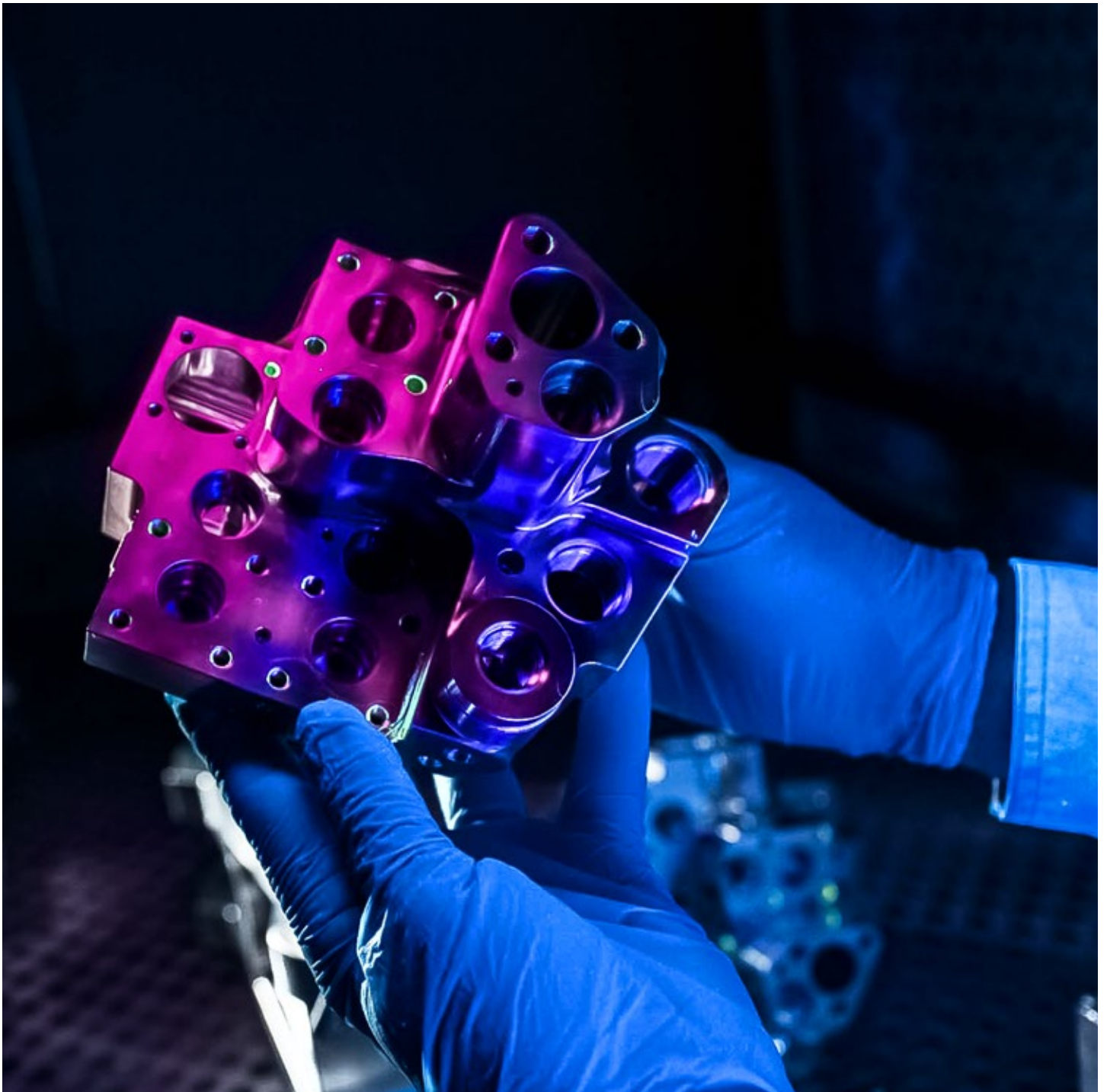


Liebherr-Aerospace News from the Company // p. 12-31

Research and Development Additive manufacturing: new technologies, infinite possibilities // p. 12

The Liebherr Group Insights // p. 38-43





From left to right:
Heiko Lütjens,
Nicolas Bonleux,
Josef Gropper,
Francis Carla

Dear reader,

Over the past few years, the continuous growth of the aerospace industry has generated many opportunities for us.

Thanks to the confidence that our customers place in us, our relentless investments into technologies and into operational excellence, and our passionate teams worldwide, we have been able to benefit from these opportunities and to transform them into highly promising paths for our future.

The contracts we were awarded are of vital importance for the future of the entire aviation industry and are the best illustration of our success. In addition, our initiatives to enlarge our customer base and diversify our markets of operation were exceptionally prolific.

Moreover, several airlines selected us, either directly or through our joint venture company OEM Services SAS, to

carry out maintenance services and supply spare parts: Asiana for the A350 XWB, Tianjin Airlines, Mandarin Airlines and Finnair for the overhaul of the E-Jet landing gears, to name only a few.

These many successes reflect both our uninterrupted effort to take technology to new horizons and our commitment to support all our customers in making sure their aircraft programs and operations meet the demanding requirements they are faced with. Going through the articles of the 2017 edition of our magazine, you will get an overview of our unique range of products and technologies.

Our teams worldwide play a key role in creating and securing a bright future for our company, and we warmly thank them for their outstanding contribution.

Best regards,

Nicolas Bonleux
Managing Director and
Chief Sales Officer

Francis Carla
Managing Director and
Chief Technology Officer
Air Management Systems

Josef Gropper
Managing Director and
Chief Operating Officer,
Production, Purchasing and
Asset Investments

Heiko Lütjens
Managing Director and
Chief Technical Officer, Flight Control
and Actuation Systems, Landing Gear
Systems and Hydraulics



Impressions 4

Research and Development 12
An Airbus A380 with a titanium valve block 3D printed by Liebherr-Aerospace took off for the first time in spring – a world premiere.

International Focus 14
Successful globally: Liebherr-Aerospace is further expanding its worldwide presence.

Programs 24
As partner to all the major aircraft manufacturers, Liebherr-Aerospace presents a selection of its worldwide projects.

Customer Service 28
Customer service is a top priority at Liebherr-Aerospace – and aircraft manufacturers greatly value this, as our examples show.

Miscellaneous 30
Viable networks and partnerships allow us to drive processes and technologies forward together.

Participation in Programs 32

Liebherr-Transportation Systems 34
Liebherr also always keeps an eye on customer requirements in the area of transport technology, both in development and in servicing.

