European Space Elevator Challenge 2018

# Handbook – Advanced Level

*Version 1.0*

VESTNER AUFZÜGE
ELEVATING PEOPLE

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Arbeitsgemeinschaft
für Raketentechnik
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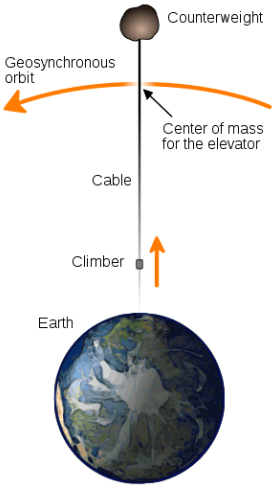
# Content

# 1. Introduction

## 1.1. The Idea of the Space Elevator

The fundamental idea of the “space elevator” goes back to 1895, when the scientist Konstantin Tsiolkovsky considered building a tower from the surface of the Earth and reaching into the geostationary orbit. The Artsutanov paper – 1960 – proposed a way to build a tensile structure to the geostationary orbit. [1]

The aim was and still is, among other objectives, to deliver payload – satellites, astronauts or other equipment – to space in an economically viable way. This idea could be an alternative solution to the expensive use of rockets.




The actual concept of the space elevator system includes a tether reaching from the surface of the Earth to the geostationary orbit. To keep the tether taut by means of gravitational and rotational forces, the center of mass of the space elevator has to be kept above this orbit. A climber is attached to the tether, which carries the payload up to the space station or to the satellite.

The energy supply is planned to be realized by “power beaming” (such as laser), as well as using solar cells.

## 1.2. European Space Elevator Challenge

The challenge is to design and build a climber structure in compliance with predetermined requirements, keeping in mind the idea of a real space elevator.

Our focus is on:

- the efficiency of the climber
- the technical implementation of the climber (especially payload systems)
- aspects which directly impact the development of the “real” space elevator system

The objectives of the European Space Elevator Challenge are:

- to inspire young engineers and scientists - especially in Europe - for the idea of the Space Elevator and to establish a bigger Space Elevator community in Europe
- to share experience and improve the understanding of the Space Elevator system
- to introduce the Space Elevator to a wider public
- to provide an opportunity for students to apply their theoretical knowledge in practice
- to excite high school students for science, technology and space travel

These aims are considered as long-term goals and cannot be accomplished with one competition. Hence, our goal is to organize the European Space Elevator Challenge annually.

[1] http://images.spaceref.com/docs/spaceelevator/Artsutanov_Pravda_SE.pdf

## 1.3. The Organizers

WARR

Scientific Workgroup for
Rocketry and Space Flight

The European Space Elevator Challenge is organized by WARR e.V., the Scientific Workgroup for Rocketry and Spaceflight at Technical University of Munich (TUM). It is directly affiliated with the Institute of Astronautics (lrt).

WARR was founded in 1962 and is one of the oldest scientific workgroups of TUM. The aim of WARR is to provide its members with the opportunity to accomplish scientific work and gain experience in practical projects as an addition to their studies. Its over 100 student members are organized in multiple groups, working on different topics such as hybrid rocket engines, cubesats, the Hyperloop and space elevators.

## 1.4. The Main Sponsor

VESTNER
AUFZÜGE
ELEVATING PEOPLE

VESTNER Aufzüge is an independent, medium-sized enterprise based in Munich operating throughout Europe. 80 years of experience in elevator construction have given them a high degree of flexibility in terms of technology, design and processing. They are able to respond quickly to the call for new and innovative technologies in its future-oriented products at all times.

VESTNER Aufzüge is proud to support the European Space Elevator Challenge as the main sponsor again this year and wishes all participants great success!

# 2. Participation

## 2.1. Levels

For the 2018 challenge, teams can take part in one of two different levels, according to their experience and scientific background:

- The Beginners' Level is aimed at high school teams and first-time participants with limited experience in the design of technical systems.

- The Advanced Level is aimed at university teams with advanced knowledge in CAD and electronics design.

This document describes the rules and requirements for the Advanced Level. For the Beginners' Level, please refer to the respective document in the Download section of the EUSPEC website.

## 2.2. Eligibility

There are no restrictions on who can enter the competition and form a team. Team members can be of any age, nationality, education level or profession. However, at least one member (the team leader) must be 18 years or older. The number of team members is not limited (and can even be just one person).

