to pursue an expansion of the project to more employees at all of its locations worldwide. The next step will also be to enable this type of digital communication with customers.

Liebherr Analytics in service

With its design knowledge and in-service experience, Liebherr-Aerospace is cross-processing aircraft data with its own manufacturing and repair shop inputs. The company’s objective is to create value for the aircraft operators. Using Liebherr Analytics Solutions will increase aircraft availability, reduce unscheduled maintenance burden, and help to optimize assets and part maintenance.

With Liebherr Analytics, the company can expand the database of its products, especially by flight data provided by its customers, i.e. aircraft operators. These data flow into the further development of Liebherr’s analytical services, including, for example, predictive maintenance, improved data management, and more efficient service for individual problems. The feedback on the behavior of Liebherr products in use is extensive.





Smart glasses make it possible: A colleague in Shanghai (China) shows his teammates in Toulouse (France) in real time a part of the new test rig for air management system components

The data platform "Artic" guarantees the customers data security and the agreed-upon use. It can collect and manage data of 1,500 aircraft. To date, data from more than 300,000 flights of 300 aircraft have been collected to support the development of Liebherr-Aerospace's digital solutions from which its customers will benefit.

A first version of the platform is already operational and used at Liebherr-Aerospace's Toulouse site in France to supervise the Airbus A220 fleet on a daily basis and to issue recommendations for the replacement of bleed equipment to airlines. Furthermore, the tool is able to analyze data from the landing gear and flight control product lines developed by the OEM Liebherr-Aerospace in Lindenberg (Germany).

New customer service platform

Liebherr-Aerospace has also recently launched a customer service platform. It introduces several brand-new functionalities and a range of training services for airlines and MROs. It also includes a new set of dedicated digital solutions to improve user experience. New features include "Repair Order Status" and "Technical Request" services as well as direct-message exchange with the company's experts. Liebherr-Aerospace will be working on additional state-of-the-art services, to be made available throughout the coming months.

Aware that aviation MRO is undergoing major transformations towards digitalization, Liebherr has been, and will be, investing heavily in smart, integrated technologies for the benefit of its customers. The company will continue to bring customer service to the next level.

Three major overhaul contracts

Throughout 2020 and 2021, Liebherr-Aerospace struck up partnerships with three airlines to perform overhauls on the landing gears of their Embraer E-Jet aircraft family. The contracts mark significant steps forward in the company's successful worldwide landing-gear-overhaul campaign.

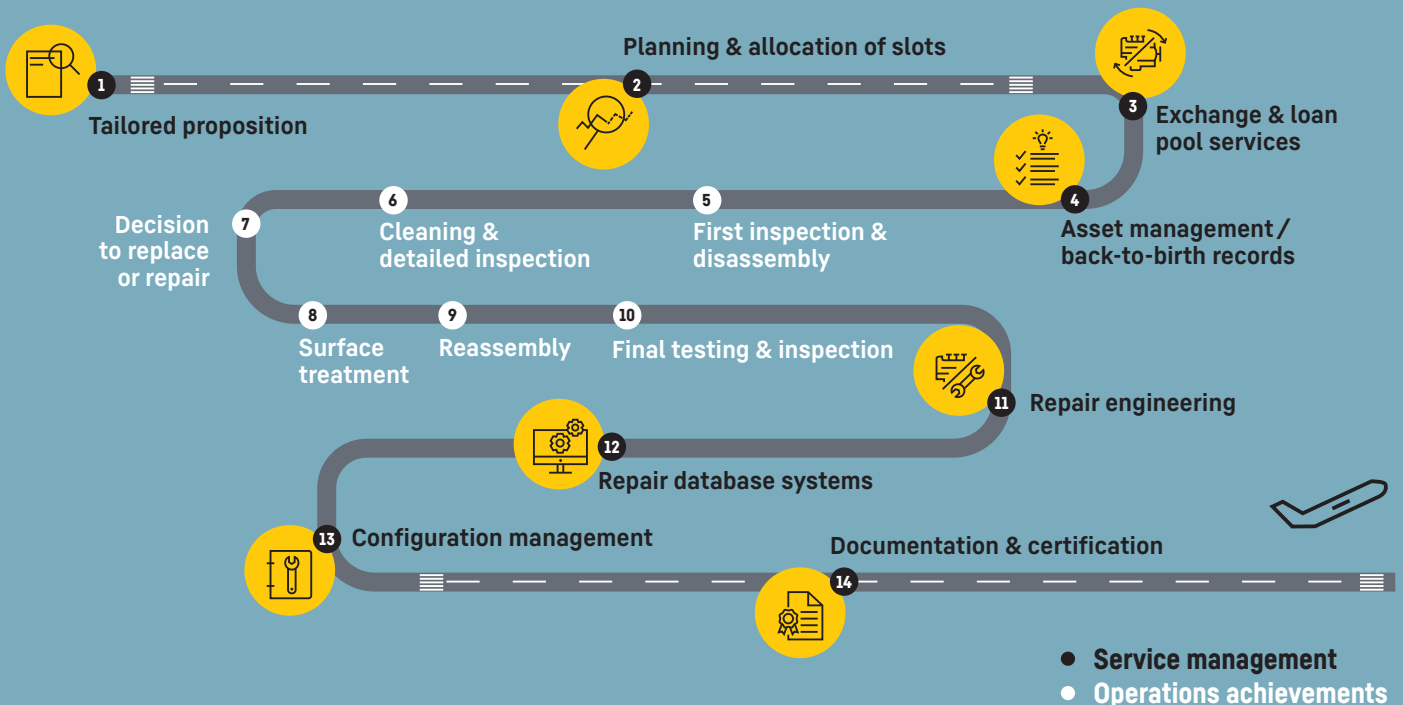
First, Austral Líneas Aereas selected Liebherr-Aerospace to overhaul the landing gears of the airline's Embraer E-Jet E190 fleet. It is the first major contract for Liebherr in Argentina, and the overhaul activities started in July 2020 by Liebherr-Aerospace's customer service facility in Saline, Michigan (USA).

This major contract with Austral (affiliated with Aerolíneas Argentinas) highlights the customer proximity that Liebherr-Aerospace has been developing in Latin America with its liaison office in São José dos Campos (Brazil). Austral is the biggest domestic airline in Argentina, also serving destinations in Brazil and Uruguay.

Next, Liebherr-Aerospace signed an agreement with Austrian Airlines, Austria's biggest airline and member of the Lufthansa Group. The goal is to overhaul the landing gears of the airline's 17 Embraer E-Jet E195 aircraft, with the first landing gear already delivered at the end of December 2020 at Liebherr-Aerospace in Lindenberg (Germany).

