((2. Kapitel))

**1880–1972**

**From a testing institution for construction materials to a modern research institute**

Today, Empa is firmly established in Switzerland's research landscape as one of the six institutions of the ETH Domain. But what are the roots of this research institute? Why was it founded in the first place 140 years ago? And how have political, economic and societal demands changed since the founding days? So let's take a brief look into the history of this astoundingly versatile Swiss institution.

The founding of Empa is closely tied to the history of the Swiss railway system. By the mid-19th century, a number of separate regional railway companies ran a fairly tight network of private railways. In order to encourage more business, in 1864 various operators organized an exhibition of construction material samples in Olten – which is commemorated to this day by a fountain in Olten's City Park. The strength of construction materials is crucial when it comes to building railway bridges – but at the time, there was no way of finding this out. A new device offered a solution: In 1852, the Swiss inventor Ludwig Werder created a machine for testing materials, which he improved over the years. In 1866, at the request of the Swiss government, parliament approved the sum of 15,000 Swiss Francs for the purchase of one of these universal testing machines that even bore the inventor's name (Werdersche Universalprüfmaschine). It was the second in a series of 21 identical machines and was intended as part of the facilities for the federal Polytechnic, founded in 1855 – which is now ETH Zurich.

The government’s purchase of the universal testing machine – a piece of cutting-edge technology at the time, which was first put into operation at the main workshop of the Swiss Central Railways in Olten – laid important foundations for the future emergence of Empa. Under the management of Carl Culmann, who was one of the 31 first professors at the Polytechnic and in charge of civil engineering, the new college used the testing machine intensively over the next few years. Culmann used the machine to test the stability of a range of construction materials for a variety of purposes, for instance materials used for railways and bridges as well as natural and artificial bricks. At the time, empirical engineering was transforming into a discipline based on scientific discoveries that required deeper knowledge of the behavior of materials under real-life conditions. The journey from Zurich to Olten was long and tedious in the 19th century, however, meaning that Culmann struggled to carry out his experiments with the testing machine on top of his teaching duties. This problem was only solved in 1871, when the machine was moved to a basic wooden shed in the Swiss Northeastern Railway’s repair workshop in Zurich.

**Foundation and pioneering era under Ludwig von Tetmajer**

At the same time, Ludwig von Tetmajer, one of Culmann’s students, was studying at the Polytechnic and announced his interest in the universal testing machine. The aspiring engineer cared about two things in particular: the spread of Carl Culmann’s work, graphic statics,and the testing of construction materials, especially structural steels. Tetmajer began – at first alone, alongside his lecturing at the Polytechnic – to determine the material properties of various construction materials. This research came at a convenient moment for the Swiss government, as Switzerland would soon be presenting the first National Exhibition in Zurich in 1883. Thus, in 1880, at the request of the Swiss School Board – the governing body of the Polytechnic at the time (now the ETH Board) – the Swiss government applied to parliament for the sum of 7,000 Swiss Francs for regular operations of the universal testing machine and for establishing a federal institution for the testing of construction materials. This is when Empa was born – although it would not officially obtain this name until quite a bit later, in 1938.

In 1880, Tetmajer became both a professor of construction mechanics at the Polytechnic and the new institute’s first director. The materials testing institute established itself in a small room in the basement of the Polytechnic, installed the necessary equipment and began work. The quality and, increasingly, the quantity of the results were outstanding, and set the bar for institutions around the world. There were no full-time employees yet; however; the Northeastern Railway made staff available to Tetmajer if required. He soon had enough data for a report on construction materials in Switzerland for the National Exhibition, which he wrote together with other experts. The future of the new institution did not look particularly bright, however. Just a year after the National Exhibition, governmental funding for the materials testing institute was called into question by the parliament's Financial Committee, which proposed the money be invested in agriculture instead.

But the newly formed institution received support from two sources: On the one hand, various industry representatives were well aware of the fact that the path to a prosperous future would be challenging without the support of independent materials testing; on the other, the Swiss School Board was receiving indications from various sides that the work of the Polytechnic – in particular in the field of applied engineering – should be expanded rather than reduced. In March 1878, the head technician for the Northern part of the Gotthard Tunnel, which was currently under construction, announced to the contracting cantons that the material costs were going to be considerably higher than anticipated: 8,151 drill heads had been worn down in the course of the construction of the Northern part of the tunnel alone. The machines being used were originally designed for the construction of a tunnel through Mont Cenis in the French Alps, the rocks of which are considerably softer than the hard granite of the central Gotthard massif. In order to curtail the explosion of costs for the tunnel’s construction, highly qualified engineers were desperately sought. On 2 December 1897, the Swiss government, therefore, increased its funding for Empa to the (then) princely sum of CHF 10,000.

**A period of rapid growth**

Since being called to head the newly founded institution, Tetmajer had been intensely engaged with testing materials and had earned both national and international recognition for his work. On the occasion of the Congress for the Unification of Testing Methods for Construction Materials, which took place for the first time in Zurich in 1895, he was voted president of the International Association of Technical Material Testing – a post he would occupy until his unexpected death in 1905.

