The following Cobot Safety Flyers summarise key aspects of cobots and a safe cobot workplace. While these aspects are addressed in detail in the other guideline parts, these flyers provide a quick and easily accessible overview of what to keep in mind. The flyers can be printed and shared separately as well as used as posters or part of workplace-specific induction and training materials to ensure staff is aware of cobot safety.

We also provide two example templates of how the topic of cobot safety could be embedded into existing work health and safety procedures and measures of your workplace and organisation.

The intent of this document is that each page represents a flyer that explains a specific key aspect around cobot safety. Each page is designed to be printed and/or shared independently or in combination with the other pages, i.e. flyers.
Human-cobot interaction

Collaborative robots (cobots) are robots that safely interact with humans. They work hand-in-hand with human workers on tasks and do not require physical fencing. Human-cobot interaction requires additional safety features that minimise risk and harms and can make programming more intuitive.

Human-cobot interactions can be generalised into four modes: collaboration, cooperation, coexistence, and cell (or non-interactive mode). Each of these modes have unique benefits and safety requirements that need to be addressed.

<table>
<thead>
<tr>
<th>Interaction mode</th>
<th>Collaboration</th>
<th>Cooperation</th>
<th>Coexistence</th>
<th>Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illustration</td>
<td>Human and cobot work together on task simultaneously</td>
<td>Human and cobot work together on task sequentially (step-by-step)</td>
<td>Human and cobot work together on task sequentially (step-by-step)</td>
<td>Human and cobot work together on task sequentially (step-by-step)</td>
</tr>
<tr>
<td>Workspace</td>
<td>Shared working space</td>
<td>Shared working space</td>
<td>Separated working space</td>
<td>Separated working space</td>
</tr>
<tr>
<td>Physical contact</td>
<td>Desired</td>
<td>Possible, not necessary</td>
<td>Possible, but should not occur</td>
<td>Hazardous</td>
</tr>
<tr>
<td>Minimum Safety Requirements</td>
<td>Speed and separation monitoring, power and force limiting, hand-guided control</td>
<td>Speed and separation monitoring and power and force limiting</td>
<td>Safety-rated monitored stops</td>
<td>Physical fencing</td>
</tr>
</tbody>
</table>

Factors that impact on safe human-cobot interaction

Purchasing a cobot does not mean that the machine is safe to use for every tool, task application, and/or workplace. Even if you have specifically purchased a machine that is marketed as a cobot, the way that you intend to use the machine can make it unsafe for humans to interact with the machine.

There are 8 key factors that can make it unsafe for a cobot to operate in an interactive mode:

1. Task Application
   Does the task create its own risks, e.g. welding?

2. Workpiece
   Is the workpiece dangerous, e.g. chemicals or nuclear materials?

3. End Effector and Tools
   Is the end-effector dangerous, e.g. drills, lasers?

4. Movement Path
   Does the path in which the cobot, end effector, and workpiece move create risks to people working in the same workspace as the machine?

5. Operating Speed and Payload
   Is the handled payload heavy or fast enough to hurt someone in the case of a collision?

6. Workspace
   Does the workspace setup cause a risk, e.g. frequently crossing paths of cobot and operator?

7. Operator’s Level of Expertise and Skills
   Does everyone know how to safely operate a cobot?

8. Integrator’s Level of Expertise and Skills
   Does everyone know how to safely install a cobot?

For more information, please see Factors that impact safe human-cobot interaction


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According to ISO/TS 15066:2016 Clause 5.5, a cobot or cobot system needs to fulfil at least one of the following modes of collaborative operation to be considered safe.

**Level 1 - Safety-rated monitored stop**

A cobot recognises when humans are in its direct proximity and stops all movements to avoid hazardous collisions.

**Level 2 - Hand guiding**

The cobot can be hand guided by a user to perform specific tasks or to be programmed. This cobot recognises the user input and stops automatically when the user lets it go.