All good things come in threes: in early 2021, Portugália Airlines and Liebherr-Aerospace entered into an agreement covering the overhaul of the landing gear systems on board the airline's 11 Embraer E190/E195 aircraft. The campaign is scheduled to begin in 2022 and end in 2024.

The complete landing gear system for the E-Jet E1 family (E170/E175/E190/E195) has been developed, manufactured, and certified by Liebherr-Aerospace Lindenberg GmbH, Liebherr's center of competence for flight controls, landing gear systems, gears, and gearboxes, as well as electronics. These major contracts are a testament to the trustworthy service level regarding landing gear overhauls executed by the Liebherr-Aerospace teams in Saline and Lindenberg.



Over 20,000 repairs in China

Liebherr's footprint in China reached a new milestone with the delivery of its 20,000th repaired unit in the region. The repair of a flow-control valve for an Airbus A320 that belongs to a Chinese operator marks this accomplishment for Liebherr in China.

Over the past five years, the company has been investing in the development of a growing range of OEM maintenance services on air management systems (ATA Chapters 21 and 36) for various airlines operating Airbus single aisle long-range as well as Bombardier and Embraer aircraft. OEM quality one-stop component maintenance services were also launched for the domestic COMAC ARJ21-700 aircraft operators.

As part of these aerospace services in China, Liebherr has built a robust team of more than 40 highly qualified employees, consisting of customer service representatives, sales, technical support, quality, procurement, and logistics experts. Additionally, its state-of-the-art MRO workshop in Shanghai is staffed with repair technicians, engineers, certifying officials, and repair instructors. The

site is fully supported by Liebherr-Aerospace centers of excellence in Toulouse (France) and Lindenberg (Germany). This strong collaboration between sites enables the extension of aerospace services for operators in the region.

Delivering the 20,000th repaired component back to a Chinese airline represents an important milestone for the Liebherr customer service team in Shanghai. Since 2016, the site has more than tripled the number of units repaired – a testament to the company's commitment to continuously supporting operators in their daily maintenance needs while adapting to a growing market. The team in Shanghai is unwaveringly committed to quality and growth, while also focused on the safe operations of China's civil aviation.



Members of the Liebherr Customer Service Team in Shanghai (China) celebrate the achieved milestone



People & Community



Liebherr helps keep a piece of aviation history in the air



Last year, the Yankee Air Museum in Belleville, Michigan (USA) reached out to Liebherr Saline Inc., Saline, Michigan (USA) with a problem and needed help. They have one of only nine airworthy B-17 “Flying Fortress” aircraft left in the world, and it needed some welding repairs to keep it in the sky. With a skilled welding department able to do much more than only repairing Liebherr components, the Liebherr-Aerospace team in Saline was willing to do what it could to keep the B-17 flying.

The B-17 was a heavy aircraft that played a key role in World War II, used by both the British Royal Air Force and the United States Army Air Corps. There were 12,731 of these planes produced between 1936 and 1945. The B-17 got its nickname “Flying Fortress” due to its size and firepower. The plane in the museum named “The Yankee Lady” has a wingspan of 103’9” (31.62 m), a length of 74’4” (22.78 m), and a height of 19’1” (5.82 m). It is powered by four 1,200 hp Wright R-1820-97 “Cyclone” turbo-supercharged radial engines. It was able to fly at a top speed of 287 mph (462 km/h) and a cruising speed of 160 mph (257 km/h) with a full crew of ten people.

The task was to develop a welding repair for the turbo housings (nozzle boxes) and bucket wheels. There are no longer parts available to replace the damaged ones. Jay Roberts, Welding Program Coordinator at Liebherr in Saline, took the lead on this project. He wrote a Welding Procedure Specification based on material type and other essential variables per AWS D17.1 Fusion Welding for Aerospace Applications. Once the procedure was developed, he repaired over eight units for the museum. The last step for the qualified repair was the weld inspection. All units were sent to a third party for a weld inspection by X-ray. All eight units passed inspection and were deemed airworthy. With the repaired housings installed, all checks and systems passed, the old girl was ready to fly!

“I got to be part of the crew and fly in this plane; this was one of the most amazing flights I have ever been part of. The roar of the engines, the feeling of power, the history is like no other,” commented Jay proudly of his experience after being on board the Flying Fortress.

“Without the help of Liebherr and their welding department we wouldn’t be able to fly our historical planes. Thank you so much for helping us and the community.”

Rich Koski
Lead Mechanic at the Yankee Air Museum

Components repair for the B-25 and the “Tin Goose”

Since the developed repairs were successful for the B-17, Jay has also repaired some components for the B-25D and Ford 4-AT-B Tri-Motor, utilizing the same validation process. The B-25 Mitchell is a medium bomber powered by twin Wright R-2600 Cyclone engines. These engines are two-row 14 cylinder, air-cooled, supercharged radials with 1,700 hp each. The wingspan is a 68' (20.73 m) long gull wing design. Maximum speed is a fast 328 mph (528 km/h) and the cruising speed 230 mph (370 km/h). These planes were the most manufactured planes during World War II. There were 9,816 manufactured from 1942 to 1944. The B-25 at the museum called “Yankee Warrior” is one of only three that are still airworthy and that have participated in combat.

The Ford 4-AT-B Tri-Motor is a true piece of early aviation history. Ford Aircraft Division in Dearborn, Michigan, produced it from 1926 until the great depression of 1933. In the late 1920s, Ford Aircraft Division was reputedly the largest manufacturer of commercial aircraft in the world. These all-metal planes got the nickname “Tin Goose,” since most aircraft at that time had cloth coverings for the flight controls. There were only 39 aircraft produced of the 4-AT-B version and this one at the Yankee Air Museum is still airworthy. It has a wingspan of 74' (22.55 m), a length of 49' (14.94 m), and stands 11'9" (3.63 m) tall.



The plane is powered by three 220 hp Wright J-5 Whirlwind radial engines that would push it to a maximum speed of 132 mph (212 km/h) and a cruising speed of 107 mph (172 km/h). The 4-AT-B was a leader in the industry at the beginning of commercial airline flights holding two pilots and 12 passengers.

“It is a great honor to be able to work on such historic planes and keep them in the air. Working for Liebherr and the aerospace industry is giving me opportunities most people will never get to experience,” says Jay Roberts.

