Summer Internship Program 2020

RESEARCH IN MUNICH

June 1 – July 31
Research in Munich!

“This 9-week long summer program designed for students in engineering is one of the best-kept secrets of study abroad programs due to its exceptionally low cost and extensive range of programming. The program offers 4 weeks of beginning German language instruction which are integrated with 9 weeks of internship placements alongside researchers in local engineering labs.”

The University of Arizona Office of Global Initiatives

The Bundeswehr University was founded in 1973 with the aim of providing officer candidates with a university education that also prepares them for civilian careers. Located on the 140-hectar grounds of a former military airbase on the outskirts of Munich, the campus university combines studying with living, research and work. Despite the size of the campus, students can get from the lecture halls and research labs to the main facilities on campus and the cafeteria in a matter of 15 minutes. It is a modern university with a beautiful green environment in the outskirts of Bavaria’s capital city Munich. And the city of Munich is just a short bus ride and a subway ride away and offers a wide range of events and cultural attractions.

Since the university first opened its doors, the number of students has steadily risen. Today there are around 2,900 registered students, including 470 women, approximately 30 international officers and 240 civilian students (as of 2018). The Bundeswehr University Munich (UniBw M) is globally networked. It has partnerships with more than 70 internationally renowned universities and institutes in Europe, the USA, Latin America, Japan, South Korea, Israel, among others. In cooperation with the International Office on campus, students can participate in a variety of exchange programs without having to pay tuition fees.

Just like at other universities, research at the Bundeswehr University Munich is open and independent. With projects ranging from electric mobility and IT security to water engineering, the university has a firm standing in the national and international research landscape – in theoretical as well as in practical research. Not only was the first autonomous car built on campus, professors also developed an essential part of the European Satellite Navigation System Galileo at the university.

The Bundeswehr University Munich has also enriched its research activities by entering into new cooperations in the past years, which include important cooperation agreements with extra-university research facilities and industrial enterprises in the fields of electrical engineering and information technology.

The following pages contain more detailed information on the different research areas and projects conducted by the University’s various departments and respective internship within these departments.

We hope that you will find our program to be both informative and attractive!

The International Office Team
Bundeswehr University Munich
Application

The Bundeswehr University Munich is pleased to invite applications for its Summer Internship Program from June 1 – July 31, 2020.

The program is open to all advanced undergraduate and graduate students who are enrolled in a course of study related to civil engineering, mechanical engineering, electrical engineering, computer science or related study programs or in a course of study related to sports science or marketing (see internship offer on page 29).

No knowledge of the German language is required.

Successful applicants will live in a university building not far from the library, dining hall, and fitness center, as well as the laboratories in which they will be working.

If you are interested in applying, please contact your university’s study abroad office. See more at: https://global.arizona.edu/study-abroad/program/research-munich#sthash.sCY2sDEK.dpuf.

Application Deadline: March 15, 2020
Road Traffic Safety and Safety of Infrastructure

Human beings are incapable of preventing natural disasters such as earthquakes or floods. However, we can learn how to assess risks and to prepare ourselves so as to minimize the damage caused by disasters or unforeseen events. Researchers at the University are working in a variety of fields towards this common goal.

Keeping our Cities Safe
Prof. Norbert Gebbeken 01

Flood Protection on a Local Scale
Prof. Andreas Malcherek 07

Construction Materials
Prof. Karl-Christian Thienel 09

Securing Energy Resources in a Responsible Way

Energy is a scarce and valuable commodity. Researchers at the University are working on technologies to exert energy in the most efficient ways possible. Using such technology energy can be saved or even gained – and the applications are both safe and innovative!

Powering the Future of Electric Mobility 12
Prof. Dieter Gerling

Plasma Technology: Surface Treatment and Surface Coating 17
Prof. Jochen Schein

Small Friction Tesla Turbines 19
Prof. Stefan Lecheler
Safety in Technology and Communication

Developments in information technology and telecommunications have helped to make our world a safer place: from security systems to biometric passports and risk evaluation, IT has been involved in a wide variety of advances in this area. One of the challenges facing our researchers is figuring out how to keep complex systems of networks manageable and how to secure digital data for future generations.

IT Security and Management Challenges: Today and Tomorrow
Prof. Gabrijela Dreo Rodosek

Operations Research: High-Dimensional Complexity Management
Prof. Stefan Pickl

Sports Business Administration and Economics
Sports Management
Prof. Christopher Huth

Safety in Space Research
Since the beginning of time, outer space has captivated the imagination of man and stimulated our scientific curiosity. The University is also active in the fields of aviation and space travel: researchers are exploring space, investigating planets, and developing technology to improve the safety and efficiency of aircrafts and space shuttles.

Turbulence Research: Microfluidics and Particle Imaging Techniques
Prof. Christian Kähler

Carbon Fiber Reinforced Plastic (CFRP)
Prof. Philipp Höfer

Social and Cultural Program
Keeping our Cities safe

Infrastructure for Safety and Peace

In recent years, terrorist attacks have increasingly been directed against so-called soft targets rather than against critical infrastructure. In this context, critical infrastructure is defined as buildings and facilities that are essential for a society’s survival in case of catastrophe. Urban areas or public spaces are considered soft targets if a considerable number of fatalities and casualties will be caused by an attack or disaster. Recent examples of terrorist attacks on soft targets in Europe include the metro attacks in Madrid in 2004 and London in 2005, the attack in Oslo in 2011 or in Paris in 2015. These attacks all caused a large number of casualties in unsecured urban areas where people were gathered; waiting for a train or bus, shopping at markets, sitting in bars and restaurants or at events. In order to protect civilians from attacks on soft targets, entirely new and innovative systematic strategies will be required.

A Variety of Different Threats

Research in this field is currently being carried out by the Federal Emergency Management Agency (FEMA) in America and the Bundeswehr University Munich, among other institutions. Scientists in Munich are using computational fluid dynamics modeling to simulate propagation and reflection of explosive blast waves in built-up areas. This is a critical question, as the initial blast wave created by an exploding bomb can reflect off buildings, increasing in intensity and travelling around corners to places not even in line of sight with the actual explosion location.

Protective architecture also has to include something to block vehicles from entering sensitive areas. Attackers can use vehicles to carry far heavier bombs, and the vehicle itself can also be part of the attack, ramming through doors and gates and crashing into walls or groups of people.
When is a Wall not a Wall? – A Variety of Protective Options

So in order to protect vulnerable locations from terrorist attacks, walls and barriers must be installed to first, keep the bomb at a maximum distance from citizens by blocking vehicles, and second, deflect or block the blast wave and any flying debris. This is where the future of urban security lies in collaboration between scientists, architects and urban planners to design these precautionary measures in such a way that they offer effective protection without detracting from the comfort and perceived safety of the location. In ideal cases, citizens might not even realize that protective features are there at all.

Terrain modeling can be used to reduce the power of a blast wave or act as a barrier to block vehicles. Sloping ground, ditches or hills deflect and reflect blast waves, or a mixed solution of sloped ground can be combined with a smaller blast wall.