The Liebherr Group 38

Legal Information 44



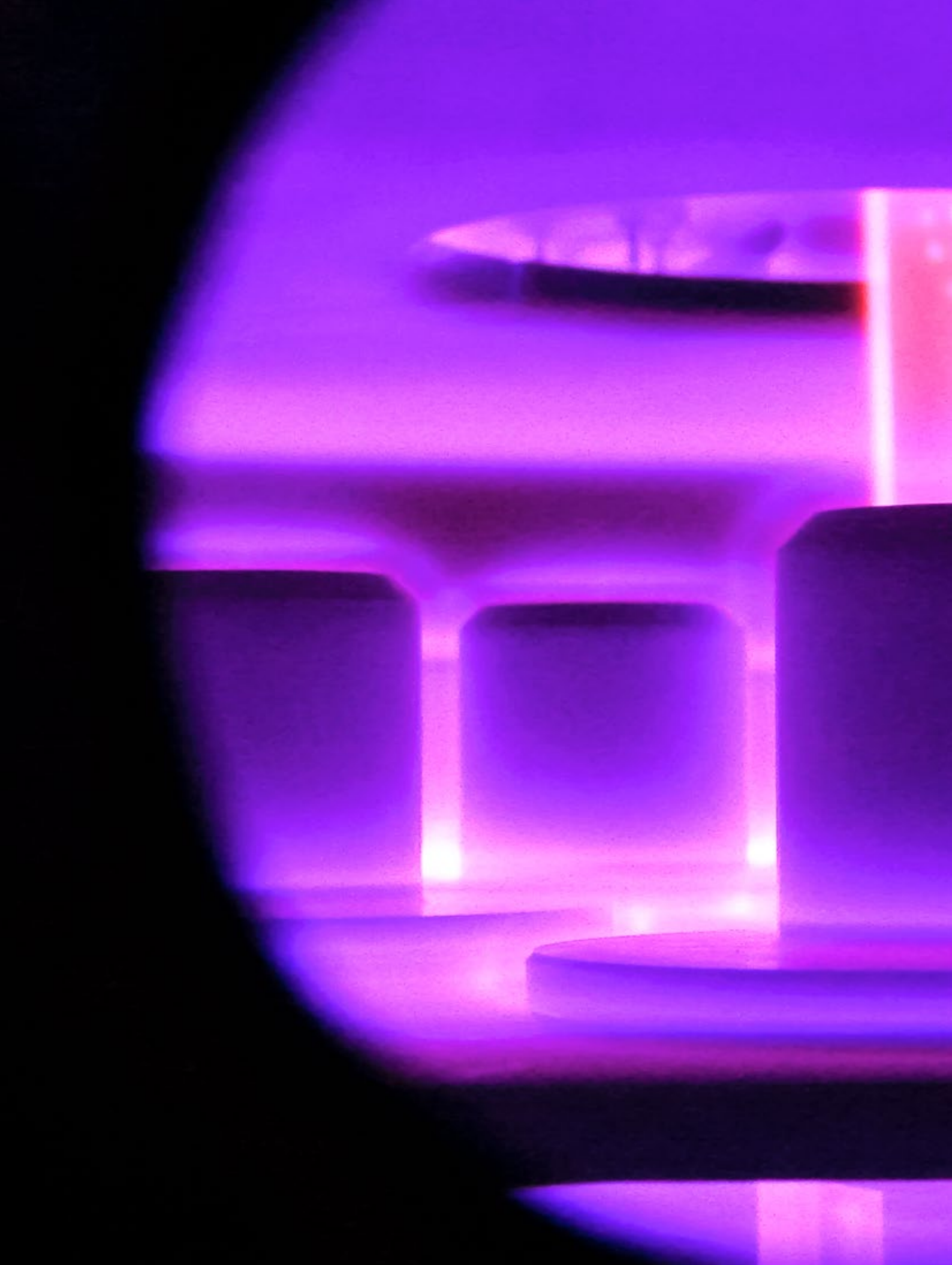
Impressions

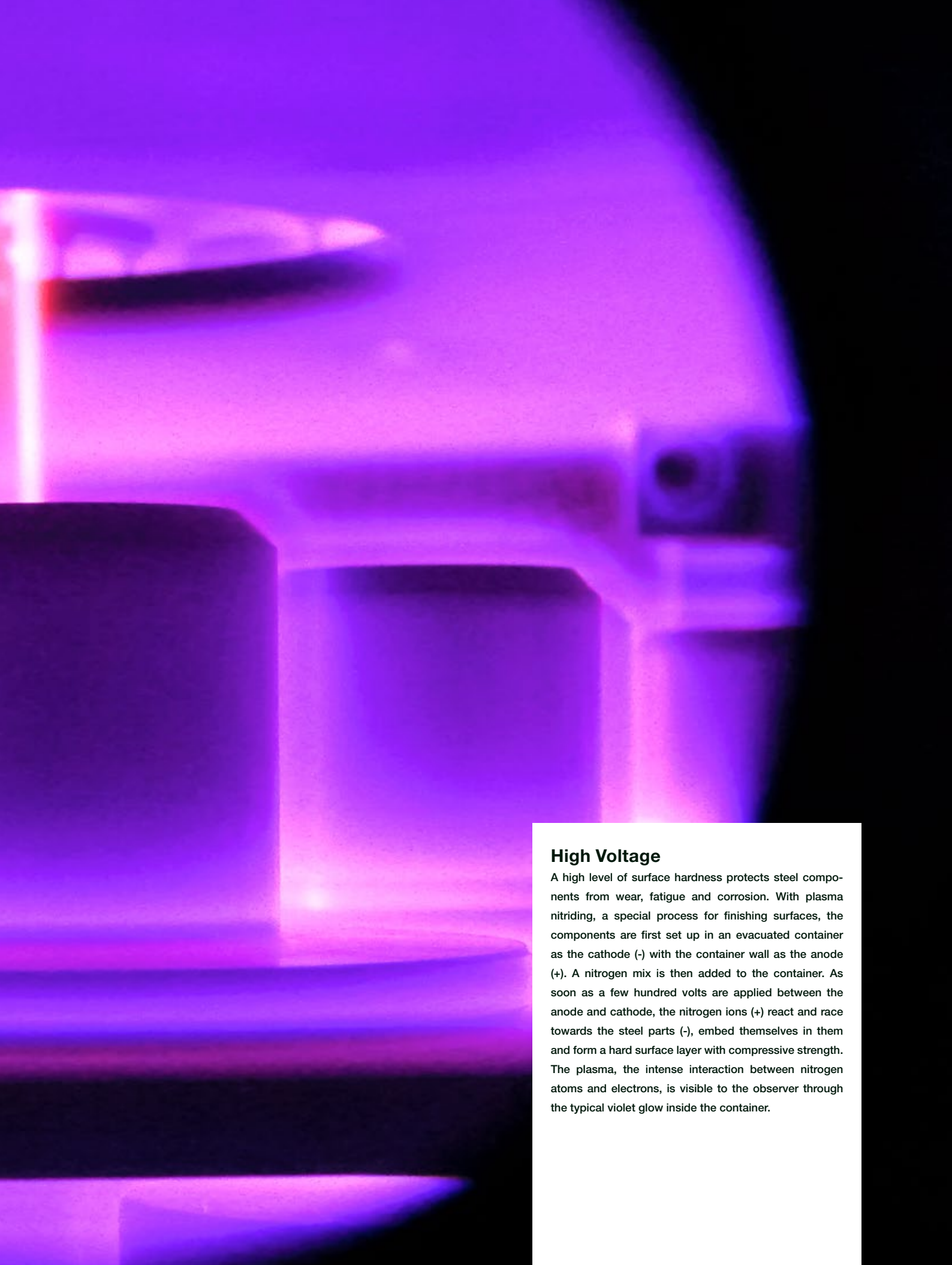
Know-how, sensitivity and absolute precision are crucial for maintaining high standards of quality. It doesn't matter whether it's for the deburring by hand of titanium components, the surface treatment of steel parts, non-destructive parts testing or the fusion welding of aluminum. With its highly skilled workers and a wide range of cutting-edge production technologies and testing methods, Liebherr-Aerospace is able to ensure that all the aviation components that it develops, manufactures and maintains function reliably and exactly as required.



The Ultimate in Precision

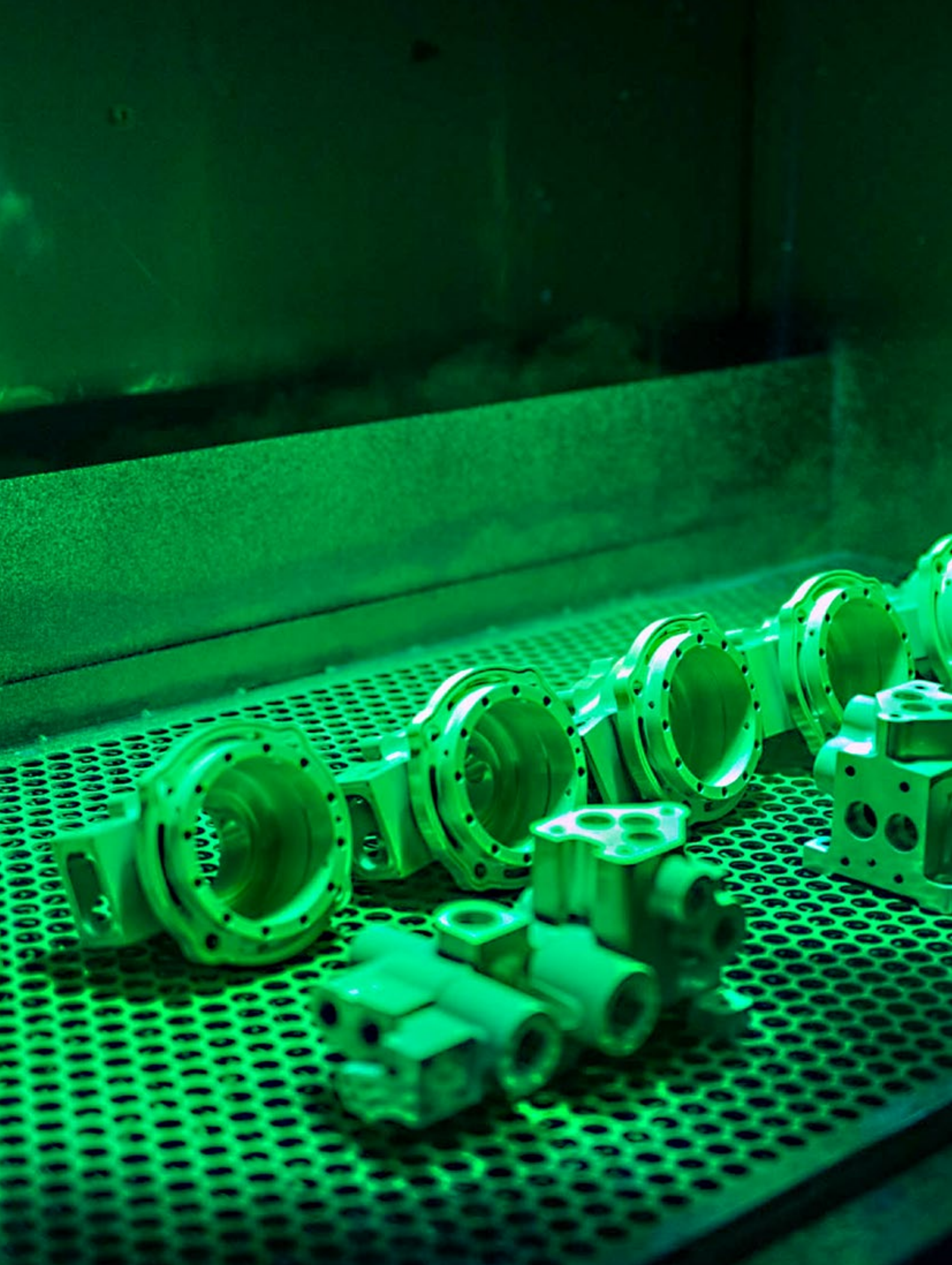
Deburring titanium valve blocks is one of the most delicate processes before assembly. It calls for absolute precision and utmost sensitivity. After the highly precise processing of the pieces at the titanium machining center, the inner contours of the parts are deburred manually using tools developed for dental technology. The skilled staff, who have undergone years of training, use special angle milling cutters and polishing tools, just like the ones used by dentists, and add precisely defined fillets and shaped contours to the part. This ensures that the oil flows smoothly and that the valves can be easily fitted during the assembly of the component.





High Voltage

A high level of surface hardness protects steel components from wear, fatigue and corrosion. With plasma nitriding, a special process for finishing surfaces, the components are first set up in an evacuated container as the cathode (-) with the container wall as the anode (+). A nitrogen mix is then added to the container. As soon as a few hundred volts are applied between the anode and cathode, the nitrogen ions (+) react and race towards the steel parts (-), embed themselves in them and form a hard surface layer with compressive strength. The plasma, the intense interaction between nitrogen atoms and electrons, is visible to the observer through the typical violet glow inside the container.

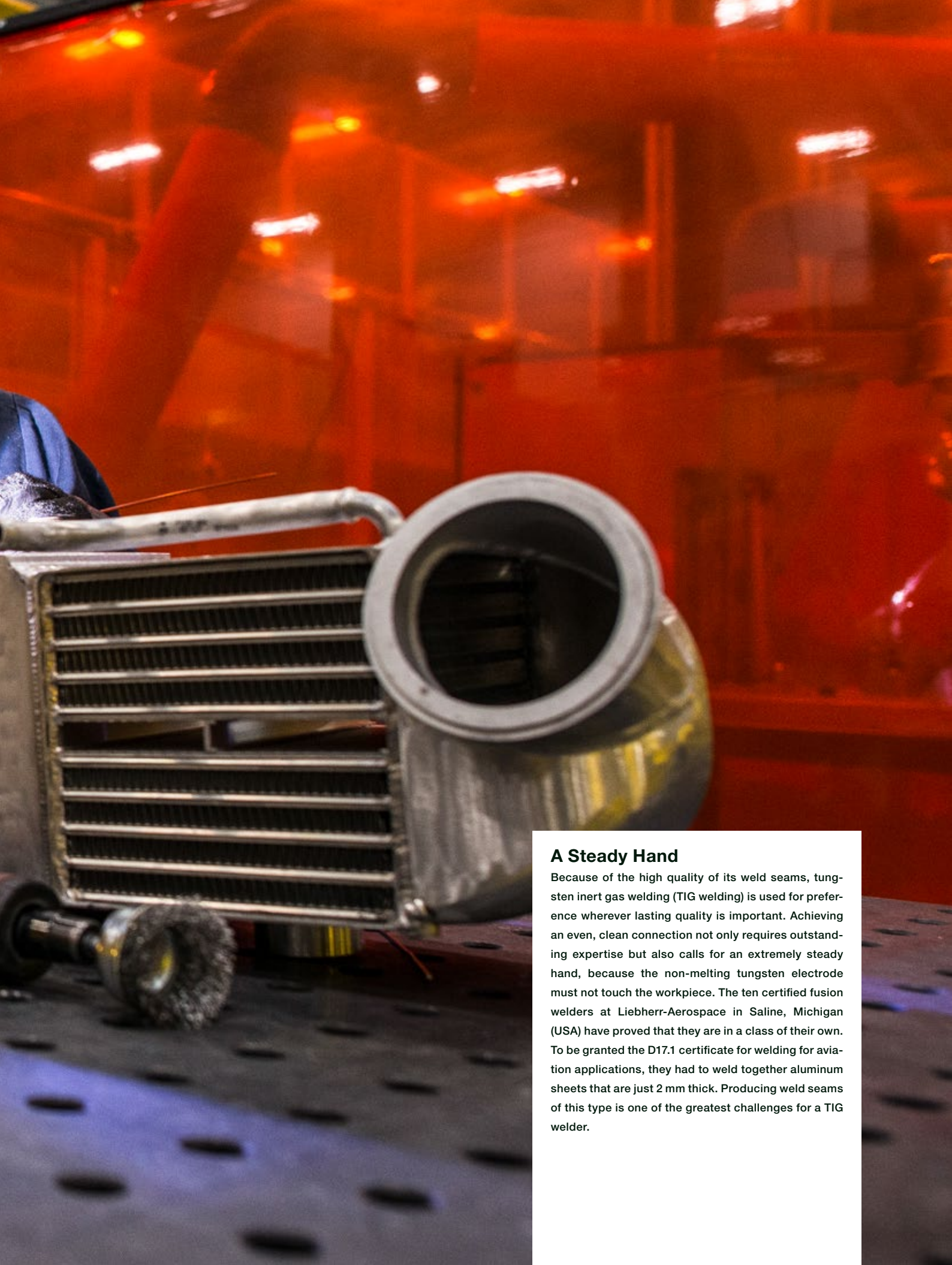




Making the Invisible Visible

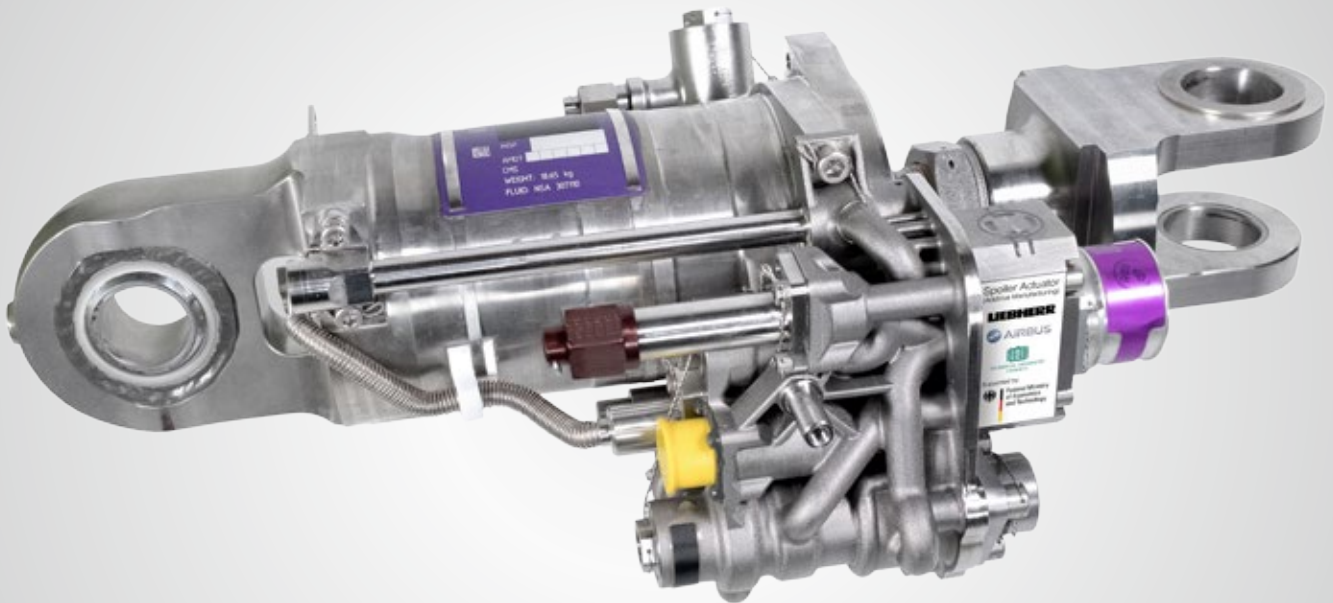
In order to find even the finest pores or material deviations, the surfaces of valve blocks and housings are sprayed during non-destructive testing with a fluorescent liquid after processing. Trained technicians can then detect the faulty areas with the naked eye under UV light.





