*Artificial Intelligence and Robotics Laboratory of Politecnico di Milano (AIRLab)*

# Risk Assessment Document
(Documento per la Valutazione dei Rischi)
2022-10-18

Each user of the AIRLab Laboratory must carry out their activities in strict compliance with the indications of:

1. this Risk Assessment Document;
2. the Regulations of the Leonardo Robotics Labs, a multi-laboratory structure of which the AIRLab is part together with the MERLIN and NearLab laboratories;
3. the training about safety received from Politecnico di Milano.

Anyone who causes harm to themselves or others by failing to comply with the directions from these three sources will be **personally liable** for such damage.

## Aims of this document

The main function of this document is to provide AIRLab users with a guide on the dangers to their own health and that of others that may arise from the activities carried out in the laboratory, and on the precautions that it is necessary and mandatory to take to avoid such dangers.

The second function of this document is to collect, to the benefit of the organisations responsible for safety management at Politecnico di Milano, the information and procedures defined by the AIRLab Safety Manager in order to make laboratory activities safe. This second function is carried out in accordance with the indications of the Rector's Decree No. 78/AG of 7/1/1999.

## Preamble on laboratory activities

The Artificial Intelligence and Robotics Laboratory is an educational and research laboratory. This means that the devices it contains (robots, electronic circuits, mechanical structures, and so on) can be experimental equipment, prototypes, or in any case incomplete or temporary objects, or commercial equipment that is partially disassembled or modified in some way. For these reasons it is almost always possible, if one is not aware of what they are doing, to handle a device in such a way that it causes damage to oneself, others, or the device itself. The safety of such an apparatus does not depend, as it happens for commercial products, from the fact that the user is physically prevented from using it incorrectly: it instead depends on the fact that the user knows how this device works, how it is made and what risks its use may present.

To the generic dangers that any laboratory containing electromechanical equipment entails for an ignorant or inattentive visitor, the AIRLab adds others, very specific, related to the presence of robots. Therefore it is necessary that every AIRLab user knows these dangers and knows how to prevent them.

All this does not mean that the work in AIRLab is in itself dangerous: it is not. But it becomes so for those who work without attention or without having documented themselves adequately, and for those who assume that someone else has the task of thinking for them. Each person is responsible for what they do.

## Prototypes

An activity frequently carried out by AIRLab users is the creation or modification of *prototypes*.

A prototype is any realization (a circuit, a mechanical structure, a robot ...) built for the purpose of study or to perform experiments. Anyone who makes or modifies a prototype is required to eliminate from it all possible causes of risk for themselves and for the other users of the laboratory. The categories and types of risks to be considered are listed in the following paragraphs.

It should be noted that it is not sufficient to eliminate dangers directed towards the users of the prototype (for example exposed or inadequately protected electrical contacts, which become dangerous only when the appliance is powered), but it is also necessary to eliminate dangers directed towards those who may accidentally come into contact with the prototype (for example, sharp or sharp metal parts).

The risks associated with a prototype and the methods to be used to eliminate them must, if necessary or in case of doubt, be discussed with one's project manager: in any case it is the responsibility of whoever builds, modifies or uses a prototype to eliminate the risks associated with it.

## Types of risk

Below is a list of risk categories to which an AIRLab user may be exposed. In the following, the term "device" is used in the most generic sense possible (it can indicate a robot, an electronic circuit, a mechanical structure, a cable, a tool, an instrument ...).

In section *Risks and precautions associated with specific equipment or structures*, these risks are associated with the specific devices capable of generating them, and detailed indications are provided on how to avoid them and on the mandatory e (PPE).

➢ **Risks due to ignorance**

The device can be dangerous if used without knowing its potential, limitations and (in the case of an experimental setup) any known problems or particularities not immediately evident. It is necessary to carefully read all the paper and electronic documentation available on it (manuals, data sheets, ...) *before* using it.

In the case of experimental devices under development, the documentation often does not exist or is partial: in these cases it is necessary to contact one of the people who are in charge of the device. This person is *required* to dedicate, to anyone who has to interact with the device under development, all the time necessary to provide in-depth explanations and clarify any doubts. While waiting for these explanations, one must not touch the device. If in doubt, they must contact their project manager.

The general rule that must govern the work of every AIRLab user is to use only the equipment, tools, materials on which the user has been explicitly trained by Politecnico di Milano. This training can take various forms (including: training courses; explanations provided verbally by AIRLab staff; careful reading of the accompanying technical documentation, including relevant theses). A user must refrain from using elements about which he has not been explicitly trained.

➢ **Mechanical risks**

The device may have sharp edges, protruding elements or sharp or pungent or abrasive parts that can injure. In addition, there may be organs capable of crushing parts of the body.

The device may include moving parts in which parts of the body (typically the hair) or clothing can become entangled.

The device, or parts of it, may be unstable. Therefore it is possible that they will tip over and fall on someone. This risk may possibly occur only in particular configurations of use (for example when the battery containers are extended).

The device may have moving parts which, during operation, can hit and injure someone. There may also be organs that can detach from the device during operation and be thrown far away, with the risk of hitting someone. The device itself can move uncontrollably (for example, a mobile robot) and hit people and objects.

The device, or parts of it, may be too heavy for one person to carry safely (see also section *Heavy objects*).

The device or parts of it may, during operation or transport, fall on someone and injure them.