An example of this method can be found in the Minneapolis Courthouse Plaza. The grassy mounds and tree trunks in the forecourt are natural elements, while at the same time acting as safety features to block undesirable access. Non-experts might not recognize these as substantial passive safety elements at all.

Another alternative to a continual, unbroken blast wall is a series of interlinked elements that provide the same protection without breaking up pedestrian flow. Options include interlocking V, T or Y-shaped wall elements. These walls can be made of mixed materials, including concrete or steel sheets, perforated steel sheets or multi-layered materials, to offer more visual variety.

A better solution than boring bollards or unattractive Jersey barriers is a combination of bollards with other protection elements such as planting buckets, trees or solid seating elements, large rocks, street lamps, bus stop areas, or even secured kiosks. Sculptures or artwork are even more inconspicuous, such as the NOGO-barrier designed by Rogers Marvel Architects for the New York City Financial District. These elements serve multiple purposes: as protective elements, sculptures and even playgrounds.

In medieval times, ponds, moats, and marshy land were used to protect the approaches to castles and palaces, while at the same time serving as natural habitats for wildlife or recreational spaces.
These kinds of features were the inspiration for another design, the so-called Tiger Trap System (TTS). The TTS is invisible to the untrained eye, consisting as it does of a deformable substrate in a ditch that is covered by a layer of collapsible material strong enough to carry pedestrians and cyclists but that will collapse under heavier loads.

Another visually appealing solution is bomb and collision-proof curtains. The protection capabilities of a fence made of steel ring-meshwork have hardly been studied at all, and further research is needed in this field.

Trees or hedges and raised planting baskets can also be used defensively. In order to offer protection all year, bushes planted in protective structures should be evergreen plants such as yew or conifers.

In order to test whether hedges are capable of mitigating the effects of blast waves, researchers at the Bundeswehr University Munich have carried out a number of simulations, showing that a thick hedge can reduce blast intensity by more than 50%. This promising research project is still ongoing. Tests in 2015 and 2016 have validated these numerical predictions.

This type of protective design promises a revolution in urban planning, but the discipline is still very new. We can look forward to many more new developments in years to come, making our cities safer to live in without spoiling the open look and feel of where we live.
INTERNSHIP OFFER

Institute of Engineering Mechanics and Structural Mechanics / Department of Civil Engineering and Environmental Sciences
Laboratory for Computational Engineering, Research Center RISK

2-3 internship positions available

The Institute of Engineering Mechanics and Structural Mechanics and its Laboratory for Computational Engineering focuses on numerical simulation in structural engineering. Fields of interest are: safety of structures and infrastructures, earthquake engineering, structural dynamics, protective structures, explosion, contact detonation, blast, impact, high-speed dynamics, mitigation of multiple threats, development of protective systems, material and fracture mechanics, rapid bridge classification, explosion safety of steel-glass-facades, numerical experiment design, mitigation of natural threats (flood, heavy storms, rock fall, etc.). Experiments are carried out in cooperation with partners.
**Flood Protection on a Local Scale**

A scientifically tested weir now protects an Austrian community that was flooded several times in the past.

The Gartnertalbach is a creek within the community of Lermoos (Austria). As a rule, its flow rate is clearly below 1m³/s. Heavy rainfalls, though, may cause it to rise quite quickly to more than 20m³/s, causing extensive flooding over the banks. The Lermoos community was flooded on various such occasions, sustaining heavy damage in the process. In order to overcome this problem, a flood protection project was developed, which comprises two flood pools positioned one after the other. Water from the Gartnertalbach is designed to flow into the lower pool via a flow-off duct system consisting of a pipe 1.8m in diameter installed below ground, with the duct system to be activated only in case of flooding. This required the Gartnertalbach creek to be suited with a water flow-off structure, for which the 'Tyrolean weir' design was chosen. It divides the water flow in such a way that – almost regardless of its total volume – a basic volume (of about 5m³/s) will be retained in the creek bed, and only water in excess of the basic volume will be directed into the flow-off duct. If floodwaters are beyond the duct’s maximum capacity (approximately 16m³/s), the excess volume of water will have to be carried off in the creek bed in addition to the basic volume.

**Using a model test for optimization**

In a Tyrolean weir, water is drawn from the main flow by means of two lateral screen-covered outlets that are fed via two openings installed one after the other on the bottom of the creek. It is not possible to calculate flow-off conditions with any degree of certainty for a Tyrolean weir because of its particular design and the fact that air will be drawn into the flow-off system by the onrush of floodwater. This is why...
a model test should be used to verify, quantify and optimize the structure’s function and performance, and the Laboratory for Hydromechanics and Hydraulic Engineering of the Bundeswehr University Munich was tasked to conduct such a test. For measuring purposes, a model of the creek bed, including the Tyrolean weir, was created on a scale of 1:12. Among other aspects, the model was successfully tested for the indispensable ventilation of the flow-off duct. However, as was shown by the measurements taken, its diameter had to be increased to 2.2 m for the pipe to be able to drain the required volume of water. Additionally, several guiding walls needed to be installed, which considerably improve the lateral deflection of water in the Tyrolean weir. Plans are under way to include the contents of the now-finished model test in the teaching program, to be supported by practical studies.

INTERNSHIP OFFER

Laboratory for Hydromechanics and Hydraulic Engineering / Department of Civil Engineering and Environmental Sciences

1 internship position available

The Institute of Hydromechanics and Hydraulic Engineering currently works on several projects comprising rheological studies, scientific analysis of a small hydro power plant, and research on a mudflows simulation model.
Prof. Karl-Christian Thienel studied civil engineering at the Technical University Brunswick and from 1988-1993 worked there as a research assistant at the Institute of Building Materials, Concrete Construction and Fire Protection. From 1993-1995 he was a Feodor-Lynen fellow of the Alexander-von-Humboldt Foundation, researching at the Center for Advanced Cement Based Materials (ACMB) at the Northwestern University, USA. From 1995-2003 he worked at Liapor GmbH & Co. KG, where he was head of research and development from 1997. Since 2003 he has been professor at the Bundeswehr University Munich and is head of the Institute for Construction Materials.

Construction Materials

Construction materials have always been of great importance for humans. Thus it is no surprise that entire epochs of the human history are named accordingly: Stone Age, Bronze Age and Iron Age. The rise of the Roman Empire was closely connected with one construction material: the Roman concrete – Opus Caementitium. It facilitated such well-known structures like Pantheon and the aqueducts, which can be admired until today. At the same time Opus Caementitium is still an inspiration for new ecological and durable construction materials.

Construction material are a basic subject. The institute for construction materials has its own laboratory with an up-to-date equipment for research and education. It is capable of investigating the properties of various types of materials starting from micro scale and running all the way to macro scale.