To be eligible to participate, a team must apply via the EUSPEC website until the stated application deadline. Only in special cases will teams be allowed to enter the competition if this deadline was missed.

We reserve the right to reject a team application in case the number of applications exceeds the capacity of the event or for any other valid reason.

## 2.3. Registration Fee

There is no registration fee for the 2018 challenge. There will only be a small fee per person to cover costs for food and drinks, collected on the first day of the competition.

Teams will have to cover costs for travel and accommodation themselves. We suggest trying to find funding through your institution, educational foundations or corporate sponsors.

## 2.4. Application Flow

### STEP 1 UNTIL APRIL 30TH, 2018

The team must register for the competition through the online application form. At this point, the level of participation must be chosen and only the team leader must be named. He or she must be 18 years or older.

The team will receive a confirmation of application if the application information was complete. The confirmation of participation is with reservation of step 2.

**After April 30th and until May 31st, applications will still be accepted on a waiting list.**

**After May 31st and until June 30th, applications will still be accepted on a waiting list if the rough climber concept is handed in together with the application.**

### STEP 2 UNTIL JUNE 30TH, 2018

The team must send in a rough concept of their climber, including estimates on parameters such as mass, size and power requirements.

After this, the team will receive a confirmation of participation if the rough concept gives reason to expect a successful participation in the competition.

A contact person from our organization team will be allocated to the team. He/she serves as a point of contact between the team and the organizers in case of any questions, problems or complaints.

### STEP 3 UNTIL AUGUST 31ST, 2018

The team must send in a short video demonstrating a working climber on a rope or tether. Otherwise, the confirmation of participation can be revoked. The team must also send in a full list of all team members and a list of the team members present at the competition.

### STEP 4 UNTIL SEPTEMBER 17TH, 2018

The team must hand in a presentation and a poster about the team, the climber and the development process. More information on this can be found in the next chapter. Also, the Authorization to Release Information Form must be signed and handed in (see Section 9.1).

# 3. Poster & Presentation

## 3.1. Poster

Each team has to prepare a poster for the competition. This poster should mainly act as an introduction of your team and your climber to the guests and visitors as well as to the press and the other teams on the days of the European Space Elevator Challenge.

### 3.1.1. Properties

- Language: English
- Format: ISO 216 A1 (cf. DIN A1)

### 3.1.2. Content

The poster may contain amongst other things:

- The name of your team
- A picture of your team
- Where your team comes from (nationality, institution)
- A picture of your climber
- The specifications of your climber
- Notable aspects of your climber

### 3.1.3. Structure

The structure of the poster is up to you. It is advisable to use pictures and charts in order to make your poster more descriptive and colourful. Please pay attention to use a large enough size of your pictures. Please choose the font and the size of your text so that it can be read easily by the viewer.

## 3.2. Presentation

Each team has to prepare a short presentation about their team and their climber. This will be presented to the other participating teams, interested members from the public and the organizing team of the European Space Elevator Challenge at a special event during the competition.

### 3.2.1. Properties

- Format: PDF or PowerPoint
- Length: NOT MORE than 10 minutes
- Speakers: any one member
- Language: English
- Location: University lecture room

### 3.2.2. Content

- The presentation should give an overview about your team, your climber and the development process
- You should show some specifications and features of your climber but also explain design decisions and problems you encountered
- Maybe finish up with some lessons learned and ideas for your next climber
- Your presentation should NOT explain what a space elevator system or a climber is in general!

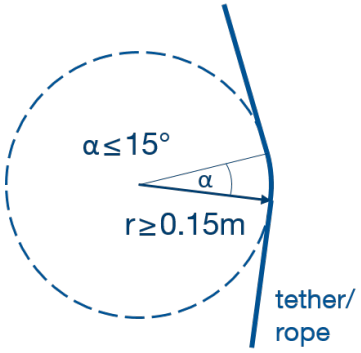
### 3.2.3. Structure

Apply standard presentation best practices. Do not overload your slides. Use illustrations and pictures to get your points across. Add slide numbers for easy referencing for questions.