The number of Empa’s testing projects grew rapidly, from 500 in its founding year to 4,500 by 1899. The number of employees also increased to 21. Together, they achieved an annual profit of CHF 80,000. In 1900, Berta Kreis became the first female lab assistant to be employed. Early records from the Empa archive show the growing number of employees. There was also photographic documentation of the laboratory equipment – something that was particularly important to a later director of Empa, Mirko Roš. Owing to the growing number of employees and the fact that the testing equipment required an increasing amount of space, in 1891, the materials testing institution was able to move to a new building in Leonhardstrasse in Zurich, close to the Polytechnic’s main campus.

**The safety of bridges becomes a pressing issue**

On 14 June 1891, the most devastating railway accident in Swiss history took place: the Münchenstein rail disaster (see page XXX). 73 passengers died and more than 170 were injured when a train fell through a bridge over the river Birs in Münchenstein near Basel. The event should affect the work of Empa and its director Ludwig von Tetmajer for many years. On the very day of the accident, the Federal Councillor responsible for the railways, Emil Welti, ordered an immediate and thorough investigation into the cause of the incident and commissioned the two professors Wilhelm Ritter – Culmann’s successor – and Ludwig von Tetmajer to carry it out. In their final investigation report for the Swiss government, the two experts explained in great detail various omissions in the structural design of the bridge – constructed in 1874 by Gustave Eiffel – that were responsible for its collapse.

A counter-assessment soon followed, however, claiming that the bridge’s collapse was not due to construction errors but to insufficient repairs following flood damage in 1881 and to the excessive weight of modern locomotives required for international travel. Ritter and Tetmajer were, for the most part, able to counter these assertions using materials-based arguments. They also carried out further experiments using Werder’s universal testing machine. As a result, Tetmajer was able to present a graphic and a formula, which soon became tied to his name: ‘Tetmajer’s formula’ became a fundamental calculation for bridge construction for decades to come. For Tetmajer, appropriate safety margins were essential when it came to bridge construction, and he released numerous publications on the subject. He also gave lectures on the use of safety margins and buckling formulas at the Polytechnic.

**Essential for large-scale projects such as the Gotthard tunnel**

Ludwig von Tetmajer’s activities as director of the new institute soon earned it a reputation that reached far beyond Swiss borders. It became renowned as a highly reputable and progressive institution that was based firmly on scientific principles. Thanks to Tetmajer and his inexhaustible personal dedication, the materials testing institute soon became indispensable on a national level. Many Swiss railway projects owed their safe, reliable construction to the early work of Empa. One of the large-scale national projects taking place at the time, in which the emerging institute was involved, was the Gotthard railway. The 15 km long tunnel was inaugurated on 1 June 1882 and represented a huge feat of contemporary engineering, with numerous additional bridges and galleries.

Besides acting as director of Empa, Tetmajer remained dedicated to his role as professor at the Polytechnic, which was a clear indication of his broad knowledge in the field of construction materials. The Tetmajer era came to an end in 1901. He stepped back from his roles in Zurich and moved to Vienna to take on another position. He only occupied it for a short time, however. As a professor of technical mechanics, he taught at the Technical University of Vienna, where he became rector in 1904. Alongside this post, he dedicated himself to developing another testing institution for construction materials akin to Empa. On 31 January 1905, however, Tetmajer suffered a fatal stroke during a lecture and passed away the following night.

**Consolidation under François Schüle**

François Schüle succeeded Ludwig von Tetmajer as director of Empa. Born on 24 November 1860, Schüle was the son of a Geneva shoemaker. Like his predecessor ten years before him, he began studying as an engineer at the Polytechnic at the age of 17. He, too, was a student of Carl Culmann. After graduating, Schüle worked at Gustave Eiffel’s engineering office in Paris from 1881 to 1891, where he was promoted to head of department in 1883. From 1887 to 1890, he represented the company in the French colony of Cochinchina (modern-day South Vietnam and parts of Cambodia) and the Philippines. It was the Münchenstein bridge collapse that brought Schüle back to Switzerland. From 1891, he acted as an inspection engineer for bridge construction at the federal Railway Department. In 1899, he moved to the École d’ingénieurs in Lausanne as a newly appointed professor.

In 1901, at the age of 41, Schüle became both the new director of Empa and a full professor of statics and civil engineering at the Polytechnic. The latter found itself in serious trouble at the turn of the century. Although the Polytechnic celebrated its 50th anniversary in 1905, it was suffering from a serious shortage of space. In 1899, the German Kaiser authorized all Prussian technical universities to award their own doctoral degrees, which put Switzerland under pressure to follow suit. The Polytechnic received the very right in 1908, which resulted in a massive increase in the number of students. A solution to the problem of space was needed as fast as possible. Existing contracts between the city and canton of Zurich and the federal government were renegotiated and adapted to the new requirements. In 1911, the Polytechnic became the Federal Institute of Technology (ETH), with a new structure and new departments.