Specimen preparation and investigation of binders and mineral supplements

- Determination of fineness (BET, Blaine)
- Determination of particle size distribution
- Calorimetric measurements
- Viscomat for rheological investigation
- Hydrothermal treatment (autoclave)
Chemical and mineralogical investigation

- Determination of structurally damaging salts
- Melt digestion
- Thermal analysis
- X-ray powder diffraction (in reflection and in transmission, non-ambient measurements in the temperature range from 3°C to 70°C, internal and external standards, in situ measurements)
- Gas chromatography

Surface and structural analysis via

- Microcomputer tomography
- Scanning electron microscopy (element analysis via EDX is possible)
- Light microscopy
- Mercury intrusion porosimetry

Strength and durability of construction materials

- Testing frame (50kN to 5000 kN)
- Water impermeability-testing rig, creep rig and shrinkage measurements
- Resistance of freeze-thaw cycles by CDF-/CIF-testing
- Climate chamber
- Intrusion of water hazardous substances
- Post cracking flexural tensile strength of steel fiber reinforced concrete acc. DAfStb-Guideline
- Determination of chloride migration coefficient

Structural condition analysis

- Destructive and non-destructive investigation of buildings
- Adhesive strength
- Localization and detection of reinforcement
- Analysis of cores and drill dust samples
- Analysis of historic building stocks
Research topics

The institute researches, develops, tests and teaches in the following fields:

- Possibilities and properties of supplementary cementitious materials
- Calcined clays as supplementary cementitious binder – availability, hydration behavior, and rheology as well as optimization of concretes with addition of calcined clays
- Development of special concretes such as infra-light concretes, concretes with special properties and aerated concrete

INTERNSHIP OFFER

Institute for Construction Materials / Department of Civil Engineering and Environmental Sciences

1 internship position available

The computer tomography is an excellent technique for non-destructive material tests. This method enables you to reckon cross sections wherever you want in your scanned test specimen. And pore size and distribution become visible and the total pore volume can be determined. During the internship you will scan different building materials (e.g. lightweight concrete, normal concrete, autoclaved aerated concrete) with the CT scanner and reconstruct the material models in 3-D. The so obtained material models should be analyzed with respect to pores (size, distribution, volume) and cracks (maybe also after testing them in compression). Additionally, a comparison can be made between the results of the total pore volume obtained with the CT-technique and the mercury intrusion porosimetry.

If there is still time left for further studies, interns are welcome to analyze correlations between pore volume and other material properties (e.g. elastic modulus, compressive strength, permanence).
Prof. Dieter Gerling obtained his diploma and doctoral degrees from Aachen University of Technology (RWTH Aachen) in 1986 and 1992 respectively. From 1986 to 2001 he held several positions in the industry, most recently as director for Robert Bosch GmbH. Since 2001 he has been professor for Electrical Drives and Actuators in the Department of Electrical Engineering.

Powering the Future of Electric Mobility

A new type of electric motor, developed at the Bundeswehr University Munich, is about to revolutionize the automobile industry. It offers lower production costs and more efficient performance than currently employed motors and will be a significant factor in the coming breakthrough that will see electric cars finally move from niche to mainstream.

There is no question that internal combustion engines have had their day. With a growing acknowledgement of the role of carbon emissions in global warming, governments around the world are putting in place strict emission targets for private vehicles: in China, 120g CO2/km from 2020, in Europe, 95g CO2/km from 2021, and in the USA, 89g CO2/km from 2025. This has driven the push for new drive technologies, but up to now electric vehicles have been the exception rather than the rule. Early models suffered from a very low range and the scarcity of public charging stations meant that these vehicles were just not practical for the average consumer.

Two Bottlenecks

The two technical bottlenecks in increasing an electric vehicle’s range and therefore its practicality are battery and motor. Weight is a vital factor in range and older batteries were heavy, but huge progress has been made in this field. Up to now, there has been less innovation on the side of the motor, but it is equally vital: if the motor can run more efficiently, then the same amount of battery power can take a driver much further. The next generation of electric cars, going on sale in 2017, has an advertised range of 300km per charge, which will be a true game changer. But there is still room for improvement, and new motor technology will be central to this.

The current generation of electric cars typically carry high voltage (HV) batteries, between 250 and 400 V.
This has some technical advantages, but requires significant equipment to keep the system safe, including galvanic decoupling and insulation monitoring, which push up the price of the drive system. These vehicles mostly use stators with distributed windings, which have the advantage of a nearly sinusoidal magnetic field in the air gap, but these motors are very complex and expensive to manufacture. Cost-effective mass production as needed for mass-market vehicles is not currently feasible.

A more cost-effective alternative is a motor using tooth-concentrated windings, but these have the disadvantage of a high harmonic content in the magnetic air-gap field, leading to noisy operation and high rotor losses. Advances have been made in cost-effective countermeasures, but this type of motor is still far from ideal.
A New Type of Motor

The search for an electrical motor with better performance that is nevertheless easier to produce led to the development of the ISCAD (Intelligent Stator Cage Drive) solution. Instead of a stator made with wound copper wire, in this new motor the slots of the stator lamination stack are filled with solid bars of metal. These bars are mounted to a short-circuit ring on one axial stator end and left open on the other.

The bars can be made of aluminum; a significant cost saving versus copper, and the slots can be filled to almost 100%. Aluminum is less conductive than copper, so eddy currents are reduced and the disadvantage in electrical resistance (DC plus AC share) over copper decreases.

Only a thin layer of insulation is needed between the iron core and the stator bars, leading to a reduction in thermal insulation and better cooling capabilities, which means a significant increase in the continuous power rating of the motor. This simple construction also reduces the number of possible failure mechanisms, when compared to wound coils.

Because of the low number of turns of the motor, DC voltage can be well below 60 V, representing a huge increase in safety. High voltage means more danger of electric shock. The switch to low voltage also means that low-voltage MOSFETs (metal-oxide-semiconductor field-effect transistor) can be used as switches instead of the high-voltage IGBTs (insulated-gate bipolar transistor) used in conventional electrical motors. And MOSFETs also have significant advantages over IGBTs, e.g. far better efficiency at partial load, bidirectional conduction capability and low switching energy.
The Perfect Motor for Electric Vehicles

Conventional electric motors usually provide peak efficiency at maximum load, but are inefficient at lower speed and torque. This is one of the problems with designing an efficient electric car, as most driving calls for a lot of low-speed activity, particularly when driving in stop-start city environments. By contrast, ISCAD is able to switch the number of pole pairs in operation and so provide efficient performance under partial load. In addition to this, there are the advantages of the MOFSET inverter.

Demonstrably Better Performance

To test how large these differences could be, a 60-phase ISCAD motor was compared against a state-of-the-art 3-phase HV motor. Both motors were designed with the same physical dimensions and for the same performance characteristics. The motors were tested according to two industry protocols: the New European Driving Cycle (NEDC) and the driving cycle of the Worldwide harmonized Light vehicles Test Procedures (WLTC). The WLTC in particular is far more dynamic than older test cycles and can be considered a fair approximation of real driving behavior.

In the two different test protocols, the ISCAD motor performed significantly better than the competition: it used 25% less electricity in the NEDC test and 20% less in the WLTC. In a real vehicle, this reduction in consumption not only means a lower cost of driving per kilometer, it can also either be translated into a smaller battery or a longer range.