➢ **Electrical risks**

*Electrical risks are associated with the occurrence of contact, direct or mediated by objects, between parts of the body and live elements. The risk of harmful or lethal* *effects resulting from such contact depends on the current in transit and is linked to a number of factors (which parts of the body make contact, humidity and sweating, contact area, individual sensitivity, ...) which are difficult to quantify. However, it is possible to give some general rules:*

- *never expose yourself to the risk of coming into contact with elements of devices powered at voltages higher than 12V without insulating protections (gloves);*
- *never touch electrical appliances with wet or damp hands (including in the case of sweaty hands);*
- *alternating voltages (sinusoidal, pulsed, ...) are more dangerous than continuous ones;*
- *sources capable of delivering high currents (for example, batteries, 230V mains, ...) are particularly dangerous;*
- *some electrical devices (capacitors, batteries,…) are dangerous even in the absence of any external power supply;*
- *never touch a person who is undergoing an electric shock with bare hands: to remove them from the source of the shock, use objects made of insulating material (plastic, wood, cardboard, ...).*

The device may have bare electrical contacts. Touching such contacts can be very dangerous. If this situation is detected, it must be reported immediately to the laboratory Safety Manager (see section *Procedures in case of emergency*). When a device is being built, it is necessary to ensure that the electrical contacts are not exposed and are properly insulated, for example by providing insulating covers for the connections that cannot be accidentally removed during handling.

For many devices, such as robots, the metal frame is used as an electrical reference (ground). In this case, touching the chassis and any point on the device that is not electrically grounded at the same time can cause an electric shock.

➢ **Risks related to acoustic noise**

*Exposure to sounds and noises, both audible (i.e. included in the conventional 20 Hz - 20 kHz band) and inaudible (i.e. external to this band) can have harmful effects. These effects depend on the intensity and spectral distribution of the noise, and to some extent on individual sensitivity. The possible effects include discomfort of various kinds (which may appear not to have an obvious cause if due to inaudible sounds), pain, temporary or permanent hearing decrease or loss.*

The device may emit, during operation, sounds or noises loud enough to be risky for all people in the vicinity (including those who are not directly involved in the activities which generate the noise).

To avoid damage it is necessary, in all cases in which intense noise is produced and in particular if those present feel discomfort or pain in the ears, that all the people affected by the phenomenon wear appropriate protections (ear muffs).

### ➢ Thermal risks

During operation, the device or some of its parts can heat up to the point that contact with body parts becomes dangerous.

Contact of hot parts of the device with flammable objects or materials (including clothing) can cause fire.

### ➢ Risks associated with laser radiation

Some devices (for example distance sensors, widely used in robotics) include emitters of laser light, either visible or invisible. The radiation emitted can harm humans; in particular, the organs of sight are particularly delicate.

Lasers are classified according to the following **risk classes**:

- Class 1: laser whose radiation is not dangerous.
- Class 2: laser whose radiation is capable of causing damage to the eye, but which are safe due to the automatic defense reactions of the eye, including the eyelid reflex. They emit visible radiation in the wavelength range between 400 and 700 nm.
- Class 3A: lasers that are safe for naked eye vision. For lasers that emit in the visible (wavelength range between 400 and 700 nm) protection is ensured by defense reactions, including the eyelid reflex. For other wavelengths, the risk to the naked eye is no higher than that of Class 1.
- Class 3B: direct vision of the beam of these lasers and its diffuse reflections (on environmental obstacles) can cause damage to the eye.
- Class 4: lasers whose diffuse reflections are dangerous to the eye. They can also cause skin injury and pose a fire hazard. Their use requires extreme caution.

The classification of a commercial laser device is indicated by the manufacturer on the body of the device itself. The devices used in robotics generally belong to classes 1 or 2. To be able to use lasers of class higher than 3A, it is essential that all people present in the area (not just the user) wear suitable protections.

Never modify a laser equipment (for example, by inserting an additional optic): this can change the danger compared to the original classification

### ➢ Chemical risks

The device can emit, under normal conditions of use (operation, recharge, ...) substances that are harmful by contact or inhalation, for example because they are poisonous or corrosive. The device may contain harmful substances that can spill out if appropriate precautions are not observed.

The device can emit harmful substances in malfunctioning conditions (overheating, short circuit, overcharge or excessive discharge of the batteries, ...).

The laboratory has (in the workshop) extractor hoods, which are however only suitable for fumes whose danger and quantity are modest (for example, fumes from tin soldering). It is not possible to carry out operations in the laboratory that could produce dangerous and / or abundant fumes.

The laboratory is not equipped for the use and disposal of acids and special chemicals, therefore their use is not allowed. As regards the disposal of chemical products, see section *Special waste disposal procedures*.

➢ **Risks related to the use of robots**

> *A robot is to all intents and purposes a mechanical, and usually electromechanical, device. Therefore it is able to generate all the types of risks listed in the Mechanical Risks and Electrical Risks sections. In addition to them, robots introduce some particular types of risk, listed below. To avoid such risks, appropriate precautions must be observed, described in detail in section "Risks and precautions associated with specific equipment or structures".*

A robot can, due to software bugs, behave in a completely different way from what was expected (for example moving in a given direction with maximum acceleration) or even anomalous (for example maneuvering one of the robot's own organs in such a way as to cause it to break with ejection of fragments), putting everyone in the surrounding area at risk.

A robot can, during autonomous movement, run over someone.

A robot can move suddenly and injure someone. This can also take place a long time after the last movement command has been sent, in the event that some delay mechanism is in place (software design errors or bugs, hardware failure, reaction to external events, ...). For this reason it is necessary that every robot that is switched on and not strictly supervised is in a locked condition (generally reached by activating special emergency buttons, which are usually red and mushroom-shaped).

➢ **Risks related to ergonomy**

Prolonged use of computers can cause damage to eyesight or to the muscular and skeletal system, if appropriate precautions are not observed (these are described in detail in the "*Risks and precautions associated with specific equipment or structures*" section).

In any task (especially if mechanical) a badly organized work station multiplies the risks. A work station is well organized if there is sufficient work space (free from any material), good visibility, chair and table are correctly adjusted (especially in height) and all the necessary tools are at hand.

