
# Safety and Mobile Manipulation
## *Experiences from the VALERI project*

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# Safety and Mobile Manipulation
## *Experiences from the VALERI Project*

1. The VALERI project
2. Applying safety standards to VALERI
   - Application specification
   - Intended Use
   - Hazard Identification
   - Novel VALERI safety technologies
   - Verification of power and force limits
3. Outlook/discussion

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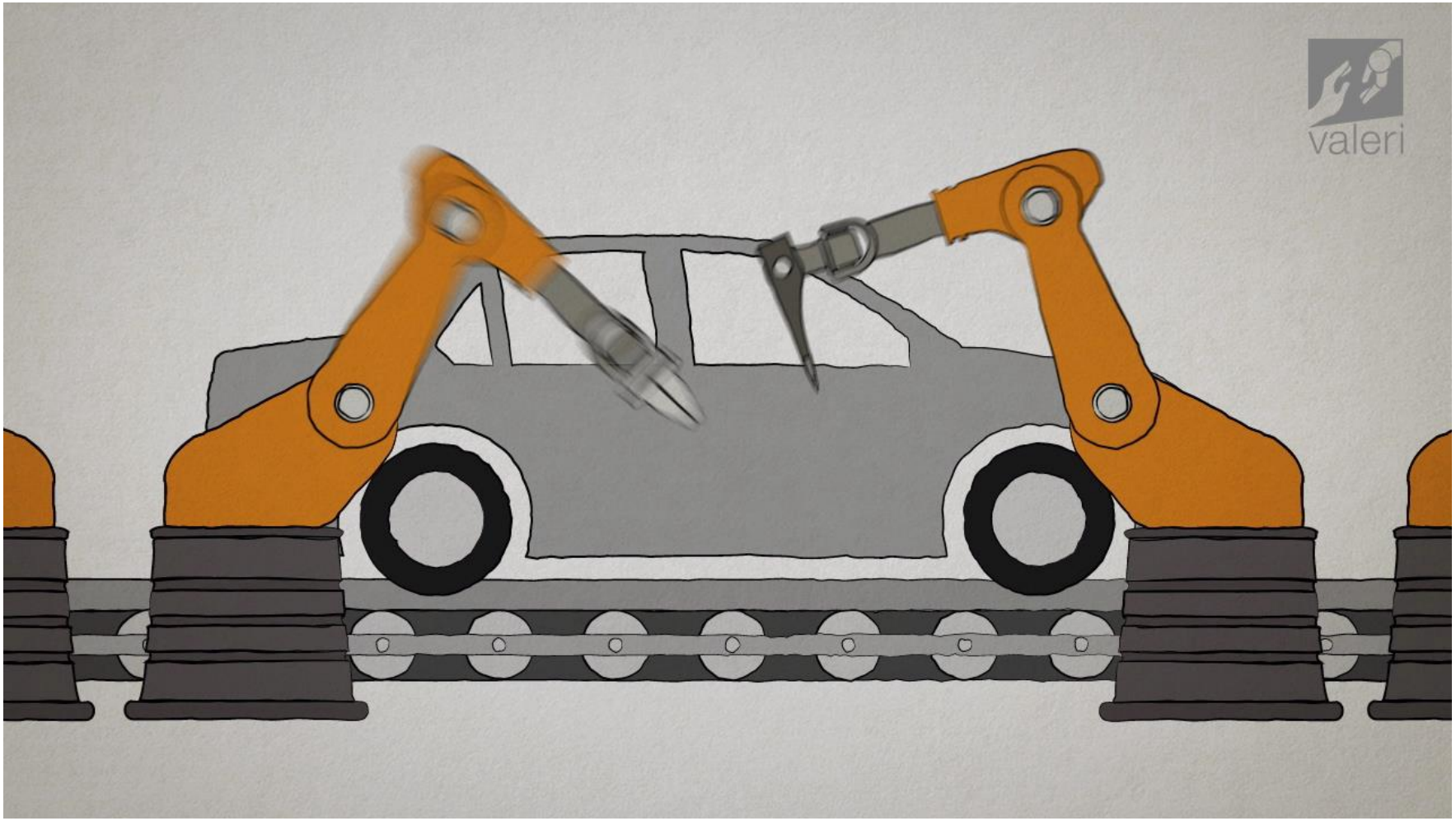
# The VALERI Project



# The VALERI Project

*Assisting human workers with a mobile manipulator in aerospace production tasks*

