Open Source 西门子

Oct. 29
Industrial Open Source

Oct. 30
Open Source Robotics

Agenda

Beijing · 2026

面向远程操作与态势感知的开源生态系统
Open Source Ecosystem for Remote Operation and Situational Awareness

Mattias LAMPE, Siemens Ltd., China

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Outline

1. Motivation
2. Remote Operation
3. Situational Awareness
4. Conclusions

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1. Motivation

Robotics seems to create synergies between consumer, industry and military applications

	Consumer / IT	Industrial	Military
Cost	Low	Medium	Very high
Product Lifecycle	Short (<10 years)	Medium (10-30 years)	Long (>30 years through upgrades)
Innovation Speed	Fast	Slow to medium	Mixed: Fast adoption of new technology, long retention of legacy tech
Ruggedness	Low	High	Very high
Design	Appealing	Practical	Stealthy

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1. Motivation

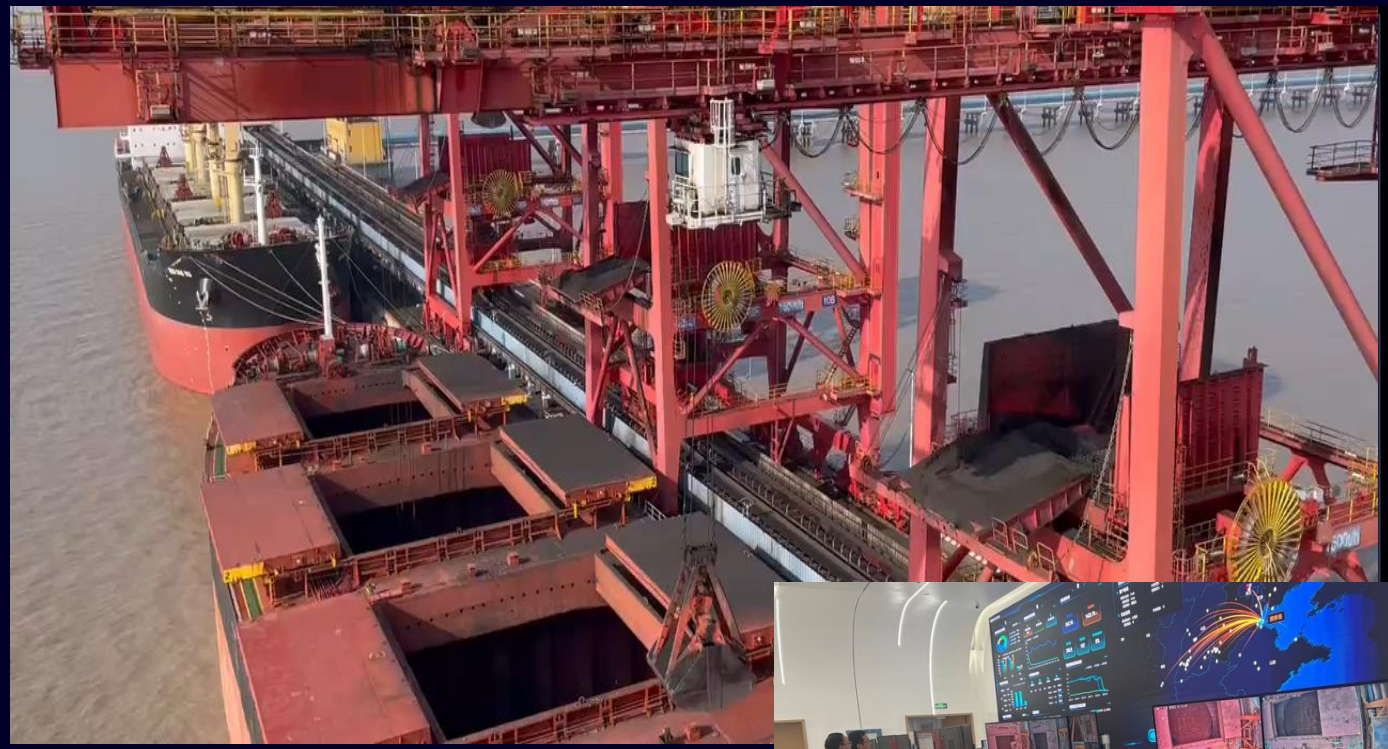
Robotics nowadays puts strong focus on autonomous systems