<https://yankeairmuseum.org/>



Environmental initiatives towards a greener future

To make a greener future possible, everyone needs to take action. Liebherr-Aerospace Toulouse SAS has launched numerous initiatives to improve its carbon footprint. Since 2014, the company has been able to achieve a 34 percent reduction in greenhouse emissions. One such initiative was the switch from regular cars towards using electric cars on both company sites – Toulouse and Campsas (France).

Liebherr-Aerospace Toulouse also aims to preserve biodiversity and has created 575 m² of flowered fallow land to attract pollinating insects. Four insect hotels and three beehives were added to this land.

The company also fosters employee engagement to become environmentally conscious by organizing annual awareness days, encouraging and supporting them to use alternative and environmentally friendly transportation to and from work.

Liebherr-Aerospace Toulouse continues to move forward with initiatives in this area and completed the installation of a 650 m² photovoltaic rooftop, which will provide significant energy savings throughout the facility.



Solar panels on one of the roofs of Liebherr's facilities in Toulouse



Liebherr for Liebherr: Balancing capacities

“At Liebherr we help each other, especially in challenging times!” Ulrich Thalhofer, Head of Human Resources at Liebherr-Aerospace in Lindenberg (Germany), has supported the initiative from the get-go. Due to the increased order volume and the introduction of a continuous shift model at Liebherr-Components in Deggendorf (Germany), there had been an additional need for personnel in production. And at that time, many employees of Liebherr-Aerospace in Lindenberg were in Short-time work.

Facing the challenges at hand, HR managers on both sides have considered lending employees to each other as a welcome solution to the underlying problem: “It was key to us to make sure we can achieve a balance in capacity as soon as possible, especially for the said employees. In order to familiarize themselves with the new working environment and the production processes in detail, the first employees arriving in Deggendorf from Lindenberg were on-site in next to no time,” says Thomas Listl, Head

of Human Resources in Deggendorf. The one crucial thing that made such an easy transfer possible was the outstanding qualification of the staff at both locations. With the help of digital communication platforms and conversations held beforehand, it was possible to coordinate the exchange in advance.

In total, 14 employees from Lindenberg have worked in Deggendorf since the start of this initiative in 2020. The exchange is purely optional and is individually limited from ten to 30 weeks. Similar exchanges also happened between the Liebherr plants in Friedrichshafen (Germany) and Biberach (Germany). “This represents a great opportunity to look beyond our own backyards and gather new experiences within the group for all of us. Furthermore, it’s just a wonderful feeling to be able to share one’s expertise with our colleagues facing current bottlenecks in production,” say Andreas Fink and Patrick Trost, who are two of the transferred employees from Lindenberg helping out.



Participation in programs

Fixed Wing Aircraft

Airbus

Airbus A220

- Integrated Air Management System
- Landing Gear System

Airbus A300-600

- Cabin Pressure Control System
- High-Lift System
- Krüger Actuator
- Latching Actuator
- Landing Gear Door Actuators
- Nose Landing Gear
- Upper Cargo Door Actuator

Airbus A310

- Cabin Pressure Control System
- High-Lift System
- Krüger Actuator
- Nose Landing Gear

Airbus Single Aisle Family ceo / neo

- Air Chillers
- Air-Conditioning System
- Avionics Cooling System
- Cargo Heating System
- Cockpit Static Inverter
- Engine Bleed Air System
- Fuel Tank Inerting System – CSAS (except A319CJ)
- High-Lift System
- High Pressure / Power Transfer Unit Manifolds
- Rudder Servo Control
- Safety Valve

Airbus Long-Range Family ceo / neo

- Air Chillers
- Air-Conditioning System
- Auxiliary Power Unit Gearbox
- Avionics Cooling System
- Engine Bleed Air System
- Cargo Heating System
- Cockpit Static Inverter (A330)
- Cargo Door Actuator
- Crew Rest Humidification System
- Fuel Tank Inerting System – CSAS
- High-Lift System
- Landing Gear Door Actuation
- Rudder Servo Control (Airbus A340 Enhanced)
- Spoiler Actuation
- Spring Strut

Airbus A350 XWB

- Flap Active Differential Gearbox
- Load Sensing Drive Strut
- Moving Damper
- Nose Landing Gear
- Slat Actuation

Airbus A380

- Air / Hydraulics Cooling System
- Cargo Heating System
- Engine Bleed Air System
- High-Lift System
- Pneumatic Distribution System
- Reservoir Air Supply Cooler
- Spoiler Actuation
- Supplemental Cooling System

Airbus BelugaXL

- Air-Conditioning System
- Conditioned Air Supply System (a subsystem of the fuel tank inerting system)
- Engine Bleed Air System Components
- High-Lift System
- Landing Gear Door Actuation
- Spoiler Actuation

Airbus (Defense and Space)

A400M

- Aileron, Elevator, Rudder Servo Control
- Air-Conditioning System
- Cabin Pressure Control System
- Door Ramp Actuation System
- Engine Bleed Air System
- Fuel Tank Inerting System - CSAS Components
- Nacelle Anti-Ice System
- Power Control Unit
- Spoiler Servo Control
- Ventilation Control System
- Wing Anti-Ice Valves
- Wing Tip Brake

Eurofighter / Typhoon

- Airbrake Actuator Servo Control
- AMAD Gearbox
- Engine-Driven Hydraulic Pump
- Filter Package Units
- Nose Landing Gear
- Nose Landing Gear Retraction Actuator
- Main Landing Gear Side Stays
- Primary Flight Control Actuators - Fly-by-Wire Technology

MRTT ARBS

- Ruddervator Control System

Antonov

AN-74 / AN-140

- Cabin Pressure Control System

AN-132 / AN-148 / AN-158 / AN-178-Prototype

- Integrated Air Management System

ATR

ATR 42 / 72

- Integrated Air Management System

AVIC

MA700

- Valve Actuator

Boeing

747-8

- Air-Conditioning System
- Engine Bleed Air System

777-200LR

- Fuel Tank Pressure Regulating Valves

777 / 777X

- Main Gear Steering System

777X

- Folding Wing Tip Actuation
- High-Lift Actuators
- Power Drive Unit and Hydraulic Motor for Leading Edge Actuation System

787

- Nose Wheel Steering Remote Electronic Unit

KC-46

- Fuel Pressure Regulating Valves
- Refueling Hose Drum Drive System

MQ-25

- Tailhook Actuator

Participation in programs

Fixed Wing Aircraft

Bombardier Aerospace

Challenger 300 / 350

- Flap System
- High- and Low-Pressure Ducting
- Integrated Air Management System