➢ **Risks related to information obtained from the internet**

From the internet it is possible to obtain information and instructions relating to almost all technical fields. Often this information is accurate, but not always; sometimes they are *dangerously* inaccurate. Therefore, it is always necessary to critically evaluate what has been obtained via the internet, and never assume that a "professional" formatting or tone also implies accuracy of contents. It is necessary to check with your project manager the adequacy of what has been found.

In particular, the safety of people, data or equipment must never be entrusted to code or instructions obtained from the Internet and not verified in any other way.

## Where to find manuals and documentation

Before using a piece of equipment it is necessary to have full knowledge of its characteristics and use. If this information is not already in your possession, you must contact the project manager.

It should be noted that the documentation associated with a piece of equipment could consist in whole or in part of one or more theses, term papers or graduation papers of the students who worked on a project. One can obtain a copy of the documents in question from their project manager.

In the case of experimental devices under development, the documentation often does not exist or is partial: in these cases there is always a person (professor, graduate student, ...) who is taking care of the project. This person is *required* to dedicate, to anyone who has to interact with the device under development, all the time necessary to provide in-depth explanations and clarify any doubts. While waiting for these explanations, one must not touch the device. If one experiences a lack of the necessary collaboration on the part of the people in charge of an experimental apparatus that they need to use, one should report the matter to their project manager or, ultimately, to the Safety Manager of the laboratory (see the *Procedures section in case of emergency*).

Before using any apparatus or device present in AIRLab it is *mandatory* to find and carefully examine all the documentation relating to it, with particular attention to the sections relating to any risks and safety procedures. This also applies if the documentation is only available in the form of an interview with the persons responsible for an experimental setup.

## Risks and precautions associated with specific equipment or structures

All types of equipment present in AIRLab and which may give rise to risks are examined below. For each of these types, the specific risks and precautions required to avoid them are highlighted, including the use of any Personal Protective Equipment (PPE). The use of these precautions is mandatory: if they are not available, the use of the equipment is <u>prohibited</u> and it is necessary to report the matter immediately to one's project manager.

If, while working in AIRLab, one detects any risk condition not considered in this document, or for which one believes that sufficient preventive measures have not been taken, one must report it immediately to the laboratory Safety Manager. Any such report is important and will be greatly appreciated.

**230 V AC power supply network**

The power supply network of the laboratory does not differ from that of a normal household; therefore the same precautions are required to avoid the dangers of electrocution. In particular, it is necessary:

- absolutely avoid touching live parts, even if they do not belong to the network itself but to equipment connected to it (for example via the power cable);
- avoid modifying, disassembling or in any case tampering with elements of the network (power sockets, raceways, cables,…). If you notice anomalies of any kind (missing lids, recessed sockets, ...) immediately notify your project manager;
- do not use damaged power cables or extension cables;
- do not build or modify power cables;
- never disconnect a power cable from a socket by pulling the cable itself: operate directly on the plug;
- do not use cables without the earth terminal (ie 2-conductor cables) to power devices that are not explicitly provide for it;
- only use power supply and extension cables with a section suitable for the power of the equipment to be powered. For devices powered at 230 V, an adequate gauge for each of the 3 conductors is at least equal to 1$mm^2$ per kW of absorbed power (e.g .: absorbed power 3 kW -> use electrical cable with 3 conductors of at least 3 $mm^2$ each).

**Work stations**

To reduce the risks associated with carrying out manual work, especially if it is critical or delicate (for example a welding), it is important to carefully organize the work station: the time dedicated to this is very well spent.

Among the rules for organizing the work station:

- place the work station in a place with good lighting
- free up sufficient space on the work surface
- get all the tools you need for the job in advance
- have tools close at hand
- adjust the seat and work surface heights so that work is comfortable and easy
- if during work one realizes that a tool is missing, they should stop working and procure the tool

With regard to the last point, it is important to avoid the temptation to use an unsuitable but available tool to replace a suitable but not immediately available one. This almost always leads to one or more of the following consequences: risks for the user, damage to the tool, poorly performed work.

At the end of the work the work station must be left clean and any residual material removed, so that the next user does not have to carry out this activity to obtain a risk-free workstation.

**Heavy objects**

> *The maximum transportable load without risk of muscle injury varies from person to person and depends on the shape and the grip points of the load. In any case, one should never move loads weighing more than 30 kg alone. To safely transport a load whose weight is P kg, <u>at least</u> P/30kg people are required.*
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> *The 30 kg threshold must be suitably reduced if the load to be moved does not have good grip points or is particularly large, or when the person or persons in charge of the transport are not trained to transport heavy and/or bulky objects.*

Never try to move too heavy a load on your own: instead, ask for help from one or more of the other users of the laboratory. If there are no people available at the moment, wait until they are.

When moving heavy objects, especially if the operation is carried out by several people, be careful not to place them or drop them on someone's feet.

The transport of heavy objects on staircases is particularly dangerous and must be performed with extreme care. Remember that in these conditions most of the weight of the object is supported by whoever is lower on the staircase.

When moving bulky objects, pay particular attention to the effects of any impact of parts of the object with surrounding obstacles (for example door frames or cabinets).

**Personal Computers and video terminals (VDT)**

> *In the laboratory, the personal computer (in accident prevention terminology, the VDU or video terminal) is the most frequently used device. Therefore, the risks associated with its use, although less critical than those associated with other equipment, should not be underestimated.*

Contrary to popular belief, the main risk deriving from the use of the video terminal is not the emission of radiation (which in normal conditions is negligible) but the risk for eyesight and the musculoskeletal system. Vision problems are generally caused by reflections on the screen, image flicker and inadequate contrast. The problems to the musculoskeletal system are instead linked to poor posture, the use of unsuitable work station components (chair, work surface), poor organization of the work station (positioning of monitor, keyboard, lectern) or poor work habits (unsuitable posture).