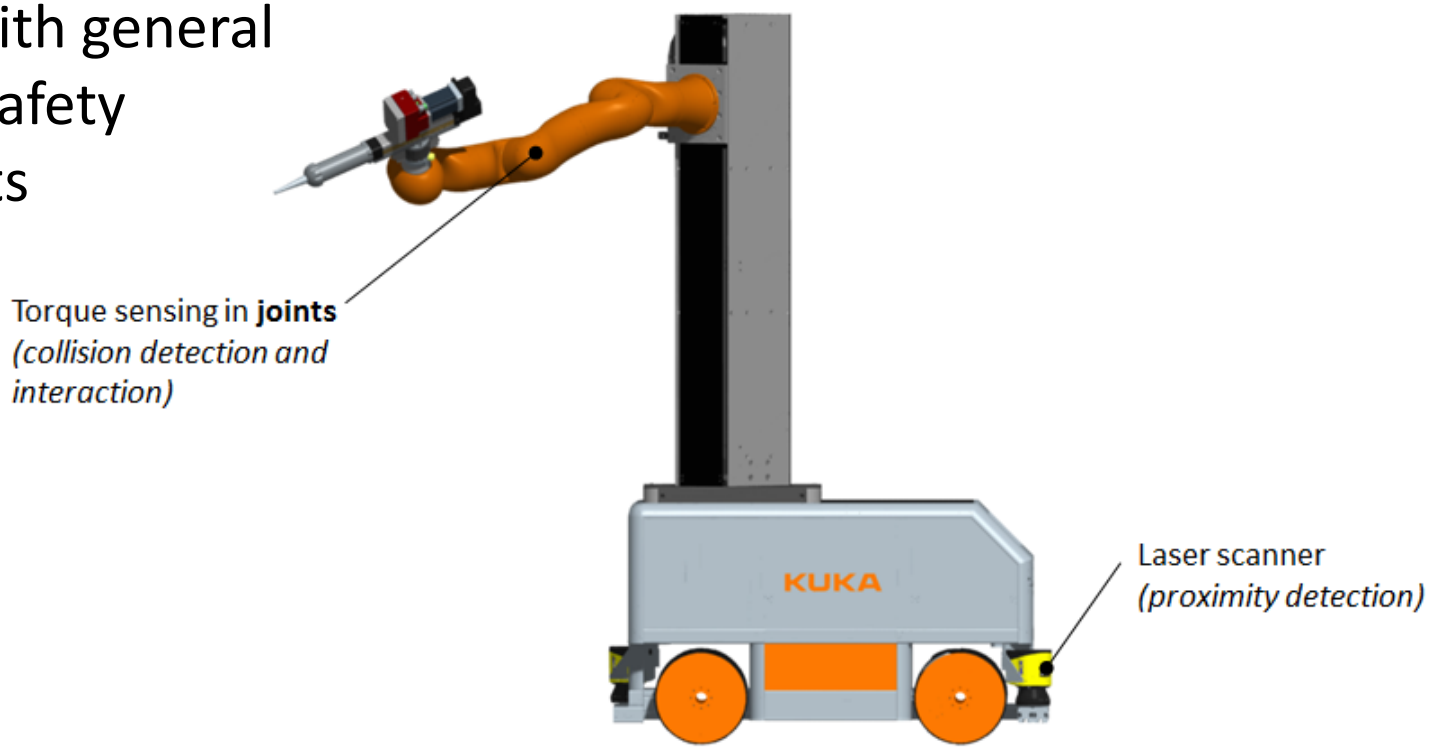

Sealant Application


Inspection

# Applying safety standards to VALERI

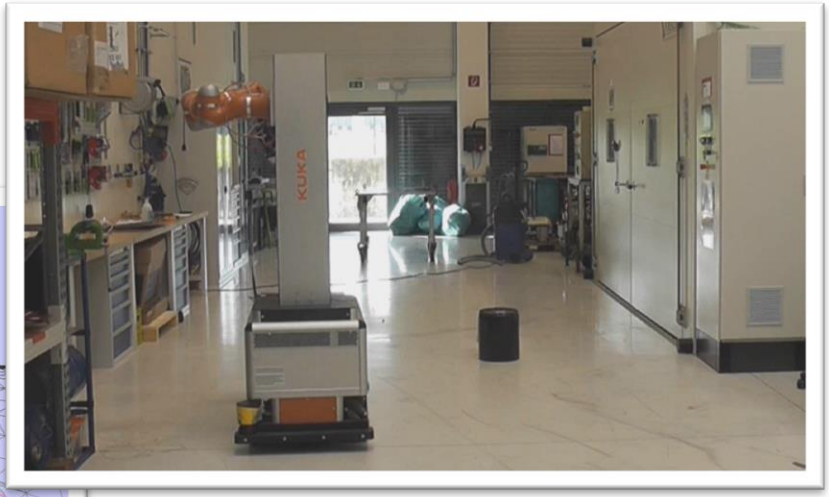
## Robotic hardware

Initial configuration compliant with general health and safety requirements

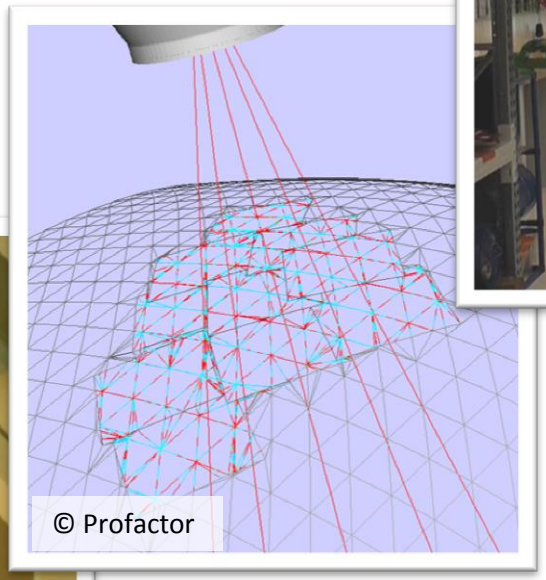


# Applying safety standards to VALERI

## Define the application

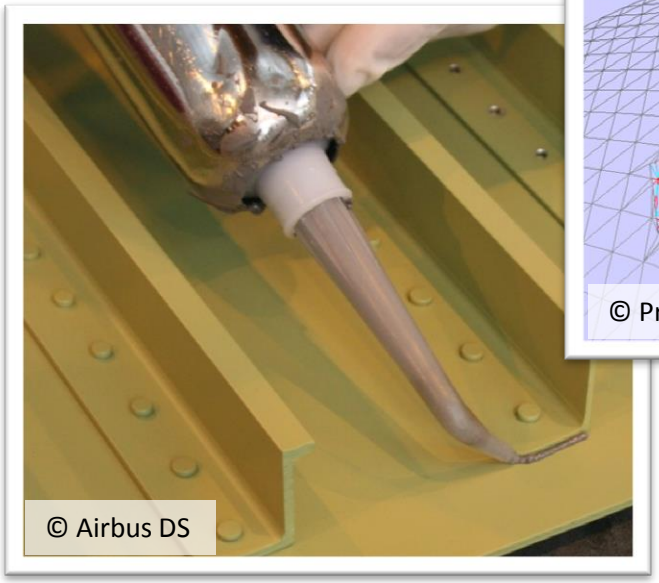



Autonomous navigation



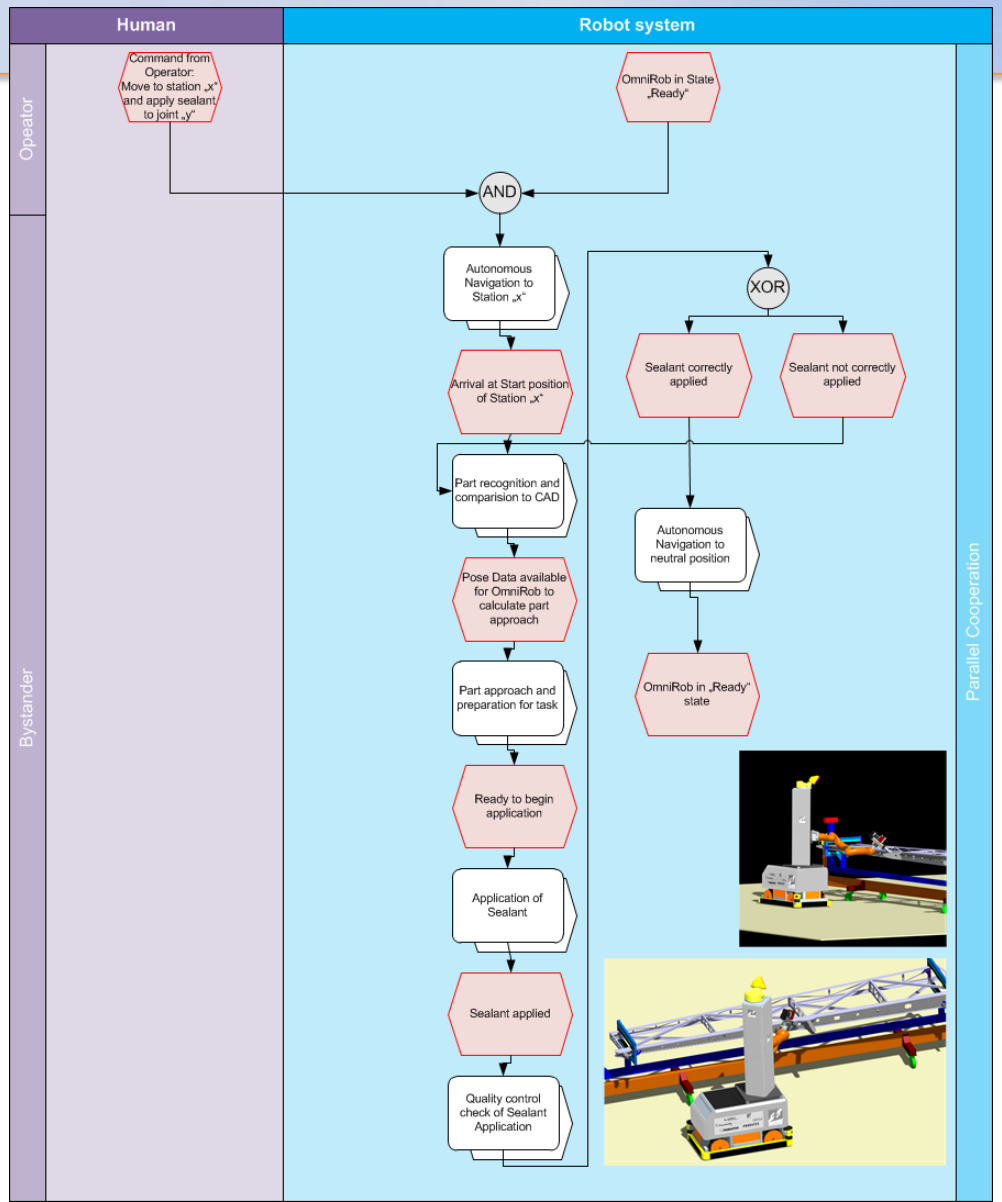

Inspection

Sealant Application



# Applying safety standards to VALERI

Event-driven process chains model the process



# Applying safety standards to VALERI

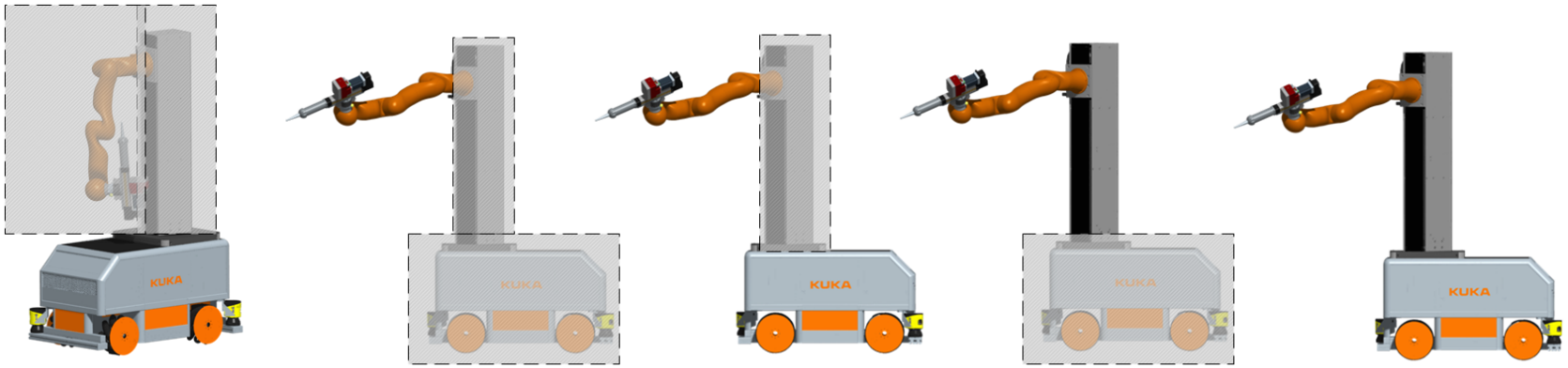
## Define the role of operator and the intended use

| Life Cycle/Task | Intended use |