Global Express / G5000 / G5500

- Cabin Air Humidification System
- Integrated Air Management System
- Nose Landing Gear Shock Strut

G6000 / G6500 / G7500 / G8000

- Integrated Air Management System

COMAC

ARJ21

- Integrated Air Management System
- Landing Gear System incl. Braking System, Wheels, and Tires
- High- and Low-Pressure Ducting

C919

- Integrated Air Management System
- Landing Gear System
- High- and Low-Pressure Ducting

Daher-Socata

TBM850 / 900

- Air-Conditioning System
- Cabin Pressure Control System
- Engine Bleed Air System

Dassault Aviation

Falcon 50EX / 900 / 2000 / 2000EX

- Air-Conditioning System
- Cabin Pressure Control System
- Engine Bleed Air System

Falcon 6X

- Integrated Air Management System
- Cabin Air Humidification System

Falcon 7X / 8X

- Cabin Air Humidification System
- Engine Bleed Air System

Falcon 10X

- Integrated Air Management System
- Landing Gear Actuation and Steering Components

Mirage 2000

- Air-Conditioning System
- Cabin Pressure Control System
- Engine Bleed Air System

Rafale

- Air-Conditioning Components
- Cabin Pressure Control System
- Engine Bleed Air System

Embraer

AMX

- Cabin Pressure Control System

C-390 Millennium

- Air-Conditioning System
- Cabin Pressure Control System
- Engine Bleed Air Valves
- Refueling Hose Drum Drive System
- Wing Anti-Ice Valves

E-Jet E1

- Landing Gear System incl. Braking System, Wheels, and Tires

E-Jet E2

- Nose Wheel Steering Control Module
- High-Lift System
- Integrated Air Management System
- Machining of Main Landing Gear (E175 E2)

Embraer 135 / 145 / Legacy 650

- Cabin Pressure Control System
- Flap System
- Nose Landing Gear

Legacy L500ER

- Fuel Tank Pressurization System

Lineage

- Landing Gear System incl. Braking System, Wheels, and Tires

Praetor 600

- Fuel Tank Pressurization Valve

Super Tucano

- Air System Components

Tucano

- Air System Components

FAdeA

IA-63 Pampa III

- Air-Conditioning, Heating, and Ventilation Components
- High-Lift Actuation Components
- Primary Flight Control Components
- Landing Gear Components

HAL

Dornier 228

- Flap System
- Landing Gear Actuators
- Nose Wheel Steering System

HJT 36

- Cabin Pressure Control System

Jaguar

- Cabin Pressure Control System

Tejas

- Cabin Pressure Control System

IAI

G200

- Cabin Pressure Control System Components
- High-Lift System

Irkut Regional Aircraft

SuperJet 100

- Fly-by-Wire Flight Control System
- Integrated Air Management System

Leonardo (Aircraft)

C27-J

- MELTEM III-MMI Auxiliary Cooling System
- MELTEM III-MMI Environmental Control Unit

M-346

- Main Landing Gear System
- Nose Landing Gear System
- Nose Wheel Steering System
- Longview / De Havilland Canada

Q400

- Cabin Pressure Control System

Mitsubishi Heavy Industries

CRJ700 / 900

- Integrated Air Management System
- Low-Pressure Ducting

CRJ1000

- Command-by-Wire Rudder Control System
- Integrated Air Management System
- Low-Pressure Ducting

RUAG Aerospace

Dornier 228 New Generation

- Flap System
- Landing Gear Actuators
- Nose Wheel Steering System

Textron Beechcraft

750 / 850XP / 900XP

- Cabin Pressure Control System

TRJet

328 Series

- Air Management System
- Flap and Spoiler Actuation Subsystem

Participation in programs

Rotor Wing Aircraft – Engines – Actuation – Pods – Space Applications

Airbus (Helicopters)

AS350 / 355 Ecureuil

- Environmental Control System Components
- Gears for Main Gearbox

AS365

- Environmental Control System

BK117

- Gears for Power Transmission Gearboxes
- Hydraulic Power Supply
- Main and Tail Rotor Servo Controls

H120

- Environmental Control System Components

H130

- Air-Conditioning System

H135 / H135M

- Gears for Power Transmission Gearboxes
- Hydraulic Power Supply
- Main and Tail Rotor Servo Controls

H145

- Gears for Power Transmission Gearboxes
- Hydraulic Power Supply
- Main and Tail Rotor Servo Controls
- Tail Gearbox

H160

- Environmental Control System Components
- Main Rotor Servo Controls
- Heating Valve
- Tail Rotor Gearbox

H175

- Environmental Control System Components

H225 / H225M

- Environmental Control System Components
- Heating System

NH90

- Actuation Control Computer
- Auxiliary Power Unit Gearbox
- Fly-by-Wire Main and Tail Rotor Servo Controls
- Environmental Control System Components

Tiger

- Gears for Tail Gearbox
- Air-Conditioning System
- Main and Tail Rotor Servo Controls
- Tail Landing Gear

UH-72A Lakota LUH

- Gears for Power Transmission Gearboxes
- Hydraulic Valve Block / Reservoir
- Main and Tail Rotor Servo Controls

AVIC HAIG

AC 312

- Air-Conditioning System

Boeing

MH-139

- Environmental Control System
- Landing Gear System

Cobham

Cobham Mission Equipment POD

- Hose Drum Drive System

HAL

ALH

- Heating and Ventilation Systems

IAI

Elta

- Environmental Control Unit for POD

Kamov

KA-226T

- Air-Conditioning System

Korean Aerospace Industries

KHP

- Environmental Control System Components

KT-1

- Cabin Pressure Control System
- Engine Bleed Air System
- Ventilation Control System

Leonardo (Helicopters)

AW109

- Environmental Control System

AW139

- Environmental Control System
- Landing Gear System

AW149 / AW189

- Environmental Control System
- Fly-by-Wire Main and Tail Rotor Actuators
- Landing Gear System

AW169

- Environmental Control System

T129

- Environmental Control System

NORDAM

A320neo Nacelle

- Anti-Ice Valve

Northrop Grumman

Litening

- Environmental Control Unit for POD

Rafael

Litening

- Environmental Control Unit for POD

Rolls-Royce

Pearl 700

- Pneumatic Component Package

Trent 7000

- High-Pressure Non-Return Valve

UltraFan®

- Power Gearbox*
- Temperature Control Valve

*In cooperation with Aerospace Transmission Technologies GmbH – a joint company of Liebherr-Aerospace and Rolls-Royce