A Steady Hand

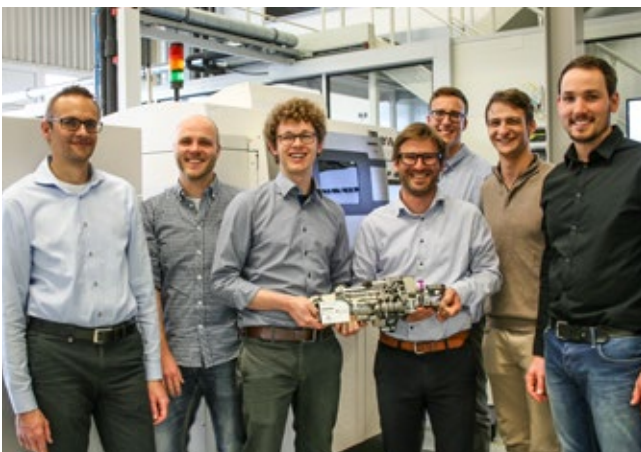
Because of the high quality of its weld seams, tungsten inert gas welding (TIG welding) is used for preference wherever lasting quality is important. Achieving an even, clean connection not only requires outstanding expertise but also calls for an extremely steady hand, because the non-melting tungsten electrode must not touch the workpiece. The ten certified fusion welders at Liebherr-Aerospace in Saline, Michigan (USA) have proved that they are in a class of their own. To be granted the D17.1 certificate for welding for aviation applications, they had to weld together aluminum sheets that are just 2 mm thick. Producing weld seams of this type is one of the greatest challenges for a TIG welder.



Research and Development

Additive Manufacturing: New Technologies, Infinite Possibilities

World premiere: In March 2017, an Airbus A380 took off for the first time with a titanium valve block from Liebherr-Aerospace's 3D printer and successfully completed its route. Never before has a hydraulic primary flight control component made from titanium powder using an additive manufacturing process been used in an Airbus. The valve block is part of Liebherr-Aerospace's spoiler actuator and fulfills a number of important functions on board the A380, when it comes to maneuvering the airplane, for example, and braking after landing. The 3D printed component works like a traditional forged valve block but has two crucial advantages: It is 35 percent lighter and is made up of fewer individual parts. Alexander Altmann, Lead Engineer Additive Manufacturing at Liebherr-Aerospace Lindenberg GmbH, Lindenberg (Germany) and Frédéric Letrange, Additive Manufacturing Project Manager at Liebherr-Aerospace Toulouse SAS, Toulouse (France) are already working on the next generation of 3D printed aerospace components.



Employees from the 3D Print Engineering department in Lindenberg present the spoiler actuator.

How has additive manufacturing developed at Liebherr-Aerospace in recent years?

Alexander Altmann: We started at Liebherr-Aerospace in Lindenberg around six years ago in a joint project with our customer Airbus and Chemnitz University of Technology. The aim was to investigate the usability of 3D printing for the production of valve blocks, which generally operate under high stress. We founded a kind of start-up within the company, because the challenge is to be able to think differently, without boundaries. Our team is made up of six mainly young people and brings together expertise from the areas of manufacturing, construction, landing gear simulation and plant and equipment research. The success of the first project convinced us of the potential of the technology in the

field of flight control and landing gears and motivated us to follow it up further.

What does the manufacturing process look like?

Frédéric Letrange: Additive manufacturing is a 3D making method of solid parts based on a CAD model. In Toulouse we focus on the selective laser powder bed fusion for nickel alloy and aluminum alloy material. The CAD model is cut into thin layers and for each layer, a laser selectively fuses a powder bed according to the profile of the part. The layers are fused one after another until the part is completely manufactured. Depending on the part the production time varies from 45 minutes to 65 hours.

What is the cooperation between Lindenberg and Toulouse like?

Alexander Altmann: We regularly exchange information, especially as we work with the same type of machine. However, we use different materials: While our colleagues in Toulouse work with nickel and aluminum, we concentrate on titanium. Our different viewpoints help us to gain new insights and to develop our skills together step by step.

Which have been the most important milestones during the developing process?

Frédéric Letrange: We took our first important step in December 2011 when we produced the first 3D-printed part, a nickel alloy bleed valve manufactured by a supplier. During this time we bought more than 60 prototypes in different materials, for example nickel, aluminum, stainless steel or titanium alloy, from several suppliers, which had been produced by different machines. Two of them were then installed in an ATR 72 and an Airbus A320 flight test bed in order to demonstrate operability with electrical air conditioning packs. These trials were carried out in 2016 and proved successful. The second milestone was the installation of an additive manufacturing machine in September 2015. During one year, we concentrated our efforts on the development of nickel alloy parts and manufactured and tested several hundred samples. This

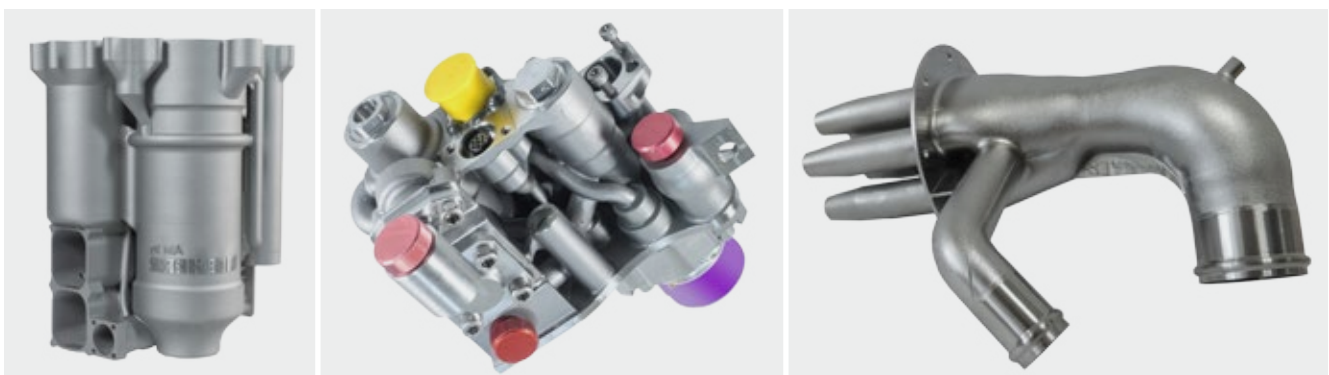


Members of the 3D Print Engineering team in Toulouse

phase ended with the qualification phase of the process. Recently we changed the material in the machine and are facing a new challenge, which is aluminum.

What potential does this process have for Liebherr and the industry?

Alexander Altmann: The potential is enormous – both at Liebherr and in general. The technology will massively change our daily lives, not just airplanes. Technologically, Liebherr-Aerospace is undoubtedly one of the leading companies throughout Europe, and can keep pace with the best. Even now, we can print parts that are not safety-critical to high quality standards and will be starting series production of a number of holders and brackets for the A350 nose landing gear soon. Our vision is that we will build completely new generations of highly integrated components and systems that are lighter and smaller and can be manufactured more cost-effectively as a part of the value creation chain. 3D printing technology is developing very quickly, and so are our products and processes.



Today, components such as a rudder actuator, a valve block for the spoiler actuator and also a jet pump can be made using additive manufacturing.

International Focus

“Footprint in India”: Strengthening of Activities in a Growth Market

In February 2017, Liebherr-Aerospace opened a new regional office in Bangalore, India’s hub for the civil and military aerospace industry and associated research and development activities. The opening is part of the company’s strategy to extend and strengthen its presence in the Asian subcontinent.

“We are expecting that India will evolve into one of the world’s largest markets for both the manufacture and the operation of aircraft”, explains Joël Cadaux, Director Business & Services, Customer Support & Services at Liebherr-Aerospace & Transportation SAS in Toulouse (France). “This is proven merely by the fact that, after the USA and China, India now comes third in the list of countries with the largest passenger flight markets, thus overtaking Japan.” And this market is set to grow further.

Liebherr-Aerospace will be using local staff at its new branch: “Alongside their specialist qualifications, they are also able to contribute their own vital expertise, such as familiarity with the various languages spoken here and a knowledge of local idiosyncrasies”, explains Cadaux. Capacities are being constantly expanded, as the team in Bangalore will be supporting Indian customers in the operation of the existing fleets of

Airbus, ATR, Embraer, Dornier or Dassault aircraft, for example. In addition, the regional office will strengthen the company’s presence among the individual operators and maintain contact with Liebherr-Aerospace’s repair station in Singapore, which is responsible for customer service in India and the Asia/Pacific region.

Expanding cooperations

Furthermore, Liebherr Aerospace is planning to expand cooperation with Indian suppliers and further develop the existing delivery chain in the country, in the areas of gearboxes and engineering services, for example. Moreover, the company intends to manufacture parts directly in India in the not too distant



Liebherr-Aerospace supports customers throughout the region from its new office in Bangalore.



Thumbs up for India: After the USA and China, the country is now 3rd in the worldwide rankings of the largest passenger flight markets.

future, and so discussions are also being held with Indian companies about possible partnerships with a view to transferring certain technologies. And not least, Liebherr would like to offer Indian aircraft manufacturers its highly integrated and engineered products in the air management, flight control and actuation and landing gear systems plus gears and gearboxes as well as electronics for upcoming aircraft projects. Liebherr-Aerospace explained what these products can do and what high-tech solutions are possible to potential customers at the Aero India trade fair in mid-February. The response to the company's first attendance at this trade fair was extremely positive, and: "It also improved our position in relation to local suppliers", Joël Cadaux states confidently.

Already successful

In fact, Liebherr-Aerospace currently already supplies and maintains many components for aircraft that are built

in India by the Indian manufacturer Hindustan Aeronautics Limited (HAL), such as heating and ventilation system components for the Advanced Light Helicopter (ALH) program, the cabin pressure control system for the Jaguar and the flap actuation system, landing gear actuators and the nose wheel steering system for the Dornier 228. From this point of view, the first steps

in the Indian subcontinent have already been successfully taken. And in pursuing its strategy further, Liebherr-Aerospace also takes advantage of the fact that the Liebherr Group already has industrial facilities in India. The company can make use of these in order to be able to react quickly, for example, if there is any demand for maintenance and assembly work locally.



Successful début at Aero India

China Takes Off!

China is regarded as one of the most important growth markets for the aerospace industry. In recent years, the volume of passengers just within China has multiplied significantly, and the demand for aircraft is growing steadily. Liebherr-Aerospace is continuing to expand its presence in China and has already been able to achieve major objectives in this market in recent years.