Although Schüle worked in Zurich as an ETH professor and director of Empa, he maintained close ties to his home town of Geneva. Colleagues and students occasionally complained that he mostly spoke French and held his lectures in French, too. One of his main lectures, ‘Construction materials’, was published by ETH’s Academic Engineering Association in German early on (1913, 1918). Schüle was also dedicated to the tradition of scientific materials testing that von Tetmajer had established at Empa. The scientific approach of these two men would influence Swiss civil engineering for many years. This period also saw the emergence of reinforced concrete as a construction material for bridges. One example of the meticulate working methods employed by Empa at the time is a report for the Association of Swiss Cement, Lime and Plaster Manufacturers written by Schüle following the Swiss National Exhibition of 1914 in Bern. The results of his research also contributed to the new official regulations for constructions using iron and reinforced concrete and the relevant binding agents. His activities also included carrying out assessments for professional associations and construction authorities.

**The pressure to innovate during World War I**

World War I had disastrous consequences for Switzerland, which traditionally relied on free trade with its neighboring countries. There had already been bottlenecks in the import of coal during the Franco-Prussian War in 1870/71, and the dependence had become even greater by 1914. International trading collapsed almost entirely. After the USA joined the war and the associated embargo came into force, coal became a scare commodity in Switzerland. Production in energy-intensive cement factories almost ground to a complete halt, and transportation also suffered as a result of the supply shortages.

Although Switzerland commissioned its first electric power plants at the end of the 19th century, electrification was not yet widespread. With a few exceptions, the low-pressure Francis turbines used in hydraulic power stations did not produce anything near enough energy to meet the demand. It wasn’t until the advancement by Austrian engineer Viktor Kaplan that the eponymous Kaplan turbine could be implemented for high water flow rates, on the rivers Rhine and Aare, for example. As a consequence of the shortages, many construction projects stopped using reinforced concrete, which was becoming rare and expensive, and turned to high-quality local wood with iron reinforcement. Empa provided the necessary data for static calculations and material evaluations in this area. *Schweizerische Bauzeitung* (‘Swiss Construction Magazine’) regularly ran reports on the experiments being carried out at Empa.

Schüle carefully navigated the testing institute through the wartime years, which were also challenging from a financial perspective. At the beginning of the war, Empa achieved a balanced budget, but the restructuring of officials’ salaries in 1917/18 hugely increased the annual expenditure, and Empa remained unprofitable for a long time owing to the ensuing financial crisis. From the early 1920s, Schüle began representing Switzerland at scientific conferences abroad. He was a patient and productive researcher, who found easy access to scientific and professional committees – as his many board positions and honorary roles testify. The Karlsruhe University of Applied Sciences, for example, awarded him an honorary doctorate for his services to materials research – an honor that was conveyed very rarely at the time. He found inner peace in his later years through a deep commitment to the Christian faith and an intense bond with his Romandy roots, which helped him to deal with a declining health that increasingly limited his activities. François Schüle died in 1925 at the age of just 65.

**Reorganization under Mirko Roš**

In 1924, a new director was chosen for the first time whose background was not in academia but in industry: Mirko Roš, born in Croatia, who was director of the Conrad Zschokke Werkstätte in Dottingen at the time. After studying in Belgrade, Roš came to Switzerland as a bridge construction engineer to work on the construction of the Gotthard railway. The new Empa director’s first responsibility was to get the materials testing institute’s finances back on track and reduce federal funding. An expert committee of representatives from both the Swiss School Board and industry was designed to help him in this endeavor. The committee quickly came up with a list of recommendations for various construction materials groups, including metals, concrete and wood, as well as various specialized areas.

Under the management of Mirko Roš, Empa was reorganized step by step. The first phase led to the integration of the Federal Testing Institute for Fuels and the appointment of its director Paul Schläpfer as Empa's deputy director. Schläpfer was born in 1881, the son of an innkeeper in Walzenhausen. He was a private lecturer for chemistry and materials science and authored numerous scientific publications. In 1924, he became an honorary professor, and in 1937 a full professor at ETH.

Despite the integration of the Federal Testing Institute for Fuels – which had played a significant role in the wartime economy – into Empa in 1928, and the resulting increase in salary costs, Roš succeeded in significantly reducing government funding within a short period. However, despite total earnings of over CHF 400,000, there remained unmet costs of CHF 178,000 in 1929. This was due to the large expenditures, partly caused by the unfavorable location: Despite having moved to a new building, there was once again a shortage of space, as the testing devices were continuing to increase in size.

**Widespread electrification in Switzerland**

The interwar period was a time of upheaval in Switzerland, as it was in many European countries. On 24 October 1929, known as Black Thursday, the New York Stock Exchange collapsed, triggering the global economic depression that endured through the 1930s. Public funding was under serious strain in Switzerland, too, and spending needed to be reduced. Europe was seized by social unrest as a result of the depression. In Germany, in particular, but also in Italy and France, there was serious hardship and a shortage of daily necessities. Switzerland was also affected – before the war, it had imported many raw materials for construction and infrastructure from neighboring countries. Imports of iron and steel ceased almost altogether, and coal was delivered only haltingly. Reparation payments by Germany and its allies to the victors according to the Treaty of Versailles impeded trade. The fact that the majority of German coal output was handed over to France meant that there was a shortage of steel being produced.