Spirit AeroSystems

- Thrust Reverser Actuation System for Rolls-Royce Pearl® 10X Engine

Thales

Damocles

- Environmental Control Unit for POD

RECO NG

- Environmental Control Unit for POD

MELTEM II

- Environmental Control Unit

Thales Alenia Space / CNES

- Evaporators and Condensers for Mechanically Pumped Loop Cooling Systems

Turkish Aerospace

Turkish Light Utility Helicopters (TLUH)

- Air-Conditioning System
- Oil Cooling System

VR-Technologies

VRT-500

- Environmental Control System



Future Technologies



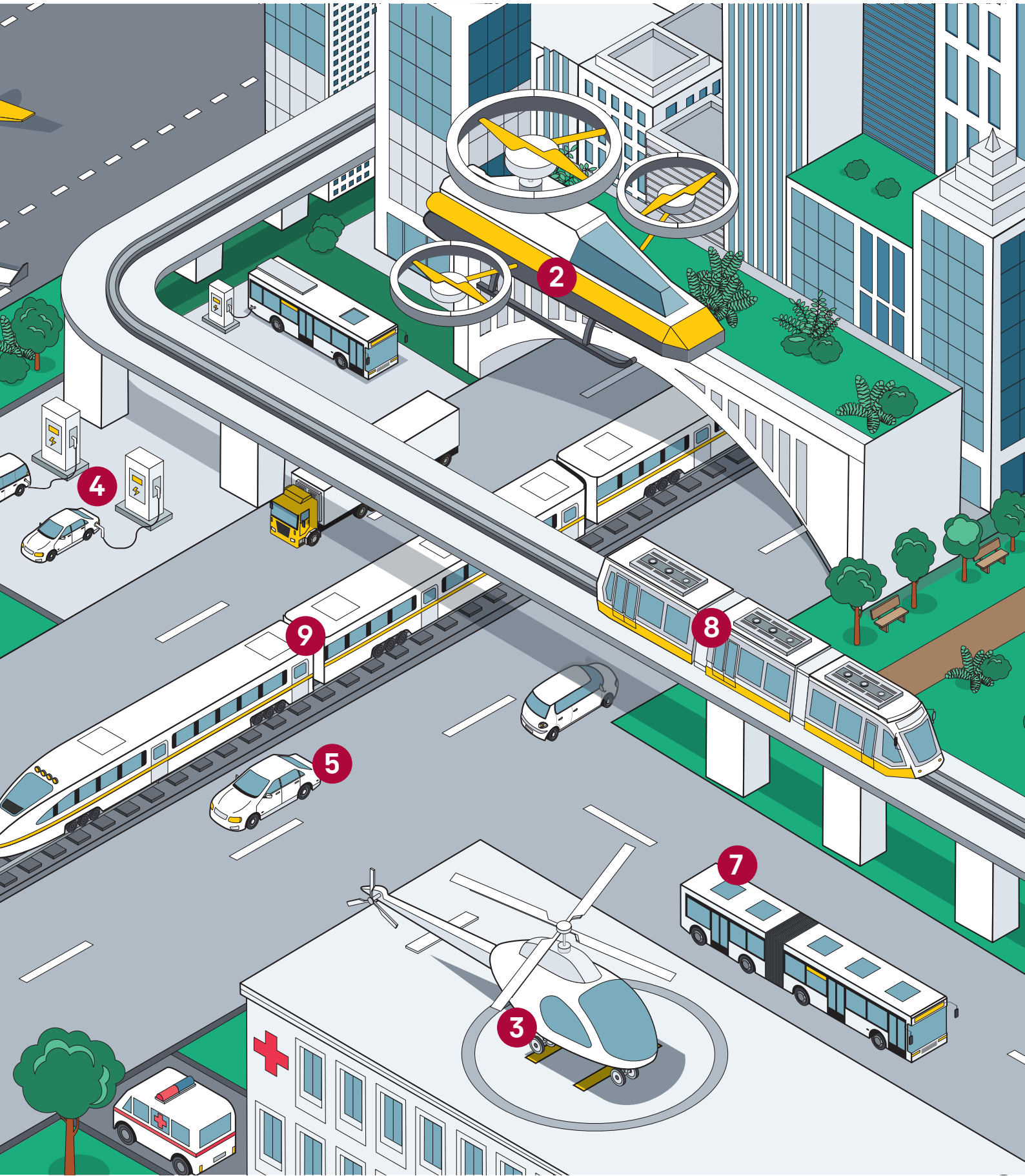
The future of transportation

Liebherr is currently developing the technologies that will enable the vehicles of the future to carry out their mission. Be it in the air, on the road, on the tracks, on the water, or even in space, the vehicles of the future will need to be more efficient, more reliable, and more respectful of the environment.

The technologies developed in the fields of Liebherr's expertise – thermal management, power management, flight control and actuation, landing gears, electronics – will bring a substantial contribution to tomorrow's vehicles being cleaner, safer, lighter, quieter, and more economic.

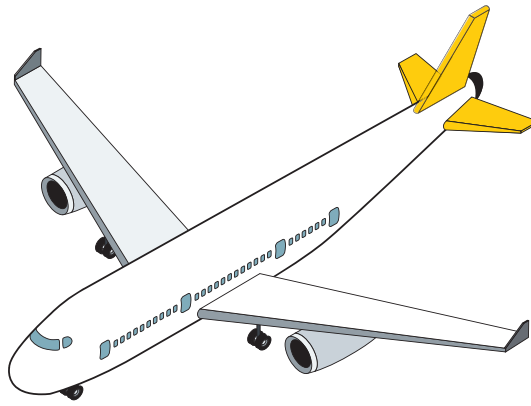
Electrification will play a major role in this evolution, as will hydrogen power generation and hydrogen propulsion, together with the resolution of the associated thermal management challenges: with onboard electronics becoming more compact and dense, heat dissipation issues will become limiting factors and will need to be addressed as specific topics.





Aircraft

1



More Electric Aircraft technologies

Higher efficiency and less weight are just two of the many advantages of a More Electric Aircraft. Liebherr focuses on creating solutions that will reduce CO₂ and NO_x emissions as well as to lower noise pollution.

The **ESTER project** (Electrohydraulic Steering, Extension, and Retraction System) aims at improving the aircrafts' landing gears using electrohydrostatic actuators in the retraction/extension and steering functions.

Liebherr is also working on the **E-WING** demonstrator platform that incorporates the system concept of a More Electric Aircraft, with a laboratory including a control room, a flight control system rig, and the ESTER rig.