To avoid visual fatigue, it is necessary to:

- position the monitor correctly with respect to light sources, to avoid reflections;
- adjust the brightness and contrast of the screen in order to make the image clear and avoid excessive contrast between the background of the monitor and the background of the room;
- in case of visual fatigue, perform eye relaxation exercises (for example, following the perimeter of the ceiling with the eyes, diverting attention from nearby objects and looking towards distant objects, closing the eyelids for a few minutes moving the eyes away from light sources).

To avoid disorders of the musculoskeletal system, it is necessary:

- regolare correttamente l'altezza della sedia rispetto al tavolo, in modo che gli avambracci risultino all'incirca orizzontali durante la digitazione su tastiera (non a caso le sedie sono regolabili…);
- mantenere posture corrette (sedersi con la schiena dritta, appoggiare i polsi al piano di lavoro quando non si sta digitando);
- posizionare la tastiera in modo da poggiare la parte terminale dell'avambraccio sul piano di lavoro, o sui braccioli della seduta, durante la digitazione;
- in caso di affaticamento cambiare posizione o eseguire esercizi di rilassamento.
- correctly adjust the height of the chair with respect to the table, so that the forearms are approximately horizontal when typing on the keyboard (it is no coincidence that the chairs are adjustable ...);
- maintain correct posture (sitting with one's back straight, resting one's wrists on the work surface when not typing);
- position the keyboard so as to rest the end of the forearm on the work surface, or on the armrests of the seat, while typing;
- in case of fatigue, change position or perform relaxation exercises.

In any case, for those who work continuously at the VDU, it is mandatory to take breaks of fifteen minutes every two hours of work, during which one should perform other activities and above all avoid remaining seated.

**Pillar drill**

The pillar drill, if used correctly, is a very safe piece of equipment. However, there are numerous risks associated with its misuse.

A piece being drilled can be forcefully thrown away from the drill if it is not well secured. Always use the clamp fixed to the base of the drill to fix the pieces to be drilled.

Never hold a piece to be drilled with your hand: it is very easy to get injured.

Never use the drill without closing the transparent plastic cover located around the bit.

When there is the slightest chance that chips or splinters will be produced, or when in doubt that this is possible, wear protective eyewear.

If the drilling of a piece produces a noise even minimally annoying, wear the appropriate ear muffs, to avoid possible hearing damage. If there are other people near the drill, male them go away or have them also wear headphones before resuming work. Do not continue working if the noise remains annoying even when wearing ear muffs. In many cases, the production of noise can be reduced by applying a suitable lubricant to the drilling area.

To minimize noise and risks when making a large diameter hole (greater than 4mm), start with a small diameter hole (e.g. 3mm) and widen it by 1mm at a time by mounting several bits with diameters scaled by 1mm in succession.

It is possible that during the drilling of a piece the drill bit breaks or bends. A broken or bent tip is a serious danger because it can give rise to serious malfunctions of the drill (for example pieces of the drill bit or the object to be drilled could be thrown in all directions). In case of breakage or bending of a tip, stop the operation immediately, disassemble the tip (or how much of it has remained fixed to the drill) and discard the tip and any pieces that have detached from it.

Do not use bits that do not appear in perfect condition (especially the bits must be perfectly straight). If you come across an imperfect bit, set it aside where other users can't find it and give it to your project manager as soon as possible.

Pay attention to the type of drilling bit used. There are four main types of bits: for metal (those normally used in AIRLab), for wood (with a main tip and two lateral sharp spikes), for wall (with head wider than the body and triangular in shape) and abrasive bits; each of them is suitable only for a specific category of materials. Never use drill bits of a category not corresponding to the material to be drilled; if in doubt, ask your project manager.

**Grinding wheel**

When using the grinding wheel, it is always mandatory to use both the appropriate heavy protective gloves and protective goggles.

Sparks can be produced during grinding, which can ignite any flammable materials. Therefore, before using the grinding wheel, any flammable material (paper, rags, chemicals, ...) must be removed from the surrounding area.

It is very easy, during the grinding operations, that fragments of material are projected. The special protections mounted on the wheel itself (splinter guards, which must never be moved or, worse, disassembled) serve to prevent this, but may not be entirely effective. Therefore it is necessary to keep any person not equipped with protective goggles away from the vicinity of the grinding wheel.

If any object gets stuck between the rotating cylinder and the horizontal plate in front of it (piece rest), immediately stop the grinding wheel, disconnect it from the 230V mains and carefully disengage the object without reconnecting or switching on the grinding wheel again.

Check that the edge of the piece rest is no more than 2mm away from the rotating cylinder. This is necessary to minimize the risk that the piece being ground can get wedged between them, getting stuck. If you find the effective distance to be greater, stop machining immediately, report this to your project manager and attach a sign to the grinding wheel with the words "DO NOT USE - WAITING FOR MAINTENANCE".

**Simple mechanical tools (pliers, screwdrivers, hammers, wrenches, ...)**

> *Most accidents occur during the use of tools that the user believes they know how to use, because this leads to a reduction in the level of attention. It is very important to remain fully attentive even when using simple tools, which have already been used hundreds of times in the past.*
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> *Even the simplest mechanical tools (screwdriver, pliers, cutter) can be very dangerous if used carelessly or without following the training received. A tool does not need to be motorized, electric or complicated for it to be dangerous.*
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> *If there is the slightest doubt about how to use a tool in complete safety to carry out a job, ask the manager of your project (or even other users, if really more experienced) for advice before carrying out the job.*
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> *Using tools safely is also a matter of experience. The first few times you do a given job, do it with the utmost calm and attention. Speed will come later.*

Never use your hands to hold the object on which you are working with a tool: in this way you can seriously injure yourself if the tool "slips". If it is available in the room where you are working, always use the vice; otherwise, use pliers or other similar tools to keep your hands (and any other part of your body) out of the work area.