# 4. Climber Requirements

## 4.1. Structure

- The climber has to be designed to operate either on a flat tether or a round rope (see Section 5.1 for the respective specifications).
- The climber (including payload) must not weigh more than 20 kg.
- The dimensions of the climber (including payload) must not exceed 1 m x 1 m x 2 m (length, width, height). The height is defined as the dimension along the tether/rope.
- The climber structure should be made from proper engineering materials such as steel, aluminium or carbon fiber.
- When attached to the tether/rope, the center of gravity of the climber along the horizontal should be close to the tether/rope.
- The climber must not bend the tether/rope with a radius of less than 0.15 m and an angle larger than 15° (see drawing). An enlacement of the tether/rope must be avoided.[2]
- The climber must not use expendables of any kind (i.e. fuels etc.).
- The climber must not contain any elements with positive buoyancy or that have aerodynamic lifting surfaces.




- The climber must neither damage the tether/rope nor degrade its properties nor leave any material on it.
- The climber must be designed in such a way that it can be mounted on and dismounted from the tether/rope without a disassembly of the latter.

## 4.2. Payload

For technical specifications of the payload cubes, see Section 5.2.

- The climber must be capable of carrying at least one standard payload cube.
- The payload has to be attached so that it is impossible to detach during the drive.
- The climber has to carry at least one but not more than eight payload cubes.
- The payload has to be attached to the climber in a way that it can be attached and detached in a reasonable amount of time (< 10 minutes).
- The center of gravity of the climber should not shift significantly with different amounts of attached payload cubes.
- The payload must be completely located within the maximum climber dimensions.
- The payload must not be required for the functional capability of the climber.

## 4.3. Power

- The climber power should primarily be provided by batteries.
- Additional power sources and energy recuperation are permitted but not required.
- Batteries are **not** provided by the organization team. Each team must bring their own.
- A measurement board will be attached to the climber to record power consumption. See Section 5.3 for the technical specifications.
- Connectors have to be provided to connect the measurement board directly to the batteries to continuously record voltage and current.

[2] Because of the tension no bending of the tether/rope would be appreciated at a real space elevator system.

## 4.4. Electronics

- The climber has to operate autonomously during the whole drive.
  - For starting the drive at the very beginning a non-autonomous mechanism is permitted to be used.
  - The climber must be able to start its drive without any external force acting on it (no pushing etc.).
  - After the start of the drive on the tether/rope, the climber must stop on the top of the tether/rope (after covering the distance of 100 m), **hold its position for at least five seconds** and restart by operating exclusively autonomously.
- The climber has to be equipped with sensors which detect the end of the climb. You may use amongst others:
  - Optical sensors. The tether/rope has black-on-white or white-on-black markings indicating the beginning and the end of the climb.
  - Mechanical sensors. There are Styrofoam bumpers at both ends of the tether/rope.
  - Odometry sensors to estimate the distance traveled.
  - It is recommended to always use mechanical sensors as a backup.
- Radio frequency utilization has to follow German regulations.

## 4.5. Safety

### 4.5.1. General

- The climber must be able to handle winds of up to 30 km/h without compromising structural integrity and it must be resistant to prevailing weather conditions of the competition area.
- The temperature of all surfaces must be lower than 50°C.
- The mechanical parts of the climber must fulfill ISO 20653 IP23:
  - Protection against penetrative contact with the fingers
  - Protection against solid foreign bodies with Ø > 12 mm
  - Protection against diagonal water drips (up to a 60° angle)
- The electronics of the climber must fulfill ISO 20653 IP54:
  - Full protection against contact
  - Protection against interior dust deposits
  - Protection against spray water from all directions
- All screws and bolts have to be secured against loosening.
- The payload cubes, the electronics and the batteries have to be attached securely to the climber structure.
- No sharp edges are allowed on the climber.
- No current-carrying components are allowed on the surface of the climber.

### 4.5.2. Emergency Shutdown

- An emergency shutdown to stop the climber must be present.
- It must be possible to activate this system whenever the climber is near the ground.
- The emergency shutdown procedure has to be accessible without endangering any team members.

# 5. Specifications

## 5.1. Tether/Rope

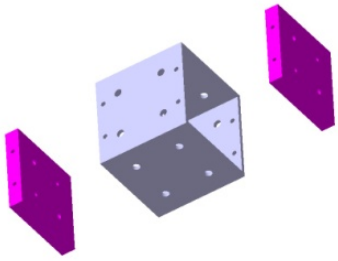
### 5.1.1. Flat Tether

- Product: Güth & Wolf Aramid Fabric Tape
- Dimensions: 38 mm width, 2 mm thickness
- Material: Teijin Twaron® Aramid
- Color: beige
- Tensile strength: 32 kN