The company is also developing technical solutions that will completely suppress the air bled from the aircraft engines. **Air systems** and **anti-ice systems** will be transformed from presently being pneumatic into **electrical** ones. The electrical systems will help to reduce fuel burn and thus the associated emissions.

Thermal management

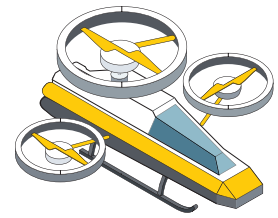
Air-conditioning systems, for example, are one of the main energy consumers on board an aircraft. That is why Liebherr is building a demonstrator of an **electrical environmental control system** (eECS) together with Airbus and 12 other consortia as part of the European Clean Sky research program. Instead of taking air from the engine, the eECS uses ambient air from outside the aircraft, which is then used for the pressurization and air-conditioning.

Engineers of Liebherr-Aerospace, Airbus, and the National Aeronautics and Space Research Center of the Federal Republic of Germany (DLR) have cooperated within the Clean Sky program to counteract the significantly increasing thermal loads and heat density in aircraft. The idea: Dissipate the heat through a so-called **liquid skin heat exchanger** developed by Liebherr-Aerospace with the help of liquid coolants. Our specialists have designed a test bench of a liquid loop system to simulate thermal loads in the aircraft and to feed the liquid skin heat exchanger with coolant. Both the liquid skin heat exchanger and the liquid loop system operate

completely independent of other systems in the aircraft. Liebherr-Aerospace is working to improve the production process in order to enable serial production of the heat exchanger, and to reduce the weight of the system using composite materials.

Fuel cell energy

The use of hydrogen on board an aircraft for propulsion or generation of electricity is expected to become reality within the next 15 years. Liebherr is investing research and technology effort to be part of this revolution. The goal is to supply a **power generation system based on fuel cell technology** that provides electrical power for all aircraft systems. This will relieve the next-generation aircraft engines from any off-takes, which are responsible for reducing the engine efficiency today.



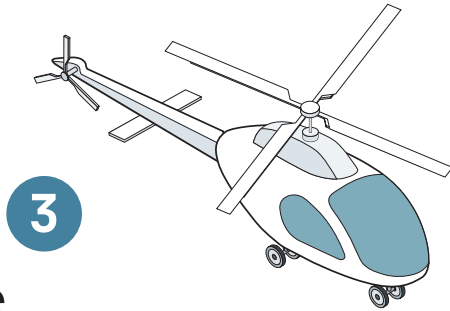
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Air taxis

Air taxis and urban mobility vehicles will enable commuting in and between cities in a sustainably way. Liebherr is working on different technologies to make this future happen: The air taxis will rely on new propulsion technologies such as hydrogen. Liebherr is developing an **onboard aerospace power generation system** for this purpose. Regardless of the propulsion technology, all these vehicles will rely on **high-power electrical drive systems**.

The **thermal management** of these electrical technologies will require systems specifically designed for those challenges, which Liebherr is also currently developing.

Finally, the control of the flight of these vehicles will require highly reliable, **highly maneuverable flight control electronics and flight control actuation**, the technology for which is also being developed by Liebherr.



Helicopters

3D printed parts

Already in 2017, Liebherr-Aerospace received the authorization from the German Federal Aviation Office (Luftfahrtbundesamt, LBA) to produce components using additive manufacturing. Additive manufacturing enables the design and production of **high-strength lightweight structures** for helicopters, which cannot be manufactured using conventional production methods.

Hydraulic power packs

A solution for an optimized system architecture is the application of decentralized hydraulic power generation by electrical Hydraulic Power Packs (HPP). The HPP is sourced by electrical power and provides local hydraulic power at the place where it is needed, for example for steering, extension, and retraction or braking of landing gears. The integrated design supports **easy modular assembly** in the helicopter.

Air quality

Cabin air quality is becoming increasingly interesting for helicopter operation to maintain crew and passenger health by VOCs (volatile organic compounds) removal using filter technology. Liebherr-Aerospace is thinking about active solutions for **pollutants removal** associated with sensor technologies for **air-quality monitoring**.

Electrical landing gear

Liebherr engineers have developed an Electro-Mechanical Actuator (EMA) for use in a helicopter landing gear. Like a hydraulic actuator, it ensures that the helicopter landing gear is retracted after take-off and extended again before landing. The difference is that with an EMA, a **hydraulic supply is no longer required**.

Fly-by-wire flight controls

With the NH90 helicopter program, Liebherr-Aerospace introduced the first full authority fly-by-wire flight control system, which entered the stage of series production. Developments by Liebherr progressed even further into a **“fly-by-light”** system installed in the ACT-FHS technology test bed based on an H135 and operated by the German National Research Center (DLR).

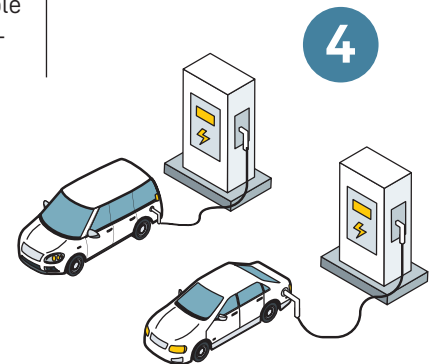
Improved cabin comfort

Temperature regulation can be improved on board a helicopter through a **vapor cycle system (VCS)** using a jet pump with variable nozzle area and with bizonal mode to best serve all sections of the cabin. Improved power efficiency is achieved by a new compressor technology like a VCS scroll compressor with double capacity (asynchronous technology) or with variable speed capability (synchronous technology).

Electric vehicles

Cooling for fast charging stations

Liebherr-Transportation Systems has developed a special **active cooling** unit for charging stations. Prototypes have already been tested by ITT Cannon in Weinstadt (Germany), one of the leading manufacturers of plugs and plug connections, together with Efacec Electric Mobility, Moreira da Maia (Portugal). They have been installed in the first network of high-power chargers in the USA and in Europe. The network has an output rating of 350 kW, a maximum power of 350 A and a high voltage of 1,000 V. Liebherr’s technology cools the high-performance charger cable and the charger plug reliably in all environmental conditions. The company is already working on other units for the world’s growing demand for charger facilities.