When you exert force on a tool (e.g. the thrust necessary for a screwdriver to get the necessary grip on the screw head), always make sure that that force is not directed towards your own body or other people’s: if necessary, move and make other people move to avoid this. In this way, if the tool were to "slip" it will not be able to injure anyone.

Never use a tool for a purpose other than that intended (classic examples: using a screwdriver as a chisel or awl, a hacksaw as a wood saw, a pliers as a wrench, any heavy tool as a hammer...).

Sometimes tools break. Often due to misuse, but not always. Predict possible risks due to breakage (example: hacksaw blade breaking and moving towards the face of the person working).

If there is a risk of crushing, cutting or otherwise injuring your hands, use heavy protective gloves.

If there is a risk of producing chips or other fragments that can injure the eyes, use protective goggles.

If you find a broken tool, put it aside where it cannot be found by other users and immediately notify your project manager, so that it can be restored as soon as possible.

**Soldering iron**

> *Even an electronic engineer may never have encountered, in theirs course of studies, the need and/or the opportunity to perform tin soldering. Soldering is a very useful technique, but it requires experience: take the time and exercise necessary to master it by doing some tests with components that have no value.*
>
> *Many tutorials on the execution of welds are available on the internet, but (as always in the case of the internet) not all the information published is correct. Refer to the AIRLab website to find reliable tutorials.*

The so-called “solder tin” may contain lead, a toxic metal. After welding, wash your hands to eliminate possible traces of lead or other harmful substances.

Tin welding generates noxious fumes, and must therefore be carried out taking care not to inhale the fumes. For this purpose it is mandatory to use the extractor hoods available in the workshop.

The tip of an electronics soldering iron heats up to about 350° C, and causes severe burns if touched. For the same reason, touching a flammable or explosive object with a soldering iron can cause a fire or explosion. Absolutely avoid unwanted contact between the soldering iron tip and other objects.

Do not place the soldering iron anywhere other than its base. This base is structured in such a way as to avoid accidental contact with the hot tip of the soldering iron. Never leave a hot soldering iron unattended: it is in fact impossible for other users to know that it is hot, except by getting burned. Do not leave the soldering iron before it has cooled down (which takes a few minutes after switching off).

Tin, in contact with the tip of an en excessively hot soldering iron, can form droplets of molten metal that can splash on the skin of the user. If you notice that droplets of this kind form, cool down the soldering iron slightly (for example by lowering its temperature or, if not adjustable, by switching it off for a short time).

Welding is the typical job that requires… three hands. One holding the iron, one holding the tin, and the third holding the piece to be welded (assuming that the structure to which this is to be welded is fixed, otherwise four hands are needed). Trying to do the job with just two hands dramatically increases the risk of burns and damage. The solution is to use the so-called *third hand*, a small tool with a heavy base and one or more adjustable clamps to hold the parts to be welded; in this way the hands of the user remain free to hold the iron and the tin.

### Multimeters ("testers") and oscilloscopes

> *Connecting the probes of an electrical measurement instrument (such as a multimeter or oscilloscope) to a circuit makes the instrument an integral part of the circuit. Therefore, before proceeding, a careful electrical analysis of what you are about to do must be performed. How will connecting the instrument affect the circuit? Will the circuit continue to work within design specifications? Can creating (through the instrument) an electrical connection between two points of the circuit give rise to risks? Does the instrument risk being subjected to excessive voltages or currents compared to those it can tolerate?*
> *If in doubt, contact your project manager before making the connection.*

When applying the probes to the circuit under test, be careful not to touch any electrical parts with your hands (including the metal parts of the probes themselves). Be careful not to put different parts of the circuit under test into contact with each other, through accidental contact of the instrument cables or probes with each other or with metal objects. This can cause short circuits (which can damage the device), sparks, component explosion, fire.

Pay particular attention if you are analyzing a circuit in which dangerous currents or voltages circulate (example: equipment connected to the 230V mains, equipment containing charged capacitors).

Never leave a measuring instrument connected to a circuit unattended: someone could touch the probes or the instrument (for example to take it, without realizing that it is in use) and receive an electric shock.

### Power supplies

> *A power supply (abbreviated form of "direct current power supply") is a device capable of generating, between a pair of output terminals, a continuous voltage of a predetermined value (for example determined by the position of a knob). Depending on the quality of the power supply, this voltage is more or less independent of the current absorbed by the load possibly connected to the output terminals; in any case, a power supply must be capable of delivering a significant current (typically of the order of a few Amps), and in particular sufficient to power the device to which it is connected.*
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> *Once the voltage has been set, which current is actually supplied by the power supply is determined by the load; the maximum deliverable current is instead part of the power supply specifications. Some power supplies are equipped with an adjustable current limiter, which allows you to reduce the current delivered to the load as desired. A power supply may or may not have protections to avoid damage in the event of excessive current demand (including the extreme case of a short circuit between the terminals, which if the power supply were an ideal voltage generator would lead to an infinite output current).*

Never touch the output terminals of a power supply with your bare hands.

Never connect a power supply to a circuit whose topology and functions one does not precisely know. Incorrect connection of a power supply to a circuit can cause irreversible damage to the circuit, sparks, fires and/or breakage of components, with potential release of toxic substances. The connection may be incorrect either because it is done in the wrong points of the circuit or because it is done in the right places but with too high output voltage of the power supply.