Strong cooperative agreements for a strong market

In 2012, Liebherr-Aerospace Lindenberg GmbH, based in Germany, and the Chinese company LAMC (AVIC Landing Gear Advanced Manufacturing Corporation) founded the joint venture Liebherr LAMC Aviation (Changsha) Co., Ltd. with the aim of developing and manufacturing landing gear systems for the Chinese aerospace industry and the international market. A further important milestone is the cooperation between Liebherr-Aerospace Toulouse SAS, Toulouse (France) and the Nanjing Engineering Institute of Aircraft Systems (NEIAS) with the aim of designing and producing components for the C919 air management system. Alongside the complete, integrated air management system, Liebherr-Aerospace provided the landing gear system for the latest passenger airplane built by COMAC, which had its maiden flight on May 5, 2017.



Impressive trade show exhibit: the nose landing gear of the A350 XWB

The first landing gear for the ARJ21 assembled in China

Last September, Liebherr LAMC Aviation (Changsha) Co., Ltd. delivered the first ARJ21 landing gear to have been completely assembled in China. The assembly line for the main landing gear of the ARJ21 at Liebherr LAMC Aviation (Changsha) Co., Ltd. was built by Liebherr. It was based on the assembly facilities and testing equipment of Liebherr-Aerospace Lindenberg GmbH, Lindenberg (Germany), Liebherr's center of competence for landing gear and flight control systems. The next main landing gears for the ARJ21 will also be assembled by Liebherr LAMC Aviation (Changsha) Co., Ltd. in Changsha. In addition, the joint venture will also gradually take over direct procurement of the parts from suitably approved suppliers. In parallel, it will also be obtaining equipment locally from LAMC and other companies for the machine processing of landing gear parts and will additionally prepare the assembly line for the nose landing gear of the ARJ21. In fall 2015, COMAC had supplied its first customer Chengdu Airlines with the first Advanced Regional Jet ARJ21-700, which was fitted with an integrated air management system and high- and low-pressure ducting made by Liebherr-Aerospace Toulouse SAS and with the landing gear system from Liebherr-Aerospace Lindenberg GmbH.

Great climate in Chinese helicopters

The supply of air management systems for the new helicopter types AC312C and AC312E manufactured by Hafei-Harbin represents a further success for Liebherr. Hafei-Harbin is Liebherr-Aerospace's first helicopter-manufacturing customer in China. For this, Liebherr had signed a contract to this effect with the company, which is part of the AVIC Group, at the beginning of last year. Hafei-Harbin, which is based in the north of China, has been manufacturing helicopters since 1952 and has been working partly in partnership with Airbus and Airbus Helicopters since the middle of the 1980s.



During the ceremony to mark the delivery of the first ARJ21 landing gear assembled in China in September 2016 at Liebherr LAMC Aviation (Changsha) Co., Ltd.

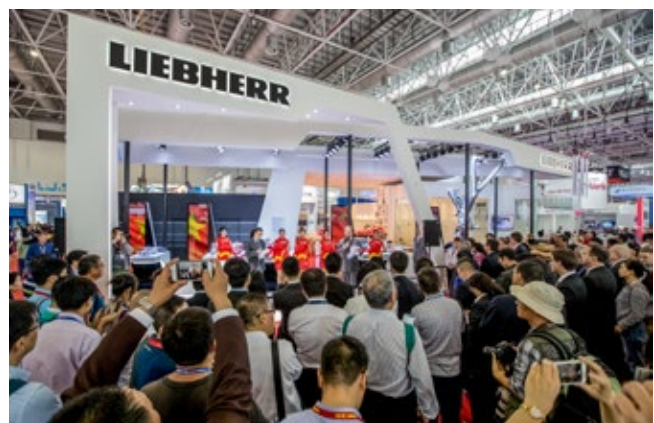
More space and better service for customers

Last November, the expanded liaison and customer service center of Liebherr-Aerospace was officially opened in Shanghai. With a total floor area of 3,700 m², the center is not only twice the size of the original, but also offers further services in the area of maintenance, repairs and overhaul. These include, for example, the maintenance of bleed air and air conditioning systems including air cycle machines. In addition, the center also offers the dynamic testing of components for air conditioning and pneumatic systems (ATA 21, 36) for Airbus single aisle and long range aircraft, Bombardier and Embraer aircraft and COMAC's ARJ21-700. Moreover, Liebherr-Aerospace China can also service flight control and hydraulic components (ATA 27, 29). Liebherr-Aerospace's

OEM inventory is available for exchange and as a rotating pool asset. The facility covers three floors and features, besides work benches, a storage area for piece parts and line replaceable units as well as areas with state-of-the-art equipment for planning, receiving, cleaning, rework, testing and inspection, plus a warehouse and additional office space. In order to guarantee the high standards of quality and safety for its OEM components, the customer service team for China was trained in the OEM facilities Liebherr-Aerospace Toulouse SAS and Liebherr-Aerospace Lindenberg GmbH. The expansion of the customer service and liaison center in Shanghai is thus a further milestone in Liebherr-Aerospace's strategy of expanding and further improving its support for customers.

Liebherr-Aerospace at the Airshow in Zhuhai

In order to make active use of the opportunities provided by the Chinese market, Liebherr-Aerospace is one of the regular exhibitors at Airshow China, which was held in Zhuhai in November 2016. Alongside exhibits from its product lines air management and flight control and actuation systems, gearboxes and landing gear systems, Liebherr-Aerospace also presented its customer service activities here.



A large crowd at the Liebherr stand at the airshow

South America – A Growing Market



Exhibition stand at LAAD

With around 37,000 visitors from 81 nations, the still relatively young LAAD Defense & Security trade fair in Rio de Janeiro is becoming an important meeting place for the South American aviation industry. Liebherr-Aerospace took part for the second time in April 2017 and used the opportunity to meet almost all the aircraft and helicopter manufacturers in the region. In addition to the latest technology in the fields of air management, flight control and actuation systems, the company also

presented the latest generation of landing gear and air conditioning systems, including those supplied to the Brazilian aircraft manufacturer Embraer. Liebherr has had an excellent working partnership with Embraer for decades and has provided on-board systems for almost all of the manufacturer's aircraft. Currently, the Liebherr team is supporting Embraer with the air conditioning system for the KC-390 military transporter, which is already in the final development phase and which is set to be certified later in 2017. Liebherr also supplied the air conditioning and flight control systems for the E195-E2 commercial airliner, which successfully completed its maiden flight recently. In addition, Liebherr-Aerospace was also selected to supply further components in the E-Jet E2 and Legacy 500 business jet programs. Alongside its new developments, Liebherr is also involved in the production phase of, for example, the Legacy 650, Super Tucano, E-Jet E1 and Embraer Regional Jet 145 programs.

Continually expanding the range of services

Liebherr-Aerospace has two sites in Brazil and has been expanding its local facilities for years. In Guaratinguetá in the east of the Federal State of São

Paulo, for example, Liebherr Aerospace Brasil Ltda. now also has a paint shop and an assembly line for high-tech products, in addition to the manufacturing area. Further measures for expanding the site and thus the range of services are currently being considered by Liebherr. The office in São José dos Campos also provides support in the areas of sales, engineering and customer service. The aim is to be able to provide more service from Brazil for the entire South America region. In this context, the company is also considering setting up a spare parts warehouse locally. Technical support for airlines and the training and servicing facilities could also be expanded. "We are experiencing an increase in demand from our customers in this respect", explains Nicolas Bonleux, Managing Director and Chief Sales Officer, Liebherr-Aerospace & Transportation SAS, emphasizing the relevance of the region. "In our view, South America will be one of the most important markets in the next 20 years – the fleet is set to grow considerably here". Alongside the manufacturers, Liebherr also supports operators of aircraft and helicopters throughout Latin America from Columbia to Chile, including all airlines that operate Airbus aircraft.



A glimpse into the manufacturing hall at the Guaratinguetá site



The new landing gear assembly hall will be officially opened in fall 2017.

Final Assembly of Bombardier C Series Landing Gear Components in Canada

As from summer 2017, Liebherr-Canada Ltd. Aerospace and Transportation Division in Laval will be taking over the final assembly of Bombardier C Series landing gear components, thereby developing from a service organization to a service and assembly site. At present, preparations are in the final stage of managing the transfer from Liebherr-Aerospace Lindenberg GmbH, Lindenberg (Germany) to Canada. In order to perform this task Liebherr-Canada has already extended the facility, which includes the set-up of assembly cells as well as the purchase of tooling and any further components needed. Moreover the company's team completed a comprehensive training at the OEM facility in Lindenberg, which means that they are now ready to take on their new tasks and responsibilities.

Following the changeover, components of the landing gear will be shipped from Lindenberg to Laval. Other components, however, will be delivered directly from suppliers that are located in Canada and the United States. All the subcomponents will be tested, quality-controlled, assembled and certified at Liebherr-Canada and then delivered to Bombardier Aerospace, which is only about 40 km away.

"The principle we put forward is a better integration between supplier and customer – that is the final assembly line for the aircraft at Bombardier. Due to the shorter distance, less transportation and protection is needed, and we can guarantee a more controlled environment", summarizes Stéphane Rioux, General Manager for Aerospace and Transportation Activities at Liebherr-Canada.

The Laval facility could support a production rate of one landing gear shipset per day. With the ramp-up of the C Series deliveries, Liebherr-Aerospace will adapt the capacity, staff and tooling to support the customer requirements.

Founded in 1973, Liebherr-Canada, is not only involved in Liebherr's aerospace and transportation activities, but it is also in charge of sales, marketing and product support of other Liebherr products such as construction machines, mobile and crawler cranes, maritime cranes, concrete technology, mining equipment and refrigerators. As for aerospace and transportation, the company offers technical support, logistics support, technical publications, final assembly line support and customer services for aerospace customers, as well as business development and customer support for railway vehicle systems.

"It's My Dream Job"

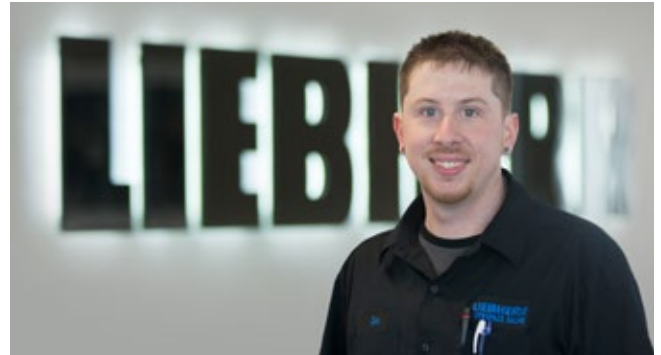
Establishing another facility in Saline, Michigan (USA) Liebherr-Aerospace added to its service portfolio the capability to repair heat exchangers, a component of the environmental control system on board an aircraft. As part of the repair process, Liebherr uses state-of-the-art production technologies such as robotic welding and non-contact precise metrology utilizing 3D laser scanning. Dan Malone serves a dual role as both a Repair Technician Supervisor and a Chemical Processing Technician at Liebherr-Aerospace in Saline, and he is very proud of his job.

How long have you been working at Liebherr-Aerospace Saline, Inc. and how has your job developed over time?

I started my career at Liebherr when I was 19 years old. Fresh out of school, I didn't know much about the company, but I saw that it was constantly growing in the community. So I recognized the opportunity to start a career instead of just a job. I have been here for eleven years now and have had the opportunity to advance my position within the company three times. Liebherr has sent me to several training sessions, as they want all of the employees to continuously grow and develop. When I started working here, I was just a kid and I was able to grow up, because of the opportunities Liebherr has given to me.

How would you describe a typical day at work?

On a typical working day, the first thing I do in the morning is to go around to everyone on the team and see if my colleagues need anything. As a Repair Technician Supervisor, I have to check exactly which heat exchangers come in and which ones go out and ensure together with my team that our customers are happy and satisfied with our performance. Furthermore, as a Chemical Processing Technician, I maintain the chemicals we use for cleaning or applying coatings. This includes a weekly chemical test in the lab to make sure that all of the chemicals are maintained at the right concentration, clean and usable.



Are there any specific challenges in regard to these activities?