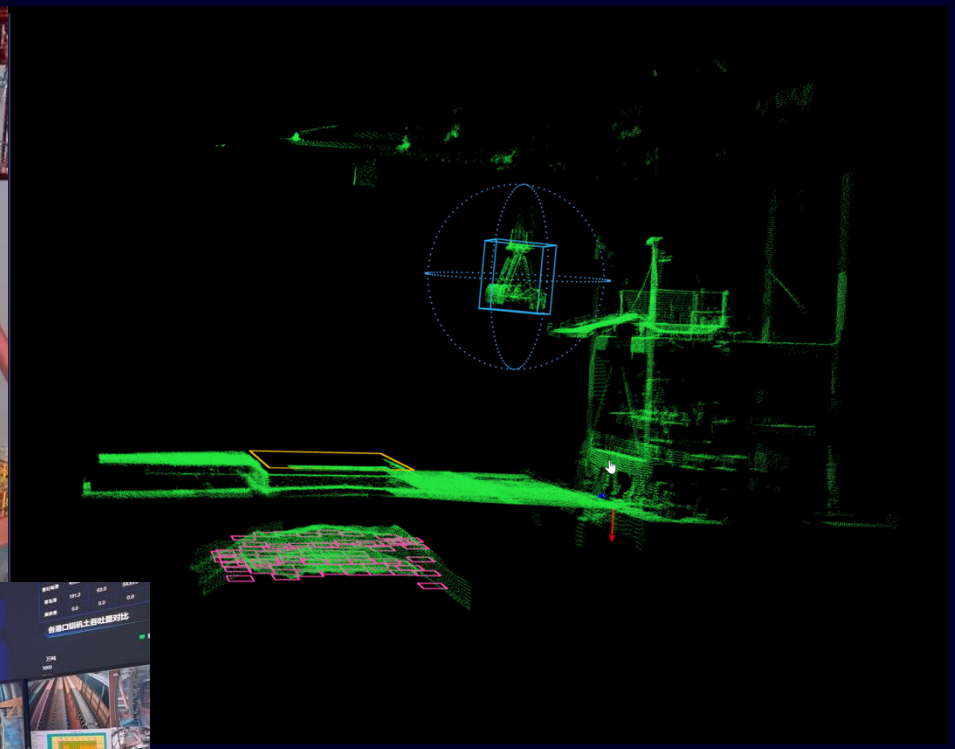


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2. Remote Operation
as a transition step towards full autonomy