The difficult interwar period provoked a great deal of invention and innovation. Electrification, in particular, benefited hugely. The first electrical household appliances entered the market, although at prices that were still almost unaffordable for the general population. The Swiss government and parliament pushed the electrification of the railway system. A range of industrial enterprises delivered the components necessary for the locomotives. Walter Boveri and Charles Brown had founded Brown, Boveri & Cie. (BBC) in Baden in 1891, which constructed important infrastructure facilities, starting with power plants. After the Ruppoldingen power plant was completed, Olten-Aarburg AG – the forerunner of Atel – was founded in 1894. As the growing demand for electricity at the end of the 19th century called for a corresponding finance company, Boveri also founded Motor AG for applied electricity in 1895. Its first projects were completed in Italy and South America before the start of World War I. It was the later director of Motor AG, Agostino Nizzola, who created the first-ever Swiss power grid in 1903, connecting the low-pressure power plant in Spiez and the high-pressure hydraulic power plant in Hagneck using a 16 kV high-voltage power line. This helped drive the supply of electricity across Switzerland.

The Gotthard railway, whose locomotives were initially coal-powered, was gradually electrified during the interwar period with the construction of the Ritom (1920) and Amsteg (1922) power plants. In 1922, the overhead line voltage was increased to 15 kV. This meant that enough energy was available to eventually stop using coal-powered trains. The pylons, insulators, metal cables and transformers used by the power plants called for safe, reliable materials. As the national materials testing institute, Empa was the obvious choice. The construction of the power plants could not have taken place without Empa’s help, either. One of Mirko Roš’s outstanding achievements was demanding cuboid samples of the same dimensions from all the buildings, whose strength was then tested by Empa. Other properties of buildings were also regularly surveyed. For the first time, the state of a building could be assessed during construction according to standardized criteria. Testing concrete elements remained one of Empa’s key tasks for many decades. Roš – a proponent of the Mediterranean lifestyle – often took part in the experiments himself, and spent the evenings contemplating the results over food and drinks. During this period, every test report, however long or short, was personally signed by the director.

**Switzerland's first civilian airport**

Starting in 1932, under Roš’s leadership, tests were carried out to establish whether the military airfield in Dübendorf would lend itself to the construction of a large-scale airport for civilian air traffic. The plan was eventually abandoned in favor of the site in Kloten that is now Zurich Airport. Before the new airport could be constructed, however, the land needed to be exchanged. From the very beginning, the project was carried out with close support of Empa. During World War II, very little information was shared across borders about the construction of large aircraft, and it was not until 1946 that a referendum was held in Zurich to approve the construction of the airport. Construction began the same year, and the airport started its operations in 1948. Numerous additional construction phases have taken place since, however.

Regular gatherings were held at Empa, during which experts discussed various norms and testing methods. The Swiss Association for Technical Materials Testing (SVMT) emerged from a series of events held in 1926, and its foundation further institutionalized materials testing in Switzerland. Article 2 of the SVMT bylaws defined the activities of the new association, which included scientific research into the technically important properties of construction materials and other technical materials, the development and agreement of unified testing processes and the standardization of the necessary equipment. From the start, Empa played a significant role within SVMT and acted as a branch of the association. Roš remained the president of SVMT until he left Empa in 1949. Alongside Roš, a number of members of Empa's senior management were always part of the SVMT board or served on its committees. In the 1930s, Roš became Switzerland’s official representative on the International Committee for Weights and Measures (CIPM).

**The testing institute in St. Gallen becomes part of Empa**

Mirko Roš’s time as director also saw the integration of the St. Gallen Testing Institute for the Textile Industry into Empa (see page xxx). For centuries, yarns and fabrics of all kinds had been made in the St. Gallen region and exported around the world. The Swiss textile industry even features in Johann Wolfgang von Goethe’s *Wilhelm Meister’s Journeyman Years.* As an important pillar of the economy in the St. Gallen area, the textile industry had survived various crises and hardships throughout the centuries, including multiple outbreaks of the plague, which killed almost a third of the population, and the trade war with France at the beginning of the 19th century. Towards the end of the 19th century, the leading textiles manufacturers in Eastern Switzerland recognized that the only way to ensure the survival of their factories was strict quality control – competition from mechanical production in nearby Zurich and abroad had become too great. Eastern Switzerland’s small-scale textile industry struggled to withstand the cost pressure. On 1 July 1885, at the request of 17 regional cotton-spinning mills, an Inspection Body for Cotton Yarn was founded under the care of the St. Gallen commercial directorate. The modest sum of CHF 438 was allocated for the initial equipment of the facilities, which allowed the inspection body to open for two hours, four days a week. To begin with, yarn inspection was free.