|---|---|
| Commissioning | Haptic feedback for task definition, creating a map and platform navigation via game pad, testing |
| Maintenance | During maintenance the operator can test all robot functions (see Commissioning). |
| Task definition | In this operational phase, a user has the opportunity to teach-in a new station via haptic feedback. In this case, the user will use the haptic interfaces of the tactile skin and the force feedback in the manipulator to guide the system. Physical contact with the robot is necessary. |
| Job submission | During this phase, there is no intended physical contact with the robot. Commands are input via the GUI on a computer or a touch panel |
| Autonomous platform movement | No intended contact with the robot. The platform operates completely autonomous. |
| Sealant application | No intended physical contact with the robot. The platform and manipulator operate completely autonomous. Operator has opportunity to pause/interrupt robot operation, if necessary. |
| Inspection | No intended physical contact with the robot. The platform and manipulator operate completely autonomous. Operator has opportunity to pause/interrupt robot operation, if necessary. |

# Applying safety standards to VALERI

## Identify hazard sources for each task

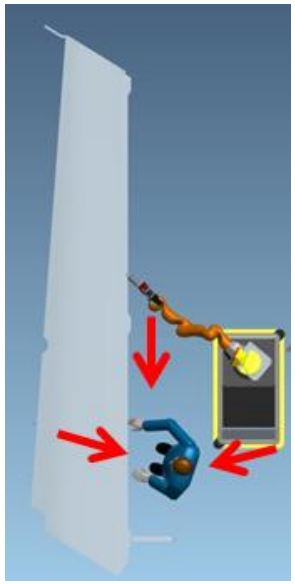
*A gray box covering a component denotes that the component is inactive and not in motion during that particular case.