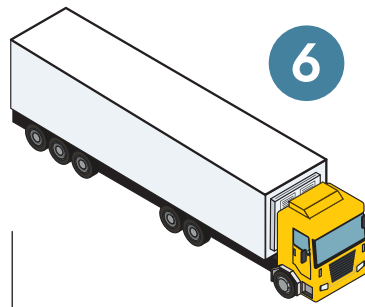
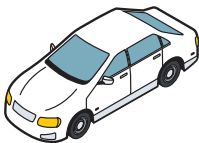


Fuel cell vehicles

Electrical compressors

Liebherr has been collaborating with major automotive manufacturers to develop the future generation of fuel cell vehicles. Liebherr-Aerospace's **air bearings technology** for centrifugal compressors has been identified as the best candidate to supply compressed and pressurized air to the fuel cell system. It was originally developed for aerospace activities and is powered by a high-speed electric motor. Liebherr's motorized compressors comply with the severe requirements of fuel cell systems for the automotive industry: they are very robust and reliable, and do not require oil; they are compact in size, highly efficient, optimized in cost and noise emissions; and they feature a fast dynamic response.

5



Trailers

Celsineo

Krone and Liebherr have entered into a partnership for the development, sales, and servicing of refrigeration units in 2019. Liebherr develops, manufactures, and supplies **refrigeration units for temperature-controlled road transport**. Krone installs these in its refrigerated semitrailers and offers them to its customers as a complete package. Krone's extensive European service network also allows it to offer expert maintenance and repair services as well as a fast supply of spare parts for all aspects of the new innovative Celsineo cooling system. Liebherr's patented system concept provides users with a modern and future-oriented solution. The entirely rethought modular design guarantees maximum availability, cost-effectiveness, as well as straightforward servicing.

Buses

Battery cooling

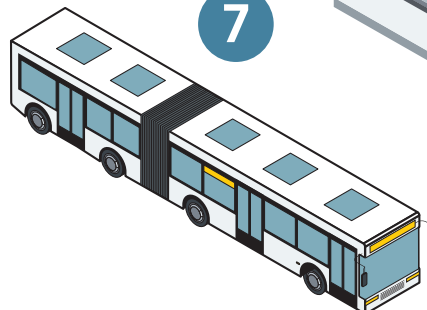
Liebherr offers battery-cooling systems for lithium-ion batteries used in electric buses. The cooling systems ensure that the lithium-ion batteries are operated under optimum thermal conditions. This improves both the operating conditions and lifetime of the batteries.

The environmentally friendly system using Liebherr technology will help to significantly reduce **the CO₂ footprint** of urban transport and provide passengers with a quiet ride through city centers.

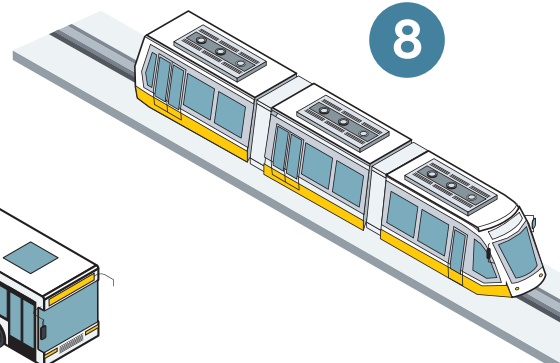
Electrical compressors

Liebherr-Aerospace Toulouse is responsible for the design and development of compressor units onboard hydrogen-powered shuttle buses manufactured by a Chinese manufacturer. The compressors are crafted to be fully eco-friendly – since they power fuel cell propulsion systems with **emissions of only water and heat**.

7



8



Urban railway vehicles

Modular air-conditioning system

Liebherr has developed a modular air-conditioning system (MACS), which responds to the most challenging market requirements of the railway industry. MACS 8.0 provides the highest degree of standardization. It has a **70 percent greater cooling power density** and consumes 8 percent less power when compared to a typical HVAC system. Its modular architecture allows flexibility and adaptability to serve diverse rolling stock applications.

Rail cars including high-speed trains

Cold air technology

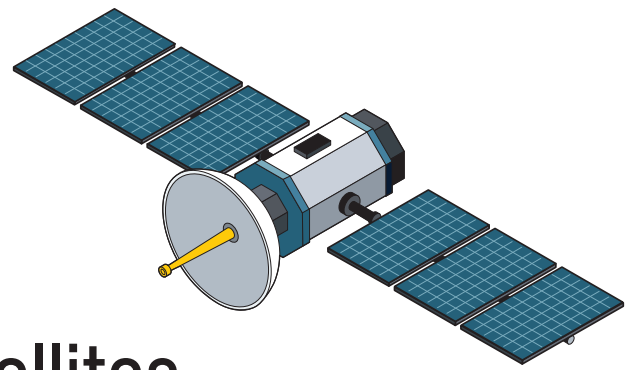
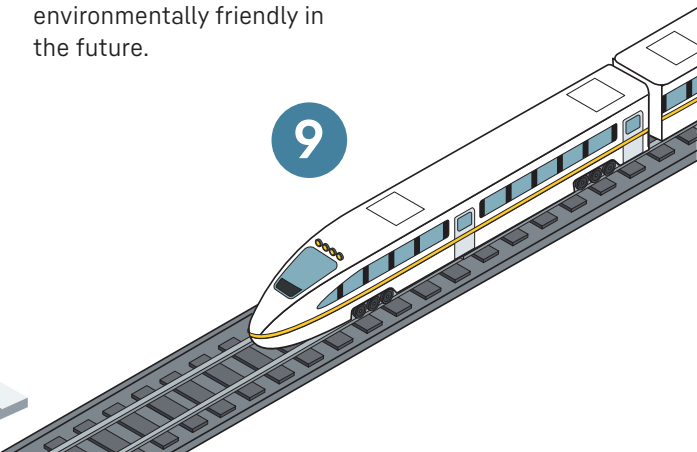
Cold air technology, also known as air cycle technology, is the only future-proof and environmentally friendly alternative that has proven successful in passenger transport. Liebherr has developed an **air cycle air-conditioning system** for rail cars based on this technology. It operates entirely without refrigerants and simply uses fresh ambient air for cooling. The system has proven extremely successful in daily passenger transport operations. The energy consumption is extremely low compared with conventional systems. This has been verified, for example, through comparative measurements by Deutsche Bahn. This is an incentive for Liebherr to work intensively on further developing air cycle technology and to make it usable for a wider spectrum of applications. Liebherr is also working in parallel on a CO₂ air-conditioning system and thus pursuing a twin-track strategy in its research to that both new and existing air-conditioning systems can cool in a way that is more environmentally friendly in the future.