The inspection body soon moved to a space in the newly built Industry and Trade Museum in St. Gallen. In 1899, the University of St. Gallen was founded, and the testing body sought a place under its roof. It wasn’t until 1911, though, when a new university building was constructed, that its wish was granted. At the same time, it also obtained a new name: the Inspection and Testing Center for the Textile Industry. In 1907, technology lecturer Johann Jovanovits became its director. The institute expanded its testing services to cover the whole field of textiles, and it acquired a chemical textile laboratory. World War I called for the testing of various materials for the wartime economy. Following a decision by the Swiss government, the testing center became a federal testing institution in April 1918 and also began testing materials such as leather, grease, oil and soap. The testing institute was also struggling with a shortage of space, and the city of St. Gallen provided it with its own building in 1931. Contrary to the original plans, however, a new building was only constructed over 60 years later.

In the summer session of 1936, the Swiss parliament decided to take federal ownership of the St. Gallen testing institut and integrate it into Empa. For a significant time, Empa would be comprised of three main sections. Following the reorganization, Mirko Roš became the head of engineering section A, which covered the construction and machine industry, while Paul Schläpfer took charge of section B, which mainly covered chemistry and operating materials. Sections A and B remained on the premises in Zurich, while Johann Jovanovits headed section C in St. Gallen.

**Poorly constructed wartime bunkers**

By the end of the 1930s, Empa had become an integral part of the Swiss testing and research community. It enjoyed an excellent reputation; anyone who had a materials query found support and advice at Empa. Political developments did not allow Empa's staff any time to rest on their laurels, however. The political climate in Europe was darkening rapidly, and World War II began on 1 September 1939 following Nazi Germany’s invasion of Poland. Once again, the Swiss population and economy had to grapple with shortages and limitations.

Empa provided help wherever it could. As a colonel of the Armed Forces, Paul Schläpfer advised the army on the manufacture of alternative fuels. On 16 May 1942, Johann Jovanovits held a lecture at the University of St. Gallen titled ‘Scientific collaboration in the wartime economy’, in which he emphasized that, in these uncertain times, wasting resources could not be tolerated – an initial, visionary call to efficient resource use and sustainability long before they became buzzwords.

As became painfully clear after the war, however, not all members of the civil economy or the military shared this vision. In 1946, countless wartime bunkers were discovered to have such major defects that the issue grew into a political scandal. Empa analyzed hundreds of concrete samples as part of a lengthy investigation. The results were devastating: The concrete used in the majority of structures, which formed part of the famous National Réduit, would not have withstood bombardment. The government was alarmed. Soldiers launched vehement protests. The country felt betrayed. With the collusion of members of the military, well-known companies had clearly delivered poor-quality concrete while charging for high-quality materials. On 25 October 1950, the ‘bunker trial’ began in Bern against 25 defendants. 300'000 pages of investigative reports were presented – an impressive volume, especially considering that, at the time, everything was documented by hand or using a typewriter. In the end, most of the defendants were given only suspended sentences. The Social Democratic Party newspaper *Volksrecht* was decrying the verdict as "class justice", while voices on the right countered this assertion.

**Eduard Amstutz at the helm**

In 1949, Empa reached a turning point. Mirko Roš and Paul Schläpfer both stepped down, leaving the management of sections A and B unoccupied. Roš died in 1962 after a long illness, while Schläpfer was able to enjoy his retirement until his death in 1973. Johann Jovanovits, head of section C, had already died back in 1943 at the age of 65, while still working at Empa. His successor, Alphons Engeler, took over in 1944. He had joined what was then the St. Gallen Testing Institute for the Textile Industry as a PhD student in 1922 and went on to fulfil a number of roles including head of the leather department. He later became both a professor at the University of St. Gallen and director of Empa St. Gallen. Engeler remained in this role until he was replaced by Paul Fink in 1968. Fink had also been working for Empa for some time, including as head of printing, paper and packaging.

Edward Amstutz succeeded Mirko Roš as director of Empa. Amstutz came from Thun and studied mechanical engineering at ETH. He was heavily influenced by his teacher Aurel Stodola, an extremely social-minded individual and an outstanding teacher, who gained international renown for establishing the machinery laboratory at ETH. Amstutz was appointed as associate professor of the newly created Chair in aircraft statics and construction at ETH in 1938. His attitude towards the military was fraught at the time, but he was nevertheless chosen above a candidate from the Federal Department of Defence (FDoD). In 1943, shortly after Stodola’s death, Amstutz became a full professor of aircraft statics and construction, and professor of materials science and materials testing six years later. While occupying this role, he also took over at Empa. Amstutz hesitated for a long time before agreeing to succeed Roš owing to his strong ties to the academic world. Eventually, the president of the Swiss School Board, Hans Pallmann – with the help of Jakob Ackeret, an aerodynamicist and friend of Amstutz’s – was able to persuade his candidate of choice to take on the role. At the time, Amstutz had the reputation of someone who never leaves but is always called.