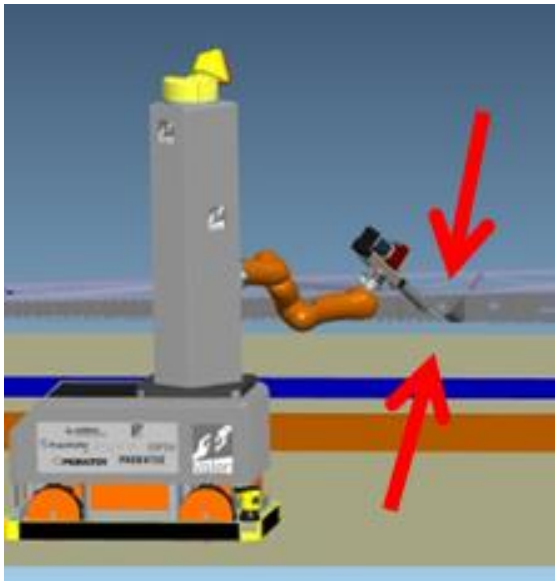


# Novel safety technologies in VALERI

## Two special cases considered in VALERI

1. Platform motion during process (sealant, inspection)
2. Tool safeguarding during process (sealant, inspection)





# Novel safety technologies in VALERI

**Sealant Inspection Camera** (*not pictured*)

**Localization Camera** (*not pictured*)

**Tactile sensors** on LWR base *(contact detection)*

2 ½D **workspace monitoring** system on pan-tilt unit *(Tool Safeguarding)*

**Column** with 2 DOF (*workspace extension*l)

**Sealant tool**

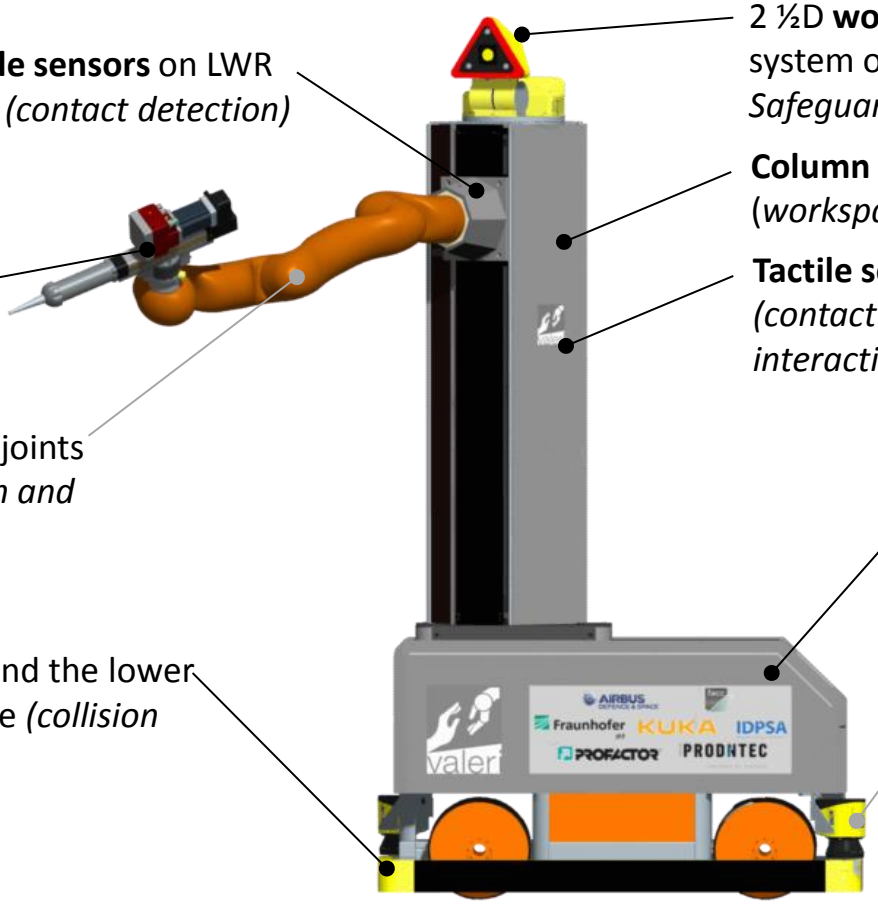
**Tactile sensors** on column *(contact detection and interaction)*

**Torque sensing** in joints *(collision detection and interaction)*

**Tactile sensor** on OmniRob base *(contact detection and interaction)*

Tactile **bumper ring** around the lower part of the OmniRob base *(collision detection)*