Never connect a power supply to a load that requires a current greater than the maximum that can be supplied by the power supply, even if the latter is equipped with output overcurrent protections; in particular, never put the output terminals of a power supply in contact with each other (short circuit). These situations can cause overheating, sparks or fire. Note that the short circuit occurs even if the terminals are connected to parts of a circuit that are different but electrically connected to each other, or due to accidental contact of the cables connected to the power supply with each other or with metal objects.

Do not delegate the prevention of short circuits to the internal protections of the power supply (if any): they may not work properly.

Never connect two different power supplies to each other or to the same circuit: the risks are the same as those that occur with short circuits, with the aggravating circumstance that any short circuit protection of the power supplies does not necessarily intervene in these conditions. For similar reasons, great care must be taken when connecting a power supply and a signal generator to the same circuit (see the next paragraph).

Adjust the output voltage of the power supply before connecting it to the circuit to be powered; adjusting it after connection leads to the risk of exceeding the correct values (the classic case of the “stuck knob” that moves abruptly).

Never connect a power supply to a battery. A power supply is <u>not</u> a battery charger!

**Electric motors**

> *An electric motor is an electromechanical device that transforms electrical energy into motion, typically of the rotary type. Electric motors are the most common type of motor used on board robots. Often, but not always, they are of the DC type (direct current), driven by a PWM (Pulse Width Modulation) circuit to regulate their rotation speed.*

A common electric motor, excluding only the smallest ones, is able to exert more than enough forces to cause damage to the user. Before operating a motor, the motor body must be securely locked so that it cannot move.

Particular attention should be paid when mechanical parts are connected to the rotating axle of the motor (for example, a wheel or an arm), because the risk increases. Particular attention must be paid to checking that the parts cannot detach when the motor starts to rotate.

To stop an engine that exhibits abnormal behavior, never act directly on it, for example by trying to stop the moving parts with your hands. On the contrary, intervene on the power supply of the engine by turning it off.

Motors can overheat with use, in particular stepper motors, or DC motors (including servomotors) under stress conditions. Avoid touching the motor body of a running motor. While building a prototype, it is necessary to avoid that the body of a motor that may overheat during use is in contact with flammable or meltable parts (for example, plastic of a 3D printed elements).

**Electrical transformers**

> *An electrical transformer is an electromagnetic device with no moving parts used to change the voltage of an electrical signal. Generally a transformer has a primary winding (usually simply called "primary") and one or more secondary windings (called "secondaries"). The primary and secondaries are accessible externally via pairs of terminals. A voltage generator is connected to the primary, and a load to each secondary: a parameter called the transformation ratio indicates the ratio between the voltages across the primary and one of the secondaries, and can be either higher or lower than 1. The coupling between the primary and secondary of a transformer it is magnetic, and the two windings are electrically insulated from each other: therefore sometimes the transformers are used precisely for this property (in this case the term used is "isolation transformers").*

It is not possible to distinguish the primary from the secondary of a transformer "by eye", or to determine the transformation ratio. If these data are not printed on the device, proceed with caution to carry out a test with a signal generator (not in direct current: at 0 Hz frequency a transformer does not work!) and a suitable measuring instrument. Don't trust any handwritten labels.

A transformer can raise a harmless voltage until it is dangerous, or raise an already dangerous voltage until it is definitely lethal. In particular, you must be very careful when you are using a transformer connected to the 230V mains.

Remember (if in doubt, consult an electrical engineering text) that the current flowing through a transformer is also affected by the transformation ratio. In particular, a decrease in voltage corresponds to an increase in current: therefore it is always necessary to make sure that the section of the cables connected to the secondary of the transformer is sufficient, and it is not certain that the section required is the same as that of the cables connected to the primary.

Do not exceed the voltage and current limits allowed by the transformer. If these limits are not clearly indicated on the transformer itself, keep to very conservative levels.

## Electric signal generators

*Un generatore di segnali è un dispositivo che fornisce in uscita una tensione variabile nel tempo secondo una gamma di possibili forme d'onda in uscita. In quanto generatore di tensione, un generatore di segnali può essere considerato come una generalizzazione del concetto di alimentatore, sebbene in pratica le funzioni dei due dispositivi siano differenti (l'alimentatore è usato per trasferire potenza, il generatore per trasferire un segnale con potenza spesso molto piccola). Un generatore può o meno possedere protezioni per evitare situazioni di eccessiva richiesta di corrente (compreso il caso limite di corto circuito tra i morsetti). Le raccomandazioni sui rischi da evitare sono simili a quelle esposte nella sezione* Alimentatori: *perciò rimandiamo a tale sezione, con l'accortezza di leggere "generatore di segnale" ogni volta che nel testo compare la parola "alimentatore".*

*A signal generator is a device that provides an output voltage that varies over time according to a range of possible output waveforms. As a voltage generator, a signal generator can be considered as a generalization of the concept of a power supply, although in practice the functions of the two devices are different (the power supply is used to transfer power, the generator to transfer a signal that is often associated to small poser). A generator may or may not have protections to avoid situations of excessive current demand (including the extreme case of shorted output terminals). The recommendations on the risks to avoid are similar to those set out in the Power Supplies section: therefore we direct the reader towards that section, with the proviso of reading "signal generator" whenever the word "power supply" appears in the text.*

## Batteries and devices incorporating batteries

*A battery is an electrochemical device capable of storing energy in the form of physical separation between electrical charges and of returning it in the form of electrical voltage between the "positive" and "negative" terminals (the first is the one with the higher electric potential).*
*As a first approximation, from the user's point of view, a battery behaves like a voltage generator. The value of the voltage supplied by a battery depends on the technology with which it is made and on the number of cells possibly connected in series to each other that make up the device.*
*Among the most common technologies used to make batteries for robots are lead/sulfuric acid (voltage of the single cell 2 V; typical voltages for complete batteries 6 V, 12 V, 24 V) and lithium (voltage of the single cell 3.7 V; voltages for complete batteries equal to 1-6 times this value). These voltage values are nominal: at full charge, a battery can supply higher voltages; as the battery gets discharged, the voltage drops according to a law that depends on the technology and construction of the device.*