**Level 3 - Speed and separation monitoring**

The cobot workplace has defined areas. For example, if a user is in the green area, the cobot can run full speed. However, if it is in the yellow area, speed should be reduced, and in the red area, speed might be further reduced or specific movements be blocked.

**Level 4 - Power and force limiting**

Through limiting the power and force of a cobot, injuries can be reduced in the case of a collision. This can also include flexible instead of stiff joints, e.g. by integrating springs.

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Typically, cobots have built-in safety features that make it easier for you to set up safe human-cobot interactive tasks. These safety features can help to avoid injuries, damage to equipment, and make it easier to program the cobot. These safety features can include speed/force/power controls, hand-guided operation, and soft edges.

Purchasing a robot that is marketed as a cobot does not automatically guarantee it is safe to use with humans.

Most cobots (especially arm-based cobots) are sold as **incomplete systems**. As incomplete systems, the machine is unable to complete its intended task. When purchasing an incomplete system, cobot manufacturers can guarantee the safety of certain components, typically the; cobot arm, control & programming interface, and computer. This can vary depending on the manufacturer and the model.

To complete a **cobot system**, you will need to install and configure additional components such as **end effectors**, task-specific tools, and additional safety peripherals and sensors.

End effectors are the ‘hand’ or ‘wrist’ of the cobot. Common end effectors include grippers, assembly tools, and sensors. A dangerous end effector tool like a drill, sharp blade, or laser can jeopardise safety features of the cobot or make it unsafe for human-cobot interaction.

Your cobot system will sit within a larger **cobot workplace**. A cobot workplace considers whether the cobot has been safely;

- Installed into the physical workplace
- Assigned an appropriate task for human-cobot interaction
- Integrated into other work processes

If a cobot itself lacks specific safety features, it is possible to install them into the cobot system or workplace to ensure work health and safety.

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**Human-cobot harms are not only limited to physical harms.**

Worker health and safety should always have the highest priority when it comes to human-cobot collaboration and should always be protected. Harms and hazards related to the work with cobots can be classified into three main categories: physical, psychological and ethical harms.

- **Physical harms** are mainly represented by collision events involving a human and can occur due to a variety of reasons leading to unexpected behaviours of the cobot.

- **Psychological harms** focus on all aspects related to the psychological safety of an operator as an individual.

- **Ethical harms** address staff as a whole, including anything that has potential to reduce psychological, societal and environmental wellbeing.

Below are the most common risks and harms identified in the human-cobot-collaboration:

<table>
<thead>
<tr>
<th>Category</th>
<th>Hazard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL</td>
<td>Hazardous collisions</td>
<td>Non-functional or unwanted contacts between human and cobot system.</td>
</tr>
<tr>
<td></td>
<td>Loss of movement control</td>
<td>The loss of movement control of a cobot system potentially causes physical harm to humans.</td>
</tr>
<tr>
<td></td>
<td>Pinch points</td>
<td>During task operation humans and/or materials and objects may be caught between moving and/or stationary parts of a cobot.</td>
</tr>
<tr>
<td></td>
<td>Debris</td>
<td>The debris generated by some collaborative tasks may harm humans.</td>
</tr>
<tr>
<td></td>
<td>Cybersecurity</td>
<td>Cyber-attacks or local hacking may cause robots to move unpredictably and harm the operator.</td>
</tr>
<tr>
<td></td>
<td>Lack of focus</td>
<td>A lack of concentration and focus may lead to not fulfilling tasks as intended, causing mishandling of the cobot.</td>
</tr>
<tr>
<td>PSYCHOLOGICAL</td>
<td>Mental strain</td>
<td>The cobot system may cause stress and could negatively affect the psychological state and mental strain.</td>
</tr>
<tr>
<td></td>
<td>Complicated interaction mechanisms</td>
<td>Complicated information exchange between operator and cobot system can cause stress and insecurities.</td>
</tr>
<tr>
<td></td>
<td>Lack of trust</td>
<td>A lack of trust from the operator towards the cobot hinders safety and the development of a sense of comfort.</td>
</tr>
<tr>
<td>ETHICAL</td>
<td>Social environment</td>
<td>The work with cobot systems can negatively affect or reduce the social environment.</td>
</tr>
<tr>
<td></td>
<td>Social impact</td>
<td>Introducing cobot systems may change the role of some operators and induce a fear of job loss.</td>
</tr>
<tr>
<td></td>
<td>Social acceptance</td>
<td>Predisposition for cobot systems influence the level of acceptance within the human work force.</td>
</tr>
<tr>
<td></td>
<td>Data collection</td>
<td>The cobot system could monitor individual performance and be able to collect, use, distribute or sell user data without user consent.</td>
</tr>
</tbody>
</table>