A Solution for Tomorrow

Within the next few years, electric vehicles will continue to grow in market share. New companies have entered this market, but all the traditional automotive manufacturers are in the game as well, and if our next car is not electric, the one after that probably will be. What is more, there is a good chance that the next electric car you buy will incorporate technology developed at the Bundeswehr University Munich. ISCAD motors are easy and cost-effective to produce, using only iron and aluminum, and they offer significant additional advantages as well. Running on lower voltage eliminates the danger of a severe electric shock, and the efficiency of the motors means an increase in range as well as a reduction in running expenses.
**INTERNSHIP OFFER**
Institute of Electrical Drives and Actuators / Department of Electrical Engineering and Information Technology

**4 internship positions available**

In the field of "Electrical Drives and Actuators" detailed knowledge of the system under consideration is a key for success. Therefore, system analysis and system design are in the focus of our activities. This means that electromagnetic power converter (motor/generator/actuator), power electronics and control have to be regarded simultaneously to come to an overall optimum (rather than optimizing single components). Depending on the needs of this application, the optimum drive system is chosen. Consequently, the electromagnetic device (motor/generator/actuator - as the key component of any drive system), the power electronics topology and the control circuitry are designed. Specialized solutions are our favorite tasks. Beside the theoretical analysis and design of drive systems, some very special (partly worldwide unique) test-benches are available for experimental investigation and validation.

Possible tasks of the internship comprise:

- Simulation of electrical drive components with Finite Element Software or MATLAB
- Programming of controllers
- Measurement of electrical drives in the lab
Prof. Jochen Schein completed his doctoral studies at the Ruhr University Bochum in the field of electrical engineering. From 2004-2008 he worked as a research scientist at the Lawrence Livermore National Laboratory, National Ignition Facility, Livermore, CA, USA. Since 2006 he has held a professorship at the Institute of Plasma Technology and Electrical Engineering at the Bundeswehr University Munich.

Plasma Technology: Surface Treatment and Surface Coating

The Institute of Plasma Technology and Mathematics’ main field of activity in research and teaching is plasma technology, more specifically, thermal surface treatment and surface coating.

Current research topics

- Development of plasma sources
- Development and optimization of process-related diagnostic measures

Based on the current state of technology, new operating principles have been identified for plasma generators. The development of plasma generators is divided into two fields:

- for plasma spraying usage, the innovative plasma generator type TRIPLEX has been developed and already been applied in the industry; the novel plasma source type DELTA is currently still being tested
- for diverse applications in the field of plasma safe surface modification, the plasma generator type LARGE, which allows the generation of a plasma jet with new physical properties, is currently being developed
INTERNSHIP OFFER

Institute of Plasma Technology and Mathematics / Department of Electrical Engineering and Information Technology

4 internship position available

The Lab for Plasma Technology team investigates plasma-material interactions for industrial and aerospace applications. Gas Metal Arc Welding, Plasma Cutting, Thermal Spray and Electric (Space-) Propulsion systems are the focus of the ongoing research. Interns will be involved at all levels from construction to operation of experimental systems with an emphasis on learning new useful skills for future employment.
Prof. Stefan Lecheler holds the professorship for technical thermodynamics in the Department of Mechanical Engineering at the Bundeswehr University Munich.

Generating Renewable Thermal Energy

**Tesla Turbines**

Performance Map Measurements and Evaluation of a Small Friction (Tesla) Turbine

According to the Renewable Energy Heat Act, at least 14% of the thermal and cooling energy demand of buildings is to be covered by renewable energies until 2020. In the laboratory for thermodynamics at the University’s Department of Mechanical Engineering, Prof. Stefan Lecheler and his team conduct research in the field of:

- Tesla turbines
- Solar technology and geothermal energy
- Numerical flow calculation

The Chair of Technical Thermodynamics deals with the efficient conversion of energy and the sustainable generation of electricity and heat. The team is happy to support Bundeswehr agencies in their search for technical solutions and companies in the development of successful products.

**Tesla Turbines**

Tesla turbines are small, robust and cheap friction turbines. They have no blades but discs with small gaps in between. Rotation is achieved only due to friction forces at the disc walls. They can run in compressor and in turbine mode. So they can be used to store excess renewable electricity from wind and solar power plants in a high compression tank and later on to generate electricity again. Power output and efficiency depend on several parameters like inflow angle, rotational speed and mass flow.

Within this project the influence of some of these parameters on power output and efficiency should be investigated experimentally in an existing Tesla turbine test bench in the thermodynamics lab at the university.
Because the turbine rotor was modified, new measurements are necessary and have to be compared to existing ones with the former rotor. The following milestones should be completed:

1. Getting familiar with Tesla turbines, test bench and previous results
2. Measurement of power and efficiency for different operating points, i.e. variation of flow inlet angle and variation of rotational speed
3. Evaluation of measurements and presentation in a typical performance map
4. Comparison to previous results with the reference rotor
5. Preparation of a final technical report

INTERNSHIP OFFER

Chair of Thermodynamics / Department of Mechanical Engineering

2 internship positions available

The institute offers student projects in the area of renewable energy and computational fluid dynamics (CFD).

Available lab equipment includes:

- Climate chamber (size 3x3x2m), temperature range - 30°C to + 40°C, humidity variation)
- High resolution thermography camera
- Modern measurement equipment for mass and heat transfer
- Computer work stations and licenses for CFD calculations
- Several demonstration solar heat and power plants
**Security for the Smart, Interconnected World**

Many of us own far more smart devices now than we did even ten years ago. You probably have a smartphone in your pocket right now. Maybe you have a fitness tracker on your wrist. If you recently bought a new car or a new TV set, those are most likely smart devices, offering you more information and features than your previous versions. Perhaps you are even reading the digital version of this magazine, on a tablet or e-reader. And this trend is only going to increase – by 2020, analysts expect 50 billion devices to be connected to the Internet.

But with this increased presence of digital smart devices comes an increasing dependence on them. What would we do if our devices stopped working one day? What would be the effect of a large-scale attack on our digital infrastructure, either as an act of terrorism or an act of war? The increase in connected devices has opened up a plethora of new attack vectors, and the question of how to prevent such an attack is at the heart of the discipline that has come to be known as cyber defense.

Attacks against information and communication technology (ICT) infrastructure are often stealthy and therefore extremely difficult to detect and defend against. In general, the inherently high complexity and sheer number of systems involved are natural enemies of security.

Cyber defense must therefore protect all stages of the lifecycle of potentially successful attacks: prevention, detection, and reaction. Researchers at the Bundeswehr
University Munich established the Research Center Cyber Defense (CODE) in 2013, and are tackling the problems of cyber defense under five main headings:

**General Cyber Defense**

The past few years have shown that data security is vital, not only for companies but also for public authorities and civil society as a whole. New threats such as ransomware or even smarter attacks targeting a specific person or organization (advanced persistent threats or APTs) have proved how important enhanced cyber defense measures are. Therefore, several necessary steps have been identified to increase the security of IT systems. It is especially important to detect malicious behavior as quickly and as accurately as possible. Researchers at the Bundeswehr University Munich have developed innovative anomaly detection techniques such as flow analysis in next-generation networks that are based on software-defined networking (SDN) technology. For example, machine-learning algorithms are applied to classify flows by comparing them with a database of malicious and benign categories, and automatically learn.