Right now, one of our biggest challenges is to monitor our workflow, as we have been growing very fast. We have a team of 27 people in the new heat exchanger building, and we continue to bring on and train new employees. At the same time, we want to be as quick and efficient as possible, and ensure we maintain the quality standards of Liebherr every day. This includes especially our responsibility to our colleagues and our community. I live here and I am raising a family in Saline. Cleanliness and safety come first. That is why Liebherr invested in a wastewater treatment plant that allows us to process waste efficiently and in the most secure way by not only meeting but exceeding the requirements of the local, state and federal regulations.

What do you value most about being a member of the Liebherr team?

I work in a very clean and positive working environment. Everybody here takes pride in what they do. Actually it's my dream job and I truly love this company. Liebherr is family orientated, takes care of me and helps me to provide for my family. Even the members of the Liebherr family come here regularly, shake hands with everyone, and you can see how happy and proud they are. And so am I. The very first year when I started here, I told my co-workers that I want to retire from this company. And it still is my goal.





New Heat Transfer Equipment Servicing is Thriving

With the opening of its new facility in 2016, Liebherr-Aerospace Saline, Inc., Michigan (USA) launched a completely new type of service in Liebherr's aerospace and transportation systems division: The servicing of heat transfer equipment or so-called heat exchangers, which are part of the aircraft's air management system. Having received the Occupancy Permit from the City of Saline and the Federal Aviation Administration (FAA) approval to release equipment to service, the team in Saline started work on the first components in the second half of the year: with a mix of Liebherr-owned equipment for exchanges and customer equipment, such as Bombardier CRJ series aircraft, Airbus Fuel Tank Inerting System equipment and Airbus ATA 21 equipment.

By the end of the year, the company had already recorded a total of 140 orders, consisting of re-cores and repairs. At this point, the site is already ahead of schedule in hiring based on input and prospects. The dedicated staff in the new facility includes a supervisor/engineer, two machinists, six process technicians and ten welders. In addition, there is a non-destructive testing inspector and a warehouse clerk.

In order to implement the latest technological developments, to ensure accuracy and generate time savings, it was furthermore decided to implement non-contact metrology. This technique which features, through laser guidance, fixturing, welding and eventually cutting, is commonplace in manufacturing,

but had not been implemented in this type of service industry. Where feasible, it will allow for robotic welding and cutting as well.

"We are enthusiastic about progress so far, and confident that 2017 will allow us to show a full year's worth of activity in a new environment for us", states Alex Vlieland, President Liebherr-Aerospace Saline, Inc..

Titanium: Low in weight but tough to machine

Component shapes tend to be very complex in the aerospace industry. Titanium valve blocks have a sophisticated inner life, with up to 1,900 test characteristics. This calls for rapid, precise testing methods in order to meet the lowest possible tolerances. In recent years, Liebherr-Aerospace has developed a high level of expertise in titanium processes and also incorporated new manufacturing techniques, such as thread milling and interpolation and lathe processes of component contours. When the titanium valve block is machined from the forged part to the finished workpiece, its weight falls from 21 kg to 9 kg. The latest 3D measuring techniques are used to check precise dimensional accuracy.

“The continuous refinement of components and technologies is always exciting”, says Daniel Mühlegg. The machine operator has been working at Liebherr-Aerospace Lindenberg GmbH since 1991, monitoring the processing centers in titanium manufacturing. “Generally, several different orders are worked on in parallel, which means that you’re following four to six working processes and controlling the relevant tool requirements. This makes the work very varied”, he reports. His work also includes measuring, monitoring and documentation. Two years ago, testing of components using 3D measurement methods during processing was added. The component contours are measured and documented during the machining process, directly on the processing machines.

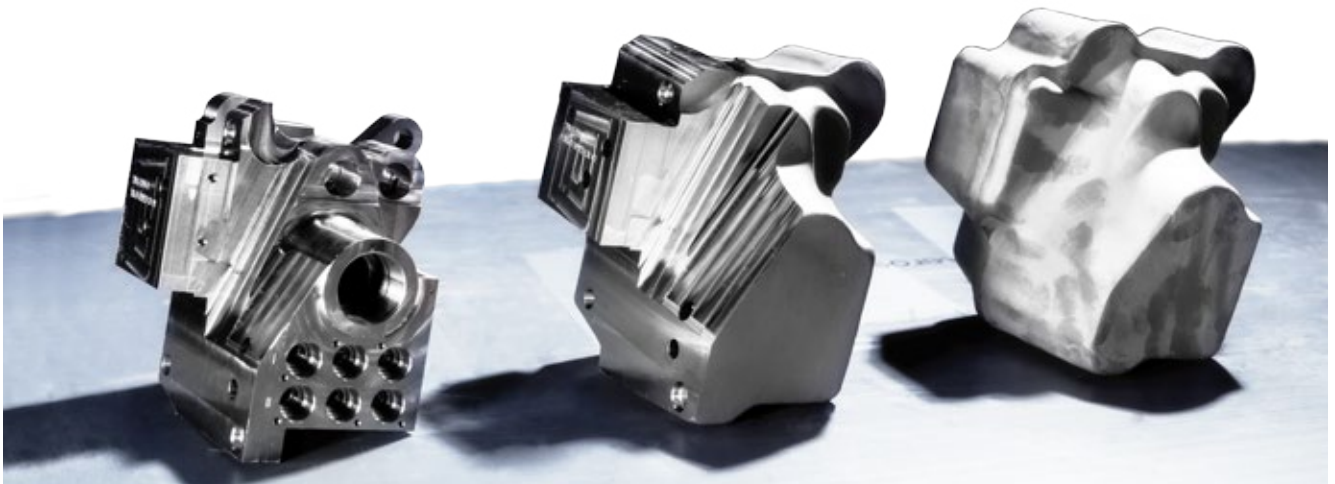
Titanium is a popular material in the aviation industry. It is light and very stable, but is very hard and tough to work with. Liebherr-Aerospace in Lindenberg decided back in 2012 to establish a Titanium Competence Center and committed itself to a high level of automation for manufacturing higher



Reinhold Haußmann (left) and Daniel Mühlegg

quantities from the start. The lead time for the components is thus 40% shorter. Despite the complete automation of the process, however, the level of expertise of the employees is crucial. “Twelve most experienced colleagues work in the Titanium Competence Center. They can tell from the sound of a machine what state a tool is in and how it is behaving”, explains Reinhold Haußmann, Head of Manufacturing / Flight Control. A high level of sensitivity and many years of experience are also required for the subsequent manual deburring.

Originally, titanium manufacturing in Lindenberg was introduced for valve blocks in flight control systems because of the very high pressure on these components. However, titanium components are now used successfully in all sorts of applications. New generations of passenger jets contain around three times more titanium than earlier ones – around 15 to 20 percent – and Liebherr-Aerospace is one of the leading suppliers.



Machining of the titanium valve block is carried out in the processing center in a number of stages. Here, we can see a forged part (right), the intermediate stage (middle) and the almost finished piece before final deburring.

Shaken for All They're Worth

Life's not a bed of roses for an air conditioning system in an airplane: It needs to combine robust, durable design with the highest possible quality standards. The components are therefore meticulously tested and, among other things, rattled and shaken in every direction on a vibration test stand for days – at up to 2,500 vibrations per second. To do this, Liebherr-Aerospace invested 1.4 million euros in a new 4 m long test rig, weighing 23 tons, in Toulouse last year. The requirements for the mandatory tests for certification of the systems under the relevant standards have increased considerably over the last ten years, as Mireille Lemasson, Head of R&D Test Department at Liebherr-Aerospace Toulouse SAS, reports: “The vibration test is carried out in two steps. First, we verify that the equipment is able to support vibration stresses representative of aircraft levels. Then, we carry out endurance tests similar to aircraft life cycle. Each year, over 50 components are subjected to vibration testing at Liebherr-Aerospace in Toulouse. Another way of saving time and costs in development is to carry out tests in a virtual environment. For some years now, Liebherr has been simulating flight control and air management systems using HIL (Hardware In the Loop) test benches

where everything is simulated except the controller and actuator. The company is investing in new, more efficient HIL rigs every year. In this way, possible weak points in the device software and systems can be detected and optimized even before the tests are carried out on the real prototypes for the flight control and air management systems.

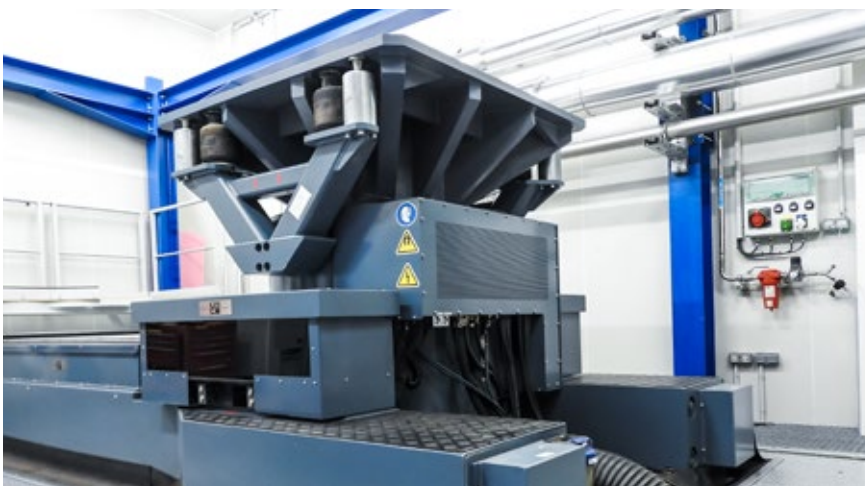
Short ways, faster processes

Manufacturing is also being constantly optimized: Cutting-edge production processes and an ideal degree of work organization make sure that the products are always one step ahead technically. The reorganization of working procedures for the production of heat exchangers in Toulouse led last year to a gain in space of 40 percent. Ergonomics at the workplaces were further improved, ways shortened and processes speeded up. “By reorganizing our manufacturing processes, we are able to provide our customers with even better support in the time-critical start-up phase of their programs in particular”, explains François Ferré. As Heat Exchangers Production Manager, the 36-year-old has been responsible for heat exchanger manufacturing for three years. “We are also planning to considerably reduce noise development at the workplaces, which will



Last check in the fully automated warehouse

increase the ability of our colleagues to concentrate.” In parallel, Liebherr-Aerospace in Toulouse invested in a new, fully automated, highly efficient, environmentally friendly line for surface treatment, which includes not only a welding robot but also three robots to apply the metal powder. Investments in two new hard soldering furnaces and a new forming press are planned for the upcoming year.



A heavyweight: the 23 ton vibration test stand



© Airbus

Programs

The Fascination of Aerospace: Everyone Gets Goose Bumps

The maiden flight is an important milestone in the development of a new airplane – even the most hardened experts feel a sense of excitement. Liebherr-Aerospace has been involved in countless first flights for 25 years. So the specialists in air management, flight control and actuation systems, landing gear and gearboxes are able to draw on a wealth of experience.

When the gates of the hangar open and the airplane rolls out to the runway, generally under the eyes of hundreds of spectators – the aircraft manufacturer’s workforce and representatives of the suppliers –, then the excitement of everyone involved is almost tangible. The test pilots will soon be taking the plane up for the very first time, and it now has to prove itself in real conditions. It also carries with it various systems and components supplied by Liebherr-Aerospace. The work involved to reach this stage is tough and nerve-wracking, and is characterized by close, routine collaboration between the supplier and aircraft manufacturer. “A maiden flight is always a very exciting affair – after all, it is the crowning point of our intense collaboration. At Liebherr, we get involved in it as early as possible”, says Bertrand Maës, Program Manager at Liebherr-Aerospace Toulouse SAS. “In this way, we support aircraft manufacturers right at the aircraft design stage – sometimes even prior to contract award”, adds Norbert

Brutscher, Director Program Management Development at Liebherr-Aerospace Lindenberg GmbH. “In this early phase, the focus is on the optimization of the system architecture in close agreement with the manufacturer. It then ends with the choice of the most suitable supplier and then passes into the definition phase in which the integration of the systems or components is defined more precisely”.