### 5.1.2. Round Rope

- Product: TENDON Aramid
- Dimensions: 10 mm diameter
- Materials: Aramid sheath, Polyamid core
- Color: black
- Weight: 66.4 g/m
- Tensile strength: 37 kN
- Elongation (50-150 kg): 0%
- Sheat slippage: 0%

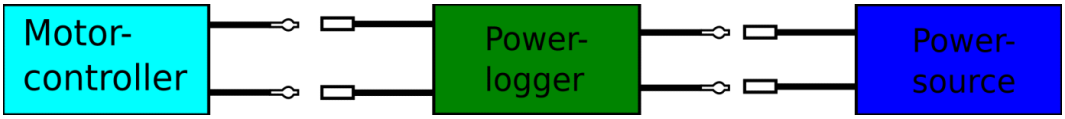
## 5.2. Payload Cube



- The payload cubes will be provided at the competition.
- The payload cube dimensions are 0.1 m x 0.1 m x 0.1 m (length, width, height) with a weight of approx. 1.1 kg.
- It is possible to combine several single cubes into one bigger unit.
- The single units can be connected in two different ways:
    1. The lids can be screwed together using two M6 screws.
    2. All side surfaces contain drilled holes to take in threaded rods with a diameter of 6 mm.
- To attach the payload to the climber both mounting options can be used.
- The materials and equipment needed to combine multiple cubes will be provided at the competition.
- A technical drawing is available on the EUSPEC website.

## 5.3. Measurement Unit

The power consumption of each climber will be logged with a measurement board directly before the motor controller:




Appropriate connectors need to be provided (standard 6 mm gold plugs – e.g. http://www.hobbyking.com/hobbyking/store/__5281__HXT_6mm_Sprung_Gold_Connectors_10pair_20pc_.html – male on motor side, female on battery side).

The measurement unit (see image to the right) will be provided by the organization team and counts towards the payload. It can be attached to the climber by velcro straps or zip ties.

It has to be possible to quickly connect and disconnect the measurement unit to and from the climber and safely stow it during the drive.

### 5.3.1. Specifications

- Climber connection:
  - to the battery: male / from battery: female (see image above)
  - to the motor: female / from motor: male (see image above)
- Dimensions: approx. 86 mm x 71 mm x 35 mm
- Weight: approx. 0.04 kg
- Voltage limit: 60 V
- Current limit: 140 A

# 6. Ground and Track Layout

## 6.1. Competition Area

### 6.1.1. General

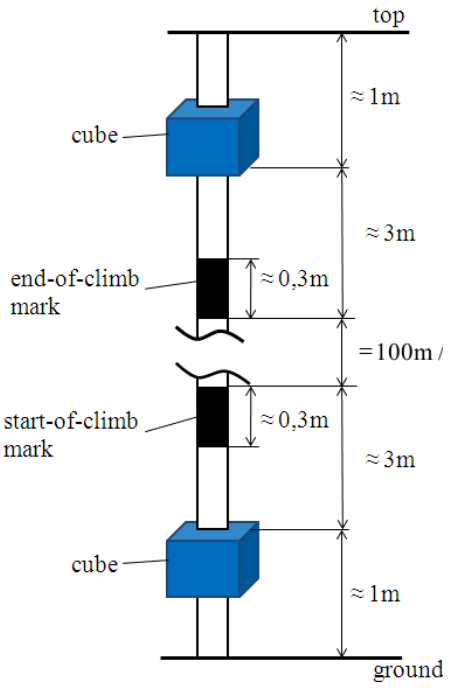
- The competition will take place at the Garching campus of the Technical University of Munich.
- The competition site consists of three main areas:
  - The team area, where each team will get a tent with a table to prepare their climber for the competition.
  - The staging area, a special tent where teams have to prepare their climber for the drive.
  - The safety area, which is the area around the drive track.

### 6.1.2. The Safety Area

- The safety area consists of two parts: the outer safety area and the inner safety area.
- The outer safety area:
  - Area around the drive track marked with a circle of warning tape with a diameter of 100 m.
  - Entering this area requires a safety helmet.
  - Only the team currently mounting the climber and the organization staff of EUSPEC are allowed to enter the outer safety area.
- The inner safety area:
  - Area directly around the bottom attachment point of the tether/rope and directly beneath the tether/rope.
  - During the drive of the climber the inner safety area has to be cleared.