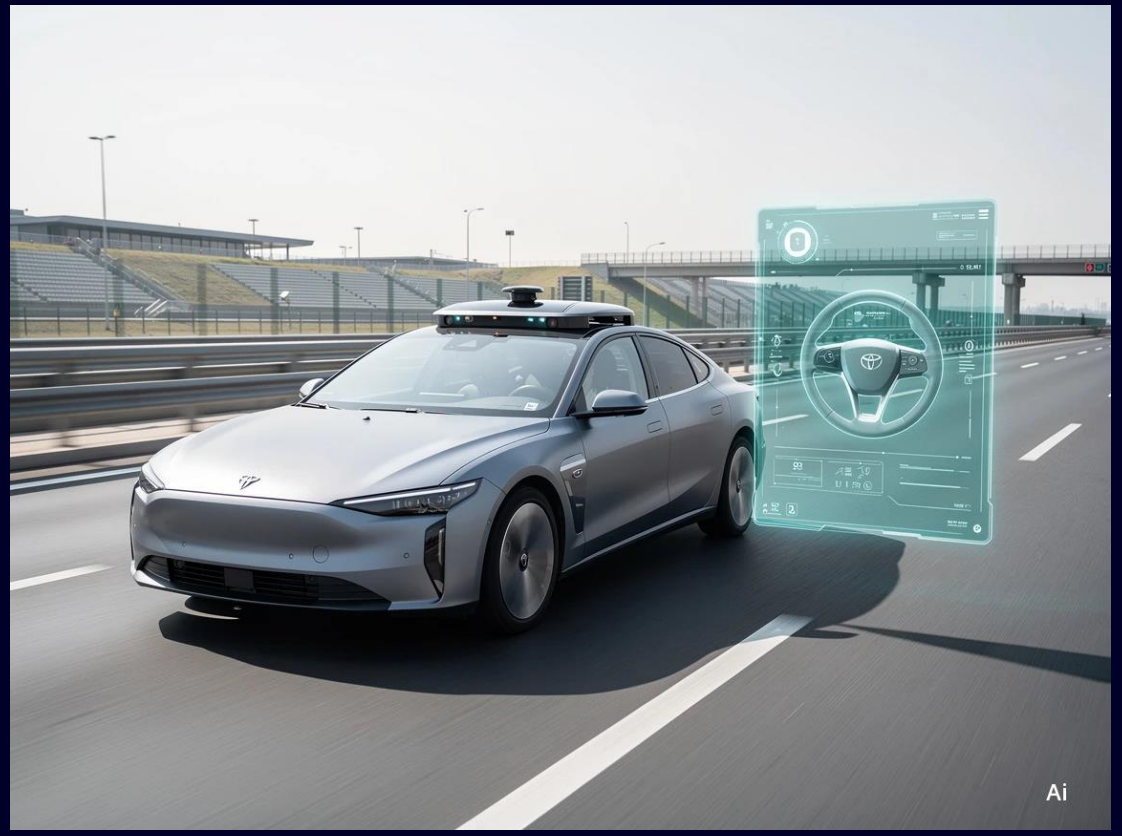






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2. Remote Operation
as a fallback/recovery mode for fully autonomous systems





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2. Remote Operation
Key system components

- **Perception**
  - cameras
  - sensors
- **Data Link**
  - high throughput digital video
  - time & safety critical control commands
  - high availability
  - wired vs. wireless
- **Visualization**
  - augmentation of camera image
  - Preprocessing/fusion of sensor data
- **Operation Input**
  - mechanical elements
  - user interface
  - configuration tools

For UAVs (“drones”), there is a comprehensive OSS ecosystem covering all these aspects (and many more)

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2. Remote Operation
Getting inspiration from the Open Source drones ecosystem

Useful resources:

- www.dronecode.org
  Collaborative project under the Linux Foundation, hosting several major Open Source software and hardware projects (px4, Pixhawk, MAVLINK, MAVSDK, QGroundControl)
- https://github.com/brandonhimpfen/awesome-open-source-drone-firmware
  “A curated list of open source drone firmware, flight controllers, tools, and related resources for UAV (Unmanned Aerial Vehicle) development and research.”
- https://github.com/twomile/open-drone-resources
  “list of Free Software and Open Hardware dedicated for multicopters as well as airplanes or flying wings.”
- (not strictly limited to Open Source)

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2. Remote Operation
Operation Input and Control Data Link for UAVs (“drones”)



Many commercial controllers (hand sets) today are based on EdgeTX, an “Operating System” primarily running on ARM Cortex-M hardware (STM32):

https://github.com/EdgeTX/edgetx
https://edgetx.org/

The actual radio link (often provided by an interchangeable hardware module) is often based on ExpressLRS:

https://www.expresslrs.org/

It supports 900MHz and/or 2.4GHz links, typically runs on Espressif SoCs (ESP8285, ESP32, …) in combination with Semtech radio chips (LoRa, FLRC[1], (G)MSK).
It provides the control and telemetry channel, but is NOT suitable for video.
Open Source hardware designs also exist.

1 Fast Long Range Communication, i.e. a proprietary radio protocol

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2. Remote Operation
Perception and video data link



FPV (First-Person View) operation requires low-latency high-resolution video transmission.