One team, one goal

In the subsequent development steps – from the design phase, prototype construction through qualification and software test phases and right up to the declaration “Safe for Flight” – the manufacturer and supplier steadily grow closer to the first flight, and to each other. There are meetings or telephone conferences every day, and in crucial phases – at the beginning of the project and shortly before the test phase – Liebherr employees also work directly with the

customer on site. “Throughout the whole period, we guide our systems through to product maturity and make sure they are fit for the first flight”, explains Bertrand Maës. For this, complete sets of equipment and corresponding back-up components are produced. Components are tested for safety and stability on a range of test stands and the results are analyzed and painstakingly documented in writing. “In addition, we also make sure that our engineers are available to the manufacturer on site for all activities relating to the maiden flight”, says Maës.

Retaining an overview on the ground too

Tight deadlines, comprehensive qualification tests, extensive assessments and the production start-up of the first system units: The challenges facing suppliers are considerable. “We rely here on streamlined project management so that we can keep an eye on the scope of the planning, timetable, costs and resources at all times”, explains Norbert Brutscher. “In

this way, we can ensure that all the steps run together and are coordinated”. The close coordination between the two Liebherr-Aerospace sites also makes this easier. The specialists from the German site in Lindenberg work closely with the specialists from Toulouse in France in interdisciplinary teams on site at the manufacturer’s works.

All’s well that ends well

Even if the maiden flight also marks the start of a whole series of other tests, during which Liebherr teams work around the clock and under the toughest climatic conditions all over the world analyzing the technology and making adjustments, everyone involved feels an overwhelming pride at the moment of the first successful flight. “When a new airplane leaves the ground for the first time and rises into the sky, it’s something very special, and everyone gets goose bumps until it lands safely again”, says Program Manager Bertrand Maës. “It’s a fitting reward for years of work”.

Bombardier Global 7000 Takes Off

In November 2016, Bombardier sent the new Global 7000, a business jet for long-haul flights, into the air for the first time. Liebherr-Aerospace Toulouse SAS supplies the fully integrated air management system for the G7000, ensuring passenger comfort on board.

During the maiden flight, the essential functionality of the systems, operability and flight properties were examined. The twin-jet airplane climbed to a height of 20,000 feet (6,096 m) and reached a speed of 240 knots, or almost 450 km/h. The new business jet

is aimed at providing comfortable travel standards: It has up to four separate lounge areas for passengers on board, plus a separate rest area for the crew.



© Bombardier

A350-1000 – Take-Off at Extra Length



The Airbus A350-1000, the longest-fuselage version of the A350 XWB, took off for the first time in Toulouse in November 2016. The airplane is fitted with a Liebherr-Aerospace nose landing gear. For its development, the company incorporated the experience it had gained from the design of the nose landing gear for the A350-900

program. The A350-1000 is larger and, with a maximum starting weight of 308 tons, also heavier than the A350-900. The Liebherr-Aerospace team therefore had to adapt the new nose landing gear to meet the new requirements.

Alongside the nose landing gear, Liebherr-Aerospace is developing, supplying and servicing further important components for the A350-1000. These include the slat actuation system, the flap active differential gearbox, plus the load sensing drive strut and the moving damper.

Maiden Flight of the AC312E Helicopter

The AC312E, a helicopter produced by the Aviation Industry Corporation (AVIC) in China, successfully completed its maiden flight in July 2016. Liebherr-Aerospace Toulouse SAS, the Liebherr competence center for air management systems developed and manufactured the air conditioning system for the civil helicopter. In addition, Liebherr was also responsible for the qualification and certification of the system and will also be carrying out the maintenance in the future.

The two-motor AC312E helicopter can take nine passengers or 600 kg of freight. It is to be used mainly for the transport of medical equipment, in

search and rescue services, as a police helicopter or for passenger transport.



Liebherr Receives 2016 Bronze SQIP Award from Airbus

Aircraft manufacturer Airbus presented the award to Liebherr-Aerospace Toulouse SAS for its excellent performance on all Airbus series programs. In addition to compliance with deadlines and product quality, particular mention was made of the environmentally friendly technology. SQIP stands for the Airbus “Supplier Quality Improvement Program”, with which the aircraft manufacturer aims to optimize its supply chain by rating its suppliers in various categories. Liebherr-Aerospace supplies more than 50,000 different systems and components to the Airbus Group, with 38,000 of these going to Airbus Commercial Aircraft alone.



Remi Courcol, Team Leader In-Service Program Management, Jean-Luc Maigne, Managing Director, and Fabien Petit, Quality Security Environment Director (front row, left to right) accepted the award on behalf of Liebherr-Aerospace Toulouse SAS.

COMAC Silver Award for Liebherr-Aerospace

Liebherr-Aerospace is providing the complete landing gear system and integrated air management system for the ARJ21 and C919 aircraft programs. Chinese aircraft manufacturer

COMAC has now presented its 2016 Silver Award to Liebherr-Aerospace for its outstanding achievements.



Wu Yue (left), Assistant to the President of COMAC, congratulated Liebherr-Aerospace’s representatives, Francis Carla, Managing Director and CTO Air Management Systems (3rd from right) and Norbert Brutscher, Director Program Management Development (2nd from right).



© Airbus

Customer Service

Maintenance of Components for Flying Heavyweight

They belong to the heavyweights of the aircraft world and are real work horses: the A300-600ST aircraft series by Airbus, also known as "Belugas", thanks to their appearance. The twin-jet freight aircraft was developed from the wide-body plane A300-600 to transport oversized freight. The dimensions are impressive: With a length of 56.16 m and height of 17.24 m, this giant weighs in at 86.5 tons of unladen weight. To keep this "whale" and its freight in the air, a wing span of 44.84 m and wing surface of 260 m² is required.

The Beluga Cargo Airlifter, the cargo area of which has a useable volume of 1,400 m³ corresponding to an average filling capacity of approx. 10,000 bath tubs, is mainly used for the transport of aircraft components between the eleven Airbus plants in Europe. Currently this is for the wings of the A320 aircraft and the parts required for the

production of the A350 program. This requires a high level of transport-safe and failsafe performance by the Beluga: If the plane has to remain on the ground due to technical events, it may result in a stop in production of the final assembly line. The cargo lifter is in the skies every day from 6 am to midnight securing the production rate of Airbus with its over 60 flights per week. Permanent readiness for operation is essential if delivery delays are to be avoided. This means that the aircraft have to be in top condition at all times, which in turn requires a seamless and well-functioning repair and maintenance service.

In October 2016, Airbus commissioned Liebherr-Aerospace with the maintenance and repair of components, which were supplied by the manufacturer of the Beluga A300-600ST fleet. Liebherr-Aerospace Lindenberg GmbH has taken over customer services

for the actuators for the nose and main landing gear doors and the high lift system of the five freight planes; Liebherr-Aerospace Toulouse SAS for the cabin pressure control system. A customized spare parts warehouse was developed by Liebherr-Aerospace and the Airbus for both areas: This stock can be accessed 24 hours a day during repair.

"Airbus will benefit from our OEM expertise and know-how in carrying out appropriate maintenance work", stated Thierry Gourmanel, Head of Sales & Marketing, Customer Support & Services, Liebherr-Aerospace & Transportation SAS.

Airline Companies Employ Liebherr-Aerospace to Maintain E190 Landing Gear Systems

Liebherr-Aerospace Lindenberg GmbH is responsible for the development and production of the landing gear system for the E170, E175, E190 and E195 E-Jet family made by the Brazilian aircraft manufacturer Embraer. Liebherr-Aerospace also offers its customers a complete, worldwide OEM customer service. This covers repair and maintenance works along with storage, spare parts and, not least, Aircraft on Ground (AOG) servicing. Various airline operators are already making use of this offer, including, most recently, Tianjin Airlines, Mandarin Airlines, Nordic Regional Airlines (Norra) and Finnair.

For Tianjin Airlines, Liebherr-Aerospace Lindenberg GmbH started with all overhaul activities of the nose and main landing gear systems of the E-Jet 190. The Chinese regional airline is the first one in the People's Republic to carry out the E-Jet 190 aircraft landing gear echelon replacement. "The overhaul conducted by Liebherr-Aerospace will contribute to the safe operation of our E-Jet 190 fleet and to our high standards in performance and reliability", comments Sun Xinkai, Director of the Maintenance Engineering Department of Tianjin Airlines. "This cooperation will provide us with data support and experience for future landing gear repair work used on the same series of aircraft in China."

Some time ago, the Taiwanese airline company Mandarin Airlines concluded a maintenance contract with the Aerospace Division of Liebherr-Singapore for the landing gear on its six E-Jet 190s. The maintenance and repair works will be carried out in Lindenberg. "Mandarin Airlines decided to make Liebherr its exclusive service-provider for the maintenance of the E-Jet 190 landing gears, in view of the high standard of service provided by Liebherr and with trust and confidence in the company", stated Dennis Lai, Senior Vice-President Maintenance & Engineering at Mandarin Airlines. The landing gear of an initial E190 aircraft set off on their travels shortly after contract signature: While the two dismantled nose and main landing gears were on the way to Germany for an overhaul, the replacement landing gears were arriving at the airline's headquarters in Taichung, around 150 km from Taipei. After intense work and subsequent technical inspection, the airplane was ready for use again within just a short time.

The contract concluded by Finnish airline Finnair and its subsidiary Norra with Liebherr-Aerospace at the end of last year covers the maintenance of the nose and main landing gears of twelve Embraer 190 regional jets. "We are satisfied to be currently working in a close relationship with Liebherr in order to ensure the success of this overhaul campaign.", explained Arne Ziessler, Head of Procurement at Finnair Technical Operations. "This new contract is a success for us as it reflects the trust our customers have in our experience and expertise that we have developed over the past five decades," stated Frank Steinmaier, Head of Sales & Marketing EUMEA, Customer Services at Liebherr-Aerospace Lindenberg GmbH, when the contract was signed.

The Turkish airline company Borajet Airlines has been using the know-how and customer service offered by Liebherr-Aerospace for around a year now. The Borajet fleet includes 13 Embraer 190/195 aircraft, each of which must be overhauled every 20,000 flight cycles or ten years, according to the requirements defined by the Maintenance Review Board. The nose and main landing gear systems of the aircraft are sent to Liebherr-Aerospace's center of excellence in Lindenberg. "We feel comfortable working with OEM Liebherr for our dense landing gear overhaul program.", explained Olcay Özbay, Technical Director at Borajet Airlines, during the contract signature ceremony. "Liebherr has a high level of flexibility and understands what we expect as an operator."



Juha Ojala, Head of Engineering (Finnair), Frank Steinmaier, Head of Sales and Marketing (Liebherr-Aerospace Lindenberg GmbH), Markku Lindholm, Procurement Manager (Finnair), Pierre Herbillon, Regional Sales Manager (Liebherr-Aerospace Lindenberg GmbH) (left to right)



Miscellaneous

Working Together for an Optimum Supply Chain

SPACE Deutschland e.V. (Supply Chain Progress towards Aeronautical Community Excellence) was founded at the end of 2016. Liebherr-Aerospace Lindenberg GmbH was one of the founding members. Hanspeter Eckert, Director of Procurement, explains the objectives and benefits of the network.

Mr. Eckert, what was the reason for the founding of SPACE Deutschland e.V.?

The idea behind SPACE is the joint further development of the supply chain by aircraft manufacturers and their direct suppliers, known as the Tier-1 suppliers. The focus is on logistics, improved production processes and quality-related matters. SPACE gives us the opportunity to adapt our activities to the particular features of the German aerospace supply chain and to provide our supplier companies with even stronger support from 2017 on. We consider the development of the supply chain and the utilization of synergies to be a major success factor for the future – which is why we founded the network along with six other stakeholders.

What are the areas of activity within SPACE?

It starts with the diagnosis of the supply chain, continues through the further training of suppliers in collaboration with competent partners to the implementation of improvement projects. Other important areas include creating a pool of aerospace experts for the supply chain and identifying and acquiring development funds.

In December 2016, Airbus Helicopters Deutschland GmbH, Airbus Operations GmbH, Autoflug GmbH, Jenoptik Advanced Systems GmbH, Liebherr-Aerospace Lindenberg GmbH, RUAG Aerospace Structures GmbH and the Bundesverband der deutschen Luft- und Raumfahrtindustrie (BDLI) founded SPACE Deutschland e.V. in Berlin, based on the European industry association SPACETM, founded in 2007.