In cyber security, it is not enough just to identify and block attacks. Although it’s very difficult to do, authorities also want to identify the people or organizations responsible for the attacks, so that they can be held accountable for their
actions. For this purpose, researchers are developing new techniques in digital forensics and geolocalization. They are working to identify how network connections and communication in ICT infrastructures can be analyzed to gather data that can later be used as evidence in a court of law.

However, developing new technical solutions alone is not enough to increase security in the digital space. Humans are often the weakest link in the ICT security chain and must be encouraged to develop a higher security awareness and discipline. Research has taken a number of different directions to this end.

**Critical Infrastructure**

This research area is focused on protecting critical infrastructure of high importance for our society, including power and gas grids, water supply, the financial sector, and public transportation as well as the communication infrastructure that is used for financial services and also the Internet itself. After all, the Internet has become vital for today’s economy and society.

A simple yet devastating way to attack such infrastructure is a distributed denial of service (DDoS) attack. In recent years, the number of DDoS attacks against critical infrastructure has significantly increased. One reason for this increase is that it has become easier than ever before to carry out an attack. Only a few years ago, an attack of this kind required advanced skills in several fields, such as computer programming and networking. Today, the only things a would-be attacker needs are a web browser and a little bit of money.

**Smart Data**

Our digital devices generate, transmit, and process a huge amount of data, and this is increasing rapidly due the tremendous growth of networks and the Internet, the omnipresence of social media, new technologies and paradigms like machine-to-machine communication and the Internet of Things. In many ways, this data is the raw material of the digital world, but efficient cyber defense is only possible if relevant information can be extracted from the huge volume of raw data. For this reason, an increasing amount of research is being conducted into how to turn Big Data into Smart Data.
Research at the Bundeswehr University Munich is focused on Smart Data analytics, based on data collected from various sources including computer and telecommunication networks, social media, finance, healthcare, and other interconnected systems. Researchers evaluate different data sources to identify the reliability and usability of structured and unstructured data for advanced processing, and to determine which public information sources are suitable. Developing intelligent algorithms for data analysis and to increase the quality of data and information is a core task of all research activities. Refinement includes creating a clearly arranged visualization of analysis results and a real-time cyber situation map, to enable more agile and comprehensive decision-making processes. Visualization is not only a technique for presenting relevant results, but also an opportunity to improve human-computer interaction and usability. Furthermore, effective and dynamic detection of known and hitherto unknown cyber threats and malicious behavior leads to the possibility of automated reactions and therefore towards building blocks that could be used in and automated cyber defense system.

**Mobile Security**

This research field investigates specific threats and security measures for standalone as well as embedded mobile devices, such as smartphones and computer systems in connected cars. Today, mobile systems are no longer isolated but connected to each other as well as to the Internet, either directly or via other devices. With the increasing prevalence of mobile systems, the impact of an attack on local and global mobile networks and communication data has skyrocketed.

On the one hand, connecting different devices together increases functionality, comfort, and usability, but these developments present new security challenges.
At the Bundeswehr University Munich, mobile security research activities focus on car-to-car as well as car-to-environment communication. For example, protecting driver assistance systems in cars against malicious manipulation of data delivered by internal and external sensors obviously not just an ICT security question, but also a safety issue for the car’s passengers and the environment.

**E-Health**

With the rise of wearable devices that collect and analyze health data in people’s day-to-day lives, a vast amount of sensor data is becoming available. In many cases, this data contains hidden information about medical conditions and health issues. Once important aspects like the protection of personal rights and personal data security have been adequately resolved, data science will support medical research by analyzing this data, to the benefit of public health. For example, a framework that supports early warning systems for a number of health conditions has the potential to increase life expectancy among users. Trends are indicative of certain illnesses can be correlated with every conceivable aspect of other medical information or with external information like regional aspects or other characteristics of the affected population. Outbreak
detection of infectious diseases and immediate information about regional distribution patterns could enable governments to react quickly, minimizing or preventing large-scale epidemics.

Researchers at the Bundeswehr University Munich worked together with the Medical Service Headquarters to develop a central platform for information management in the area of Medical Intelligence (MedIntel). The requirements for such a platform are highly complex. Every day new disease outbreaks and other medically relevant messages are recorded and processed. This data is then enriched with location information so that it can be associated with current and planned operations. In addition to information from open sources, knowledge gathered by the forces on the ground is also incorporated into the system. As part of the research project RAAPIT (Routine Analysis, Assessment and Publishing Medical Intelligence Tool), a prototype system that implements these requirements was developed.

**INTERNSHIP OFFER**

**Institute for Technical Informatics / Department of Computer Science**

**Chair of Communication Systems and Network Security, Research Center CODE**

*2 internship positions available*

Information and communication technology (ICT) permeates all areas of modern society and is the driver of innovation in business and research. This ubiquity has already led to strong dependencies in the public and private sectors. The security of ICT as well as the defense against cyber-attacks is an essential challenge.

The Research Center Cyber Defense (CODE) brings researchers from different scientific disciplines across faculties together and integrates experts from industry and public service. CODE holistically and interactively approaches technical innovations for the protection of data and systems, anomaly detection, smart attacks, security of mobile devices, critical Infrastructures for various application areas such as automotive, logistics and energy.
**Prof. Stefan Pickl** studied mathematics, electrical engineering, and philosophy at TU Darmstadt and EPFL Lausanne and received his venia legendi at Cologne University. He has been Chair of Operations Research at the Bundeswehr University Munich since 2005. He was visiting professor at the University of New Mexico and University of California at Berkeley, University Graz, University of Copenhagen and visiting scientist at SANDIA, Los Alamos National Lab, Santa Fe Institute for Complex Systems and MIT. In 2010 he chaired the International Operations Research Conference in Munich.

**Operations Research: High-Dimensional Complexity Management**

System dynamics models and algorithmic optimization procedures contribute to decision-making with regard to global challenges

**Institute of Theoretical Informatics, Mathematics and Operations Research**

Operations research is closely associated with the developmental history of the Bundeswehr University Munich. At first, classic operations research was militarily motivated before it found its way into industrial process management and, later, into economic studies and systems analyses. The Chair of Operations Research today focuses its research on studying the co-functioning of such different systems, analyzing them and optimizing them based on certain criteria.