Analog video links via 5.8GHz radio are still common. Cutting-edge digital FPV systems often use proprietary technology, but Open Source solutions becon increasingly mature and popular.

Image acquisition, preprocessing, encoding and streaming can be handled with OpenIPC:

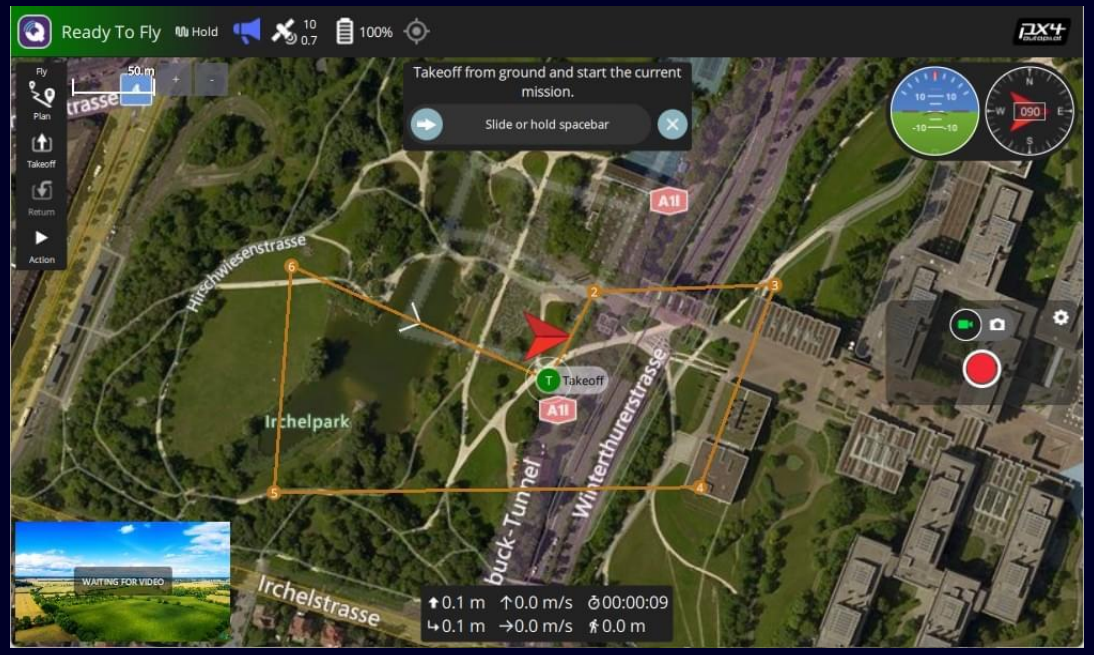
https://openipc.org/

Robust low-latency wireless transmission is typically based on a customized WiFi protocol:

https://github.com/svpcom/wfb-ng

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2. Remote Operation
Visualization



QGroundControl allows flight planning (for autonomous flights), system configurations, and visualization of flight telemetry and video

https://qgroundcontrol.com/

Image source: https://docs.qgroundcontrol.com/Stable_V4.3/en/qgc-user-guide/



RubyFPV is an end-to-end solution (providing also the wireless link) with low-latency video display and rendering of telemetry data into the video image (OSD, On-Screen Display):

https://rubyfpv.com/

Image source: https://rubyfpv.com/

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2. Remote Operation
Visualization



OpenHD has a similar feature set to RubyFPV RubyFPV, i.e. it includes the Wifi-based wireless link and offers video with OSD of telemetry data:

https://github.com/OpenHD/OpenHD

Image source: https://github.com/OpenHD/OpenHD

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2. Remote Operation
Links to the robotics ecosystem

Telemetry and high-level control data can be exchanged between the UAV and ROS via a MAVLINK-to-ROS bridge:

https://github.com/mavlink/mavros

Alternatively, the most popular flight controllers can interface to ROS 2 via MicroXRDC-DDS:

https://deepwiki.com/ArduPilot/ardupilot/6.4-ros2-and-dds-integration

https://docs.px4.io/main/en/middleware/uxrce_dds

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3. Situation(al) Awareness: Definition