How do you see the role of Liebherr-Aerospace within the network?

From our position on the Board of SPACE, we intend to help shape its activities. In this, we are not just concentrating on topics such as sustainable quality and excellent supply service – we are also looking at professionalizing communication and procedures along the entire supply chain. We are pursuing the objective of using a well developed, professional network plus the synergies with other development programs within which we are developing suppliers. We can promote and support this with SPACE, and thus achieve a lot.



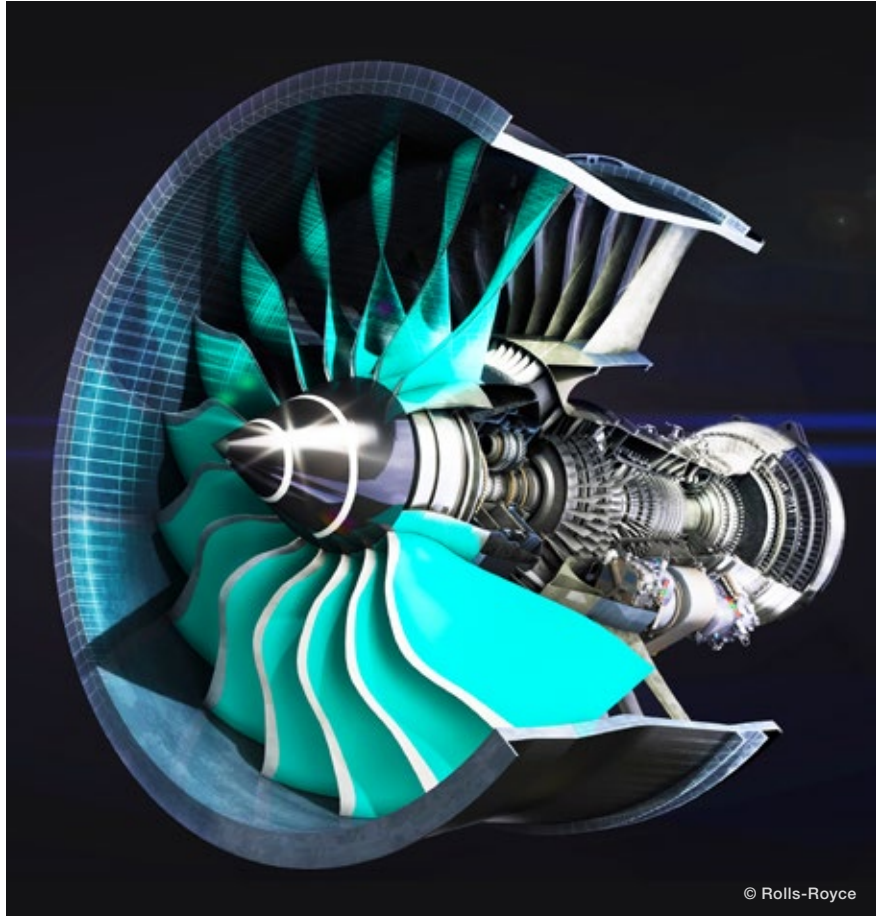
Participants at the founding meeting of SPACE Deutschland

Joint Venture with Rolls-Royce: Young Company Reaches First Milestones

The joint venture, Aerospace Transmission Technologies GmbH (ATT), founded in 2015 by Liebherr and Rolls-Royce, has combined their know-how and capacity to develop the manufacturing technology to produce the power gearbox for the Rolls-Royce UltraFan™ engine design. In fall 2016 the company was able to reach two milestones at once in its young history: successful certification according to EN 9100 and delivery of components for the first run of the Rolls-Royce gearbox (Power-Gearbox - PGB).

“The EN 9100 certification marks a significant step forward for Aerospace Transmission Technologies“, stated Rob Harvey, Managing Director of Technology in the joint venture. “It proves the success of our activities and high standards of quality management and its continual improvement.“ The standard certifies that ATT concretely shows that not only the complete supply chain of single product components can be thoroughly proven but that the interface to customers and suppliers is defined in processes. In addition, the standard regulates processes from verification and validation activities as well as initial sample inspections. This is important for Rob Harvey: “The EN 9100 is a success for us; however, it is seen as a matter of course for our customer. That’s why we are even prouder that we’ve achieved this certification within approx. twelve months – significantly before our actual schedule.“

At about the same time as the certification, at the end of October 2016, Rolls-Royce tested its new power gearbox for the first time in the company’s test center in Dahlewitz, 25 kilometers south of Berlin. “It was overwhelming being in that huge test facility built



Section through the new UltraFan™ engine

especially for this development“, reminisces Heike Liebe, Managing Director of Finances at ATT. In an attitude rig, a so-called position test stand, the engineers simulated all possible effects which could occur in an aircraft engine: the ascent after takeoff, the flying of an incline and the landing approach. The power gearbox is a central component of the UltraFan™, which allows the engine to provide efficient performance over a broad take-off thrust.

The first run was the beginning of a long test series, during which up to 100,000 horse power are applied on

the gearbox. High performance tests, in which the engine can achieve its full performance, are planned for 2017. “We are incredibly proud of being able to see a concrete result in our work“, commented Heike Liebe. Rob Harvey added: “The certification and successful first run gives us confidence and marks progress for Aerospace Transmission Technologies GmbH.“

Participation in Programs

Airbus

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
- 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 (Long Range)
- Avionics Cooling System
- Engine Bleed Air System
- Cargo Heating System
- 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 Defence 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

Cobham

Cobham Mission Equipment

Pod

- Hose Drum Drive System

Airbus Helicopters

AS350/355 Ecureuil

- Environmental Control System Components
- Gears for Main Gearbox

AS365

- Environmental Control System

BK117

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

H145

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

H160

- Environmental Control System Components
- Main- and Tail Rotor Servo Controls
- Tail Rotor Gearbox

H175

- Environmental Control System Components

H225 / H225M

- Environmental Control System Components
- Heating System

NH90

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

Tiger

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

UH-72A Lakota LUH

- Gears for Power Transmission Gearboxes (ZFL)
- Hydraulic Valveblock/Reservoir
- Main- and Tail Rotor Servo Controls

Alenia

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

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

- Cabin Pressure Control System
- Anti-Ice Valves

AVIC HAIG

AC 312

- Air Conditioning System

Boeing

B747-8

- Air Conditioning System
- Engine Bleed Air System

B767 Tanker

- Fuel Tank Inerting Valves

B777-200LR

- Auxiliary Tank Pressurization System

B777X

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

Bombardier Aerospace

Challenger 300/350

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

CRJ700/900

- Integrated Air Management System
- Low Pressure Ducting

CRJ1000

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

C Series

- Integrated Air Management System
- Landing Gear System

Dash8-400

- Cabin Pressure Control System

Global Express

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

G5000

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

G6000 / G7000 / 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 5X

- Integrated Air Management System
- Cabin Air Humidification System

Falcon 7X / 8X

- Cabin Air Humidification System
- Engine Bleed Air System

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

ALX

- Cabin Pressure Control System

E-Jets E1

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

E-Jets E2

- Nose Wheel Steering Control Module
- High-Lift System
- Integrated Air Management System

Embraer 135/145/Legacy 650

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

Lineage

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

KC-390

- Air Conditioning System
- Cabin Pressure Control System
- Engine Bleed Air Valves
- Wing Anti Ice Valves

FAdeA

IA-63 Pampa III

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

HAL

ALH

- Heating and Ventilation Systems

Dornier 228

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

HJT 36

- Cabin Pressure Control System

Jaguar

- Cabin Pressure Control System

LCA

- Cabin Pressure Control System

IAI

Elta

- Environmental Control Unit

G200

- Cabin Pressure Control System Components
- High-Lift System

Kamov

KA-226T

- Air Conditioning System

Korean Aerospace Industries

KHP

- Cabin Pressure Control System Components

KT-1

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

Leonardo

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

Northrop Grumman

Litening

- Environmental Control Unit for POD

Rafael

Litening

- Environmental Control Unit for POD

Rolls-Royce

Trent 7000

- High-Pressure Non-Return Valve

RUAG Aerospace

Dornier 228 New Generation

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

Snecma

Silvercrest

- Engine Bleed Air System

Sukhoi Civil Aircraft Company

SuperJet 100

- Fly-by-Wire Flight Control System
- Fuel Tank Inerting System – CSAS
- Integrated Air Management System

Textron Beechcraft

750/850XP/900XP

- Cabin Pressure Control System

Thales

Damocles

- Environmental Control Unit for POD

RECO NG

- Environmental Control Unit for POD

MELTEM II

- Environmental Control Unit

TRJet

328 Series

- Air Management System
- Flap and Spoiler Actuation Subsystem

Turkish Aerospace Industries

Turkish Light Utility Helicopters (TLUH)

- Air Conditioning System



Liebherr-Transportation Systems

An Effective Lightweight: The New MACS 8.0 Air Conditioning System

Efficient, energy-saving, flexible, flat and light: MACS 8.0, the new Liebherr air conditioning system for all rail vehicle types, is the most multi-talented of all HVAC systems. It was presented for the first time in September 2016 at InnoTrans in Berlin; presentation to customers and integration studies followed. There is a high level of interest in the market: The advantages of the MACS 8.0 are taken into consideration by customers when incorporating future product developments into the planning of new projects.

MACS stands for Modular Air Conditioning System. The basic module is just 220 millimeters high, weighs only 125 kilograms and has a cooling performance of 8 kW. If a higher performance is needed, additional identical modules can be added. For a capacity of 32 kW, for example, three modules are added to the basic module. This is possible due to the high level of standardization of the MACS 8.0. The individual modules are identical in their plug-and-play construction and performance, so that they can easily be installed in the passenger compartment or driver's cabin in combination, depending on the cooling and heating requirement. In addition, the space-saving roof-top air conditioning concept can be used easily in various rail vehicle segments, including trams, subways and local and regional rail systems. The vehicle is thus ideal both for new vehicles and for retrofitting air conditioning systems in existing vehicles.



Flat and lightweight: the MACS 8.0 basic module

With its variable modularity, the MACS 8.0 offers servicing operations and manufacturers of rail vehicles a whole series of further advantages. In comparison with other HVAC systems with a cooling performance of 32 kW, a corresponding quadruple combination of MACS modules is around 300 kg lighter and allows air conditioning systems to be installed in existing vehicles at a later date. In this combination, it offers around 70% greater cooling power density per kilogram of weight –with 8% less power consumption.

Thanks to its multiple cycle redundancy, the MACS 8.0 also ensures maximum availability in operation. If a module should actually shut down, the system can continue to partially function. If the faulty module has to be replaced, this can be done quickly because of the plug-and-play design. This means shorter downtimes for the affected vehicles. This uncomplicated handling means that cost-effective servicing concepts can be realized, which also has a positive effect on total cost of ownership.

Liebherr-Transportation Systems will be presenting the MACS 8.0 systems to customers in Europe, North America and the UK in the near future as part of a large-scale road show. The first deliveries of the equipment to customers in Europe are expected in fall 2017.



Because of its flexibility, the MACS 8.0 is the chameleon of HVAC systems.

“One Team One Goal Award” for Outstanding Performance



Nicholas Crooks (Liebherr-Transportation Systems) and Nicola Phillips (Siemens) at the awards ceremony

Liebherr-Transportation Systems has been presented with the 2016 “One Team One Goal Award”. With this award, Siemens Rail Systems acknowledges Liebherr’s outstanding performance in terms of delivery, reliability and quality. The prize is a tribute from the rail vehicle manufacturer for Liebherr’s efforts in working in close partnership to set up the service agreement for the maintenance and support of the Thameslink Class 700 fleet.

Nicola Phillips, Director of Supply Chain Management at Siemens AG, presented the Award at the Siemens Rail Supplier Summit at the end of 2016 in London Gatwick. Nicholas Crooks, Business Development Manager, accepted the award on behalf of Liebherr-Transportation Systems and in particular the local service team in Gatwick and commented: “This project helped foster a culture of mutual teamwork and collaboration between Siemens and Liebherr.”