**Networked research**

With the research center COMTESSA (Competence Center for Operations Research, Management of Intelligent Engineered Secure Systems & Algorithms) the Chair is involved in international research projects and EU framework programs which take on these scientific challenges in the context of concrete application examples. Within the RWTH Aachen University’s excellence initiative the implementation of the Kyoto Protocol, the establishing of international energy systems and the associated resource conflicts are studied.
IT-based and service-oriented decision-making assistance

The design and conduct of global experiments and economic scenarios are dealt with in particular under the ERASMUS cooperation with the Karl Franzens University and Technical University of Graz. Within the framework of current EU research programs and the ICT 2020 (Information and Communications Technologies) Initiative “Sustainability in a Connected World”, IT-based and service-oriented decision-making assistance is developed within general cybernetic systems to study rational behavior. Using system dynamics models and algorithmic optimization procedures, the systems are studied topologically as to “energy efficiency improvement”, “aspects of resource security” as well as “susceptibility to terror” of networked infrastructures. The studies conducted so far have taken place in a project supported at the EU level by the German Institute for Economic Research (DIW Berlin).

Optimal behavioral strategies

Within these networks, researchers are looking for optimal behavioral strategies as well as for stable regions, which characterize such cybernetic systems. Frequently, these regions can be determined and characterized only by using very complex algorithmic procedures. This is why several scientists of the working group are looking into the future-oriented fields of “swarming” and “computational intelligence” as well as high-dimensional network studies. These results are embedded in the development of suitable concrete solution and reach back strategies for the protection of those networks. To this effect, tests are conducted jointly with the Bundeswehr Transformation Center’s OR Cell, the Center for Excellence “Confined and Shallow Waters” of the German Navy, and the U.S. Navy’s Task Force Energy coordinated by the Naval Postgraduate School, Monterey.

INTERNSHIP OFFER

Institute of Operations Research / Department of Computer Sciences

Research Center COMTESSA

2 internship positions available

- Modelling, simulation and optimization of complex systems
- Explainable Artificial Intelligence
- Data Mining
- Predictive and Visual Analytics
Sports Business Administration and Sports Economics

Department of Sports Science

Institute of Sports Management

The Department of Sports Science offers a broad sports science education. Some of their teaching contents are:

- movement science
- sports biology
- sports management
- sports pedagogy
- sports psychology
- training science

These theoretical fields are currently represented by six professorships and experience a topic-specific differentiation at the interface between sports and health. Currently about 200 officer candidates are majoring in "Sports Science" with the degrees B.Sc. and M.Sc. The Department is strongly involved in sports science research in addition to teaching. For this purpose, in addition to laboratories for movement and training science as well as sports psychology, the department has numerous sports and training facilities directly at its disposal.

The field of sports management covers all subjects of sports business administration and sports economics.

Prof. Christopher Huth’s research priorities are:

- aspects of financing in sports organizations
- development and design of sports organizations
- health management

Prof. Christopher Huth
christopher.huth@unibw.de
Here are some titles of his research articles in peer-reviewed journals:

- *Back to Traditional Stadium Names – Fans’ Role in Financing Naming Rights through Crowdfunding* (2018)

**INTERNSHIP OFFER**

**Institute of Sports Management / Department of Sports Science**

**4-6 internship positions available**

Student projects are available in the field of sports and health management, i.e.

- golf management (ecological and health aspects)
- sports marketing
- health management (digitalization, occupational health management, costs of sports injuries)
- sports innovation management & ecosystems
- entrepreneurial athlete
Prof. Christian Kähler was amongst others head of the research group "Flow Control and Measurement Techniques" at the Institute of Fluid Mechanics at the Technical University Brunswick from 2001-2008. Since 2008 he has been professor for fluid dynamics and head of the Institute of Fluid Mechanics and Aerodynamics at the Bundeswehr University Munich.

Turbulence Research: Microfluidics and Particle Imaging Techniques

Achievements in sheet and volumetric PIV techniques with micron resolution

My first contact with PIV happened on a demonstration performed by Chris Willert, Markus Raffel and Jürgen Kompenhans at the Technical University of Clausthal, in the spring-time of 1995. Coincidentally, I had a deep interest in coherent near wall flow structures in turbulent boundary layers at the time and the demonstration made a strong impression on me. I became excited about using this method and fortunately I had the opportunity to join the PIV group of Jürgen Kompenhans at DLR Göttingen to work on my diploma project. In August of 1995 I started my first measurements using photographic PIV with the rotating mirror system, developed by Markus. For the illumination, a heavy 70 mJ Lumonics HY 200 SPECIAL Nd:YAG laser was available. Instead of optically evaluating the contact copies of the 36mm film after the experiment, which was the state-of-the-art at that time, I digitized the recordings with a brand-new scanner in order to evaluate them digitally. I was deeply impressed by the large-scale coherent flow structures I could resolve with the system (figure 1), but the spatial resolution was far too low to resolve the velocity profile down to the viscous sub-layer.

In February of 1996 Chris had integrated a 1k×1k digital camera (Pulnix) in the DLR PIV system. Apart from the low spatial resolution compared to photographic PIV, digital PIV was a fantastic improvement, particularly due to the multi-pass cross-correlation analysis with window-shifting (already of second order at that time). I was able to much better resolve the velocity profiles (up to the buffer layer, see figure 2) but when I plotted the histogram, I saw what today we refer to as peak-locking (figure 3). This effect was not known from photographic PIV (probably due to the noise) and none...
of my famous colleagues or visitors at the DLR at that time (Jerry Westerweel and others) had observed it before. As the implication of this effect on velocity measurements was obvious, Jürgen Kompenhans recommended that we do not publish the graph in my diploma thesis, though I did nevertheless.

Enthusiastic by the technical improvements and my first findings, in March 1996 Jürgen Kompenhans sent me to Ron Adrian at Urbana Champaign to get familiar with digital stereo PIV. Learning from Ron was a great honor for me. Additionally, Jerry spent some weeks visiting Ron during the same period to work on “The Book”. So I was able to discuss all my findings at lunch with Jerry and, at least once a week, with Ron. Back in Germany, I evaluated the 2k×2k stereo PIV recordings made during my stay at Urbana Champaign, with the stereo software that Chris developed in my absence. Surprisingly the out-of-plane motion was always on the same side of the low-speed streaks. I realized that this effect was caused by slight differences between the calibration and the measurement configuration. So I worked on a way to compensate for this effect, which is known today as disparity correction, and I learned that even when you are doing everything right there might still be something wrong!

After finishing my Diploma thesis, I continued the work at DLR during my Ph.D. with the development of the multi-plane stereo-PIV technique, to estimate unsteady and 3D flow characteristics in air, and I was able to analyze turbulent boundary layers in much more detail. Thanks to Michel Stanislas and Jürgen Kompenhans I could perform the experiments in Lille, which is greatly appreciated. Besides my work on boundary layers, I was also involved in many international test campaigns where I learned to apply PIV with a team in large scale catapult and wind tunnels and in 1998 I had the privilege, together with my colleague Andreas Schröder, to work in Mory Gharib’s group at Caltech.
From October, 2001 until April, 2008 I focused my attention on intrusive and non-intrusive flow control concepts and the development, improvement and application of all kinds of PIV variants at the Technical University Brunswick. I worked, particularly, on a long-range micro-PIV system with single pixel resolution in order to resolve the viscous sublayer. In 2005 I was able to measure the boundary layer velocity profile with a resolution of 0.028 viscous units in a wind-tunnel, at a free stream velocity of 10 m/s. The resolution of one thousand measurement points within a millimeter over a distance of 0.5 m was far beyond my highest expectations when I began my research in 1995 at DLR Göttingen. So I tend to believe that there is always a solution, we just have to explore it!