*"Situation awareness is the **perception** of the elements in the environment within a volume of time and space, the **comprehension** of their meaning, and the **projection** of their status in the near future."*[1]

1 Endsley, Mica: "*Toward a Theory of Situation Awareness in Dynamic Systems",* Human Factors: The Journal of the Human Factors and Ergonomics Society, Vol. 37 (1995), pp 32-64

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3. Situational Awareness in Everyday Life

Example Scenario: Field Trip with a Kindergarten Group



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3. Situational Awareness in the Robotics Context

How do autonomous robots differ from kindergarten kids?



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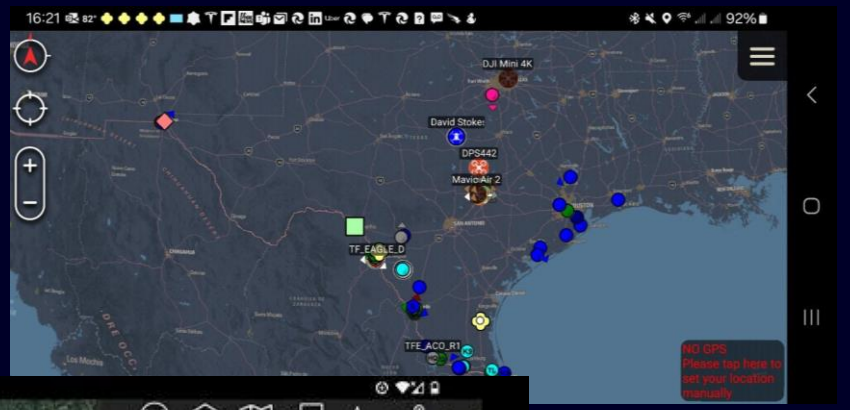
3. Situational Awareness
Beyond the UAV world: The TAK ecosystem

- ATAK (Android Tactical Assault Kit) was first created in 2010 by the US Air Force Research Laboratory (AFRL) for the US military
- An Open Source version (Android Team Awareness Kit) for civilian use was released to the public in 2020 (sometimes called CivTAK or ATAK-CIV)
- Original purpose: provide soldiers with a “God’s eye view” of the environment on the smartphone/tablet
- Main features/capabilities:
  - Sharing of location and mission-related geo-spatial information within a team
  - Visualization/mapping
  - Team communication via chat and voice (PTT)
  - Document sharing
  - Network agnostic (can work over Cellular, WiFi, Mesh, …)
  - Can work with or without a TAK server
  - Plugin architecture for functionality extension (e.g. UAS tool, PTT, wearables, …)

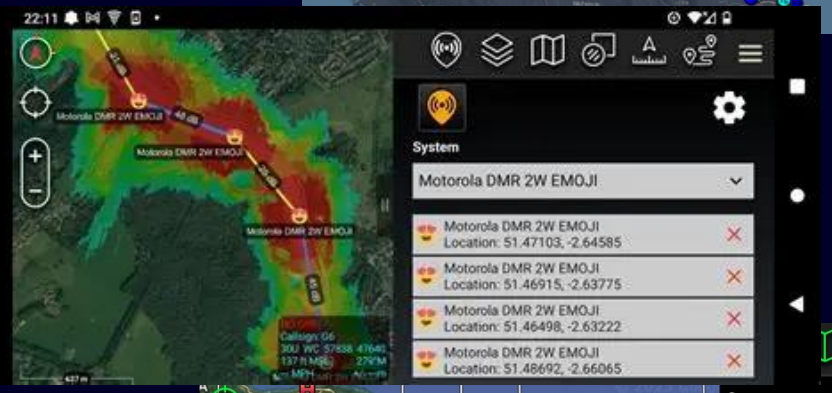
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3. Situational Awareness
Beyond the UAV world: The TAK ecosystem













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3. Situational Awareness
The TAK ecosystem: Noteworthy projects