CO₂ Sensors for Deutsche Bahn Double-Deck Cars

Around 40% of on-board power consumption for rail vehicles is for air conditioning – almost irrespective of whether the train is fully occupied or half-empty. To reduce power consumption and thus costs significantly, Liebherr-Transportation Systems is offering a solution by which the supply of fresh air is regulated flexibly in line with the number of passengers in the compartment. This is done using sensors

that measure the CO₂ content of the air inside the car; from this, they then reliably calculate the level of occupation in the compartment and thus regulate the necessary fresh air supply as required. Until the end of 2017, Liebherr will be supplying DB Regio with 120 retrofitting kits for installation in passenger compartment air conditioning units in a total of 60 double-deck carriages in the DoSto '94 and 2003 series. The

modified mixture of circulating air and fresh air reduces power consumption by up to 28%, as measurements in DB's own air conditioning chamber for rail vehicles in Minden (Germany) have shown. The contract with DB Regio also now includes the option for more than 842 retrofitting kits for a further 421 double-deck cars.

Roll Coupling Components for Potsdam Trams

Siemens AG, Vienna, has commissioned Liebherr-Transportation Systems to supply roll coupling components for eight Combino low-floor trams. The trams will be operated by Verkehrsbetrieb Potsdam GmbH and are being extended from five to seven cars each. This increases torsion along the entire length of the vehicle as it drives on bends in the tracks. The roll coupling system enables this twisting to be absorbed in the joints. By allowing rotary movements between the car bodies, the hydraulically coupled roll joints developed by

Siemens and Liebherr in collaboration reduce the stress on the car body structure and the chassis if tracks are uneven or winding. Misalignments are automatically corrected using the patented circuit configuration.

The parts supplied by Liebherr include 48 control cylinders, 24 hydraulic accumulators and 24 stop valves, which are to be delivered by the end of 2017.



The low-floor trams operated by Verkehrsbetrieb Potsdam GmbH are fitted with roll coupling components made by Liebherr-Transportation Systems.

News from the “Eco-Clim” Project

It's been traveling through the Région Midi-Pyrénées (southern France) since September 2015: An SNCF regional train fitted with Liebherr's environmentally friendly air conditioning air cycle technology, which is being tested in real operating conditions in everyday passenger operation. The train is also carrying a comprehensive range of measuring and test equipment which allows Liebherr-Transportation Systems to continuously collect all the relevant data, such as temperature inside the car and power consumption. In parallel with the technical analyses, the operating company is regularly carrying out surveys among the passengers.

These show that the passengers clearly rate comfort more highly in the car with the air cycle technology system. The 24-month test phase ends in September 2017. The findings will subsequently be incorporated into the further development of Air Cycle technology. The test is already having a positive side-effect today: On the basis of the measurements to date, Liebherr-Transportation Systems has been able to verify and refine the existing Life Cycle Cost Model for practical application. Once again, it is clear that air cycle technology offers clear cost advantages over the entire life cycle.



An SNCF regional train has been traveling around since September 2015 demonstrating environmentally friendly air cycle technology, which uses normal air for cooling.



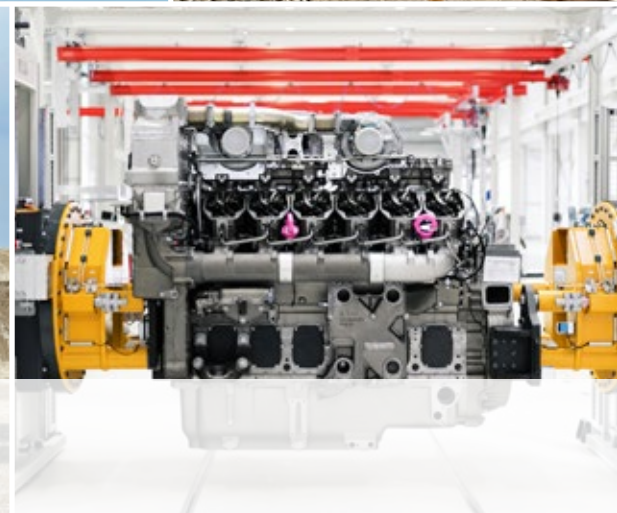
The Liebherr Group

In 2016, in a difficult market environment Liebherr achieved the third-highest turnover in its history, with total sales of €9,009 million.

There were marked differences in business performance in the individual sales regions. In Western Europe, Liebherr's most important sales region, turnover increased. This was due in part to renewed growth in its largest market, Germany, as well as to upward trends in other important markets such as France and the Netherlands. In Italy, too, the last business year was an encouraging one. In the UK, one of the regions most important markets, turnover declined slightly.

In Eastern Europe, particularly in Russia and Poland, sales revenues also developed positively. In the Near and Middle East, sales remained at the previous year's level. In America, by contrast, a slight fall was recorded. In Africa and the Far East / Australia, turnover was below the previous year's level.

In 2016, the Liebherr Group saw a further increase in its workforce. At the end of the year, Liebherr had 42,308 employees



worldwide. Compared to the previous year, this constituted an increase of 763 or 1.8%, and the number will rise again this year. The Group has traditionally emphasised the importance of making regular investments in its production facilities and its global distribution and service networks. As a consequence, the investment rate last year remained at a very high level. Overall, the Group invested €751 million in 2016 and will continue to invest substantially this year as well.

It is anticipated that the coming year will see slight positive growth in the global economy, compared to 2016. The growth trend is expected to increase slightly, both in industrialised countries and in emerging and developing economies and the Group anticipates an increase in turnover this year.

 **Discover more:**
www.liebherr.com

Crawler Cranes

Crane Planner 2.0 – Smart Software for Tough Hardware Challenges

Jobsite installations can be very challenging for planners and engineers. Lack of space, difficult soil conditions or limited crane capacity are all relevant factors. In such situations, Crane Planner 2.0 is the ideal tool for selecting the perfect equipment for the particular application. This not only saves both time and money, but it ensures that safety standards for challenging heavy lifts are observed.

Crane Planner 2.0 combines highly detailed, interactive 3D models with all relevant planning data for Liebherr's crawler crane portfolio (LR 1100 to LR 1300), based on the machine's load moment limitation (LML). Any change in the crane's geometry instantly triggers a new calculation of the entire situation. The software displays a warning should it recognize potential collisions between the crane, the load and the surrounding

area, or non-compliance with safety distances. Additionally, typical dimensioning such as lifting height or radius can be activated and user-specific dimensioning (in both metric and imperial units) can be defined accordingly.

As such, this application is the ideal tool for all planners and engineers who demand both up-to-date as well as accurate 3D models of the utilized crane configuration. Helpful features like Quick-Config, Rigging Editor or the export of crucial planning data (load capacity, ground pressure distribution, and specified geometric information) in a lift plan for each defined step make Crane Planner 2.0 notably faster and considerably more user-friendly than the preceding version.

On top of that, the possibility to supply any configuration of all supported cranes in all positions is unique to Liebherr.



Domestic Appliances

For the premium wine collector or frequent entertainer

Liebherr introduces the innovatively designed HWg 1803. The wine cabinets prove it is possible to save energy without compromising on convenience and design. With advanced energy efficiency, these compact wine storage cabinets are equipped with the latest in climate technology. An easy-to-read LCD screen guarantees exact temperature adjustment between 5 and 20 °C. The dimmable LED lighting provides enhanced illumination and a better view of the stored bottles. Thanks to the minimal heat emitted by

the LED lights the stored wines can be presented without affecting quality. The doors equipped with safety glass ensure protection against UV radiation, guarantee vibrant colors and preserve the taste of the wine. When the glass door is gently tapped, TipOpen technology partially opens the door. If the door is not opened fully within three seconds, it will self-close. The Liebherr HWg 1803 wine cabinets feature secure, handcrafted shelves, designed to offer safe storage for up to 18 Bordeaux bottles. The HWg 1803



is therefore ideal for the premium wine collector and frequent entertainer. It is now available from authorized Liebherr dealers.

Maritime Cranes

Two Giants in South America

Liebherr recently delivered two of the company's most powerful mobile harbor cranes, type LHM 800, to its customer Montecon in the port of Uruguay's capital Montevideo. In 2015, Montecon ordered their first giant mobile harbor crane, type LHM 800, for container operation. Due to their increasing demand for mobile container handling solutions, they subsequently ordered a second unit. Both machines started their nearly 13,000 km long journey from Liebherr's German plant in Rostock in the Baltic Sea to South America.

The LHM 800 is the most advanced mobile solution for the handling of large container vessels. In container handling configuration the eye level is above 40 m, which naturally eases the handling of large vessels. Thanks to its mighty outreach of 64 m, the LHM 800 is able to efficiently operate fully loaded containers, even in the 22nd row. The LHM 800 continues the LHM range's tradition of high working speeds by hoisting and lowering containers with up to 120 m/min. This allows for up to 40 boxes per hour, when the machine is equipped with Liebherr's hybrid power booster Pactronic.



Hotels

Discover Ireland

The Liebherr Group owns six hotels in Ireland, Austria and Germany. Named as Best Overall Hotel at the European Hospitality Awards 2016, The Europe Hotel & Resort in Killarney, Ireland, welcomes its guests with an exquisite interior, exclusive restaurants and a 4,500 m² wellness area. The prize-winning spa with its panoramic views of the boat-house, lake and mountains leaves nothing to be desired.

Built in 1913 in Victorian style, the Ard na Sidhe Country House with its outstanding gardens, antique furnishings and beautiful paintings is located directly on the shore of Caragh Lake. Far away from time and pressure, these unique hotels invite people to unwind and relax.



The Ard na Sidhe Country House on Caragh Lake



The Europe Hotel & Resort has won numerous awards

Crawler Cranes

Spectacular Dredging in the Swiss Alps

A 130-ton Liebherr duty cycle crawler crane is currently operating in the midst of an impressive mountain backdrop in the Swiss Canton of Ticino. Its mission is to clear the sediment deposits from the reservoir's drain. For this purpose, the machine is mounted on a barge and is equipped with a specially designed mechanical clamshell bucket.

Since the beginning of summer 2016, the HS 8130 HD duty cycle crawler crane has been operating in the Swiss Alps dredging large amounts of sediment on the filter grids of the Lake Luzzone reservoir. "In the future, this should ensure the unhindered flow of water to the power station in the Ticino town of Olivone," explains Andrea Baumler, one of the Directors of the Maggia Kraftwerke AG.

At depths of up to 200 m, a total of 125,000 m³ of material has accumulated in close proximity to the power station. The HS 8130 HD is equipped with a mechanical clamshell bucket designed by Negrini, an Italian manufacturer, for this specific assignment. The HS 8130 HD is fitted with a Liebherr V-8 diesel engine with 505 kW that meets the European Stage IV emission standards and U.S. Tier 4 final standards.

The delivery of the HS 8130 HD to Lake Luzzone imposed an immense challenge. On the way to the jobsite the duty cycle crawler crane had to negotiate numerous hairpin bends, pass through two narrow tunnels and cross a 225 m high dam. In addition, shortly before transportation the road had to be cleared of fallen rock. In order to pass through the two narrow tunnels, the duty cycle crawler crane had to be transferred to a smaller carrier shortly before its destination. Due to the extremely limited amount of space, the upper carriage and the undercarriage of the duty cycle crawler crane were delivered separately. Thus, the basic machine's low transport

weight of only 50 tons and the maximum transport width of a mere 3.5 m were an enormous advantage.

As successor to the proven and popular HS 885 HD, the HS 8130 HD has two hydraulic free-fall winches with 35 tons line pull each – about 17 percent more than the previous model. An intelligent control system provides easy handling of the machine and allows for short working cycles. Liebherr's customer, S.E. Levage, is very impressed with the high level of operator comfort. "The handling of the HS 8130 HD is extremely smooth and precise. This contributes immensely to the fact that, so far, the work has progressed according to plan."

It is anticipated that the duty cycle crawler crane will be operating on the high altitude reservoir in the Swiss Alps between May and December for two years. Only after the completion of this work can the power station in Olivone be put back into full operation.

1. In the midst of an imposing mountain backdrop in Ticino.
2. The 130-ton crane on a barge.
3. One shovel of the total 125,000 m³ accumulated material.
4. Crossing a 225 m high reservoir dam.
5. Going uphill at an altitude of 1,600 m above sea level.
6. The transport width of 3.5 m was an enormous advantage.
7. Negotiating one of the numerous hairpin bends.





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