> *A battery contains energy, often in large quantities. Energy is extracted in the form of current when a load is connected to the terminals. Since (at least until the battery is discharged) the voltage V between the terminals remains constant, the power delivered by a battery delivering a current I is equal to $P = V \cdot I$. Since I can reach high values, P can be very high. The value of I depends on the electrical load connected to the battery.*

When using a battery (for example as part of a robot) extreme care must be taken to avoid electrical contact between the battery terminals. Short-circuiting the two terminals leads the battery to deliver the maximum current made possible by its internal chemistry, which in some cases can even reach thousands of A. Such high currents quickly cause the battery to overheat, and sometimes to explode. Since the substances contained in batteries are (depending on the technology) flammable, toxic and/or highly corrosive, this type of event must be avoided absolutely.

The batteries should only be recharged with suitable power supplies and cables, as specified by the person in charge of the equipment they power. In particular, please note that the battery charging process can cause overheating of all the elements involved, including cables, which must therefore be kept away from any flammable materials (for example wood and paper).

Each battery needs a specific charging process (time, voltages, currents, ...), whose parameters are generally not suitable for other batteries, even those sharing the same basic technology (Pb, Ni-Cd, Ni-MH, LiIon, LiPo, ...). Therefore, it is generally not possible to use a battery charger suitable for a given battery with another battery, however "similar" it may seem to the first.

Qualora si riscontrino surriscaldamenti, deformazioni o altri comportamenti anomali in una batteria (di qualunque tipo) non toccarla, coprirla con una scatola senza spostarla da dove si trova (per evitare la proiezione di gocce in caso di esplosione o rottura) e contattare immediatamente il responsabile del proprio progetto o il Responsabile per la Sicurezza dell’AIRLab.

A charger is not a power supply. It is a complex device, which during recharging supplies the battery with voltages and currents with particular and controlled evolutions over time. Never connect a power supply to a battery.

In battery-powered devices, the batteries and the elements directly connected to them are always live, even when all the power switches of the device are in the “off” position. These elements must be touched only with insulating protections (gloves) or with insulated tools.

Any battery, if short-circuited (for example by touching both terminals with a metal object), can explode, disperse toxic substances, emit poisonous fumes and cause fires. These phenomena can also occur long after the short circuit has started (for example at night), and can thus be even more dangerous.

Lead-acid batteries (such as those for automotive use) contain sulfuric acid, a highly corrosive liquid. To avoid serious injuries, never touch the liquid contained in the batteries with your hands. One must wear protective gloves before performing any operation that requires opening the battery cells or moving the batteries (ask your project manager for instructions before undertaking this type of operations). In case of contact of the liquid with the skin or eyes, rinse immediately and abundantly with water and contact a doctor.

Never open the cells of a lead-acid battery during charging or shortly after the end of it: the gas that can be produced inside the cells during charging can, by escaping, make the liquid contained in the battery splash around.

Lithium batteries (LiIon, LiPo) require extreme attention in use, charging and storage. In fact, despite their widespread use -and unlike batteries based on other technologies- they are flammable and explosive. If punctured, physically deformed and/or subjected to excessive currents (either discharging or charging), these batteries can cause fires and severe burns to the user.

Any fire caused by lithium batteries cannot be extinguished with water.

In particular, it is recommended to never leave lithium batteries under charge without the physical presence and direct surveillance of the user. If the user needs to leave, they must interrupt the charging process.

If one detects overheating, deformation or other abnormal behavior in a battery (of any type) they must avoid touch it, cover it with a box without moving it from where it is (to avoid the projection of drops in case of explosion or breakage) and contact their project manager immediately,  of your project or AIRLab's Safety Manager.

### Experimental devices

Per sua natura l'AIRLab contiene diversi dispositivi sperimentali, ovvero oggetti in fase di progettazione e/o di test e le cui caratteristiche non sono documentate affatto o lo sono solo parzialmente. Tali dispositivi possono appartenere a diverse categorie: elettrici, elettronici, meccanici, elettromeccanici, … .

In ogni caso un dispositivo sperimentale è per sua natura particolarmente pericoloso. Esiste sempre una persona o gruppo di persone che si sta occupando di un dato dispositivo sperimentale, ed è ad essi che occorre chiedere istruzioni dettagliate (che sono *tenuti* a dare) prima di compiere qualsiasi operazione con il dispositivo. Lo stesso referente va contattato anche in caso di dubbi o incertezze, o per segnalare qualsiasi comportamento anomalo dell'apparato.

In caso di problemi o dubbi di qualsiasi tipo, incluso il caso in cui i responsabili dell'apparecchiatura sperimentale da utilizzare siano irreperibili o si rifiutino di dedicare il tempo necessario alle spiegazioni sul suo uso, rivolgersi al responsabile del proprio progetto.

By its nature, the AIRLab contains various experimental devices, or objects in the design and/or testing phase and whose characteristics are not documented at all or are only partially documented. These devices can belong to different categories: electrical, electronic, mechanical, electromechanical,….

In any case, an experimental device is by its nature particularly dangerous. There is always a person or group of people who is in charge of a given experimental device, and it is them that must be asked for detailed instructions (which they are *required* to provide) before carrying out any operation with the device. The same people should also be contacted in case of doubts or uncertainties, or to report any abnormal behavior of the device.