**A dedication to Swiss aircraft technology and aviation**

During the first few years of the war, little attention was given to the importance of materials science. This changed when ETH graduate and Federal Councillor Karl Kobelt became head of the FDoD in 1941. It was the middle of the war, and the country needed all the resources it could get. Amstutz and Ackeret took positions on the committee for aircraft procurement. Together with the mechanical engineer and thermodynamicist Gustav Eichelberg, they formed a legendary trio of aviation mechanics at ETH during the mid-20th century. All three were former students of Aurel Stodola.

A quote from Amstutz from 1958 reflects the atmosphere in the country at the time: It was ‘the chaos of different opinions about the kinds of aircraft needed to defend our country’ that posed the greatest threat to ‘Switzerland’s successfully developing its own military aircraft’. In a speech on the occasion of Jakob Ackeret’s 60th birthday, he remarked that, ‘The Swiss aviation industry never lived up to what we imagined it would be as students.’Amstutz was referring to the failed project of the Swiss fighter plane N-20 and the follow-up model P-16. The trial machines of the 1950s had a range of innovative features and a cutting-edge construction concept for the time. The Swiss parliament cancelled its original order of 100 P-16 machines in 1958 after two of the five prototypes crashed during the test flights, however. The design of the fighter plane was later pursued in Italy and the USSR. Both countries succeeded in getting their planes off the ground and into serial production. Amstutz found it hard to conceal his disappointment. He repeatedly expressed his deep desire for Switzerland to develop its own aircraft in the popular *Flugwehr und -technik* magazine. In the March issue of 1958, for example, he wrote that, of the three options for procuring aircraft – purchase, licensing following by construction in Switzerland, and domestic development and construction – only the latter could be considered by an engineer.

As an ETH professor and director of Empa, Amstutz promoted aviation in Switzerland whenever the opportunity arose. He assisted the FDoD with queries about aircraft procurement and played a major role in the development of civil aviation. From 1941 to 1948, he acted as the civil aviation delegate on behalf of the Federal Post and Railway Department. In this role, he was responsible, among other things, for the strategic concepts for the development of Swissair – where he was a member of the supervisory board for around 25 years. Amstutz was also closely involved in the construction of Zurich Airport.

Ernst Brandenberger became the new head of section B of Empa in 1949. Brandenberger had been working for Empa on and off since 1932. He came from Flaach and studied mineralogy and crystallography at ETH. As a young private lecturer, he played an unfortunate role as regional party leader of the National Front in Zurich, a far-right party. ETH temporarily withdrew his title in 1942, in part for organizing an unauthorized National Front torchlight parade on 1 August 1938. His military career also ground to a halt. In the latter years of the war, however, he largely abandoned his activities for the National Front. Brandenberger enjoyed an impeccable reputation in his scientific field, and by 1947, he had been made an assistant professor. He acted as both a professor at ETH and head of section B at Empa from 1949 until his death. His military career also regained speed, and he acted as commander of Border Brigade 6 from 1958 until 1965. Alongside his scientific activities, Brandenberger also acted as a consultant for the Swiss watchmaking industry and was an active, longstanding member of SVMT. The ETH Library contains more than 250 scientific publications under his name, including several books.

**A new building at last: the move to Dübendorf**

In the mid-20th century, Switzerland experienced a fresh start. Unlike its neighboring countries, it was not suffering from wartime damage. The economy was soon able to start producing civilian goods on a large scale again. A wide range of social classes benefited from the new products that emerged. It was a prosperous time for Empa, too. Its revenue had increased from CHF 35,270 in 1894 to well over CHF 4 million. The number of employees increased to 260. The only issue was the enduring lack of space in the buildings on Zurich's Leonhardstrasse. The institution had been considering expansion since the days of Mirko Roš. While the Swiss government acknowledged the problem, public resources needed to be allocated sparingly for a long time. The question of location was also touchy. After many controversial discussions, and with the support of the Swiss School Board and influential industry circles, the change finally came in 1953. On 11 June, a draft legislation from the Swiss government concerning the construction of new buildings for Empa in Dübendorf reached parliament, and the requested means of CHF 62.5 million were approved. The buildings were finally completed in 1962, and the relocation from Zurich to Dübendorf took place a year later (see page xxx). The spacious new premises offered enough room for the entire research infrastructure and all employees. At the official opening, Federal Councillor Hans-Peter Tschudi conveyed the government’s best wishes for the future.

Shortly after the relocation, Empa required all of the analytical resources at its disposal: On 4 September 1963, a Caravelle Swissair plane crashed in Dürrenäsch in Aargau, killing 74 passengers and six crew members. As a former professor of aircraft construction at ETH, the search for the cause of the crash was a top priority for Eduard Amstutz. Tracing the cause of the accident required substantial knowledge of the aircraft’s components and the take-off process. In the end, the failure of the plane’s hydraulics was identified as the reason for the crash. This, in turn, was caused by brakes that had overheated, setting fire to the highly flammable hydraulic fluid that had leaked (see page xxx).