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The characteristics of collaborative robots bring together a unique combination of social and technical dimensions, calling for safety measures that go beyond mitigating physical risks. Existing safety measures can be categorised into cobot-specific, working system, and enterprise and context.

Below are the most common measures summarised that improve the operator’s safety when working with a cobot in a collaborative workplace:

<table>
<thead>
<tr>
<th>Safety measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cobot-specific</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cobot type</strong></td>
<td>Lightweight cobots with inherent active/passive safety mechanisms often represent a safer option than covert industrial robots for collaborative tasks.</td>
</tr>
<tr>
<td><strong>Cobot appearance</strong></td>
<td>Heavy, stiff, and rigid cobots can cause distress and discomfort to the humans that operate in their vicinity.</td>
</tr>
<tr>
<td><strong>Fail-safe system structure</strong></td>
<td>Integrating general non-safety devices into collaborative systems may cause unwanted behaviours and loss of movement control.</td>
</tr>
<tr>
<td><strong>Tool/design operation</strong></td>
<td>How tools are selected and integrated into the cobot can impact operators’ physical safety and psychological state.</td>
</tr>
<tr>
<td><strong>Collision avoidance</strong></td>
<td>Monitoring the working area through software and sensors allows for avoiding and preventing collisions.</td>
</tr>
<tr>
<td><strong>Collision detection and mitigation</strong></td>
<td>When collisions occur, they can be detected and mitigated through appropriate software and sensors.</td>
</tr>
<tr>
<td><strong>Situational awareness</strong></td>
<td>Easily interpretable feedback from the cobot reduces both physical and psychological risks.</td>
</tr>
<tr>
<td><strong>Intuitive cobot programming</strong></td>
<td>Intuitive programming allows operators to communicate commands more easily, reducing both physical and psychological risks.</td>
</tr>
<tr>
<td><strong>Work cell design</strong></td>
<td>Designing a cobot work cell to work harmoniously with the application, existing workspace, operators, and other staff.</td>
</tr>
<tr>
<td><strong>Human-friendly work distribution</strong></td>
<td>Distributing tasks adequately reduces the risk of physical stress and musculoskeletal injuries.</td>
</tr>
<tr>
<td><strong>Human-friendly workplace arrangement</strong></td>
<td>Arranging the workspace to allow enough distance/space between humans and cobots can reduce the risk of collisions and distress.</td>
</tr>
<tr>
<td><strong>Risk assessments</strong></td>
<td>Systematic evaluation process that considers potential risks and harms that may occur when working with cobots.</td>
</tr>
<tr>
<td><strong>Simulation</strong></td>
<td>Use of simulation programming to virtually visualise and assess the intended programmed operation for risks and other potential issues.</td>
</tr>
<tr>
<td><strong>Physical testing</strong></td>
<td>Multi-step process of assessing various components of a cobot to ensure safe operation.</td>
</tr>
<tr>
<td><strong>Training to build knowledge and skills</strong></td>
<td>Ensuring that cobot user groups and other stakeholders possess the appropriate competencies, skills, and knowledge to ensure safe operation.</td>
</tr>
<tr>
<td><strong>Training to improve acceptance</strong></td>
<td>Introducing predictability and familiarity to mitigate physical, psychological, and ethical risks.</td>
</tr>
<tr>
<td><strong>Assistive technology for training</strong></td>
<td>Using virtual or augmented reality to prepare and train the operator before they come into contact with cobots.</td>
</tr>
<tr>
<td><strong>Supporting worker agency</strong></td>
<td>Consulting and co-designing cobot solutions with operators and collaboration between operators and management teams.</td>
</tr>
</tbody>
</table>
The following principles provide general guidance on how to ensure safe and healthy cobot workplaces across its entire life-cycle.