In case of problems or doubts of any kind, including the case in which those in charge of the experimental equipment to be used are unavailable or refuse to devote the necessary time to explain its use, a user must contact their project manager.

**Devices incorporating laser emitters**

> *In this regard, see also section "Risks associated with laser radiation".*
> *La pericolosità di un laser varia a seconda dell'intensità e della frequenza della luce emessa. Ogni laser è caratterizzato, in termini di sicurezza, dalla sua* classe di appartenenza.
> *The danger of a laser varies according to the intensity and frequency of the light emitted. Each laser is characterized, in terms of safety, by its class.*

Depending on the class to which a laser belongs, it may be necessary to use (and have anyone else in the area use) suitable protection devices.

Many lasers emit radiation at frequencies not visible to the human eye (for example, infrared). These lasers can be as dangerous as the visible ones, and even more: in fact the eye tends to protect itself from very intense visible light sources (for example by closing the eyelids) but does not react to invisible light sources.

Never direct a laser emitter of any kind, no matter how low its power, towards a person's face (and in particular the eyes). Laser light can cause severe eye damage. This is true even if there is a large distance between the emitter and the affected person, since the dispersion of laser radiation with the distance is minimal.

Never use a laser emitter that is not firmly secured to a base capable of preventing it from falling or changing its aim, even in the event of a collision. (For example: never simply place a laser sensor above a mobile robot - attach it to the robot instead.)

Do not use a laser emitter that appears damaged, malfunctioning or tampered with. Never modify a laser equipment (e.g., by inserting additional optics).

**Robot**

> *In this regard, see also section "Risks related to the use of robots".*

An unblocked robot can move unexpectedly and injure someone. This can also take place a long time after sending the last movement command. It is therefore always necessary to block robots in every time interval in which no one is observing them continuously; furthermore, in every moment in which the robot is not blocked, the user must be ready to intervene, blocking it, in the event of abnormal behavior.

The blocking of a robot is performed by activating the appropriate safety switches (if present) or by interrupting the power supply. Never rely on software alone to block a robot.

Some of the most common causes of unexpected motion are listed below:

- errors in the control software (when writing control software for a robot, unlike in the case of generic software, it must be remembered that any error can cause a physical danger: therefore much more attention is needed in the debugging phase);
- effects of the robot's home start state (for example, its initial position);
- effects of the insufficient state of charge of the batteries (for example some subsystems can operate in an unexpected way, while others fail to operate);
- hardware failures;
- intermittent hardware failures (for example, a false contact can lead to the execution of a command previously given but not executed);
- old motion commands queued for some reason;
- presence of transient signals when switching on or off the PC that controls the robot (never carry out these operations with the robot not blocked).

Unlike wanted and controlled movements, often anomalous movements of robots occur with maximum speed and acceleration, and are therefore particularly dangerous.

<u>Every AIRLab user who builds a robot capable of causing harm to people (due to its mass and/or speed of movement of the parts and/or mode of operation) is obliged to install an emergency stop device on board</u>. This obligation also applies to users who work on pre-existing robots, if these are not already equipped with the device.

An emergency stop device must be: (i) easily visible and operable; (ii) installed *before* the robot is put into operation for the first time; (iii) carefully tested to verify its correct operation.

The emergency stop device must, when activated, *physically interrupt the electrical supply lines to the robot motors*. This is in fact the only type of block that ensures the interruption of the movement of a malfunctioning robot regardless of the origin of the malfunction.

**Chemical products (paints, solvents, detergents, ...)**

*In this regard, see also section “Chemical risks”.*

Many chemicals are dangerous because of their toxicity, flammability, or other properties. Before using any chemical product, always carefully read the information that by law must appear on the packaging label.

Never use chemicals, no matter how harmless they may seem, found in unlabeled containers. The content may not necessarily be what one expects.

Never mix chemicals.

Never throw away a chemical product (even if it is exhausted) without following the procedures indicated in the "*Special waste disposal procedures*" section. In particular, nothing should ever be thrown into the sewage system.

## Special waste disposal procedures

If it is required to eliminate any type of special waste (electronic equipment or their parts, mechanical components, chemicals, objects or materials that are sharp or dangerous in any other way, ...) it is absolutely forbidden to make use of the waste baskets or bins present in the premises of the AIRLab or in the buildings that house them, or to make use of sewage drains. On the contrary, it is necessary to contact the personnel responsible for the safe removal of special waste, and at the same time inform one's project manager.

The person to contact is Eng. Fausto Berton.

## Procedures in case of emergency

The procedures to be observed in the event of an emergency are the general ones of the Department of Electronics, Information and Bioengineering of the Politecnico di Milano, shown on this web page.

In addition to what is specified by the procedures, anyone who detects an alarm or emergency situation must immediately report it to the Safety Manager of AIRLab: prof. Andrea Bonarini, tel. (02 2399) 3525.

Any alarm situation must be immediately reported to all the other occupants of the AIRLab. In an emergency, shout to make sure everyone is aware of the danger. Rescue any injured persons but do not carry out operations that you are not sure of (for example, never move people who have suffered physical trauma, as it can cause them serious injuries).

Useful telephone numbers in case of emergency:

| | |
|---|---|
| **Politecnico di Milano, EMERGENZE** .................................. | **(02 2399) 9399** |
| Politecnico di Milano, central concierge Leonardo Campus.. | (02 2399) **2006** |
| Politecnico di Milano, call center 24h/24h ............................. | (02 2399) **9300** |
| Medical assistance (ambulance) ........................................... | **112** o **118** |
| Other types of emergency .................................................... | **112** |

ATTENTION: numbers outside the Politecnico di Milano phone network can only be called by phones capable of calling outside the internal network (for instance, mobile phones).