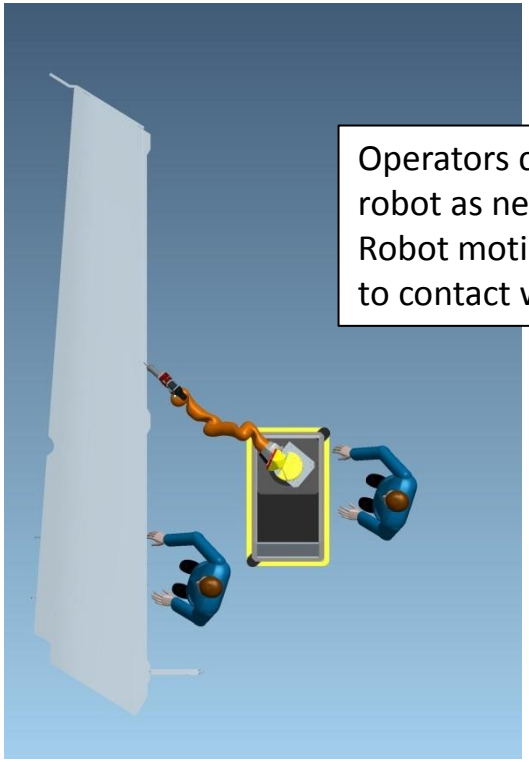
**Laser scanner** *(proximity detection)*



# Novel safety technologies in VALERI

**Safeguarding method:**
**Speed and separation monitoring**
**(Laser scanners)**

**Safeguarding method:**
**Power and force limiting**
**(Tactile sensors)**

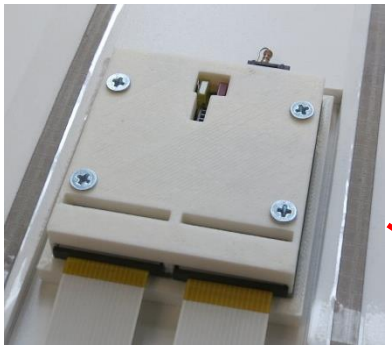


Operators can get as close to robot as necessary.
Robot motion will only stop due to contact with human.

# Novel safety technologies in VALERI


4 tactile transducers, geometrically adapted to the robot‘s geometry

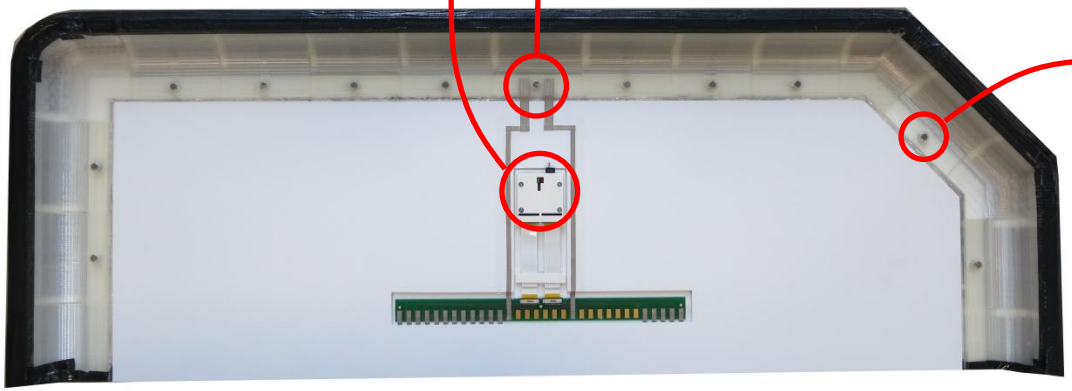
# Novel safety technologies in VALERI



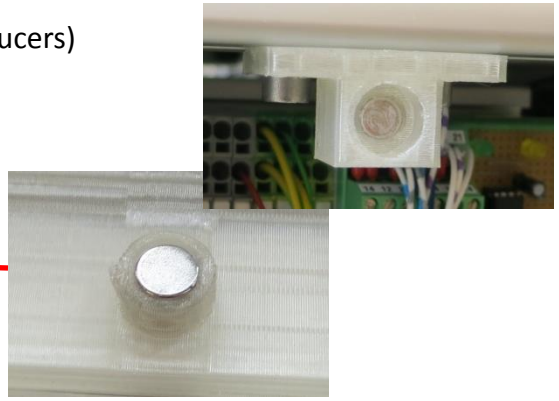
Integrated sensor electronics

Integrated safety contacts

(monitor proper mounting of tactile transducers)



back side of a tactile transducer

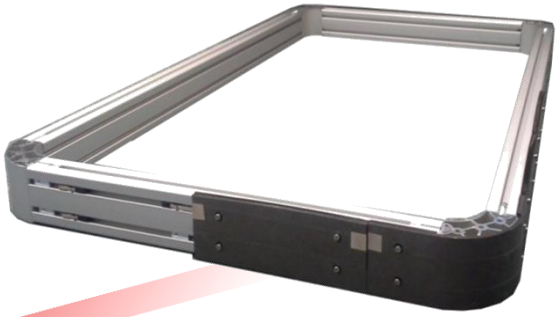


Magnetic Fastening Systems

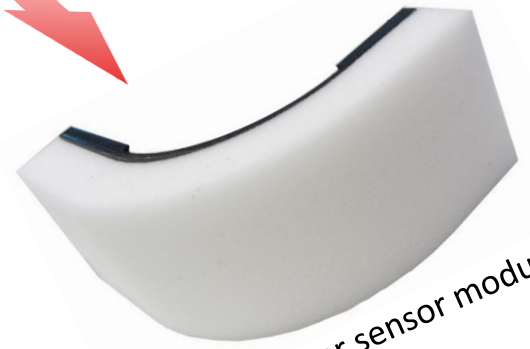
(allows quick and easy removal of tactile transducers for maintainance or exchange)