- Official ATAK websites:
  https://tak.gov/
  https://www.civtak.org/
  https://github.com/deptofdefense/AndroidTacticalAssaultKit-CIV
- Other clients:
  - omni-TAK (TAK client/aggregator for Windows, MacOS, Linux):
    https://github.com/engindearing-projects/omni-TAK
  - CloudTAK (In-browser TAK Client & ETL integration of non-TAK data sources into a TAK Server)
    https://github.com/dfpc-coe/CloudTAK/
- TAK servers
  - FreeTAKServer:
    https://github.com/FreeTAKTeam/FreeTakServer
  - OpenTAKServer
    https://opentakserver.io/
- AryaOS (TAK-ready Linux distribution for Raspberry Pi):
  https://aryaos.org/
  https://github.com/snstac/aryaos

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3. Situational Awareness

The TAK ecosystem: CoT (Cursor-on-Target) protocol

"The sum of the wisdom of this horizontal integration[1] will result in a cursor over the target."[2]

1 Referring to horizontal integration of manned, unmanned, and space capabilities of the armed forces
2 Source: Gen. John P. Jumper, USAF Chief of Staff, Air Force Association National Symposium, Los Angeles, Nov. 16, 2001

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3. Situational Awareness
The TAK ecosystem: CoT protocol up-close

- Developed in 2002 by MITRE Corporation and the U.S. Air Force Research Laboratory (AFRL)
- Main objective: Share tactical “W3” data (What, Where, When) across different systems (drones, sensors, soldiers, …
- Based on a lightweight (and somewhat weird) XML schema
- Mapping to MIL-STD-2525; CoT itself is formalized under MIL-STD-6090
- Popular libraries:
  - Python: https://github.com/snstac/pytak
  - Typescript: https://github.com/dfpc-coe/node-CoT
- Integration with ROS via rostak: https://github.com/westpoint-robotics/rostak
- CoT Developer Guide: https://nps.edu/documents/104517539/109705106/COT+Developer+Guide.pdf

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3. Situational Awareness
The TAK ecosystem: CoT protocol up-close

Simple example: (basic position marker)

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<event version="2.0" uid="Biped_Walker_01" type="a-f-G-U-C" how="m-g“
        time="2026-10-27T08:00:00Z" start="2026-10-27T08:00:00Z" stale="2026-10-27T08:05:00Z">
        <point lat="48.1371" lon="11.5754" hae="519.0" ce="5.0" le="2.0" />
        <detail>
                <contact callsign="WALKER-01" />
        </detail>
</event>
```

Encoding of the “type” and “how” fields is designed to map to MIL-STD-2525 and defines the icon for visualization

“a-f-G-U-C” = Atom-Friendly-Ground-Unit-Combat

“m-g” = Machine Generated

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3. Situational Awareness
The TAK ecosystem: CoT protocol up-close

Extended example: (adding movement information)

```
<event version="2.0" uid="Biped_Walker_01" type="a-f-G-U-C" how="m-g"
        time="2026-10-27T08:01:00Z" start="2026-10-27T08:01:00Z" stale="2026-10-27T08:01:30Z">
        <point lat="48.1370" lon="11.5754" hae="519.0" ce="1.0" le="1.0" />
        <detail>
                <contact callsign="WALKER-01" />
                <track course="180.0" speed="1.5" />
                <status battery="85" />
                <remarks>Walking down 5-degree ramp</remarks>
        </detail>
</event>
```

Application specific information goes into the <detail> section.

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4. Conclusions

- Open Source can promote technology reuse and co-innovation between consumer, industrial and military domains.
- Robotics are an area in which such co-innovation might be particularly effective.
- Technologies used for remote control of UAVs are not directly applicable for remote operation of industrial equipment, but they can provide a lot of inspiration and building blocks.
- Situational Awareness will become increasingly important for scenarios where humans and autonomous robots are working together in the same environment.
- Situational Awareness tools and technologies from the military domain, such as ATAK and CoT, may not be a perfect fit for industry, but they can serve as a basis for PoC implementation and exploration of human-robot-collaboration scenarios.

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