<table>
<thead>
<tr>
<th>Design principle</th>
<th>Description</th>
</tr>
</thead>
</table>
| **UNDERSTAND COBOT & SAFETY FEATURES**    | - Understand what your cobot can and cannot do in terms of tasks, behaviour, and safety features.  
- Understand how your cobot system ensures safety and how activities might impact safety features.  
- Ensure everyone in your workplace has the same understanding.                                                                                                                                                                                                                                                                                                                                                                    |
| **MAINTAIN A HUMAN FOCUS**                | - Consider different cobot experience levels of operators and ‘temporary workplace visitors’.  
- Involve your staff in the cobot workplace design to maximise their benefits and provide upskilling and social contacts.  
- Be realistic about the workforce implications of introducing cobots.                                                                                                                                                                                                                                                                                                           |
| **ALIGN COBOT, TOOL, WORKSPACE, AND WORKFLOW** | - Build an understanding that the cobot is only one part of a socio-technical cobot system.  
- Treat cobot, end effector tools, workplace, and workflow processes as interconnected systems, which must be aligned to ensure safety (“cobot readiness” of all parts).                                                                                                                                                                                                                                      |
| **ENSURE SECURITY AND PROTECTION**        | - Prevent and identify disallowed tempering with cobot hardware and software.  
- Look out for potential issues and consequences of tampering with the cobot, human, end effector tools, workplace, and workflow processes.  
- Ensure that the cobot does not cause any harm if the hardware or software fails.                                                                                                                                                                                                                                                                                        |
| **SUPPORT EASE OF USE**                   | - Ensure that the cobot and its safety features are user-friendly, and support, rather than impede, the user’s work.  
- Ensure that both the positive and negative impacts of engaging with the cobot are considered.                                                                                                                                                                                                                                                                                                         |
Template: Daily Safety Checklist

Only operate when all questions are answered with “Yes”. If you answer a question with “No”, fix the specific issue before you operate the cobot.

<table>
<thead>
<tr>
<th>Safety requirements</th>
<th>Daily check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do only authorised and trained personnel have access to the cobot workplace?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Is the tool at the end of the cobot arm securely attached?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Do the cobot, cobot system and cobot workplace look as originally designed?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Is the cobot working as intended and expected?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Do you feel comfortable working next to the cobot?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Have all cables been managed?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Is the cobot undamaged?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Is there enough space for the cobot arm to move freely?</td>
<td>☐ Yes</td>
</tr>
<tr>
<td>Is the workspace free from clutter?</td>
<td>☐ Yes</td>
</tr>
</tbody>
</table>

This flyer serves as a template to create a daily safety checklist for your own workplace. For this purpose, cobot, cobot system, and cobot workplace should be marked in a representative photo. In addition, safety requirements should be listed, which result from the assessment of the workplace by means of the safety checklist.

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This flyer serves as a template to create a descriptive hazard overview of one's own workplace. For this purpose, all hazards identified in the cobot risk assessment which are not eliminated are visualised using a representative photo of the workplace. This flyer is then provided to all operators, and visibly placed at every entrance to the workplace and within sight of the operator.

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**Hazardous Chemicals**
- Follow safety measures

**Non-sensitive Gripper**
- Do not put your finger or any other body part into the gripper

**Physical collision**
- Move mindfully close to mobile platform

**Unpredictable behaviour**
- Do not alter cobot control

**Physical collision**
- Be aware of cobot motion

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