# Novel safety technologies in VALERI

- Modular bumper solution
- Compatible with the ITEM Profile 8 series
- Quick and easy replacement of damaged sensor elements

flat sensor module

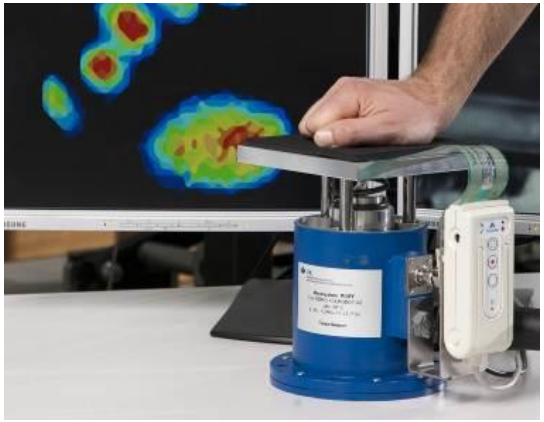


corner sensor module

# Novel safety technologies in VALERI

Max allowable forces

- 400 N clamping force (DIN 1525 )
- 125 N clamping force, 250 N dynamic collision force (upcoming ISO TS 15066)



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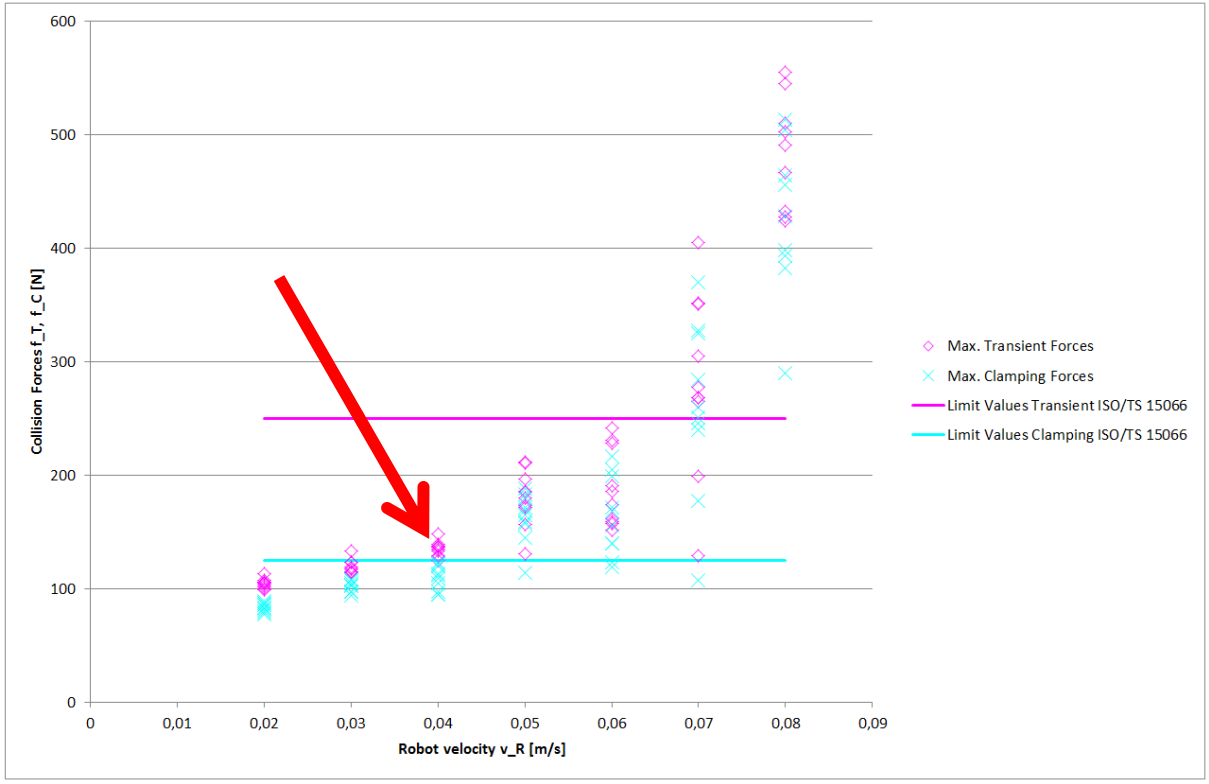