## 6.2. Drive Track

- One end of the tether/rope is attached to the ground, the other end is attached to a gas balloon filled with Linde helium gas.
- The climber-assembly-range is at about 1m above the ground.
- At the bottom and the top of the tether or rope are foamed polystyrene cubes with approximate dimensions of 0.5 m x 0.5 m x 0.5 m.
- The climber-assembly-range is 3 m between the bottom cube and the start-of-climb mark.
- The start-of-climb mark is a 0.3 m long black-on-white or white-on-black line.
- The distance between the start-of-climb and end-of-climb mark is 100 m.
- The same arrangement is on the top.
- The tether/rope will normally be within 45° from the vertical. Close to the ground and depending on the weight of the climber this value can be exceeded locally.



# 7. Procedures

## 7.1. General

- The competition is composed of consecutive time slots, distributed over two days, in which the teams will perform drives with their climber.
- Changes in the contest operation will be announced to all team leaders at once.
- A separate drive track for climber testing will be available during the competition.
- Teams must clean up their workspace at the end of the day and not damage property.
- Please respect the other teams!

## 7.2. Climber Check-Up

- The climber check-up will be held on the first day of the event.
- All teams have to participate with their climbers.
- The climbers will be checked to ensure that they obey the rules and regulations of the competition. If not, the teams will be given time until the beginning of the next day to fix the issues, when they will be checked again.

## 7.3. Trial Run

- Before the regular runs there will be a trial run in which every team has to participate.
- The trial run will be held on the small testing crane with a total track length of 20 m.
- The teams have to prove that their climber is able to operate under real conditions.
- If a climber shows significant design flaws, operational problems or safety issues during the trial run, a run on the 100 m track can be denied until the issues are fixed.

## 7.4. Pre-Drive

- The team members have to arrive at the staging area at least 15 minutes before the beginning of their time slot.
- During the preparation time within the staging area, the payload and the measurement unit will be mounted. Also the climber will be weighed.
- All team members will receive safety helmets and safety gloves at the staging area which are manadatory to be worn while in the safety area.
- Should any issues with regards to safety or regulatory compliance of the climber arise while in the staging area, the team can be denied to drive.

## 7.5. Drive

- During their time slot, a team has to mount their climber to the tether/rope, climb up and down and demount their climber. Within the time slot the climber can drive up and down as many times as the team wants.
- The climber payload configuration cannot be changed during a time slot.
- For a drive to be valid with regards to scoring, the climber must cross both the start-of-climb mark and the end-of-climb mark with its full length while driving up and down.
- Additionally, the climber must hold its position for at least five seconds at the top of the rope/tether. This is to ensure a valid measurement of the climbing height.
- The average speed is calculated using the duration of the climb and the height, measured by a barometer in the Measurement Unit.
- All measurements must be from the same run. It is not possible to count the energy consumption of one run and the average speed of another.
- The drive downwards has to be performed in a controlled and safe manner.
- The remaining time slot time will be indicated on a widely visible digital clock.

- A team has to leave the safety area **before** the time of its time slot runs out. Otherwise it will incur a penalty (see Section 8.2).
- The organisation team has the authority to end a time slot prematurely if the rules are violated or due to bad weather conditions.
- The number of team members for mounting, dismounting and climber operation is limited to five. Additional persons need the permission of the organisation team.

## 7.6. Post-Drive

- The payload and the measurement unit will be dismounted at the staging area. The safety helmets and gloves have to be returned to the organisation team.
- Teams must pick up all their hardware from the staging area after their time slot.

## 7.7. Safety

As is evident from our competition design, safety is our first priority. Unsafe behavior during the event will not be tolerated. Generally, please behave in a safe and polite way.

- Within the safety area you must wear a safety helmet and safety gloves. Both will be provided by the organizers.
- The inner safety area has to be cleared immediately after starting the climber and can only be re-entered when the climber is at a standstill in the bottom climber-assembly-range.
- You are responsible for your team's tent. Try to keep it clean and organized. Do not leave any tools lying around unnecessarily. Minimize any possible exposure to current carrying components, sharp edges or moving parts.
- Always turn off your climber and any electrical tools when leaving your tent.
- Keep in mind the safety of potential visitors or jury members, especially when leaving your tent.
- If you use electrical devices at the competition area or the TU Munich keep in mind the specifications of the European power grid (230 V, 50 Hz).
- The emergency numbers are **112** or **+49 89 289 112** for mobile phones.

# 8. Evaluation

## 8.1. Scoring

The score for each valid climb is composed of the efficiencies for payload weight and energy consumption.