Today, I still like the Particle Image Velocimetry, mainly because

1. the technique still puzzles and inspires me to come up with improvements,
2. as a physicist, I like the components involved (laser, CCD camera, optics, image analysis)
3. I met many good people in this community and it is always a pleasure to meet them at conferences or events such as the 25 years of PIV at DLR Göttingen in 2009.

**Analysis of mixing and mass transport processes in bubble swarms under the influence of bubble-induced turbulence**

Aim of this project is to investigate the mixing and mass transport processes in bubble swarms taking into account the effect of bubble-induced flow turbulence. High resolution 3D optical measurement techniques will be applied to determine the underlying physical processes, in order to verify existing mass transport models and to validate numerical simulations carried out by the project partners. The experiments will be conducted in a custom built channel. Fractal and active turbulence grids will be used to adapt the turbulence level over a wide range of scales and intensities in order to simulate the intensity, spectral characteristics and coherence of real bubble-induced turbulence. This unique approach is applied to study the behavior of a single bubble or groups of bubbles in a realistic turbulent flow. In particular, bubble motion, bubble deformation, bubble vibration, mass transport into the turbulent flow, and mixing processes caused by the bubble-induced turbulence will be systematically investigated using state-of-the-art, non-intrusive 3D optical measurement techniques and compared with numeric.
INTERNSHIP OFFER
Institute of Fluid Mechanics and Aerodynamics/Department of Aerospace Engineering

**up to 4 internship positions available**

Our research focuses on experimental fluid mechanics, reaching from microfluidics to airplane aerodynamics. The facilities of the Institute comprise several wind tunnels, including a supersonic tunnel, as well as a well-equipped microfluidics lab with state-of-the-art microscopes. The Institute is one of the leading developers of PIV (particle image velocimetry) and PTV (particle tracking velocimetry) techniques, including challenging three-dimensional flow measurement methods. Thus, we can offer fascinating internship opportunities in the following fields:

1. **Microfluidics** (1-2 positions available): Microfluidics investigates flow phenomena in the smallest scales. In this internship you will learn how to use microscopes and how to set up a micro-scale experiment. At the end of your work you will be able to measure three-dimensional flow fields in micro channels.

2. **Turbulence Research** (1-2 positions available): Turbulence research is a fascinating and challenging topic. To this day, turbulence is not fully understood, and thus numerous research activities are devoted to this field. This internship gives you an insight on experimental techniques to capture turbulent flows.

3. **Particle Imaging Techniques** (1-2 positions available): Particle imaging techniques, such as PIV and PTV, are powerful tools for a comprehensive flow analysis. Not only do these methods provide velocity fields with excellent resolution, but also related information, like wall shear stress, turbulence intensity, and many others. In this internship you will get an overview of different particle imaging techniques. You will have the possibility to measure three-dimensional, macroscopic flow fields during your stay.
Prof. Philipp Höfer studied aerospace engineering at UniBw M and obtained a PHD at the institute of mechanics. He was employed as a technical officer for the repair of jet and shaft power engines. At Cassidian Air Systems, he worked as a development engineer and project manager on repair procedures for composite structures and structural health monitoring for the Eurofighter. At the end of his 13-year military service, he joined Airbus Helicopters, where he was most recently responsible for the structural design of the cell of the newly developed X6 helicopter. He returned to UniBw M as professor in 2016.

Carbon Fiber Reinforced Plastic (CFRP)

An exceptional material

Lightweight structures are usually designed as thin walled, slender structures (like membranes or shells), where failure is often related to global or local instabilities (e.g. buckling, flange crippling, wrinkling). Besides such geometry or shape dependent properties, the utilization of light and high-strength/stiffness materials is of central importance. Due to their excellent strength and stiffness properties, carbon fiber reinforced materials (CFRP) are especially well suited materials for all kinds of lightweight structures. E.g., more than 50 percent of the structural mass of the Airbus A350 and the Boeing Dreamliner aircrafts consist of these "black" materials. Since several years, these materials spread more and more into applications outside of the aerospace industry (e.g. automotive, civil or mechanical engineering).

The institute pursues application-oriented, industry-oriented research in the following subject areas:

- Fatigue and damage tolerance of fiber composite materials
- Structural optimization of lightweight structures
- Crash and impact behavior of FVW structures

The laboratory is focused on the production and testing of components made of fiber composites.

Manufacture: Different manufacturing processes are available for the production of samples and components.

Quality assurance: The components can be inspected for manufacturing defects with the aid of a powerful ultrasonic inspection system and various other inspection methods.

Machining: In the available workshop laminating moulds can be produced and the samples and components can be reworked.

Testing: Testing facilities are available for testing samples
INTERNSHIP OFFER

Chair of Composite Materials and Technical Mechanics / Department of Aerospace Engineering

1-2 internship positions available

At the institute of Lightweight Structures, we focus our research on different aspects of lightweight structures:

- Damage and fatigue of carbon fiber reinforced plastics (CFRP)
- Crash and energy absorption capability of lightweight structures
- Novel lightweight design concepts (i.a. structural optimization, additive manufacturing)

For structural tests and investigations on coupons and components, a large laboratory with test equipment up to 2,000 kN is available. Usually, these tests are supported by FE-simulations.

During your internship, you will be involved in the research activities of the institute. Typically, this can comprise the preparation and evaluation of structural tests or FE-simulations (e.g. structural optimization, certain phenomena in CFRP).
Social and Cultural Program

Meet other students, get to know Munich and take a trip to Germany’s capital!

Buddy Program

The University’s international buddy program was launched by the International Office in 2009 to provide newly arriving international exchange students at the Bundeswehr University Munich with additional support from regular students in order to help them get situated on campus, help them adjust to the new environment and ensure that their stay in Munich is a pleasant one.

We try to allocate every new international student a so called “Buddy”, i.e. a German student who is familiar with the university’s structures and who will be able to give a helping hand during your stay abroad in Germany. Our international tutors or “buddies” also organize events, excursions and activities – an excellent opportunity to meet people from all over the world, to exchange experiences and socialize with other students and to explore Munich and surroundings with like-minded people!

Participating in the program will provide you with valuable advice on everyday life at our university and in Munich and will help you to get in touch with German students more easily. In the past, we witnessed that the program really helped to foster friendships and mutual understanding and broadened the cultural horizon of all participants.
Life in and around Munich

*Munich – Bavaria’s Capital City*

With a population of over 1.5 million people, Munich is the third largest city in Germany, and is an important center of art, culture, technology, and business. This “city on the Isar” is known for its impressive historic buildings, numerous museums, and beautiful parks and gardens. Last but not least, Munich’s scenic surroundings add to the city’s popularity: on a clear day, the Alps can be seen from the city, and there are a variety of magnificent lakes on the city’s outskirts.