# Novel safety technologies in VALERI

Optical workspace monitoring system for tool safeguarding

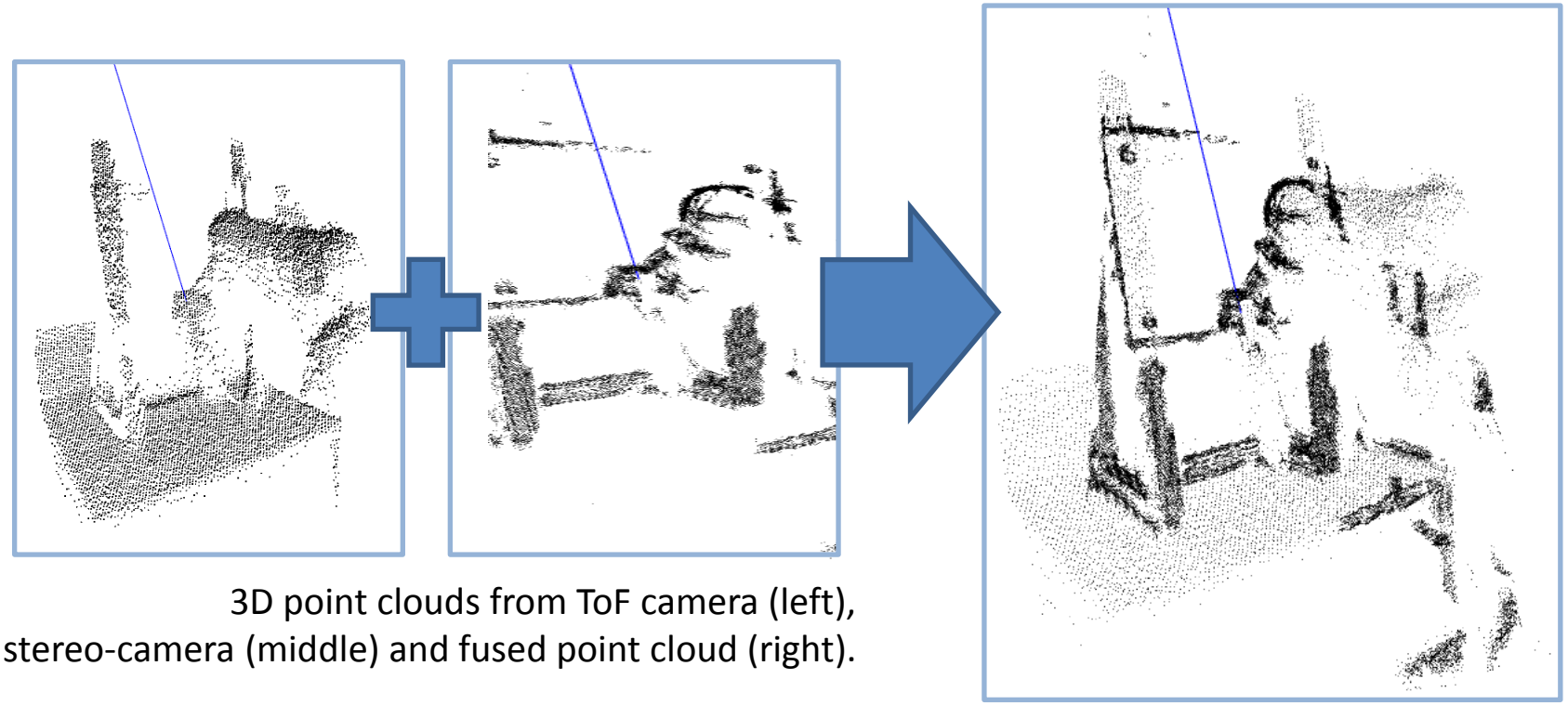
**→Speed and separation monitoring**

**Set-up**

- 3 grayscale (NIR/VIS) cameras for redundant stereo
- 1 Time-of-Flight camera with NIR illumination in the center

# Novel safety technologies in VALERI

- Combining 3D point clouds from stereo-camera and ToF-camera using extrinsic parameters and distance calibration



3D point clouds from ToF camera (left), stereo-camera (middle) and fused point cloud (right).

# Novel safety technologies in VALERI

# Conclusion

**Systematic approach to safety**

- Define the application
- Define user roles and intended use
- Identify hazards
- Mitigate hazards
- Verify (when using power and force limiting)

# Validation of Advanced, Collaborative Robotics for Industrial Applications

- Research and Development Partners
  - Fraunhofer IFF, Germany *(Coordinator)*
  - Profactor GmbH, Austria
  - PRODINTEC, Spain

- Industrial Partners
  - KUKA, Germany
  - Airbus DS, Spain
  - IDPSA, Spain
  - FACC, Austria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# Thanks for your attention

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