**Environmental protection as a research topic**

After Amstutz’s departure in 1969, Empa fell into crisis. The new director, Theodor Erismann, was given the task of reorganizing Empa – a process that had been looming for years. The three sections, which were divided into more than 20 laboratories and were in some cases under a somewhat authoritarian leadership, were reorganized into six departments. The Swiss School Board expected the new organization to result in greater efficiency when it came to tackling large-scale problems like the Swissair crash. Applied research activities were also gradually introduced. Environmental protection was becoming a matter of urgency at the time. Empa researchers had long since begun analyzing air and water pollution (see page xxx). The new organizational structure was established over the next years and remained in place for many years afterwards. It is the basis of the innovative, interdisciplinary, highly networked structure of today's Empa.

((Einschub 1))

**The worst accident in the history of the Swiss railways**

‘It’s impossible to even come close to describing the state of the iron structure after the crash,’ wrote Empa founder Ludwig von Tetmajer about the sight of the collapsed railway bridge in Münchenstein. In the early afternoon of 14 June 1891, on a beautifully sunny Sunday, a fully booked train with 500 people belonging to the Jura-Simplon Railways left Basel main station. The train had 10 passenger carriages, a post carriage and a luggage carriage, attached to two locomotives. The disaster occurred as the train traversed the bridge over the river Birs. A terrible cracking and crashing could be heard, and the bridge broke in two between the two locomotives. The front passenger carriages fell into the river, which was flooded at the time. The next carriages fell behind them, pushing the passenger carriages deeper into the water. Many people were trapped in the wreckage. One carriage remained suspended on the broken edge of the bridge, and was torn in two. The passengers in the rear carriages were fortunate: Because the brake system pipes were severed when the first carriage fell, the brakes were activated, enabling the rear carriages to stop in time.

**The accident raises questions**

73 people lost their lives, and over 170 were injured. The first question to be asked was how such an accident could have happened. Had the locomotives been too heavy? Or did the engineer make a mistake when designing the railway bridge? This was a serious allegation considering the bridge was built by Gustave Eiffel himself, the engineer behind the Eiffel Tower. To establish who was to blame, the Swiss government commissioned two professors at the federal Polytechnic to investigate: civil engineer Wilhelm Ritter and Empa director Ludwig von Tetmajer. They visited the site of the accident the very next day.

After conducting investigations on site and carrying out numerous experiments, the two experts produced a detailed report. Their conclusion was that the bridge had been inadequately constructed using inferior-quality steel. The flooding in 1881 had also damaged the bridge, and attempts to strengthen it had not rectified the weaknesses. The static calculations carried out by Tetmajer and Ritter indicated that the individual struts were far too weak. Their report states that the bridge had been ‘at the edge of its load-bearing capacity, and it only needed a small incident to cause it to collapse’. Based on the results, Tetmajer urged the federal government to revise the standards for calculations relating to iron bridges. He felt it was his responsibility to help avoid disasters caused by technical faults and protect human lives.

**Work and recognition for Empa**

The federal government followed Tetmajer’s advice. The first bridge construction standard was introduced a year after the Münchenstein railway accident. The federal government also ordered all railway bridges in Switzerland to be evaluated as a precautionary measure. This meant a lot of work for Empa, which was still a young institution at the time, but it also earned it a great deal of recognition and public attention. Based on the defects uncovered by the investigations, all railway bridges in Switzerland were strengthened.

The replacement bridge that had been constructed in Münchenstein in the wake of the collapse is still standing today. Empa researchers strengthened the bridge with carbon fiber-reinforced polymers (CFRP) in 2018 to ensure that it will remain safe for the future.

((Einschub 2))

**Two institutes merge**

In 1935, the St. Gallen Testing Institute for the Textile Industry had 22 employees. It had existed for 50 years, since its humble beginnings as the free Inspection Body for Cotton Yarn, which was run by weaving instructors and, in the year of its opening in 1885, was open for just two hours a day. In 1911, it became part of the physical chemistry department at the University of St. Gallen. A professor was put in charge, and its field of testing was expanded to include the whole textile, leather and soap industry. By 1935, what had begun as a local testing center had become a research institute offering important services across Switzerland. While it still received financial support from local sponsors, the Swiss government began awarding direct grants to the research institute from 1925. Despite this, however, the institute was facing challenges: It was suffering from a shortage of space. Its staff were working in the basement of the university in laboratories that were originally designed as storage and packing rooms.

In 1935, the Swiss government, therefore, suggested that the Federation take over the testing institute in St. Gallen. But that wasn’t all. The government also wanted to eliminate any overlap between the various institutes under the oversight of the Swiss School Board. As Empa and the St. Gallen testing institute carried out similar tasks in some areas, the government suggested combining the two institutions. The two separate locations – Zurich and St. Gallen – were to remain intact, however. The government indicated that combining the two locations would have been more efficient, but it declined to do so owing to regional political considerations.

The moment came in 1937. The St. Gallen testing institute became part of Empa in the form of section C. This allowed its employees to finally move out of the basement. But at a price tag of CHF 1 million, the new building that was originally planned was too expensive for the Swiss government – at least, the institute was allowed to occupy an empty office building in St. Gallen instead.