*Neubiberg*

Situated just outside of Munich with a population of 14,500 people, Neubiberg is home to our University. You will find a number of small shops and a few restaurants on the main street. The former airfield between Neubiberg and the town of Unterhaching has been made into a recreation center. Neubiberg is the only true university town in Germany.
New Town Hall and the Marienplatz

The Neue Rathaus (New Town Hall) is a magnificent neo-gothic building from the turn of the century which architecturally dominates the north side of Munich’s Marienplatz.

At the top of the 85-meter-high (255 feet) tower on the city hall is an observation deck that can be accessed with an elevator and offers a grandiose view of the roofs of the city, even as far as the Alps in nice weather.
Beer Gardens

For centuries, beer is and has been an important part of the culinary and cultural heritage of Bavaria and Munich. The best choice for having an authentic “beer experience” are the traditional beer halls (indoors) and beer gardens (outdoors).
**Allianz Arena**

The Munich Allianz Arena is the soccer temple in the northern part of the city and the home of the FC Bayern München and TSV 1860 München soccer teams.

**Nymphenburg Palace**

Nymphenburg Palace owes its foundation as a summer residence to the birth of the long-awaited heir to the throne, Max Emanuel, who was born in 1662 to the Bavarian Elector Ferdinand Maria and his wife, Henriette Adelaide of Savoy, after some ten years of marriage. With its unique combination of architecture and garden design, Nymphenburg is one of the best examples in Europe of a synthesis of the arts and a great place to visit.
The Englische Garten ("English Garden") is one of the largest urban parks in the world. The layout has undergone constant change throughout the centuries as new buildings and green spaces were added time and again.
The ensemble comprising BMW Welt, plant and museum at the Munich Oberwiesenfeld represents the internationally unique BMW world of experience. The synchronous integration of automobile delivery and thrilling temporary exhibitions about the past, present and future of the brands as well as a multifaceted daily event program have turned BMW Welt into an attractive place of encounter and exchange.

The German Museum

Sailing ships, models of atoms, windmills, space probes, diesel locomotives, industrial robots, organs, lifeboats, this unbelievable abundance of technical achievement – and lots more – can be found in the German Museum.
**Dachau Concentration Camp Memorial Site**

A memorial has been erected on the previous grounds of the Dachau concentration camp.

On March 21, 1933, Hitler ordered the construction of a concentration camp in Dachau, the first in Germany. The first commander, Theodor Eicke, developed an organizational scheme that would later be applied to all camps. He made Dachau into a “school of violence” for the members of the SS. In the end of April, 1945, the SS began evacuating the 169 field camps and field commanders, and on April 29, 1945, the camp was freed by US Army units. Until the liberation, the SS had held over 200,000 prisoners from 34 nations in the concentration camp in Dachau.

In addition to a documentary exhibit in the former work buildings, the bunker, both crematoriums, and a reconstructed prisoners barracks can be viewed.
Castle Neuschwanstein

The royal castle of Ludwig II near Füssen is one of the most visited castles and fortresses in Europe. The architecture and interior furnishings reflect the historically and eclectically oriented ideals of the Bavarian “fairy tale king”.

The King’s Lake

This 10 km long emerald-green mountain lake is considered to be the pearl of the Berchtesgadener Land. Some of the most magnificent panorama views across all of Bavaria can be found here. To preserve the purity and tranquility of the water only electrically-powered boats have been allowed on the lake since 1909.
Hiking in the Alps

Climb mountains, revel in majestic views, fill your lungs with fresh mountain air and indulge in mouth-watering local specialties at quaint mountain huts amid spectacular Alpine sceneries.

The Alps are one of the best hiking regions in the world!
Berlin Excursion

Below you will find some of the tours and activities planned for the excursion to Berlin, which is part of the program.

Boat Ride – Spree

This leisurely boat ride down the Spree River is a great way to familiarize with some of the sights in downtown Berlin.

Federal Chancellery

The Federal Chancellery is the office and department of the German Chancellor. After the fall of the Berlin Wall, it was decided that Berlin would be the capital of reunified Germany. The Federal Chancellery was accordingly moved from Bonn back to Berlin some years later. The current Chancellery building, finished in 2001, occupies almost 130,000 square feet – roughly 8 times the size of the White House in Washington, D.C.
Checkpoint Charlie

Checkpoint Charlie, along with Glienicker Brücke (Glienicker Bridge) was the best known border-crossing during the days of the Cold War. The sign, which became a symbol of the division of Cold War Berlin and read like a dire warning to those about to venture beyond the Wall – YOU ARE NOW LEAVING THE AMERICAN SECTOR – in English, Russian, French and German – stood here. Today it is an iconic marker of territorial boundary and political division. Until the fall of the Berlin Wall on November 9, 1989, it signified the border between West and East, capitalism and communism, freedom and confinement.
Brandenburg Gate

The Brandenburg Gate is one of Berlin’s most important monuments – a landmark and symbol all in one with over two hundred years of history. A former symbol of the divided city, it attracted visitors who used to climb up an observation platform in order to get a glimpse of the world behind the Iron Curtain on the other side of the barren “death-strip”, which separated East from West Berlin – both geographically and politically.
Tour – Berlin Wall

The Berlin Wall divided the city into Eastern and Western zones from 1961 to 1989 and had an enormous impact on the residents of Berlin. On a walking tour you will visit landmarks such as Checkpoint Charlie and learn more about Berlin’s unique situation during the Cold War.
The Foundation Memorial to the Murdered Jews of Europe

Berlin’s Holocaust Memorial, located right in the center of Berlin on a stretch of the former “death strip”, where the Wall once stood near the Brandenburg Gate, is Berlin’s stunning monument to the Holocaust, dedicated to the Jewish victims of the Nazi genocide of World War II.

Museum Island

Home to 5 remarkable museums, the „Museum Island“ is an island in the Spree River in central Berlin. The Old Museum, New Museum, Pergamon Museum, Bode Museum, and the Old National Gallery are all located on the island. These museums focus mainly on art and archeological finds of the 19th century. Today the former prison is a memorial dedicated to increasing awareness of the methods and consequences of political persecution.
German Parliament

The Bundestag is Germany’s parliament – the legislative branch of the German political system. The representatives in the Bundestag are elected by the voters for a term of four years. There are always at least 598 representatives in the Bundestag; however, this number is usually higher due to so-called “overhang seats”.

On this tour you will learn more about the organization as well as the various tasks and activities of the Bundestag.
**Hohenschönhausen**

In the former East German prison of Hohenschönhausen, you will experience first-hand the conditions which those persecuted by the GDR were forced to endure. The prison was used as a remand center from 1951 to 1989.

**Bellevue Palace**

Constructed in 1785, the neoclassical Bellevue Palace was used by the royal family of Prussia, the Hohenzollerns, until 1918, when the Weimar Republic forced them to abdicate. After 1957 it was used as a residence for the Federal President; however, since the latest renovations, the palace no longer contains an apartment for the President and his family.