The formula is:

$$Score = \left(\frac{m_{pl}}{m_{tot}}\right) \cdot 100 + \left(\frac{E_{pot}}{E_{bat}}\right) \cdot 100 + v$$

With: $m_{pl}$ ≙ payload mass
$m_{tot}$ ≙ total mass of the climber
$E_{pot} = m_{tot} \cdot g \cdot h$ ($g$ = gravitational acceleration, $h$ = climbed height)
$E_{bat}$ ≙ expended energy by the battery (measured by the power measurement unit)
$v$ ≙ average speed of the climber in m/s

- The score will be rounded to integers.
- For the final ranking of the teams, the highest score of each team will be used.
- In case of a draw the team with the faster climb upwards will be ranked higher (only taking into account climbs with the highest score).
- Only the data measured by European Space Elevator Challenge organizers is relevant for the scoring.

The evaluation of the jury for the special awards will be done during the competition days. Please be prepared that the jury members will visit you at your tent to examine your climber.

## 8.2. Penalties

- If the climber does not fulfill the requirements of the rulebook, the team will not be allowed to participate until all issues are resolved.
- If a team exceeds its time slot time, the scoring of all measured climbes within this slot will be reduced by 25%.
- Not obeying the safety procedures will result in a warning (yellow card) and, if continued, in a cancellation of the current time slot (red card).
- Grave disobedience of the rules or unsportsmanlike behavior will result in immediate disqualification from the competition.

## 8.3. Prizes and Awards

### 8.3.1. Prizes

The three teams with the highest scores according to the scoring system mentioned in Section 8.1 will be awarded:

- The team in 1st place will receive a prize money of 1000 €.
- The team in 2nd place will receive a prize money of 500 €.
- The team in 3rd place will receive a prize money of 250 €.

### 8.3.2. Special Awards

There are three categories for special awards:

- The “Innovation” award goes to the team with the most outstanding and innovative concept for their climber. The evaluation of the jury in conjunction with the organizers of the European Space Elevator Challenge determines the result in this category.

- The winner of the “Construction Quality” award is evaluated by the jury alone. The following criteria are important for this prize: neat manufacturing, adaptability, practical solutions, proper use of engineering materials (composites, aluminum, steel), lightweight constructions.

- The “Safety” award goes to the team whose climber obeys the safety requirements in the best and most elegant way and whose overall behavior with respect to safety is the most exemplary. The evaluation of the jury in conjunction with the organizers of the European Space Elevator Challenge determines the result in this category.

Each team receiving a special award will receive a prize money of 250 €.

## 8.4. Complaints

- If a team feels that a judgment is flawed, it can file a complaint. Complaints are accepted only on the date of competition or before it but in no cases afterwards.
- Complaints are not accepted on the judgment for the award categories “Innovation”, “Construction Quality” and “Safety”.
- For complaints during the competition or before, the team shall contact the respective team contact person.

# 9. Additional Information

## 9.1. Authorization to Release Information Form

The Authorization to Release Information form allows us to avoid legal trouble when publishing any information or media generated during the event. Each team member must sign the form and hand it in until the deadline. To do this, please download the blank form from the EUSPEC website.

**DEADLINE: SEPTEMBER 17TH, 2018**

## 9.2. Media

- All published material in conjunction with the European Space Elevator Challenge must be approved by the organizers.
- During the competition, each team must cooperate with the media partners present. This includes complying with the preparation of materials (e.g. posters) as well as responding appropriately when interacting with the media.

## 9.3. Changes

No liability will be accepted in result of any changes, errors and omissions in this handbook. Every team has the responsibility to ensure that they have the most recent version of this handbook from the EUSPEC website.

## 9.4. Contact Information

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85748 Garching b. München
GERMANY

Email: euspec@warr.de
Website: http://euspec.warr.de/

# 10. Acknowledgements

## 10.1. Partners

We would like to thank the following partners for making the event possible:

VESTNER AUFZÜGE ELEVATING PEOPLE

hochhinaus.de balloons, inflatables & helium

THE LINDE GROUP Linde

tendon tied to be free

GÜTH & WOLF BAND- UND GURTWEBEREIEN

TEIJIN

Department of Mechanical Engineering
Technical University of Munich

WIESE FOTO+FILM

DGLR Deutsche Gesellschaft für Luft- und Raumfahrt Lilienthal-Oberth e.V.

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