((Einschub 3))

**Empa gets its own campus**

‘A patchwork mishmash’ – that was how the Empa sites were described by the Swiss government back in 1938. Empa had been forced to occupy spaces in more than 20 (!) different buildings in the city of Zurich. Not only was it suffering from an acute shortage of space but, upon inspection, the operational safety of the facilities left much to be desired. This and the high importance of materials research during the post-war period caused the Swiss parliament to allocate the grand sum of CHF 62.5 million to Empa’s relocation to Dübendorf in June 1953. This signaled the start of the most expensive post-war construction project to date. CHF 62.5 million was a truly enormous amount of money at the time – as a comparison, Empa’s annual budget was just CHF 4 million. The same investment would amount to more than CHF 1.5 billion today.

**Dübendorf was only the second choice**

Schlieren was originally selected as the location for the new buildings. But the Swiss Federal Railways (SBB) suddenly laid claim to parts of the plot that had been designated for Empa, and so the new campus was shifted to Dübendorf. It took around ten years from the approval of the funding for the researchers to be able to move into the brand new campus, which was located just outside of Zurich.

Construction was completed in 1962, and many of the buildings have not changed since, at least from the outside. A large part of the site still radiates the classical modernism that Zurich architect Werner Forrer strove for with his award-winning design. The only additions to the Dübendorf campus have been the Empa-Akademie, built in 2000, and the NEST and move demonstration platforms (see pages xxx and xxx). These new buildings represent the metamorphosis of Empa from a venerable testing institute into a cutting-edge, innovative research institute. And this transformation continues. The Empa campus will continue to adapt to meet researchers’ demands for state-of-the-art infrastructure. The master plan for the Dübendorf campus includes, among other things, a new laboratory building located directly behind NEST.

((Einschub 4))

**Why did the Caravelle crash?**

Six crewmembers and 74 passengers were on board the Caravelle plane when it left Zurich Airport for Rome at 7:13 am on 4 September 1963. The flight ended in a smoking crater on the outskirts of the village of Dürrenäsch in the canton of Aargau just seven minutes later. It remains the second biggest airplane accident in Switzerland to this day.

Led by the aircraft accident investigation authority, a reconstruction of the events began immediately after the crash. Half a dozen Empa experts investigated the wheels, brakes, fuel and operating materials, in particular, which were considered possible causes for the crash. They reassembled fragments, carried out chemical and metallurgical analyses and painstakingly examined numerous X-ray pictures.

**A tragic chain of events**

A year after the accident, the cause was uncovered: 4 September 1963 was a foggy day. Before take-off, the pilot taxied up and down the runway to assess visibility and clear the fog using the hot exhaust fumes, which was a standard procedure at the time. But the Caravelle’s parking brake was slightly on, causing the wheel rims to become extremely hot. This damaged the magnesium alloy, resulting in one of the wheel rims bursting as the plane turned. One of the fragments must have punctured the hydraulic tubing, and the leaked hydraulic fluid caught fire. After take-off, once the wheels were retracted into the landing gear, the fire quickly spread to the tires, eventually burning through a fuel pipe. As the fire spread, the hydraulic system failed, the crew lost control of the Caravelle, and it crashed.

The results of the investigation had huge consequences: The fuel pipes in all Caravelle aircraft were shielded, the hydraulic system was improved and the hydraulic fluid was changed to one that was less flammable. Temperature sensors also became part of the standard equipment for all passenger planes from that point on. Taxiing up and down the runway in foggy weather is no longer necessary today thanks to effective radar systems.

((Einschub 5))

**Atmospheric research at the ‘Top of Europe’**

In the early 1930s, when many European countries were shutting themselves off, Switzerland opened the international Jungfraujoch research station. Empa has now been conducting research at the ‘Top of Europe’ for almost 50 years. Empa researchers specialized in the impact of air pollution on air quality and climate. Its central location in the heart of highly industrialized Europe and the low level of local pollution made the research station at Jungfraujoch the perfect place for investigating harmful emissions in Switzerland and other European countries. Empa established the laboratory next to the Sphinx Observatory itself, and began taking its first measurements in 1972. Initially, the researchers examined only a few substances such as sulphur dioxide (SO2); today, their measurements monitor over 70 different chemical compounds – some of which are only present in minute amounts.

And it’s not just Europe that benefits from the investigative prowess of this team working at an altitude of 3,500 meters: The research station is part of an international network, which includes the research network AGAGE (Advanced Global Atmospheric Gases Experiment) with 13 measuring stations around the world and GAW (Global Atmosphere Watch) with 31 global and 400 regional stations.

Based on the data collected at Jungfraujoch, and in collaboration with international partners, Empa researchers analyses the spread of pollutants and trends in terms of damage to our atmosphere, ecosystems and the oceans. This enables them to identify the sources of pollutants or even forbidden substances – such as chlorofluorocarbon CFC-11, emissions of which have risen in China in recent years despite the ban set out in the Montreal Protocol. The data and computer models provided by Empa researchers are thus ideal for monitoring compliance to international treaties for the protection of our atmosphere.