High-speed air compressors

High-speed air compressors by Liebherr incorporate a unique type of technology involving the use of air bearings, which helps to ensure that the air injected into the fuel cell includes no oil that can degrade the membrane performance. These compact compressors will be used in the rail transport sector to provide compressed air to propulsion systems powered by fuel cells. The final fuel cell product itself will generate **no CO₂ emissions** and provide an alternative for a new generation of trains.

Liebherr is offering an **active radial suspension system** called LiCAS. This electrohydraulic control system actively steers the bogie axles and adapts the wheelset to the curve radius of the rail during cornering. Each wheel is optimally placed on the track, which reduces the strain on the network. The lower rolling resistance reduces energy consumption, and train operators can extend the life span of their vehicles.

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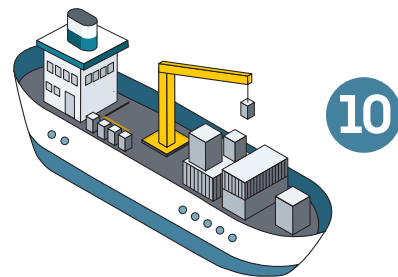


Satellites

Together with European space manufacturer Thales Alenia Space and Centre National d'Etudes Spatiales (CNES), Liebherr is working on **thermal management capabilities for a Mechanically Pumped Loop (MPL) cooling system** for satellites.

The partners are developing industrial production and codesign capabilities for evaporators and condensers. These are key

components of the next-generation telecommunication satellite's technology payload and platform cooling system, which actively manages the electronic heat dissipation. They will be in space for at least 15 years without maintenance and have to be completely free from leakage as well as extremely reliable and robust to operate flawlessly during this period at high heat-exchange performances.



Maritime applications

Sea vessels need to shift their propulsion and power generation systems to technologies that do not damage the environment. In particular, ships of the future will need to use onboard power generation systems that do not pollute when they will stay in

harbor for several hours or several days in a row. The technologies developed by Liebherr for fuel cell power generation systems will enable those ships to generate **onboard power without generating CO₂ emissions**.

Innovative steps towards hydrogen mobility

Liebherr-Aerospace's commitment to developing technologies towards green mobility goes far beyond its main field of aviation components. Through the integrated work of Liebherr-Aerospace Toulouse SAS (France) and Liebherr-Elektronik GmbH (Germany) the company is moving full speed ahead in product diversification, and is developing its expertise in electrically powered turbochargers for other applications such as automotive, maritime, and railways.

In the second half of 2020, Liebherr delivered the first fuel cell air compressors for Maxus Automotive's new MPV model EUNIQ 7, of Chinese car manufacturer Shanghai Automobile Group (SAIC). Liebherr-Aerospace and Liebherr-Elektronik were responsible for the design, development, and production of the key components of the compact and reliable compressors that power fuel cell propulsion systems through emissions of only water and heat.

"Liebherr has prepared for the future. We developed this technology not only for cars, but also for commercial and construction vehicles, long haul trucks, buses, maritime, heavy-duty, and railway vehicles, as well as aviation applications," says Willem de Grooth, Business Development Manager at Liebherr-Aerospace Toulouse. "Our compressors, depending on the fuel cell system integrated architecture, can be operated in a stand-alone function as one compressor for one stack, or one compressor for two stacks in line."

A comprehensive system approach

According to Malek Chakri, Program Manager for the new compressors at Liebherr-Aerospace Toulouse, "the technology is reliable and easy to integrate in the vehicle. The development of all these different compressors is based on a system design approach between the compressor and the power electronics managed by Liebherr-Elektronik. Both systems are developed and produced in-house. This combined development offers several benefits for our customers: durability, high reliability, optimized operating performance, and a docile, simplified, vehicle system integration. We have developed a good range of systems and compressors, from 15 kW up to 55 kW. We propose an optimized design of the motorized compressor that is aimed to comply with customer-specific requirements and reduce weight and costs."



SAIC Maxus EUNIQ 7

Turbochargers for a fuel cell commercial vehicle in the UK

Liebherr-Aerospace Toulouse is also testing 25 kW / 400 V double-stage electric turbochargers. The company had been selected by AVL Powertrain UK Ltd., one of the largest private companies dedicated to the development of power train systems and test systems, to deliver the turbochargers for the development of a fuel cell electric demonstrator commercial vehicle in collaboration with Ford UK, as part of the APC UK project, "Fuel-cell Commercial Vehicle Generation 1.0."

AVL Powertrain UK and Ford Motor Company aim to present this commercial vehicle with fuel-cell propulsion in fall 2021. The first delivery of the turbochargers happened in January 2021 for a six-week run on a test rig, followed by a second test campaign on the vehicle. "Liebherr has provided excellent technical and proactive support which has met not only the technical requirements of the project, but also the aggressive timescales," says Dr. Bernadette Longridge, Engineering Center Manager, AVL Powertrain UK Ltd.

Local production and services

“We are close to the market with production sites in Europe and China. To support our customers, we are going to produce more and more locally to offer them the best services. Our production sites are or will be located in Europe as well as in China to be as close as possible to our customers and to sustain the dynamic growth of the fuel cell market. Liebherr has been preparing its product line and processes for higher volume to keep up with this growth, all the while offering machining with fully integrated machines, which allows the highest flexibility during development as well as during product phase,” emphasizes Malek Chakri.

Liebherr had already delivered an electrical compressor to SAIC for the hydrogen-based fuel cell system of the passenger shuttle buses in two of Shanghai’s major airports. The buses, however, are only the first step in the project led by SAIC and Shanghai Airport Group, who signed an agreement to expand the use of fuel cell propulsion for ground support vehicles and road maintenance equipment.

The support of electric vehicles is considered by the Organization for Economic Co-Operation and Development (OECD) to be one of the key policies in transportation to achieve “green growth.” Within the scope of its corporate social responsibility and strategic planning, Liebherr is positioned as an innovative company fully dedicated to developing technologies that allow the reduction of negative climate impacts derived from transportation. For that purpose, Liebherr has been forging partnerships with

several organizations aligned with the same principles in search of solutions that aggregate value to the customers’ products in terms of performance, while actively lowering both financial and environmental costs.

“We prepare the future and develop this technology also for commercial and construction vehicles, long haul trucks, buses, maritime, heavy-duty, and railway vehicles, and aerospace applications.”

Willem de Grooth

Business Development Manager at Liebherr-Aerospace Toulouse (France)



Willem de Grooth and Malek Chakri proudly present an electrically powered turbocharger



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